EXPLANATIONS AND SAILING DIRECTIONS

TO ACCOMPANY THE

WIND AND CURRENT CHARTS,

APPROVED BY

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CHIEF OF THE BUREAU OF ORDNANCE AND HYDROGRAPHY,

AND PUBLISHED BY AUTHORITY OF

HON. ISAAC TOUCEY,
SECRETARY OF THE NAVY.

BY

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WASHINGTON.

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INTRODUCTION.

THE introduction of a book, though the first in order to the reader, is generally the last to the writer, at least it is so in the present instance; and it is proper to state this fact in order to explain and apologize for the appearance of matter here which otherwise would seem out of place, as it might be considered to belong more properly to the body of the work. This work is the fruit of common labors. By concert, and with the most commendable spirit, sailors of all nations are engaged in conducting a most noble and ennobling system of philosophical inquiry, the results of which, so far, have been announced either by the Dutch through the Royal Meteorological Institute at Utrecht, or by the English through the Meteorological Papers of the Board of Trade, or by the French in the Revue Coloniale, or in these sailing directions. This is the time to report progress.

But, before I go further, I wish to announce a rule of conduct by which I have been guided from the commencement of this work, and by which I mean to be guided to the end; for not only has experience proved it wise, but it is in principle so good that to it I attribute much of the success which has attended these labors. This rule has been to keep the mind unbiassed by theories and speculations; never to have any wish that an investigation would result in favor of this view in preference to that, and never to attempt by premature speculation to anticipate the results of investigation, but always to trust to the observations themselves.

After these have been discussed, until the phenomena they conceal have been sufficiently developed, or developed as far as, with the materials on hand, I have found myself capable of developing them, then, and not till then, has an explanation been sought. The plan has been first the fact, and then the cause; and in seeking to account for any one fact, though several explanations may present themselves, that one is preferred which, besides satisfying the case in hand, will serve also to explain the greatest number of other known facts. And even then such explanation is offered only in place of a better, and it is held only until another, come whence it may, is presented, which will reconcile equally as well a still greater number of facts. In truth, these investigations have been strict investigations of facts, with the full conviction that facts, when grouped together in sufficient numbers, and catechized with reverence, will themselves reveal their cause, or place in our hands the clew to such explanation as man is permitted to comprehend.

In some cases, hypothesis is not only wholesome in its bearings, but necessary to progress. When I have deemed such to be the case, I have felt it my duty to offer hypothesis. But whenever in this work I have ventured an hypothesis, it has been for the purpose of stimulating observers or thinkers; expecting thus to make a step towards some hidden truth, by proving the hypothesis wrong, or by proving it right, for in either case there is generally a triumph and a step gained. That such is the spirit among those who, in foreign countries, may participate with me in the labors of discussion, I feel confident when I consider the character of the men and institutions employed, such as the Royal Academy of Science in

Sweden, such as FitzRoy and Playfair in England, Ballot and Jansen, Van Gough, Andrau, and Bowier in Holland, Vaneéchout, Tricault, and Le Gras in France, Wrangell and Gorkovenko in Russia, and Pegado in Portugal. And that such has been the spirit presiding here over this beautiful system of investigation, I hope the pages of these Sailing Directions, and the face of the "Wind and Current Charts" themselves have shown. The facts they contain I believe to be true and faithful results of what the log-books contain, and so believing I will not yield them for any others, unless these others be derived from a greater number of observations, from more faithfully kept abstract logs, or from some more thorough system of investigation. But as for theory, if I have anywhere carried theory where the scaffolding of abstract logs and pertinent facts is not sufficient to support me, I am, as I have been and hope to be, most happy to see sound opinions take its place.

I reverence truth, and know that this work which I have so much at heart, and which has cost me so many hours of precious time, will stand, prosper and flourish only as I am right and it is true. Such are the principles which have guided me in its progress, and to the observance of which I attribute whatever of success or of good has been awarded to it.

The demand for the fruits of our labor is continually on the increase; upwards of 210,000 sheets of the Wind and Current Charts have been distributed; and with this edition there will have been printed, published, and put into use more that 20,000 copies of these Sailing Directions. The work has met with favor in all parts of the commercial world and with all maritime people. The most experienced seamen, the ablest navigators, the wisest philosophers, the greatest statesmen, and the most powerful nations, have given it not only their approval, but their encouragement; they have lent it their aid also.

All nations that may be called maritime are now co-operating with us through their navies and merchantmen, in making the required observations and in keeping the abstract log; and some of these—Spain, Portugal, and Holland, England, France, and Denmark, Norway, Russia, and Sweden—have gone further, and provided for a discussion of the sea journals returned from their shipping, and for the contribution to the general stock of the results that may be obtained therefrom, or for the translation of said results.

In the preface to the 7th edition it was stated that Prussia was entertaining the idea of establishing a Hydrographical Office, for the purpose of entering the field of discussion as well as that of observation; that Russia was about to do the same, with Baron Wrangell at the head of it, and that that distinguished admiral was then engaged in translating from this work, and rendering it, with the formula of the abstract log, into Russian, for the use of the imperial marine :—

That the Holy See had established a decoration for the seamen of the Papal states, which can be reached only by keeping the abstract log of the Brussels Conference; and that a society had been established for the encouragement of nautical science in that country* :—

[Translation.]

* NOTICE.

"PONTIFICAL GOVERNMENT,

"*Ministry of Commerce and Public Works.*

"Among the subjects which have always received the attention and care of the Pontifical Government not the least has been that of the Mercantile Marine, and wishing to encourage, as much as possible, those who, by their industry, their courage, and their conduct, shall contribute to the increase and development of this marine, the council of ministers having proposed and received the special sanction of His Holiness, do arrange and decree as follows :—

That lectures were made in Holland, translated, illustrated, and published in England to make known and encourage this plan of research.

I have now the satisfaction of announcing that since the publication of the 7th edition France has entered the field with us; she has set about the work in hand in such good earnest that we may expect soon to see her occupying that proud eminence upon which her navigators and *savans* are so well able to place her.

A more zealous, able, and accomplished fellow laborer I could not desire than Lieutenant Vaneéchout, of that service, has proved himself to be. To him has been assigned the task of preparing, from the data already obtained, sailing directions for the French marine. To him, as also to Captain M. E. Tricault, of the French navy, the friends of our cause are deeply indebted. They have done much to make its merits known and understood by the French people, as well as by French seamen. Captain Tricault has epitomised the sailing directions, and published in the "Revue Coloniale" a complete account, with explanations and transcripts, of the Wind and Current Charts.

Nor have friends been wanting elsewhere: The Astronomer Royal of Belgium, M. Quetelet, the most amiable of men and excellent of philosophers, has never ceased to take the most lively interest and active concern for the expansion of our researches, so that they may include the land also. Others of the most eminent savans of Europe have united with him and given him a most hearty second.

By these researches the mariner's knowledge concerning the prevailing winds and currents at the different seasons and over the frequented parts of the ocean has been greatly enlarged. In consequence thereof the time required to make a voyage to distant parts of the world has been lessened, and the dangers of the sea proportionally diminished. The time already saved to the commerce of the world by these researches has been calculated by philosophers in England and France, Holland, and the United States; and in each country the money value is estimated at millions; yet the observations out of which such results have been elaborated have been made without the cost of one cent to government.

Sailing vessels, availing themselves of the power derived from this increase of knowledge of sea, wind, and weather, have driven steam out of the Australian trade, and put to rest for the present, at least, the question of a line of steamers between China and California.

"Art. 1. Honorary distinctions shall henceforth be accorded to such captains of armed or mercantile ships of the Pontificate as shall have merited well of their State and Sovereign.

"Art. 2. Every Pontifical subject who, on his own account, shall ship, in quantities of not less than 300 tons per vessel, a thousand or more tons of merchandise, in vessels entirely equipped and constructed in the dock-yards of the State, according to the law of December 10, 1825, shall, besides the reward of construction, be entitled to an honorary distinction by the Pontifical Government.

"Art. 3. Two flags, or honorary distinctions, are instituted; one of the first, the other of the second class, to be given to those captains who, legally qualified for the *gran corso o lungo corso*, shall make distant voyages.

"Art. 4. The form of these flags shall be the following:—

"Those of the first class shall be yellow and white—the yellow being nearest the staff—turned up with a red band, and in the middle the full length figures of the Holy Apostles Peter and Paul.

"Those of the second class shall be all white, turned up with a yellow band, and in the middle the full length figures of the Holy Apostles Peter and Paul.

"Art. 5. The dimensions of the flags shall be regulated by the size and quality of the ship; but their length shall be once and a half times, and the border one-sixth of their breadth.

"Art. 6. These flags, or honorary distinctions, shall be hoisted at the mast-head by the captains to whom they are given; hose of the first class at the head of the mainmast, and those of the second class, at the head of the mizzen. But neither of these flags shall be hoisted without, at the same time, hoisting the flag of the State at the peak, in accordance with the law of September 17, 1825.

In this connexion, the following statement is interesting; it shows the estimated number of vessels, and amount of tonnage belonging to the various States of Christendom in 1858—

THAT ARE CO-OPERATING.

	VESSELS.	TONNAGE.
England	38,000	5,400,000
United States	30,000	5,200,000
France	15,000	800,000
Russia	1,000	300,000
Sweden and Norway	2,100	550,000
Denmark	4,000	200,000
Holland	2,100	460,000
Belgium	150	36,000
Prussia	2,000	370,000
Hamburg	2,400	220,000
Bremen	500	160,000
Portugal	800	90,000
Spain	8,000	380,000
Sardinia	4,200	150,000
Papal States	4,000	120,000
Austria	7,600	324,000
Brazil	7,000	100,000
Chili	250	30,000
Peru	250	30,000
	124,150	14,840,000

THAT ARE NOT CO-OPERATING.

	VESSELS.	TONNAGE.
Tuscany and Naples	8,000	270,000
Greece	4,000	265,000
German Principalities	700	75,000
Sandwich Islands, &c.	600	70,000
	13,300	680,000

"ART. 7. In order to obtain the honor of these flags, the sea captains of the Pontificate must prove, from documents of the proper authorities of the State, or its representatives abroad, or, in their absence, of those of friendly powers, that they have made, in ships registered in the Pontifical State and qualified for 'il lungo corso é il gran corso,' a given number of voyages to foreign ports, leaving the Pontifical ports with merchandise of the State, and returning with foreign merchandise.

"It is also required of captains who shall wish to obtain the said distinctions, either of the first or second class, that they shall keep, especially in voyages out of the Straits of Gibraltar, a meteorological journal, with observations made daily at four o'clock in the morning, at noon, and at eight in the evening. The Minister of Commerce will, through the Board of Health and Police, in the ports Ancona and Civita Vecchia, furnish gratuitously to shipmasters undertaking such voyages the form of the journal, with requisite printed instructions for its compilation. At the return of the ship to the port whence it started, the officials of the port shall, without delay, receive back the original of this journal, signed by the captain and his secretary, whence it shall be forthwith transmitted to the said minister for its proper use.

"ART. 8. The foreign ports to which the captains may sail in order to obtain the flags are classified into the following four categories:

"1. Ports of the Black Sea.

"2. Ports of Spain, France, Belgium, Holland, and English seaports, ports of the Baltic, and African seaports, as far as the Cape of Good Hope.

"3. Atlantic seaports of North and South America, and ports of the Arctic Ocean.

"4. Ports of India and the Great Southern Ocean.

"ART. 9. The honor of the flags shall be awarded with a certificate from the Minister of Commerce, when the following voyages shall be proved to have been made according to Art 7:

"To obtain that of the first class—

"Either one voyage of the fourth category, or three of the third, or five of the second.

"To obtain that of the second class—

This estimate includes coasters, fishing-smacks, river craft, and vessels of all sorts that the government takes cognizance of. Of this grand total of 137,450 vessels and 15,520,000 tons, the nations to which more than nineteen-twentieths of the tonnage belongs have already joined hands, and are co-operating with us in collecting materials for the further prosecution of these researches. These vessels employ, at a moderate calculation, not less than a million of men and boys. Perhaps not more than one-tenth of the vessels are engaged in foreign trade, or perform voyages during which observations useful to us might be made; and, of this tenth, perhaps not more than one-half are capable of contributing. Nevertheless, after allowing for these deductions, the size of the fleets that are already engaged in this work is very imposing. It is the largest fleet that has ever been seen to act in concert, for any purpose whatever, since the world began.

Thus all who have lent a hand in bringing these investigations to their present state have cause for mutual congratulation, for the work goes bravely on, and friends to encourage by precept, or to help with contributions, are springing up in all parts of the world. But, in reviewing our labors, our object is not to boast, it is to gather strength to do more and to do it better; for the eyes of the world are upon us.

We are investigating the laws of the atmosphere. It covers the land as well as the sea. It is a whole, and for its influences to be rightly understood it must be treated as a whole: for it would be quite as reasonable to expect, by observing the currents of the Mediterranean, to gain a complete knowledge of those of the whole ocean, as it is to expect, by observing the winds at sea, to understand the movements of the whole atmosphere.

Often, in the course of these investigations, I have been compelled to give up a most interesting inquiry, because the observations that relate to it do not extend beyond the sea. I find, for instance, in the abstract logs, some phenomenon or another recorded which I am induced to trace to its genesis. I follow it up, trace it from the sea to the land, and there, having the mastery of it almost within my grasp, have to let it escape for the want of corresponding observations. This ought not to be. Agricultural and sanitary meteorology is as important as nautical. Farmers and invalids are quite as much interested in the development of meteorological facts and laws on the land as merchants and sailors are on the sea. The farmers and the *savans* of the shore are therefore appealed to, to come up, join forces, and do for the land what seamen and shipping merchants have done for the sea.

"Either one voyage of the third category, or two of the second, or four of the first.

"Art. 10. To any merchant captain who shall have made four voyages of the third category, or two of the fourth, according to Art. 8, besides the flag of honor of the first class, shall be given the right to wear the official uniform of the navy of the Pontificate, with the rank of honorary lieutenant.

"Art. 11. When a vessel, carrying one of these flags of honor, approaches a Pontifical port, it shall be saluted by the port-ship by hoisting the Pontifical flag at the head of the mainmast, or mizzen, according to the class to which the flag of honor belongs If, also, the captain of the ship shall have the rank of lieutenant in the navy, he shall receive, in addition, the salute of three guns.

"Art. 12. In cases of extraordinary voyages, or those not contemplated above; or of very honorable actions performed by captains, which shall redound to the honor of the service and the glory of the Pontifical flag, the Government reserves the reward of these for special action.

"Art. 13. The present arrangements shall not apply to voyages now in progress, or those anterior to the date of this notification.

"Art. 14. The Board of Health and Police of the ports of Ancona and Civita Vecchia, and the Consular Pontifical representatives abroad, are charged with the execution of these arrangements, each for the part which appertains to him.

"Given at Rome, from the Ministry of Commerce and Public Works, January 8, 1855.

The Minister, G. MILESI."

The investigations for the land may be carried on in a way quite as unexpensive as those for the sea; but it is as necessary in one case as in the other that governments should lead. The States of Christendom were invited to a conference upon the subject of a uniform system of observations at sea. After three weeks of free discussion and deliberation, a system was agreed upon; and nations owning nineteen-twentieths of all the shipping in the world are now, through their navies and the voluntary co-operation of their merchantmen, engaged in carrying out that system; the governments simply undertaking the office expenses incident to the discussion and publication of the observations that are thus gratuitously made.

There are public-spirited men ashore, and amateur meteorologists on the land in all countries, who, I am assured, would be most happy, at their own expense, to equip their meteorological observatories with the requsite instruments, and to observe according to a prescribed and uniform plan, provided the government would agree to have the observations so made compared, discussed, and published, for the benefit of the world. Every nation has already, and upon a scale more or less extensive, its own meteorological observations on the shore; they have also an office in which the observations are treated with more or less care, and published in some shape or another. So that, different from the system at sea, the nuclei for the observations on the land, their treatment and publication, are already established; and to cover both sea and land with observers and to make the plan universal, but little now is wanting save that spirit of good will and co-operation for the land which has been found so beneficial and admirable for the sea.

This extension of the system landward was proposed in the beginning as a part of the original plan. I have never ceased to advocate it since, and to couple with it a system of daily weather reports through the telegraph. As much as we have accomplished at sea, more yet can be accomplished through the magnetic telegraph on the land. With a properly devised system of meteorological observations to be made at certain stations wherever the telegraph spreads its meshes, and to be reported daily by telegrams to a properly organized office, the shipping in the harbors of our seaport towns, the husbandman in the field, and the traveller on the road, may all be warned of every extensive storm that visits our shores, and while yet it is a great way off.

The laurels to be anticipated from such extension of our beautiful field of research would crown the results already obtained, and probably entitle the whole to be regarded as among the most splendid achievements of the age. With this system established, and conducted as it ought to be, no ship need ever put to sea, from any of our sea ports, in ignorance of the approaching storm.

A like system for the British Islands and the continent would lead to like results there; many storms, after visiting our shores, travel across the ocean and carry devastation there. Should the sub-Atlantic telegraph be laid, and when laid, should it answer its ends, warnings of all such storms may be sent across the ocean several days in advance. The annual losses at sea range from two to sixteen millions of dollars; and the losses on the northern lakes have amounted, for the four years from 1854 to 1857, inclusive, to no less than $10,000,000 in the gross. The loss of life during the same period on the lakes was 1,000 souls. The loss of life at sea is still more astounding. The lakes are already surrounded with a cordon of telegraphic stations, which no storm could pass without being reported at headquarters, and thence warning to the shipping and people could be sent out right and left, and as far as the wires extend.

I hope that the friends of our cause, wherever they be, will act upon the principle that our labors cannot be considered as half begun until we are permitted to extend them from the sea to the land, and call to our aid also the electric telegraph.

With our observations at sea, we have arrived at a point at which we may pause and turn to take a retrospect; and in that retrospect we discover that certain parts of the wide field that lies spread out before us have been sufficiently traversed by present laborers with certain implements; and that our knowledge of routes and winds over particular parts of the ocean is as ample as, in the present stage of meteorological science, it probably ever will be. In short, it will probably be several years before we shall be able to give any new lights as to certain routes and sailing directions herein laid down.

Moved by considerations of this sort, the number of copies to be issued of the 8th edition will exceed any of its predecessors.

This arrangement will give me more leisure for further investigations, the results of which will from time to time be issued in separate monographs.

ROYAL SOCIETY'S APARTMENTS, SOMERSET HOUSE,
London, *June* 19, 1854.

SIR: I have the honor to inclose a letter which has been received by the President and Council of the Royal Society of London, announcing the intention of the British Government to institute an office for the discussion of the observations on meteorology to be made at sea, in all parts of the globe, by British vessels, in conformity with the recommendation of the Conference held at Brussels last year, and requesting the opinion of the Royal Society as to the expediency of giving such an extension to the system of meteorological observations as may cause it to include, in addition to the information required for the purposes of navigation, such scientific desiderata as may be decided best calculated for the investigation and establishment of great atmospheric and oceanic laws, and may be obtainable by observation either on land or at sea.

The inquiry thus opened being one of general concernment, the President and Council of the Royal Society, before they make their reply, are desirous of obtaining the opinion of those amongst their foreign members, who are known as distinguished cultivators of meteorological science, as well as of others in foreign countries, who either hold offices connected with the advancement of meteorology, or have devoted themselves to this branch of science and may thus be consulted with advantage.

In addressing this letter to you, sir, I have therefore to express the gratification with which the Royal Society will receive a communication from you; and to assure you that the fullest consideration will be given to the opinions or suggestions with which you may be pleased to favor them.

I have the honor to be, sir, your obedient servant,

ROSSE.

P. S. In addressing your reply, be pleased to write "meteorology" in the corner of the direction. The English language need not be used unless perfectly agreeable to yourself.

To LIEUT. MAURY, U. S. N.

OFFICE OF COMMITTEE OF PRIVY COUNCIL FOR TRADE,
Marine Department, *June* 3, 1854.

SIR: I am directed by the Lords of the Committee of the Privy Council for trade to acquaint you that, with the concurrence of the Lords Commissioners of the Treasury, my Lords have determined to submit to Parliament an estimate for an office for the discussion of the observations on meteorology which it is proposed shall be made at sea, in all parts of the globe, in conformity with the recommendation of the Conference held at Brussels last year, and they are about to construct a set of forms for the use of that office, in which it is proposed to publish from time to time and to circulate such statistical results as may be considered most desirable by men learned in the science of meteorology, in addition to such other information as may be required for the purposes of navigation.

Before doing so, however, they are desirous of having the opinion of the Royal Society as to what are the great desiderata in meteorology, and as to what forms that Society consider the best calculated to exhibit the great atmospheric laws which it may be deemed most desirable to develop.

I herewith inclose a form of log (this is in the report of the Brussels Conference) which will contain all that is proposed to execute at sea, but it may possibly happen that observations on land, upon an extended scale, may hereafter be made and discussed in the same office; and in framing your reply it is desirable that such a contingency should be borne in mind and provided for.

I am, sir, your obedient servant,

JAMES BOOTH.

The SECRETARY OF THE ROYAL SOCIETY.

NATIONAL OBSERVATORY,
Washington, July 27, 1854.

MY LORD: I have had the honor to receive your Lordship's communication on the 19th June, 1854, covering a copy of one of the 3d June, 1854, made by command of the Lords of the Committee of Privy Council for Trade, to the Royal Society, concerning meteorological observations by sea and land.

The British Government having determined to institute an office for the discussion of observations to be made in conformity with the recommendations of the Maritime Conference of Brussels, solicits the opinion of the President and Council of the Royal Society as to the expediency of enlarging the plan so as to include such scientific desiderata as may be deemed best calculated for the investigation and establishment of great atmospherical and oceanic laws, and which may be obtained by observations either on land or at sea.

Before expressing their views in reply, the President and Council of the Royal Society desire to obtain the opinion, among others, of those in foreign countries who either hold offices connected with meteorological research, or who have devoted themselves to this branch of science.

In furtherance of this desire, your Lordship has done me the honor to address the communication aforesaid. I think my opinion is scarcely worth the having, though as the President and Council of the Royal Society are pleased to think differently, I do not feel myself quite at liberty to set the example of withholding small mites.

In my judgment, the best plan of procedure for procuring such expansions for the system of meteorological observations as will include the desiderata indicated is, to carry out the idea of a universal system of meteorological observations, which formed the subject of correspondence between the governments of Great Britain and America in 1851.

The Brussels Conference recommended a mode for carrying out this system in so far as it relates to the sea. No less than twelve nations* have approved these recommendations, and

* All the maritime States of Christendom have now—1858—given in their adhesion to the plan of the Brussels Conference.

have signified their intentions of carrying them out through the instrumentality of their naval and mercantile marine.

By referring to the detail of the plan of the Brussels Conference, it will be perceived that it is somewhat in the nature of a compact. In carrying out this plan, much is expected of the merchant service. We look to this branch for a large and valuable corps of observers; and to the merchantmen, the plan especially in this country is recommendatory, for the government has no power to *require* services of the kind from American or other shipmasters. The American Government, therefore, has caused it to be proclaimed, that it will grant certain works to the intelligent shipmasters of any country, who will render abstract logs according to a prescribed formula.* Merchant-service observers are invited to give more than this formula requires; but to *demand* more might, under present circumstances, be considered not altogether fair.

This is one reason why the recommendations of the Brussels Conference should be adhered to, at least for the present, but there is another.

Nations owning more than nine-tenths of all the shipping in the world have come into this plan. Arrangements for carrying it out have either just been made, or are in progress, and I should tremble with apprehension were the idea to get abroad that this plan is to be changed, or that a proposition was seriously entertained at this early day for altering or amending it, or for materially interfering in any manner whatever with the arrangements which are in progress for carrying it out.

The plan proposed by the Maritime Conference of Brussels may be faulty, it no doubt is. My reluctance to any alterations, my opposition to any material amendment to it whatever, does not grow out of any idea that I may entertain as to its completeness of purpose, or its perfection, but from the fact that with it we have on hand a grand experiment; it is an attempt to bring the sea, by means of machinery already at work, regularly within the domains of systematic and scientific research; to change, without cost, the common implements of navigation into philosophical instruments, and to convert the ships, for the safety of which these instruments are employed, into so many floating observatories, all co-operating together for the advancement of science and the good of mankind.

After this plan has been tried, after we shall have had an opportunity of ascertaining by actual trial the degree of skill possessed or attainable by such a corps of observers, and after experience shall have afforded us the benefit of its lights as to the workings of this scheme, then no one will be more ready than myself to profit by these lights, and to go into another conference for amendments and improvements.

I take it for granted, therefore, that the points of inquiry now presented do not involve any question that relates to any alteration or amendment in the plan of the Brussels Conference [*at present.*]

The subjects upon which opinions are invited relate, according to my view, to concert of action among meteorologists and meteorological observers on the land, as to how far they may assist in carrying out this plan, while at the same time the field may be enlarged so as to include observations on the sea also.

This would make the plan complete, and an inquiry like this, having for its object the establishment of great atmospherical and oceanic laws, being, as the President and Council remark "of general concernment," ought to be undertaken under governmental auspices, for

* *Vide* a letter from Secretary of the Navy, December 6, 1851, page 11 of pamphlet, on the establishment of a system of meteorological observations by land and sea.

I conceive that neither individual enterprise, nor the activity of societies, can do much more than accomplish specialities in so great a field as the atmosphere.

It is a whole; as a whole its workings and its laws should be investigated, and as a whole it should be occupied with observers and treated by computers.

Therefore I am among those who advocate another meteorological Congress, for the purpose of arranging forms for observers and recommending a plan for co-operation on the land. In my judgment, co-operation, to the extent desired, is only obtainable by bringing meteorologists together for mutual consultation and advice, with the assurance that should their counsels be judged practicable, enlightened nations stand ready to adopt and carry them out.

This Congress should, I conceive, be international; that is, the members of it should be appointed by those governments that may be disposed to lend their co-operation or their countenance to a scheme so rich with the promise of universal good.

Men have entered this field single handed and gathered laurels in abundance; but they with their labors have satisfied us that, though there still remains a harvest rich and plenteous, they are not, after reaping it and gathering it together, equal also to the task of threshing it; for with such gleanings it requires patient labor to separate the wheat from the chaff. For such a field and harvest multitudes of laborers are wanted; they are wanted in numbers that will not come at the call of individuals or societies, however wise and excellent, but only at the call of nations. Indeed, it is not so difficult to procure meteorological observations as it is to have them properly discussed and published.

Wherever the English language is spoken, wherever Christian churches have their missionaries and science its followers, there are to be found laborers ready to enter this field.

"Man by nature is a meteorologist," but no man likes to labor in vain; and when men are invited to enter this field as recording observers, to whom, or to what office shall each one be directed to send his observations, that they may be prepared and discussed for use; so that none shall have labored in vain?

Almost every government among the states of Christendom has already established its system of meteorological observations, and has also provided to a greater or less extent for their publication. These observations are made for the most part at hospitals, military posts, and public institutions and establishments of various kinds. Many of them are well furnished with self-registering instruments. They therefore constitute what, in the proposed plan, may be called government establishments. They occupy on the land the place which, in the Brussels plan, the man-of-war occupies on the sea, where the most complete meteorological journals may be kept.

Many private observatories are, like many merchant ships, equally well fitted and found, and ready to undertake a series of observations according to the most elaborate formula that may be thought desirable. But the great body of laborers on the land, like the great majority of co-operators at sea, will be observers only of the minimum order. Many of these will be prepared to furnish such data alone as the eye, assisted by the thermometer and judgment, may gather. But even such observations—especially in a comprehensive system, one object of which is to develop the great laws and plan of atmospherical circulation—will be far from useless; for the value of such will be greatly enhanced by geographical position or by the numbers of the stations at which they may be made.

The British Government has taken the lead in the plan of concert of action among meteorologists on the land. The plan could not be in better hands, nor could it be brought forward under better auspices. Such a system of research, though it may be as extensive as the air, and though it may look to the establishment of meteorological observatories in all habitable parts of the globe, is simple, and, in my judgment, is susceptible of ready and successful execution without any more than really a trifling expense.

I beg to make myself clear upon this point, and, that I may do so, crave indulgence for an illustration.

Most of the governments, it is presumed, that will be represented in the proposed Congress have already a system of meteorological observations, which they are in the habit of publishing more or less in detail. The formula of observations for these establishments should be the most comprehensive; but each government, upon whose territories the Congress may deem it advisable to multiply stations, should encourage the establishment of them, by such means as to it may seem good; let the Congress, however, propose a form for these also—a minimum of desiderata—with the suggestion that each government invite its amateur meteorologists to co-operate in this plan, at least so far as to satisfy the minimum formula with observations; accompanying the invitation with an offer to every co-operator of a copy of published results.

In case there be any governments, as there probably will be, that may not find it convenient or deem it expedient to make such publications of the observations to be made within its dominions, then let the British Government do for the land what another government of kindred people has done for the sea, viz: offer to take charge of all the observations that no other government shall care for, discuss them, and send each one whose labors may be there recorded a copy of the printed results.

What instruments shall be used at the stations, public and private, what forms of observation, and what the subjects,—in short, what the details of the plan may be, should be left for the deliberations of a meeting of meteorologists, invited for the purpose and representing nationalities. I conceive it very desirable, that so far as it may be practicable without interfering with the Brussels plan, that the proposed plan for the land should contemplate co-operation between the observers ashore and afloat; for in discussing the observations at sea, I am daily reminded of the want of such co-operation on the land. There are many phenomena that cannot well be traced out without such concert. I hope I may be excused for mentioning a case that just now happens to be before me.

I have lately received from Commodore Mayo, in command of the African squadron, a meteorological journal, kept at the American mission, Gaboon, for 1852 and 1853, by Dr. Henry Ford; by which it appears that the dry season there is from June to September, inclusive, that the other eight months comprise the rainy season. Now, though this journal does not give the direction of the wind at all, and though it only makes record of the thermometer, the rains, and state of sky, yet by referring to our investigations at sea, it appears that this prolonged rainy season is due to two causes which operate in succession; one a monsoon which brings rain, and before that is over, the equatorial cloud-ring in its annual vibrations from north to south has overshadowed Gaboon (latitude 0° 22′ N.) with its vapors, and thus, like the lunar and solar tides when in conjunction, we have one rainy season overriding and overleaping another.

Begging pardon for having said so much in a case upon which there was need of but little from me, I have the honor to be,

Respectfully, &c.,

M. F. MAURY.

To the Hon. Lord Rosse,
President of the Royal Society, London.

Reply of the President and Council of the Royal Society to a letter from the Board of Trade, dated January 15 (June 3, ?) 1854.

ROYAL SOCIETY, SOMERSET HOUSE,
February 22, 1855.

SIR: In the month of June last the Lords of the Committee of the Privy Council for Trade caused a letter to be addressed to the President and Council of the Royal Society, acquainting them that their Lordships were about to submit to Parliament an estimate for an office for the discussion of the observations on meteorology, to be made at sea in all parts of the globe, in conformity with the recomendation of a conference held at Brussels in 1853; and that they were about to construct a set of forms for the use of that office, in which they propose to publish from time to time, and to circulate such statistical results, obtained by means of the observations referred to, as might be considered most desirable by men learned in the science of meteorology, in addition to such other information as might be required for the purposes of navigation.

Before doing so, however, their Lordships were desirous of having the opinion of the Royal Society as to what were the great desiderata in meteorological science; and as to the forms which may be best calculated to exhibit the great atmospheric laws which it may be most desirable to develop.

Their Lordships further state, that as it may possibly happen that observations on land upon an extended scale may hereafter be made and discussed in the same office, it is desirable that the reply of the Royal Society should keep in view and provide for such a contingency.

Deeply impressed with a sense of the magnitude and importance of the work which has been thus undertaken by Her Majesty's Government and confided to the Board of Trade, and fully appreciating the honor of being consulted, and the responsiblity of the reply which they are called upon to make; considering also that by including the contingency of *land* observations, the inquiry is, in fact, co-extensive with the requirements of meteorology over all accessible parts of the earth's surface; the President and Council of the Royal Society deemed it advisable, before making their reply, to obtain the opinion of those amongst their foreign members who are known as distinguished cultivators of meteorological science, as well as of others in foreign countries, who either hold offices connected with the advancement of meteorology, or have otherwise devoted themselves to this branch of science.

A circular was accordingly addressed to several gentlemen whose names were transmitted to the Board of Trade in June last, containing a copy of the communication from the Board of Trade, and a request to be favored with any suggestions which might aid Her Majesty's Government in an undertaking which was obviously one of general concernment.

Replies in some degree of detail have been received from five of these gentlemen,* copies of which are herewith transmitted.

The President and Council are glad to avail themselves of this opportunity of expressing their acknowledgments to these gentlemen, and more particularly to Professor Dové, director of the meteorological establishments and institutions in Prussia, whose zeal for the advancement of meteorology induced him to repair personally to England, and to join himself to the Committee by whom the present reply has been prepared. Those who are most familiar with the

* Dr. Erman, of Berlin; Dr. Heis, of Münster; Professor Kriel, of Vienna; Lieutenant Maury, of Washington; and M. Quetelet, of Brussels.

labors and writings of this eminent meteorologist will best be able to appreciate the value of his co-operation.

The President and Council have considered it as the most convenient course to divide their reply under the different heads into which the subject naturally branches. But before they proceed to treat of these, they wish to remark generally, that one of the chief impediments to the advancement of meteorology consists in the very slow progress which is made in the transmission from one country to another of the observations and discussions on which, under the fostering aid of different governments, so much labor is bestowed in Europe and America; and they would therefore recommend that such steps as may appear desirable should be taken by Her Majesty's Government, to promote and facilitate the mutual interchange of meteorological publications emanating from the governments of different countries.

Barometer.—It is known that considerable differences, apparently of a permanent character, are found to exist in the mean barometric pressure in different places; and that the periodical variations in the pressure in different months and seasons at the same place, are very different in different parts of the globe, both as respects period and amount; insomuch that, in extreme cases, the variations have even opposite features in regard to period, in places situated in the same hemisphere, and at equal distances from the equator.

For the purpose of extending our knowledge of the facts of these departures from the state of equilibrium, and of more fully investigating the causes thereof, it is desirable to obtain, by means of barometric observations strictly comparable with each other, and extending over all parts of the globe accessible by land or sea, *tables*, showing the mean barometric pressure *in the year*, *in each month of the year*, and *in the four meteorological seasons*—on land, at all stations of observation—and at sea, corresponding to the middle points of spaces bounded by geographical latitudes and longitudes, not far distant from each other.

The manner of forming such tables from the marine observations which are now proposed to be made, by collecting together observations of the same month in separate ledgers, each of which should correspond to a *geographical space* comprised between specified meridians and parallels, and to a *particular month*, is too obvious to require to be further dwelt upon. The distances apart of the meridians and parallels will require to be varied in different parts of the globe, so that the magnitudes of the spaces which they inclose, and for each of which a table will be formed, may be more circumscribed when the rapidity of the variation of the particular phenomenon to be elucidated is greatest in regard to geographical space. Their magnitude will also necessarily vary with the number of observations which it may be possible to collect in each space, inasmuch as it is well known that there are extensive portions of the ocean which are scarcely ever traversed by ships, whilst other portions may be viewed as the highways of a constant traffic.

The strict comparability of observations made in different ships, may perhaps be best assured by limiting the examination of the instruments to comparisons which it is proposed to make at the Kew Observatory, before and after their employment in particular ships. From the nature of their construction, the barometers with which Her Majesty's navy and the mercantile marine are to be supplied are not very liable to derangement, except from such accidents as would destroy them altogether. Under present arrangements, they will all be carefully compared at Kew before they are sent to the Admiralty or to the Board of Trade; and similar arrangements may easily be made by which they may be returned to Kew for re-examination, at the expiration of each tour of service. The comparison of barometers when embarked and in use, with standards, or supposed standards at ports which the vessels may visit, entails many inconveniences, and is in many respects a far less satisfactory method. The limitation here recommended is not, however, to be understood as applicable in the case of other establishments than Kew, where a special provision may be made for an equally careful and correct examination.

At land stations, in addition to proper measures to assure the correctness of the barometer, and consequent comparability of the observations, care should be taken to ascertain by the best possible means (independently of the barometer itself) the height of the station above the level of the sea at some stated locality. For this purpose the extension of levels for the construction of railroads will often afford facilities.

It may be desirable to indicate some of the localities where the data, which tables such as those which have been spoken of would exhibit, are required for the solution of problems of immediate interest.

1°. It is known that, over the Atlantic Ocean, a low mean annual pressure exists near the equator, and a high pressure at the north and south borders of the torrid zone, (23° to 30° north and south latitudes;) and it is probable that from similar causes similar phenomena exist over the corresponding latitudes in the Pacific Ocean; the few observations which we possess are in accord with this supposition; but the extent of space covered by the Pacific is large, and the observations are few; they may be expected to be greatly increased by the means now contemplated. But it is particularly over the Indian Ocean, both at the equator and at the borders of the torrid zone, that the phenomena of the barometric pressure, not only annual, but also monthly, require elucidation by observations. The trade-winds, which would prevail generally round the globe if it were wholly covered by a surface of water, are interrupted by the large continental spaces in Asia and Australia, and give place to the phenomena of monsoons, which are the indirect results of the heating action of the sun's rays on those continental spaces. These are the causes of that displacement of the trade-winds, and substitution of a current flowing in another direction, which occasion the atmospheric phenomena over the Indian Ocean, and on the north and south sides of that Ocean, to be different from those in corresponding localities over and on either side of the equator in the Atlantic Ocean, and (probably generally also) in the Pacific Ocean.

It is important alike to navigation and to general science to know the limits where the phenomena of the trade-winds give place to those of the monsoons, and whether any and what variations take place in those limits in different parts of the year. *The barometric variations are intimately connected with the causes of these variations, and require to be known for their more perfect elucidation.*

The importance, indeed, of a full and complete knowledge of the variations which take place in the limits of the trade-winds generally in both hemispheres, at different seasons of the year, has long been recognized. On this account, although the present section is headed "Barometer," it may be well to remark here, that it is desirable that the forms supplied to ships should contain headings, calling forth a special record of the latitude and longitude where the trade-wind is first met with, and where it is first found to fail.

2°. The great extent of continental space in Northern Asia causes, by reason of the great heat of the summer, and the ascending current produced thereby, a remarkable diminution of atmospheric pressure in the summer months, extending in the north to the Polar Sea, and on the European side as far as Moscow. Towards the east it is known to include the coasts of

China and Japan, but the extent of this great diminution of summer pressure beyond the coasts thus named is not known. A determination of the monthly variation of the pressure over the adjacent parts of the Pacific Ocean is therefore a desideratum; and for the same object, it is desirable to have a more accurate knowledge than we now possess of the prevailing direction of the wind in different seasons in the vicinity of the coasts of China and Japan.

3°. With reference to regions or districts of increased or diminished *mean annual* pressure, it is known that in certain districts in the temperate and polar zones, such as in the vicinity of Cape Horn, extending into the Antarctic Polar Ocean, and in the vicinity of Iceland, the mean annual barometric pressure is *considerably* less than the average pressure on the surface of the globe generally; and that anomalous differences, also of considerable amount, exist in the mean annual pressure in different parts of the Arctic Ocean. These all require special attention, with a view to obtain a more perfect knowledge of the facts, in regard to their amount, geographical extension, and variation with the change of seasons, as well as to the elucidation of their causes.

Dry Air and Aqueous Vapor—The apparently anomalous variations which have been noticed to exist in the mean annual barometric pressure, and in its distribution in the different seasons and months of the year, are also found to exist in each of the two constituent pressures which conjointly constitute the barometric pressure. In order to study the problems connected with these departures from a state of equilibrium under their most simple forms—and generally for the true understanding of almost all the great laws of atmospheric change—it is necessary to have a separate knowledge of the two constituents (viz: the pressures of the dry air and of the aqueous vapor) which we are accustomed to measure together by the barometer. This separate knowledge is obtained by means of the hygrometer, which determines the elasticity of the vapor, and leads to the determination of that of the dry air, by enabling us to deduct the elasticity of the vapor from that of the whole barometric pressure. It is therefore extremely desirable that tables, similar to those recommended under the preceding head of the barometer, should be formed at every land station, and over the ocean at the centres of geographical spaces bounded by certain values of latitude and longitude, for the *annual*, *monthly*, and *season* pressures—1. Of the aqueous vapor; and 2. Of the dry air; each considered separately. Each of the said geographical spaces will require its appropriate ledger for each of the twelve months.

It may be desirable to notice one or two of the problems connected with extensive and important atmospherical laws, which may be materially assisted by such tables.

1°. By the operation of causes, which are too well known to require explanation here, the dry air should always have a minimum pressure in the hottest months of the year. But we know that there are places where the contrary prevails, namely, that the pressure of the dry air is greater in summer than in winter. We also know that, when comparison is made between places in the same latitude, and having the same, or very nearly the same, difference of temperature in summer and in winter, the differences between the summer and winter pressures of the dry air are found to be subject to many remarkable anomalies. The variations in the pressure of the dry air do not, therefore, as might be at first imagined, depend altogether on the differences between the summer and winter temperatures at the places where the variations themselves occur. The increased pressure in the hottest months appears rather to point to the existence of an overflow of air in the higher regions of the atmosphere from *lateral sources;* the statical pressure at the base of the column being increased by the augmentation of the superincumbent mass of air arising from an influx in the upper portion. Such lateral sources may well be supposed to be due to *excessive ascensional currents* caused by *excessive summer heats* in certain places of the globe, (as, for example, in Central Asia.) Now, the lateral overflow from such sources, traversing in the shape of currents the higher regions of the atmosphere, and encountering the well-known general current flowing from the equator towards the pole, has been recently assigned with considerable probability (derived from its correspondence with many otherwise anomalous phenomena already known, and which all receive an explanation from such supposition) to be the original source or primary cause of the *rotating storms* or *cyclones*, so well known in the West Indies and in China under the names of hurricanes and typhoons. A single illustration may be desirable. Let it be supposed that such an excessive ascensional current exists over the greatly heated parts of Asia and Africa in the northern tropical zone—giving rise, in the continuation of the same zone over the Atlantic Ocean, to a lateral current in the upper regions; this would then be a current prevailing in those regions from east to west; and it would encounter over the Atlantic Ocean the well-known upper current proceeding from the equator towards the poles, which is a current from the southwest. An easterly current impinging on a southwest current may give rise, by well-known laws, to a rotatory motion in the atmosphere, of which the direction may be the same as that which characterizes the cyclones of the northern hemisphere. To test the accuracy of this explanation, we desire to be acquainted with the variations which the *mean pressure of the dry air undergoes in the different seasons* in the part of the globe where, according to this explanation, considerable variations, having particular characters, ought to be found.

2°. We have named one of the explanations which have been recently offered of the primary cause of the northern cyclones. Another mode of explanation has been proposed, by assuming the condensation of large quantities of vapor, and the consequent influx of air to supply the place. In such case, the phenomena are to be tested in considerable measure by the variations which the *other constituent* of the barometric pressure, namely, the *aqueous vapor*, undergoes.

3°. The surface of sea in the southern hemisphere *much* exceeds that in the northern hemisphere. It is therefore probable that, at the season when the sun is over the southern hemisphere, evaporation over the whole surface of the globe is more considerable than in the opposite season when the sun is over the northern hemisphere. Supposing the pressure of the dry air to be a constant, the difference of evaporation in the two seasons may thus produce for the whole globe an *annual barometric variation*, the aggregate barometric pressure over the *whole* surface being highest during the northern winter. The separation of the barometric pressure into its two constituent pressures, would give direct and conclusive evidence of the cause to which such a barometric variation should be ascribed. It would also follow that evaporation being greatest in the south, and condensation greatest in the north, the water which proceeds from south to north in a state of vapor would have to return to the south in a liquid state, and might possibly exert some discernible influence on the currents of the ocean. The tests by which the truth of the suppositions thus advanced may be determined, are the variations of the meteorological elements in different seasons and months, determined by methods and instruments strictly comparable with each other, and arranged in such tables as have been suggested. A still more direct test would indeed be furnished by the fact (if it could be ascertained) that the quantity of rain which falls in the northern is greater than that which falls in the southern hemisphere; and by examining its distribution into the different months and seasons of its occurrence. Data for such conclusions are as yet very insufficient; they should always, however, form a part of the record at all land stations where registers are kept.

In order that all observations of the elasticity of the aqueous vapor may be strictly comparable, it is desirable that all should be computed by the same tables; those founded upon the experiments of MM. Regnault and Magnus may be most suitably recommended for this purpose, not only on their general merits, but also as being likely to be most generally adopted by observers in other countries.

Temperature of the air.—Tables of the mean temperature of the air in the year, and in the different months and seasons of the year, at above 1,000 stations on the globe, have recently been computed by Professor Dové, and published under the auspices of the Royal Academy of Sciences at Berlin. This work—which is a true model of the method in which a great body of meteorological facts, collected by different observers and at different times, should be brought together and co-ordinated—has conducted, as is well known, to conclusions of very considerable importance in their bearing on climatology and on the general laws of the distribution of heat on the surface of the globe. These tables have, however, been formed exclusively from observations made *on land.* For the completion of this great work of physical geography, there is yet wanting a similar investigation for the *oceanic* portion; and this we may hopefully anticipate as likely to be now accomplished by means of the marine observations about to be undertaken. In the case of the temperature of the air, as in that of the atmospheric pressure previously adverted to, the centres of geographical spaces bounded by certain latitudes and longitudes will form points of concentration for observations, which may be made within those spaces, not only by the same but also by different ships; provided that the system be steadily maintained of employing only instruments which shall have been examined, and their inter-comparability ascertained, by competent and responsible authority; and provided that no observations be used but those in which careful attention shall have been given to the precautions which it will be necessary to adopt, for the purpose of obtaining the correct knowledge of the temperature of the external air amidst the many disturbing influences from heat and moisture so difficult to escape on board ship. In this respect, additional precautions must be used if *night observations* are to be required, since the ordinary difficulties are necessarily much enhanced by the employment of artificial light. Amongst the instructions which will be required, perhaps there will be none which will need to be more carefully drawn than those for obtaining the correct temperature of the external air under the continually varying circumstances that present themselves on board ship.

In regard to *land stations,* Professor Dové's tables have shown that data are still pressingly required from the British North American possessions intermediate between the stations of the Arctic Expeditions and those of the United States; and that the deficiency extends across the whole North American continent in those latitudes from the Atlantic to the Pacific. Professor Dové has also indicated as desiderata, observations at the British military stations in the Mediterranean, (Gibraltar, Malta, and Corfu,) and around the coast of Australia and New Zealand; and also that *hourly* observations, continued for at least one year, are particularly required at some one station in the West Indies to supply the diurnal corrections for existing observations.

Whilst the study of the distribution of heat at the surface of the globe has thus been making progress, in respect to the *mean annual temperature* in different places, and to its *periodical variations* in different parts of the year at the same place, the attention of physical geographers has recently been directed (and with great promise of important results to the material interests of men as well as to general science) to the causes of those fluctuations in the temperature, or departures from its mean or normal state at the same place and at the same period of the year, which have received the name of "non-periodic variations." It is known that these frequently affect extensive portions of the globe at the same time, and are generally, if not always, accompanied by a fluctuation of an opposite character, prevailing at the same time in some adjoining but distant region; so that by the comparison of synchronous observations a progression is traceable, from a locality of maximum increased heat in one region, to one maximum diminished heat in another region. For the elucidation of the non-periodic variations even *monthly* means are insufficient; and the necessity has been felt of computing the mean temperatures for periods of much shorter duration. The Meteorological Institutions of those of the European States which have taken the foremost part in the prosecution of meteorology, have in consequence adopted *five-day means*, as the most suitable intermediate gradation between daily and monthly means; and as an evidence of the conviction which is entertained of the value of the conclusions to which this investigation is likely to lead, it has been considered worth while to undertake the prodigious labor of calculating the five-day means of the most reliable existing observations during a century past. This work is already far advanced; and it cannot be too strongly recommended, that at all fixed stations, where observations shall hereafter be made with sufficient care to be worth recording, five-day means may invariably be added to the daily, monthly, and annual means into which the observations are usually collected. The five-day means should always commence with January 1, for the purpose of preserving the uniformity at different stations, which is essential for comparison; in leap year, the period which includes the 29th of February will be of six days.

In treating climatology as a *science*, it is desirable that some correct and convenient mode should be adopted for computing and expressing the *comparative variability* to which the temperature in different parts of the globe, and in different parts of the year in the same place, is subject from non-periodic causes. The *probable variability*, computed on the same principle as the *probable error* of each of a number of independent observations, has recently been suggested as furnishing an index "of the probable daily non-periodic variation" at the different seasons of the year; and its use in this respect has been exemplified by calculations of the "index" from the five-day means of twelve years of observations at Toronto, in Canada, (*Phil. Trans.*, 1853, Art. V.) An index of this description is, of course, of absolute and general application; supplying the means of comparing the probable variability of the temperature in different seasons at *different places* (where the same method of computation is adopted) as well as at the *same place*. It is desirable that this (or some preferable method if such can be devised for obtaining the same object) should be adopted by those who may desire to make their observations practically useful for sanitary or agricultural purposes or for any of the great variety of objects for which climatic peculiarities are requred to be known. Having these three data, viz: the mean annual temperature, its periodical changes in respect to days, months, and seasons, and the measure of its liability to non-periodic (or what would commonly be called irregular) variations, we may consider that we possess as complete a representation of the climate of any particular place (so far as temperature is concerned) as the present state of our knowledge permits.

It is obvious that much of what has been said under this article is more applicable to land than to sea observations; but the letter of the Board of Trade, to which this is a reply, requests that both should be contemplated.

Temperature of the sea, and Investigations regarding Currents.—It is unnecessary to dwell on the practical importance to *navigation* of a correct knowledge of the currents of the ocean; their direction, extent, velocity, and the temperature of the surface water relatively to the ordinary ocean temperature in the same latitude; together with the variations in all these respects which currents experience in different parts of the year and in different parts of their course. As the information on these points, which may be expected to follow from the measures adopted by the Board of Trade, must necessarily depend in great degree on the *intelligence*, as well as the *interest* taken in them by the observers, it is desirable that the instructions to be supplied with the meteorological instruments should contain a brief summary of what is already known in regard to the principal oceanic currents; accompanied by charts on which their supposed limits in different seasons, and the variations in those limits which may have been observed in particular years, may be indicated, with notices of the particularities of the temperature of the surface water by which the presence of the current may be recognized. Forms will also be required for use in such localities, in which the surface temperatures may be recorded at hourly or half-hourly intervals, with the corresponding geographical positions of the ship, as they may be best inferred from observation and reckoning. For such localities also it will be necessary that the tables, into which the observations of different ships at different seasons are collected, should have their bounding lines of latitude and longitude brought nearer together than may be required for the ocean at large.

In looking forward to the results which are likely to be obtained by the contemplated marine observations, it is reasonable that those which may bear practically on the interests of navigation should occupy the first place; but, on the other hand, it would not be easy to overestimate the advantages to physical geography of general tables of the surface temperature of the ocean in the different months of the year, exhibiting, as they would do, its normal and its abnormal states, the mean temperature of the different parallels, and the deviations therefrom, whether permanent, periodical, or occasional. The knowledge which such tables would convey is essentially required for the study of climatology *as a science.*

The degree in which climatic variations, extending over large portions of the earth's surface, may be influenced by the variable phenomena of oceanic currents in different years, may perhaps be illustrated by circumstances of known occurrence in the vicinity of our own coasts. The admirable researches of Major Rennell have shown that in ordinary years the warm water of the great current known by the name of the Gulf Stream is not found to the east of the meridian of the Azores; the sea being of ordinary ocean temperature for its latitude at all seasons and in every direction, in the great space comprised between the Azores, and the coasts of Europe and North Africa; but Major Rennel has also shown that on two occasions, viz: in 1776 and in 1821, 1822, the warm water by which the Gulf Stream is characterized throughout its whole course, (*being several degrees* above the ordinary ocean temperature in the same latitude, was found to extend across this great expanse of ocean, and in 1776 (in particular) was traced (by Dr. Franklin) quite home to the coast of Europe. The presence of a body of unusually heated water, extending for several hundred miles both in latitude and in longitude, and continuing for several weeks, at a season of the year when the prevailing winds blow from that quarter on the coasts of England and France, can scarcely be imagined to be without a considerable influence on the relations of temperature and moisture in those countries. In accordance with this supposition, we find in the meteorological journals of the more recent period, (which are more easily accessible,) that the state of the weather in November and December, 1821, and January, 1822, was so unusual in the southern parts of Great Britain and in France as to have excited general observation; we find it characterized as "most extraordinarily hot, damp, stormy and oppressive," that "the gales from the W. and SW. were almost without intermission," "the fall of rain was excessive" and "the barometer lower than it had ever been known for 35 years before."

There can be little doubt that Major Rennell was right in ascribing the unusual extension of the Gulf Stream in particular years to its greater initial velocity, occasioned by a more than ordinary difference in the levels of the Gulf of Mexico and of the Atlantic in the preceding summer. An unusual height of the Gulf of Mexico at the head of the stream, or an unusual velocity of the stream at its outset in the Strait of Florida, are facts which may admit of being recognized by properly directed attention; and as these must precede, by many weeks, the arrival of the warm water of the stream at above 3,000 miles distance from its outset, and the climatic effects thence resulting, it might be possible to anticipate the occurrence of such unusual seasons upon our coasts.

Much, indeed, may undoubtedly be done towards the increase of our partial acquaintance with the phenomena of the Gulf Stream, and of its counter currents, by the collection and co-ordination of observations made by casual passages of ships in different years and different seasons across different parts of its course; but for that full and complete knowledge of all its particulars which should meet the maritime and scientific requirements of the period in which we live, we must await the disposition of Government to accede to the recommendation so frequently made to them by the most eminent hydrographical authorities, of a specific survey of the stream by vessels employed for that special service. What has been recently accomplished by the Government of the United States in this respect shows both the importance of the inquiry and the great extent of the research; and lends great weight to the proposition which has been made to Her Majesty's Government on the part of the United States, for a joint survey of the whole stream by vessels of the two countries. The establishment of an office under the Board Trade, specially charged with the reduction and co-ordination of such data, may materially facilitate such an undertaking.

Storms or Gales.—It is much to be desired, both for the purposes of navigation and for those of general science, that the captains of Her Majesty's ships, and masters of merchant vessels, should be correctly and thoroughly instructed in the methods of distinguishing *in all cases*, between the rotatory storms or gales, which are properly called *cyolnes*, and gales of a more ordinary character, but which are frequently accompanied by a veering of the wind, which, under certain circumstances, might easily be confounded with the phenomena of cyclones, though due to a very different cause. It is recommended, therefore, that the instructions proposed to be given to ships supplied with meteorological instruments should contain clear and simple directions for distinguishing, *in all cases* and *under all circumstances*, between these two kinds of storms; and that the forms to be issued for recording the meteorological phenomena during great atmospheric disturbances should comprehend a notice of all the particulars which are required for forming a correct judgment in this respect.

Thunder-storms.—It is known that in the high latitudes of the northern and southern hemispheres thunder-storms are almost wholly unknown; and it is believed that they are of very rare occurrence over the ocean in the middle latitudes when distant from continents. By a suitable classification and arrangement of the documents which will be henceforward received by the Board of Trade, statistical tables may in process of time be formed, showing the comparative frequency of these phenomena in different parts of the ocean, and in different months of the year.

It is known that there are localities on the globe where, during certain months of the year, thunder-storms may be considered as a periodical phenomenon of daily occurrence. In the Port Royal Mountains in Jamaica, for example, thunder-storms are said to take place *daily*, about the hour of noon, from the middle of November to the middle of April. It is much to be desired that a full and precise account of such thunder-storms, and of the circumstances in which they appear to originate, should be obtained.

In recording the phenomena of thunder and lightning, it is desirable to state the duration of the interval between the flashes of lightning and the thunder which follows. This may be done by means of a seconds-hand watch, by which the time of the apparition of the flash, and of the commencement (and of the conclusion also) of the thunder may be noted. The interval between the flash and the commencement of the thunder has been known to vary, in different cases, from less than a single second to between 40 and 50 seconds, and even on very rare occasions to exceed 50 seconds. The two forms of ordinary lightning, viz: zigzag (or forked) lightning, and sheet lightning, should always be distinguished apart; and particular attention should be given both to the observation and to the record, in the rare cases when zigzag lightning either bifurcates or returns upwards. A special notice should not fail to be made when thunder and lightning, or either separately, occur in a perfectly cloudless sky. When globular lightning (balls of fire) are seen, a particular record should be made of all the attendant circumstances. These phenomena are known to be of the nature of lightning, from the injury they have occasioned in ships and buildings that have been struck by them; but they differ from ordinary lightning not only by their globular shape, but by the length of time they continue visible, and by their slow motion. They are said to occur sometimes without the usual accompaniments of a storm, and even a perfectly serene sky. Conductors are now so universally employed in ships, that it may seem almost superfluous to remark that, should a ship be struck by lightning, the most circumstantial account will be desirable of the course which the lightning took, and of the injuries it occasioned; or to remind the seaman that it is always prudent, after such an accident has befallen a ship, to distrust her compasses until it has been ascertained that their direction has not been altered. Accidents occuring *on land* from lightning will, of course, receive the fullest attention from meteorologists who may be within convenient distance of the spot.

Auroras and Falling Stars.—Auroras are of such rare occurrence in seas frequented by ships engaged in commerce, that it may seem superfluous to give any particular directions for their observations *at sea;* and land observatories are already abundantly furnished with such. It is, of course, desirable that the meteorological reports received from ships should always contain a notice of the time and place where auroras may be seen, and of any remarkable features that may attract attention.

The letter from Professor Heis, which is one of the foreign communications annexed, indicates the principal points to be attended to in the instructions which it may be desirable to draw up for the observation of "Falling Stars." For directions concerning halos and parhelia, a paper by Monsieur Bravais, in the *Annuaire Météorologique de la France* for 1851, contains suggestions which will be found of much value.

Charts of the Magnetic Variation.—Although the variation of the compass does not belong in strictness to the domain of meteorology, it has been included, with great propriety, amongst the subjects treated of by the Brussels Conference, and should not therefore be omitted here. It is scarcely necessary to remark, that whatever may have been the practice in times past, when the phenomena of the earth's magnetism were less understood than at present, it should in future be regarded as indispensable that variation charts should always be constructed for a *particular epoch*, and that *all parts* of the chart should show *the variation corresponding to the epoch for which it is constructed.* Such charts should also have, either engraved on the face or attached in some convenient manner, a table, showing the approximate annual rate of the secular change of the variation in the different latitudes and longitudes comprised; so that, by means of this table, the variation taken from the chart for any particular latitude and longitude may be corrected to the year for which it is required, if that should happen to be different from the epoch for which the chart is constructed.

A valuable service would be rendered to this very important branch of hydrography if, under the authority of the new department of the Board of Trade, variation charts for the North and South Atlantic Oceans, for the North and South Pacific Oceans, for the Indian Ocean, and for any other localities in which the requirements of navigation might call for them, were published at *stated intervals*, corrected for the secular change that had taken place since the preceding publication. Materials would be furnished for this purpose by the observations which are now intended to be made, supposing them to be collected and suitably arranged with proper references to date and to geographical position, and to the original reports in which the results and the data on which they were founded were communicated.

By means of these observations, the tables of approximate correction for secular change might also be altered from time to time as occasion should require, since the rate of secular change itself is not constant.

All observed variations, communicated or employed as data upon which variation charts may be either constructed or corrected, should be accompanied by other observational data (the nature of which ought now to be well understood) for correcting the observed variation for the error of the compass occasioned by the ship's iron. It also is strongly recommended that no observations be received as data for the formation or correction of variation charts but such as are accompanied by a detailed statement of the principal elements both of observation and of calculation. Proper forms should be supplied for this purpose; or, what is still better, books of blank forms may be supplied, in which the observations themselves may be entered, and the calculation performed by which the results are obtained. Such books of blank forms would be found extremely useful, both for the variation of the needle and for the chronometrical longitude, (as well as for lunar observations, if the practice of lunar observations be not, as there is too much reason to fear it is, almost wholly discontinued.) By preparing and issuing books of blank forms suitable for these purposes, and by requesting their return in accompaniment with the other reports to be transmitted to the Board of Trade at the conclusion of a voyage, the groundwork would be laid for the attainment of greatly improved habits of accuracy in practical navigation in the British mercantile marine.

The President and Council are aware that they have not exhausted the subject of this reply in what they have thus directed me to address to you; but they think that perhaps they have noticed as many points as may be desirable for *present* attention; and they desire me to add that they will be at all times ready to resume the consideration, if required, and to supply any further suggestions which may appear likely to be useful. I have the honor to be, &c.,

W. SHARPEY, *Sec. R. S.*

To the Secretary of the Lords of the Committee of Privy Council for Trade.

With returning peace and quiet to Europe, we find encouragement to hope that the subject of another meteorological conference will again occupy the attention of the great powers of the earth. The magnetic telegraph, the improved instruments, the consent of meteorologists,—nay, the expressed wishes and earnest desire of the most eminent among them,—the co-operation of navigators as observers at sea, the progress which the science of meteorology has been making, and its present condition, seem propitious; they all conspire to make a general system of meteorological co-operation and research for sea and land more and more desirable; nay, they indicate and point to it as *a requirement of the age.*

Every state in christendom is doing something in the meteorological way. Every sovereignty in Europe has established meteorological observatories, provided instruments, and organized a working force of more or less power within its own limits. Thus the expense is incurred, laborers are standing ready in the field, and all the machinery for a universal system is at hand. It only remains to gear it together so that it may move and act in concert. Harmony and glorious results will follow. Spain and Portugal have each within a few years established a system of meteorological observations—the former under the able superintendence of Señor Don Ma. Rico y Sinobas; the latter under that of Dr. G. J. A. D. Pegado. The imperial observatory in Paris has gone a step further: It receives by telegraph a report as to the state of the weather, at 7 A. M., daily, from no less than 24 stations, of which St. Petersburgh, Constantinople, Alger, Rome, and Lisbon are outposts.

The French Academy of Sciences has always favored the plan of a general system; Kupffer, of Russia, is one of its earliest projectors and advocates. The British Government, at the instance of General Burgoyne and Colonel James, once proposed to all nations a uniform plan for certain shore stations; unfortunately it was suffered to fall through. That admirable man of science, M. Quetelet, the President of the Brussels Conference, is most earnest and active in favor of establishing an international plan of meteorological co-operation on the land, and of connecting it with our system for the sea; so are Jomard of Paris, and Leverrier. M. Dové, one of the great meteorologists of the Continent, went from Berlin to Liverpool, to attend the meeting of the British Association, there to advocate the measure in person. Kamtz of Dorpat, Heis of Münster, Kreil of Vienna, Lamont of Bavaria, and Secchi of Rome, are also understood to be warm friends and advocates of such a universal system. Spain, Naples, and the Holy See have already signified their readiness to join other States in a universal system of meteorological observations. The governments of South America, the authorities of India, Portugal, Holland, Denmark, Norway and Sweden, have also either directly signified their readiness to go into conference on such a system, or, by their enlightened and liberal course, given us reason to infer that, when properly solicited, they would not be found in opposition to any such plan for advancing the cause of meteorological science, and through it the good of the human family. I am assured by the friends of this measure in Europe, that if the United States will but do for the extension of our observations to the land what was done by Mr. Everett and Mr. Webster, while Secretaries of State, and by Governor Graham and Mr. Dobbin, while Secretaries of the Navy, for the establishing of them at sea, the nations, and meteorologists of Great Britain and the Continent, would meet us as readily again, and join hands with us as cordially, as they did at Brussels in 1853.

EXPLANATION OF THE PLATES.

Plate I is intended to illustrate the Pilot Charts, and is a section taken from one of the manuscripts of that series. It illustrates the method for co-ordinating for these charts the winds as reported in the abstract logs. For this purpose the ocean is divided into convenient sections, usually five degrees of latitude by five degrees of longitude. These parallelograms are then subdivided into a system of engraved squares; the months of the year being the ordinates, and the points of the compass being the abscissas. As the wind is reported by a vessel that passes through any part of the parallelogram, so it is assumed to have been at that time all over the parallelogram. From such investigations as this the Pilot Charts are constructed. (*Vide* p. 297, *et seq.*)

Plate II is explanatory of the Pilot Charts as they appear when published. It is a sample of them, and is fully explaned at p. 297, *et seq.*

Plate III is a diagram of the winds, and is intended especially to illustrate the circulation of the atmosphere, as described in Chapter II, p. 16. The arrows and bands within the circumference of the circle are intended to show the calm belts, and prevailing direction of the wind on each side of those belts. The arrows exterior to the periphery of the circle—which is a section of the earth supposed to be made in the plane of the meridian—are intended to show the direction of the upper strata of winds in the general system of atmospherical circulation; and also to illustrate how the air, brought by each stratum to the calm belts, there ascends, or descends, as the case may be; and then, continuing to flow on, how it crosses over in the direction in which it was travelling when it arrived at the calm zone. (*Vide* p. 17.)

Plate IV is a sample of the Storm and Rain Charts. It is an extract from one of them. (*Vide* p. 317.)

Plate V: the data for this Plate are furnished by the Storm and Rain Charts, including observations for 107,277 days in the North Atlantic, and 158,025 in the South; collated by Lieutenant J. J. Guthrie, at the Washington Observatory, in 1855.

The heavy vertical lines, 5°, 10°, 15°, &c., represent parallels of latitude, the other vertical lines, months; and the horizontal lines, per cents., or the number of days in a hundred on which storms, rain, &c., occur.

The continuous curve line stands for phenomena in the North, and the broken curve line for phenomena in the South Atlantic. Thus the Gale Curve shows that in every hundred days, and on the average, in the month of January of different years, there have been observed, in the northern hemisphere, 36 gales (36 per cent.) between the parallels of 50° and 55°; whereas during the same time and between the corresponding parallels in the southern hemisphere, only 10 gales on the average (10 per cent.) have been reported.

The fact is here developed that the atmosphere is in a more unstable condition in the North than in the South Atlantic; that we have more calms, more rains, more fogs, more gales, and more thunder in the northern than in the southern hemisphere, particularly between the equator and the 55th parallel. Beyond that, the influence of Cape Horn becomes manifest.

Plate VI is intended to demonstrate how the winds may become geological agents. It shows whence the winds that blow, in the general system of atmospherical circulation, over the deserts and thirsty lands in Asia and Africa (where the annual amount of precipitation is small,) are supposed to get their vapors; where, as surface winds, they are supposed to condense portions of it; and whither they are supposed to transport the residue thereof through the upper regions, retaining it until they again become surface winds. To make clear the course of such vapor-bearing winds, let A be a breadth or *swarth* of winds in the northeast trades; B, the same wind as the upper and counter-current to the southeast trades; and C, the same wind after it has descended in the calm belt of Capricorn, and come out on the polar side thereof, as the rain winds and prevailing northwest winds of the extra-tropical regions of the southern hemisphere.

This wind, when in the northeast trades, was the evaporating wind; as the northeast trade-wind, it swept over a great waste of waters lying between the tropic of Cancer and the equator.

Meeting no land in this long oblique track, over the tepid waters of a tropical sea, it would, if such were its route, arrive somewhere about the meridian of 140° or 150° west, at the belt of equatorial calms, which always divides the northeast from the southeast trade-winds. Here, depositing a portion of its vapor as it ascends, it would, with the residuum, take, on account of diurnal rotation, a course in the upper region of the atmosphere to the southeast as far as the calms of Capricorn. Here, according to the hypothesis which this plate is used to illustrate, it descends and continues on toward the coast of South America, in the same direction, appearing now as the prevailing northwest wind of the extra-tropical regions of the southern hemisphere. Travelling on the surface from warmer to colder regions, it must, in this part of its circuit, precipitate more than it evaporates.

Now it is a coincidence, at *least*, that this is the route by which, on account of the land in the northern hemisphere, the northeast trade-winds have the fairest sweep over that ocean; that this is the route by which they are longest in contact with an evaporating surface; that this is the route by which all circumstances are most favorable to complete saturation; and that this is the route by which such winds can pass over into the southern hemisphere most heavily laden with vapors for the extra-tropical regions of that half of the globe; and, moreover, that this is the supposed route which the northeast trade-winds of the Pacific do take to reach the equator, and to pass from it.

I have also marked on this plate the supposed track of the sea-dust, showing where it was taken up in South America, as at P, P, and where it was found as at S, S; the part of the line in dots denoting where it was in the upper current, and the unbroken line where it was wafted by a surface current; also, on the same plate is designated the part of the South Pacific in which the vapor-springs for the Mississippi rains are supposed to be. The hands (☞) point out the direction of the vapor-bearing wind. Where the shading is light, the vapor is supposed to be carried by an upper current.—(See p. 47, *et seq.*)

Plates VII and VIII are drawings of Brooke's Improved Deep-Sea Sounding Apparatus, which is fully described at p. 120.

Plate IX illustrates the method of co-ordinating for the Whale Charts, in order to show how many days in each month for each district have been spent by vessels in search of whales, and on how many of these days whales have been seen. It is fully explained at p. 319.

Plate X is a sample of the Whale Charts that are constructed after the materials for it have been co-ordinated in the manner of Plate IX. It is fully explained at p. 319, *et seq.*

Plates XI and XII are orographic of the Atlantic Ocean, and exhibit completely the present state of our knowledge with regard to the elevations and depressions in the bed of that sea. The first and darkest shade of stippling—Plate XI—going from the shore, represents all depths of less than 1,000 fathoms; the next, of more than 1,000, but less than 2,000; the next, of more than 2,000, but less than 3,000, and so on, each shade representing 1,000 fathoms. The unshaded place south of Newfoundland is, probably, the deepest part of the North Atlantic. (*Vide* p. 167.)

Fig. 3, Plate XII is the profile of the Atlantic as to depth along the Telegraphic Plateau, according to Lieutenant Berryman's soundings, as actually recorded in the abstract log of the United States steamer Arctic, at the time the soundings were made. Figs. 1 and 2, of the same plate, are the profiles of the same as projected at different times by that officer from said soundings. They are given to show the true character of those soundings, and to satisfy those who are interested in the problem of deep-sea soundings that those of the Arctic are not entitled to the confidence of any physicist. *Vide* pp. 154, 156. Fig. 4 is the profile of the same according to the soundings of Commander Dayman in her Britannic Majesty's steamer "Cyclops." That officer proceeded in the most faithful manner to execute this duty. A complete record of the work in all desirable detail has been published by the admiralty. He used sometimes a Massey's sounding machine, sometimes the common deep sea hand line, weighing 23 pounds to the 100 fathoms, sometimes a tapered whale line, weighing 96 pounds to the 100 fathoms, and sometimes a silk thread about 1 of an inch in diameter. His weights also varied from 32 to 96 pounds. This difference as to line, sinker, and method may help to account for the apparent regularity in the undulation of the bottom. *These soundings make the sea to appear deeper than it really is.** Figs. 5 and 6 are sections, natural size of the sub-Atlantic telegraphic cord of 1857. *Vide* p. 181.

Plate XIII illustrates many phenomena connected with the Gulf Stream, and the general movement of the waters in the North Atlantic Ocean. It shows the mean place of the Sargasso Sea, also the channel way of the Gulf Stream. The diagram A shows a thermometrical profile presented by cross sections of the Gulf Stream, according to observations made by the hydrographical parties of the United States Coast Survey. The elements for this diagram were kindly furnished me by the superintendent of that work. They are from a paper on the Gulf Stream, read by him before the American Association for the Advancement of Science, at its meeting in Washington, 1854. Imagine a vessel to sail from the Capes of Virginia straight out to sea, crossing the Gulf Stream at right angles, and taking the temperature of its waters, both at the surface and at various depths. This diagram shows the elevation and depression of the thermometer across this section, as they were actually observed by such a vessel.

The black lines x, y, z, in the Gulf Stream, show the course which those threads of warm waters take. The lines a, b, show the route that the unfortunate steamer San Francisco would, according to calculation, take after her terrible disaster in December, 1853. (*Vide* pp. 101, 108, &c.)

Plate XIV is a diagram illustrative of the general circulation of the ocean as induced chiefly by changes of temperature as well as differences of temperature; it also shows the most favorite places of resort to the whale. (*Vide* pp. 84, 88.) Just west of South America, there is a large region of the Pacific which seems to be avoided by the whales as well as by other creatures. Seamen have described it to me as the most desolate and lifeless part of

*A copy of these soundings was not received in time for discussion in the appropriate place.

the ocean through which they have ever passed. Even the birds, the cape pigeons and stormy petrels, and others, which have followed them for many days, disappear here, and almost all signs of animation cease. It is traversed by the homeward bound vessels from Australia, including those that go to Peru for guano. Captain Leighton, of the English ship Marion, in an abstract log kept by him, on a voyage, in 1855, from Australia to Callao, and returned to this office, thus speaks of it:—

"Between the positions of 44° and 39° S. and 122° and 88° W. appeared to me remarkably desolate. There was nothing seen in the water and the air, which, in the great Southern Ocean, are so generally alive with birds; we were almost deserted. Those desirable companions, the cape pigeons, were never seen, and very rarely the whale bird; but the universal petrel was never seen, and they had stuck to us constantly even through the tropics. Two or three albatrosses, or the bird like and next in size to it, were all that we saw."

The attention of navigators is invited to this place and circumstance, for I should be glad to have more light upon this subject.

Plate XV is intended simply to show, in a very general way, the prevailing *quarter* of the winds, the calm belts, and some of the principal routes, as derived from the series of investigations illustrated on Plate I, Vol. II. When the cross lines representing the yards are oblique to the keels of the vessels on the plate, they indicate that the winds are, for the most part, ahead; when perpendicular or square, that the winds are, for the most part, fair. The figures on or near the diagrams representing the vessels show the average length of the passage in days.

The arrows denote the prevailing quarter of the wind; they are supposed to fly *with* it; so that the wind is going as the arrows point. The half-bearded and half feathered arrows represent monsoons; and the stippled or shaded belts, the calm zones.

In the regions on the polar side of the calms of Capricorn and of Cancer, where the arrows are flying both from the northwest and the southwest, the idea intended to be conveyed is, that the prevailing direction of the wind is between the northwest and the southwest, and that their frequency is from these two quarters, in proportion to the number of arrows. (*Vide* pp. 36, 41.)

Plate XVI:—Isotherms for March and September in North and South Atlantic. It is very instructive, and shows at a glance not only that there is a marked difference of the climates of countries situated at equal distances from the equator north and south, but the cause of that difference. The isotherms of 50° and 60° run nearly east and west across the South Atlantic; but in the North, they run northeast with the Gulf Stream. (*Vide* p. 103.)

Plate XVII exhibits the curves of temperature and specific gravity for every parallel of latitude from Behring's Straits to Cape Horn, and thence to New York; also, for every meridian in the North Pacific between China and California, and in the South Indian Ocean between Africa and Australia. *Vide* p. 236.

Plate XVIII exhibits the curves of the thermal dilatation of sea water for every degree of temperature from 22° to (90°?) It also exhibits drawings of the instruments used for these determinations. *Vide* p. 237, *et seq.*

Plate XIX is offered in explanation of the use to be made at sea of the blank barometric chart of engraved squares which accompanies the abstract log. *Vide* p. 367, 368.

Plates XX and XXXIX are the drawings of the "insects of the sea" taken on board the "Gloriana" and the "Metropolis." They are described at p. 223, *et seq.*

THE TWELVE "SPOTTED" PLATES.—(GALES IN THE ATLANTIC.)

The twelve plates, *i. e.*, one for each month, relate to gales in the Atlantic. They are derived from the Storm and Rain Charts, (pp. 317, 318;) they are expressed in colors and addressed to the eye; and are intended simply to show the relative frequency of gales during each month in various parts of the Atlantic Ocean, North and South.

They are compiled from the abstract logs of the observatory, and embody the results of 265,292 days of observation.

These observations show, that in those parts of the ocean which are colored purple a gale of wind is recorded, at least, as often as once in every six days; and so on for the blue and pink as per explanation on the plates.

In those parts of the ocean which are not colored, the logs show that a gale has not been encountered as often on the average as once a fortnight. It should, however, be borne in mind that the absence of these colors does not *necessarily* indicate a tranquil sea; many, and probably stormy, parts are left blank for the want of observations. Take the plate for January, by way of illustration: The abstract logs contain few or no records on the Polar side of the colored spaces either in the North or South Atlantic. The waters on the Polar side of these spaces lie in anti-commercial regions of the sea; none of the frequented routes of trade lead through them, and our information, therefore, as to the frequency of storms in them is simply negative.

On the equatorial side of these colored spaces, on the contrary, our information for the most part is abundant, and it shows that however severe the tornadoes and hurricanes of the inter-tropical seas may be, they do not occur, on the average, as frequently as the storms of extra-tropical seas.

The limits of the stormy regions are traced with a free hand. Owing to the manner in which the gales are "got out," this must be so. Each one of the parallelograms made by the intersection of the 5° meridians with the 5° parallels of latitude, is called a *field*, and all the observations that are made by vessels during their passage through any one field are grouped together; and whether these vessels happen to pass through one corner of the field only, or through all parts of it, the observations are held to give character to the whole field.

But certainly the storms in their ragings are not confined by these sides of imaginary figures or arbitrarily described parallelograms. Nevertheless, for the sake of connecting one stormy parallelogram with another, *the outlines* of a stormy region have often been arbitrarily drawn. Take the eastern end of the purple in the South Atlantic for January as an illustration: It so happens that we have but few observations in the field between the meridians of 5° and 10° west, and the parallels of 40° and 45° south. In the field to the east of that the records were more abundant; they mention 82 gales in 489 days. Should the former field be left blank because there are not so many observations in it? I have thought not.

With this explanation, we are surprised to see how very much more stormy are some months than others, how tranquil the trade-wind regions are, and how very much more boisterous is the North than the South Atlantic.

At no season of the year can the passage around either of the "Stormy Capes," as poets call them, vie for storms with the winter passage between England and America.

I have gone into an investigation of the abstract logs for the purpose of ascertaining the most tranquil and favorable time for laying the sub-Atlantic Telegraph, with reference to gales, fogs, and ice. The season that presents the most favorable combination of these is also the most favorable season for passenger travel across the Atlantic; and that season is found to be about the last of July and first of August. This part of the ocean is most tranquil in summer. Taking averages, we have in it fewer gales but more fogs and ice in June than in July or August, but fewer fogs and least ice in August. The last of July and first of August appear to be the most favorable time for laying the sub-Atlantic Telegraph. This information may be useful to invalids and others crossing the Atlantic, as well as those engaged in this enterprise.

These plates are obviously suggestive. They are the fruits of a beautiful system of physical research, in the prosecution of which the leading nations of the world are vieing with each other; and they are respectfully submitted as a small mite among the many offerings that are daily cast into the common treasury, which I hope soon to see so enlarged that it will comprehend the results of a like system of co-operation and research for the land also.

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THE WIND AND CURRENT CHARTS.

CHAPTER I.

Investigations should be extended to the land, § 1.—The field of research, § 2.—Some of the practical advantages already obtained for navigation, § 3.—Their importance to other nations, § 4.

THE great demand among seamen for these Charts, and the interest they have excited among philosophers, make it proper to give some account of their origin and progress. We will also take a survey of the field of research from which these Charts have been gathered, and show the steps that have been taken to occupy it with laborers.

This seems to be the more proper, since I hope, by giving such an account, to impress with the importance of the undertaking seafaring men, and others who have it in their power to facilitate the work.

"In the present condition of the surface of our planet," says Baron Humboldt, the most celebrated philosopher of the age, "the area of the solid is to that of the fluid parts as 1 to $2\frac{4}{5}$, (according to Rigaud, as 100 to 270.) The islands form scarcely $\frac{1}{23}$ of the continental masses, which are so unequally divided that they consist of three times more land in the northern than in the southern hemisphere; the latter being, therefore, pre-eminently oceanic. From 40° south latitude to the antarctic pole the Earth is almost entirely covered with water. The fluid element predominates in like manner between the eastern shores of the old and the western shores of the new continent, being only interspersed with some few insular groups. The learned hydrographer Fleurieu has very justly named this vast oceanic basin, which, under the tropics, extends over 145° of longitude, the Great Ocean, in contradistinction to all other seas. The southern and western hemispheres (reckoning the latter from the meridian of Teneriffe) are therefore more rich in water than any other region of the whole earth.

"These are the main points involved in the consideration of the relative quantity of land and sea, a relation which exercises so important an influence on the distribution of temperature, the variation in atmospheric pressure, the direction of the winds, and the quantity of moisture contained in the air, with which the development of vegetation is so essentially connected. When we consider that nearly three-fourths of the upper surface of our planet are covered with water, we shall be less surprised at the imperfect condition of meteorology before the beginning of the present century; since it is only during the subsequent period that numerous accurate observations on the temperature of the sea at different latitudes, and at different seasons, have been made and numerically compared together."—*Humboldt's Cosmos.*

1. "I beg you to express to Lieut. Maury, the author of the beautiful *Charts of the Winds and Currents,* prepared with so much care and profound learning, my hearty gratitude and esteem. It is a great undertaking, equally important to the practical navigator and for the advance of meteorology in general. It has been viewed in this light in Germany by all persons who have a taste for physical geography. In an analogous way, my theory of isothermal

lines (equal annual temperature) has for the first time become really fruitful, since Dove has taught us the isotherms of the several months chiefly on the land; since two-thirds of the atmosphere rest upon the sea, Maury's work is so much the more welcome and valuable, because it includes at the same time the oceanic currents, the course of the winds, and the temperature. How remarkable are the relations of temperatures in Sheet No. 2, South Atlantic, east and west of longitude 40; how much would this department of meteorology gain if it were filled up according to Maury's proposition to Commodore Lewis Warrington concerning the Abstract Log. The shortening of the voyage from the United States to the equator, is a beautiful result of this undertaking. The bountiful manner in which these Charts are distributed raises our expectations still higher."—*Baron Von Humboldt to Dr. Flügel, U. S. Consul, Leipsic.*

2. It is not for the benefit of navigation alone that seamen are invited to make observations and collect materials for the Wind and Current Charts; other great interests besides those of commerce have their origin in the ocean, or the air; and these interests are doubtless to be advanced as we gain knowledge of the laws which govern the circulation of the atmosphere, and regulate the movements of the aqueous portions of our planet. All knowledge is interesting.

The agricultural capacities of any place are as dependent upon the hygrometrical as they are upon the thermometrical condition of the atmosphere. This is obvious and easily illustrated.

Each kind of plant requires, for its most perfect development, a certain degree of moisture, and the winds which bring that moisture can get it only from the sea, or other evaporating surfaces.

It is often argued because wine, olives, or other products are raised on a given parallel of latitude, that they should be produced upon the same parallel wherever the proper soil is to be found; but the route which the winds from the ocean take in reaching the supposed parallel should not be overlooked.

Virginia and California are between the same parallels, yet how different their agricultural resources, the character and flavor of their fruits! all owing, not so much to difference of soil as to the way the winds blows, the quantity of moisture they bring, the proportion of clouds and sunshine allotted to each place.

The system of researches embraced by the Wind and Current Charts, therefore, concern the philosopher and the husbandman, as well as the mariner, the merchant, and the statesman.

A wider field, or one more rich with promise, has never engaged the attention of the philosopher. Though so often frequented, it has never been explored, if by exploration we mean collecting and grouping, with the view of tracing, in the true spirit of inductive philosophy, fact into effect, and effect up to cause, all those phenomena which mariners observe in connection with the ocean and the air above it.

The mariner, therefore, when he is making and recording out at sea an observation in connection with these Charts, should always remember that upon the fidelity of the observation and the record depends the ability of the Philosopher to read aright the workings of those agents that are employed to produce, in the grand scheme of creation, those results which are the subjects of his observations.

The wind and rain; the vapor and the cloud; the tide, the current, the saltness, depth, warmth, and color of the sea; the shade of the sky; the temperature of the air; the tint and form of the clouds; the height of the tree on the shore, the size of its leaves; the brilliancy of the flowers;—each and all may be regarded as the exponent of certain physical combinations, and, therefore, as the expression in which Nature chooses to announce her meaning, or the language in which she writes the operation of her laws. To understand that language, and to interpret aright those laws, is the object of the undertaking which those who co-operate with me have in hand. To those who tread the walks of inductive philosophy no fact gathered in such a field as this can come amiss; for, in the handbook of Nature, every such fact is a syllable; and it is by patiently collecting fact after fact, and by joining syllable after syllable, that we may finally hope to read with understanding in the great volume which, in sea and air, is continually spread out before sailor and philosopher.

3. Dr. Buist, a learned and eminent *savant* of India, has drawn a beutiful picture of our field of research.

In the report on the affairs of the "Bombay Geographical Society," presented by the Secretary at the annual meeting in May, 1850, he remarks: "The Assistant Secretary of your Society,* Mr. Macfarlane, has made considerable progress in the construction of Wind and Current Charts founded on the information supplied by ships' logs, and on the principle of Lieutenant Maury. It is more than probable that, besides the currents occasioned by the trade-winds, monsoons, and set of the tides, we have a group of movements intermingled with those dependent mainly on evaporation. When it is remembered that on the western shore of the Arabian Sea, including in this the Red Sea and Persian Gulf, from the line northward, we have an expanse of coast of not less than 6,000 miles, and a stretch of country of probably not less than 100 miles inland from this, where the average fall of rain does not amount to four inches annually, where not one-half of this ever reaches the sea, and where, to the best of our knowledge, the evaporation over the ocean averages at least a quarter of an inch daily, all the year round, or close on eight feet annually, some idea of the enormous abstraction of water in the shape of vapor may be formed. On the assumption that this extends no further, on an average, than 50 miles out to sea, we shall have no less than 39 cubic miles of water raised annually in vapor from the northern and northwestern side of the basin, which must be supplied from the open ocean on the south or the rain on the east. The fall of rains on the western side of the ridge of the mountain chain, from Cape Comorin to Cutch, averages pretty nearly 180 inches annually, and of this at least 160 is carried off to the sea; that on the Concan, to 70 inches, of which probably 30 flow off to the ocean; or betwixt the two, over an area of twenty miles from the sea-shore to the Ghauts, and about 1,200 miles from the north to the south, or an area of 24,000 square miles in all, we shall probably have an average discharge of nine feet, or close on forty cubic miles of water—an amount sufficient, were it not diffused, to raise the sea on our shores three feet high, over an area of 72,000 square miles.

"The waters of the ocean cover nearly three-fourths of the surface of the globe; and of the thirty-eight millions of miles of dry land in existence, twenty-eight millions belong to the northern hemisphere. The mean depth of the ocean is somewhere about four miles—the greatest depth the sounding-line has ever reached is five and a quarter miles. The mean elevation of the land, again, is about one thousand feet—the highest point known to us is nearly as much above the level of the sea as the great depth that has been measured is below it. The atmosphere, again, surrounds the earth like a vast envelope; its depth, by reason of the tenuity attained by it, as the superincumbent pressure is withdrawn, is unknown to us; but is guessed at somewhere betwixt fifty and five hundred miles. Its weight, and its constituent elements, have been determined with the utmost accuracy. The weight of the mass

* *Vide* Transactions Bombay Geographical Society, Vol. IX, 1850, p. 80, *et seq.*

is equal to that of a solid globe of lead sixty miles in diameter. Its principal elements are oxygen and nitrogen gases, with a vast quantity of water suspended in them in the shape of vapor, and commingled with these a quantity of carbon in the shape of fixed air, equal to restore from its mass many fold the coal that now exists in the world. In common with all substances, the ocean and the air are increased in bulk, and consequently diminished in weight, by heat; like all fluids, they are mobile, tending to extend themselves equally in all directions, and to fill up depressions in whatever vacant space will admit them; hence, in these respects, the resemblance betwixt their movements. Water is not compressible or elastic, and it may be solified into ice, or vaporized into steam; the air is elastic, it may be condensed to any extent by pressure, or expanded to an indefinite degree of tenuity by pressure being removed from it; it is not liable to undergo any change in its constitution beyond these by any of the ordinary influences by which it is affected. These facts are few and simple enough—let us see what results arise from them. As the constant exposure of the equatorial regions of the Earth to the Sun must necessarily here engender a vast amount of heat—and as his absence from the polar regions must in like manner promote an infinite accumulation of cold—to fit the entire Earth for a habitation to similar races of beings, a constant interchange and communion, betwixt the heat of the one and the cold of the other, must be carried on. The ease and simplicity with which this is effected surpass all description. The air, heated near the equator by the overpowering influence of the Sun, is expanded and lightened; it ascends into upper space, leaving a partial vacuum at the surface to be supplied from the regions adjoining. Two currents from the poles towards the equator are thus established at the surface, while the sublimated air, diffusing itself by its mobility, flows in the upper regions of space from the equator towards the poles. Two vast whirlpools are thus established, constantly carrying away the heat from the torrid towards the icy regions, and these becoming cold by contact with the ice, carry back their gelid freight to refresh the torrid zone. Did the Earth, as was long believed, stand still while the Sun circled around it, we should have had two sets of meridional currents blowing at the surface of the earth, directly from north and south, towards the equator, in the upper regions flowing back again to the place whence they came. On the other hand, were the heating and cooling influences, just referred to, to cease, and the earth to fail in impressing its own motion on the atmosphere, we should have a furious hurricane rushing round the globe, at the rate of one thousand miles an hour—tornadoes of ten times the speed of the most violent now known to us sweeping everything before them. A combination of the two influences, modified by the friction of the Earth, which tends to draw the air after it, gives us the trade-winds, which sweep round the equatorial region of the globe unceasingly, at the speed of from ten to twenty miles an hour; the aerial current, quitting the polar regions with the comparatively tardy speed, from east to west, imposed on it by the velocity due to the 70th parallel, is left behind the globe, and deflected into an oblique current as it advances southward, till meeting the current from the opposite pole near the equator the two combine and form the vast stream known as the trades—separated in two, where the air ascends by the belt of variable winds and rains. Impressed with the motion of the air, constantly sweeping its surface in one direction, and obeying the same laws of motion, the great sea itself would be excited into currents similar to those of the air, were it not walled in by continents and subjected to other control. As it is, there are constant currents flowing from the torrid towards the frigid zone, to supply the vast mass of vapor there drained off; while other whirlpools and currents, such as the gigantic Gulf Stream, come to perform their part in the same stupendous drama. The currrent just named sweeps across the Atlantic to the Gulf of Mexico, and by the Straits of the Bahamas. Here it turns to the eastward, again travelling along the coast of America at the rate of from forty to a hundred miles a day. It now stands once more across the Atlantic, and divides itself into two branches; one finds its way into the northern sea, warming the adjoining waters as it advances, and turning back, most likely to form a second great whirlpool, rejoining the original stream near Newfoundland. The main branch seeks the northern shores of Europe, and, sweeping along the coast of Spain and Portugal, travels southward by the Azores to rejoin the main whirlpool. The waters of this vast ocean river are, to the north of the tropic, greatly warmer than those around; the climate of every country it approaches is improved by it, and the Laplander is enabled by its means to live and cultivate his barley in a latitude which everywhere else throughout the world is condemned to perpetual sterility. But there are other laws which the great sea obeys, which peculiarly adapt it as the vehicle of interchange of heat and cold betwixt those regions where either exists in excess. Water which contracts regularly from the boiling point downwards, at a temperature of 40° has reached its maximum of density, and thence begins to grow lighter and expand. But for this most beneficent provision the vast recesses of the Northern Ocean would be continually occupied with a fluid at the freezing point, which the least access of cold would convert into one solid mass of ice. The non-conducting power of water, which at present acts so valuable a part in the general economy, so far from being a blessing would be a curse. No warmth could ever penetrate to thaw the foundations of the frozen mass—no water find its way to float it from its foundations; so that, like the everlasting hills themselves, rooted immovable in its place, every year adding to its mass, the solid structure would continually advance to the southward, hermetically sealing the polar ocean, thus condemned to utter desolation, and encroaching on the North Sea itself. Under existing circumstances, so soon as water is cooled down to 40°, it sinks to the bottom, and, still eight degrees warmer than ice, it attacks the basis and saps the foundations of the icebergs, themselves gigantic glaciers, which have fallen from the mountains into the sea, or which have grown to their present size in the shelter of bays and estuaries, and by accumulations from above. Once forced from their anchorage, the first storm that arises drifts them to sea, where the beautiful law which renders ice lighter than the warmest water enables it to float, and drifts southward a vast magazine of cold to cool the tepid water which bears it along; the evaporation at the equator causing a deficit, the melting and accumulation of the ice in the frigid zone giving rise to an excess of accumulation, which tends, along with the action of the air and other causes, to institute and maintain the transporting current. These stupendous masses, which have been seen at sea in the form of church spires, and gothic towers, and minarets, rising to the height of from 300 to 600 feet, and extending over an area of not less than six square miles, the masses above water being only one-tenth of the whole, are often to be found within the tropics. A striking fact, dependent on this general law, has just been brought to light; there is a line extending from pole to pole, at or under the surface of the ocean, where an invariable temperature of 39.5 is maintained. The depth of this varies with the latitude; at the equator it is 7,200 feet; at latitude 56° it ascends to the surface, the temperature of the sea being here uniform throughout. North and south of this the cold water is uppermost, and at a latitude 70° the line of uniform temperature descends to 4,500. But these, though amongst the most regular and magnificent, are but a small number of the contrivances by which the vast and beneficent ends of nature are brought about. Ascent from the surface of the Earth produces the same change, in point of climate, as an approach to the poles; even under the torrid zone, mountains reach the line of perpetual congelation at nearly a third less altitude than the extreme elevation which they sometimes attain. At the poles snow is perpetual at the ground, and at the different intervening latitudes reaches some intermediate point of congelation, betwixt one and 20,000 feet. In America, from the line south to the tropics, as also, as there is now every reason to believe, in Africa, within similar latitudes, vast ridges of mountains, covered with perpetual snow, run northward and southward in the line of meridian, right across the path of the trade-winds. A similar ridge, though of less magnificent dimensions, traverses the peninsula of Hindoostan, increasing in altitude as it approaches the line—attaining an elevation of 8,500 feet at Dodabetta, and above 6,000 in Ceylon. The Alps in Europe, and the gigantic chain of the Himalayas in Asia, both far south in the temperate zone, stretch from east to west, and intercept the aerial current from the north. Others of lesser note, in the equatorial or meridional, or some intermediate direction, cross the paths of the atmospherical currents in every direction, imparting to them fresh supplies of cold, as they themselves obtain from them warmth in exchange; in strictness, the two operations are the same. Magnificent and stupendous as are the effects and results of the water and of air acting independently on each other, in equalizing the temperature of the globe, they are still more so when combined. One cubic inch of water, when invested with a sufficiency of heat, will form one cubic foot of steam; the water before its evaporation and the vapor which it forms being exactly of the same temperature; though in reality, in the process of conversion, 1,700 degrees of heat have been absorbed or carried away from the vicinage, and rendered latent or imperceptible; this heat is returned in a sensible and perceptible form the moment the vapor is converted once more into water. The general fact is the same in the case of vapor carried off by dry air at any temperature that may be imagined; for, down far below the freezing point evaporation proceeds uninterruptedly, or raised into steam by artificial means. The air, heated and dried as it sweeps over the arid surface of the soil, drinks up by day the myriads of tons of moisture from the sea; as much, indeed, as would, were no moisture restored to it, depress its whole surface at the rate of four feet annually over the surface of the globe. The quantity of heat thus converted from a sensible or perceptible to an insensible or latent state is almost incredible. The action equally goes on, and with the like results, over the surface of the earth as over that of the sea, where there is moisture to be withdrawn. But night and the seasons of the year come around, and the surplus temperature thus withdrawn and stored away, at the time it might have proved superfluous or inconvenient, is reserved, and rendered back so soon as it is required; and the cold of night and the rigor of winter are modified by the heat given out at the point of condensation by dew, rain, hail, and snow.

"There are, however, cases in which, were the process of evaporation to go on without interruption and without limit, that order and regularity might be disturbed, which is the great object of the Creator apparently for an indefinite time to maintain, and in the arrangements for equalizing temperature the equilibrium of saltness be disturbed in certain portions of the sea, and that of moisture under ground in the warmer regions of the earth. To prevent this, checks and counterpoises interpose just as their services come to be required. It could scarcely be imagined that in such of our inland seas as were connected by a narrow strait with the ocean, and were thus cut off from free access to its waters, the supply of fresh water which pours into them from the rivers around would exactly supply the amount carried away by evaporation. Salt never rises in steam, and it is the pure element alono that is drawn off. We have in such cases as the Baltic and Black Seas an excess of supply over what is required, the surplus in the latter case flowing off through the Dardanelles, in the former through the Great and Little Belts. The vapor withdrawn from the Mediterranean exceeds by about a third the whole amount of fresh water poured into it; the difference is made up by a current through the Straits of Gibraltar in the latter; and a similar arrangement, modified by circumstances, must exist in all cases where circumstances are similar—the supply of water rushing through the strait from the open ocean being in exact proportion to the difference betwixt that provided from rain or by rivers and that required by the afflux of vapor; seas wholly isolated, such as the Caspian and the Dead Sea, attain in course of time a state of perfect equilibrium—their surface becoming lowered in level and diminished in area, till it becomes exactly of the proper size to yield in vapor the whole waters poured in. The Dead Sea, before attaining this condition of repose, has sunk thirteen hundred feet below the Mediterranean, the Caspian about one-fourth of this. Lakes originally salt, and which to all appearance are no more than fragments severed from the sea by the earthquake or volcano, and which have no river or rain supplies whatever, in process of time dry up and become a mass of rock salt in their former basin. Such is the formation in progress in the lake near Tadjurra, nearly five hundred feet below the level of the sea, its waters having been thus much depressed by evaporation, having now almost altogether vanished, one mass of salt remaining in their room. As it is clear in a case such as that of the Mediterranean, that where salt water to a large extent was poured in and fresh water only was drawn off, a constant concentration of brine must occur, the proposition was laid down by the most distinguished of our geologists, and long held unquestionable, that huge accumulations of salt, in masses larger than all that Cheshire contains, were being formed in its depths. The doctrine, eminently improbable in itself, is now met by the discovery of an under-current, in all likelihood of brine. It is matter of easy demonstration that, without some such arrangement as this, the Red Sea must long ere now have been converted into one mass of salt, its upper waters at all events being known in reality to differ at present but little in saltness from those of the Southern Ocean. The Red Sea forms an excellent illustration of all kindred cases. Here we have salt water flowing in perpetually through the Straits of Babelmandeb, to furnish the supplies for a mass of vapor calculated, were the straits shut up, to lower the whole surface of the sea eight feet annually—and even with the open strait, to add to its contents a proportionate quantity of salt. But an under-current of brine, which, from its gravity, seeks the bottom, flows out again to mingle with the waters of the great Arabian Sea, where, swept along by currents and raised to the surface by tides and shoals, it is mingled by the waves, through the other waters, which yearly receive the enormous monsoon torrents, the Concan and the Ghaut's supply become diluted to the proper strength of sea water, and rendered uniform in their constitution by the agitation of the storms which then prevail. Flowing back again from the coasts of India, where they are now in excess, to those of Africa, where they suffer from perpetual drainage, the same round of operations go on continually; and the sea, with all its estuaries and its inlets, retains the same limit, and nearly the same constitution, for unnumbered ages. A like check prevents on shore the extreme heating and desiccation from which the ground would otherwise suffer. The Earth is a bad conductor of heat; the rays of the Sun which enter its surface, and raise its temperature to 100 or 150°, scarcely penetrate a foot into the ground; a few feet down the warmth of the ground is nearly the same night and day. The moisture which is there preserved free from the influence of currents of air is never raised into vapor; so soon as the upper stratum of earth becomes thoroughly dried, capillary action, by means of which all excess of water was withdrawn, ceases; and even under the heats of the tropics the soil two feet down will be found on the approach of the rains sufficiently moist for the nourishment of plants. The splendid flowers and vigorous foliage which burst forth in May, when the parched soil would lead us to look for nothing but sterility, need in no way surprise us; fountains of water boundless in extent and limited in depth by the thickness of the soil which contains them, have been set aside and sealed up for their use beyond the reach of those thirsty winds or burning rays, which are suffered only to carry off the water which is superfluous, and would be pernicious, removing it to other lands where its agency is required, or treasuring it up in the crystal vault of the firmament as the material of clouds and dew, and the source, when the fitting season comes round again, of those deluges of rain which provide for the wants of the year.

"Such are some of the examples which may be supplied of general laws operating over nearly the whole surface of the terraqueous globe. Amongst the local provisions ancillary to these are the monsoons of India and the land and sea-breezes prevalent throughout the tropical coasts. When a promontory, such as that of India, intrudes into the region of the trade-winds, the continuous western current is interrupted, and in its room appear alternating currents from the northeast and southwest, which change their direction as the Sun passes the latitude of the place. On the Malabar coast, as the Sun approaches from the southward, clouds and variable winds attend him, and his transit northward is in a week or ten days followed by that furious burst of thunder and tempest which herald the rainy season. His southward transit is less distinctly marked; it is the sign of approaching fair weather, and is also attended by thunder and storm. The alternating land and sea-breezes are occasioned by the alternate heating and cooling of the soil, the temperature of the sea remaining nearly uniform. At present, when most powerfully felt, the earth by noon will often be found to have attained a temperature of 120°, while the sea rarely rises above 80°*. The air, heated and expanded, of course ascends, and draws from the sea a fresh supply to fill its room; the current thus generated constitutes the breeze. During the night the earth often sinks to a temperature of 50° or 60°, cooling the conterminous air and condensing, in the form of dew, the moisture floating around. The sea is now from 15° to 20° warmer than the earth—the greatest difference between the two existing at sunrise; and in then rushes the air and draws off a current from the shore.

"We have not noticed the tides, which, obedient to the Sun and Moon, daily convey two vast masses of water round the globe, and which twice a month rising to an unusual height, visit elevations which otherwise are dry. During one-half of the year the highest tides visit us by day, the other half by night, and at Bombay, at Springs, the depths of the two differ by two or three feet from each other. The tides simply rise and fall, in the open ocean, to an elevation of two or three feet in all; along our shores, and up gulfs and estuaries, they sweep with the violence of a torrent, having a general range of ten or twelve feet; sometimes, as at Fundy, in America, at Brest and Milford Haven, in Europe, to a height of from forty to sixty feet. They sweep our shores from filth and purify our rivers and inlets, affording to the residents of our islands and continents the benefits of a bi-diurnal ablution, and giving a health and freshness and purity wherever they appear. Obedient to the influence of bodies many millions of miles removed from them, their subjection is not the less complete; the vast volume of water capable of crushing by its weight the most stupendous barriers that can be opposed to

* The temperature of certain parts of the Indian Ocean, the hottest sea in the world, is 90°.—M.

it, and bearing on its bosom the navies of the world, impetuously rushing against our shores, gently stops at a given line, and flows back again to its place when the word goes forth: 'Thus far shalt thou go, and no farther;' and that which no human power or contrivance could have repelled, returns at its appointed time so regularly and surely that the hour of its approach, and measure of its mass, may be predicted with unerring certainty centuries beforehand. The hurricanes which whirl with such fearful violence over the surface, raising the waters of the sea to enormous elevations, and submerging coasts and islands, attended as they are by the fearful attributes of thunder and deluges of rain, seem requisite to deflagrate the noxious gasses which have accumulated, to commingle in one healthful mass the polluted elements of the air, and restore it fitted for the ends designed for it. It is with the ordinary, not with the exceptionable, operations we have at present to deal, and the laws which rule the hurricane form themselves the subject of a treatise.

"We have hitherto dealt with the sea and air—the one the medium through which the commerce of all nations is transported, the other the means by which it is moved along—as themselves the great vehicles of moisture, heat, and cold, throughout the regions of the world—the means of securing the interchange of these inestimable commodities, so that excess may be removed to where deficiency exists, deficiency substituted for excess, to the unbounded advantage of all. We have selected this group of illustrations for our views because they are the most obvious, the most simple, and the most intelligible and beautiful that could be chosen. Short as our space is, and largely as it has already been trenched upon, we must not confine ourselves to these.

"We have already said that the atmosphere forms a spherical shell, surrounding the Earth to a depth which is unknown to us, by reason of its growing tenuity, as it is released from the pressure of its own superincumbent mass. Its upper surface cannot be nearer to us than fifty, and can scarcely be more remote than five hundred miles. It surrounds us on all sides, yet we see it not; it presses on us with a load of fifteen pounds on every square inch of surface of our bodies, or from seventy to one hundred tons on us in all, yet we do not so much as feel its weight. Softer than the finest down, more impalpable than the finest gossamer, it leaves the cobweb undisturbed, and scarcely stirs the lightest flower that feeds on the dew it supplies; yet it bears the fleets of nations on its wings around the world, and crushes the most refractory substances with its weight. When in motion, its force is sufficient to level the most stately forests and stable buildings with the earth; to raise the waters of the ocean into ridges like mountains, and dash the strongest ships to pieces like toys. It warms and cools by turns the earth and the living creatures that inhabit it. It draws up vapors from the sea and land, retains them dissolved in itself, or supended in cisterns of clouds, and throws them down again as rain or dew, when they are required. It bends the rays of the sun from their path, to give us the twilight of evening and of dawn; it disperses and refracts their various tints to beautify the approach and the retreat of the orb of day. But for the atmosphere, sunshine would burst on us and fail us at once, and at once remove us from midnight darkness to the blaze of noon. We should have no twilight to soften and beautify the landscape; no clouds to shade us from the scorching heat; but the bald Earth, as it revolved on its axis, would turn its tanned and withered front to the full and unmitigated rays of the lord of day. It affords the gas which vivifies and warms our frames, and receives into itself that which has been polluted by use and is thrown off as noxious. It feeds the flame of life exactly as it does that of the fire; it is in both cases consumed, and affords the food of consumption; in both cases it becomes combined with charcoal, which requires it for combustion, and is removed by it when this is over. 'It is only the girdling encircling air,' says a writer in the *North British Review*, 'that flows above and around all that makes the whole world kin. The carbonic acid, with which to-day our breathing fills the air, to-morrow seeks its way round the world. The date trees that grow round the falls of the Nile will drink it in by their leaves; the cedars of Lebanon will take of it to add to their stature; the cocoa-nuts of Tahiti will grow rapidly upon it; and the palms and bananas of Japan will change it into flowers. The oxygen we are breathing was distilled for us some short time ago by the magnolias of the Susquehanna, and the great trees that skirt the Orinoco and the Amazon; the giant rhododendrons of the Himalayas contributed to it; and the roses and myrtles of Cashmere, the cinnamon tree of Ceylon, and the forest older than the flood, buried deep in the heart of Africa, far behind the Mountains of the Moon. The rain we see descending was thawed for us out of the icebergs which have watched the Polar Star for ages; and the lotus lilies have soaked up from the Nile, and exhaled as vapor, snows that rested on the summits of the Alps.' 'The atmosphere,' says Maun, 'which forms the outer surface of the habitable world is a vast reservoir, into which the supply of food designed for living creatures is thrown; or, in one word, it is itself the food, in its simple form, of all living creatures. The animal grinds down the fibre and the tissue of the plant, or the nutritious store that has been laid up within its cells, and converts these into the substance of which its own organs are composed. The plant acquires the organs and nutritious store, thus yielded up as food to the animal, from the invulnerable air surrounding it.' But animals are furnished with the means of locomotion and of seizure; they can approach their food, and lay hold of and swallow it; plants must await till their food comes to them. No solid particles find access to their frames; the restless ambient air which rushes past them loaded with the carbon, the hydrogen, the oxygen, the water—everything they need in the shape of supplies, is constantly at hand to minister to their wants, not only to afford them food in due season, but in the shape and fashion in which alone it can avail them."

These researches have for their object also the figure and shape of the bed of the ocean, and they therefore belong in some measure to that class which, of all others pertaining to the physical condition of our planet, has most abounded in valuable contributions to human knowledge.

"The dimensions and *figure* of the earth constitute," says Sir John Herschel, "a branch of inquiry on which, perhaps, more pains, labor, and refinement have been lavished than on any other subject of human research. 'The history of science,' says M. de Humboldt, 'presents no problem in which the object obtained, the knowledge of the mean compression of the earth, and the certainty that its figure is not a regular one, is so far surpassed in importance by the incidental gain which, in the course of its long and arduous pursuit, has accrued in the general cultivation and advancement of mathematical and astronomical knowledge.' In fact, however, the benefit conferred has not been confined to these. The continual heaping on of refinement upon refinement, in respect both of instruments and methods, has been far from a mere barren and ostentatious accumulation. On the contrary, it has overflowed on all sides, and fertilized every other field of physical research, by the example it has set, and the necessity it has imposed of exactness of numerical determination, mathematical precision of statement, and rigorous account taken of every influential circumstance, as well as by the numerous physical elements whose exact measures and laws it has incidentally required to be known as data. By the improvement of our knowledge of these, the aspect of all science has been changed, and the apparently disproportionate application of talent and cost which have been brought to bear upon the subject repaid with interest. The fixation of national standards of weight and measure, which has become indissolubly interwoven with it, has ever marked, and will ever continue to mark, the highest point to which human skill and refinement in the application of science to practical objects are capable of attaining."

The field into which we are about to enter includes also the orography of the great oceanic floor, and our inquiries here, though but just begun, have led to the discovery that there is no running water at the bottom of the deep sea; a fact from which we learn lessons concerning the dynamics of the ocean, a naked fact, the knowledge of which is of the utmost importance in submarine telegraphy.

The field of our labors reaches from the temperature and saltness of the waters of the sea to its microscopic inhabitants.

Changes in the thermal condition of the globe would suggest changes in the time of rotation of the earth on its axis, changes in the length of the day, and changes in the stability of our planet. Is the mean temperature of the whole ocean a constant? We must wait for ages to help us to give a perfectly satisfactory answer to this question; but it is meet for us in our day to inaugurate that long series of observations and patient research by which alone posterity can hope to arrive at truthful results. "The mean temperature," remarks Herschel, "at which the *surface* of the earth is maintained, if we consider the average of the whole globe, depends solely on external causes, the only one of which, worth considering as really influential, is the sun's radiation. Of the constancy or variability of this from year to year, or from century to century, we know nothing, though from the analogy of periodical or changeable stars we may surmise anything. But it by no means follows that this ignorance on a point of such immense importance is to continue. It is to the temperature of the ocean, continually and carefully observed in those parts of its surface where its changes are least, (in the equatorial region, from 10° N. to 10° S.,) that we must look with the greatest probability of ultimate success for the solution of this difficult but interesting problem. In these regions the observations and researches of M. de Humboldt himself have established the fact of 'a wonderful uniformity and constancy of temperature over spaces of many thousand square miles.' It is here, therefore, that observations directed to this object can be made to the greatest advantage, and least exposed to the influence of casual and temporary disturbance. We know of no class of observations deserving more the attention of voyagers."

Surely a more tempting field for philosophical research, for useful and honorable labor, or a field more abounding with harvests of useful and practical results, never engaged the attention of man.

By studying the winds at sea, we might expect to find them blowing more conformably there than on the land to the general laws which govern the circulation of the atmosphere. And in endeavoring to learn these laws we may look to the sea for the rule, to the land for the exceptions. It might, therefore, be expected that any systematic attempt to group the numerous observations made on the winds by mariners in all parts of the ocean and at all seasons of the year would be regarded, as the illustrious Humboldt says it is, and as the learned Dr. Buist shows it to be, with no little interest by philosophers and philanthropists, by good and wise men in all conditions of life, and in all parts of the world.

In the progress of this undertaking many new facts of interest to science have been brought to light, or their existence suggested by them. Our knowledge of the laws which govern the circulation of the atmosphere, which control the currents of the sea, which regulate climates, and by which heat and moisture, clouds and sunshine, are distributed over the surface of the earth, has been considerably enlarged.

4. Navigation has already reaped rich fruits from this enterprise, and commerce is profiting by it. In consequence of the increase of knowledge which it has given to the practical navigator concerning the prevailing winds and currents of the sea, the average sailing passage between distant parts of the earth has been materially shortened.

Practically, for commercial purposes, these investigations have lifted up, as it were, the markets of the southern hemisphere and set them down by many days' sail nearer to our doors than they were before; for the time which it required a ship to carry a cargo from the United States to the equator, in the Atlantic, has been shortened more than two weeks at some seasons of the year; and it is not going too far to say that the voyage hence to California has, in consequence of these researches, been shortened to a more remarkable extent. The average passage out, by vessels not having the results of these researches to guide them, is upwards of 180 days; but vessels with these Charts on board have made it in 107, in 97, in 96, in 91, and even in 90 days; and their masters, after making allowances for the improved models of their ships, ascribe this great success to the information they derived from these Charts as to the winds and currents by the way.

When I was in England, in 1853, I promised the merchants and ship owners there, if they would lend their co-operation in keeping Abstract Logs, that I would point out a route to Australia by which that land of gold should be brought practically one month nearer to Europe and America, by shortening the passage for sailing vessels that much. I have received from Captain Wood a list, taken from the *Melbourne Argus*, of all the vessels that arrived there from Europe and America between the 31st December, 1853, and the 7th July, 1854. This list contains the names, with the length of passage of 362 sailing vessels. Their average passage is 124 days. The average passage of those that take the wind and current charts for their guide is a little over 90 days. The passage has since been frequently made under canvas alone in 72 days or less.

In former editions of this work, I predicted that on the homeward voyage the run from Australia to Cape Horn could be made in less time than the same distance over water has ever been run under steam. I also predicted that vessels in the Australian trade would yet perform a voyage of circumnavigation in less time than the passage had ever been made to California. Both of these predictions have been fulfilled; the run to Cape Horn has been made in less than twenty-five days; and the feat of circumnavigation has been accomplished in less than eighty-nine days.

5. The official statement of the New York underwriters of the annual disasters at sea, show that the marine losses for the year, including 31st December, 1857, were valued at $17,000,000, and 558 vessels. This is exclusive of the losses under other flags, nor does this statement make any mention of the loss of human life, more precious than gold. The sum total for all flags would amount to thousands of souls, and more than $50,000,000 of treasure. These researches, by the knowledge of wind and weather which they afford the mariner, have the diminution of these losses for their object. Of course, a system of investigation, having among its aims such objects as the improvement of navigation and the benefit of commerce, and counting among its results such achievements as these, could not fail to attract the attention of merchants, or to commend itself to the favorable consideration of seafaring people generally. Taking advantage of this circumstance, the government of the United States caused the researches to be brought to the attention of other governments, and invited them to join in a conference upon the subject of a uniform system of observations at sea. This Conference met on the 23d August, 1853, in

Brussels, and continued its sessions from day to day until the 8th of September. The form of the Abstract Log, and the plan of observations at sea there recommended, have been adopted by all the maritime nations of Christendom. So that now we have co-operating with us the nations that own at least nineteen-twentieths of all the shipping in the world.

At the Conference I had the pleasure of meeting master spirits. I find a difficulty in expressing my ideas as to the importance of the services which they have rendered to the cause of navigation and marine meteorology. Suffice it to say, I think a new era in the history of meteorological science will be dated from that Conference. In all things connected with it the friends of this science have but one cause of regret, and that is, that the instructions under which those twelve men met did not go further and authorize them to include the land as well as the sea in their system of observations, and so make the plan universal.

I hope that will yet be done, for the great atmospherical ocean, at the bottom of which we are creeping along, and the laws of which touch so nearly the well-being of the whole human family, embraces the land as well as the sea, and neither of those laws nor the movement and phenomena of the atmosphere can be properly studied or thoroughly investigated until observations, both by sea and land, shall enable us to treat the atmosphere as a whole.

It is estimated that the system of investigations out of which the Wind and Current Charts have grown has already led, by practically shortening the duration of voyages, to the annual saving of many millions of dollars, in the aggregate, to those who go by them. As great, therefore, as is the benefit which commerce is deriving from the results of these observations at sea, a similar system for the shore would, I have no doubt, confer benefits as signal upon agriculture and other industrial pursuits on land. The field of agricultural and sanitary meteorology is as rich with the promise of good "as is the ooze and bottom of the sea with sunken wrecks and sunless treasures," and I therefore hope yet to see the day when the observer at sea and the observer on shore will be acting in concert, and observing according to one uniform plan; and the more so, as such a universal system can be set on foot and carried out without involving the government that will take the initiative, or those that may second, in any expense, save the comparatively trifling cost of having the observations, after they are made, properly treated and published. The field is already filled with amateur meteorologists of all Christian tongues, who, I am assured, would most gladly volunteer their services and instruments in carrying out such a system.

Let us hope that before another edition of this work is published another conference may be called for examining the progress that has been made under the Brussels recommendations, and for considering the improvements that experience shall have suggested in the present plan of observation, as well as for the purpose of devising a similar plan of observations for the land, and so let the world have the benefit, and science the advantages, of a universal system of meteorological observations.

In the progress of this system of research, facts have been elicited which, though they have no direct relation to the course of navigation, have, nevertheless, obvious bearings upon the physical geography of the sea, and therefore are not without interest to the navigator. A small volume, treating of these facts and their bearings, has been published by the Messrs. Harper, of New York. I am permitted to transfer to these pages several chapters of that work. Indeed, were it not for swelling out the dimensions of these Sailing Directions, the entire contents of the *Physical Geography of the Sea* might, with advantage, be transferred to these pages. It is hoped that the sailor at sea will find instruction and profit by the study of them.

CHAPTER II.

THE ATMOSPHERE.*

The Circulation of the Atmosphere, Plate III. § 7.—Southeast Trade-wind Region the larger, § 13.—The Offices of the Atmosphere, § 14.—It is a powerful Machine, § 17.—Whence come the Rains that feed the great Rivers? § 19.—How vapor passes from one Hemisphere to the other, § 20.—Evaporation greatest about Latitude 17°-20°, § 24.—The Rainy Seasons, § 28.—Rainless Regions, § 30.—Why Mountains have a dry and a rainy Side, § 31.—The immense Fall of Rain upon the Western Ghauts in India: how caused, § 33.—Vapor for the Patagonia Rains comes from the North Pacific, § 34.—The mean annual Fall of Rain, § 35.—Evaporation from the Indian Ocean, § 36.—Evidences of Design, § 37.—Adaptation, § 38.

6. THERE is no employment more worthy of the human mind than that which is afforded by tracing the evidences of design and purpose, which are visible in any parts of the creation. Hence, to the right-minded mariner, and to him who studies the physical relations of earth, sea, and air, the atmosphere is something more than a shoreless ocean, at the bottom of which his barque is wafted or driven along. It is an envelop or covering for the dispersion of light and heat over the surface of the earth; it is a sewer into which, with every breath we draw, we cast vast quantities of dead animal matter; it is a laboratory for purification, in which that matter is recompounded, and wrought again into wholesome and healthful shapes; it is a machine for pumping up all the rivers from the sea, and conveying the waters for their fountains on the ocean to their sources in the mountains.

Upon the proper working of this machine depends the well-being of every plant and animal that inhabits the earth; therefore, the management of it, its movement, and the performance of its offices, cannot be left to chance. They are, we may rely upon it, guided by laws that make all parts, functions, and movements of the machinery as obedient to order as are the planets in their orbits.

An examination into the economy of the universe will be sufficient to satisfy the well-balanced minds of observant men that the laws which govern the atmosphere and the laws which govern the ocean are laws which were put in force by the Creator when the foundations of the earth were laid; therefore, they are laws of order; else, why should the Gulf Stream, for instance, be always where it is, and running from the Gulf of Mexico, and not somewhere else, and sometimes running into it? Why should there be a perpetual drought in one part of the world and continual showers in another? Or why should the winds and sea obey the voice of rebuke?

To one who looks abroad to contemplate the agents of nature, as he sees them at work upon our planet, no expression uttered nor act performed by them is without meaning. By such an one, the wind and rain, the vapor and the cloud, the tide, the current, the saltness, and depth, and warmth, and color of the sea, the shade of the sky, the temperature of the air, the tint and shape of the clouds, the height of the tree on the shore, the size of its leaves, the brilliancy of its flowers—each and all may be regarded as the exponent of certain physical combinations, and therefore as the expression in which Nature chooses to announce her own doings, or, if we please, as the language in which she writes down or chooses to make known her own laws. To help us to understand that language, and to interpret aright those laws, is the object of the call which we have made upon sailors for observations at sea. No fact gathered in such a field, therefore, comes amiss to those who tread the walks of inductive philosophy;

* *Vide* "Maury's Physical Geography of the Sea;" Harper and Brothers, New York.

for, in the hand-book of nature, every such fact is a syllable; and it is by patiently collecting fact after fact, and by joining together syllable after syllable, that we may finally seek to read aright from the great volume which the mariner at sea and the philosopher on the mountain see spread out before them.

7. From the parallel of about 30° north and south, nearly to the equator, and extending entirely around the earth, are two zones of perpetual winds, viz: the zone of northeast trades on this side, and of southeast on that. They blow perpetually, and are as steady and as constant as the currents of the Mississippi river—always moving in the same direction, (Plate III.) As these two currents of air are constantly flowing from the poles toward the equator, we are safe in assuming that the air which they keep in motion must return by some channel or other to the place near the poles whence it came in order to supply the trades. If this were not so, these winds would soon exhaust the polar regions of atmosphere, and pile it up about the equator, and then cease to blow for the want of air to make more wind of.

This return or counter-current, therefore, must be in the upper regions of the atmosphere, at least until it passes over those parallels between which the trade-winds are always blowing on the surface. These direct and counter-currents are also made to move in a sort of spiral or loxodromic curve, turning to the west as they go from the poles to the equator, and in the opposite direction as they move from the equator to the poles. This turning is caused by the rotation of the earth on its axis.

The earth, we know, moves from west to east. Now, if we imagine a particle of atmosphere at the north pole, where it is at rest, to be put in motion in a straight line toward the equator, we can easily see how this particle of air, coming from the very axis of the pole, where it did not partake of the diurnal motion of the earth, would, in consequence of its *vis inertiæ*, find, as it travels south, the earth slipping from under it, as it were, and thus it would appear to be coming from the northeast and going towards the southwest; in other words, it would be a northeast wind.

The better to explain, let us take a common terrestial globe for the illustration. Bring the island of Madeira, or any other place about the same parallel, under the brazen meridian; put a finger of the left hand on the island; then, moving the finger down along the meridian to the south, to represent the particle of air, turn the globe on its axis from west to east, to represent the diurnal rotation of the earth, and when the finger reaches the equator, stop. It will now be seen that the place on the globe under the finger is to the southward and westward of Madeira or the place from which the finger started; in other words, the track of the finger over the surface of the globe, like the track of the particle of air upon the earth, has been from the northward and eastward.

On the other hand, we can perceive how a like particle of atmosphere that starts from the equator, to take the place of the other at the pole, would, as it travels north, in consequence of its *vis inertiæ*, be going toward the east faster than the earth. It would, therefore, appear to be blowing from the southwest, and going towards the northeast, and exactly in the opposite direction to the other. Writing south for north, the same takes place between the south pole and the equator.

Such is the process which is actually going on in nature; and if we take the motions of these two particles as the type of the motion of all, we shall have an illustration of the great currents in the air, the equator being near one of the nodes, and there being two systems of currents, an upper and an under, between it and each pole.

Halley, in his theory of the trade-winds, pointed out the key to the explanation, so far, of the atmospherical circulation; but, were the explanation to rest here, a northeast trade-wind extending from the pole to the equator would satisfy it; and were this so, we should have, on the surface, no winds but the northeast trade-winds on this side, and none but southeast trade-winds on the other side of the equator.

8. Let us return now to our northern particle, (Plate III,) and follow it in a round from the north pole across the equator to the south pole, and back again. Setting off from the polar regions, this particle of air, for some reason which does not appear to have been very satisfactorily explained by philosophers, instead of travelling (§ 7) on the surface all the way from the pole to the equator, travels in the upper regions of the atmosphere for a part of the way, and until it gets near the parallel of 30°. Here it meets, also in the clouds, the hypothetical particle that is coming from the south, and going north to take its place.

About this parallel of 30° north, then, these two particles press against each other with the whole amount of their motive power, and produce a calm, and an accumulation of atmosphere; this accumulation is sufficient to balance the pressure of the two winds from the north and south.

From under this bank of calms, which seamen call the "horse latitudes," (I have called them the calms of Cancer,) two surface currents of wind are ejected: one towards the equator, as the northeast trades, the other toward the pole, as the southwest passage winds.

These winds come out at the lower surface of the calm region, and consequently the place of the air borne away in this manner must be supplied, we may infer, by downward currents from the superincumbent air of the calm region. Like the case of a vessel of water which has two streams from opposite directions running in at the top, and two of equal capacity discharging in opposite directions at the bottom, the motion of the water would be downward, so is the motion of the air in this calm zone.

The barometer, in this calm region, is said to stand higher than it does either to the north or to the south of it; and this is another proof as to the banking up here of the atmosphere, and pressure from its downward motion.

9. Following our imaginary particle of air from the north across this calm belt, we now feel it moving on the surface of the earth as the northeast trade-wind; and as such it continues till it arrives at the equator, where it meets a like particle, which, starting from the south pole at the same time the other started from the north pole, has blown as the southeast trade-wind.

Here, at this equatorial place of meeting, there is another conflict of winds, and another calm region, for a northeast and southeast wind cannot blow at the same time in the same place. The two particles have been put in motion by the same power; they meet with equal force; and, therefore, at their place of meeting, are stopped in their course. Hence this calm belt.

10. Warmed now by the heat of the sun, and pressed on each side by the whole force of the northeast and southeast trades, these two hypothetical particles, taken as the type of the whole, cease to move onward and ascend. This operation is the reverse of that which took place at the meeting (§ 8) near the parallel of 30°.

11. This imaginary particle, then, having ascended to the upper regions of the atmosphere again, travels there counter to the southeast trades until it meets, near the calm belt of Capricorn, another particle from the south pole; here there is a descent as before, (§ 8;) it then (§ 7) flows on toward the south pole as a surface wind from the northwest.

Entering the polar regions obliquely, it is pressed upon by similar particles flowing in oblique currents across every meridian; and here again is a calm place or node; for, as our imaginary particle approaches the parallels near the polar calms more and more obliquely, it, with all the rest, is whirled about the pole in continued gyrations; finally, reaching the vortex or the calm place, it is carried upward to the regions of atmosphere above, whence it commences again its circuit to the north as an upper current as far as the calm belt of Capricorn; here it encounters (§ 11) its fellow from the north, (§ 7;) they stop, descend, and flow out as surface currents, (§ 8,) the one with which the imagination is travelling, to the equatorial calms as the southwest trade-wind; here (§ 9) it ascends, travelling thence to the calm belt of Cancer as an upper current counter to the northeast trades. Here (§ 8) it ceases to be an upper current, but, descending, (§ 8,) travels on with the southwest passage winds toward the pole.

Now, the course we have imagined an atom of air to take is this, (Plate III:) an ascent at P, the north pole; an efflux thence as an upper current (§ 8) until it meets G (also an upper current) over the calms of Cancer. Here (§ 8) there is supposed to be a descent, as shown by the arrows along the wavy lines which envelop the circle. This upper current from the pole (§ 7) now becomes the northeast trade-wind B (§ 9) on the surface until it meets the southeast trades in the equatorial calms, when it ascends and travels as C with the upper current to the calms of Capricorn, then as D with the prevailing northwest surface current to the south pole, thence up with the arrow P, and around with the hands of a watch, and back, as indicated by the arrows along E, F, G, and H.

The Bible frequently makes allusions to the laws of nature, their operation and effects. But such allusions are often so wrapped in the folds of the peculiar and graceful drapery with which its language is occasionally clothed, that the meaning, though peeping out from its thin covering all the while, yet lies in some sense concealed until the lights and revelations of science are thrown upon it; then it bursts out and strikes us with great force and beauty.

As our knowledge of nature and her laws has increased so has our understanding of many passages in the Bible been improved. The Bible called the earth "the round world;" yet for ages it was considered a heresy for Christian men to say the world is round; and, finally, sailors circumnavigated the globe, proved the Bible to be right, and confounded theologians so called.

"Canst thou bind the sweet influences of Pleiades?"

Astronomers of the present day, if they have not answered this question, have thrown so much light upon it as to show that, if ever it be answered by man, he must consult the science of astronomy. It has been recently established that the earth and sun, with their splendid retinue of comets, satellites, and planets, are all in motion around some point or centre of attraction inconceivably remote, and that that point is in the direction of the star Alcyon, one of the Pleiades!

Who, therefore, can ever "bind the sweet influences?"

And as for the general system of atmospherical circulation which I have been so long endeavoring to describe, the Bible tells it all in a single sentence: "The wind goeth toward the south, and turneth about unto the north; it whirleth about continually, and the wind returneth again according to his circuits."*

12. Of course, as the surface winds H and D (Plate III) approach the poles, there must be a sloughing off, if I may be allowed the expression, of air from the surface winds, in conse-

* Eccl., i. 6.

quence of their approaching the polls. For as they near the polls the parallels become smaller and smaller, and the surface current must either extend much higher up, and blow with greater rapidity as it approaches the polls, or else a part of it must be sloughed off above, and so turn back before reaching the polls. The latter is probably the case.

Investigations have shown that the southeast trade-wind region is much larger than the northeast. I speak now of its extent over the Atlantic ocean only; that the southeast trades are the fresher, and that they often push themselves up to 10° or 15° of north latitude; whereas the northeast trade-winds of the Atlantic seldom get south of the equator.

The peculiar clouds of the trade-winds are formed between the upper and lower currents of air. They are probably formed of vapor condensed from the upper current, and evaporated, as it descends, by the lower and dry current from the polls. It is the same phenomenon up there which is so often observed here below; when a cold and dry current of air meets a warm and wet one an evolution of vapor or fog ensues.

We now see the general course of the "wind in his circuits," as we see the general course of the water in a river. There are many abrading surfaces, irregularities, &c., which produce a thousand eddies in the main stream; yet, nevertheless, the general direction of the whole is not disturbed nor affected by those counter currents; so with the atmosphere and the variable winds which we find here in this latitude.

Have I not, therefore, very good grounds for the opinion (§ 6) that the "wind in his circuits," though apparently to us never so wayward, is as obedient to law, and as subservient to order, as were the morning stars when they "sang together?"

13. There are at least two forces concerned in driving the wind through its circuits. We have seen (§ 7) whence that force is derived which gives easting to the winds as they approach the equator, and westing as they approach the polls; and allusion, without explanation, has been made (§ 10) to the source whence they derive their northing and their southing. The trade-winds are caused, it is said, by the intertropical heat of the sun, which, expanding the air, causes it to rise up near the equator; it then flows off in the upper currents north and south, and there is a rush of air at the surface, both from the north and the south, to restore the equilibrium—hence the trade-winds. But to the north side of the trade-wind belt in the northern, (§ 6,) and on the south side in the southern hemisphere, (§ 11,) the prevailing direction of the winds is not toward the source of heat about the equator, but exactly in the opposite direction. In the extra-tropical region of each hemisphere the prevailing winds blow from the equator toward the polls. It therefore at first appears paradoxical to say that heat makes the easterly winds of the torrid zone blow toward the equator, and the westerly winds of the temperate zones to blow toward the polls. Let us illustrate:

The *primum mobile* of the extra-tropical winds toward the equator is, as just intimated, generally ascribed to heat, and in this wise, viz: Suppose, for the moment, the earth to have no diurnal rotation; that it is at rest; that the rays of the sun have been cut off from it; that the atmosphere has assumed a mean uniformity of temperature, the thermometer at the equator and the thermometer at the poles giving the same reading; that the winds are still, and that the whole aerial ocean is in equilibrium and at rest. Now imagine the screen which is supposed to have shut off the influence of the sun to be removed, and the whole atmosphere to assume the various temperatures in the various parts of the world that it actually has at this moment, what would take place, supposing the uniform temperature to be a mean between the actual temperature at the equator and that at the poles? Why, this would take place: a swelling up of the atmosphere about the equator by the expansive force of intertropical heat, and a contraction of it about the poles in consequence of the cold. These two forces, considering them under their most obvious effects, would disturb the supposed atmospherical equilibrium by altering the level of the great aerial ocean; the expansive force of heat elevating it about the equator, and the contracting powers of cold depressing it about the poles. And forthwith two systems of winds would commence to blow, viz: one in the upper regions from the equator towards the poles, and as this warm and expanded air should flow towards either pole, seeking its level, a wind would blow on the surface from either pole to restore the air to the equator which the upper current had carried off.

These two winds would blow due north and south; the effects of heat at the equator, and cold at the poles, would cause them so to do. Now suppose the earth to commence its diurnal rotation; then, instead of having these winds north and south winds, they will, for reasons already explained (§ 7,) approach the equator on both sides with *easting* in them, and each pole with westing.

The circumference of the earth, measured on the parallel of 60°, is only half what it is when measured on the equator. Therefore supposing velocity to be the same, only half the volume of atmosphere (§ 13) that sets off from the equator as an upper current toward the poles can cross the parallel of 60° north or south. The other moiety has been gradually drawn in and carried back (§ 12) by currents which are moving in the opposite direction.

Such, and such only, would be the extent of the power of the sun to create a polar and equatorial flow of air, were its power confined simply to a change of level. But the atmosphere has been invested with another property which increases its mobility, and gives the heat of the sun still more power to put it in motion, and it is this: as heat changes the atmospherical level, it changes also the specific gravity of the air acted upon. If, therefore, the level of the great aerial ocean were undisturbed by the the sun's rays, and if the air were adapted to a change of specific gravity alone, without any change in volume, this quality would also be the source of at least two systems of currents in the air, viz: an upper and a lower. The two agents combined, viz: that which changes level or volume, and that which changes specific gravity, give us the general currents under consideration. Hence we say that the *primum mobile* of the air is derived from change of specific gravity induced by the freezing temperature of the polar regions, as well as from change of specific gravity due the expanding force of the sun's rays within the tropics.

Therefore, fairly to appreciate the extent of the influence due the direct heat of the sun in causing the winds, it should be recollected that we may with as much reason ascribe to the intertropical heat of the sun the northwest winds, which are the prevailing winds of the extra-tropical regions of the southern hemisphere, on the southwest winds, which are the prevailing winds of the extra-tropical regions of the northern hemisphere, as we may the trade-winds, which blow in the opposite directions. Paradoxical, therefore, as it seems for us to say that the heat of the sun causes the winds between the parallels of 25° or 30° north and south to blow toward the equator, and that it also causes the prevailing winds on the polar sides of the same parallels to blow toward the poles, yet the paradox ceases when we come to recollect that by the process of equatorial heating and polar cooling which is going on in the atmosphere, the specific gravity of the air is changed as well as its level. Nevertheless, as Halley said, in his paper read before the Royal Society in London in 1686, "it is likewise very hard to conceive why the limits of the trade-wind should be fixed about the parallel of latitude 30° all around the globe, and that they should so seldom exceed or fall short of those bounds."

14. Operated upon by the equilibrating tendency of the atmosphere and by diurnal rotation, the wind approaches the north pole, for example, by a series of spirals from the southwest (§ 11.) If we draw a circle about this pole on a common terrestrial globe, and intersect it by spirals to represent the direction of the wind, we shall see that the wind enters all parts of this circle from the southwest, and, consequently, that a whirl ought to be created thereby, in which the ascending column of air revolves from right to left, or *against* the hands of a watch. At the south pole the winds come from the northwest (§ 11,) and consequently there they revolve about it *with* the hands of a watch.

That this should be so will be obvious to any one who will look at the arrows on the polar sides of the calms of Cancer and Capricorn (Plate III.) These arrows are intended to represent the prevailing direction of the wind at the surface of the earth.

It is a singular coincidence between these two facts thus deduced, and other facts which have been observed, and which have been set forth by Redfield, Reid, Piddington, and others, viz: that all rotary storms in the northern hemisphere revolve as do the whirlwinds about the north pole, viz: from right to left, and that all circular gales in the southern hemisphere revolve in the opposite direction, as does the whirl about the south pole.

How can there be any connexion between the rotary motion of the wind about the pole and the rotary motion of it in a gale caused here by local agents?

That there is probably such a connexion has been suggested by other facts and circumstances, for, although the theory of heat satisfies many conditions of the problem, and though heat, doubtless, is one of the chief agents in keeping up the circulation of the atmosphere, yet it can be made to appear that it is not the *sole* agent; magnetism, probably, has something to do with it.

15. So far, we see how the atmosphere moves; but the atmosphere, like every other department in the economy of nature, has its offices to perform, and they are many. I have already alluded to some of them; but I only propose, at this time, to consider some of the meteorological agencies at sea, which, in the grand design of creation, have probably been assigned to this wonderful machine.

To distribute moisture over the surface of the earth, and to temper the climate of different latitudes, it would seem, are two great offices assigned by their Creator to the ocean and the air.

When the northeast and southeast trades meet, and produce the equatorial calms (§ 9), the air, by this time, is heavily laden with moisture, for in each hemisphere it is travelled obliquely over a large space of the ocean. It has no room for escape but in the upward direction (§ 10.) It expands as it ascends, and becomes cooler; a portion of its vapor is thus condensed, and comes down in the shape of rain. Therefore it is that, under these calms, we have a region of constant precipitation. Old sailors tell us of such dead calms of long continuance here, of such heavy and constant rains, that they have scooped up fresh water from the surface of the sea.

The conditions to which this air is exposed here under the equator are probably not such as to cause it to precipitate all the moisture that it has taken up in its long sweep across the waters. Let us see what becomes of the rest; for nature, in her economy, permits nothing to be taken away from the earth which is not to be restored to it again in some form, and at some time or other.

Consider the great rivers—Amazon and the Mississippi, for example. We see them day after day and year after year discharging an immense volume of water into the ocean.

"All the rivers run into the sea, yet the sea is not full."—Ecc., i. 7. Where do the waters so discharged go, and whence do they come? They come from their sources you will say.

But whence are their sources supplied? for, unless what the fountain sends forth be returned to it again, it will fail and be dry.

16. We see simply, in the waters that are discharged by these rivers, the amount by which the precipitation exceeds the evaporation throughout the whole extent of valley drained by them; and by precipitation I mean the total amount of water that falls from, or is deposited by the atmosphere, whether as dew, rain, hail or snow.

The springs of these rivers are supplied from the rains of heaven, and these rains are formed of vapors which are taken up from the sea, that "it be not full," and carried up to the mountains through the air.

"Note the place whence the rivers come, thither they return again."

17. Behold now the waters of the Amazon, of the Mississippi, the St. Lawrence, and all the great rivers of America, Europe, and Asia, lifted up by the atmosphere, and flowing in invisible streams back through the air to their sources among the hills, and that through channels so regular, certain, and well defined, that the quantity thus conveyed one year with the other is nearly the same: for that is the quantity which we see running down to the ocean through these rivers; and the quantity discharged annually by each river is, as far as we can judge, nearly constant.

We now begin to conceive what a powerful machine the atmosphere must be; and, though it is apparently so capricious and wayward in its movements, here is evidence of order and arrangement which we must admit, and proof which we cannot deny, that it performs this mighty office with regularity and certainty, and is, therefore, as obedient to law as is the steam engine to the will of its builder.

18. It, too, is an engine. The South Seas themselves, in all their vast inter-tropical extent, are the boiler for it, and the northern hemisphere is its condenser.

19. *Where does the vapor that makes the rains which feed the rivers of the northern hemisphere come from?*

The proportion between the land and water in the northern hemisphere is very different from the proportion between them in the southern. In the northern hemisphere the land and water are nearly equally divided. In the southern there is several times more water than land. Most of the great rivers in the world are in the northern hemisphere, where there is less ocean to supply them. Whence, then, are their sources replenished? Those of the Amazon are supplied with rains from the equatorial calms and trade-winds of the Atlantic. That river runs east, its branches come from the north and south; it is always the rainy season on one side or the other of it; consequently, in its lower parts, it is without periodic stages of a very marked character. There it is always near its high-water mark. For one-half of the year its northern tributaries are flooded, and its southern for the other half. It discharges under the line, and as its tributaries come from both hemispheres it cannot be said to belong exclusively to either. It is supplied with water from the Atlantic Ocean. Taking the Amazon, therefore, out of the count, the Rio de la Plata is the only great river of the southern hemisphere.

There is no large river in New Holland. The South Sea Islands give rise to none nor is there one in South Africa that we know of.

The great rivers of North America and North Africa, and all the rivers of Europe and Asia, lie wholly within the northern hemisphere. How is it, then, considering that the evaporating surface lies mainly in the southern hemisphere—how is it, I say, that we should have the evaporation to take place in one hemisphere and the condensation in the other? The total amount of rain which falls in the northern hemisphere is much greater, meteorologists tell us, than that which falls in the southern. The annual amount of rain in the north temperate zone is half as much again as that of the south temperate.

20. How is it, then, that this vapor gets, as stated (§ 18), from the southern into the northern hemisphere, and comes with such regularity that our rivers never go dry, and our springs fail not? It is because of the beautiful operations and the exquisite *compensation* of this grand machine, the atmosphere. It is exquisitely and wonderfully counterpoised. Late in the autumn of the north, throughout its winter, and in early spring, the sun is pouring his rays with the greatest intensity down upon the seas of the southern hemisphere, and this powerful engine which we are contemplating is pumping up the water there (§ 18) for our rivers with the greatest activity. At these seasons the mean temperature of the entire southern hemisphere is said to be about 10° higher than the northern.

The heat which this heavy evaporation absorbs becomes latent, and, with the moisture, is carried through the upper regions of the atmosphere until it reaches our climates. Here the vapor is formed into clouds, condensed, and percipitated. The heat which held this water in the state of vapor is set free, it becomes sensible heat, and it is that which contributes so much to temper our winter climate. It clouds up in winter, turns warm, and we say we are going to have falling weather. That is because the process of condensation has already commenced, though no rain or snow may have fallen: thus we feel this southern heat that has been collected from the rays of the sun by the sea, been bottled away by the winds in the clouds of a southern summer, and set free in the process of condensation in our northern winter.

21. If Plate III fairly represent the course of the winds, the southeast trade-winds would enter the northern hemisphere, and, as an upper current, bear into it all their moisture, except that which is precipitated in the region of equatorial calms.

The south seas, then, according to § 18, should supply mainly the water for this engine, while the northern hemisphere condenses it; we should, therefore, have more rain in the northern hemisphere. The rivers tell us that we have—at least on the land: for the great water courses of the globe (§ 19), and half the fresh water in the world, are found on our side of the equator. This fact alone is strongly corroborative of this hypothesis.

The rain gauge tells us also the same story. The yearly average of rain in the north temperate zone is, according to Johnston, thirty-seven inches. He gives but twenty-six in the south temperate.

22. Moisture is never extracted from the air by subjecting it from a low to a higher temperature, but the reverse. Thus, all the air which comes loaded with moisture from the other hemisphere, and is borne into this with the southeast trade-winds, travels in the upper regions of the atmosphere (§ 8) until it reaches the calms of Cancer; here it becomes the surface wind that prevails from the southward and westward. As it goes north it grows cooler, and the process of condensation commences.

We may now liken it to the wet sponge, and the decrease of temperature to the hand that squeezes that sponge. Finally reaching the cold latitudes, all the moisture that a dew-point of zero, and even far below, can extract is wrung from it; and this air then commences "to return according to his circuits" as dry atmosphere; and being dry, it licks up the clouds it meets on its way south, making clear weather as it goes. And here we can quote Scripture again: "The north wind driveth away rain." This is a meteorological fact of high authority and great importance in the study of the circulation of the atmosphere.

23. By reasoning in this manner we are led to the conclusion that our rivers are supplied with their waters principally from the trade-wind regions—the extra-tropical northern rivers from the southern trades, and the extra-tropical southern rivers from the northern trade-winds, for the trade-winds are the evaporating winds.

Taking for our guide such faint glimmerings of light as we can catch from these facts, and supposing these views to be correct, then the saltest portions of the sea should be in the trade-wind regions, where the water for all the rivers is evaporated; and there the saltest portions are found.

24. Dr. Ruschenberger, of the navy, on his late voyage to India, was kind enough to conduct a series of observations on the specific gravity of sea water. In about the parallel of 17° north and south—midway of the trade-wind regions—he found the heaviest water. Though so warm, the water there was heavier than the cold water to the south of the Cape of Good Hope. Lieutenant D. D. Porter, in the steamship Golden Age, found the heaviest water about the parallels of 20° north and 17° south.

In summing up the evidence in favor of this view of the general system of atmospherical circulation, it remains to be shown how it is, if the view be correct, there should be smaller rivers and less rain in the southern hemisphere.

25. The winds that are to blow as the northeast trade-winds, returning as upper currents from the polar regions, where the moisture (§ 22) has been compressed out of them, remain, as we have seen, dry winds until they cross the calm zone of Cancer, and are felt on the surface as the northeast trades. About two-thirds of them only can then blow over the ocean; the rest blow over the land, over Asia, Africa, and North America, where there is but comparatively a small portion of evaporating surface exposed to their action.

The zone of the northeast trades extends, on an average, from about 29° north to 7° north. Now, if we examine the globe to see how much of this zone is land and how much water, we shall find, commencing with China and coming over Asia, the broad part of Africa, and so on, across the continent of America to the Pacific, land enough to fill up, as nearly as may be, just one-third of it. This land, if thrown into one body between these parallels, would make a belt equal to 120° of longitude by 22° of latitude.

According to the hypothesis, illustrated by Plate III, as to the circulation of the atmosphere, it is these northeast trade-winds that take up and carry over, after they rise up in the belt of equatorial calms, the vapors which make the rains that feed the rivers in the extra-tropical regions of the southern hemisphere.

Upon this supposition, then, two-thirds only of the northeast trade-winds are fully charged with moisture, and only two-thirds of the amount of rain that falls in the northern hemisphere should fall in the southern, and this is just about the proportion (§ 21) that observation gives.

26. In like manner, the southeast trade-winds take up the vapors which make our rivers, and as they prevail to a much greater extent at sea, and have exposed to their action about three times as much ocean as the northeast trade-winds have, we might expect, according to this hypothesis, more rains in the northern—and, consequently, more and larger rivers—than in the southern hemisphere. A glance at Plate XV will show how very much larger that part of the ocean over which the southeast trades prevail is than that that where the northeast trade-winds blow.

27. This estimate as to the quantity of rain in the two hemispheres is one which is not capable of verification by any more than the rudest approximations; for the greater extent of southeast trades on one side, and of high mountains on the other, must each of necessity, and

independent of other agents, have their effects. Nevertheless, this estimate gives as close an approximation as we can make out from any other data.

28. *The rainy seasons, how caused.*—The calm and trade-wind regions or belts move up and down the earth, annually, in latitude nearly a thousand miles. In July and August the zone of equatorial calms is found between 7° north and 12° north; sometimes higher; in March and April, between latitude 5° south and 2° north.

With this fact and these points of view before us, it is easy to perceive why it is that we have a rainy season in Oregon, a rainy and dry season in California, another at Panama, two at Bogotá, none in Peru, and one in Chili.

In Oregon it rains every month, but more in the winter months.

The winter there is the summer of the southern hemisphere, when this steam engine is working with the greatest pressure. The vapor that is taken up by the southeast trades is borne along over the region of northeast trades to latitude 35° or 40° north (§ 21), where it descends and appears on the surface with the southwest winds of those latitudes. Driving upon the highlands of the continent, this vapor is condensed and precipitated, during this part of the year, almost in constant showers.

In the winter, the calm belt of Cancer approaches the equator. This whole system of zones, viz: of trades, calms, and westerly winds, follows the sun in declination; and they of our hemisphere are nearer the equator in the winter and spring months than at any other season.

The southwest winds commence at this season to prevail as far down as the lower part of California. In winter and spring the land in California is cooler than the sea air, and is quite cold enough to extract moisture from it. But in summer and autumn the land is the warmer, and can not condense the vapors of water held by the air. So the same cause which made it rain in Oregon, now makes it rain in California. As the sun returns to the north, he brings the calm belt of Cancer and the northeast trades along with him; and now, at places where, six months before, the southwest winds were the prevaling winds, the northeast trades are found to blow. This is the case in the latitude of California. The prevailing winds, then, instead of going from a former to a cooler climate, as before, are going the opposite way. Consequently, they cannot, if they have the moisture in them to make rains of, precipitate it under such circumstances.

Panama is in the region of equatorial calms. This belt of calms travels during the year back and forth, over about 17° of latitude, coming further north in the summer, where it tarries for several months, and then returns so as to reach its extreme southern latitude some time in March or April. Where these calms are, it is always raining, and the Chart shows that they hang over the latitude of Panama from June to November; consequently, from June to November is the rainy season at Panama. The rest of the year that place is in the region of the northeast trades, which, before they arrive there, have to cross the mountains of the isthmus, on the cool tops of which they deposit their moisture, and leave Panama rainless and pleasant until the sun returns north with the belt of equatorial calms after him. They then push the belt of northeast trades further to the north, occupy a part of the winter zone, and refresh that part of the earth with summer rains. This belt of calms moves over more than double of its breadth, and nearly the entire motion from south to north is accomplished generally in two months, May and June.

Take the parallel of 4° north as an illustration: during these two months, the entire belt of calms crosses this parallel, and then leaves it in the region of the southeast trades. During these two months, it was pouring down rain on that parallel. After the calm belt passes it, the rains cease, and the people in that latitude have no more wet weather till the fall, when the belt of calms recrosses this parallel on its way to the south. By examining the "Trade-wind Chart," it may be seen what the latitudes are that have two rainy seasons, and that Bogotá is within the bi-rainy latitudes.

29. *The Rainless Regions.*—The coast of Peru is within the region of perpetual southeast trade-winds. Though the Peruvian shores are on the verge of the great South Sea boiler, yet it never rains there. The reason is plain.

The southeast trade-winds in the Atlantic Ocean first strike the water on the coast of Africa. Travelling to the northwest, they blow obliquely across the ocean until they reach the coast of Brazil. By this time they are heavily laden with vapor, which they continue to bear along across the continent, depositing it as they go, and supplying with it the sources of the Rio de la Plata and the southern tributaries of the Amazon.

Finally, they reach the snow-capped Andes, and here is wrung from them the last particle of moisture that that very low temperature can extract.

Reaching the summit of that range, they now tumble down as cool and dry winds on the Pacific slopes beyond. Meeting with no evaporating surface, and with no temperature *colder* than that to which they were subjected on the mountain-tops, they reach the ocean before they become charged with fresh vapor, and before, therefore, they have any which the Peruvian climate can extract. Thus we see how the top of the Andes becomes the reservoir from which are supplied the rivers of Chili and Peru.

The other rainless or almost rainless regions are the western coasts of Mexico, the deserts of Africa, Asia, North America, and Australia. Now study the geographical features of the country surrounding those regions; see how the mountain ranges run; then turn to Plate XV to see how the winds blow, and where the sources are (§ 18) which supply them with vapors. This plate shows the prevailing direction of the wind only at sea; but knowing it there, we may infer what it is on the land. Supposing it to prevail on the land as it generally does in corresponding latitudes at sea, then the plate will suggest readily enough how the winds that blow over these deserts came to be robbed of their moisture, or, rather, to have so much of it taken from them as to reduce their dew-point below the desert temperature; for *the air* (§ 22) *can never deposit its moisture when its temperature is higher than its dew-point.*

We have a rainless region about the Red Sea, because the Red Sea, for the most part, lies within the northeast trade-wind region, and these winds, when they reach that region, are dry winds, for they have as yet, in their course, crossed no wide sheets of water from which they could take up a supply of vapor.

30. Most of New Holland lies within the southeast trade-wind region; so does most of inter-tropical South America. But inter-tropical South America is the land of showers. The largest rivers and most copiously watered country in the world are to be found there, whereas almost exactly the reverse is the case in Australia. Whence this difference? Examine the direction of the winds with regard to the shore-line of these two regions, and the explanation will at once be suggested. In Australia—east coast—the shore line is stretched out in the direction of the trades; in South America—east coast—it is perpendicular to their direction. In Australia, they fringe this shore only with their vapor, and so stint that thirsty land with showers that the trees cannot afford to spread their leaves out to the sun, for it evaporates all the moisture from them; their instincts, therefore, teach them to turn their edges to his rays. In America, they blow perpendicularly upon the shore, penetrating the very heart of the country

with their moisture. Here the leaves, as the plantain, &c., turn their broad sides up to the sun, and court his rays.

31. *Why there is more rain on one side of a mountain than on the other.*—We may now, from what has been said, see why the Andes, and all other mountains which run north and south, have a dry and a rainy side, and how the prevailing winds of the latitude determine which is the rainy and which the dry side.

Thus, let us take the southern coast of Chili for illustration. In our summer time, when the sun comes north, and drags after him his belts of perpetual winds and calms, that coast is left within the regions of the northwest winds—the winds that are counter to the southeast trades—which, cooled by the winter temperature of the high lands of Chili, deposit their moisture copiously. During the rest of the year, the most of Chili is in the region of the southeast trades, and the same causes which operate in California to prevent rain there operate in Chili; only the dry season in one place is the rainy season of the other.

Hence we see that the weather side of all such mountains as the Andes is the wet side, and the lee side the dry.

32. The same phenomenon, from a like cause, is repeated in inter-tropical India, only in that country each side of the mountain is made alternately the wet and the dry side by a change in the prevailing direction of the wind. Plate XV shows India to be in one of the monsoon regions; it is the most famous of them all. From October to April the northeast trades prevail. They evaporate from the Bay of Bengal water enough to feed with rains, during this season, the western shores of this bay and the Ghauts range of mountains. This range holds the relation to these winds that the Andes of Peru (§ 29) hold to the southeast trades; it first cools and then relieves them of their moisture, and they tumble down on the western slopes of the Ghauts, Peruvian-like, (§ 31,) cool, rainless, and dry; wherefore that narrow strip of country between the Ghauts and the Arabian Sea would, like that in Peru between the Andes and the Pacific, remain without rain forever, were it not for other agents which are at work about India and not about Peru. The work of the agents to which I allude is felt in the monsoons, and these prevail in India and not in Peru.

33. After the northeast trades have blown out their season, which in India ends in April, (§ 32,) the great arid plains of Central Asia, of Tartary, Thibet, and Mongolia, become heated up, react upon these northeast trades, turn them back, and convert them, during the summer and early autumn, into southwest monsoons. These then come from the Indian Ocean and Sea of Arabia loaded with moisture, and striking with it perpendicularly upon the Ghauts, precipitate upon that narrow strip of land between this range and the Arabian Sea an amount of water that is truly astonishing. Here, then, are not only the conditions for causing more rain, now on the west, now on the east side of this mountain range, but the conditions also for the most copious precipitation. Accordingly, when we come to consult rain gauges, and to ask meteorological observers in India about the fall of rain, they tell us that on the western slopes of the Ghauts it sometimes reaches the enormous depth of twelve or fifteen inches in one day.*

These winds then continue their course to the Himalaya range as dry winds. In crossing this range, they are subjected to a lower temperature than that to which they were exposed in crossing the Ghauts. Here they drop more of their moisture in the shape of snow and rain, and then pass over into the thirsty lands beyond with scarcely enough vapor in them to make even a cloud. Thence they ascend into the upper air, there to become counter-currents in the

* Keith Johnston.

general system of atmospherical circulation. By studying Plate XV, where the rainless regions and inland basins, as well as the course of the prevailing winds, are shown, these facts will become obvious.

34. *The Regions of Greatest Precipitation.*—We shall now be enabled to determine, if the views which I have been endeavoring to present be correct, what parts of the earth are subject to the greatest fall of rain. They should be on the slopes of those mountains which the trade-winds first strike, after having blown across the greatest tract of ocean. The more abrupt the elevation, and the shorter the distance between the mountain top and the ocean, the greater the amount of precipitation.

If, therefore, we commence at the parallel of about 30° north in the Pacific, where the northeast trade-winds first strike that ocean, and trace them through their circuits till they first strike high mountains, we ought to find such a place of heavy rains.

Commencing at this parallel of 30°, therefore, in the north Pacific, and tracing thence the course of the northeast trade-winds, we shall find that they blow thence, and reach the region of equatorial calms near the Caroline Islands. Here they rise up; but, instead of pursuing the same course in the upper stratum of winds through the southern hemisphere, they, in consequence of the rotation of the earth, are made to take a southeast course. They keep in this upper stratum until they reach the calms of Capricorn, between the parallels of 30° and 40°; after which they become the prevailing northwest winds of the sou hern hemisphere, which correspond to the southwest of the northern. Continuing on to the southeast, they are now the surface winds; they are going from warmer to cooler latitudes; they become as the wet spong, (§ 22,) and are abruptly intercepted by the Andes of Patagonia, whose cold summit compresses them, and with its low dew-point squeezes the water out of them. Captain King found the astonishing fall of water here of nearly thirteen feet (one hundred and fifty-one inches) in forty-one days; and Mr. Darwin reports that the sea water along this part of the South American coast is sometimes quite fresh from the vast quantity of rain that falls.

We ought to expect a corresponding rainy region to be found to the north of Oregon; but there the mountains are not so high, the obstruction to the southwest winds is not so abrupt, the high lands are further from the coast, and the air which these winds carry in their circulation to that part of the coast, though it be as heavily charged with moisture as at Patagonia, has a greater extent of country over which to deposit its rain, and consequently the fall to the square inch will not be as great.*

In like manner, we should be enabled to say in what part of the world the most equable climates are to be found. They are to be found in the equatorial calms, where the northeast and southeast trades meet fresh from the ocean, and keep the temperature uniform under a canopy of perpetual clouds.

35. *Amount of Evaporation.*—The mean annual fall of rain on the entire surface of the earth is estimated at about five feet.

To evaporate water enough annually from the ocean to cover the earth, on the average, five feet deep with rain; to transport it from one zone to another; and to precipitate it in the right places, at suitable times, and in the proportions due, is one of the offices of the grand atmospherical machine. This water is evaporated principally from the torrid zone. Supposing

*I have, through the kindness of A. Holbrook, Esq., United States Attorney for Oregon, received the *Oregon Spectator* of February 13, 1851, containing the Rev. G. H. Atkinson's Meteorological Journal, kept in Oregon City during the month of January, 1851. The quantity of rain and snow for that month is 13.63 inches, or about one third the average quantity that falls at Washington city during the year.

it all to come thence, we shall have, encircling the earth, a belt of ocean three thousand miles in breadth, from which this atmosphere evaporates a layer of water annually sixteen feet in depth. And to hoist up as high as the clouds, and lower down again all the water in a lake sixteen feet deep, and three thousand miles broad, and twenty-four thousand long, is the yearly business of this invisible machinery. What a powerful engine is the atmosphere! and how nicely adjusted must be all the cogs, and wheels, and springs, and pinions of this exquisite piece of machinery, that it never wears out nor breaks down, nor fails to do its work at the right time and in the right way.

36. In his annual report to the society, (*Transactions of the Bombay Geographical Society*, from May, 1849, to August, 1850, vol. ix,) Dr. Buist, the secretary, states, on the authority of Mr. Laidly, that the evaporation at Calcutta is "about fifteen feet annually; that between the Cape and Calcutta it averages, in October and November, nearly three-fourths of an inch daily; between 10° and 20° in the Bay of Bengal, it was found to exceed an inch daily. Supposing this to be double the average throughout the year, we should," continues the doctor, "have eighteen feet of evaporation annually."

If, in considering the direct observations upon the daily rate of evaporation in India, it be remembered that the seasons there are divided into wet and dry; that in the dry season, evaporation in the Indian Ocean, because of its high temperature, and also of the high temperature and dry state of the wind, probably goes on as rapidly as it does anywhere else in the world; if, moreover, we remember that the regular trade-wind regions proper are, for the most part, rainless regions at sea; that evaporation is going on from them all the year round, we shall have reason to consider the estimate of sixteen feet annually for the trade-wind surface of the ocean not too high.

37. We see the light beginning to break upon us, for we now begin to perceive why it is that the proportions between the land and water were made as we find them in nature. If there had been more water and less land, we should have had more rain, and *vice versa;* and then climates would have been different from what they now are, and the inhabitants, animal or vegetable, would not have been as they are. And as they are, that wise Being who, in his kind providence, so watches over and regards the things of this world that he takes notice of the sparrow's fall, and numbers the very hairs of our head, doubtless designed them to be.

The mind is delighted, and the imagination charmed, by contemplating the physical arrangements of the earth from such points of view as this is which we now have before us; from it the sea, and the air, and the land, appear each as a part of that grand machinery upon which the well-being of all the inhabitants of earth, sea, and air depends; and which, in the beautiful adaptations that we are pointing out, affords new and striking evidence that they all have their origin in ONE omniscient idea, just as the different parts of a watch may be considered to have been constructed and arranged according to *one* human design.

In some parts of the earth the precipitation is greater than the evaporation; thus the amount of water borne down by every river that runs into the sea may be considered as the excess of the precipitation over the evaporation that takes place in the valley drained by that river.

This excess comes from the sea; the winds convey it to the interior; and the forces of gravity, dashing it along in mountain torrents or gentle streams, hurry it back to the sea again.

In other parts of the earth the evaporation and precipitation are exactly equal, as in those inland basins such as that in which the City of Mexico, Lake Titicaca, the Caspian Sea, &c., &c., are situated, which basins have no ocean drainage.

If more rain fell in the valley of the Caspian Sea than is evaporated from it, that sea would finally get full and overflow the whole of that great basin. If less fell than is evaporated from it again, then that sea, in the course of time, would dry up, and plants and animals there would all perish for the want of water.

In the sheets of water which we find distributed over that and every other inhabitable inland basin we see reservoirs or evaporating surfaces just sufficient for the supply of that degree of moisture which is best adapted to the well-being of the plants and animals that people such basins.

In other parts of the earth still, we find places, as the Desert of Sahara, in which neither evaporation nor precipitation takes place, and in which we find neither plant nor animal.

38. ADAPTATIONS.—In contemplating the system of terrestrial adaptations, these researches teach one to regard the mountain ranges and the great deserts of the earth as the astronomer does the counterpoises to his telescope; though they may be mere dead weights, they are, nevertheless, necessary to make the balance complete—the adjustments of this machine perfect. These counterpoises give ease to the motions, stability to the performance, and accuracy to the workings of the instrument. They are *compensations*.

Whenever I turn to contemplate the works of nature, I am struck with the admirable system of compensation, with the beauty and nicety with which every department is poised by the others; things and principles are meted out in directions the most opposite, but in proportions so exactly balanced and nicely adjusted, that results the most harmonious are produced.

It is by the action of opposite and compensating forces that the earth is kept in its orbit, and the stars are held suspended in the azure vault of heaven; and these forces are so exquisitely adjusted, that, at the end of a thousand years, the earth, the sun, and moon, and every star in the firmament, is found to come to its proper place at the proper moment.

Nay, philosophy teaches us, when the little snow drop, which in our garden walks we see raising its beautiful head to remind us that spring is at hand, was created, that the whole mass of the earth from pole to pole, and from circumference to centre, must have been taken into account and weighed, in order that the proper degree of strength might be given to the fibres of even this little plant.

Botanists tell us that the constitution of this plant is such as to require that at a certain stage of its growth the stalk should bend, and the flower should bow its head, that an operation may take place, which is necessary in order that the herb should produce seed after its kind; and that after this its vegetable health requires that it should lift its head again and stand erect. Now if the mass of the earth had been greater or less, the force of gravity would have been different; in that case the strength of fibre in the snow drop, as it is, would have been too much or too little; the plant could not bow or raise its head at the right time, fecundation could not take place, and its family would have become extinct with the first individual that was planted, because its "seed" would not have been "in itself," and therefore it could not reproduce itself.

Now if we see such perfect adaption, such exquisite adjustment, in the case of one of the smallest flowers of the field, how much more may we not expect "compensation" in the atmosphere and the ocean, upon the right adjustment and due performance of which depends not only the life of that plant, but the well-being of every individual that is found in the entire vegetable and animal kingdoms of the world?

When the east winds blow along the Atlantic coast for a little while, they bring us air saturated with moisture from the Gulf Stream, and we complain of the sultry, oppressive, heavy atmosphere; the invalid grows worse, and the well man feels ill, because when he takes this atmosphere into his lungs it is already so charged with moisture that it cannot take up and carry off that which encumbers his lungs, and which nature has caused his blood to bring and leave there, that respiration may take up and carry off. At other times the air is dry and hot; he feels that it is conveying off matter from the lungs too fast; he realizes the idea that it is consuming him, and he calls the sensation parching.

39. Therefore, in considering the general laws which govern the physical agents of the universe, and regulate them in the due performance of their offices, I have felt myself constrained to set out with the assumption that if the atmosphere had had a greater or less capacity for moisture, or if the proportion of land and water had been different—if the earth, air, and water, had not been in exact counterpoise—the whole arrangement of the animal and vegetable kingdoms would have varied from their present state. But God chose to make those kingdoms what they are; for this purpose it was necessary, in his judgment, to establish the proportions between the land and water, and the desert, just as they are, and to make the capacity of the air to circulate heat and moisture just what it is, and to have it to do all its work in obedience to law and in subservience to order. If it were not so why was power given to the winds to lift up and transport moisture, or the property given to the sea by which its waters may become first vapor and then fruitful showers or gentle dews? If the proportions and properties of land, sea, and air, were not adjusted according to the reciprocal capacities of all to perform the functions required by each, why should we be told that he "measured the waters in the hollow of his hand, and comprehended the dust in a measure, and weighed the mountains in scales, and the hills in a balance?" Why did he span the heavens, but that he might mete out the atmosphere in exact proportion to all the rest, and impart to it those properties and powers which it was necessary for it to have, in order that it might perform all those offices and duties for which he designed it?

Harmonious in their action, the air and sea are obedient to law and subject to order in all their movements; when we consult them in the performance of their offices they teach us lessons concerning the wonders of the deep, the mysteries of the sky, the greatness and the wisdom, and goodness of the Creator. The investigations into the broad-spreading circle of phenomena connected with the winds of heaven and the waves of the sea are second to none for the good which they do, and the lessons which they teach. The astronomer is said to see the hand of God in the sky; but does not the right-minded mariner, who looks aloft as he ponders over these things, hear his voice in every wave of the sea that "claps its hands," and feel his presence in every breeze that blows?

CHAPTER III.

RED FOGS AND SEA DUST.*

Where found, § 40.—Tallies on the wind, 41.—Where taken up, 42.—Information derived from Sea Dust, 43.—Its bearings upon the theory of atmospherical circulation, 44.—Suggests magnetic agency, 45.

40. SEAMEN tell us of "red fogs" which they sometimes encounter, especially in the vicinity of the Cape de Verde Islands. In other parts of the sea, also, they meet showers of dust. What these showers precipitate into the Mediterranean is called "sirocco dust," and in other parts "African dust," because the winds which accompany them are supposed to come from the Sirocco Desert or some other parched land of the continent of Africa. It is of a brick-red or cinnamon color, and it sometimes comes down in such quantities as to cover the sails and rigging, though the vessel may be hundreds of miles from the land.

Now the patient reader, who has had the heart to follow me in the preceding chapters around with "the wind in his circuits," will perceive that proof is yet wanting to establish it as a fact that the northeast and southeast trades, after meeting and rising up in the equatorial calms, do cross over and take the tracks represented by C and G, Plate III.

Statements and reasons, and arguments enough, have already been made and adduced to make it highly probable, according to human reasoning, that such is the case; and though the theoretical deductions showing such to be the case be never so good, positive proof that they are true cannot fail to be received with delight and satisfaction.

Were it possible to take a portion of this air, as it travels down the southeast trades, representing the general course of atmospherical circulation, and to put a tally on it by which we could always recognize it again, then we might hope actually to prove, by evidence the most positive, the channels through which the air of the trade-winds, after ascending at the equator, returns whence it came.

But the air is invisible; and it is not easily perceived how either marks or tallies may be put upon it, that it may be traced in its paths through the clouds.

The skeptic, therefore, who finds it hard to believe that the general circulation is such as Plate III represents it to be, might consider himself safe in his unbelief were he to declare his willingness to give it up the moment any one should put tallies on the wings of the wind, which would enable him to recognize that air again, and those tallies when found at other parts of the earth's surface.

As difficult as this seems to be, it has actually been done. Ehrenberg, with his microscope, has established, almost beyond a doubt, that the air which the southeast trade-winds bring to the equator does rise up there and pass over into the northern hemisphere.

41. The Sirocco, or African dust, which he has been observing so closely has turned out to be tallies put upon the wind in the other hemisphere; and this beautiful instrument of his enables us to detect the marks on these little tallies as plainly as though those marks had been written upon labels of wood and tied to the wings of the wind.

This dust, when subjected to microscopic examination, is found to consist of infusoria and organisms, whose *habitat* is not Africa, but South America, and in the southeast trade-wind region of South America. Professor Ehrenberg has examined specimens of sea dust from the

* *Vide* Maury's Physical Geography of the Sea.

Cape de Verdes and the regions thereabout, from Malta, Genoa, Lyons, and the Tyrol, and he has found a similarity among them as striking as it would have been had these specimens been all taken from the same pile. South American forms he recognizes in all of them; indeed, they are the prevailing forms in every specimen he has examined.

It may, I think, be now regarded as an established fact that there is a perpetual upper current of air from South America to North Africa; and that the volume of air which flows to the northward in these upper currents is nearly equal to the volume which flows to the southward with the northeast trade-winds, there can be no doubt.

The "rain dust" has been observed most frequently to fall in spring and autumn—that is, the fall has occurred after the equinoxes, but at intervals from them varying from thirty to sixty days, more or less. To account for this sort of periodical occurrence of the falls of this dust, Ehrenberg thinks it "necessary to suppose *a dust-cloud to be held constantly swimming in the atmosphere by continuous currents of air, and lying in the region of the trade-winds, but suffering partial and periodical deviations.*"

It has already been shown (§ 28) that the rain or calm belt between the trades travels up and down the earth from north to south, making the rainy season wherever it goes. This dust is probably taken up in the dry, and not in the wet season; instead, therefore, of its being "held in clouds suffering partial and periodical deviations," as Ehrenberg suggests, it more probably comes from one place about the vernal, and from another about the autumnal equinox; for places which have their rainy season at one equinox have their dry seasons at the other.

42. At the time of the vernal equinox the valley of the Lower Oronoco is then in its dry season—everything is parched up with the drought; the pools are dry, and the marshes and plains arid wastes. All vegetation has ceased; the great serpents and reptiles have buried themselves for hibernation;* the hum of insect life is hushed, and the stillness of death reigns through the valley.

Under these circumstances, the light breeze, raising dust from lakes that are dried up, and lifting motes from the brown savannas, will bear them away like clouds in the air.

This is the period of the year when the surface of the earth in this region, strewed with impalpable and feather-light remains of animal and vegetable organisms, is swept over by whirlwinds, gales, and tornadoes of terrific force; this is the period for the general atmospheric disturbances which have made characteristic the equinoxes. Do not these conditions appear sufficient to afford the "rain dust" for the spring showers?

At the period of the autumnal equinox another portion of the Amazonian basin is parched with drought, and liable to winds that fill the air with dust, and with the remains of dead animal and vegetable matter; these impalpable organisms, which each rainy season calls into being, to perish the succeeding season of drought, are perhaps distended and made even lighter by the gases of decomposition which has been going on in the period of drought.

May not, therefore, the whirlwinds which accompany the vernal equinox, and sweep over the lifeless plains of the Lower Oronoco, take up the "rain dust" which descends in the northern hemisphere in April and May? and may it not be the atmospherical disturbances which accompany the autumnal equinox that take up the microscopic organisms from the Upper Oronoco and the great Amazonian basin for the showers of October?

43. Baron Humboldt, in his *Aspects of Nature*, thus contrasts the wet and the dry seasons there:

* Humboldt.

"When, under the vertical rays of the never-clouded sun, the carbonized turfy covering falls into dust, the indurated soil cracks asunder as if from the shock of an earthquake. If at such times two opposing currents of air, whose conflict produces a rotary motion, come in contact with the soil, the plain assumes a strange and singular aspect. Like conical-shaped clouds, the points of which descend to the earth, the sand rises through the rarefied air on the electrically-charged centre of the whirling current, resembling the loud water-spout, dreaded by the experienced mariner. The lowering sky sheds a dim, almost straw-colored light on the desolate plain. The horizon draws suddenly nearer, the steppe seems to contract, and with it the heart of the wanderer. The hot, dusty particles, which fill the air, increase its suffocating heat, and the east wind, blowing over the long heated soil, brings with it no refreshment, but rather a still more burning glow. The pools, which the yellow, fading branches of the fan palm had protected from evaporation, now gradually disappear. As in the icy north the animals become torpid with cold, so here, under the influence of the parching drought, the crocodile and the boa become motionless, and fall asleep deeply buried in the dry mud. . . . .

"The distant palm-bush, apparently raised by the influence of the contact of unequally heated and therefore unequally dense strata of air, hovers above the ground, from which it is separated by a narrow intervening margin. Half concealed by the dense clouds of dust, restless with the pain of thirst and hunger, the horses and cattle roam around, the cattle lowing dismally, and the horses stretching out their long necks and snuffing the wind, if haply a moister current may betray the neighborhood of a not wholly dried-up pool. . . . . .

"At length, after the long drought, the welcome season of the rain arrives; and then how suddenly is the scene changed! . . . . . .

"Hardly has the surface of the earth received the refreshing moisture, when the previously barren steppe begins to exhale sweet odors, and to clothe itself with killingias, the many panicles of the paspulum, and a variety of grasses. The herbaceous mimosas, with renewed sensibility to the influence of light, unfold their drooping, slumbering leaves to greet the rising sun; and the early song of birds and the opening blossoms of the water plants join to salute the morning."

The color of the "rain dust," when collected in parcels and sent to Ehrenberg, is "brick red," or "yellow ochre;" when seen by Humboldt in the air, it was less deeply shaded, and is described *by him* as imparting a "straw-color" to the atmosphere. In the search of spider lines for the diaphragm of my telescopes, I procured the finest and best threads from a cocoon of a mud-red color; but the threads of this cocoon, as seen singly in the diaphragm, were of a golden color; there would seem, therefore, no difficulty in reconciling the difference between the colors of the rain dust, when viewed in little piles by the microscopist, and when seen attenuated and floating in the wind by the great traveller.

It appears, therefore, that we here have placed in our hands a clew, which, attenuated and gossamer-like though it at first appears, is nevertheless palpable and strong enough to guide us along the "circuits of the wind" till we enter "the chambers of the south."

The frequency of the fall of "rain dust" between the parallels of 17° and 25° north, and in the vicinity of the Cape Verde Islands, is remarked upon with emphasis by the microscopist. It is worthy of remark, because, in connection with the investigations at the Observatory, it is significant.

The latitudinal limits of the northern edge of the northeast trade-winds are variable. In the spring they are nearest to the equator, extending sometimes, in this season, not further from the equator than the parallel of 15° north.

44. The breadth of the calms of Cancer is also variable; so also are their limits. The extreme vibration of this zone is between the parallels of 17° and 38° north, according to the season of the year.

According to the hypothesis suggested by my researches, this is the zone in which the upper currents of atmosphere that ascended in the equatorial calms, and flowed off to the northward and eastward, are supposed to descend. This, therefore, is the zone in which the atmosphere that bears the "rain dust," or "African sand," descends to the surface; and this, therefore, is the zone, it might be supposed, which would be the most liable to showers of this "dust." This is the zone in which the Cape Verde Islands are situated; they are in the direction which theory gives to the upper current of air from the Oronoco and Amazon with its "rain dust," and they are in the region of the most frequent showers of "rain dust," all of which are in striking conformity with this theory as to the circulation of the atmosphere.

It is true that, in the present state of our information, we cannot tell why this "rain dust" should not be gradually precipitated from this upper current, and descend into the stratum of trade-winds as it passes from the equator to higher northern latitudes; neither can we tell why the vapor which the same winds carry along should not in like manner be precipitated on the way; nor why we should have a thunder-storm, a gale of wind, or the display of any other atmospherical phenomenon to-morrow, and not to-day; all that we can say is, that the conditions of to-day are not such as the phenomenon requires for its own development.

Therefore, though we cannot tell why the sea dust should not fall always in the same place, we may nevertheless suppose that it is not always in the atmosphere, for the storms that take it up occur only occasionally, and that when up, and in passing the same parallels, it does not always meet with the conditions—electrical and others—favorable to its descent, and that these conditions might occur now in this place, now in that. But that the fall does occur always in the same atmospherical vein or general direction, my investigations would suggest, and Ehrenberg's researches prove.

Judging by the fall of sea or rain dust, we may suppose that the currents in the upper regions of the atmosphere are remarkable for their general regularity, as well as for their general direction and sharpness of limits, so to speak.

We may imagine that certain electrical conditions are necessary to a shower of "sea dust" as well as to a thunder-storm; and that the interval between the time of the equinoctial disturbances in the atmosphere and the occurrence of these showers, though it does not enable us to determine the true rate of motion in the general system of atmospherical circulation, yet it assures us that it is not less on the average than a certain rate.

I do not offer these remarks as an explanation with which we ought to rest satisfied, provided other proof can be obtained; I rather offer them in the true philosophical spirit of the distinguished microscopist himself, simply as affording, as far as they are entitled to be called an explanation, that explanation which is most in conformity with the facts before us and which is suggested by the results of a novel and beautiful system of philosophical research.

45. Thus, though we may have tallied the air, and put labels on the wind, to "tell whence it cometh and whither it goeth," yet there evidently is an agent concerned in the circulation of the atmosphere whose functions are manifest, but whose presence has never yet been clearly recognized.

When the air which the northeast trade-winds bring down meets in the equatorial calms that which the southeast trade-winds convey, and the two rise up together, what is it that makes them cross? where is the power that guides that from the north over to the south, and that from the south up to the north?

CHAPTER IV.

THE WINDS.*

46. PLATE XV is a chart of the winds based on information derived from the Pilot Charts. The object of this chart is to make the young seamen acquainted only with the *prevailing* direction of the wind in every part of the ocean.

The arrows of the plate are supposed to fly with the wind; the half-bearded and half-feathered arrows denoting monsoons or periodic winds; the dotted belts, the regions of calm and baffling winds.

47. Monsoons, properly speaking, are winds which blow one-half of the year from one direction, and the other half from an opposite or nearly an opposite direction.

Let us commence the study of Plate XV, by examining the trade-wind region; for that is the region in which monsoons are most apt to be found.

48. The belt or zone of the southeast trade-winds is broader (§ 12), it will be observed, than the belt or zone of northeast trades. This phenomenon is explained by the fact that there is more land in the northern hemisphere, and that most of the deserts of the earth—as the great deserts of Asia and Africa—are situated in the rear, or behind the northeast trades; so that as these deserts become more or less heated, there is a call—a pulling back, if you please—upon these trades to flow back and restore the equilibrium which the deserts destroy. There being no, or few such regions in the rear of the southeast trades, they obey the first impulse, push and press over into the northern hemisphere.

By resolving the forces which it is supposed are the principal forces that put these winds in motion, viz: calorific action of the sun and diurnal rotation of the earth, we are led to the conclusion that the latter is much the greater of the two in its effects upon those of the northern hemisphere. But not to such an extent is it greater in its effects upon those of the southern. We see by the plate that those two opposing currents of wind are so unequally balanced that the one recedes before the other, and that the current from the southern hemisphere is larger in volume; *i. e.*, it moves a greater zone or belt of air. The southeast trade-winds discharge themselves over the equator—*i. e.*, across a great circle—into the region of equatorial calms, while the northeast trade-winds discharge themselves into the same region over a parallel of latitude, and consequently over a small circle. If, therefore, we take what obtains in the Atlantic as the type of what obtains entirely around the earth, as it regards the trade-winds, we shall see that the southeast trade-winds keep in motion more air than the northeast do, by a quantity at least proportioned to the difference between the circumference of the earth at the equator, and at the parallel of latitude of 9° north. For, if we suppose that those two perpetual currents of air extend the same distance from the surface of the earth, and move

* *Vide* Physical Geography of the Sea. Harper and Brothers, New York.

with the same velocity, a greater volume from the south would flow across the equator in a given time than would flow from the north over the parallel of 9° in the same time; the ratio between the two quantities would be as radius to the secant of 9°. Besides this, the quantity of land lying within and to the north of the region of the northeast trade-winds is much greater than the quantity within and to the south of the region of the southeast trade-winds. In consequence of this, the mean level of the earth's surface within the region of the northeast trade-winds is, it may reasonably be supposed, somewhat above the mean level of that part which is within the region of the southeast trade-winds. And as the northeast trade-winds blow under the influence of a greater extent of land surface than the southeast trades do, the former are more obstructed in their course than the latter by the forests, the mountain ranges, unequally heated surfaces, and other such like inequalities.

As already stated, the investigations show that the momentum of the southeast trade-winds is sufficient to push the equatorial limits of their northern congeners back into the northern hemisphere, and to keep them, at a mean, as far north as the ninth parallel of north latitude. Besides this fact, they also indicate that while the northeast trade-winds, so called, make an angle in their general course of about 23° with the equator, (east-northeast,) those of the southeast make an angle of 30° or more with the equator (southeast by east). I speak of those in the Atlantic, thus indicating that the latter approach the equator more directly in their course than do the others, and that, consequently, the effect of the diurnal rotation of the earth being the same for like parallels, north and south, the calorific influence of the sun exerts more power in giving motion to the southern than to the northern system of Atlantic trade-winds.

49. That such is actually the case is rendered still more probable from this consideration: All the great deserts are in the northern hemisphere, and the land surface is also much greater on our side of the equator. The action of the sun upon these unequally absorbing and radiating surfaces in and behind, or to the northward of the northeast trades, tends to retard these winds, and to draw large volumes of the atmosphere, that otherwise would be moved by them, back to supply the partial vacuum made by the heat of the sun, as it pours down its rays upon the vast plains of burning sands and unequally heated land surfaces in our overheated hemisphere. The northwest winds of the southern are also and consequently stronger than the southwest winds of the northern hemisphere.

The investigations that have taken place show that the influence of the land upon the normal directions of the wind at sea is an immense influence. It is frequently traced for a thousand miles or more out upon the ocean. For instance, the action of the sun's rays upon the great deserts and arid plains of Africa, in the summer and autumnal months, is such as to be felt nearly across the Atlantic Ocean between the equator and the parallel of 13° north. Between this parallel and the equator, the trade-winds are turned back by the heated plains of Africa, and are caused to blow a regular southwardly monsoon for several months. They bring the rains which divide the season in these parts of the African coast. The region of the ocean embraced by the monsoons is cuneiform in its shape, having its base resting upon Africa, and its apex stretching over till within 10° or 15° of the mouth of the Amazon.

Indeed, when we come to study the effects of South America and Africa (as developed by the Wind and Current Charts) upon the winds at sea, we should be led to the conclusion—had the foot of civilized man never trod the interior of these two continents—that the climate of one is humid; that its valleys are, for the most part, covered with vegetation, which protects its surface from the sun's rays; while the plains of the other are arid and naked, and, for the most part, act like furnaces in drawing the winds from the sea to supply air for the ascending columns which rise from its overheated plains.

Pushing these facts and arguments still further, these beautiful and interesting researches seem already sufficient almost to justify the assertion that, were it not for the Great Desert of Sahara, and other arid plains of Africa, the western shores of that continent, within the trade-wind region, would be almost, if not altogether, as rainless and sterile as the desert itself.

These investigations, with their beautiful developments, eagerly captivate the mind; giving wings to the imagination, they teach us to regard the sandy deserts, and arid plains, and the inland basins of the earth, as compensations in the great system of atmospherical circulation. Like counterpoises to the telescope, which the astronomer regards as incumbrances to his instrument, these wastes serve as make-weights, to give certainty and smoothness of motion—facility and accuracy to the workings of the machine.

50. When we travel out upon the ocean, and get beyond the influence of the land upon the winds, we find ourselves in a field particularly favorable for studying the general laws of atmospherical circulation. Here, beyond the reach of the great equatorial and polar currents of the sea, there are no unduly heated surfaces, no mountain ranges, or other obstructions to the circulation of the atmosphere—nothing to disturb it in its natural courses. The sea, therefore, is the field for observing the operations of the general laws which govern the movements of the great aerial ocean. Observations on the land will enable us to discover the exceptions. But from the sea we shall get the rule. Each valley, every mountain range and local district, may be said to have its own peculiar system of calms, winds, rains, and droughts. But not so the surface of the broad ocean; over it the agents which are at work are of a uniform character.

51. Rain-winds are the winds which convey the vapor from the sea, where it is taken up, to other parts of the earth, where it is let down either as snow, hail, or rain. As a general rule, the trade-winds may be regarded as the evaporating winds; and when, in the course of their circuit, they become monsoons, or the variables of either hemisphere, they then generally become also the rain-winds—especially the monsoons for certain localities. Thus, the southwest monsoons of the Indian Ocean are the rain-winds for the west coast of the Peninsula (§ 33). In like manner, the African monsoons of the Atlantic are the winds which feed the springs of the Niger and the Senegal with rains.

52. Upon every water-shed which is drained into the sea, the precipitation may be considered as greater than the evaporation, for the whole extent of the shed so drained, by the amount of water which runs off through the river into the sea. In this view, all rivers may be regarded as immense rain-gauges, and the volume of water annually discharged by any one, as an expression of the quantity which is annually evaporated from the sea, carried back by the winds, and precipitated throughout the whole extent of the valley that is drained by it. Now, if we knew the rain-winds from the dry, for each locality and season generally throughout such a basin, we should be enabled to determine, with some degree of probability at least, as to the part of the ocean from which such rains were evaporated. And thus, notwithstanding all the eddies caused by mountain chains, and other uneven surfaces, we might detect the general course of the atmospherical circulation over the land as well as the sea, and make the general courses of circulation in each valley as obvious to the mind of the philosopher as is the current of the Mississippi, or of any other great river, to his senses.

53. These investigations as to the rain-winds at sea, indicate that the vapors which supply the sources of the Amazon with rain are taken up from the Atlantic Ocean by the northeast

and southeast trade-winds; and many circumstances, some of which have already been detailed, tend to show that the winds which feed the Mississippi with rains get their vapor in the southeast trade-wind region of the other hemisphere. For instance, we know from observation that the trade-wind regions of the ocean, beyond the immediate vicinity of the land, are, for the most part, rainless regions, and that the trade-wind zones may be described, in a hyetographic sense, as the evaporating regions. They also show, or rather indicate as a general rule, that, leaving the polar limits of the two trade-wind systems, and approaching the nearest pole, the precipitation is greater than the evaporation until the point of maximum cold is reached.

And we know, also, that, as a *general* rule, the southeast and northeast trade-winds which come from a lower and go to a higher temperature are the evaporating winds—*i. e.*, they evaporate more than they precipitate; while those winds which come from a higher and go to a lower temperature are the rain-winds—*i. e.*, they precipitate more than they evaporate. That such is the case, not only do researches indicate, but reason teaches, and philosophy tells.

These views, therefore, suggest the inquiry as to the sufficiency of the Atlantic, after supplying the sources of the Amazon and its tributaries with their waters, to supply also the sources of the Mississippi and the St. Lawrence, and of all the rivers, great and small, of North America and Europe.

A careful study of the rain-winds, in connection with the Wind and Current Charts, will probably indicate to us the "springs in the ocean" which supply the vapors for the rains that are carried off by those great rivers. "All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again."

54. MONSOONS (§ 47) are, for the most part, formed of trade-winds. When a trade-wind is turned back or diverted by overheated districts from its regular course at stated seasons of the year, it is regarded as a monsoon. Thus the African monsoons of the Atlantic (Plate XV), the monsoons of the Gulf of Mexico, and the Central American monsoons of the Pacific, are, for the most part, formed of the northeast trade-winds, which are turned back to restore the equilibrium which the overheated plains of Africa, Utah, Texas, and New Mexico have disturbed. When the monsoons prevail for five months at a time, for it takes about a month for them to change and become settled, then both they and the trade-winds, of which they are formed, are called monsoons.

55. The northeast and the southwest monsoons of the Indian Ocean afford an example of this kind. A force is exerted upon the northeast trade-winds of that sea by the disturbance which the heat of summer creates in the atmosphere over the interior plains of Asia, which is more than sufficient to neutralize the forces which cause those winds to blow as trade-winds; it turns them back; and were it not for the peculiar conditions of the land about that ocean, what are now called the northeast monsoons would blow the year round; there would be no southwest monsoons; and the northeast winds, being perpetual, would become all the year, what in reality for five months (§ 54) they are, viz: northeast trade-winds.

56. The agents which produce monsoons reside (§ 55) on the land. These winds are caused by the rarefaction of the air over large districts of country situated on the polar edge, or near the polar edge of the trade-winds. Thus the monsoons of the Indian Ocean are caused by the intense heat which the rays of a cloudless sun produce during the summer time upon the Desert of Cobi and the burning plains of Central Asia. When the sun is north of the equator, the force of his rays, beating down upon these wide and thirsty plains, is such as to cause the vast superincumbent body of air to expand and ascend. There is, consequently, a rush of air, especially

from toward the equator, to restore the equilibrium; and in this case, the force which tends to draw the northeast trade-winds back becomes greater than the force which is acting to propel them forward. Consequently, they obey the stronger power, turn back, and become the famous southwest monsoons of the Indian Ocean, which blow from May to September, inclusive.

Of course, the vast plains of Asia are not brought up to monsoon heat *per saltum* or in a day. They require time both to be heated up to this point and to be cooled down again. Hence, there is a conflict for a few weeks about the change of the monsoon, when neither the trade-wind nor the monsoon force has fairly lost or gained the ascendency. This debatable period amounts to about a month at each change. So that the monsoons of the Indian Ocean prevail really for about five months each way, viz: from May to September, from the southwest, in obedience to the influence of the overheated plains, and from November to March, inclusive, from the northeast, in obedience to the trade-wind force.

57. The monsoon season may be always known by referring to the cause which produces these winds. Thus, by recollecting where the thirsty and overheated plains are which cause the monsoons, we know at once that these winds are rushing with greatest force toward these plains at the time that is the hottest season of the year upon them.

The influence of these heated plains upon the winds at sea is felt for a thousand miles and more. Thus, though the Desert of Cobi and the sun-burnt plains of Asia are, for the most part, north of latitude 30°, their influence in making monsoons is felt south of the equator (Plate XV). So, too, with the great Desert of Sahara and the African monsoons of the Atlantic; also, with the Salt Lake country and the Mexican monsoons on one side, and those of Central America in the Pacific on the other. The influence of the deserts of Arabia upon the winds is felt in Austria and other parts of Europe, as the observations of Kriel, Lamont, and others show.

58. It would appear, therefore, that these desert countries exercise a powerful influence in checking, and consequently in weakening, the force of the northeast trade-winds. There are no such extensive influences at work checking the southeast trades. On the contrary, these are accelerated; for the same forces that serve to draw the northeast trade-winds back, or retard them, tend also to draw the southeast trade-winds on or to accelerate them. Hence, the ability of the southeast trade-winds to push themselves over into the northern hemisphere.

Hence, also, we infer that, between certain parallels of latitude in the northern hemisphere, the sun's rays, by reason of the great extent of land surface, operate with much more intensity than they do between corresponding parallels in the southern; and that, consequently, the mean summer temperature on shore, north of the equator, is higher than it is south—a beautiful physical fact which the winds have revealed, in corroboration of what observations with the thermometer had already induced meteorologists to suspect.

59. It appears, from what has been said (§54), that it is the rays of the sun operating upon the land, not upon the water, which causes the monsoons. Now let us turn to Plate XV, and examine into this view. The monsoon regions are marked with half-bearded and half-feathered arrows; and we perceive, looking at the northern hemisphere, that all of Europe, some of Africa, most of Asia, and nearly the whole of North America, are to the north, or on the polar side of the northeast trade-wind zone; whereas but a small part of Australia, less of South America, and still less of South Africa, are situated on the polar side of the zone of southeast trade-winds. In other words, there are no great plains on the polar side of the southeast trade-winds upon which the rays of the sun, in the summer of the other hemisphere, can play with force enough to rarefy the air sufficiently to materially interrupt these winds in their course, or to spread out

over large portions of the sea systems of monsoons. But, besides the vast area of such plains on the polar side of its trade-wind belt in the northern hemisphere, the heat of which is sufficient (§ 57) to draw these trade-winds back, there are numerous other districts in the extra-tropical regions of our hemisphere, the summer heat of which, though it be not sufficient to turn the northeast trade-winds back, and make a monsoon of them, yet may be sufficient to weaken them in their fôrce, and, by retarding them (§ 58), draw the southeast trade-winds over into the northern hemisphere.

60. Now, as this interference from the land takes place in the summer only, we might infer, without appealing to actual observation, that the position of these trade-wind zones is variable; that is, that the equatorial edge of the southeast trade-wind zones is further to the north in our summer, when the northeast trades are most feeble, than it is in winter, when they are strongest.

We have here, then, at work upon these trade-wind zones, a force now weak, now strong, which, of course, would cause these zones to vibrate up and down the ocean, and within certain limits, according to the season of the year. These limits are given on Plate XV for spring and autumn. During the latter season, these zones reach their extreme northern declination, and in our spring their utmost limits toward the south.

61. The Calm Belts.—There is between the two systems of trade-winds a region of calms, known as the equatorial calms. It has a mean average breadth of about six degrees of latitude. In this region, the air which is brought to the equator by the northeast and southeast trades ascends. This belt of calms always separates these two trade-wind zones, and travels up and down with them. If we liken this belt of equatorial calms to an immense atmospherical trough, extending, as it does, entirely around the earth, and if we liken the northeast and southeast trade-winds to two streams discharging themselves into it, we shall see that we have two currents perpetually running in at the bottom, and that, therefore, we must have as much air as the two currents bring in at the bottom to flow out at the top. What flows out at the top is carried back north and south by these upper currents, which are thus proved to exist and to flow counter to the trade-winds.

Using still further this mode of illustration: if we liken the calm belt of Cancer and the calm belt of Capricorn each to a great atmospherical trough extending around the earth also, we shall see that in this case the currents are running in at the top and out at the bottom (§ 8).

The belt of equatorial calms is a belt of constant precipitation. Captain Wilkes, of the Exploring Expedition, when he crossed it in 1838, found it to extend from 4° north to 12° north. He was ten days in crossing it, and during those ten days rain fell to the depth of 6.15 inches, or at the rate of eighteen feet and upward during the year. In the summer months, this belt of calms is found between the parallels of 8° and 14° of north latitude; and, in the spring, between 5° south and 4° north.

This calm belt carries with it the rainy seasons of the torrid zone, always, in its motions from south to north and back, arriving at certain parallels at stated periods of the year; consequently, by attentively considering Plate XV, one can tell what places within the range of this zone have, during the year, two rainy seasons, what one, and what are the rainy months for each locality.

Were the northeast and the southeast trades, with the belt of equatorial calms, of different colors, and visible to an astronomer in one of the planets, he might, by the motion of these belts or girdles alone, tell the seasons with us. He would see them at one season going north, then appearing stationary, and then commencing their return to the south. But, though he would observe (§ 28) that they follow the sun in his annual course, he would remark that they do not change their latitude as much as the sun does his declination; he would, therefore, discover that their extremes of declination are not so far asunder as the tropics of Cancer and Capricorn, though in certain seasons the changes from day to day are very great. He would observe that these zones of winds and calms have their tropics or stationary nodes, about which they linger near three months at a time; and that they pass from one of their tropics to the other in a little less than another three months. Thus he would observe the whole system of belts to go north from the latter part of May till some time in August. Then they would stop and remain stationary till winter, in December; when again they would commence to move rapidly over the ocean, and down toward the south, until the last of February or the first of March; then, again, they would become stationary, and remain about this, their southern tropic, till May again.

62. THE HORSE LATITUDES.—Having completed the physical examination of the equatorial calms and winds, if the supposed observer should now turn his telescope toward the poles of our earth, he would observe a zone of calms bordering the northeast trade-winds on the north (§ 8,) and another bordering the southeast trade-winds on the south, (§ 11.) These calm zones also would be observed to vibrate up and down with the trade-wind zones, partaking (§ 28) of their motions, and following the declination of the sun.

On the polar side of each of these two calm zones there would be a broad band extending up into the polar regions, the prevailing winds within which are the opposites of the trade-winds, viz: southwest in the northern and northwest in the southern hemisphere.

The equatorial edge of these calm belts is near the tropics, and their average breadth is 10° or 12°. On one side of these belts (§ 8) the wind blows perpetually toward the equator; on the other, their prevailing direction is towards the poles. They are called (§ 8) the "horse latitudes" by seamen.

Along the polar borders of these two calm belts (§ 28) we have another region of precipitation, though generally the rains here are not so constant as they are in the equatorial calms. The precipitation near the tropical calms is nevertheless sufficient to mark the seasons; for whenever these calm zones, as they go from north to south with the sun, leave a given parallel, the rainy season of that parallel, if it be in winter, is said to commence. Hence, we may explain the rainy season in Chili at the south, and in California at the north.

63. THE WESTERLY WINDS.—To complete the physical examination of the earth's atmosphere, which we have supposed an astronomer in one of the planets to have undertaken, according to the facts developed by the Wind and Current Charts, it remains for him to turn his telescope upon the southwest passage winds of the northern hemisphere, pursue them into the arctic regions, and see theoretically how they get there, and, being there, what becomes of them.

From the parallel of 40° up toward the north pole, the prevailing winds, as already remarked, are the southwest passage winds, (Plate XV,) or, as they are more generally called by mariners, the "westerly" winds; these, in the Atlantic, prevail over the "easterly" winds in the ratio of about two to one.

Now if we suppose, and such is probably the case, these "westerly" winds to convey in two days a greater volume of atmosphere toward the arctic circle than those "easterly" winds can bring back in one, we establish the necessity for an upper current by which this difference may be returned to the tropical calms of our hemisphere, (§ 13.) Therefore, there must be some place in the polar regions at which these southwest winds cease to go north, and from which they commence their return to the south, and this locality must be in a region peculiarly liabl to calms. It is another atmospherical node in which the motion of the air is upward, with a decrease of barometric pressure. It is marked P, Plate III.

If we now return to the calm belt of the northern tropic, and trace theoretically a portion of air that, in its circuit, shall fairly represent the average course of these southwest passage winds, we shall see (§ 14) that it approaches the pole in a loxodromic curve; that as it approaches the pole it acquires, from the spiral convolutions of this curve, which represent its path, a whirling motion, in a direction *contrary* to that of the hands of a watch; and that the portion of atmosphere whose path we are following would gradually contract its gyrations, until it would finally ascend, turning against the hands of a watch as it whirls around.

In the southern hemisphere a like process is going on; only there the northwest passage wind would, as it arrives near the antarctic calms, acquire a motion with the sun, or in the direction of the hands of a watch.

CHAPTER V.

ON THE GEOLOGICAL AGENCY OF THE WINDS.*

To appreciate the offices of the Winds and Waves, Nature must be regarded as a whole, § 64.—The Dead Sea, § 65.—The Effect produced by the upheaval of Mountains across the course of vapor-bearing Winds, § 67.—Effect of the Andes upon vapor-bearing Winds, § 69.—Geological Age of the Andes and Dead Sea compared, § 70.—Rain and Evaporation in the Mediterranean, § 71.—Evaporation and Precipitation in the Caspian Sea equal, § 72.—The Quantity of Moisture the Atmosphere keeps in Circulation, § 73.—Where Vapor for the Rains that feed the Nile comesfrom, § 74.—Lake Titicaca, § 75.

64. Properly to appreciate the various offices which the winds and the waves perform, we must regard nature as a whole, for all the departments thereof are intimately connected. If we attempt to study one of them, we often find ourselves tracing clews which lead us off insensibly into others, and, before we are aware, we discover ourselves exploring the chambers of some other department.

The study of drift takes the geologist out to sea, and reminds him that a knowledge of waves, winds, and currents, of navigation and hydrography, are closely and intimately connected with his favorite pursuit.

The astronomer directs his telescope to the most remote star, or to the nearest planet in the sky, and makes an observation upon it. He cannot reduce this observation, nor make any use of it until he has availed himself of certain principles of optics; until he has consulted the thermometer, gauged the atmosphere, and considered the effect of heat in changing its powers of refraction. In order to adjust the pendulum of his clock to the right length he has to measure the water of the sea and weigh the earth. He, too, must therefore go into the study of the tides; he must examine the earth's crust, and consider the matter of which it is composed from pole to pole, circumference to centre; and in doing this he finds himself, in his researches, right alongside of the navigator, the geologist, and the meteorologist, with a host of other good fellows, each one holding by the same thread, and following it up into the same labyrinth—all, it may be, with different objects in view, but, nevertheless, each thread will be sure to lead them where there are stores of knowledge for all, and instruction for each one

* *Vide* Maury's Physical Geography of the Sea.

in particular. And thus, in undertaking to explore the physical geography of the sea, I have found myself standing side by side with the geologist on the land, and with him, far away from the sea-shore, engaged in considering some of the phenomena which the inland basins of the earth, those immense indentations on its surface that have no sea-drainage, present for contemplation and study.

65. Among the most interesting of these is that of the Dead Sea. Captain Lynch, of the United States Navy, has run a level from that sea to the Mediterranean, and finds the former to be about one thousand three hundred feet below the general sea-level of the earth. In seeking to account for this great difference of water-level, the geologist examines the neighboring region, and calls to his aid the forces of elevation and depression which are supposed to have resided in the neighborhood; he then points to them as the agents which did the work. Truly they are mighty agents, and they have diversified the surface of the earth with the most towering monuments of their power. But is it necessary to suppose that they resided in the vicinity of this region? May they not have come from the sea, and been, if not in this case, at least in the case of other inland basins as far removed as the other hemisphere? The inquiry as to the geological agency of the winds in such cases is a question which my investigations have suggested; and I propound it as one which, in accounting for the formation of this or that inland basin, is worthy, at least, of consideration.

Is there any evidence that the annual amount of precipitation upon the water-shed of the Dead Sea, at some former period, was greater than the annual amount of evaporation from it now is? If yea, from what part of the sea did the vapor that supplied the excess of that precipitation come, and what has cut off that supply? The mere elevation and depression of the lake basin (§ 65) would not do it.

If we establish the fact that the Dead Sea at a former period did send a river to the ocean, we carry along with it the admission that when the sea overflowed into that river, then the water that fell from the clouds over the Dead Sea basin was more than the winds could convert into vapor and carry away again; the river carried off the excess to the ocean whence it came, (§ 15.)

In the basin of the Dead Sea, in the basin of the Caspian, of the Sea of Aral, and in the other inland basins of Asia, we are entitled to infer that the precipitation and evaporation are at this time exactly equal. Were it not so, the level of these seas would be rising or sinking. If the precipitation were in excess, these seas would be gradually becoming fuller; and if the evaporation were in excess, they would be gradually drying up; but observation does not show, nor history tell us, that either is the case. As far as we know, the level of these seas is as permanent as that of the ocean, and it is difficult to realize the existence of subterranean channels between it and the great ocean. Were there such a channel, the Dead Sea being the lower, it would be the recipient of ocean waters; and we cannot conceive how it should be such a recipient without ultimately rising to the level of its feeder.

66. It may be that the question suggested by my researches has no bearing upon the Dead Sea; that local elevations and subsidences alone were concerned in placing the level of its waters where it is. But is it probable that, throughout all the geological periods, during all the changes which have taken place in the distribution of land and water surface over the earth, the winds, which in the general channels of circulation pass over the Dead Sea, have alone been unchanged? Throughout all ages, periods, and formations, is it probable that the winds have just brought us as much moisture to that sea as they now bring, and have just

taken up as much water from it as they now carry off? Obviously and clearly not. The salt-beds, the water-marks, the geological formations, and other facts traced by Nature's own hand upon the tablets of the rock, all indicate plainly enough that not only the Dead Sea, but the Caspian also, had upon them, in former periods, more abundant rains than they now have. Where did the vapor for those rains come from? and what has stopped the supply? Surely not the elevation or depression of the Dead Sea basin.

My researches with regard to the winds have suggested the probability (§ 19) that the vapor which is condensed into rains for the lake valley, and which the St. Lawrence carries off to the Atlantic Ocean, is taken up by the southeast trade-winds of the Pacific Ocean. Suppose this to be the case, and that the winds which bring this vapor arrive with it in the lake country at a mean dew-point of 56°. This would make the southwest winds the rain winds for the lakes generally, as well as for the Mississippi valley; there are also, speaking generally, the rain winds of Europe, and, I have no doubt, of extra-tropical Asia.

67. Now suppose a certain mountain range, hundreds of miles to the southwest of the lakes, but across the path of these winds, were to be suddenly elevated, and its crest pushed up into the regions of snow, having a mean temperature of 30° Fahrenheit. The winds, in passing that range, would be subjected to a mean dew-point of 30°; and, not meeting with any more evaporating surface between such range and the lakes, (§ 22,) they would have no longer any moisture to deposit at the supposed lake temperature of 50°; they could not yield their moisture to anything above 30°. Consequently, the amount of precipitation in the lake country would fall off; the winds which feed the lakes would cease to bring as much water as the lakes now give to the St. Lawrence. In such a case, that river and the Niagara would drain them to the level of their bed; evaporation would be increased by reason of the dryness of the atmosphere and the want of rain, and the lakes would sink to that level at which, as in the case of the Caspian Sea, the precipitation and evaporation would finally become equal.

There is a self-regulating principle that would bring about this equality; for as the water in the lakes becomes lower, the area of its surface would be diminished, and the amount of vapor taken from it would consequently become less and less as the surface was lowered, until the amount of water evaporated would become equal to the amount rained down again, precisely in the same way that the amount of water evaporated from the sea is exactly equal to the whole amount poured back into it by the rains, the fogs, and the dews.* Thus the great lakes of this continent would remain inland seas at a permanent level; the salt brought from the soil by the washings of the rivers and rains would cease to be taken off to the ocean as it now is; and finally, too, the great American lakes, in the process of ages, would become first brackish and then briny.

Now suppose the water basins which hold the lakes to be over a thousand fathoms (six thousand feet) deep. We know they are not more than four hundred and twenty feet deep; but suppose them to be six thousand feet deep. The process of evaporation, after the St. Lawrence had gone dry, might go on until one or two thousand feet or more were lost from the surface, and we should then have another instance of the level of an inland water-basin being far below the sea-level, as in the case of the Dead Sea; or it would become a rainless district, when the lakes themselves would go dry.

Or let us take another case for illustration. Corallines are at work about the Gulf Stream; they have built up the Florida Reefs on one side, and the Bahama Banks on the

* The quantity of dew in England is about five inches during a year.—*Glaisher.*

other. Suppose they should build up a dam across the Florida Pass, and obstruct the Gulf Stream, and that in like manner they were to connect Cuba with Yucatan, by damming up the Yucatan Pass, so that the waters of the Atlantic should cease to flow into the Gulf. What should we have?

The depth of the marine basin which holds the waters of the Gulf is, in the deepest part, about a mile. The officers of the United States ship Albany have run a line of deep-sea soundings from west to east across the Gulf; the greatest depth they reported was about eight thousand feet. Subsequent experiments, however, induce the belief that the depth is not quite so great.

We should therefore have, by stopping up the channels between the Gulf and the Atlantic, not a sea-level in the Gulf, but we should have a mean level between evaporation and precipitation. If the former were in excess, the level of the Gulf waters would sink down until the surface exposed to the air would be just sufficient to return to the atmosphere, as vapor, the amount of water discharged by the rivers—the Mississippi and others—into the Gulf. As the waters were lowered, the extent of evaporating surface would grow less and less, until Nature should establish the proper ratio between the ability of the air to take up and the capacity of the rain to let down. Thus we might have a sea whose level would be much further below the water level of the ocean than is the Dead Sea.

68. There is still another process, besides the two already alluded to, by which the drainage of these inland basins may, through the agency of the sea winds, have been cut off from the great salt seas, and that is by the elevation of continents from the bottom of the sea in distant regions of the earth, and the substitution caused thereby of dry land instead of water for the winds to blow upon.

Now, suppose that a continent should rise up in that part of the ocean, wherever it may be, that supplies the clouds with the vapor that makes the rain for the hydrographic basin of the great American lakes. What would be the result? Why, surely, fewer clouds and less rain, which would involve a change of climate in the lake country; an increase of evaporation from it, because a decrease of precipitation upon it; and consequently a diminution of cloudy screens to protect the waters of the lakes from being sucked up by the rays of the sun; and consequently, too, there would follow a low stage for water-courses, and a lowering of the lake level would ensue.

So far, I have instanced these cases only hypothetically; but, both in regard to the hydrographical basins of the Mexican Gulf and American lakes, I have confined myself strictly to analogies. Mountain ranges have been upheaved across the course of the winds, and continents have been raised from the bottom of the sea; and, no doubt, the influence of such upheavals has been felt in remote regions by means of the winds, and the effects which a greater or less amount of moisture brought by them would produce.

In the case of the Salt Lake of Utah, we have an example of drainage that has been cut off, and an illustration of the process by which Nature equalizes the evaporation and precipitation. To do this, in this instance, she is salting up the basin which received the drainage of this inland water-shed. Here we have the appearance, I am told, of an old channel, by which the water used to flow from this basin to the sea. Supposing there was such a time and such a water-course, the water returned through it to the ocean was the amount by which the precipitation used to exceed the evaporation over the whole extent of country drained through this now dry bed of a river. The winds have had something to do with this; they are the agents which used to bring more moisture from the sea to this water-shed than they took away; and they are the agents which now carry off from that valley more moisture than is brought to it, and which, therefore, are making a salt-bed of places that used to be covered by water. In like manner there is evidence that the great American lakes formerly had a drainage with the Gulf of Mexico. Steamers have been actually known, in former years, and in times of freshets, to pass from the Mississippi over into the lakes. At low water the bed of a dry river can be traced between them. Now, the Salt Lake of Utah is to the southward and westward of our northern lake basin; that is, the quarter whence the rain winds have been supposed to come. May not the same cause which lessened the precipitation or increased the evaporation in the Salt Lake water-shed, have done the same for the water-shed of the great American system of lakes?

If the mountains to the west—the Sierra Nevada, for instance—stand higher now than they formerly did, and if the winds which fed the Salt Lake valley with precipitation had, as I suppose they have, to pass the summits of the mountains, it is easy to perceive why the winds should not convey as much vapor across them now as they did when the summit of the ranges was lower and not so cool.

69. The Andes, in the trade-wind region of South America, stand up so high that the wind, in order to cross them, has to part with all its moisture, (§ 29,) and consequently there is, on the other side, a rainless region. Now, suppose a range of such mountains as these to be elevated across the track of the winds which supply the lake country with rains; it is easy to perceive how the whole country, watered by the vapor which such winds bring, would be converted into a rainless region.

I have used these cases to illustrate a position which any philosopher, who considers the geological agency of the winds, may with propriety consult, when he is told of an inland basin, the water-level of which, it is evident, was once higher than it now is; and that position is that, though the evidences of a higher water-level be unmistakable and conclusive, it does not follow, therefore, that there has been a subsidence of the lake basin itself, or an upheaval of the water-shed drained by it.

The cause which has produced this change in the water-level, instead of being local and near, may be remote; it may have its seat in the obstructions which have been interposed in some other quarter of the world, which obstructions may prevent the winds from taking up or from bearing off their wonted supplies of moisture for the region whose water-level has been lowered.

Having, therefore, I hope, made clear the meaning of the question proposed, by showing the manner in which winds may become important geological agents, and having explained how the upheaving of a mountain range in one part of the world may, through the winds, bear upon the physical geography of the sea, affect climates, and produce geological phenomena in another, I return to the Dead Sea and the great inland basins of Asia, and ask, How far is it possible for the elevation of the South American continent, and the upheaval of its mountains, to have had any effect upon the water-level of those seas? There are indications (§ 66) that they all once had a higher water-level than they now have, and that formerly the amount of precipitation was greater than it now is; then what has become of the sources of vapor? What has diminished its supply? Its supply would be diminished (§ 68) by the substitution of dry land in those parts of the ocean which used to supply that vapor; or the quantity of vapor deposited in the hydrographical basins of those seas would have been lessened if a snow-capped range of mountains (§ 67) had been elevated across the path of these winds, and between these basins and the places where they were supplied with vapor.

Now, if it be true (§ 21) that the trade-winds from the southern hemisphere take up the water which is to be rained in the extra-tropical north, the path (§ 11) ascribed to the southeast trades of Africa and America, after they descend and become the prevailing southwest winds of the northern hemisphere, should pass over a region of less precipitation generally than they would do if, while performing the office of southeast trades, they had blown over water instead of land. The southeast trade-winds, with their load of vapor, whether great or small, take, after ascending into the equatorial calms, a northeasterly direction; they continue to flow in the upper regions of the air in that direction until they cross the tropic of Cancer. The places of least rain then, between this tropic and the pole, should be precisely those places which depend for their rains upon the vapor which the winds that blow over southeast trade-wind, Africa and America, convey.

Now, if we could trace the path of these winds through the extra-tropical regions of the northern hemisphere, we should be able to identify it by the foot-prints of the clouds; for the path of the winds, which depend for their moisture upon such sources of supply as the dry land of Central South America and Africa, cannot run through a country that is abundantly watered.

It is a remarkable *coincidence*, at least, that the countries in the extra-tropical regions of the north, that are situated to the northeast of the southeast trade-winds of South Africa and America—that the countries in our hemisphere, over which theory makes these winds to blow, include all the great deserts of Asia, and the districts of least precipitation in Europe. A line from the Gallipagos Islands, through Florence, in Italy, another from the mouth of the Amazon through Aleppo, in Holy Land, (Plate VI,) would, after passing the tropic of Cancer, mark upon the surface of the earth the route of these winds; this is that "lee country," which, if such be the system of atmospherical circulation, ought to be scantily supplied with rains. Now, the hyetographic map of Europe, in Johnston's beautiful *Physical Atlas*, places the region of least precipitation between these two lines, (Plate VI.)

It would seem that Nature, as if to reclaim this "lee" land from the desert, had stationed by the way-side of these winds a succession of inland seas, to serve them as relays for supplying with moisture this thirsty air. There are the Mediterranean Sea, the Caspian Sea, and the Sea of Aral, all of which are situated exactly in this direction, as though these sheets of water were designed, in the grand system of aqueous arrangements, to supply with fresh vapor winds that had already left rain enough behind them to make an Amazon and an Oronoco of.

70. Now that there has been such an elevation of land out of the water, we infer from the fact that the Andes were once covered by the sea, for their tops are now crowned with the remains of marine animals. When they and their continent were submerged—admitting that Europe in general outline was then as it now is—it cannot be supposed, if the circulation of vapor were then such as it is supposed now to be, that the climates of that part of the Old World which is under the lee of those mountains were then as scantily supplied with moisture as they now are. When the sea covered South America, the winds had nearly all the waters which now make the Amazon to bring away with them, and to distribute among the countries situated along the route (Plate VI) ascribed to them.

If ever the Caspian Sea exposed a larger surface for evaporation than it now does—and no doubt it did—if the precipitation in that valley ever exceeded the evaporation from it, as it does in all valleys drained into the open sea, then there must have been a change of hygrometrical condition there. And admitting the vapor-springs for that valley to be situated in the direction supposed, the rising up of a continent from the bottom of the sea, or the upheaval of a range of mountains in certain parts of America, Africa, or Spain, across the route of the winds which brought the rain for the Caspian water-shed, might have been sufficient to rob them of the moisture which they were wont to carry away, and precipitate upon this great inland basin. See how the Andes have made Atacama a desert, and of Western Peru a rainless country; these regions have been made rainless simply by the rising up of a mountain range between them and the vapor-springs in the ocean which feed with moisture the winds that blow over these now rainless regions.

That part of Asia, then, which is under the lee of southern trade-wind Africa, lies to the north of the tropic of Cancer, and between two lines, the one passing through Cape Palmas and Medina, the other through Aden and Delhi. Being extended to the equator, they will include that part of it which is crossed by the continental southeast trade-winds of Africa, after they have traversed the greatest extent of land surface, (Plate VI.)

The range which lies between the two lines that represent the course of the American winds with their vapors, and the two lines which represent the course of the African winds with their vapors, is the range which is under the lee of winds that have, for the most part, traversed water-surface, or the ocean, in their circuit as southeast trade-winds. But a bare inspection of Plate VI will show that the southeast trade-winds which cross the equator between longitude 15° and 50° west, and which are supposed to blow over into this hemisphere between these two ranges, have traversed land as well as water; and the Trade-wind Chart shows that it is precisely those winds, which in the summer and fall are converted into southwest monsoons for supplying the whole extent of Guinea with rains to make rivers of. Those winds, therefore, it would seem, leave much of their moisture behind them, and pass along to their channels, in the grand system of circulation, for the most part as dry winds. Moreover, it is not to be supposed that the channels through which the winds blow that cross the equator at the several places named, are as sharply defined in nature as the lines suggested, or as Plate VI would represent them to be.

The whole region of the extra-tropical Old World that is included within the ranges marked, is the region which has most land to windward of it in the southern hemisphere. Now, it is a curious *coincidence*, at least, that all the great extra-tropical deserts of the earth, with those regions in Europe and Asia which have the least amount of precipitation upon them should lie within this range. That they are situated under the lee of the southern continents and have but little rain, may be a coincidence, I admit; but that these deserts of the Old World are placed where they are is no coincidence, no accident: they are placed where they are, and as they are, by design; and in being so placed, it was intended that they should subserve some grand purpose in the terrestrial economy. Let us see, therefore, if we can discover any marks of that design, any of the purposes of such an arrangement, and trace any connexion between that arrangement, and the supposition which I maintain as to the place where the winds that blow over those regions derive their vapors.

It will be remarked at once that all the inland seas of Asia, and all those of Europe, except the semi-fresh-water gulfs of the north are within this range. The Persian Gulf and the Red Sea, the Mediterranean, the Black, and the Caspian, all fall within it. And why are they planted within it? Why are they arranged to the northeast and southwest under this lea, and in the very direction in which theory makes this breadth of thirsty winds to prevail? Clearly and obviously, one of the purposes in the Divine economy was, that they might replenish with vapor the winds which are almost vaporless when they arrive at these regions in the general system of circulation. And why should these winds be almost vaporless? They are almost vaporless, because their route in the general system of circulation is such that they are not brought into contact with the water-surface from which the needful supplies of vapor are to be had; or being obtained, the supplies have since been taken away by the cool tops of mountain ranges over which these winds have had to pass.

In the Mediterranean the evaporation is greater than the precipitation. Upon the Red Sea there never falls a drop of rain; it is all evaporation. Are we not, therefore, entitled to regard the Red Sea as a make-weight thrown in to regulate the proportion of cloud and sunshine, and to dispense rain to certain parts of the earth in due season and in proper quantities? Have we not, in these two facts, evidence conclusive that the winds which blow over these two seas come, for the most part, from a dry country, from regions which contain few or no pools to furnish supplies of vapor.

Indeed, so scantily supplied with vapor are the winds which pass in the general channels of circulation over the water-shed and sea-basin of the Mediterranean, that they take up there more water as vapor than they deposit. But, throwing out of the question what is taken up from the surface of the Mediterranean itself, these winds deposit more water on the water-shed whose drainage leads into that sea than they take up from it again. The excess is to be found in the rivers which discharge into the Mediterranean; but so thirsty are the winds which blow across the bosom of that sea, that they not only take up again all that those rivers pour into it, but they are supposed, by philosophers, to create a demand for an immense current from the Atlantic to supply the waste.

71. It is estimated that three* times as much water as the Mediterranean receives from its rivers is evaporated from its surface. This may be an over-estimate, but the fact that evaporation from it is in excess of the precipitation, is made obvious by the current which the Atlantic sends into it through the Straits of Gibraltar; and the difference, we may rest assured, whether it be much or little, is carried off to modify climate elsewhere—to refresh with showers and make fruitful some other part of the earth.

The great inland basin of Asia, in which are the Aral and Caspian Seas, is situated on the route which this hypothesis requires these thirsty winds from southeast trade-wind Africa and America to take; and so scant of vapor are these winds when they arrive in this basin, that they have no moisture to leave behind; just as much as they pour down they take up again and carry off. We know that the volume of water returned by the rivers, the rains, and the dews, into the whole ocean, is exactly equal to the volume which the whole ocean gives back to the atmosphere; as far as our knowledge extends, the level of each of these two seas is as permanent as that of the great ocean itself. Therefore, the volume of water discharged by rivers, the rains, and the dews, into these two seas, is exactly equal to the volume which two seas give back as vapor to the atmosphere.

These winds, therefore, do not begin permanently to lay down their load of moisture, be it great or small, until they cross the Oural Mountains. On the steppes of Issam, after they have supplied the Amazon and the other great equatorial rivers of the south, we find them first beginning to lay down more moisture than they take up again. In the Obi, the Yenesi, and the Lena, is to be found the volume which contains the expression for the load of water which these winds have brought from the southern hemisphere, from the Mediterranean, and the Red Sea; for in these almost hyperborean river basins do we find the first instance in which, throughout

* *Vide* article "Physical Geography," Encyclopædia Britannica.

the entire range assigned these winds, they have, after supplying the Amazon, &c., left more water behind them than they have taken up again and carried off. The low temperatures of Siberian Asia are quite sufficient to extract from these winds the remnants of vapor which the cool mountain tops and mighty rivers of the southern hemisphere have left in them.

Here I may be permitted to pause, that I may call attention to another remarkable coincidence, and admire the marks of design, the beautiful and exquisite adjustments that we see here provided, to insure the perfect workings of the great aqueous and atmospherical machine. This coincidence—may I not call it cause and effect?—is between the hygrometrical conditions of all the countries within, and the hygrometrical conditions of all the countries without the range included within the lines which I have drawn (Plate VI) to represent the route in the northern hemisphere, of the southeast trade-winds *after* they have blown their course over the land in South Africa and America. Both to the right and left of this range are countries included between the same parallels in which it is, yet these countries all receive more water from the atmosphere than they give back to it again; they all have rivers running into the sea. On the one hand, there are in Europe the Rhine, the Elbe, and all the great rivers that empty into the Atlantic; on the other hand, there are in Asia the Ganges, and all the great rivers of China; and in North America, in the latitude of the Caspian Sea, is our great system of fresh-water lakes; all of these receive from the atmosphere immense volumes of water, and pour it back into the sea in streams the most magnificent.

It is remarkable that none of these copiously supplied water-sheds have, to the southwest of them in the trade-wind regions of the southern hemisphere, any considerable body of land; they are, all of them, under the lee of evaporating surfaces, of ocean waters in the trade-wind regions of the south. Only those countries in the extra-tropical north, which I have described as lying under the lee of trade-wind South America and Africa, are scantlily supplied with rains.

72. The surface of the Caspian Sea is about equal to that of our lakes; in it, evaporation is just equal to the precipitation. Our lakes are between the same parallels, and about the same distance from the western coast of America that the Caspian Sea is from the western eoast of Europe; and yet the waters discharged by the St. Lawrence give us an idea of how greatly the precipitation upon it is in excess of the evaporation. To windward of the lakes, and in the trade-wind regions of the southern hemisphere, is no land; but to windward of the Caspian Sea, and in the trade-wind region of the southern hemisphere, there is land. Therefore, supposing the course of the vapor distributing winds to be such as I maintain it to be, ought they not to carry more water from the ocean to the American lakes than it is possible for them to carry from the land—from the interior of South Africa and America—to the valley of the Caspian Sea?

In like manner, extra-tropical New Holland and South Africa have each land—not water—to the windward of them in the trade-wind regions of the northern hemisphere, where, according to this hypothesis, the vapor for their rains ought to be taken up; they are both countries of little rain; but extra-tropical South America has, in the trade-wind region to windward of it in the northern hemisphere, a great extent of ocean, and the amount of precipitation in extra-tropical South America is wonderful. The coincidence, therefore, is remarkable, that the countries in the extra-tropical regions of this hemisphere, which lie to the northeast of large districts of land in the trade-wind regions of the other hemisphere, should be scantily supplied with rains; and, likewise, that those so situated in the extra-tropical south, with regard to land in the trade-wind region of the north, should be scantily supplied with rains.

Having thus remarked upon the coincidence, let us turn to the evidences of design, and contemplate the beautiful harmony displayed in the arrangement of the land and water, as we find them along this conjectural "wind-road." (Plate VI.)

Those who admit design among terrestrial adaptations, or have studied the economy of cosmical arrangements, will not be loth to grant that by design the atmosphere keeps in circulation a certain amount of moisture; that the water of which this moisture is made is supplied by the aqueous surface of the earth, and that it is to be returned to the seas again through rivers and the process of precipitation; that a permanent increase or decrease of the quantity of water thus put and kept in circulation by the winds would be followed by a corresponding change of hygrometrical conditions, which would draw after it permanent changes of climate, and that permanent change of climate would involve the ultimate well-being of myriads of organisms, both in the vegetable and animal kingdoms.

73. The quantity of moisture that the atmosphere keeps in circulation is, no doubt, just that quantity which is best suited to the well-being, and most adapted to the proper development of the vegetable and animal kingdoms; and that quantity is dependent upon the arrangement and the proportions that we see in nature between the land and the water—between mountain and desert, river and sea. If the seas and evaporating surfaces were changed, and removed from the places they occupy to other places, the principal places of precipitation probably would also be changed; whole familes of plants would wither and die for want of cloud and sunshine, dry and wet, in proper proportions and in due season; and, with the blight of plants, whole tribes of animals would also perish. Under such a chance arrangement, man would no longer be able to rely upon the early and the latter rain, or to count with certainty upon the rains being sent in due season for seed-time and harvest. And that the rain will be sent in due season we are assured from on high; and when we recollect who it is that "sendeth" it, we feel the conviction strong within us that He that sendeth the rain has the winds for his messengers; and that they may do his bidding the land and the sea were arranged, both as to position and relative proportions, where they are, and as they are.

It should be borne in mind that the southeast trade-winds, after they rise up at the equator (Plate XV) have to overleap the northeast trade-winds. Consequently, they do not touch the earth until near the tropic of Cancer, (see the bearded arrows, Plate VI,) more frequently to the north than to the south of it; but for a part of every year, the place where these vaulting southeast trades first strike the earth, after leaving the other hemisphere, is very near this tropic. On the equatorial side of it, be it remembered, the northeast trade-winds blow; on the polar side, what were the southeast trades, and what are now the prevailing southwesterly winds of our hemisphere, prevail. Now examine Plate VI, and it will be seen that the upper half of the Red Sea is north of the tropic of Cancer; the lower half is to the south of it; that the latter is within the northeast trade-wind region; the former, in the region where the southwest passage winds are the prevailing winds.

74. The river Tigris is probably evaporated from the upper half of this sea by these winds; while the northeast trade-winds take up from the lower half those vapors which feed the the Nile with rain, and which the clouds deliver to the cold demands of the Mountains of the Moon. Thus there are two "wind-roads" crossing this sea; to the windward of it, each road runs through a rainless region; to the leeward, there is, in each case, a river to cross.

The Persian Gulf lies, for the most part, in the track of the southwest winds; to the windward of the Persian Gulf is a desert; to the leeward, the river Indus. This is the route by which theory would require the vapor from the Red Sea and Persian Gulf to be conveyed;

and this is the direction in which we find indications that it is conveyed. For to leeward do we find, in each case, a river, telling us, by signs not to be mistaken, that it receives more water from the clouds than it gives back to the winds.

Is it not a curious circumstance, that the winds which travel the road suggested from the southern hemisphere should, when they touched the earth on the polar side of the tropic of Cancer, be so thirsty, more thirsty, much more, than those which travel on either side of their path, and which are supposed to have come from southern seas, not from southern lands?

The Mediterranean has to give those winds three times as much vapor as it receives from them (§ 71;) the Red Sea gives them as much as they can take, and receives nothing back in return but a little dew; the Persian Gulf also gives more than it receives. What becomes of the rest? Doubtless it is given to the winds, that they may bear it off to distant regions, and make lands fruitful, that, but for these sources of supply, would be almost rainless, if not entirely arid, waste, and barren.

These seas and arms of the ocean now present themselves to the mind as counterpoises in the great hygrometrical machinery of our planet. As sheets of water placed where they are to balance the land in the trade-wind region of South America and South Africa, they now present themselves. When the foundations of the earth were laid, we know who it was that "measured the waters in the hollow of his hand, and meted out the heavens with a span, and comprehended the dust of the earth in a measure, and weighed the mountains in scales, and the hills in a balance." And hence we know also that they are arranged both according to proportion and to place.

Here, then, we see harmony in the winds, design in the mountains, order in the sea, arrangement in the dust, and form for the desert. Here are signs of beauty and works of grandeur; and we may now fancy that, in this exquisite system of adaptations and compensations, we can almost behold, in the Red and Mediterranean Seas, the very waters that were held in the hollow of the Almighty hand when he weighed the Andes of America, and balanced the hills of Africa in his comprehensive scales.

In that great inland basin of Asia which holds the Caspian Sea, and embraces an area of one million and a half of geographical square miles, we see the water-surface so exquisitely adjusted that it is just sufficient, and no more, to return to the atmosphere as vapor exactly as much moisture as the atmosphere lends, in rain, to the rivers of that basin.

Thus we are entitled to regard the Mediterranean, the Red Sea, and Persian Gulf as relays, distributed along the route of these thirsty winds from the continents of the other hemisphere, to supply them with vapors, or to restore to them that which they have left behind to feed the sources of the Amazon, the Niger, and the Congo.

The hypothesis that the winds from South Africa and America do take the course through Europe and Asia which I have marked out for them (Plate VI,) is supported by so many coincidences, to say the least, that we are entitled to regard it as probably correct, until a train of coincidences as striking can be adduced to show that such is not the case.

Returning once more to a consideration of the geological agency of the winds in accounting for the depression of the Dead Sea, we now see the fact most strikingly brought out before us that if the Straits of Gibraltar were to be barred up so that no water could pass through them, we should have a great depression of water level in the Mediterranean. Three times as much water is evaporated from that sea as is returned to it through the rivers. A portion of water evaporated from it is probably rained down and returned to it through the rivers; but, supposing it to be barred up, as the demand upon it for vapor would exceed the supply by rains and rivers, it would commence to dry up. As it sinks down, the area exposed for evaporation would decrease, and the supplies to the rivers would diminish, until finally there would be established between the evaporation and precipitation an equilibrium, as in the Dead and Caspian Seas; but, for aught we know, the water-level of the Mediterranean might, before this equilibrium were attained, have reached a stage far below that of the Dead Sea level.

The Lake Tadjura is now in the act of attaining such an equilibrium. There are connected with it the remains of a channel by which the water ran into the sea; but the surface of the lake is now five hundred feet below the sea-level, and it is salting up. If not in the Dead Sea, do we not, in the valley of this lake, find outcropping some reason for the question, What have the winds had to do with the phenomena before us?

The winds, in this sense, are geological agents of great power. It is not impossible but that they may afford us the means of comparing, directly, geological events which had taken place in one hemisphere with geological events in another: *e. g.*, the tops of the Andes were once at the bottom of the sea. Which is the oldest formation, that of the Dead Sea or the Andes? If the former be the older, then the climate of the Dead Sea must have been hygrometrically very different from what it now is.

In regarding the winds as geological agents, we can no longer consider them as the type of instability. We would rather behold them now in the light of ancient and faithful chroniclers, which, upon being rightly consulted, will reveal to us truths which Nature has written upon their wings in characters as legible and enduring as she has ever engraved the history of geological events upon the tablet of the rock.

75. The waters of Lake Titicaca, which receives the drainage of the great inland basin of the Andes, are only brackish, not salt. Hence we may infer that this lake has not been standing long enough to become brine, like the waters of the Dead Sea; consequently, it belongs to a more recent period. On the other hand, it will also be interesting to hear that my friend, Captain Lynch, informs me that, in his exploration of the Dead Sea, he saw what he took to be the dry bed of a river that once flowed from it. And thus we have two more links, stout and strong, to add to the circumstantial evidence going to sustain the testimony of this strange and fickle witness, which I have called up from the sea to testify in this presence concerning the works of Nature, and to tell us which be the older, the hoary-headed Andes, watching the stars, or the Dead Sea, sleeping upon its ancient beds of crystal salt.

CHAPTER VI.

THE EQUATORIAL CLOUD-RING.*

Equatorial Doldrums, § 76.—The Offices performed by Clouds in the terrestrial Economy, § 78.—The Barometer and Thermometer under the Cloud-ring, § 79.—How its Vapors are brought by the Trade-Winds, § 81.—Breadth of the Cloud-ring, § 82.—How it would appear if seen from one of the Planets, § 83.—Observations at Sea interesting, § 84.

76. SEAFARING people have, as if by common consent, divided the ocean off into regions, and characterized them according to the winds: *e. g.*, there are the trade-wind regions, the variables, the horse latitudes, the "doldrums," &c. The "horse latitudes" are the belts of

* *Vide* Maury's Physical Geography of the Sea.

calms and light airs (§ 8) which border the polar edge of the northeast trades. They were so called from the circumstance that vessels formerly bound from New England to the West Indies, with a deck load of horses, were often so delayed in this calm belt of Cancer, that, for the want of water for their animals, they were compelled to throw a portion of them overboard.

The equatorial doldrums is another of these calm places, (§ 9.) Besides being a region of calms and baffling winds, it is a region noted for its rains and clouds, which make it one of the most oppressive and disagreeable places at sea. The emigrant ships from Europe for Australia have to cross it. They are often baffled in it for two or three weeks; then the children and the passengers who are of delicate health suffer most. It is a frightful graveyard on the wayside to that golden land.

77. A vessel bound into the southern hemisphere from Europe or America, after clearing the regions of variable winds and crossing the "horse latitudes," enters the northeast trades. Here the mariner finds the sky sometimes mottled with clouds, but for the most part clear. Here, too, he finds his barometer rising and falling under the ebb and flow of a regular atmospherical tide, which gives a high and low barometer every day, with such regularity, that the time of day within a few minutes may be told by it. The rise and fall of this tide, measured by the barometer, amounts to about one-tenth (0.1) of an inch, and it occurs daily, and everywhere between the tropics; the maximum about 10h. 30m. A. M., the minimum between 4h. and 5h. P. M., with a second maximum and minimum about 10 P. M. and 5 A. M.* The diurnal variation of the needle changes also with the turning of these invisible tides. Continuing his course toward the equinoctial line, he observes his thermometer to rise higher and higher as he approaches it; at last, entering the region of equatorial calms and rains, he feels the weather to become singularly close and oppressive; he discovers here that the elasticity of feeling which he breathed from the trade-wind air has forsaken him; he has entered the doldrums, and is under the "cloud-ring."

Escaping from this gloomy region, and entering the southeast trades beyond, his spirits revive, and he turns to his log-book to see what changes are recorded there. He is surprised to find that, notwithstanding the oppressive weather of the rainy latitudes, both his thermometer and barometer stood, while in them, lower than in the clear weather on either side of them; that just before entering and just after leaving the rainy parallels, the mercury of the thermometer and barometer invariably stands higher than it does when within them, even though they include the equator. In crossing the equatorial doldrums, he has passed a ring of clouds that encircles the earth.

I find in the journal of the late Commodore Arthur Sinclair, kept on board the United States frigate Congress, during a cruise to South America in 1817–'18, a picture of the weather under this *cloud-ring* that is singularly graphic and striking. He encountered it in the month of January, 1818, between the parallel of 4° north and the equator, and between the meridians of 19° and 23° west. He says of it:

"This is certainly one of the most unpleasant regions in our globe. A dense close atmosphere, except for a few hours after a thunder-storm, during which time torrents of rain fall, when the air becomes a little refreshed; but a hot, glowing sun heats it again, and but for your awning, and the little air put in circulation by the continual flapping of the ship's sails,

* See paper on Meteorological Observations in India, by Colonel Sykes, Philosophical Transactions for 1850, Part II, p. 297.

it would be almost insufferable. No person who has not crossed this region can form an adequte idea of its unpleasant effects. You feel a degree of lassitude unconquerable, which not even the sea-bathing, which everywhere else proved so salutary and renovating, can dispel. Except when in actual danger of shipwreck, I never spent twelve more disagreeable days, in the professional part of my life, than in these calm latitudes.

"I crossed the line on the 17th of January, at eight A. M., in longitude 21° 20′, and soon found I had surmounted all the difficulties consequent to that event; that the breeze continued to freshen and draw round to the south-southeast, bringing with it a clear sky and most heavenly temperature, renovating and refreshing beyond description. Nothing was now to be seen but cheerful countenances, exchanged, as by enchantment, from that sleepy sluggishness which had borne us all down for the last two weeks."

78. One need not go to sea to perceive the grand work which the clouds perform in collecting moisture from the crystal vaults of the sky, in sprinkling it upon the fields, and making the hills glad with showers of rain. Winter and summer, "the clouds drop fatness upon the earth." This part of their office is obvious to all, and I do not propose to consider it now. But the sailor at sea observes phenomena and witnesses operations in the terrestrial economy which tell him that, in the beautiful and exquisite adjustments of the grand machinery of the atmosphere, the clouds have other important offices to perform besides those merely of dispensing showers, of producing the rains, and of weaving mantles of snow for the protection of our fields in winter. As important as are these offices, the philosophical mariner, as he changes his sky, is reminded that the clouds have commandments to fulfil, which, though less obvious, are not therefore the less benign in their influences, or the less worthy of his notice. He beholds them at work moderating the extremes of heat and cold, and in mitigating climates. At one time they spread themselves out; they cover the earth as with a mantle; they prevent radiation from its crust, and keep it warm. At another time they interpose between it and the sun; they screen it from his scorching rays, and protect the tender plants from his heat, the land from the drought; or, like a garment, they overshadow the sea, defending its waters from the intense forces of evaporation. Having performed these offices for one place, they are evaporated and given up to the sunbeam and the winds again, to be borne on their wings away to other places which stand in need of like offices.

Familiar with clouds and sunshine, the storm and the calm, and all the phenomena which find expression in the physical geography of the sea, the right-minded mariner, as he contemplates "the cloud without rain," ceases to regard it as an empty thing; he perceives that it performs many important offices; he regards it as a great moderator of heat and cold—as a "compensation" in the atmospherical mechanism, which makes the performance of the grand machine perfect.

Marvellous are the offices and wonderful is the constitution of the atmosphere. Indeed, I know of no subject more fit for profitable thought on the part of the truth-loving, knowledge-seeking student, be he seamen or landsman, than that afforded by the atmosphere and its offices. Of all parts of the physical machinery, of all the contrivances in the mechanism of the universe, the atmosphere, with its offices and its adaptations, appears to me to be the most wonderful, sublime, and beautiful. In its construction the perfection of knowledge is involved. The perfect man of Uz, in a moment of inspiration, thus demands of his comforters: "But where shall wisdom be found, and where is the place of understanding? The depth saith, It is not in me; and the sea saith, It is not with me. It cannot be gotten for gold, neither shall silver be weighed for the price thereof. No mention shall be made of coral or of pearls, for the price of wisdom is above rubies.

"Whence, then, cometh wisdom, and where is the place of understanding? Destruction and Death say, We have heard the fame thereof with our ears.

"God understandeth the way thereof, and he knoweth the place thereof; for he looketh to the ends of the earth, and seeth under the whole heaven; *to make the weight for the winds;* and he weigheth the waters by measure. When he made a decree for the rain, and a way for the lightning of the thunder; then did he see it, and declare it; he prepared it, yea, and searched it out."*

When the pump-maker came to ask Galileo to explain how it was that his pump would not lift water higher than thirty-two feet, the philosopher thought, but was afraid to say, it was owing to the "weight of the winds;" and though the fact that the air has weight is here so distinctly announced, the philosophers never knew it until within comparatively a recent period, and then it was proclaimed by them as a great discovery. Nevertheless, the fact was set forth as distinctly in the book of Nature as it is in the book of Revelation; for the infant, in availing itself of atmospherical pressure to suck the milk from its mother's breast, unconsciously proclaimed it.

79. Both the thermometer and the barometer (§ 77) stand lower under this cloud-ring than they do on either side of it. After having crossed it, and referred to the log-book to refresh his mind as to the observations there entered with regard to it, the attentive navigator may perceive how this belt of clouds, by screening the parallels over which he may have found it to hang, from the sun's rays, not only promotes the precipitation which takes place within these parallels at certain periods, but how, also, the rains are made to change the places upon which they are to fall; and how, by travelling with the calm belt of the equator up and down the earth, this cloud-ring shifts the surface from which the heating rays of the sun are to be excluded; and how, by this operation, tone is given to the atmospherical circulation of the world, and vigor to its vegetation.

Having travelled with the calm belt to the north or south, the cloud-ring leaves the sky about the equator clear; the rays of the torrid sun pour down upon the crust of the earth there, and raise its temperature to a scorching heat. The atmosphere dances, and the air is seen trembling in ascending and descending columns, with busy eagerness to conduct the heat off and deliver it to the regions aloft, where it is required to give momentum to the air in its general channels of circulation. The dry season continues; the sun is vertical; and, finally, the earth becomes parched and dry; the heat accumulates faster than the air can carry it away; the plants begin to wither, and the animals to perish. Then comes the mitigating cloud-ring. The burning rays of the sun are intercepted by it. The place for the absorption and reflection, and the delivery to the atmosphere of the solar heat, is changed; it is transferred from the upper surface of the earth to the upper surface of the clouds.

Radiation from the land and the sea below the cloud-belt is thus interrupted, and the excess of heat in the earth is delivered to the air, and by absorption carried up to the clouds, and there transferred to their vapors to prevent excess of precipitation.

In the mean time, the trade-winds north and south are pouring into this cloud-covered receiver, as the calm and rain-belt of the equator may be called, fresh supplies in the shape of ceaseless volumes of heated air loaded to saturation with vapor, which has to rise above and

* Job, chapter xxviii.

get clear of the clouds before it can commence the process of cooling by radiation. In the mean time, also, the vapors which the trade-winds bring from the north and the south, expanding and growing cooler as they ascend, are being condensed on the lower side of the cloud stratum, and their latent heat is set free, to check precipitation and prevent a flood.

While this process and these operations are going on upon the nether side of the cloud-ring, one not less important is going on upon the upper side. There, from sunrise to sunset, the rays of the sun are pouring down without intermission. Every day and all day long, they operate with ceaseless activity upon the upper surface of the cloud stratum. When they become too powerful, and convey more heat to the cloud vapors than the cloud vapors can reflect and give off to the air above them, then, with a beautiful elasticity of character, the clouds absorb the surplus heat. They melt away, become invisible, and retain, in a latent and harmless state, until it is wanted at some other place and on some other occasion, the heat thus imparted.

We thus have an insight into the operations which are going on in the equatorial belt of precipitation, and this insight is sufficient to enable us to perceive that exquisite indeed are the arrangements which Nature has provided for supplying this calm belt with heat, and for pushing the snow-line there high up above the clouds, in order that the atmosphere may have room to expand, to rise up, overflow, and course back into its channels of healthful circulation. As the vapor is condensed and formed into drops of rain, a twofold object is accomplished: coming from the cooler regions of the clouds, the rain-drops are cooler than the air and earth below; they descend, and by absorption take up the heat which has been accumulating in the earth's crust during the dry season, and which cannot now escape by radiation. Thus this cloud-ring modifies the climate of all places beneath it; overshadowing, at different seasons, all parallels from 5° south to 15° north.

In the process of condensation, these rain-drops, on the other hand, have set free a vast quantity of latent heat, which has been gathered up with the vapor from the sea by the trade-winds and brought hither. The caloric thus liberated is taken by the air and carried up aloft still further, to keep, at the proper distance from the earth, the line of perpetual congelation. Were it possible to trace a thermal curve in the upper regions of the air to represent this line, we should no doubt find it mounting, sometimes at the equator, sometimes on this side, and sometimes on that of it, but always so mounting as to overleap this cloud-ring. This thermal line would not ascend always over the same parallels: it would ascend over those between which this ring happens to be; and the distance of this ring from the equator is regulated according to the seasons.

If we imagine the atmospherical equator to be always where the calm belt is which separates the northeast from the southeast trade-winds, then the loop in the thermal curve, which should represent the line of perpetual congelation in the air, would be always found to stride this equator; and it may be supposed that a thermometer, kept sliding on the surface of the earth so as always to be in the middle of this rain-belt, would show very nearly the same temperature all the year round; and so, too, would a barometer the same pressure.

80. Returning, and taking up the train of contemplation as to the office which this belt of clouds, as it encircles the earth, performs in the system of oceanic adaptations, we may see that the cloud-ring and calm zone which it overshadows perform the office both of ventricle and auricle in the immense atmospherical heart, where the heat and the forces which give vitality and power to the system are brought into play—where dynamical strength is gathered, and an impulse given to the air sufficient to send it coursing thence through its long and tortuous channels of circulation.

Thus this ring, or band, or belt of clouds, is stretched around our planet to regulate the quantity of precipitation in the rain-belt beneath it; to preserve the due quantum of heat on the face of the earth; to adjust the winds; and send out for distribution to the four corners vapors in proper quantities to make up to each river-basin, climate, and season, its quota of sunshine, cloud, and moisture. Like the balance-wheel of a well-constructed chronometer, this cloud-ring affords the grand atmospherical machine the most exquisitely arranged *self-compensation.* If the sun fail in his supply of heat to this region, more of its vapors are condensed, and heat is discharged from its latent store-houses in quantities just sufficient to keep the machine in the most perfect compensation. If, on the other hand, too much heat be found to accompany the rays of the sun, as they impinge upon the upper circumference of this belt, then, again, on that side, are the means of self-compensation ready at hand; so much of the cloud-surface as may be requisite is then resolved into invisible vapor—the vessels wherein the surplus heat from the sun is stored away and held in the latent state until it is called for—when instantly it is set free, and becomes an active and palpable agent in the grand design.

That the thermometer stands *invariably* lower (§ 79) beneath this cloud-belt than it does on either side of it, has not, so far as my researches are concerned, been made to appear by actual observation, for the observations in my possession have not yet been *fully* discussed concerning the temperature of the air. But that the temperature of the air at the surface under this cloud-ring is lower, is a theoretical deduction as susceptible of demonstration as is the rotation of the earth on its axis. Indeed, Nature herself has hung a thermometer under this cloud-belt that is more perfect than any that man can construct, and its indications are not to be mistaken.

81. Where do the vapors which form this cloud-ring, and which are here condensed and poured down into the sea as rain, come from? They come from the trade-wind regions, (§ 15); under the cloud ring they rise up; as they rise up they expand; and as they expand, they grow cool, form clouds, then are condensed into rains; moreover, it requires no mercurial instrument of human device to satisfy us that the air which brings the vapor for these clouds cannot take it up and let it down at the same temperature. Precipitation and evaporation are the converse of each other; and the same air cannot precipitate and evaporate, take up and let down water, at one and the same temperature. As the temperature of the air is raised, its capacity for receiving and retaining water in the state of vapor is increased; as the temperature of the air is lessened, its capacity for retaining that moisture is diminished. These are physical laws, and therefore, when we see water dripping from the atmosphere, we need no instrument to tell us that the elasticity of the vapor so condensed, and falling in drops, is less than was its elasticity when it was taken up from the surface of the ocean as water and went up into the clouds as vapor.

Hence we infer that, when the vapors of sea water are condensed, the heat which was necessary to sustain them in the vapor state, and which was borrowed from the ocean, is parted with, and that therefore they were subjected, in the act of condensation, to a lower temperature than they were in the act of evaporation. Ceaseless precipitation goes on under this cloud-ring. Evaporation under it is suspended almost entirely. We know that the trade-winds encircle the earth; that they blow perpetually; that they come from the north and the south, and meet each other near the equator; therefore we infer that this line of meeting extends around the world. By the rainy seasons of the torrid zone we can trace the declination of this cloud-ring stretched like a girdle round about the earth; it travels up and down the ocean as from north to south and back.

82. It is broader than the belt of calms out of which it rises. As the air with its vapors rises up in this calm belt and ascends, these vapors are condensed into clouds, (§ 81,) and this condensation is followed by a turgid intumescence, which causes the clouds to overflow the calm belt, as it were, both to the north and the south. The air flowing off in the same direction assumes the character of winds that form the upper currents that are counter (Plate II) to the trade-winds. These currents carry the clouds still further to the north and south, and thus make the cloud-ring broader. At least we infer such to be the case, for the rains are found to extend out into the trade-winds, and often to a considerable distance both to the north and the south of the calm belt.

83. Were this cloud-ring luminous, and could it be seen by an observer from one of the planets, it would present to him an appearance not unlike the rings of Saturn do to us. Such an observer would remark that this cloud ring of the earth has a motion contrary to that of the axis of our planet itself; that while the earth was revolving rapidly from west to east, he would observe the cloud-ring to go slowly, but only relatively, from east to west. As the winds which bring the cloud-vapor to this region of calms rise up with it, the earth is slipping from under them; and thus the cloud-ring, though really moving from west to east with the earth, goes relatively slower than the earth, and would therefore appear to require a longer time to complete a revolution.

But, unlike the rings of Saturn through the telescope, the outer surface, or the upper side to us, of this cloud-ring would appear exceedingly jagged, rough, and uneven.

The rays of the sun, playing upon this peak and then upon that of the upper cloud-surface melt away one set of elevations and create another set of depressions. The whole stratum is, it may be imagined, in the most turgid state; it is in continued throes when viewed from above; the heat which is liberated from below in the process of condensation, the currents of warm air ascending from the earth, and of cool descending from the sky, all, we may well conceive, tend to keep the upper cloud-surface in a perpetual state of agitation, upheaval, and depression.

Imagine, in such a cloud stratum, an electrical discharge to take place; the report, being caught up by the cloud-ridges above, is passed from peak to peak, and repeated from valley to valley, until the last echo dies away in the mutterings of the distant thunder. How often do we hear the voice of the loud thunder rumbling and rolling away above the cloud surface like the echo of artillery discharged among the hills!

Hence we perceive or infer that the clouds intercept the progress of sound, as well as of light and heat, through the atmosphere, and that this upper surface is often like Alpine regions, which echo back and roll along with rumbling noise the mutterings of the distant thunder.

84. It is by trains of reasoning like this that we are continually reminded of the interest which attaches to the observations which the mariner is called on to make. There is no expression uttered by Nature which is unworthy of our most attentive consideration, for no physical fact is too bald for observation; and mariners, by registering in their logs the kind of lightning, whether sheet, forked, or streaked, and the kind of thunder, whether rolling, muttering, or sharp, may be furnishing facts which will throw much light on the features and character of the clouds in different latitudes and seasons. Physical facts are the language of Nature, and every expression uttered by her is worthy of our most attentive consideration.

CHAPTER VII.

THE SALTS OF THE SEA.*

What the Salt in Sea Water has to do with Currents, § 85.—Coral Islands, § 87.—What would be the Effect of no System of Circulation for Sea Water? § 88.—Its Components, § 89—The principal Agents from which Dynamical Force in the Sea is derived, § 90.—Sea and Fresh Water have different Laws of Expansion, § 95.—The Gulf Stream could not exist in a Sea of Fresh Water, § 96.—The Effect of Evaporation in producing Currents, § 97.—How the Polar Sea is supplied with Salt, § 101.—The Influence of under Currents upon open Water in the Frozen Ocean, § 102.—The Influence exerted by Shell-fish upon Currents, § 103.—They assist in regulating Climates, § 104.—How Sea Shells and Salts act as Compensations in the Machinery by which Oceanic Circulation is conducted, § 105.—Whence come the Salts of the Sea? § 106.

85. In order to comprehend aright the currents of the sea, and to study with advantage its physical adaptations, it is necessary to understand the effects produced by the salts of the sea upon the equilibrium of its waters; for wherever equilibrium be destroyed, whether in the air or water, it is restored by motion, and motion among fluid particles give rise to currents, which, in turn, constitute circulation.

The question is often asked, "Why is the sea salt?" I think it can be shown that the circulation of the ocean depends, in a great measure, upon the salts of sea water; certainly its influences upon climate are greatly extended by reason of its saltness.

As a general rule, the sea is nearly of a uniform degree of saltness, and the constituents of sea water are as constant in their proportions as are the components of the atmosphere. It is true that we sometimes come across arms of the sea, or places in the ocean, where we find the water more salt or less salt than sea water is generally; but this circumstance is due to local causes of easy explanation. For instance, when we come to an arm of the sea, as the Red Sea, upon which it never rains, and from which the atmosphere is continually abstracting, by evaporation, fresh water from the salt, we may naturally expect to find a greater proportion of salt in the sea water that remains than we do near the mouth of some great river, as the Amazon, or in the regions of constant precipitation, or other parts where it rains more than it evaporates. Therefore we do not find sea water from all parts of the ocean actually of the same degree of saltness, yet we do find, as in the case of the Red Sea, sea water that is continually giving off to evaporation fresh water in large quantities: nevertheless, for such water there is a degree, and a very moderate degree, of saltness which is a maximum; and we moreover find that, though the constituents of sea water, like those of the atmosphere, are not for every place invariably the same as to their proportions, yet they are the same, or nearly the same, as to their character.

When, therefore, we take into consideration the fact that, as a general rule, sea water is, with the exceptions above stated, everywhere and always the same, and that it can only be made so by being well shaken together, we find grounds on which to base the conjecture that the ocean has its system of circulation, which is probably as complete and not less wonderful than is the circulation of blood through the human system.

In order to investigate the currents of the sea, and to catch a glimpse of the laws by which the circulation of its waters is governed, hypothesis, in the present meagre state of absolute knowledge with regard to the subject, seems to be as necessary to progress as is a

* *Vide* Maury's Physical Geography of the Sea. Harper and Brothers, New York.

corner-stone to a building. To make progress with such investigations, we want something to build upon. In the absence of facts, we are sometimes permitted to suppose them; only, in supposing them, we should take not only the possible, but the probable; and in making the selection of the various hypotheses which are suggested, we are bound to prefer that one by which the greatest number of phenomena can be reconciled. When we have found, tried, and offered such an one, we are entitled to claim for it a respectful consideration, at least until we discover it leading us into some palpable absurdity, or until some other hypothesis be suggested which will account equally as well, but for a greater number of phenomena. Then, as honest searchers after truth, we should be ready to give up the former, to adopt the latter, and to try it until some other, better than either of the two, be offered.

86. With this understanding, I venture to offer an hypothesis with regard to the agency of the salts or solid matter of the sea in imparting dynamical force to the waters of the ocean, and to suggest that one of the purposes which, in the grand design, it was probably intended to accomplish by having the sea salt, and not fresh, was to impart to its waters the forces and powers necessary to make their circulation complete.

In the first place, we do but conjecture when we say that there is a set of currents in the sea by which its waters are conveyed from place to place with regularity, certainty, and order. But this conjecture appears to be founded on reason; for if we take a sample of water which shall fairly represent, in the proportion of its constituents, the average water of the Pacific Ocean, and analyze it, and if we do the same by a similar sample from the Atlantic, we shall find the analysis of the one to resemble that of the other as closely as though the two samples had been taken from the same bottle after having been well shaken. How, then, shall we account for this, unless upon the supposition that sea water from one part of the world is, in the process of time, brought into contact and mixed up with sea water from all other parts of the world? Agents, therefore, it would seem, are at work, which shake up the waters of the sea as though they were in a bottle, and which, in the course of time, mingle those that are in one part of the ocean with those that are in another as thoroughly and completely as it is possible for man to do in a vessel of his own construction.

This fact, as to uniformity of components, appears to call for the hypothesis that sea water which to-day is in one part of the ocean, will, in the process of time, be found in another part the most remote. It must, therefore, be carried about by currents; and as these currents have their offices to perform in the terrestrial economy, they probably do not flow by chance, but in obedience to physical laws; they no doubt, therefore, maintain the order and preserve the harmony which characterize every department of God's handiwork, upon the threshold of which man has as yet been permitted to stand, to observe, and to comprehend.

87. Nay, having reached this threshold, and taken a survey of the surrounding ocean, we are ready to assert, with all the confidence of knowledge, that the sea has a system of circulation for its waters. We rest this assertion upon our faith in the physical adaptations with which the sea is invested. Take, for example, the coral islands, reefs, beds, and atolls with which the Pacific Ocean is studded and garnished. They were built up of materials which a certain kind of insect quarried from the sea water. The currents of the sea ministered to this little insect—they were its *hod carriers;* when fresh supplies of solid matter were wanted for the coral rock upon which the foundations of the Polynesian Islands were laid, they brought them; the obedient currents stood ready with fresh supplies in unfailing streams of sea water from which the solid ingredients had not been secreted. Now, unless the currents of the sea

had been employed to carry off from this insect the waters that had been emptied by it of their lime, and to bring to it others charged with more, it is evident the little creature would have perished for want of food long before its task was half completed. But for currents, it would have been impaled in a nook of the very drop of water in which it was spawned; for it would have soon secreted the lime contained in this drop of water, and then, without the ministering aid of currents to bring it more, it would have perished for the want of food for itself and materials for its edifice; and thus, but for the benign currents which took this exhausted water away, there we perceive this emptied drop would have remained, not only as the grave of the little architect, but as a monument in attestation of the shocking monstrosity that there had been a failure in the sublime system of terrestrial adaptations—that the sea had not been adapted by its Creator to the well-being of all its inhabitants. Now we do not know that its adaptations are suited to all the wants of every one of its inhabitants—to the wants of the coral insect as well as to those of the whale. Hence we say *we know* that the sea has its system of circulation, for it transports materials for the coral rock from one part of the world to another; its currents receive them from the rivers, and hand them over to the little mason for the structure of the most stupendous works of solid masonry that man has ever seen—the coral islands of the sea.

And thus, by a process of reasoning which is perfectly philosophical, we are irresistibly led to conjecture that there are regular and certain, if not appointed channels, through which the water travels from one part of the ocean to another, and that those channels belong to an arrangement which may make, and, for aught we know to the contrary, which does make the system of oceanic circulation as complete, as perfect, and as harmonious as is that of the atmosphere or the blood. Every drop of water in the sea is as obedient to law and order as are the members of the heavenly host in the remotest regions of space. For when the morning stars sang together, "the waves also lifted up their voice" in the almighty anthem; and doubtless, therefore, the harmony in the depths of the ocean is in tune with that which comes from the spheres above. We cannot doubt it; for, were it not so—were there no channels of circulation from one ocean to another, and if, accordingly, the waters of the Atlantic were confined to the Atlantic, or if the waters of the arms and seas of the Atlantic were confined to those arms and seas, and had no channels of circulation by which they could pass out into the ocean, and traverse different latitudes and climates—if this were so, then the machinery of the ocean would be as incomplete as that of a watch without a balance-wheel; for the waters of these arms and seas would, as to their constituents, become, in the process of time, very different from the sea waters in other parts of the world, and their inhabitants would perish for the want of brine of the right strength, or of water of the right temperature.

88. For instance, take the Red Sea and the Mediterranean by way of illustration. Upon the Red Sea there is no precipitation; it is a rainless region; not a river runs down to it, not a brook empties into it; therefore there is no process by which the salts and washings of the earth, which are taken up and held in solution by rain or river water, can be brought down into the Red Sea. Its salts come from the ocean; and the air takes up from it, in the process of evaporation, fresh water, leaving behind all the solid matter which this sea holds in solution.

On the other hand, numerous rivers discharge into the Mediterranean, some of which are filtered through soils and among minerals which yield one kind of salts or soluble matter, another river runs through a limestone or volcanic region of country, and brings down in solution solid matter—it may be common salt, sulphate or carbonate of lime, magnesia, soda, potash, or iron—either or all may be in its waters. Still, the constituents of sea water from the Mediterranean and of sea water from the Red Sea are quite the same. But the waters of the Dead Sea have no connexion with those of the ocean; they are cut off from its channels of circulation, and are, therefore, quite different, as to their components, from any arm, frith, or gulf of the broad ocean. Its inhabitants are also different from those of the high seas.

89. "The solid constituents of sea water amount to about 3½ per cent. of its weight, or nearly half an ounce to the pound. Its saltness may be considered as a necessary result of the present order of things. Rivers which are constantly flowing into the ocean contain salts, varying from ten to fifty, and even one hundred grains per gallon. They are chiefly common salt, sulphate and carbonate of lime, magnesia, soda, potash, and iron; and these are found to constitute the distinguishing characteristics of sea water. The water which evaporates from the sea is nearly pure, containing but very minute traces of salts. Falling as rain upon the land, it washes the soil, percolates through the rocky layers, and becomes charged with saline substances, which are borne seaward by the returning currents. The ocean, therefore, is the great depository of everything that water can dissolve and carry down from the surface of the continents; and, as there is no channel for their escape, they, of course, consequently accumulate."—*Yeoman's Chemistry.*

"The case of the sea," says Fownes, "is but a magnified representation of what occurs in every lake into which rivers flow, but from which there is no outlet except by evaporation. Such a lake is invariably a salt lake. It is impossible that it can be otherwise; and it is curious to observe that this condition disappears when an artificial outlet is produced for the waters."

How, therefore, shall we account for this sameness of compound, this structure of coral, (§ 87,) this stability as to animal life in the sea, but upon the supposition of a general system of circulation in the ocean, by which, in process of time, water from one part is conveyed to another part the most remote, and by which a general interchange and commingling of the waters take place? In like manner, the constituents of the atmosphere, whether it be analyzed at the equator or the poles, are the same. By cutting off and shutting up from the general channels of circulation any portion of sea water, as in the Dead Sea or of atmospheric air, as in mines or wells, we can easily fill either with gases or other matter that shall very much affect its character, or alter the proportion of its ingredients, and affect the health of its inhabitants.

90. The principal agents that are supposed to be concerned in giving circulation to the atmosphere, and in preserving the ratio among its components, are light, heat, electricity, and magnetism. But with regard to the sea, it is not known what office is performed by electricity and magnetism, in giving dynamical force to its waters in their system of circulation. The chief motive power from which marine currents derive their velocity has been ascribed to heat; but a close study of the agents concerned has suggested that an important—nay, a powerful and active agency in the system of oceanic circulation is derived from the salts of the sea water, through the instrumentality of the winds, of marine plants, and animals. These give the ocean great dynamical force.

91. Let us, for the sake of illustrating and explaining this force, suppose the sea in all its parts—in its depths and at the surface, at the equator and about the poles—to be of one uniform temperature, and to be all of fresh water; and, moreover, that there be neither wind to disturb its surface, nor tides nor rains to raise the level in this part, or to depress it

in that. In this case, there would be nothing of heat to disturb its equilibrium, and there would be no motive power (§ 85) to beget currents, or to set the water in motion by reason of the difference of level or of specific gravity due to water at different densities and temperatures.

Now let us suppose the winds, for the first time since the creation, to commence to blow upon this quiescent sea, and to ruffle its surface; they, by their force, would create partial surface currents, and thus agitating the waters to a certain depth, would give rise to a feeble and partial aqueous circulation in the supposed sea of fresh water.

92. This, then, is one of the sources whence power is given to the system of oceanic circulation; but, though a feeble one, it is one which exists in reality, and, therefore, need not be regarded as hypothetical.

Let us next call in evaporation and precipitation, with heat and cold—more powerful agents. Suppose the evaporation to commence from this imaginary fresh-water ocean, and to go on as it does from the seas as they are. In those regions, as in the trade-wind regions, where evaporation is in excess of precipitation, (§ 23,) the general level of this supposed sea would be altered, and immediately as much water as is carried off by evaporation would commence to flow in from north and south towards the trade-wind or evaporation region, to restore the level.

93. On the other hand, the winds have taken this vapor, borne it off to the extra-tropical regions, and precipitated it, (§ 28,) we will suppose, where precipitation is in excess of evaporation. Here is another alteration of sea level by elevation instead of by depression; and hence we have the motive power for a surface current from each pole toward the equator, the object of which is only to supply the demand for evaporation in the trade-wind regions—demand for evaporation being taken here to mean the difference between evaporation and precipitation for any part of the sea.

94. Now imagine this sea of uniform temperature (§ 91) to be suddenly stricken with the invisible wand of heat and cold, and its waters brought to the various temperatures at which they at this instant are standing. This change of temperature would make a change of specific gravity in the waters, which would destroy the equilibrium of the whole ocean, upon which a set of currents would immediately commence to flow, viz: a current of cold and heavy water to the warm, and a current of warm and lighter to the cold.

The motive power of these would be difference of specific gravity due difference of temperature in fresh water.

95. We have now traced (§§ 92 and 94) the effect of two agents, which, in a sea of fresh water, would tend to create currents, and to beget a system of aqueous circulation; but a set of currents and a system of circulation which, it is readily perceived, would be quite different from those which we find in the salt sea. One of these agents would be employed (§ 93) in restoring, by means of one or more polar currents, the water that is taken from one part of the ocean by evaporation, and deposited in another by precipitation. The other agent would be employed in restoring, by the forces due difference of specific gravity, (§ 94,) the equilibrium, which has been disturbed by heating, and, of course, expanding, the waters of the torrid zone on one hand, and by cooling, and consequently contracting, those of the frigid zone on the other. This agency would, if it were not modified by others, find expression in a system of currents and counter currents, or rather in a set of surface currents of warm and light water from the equator toward the poles, and in another set of under currents of cooler, dense, and heavy water from the poles toward the equator.

Such, keeping out of view the influence of the winds, which we may suppose would be the same, whether the sea were salt or fresh, would be the system of oceanic circulation were the sea all of fresh water. But fresh water, in cooling, begins to expand near the temperature of 40°, and expands more and more till it reaches the freezing point, and ceases to be fluid. This law of expansion by cooling would impart a peculiar feature to the system of oceanic circulation were the waters all fresh, which it is not necessary to notice further than to say it cannot exist in seas of salt water, for salt water contracts by cooling, until its temperature is brought as low as the melting point of fresh water ice. Hence, in consequence of its salts, changes of temperature derive increased power to disturb the equilibrium of the ocean.

96. If this train of reasoning be good, we may infer that, in a system of oceanic circulation, the dynamical force to be derived from difference of temperature, where the waters are all fresh, would be quite feeble; and that, were the sea not salt, we should probably have no such current in it as the Gulf Stream.

So far we have been reasoning hypothetically, to show what would be the chief agents, exclusive of the winds, in disturbing the equilibrium of the ocean were its waters fresh and not salt. And whatever disturbs equilibrium there, may be regarded as the *primum mobile* in any system of marine currents.

Let us now proceed another step in the process of explaining and illustrating the effect of the salts of the sea in the system of oceanic circulation. To this end, let us suppose this imaginary ocean of fresh water suddenly to become that which we have, viz: an ocean of salt water, which contracts as its temperature is lowered (§ 95) till it reaches 28° or thereabout.

97. Let evaporation now commence in the trade-wind region, as it was supposed to do (§ 92) in the case of the fresh-water seas, and as it actually goes on in nature—and what takes place? Why, a lowering of the sea level, as before. But as the vapor of salt water is fresh, or nearly so, fresh water only is taken up from the ocean; that which remains behind is therefore more salt. Thus, while the level is lowered in the *salt* sea, the equilibrium is destroyed because of the saltness of the water; for the water that remains after the evaporation takes place is, on account of the solid matter held in solution, specifically heavier than it was before any portion of it was converted into vapor.

The vapor is taken from the surface water; the surface water thereby becomes more salt and, under certain conditions, heavier; when it becomes heavier, it sinks; and hence we have, due to the salts of the sea, a vertical circulation, viz: a descent of heavier—because salter and cooler—water from the surface, and an ascent of water that is lighter—because it is not so salt—from the depths below.

98. This vapor, then, which is taken up from the evaporating regions (§23), is carried by the winds through their channels of circulation, and poured back into the ocean where the regions of precipitation are; and by the regions of precipitation I mean those parts of the ocean, as in the polar basins, where the ocean receives more fresh water in the shape of rain, snow, &c., than it returns to the atmosphere in the shape of vapor.

In the precipitating regions, therefore, the level is destroyed, as before explained, by elevation; and in the evaporating regions, by depression; which, as already stated (§ 93), gives rise to a system of surface currents, moved by gravity alone, from the poles toward the equator.

But we are now considering the effects of evaporation and precipitation in giving impulse to the circulation of the ocean where its waters are *salt*.

The fresh water that has been taken from the evaporating regions is deposited upon those of precipitation, which, for illustration merely, we will locate in the north polar basin. Among the sources of supply of fresh water for this basin, we must include not only the precipitation which takes place over the basin itself, but also the amount of fresh water discharged into it by the rivers of the great hydrographical basins of Arctic Europe, Asia, and America.

This fresh water, being emptied into the Polar Sea, and agitated by the winds, becomes mixed with the salt; but, as the agitation of the sea by the winds extends to no great depth (§ 91), it is only the upper layer of salt water, and that to a moderate depth, which becomes mixed with the fresh. The specific gravity of this upper layer, therefore, is diminished just as much as the specific gravity of the sea water in the evaporating regions was increased. And thus we have a surface current of saltish water from the poles toward the equator, and an under current of water, salter and heavier, from the equator to the poles. This under current supplies, in a great measure, the salt which the upper current, freighted with fresh water from the clouds and rivers, carries back.

Thus it is to the salts of the sea that we owe that feature in the system of oceanic circulation which causes an under current to flow from the Mediterranean into the Atlantic, and another from the Red Sea into the Indian Ocean. And it is evident, since neither of these seas is salting up, that just as much, or nearly just as much salt as the under current brings out, just so much the upper currents carry in.

We now begin to perceive what a powerful impulse is derived from the salts of the sea in giving effective and active circulation to its waters.

99. Hence we infer that the currents of the sea, by reason of its saltness, attain their maximum of volume and velocity. Hence, too, we infer that the transportation of warm water from the equator toward the frozen regions of the poles, and of cold water from the frigid toward the torrid zone, is facilitated; and consequently here, in the saltness of the sea, have we not an agent by which climates are mitigated—by which they are softened and rendered much more salubrious than than it would be possible for them to be were the waters of the ocean deprived of this property of saltness?

This property of saltness imparts to the waters of the ocean another peculiarity, by which the sea is still better adapted for the regulation of climates, and it is this: by evaporating fresh water from the salt in the tropics, the surface water becomes heavier than the average of sea water, (§24.) This heavy water is also warm water; it sinks, and being a good retainer, but a bad conductor of heat, this warm water is employed in transporting through under currents heat for the mitigation of climates in far-distant regions. Now this, also, is a property which a sea of fresh water could not have. Let the winds take up their vapor from a sheet of fresh water, and that at the bottom is not disturbed, for there is no change in the specific gravity of that at the surface by which that at the bottom may be brought to the top; but let evaporation go on, though never so gently, from salt water, and the specific gravity of that at the top will soon be so changed as to bring that from the very lowest depths of the sea speedily to the top.

If these inferences as to the influence of the salts upon the currents of the sea be correct, the same cause which produces an under current from the Mediterranean, and an under current from the Red Sea into the ocean, should produce an under current from the ocean into the north polar basin. In each case, the hypothesis with regard to the part performed by the salt in giving vigor to the system of oceanic circulation, requires that, counter to the surface current of water with less salt, there should be an under current of water with more salt in it.

That such is the case with regard both to the Mediterranean and the Red Sea, is amply shown in other parts of this work, and abundantly proved by other observers.

100. That there is a constant current setting out of the Arctic Ocean through Davis's and other straits thereabout, which connect it with the Atlantic Ocean, is generally admitted. Lieutenant De Haven, United States Navy, when in command of the American expedition in search of Sir John Franklin, was frozen up with his vessels in the main channel of Wellington Straits; and during the nine months that he was so frozen, his vessels, holding their place in the ice, were drifted with it bodily for than a thousand miles toward the south.

The ice in which they were bound was of sea water, and the currents by which they were drifted were of sea water—only, it may be supposed, the latter were not quite so salt as the sea water generally is. The same phenomenon is repeated in the Sound, where (§113) an under current of salt water runs in, and an upper current of brackish water (§§ 135 and 142) runs out.

Then, since there is salt always flowing out of the north polar basin, we infer that there must be salt always flowing into it, else it would either become fresh, or the whole Atlantic Ocean would be finally silted up with salt.

It might be supposed, were there no evidence to the contrary, that this salt was supplied to the polar seas from the Atlantic around North Cape, and from the Pacific through Behring's Straits, and through no other channels.

101. But, fortunately, Artic voyagers, who have cruised in the direction of Davis's Straits, have afforded us, by their observations, proof positive as to the fact of this other source for supplying the polar seas with salt. They tell us of an under current setting from the Atlantic toward the polar basin. They describe huge icebergs, with tops high up in the air, and of course the bases of which extend far down into the depths of the ocean, ripping and tearing their way, with terrific force and awful violence, through the surface ice or against a surface current, on their way into the polar basin.

Passed Midshipman S. P. Griffin, who commanded the brig Rescue in the American searching expedition after Sir John Franklin, informs me that, on one occasion, the two vessels were endeavoring to warp up to the northward, in or near Wellington Channel, against a strong surface current, which of course was setting to the south; and that while so engaged, an iceberg, with its top many feet above the water, came "drifting up" from the south, and passed by them "like a shot." Although they were stemming a surface current against both the berg and themselves, such was the force and velocity of the under current, that it carried the berg to the northward faster than the crew could warp the vessel against a surface but counter-current.

Captain Duncan, master of the English whale-ship Dundee, says, at page 76 of his interesting little narrative:—*

"*December* 18, (1826.) It was awful to behold the immense icebergs working their way to the northeast from us, and not one drop of water to be seen; they were working themselves right through the middle of the ice."

And again, at page 92, &c.:—

"*February* 23. Latitude 68° 37′ north, longitude about 63° west.

"The dreadful apprehensions that assailed us yesterday, by the near approach of the ice-

* Artic Regions; Voyage to Davis's Straits, by Dorea Duncan, Master of ship Dundee, 1826, 1827.

berg, were this day most awfully verified. About three P. M., the iceberg came in contact with our floe, and in less than one minute it broke the ice; we were frozen in quite close to the shore; the floe was shivered to pieces for several miles, causing an explosion like an earthquake, or one hundred pieces of heavy ordnance fired at the same moment. The iceberg, with awful but majestic grandeur (in height and dimensions resembling a vast mountain,) came almost up to our stern, and every one expected it would have run over the ship. . . . . .

"The iceberg, as before observed, came up very near to the stern of our ship; the intermediate space between the berg and the vessel was filled with heavy masses of ice, which, though they had been previously broken by the immense weight of the berg, were again formed into a compact body by its pressure. The berg was drifting at the rate of about four knots, and by its force on the mass of ice, was pushing the ship before it, as it appeared, to inevitable destruction."

"*Feb.* 24. The iceberg still in sight, but driving away fast to the northeast."

"*Feb.* 25. The iceberg, that so lately threatened our destruction, had driven completely out of sight to the northeast from us."

Now, then, whence, unless from the difference of specific gravity due sea water of different degrees of saltness, can we derive a motive power with force sufficient to give such tremendous masses of ice such a velocity?

102. What is the temperature of this under current? Be that what it may, it is probably above the freezing point of sea water. Suppose it to be at 32°. (Break through the ice in the northern seas, and the temperature of the surface water is always 28°. At least Lieutenant De Haven so found it in his long imprisonment, and it may be supposed that, as it was with him, so it generally is.) Assuming, then, the water of the surface current which runs out with the ice to be all at 28°, we observe that it is not unreasonable to suppose that the water of the under current, inasmuch as it comes from the south, and therefore from warmer latitudes, is probably not so cold; and if it be not so cold, its temperature, before it comes out again, must be reduced to 28°, or whatever be the average temperature of the outer but surface current.

Moreover, if it be true, as some philosophers have suggested, that there is in the depths of the ocean a line from the equator to the poles along which the water is of the same temperature all the way, then the question may be asked, should we not have in the depths of the ocean a sort of isothermal floor, as it were, on the upper side of which all the changes of temperature are due to agents acting from above, and on the lower side of which, the changes, if any, are due to agents acting from below?

This under polar current water, then, as it rises to the top, and is brought to the surface by the agitation of the sea in the Arctic regions, gives out its surplus heat and warms the atmosphere there till the temperature of this warm under current water is lowered to the requisite degree for going out on the surface. Hence the water-sky of those regions.

And the heat that it loses in falling from its normal temperature, be that what it may, till it reaches the temperature of 28°, is so much caloric set free in the polar regions, to temper the air and mitigate the climate there. Now, is not this one of those modifications of climate which may be fairly traced back to the effect of the saltness of the sea in given energy to its circulation?

Moreover, if there be a deep sea in the polar basin, which serves as a receptacle for the waters brought into it by this under current, which, because it comes from toward the equatorial regions, comes from a milder climate, and is therefore warmer, we can easily imagine why there might be an open sea in the polar regions—why Lieutenant De Haven, in his instructions, was directed to look for it; and why both he and Captain Penny, of one of the English searching vessels, found it there.

And in accounting for this polynia, we see that its existence is not only consistent with the hypothesis with which we set out, touching a perfect system of oceanic circulation, but that it may be ascribed in a great degree, at least, if not wholly, to the effect produced by the salts of the sea upon the mobility and circulation of its waters.

Here, then, is an office which the sea performs in the economy of the universe by virtue of its saltness, and which it could not perform were its waters altogether fresh. And thus philosophers have a clew placed in their hands which will probably guide them to one of the many hidden reasons that are embraced in the true answer to the question, "Why is the sea salt?"

103. We find in sea water other matter besides common salt. Lime is dissolved by the rains and the rivers, and emptied in vast quantities into the ocean. Out of it, coral islands and coral reefs of great extent, marl-beds, shell-banks, and infusorial deposits of enormous magnitude have been constructed by the inhabitants of the deep. These creatures are endowed with the power of secreting, apparently for their own purposes only, solid matter which the waters of the sea hold in solution. But this power was given to them that they also might fulfil the part assigned them in the economy of the universe. For to them, probably, has been allotted the important office of assisting in giving circulation to the ocean, of helping to regulate the climates of the earth, and of preserving the purity of the sea.

The better to comprehend how such creatures may influence currents and climates, let us suppose the ocean to be perfectly at rest—that, throughout, it is in a state of complete equilibrium—that, with the exception of those tenants of the deep which have the power of extracting from it the solid matter held in solution, there is no agent in nature capable of disturbing that equilibrium—and that all these fish, &c., have suspended their secretions, in order that this state of a perfect aqueous equilibrium and repose throughout the sea might be attained.

In this state of things—the waters of the sea being in perfect equilibrium—a single mollusk or coral-line, we will suppose, commences his secretions, and abstracts from the sea water (§ 87) solid matter for his cell. In that act, this animal has destroyed the equilibrium of the whole ocean, for the specific gravity of that portion of water from which this solid matter has been extracted is altered. Having lost a portion of its solid contents, it has become specifically lighter than it was before; it must, therefore, give place to the pressure which the heavier water exerts to push it aside and to ccupy its place, and it must consequently travel about and mingle with the waters of the other parts of the ocean until its proportion of solid matter is returned to it, and until it attains the exact degree of specific gravity due sea water generally.

How much solid matter does the whole host of marine plants and animals abstract from sea water daily? Is it a thousand pounds or a thousand millions of tons? No one can say. But, whatever be its weight, it is so much of the power of gravity applied to the dynamical forces of the ocean. And this power is derived from the salts of the sea, through the agency of sea-shells and other marine animals, that of themselves scarcely possess the power of locomotion. Yet they have power to put the whole sea in motion, from the equator to the poles, and from top to bottom.

Those powerful and strange equatorial currents (§ 121) which navigators tell us they encounter in the Pacific Ocean, to what are they due? Coming from sources unknown, they are lost in the midst of the ocean. They are due, no doubt, to some extent, to the effects of precipitation and evaporation, and the change of heat produced thereby. But we have yet to inquire, how far may they be due to the derangement of equilibrium arising from the change of specific gravity caused by the secretions of the myriads of marine animals that are continually at work in those parts of the ocean? These abstract from sea water solid matter enough to build continents of. And, also, we have to inquire as to the extent to which equilibrium in the sea is disturbed by the salts which evaporation leaves behind.

Thus, when we consider the salts of the sea in one point of view, we see the winds and the marine animals operating upon the waters, and, in certain parts of the ocean, deriving from the solid contents of the same those very principles of antagonistic forces which hold the earth in its orbit, and preserve the harmonies of the universe.

In another point of view, we see how the sea-breeze and the sea-shell, in performing their appointed offices, act so as to give rise to a reciprocating motion in the waters; and thus they impart to the ocean dynamical forces also for its circulation.

The sea-breeze plays upon the surface; it converts only fresh water into vapor and leaves the solid matter behind. The surface water thus becomes specifically heavier, and sinks. On the other hand, the little marine architect below, as he works upon his coral edifice at the bottom, abstracts from the water there a portion of its solid contents; it therefore becomes specifically lighter, and up it goes, ascending to the top with increased velocity to take the place of the descending column, which, by the action of the winds, has been sent down loaded with fresh food and materials for the busy little mason in the depths below.

Seeing, then, that the inhabitants of the sea, with their powers of secretion, are competent to exercise at least some degree of influence in disturbing equilibrium, are not these creatures entitled to be regarded as agents which have their offices to perform in the system of oceanic circulation, and do not they belong to its physical geography? It is immaterial how great or how small that influence may be supposed to be; for, be it great or small, we may rest assured it is not a chance influence, but it is an influence exercised—if exercised at all—by design, and according to the commandment of Him whose "voice the winds and the sea obey." Thus God speaks through sea-shells to the ocean.

It may therefore be supposed that the arrangements in the economy of nature are such as to require that the various kinds of marine animals whose secretions are calculated to alter the specific gravity of sea water, to destroy its equilibrium, to beget currents in the ocean, and to control its circulation, should be distributed according to order.

104. Upon this supposition—the like of which nature warrants throughout her whole domain—we may conceive how the marine animals of which we have been speaking may impress other features upon the physical relations of the sea by assisting also to regulate climates, and to adjust the temperature of certain latitudes. For instance, let us suppose the waters in a certain part of the torrid zone to be 70°, but by reason of the fresh water which has been taken from them in a state of vapor, and consequently by reason of the proportionate increase of salts, these waters are heavier than waters that may be cooler, but not so salt.

This being the case, the tendency would be for this warm, but salt and heavy water, to flow off as an under current toward the polar or some other regions of lighter water.

Now, if the sea were not salt, there would be no coral islands to beautify its landscape and give variety to its features; sea-shells and marine insects could not operate upon the specific gravity of its waters, nor give variety to its climates; neither could evaporation give dynamical force to its circulation, and they, ceasing to contract as their temperature falls below 40°, would give but little impulse to its currents, and thus its circulation would be torpid, and its bosom lack animation.

This under current may be freighted with heat to temper some hyperborean region or to soften some extra-tropical climate, (§ 147,) for we know that such is among the effects of marine currents. At starting, it might have been, if you please, so loaded with solid matter, that, though its temperature were 70°, yet, by reason of the quantity of such matter held in solution, its specific gravity might have been greater even than that of extra-tropical sea water generally at 28°.

Notwithstanding this, it may be brought into contact, by the way, with those kinds and quantities of marine organisms that shall abstract solid matter enough to reduce its specific gravity, and, instead of leaving it greater than common sea water at 28°, make it less than common sea water at 40°; consequently, in such a case, this warm sea water, when it comes to the cold latitudes, would be brought to the surface through the instrumentality of shell-fish, and various other tribes that dwell far down in the depths of the ocean. Thus we perceive that these creatures, though they are regarded as being so low in the scale of creation, may nevertheless be regarded as agents of much importance in the terrestrial economy; for we perceive that they are capable of spreading over certain parts of the ocean those benign mantles of warmth which temper the winds, and modify, more or less, all the marine climates of the earth.

105. The makers of nice astronomical instruments, when they have put the different parts of their machinery together, and set it to work, find, as in the chronometer, for instance, that it is subject in its performance to many irregularities and imperfections—that in one state of things there is expansion, and in another state contraction among cogs, springs, and wheels, with an increase or diminution of rate. This defect the makers have sought to overcome; and, with a beautiful display of ingenuity, they have attached to the works of the instrument a contrivance which has had the effect of correcting these irregularities by counteracting the tendency of the instrument to change its performance with the changing influences of temperature.

This contrivance is called a *compensation;* and a chronometer that is well regulated and properly compensated will perform its office with certainty, and preserve its rate under all the vicissitudes of heat and cold to which it may be exposed.

In the clock work of the ocean and the machinery of the universe order and regularity are maintained by a system of compensations. A celestial body, as it revolves around its sun, flies off under the influence of centrifugal force; but immediately the forces of compensation begin to act; the planet is brought back to its elliptical path, and held in the orbit for which its mass, its motions, and its distance were adjusted. Its compensation is perfect.

So, too, with the salts and the shells of the sea in the machinery of the ocean; from them are derived principles of compensation the most perfect; through their agency the undue effects of heat and cold, of storm and rain, in disturbing the equilibrium, and producing thereby currents in the sea, are compensated, regulated, and controlled.

The dews, the rains, and the rivers are continually dissolving certain minerals of the earth, and carrying them off to the sea. This is an accumulating process; and if it were not *compensated*, the sea would finally become as the Dead Sea is, saturated with salt, and therefore unsuitable for the habitation of many fish of the sea.

The sea-shells and marine insects afford the required *compensation*. They are conservators of the ocean. As the salts are emptied into the sea, these creatures secrete them again and pile them up in solid masses, to serve as the bases of islands and continents, to be in the process of ages upheaved into dry land, and then again dissolved by the dews and rains, and washed by the rivers away into the sea.

The question as to whence the salts of the sea were originally derived, of course, has not escaped the attention of philosophers.

"I once thought with Darwin and those other philosophers who hold that the sea derived its salts originally from the washings of the rains and rivers. I now question that opinion; for, in the course of the researches connected with the 'Wind and Current Charts,' I have found evidence, from the sea and in the Bible, which seems to cast doubt upon it. The account given in the first chapter of Genesis, and that contained in the hieroglyphics which have been traced by the hand of Nature on the geological column as to the order of creation, are marvellously accordant. The Christian man of science regards them both as true; and he never overlooks the fact that, while they differ in the mode and manner as well as in the things they teach, yet they never conflict; and they contain no evidence going to show that the sea was ever fresh; on the contrary, they both afford circumstantial evidence sufficient for the belief that the sea was salt as far back as the morning of creation, or, at least, as the evening and the morning of the day when the dry land appeared.

"That the rains and the rivers do dissolve salts of various kinds from the rocks and soil, and empty them into the sea, there is no doubt. These salts cannot be evaporated, we know; and we also know that many of the lakes, as the Dead Sea, which receive rivers and have no outlet, are salt. Hence the inference by some philosophers that these inland water-basins received their salts from the washings of the soil; and consequently the conjecture arose that the great sea derived its salts from the same source and by the same process. But, and per contra, though these solid ingredients cannot be taken out of the sea by evaporation, they can be extracted by other processes. We know that the insects of the sea do take out a portion of them, and that the salt ponds and arms which, from time to time in the geological calendar, have been separated from the sea, afford an escape by which the quantity of chloride of sodium in its waters—the most abundant of its solid ingredients—is regulated. The insects of the sea cannot build their structures of this salt, for it would disolve again, and as fast as they could separate it. But hear the ever-ready atmosphere comes into play, and assists the insects in regulating the salts. It cannot take them up from the sea, it is true, but it can take the sea away from them; for it pumps up the water from these pools that have been barred off, transfers it to the clouds, and they deliver it back to the sea as fresh water, leaving the salts it contained in a solid state behind.

"These are operations that have been going on for ages; proof that they are still going on is continually before our eyes; for the 'hard water' of our fountains, the marl-banks of the valleys, the salt-beds of the plains, Albion's chalky cliffs, and the coral islands of the sea, are monuments in attestation.

"There is no proof, nor is there any reason for the belief that the sea is growing salter or fresher. Hence we infer that the operations of briny addition and extraction are reciprocal and equal; that the effect of rains and rivers in washing down is compensated by the processes of evaporation and secretion in taking out.

"If the sea derived its salts originally from the rivers, the geological records of the past would show that river beds were scoured out in the crust of our planet before the sea had deposited any of its fossil shells and infusorial remains upon it. If, therefore, we admit the Darwin theory, we must also admit that there was a period when the sea was without salt, and consequently without shells or animals either of the silicious or calcareous kind. If ever there were such a time, it must have been when the rivers were collecting and pouring in the salts which now make the brine of the ocean. But while the palæontological records of the earth, on one hand, afford no evidence of any such fresh water period, the Mosaic account is far from being negative with its testimony on the other. According to it, we infer that the sea was salt as early, at least, as the fifth day, for it was on that day of creation that the waters were commanded to 'bring forth abundantly the moving creature that hath life.' It is in obedience to that command that the sea now teems with organisms; and it is marvelous how abundantly the obedient waters do bring forth, and how wonderful for variety as well as multitude their progeny is. All who pause to look are astonished to see how the prolific ocean teams and swarms with life. The moving creatures in the sea constitute in their myriads of multitudes one of the 'wonders of the deep.'

"It is the custom of Captain Foster, of the American ship 'Garrick,' who is one of my most patient of observers, to amuse himself by making drawings in his abstract log of the curious animalculæ which, with the microscope, he finds in the surface water alongside; and though he has been following the sea for many years, he never fails to express his wonder and amazement at the immense numbers of living creatures that the microscope reveals to him in sea water. Hitherto his examinations related only to the surface waters, but in the log now before me he went into the depths, and he was more amazed than ever to see how abundantly the waters even there bring forth.

"'*January* 28, 1855. In examining animalculæ in sea water, I have,' says he, 'heretofore used surface water. This afternoon, after pumping for some time from the stern pump seven feet below the surface, I examined the water, and was suprised to find that the fluid was literally alive with animated matter, embracing beautiful varieties.' Of some he says, 'Numerous heads, purple, red, and variegated.'

"There is wonderful meaning in that word ABUNDANTLY, as it stands recorded in that Book and as it is even at this day repeated by the great waters.

"So far the two records agree, and the evidence is clear that the sea was salt when it received this command. Do they afford any testimony as to its condition previously? Let us examine.

"On the second day of creation the waters were gathered together unto one place, and the dry land appeared. Before that period, therefore, there were no rivers, and consequently no washings of brine by mists, nor dew, nor rains from the valleys among the hills. The water covered the earth. This is the account of Revelation; and the account which Nature has written, in her own peculiar characters, on the mountain and in the plain, on the rock, and in the sea, as to the early condition of our planet, indicates the same. The inscriptions on the geological column tell that there was a period when the solid parts of the earth's crust, which now stand high in the air, were covered by water. The geological evidence that it was so, with perhaps the exception of a solitary mountain peak here and there, is conclusive; and when we come to examine the fossil remains that are buried in the mountains, and scattered over the plains, we have as much reason to say that the sea was salt when it covered or nearly covered the earth, as the naturalist, when he sees a skull or bone whitening on the wayside, has to say that it was once covered with flesh.

"Therefore we have reason for the conjecture that the sea was salt 'in the beginning,' when 'the waters under heaven were gathered together unto one place,' and the dry land first appeared; for go back as far as we may in the dim records which young Nature has left inscribed upon the geological column of her early processes, and there we find the fossil shell, and the remains of marine organisms to inform us that when the foundations of our mountains were laid with granite, and immediately succeeding that remote period, when the primary formations were completed, the sea was, as it is now, salt; for had it not been salt, whence could those creeping things which fashioned the sea-shells that cover the tops of the Andes, or those madrepores that strew the earth with solid matter that has been secreted from briny waters, or those infusorial deposits which astound the geologist with their magnitude and extent, or those fossil remains of the sea, which have astonished, puzzled, and bewildered man in all ages—whence, had not the sea been salt when its metes and bound were set, could these creatures have obtained solid matter for their edifices and structures. Much of that part of the earth's crust which man stirs up in cultivation, and which yields him bread, has been made fruitful by these 'salts,' which all manner of marine insects, aqueous organisms, and sea-shells have secreted from the ocean. Much of this portion of our planet has been filtered through the sea, and its insects and creeping things are doing now precisely what they were set about when the dry land appeared, namely, preserving the purity of the ocean, and regulating it in the due performance of its great offices. As fast as the rains dissolve the salts of the earth, and send them down through the rivers to the sea, these faithful and everlasting agents of the Creator elaborate them into pearls, shells, corals, and precious things; and so, while they are preserving the sea, they are also embellishing the land by imparting new adaptations to its soil, fresh beauty and variety to its landscapes.

"In every department of nature there is to be found this self-adjusting principle—this beautiful and exquisite system of *compensation*, by which the operations of the grand machinery of the universe are maintained in the most perfect order.

"Whence came the salts of the sea originally is a question which perhaps never will be settled satisfactorily to every philosophic mind, but it is sufficient for the Christian philosopher to recollect that the salts of the sea, like its waters and the granite of the hills, are composed of substances which, when reduced to their simple state, are found, for the most part, to be mere gaseous or volatile matter of some kind or other. Thus we say that granite is generally compose of feldspar, mica, and quartz, yet these three minerals are made of substances more or less volatible in combination with oxygen gas. Iron, of which there is merely a trace, is the only ingredient which, in its uncombined and simple state is not gaseous or volatile. Now was the feldspar of the granite originally formed in one heap, the mica in another, and the quartz in a third, and then the three brought together by some mighty power, and welded into the granitic rock for the everlasting hills to stand upon? or were they made into rock as they were formed of the chaotic matter?

"Sea water is composed of oxygen and hydrogen, and its salts, like the granite, also consist of gases and volatile metals. But whether the constituents of sea water, like those of the primitive rocks, were brought together in the process of formation, and united in combination as we now find them in the ocean, or whether the sea was fresh 'in the beginning,' and became salt by some subsequent process, is not material to our present purpose. Some geologists suppose that in the chalk period, when the ammonites, with their huge chambered shells, lived in the sea, the carbonaceous material required by these creatures for their habitations must have been more abundant in its waters than it now is; but, though the constituents of sea water may have varied as to proportions, they probably were never, at least since 'its waters commenced to bring forth,' widely different from what they now are.

"It is true, the strange cuttle-fish, with its shell twelve feet in circumference, is no longer found alive in the sea; it died out with the chalk period; but then its companion, the tiny nautilus, remains to tell us that even in that remote period the proportion of salt in sea water was not unsuited to its health, for it and the coral insect have lived through all the changes that our planet has undergone since the sea was inhabited, and they tell us that its waters were salt as far back, at least, as their records extend, for they now build their edifices, and make their habitations of the same materials, collected in the same way that they did then, and, had the sea been fresh in the interim, they too would have perished, and their family would have become extinct, like that of the great ammonite, which perhaps ceased to find the climates of the sea, not the proportion of its salts, suited to its well-being.

"Did any one who maintains that the salts of the sea were originally washed down into it by the rivers and the rains, ever take the trouble to compute the quantity of solid matter that the sea holds in solution as salts? Taking the average depth of the ocean at two miles, and its average saltness at 3½ per cent., it appears that there is salt enough in the sea to cover to the thickness of one mile an area of seven millions of square miles. Admit a transfer of such a quantity of matter from an average of half a mile above to one mile below the sea level, and astronomers will show by calculation that it would alter the length of the day.

"These seven millions of cubic miles of crystal salt have not made the sea any fuller. All this solid matter has been received into the interstices of sea water without swelling the mass; for chemists tell us that water is not increased in volume by the salt it dissolves. Here is therefore started up before us an economy of space calculated to surprise even the learned author himself, of the 'Plurality of Worlds.'

"There has been another question raised which bears upon what has already been said concerning the offices which, in the sublime system of terrestrial arrangements, have been assigned to the salts of the sea.

"On the 20th of January, 1855, Professor Chapman, of the University College, Toronto, communicated to the Canadian Institute a paper on the 'Object of the Salt Condition of the Sea,' which he maintains, is '*mainly intended to regulate evaporation.*' To establish this hypothesis, he shows by a simple but carefully conducted set of experiments, that the salter the water, the slower the evaporation from it; and that the evaporation which takes place in 24 hours from water about as salt as the average of sea water, is 0.54 per cent. less in quantity than from fresh water.

"This suggestion and these experiments give additional interest to our investigations into the manifold and marvelous offices which, in the economy of our planet, have been assigned by the Creator to the salts of the sea. It is difficult to say what, in the Divine arrangement, was the *main* object of making the sea salt and not fresh. Whether it was to assist in the regulation of climates, or in the circulation of the ocean, or in re-adapting the earth for new conditions, by transferring solid portions of its crust from one part to another, and giving employment to the corallines and insects of the sea in collecting this solid matter into new forms, and presenting it under diffierent climates and conditions, or whether the *main* object was, as the distinguished professor suggests, to regulate evaporation, it is not necessary now or here to discuss. I think we may regard all the objects of the salts of the sea as *main* objects.

"But we see in the professor's experiments the dawn of more new beauties, and the appearance of other exquisite compensations, which, in studying the 'wonders of the deep,' we have so often paused to contemplate and admire. As the trade-wind region feeds the air with the vapor of fresh water, the process of evaporation is checked, for the water which remains, being salter, parts with its vapor less readily; and thus, by the salts of the sea, floods may be prevented. But again, if the evaporating surface were to grow salter and salter, whence would the winds derive vapor duly to replenish the earth with showers; for the salter the surface, the more scanty the evaporation. Here is compensation, again, the most exquisite; and we perceive how, by reason of the salts of the sea, drought and famine, if not prevented, may be, and probably are regulated and controled; for that compensation which assists to regulate the amount of evaporation, is surely concerned in adjusting also the quantity of rain. Were the salts of the sea lighter instead of heavier than the water, they would, as they feed the winds with moisture for the cloud and the rain, remain at its surface, and become more niggardly in their supplies, and finally the winds would howl over the sea in very emptiness, and instead of cool and refreshing sea breezes to fan the invalid and nourish the plants, we should have the gentle trade-wind coming from the sea in frightful blasts of parched, and thirsty, and blighting air. But their salts, with their manifold and marvelous adaptations, come in here as a counterpoise, and, as the waters attain a certain degree of saltness, they become too heavy to remain longer in contact with the thirsty trade-winds, and are carried down, because of their salts, into the depths of the ocean; and thus the winds are *dieted* with vapor in due and wholesome quantities."—MAURY'S *Physical Geography of the Sea, 6th ed., p.* 200.

[In this view of the subject, and for the purpose of carrying on the investigations which Professor Chapman's interesting paper suggests, observations upon the specific gravity of sea water become still more interesting. It is to be hoped, therefore, that my fellow-laborers at sea will not slight the specific gravity column of the man-of-war abstract log.]

106. Thus we behold sea-shells and animalculæ in a new light. May we not now cease to regard them as beings which have little or nothing to do in maintaining the harmonies of creation? On the contrary, do we not see in them the principles of the most admirable compensation in the system of oceanic circulation? We may even regard them as regulators, to some extent, of climates in parts of the earth far removed from their presence. There is something suggestive, both of the grand and the beautiful, in the idea that, while the insects of the sea are building up their coral islands in the perpetual summer of the tropics, they are also engaged in dispensing warmth to distant parts of the earth, and in mitigating the severe cold of the polar winter.

Surely an hypothesis which, being followed out, suggests so much design, such perfect order and arrangement, and so many beauties for contemplation and admiration as does this, which, for the want of a better, I have ventured to offer with regard to the solid matter of the sea water, its salts and its shells—surely such an hypothesis, though it be not based entirely on the results of actual observation, cannot be regarded as wholly vain or as altogether profitless.

CHAPTER VIII.

CURRENTS OF THE SEA.*

Governed by Laws, § 107.—The Inhabitants of the Sea the Creatures of Climate, § 108.—First Principles, § 109.—Currents of the Red Sea, § 110.—How an under current from it is generated, § 111.—Why the Red Sea is not salting up, § 112.—MEDITERRANEAN CURRENT, § 113.—CURRENTS OF THE INDIAN OCEAN, § 114.—A Gulf Stream along the Coast of China, § 115.—Points of Resemblance between it and the Gulf Stream of the Atlantic, § 116.—Geographical Features unfavorable to large Icebergs in the North Pacific, § 117.—Arguments in favor of return Currents, because the Sea Water is salt, § 118.—CURRENTS OF THE PACIFIC, § 119.—Discovery of an immense Body of Warm Water drifting South, § 120.—Currents about the Equator, § 121.—UNDER CURRENTS: Proof of, afforded deep Sea Soundings, § 122.—Currents caused by Changes in Specific Gravity of Sea Water, § 123.—The great Equatorial Current of the Atlantic, § 124.—The Cape St. Roque Current not a constant Current, § 125.

107. LET us, in this chapter, set out with the postulate that the sea, as well as the air, has its system of circulation, and that this system, whatever it be, and wherever its channels lie, whether in the waters at or below the surface, is in obedience to physical laws. The sea, by the circulation of its waters, has its offices to perform in the terrestrial economy; and when we see the currents in the ocean running hither and thither, we feel that they were not put in motion without a cause. On the contrary, reason assures us that they move in obedience to some law of Nature, be it recorded down in the depths below, never so far beyond the reach of human ken; and being a law of Nature, we know who gave it, and that neither chance nor accident had anything to do with its enactment.

Nature grants us all that this postulate demands, repeating it to us in many forms of expression; she utters it in the blade of green grass which she causes to grow in climates and soils made kind and genial by warmth and moisture, that some current of the sea or air has conveyed far away from under a tropical sun. She murmurs it out in the cooling current of the north; the whales of the sea tell of it, and all its inhabitants proclaim it.

108. The fauna and the flora of the sea are as much the creatures of climate, and are as dependent for the well-being upon temperature as are the fauna and the flora of the dry land. Were it not so, we should find the fish and the algæ, the marine insect and the coral, distributed equally and alike in all parts of the ocean. The polar whale would delight in the torrid zone, and the habitat of the pearl oyster would be also under the iceberg, or in frigid waters colder than the melting ice.

Now water, while its capacities for heat are scarcely exceeded by those of any other substance, is one of the most complete of non-conductors. Heat does not permeate water as it does iron, for instance, or other good conductors. Heat the top of an iron plate and the bottom becomes warm; but heat the top of a sheet of water, as in a pool or basin, and that at the bottom remains cool. The heat passes through iron by conduction, but to get through water it requires to be conveyed by a motion, which in fluids we call currents.

Therefore the study of the climates of the sea involves a knowledge of its currents, both cold and warm. They are the channels through which the waters circulate, and by means of which the harmonies of old ocean are preserved.

109. Hence, in studying the system of oceanic circulation, we set out with the very simple assumption, viz: that from whatever part of the ocean a current is found to run, to the same

* *Vide* Maury's Physical Geography of the Sea. Harper and Brothers, New York.

part a current of equal volume is obliged to return; for, upon this principle is based the whole system of currents and counter-currents of the air as well as of the water.

It is not necessary to associate with oceanic currents the idea that they must of necessity, as on land, run from a higher to a lower level. So far from this being the case, some currents of the sea actually run up hill, while others run on a level.

The Gulf Stream is of the first class.

110. The currents which run from the Atlantic into the Mediterranean, and from the Indian Ocean into the Red Sea, are the reverse of this. Here the bottom of the current is probably a water-level, and the top an inclined plane, running *down hill.* Take the Red Sea current as an illustration. That sea lies, for the most part, within a rainless and riverless district. It may be compared to a long and narrow trough. Being in a rainless district, the evaporation from it is immense; none of the water thus taken up is returned to it, either by rivers or rains. It is about one thousand miles long; it lies nearly north and south, and extends from latitude 13° to the parallel of 30° north.

From May to October the water in the upper part of this sea is said to be two feet lower than it is near the mouth.* This change or difference of level is ascribed to the effect of the wind, which, prevailing from the north at that season, is supposed to blow the water out.

But, from May to October is also the hot season; it is the season when evaporation is going on most rapidly; and when we consider how dry and how hot the winds are which blow upon this sea at this season of the year, we may suppose the daily evaporation to be immense; not less, certainly, than half an inch, and probably twice that amount. We know that the waste from canals by evaporation, in the summer time, is an element which the engineer, when taking the capacity of his feeders into calculation, has to consider. With him it is an important element; how much more so must the waste by evaporation from this sea be, when we consider the physical conditions under which it is placed. Its feeder, the Arabian Sea, is a thousand miles from its head; its shores are burning sands; the evaporation is *ceaseless;* and none of the vapors, which the scorching winds that blow over it carry away, are returned to it again in the shape of rains.

The Red Sea vapors are carried off and percipitated elsewhere. The depression in the level of its head waters in the summer time, therefore, it appears, is owing quite as much to the effect of evaporation as to that of the wind blowing the waters back.

The evaporation in certain parts of the Indian Ocean is from three-fourths of an inch to an inch daily. Suppose it for the Red Sea, in the summer time, to average only half an inch a day.

Now, if we suppose the velocity of the current which runs into that sea to average, from mouth to head, twenty miles a day, it would take the water fifty days to reach the head of it. If it lose half an inch from its surface by evaporation daily, it would, by the time it reaches the Isthmus of Suez, lose twenty-five inches from its surface.

Thus the waters of the Red Sea ought to be lower at the Isthmus of Suez than they are at the Straits of Babelmandeb. Independently of the waters forced out by the wind, they ought to be lower from two other causes, viz: evaporation and temperature, for the temperature of that sea is necessarily lower at Suez, in latitude 30°, than it is at Babelmandeb, in latitude 13°.

To make it quite clear that the surface of the Red Sea is not a sea level, but is an inclined plane, suppose the channel of the Red Sea to have a perfectly smooth and level floor, with no water in it, and a wave ten feet high to enter the Straits of Babelmandeb, and to flow up the

* Johnston's Physical Atlas.

channel at the rate of twenty miles a day for fifty days, losing daily, by evaporation, half an inch; it is easy to perceive that, at the end of the fiftieth day, this wave would not be so high, by two feet (twenty-five inches,) as it was the first day it commenced to flow.

The top of that sea, therefore, may be regarded as an inclined plane, made so by evaporation.

111. But the salt water, which has lost so much of its freshness by evaporation, becomes salter, and therefore heavier. The lighter water at the Straits cannot balance the heavier water at the Isthmus, and the colder and salter, and therefore heavier water, must either run out as an under current, or it must deposit its surplus salt in the shape of crystals, and thus gradually make the bottom of the Red Sea a salt bed, or it must abstract all the salt from the ocean to make the Red Sea brine—and we know that neither the one process nor the other is going on. Hence we infer that there is from the Red Sea an under or outer current, as there is from the Mediterranean through the Straits of Gibraltar, and that the surface waters near Suez are salter than those near the mouth of the Red Sea.

And, to show why there should be an outer and under current from each of these two seas, let us suppose the case of a long trough, opening into a vat of oil, with a partition to keep the oil from running into the trough. Now, suppose the trough to be filled up with wine on one side of the partition to the level of the oil on the other. The oil is introduced to represent the lighter water as it enters either of these seas from the ocean, and the wine the same water after it has lost some of its freshness by evaporation, and therefore has become salter and heavier. Now, suppose the partition to be raised, what would take place? Why, the oil would run in as an upper current, overflowing the wine, and the wine would run out as an under current.

The rivers which discharge in the Mediterranean are not sufficient to supply the waste of evaporation, and it is by a process similar to this that the salt which is carried in from the ocean is returned to the ocean again; were it not so, the bed of that sea would be a mass of solid salt. The equilibrium of the seas is preserved, beyond a doubt, by a system of compensation as exquisitely adjusted as are those by which the "music of the spheres" is maintained.

The above about under currents is theory: Now let us see the results of actual observation upon the density of water in the Red Sea and the Mediterranean, and upon the under currents that run out from these seas.

Four or five years ago, Mr. Morris, chief engineer of the Oriental Company's steamship Ajdaha, collected specimens of Red Sea water all the way from Suez to the Straits of Babelmandeb, which were afterward examined by Dr. Giraud, who reported the following results:*

	Latitude.	Longitude.	Spec. Grav.	Saline Cont.
	°	°		1000 parts.
No. 1. Sea at Suez	—	—	1027	41.0
No. 2. Gulf of Suez	27.49	33.44	1026	40.0
No. 3. Red Sea	24.29	36.	1024	39.2
No. 4. do	20.55	38.18	1026	40.5
No. 5. do	20.43	40.03	1024	39.8
No. 6. do	14.34	42.43	1024	39.9
No. 7. do	12.39	44.45	1023	39.2

These observations agree with the theoretical deductions just announced, and show that the surface waters at the head are heavier and salter than the surface waters at the mouth of the Red Sea.

* Transact. of the Bombay Geograph. Soc., vol. ix., May, 1849, to August, 1850.

In the same paper, the temperature of the air between Suez and Aden often rises, it is said, to 90°, "and probably averages little less than 75° day and night all the year round. The surface of the sea varies in heat from 65° to 85°, and the difference between the wet and dry bulb thermometers often amounts to 25°, in the kamsin or desert winds, to from 30° to 40°; the average evaporation at Aden is about eight feet for the year." "Now, assuming," says Dr. Buist, "the evaporation of the Red Sea to be no greater than that of Aden, a sheet of water eight feet thick, equal in area to the whole expanse of the sea, will be carried off annually in vapor; or assuming the Red Sea to be eight hundred feet in depth at an average—and this, most assuredly is more than double the fact—the whole of it would be dried up, were no water to enter from the ocean, in one hundred years. The waters of the Red Sea, throughout, contain some four per cent. of salt by weight, or, as salt is a half heavier than water, some 2.7 per cent. in bulk, or, in round numbers, say three per cent. In the course of three thousand years, on the assumptions just made, the Red Sea ought to have been one mass of solid salt, if there were no current running out."

112. Now we know the Red Sea is more than three thousand years old, and that it is not filled with salt; and the reason is, that as fast as the upper currents bring the salt in at the top, the under currents carry it out at the bottom.

113. Mediterranean Currents.—With regard to an under current from the Mediterranean, we may begin by remarking that we know that there is a current always setting in at the surface from the Atlantic, and that this is a salt water current, which carries an immense amount of salt into that sea. We know, moreover, that that sea is not salting up; and therefore, independently of the postulate (§ 109) and of observations, we might infer the existence of an under current through which this salt finds its way out into the broad ocean again.*

With regard to this outer and under current, we have observations telling of its existence as long ago as 1712.

"In the year 1712," says Dr. Hudson, in a paper communicated to the Philosophical Society in 1724, "Monsieur du L'Aigle, that fortunate and generous commander of the privateer called the Phœnix, of Marseilles, giving chase near Ceuta Point to a Dutch ship bound to Holland, came up with her in the middle of the Gut between Tarriffa and Tangier, and there gave her one broadside which directly sunk her, all her men being saved by Monsieur du L'Aigle; and in a few days after the Dutch ship, with her cargo of brandy and oil, arose on the shore near Tangier, which is at least four leagues to the westward of the place where she sunk, and directly against the strength of the current, which has persuaded many men that there is a recurrency in the deep water in the middle of the Gut that sets outward to the grand ocean, which this accident very much demonstrates; and, possibly, a great part of the water which

* Dr. Smith appears to have been the first to *conjecture* this explanation, which he did in 1683 (vide *Philosophical Transactions.*) This continual indraught into the Mediterranean appears to have been a vexed question among the navigators and philosophers even of those times. Dr. Smith alludes to several hypotheses which had been invented to solve these phenomena, such as subterraneous vents, cavities, exhalation by the sun's beams, &c., and then offers his *conjecture*, which, in his own words, is, "that there is an under current, by which as great a quantity of water is carried out as comes flowing in. To confirm which, besides what I have said above about the difference of tides in the offing and at the shore in the Downs, which necessarily supposes an under current, I shall present you with an instance of the like nature in the Baltic Sound, as I received it from an able seaman, who was at the making of the trial. He told me that, being there in one of the king's frigates, they went with their pinnace into the mid stream, and were carried violently by the current; that, soon after this, they sunk a bucket with a heavy cannon ball to a certain depth of water, which gave a check to the boat's motion; and sinking it still lower and lower, the boat was driven ahead to the windward against the upper current; the current aloft, as he added, not being over four or five fathoms deep, and that the lower the bucket was let fall, they found the under current the stronger."

runs into the Straits returns that way, and along the two coasts before mentioned; otherwise, this ship must, of course, have been driven toward Ceuta, and so upward. The water in the Gut must be very deep; several of the commanders of our ships-of-war having attempted to sound it with the longest lines they could contrive, but could never find any bottom."

In 1828, Dr. Wollaston, in a paper before the Philosophical Society, stated that he found the specific gravity of a specimen of sea water, from a depth of six hundred and seventy fathoms, fifty miles within the Straits, to have a "density exceeding that of distilled water by more than four times the usual excess, and accordingly leaves, upon evaporation, more than four times the usual quantity of saline residuum. Hence it is clear that an under current outward of such denser water, if of equal breadth and depth with the current inward near the surface, would carry out as much salt as it brought in above, although it moved with less than one-fourth part of the velocity, and would thus prevent a perpetual increase of saltness in the Mediterranean Sea beyond that existing in the Atlantic."

The doctor obtained this specimen of sea water from Captain, now Admiral Smyth, of the English Navy, who had collected it for Dr. Marcet. Dr. Marcet died before receiving it, and it had remained in the admiral's hands some time before it came into those of Wollaston.

It may therefore have lost something by evaporation; for it is difficult to conceive that all the river water, and three-fourths of the sea water which runs into the Mediterranean, is evaporated from it, leaving a brine for the under current having four times as much salt as the water at the surface of the sea usually contains. Very recently, M. Coupvent des Bois is said to have shown, by actual observation, the existence of an outer and under current from the Mediterranean.

However that may be, these facts, and the statements of the Secretary of the Geographical Society of Bombay, (§ 111,) seem to leave no room to doubt as to the existence of an under current both from the Red Sea and Mediterranean, and as to the cause of the surface current which flows into them. I think it a matter of demonstration. It is accounted for (§ 111) by the salts of the sea.

Writers, whose opinions are entitled to great respect, differ with me as to the proof of this demonstration. Among these writers are Admiral Smyth, of the British Navy, and Sir Charles Lyell, who also differ with each other. In 1820 Dr. Marcet, being then engaged in studying the chemical composition of sea water, the admiral, with his usual alacrity for doing "a kind turn," undertook to collect for the doctor specimens of Mediterranean water from various depths, especially in and about the Straits of Gibraltar. Among these was the one taken fifty miles within the Straits from the depth of six hundred and seventy fathoms, (four thousand and twenty feet,) which, being four times salter than common sea water, left, as we have just seen, no doubt in the mind of Dr. Wollaston as to the existence of this under current of brine.

But the indefatigable admiral, in the course of his celebrated survey of the Mediterranean, discovered that, while inside of the Straits the depth was upwards of nine hundred fathoms, yet, in the Straits themselves, the depth across the shoalest section is not more than one hundred and sixty* fathoms.

"Such being the case, we can now prove," exclaims Sir Charles Lyell, "that the vast amount of salt brought into the Mediterranean *does not* pass out again by the Straits; for it appears by Captain Smyth's soundings, which Dr. Wollaston had not seen, that between the Capes of

* The Mediterranean.

Trafalgar and Spartel, which are twenty-two miles apart, and where the Straits are shallowest, the deepest part, which is on the side of Cape Spartel, is only two hundred and twenty fathoms.* It is therefore evident, that if water sinks in certain parts of the Mediterranean, in consequence of the increase of its specific gravity, to greater depths than two hundred and twenty fathoms, it can never flow out again into the Atlantic, since it must be stopped by the submarine barrier which crosses the shallowest part of the Straits of Gibraltar."†

According to this reasoning, all the cavities, the hollows, and the valleys at the bottom of the sea, especially in the trade-wind region, where evaporation is so constant and great, ought to be salting up or filling up with brine. Is it probable that such a process is actually going on? No.

According to this reasoning, the water at the bottom of the great American lakes ought to be salt, for the rivers and the rains, it is admitted, bring the salts from the land and empty them into the sea. It is also admitted that the great lakes would, from this cause, be salt, if they had no sea drainage. The Niagara River passes these river salts from the upper lakes into Ontario, and the St. Lawrence conveys them thence to the sea. Now, the basins or bottoms of all these upper lakes are far below the *top* of the rock over which the Niagara pitches its flood. And, were the position assumed by this writer correct, viz: that if the water in any of these lakes should, in consequence of its specific gravity, once sink below the level of the shoals in the rivers and straits which connect them, it never could flow out again, and consequently must remain there forever.‡ Were this principle physically correct, would not the water at the bottom of the lakes gradually have received salt sufficient, during the countless ages that they have been sending it off to the sea, to make this everlastingly pent up water briny, or at least quite different in its constituents from that of the surface? We may presume that the water at the bottom of every extensive and quiet sheet of water, whether salt or fresh, is at the bottom by reason of specific gravity; but that it does not remain there forever we have abundant proof. If so, the Niagara River would be fed by Lake Erie only from that layer of water which is above the level of the top of the rock at the Falls. Consequently, wherever the breadth of that river is no greater than it is at the Falls, we should have a current as rapid as it is at the moment of passing the top of the rock to make the leap. To see that such is not the way of Nature, we have but to look at any common mill-pond when the water is running over the dam. The current in the pond that feeds the overflow is scarcely perceptible, for "still water runs deep." Moreover, we know it is not such a skimming current as the geologist would make, which runs from one lake to another; for, wherever above the Niagara Falls the water is deep, there we are sure to find the current sluggish, in comparison with the rate it assumes as it approaches the Falls; and it is sluggish in deep places, rapid in shallow ones, because it is fed from below. Every mill-dam over which the water falls, also the common "wastes" in our canals, teach us this fact.

The reasoning of this celebrated geologist appears to be founded upon the assumption that when water, in consequence of its specific gravity, once sinks below the bottom of a current where it is shallowest, there is no force of traction in fluids, nor any other power, which can draw this heavy water up again. If such were the case, we could not have deep water immediately inside of the bars which obstruct the passage of the great rivers into the

* One hundred and sixty, Smyth.

† Lyell's Principles of Geology, p. 334–5, ninth edition. London, 1853.

‡ See paragraph quoted (§ 113) from Lyell's Principles of Geology.

sea. Thus the bar at the mouth of the Mississippi, with only fifteen feet of water on it, is estimated to travel out to sea at rates varying from one hundred to twenty yards a year.

In the place where that bar was when it was one thousand yards nearer to New Orleans than it now is, whether it were fifteen years ago or a century ago, with only fifteen or sixteen feet of water on it, we have now four or five times that depth. As new bars were successively formed seaward from the old, what dug up the sediment which formed the old, and lifted it up from where specific gravity had placed it, and carried it out to sea over a barrier not more than a few feet from the surface? Indeed, Sir Charles himself makes this majestic stream to tear up its own bottom to depths far below the top of the bar at its mouth. He describes the Mississippi as a river having nearly a uniform breadth to the distance of two thousand miles from the sea.* He makes it cut a bed for itself out of the soil, which is heavier than Admiral Smyth's deep sea water, to the depth of more than two hundred feet† below the top of the bar which obstructs its entrance into the sea. Could not the same power which scoops out this solid matter draw the brine up from the pool in the Mediterranean, and pass it out across the barrier in the Straits.

The gallant admiral—appearing to withhold his assent both from Dr. Wollaston in his conclusions as to this under current, and from the geologist in his inferences as to the effect of the barrier in the Straits—suggests the probability that in sounding for the heavy specimen of sea water, he struck a brine spring. But the specimen, according to analysis, was of sea water, and how did a brine spring of sea water get under the sea but through the process of evaporation on the surface, or by parting with a portion of its fresh water in some other way.

If we admit the principle assumed by Sir Charles Lyell, that water from the great pools and basins of the sea can never ascend to cross the ridges which form these pools and basins, then the harmonies of the sea are gone, and we are forced to conclude they never existed. Every particle of water that sinks below a submarine ridge is, *ipso facto*, by his reasoning, striken from the channels of circulation, to become thenceforward forever motionless matter. The consequence would be "cold obstruction" in the depths of the sea, and a system of circulation between different seas of the waters only that float above the shoalest reefs and barriers. I do not believe in the existence of any such imperfect terrestrial mechanism, or in any such failures of design. To my mind, the proofs—the theoretical proofs—the proofs derived exclusively from reason and analogy—are as clear in favor of this under current from the Mediterranean as they were in favor of the existence of Leverrier's planet before it was seen through the telescope at Berlin.

Now suppose, as Sir Charles Lyell maintains, that none of these vast quantities of salt which this surface current takes into the Mediterranean find their way out again. It would not be difficult to show, even to the satisfaction of that eminent geologist, that this indraught conveys salt away from the Atlantic faster than all the *fresh* water rivers empty fresh supplies of salt into the ocean. Now, besides this drain, vast quantities of salt are extracted from sea water for madrepores, coral reefs, shell banks, and marl beds; and by such reasoning as this, which is perfectly sound and good, we establish the existence of this under current, or else we are forced to the very unphilosophical conclusion that the sea must be losing its salts, and becoming less and less briny.

* "From near its mouth at the Balizo, a steamboat may ascend for nearly two thousand miles with scarcely any preceptible difference in the width of the river."—*Lyell*, p. 263

† "The Mississippi is continually shifting its course in the great alluvial plain, cutting frequently to the depth of one hundred, and even sometimes to the depth of two hundred and fiftv feet."—*Lyell*, p. 273.

114. THE CURRENTS OF THE INDIAN OCEAN.—By carefully examining the physical features of this sea, (Plates XV and XIV,) and studying its conditions, we are led to look for warm currents that have their genesis in this ocean, and that carry from it volumes of overheated water, probably exceeding in quantity many times that which is discharged by the Gulf Stream from its fountains, (Plate XIII.)

The Atlantic Ocean is open at the north, but tropical countries bound the Indian Ocean in that direction. The waters of this ocean are hotter than those of the Caribbean Sea, and the evaporating force there (§ 36) is much greater. That it is greater we might, without observation, infer from the fact of a higher temperature and a greater amount of precipitation on the neighboring shores, (§ 33.) These two facts, taken together, tend, it would seem, to show that large currents of warm water have their genesis in the Indian Ocean. One of them is the well-known Mozambique current, called at the Cape of Good Hope the Lagullas current.

115. Another of these currents makes its escape through the Straits of Malacca, and, being joined by other warm streams from the Java and China Seas, flows out into the Pacific, like another Gulf Stream, between the Philippines and the shores of Asia. Thence it attempts the great circle route for the Aleutian Islands, tempering climates, and losing itself in the sea on its route toward the northwest coast of America.

116. Between the physical features of this current and the Gulf Stream of the Atlantic there are several points of resemblance. Sumatra and Malacca correspond to Florida and Cuba; Borneo to the Bahamas, with the Old Providence Channel to the south, and the Florida Pass to the west. The coasts of China answer to those of the United States, the Philippines to the Bermudas, the Japan Islands to Newfoundland. As with the Gulf Stream, so also here with this China current, there is a counter current of cold water between it and the shore. The climates of the Asiatic coast correspond with those of America, along the Atlantic, and those of Columbia, Washington, and Vancouver are duplicates of those of Western Europe and the British Islands; the climate of California (State) resembling that of Spain; the sandy plains and rainless regions of Lower California reminding one of Africa, with its deserts between the same parallels, &c.

Moreover, the North Pacific, like the North Atlantic, is enveloped, where these warm waters go, with mists and fogs, and streaked with *lightning*. The Aleutian Islands are as renowned for fogs and mists as are the Grand Banks of Newfoundland.

A surface current flows north through Behring's Strait into the Artic Sea; but, in the Atlantic, the current is from, not into the Artic Sea: it flows south on the surface, north below; Behring's Strait being too shallow to admit of mighty under currents, or to permit the introduction from the polar basin of any large icebergs into the Pacific.

Behring's Strait, in geographical position, answers to Davis' Strait in the Atlantic; and Alaska, with its Aleutian chain of islands, to Greenland. But, instead of there being to the east of Alaska, as there is to the east of Greenland, an escape into the polar basin for these warm waters, the Pacific shore-line intervenes and turns them down through a sort of North Sea, along the western coast of the continent toward Mexico. And in this feature we may perceive why there cannot be in the North Pacific a Gulf Stream equal to that of the North Atlantic. The heat of the torrid and the cold of the frigid zone are perpetually destroying the equilibrium of the ocean, by changing with temperature the specific gravity of sea water; and the mere change of specific gravity there begets currents as surely as the change of weight at one end of the balance will cause it to kick the beam. The polar waters, having their specific gravity changed, seek the torrid zone by the North Sea and Davis' Strait; Behring's Strait is so shallow and so narrow that they cannot in sufficient volume get out that way, neither can large volumes of warm water enter the polar basin that way. Hence, there is no call in the Pacific for a Gulf Stream like ours to supply the polar seas with intertropical waters.

117. These contrasts show the principal points of resemblance and of difference between the currents and aqueous circulation in the two oceans. The ice-bearing currents of the North Atlantic are not repeated, as to degree, in the North Pacific, for there is no nursery for icebergs like the Frozen Ocean and its arms. The seas of Okotsk and Kamtschatka alone, and not the frozen seas of the Arctic, cradle the icebergs for the North Pacific.

There is, at times at least, another current of warm water from the Indian Ocean. It finds its way south midway between Africa and Australia. The whales (Plate IX) give indications of it. Nor need we be surprised at such a vast flow of warm water as these three currents indicate from the Indian Ocean, when we recollect that this ocean (§ 114) is land-locked on the north, and that the temperature of its waters is frequently as high as 90° Fahr.

There must, therefore, be immense volumes of water flowing into the Indian Ocean to supply the waste created by these warm currents, and the fifteen or twenty feet of water that observations tell us are yearly carried off from this ocean by evaporation.

On either side of this warm current that escapes from the inter-tropical parts of the Indian Ocean, midway between Africa and Australia, an ice-bearing current (Plate XIV) is found wending its way from the Antarctic regions, with supplies of cold water, to modify climates and restore the aqueous equilibrium in that part of the world. These cold currents sometimes get as far north with their icebergs as 40° south. The Gulf Stream seldom permits them to get so near the equator as that in the North Atlantic, but I have known the ice-bearing current which passes east of Cape Horn into the South Atlantic, to convey its bergs as far as the parallel of 37° south latitude. This is the nearest approach of icebergs to the equator.

118. The currents which run out from the inter-tropical basin of that immense sea—Indian Ocean—are active currents. They convey along immense volumes of water containing vast quantities of salt, and we know that sea water enough to convey back equal quantities of salt, and salt to keep up supplies for the outgoing currents, must flow into or return to the inter-tropical regions of the same sea; therefore, if observations were silent upon the subject, reason would teach us to look for currents here that keep in motion immense volumes of water.

119. The Currents of the Pacific.—The contrast has been drawn (§ 116) between the China or "Gulf Stream" of the North Pacific, and the Gulf Stream of the North Atlantic. The course of the China stream has never been traced out. There is, (Plate XIV,) along the coast of California and Mexico, a southwardly movement of waters, as there is along the west coast of Africa towards the Cape de Verde Islands.

In the open space west of this southwardly set, along the African coast, there is the famous Sargasso Sea, (Plate XIV,) which is the general receptacle of the drift-wood and sea-weed of the Atlantic. So, in like manner, to the west from California of this other southwardly set, lies the pool into which the drift-wood and sea-weed of the North Pacific are generally gathered.

The natives of the Aleutian Islands, where no trees grow, depend upon the drift-wood cast ashore there for all the timber used in the construction of their boats, fishing tackle, and household gear. Among this timber the camphor-tree, and other woods of China and Japan, are said to be often recognized. In this fact we have additional evidence touching this China Stream, as to which (§ 119) but little, at best, is known.

THE COLD ASIATIC CURRENT.—Inshore of, but counter to the China current, along the eastern shores of Asia, is found (§ 116) a streak or layer, or current of cold water answering to that between the Gulf Stream and the American coast. This current, like its fellow in the Atlantic, is not strong enough at all times sensibly to affect the course of navigation; but, like that in the Atlantic, it is the nursery of most valuable fisheries. The fisheries of Japan are quite as extensive as those of Newfoundland, and the people of each country are indebted for their valuable supplies of excellent fish to the cold waters which the currents of the sea bring down to their shores.

HUMBOLDT'S CURRENT.—The currents of the Pacific are but little understood. Among those about which most is thought to be known is the Humboldt Current of Peru, which the great and good man, whose name it bears, was the first to discover. It has been traced on Plate XIV, according to the best information—defective at best—upon the subject. This current is felt as far as the equator.

120. I have, I believe, discovered the existence of a warm current in the inter-tropical regions of the Pacific, midway between the American coast and the shore-lines of Australia.

This region affords an immense surface for evaporation. No rivers empty into it; the annual fall of rain, except in the "equatorial doldrums," is small, and the evaporation is all that both the northeast and the southeast trade-winds can take up and carry off. I have marked on Plate XIV the direction of the supposed warm water current which conducts these overheated and briny waters from the tropics in mid ocean to the extra-tropical regions where precipitation is in excess. Here being cooled and agitated, and mixed up with waters that are less salt, these overheated and over-salted waters from the tropics may be replenished and restored to their rounds in the wonderful system of oceanic circulation.

121. There are also about the equator in this ocean some curious currents which I do not understand, and as to which observations are not sufficient yet to afford the proper explanation or description. There are many of them, some of which, at times, run with great force. On a voyage from the Society to the Sandwich Islands, I encountered one running at the rate of ninety-six miles a day.

And what else should we expect in this ocean but a system of currents and counter-currents apparently the most uncertain and complicated? The Pacific Ocean and the Indian Ocean may, in the view we are about to take, be considered as one sheet of water. This sheet of water covers an area quite equal in extent to one-half of that embraced by the whole surface of the earth; and, according to Professor Alexander Keith Johnson, who so states it in the new edition of his splendid *Physical Atlas*, the total annual fall of rain on the earth's surface is one hundred and eighty-six thousand two hundred and forty cubic imperial miles. Not less than three-fourths of the vapor which makes this rain comes from this waste of waters; but supposing that only half of this quantity, *i. e.*, ninety-three thousand one hundred and twenty cubic miles of rain falls upon this sea, and that that much, at least, is taken up from it again as vapor, this would give two hundred and fifty-five cubic miles as the quantity of water which is daily lifted up and poured back again into this expanse. It is taken up at one place and rained down at another, and in this process, therefore, we have agencies for multitudes of partial and conflicting currents, all, in their set and strength, apparently as uncertain as the winds.

The better to appreciate the operation of such agencies in producing currents in the sea, now here, now there, first this way, and then that, let us, by way of illustration, imagine a district of two hundred and fifty-five square miles in extent to be set apart in the midst of the Pacific Ocean, as the scene of operations for one day. We must now conceive a machine capable of pumping up, in the twenty-four hours, all the water to the depth of one mile in this district. The machine must not only pump up and bear off this immense quantity of water, but it must discharge it again into the sea on the same day, but at some other place. Now here is a force for creating currents that is equivalent in its results to the effects that would be produced by baling up, in twenty-four hours, two hundred and fifty-five cubic miles of water from one part of the Pacific Ocean and emptying it out again upon another part. The currents that would be created by such an operation would overwhelm navigation and desolate the sea; and, happily for the human race, the great atmospherical machine, which actually does perform every day, on the average, all this lifting up, transporting, and letting down of water upon the face of the grand ocean, does not confine itself to an area of two hundred and fifty-five square miles, but to an area three hundred thousand times as great; yet, nevertheless, the same quantity of water is kept in motion, and the currents, in the aggregate, transport as much water to restore the equilibrium as they would have to do were all the disturbance to take place upon our hypothetical area of one mile deep over the space of two hundred and fifty-five square miles. Now when we come to recollect that evaporation is lifting up, that the winds are transporting, and that the clouds do let down every day actually such a body of water, but that it is done by little and little at a place, and by hair's breadths at a time, not by parallelopipedons one mile thick—that the evaporation is most rapid and rains most copious, not always at the same place, but now here, now there, we shall see actually existing in nature a force sufficient to give rise to just such a system of currents as that which mariners find in the Pacific—currents which appear to rise in mid ocean run at unequal rates, sometimes east, sometimes west, but which always lose themselves where they rise, viz: in mid ocean.

UNDER CURRENTS.—Lieutenant J. C. Walsh, in the United States schooner Taney, and Lieutenant S. P. Lee, in the United States brig Dolphin, both, while they were carrying on a system of observations in connexion with the Wind and Current Charts, had their attention directed to the subject of submarine currents.

They made some interesting experiments upon the subject. A block of wood was loaded to sinking, and, by means of a fishing-line or a bit of twine, let down to the depth of one hundred or five hundred fathoms (six hundred or three thousand feet.) A small float, just sufficient to keep the block from sinking further, was then tied to the line, and the whole let go from the boat.

To use their own expressions, "It was wonderful, indeed, to see this *barrega* move off, against wind, and sea, and surface current, at the rate of over one knot an hour, as was generally the case, and on one occasion as much as $1\frac{3}{4}$ knots. The men in the boat could not repress exclamations of supprise, for it really appeared as if some monster of the deep had hold of the weight below, and was walking off with it."* Both officers and men were amazed at the sight.

122. The experiments in deep-sea soundings have also thrown much light upon the subject of under currents. There is reason to believe that they exist in all, or almost all parts of the deep sea, for never in any instance yet has the deep-sea line ceased to run out, even after the plummet had reached the bottom.

If the line be held fast in the boat, it invariably parts, showing, when two or three miles

* Lieutenant Walsh.

of it are out, that the under currents are sweeping against the bight of it with what seamen call a *swigging force*, that no sounding twine has yet proved strong enough to withstand.

Lieutenant J. P. Parker, of the United States frigate Congress, attempted, in 1852, a deep-sea sounding off the coast of South America. He was engaged with the experiment eight or nine hours, during which time a line nearly ten miles long was paid out. Night coming on, he had to part the line (which he did simply by attempting to haul it in,) and return on board. Examination proved that the ocean there, instead of being over ten miles in depth, was not over three, and that the line was swept out by the force of one or more under currents. But in what direction these currents were running is not known.

123. It may therefore, without doing any violence to the rules of philosophical investigation, be conjectured that the equilibrium of all the seas is preserved to a greater or less extent by this system of currents and counter currents at and below the surface.

If we except the tides and the partial currents of the sea, such as those that may be created by the wind, we may lay it down as a rule that all the currents of the ocean owe their origin to difference of specific gravity between sea water at one place and sea water at another; for wherever there is such a difference, whether it be owing to difference of temperature or to difference of saltness, &c., it is a difference that disturbs equilibrium, and currents are the consequence. The heavier water goes toward the lighter, and the lighter whence the heavier comes; for two fluids, differing in specific gravity, (§ 36,) and standing at the same level, cannot balance each other. It is immaterial, as before stated, whether this difference of specific gravity be caused by temperature, by the matter held in solution, or by any other thing; the effect is the same, namely, a current.

That the sea, in all parts, holds in solution the same kind of solid matter; that its waters in this place, where it never rains, are not salter than the strongest brine; and that in another place, where the rain is incessant, they are not entirely without salt, may be taken as evidence in proof of a system of currents or of circulation in the sea, by which its waters are shaken up and kept mixed together as though they were in a phial. Moreover, we may lay it down as a law in the system of oceanic circulation, that every current in the sea has its counter current; in other words, that the currents of the sea are, like the nerves of the human system, arranged in pairs; for wherever one current is found carrying off water from this or that part of the sea, to the same part must some other current convey an equal volume of water, or else the first would, in the course of time, cease for the want of water to supply it.

124. Currents of the Atlantic.—The principal currents of the Atlantic have been described in the chapter on the Gulf Stream. Besides this, its eddies and its offsets are the equatorial current, (Plate XIII,) and the St. Roque or Brazil Current. Their fountain head is the same. It is in the warm waters about the equator, between Africa and America. The former, receiving the Amazon and the Oronoco as tributaries by the way, flows into the Caribbean Sea, and becomes, with the waters in which the vapors of the trade-winds leave their salts, the feeder of the Gulf Stream. The Brazil Current, coming from the same fountain, is supposed to be divided by Cape St. Roque, one branch going to the south under this name, (Plate XIV,) the other to the westward. This last has been a great bugbear to navigators, principally on account of the difficulties which a few dull vessels falling to leeward of St. Roque have found in beating up against it. It was said to have caused the loss of some English transports in the last century, which fell to leeward of the Cape on a voyage to the other hemisphere; and navigators, accordingly, were advised to shun it as a danger.

125. This current has been an object of special investigation during my researches connected with the Wind and Current Charts, and the result has satisfied me that it is neither a dangerous nor a constant current, notwithstanding older writers. Horsburgh, in his *East India Directory*, continues to caution navigators against it.

I receive almost daily the abstract logs of vessels that cross the equator west of 30° west, and in three days from that crossing they are generally clear of that cape. A few of them report the current in their favor; most of them experience no current at all; but, now and then, some do find a current setting to the northward and westward, and operating against them; but such cases are the exception, not the rule. The inter-tropical regions of the Atlantic, like those of the other oceans, (§ 121,) abound with conflicting currents, which no researches yet have enabled the mariner to unravel; therefore, the hydrographer does not at all times know where they are, nor can he always tell how they run, in order that the navigator may be certain of their help when favorable, or sure of avoiding them if adverse.

I may here remark, that there seems to be a larger flow of polar waters into the Atlantic than of other waters from it, and I cannot account for the preservation of the equilibrium of this ocean by any other hypothesis than that which calls in the aid of under currents. They, I have no doubt, bear an important part in the system of oceanic circulation.

The Gulf Stream is unique; it is the anomaly of the sea; its bearings upon commerce and navigation are highly important—a separate chapter will be devoted to it in this light.

CHAPTER IX.

THE GULF STREAM.*

Its color, § 126.—The Sargasso Sea, § 129.—Galvanic Properties of Gulf Stream Waters, § 130.—Agents that make Water in one part of the Sea heavier than in another, § 132.—Temperature of the Gulf Stream, 136.—Why the Drift Matter of the Gulf Stream is sloughed off to the right of its Course, § 138.—Currents run along arcs of Great Circles, § 142.—The Force derived from Changes of Temperature, § 143.—Limits of the Gulf Stream for March and September, § 144.—A Cushion of Cold Water between the Bottom of the Sea and the Waters of the Gulf Stream, § 145.—It runs up hill, § 146.

§ 126. The water of the Gulf Stream, as far out from the Gulf as the Carolina coasts, is of an indigo blue. It is so distinctly marked, that the line of junction with the common sea water may be traced by the eye. Often one half of the vessel may be perceived floating in Gulf Stream water, while the other half is in common water of the sea; so sharp is the line, and such the want of affinity between those waters, and the reluctance, on the part of those of the Gulf Stream, to mingle with the common water of the sea.

What is the cause of the Gulf Stream has always puzzled philosophers. Modern investigations and examinations are beginning to throw some light upon the subject, though all is not yet clear.

1. Early writers maintained that the Mississippi River was the father of the Gulf Stream. Its floods, they said, produce it; for its velocity, it was held, could be computed by the rate of the current of the river.

* *Vide* Maury's Physical Geography of the Sea.

Captain Livingston overturned this hypothesis by showing that the volume of water which the Mississippi River empties into the Gulf of Mexico is only equal to about the three-thousandth part of that which escapes from it through the Gulf Stream.

2. Moreover, the water of the Gulf Stream is salt—of the Mississippi, fresh; and those philosophers forgot that just as much salt as escapes from the Gulf of Mexico through this stream must enter the Gulf through some other channel from the main ocean; for, if it did not, the Gulf of Mexico, unless it had a salt bed at the bottom, or was fed with salt springs below—neither of which is probable—would, in process of time, become a fresh water basin.

The above quoted argument of Captain Livingston, however, was held to be conclusive; and upon the remains of the hypothesis which he had so completely overturned he set up another, which, in turn, has been upset. In it he ascribed the velocity of the Gulf Stream as depending "on the motion of the sun in the ecliptic, and the influence he has on the waters of the Atlantic."

But the opinion that came to be the most generally received and deep rooted in the mind of seafaring people was the one repeated by Dr. Franklin, and which held that the Gulf Stream is the escaping of the waters that have been *forced* into the Caribbean Sea by the trade-winds, and that it is the pressure of those winds upon the water which forces up into that sea a head, as it were, for this stream.

We know of instances in which waters have been accumulated on one side of a lake, or in one end of a canal, at the expense of the other. But they are rare, sudden, and partial, and, for the most part, confined to sheets of shoal water where the ripples are proportionably great. As far as they go, the pressure of the trade-winds may *assist* to give the Gulf Stream its initial velocity, but is it of itself adequate to such an effect? To my mind, the laws of hydrostatics, as at present expounded, appear by no means to warrant the conclusion that it is, unless the aid of other agents also be brought to bear.

Admiral Smyth, in his valuable memoir on the Mediterranean, (p. 162,) mentions that a continuance in the Sea of Tuscany of *gusty gales* from the southwest has been known to raise its surface no less than twelve feet above its ordinary level. This, he says, occasions a strong surface drift through the Strait of Bonifaccio. But in this we have nothing like the Gulf Stream; no deep and narrow channel way to conduct these waters off like a miniature river even in the sea, but a mere surface flow, such as usually follows the piling up of water in any pond or gulf above the ordinary level. The Bonifaccio current does not flow like a river in the sea across the Mediterranean, but it spreads itself out as soon as it passes the Straits, and, like a circle on the water, loses itself by broad spreading as soon as it gets to sea.

127. Supposing the pressure of the waters that are *forced* into the Caribbean Sea by the trade-winds to be the *sole* cause of the Gulf Stream, that sea and the Mexican Gulf should have a much higher level than the Atlantic. Accordingly, the advocates of this theory require for its support "a great degree of elevation." Major Rennel likens the stream to "an immense river descending from a higher level into a plain." Now we know very nearly the average breadth and velocity of the Gulf Stream in the Florida Pass. We also know, with a like degree of approximation, the velocity and breadth of the same waters off Cape Hatteras. Their breadth here is about seventy-five miles against thirty-two in the "Narrows" of the Straits, and their mean velocity is three knots off Hatteras against four in the "Narrows." This being the case, it is easy to show that the depth of the Gulf Stream off Hatteras is not so great as it is in the "Narrows" of Bemini by nearly 50 per cent., and that, consequently,

instead of *descending*, its bed represents the surface of an inclined plane tilted down from the north, and *up* which the lower depths of the stream *must* ascend. If we assume its depth off Bemini to be two hundred fathoms, which are thought to be within limits, the above rates of breadth and velocity will give one hundred and fourteen fathoms for its depth off Hatteras. The waters, therefore, which in the Straits are below the level of the Hatteras depth, so far from descending, are actually forced up an inclined plane, whose submarine ascent is not less than ten inches to the mile.

The Niagara is an "immense river descending into a plain." But instead of preserving its character in Lake Ontario as a distinct and well-defined stream for several hundred miles, it spreads itself out, and its waters are immediately lost in those of the lake. Why should not the Gulf Stream do the same? It gradually enlarges itself, it is true; but, instead of mingling with the ocean by broad spreading, as the "immense rivers" descending into the northern lakes do, its waters, like a stream of oil in the ocean, preserve a distinctive character for nearly three thousand miles.

128. Moreover, while the Gulf Stream is running to the north, from its supposed elevated level at the south, there is a cold current coming down from the north; meeting the warm waters of the Gulf midway the ocean, it divides itself and runs by the side of them right back into those very reservoirs at the south, to which theory gives an elevation sufficient to send out entirely across the Atlantic a jet of warm water said to be more than three thousand times greater in volume than the Mississippi River. This current from Baffin's Bay has not only no trade-winds to give a head, but the prevailing winds are unfavorable to it, and for a great part of the way it is below the surface, and far beyond the propelling reach of any wind. And there is every reason to believe that this polar current is quite equal in volume to the Gulf Stream. Are they not the effects of like causes? If so, what have the trade-winds to do with the one more than the other?

It is a custom often practiced by seafaring people to throw a bottle overboard, with a paper, stating the time and place at which it was done. In the absence of other information as to currents, that afforded by these mute little navigators is of great value. They leave no tracks behind them, it is true, and their routes cannot be ascertained. But knowing where they were cast, and seeing where they are found, some idea may be formed as to their course. Straight lines may at least be drawn, showing the shortest distance from the beginning to the end of their voyage, with the time elapsed. The late Admiral Beechey, R. N., prepared a chart some years ago,* representing, in this way, the tracks of more than one hundred bottles. From it, it appears that the waters from every quarter of the Atlantic tend toward the Gulf of Mexico and its stream. Bottles cast into the sea midway between the Old and the New Worlds, near the coasts of Europe, Africa, and America, at the extreme north or furthest south, have been found either in the West Indies or within the well-known range of Gulf Stream waters.

Of two cast out together in south latitude on the coast of Africa, one was found on the Island of Trinidad; the other on Guernsey, in the English Channel.

In the absence of positive information on the subject, the circumstantial evidence that the latter performed the tour of the Gulf is all but conclusive.

Another bottle, thrown over off Cape Horn by an American master in 1837, has been recently picked up on the coast of Ireland. An inspection of the chart, and of the drift of the

* *Vide* Naut. Magazine, (Eng.) passim.

other bottles, seems to *force* the conclusion that this bottle, too, went even from that remote region to the so-called *higher* level of the Gulf Stream reservoir.

129. Midway the Atlantic, in the triangular space between the Azores, Canaries, and the Cape de Verde Islands, is the Sargasso Sea. (Plate XIII.) Covering an area equal in extent to the Mississippi Valley, it is so thickly matted over with Gulf weed (*fucus natans*) that the speed of vessels passing through it is often much retarded. When the companions of Columbus saw it, they thought it marked the limits of navigation, and became alarmed. To the eye, at a little distance, it seems substantial enough to walk upon. Patches of the weed are always to be seen floating along the Gulf Stream. Now, if bits of cork or chaff, or any floating substance, be put into a basin, and a circular motion be given to the water, all the light substances will be found crowding together near the centre of the pool, where there is the least motion. Just such a basin is the Atlantic Ocean to the Gulf Stream, and the Sargasso Sea is the centre of the whirl. Columbus first found this weedy sea in his voyage of discovery; there it has remained to this day; and certain observations as to its limits, extending back for fifty years, assure us that its position has not been altered since that time. This indication of a circular motion by the Gulf Stream is corroborated by the bottle chart and other sources of information. If, therefore, this be so, why give the endless current a higher level in one part of its course than another?

Nay, more; at the very season of the year when the Gulf Stream is rushing in greatest volume through the Straits of Florida, and hastening to the north with the greatest rapidity, there is a cold stream from Baffin's Bay, Labrador, and the coasts of the north, running to the south with equal velocity. Where is the trade-wind that gives the high level to Baffin's Bay, or that even presses upon or assists to put this current in motion? The agency of winds in producing currents in the deep sea must be very partial. These two currents meet off the Grand Banks, where the latter is divided. One part of it underruns the Gulf Stream, as is shown by the icebergs which are carried in a direction tending across its course. The probability is, that this "fork" continues on toward the south and runs into the Caribbean Sea, for the temperature of the water at a little depth there has been found far below the mean temperature of the earth, and quite as cold as at a corresponding depth off the Artic shores of Spitzbergen.

More water cannot run from the equator or the pole than to it. If we make the trade-winds cause the former, some other wind must produce the latter; but these, for the most part, and for great distances, are *submarine*, and therefore beyond the influence of winds. Hence, it should appear that *winds* have little to do with the general system of aqueous circulation in the ocean.

The other "fork" runs between us and the Gulf Stream to the south, as already described. As far as it has been traced, it warrants the belief that it, too, runs *up* to seek the so-called *higher* level of the Mexican Gulf.

The power necessary to overcome the resistance opposed to such a body of water as that of the Gulf Stream, running several thousand miles without any renewal of impulse from the forces of gravitation or any other known cause, would be truly surprising.

The facts so far derived from observation, afford us, at best, but a mere glimmer of light, by no means sufficient to make any mind clear as to a *higher level* of the Gulf, or as to the sufficiency of any other of the causes assigned for this wonderful stream. If it be necessary to resort to a higher level in the Gulf to account for the velocity off Hatteras, I cannot perceive why we should not, with like reasoning, resort to a higher level off Hatteras, also, to account for the velocity off the Grand Banks, and thus make the Gulf Stream, throughout its circuit, a *descending* current, and, by the *reductio ad absurdum*, show that the trade-winds are not adequate to the effect ascribed.

When facts are wanting it often happens that hypothesis will serve, in their stead, all the purposes of mere illustration. Let us, therefore, suppose a globe of the earth's size, having a solid nucleus, and covered all over with water two hundred fathoms deep; and that every source of heat and cause of radiation be removed, so that its fluid temperature becomes constant and uniform throughout. On such a globe, the equilibrium remaining undisturbed, there would be neither wind nor current.

Let us now suppose that all the water within the tropics, to the depth of one hundred fathoms, suddenly becomes oil. The aqueous equilibrium of the planet is thereby disturbed, and a general system of currents and counter-currents is immediately commenced; the oil, in an unbroken sheet on the surface, running toward the poles, and the water, in an under current, toward the equator. The oil is supposed, as it reaches the polar basin, to be reconverted into water, and the water to become oil as it crosses Cancer and Capricorn, rising to the surface and returning as before.

Thus, *without wind*, we should have a perpetual and uniform system of tropical and polar currents. In consequence of diurnal rotation of the planet on its axis, each particle of oil, were resistance small, would approach the poles on a spiral turning to the east, with a relative velocity greater and greater, until, finally, it would reach the pole and whirl about at the rate of nearly a thousand miles the hour. Becoming water, and losing its velocity, it would approach the tropics by a similar but inverted spiral, turning toward the west. Owing to the principal here alluded to, all currents from the equator to the poles should have an eastward tendency, and all from the poles toward the equator a westward.

Let us now suppose the solid nucleus of this hypothetical globe to assume the exact form and shape of the bottom of our seas, and in all respects, as to figure and size, to represent the shoals and islands of the sea, as well as the coast lines and continents of the earth. The uniform system of currents just described would not be interrupted by obstructions and local causes of various kinds, such as unequal depth of water, contour of shore-lines, &c.; and we should have at certain places currents greater in volume and velocity than at others. But still there would be a system of currents and counter-currents to and from either pole and the equator. Now, do not the cold waters of the north, and the warm waters of the Gulf, made specifically lighter by tropical heat, which we see actually preserving such a system of counter-currents, hold, at least in some degree, the relation of the supposed water and oil?

In obedience to the laws here hinted at, there is a constant tendency of polar waters toward the tropics, and of tropical waters toward the poles. Captain Wilkes, of the United States Exploring Expedition, crossed one of these hyperborean under currents two hundred miles in breadth at the equator.

Assuming the maximum velocity of the Gulf Stream at five knots, and its depth and breadth in the Narrows of Bemini as before (§ 127), the vertical section across would present an area of two hundred millions of square feet moving at the rate of seven feet three inches per second. The difference of specific gravity between the volume of Gulf water that crosses this sectional line in one second, and an equal volume of water at the ocean temperature of the latitude is fifteen millions of pounds. If these estimated dimensions (assumed merely for the purposes of illustration) be within limits, the then force per second, operating here to propel the waters of the Gulf toward the pole, is the equilibrating tendency due to fifteen millions of pounds of water in the latitude of Bemini.

In investigating the currents of the seas such agencies should be taken into account. I doubt whether this one is sufficient of itself to produce a stream of such great velocity as that of the Gulf; for, assuming its estimated discharge to be correct, the proposition is almost susceptible of mathematical demonstration, that to overcome the resistance opposed in consequence of its velocity would require a force at least sufficient to drive, at the rate of three miles the hour, ninety thousand millions of tons up an inclined plane having an ascent of three inches to the mile.* Yet the very principle from which this agent is derived is admitted to be one of the chief causes of those winds which are said to be the sole cause of this current.

130. The chemical properties, or, if the expression be admissible, the *galvanic* properties of the Gulf Stream waters, as they come from their fountains, are different, or, rather, more intense than they are in sea water generally.

131. In 1843 the Secretary of the Navy took measures for procuring a series of observations and experiments with regard to the corrosive effects of sea water upon the copper sheathing of ships. With patience, care, and labor, these researches were carried on for a period of ten years; and it is said the fact has been established that the copper on the bottom of ships cruising in the Caribbean Sea and Gulf of Mexico suffers more from the action of sea water upon it than does the copper of ships cruising in any other part of the ocean. In other words, the salts of these waters create the most powerful galvanic battery that is found in the ocean.

132. There are physical agents that are known to be at work in different parts of the ocean, the tendency of which is to make the waters in one part of the ocean salter and heavier, and in another part lighter and less salt than the average of sea water. These agents are those employed by sea-shells in secreting solid matter for their structures, also of heat† and radiation, evaporation and precipitation.

In the trade-wind regions at sea (Plate XV) evaporation is generally in excess of precipitation, while in the extra-tropical regions the reverse is the case; that is, the clouds let down more water than the winds take up again; and these are the regions in which the Gulf Stream enters the Atlantic.

133. Along the shores of India, where experiments have been carefully made, the evaporation amounts to three-fourths of an inch daily. Suppose it in the trade-wind region of the Atlantic to amount to only half an inch, that would give an annual evaporation of say fifteen feet. In the process of evaporation from the sea fresh water only is taken up, the salts are left behind.

Now a layer of sea water fifteen feet deep, and as broad as the trade-wind belts of the Atlantic, and reaching across the ocean, contains an immense amount of salts.

134. The great equatorial current (Plate XIII) which sweeps from the shores of Africa across the Atlantic into the Caribbean Sea, is a surface current; and may it not bear into that sea a large portion of those waters that have satisfied the thirsty trade-winds with saltless vapor? If so, and it probably does, have we not detected here the foot-prints of an agent that does tend to make the waters of the Caribbean sea salter, and, therefore, heavier than the average of sea water?

It is immaterial, so far as the correctness of the principle upon which this reasoning

* Supposing there be no resistance from friction.

† According to Doctor Marcet, sea water contracts down to 28°.

depends is concerned, whether the annual evaporation from the trade-wind regions of the Atlantic be fifteen, ten, or five feet. The layer of water, whatever be its thickness, that is evaporated from this part of the ocean, is not all poured back by the clouds in the same place whence it came. But they take it and pour it down in showers upon the extra-tropical regions of the earth, on the land as well as in the sea, where, as a rule, more water is let down than is taken up into the clouds again. Suppose the excess of precipitation in these extra-tropical regions of the sea amounts to but twelve inches, or even but to two, it is twelve inches or two inches, as the case may be, of fresh water added to the sea in those parts, and which, therefore, tends to lessen the specific gravity of sea water there to that extent; and for the simple reason, that what is taken from one scale, by being put into the other, reduplicates the difference.

Now, that we may form some idea as to the influence, which the salts left by the vapor that the trade-winds, northeast and southeast, take up from sea water, is calculated to exert in creating currents, let us make a partial calculation to show how much salt this vapor held in solution before it was taken up, and, of course, while yet in the state of sea water. The northeast trade-wind regions of the Atlantic embrace an area of at least three million square miles; and the yearly evaporation from it is, (§ 133,) we will suppose, fifteen feet. The salt that is contained in a mass of sea water, covering to the depth of fifteen feet and area of three million square miles in superficial extent, would be sufficient to cover the British islands to the depth of fourteen feet. As this water supplies the trade-wind with vapor, it therefore becomes salter, and as it becomes salter, the forces of aggregation among its particles are increased, as we may infer from the fact that the waters of the Gulf Stream are reluctant to mix with those of the ocean.

Now, whatever may be the cause that enables these waters to remain on the surface, whether it be from the fact just stated, and in consequence of which the waters of the Gulf Stream are held together in their channel; or whether it be from the fact that the expansion from the heat of the torrid zone is sufficient to compensate for this increased saltness; or whether it be from both of these influences together that these waters are kept on the surface, suffice it to say, we do know that they go into the Caribbean Sea (§ 134) as a surface current. The trade-winds, by their constant force, may assist to skim them off from the Atlantic, and push them along into the Caribbean Sea, whence, for causes unknown, they escape by the channel of the Gulf Stream in preferance to any other.

135. In the present state of our knowledge concerning this wonderful phenomenon—for the Gulf Stream is one of the most marvellous things in the ocean—we can do little more than conjecture. But we have two causes in operation which we may safely assume are among those concerned in producing the Gulf Stream. One of these is in the increased saltness of its water after the trade-winds have been supplied with vapor from it, and the other is in the diminished quantum of salt which the Baltic and the North Sea contain. The waters of the Baltic are nearly fresh; they contain only about half as much salt as sea water does generally.

Now here we have, on one side, the Caribbean Sea and Gulf of Mexico, with their waters of brine; on the other, the Baltic and the North Sea, with waters that are but a little more than brackish. In one set of these sea-basins the water is heavy; in the other it is light. Between them the ocean intervenes; but water is bound to seek and maintain its level; and here, therefore, we unmask one of the agents concerned in causing the Gulf Stream. What is the influence of this agent—that is, how great is it, and to what extent does it go—we cannot say; only it is, at least, one of the agents concerned. Moreover, speculate as we may as to all the agencies concerned in collecting these waters, that have supplied the trade-winds with vapor, into the Caribbean Sea, and then in driving them across the Atlantic, of this we may be sure, that the salt which the trade-wind vapor leaves behind in the tropics has to be conveyed away from the trade-wind region, to be mixed up again in due proportion with the other water of the sea—the Baltic included—and that these are the waters which we see running off through the Gulf Stream. To convey them away is one of the offices which, in the economy of the ocean, has been assigned to it.

136. As to the temperature of the Gulf Stream, there is, in a winter's day, off Hatteras, and even as high up as the Grand Banks in mid ocean, a difference between its waters and those of the ocean of nearly 20°, and even 30°. Water, we know, expands by heat, and here the difference of temperature may more than compensate for the difference of saltness, and leave, therefore, the waters of the Gulf lighter by reason of their warmth.

137. Being lighter and adhesive, they should therefore occupy a higher level than those through which they flow. Assuming the depth off Hatteras to be one hundred and fourteen fathoms, and allowing the usual rates of expansion for sea water, figures show that the middle or axis of the Gulf Stream there should be nearly two feet higher than the contiguous waters of the Atlantic. Hence the surface of the stream should present a double inclined plane, from which the water would be running down on either side, as from the roof of a house. As this runs off at the top, the same weight of colder water runs in at the bottom, and so raises up the cold-water bed of the Gulf Stream, and causes it to become shallower and shallower as it goes north.

That the Gulf Stream is roof-shaped, causing the waters on its surface to flow off to either side from the middle, we have not only circumstantial evidence to show, but observations to prove.

Navigators, while drifting along with the Gulf Stream, have lowered a boat to try the surface current. In such cases the boat would drift either to the east or to the west, as it happened to be on one side or the other of the axis of the stream, while the vessel herself would drift along with the stream in the direction of its course, thus showing the existence of a shallow roof-current from the middle toward either edge, which would carry the boat along, but which, being superficial, does not extend deep enough to affect the drift of the vessel.

That such is the case, (§137,) is also indicated by the circumstance that the sea-weed and drift-wood which are found in such large quantities along the outer edge of the Gulf Stream, are never, even with the prevalence of easterly winds, found along its inner edge, and for the simple reason that to cross the Gulf Stream, and to pass over from that side to this, they would have to drift up stream, as it were—that is, they would have to stem this roof-current until they reached the middle of the stream. We never hear of planks, or wrecks, or of any floating substance which is cast into the sea on the other side of the Gulf Stream being found along the coasts of the United States. Drift-wood, trees, and seeds from the West India Islands, are said to have been cast up on the shores of Europe, but never, that I ever heard, on the Atlantic shores of this country.

We are treating now of the effects of physical causes. The question to which I ask attention is, Why does the Gulf Stream slough off and cast upon its outer edge sea-weed, drift-wood, and all other solid bodies that are found floating upon it?

138. One cause has been shown to be in its roof-shaped current; but there is another which tends to produce the same effect, and because it is a physical agent, it should not, in a treatise of this kind, be overlooked, be its action never so slight. I allude now to the effects (upon the drift matter of the stream) produced by the diurnal rotation of the earth.

Take, for illustration, a railroad that runs north and south. It is well known to engineers that when the cars are going north on such a road, their tendency is to run off on the east side; but when the train is going south, their tendency is to run off on the west side of the track—*i. e.* always on the right-hand side. Whether the road be one mile or one hundred miles in length, the effect of diurnal rotation is for any one mile the same, and the tendency to run off, as you cross a given parallel at a stated rate of speed, is also the same, whether the road be long or short, the tendency to fly the track being in proportion to the speed of the trains, and not at all in proportion to the length of the road.

Now *vis inertiæ* and velocity being taken into the account, the tendency to obey the force of this diurnal rotation, and to trend to the right, is proportionably as great in the case of a patch of sea-weed as it drifts along the Gulf Stream, as it is in the case of the train of cars as they speed to the north, along the iron track of the Hudson River Railway, or the Great Western Railway of England.

The rails restrain the cars and prevent them from flying off; but there are no rails to restrain the sea-weed, and nothing to prevent the drift matter of the Gulf Stream from going off in obedience to this force. The slightest impulse tending to turn aside bodies moving freely in water is immediately felt and implicitly obeyed.

139. It is in consequence of this diurnal rotation that drift-wood coming down the Mississippi is so very apt to be cast upon the west or right bank. This is the reverse of what obtains upon the Gulf Stream, for it flows to the north; it therefore sloughs off to the east.

The effect of diurnal rotation upon the winds and upon the currents of the sea is admitted by all; the trade-winds derive their *easting* from it. It must, therefore, extend to all the matter which these currents bear with them—to the largest iceberg as well as to the merest sprig of grass that floats upon the waters, or the minutest organism that the most powerful microscope can detect among the impalpable particles of sea-dust. This effect of diurnal rotation will be frequently alluded to in the pages of this work.

140. In its course to the north, the Gulf Stream gradually trends to the eastward, until it is bifurcated by the British Islands. One fork of it then finds its way up around North Cape into the Arctic Ocean; the other, sweeping to the right as an eddy, finds its way back to the torrid zone along the coast of Africa. Near the Grand Banks the frigid current, already spoken of, (§128,) with its icebergs from the north, are met and melted by the warm waters of the Gulf. Of course, the loads of earth, stones, and gravel brought down upon them are here deposited. Captain Scoresby, far away in the north, counted five hundred icebergs setting out from the same vicinity upon this cold current for the south. Many of them, loaded with earth, have been seen aground on the Banks. This process of transferring deposits for these shoals has been going on for ages, and, with time, seems altogether inadequate to the effect described.

The deep-sea soundings that have been made by vessels of the navy (Plate XI) tend to confirm this view as to the formation of these Banks. The greatest contrast in the bottom of the Atlantic is just to the south of these Banks. Nowhere in the open sea has the water been found to deepen so suddenly as here. Coming from the north, the bottom of the sea is shelving; but suddenly, after passing these Banks, its depth increases by almost a precipitous descent for many thousand feet, thus indicating that the debris which forms the Grand Banks comes from the north.

141. From the Straits of Bemini the course of the Gulf Stream (Plate XIII) describes (as far as it can be traced over toward the British Islands which are in the midst of its waters) the arc of a great circle as nearly as may be, and its course is very nearly such a course as a cannon-ball, could it be shot from these straits to those islands, would take.

If it were possible to see Ireland from Bemini, and to get a cannon that would reach that far, the person standing on Bemini and taking aim, intending to shoot at Ireland as a target, would, if the earth were at rest, sight along the plane of a great circle, for the path of the ball would be in such a plane.

But there *is* diurnal rotation; the earth *does* revolve on its axis; and since Bemini is nearer than Ireland is to the equator, the gun would be moving in diurnal rotation faster than the target, and, therefore, the marksman, taking aim point blank at his target, would miss. He would find, on examination, that he had shot ahead of his mark.

It is the case of the passenger in the railroad car throwing an apple, as the train sweeps by, to a boy standing by the wayside. If he throw straight at the boy, he will miss, for the apple, partaking of the motion of the cars, will go ahead of the boy, and for the very reason that the shot will pass in advance of the target, for both the marksman and the passenger are going faster than the object at which they aim.

142. Hence we may assume it as a law, that the natural tendency of all currents in the sea, like the natural tendency of all projectiles through the air, is to describe their curves of flight in the planes of great circles, departing therefrom—unless *forced* to depart by obstructions—only so much as the forces of diurnal rotation may impel.

The arc of a great circle is the shortest distance between any two points on the surface of a sphere. Light, heat, and electricity, running water, and all substances, whether ponderable or imponderable, seek, when in motion, to pass from point to point by the shortest lines practicable. Electricity may be turned aside from its course, and so may the cannon-ball or running water; but remove every obstruction, and leave the current or the shot free to continue on in the direction of the first impulse, or to turn aside of its own volition, so to speak, and straight it will go, and continue to go—if on a plane, in a straight line; if on a sphere, in the arc of a great circle—thus showing that it has no volition except to obey impulse, and the physical requirements to take the shortest way to its point of destination.

The waters of the Gulf Stream, as they escape from the Gulf, (§ 135,) are bound over to the British Islands, to the North Sea, and Frozen Ocean, (Plate XIV.) Accordingly, they take, (§ 141,) in obedience to this physical law, the most direct course by which nature will permit them to reach their destination. And this course, as already remarked, is nearly that of the great circle, as the physical obstacles in the way will permit.

Many philosophers have expressed the opinion—indeed, the belief is common among mariners, (§ 140)—that the coasts of the United States and the Shoals of Nantucket turn the Gulf Stream toward the east; but if the view I have been endeavoring to make clear be correct—and I think it is—it appears that the course of the Gulf Stream is fixed and prescribed by exactly the same laws that require the planets to revolve in orbits, the planes of which shall pass through the centre of the sun; and that, were the Nantucket Shoals not in existence, the course of the Gulf Stream, in the main, would be exactly as it is, and where it is. The Gulf Stream is bound over to the North Sea and Bay of Biscay partly for the reason, perhaps, that the waters there are lighter than those of the Mexican Gulf, (§ 135;)* and if the Shoals of Nantucket were not in existence, it could not pursue a more direct route. The Grand Banks, however, are encroaching, and cold currents from the north come down upon it; they may, and probably do, assist to turn it aside.

Now, if this explanation as to the *course* of the Gulf Stream and its eastward tendency hold good, a current setting from the north toward the south should have a westward tendency. It should also move in a great circle, or rather in the circle of trajection, calling thus the circle traced upon the earth which would be described by a trajectile moving through the air without resistance and for a great distance. Accordingly, and in obedience to the propelling powers, derived from the rate at which different parallels are whirled around in diurnal motion, we find the current from the north, which meets the Gulf Stream on the Grand Banks, (Plate XIV,) taking a south*westwardly* direction, as already described, (§ 139.) It runs down to the tropics by the side of the Gulf Stream, and stretches as far to the west as our own shores will allow.

143. But there are other forces operating upon the Gulf Stream. They are derived from the effect of changes in the waters of the whole ocean, as produced by changes in their temperature from time to time. As the Gulf Stream leaves the coasts of the United States, it begins to vary its position according to the seasons; the limit of its northern edge, as it passes the meridian of Cape Race, (Plate XIII,) being in winter about latitude 40°–41°, and in September, when the sea is hottest, about latitude 45°–46°. The trough of the Gulf Stream, therefore, may be supposed to waver about in the ocean not unlike a pennon in the breeze. Its head is confined between the shoals of the Bahamas and the Carolinas, but that part of it which stretches over toward the Grand Banks of Newfoundland is, as the temperature of the waters of the ocean changes, first pressed down toward the south, and then again up toward the north, according to the season of the year.

To appreciate the extent of the force by which it is so pressed, let us imagine the waters of the Gulf Stream to extend all the way to the bottom of the sea, so as completely to separate, by an impenetrable liquid wall, if you please, the waters of the ocean on the right from the waters in the ocean on the left of the stream. It is the height of summer: the waters of the sea on either hand are for the most part in a liquid state, and the Gulf Stream, let it be supposed, has assumed a normal condition between the two divisions, adjusting itself to the pressure on either side so as to balance them exactly and be in equilibrium. Now, again, it is the dead of winter, and the temperature of the waters over an area of millions of square miles in the North Atlantic has been changed many degrees, and this change of temperature has been followed by a change in the specific gravity of those waters, amounting, no doubt, in the aggregate, to many hundred millions of tons, over the whole ocean; for sea water, unlike fresh (§ 132,) contracts to freezing. Now, is it probable that, in passing from their summer to their winter temperature, the sea waters to the right of the Gulf Stream should change their specific gravity exactly as much in the aggregate as do the waters in the whole ocean to the left of it? If not, the difference must be compensated by some means. Sparks are not more prone to fly upward, nor water to seek its level, than Nature is sure, with her efforts, to restore equilibrium in both sea and air whenever, wherever, and by whatever it be disturbed. Therefore, though the waters of the Gulf Stream do not extend to the bottom, and though they be not impenetrable to the waters on either hand, yet, seeing that they have a waste of waters on the right

* The waters of the Atlantic generally contain 5¼ per cent. more of saline matter than those of the English Channel.—*M. Bouillon la Grange.*

and a waste of waters on the left, to which (§ 126) they offer a sort of resisting permeability, we are enabled to comprehend how the waters on either hand, as their specific gravity is increased or diminished, will impart to the trough of this stream a vibratory motion, pressing it now to the right, now to the left, according to the seasons and the consequent changes of temperature in the sea.

Every one who studies the Gulf Stream is struck with the fact that the line of separation between its waters and the water through which it flows is for a certain distance sharp and well defined, and that its waters seem to *cling* together, in the midst of the sea, for a long way. This is with many a matter for great wonderment. Now, it need not be so when we recollect this physical fact, viz: that all fluids, how yielding soever they may be, are not, especially when in motion, *perfectly* permeable; that is, it requires *force* to make water at rest, or water moving with a given velocity, to penetrate and mingle with water in another status—as that of another current, for instance, differing either in temperature or velocity from that through which or by which it is flowing. Hence, where rivers meet, a line of demarcation is always observable between their waters for a considerable distance, especially if they be differently colored. So, too, with currents in the air; we find the desolating breath of the tornado in a breadth sometimes of a few miles, and sometimes of a few yards only, sweeping over sea and land for great distances, and carrying away everything in its path, and yet even the air at a little distance on one side of it will remain calm or comparatively undisturbed. Why the tendency of water when put in motion should be to continue in motion, and when placed at rest to continue at rest, is perfectly philosophical. That force should be required to change the status of either, is plain; and, therefore, it is not difficult to conceive why the running water of the Gulf Stream and the cold water of its banks and bed should each in a measure preserve its status; from this premise we can perceive readily enough how force is required to change the status of either, and how, therefore, the two waters act as though there was a *viscosity*, so to speak, among the particles of each to prevent a ready commingling of them. Imagine a drop of water to be set in motion in a standing pool: it tends to draw along with it the drops that are immediately adjacent to it; but the drops at rest tend to hold these back; the initial drop consequently glides by them on its way, leaving them to compound with the two forces. Expanding this illustration on a grand scale, it will satisfy perfectly the phenomenon presented by this "River in the Ocean."

144. Plate XIII shows the limits of the Gulf Stream for March and September. The reason for this change of position is obvious. The banks of the Gulf Stream are cold water. In winter, the volume of cold water on the American, or left side of the stream, is greatly increased. It must have room, and gains it by pressing the warmer waters of the stream further to the south, or right. In September, the temperature of these cold waters is modified; there is not such an extent of them, and then the warmer waters, in turn, press them back, and so the pendulum-like motion is preserved.

The observations made by the United States Coast Survey indicate that there are in the Gulf Stream threads of warmer, separated by streaks of cooler water. See Plate XIII, in which these are shown. Figure A may be taken to represent a thermometrical cross section of the stream opposite the Capes of Virginia, for instance; the top of the curve representing the thermometer in the threads of the warmer water, and the depressions the height of the same instrument in the streaks of cooler water between, thus exhibiting, as one sails from America across the Gulf Stream, a remarkable series of thermometrical elevations and depressions in the surface temperature of this mighty river in the sea.

145. As a rule, the hottest water of the Gulf Stream is at or near the surface; and as the deep-sea thermometer is sent down, it shows that these waters, though still far warmer than the water on either side at corresponding depths, gradually become less and less warm until the bottom of the current is reached. There is reason to believe that the warm waters of the Gulf Stream are nowhere permitted, in the oceanic economy, to touch the bottom of the sea. There is everywhere a cushion of cool water between them and the solid parts of the earth's crust. This arrangement is suggestive, and strikingly beautiful. One of the benign offices of the Gulf Stream is to convey heat from the Gulf of Mexico, where otherwise it would become excessive, and to disperse it in regions beyond the Atlantic for the amelioration of the climates of the British Islands and of all Western Europe. Now, cold water is one of the best non-conductors of heat; and if the warm water of the Gulf Stream was sent across the Atlantic in contact with the solid crust of the earth—comparatively a good conductor of heat—instead of being sent across, as it is, in contact with a cold, non-conducting cushion of cool water to fend it from the bottom, all its heat would be lost in the first part of the way, and the soft climates of both France and England would be as that of Labrador, severe in the extreme, and ice-bound.

146. But to return to the streaks and reservoirs of hot water below. The hottest water is the lightest; as it rises to the top, it is cooled both by evaporation and exposure, when the surface is replenished by fresh supplies of hot water from below. Thus, in a winter's day, the waters at the surface of the Gulf Stream off Cape Hatteras may be at 80°, and at the depth of five hundred fathoms—three thousand feet—as actual observations show, the thermometer will stand at 57°. Following the stream thence off the Capes of Virginia, one hundred and twenty miles, it will be found—the water-thermometer having been carefully noted all the way—that it now stands a degree or two less at the surface, while all below is cooler. In other words, the stratum of water at 57°, which was three thousand feet below the surface off Hatteras, has, in a course of one hundred and twenty or one hundred and thirty miles in a horizontal direction, ascended, vertically, six hundred feet; that is, this stratum has run up hill with an ascent of five or six feet to the mile.

In the case of boiling springs, we perceive how all the ascending water comes up in one column; that there is no descent of surface water through that which is boiling up, but at the side of the bubbling. Moreover, in a cold winter's day, the water, as it boils up, is relatively warm; it smokes, grows cool, and the surface thermometer will stand highest where it is boiling, lowest off a little way toward the verge of the fountain. Just so with these warmer and cooler streaks in the Gulf Stream. This warm water, in its ascent of five feet to the mile—suppose we are considering the streak which is the hottest, and is, also, the nearest to the American shore—represents the boiling in the fountain; the warm, ascending water rising up in one body, and the cooler and heavier water going off to the side in another body, to sink and take its place with the other waters of the stream according to gravity and temperature. See the streaks *x*, *y*, *z*, Plate XIII.

Now, when these waters come to the top and cool, they are travelling with the current toward the north, and the effect of diurnal rotation is to turn them, as it turns any other drift (§ 139,) to the eastward. They obey this influence to a certain extent, sinking down as they obey, in consequence of their greater specific gravity; beyond this sinking—*i. e.*, further from the shore—is another rising-up place, each thread of the hot water being less and less warm, and each stream of cooler water more and more cool. The forces of diurnal rotation, operating upon the waters as they are successively sloughed off from each thread and streak alternately above and below, are quite enough to determine them to the east. A rod being poised on a point at one end, so as to stand alone, has no more tendency to fall to the east than to the west; but the smallest force, the slightest breath will determine it either way. So with the forces of diurnal rotation, and these streaks of warm and cool water; the water that has been to the top and is cooled must give way to warmer water that is pressing up from below; it must flow either to the west or to the east, and diurnal rotation assists in determining it. When it sinks and reaches its proper level, it must again go to the east or to the west to get into the ascending column, and rise again to the surface in its proper turn. There is no more tendency for it to go to the west than to the east, and diurnal rotation like the weight of the feather is sufficient; it again plies its forces, and they are obeyed.

Taking all these facts and views into consideration, we are led to the conclusion with which we set out, (§ 142,) that it is the law of matter in motion, and not the Shoals of Nantucket, that controls the Gulf Stream in its course.

CHAPTER X.

INFLUENCE OF THE GULF STREAM UPON CLIMATES.*

The Sea a Part of a Grand Machine, § 148.—*Influence of the Gulf Stream upon the Meteorology of the Sea*, 149.—Dampness of Climate of England due to it, 150.—The Pole of Maximum Cold, 151.—Gales of the Gulf Stream, 152.—*Influence of the Gulf Stream upon Commerce and Navigation*, 153.—Thermal Navigation, 154.

147. MODERN ingenuity has suggested a beautiful mode of warming houses in winter. It is done by means of hot water. The furnace and the caldron are sometimes placed at a distance from the apartments to be warmed. It is so at the Observatory. In this case, pipes are used to conduct the heated water from the caldron under the Superintendent's dwelling over into one of the basement rooms of the Observatory, a distance of one hundred feet. These pipes are then flared out so as to present a large cooling surface; after which they are united into one again, through which the water, being now cooled, returns of its own accord to the caldron. Thus cool water is returning all the time and flowing in at the bottom of the caldron, while hot water is continually flowing out at the top.

The ventilation of the Observatory is so arranged that the circulation of the atmosphere through it is led from this basement room, where the pipes are, to all other parts of the building; and in the process of this circulation, the warmth conveyed by the water to the basement is taken thence by the air and distributed over all the rooms. Now, to compare small things with great, we have, in the warm waters which are confined in the Gulf of Mexico, just such a heating apparatus for Great Britain, the North Atlantic, and Western Europe.

The furnace is the torrid zone; the Mexican Gulf and Caribbean Sea are the caldrons; the Gulf Stream is the conducting pipe. From the Grand Banks of Newfoundland to the shores of Europe is the basement—the hot-air chamber—in which this pipe is flared out so as to present a large cooling surface. Here the circulation of the atmosphere is arranged by nature; and it is such that the warmth thus conveyed into this warm-air chamber of mid-ocean is taken

* *Vide* Maury's Physical Geography of the Sea.

up by the genial west winds, and dispensed, in the most benign manner, throughout Great Britain and the west of Europe.

The maximum temperature of the water-heated air-chamber of the Observatory is about 90°. The maximum temperature of the Gulf Stream is 86°, or about 9° above the ocean temperature due the latitude. Increasing its latitude 10°, it loses but 2° of temperature; and, after having run three thousand miles toward the north, it still preserves, even in winter, the heat of summer. With this temperature, it crosses the 40th degree of north latitude, and there, overflowing its liquid banks, it spreads itself out for thousands of square leagues over the cold waters around, and covers the ocean with a mantle of warmth that serves so much to mitigate in Europe the rigors of winter. Moving now more slowly, but dispensing its genial influences more freely, it finally meets the British Islands. By these it is divided, (Plate XIV,) one part going into the polar basin of Spitzbergen, the other entering the Bay of Biscay, but each with a warmth considerably above the ocean temperature. Such an immense volume of heated water cannot fail to carry with it beyond the seas a mild and moist atmosphere. And this it is which so much softens climate there.

We know not, except approximately in one or two places, what the depth or the under temperature of the Gulf Stream may be; but *assuming* the temperature and velocity at the depth of two hundred fathoms to be those of the surface, and taking the well-known difference between the capacity of air and of water for specific heat as the argument, a simple calculation will show that the quantity of heat discharged over the Atlantic from the waters of the Gulf Stream in a winter's day would be sufficient to raise the whole column of atmosphere that rests upon France and the British Islands from the freezing point to summer heat.

Every west wind that blows crosses the stream on its way to Europe, and carries with it a portion of this heat to temper there the northern winds of winter. It is the influence of this stream upon climate that makes Erin the "Emerald Isle of the Sea," and that clothes the shores of Albion in evergreen robes; while in the same latitude, on this side, the coasts of Labrador are fast bound in fetters of ice. In a valuable paper on currents,* Mr. Redfield states that in 1831 the harbor of St. John's, Newfoundland, was closed with ice as late as the month of June; yet who ever heard of the port of Liverpool, on the other side, though 2° further north, being closed with ice, even in the dead of winter?

The Thermal Chart (Plate XVI) shows this. The isothermal lines of 60°, 50°, &c., starting off from the parallel of 40° near the coasts of the United States, run off in a northeastwardly direction, showing the same oceanic temperature on the European side of the Atlantic in latitude 55° or 60°, that we have on the western side in latitude 40°. Scott, in one of his beautiful novels, tells us that the ponds in the Orkneys (latitude near 60°) are not frozen in winter. The people there owe their soft climate to this grand heating apparatus, for driftwood from the West Indies is occasionally cast ashore there by the Gulf Stream.

Nor do the beneficial influences of this stream upon climate end here. The West Indian Archipelago is encompassed on one side by its chain of islands, and on the other by the Cordilleras of the Andes contracting with the Isthmus of Darien, and stretching themselves out over the plains of Central America and Mexico. Beginning on the summit of this range, we leave the regions of perpetual snow, and descend first into the *tierra témplada*, and then into the *tierra caliente*, or burning land. Descending still lower, we reach both the level and the surface of the Mexican seas, where, were it not for this beautiful and benign system of aqueous circulation,

* American Journal of Science, vol. xiv. p. 293.

the peculiar features of the surrounding country assure us we should have the hottest, if not the most pestilential climate in the world. As the waters in these two caldrons become heated, they are borne off by the Gulf Stream, and are replaced by cooler currents through the Caribbean Sea; the surface water, as it enters here, being 3° or 4°, and that in depth 40°* cooler than when it escapes from the Gulf. Taking only this difference in surface temperature as an index of the heat accumulated there, a simple calculation will show that the quantity of specific heat daily carried off by the Gulf Stream from those regions, and discharged over the Atlantic, is sufficient to raise mountains of iron from zero to the melting point, and to keep in flow from them a molten stream of metal greater in volume than the waters daily discharged from the Mississippi River. Who, therefore, can calculate the benign influence of this wonderful current upon the climate of the south? In the pursuit of this subject, the mind is led from nature up to the Great Architect of nature; and what mind will the study of this subject not fill with profitable emotions? Unchanged and unchanging alone, of all created things, the ocean is the great emblem of its everlasting Creator. "He treadeth upon the waves of the sea," and is seen in the wonders of the deep. Yea, "He calleth for its waters, and poureth them out upon the face of the earth."

In obedience to this call, the aqueous portion of our planet preserves its beautiful system of circulation. By it heat and warmth are dispensed to the extra-tropical regions; clouds and rain are sent to refresh the dry land; and by it cooling streams are brought from polar seas to temper the heat of the torrid zone. At the depth of two hundred and forty fathoms, the temperature of the currents setting into the Caribbean Sea has been found as low as 48°, while that of the surface was 85°. Another cast with three hundred and eighty-six fathoms gave 43° below, against 83° at the surface. The hurricanes of those regions agitate the sea to great depths; that of 1780 tore rocks up from the bottom in seven fathoms, and cast them on shore. They therefore cannot fail to bring to the surface portions of the cooler water below.

At the very bottom of the Gulf Stream, when its surface temperature was 80°, the deep-sea thermometer of the Coast Survey has recorded temperatures as low as 38° Fahrenheit.

These cold waters doubtless come down from the north to replace the warm water sent through the Gulf Stream to moderate the cold of Spitzbergen; for, within the Arctic Circle, the temperature at corresponding depths off the shores of that island is only one degree colder than in the Caribbean Sea, while on the coasts of Labrador the temperature in depth is said to be 25°, or 7° below the melting point of fresh water. Captain Scoresby relates that on the coast of Greenland, in latitude 72°, the temperature of the air was 42°; of the water, 34°; and 39° at the depth of one hundred and eighteen fathoms. He there found a current setting to the south, and bearing with it this extremely cold water, with vast numbers of icebergs, whose centres, perhaps, were far below zero. It would be curious to ascertain the routes of these under currents on their way to the tropical regions, which they are intended to cool. One has been found at the equator two hundred miles broad, and 23° colder than the surface water. Unless the land or shoals intervene, it no doubt comes down in a spiral curve, approaching the great circle.

Perhaps the best indication as to these cold currents may be derived from the fish of the sea. The whales first pointed out the existence of the Gulf Stream by avoiding its warm

*Temperature of the Caribbean Sea (from the journals of Mr. Dunsterville):—

Surface temperature 83°, September; 84° July; 83°–86½° Mosquito Coast.

Temperature in depth, 48°, 240 fathoms; 43°, 386 fathoms; 42°, 450 fathoms; 43°, 500 fathoms.

waters. Along our own coasts, all those delicate animals and marine productions which delight in warmer waters are wanting; thus indicating, by their absence, the cold current from the north now known to exist there. In the genial warmth of the sea about the Bermudas on one hand, and Africa on the other, we find, in great abundance, those delicate shell-fish and coral formations which are altogether wanting in the same latitudes along the shores of South Carolina. The same obtains in the west coast of South America; for there the cold current almost reaches the line before the first sprig of coral is found to grow.

A few years ago, great numbers of bonita and albercore—tropical fish—following the Gulf Stream, entered the English Channel, and alarmed the fishermen of Cornwall and Devonshire by the havoc which they created among the pilchards there.

It may well be questioned if our Atlantic cities and towns do not owe their excellent fish-markets, as well as our watering-places their refreshing sea-bathing in summer, to this stream of cold water. The temperature of the Mediterranean is 4° or 5° above the ocean temperature of the same latitude, and the fish there are very indifferent. On the other hand, the temperature along our coast is several degrees below that of the ocean, and from Maine to Florida our tables are supplied with the most excellent of fish. The sheephead, so much esteemed in Virginia and the Carolinas, when taken on the warm coral banks of the Bahamas, loses its flavor, and is held in no esteem. The same is the case with other fish: when taken in the cold water of that coast, they have a delicious flavor and are highly esteemed; but when taken in the warm water on the other edge of the Gulf Stream, though but a few miles distant, their flesh is soft and unfit for the table. The temperature of the water at the Balize reaches 90°. The fish taken there are not to be compared with those of the same latitude in this cold stream. New Orleans, therefore, resorts to the cold waters on the Florida coasts for her choicest fish. the same is the case in the Pacific. A current of cold water from the south sweeps the shores of Chili, Peru, and Columbia, and reaches the Gallipagos Islands under the line. Throughout this whole distance, the world does not afford a more abundant or excellent supply of fish. Yet out in the Pacific, at the Society Islands, where coral abounds, and the water preserves a higher temperature, the fish, though they vie in gorgeousness of coloring with the birds, and plants, and insects of the tropics, are held in no esteem as an article of food. I have known sailors, even after long voyages, still to prefer their salt beef and pork to a mess of fish taken there. The few facts which we have bearing upon this subject seem to suggest it as a point of the inquiry to be made, whether the habitat of certain fish does not indicate the temperature of the water; and whether these cold and warm currents of the ocean do not constitute the great highways through which migratory fishes travel from one region to another.

Navigators have often met with vast numbers of young sea-nettles (*medusæ*) drifting along with the Gulf Stream. They are known to constitute the principal food for the whale; but whither bound by this route has caused much curious speculation, for it is well known that the habits of the right whale are averse to the warm waters of this stream. An intelligent sea captain informs me that, two or three years ago, in the Gulf Stream on the coast of Florida, he fell in with such a "school of young sea-nettles as had never before been heard of." The sea was covered with them for many leagues. He likened them, in appearance on the water, to acorns floating on a stream; but they were so thick as to completely cover the sea. He was bound to England, and was five or six days in sailing through them. In about sixty days afterward, on his return, he fell in with the same school off the Western Islands, and here he was three or four days in passing them again. He recognized them as the same, for he had never before seen any like them; and on both occasions he frequently hauled up buckets full and examined them.

Now the Western Islands is the great place of resort for whales; and at first there is something curious to us in the idea that the Gulf of Mexico is the harvest field, and the Gulf Stream the gleaner which collects the fruitage planted there, and conveys it thousands of miles off to the hungry whale at sea. But how perfectly in unison is it with the kind and providential care of that great and good Being which feeds the young ravens when they cry, and caters for the sparrow!

The sea has its climates as well as the land. They both change with the latitude; but one varies with the elevation above, the other with the depression below the sea level. Each is regulated by circulation; but the regulators are, on the one hand, winds; on the other, currents.

148. The inhabitants of the ocean are as much the creatures of climate as are those of the dry land; for the same Almighty hand which decked the lily and cares for the sparrow, fashioned also the pearl, and feeds the great whale. Whether of the land or the sea, they are all his creatures, subjects of his laws, and agents in his economy. The sea, therefore, we infer, has its offices and duties to perform; so, may we infer, have its currents, and so, too, its inhabitants; consequently, he who undertakes to study its phenomena, must cease to regard it as a waste of waters. He must look upon it as a part of the exquisite machinery by which the harmonies of nature are preserved, and then he will begin to perceive the developments of order, and the evidences of design, which make it a most beautiful and interesting subject for contemplation.

To one who has never studied the mechanism of a watch, its main-spring or the balance-wheel, is a mere piece of metal. He may have looked at the face of the watch, and, while he admires the motion of its hands, and the time it keeps, or the tune it plays, he may have wondered in idle amazement as to the character of the machinery which is concealed within. Take it to pieces and show him each part separately; he will recognize neither design nor adaption, nor relation between them; but put them together, set them to work, point out the offices of each spring, wheel, and cog, explain their movements, and then show him the result; now he perceives that it is all *one* design; that, notwithstanding the number of parts, their diverse forms and various offices, and the agents concerned, the whole piece is of *one* thought, the expression of *one* idea. He now perceives that when the main-spring was fashioned and tempered, its relation to all the other parts must have been considered; that the cogs on this wheel are cut and regulated—*adapted*—to the rachets on that, &c.; and his conclusion will be that such a piece of mechanism could not have been produced by chance; the adaption of the parts is such as to be according to design, and obedient to the will of *one* intelligence. So, too, when one looks out upon the face of this beautiful world, he may admire the lovely scene, but his admiration can never grow into adoration unless he will take the trouble to look behind and study, in some of its details at least, the exquisite system of machinery by which such beautiful results are accomplished. To him who does this, the sea, with its physical geography, becomes as the main-spring of a watch; its waters, and its currents, and its salts, and its inhabitants, with their adaptions, as balance-wheels, cogs and pinions, and jewels. Thus he perceives, that they, too, are according to design; that they are the expression of One Thought, a unity with harmonies which One Intelligence, and One Intelligence alone, could utter. And when he has arrived at this point, he feels that the study of the sea, in its physical aspect, is truly sublime. It elevates the mind and ennobles the man. The Gulf Stream is now no longer, therefore, to be regarded by such an one merely as an immense current of warm water running across the ocean, but as a balance-wheel; a part of that grand machinery by which air and water are adapted to each other, and by which this earth itself is adapted to the well-being of its inhabitants—of the flora which deck, and the fauna which enlivens its surface.

149. Let us therefore consider the influence of the Gulf Stream upon the meteorology of the ocean.

To use a sailor expression, the Gulf Stream is the great "weather breeder" of the North Atlantic Ocean. The most furious gales of wind sweep along with it; and the fogs of Newfoundland, which so much endanger navigation in winter, doubtless owe their existence to the presence, in that cold sea, of immense volumes of warm water brought by the Gulf Stream. Sir Philip Brooke, found the air on each side of it at the freezing point, while that of its waters was 80°. "The heavy, warm, damp air over the current, produced great irregularities in his chronometers." The excess of heat, daily brought into such a region by the waters of the Gulf Stream, would, if suddenly stricken from them, be sufficient to make the column of superincumbent atmosphere hotter than melted iron.

With such an element of atmospherical disturbance in its bosom, we might expect storms of the most violent kind to accompany it in its course. Accordingly, the most terrific that rage on the ocean have been known to spend their fury in and near its borders.

Our nautical works tell us of a storm which forced this stream back to its sources, and piled up the water in the Gulf to the height of thirty feet. The Ledbury Snow attempted to ride it out. When it abated, she found herself high upon the dry land, and discovered that she had let go her anchor among the tree tops on Elliott's Key. The Florida Keys were inundated many feet, and, it is said, the scene presented in the Gulf Stream was never surpassed in awful sublimity on the ocean. The water thus dammed up is said to have rushed out with wonderful velocity against the fury of the gale, producing a sea that beggared description.

The "great hurricane" of 1770 commenced at Barbadoes. In it the bark was blown from trees, and the fruits of the earth destroyed; the very bottom and depths of the sea were uprooted, and the waves rose to such a height that forts and castles were washed away, and their great guns carried about in the air; houses were blown down, ships were wrecked, and the bodies of men and beasts lifted up above the earth and dashed to pieces in the storm. At the different islands, not less than twenty thousand persons lost their lives on shore, while further to the north, the Sterling Castle and the Dover Castle, men-of-war, were wrecked at sea, and fifty sail driven on shore at the Bermudas.

Several years ago the British Admiralty set on foot inquiries as to the cause of the storms in certain parts of the Atlantic, which so often rage with disastrous effects to navigation. The result may be summed up in the conclusion to which the investigation led: that they are occasioned by the irregularity between the temperature of the Gulf Stream and of the neighboring regions, both in the air and water.

150. The habitual dampness of the climate of the British Islands, as well as the occasional dampness of that along the Atlantic coast of the United States when easterly winds prevail, is attributable also to the Gulf Stream. They come to us loaded with vapors gathered from its warm and smoking waters.

It carries the temperature of summer, even in the dead of winter, as far north as the Grand Banks of Newfoundland.

151. One of the poles of maximum cold is, according to theory, situated in latitude 80°

north, longitude 100° west. It is distant but little more than two thousand miles, in a northwestwardly direction from the summer-heated waters of this stream. This proximity of extremes of greatest cold and summer heat, will, as observations are multiplied and discussed, be probably found to have much to do with the storms that rage with such fury on the left side of the Gulf Stream.

152. I am not prepared to maintain that the Gulf Stream is really the "Storm King" of the Atlantic, which has power to control the march of every gale that is raised there; but the course of many gales has been traced from the place of their origin directly to the Gulf Stream. Gales that take their rise on the coast of Africa, and even as far down on that side as the parallel of 10° or 15° north latitude, have, it has been shown by an examination of log-books, made straight for the Gulf Stream; joining it, they have then been known to turn about, and, travelling with this stream, to recross the Atlantic, and so reach the shores of Europe. In this way, the tracks of storms have been traced out and followed for a week or ten days. Their path is marked by wreck and disaster. At the meeting of the American Association for the advancement of Science in 1854, Mr. Redfield mentioned one which he had traced out, and in which no less than seventy odd vessels had been wrecked, dismasted, or damaged.

In the month of December, 1853, the fine new steamship San Francisco sailed from New York with a regiment of United States troops on board, bound around Cape Horn for California. She was overtaken, while crossing the Gulf Stream, by a gale of wind, in which she was terribly crippled. Her decks were swept, and by one single blow of those terrible seas that the storms there raise, one hundred and seventy-nine souls, officers and soldiers, were washed overboard and drowned.

The day after this disaster she was seen by one vessel, and again the next day, December 26th, by another; but neither of them could render her any assistance.

When they arrived in the United States and reported what they had seen, the most painful apprehensions were entertained, by friends, for the safety of those on board. Vessels were sent out to search for and relieve her. But which way should these vessels go? Where should they look?

An appeal was made to know what light the system of researches carried on at the National Observatory concerning winds and currents could throw upon the subject.

The materials that had been discussed were examined, and a chart was prepared to show the course of the Gulf Stream at that season of the year. (See the limits of the Gulf Stream for March, Plate XIII.) Upon the supposition that the steamer had been completely disabled, the lines *a b* were drawn to define the limits of her drift. Between these two lines, it was said, the steamer, if she could neither steam nor sail after the gale, had drifted.

By request, I prepared instructions for two revenue cutters that were sent to search for her. One of them, being at New London, was told to go along the dotted track leading to *c*, expecting thereby to keep inside of the line along which the steamer had drifted, with the view of intercepting and speaking homeward bound vessels that might have seen the wreck.

The cutter was to proceed to *c*, where she might expect to fall in with the line of drift taken by the steamer. The last that was seen of that ill-fated vessel was when she was at *o*. So, if the cutter had been in time, she had instructions that would have taken her in sight of the object of her search.

It is true that, before the cutter sailed, the Kilby, the Three Bells, and the Antarctic, unknown to anxious friends at home, had fallen in with and relieved the wreck; but that does not detract from the system of observations, of the results of which, and their practical application, it is the object of this work to treat.

A beautiful illustration of their usefulness is the fact that, though the barque Kilby lost sight of the wreck at night, and the next morning did not know which way to look for it, and could not find it, yet, by a system of philosophical deduction, we on shore could point out the whereabouts of the disabled steamer so closely that vessels could be directed to look for her exactly where she was to be seen.

These storms, for which the Gulf Stream has such attraction, and over which it seems to exercise so much control, are said to be, for the most part, whirlwinds. All boys are familiar with miniature whirlwinds on shore. They are seen, especially in the autumn, sweeping along the roads and streets, raising columns of dust, leaves, &c., which rise up like inverted cones in the air, and gyrate about the centre or axis of the storm. Thus, while the axis, and the dust, and the leaves, and all those things which mark the course of the whirlwind, are travelling in one direction, it may be seen that the wind is blowing around this axis in all directions.

Just so with some of these Gulf Stream storms. Mr. Piddington, an eminent meteorologist of Calcutta, calls them *Cyclones.*

Now, what should make these storms travel toward the Gulf Stream, and then, joining it, travel along with its current? It is the high temperature of its waters, say mariners. But why, or wherefore, should the spirits of the storm obey in this manner the influence of these high temperatures, philosophers have not been able to explain.

153. *The influence of the Gulf Stream upon commerce and navigation.*

Formerly, the Gulf Stream controlled commerce across the Atlantic by governing vessels in their routes through this ocean to a greater extent than it does now, and simply for the reason that ships are faster, instruments better, and navigators are more skillful now than formerly they were.

Up to the close of the last century, the navigator *guessed* as much as he *calculated* the place of his ship; vessels from Europe to Boston frequently made New York, and thought the land-fall by no means bad. Chronometers, now so accurate, were then an experiment. The Nautical Ephemeris itself was faulty, and gave tables which involved errors of thirty miles in the longitude. The instruments of navigation erred by *degrees* quite as much as they now do by *minutes;* for the rude "cross staff" and "back staff," the "sea ring" and "mariner's bow," had not yet given place to the nicer sextant and circle of reflection of the present day. Instances are numerous of vessels navigating the Atlantic in those times being 6°, 8°, and even 10° of longitude out of their reckoning in as many days from port.

Though navigators had been in the habit of crossing and recrossing the Gulf Stream almost daily for three centuries, it never occurred to them to make use of it as a means of giving them their longitude, and of warning them of their approach to the shores of this continent.

Dr. Franklin was the first to suggest this use of it. The contrast afforded by the temperature of its waters and that of the sea between the Stream and the shores of America was striking. The dividing line between the warm and the cool waters was sharp (§ 126;) and this dividing line, especially that on the western side of the stream, never changed its position as much in longitude as mariners erred in their reckoning.

When he was in London, in 1770, he happened to be consulted as to a memorial which the Board of Customs at Boston sent to the Lords of the Treasury, stating that the Falmouth packets were generally a fortnight longer to Boston than common traders were from London to Provi dence, Rhode Island. They therefore asked that the Falmouth packets might be sent to Providence instead of to Boston. This appeared strange to the Doctor, for London was much further than Falmouth, and from Falmouth the routes were the same, and the difference should have been the other way. He, however, consulted Captain Folger, a Nantucket whaler, who chanced to be in London also; the fisherman explained to him that the difference arose from the circumstance that the Rhode Island captains were acquainted with the Gulf Stream, while those of the English packets were not. The latter kept in it, and were set back sixty or seventy miles a day, while the former avoided it altogether. He had been made acquainted with it by the whales which were found on either side of it, but never in it. At the request of the doctor, he then traced on a chart the course of this stream from the Straits of Florida. The doctor had it engraved at Tower Hill, and sent copies of it to the Falmouth captains who paid no attention to it. The course of the Gulf Stream, as laid down by that fisherman from his general recollection of it, has been retained and quoted on the charts for navigation, we may say, until the present day.

But the investigations of which we are treating are beginning to throw more light upon this subject; they are giving us more correct knowledge in every respect with regard to it, and to many other new and striking features in the physical geography of the sea.

No part of the world affords a more difficult or dangerous navigation than the approaches of our northern coast in winter. Before the warmth of the Gulf Stream was known, a voyage at this season from Europe to New England, New York, and even to the Capes of the Delaware or Chesapeake, was many times more trying, difficult, and dangerous than it now is. In making this part of the coast, vessels are frequently met by snow-storms and gales which mock the seaman's strength and set at naught his skill. In a little while his barque becomes a mass of ice; with her crew frosted and helpless, she remains obedient only to her helm, and is kept away for the Gulf Stream. After a few hours' run, she reaches its edge, and almost at the next bound passes from the midst of winter into a sea at summer heat. Now the ice disappears from her apparel; the sailor bathes his stiffened limbs in tepid waters; feeling himself invigorated and refreshed with the genial warmth about him, he realizes, out there at sea, the fable of Antæus and his mother Earth. He rises up and attempts to make his port again, and is again as rudely met and beat back from the northwest; but each time that he is driven off from the contest, he comes forth from this stream, like the ancient son of Neptune, stronger and stronger, until, after many days, his freshened strength prevails, and he at last triumphs and enters his haven in safety—though in this contest he sometimes falls to rise no more, for it is often terrible. Many ships annually founder in these gales; and I might name instances, for they are not uncommon, in which vessels bound to Norfolk or Baltimore, with their crews enervated in tropical climates, have encountered, as far down as the Capes of Virginia, snow-storms that have driven them back into the Gulf Stream time and again, and have kept them out for forty, fifty, and even for sixty days, trying to make an anchorage.

Nevertheless, the presence of the warm waters of the Gulf Stream, with their summer heat in mid-winter, off the shores of New England, is a great boon to navigation. At this season of the year especially, the number of wrecks and the loss of life along the Atlantic sea-front are frightful. The month's average of wrecks has been as high as three a day. How many escape by seeking refuge from the cold in the warm waters of the Gulf Stream is a matter of conjecture. Suffice it to say, that before their temperature was known, vessels thus distressed knew of no place of refuge short of the West Indies; and the newspapers of that day—Franklin's

Pennsylvania Gazette among them—inform us that it was no uncommon occurrence for vessels, bound for the Capes of the Delaware in winter, to be blown off and to go to the West Indies, and there wait for the return of spring before they would attempt another approach to this part of the coast.

154. Accordingly, Dr. Franklin's discovery with regard to the Gulf Stream temperature was looked upon as one of great importance, not only on account of its affording to the frosted mariner in winter a convenient refuge from the snow-storm, but because of its serving the navigator with an excellent landmark or beacon for our coast, in all weathers. And so viewing it, the doctor concealed his discovery, for we were then at war with England. It was then not uncommon for vessels to be as much as 10° out in their reckoning. He himself was 5°. Therefore, in approaching the coast, the current of warm water in the Gulf Stream, and of cold water on the side of it, if tried with the thermometer, would enable the mariner to judge with great certainty, and in the worst of weather, as to his position. Jonathan Williams afterward, in speaking of the importance which the discovery of these warm and cold currents would prove to navigation, pertinently asked the question, "If these stripes of water had been distinguished by the colors of red, white, and blue, could they be more distinctly discovered than they are by the constant use of the thermometer?" And he might have added, could they have marked the position of a ship more clearly?

When his work on *Thermometrical Navigation* appeared, Commodore Truxton wrote to him: "Your publication will be of use to navigation, by rendering sea voyages secure far beyond what even you yourself will immediately calculate, for I have proved the utility of the thermometer very often since we sailed together.

"It will be found a most valuable instrument in the hands of mariners, and particularly as to those who are acquainted with astronomical observations; . . . . . these particularly stand in need of a simple method of ascertaining their approach to or distance from the coast, especially in the winter season; for it is then that passages are often prolonged, and ships blown off the coast by hard westerly winds, and vessels get into the Gulf Stream without its being known; on which account they are often hove to by the captains' supposing themselves near the coast when they are very far off (having been drifted by the currents.) On the other hand, ships are often cast on the coast by sailing in the eddy of the Stream, which causes them to outrun their common reckoning. Every year produces new proofs of these facts, and of the calamities incident thereto."

Though Dr. Franklin's discovery was made in 1775, yet, for political reasons, it was not generally made known till 1790. Its immediate effect in navigation was to make the ports of the North as accessible in winter as in summer. What agency this circumstance had in the decline of the direct trade of the South, which followed this discovery, would be, at least to the political economist, a subject for much curious and interesting speculation. I have referred to the commercial tables of the time, and have compared the trade of Charleston with that of the northern cities for several years, both before and after the discovery of Dr. Franklin became generally known to navigators. The comparison shows an immediate decline in the Southern trade, and a wonderful increase in that of the North. But whether this discovery in navigation and this revolution in trade stand in the relation of cause and effect, or be merely a coincidence, let others judge.

In 1769 the commerce of the two Carolinas equalled that of all the New England States together; it was more than double that of New York, and exceeded that of Pennsylvania by one third.* In 1792 the exports from New York amounted in value to two millions and a half; from Pennsylvania, to $3,820,000; and from Charleston alone, to $3,834,000.

But in 1795—by which time the Gulf Stream began to be as well understood by navigators as it now is, and the average passages from Europe to the North were shortened nearly one-half, while those to the South remained about the same—the customs at Philadelphia alone amounted to $2,941,000;† or more than one-half of those collected in all the States together.

Nor did the effect of the doctor's discovery end here. Before it was made, the Gulf Stream was altogether insidious in its effects. By it vessels were often drifted many miles out of their course, without knowing it; and in bad and cloudy weather, when many days would intervene from one observation to another, the set of the current, though really felt for but a few hours, during the interval, could only be proportioned out equally among the whole number of days. Therefore, navigators could have only very vague ideas, either as to the strength or actual limits of the Gulf Stream, until they were marked out to the Nantucket fishermen by the whales, or made known by Captain Folger to Dr. Franklin. The discovery, therefore, of its high temperature, assured the navigator of the presence of a current of surprising velocity,

* *From McPherson's Annals of Commerce—Exports and Imports in 1769, valued in Sterling Money.*

EXPORTS.

	To Great Britain.			South of Europe.			West Indies.			Africa.			Total.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
New England	142,775	12	9	81,173	16	2	308,427	9	6	17,713	0	9	550,089	19	2
New York	113,382	8	8	50,885	13	0	66,324	17	5	1,313	2	6	231,906	1	7
Pennsylvania	28,112	6	9	203,762	11	11	178,331	7	8	560	9	9	410,756	16	1
North and South Carolina	405,014	13	1	76,119	12	10	87,758	19	3	691	12	1	569,584	17	3

IMPORTS.

	From Great Britain.			South of Europe.			West Indies.			Africa.			Total.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
New England	223,695	11	6	25,408	17	9	314,749	14	5	180	0	0	564,034	3	8
New York	75,930	19	7	14,927	7	8	97,420	4	0	697	10	0	188,976	1	3
Pennsylvania	204,979	17	4	14,249	8	4	180,591	12	4	....			399,830	18	0
North and South Carolina	327,084	8	6	7,099	5	10	76,269	17	11	137,620	10	0	535,714	2	3

† *Value of Exports in dollars.* (*a*)

	1791.	1792.	1793.	1794.	1795.	1796.
Massachusetts	2,519,651	2,888,104	3,755,347	5,292,441	7,117,909	9,949,345
New York	2,505,465	2,535,790	2,932,370	5,442,000	10,304,000	12,208,027
Pennsylvania	3,436,000	3,820,000	6,958,000	6,643,000	11,518,000	17,513,866
South Carolina	2,693,000	2,428,000	3,191,000	3,868,000	5,988,000	7,620,000

Duties on imports in dollars.

	1791.	1792.	1793.	1794.	1795.	1796.	1833.
Massachusetts	1,006,000	723,000	1,044,000	1,121,000	1,520,000	1,460,000	3,055,000
New York	1,334,0'0	1,173,000	1,204,000	1,878,000	2,028,000	2,187,000	10,713,000
Pennsylvania	1,466,000	1,100,000	1,823,000	1,498,000	2,300,000	2,050,000	2,207,000
South Carolina	523,000	359,000	360,000	661,000	722,000	66,000	389,000

(*a*) Doc. No. 330, H. R., 2d session 25th Congress. Some of its statements do not agree with those taken from McPherson, and previously quoted.

and which, now turned to certain account, would hasten, as it had retarded, his voyage in a wonderful degree.

Such, at the present day, is the degree of perfection to which nautical tables and instruments have been brought, that the navigator may now detect, and with great certainty, every current that thwarts his way. He makes great use of them. Colonel Sabine, in his passage, a few years ago, from Sierra Leone to New York, was drifted one thousand six hundred miles of his way by the force of currents alone; and, since the application of the thermometer to the Gulf Stream, the average passage from England has been reduced from upward of eight weeks to a little more than four.

Some political economists of America have ascribed the great decline of southern commerce, which followed the adoption of the Constitution of the United States, to the protection given by legislation to northern interests. But I think these statements and figures show that this decline was in no small degree owing to the Gulf Stream and the water thermometer; for they changed the relations of Charleston—the great southern emporium of the times—removing it from its position as a half-way house, and placing it in the category of an outside station.

CHAPTER XI.

THE DEPTHS OF THE OCEAN.*

State of our Knowledge concerning the Depths of the Sea when these researches commenced, § 155.—Results of former Methods of Deep-sea Soundings not entitled to Confidence, § 156.—The deepest Soundings reported, § 157.—Plan adopted in the Navy, § 158.—Why the Sounding-twine will not stop running out when the Plummet reaches Bottom, § 159 —Indications of Under Currents, § 160.—Soundings to be made from a Boat, § 161.—Brooke's Deep-sea Sounding Apparatus, § 162.—Deep-sea temperature, § 163.—Rate of Descent, § 164.—Deep-sea Soundings in the United States Steamer Arctic, § 165.—Specimens from the Bottom, § 166.—The greatest Depths at which Bottom has been found, § 167.

155. PHILOSOPHERS have greatly desired to ascertain the mean depression of the bed of the ocean *below*, as well as the mean elevation of the continental masses *above*, the sea level. Humboldt, after much labor, gives the mean elevations of the continents: North America, 748 feet; South America, 1,151; Europe, 671; and Asia, 1,132.† For Africa and Australia data are wanting. Laplace computed, according to theory and astronomical arguments, the mean height of the continents to be about three times greater than the above by Humboldt. "That illustrious geometer," says Sir John Herschel, "was conducted to this erroneous result by hypothesis as to the mean depth of the sea."

The best theoretical deductions, however, indicate, according to Humboldt, "a small fraction of the elipticity of the earth" as the mean sea depth, which can scarcely exceed four or five miles. Up to the time when these researches, concerning the physics of the sea commenced the deepest sounding that had been attempted, was by Ross in 15° 3′ south, 23° 14′ west, with 4,600 fathoms, without, however, finding bottom.

Such was the state of our knowledge concerning the orography of the great sea floor of

* *Vide* Maury's Physical Geography of the Sea. Harper and Brothers, New York.

† Cosmos, vol. I.

the world, when, the present system of dee-psea soundings was inaugurated as a branch of physical research, connected with the "Wind and Current Charts."

Up to that time, the bottom of what sailors call "blue water" was as unknown to us as is the interior of any of the planets of our system. Besides Ross, Dupetit Thouars with other officers of the English, French, and Dutch navies, had attempted to fathom the blue water, some with silk thread, some with spun-yurn, and some with the common lead and line. All these attempts were made upon the supposition that when the lead reached the bottom, either a shock would be felt, or the line, becoming slack, would cease to run out.

156. The series of systematic experiments recently made upon this subject, shows that there is no reliance to be placed on such a supposition, for the shock caused by striking bottom cannot be communicated through very great depths, and therefore it does not follow that the line will become slack and cease to run out when the plummet reaches bottom. Furthermore, the lights of experience show, that ,as a general rule, the under currents of the deep sea have force enough to take the line out long after the plummet has ceased to do so. Consequently, there is but little reliance to be placed upon deep-sea soundings of former methods, when the depths reported exceeded eight or ten thousand feet.

Attempts to fathom the ocean, both by sound and pressure, had been made, but in "blue water" every trial was only a failure repeated. The most ingenious and beautiful contrivances for deep-sea soundings were resorted to. By exploding heavy charges of powder in the deep sea, when the winds were hushed and all was still, the echo or reverberation from the bottom might, it was held, be heard, and the depth determined from the rate at which sound travels through water. But, though the explosion took place many feet below the surface, echo was silent, and no answer was received from the bottom. Ericsson and others constructed deep-sea leads, having a column of air in them, which, by compression, would show the aqueous pressure to which they might be subjected. This was found to answer well for ordinary purposes, but in the depths of "blue water," where the pressure would be equal to several hundred atmosperes, the trial was more than this instrument could stand.

Mr. Baur, an ingenious mechanician of New York, constructed, according to a plan which I furnished him, a deep-sea sounding apparatus. To the lead was attached, upon the principle of the screw propeller, a small piece of clock-work, for registering the number of revolutions made by the little screw during the descent; and, it having been ascertained by experiment in shoal water, that the apparatus, in descending, would cause the propeller to make one revolution for every fathom of perpendicular descent, hands, provided with the power of self-registration, were attached to a dial, and the instrument was complete. It worked beautifully in moderate depths, but failed in blue water, from the difficulty of hauling it up if the line used were small, and from the difficulty of getting it down if the line used were large enough to give the requisite strength for hauling up.

But, notwithstanding these failures, there was encouragement, for greater difficulties had been overcome in other departments of physical research. Astronomers had measured the volumes and weighed the masses of the most distant planets, and increased thereby the stock of human knowledge. Was it creditable to the age that the depths of the sea should remain in the category of an unsolved problem? Beneath its surface was a sealed volume, abounding in knowledge and instruction that might be both useful and profitable to man. The seal which covered it was of rolling waves many thousand feet in thickness. Could it not be broken? Curiosity had always been great, still, neither the enterprise nor ingenuity of man had as yet proved itself equal to the task. No one had succeeded in penetrating, and bringing up from beyond the depth of two or three hundred fathoms below the aqueous covering of the earth, any specimens of solid matter for the study of philosophers.

The sea, with its myths, has suggested attractive themes to all people in all ages. Like the heavens, it affords an almost endless variety of subjects for pleasing and profitable contemplation, and there has remained in the human mind a longing to learn more of its wonders and to understand its mysteries. The Bible often alludes to them. Are they past finding out? How deep is the great and wide sea? And what is at the bottom of it? Could not the ingenuity and appliances of the age throw some light upon these questions?

The government was liberal and its ministers enlightened; times seemed propitious; but when or how to begin, after all these failures, with this interesting problem, was one of the difficulties first to be overcome.

It was a common opinion, derived chiefly from a supposed physical relation, that the depths of the sea are about equal to the heights of the mountains. But this conjecture was, at best, only a speculation. Though plausible, it did not satisfy. There were, in the depths of the sea, untold wonders and inexplicable mysteries. Therefore, the contemplative mariner, as in mid-ocean he looked down upon the heaving bosom of the ocean, continued to experience sentiments akin to those which fill the mind of the devout astronomer when, in the stillness of the night, he looks out upon the stars, and wonders.

Nevertheless, the depths of the sea still remain as fathomless and as mysterious as the firmament above. Indeed, telescopes of huge proportions and of vast space-penetrating powers had been erected here and there by the munificence of individuals, and attempts made with them to gauge the heavens and sound out the regions of space. Could it be more difficult to sound out the sea than to gauge the blue ether and fathom the vaults of the sky? The result of the astronomical undertakings* lies in the discovery that what, through other instruments of less power, appeared as clusters of stars, where, by these of larger powers, separated into groups, and what had been reported as nebulæ, could now be resolved into clusters; that, in certain directions, the abyss beyond these faint objects is decked with other nebulæ, which these great instruments may bring to light, but cannot resolve; and that there are still regions and realms beyond, which the rays of the brightest sun in the sky have neither the intensity nor the force to reach, much less to penetrate.

So, too, with the bottom of the sea, and the knowledge-seeking mariner. Though nothing thence had been brought to the light, exploration had invested the subject with additional interest, and increased the desire to know more. In this state of the case, the idea of a common twine thread for a sounding-line, and a cannon ball for a sinker, was suggested. It was a beautiful conception; for, besides its simplicity, it had in its favor the greatest of recommendations: it could be readily put into practice.

Well-directed attempts to fathom the ocean began now to be made, and the public mind was astonished at the vast depths that were at first reported.

157. Lieutenant Walsh, of the United States schooner Taney, reported a cast with the deep-sea lead at thirty-four thousand feet without bottom. His sounding-line was an iron wire more than eleven miles in length. Lieutenant Berryman, of the United States brig Dolphin, reported another unsuccessful attempt to fathom mid-ocean with a line thirty-nine thousand feet in length. Captain Denham, of her Britannic majesty's ship Herald, reported bottom in

* See the works of Herschel and Ross, and their telescopes.

the South Atlantic at the depth of forty-six thousand feet; and Lieutenant J. P. Parker, of the United States frigate Congress, afterward, in attempting to sound near the same region, let go his plummet, and saw a line fifty thousand feet long run out after it as though the bottom had not been reached.

The three last-named attempts were made with the sounding-twine of the American Navy, which has been introduced in conformity with a very simple plan for sounding out the depths of the ocean. It involved for each cast only the expenditure of a cannon ball, and twine enough to reach the bottom. This plan was introduced as a part of the researches conducted at the National Observatory, and which have proved so fruitful and beneficial, concerning the winds and currents, and other phenomena of the ocean. These researches had already received the approbation of the Congress of the United States; for that body, in a spirit worthy of the representatives of a free and enlightened people, had authorized the Secretary of the Navy to employ three public vessels to assist in perfecting the discoveries, and in conducting the investigations connected therewith.

The following circular order to the commanders of all vessels of the navy has been issued, and is now in force.

CIRCULAR.

BUREAU OF ORDNANCE AND HYDROGRAPHY, *November* 22, 1851.

158. SIR: Your attention is particularly invited to the accompanying Directions relative to deep-sea soundings.

You will take care that they be diligently and faithfully carried out on board the vessel under your command.

You will report, from time to time, to this Bureau, the latitude, longitude, depth, drift, time, and all the circumstances connected with each cast, whether successful in reaching bottom or not—stating the kind of sinker used, its weight, and whether the large or small twine was used.

This order is to supersede that of June 1, 1850, on the same subject, and the Directions given at pages 70 and 71 of Maury's 3d edition of *Sailing Directions*, so far as they may conflict with these.

Respectfully, your obedient servant,

C. MORRIS,
Chief of Bureau.

APPROVED: WILL. A. GRAHAM,
Secretary of the Navy.

To ———

Instructions for using the Sounding-Twine.

The twine for deep-sea soundings is of two sizes; the smaller size is intended to be used when no attempt is made to bring up specimens from the bottom. It is calculated to bear 60 pounds' weight in the air; it is about seven-hundredths of an inch in diameter, and measures 180 fathoms to the pound. It is marked at every 100 fathoms, and furnished on reels containing 10,000 fathoms each.

The larger size is to be used for bringing up specimens. It is calculated to bear a weight in the air of 150 pounds; it is about one-tenth of an inch in diameter, and measures about 80 fathoms to the pound. It is furnished on reels of 5,000 fathoms each.

It is desired, as a general rule, to have one deep-sea sounding only for every space of five degrees square, on a chart which is constructed with its meridians and parallels drawn only for every five degrees of latitude and longitude respectively.

The spaces in which deep-sea soundings have been made in the North Atlantic Ocean are shown on Plate XI. It is desirable to have the soundings on that Plate with a note of interogation after them, verified.

Attempts should be made to bring up specimens of the bottom whenever practicable; for this purpose, the large twine should be bent on to Brooke's deep-sea sounding apparatus.

A small Stellwagen cup attached to the bolt of Brooke's lead, may be substituted with advantage for the arming. (Quills have been found to answer much better.—*Vide* p. 122. M. F. M.)

After a little experience, the officer charged with making deep-sea soundings will, it is thought, acquire skill enough, especially when the sea is not more than 2,000 fathoms deep, to bring up specimens with Brooke's apparatus and the small twine.

When the small twine is used without a Brooke's apparatus, double it for the first 200 fathoms, and use two 32 lb. shot as the sinker; when the shot reaches the bottom, the boat may ride by it, until the surface current shall be determined, when the line should be hauled in until it parts.

The sounding should in all cases be taken from a boat, and not from the vessel. The boat with its oars can be kept over the line, whereas the vessel will drift.

For deep-sea temperatures, a self-registering metallic thermometer should be used, especially at great depths. When no metallic thermometer is on board, then a resort to a non-conducting cylinder for bringing up the water should be had.

Approved: C. MORRIS.
December 17, 1853.

Directions for taking Deep-sea Soundings.

The information acquired from experience upon the subject of deep-sea soundings, enables me to say that I now consider it as practicable to fathom the greatest depths of the ocean, whatever they may be, as it is to sound out one of our bays or harbors.

Lieut. Walsh's experiments in the Taney satisfied me that no reliance could be put upon results obtained by sounding at great depths with wire. His great sounding, therefore, was most valuable and important, for it led the way to the use of twine.

159. It was thought that, upon the new plan, the common wrapping thread or twine used in the shops would answer for deep soundings. For it was supposed that bottom might be reached always and at any depth, especially in calm weather, simply by fastening the end of twine from such a reel to a common 32 lb. shot, throwing the shot overboard, and then paying out the twine as fast as the shot would take it from the reel. When the shot reached bottom, it was supposed that the line would stop running out; and then, cutting the thread, and seeing how much was left on the reel, the depth would, it was thought, be ascertained.

This required the loss of the shot and the twine, but they were cheap; for it was supposed that a mere thread, which had strength to hold together, would be strong enough.

But the experiments of Lieut. Wm. Rogers Taylor, on board the Albany, Captain Platt, (a full accouut of which is contained in the 5th edition of this work,) proved these notions to be wrong. The casts for deep-sea soundings, made on board that vessel, showed that it required twine of considerable strength for the purpose.

160. The existence of a physical state of things which bears upon the question was also suggested by Taylor's experiments; and that is, the probable existence in all parts of the sea of one or more under currents. In other words, these deep-sea soundings appear to confirm what I have been endeavoring to maintain in the chapter on the "Saltness of the Sea," and elsewhere, viz: That the ocean has its system of circulation, so ordered that its waters, whether at the surface or in the depths below, are seldom or never at rest; that this circulation is all-pervading, and perpetual, and is as constant in the horizontal as it is in the vertical direction.

This system of circulation commenced on the third day of creation, with the "gathering together of the waters," which were "called seas," and doubtless will continue as long as sea water shall possess the properties of saltness and fluidity.

The confirmation which the experiments in sounding out the depths of the ocean seem to afford for this conjecture, is derived from the inference, in the first place, that I draw from the experiments which, in a few cases, have been made in sounding at the same place, first with one and then with two 32 pound shot as a sinker. The results as to depths have been accordant; but invariably the depth, as given by the *two* shots is a little less than by one. The two shots sink faster than the one, the bight of the line in the former case, therefore, is not exposed so long to the action of the under currents; consequently, it is not swept so far out of the perpendicular with the two as it is with but the one shot.

In the next place, a degree of confirmation as to the correctness of this conjecture is afforded by the fact that, though the shot may reach the bottom, the line has, in no instance, ceased for any considerable length of time to run out; and, moreover, that after the shot has landed, there is, at very great depths, such a force brought upon the line, if it be held, as always to part it.

Imagine a line two or three, or four miles long, hanging perpendicularly in the ocean, that the plummet to which it is attached has reached the bottom, and that there be one or more under currents moving in opposite or different directions, and operating upon it. They would operate with what sailors call a "swigging force," and that, too, with a power which no line would be strong enough to withstand for any considerable length of time.

Thus the importance of strong twine was pointed out; and it was also discovered that, to know when the shot had reached the bottom, it was necessary to time the intervals which were occupied by given lengths of line in going out. The most convenient lengths for this purpose are lengths of 100 fathoms each; and as mark after mark, which denotes these 100 fathoms lengths, passes from the sounding-reel, the time per watch is as carefully noted, by the officer who makes the sounding, as it should be if he were taking sights for the chronometer.

The soundings by the Albany, and others, were made from on board ship. In the first place, it was rarely that an opportunity favorable enough for a good cast from on board ship occurred. Moreover, the complaint was almost universal throughount the service of bad twine. Attempts to sound from the vessel were so often frustrated by the parting of the line, that officers were very much deterred from the trial. These failures were disheartening.

Furthermore, when the ship was hove to for the purpose, as the Albany frequently was, there was not only the drift of the ship to be taken into account, but the question as to the result still remained to perplex. Had the bottom been reached? And if so, was there any certainty that the depth was what the experiments seemed to indicate? Certainty as to this was greatly impaired by inequalities in the times of running, caused by the change in the rate of motion of the vessel as she "came up and fell off."

Such was the amount of our experience upon the subject of deep-sea soundings when Lieutenant S. P. Lee was ordered to the command of the Dolphin.

With characteristic energy he set about making preparations for this new service. His first business was to give the twine, furnished for deep-sea soundings, a thorough examination. He carefully overhauled, tested, and tried several hundred thousand fathoms. Much of it he found so defective that it had to be rejected, and the vessel detained until better could be procured. It was well he did so; for although the line with which he proceeded to sea was better than that which was rejected, nevertheless, experince proved that much of it, though new, was not strong enough. Its average strength was not even then sufficient to bear a weight of fifty-five pounds, nor was it all quite of the same size, as it should have been.

161. When he got to sea, he determined not to sound from the vessel at all, but to use a boat for sounding altogether.

A BOAT SHOULD ALWAYS BE USED.

At first Lee encountered many unexpected difficulties; but with industry, his ingenuity and perseverance, these, one after another, were overcome, until the way was made plain, and the operation stripped of a vast amount of the uncertainties which had impaired, to a greater or less extent, the value of all the results hitherto obtained.

In the first place, though the small twine, furnished for the deepest soundings, would, much of it, bear a weight of seventy or even eighty pounds, yet, when he came to attach to it a thirty-two pound shot, to throw the shot overboard, and let it take the line from the reel as fast as it would, he found the line would part.

He then resorted to the expedient of doubling and even of trebling the line for the first two or three hundred fathoms. Thus, the parting was prevented. He found, moreover, that the operation was greatly facilitated by watching the trending of the line from the bows of the boat, and, with one or two oars of a side, directing the men how to pull, in order to keep the line "up and down."

Accordingly, we find him, when he first put to sea, occupied for more than a month, availing himself of every opportunity for sounding during the interval, and making, day after day, unsuccessful attempts.

Finally, he succeeded in getting out seventeen hundred fathoms without parting. Bottom was reached at this depth.

Out of the first seventeen casts that were made, this was the only successful one.

He was now in the fair way to get at the secret. The plan is to double or triple the line for the first three hundred fathoms; and, instead of letting the shot take it as fast it will, and so bring up occasionally with a violent jerk and parting—and this, as experience abundantly proves, is very liable to be the case, particularly at the first going off, when the shot is sinking rapidly—Lee also adopted the expedient of keeping a gentle strain on the line at first; and this was accomplished by allowing a little friction to be applied to the reel, so that it would not, for the first three hundred fathoms, give the line to the shot quite as fast as the shot wanted to take it.

An important part of the plan, also, was that of keeping the boat, by means of a couple or more of oars, perpendicularly over the shot. To be sure that he had reached bottom, he on several occasions repeated the trial, using in this case two instead of one thirty-two pound shot for a sinker. The result was the same agreement as to depth.

Success crowned his efforts so far, and he now began to have such confidence in his results—for the mark of each successive hundred fathoms, as it went out, was carefully timed—that, with his shot on the bottom at the depth of three or four miles, he would use it as an anchor, ride by it in his boat out there in mid-ocean, while the force and set of the surface current, out upon blue water in the open sea, were accurately determined. This was the first time that such a thing had been done.

Thus, the egg was made to stand upon its end, and the plan of deep-sea soundings finally adopted, and now in practice, is this: Every vessel of the navy, when she is preparing for sea, is, if her commander, or, with his consent, any officer on board will pledge himself to attend to the deep-sea soundings, furnished with a sufficient quantity of sounding-twine, carefully marked at every length of one hundred fathoms—six hundred feet—and wound on reels of ten thousand fathoms each. It is the duty of the commander to avail himself of every favorable opportunity to try the depth of the ocean whenever he may find himself out upon "blue water." For this purpose, he is to use a cannon ball of thirty-pounds as a plummet. Having one end of the twine attached to it, the cannon ball is to be thrown overboard from a boat, and suffered to take the twine from the reel as fast as it will; and the reel is made to turn easily.

When Lieutenant Berryman took charge of the brig, and went to sea, of course he availed himself of Lee's experience, and commenced where Lee had left off.

162. But there was still one thing wanting: for Lee and his predecessors had no positive evidence that the plummet had reached bottom; and hitherto, the plan had not contemplated the bringing up of specimens of the bottom, inasmuch as the hauling up of the shot from such great depths was regarded as an impracticability.

In this stage of the matter, Passed Midshipman J. M. Brooke, a clever young officer, who was at the time doing duty at the observatory, proposed to me a contrivance by which he thought the shot might be detached as soon as it touched the bottom, and specimens brought up in its stead.

The following letter explains the instrument as it has been recently perfected by him:

WASHINGTON, *November* 9, 1857.

DEAR SIR: I herewith send you a description of the "deep-sea sounding lead," (Plates VII and VIII) so arranged as to avoid some of the difficulties that heretofore attended its use by those who had not given the subject much consideration.

This form of *one arm* possesses many advantages over that of *two;* for instance, in the latter form, if one arm discharges before the other, the whole apparatus immediately inclines and hangs firmly suspended from the remaining arm, which then becomes a mere hook, rendering detachment difficult; and thus accident is particularly apt to occur when long leads and long slings are used. Again, the arms not lying in the same plane, but connected by a single span, cause rotation of the lead in its descent; so that should it be desirable at any time to experiment with indicators, such as have been applied, depending upon rotation of a propeller shaped wheel, no dependence could be placed upon their performance. And, again, the two arms may be prevented from turning down by the twisting of the span above them, as swivels do not always turn when subjected to heavy strain, such as they experience at great depths in towing down the line. The present form presents a light rod which, with small twine, may be easily recovered from the greatest depths.

In some instances the instrument has been so altered by experimenters as to seriously impair its efficiency in sounding to moderate depths, and to effectually prevent successful detachment or recovery in depths but little exceeding two and a half miles.

It is essential that a deep-sea sounding apparatus should detach the weight, used to sink the line, with certainty on reaching hard or soft bottom.

That the rod should be light enough to admit of easy recovery with small twine, so light, in proportion to the area of its base, as to enable it to perform its function of tripping the arm and throwing off the weight on *soft* bottom.

In some instances, however, rods weighing ten or twelve pounds have been used for this purpose, with appendages adding six or seven more. Such arrangements involve the use of large line, and consequent loss of time; for we do not gain strength in proportion to the increase of friction, by enlarging our lines. Of such lines as are used, experiment shows that a given length of smaller may be drawn more rapidly through the water without breaking than an equal length of larger line. This increase of time and difficulty of recovery, even from depths of two and a half miles, together with the tendency of such compound instruments—to deflection from the vertical line of descent, and the fact that the indicators used in this connexion are unreliable under any circumstances, even in the favorable depth of 160 fathoms—(see remarks of Captain E. Belcher, "Nautical Surveying," page 19,) leads to the conclusion that such arrangements are injudicious, and not calculated to promote the progress of this branch of research, further than as illustrating the importance of exercising a just discrimination in altering and compounding instruments.

Very respectfully, your obedient servant,

J. M. BROOKE,
Lieutenant United States Navy.

Lieutenant M. F. MAURY, *U. S. N.*,
Superintendent National Observatory, Washington, D. C.

EXTRACT FROM BELCHER'S NAUTICAL SURVEYING, WITH APPLICATION.—J. M. B.

"The general use of the patent log in surveying operations is of itself a proof of its value." "The patent sounding machine does not stand in such repute as the last. At one time I strongly defended it on the firmest reliance on its mechanical principles. Constant practice, however, has caused me to change my mind; but I think that it is worthy of the attention of the inventor. If it is to be made use of, and very carefully it must, the wings should be as decidedly large as those of the log. It never can travel so fast, and, therefore, ought to be larger. I tried some experiments with one of these machines in 1830; the rotator burst at 156 by the index; therefore, the tube ought to be plugged with care, dipped in wax. Although not a favorite in surveying, I should be sorry to detract from its merits; but in surveying operations time is too valuable to sacrifice, when we know that above a certain depth we must stop the line or sacrifice the instrument, as we know the rotator must burst below 160 or cease."

"The first part of this quotation, 'continues Brooke,' is still applicable, as the wings are of diminutive proportions. As Captain Belcher was limited to depths not exceeding 160 fathoms, and had *constant* practice in such sounding, when the lead sinks rapidly, his objection applies with conclusive force to the use of this instrument in *deep-sea sounding*, when the lead, in most instances, even with the smallest twine, sinks with a velocity of less than one mile an hour towards the latter part of its descent."

Plate VII, figure 1. Detaching apparatus. Figure 2. Lead ready for sounding.

Plate VIII, figure 3. In act of detaching. Figure 4. Slings.

A is a shot cast with a hole through it, and slight grooves on its sides to receive and steady the slings E.

B is a rod to which is attached an arm C.

C is an arm moving vertically about the pin D, and from which the shot A is suspended by slings E.

E slings and washer which are thrown off with the shot.

The lower end of the rod B is tubular, receiving the barrels of several goose quills, open at both ends, retaining their places by their elasticity.

F is a valve of thin leather opening outward, it permits the water to flow through the quills (Q) as the rod descends, but, closing as it is drawn up, preserves the specimen intact. This provision for the escape of the water permits the entrance of the specimen and guards against the capture of infusoria or substances suspended in the water which would depreciate the value of the specimen by leading to false conclusions.

The proportions of this instrument are such that when the shot is suspended from the arm C, the point of contact X, the point of suspension Y, and the point of resistance Z, all lie in the same vertical line; the weight of the rod B will then give the arm C a slight inclination, which with the friction of the water on the line, holding it back, guards against premature detachment.

It is obvious that the sensitiveness of this detaching apparatus will depend upon the relative positions of these three points; for the arm C may be regarded as a lever of the second order with its fulcrum at D; the gravity of the shot as the power acting upon the resistance of the line. So that by increasing or diminishing the distance of the ring H from the pin D, the detachment is rendered more or less difficult.

In order that change of position in the arm C, as it yields to the pull of the shot in the act of detaching, may not interfere, it is so made as to permit the ring to slip back as the arm inclines, as shown in figure 3.

On soft bottom it should work as well as on hard, for it is only necessary that there shall be a retardation of the descent of the rod, while the heavier shot continues to descend into the mud, to cause the turning of the arm and discharge of the shot.

Before using the instrument the operator may test its sensitiveness and adapt it to the depth of water; in deep sounding it should be so delicately adjusted as to act upon the slightest touch, and should be eased down for the first fifty fathoms or more.

The quills are cut as for figure (Q,) with the cut downward, and then several of them are wedged into the cell or holder. The advantages of this arrangement are, we have more abundant specimens than an ordinary arming will bring up, and then we have the gratification of sending them, for further examination and study, to the microscopist, free of grease or soap —a great desideratum. This saves him trouble, also, and enables him to place the specimens on his slides in the best condition possible.

The double armed detachment, as originally designed and described in previous editions of this work, required, as experience demonstrated, nicety of construction and manipulation to insure its working. These it did not always get; hence the improved model now presented. If the slings in the old plan were short, they would prevent the arms from opening to let the shot go; or, unless the shot was attached with the arms well spread, so as to be almost ready to let go when the shot was first lowered into the water, the shot would often fail to be tripped on reaching bottom.

Brooke, therefore, in a note to me, adds this caution, which may be useful to those who still use the double-armed detachment:

"I have already, in a previous communication, called your attention to the errors committed in the construction of this detaching instrument by various persons, and I trust that *you* will call attention to the fact, that the principles which were observed in the construction of the original instruments have been disregarded in such instances of imitation as have fallen under my observation.

"In the construction of the apparatus with *two arms, the points of attachment of the span should be directly over the points of attachment of the slings* which support the weight; and the arms should set nearly at right angles to the rod, with a span *several feet in length* attached by a swivel to the sounding line.

"A spherical weight is to be preferred, and the rod should only be long enough to admit of a projection of *four* or *five* inches below the weight.

"The sensitiveness of this instrument, with a light and proper rod, depends altogether upon the inclination of the arms and the relative positions of the points alluded to with reference to the axis on which the arms turn; and as these arms may be considered levers, with fulcrums at the axis, admitting of change from the second to the third order, the gravity of the suspended weight is the power, and the resistance of the line from friction of the water is only to be thus overcome.

"The form of *one arm*, Plates VII and VIII, is intended to guard against these errors of construction and adjustment."

With this apparatus, Brooke has obtained specimens in the Pacific from the depth of 3,500 fathoms, (21,000 feet.) Midshipman John G. Mitchell, of the Dolphin, and the men employed with him, became so expert during her cruise of 1853—always doubling the line for the first 300 fathoms, applying friction to the reel at first, so as to offer a little resistance to the shot for that depth, and keeping, with the help of the oars, the line up and down—that failure to get bottom seldom occurred, unless in cases where the twine had been injured by the mice, or damaged by lime getting upon it in the hold.

The sounding-twine is now made in the Boston Navy Yard. To have it so made has been found the most economical. That which was furnished to the Dolphin, when Lieutenant Lee had her, was bought ready made. The strength of the weakest part is the strength of the whole; and so inferior did much of it prove, that, though he expended upwards of 140,000 fathoms of twine, and 116 32-pound shot, in attempting to sound, only 73,000 fathoms of this quantity, and 30 shot, were actually employed in getting bottom; the rest were lost by the parting of the line, &c.

Commodore Morris has (by his instructions, as given on page 117,) directed the small twine to be made strong enough to bear a strain of 60 pounds. It weighs about 1 pound per 180 fathoms, and is put on reels of 10,000 fathoms.

The large twine will bear a weight of 150 pounds. It is put up for use on reels of 5,000 fathoms. This is the twine to be generally used with Brooke's apparatus.

Seeing that, for success in deep-sea soundings, so much depends upon the interest which the officer charged with the sounding feels in the matter, it has been decided to give twine to those vessels only that have on board some one or more officers who will volunteer to undertake a series of deep-sea soundings.

An outfit of sounding materials will be supplied to any vessel, either upon requisition of her commander, or at the request of any officer on board, who is willing to undertake a series of deep-sea soundings. (Such requisition, I am sorry to say, is rare.)

As to the *modus operandi* in sounding, officers are referred to what has already been said, and they are reminded that uniformity of method is of great consequence. Always use the same twine and the same weight; always time every one hundred fathoms; always keep the line up and down, and *always* sound from a boat. The experience of the Dolphin is in favor of two 32-pound shot, or one 64, as a sinker for the small-sized twine. Her soundings, particularly those taken by Mitchell during her last cruise, are referred to by way of example.

Whenever specimens of the bottom are obtained, they should be labelled with date, name of ship and of officer, latitude, longitude, and depth, and carefully preserved and forwarded to the Chief of the Bureau of Ordnance and Hydrography.

In the North Atlantic, the deep-sea soundings that are principally required, are in the white space (Plate XI) to the southward of the Grand Banks; in the open space about the Bermudas; in the middle of the Atlantic, between 25° and 30° N., 45° and 55° W., and in all the regions below the parallel of 15°, except where Lee sounded.

It would be very interesting, also, to have a series of deep-sea soundings made from *boats* in the Gulf of Mexico and Caribbean Sea, to test those which were made from the vessel by Rogers Taylor, of the Albany.

The deepest parts of the ocean will probably be found south of the parallel of 35° south. Soundings by vessels bound around either of the capes, therefore, would be possessed of a peculiar interest.

As to the physics of the sea, it may be said we know nothing, or only what may be gathered from a few faint rays that modern explorations have cast upon them; and the officers of the American Navy have here afforded them the rare opportunity of building up a new department in physical geography.

The problem before them is an old one. To fathom the depths of the ocean is the proposition. Heretofore it has either appalled by its magnitude, or baffled with its difficulties. At any rate, no systematic attempts have ever been made to gauge its depths "off soundings." But now, with means the most simple, this first great problem in the physical geography of the sea seems to be in a fair way of receiving a satisfactory solution, at least, so far as to enable us to form a tolerably correct idea as to the general forms of the great oceanic basins, and the troughs, which, like inverted casts of the spurs from mountain ranges, start out from the depressions in the solid crust below its waters, into bays, gulfs, and arms of the sea.

Of all contrasts in nature, perhaps none would be more striking than that afforded between the elevations of the earth's crust into mountains, on the one hand, and its depressions below the sea-level into hollows for the bed of the ocean, on the other. Certainly, few would be more grand—none can be more imposing.

I may refer to Lee's abstract log* in the Dolphin, also, for deep-sea temperatures, as well as remarks about drift.

For deep-sea temperatures, non-conducting cylinders have generally been used. The common self-registering thermometer I consider wholly unreliable for this purpose, by reason of the liability of the index to be moved while the instrument is being hauled in. Moreover, at great depths, pressure will crush it. Saxton's self-registering metallic deep-sea thermometer will, it has been thought, give good results in *careful hands.* I have, upon reflection, been led to question the ability of this instrument to give accurately sub-marine temperatures at very great depths. It is made of spiral strips of silver and platinum, soldered together; the silver is on the outside, and is the more expansible; a coil of two metals thus arranged, and possessed of different degrees of compressibility, would, I apprehend, behave under very great pressure, as it does under a diminution of temperature: its tendency would be to uncoil. If I be not mistaken, a coil to a "Saxton," having the silver on the inside, would, if let down through a great depth to the bottom of the sea, register a very high instead of a very low temperature there.

But, be this as it may, such instruments are practically but of little value here; a single one costs about $70. They are, therefore, too expensive for a system of research like this, which depends, for the most part, upon the voluntary co-operation of navigators, and that, too, with the ordinary means and appliances that are to be found on board almost every well appointed ship. Vessels fitted out especially for exploration or surveys should have them.

One of the excellencies—and a most beautiful and striking feature it is—of this system of research is that, without expense, it enables every navigator, who will, to become a co-operator in an enlarged, comprehensive, and most useful field of philosophical investigation; it enables the philosopher to use as data for his investigations, observations that had been thrown away after answering their immediate purpose; and to employ, in obtaining his data, the usual instruments and implements of navigation. If anything beyond these be needed, it must be cheap and handy, otherwise the expense on one hand, or the difficulties of use on the other, will be sure to mark with failure the attempt to introduce it.

It is precisely for this reason that the plan of deep-sea soundings, with a cannon ball and bit of twine, is, in the general way preferred to all others. For this reason, also, it is that for deep-sea temperatures the non-conducting cylinder of water is preferred to the Saxton's deep-sea thermometer even for moderate depths.

If we depend upon contrivances any more costly than shot and twine for deep-sea soundings, or than non-conducting cylinders for deep-sea temperatures, it is certain that we will go without either deep-sea soundings or temperatures, or else depend exclusively for them upon vessels equipped especially for the purpose of making and obtaining them; and they are few.

Commander Rodgers, in the United States sloop Vincennes, made some interesting observations upon deep-sea temperatures in the Arctic Ocean in August, 1855.

I quote them as an example to the navy, showing what valuable results may be obtained where there is really a will. He used both the non-conducting cylinder and Saxton's self-registering thermometer. The result shows how, with the help of a little ingenuity and care, the most valuable and interesting results may be obtained with means the most simple. In such hands the cylinders give the most consistent, the truest, and most reliable results.

* This has been printed by Congress, in a neat volume entitled "The Cruise of the Dolphin," Senate, 33d Congress, 1st session, No. 59.—(Executive.)

OBSERVATIONS ON DEEP-SEA TEMPERATURE—BY COM. RODGERS.

	Saxton's metallic thermometer.		Water cylinder.	Specific gravity.	Remarks.
	No. 1.	No. 3.			
FIRST TRIAL.					
Temperature at surface	43.8	43.8	43.8	1.0264	Aug. 13, 1855, 6h. 45m. p. m.—Lat. 72° 2′ 27″ N., long. 174° 37′ W.; sea smooth; temp. of air 45°.2.
Temperature at 5 fathoms	35.3	36.8	37.0	.0265	
Temperature at 10 fathoms	34.3	35.3	35.5	.0265	
Temperature at 15 fathoms; the temperature rises between 20 and 30 at 15 fathoms from bottom	31.3	34.8	35.0	.0265	
Temperature at 20 fathoms	27.8	31.3	33.5	.0266	
Temperature at 30 fathoms	27.6	31.3	34.0	.0266	
Temperature at 40 fathoms within 2 feet of the bottom	27.6	31.3	40.5	.0266	
SECOND TRIAL.					
Temperature of surface	43.7	43.7	43.7	1.0264	
Temperature at 20 fathoms	28.7	31.7	34.	.0266	
Temperature at 40 fathoms within 2 feet of the bottom	28.2	31.7	41.	.0266	
FIRST OBSERVATION.					
Temperature at surface	44	44	44	1.0256	Aug. 14, 1855, 4 p. m.—At anchor near Herald island, lat. 71° 21′ 30″ N., long. 175° 22′ W.; sea smooth; temp. of air 45°.
Temperature at 12 fathoms	32.5	33	33 5	.027	
Temperature at 15 fathoms, near the bottom	32.5	33	37.5	.027	
SECOND OBSERVATION.					
Temperature at surface	43.8	43.8	43.8	1.0256	
Temperature at 12 fathoms	31.8	33.8	33	.0268	
Temperature at 15 fathoms, near the bottom	31.8	33.3	37	.0270	
Temperature of surface water	44	44	44	1.0256	Aug. 14, 1855, 9 p. m.—At anchor near Herald island, lat 70° 21′ 30″ N., long. 175° 22′ W.; sea smooth; strong current to N. by W.; temp. of air 45°.
Temperature at 5 fathoms	36.5	39	38.2	.0267	
Temperature at 10 fathoms	30.5	34	33.4	.0268	
Temperature at 25 fathoms, near the bottom	30	33.5	37.3	.0268	
Temperature at surface	42.5	42.5	42.5	1.0258	Aug. 15, 1855, 10 a. m.—At anchor off Herald island, lat 71° 21′ 30″ N., long. 175° 22′ W.; temp. of air 45°.
Temperature at 12 fathoms	38.5	39	39.8	.0264	
Temperature at 25 fathoms, very near the bottom	38.5	38	40.2	.0264	
Temperature at surface	38.2	38.2	38.2	1.0246	Aug. 10, 1855, 8h. 30m. a. m.—Ice barrier 2 miles distant; lat 71° 16′ N., long. 176° 5′ W.; temp. of air 45°.
Temperature at 15 fathoms	30.7	31.2	31.6	.0256	
Temperature at 31 fathoms, very near the bottom	30.2	30.7	34	.0258	
* Temperature at surface	45	45	45	1.0264	Aug. 17, 1855, 11 a. m.—Lat. 68° 42′ N., long. 174° 27′ 30″ W.; sea smooth; calm; temp. of air 48°.6.
Temperature at 7 fathoms	40	38.5	42.5	.0267	
Temperature at 14 fathoms	39.5	38.5	41.3	.0267	
Temperature at 20 fathoms	37	35	38	.0271	
Temperature at 28 fathoms, very near the bottom	36.5	35	40.2	.0271	

* Sent a boat to try the current; found surface current .584 knot per hour, N. W. by comp.; at 2 fathoms, .642 per hour; at 5 fathoms, .817 per hour; at 15 fathoms, .758 per hour.

164. In making these deep-sea soundings by the means and methods proposed, the practice is to time the hundred-fathom marks as they successively go out; and by always using a line of the same size and "make," and a sinker of the same shape and weight, we at last established the law of descent. Thus the mean of our experiments have given us, for the sinker and twine used, the results of the following tabular statements:

Summary statement of all reliable Deep-sea soundings, as far as the same have been received at this office, December, 1857.

U. S. SHIP ALBANY.

Date.	Latitude.	Longitude.	Fathoms.
1850.			
December 6	38° 38′ N.	66° 31′ W.	1625*
9	33 34	61 38	1950*
11	30 05	58 52	1000*
11	29 58	58 48	1500
16	21 34	63 24	1600
29	17 54	67 28	1200
1851.			
January 4	18 20	69 49	370
5	17 16	71 26	1275
13	19 12	76 05	1200
16	22 29	84 35	420
16	22 32	84 32	720
28	24 05	82 05	470
29	24 37	79 48	500
February 6	19 57	72 11	640
18	15 40	77 07	1300
19	11 07	79 13	600
28	17 54	80 25	895
March 3	19 20	81 50	660
4	21 25	84 45	990
5	22 05	86 22	445
16	19 30	94 30	530
16	19 37	94 49	967
April 3	25 56	95 51	490
4	26 58	92 58	725
5	26 36	88 56	962
6	26 43	85 27	795
7	25 23	85 19	693
8	24 39	85 12	916
1851.			
April 10	23° 47′ N.	83° 22′ W.	593
19	23 21	82 44	995
21	25 19	83 41	52
22	26 43	84 41	137
23	29 12	86 01	152
June 13	27 00	85 43	1310
14	27 55	85 44	376
14	28 27	85 54	220
December 2	26 25	83 23	1502†
10	27 04	79 44	380
11	27 16	79 49	274
11	27 16	79 49	284
11	27 55	79 45	440
11	27 51	79 09	647
11	27 34	77 54	631
12	27 19	77 18	690
12	27 10	76 59	1180
13	27 10	75 06	1806
14	26 31	74 10	1590
14	26 28	73 50	1778
15	25 30	72 07	4100
16	24 48	70 22	1893
17	24 41	69 39	3600†
19	22 40	69 00	2762
1852.			
January 9	9 44	81 01	1650
February 15	11 23	79 36	2290
16	12 25	78 22	2320

* No bottom. † Doubtful.

Deep-sea soundings on board U. S. brig Dolphin, Lieutenant S. P. Lee commanding.

Date.	Latitude.	Longitude.	Fathoms.
1851.			
November 24........	25° 30′ N.	37° 44′ W.	1720
30........	23 42	32 39	2180
30........	23 41	32 39	2200
December 1........	23 15	32 24	2200
7........	18 39	25 24	1970
7........	18 19	25 05	1675
10........	18 11	23 48	1612
11........	17 34	22 50	1370
13........	16 29	20 58	1941
14........	16 34	20 47	1875
15........	16 59	21 38	1580
16........	15 24	20 46	1220
16........	15 09	22 28	1380
17........	15 08	22 57	1120
17........	15 02	23 12	790
1852.			
January 7........	11 07	21 56	1160
7........	11 07	21 56	1120
8........	8 43	20 52	2270
9........	7 17	20 07	2050
9........	7 17	20 07	1940
13........	4 14	19 20	2670
14........	3 42	19 06	2760
15........	3 51	19 06	2760
17........	3 01	18 36	2725
18........	2 36	19 22	2840
19........	2 10	19 57	2750
1852.			
January 19........	2° 10′ N.	19° 57′ W.	2690
20........	0 23	21 45	2000*
22........	2 27 S.	23 38	3020
24........	5 42	25 40	2970
25........	6 59	25 43	3250
27........	4 11	24 00	3200
29........	3 33	22 38	3575
31........	2 26	20 47	3450
February 3........	0 18 N.	18 40	2000*
5........	0 45	18 28	2680
13........	0 31 S.	17 45	2840
29........	5 32	32 43	2490
March 13........	3 51	33 02	2150
28........	4 20	34 45	2440*
31........	4 24	35 23	2700
April 9........	0 57 N.	41 06	2980
12........	1 06	43 43	2000*
May 26........	7 57	47 51	1970
31........	13 28	52 26	1960*
31........	12 47	52 57	2780
June 2........	12 20	54 48	2570
4........	15 25	55 01	3020
8........	19 02	59 33	3300
12........	26 32	60 06	3825
14........	24 11	61 43	3450
20........	24 36	65 12	3560
28........	36 04	73 59	1460

* No bottom.

Deep-sea soundings on board the U. S. brig Dolphin, Lieut. O. H. Berryman, commanding.

Date.	Latitude.	Longitude.	Fathoms.
1852.			
October 4	39° 39′ N.	70° 30′ W.	1000*
6	40 50	64 44	2200
7	41 12	62 38	2200
9	41 40	59 23	2600
10	41 40	56 01	2595
11	40 36	54 18	3450
20	41 07	49 23	4580
24	43 40	42 55	2700
25	44 41	40 16	1800
26	. .	. .	1500
December 26	33 08	16 10	2950*
1853.			
January 3	34 18	16 45	2298
9	36 59	19 58	2500
9	36 49	19 54	2750
29	30 49	27 25	1100*
29	30 49	27 25	2200*
February 3	27 05	28 21	1700
4	27 21	30 48	2580
5	31 17	33 08	2400
6	28 55	35 49	1880*
8	29 14	41 21	2270
9	31 16	43 28	2080
10	32 01	44 21	2250
11	32 29	47 02	1950*
12	32 55	47 58	6600*
13	33 03	48 36	3550
15	32 47	50 00	3250*
20	29 26	56 42	1480
22	28 20	59 44	2900
23	28 04	61 44	3080
24	28 23	64 17	2518
26	26 49	66 54	2720
28	28 14	69 24	2950
June 2	37 24	68 52	2920
3	38 03	67 14	4920*
7	40 34	58 30	2750
10	41 07	54 37	2710
14	41 43	51 31	3130
17	42 22	50 00	1650
21	41 09	43 40	1975
24	39 36	41 06	2675
29	42 10	42 04	1850
July 2	46 53	37 46	2000
3	48 16	35 22	2100
4	49 53	31 34	1900
5	51 40	28 33	1750
6	53 28	25 01	1900
7	54 17	22 33	2000
9	57 18	16 07	620
12	54 26	12 10	1625
1853.			
July 14	50° 54′ N.	17° 02′ W.	2675
16	46 48	21 42	2465
17	44 42	24 35	1500
18	44 43	24 35	1370
19	43 47	25 24	1850
20	45 07	26 08	1500
21	46 26	26 55	1400
22	45 13	27 38	1320
24	42 44	28 20	1210
25	40 49	29 00	1080
26	40 48	30 02	830
August 10	38 54	33 30	1500
12	40 35	31 56	1230
13	42 40	31 11	1680
14	44 52	30 38	1560
15	46 15	30 04	1760
16	47 58	29 35	1900
21	49 59	17 35	2700
22	49 57	13 16	1580
Sept. 18	47 38	9 08	1800
21	46 32	12 49	2190
23	44 05	13 29	2560
24	42 07	15 29	2500
25	40 20	17 48	2650
26	39 14	19 01	2820
29	34 23	20 57	2150
30	31 46	22 03	2850
October 1	29 12	22 50	2800
3	23 58	24 20	2700
4	21 06	24 38	2625
5	18 14	24 51	2080
10	17 02	28 08	2460
11	18 44	29 18	2520
12	20 02	31 06	2560
13	21 48	32 36	7020
14	20 29	34 18	2850
15	18 49	36 16	2820
17	19 23	40 23	2580
18	21 16	42 09	2370
19	23 06	44 00	1760
20	21 18	46 14	1875
21	19 51	48 02	2240
22	18 32	49 48	2370
23	21 26	51 31	2300
24	22 27	53 15	2390
25	21 45	55 46	2900
26	20 51	58 26	2800
27	20 02	61 02	2810
November 3	21 19	66 27	2960
4	23 42	67 37	2940

* No bottom.

Deep-sea soundings on board the United States ship Jamestown.

Date.	Latitude.	Longitude.	Fathoms.	Date.	Latitude.	Longitude.	Fathoms.
1851.				1851.			
January 3........	36° 43′ N.	74° 10′ W.	1500*	June 13........	38° 50′ N.	43° 49′ W.	1600†
4........	36 33	73 00	1900*	18	37 50	32 07	2000
5........	37 06	68 02	2000	23...	36 00	27 20	4000*
6........	38 13	62 32	3700	24........	35 06	26 52	2000*
7........	38 50	45 33	2000				

United States ship Plymouth.

Date.	Latitude.	Longitude.	Fathoms.	Date.	Latitude.	Longitude.	Fathoms.
1851.				1851.			
September 2........	37° 28′ N.	56° 22′ W.	5000	September 9........	34° 11′ N.	43° 21′ W.	2800

United States ship Portsmouth.

Date.	Latitude.	Longitude.	Fathoms.	Date.	Latitude.	Longitude.	Fathoms.
1851.				1853.			
December 31........	21° 19′ N.	38° 10′ W.	4700†	August 4........	39° 55′ N.	140° 13′ W.	2500*
				5........	39 40	139 26	2850

U. S. schooner Taney. / *U. S. ship Saratoga.*

Date.	Latitude.	Longitude.	Fathoms.	Date.	Latitude.	Longitude.	Fathoms.
1849.				1850.			
November 15........	31° 59′ N.	56° 43′ W.	5700*	November 28........	28° 21′ S.	29° 31′ W.	3100

United States ship Congress.

Date.	Latitude.	Longitude.	Fathoms.	Date.	Latitude.	Longitude.	Fathoms.
1851.				1851.			
June 12........	28° 46′ S.	43° 46′ W.	2880	April 15........	34° 50′ S.	51° 40′ W.	950
August 7........	23 59	43 44	90	May 12........	28 00	45 58	800
April 1........	35 20	51 30	1000	13........	27 32	47 08	320
3...	35 23	47 27	2550	September 10........	30 28	45 41	1780
9........	34 37	44 11	2093*				

United States ship John Adams.

Date.	Latitude.	Longitude.	Fathoms.	Date.	Latitude.	Longitude.	Fathoms.
1851.				1851.			
May 3........	33° 50′ N.	52° 34′ W.	2600	May 10........	31° 01′ N.	44° 31′ W.	2300
9........	32 06	44 47	5500†	21........	35 07	25 43	1040

U. S. ship Susquehanna. / *U. S. ship St. Louis.*

Date.	Latitude.	Longitude.	Fathoms.	Date.	Latitude.	Longitude.	Fathoms.
1851.				1852.			
June 18........	33° 35′ N.	38° 32′ W.	1800	October 4........	36° 16′ N.	46° 52′ W.	5070*

* No bottom. † Uncertain.

United States steamer Saranac.

Date.	Latitude.	Longitude.	Fathoms.
1853. July 24........	12° 09′ N.	55° 17′ W.	2435

With the view of showing the law of descent, both from boats and ships, for the various weights used with the small twine, the following tables have been prepared by Lieutenants S. P. Lee and R. H. Wyman. This law, owing to various circumstances connected with the commencement of almost every sounding, does not begin fairly to develop itself until 400 or 500 fathoms have run out. Notwithstanding this, certain anomalies remain for which it is difficult to account. They warn us, however, of the importance of close attention to the timing of every 100 fathoms, as the marks go out, and to keeping the line up and down from the boat by aid of the oars.

Berryman's line was of a more uniform size than Lee's, which, therefore, gives the more weight to his values of the rate of descent. Though these tables exhibit anomalies which we cannot satisfactorily account for, yet they are exceedingly valuable by reason of the check and the guide they afford for our future deep-sea soundings. They admonish operators as to the importance of *always* sounding from a boat, of using the same weights and the same twine, and of timing accurately.

Time of descent for every 100 *fathoms. Small line waxed; one* 32 *lb. shot. From U. S. Ship Albany.*

FATHOMS	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700
December 10, 1853	1.02	1.16															
10, 1853	1.02	1.16	1.06														
10, 1853	0.57	1.13	1.22	1.35													
11, 1853	1.02	1.12	1.29	1.52	1.42	2.01											
12, 1853	0.53	1.11	1.21	1.35	1.39	1.40											
12, 1853	0.53	1.12	1.32	1.37	2.07	2.23	2.20	2.28	2.49	2.41	2.13						
1, 1853	0.54	1.00	0.59	0.59	1.16	1.48	1.43	1.56	1.56	1.29	1.45	2.07	1.35	1.33	1.49		
13, 1853	0.59	1.14	1.27	1.35	1.35	1.35	1.48	2.05	2.28	1.50	2.21	3.10	2.17	3.34	2.44	2.24	3.33
16, 1851	0.57	1.17	1.22	1.35	1.42	1.49	2.03	2.14	2.06	2.06	2.34	2.31	2.03	2.25	2.45	2.35	2.41
February 15, 1852, *a*			1.04	1.21	1.46	1.51	1.33	1.59	2.11	1.39	2.03	2.17	1.52	2.21	2 04	2.02	2.40
16, 1852, *b*	1.00	1.13	1.22	1.18	1.26	1.36	1.46	2.02	2.09	1.41	1.40	1.50	2.25	2.43	1.59	2.10	2.51
December 19, 1851, *c*	0.54	1.13	1.29	1.42	1.52	1.58	2.12	2.23	2.15	2.18	2.28	2.35	2.44	2.41	2.38	2 46	3.20
15, 1851, *d*	0.55	1.05	1.09	1.13	1.45	1.52	1.49	1.50	2.07	2.12	1.56	2.20	2.17	2.14	2.41	2.17	2.20
Average interval, (min. and sec.)	0.52	1.12	1.18	1.29	1.35	1.51	1.54	2.07	2.15	1.59	2.07	2.24	2.10	2.32	2.23	2.22	2.54
Number of casts	12	12	11	11	10	10	8	8	8	8	8	7	7	7	7	6	6

FATHOMS		1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300
December 10, 1853																											
10, 1853																											
10, 1853																											
11, 1853																											
12, 1853																											
12, 1853																											
1, 1853																											
13, 1853		3.03	2.52																								
16, 1851		3.08	2.45	3.27																							
February 15, 1852, *a*	*a.*	2.09	2.23	2.52	1.59	2.33	2.55	1.58																			
16, 1852, *b*	*b.*	2.12	2.57	1.06	3.45	3.23	4.49	2.41																			
December 19, 1851, *c*	*c.*	2.58	2.36	3.20	3.29	3.11	3.25	3.16	3.19	3.19	2.23	4.15	3.01														
15, 1851, *d*	*d.*	2.51	2.16	2.40	3.55	2.31	3.02	2.59	2.26	2.56	3.15	2.39	3.36	2.35	3.00	3.09	2.52	3.13	2.47	3.14	2.42	3.16	2.56	3.22	2.48	2.51	4.10
Average interval, (min. and sec.)		3.03	2.38	2.41	3.17	2.39	3.35	2.43	2.52	3.07	2 49	3.27	3.18	2.35	3.00	3.09	2.52	3.13	2.47	3.14	2.42	3.16	2.56	3.22	2.48	2.51	4.10
Number of casts		6	6	5	4	4	4	4	2	2	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Time of descent for every 100 *fathoms. Small line; one* 32 *lb. shot. Boat Dolphin*—(Lee.)

	FATHOMS.										
	300	400	500	600	700	800	900	1000	1100	1200	1300
	INTERVALS.										
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
January 3, 1852	1.52	2.17	2.25	2.20							
20, 1852	1.40	1.54	2.11	2.25	2.47						
3, 1852	1.46	2.00	3.34	3.42	2.52	3.07	2.12				
October 25, 1851	1.43	2.06	2.21	2.40	2.59	3.00	3.17	3.42			
November 28, 1851	1.42	1.58	2.26	2.40			3.17	3.26			
February 14, 1852	1.50	2.03	2.26	1.22	2.49	3.00	3.15	3.15			
June 9, 1852	1.56	2.14	2.32	2.48	3.00	3.17	3.25	3.28			
December 17, 1851	1.55	2.05	2.22	2.33	2.52	2.17	3.09	3.39	3.28		
June 9, 1852	1.52	2.10	2.30	2.40	2.56	3.08	3.09	3.37	3.41	4.54	
December 16, 1851	1.53	2.15	2.26	2.39	2.40	3.00	3.10	3.15	3.19	3.31	3.39
February 18, 1852	1.50	2.20	2.44	2.58	3.08	3.20	3.37	3.41	3.46	3.55	
15, 1852	1.46	2.01	2.14	2.33	2.43	2.52	3.03	3.15	3.23	3.29	3.39
December 14, 1851	1.49	2.06	2.29	3.20	2.00	2.18	4.02	3.20	3.30	3.35	4.03
January 10, 1852	1.45	2.00	2.14	2.28	2.40	2.59	3.04	3.16	3.16	3.32	3.39
December 7, 1851	2.14	2.29	2.42	2.53	3.00	3.15	3.20	3.30	3.55	4.09	3.51
January 10, 1852	1.50	2.06	2.21	2.35	2.45	2.58	3.09	3.25	3.25	3.32	3.38
May 31, 1852	1.54	2.11	2.16	2.34	2.49	2.52	3.14	3.22	3.28	3.50	3.56
November 30, 1851	2.05	2.41	2.17	3.12	3.10	3.20	3.40	3.45	3.55	4.10	4.10
January 8, 1852	1.47	2.08	2.19	2.29	2.50	2.50	2.52	3.28	3.23	3.44	3.37
20, 1852	1.43	1.50	1.57	2.32	2.25	2.43	2.45	2.42	2.56	2.56	2.52
April 12, 1852	2.13	2.32	2.48	2.52	3.15	3.20	3.46	3.56	3.59	4.11	4.13
January 23, 1852	2.01	2.14	2.29	2.52	2.54	3.03	3.12	3.22	3.22	3.30	3.44
21, 1852	1.54	2.12	2.26	2.30	2.50	3.06	3.20	3.31	3.36	3.51	4.00
9, 1852	1.48	2.05	2.22	2.17	2.52	2.57	3.17	3.07	3.31	3.33	3.42
June 21, 1852	1.44	2.01	2.15	2.39	2.46	3.00	3.08	3.27	3.40	3.50	3.40
anuary 13, 1852	1.40	1.47	2.11	2.32	2 39	2.54	3.08	3.09	3.27	3.35	3.29
14, 1852	1.40	1.56	2.12	2.25	2.37	2.34	2.55	3.05	3.22	3.36	3.35
17, 1852	1.56	2.11	2.27	2.42	2.59	3.09	3.19	3.29	3.39	3.45	3.59
22, 1852	1.57	2.25	2.35	2.40	2.59	3.00	3.20	3.19	3.21	3.34	3.38
Average interval	1.51	2.09	2.25	2.39	2.49	2.58	3.13	3.24	3.31	3.45	3.45
Number of casts	29	29	29	29	27	26	27	26	22	21	19

	FATHOMS.																
	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
	INTERVALS.																
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
January 3, 1852																	
20, 1852																	
3, 1852																	
October 25, 1851																	
November 28, 1851																	
February 14, 1852																	
June 9, 1852																	
December 17, 1851																	
June 9, 1852																	
December 16, 1851																	
February 18, 1852		4.35															
15, 1852	3.47	3.51															
December 14, 1851	4.22	4.20	4.21	4.21	4.28												
January 10, 1852	3.50	4.01	4.18	4.08	4.17												
December 7, 1851	3.58	4.27	4.05	4.35	4.28	4.46											
January 10, 1852	3.48	4.01	4.08	4.28	4.14	3.44											
May 31, 1852	4.02	4.16	4.30	4.23	4.28	5.07											
November 30, 1851	4.40	4.25	4.41	4.43	4.50	4.53	4.57										
January 8, 1852	3.58	4.15	4.11	4.34	4.32	4.32	4.28										
20, 1852	3.08	3.07	3.28	3.26	3.21	3.32	3.34										
April 12, 1852	4.24	4.38	4.41	4.38	5.32	4.48	5.16										
January 23, 1852	3.53	3.50	3.56	4.11	4.16	4.26	4.49	4.48									
21, 1852	4.06	4.09	4.21	4.35	4.25	4.50	4.59	5.09									
9, 1852	3.45	4.00	4.16	4.09	4.23	4.34	4.44	4.34	4.49								
June 21, 1852	3.55	4.13	4.18	4.39	4.35	4.49	4.54	5.19	5.01	5.11							
anuary 13, 1852	3.53	4.04	4.04	4.14	4.19	4.29	4.45	4.44	4.49	4.50	5.07	5.08					
14, 1852	3.48	3.55	4.04	4.08	4.30	4.23	4.29	4.49	4.53	5.05	5.04	5.17	5.15	6.31			
17, 1852	3.57	4.02	4.18	4.21	4.39	4.45	4.47	4.49	5.03	5.06	5.06	5.17	5.25	5.42			
22, 1852	3.47	3.58	4.03	4.01	4.08	4.02	4.11	4.08	4.15	4.16	5.36	4.21	4.08	4.09	4.30	4.44	4.40
Average interval	3.57	4.07	4.13	4.20	4.26	4.31	4.39	4.47	4.48	4.54	5.13	5.01	4.56	5.27	4.30	4.44	4.40
Number of casts	18	19	17	17	17	15	12	8	6	5	4	4	3	3	1	1	1

Time of descent for every 100 *fathoms. Small line waxed; one* 32 *lb. shot. Boat Dolphin*—(LEE.)

FATHOMS.	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
INTERVALS.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
June 28, 1852	.....	.....	1.52	2.07	2.15	2.23	2.33	2.40	2.48	2 51	3.02	3.06	.....	.....
May 26, 1852	1.36	1.45	1.55	2.07	2.14	2.24	2.38	2.49	2.53	3.11	3.06	3.19	3.14	3.15
24, 1852	1.37	1.43	2.11	2.24	2.28	2.30	2.53	2.57	3.05	3.08	3.20	3.22	3 38	3 38
Feb. 3, 1852	1.46	1.59	2.15	2.19	2.26	2.40	2.52	2.58	3.02	3.10	3.12	3.14	3.28	3.18
4, 1852	1.39	1.55	2.07	2.18	2 35	2.39	2.47	3.19	3.02	2.48	2.54	3.01	3.06	3.16
16, 1852	1.33	1.54	2.05	1.29	2.25	2.33	2.42	2.55	3.00	3.04	3.13	3 19	3.19	3 31
March 13, 1852	1.43	1.53	2.06	2.17	2.29	2.28	2.47	2.50	3.07	3.07	3.11	3.24	3 32	3.30
28, 1852	1.38	1.49	2.00	2.08	2.14	2.25	2.32	2.37	2.45	2.58	.....	.....	3.12	3.11
Feb. 29, 1852	1.39	1.57	2.10	2.19	2.25	2 43	2.49	2.53	3.07	3.18	3.27	3.40	3.46	3.47
June 2, 1852	1.44	1.52	2.05	2.18	2.30	2.35	2.49	2.49	2.52	2.57	3.09	3.20	3.15	3 27
Feb. 5, 1852	1.16	1.25	1.33	1.34	1.42	1.44	1.50	1.59	2.07	2.07	2.13	2.20	2.21	2.28
Jan. 15, 1852	1.27	1.41	1.44	1.14	1.48	1.53	1.58	2.03	2.07	2.08	2.15	2.20	2.23	2.30
18, 1852	1.41	1.51	2.03	2.11	2.23	2.34	2.41	2.41	2.52	2.59	3.10	3.15	3.28	3.23
March 31, 1852	2.07	2.23	2.29	2.46	2.56	3.06	3.13	3.14	3.20	3.33	3.36	.....	.....	3 53
May 31, 1852	1.35	1.55	2.10	2.20	2.30	2 55	3.00	3.05	3.15	3.15	3.25	3.35	3.40	3.50
Feb. 13, 1852	1.47	2.05	2.15	2.29	2.29	2.38	2.53	2.55	3.10	3.10	3.16	3.30	3.30	3.32
Jan. 24, 1852	1.35	1.49	1.59	2.14	2.16	2.27	2.30	2.41	2.47	2.55	3.05	3.12	3.15	3.18
April 9, 1852	1.42	1.56	2.11	2.16	2.38	2.43	2.42	2.15	2.57	3.05	3.05	3.07	3.47	3.52
June 4, 1852	1.42	2.07	2.03	2.19	2.37	2.39	2.52	3.09	3.20	3.24	3.33	3.48	3.44	3.49
Jan. 25, 1852	1.37	1.48	1.52	1.58	2.20	2.14	2.21	1.58	2.39	2.43	2.52	2.50	3.03	3.11
27, 1852	1.40	2.00	2.05	2.13	2.22	2.30	2.38	2.47	2.55	2.58	3.12	3.12	3.16	3.25
June 6, 1852	1.41	1.55	2.04	2.15	2.25	2.33	2.38	2.47	2.52	3.00	3.05	3.20	3.19	3.26
8, 1852	1.48	2.00	2.12	2.20	2.28	2.42	2.52	2.55	3.08	3.15	3.20	3.20	3.35	3.36
Jan. 31, 1852	1.45	2.09	2.31	2.43	3.00	3.12	3.17	.....	3.30	3.33	3.46	3.55	3.44	.....
June 14, 1852	1.19	1.28	1.40	1.48	1.53	2.02	2.20	2.28	2.32	2.50	2.50	2.58	3.01	3.02
Jan. 29, 1852	1.50	1.59	2.12	2.14	2.45	3.22	2.53	2.48	2.57	3.02	3.14	3.17	3.18	3.14
June 12, 1852	.....	1.41	1.49	1.51	1.58	2.02	2.10	2.14	2.26	2.32	2.32	2.34	2.42	2.36
Average interval	1.39	1.53	2.03	2.10	2.23	2.32	2.40	2.43	2.54	3.00	3.07	3.12	3.18	3.21
Number of casts	25	26	27	27	27	27	27	26	27	27	26	25	25	25

FATHOMS.	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800
INTERVALS.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
June 28, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
May 26, 1852	3.20	3.35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
24, 1852	3.51	3.50	3.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Feb. 3, 1852	3.25	3.18	3.46	2.49	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
4, 1852	3.32	3.56	4.02	4.11	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16, 1852	3 30	3.32	3.42	3.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
March 13, 1852	3.30	3.42	4.02	3.50	3.51	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
28, 1852	3.16	3.14	3.24	3.25	3.43	.....	.....	3.38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Feb. 29, 1852	4.00	4.07	4.13	4.15	4.23	4.33	4.46	4.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
June 2, 1852	3.36	3.46	3.54	3.58	3.39	3.50	4.02	4.07	4.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Feb. 5, 1852	2.37	2.42	2.45	2.52	2.50	2.50	3.06	3.07	3.17	2.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jan. 15, 1852	2.27	2.32	2.39	2.45	2.42	2.54	2.54	2.51	3.01	2.57	3.12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
18, 1852	3.28	3.33	3.36	3.50	3.50	4.07	4.06	4.12	4.06	4.14	4.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
March 31, 1852	4.05	3.44	3.51	3.32	4.03	3.55	3.38	2.56	3.53	4.12	4.39	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
May 31, 1852	4.45	4.00	3.00	3.59	4.01	4.00	4.15	4.10	4.20	4.15	4 20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Feb. 13, 1852	3.30	3.46	4.25	3.39	4.11	4.01	4.03	3.35	3.59	4.02	4.15	5.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jan. 24, 1852	3.22	3.28	3.29	3.35	3.43	3.44	3.50	3.56	4.04	3.59	4.13	4.22	4.21	.....	.....	.....	.....	.....	.....	.....	.....	.....
April 9, 1852	3.49	3.55	4.02	3.58	3.05	4.05	3.40	5.27	4.50	4.15	.....	4.20	4.30	.....	.....	.....	.....	.....	.....	.....	.....	.....
June 4, 1852	4.06	4.19	4.06	4.15	4.15	4 25	4.15	4.59	4.41	4 48	4.52	5.00	4.53	5.28	.....	.....	.....	.....	.....	.....	.....	.....
Jan. 25, 1852	3.17	3.17	3.30	3.31	3.37	3.37	3.48	3.44	3.57	3.58	4.00	4.02	4.00	4.13	4.11	4.10	.....	.....	.....	.....	.....	.....
27, 1852	3.31	3.43	3.48	3.54	4.11	3.50	4.01	4.07	4.07	4.24	4.26	4.21	4.47	4.35	5.34	5.52	.....	.....	.....	.....	.....	.....
June 6, 1852	3.33	3.38	3.45	3.49	3.52	4.00	4.07	4.11	4.15	4.25	4.26	4.29	4.29	4.34	5.12	5 12	.....	.....	.....	.....	.....	.....
8, 1852	3.49	3.50	3.54	3.56	4.00	4.06	4.23	4.16	4.25	4.27	4.40	4.36	4.32	4.35	4.52	5.03	6.15	.....	.....	.....	.....	.....
Jan. 31, 1852	4.16	4.15	4.24	4.27	.....	.....	4.24	4.17	4.47	4.49	5.10	4.57	5.00	5.18	5.27	6.48	7.25	8.07	.....	.....	.....	.....
June 14, 1852	3.08	3.26	3.30	3.35	3.38	3.39	3.46	3.52	4.02	4.08	4.12	4.16	4.24	4.31	4.31	4.36	4.37	4.39	.....	.....	.....	.....
Jan. 29, 1852	3.25	3.28	3.29	3.33	3.38	3.34	3.40	3.33	3.34	3.31	3.43	4.07	5.25	4.08	4.20	4.59	4.39	5.09	4.22	.....	.....	.....
June 12, 1852	2.43	2.41	2.44	2.44	2 46	2.51	2.53	2.59	3.07	3 07	3.08	3.08	3.09	3.10	3.10	3.10	3.12	3.13	3.20	3.23	3.28	3.34
Average interval	3.31	3.35	3.40	3.40	3.41	3.46	3.52	3.55	4.01	4.01	4.15	4.27	4.30	4.30	4.39	4.58	5.13	5.17	3.51	3.23	3.28	3.34
Number of casts	26	26	25	24	20	18	19	20	18	17	15	12	11	9	8	8	5	4	2	1	1	1

Time of descent for every 100 *fathoms. Two* 32 *lb. shot; small line. U. S. Brig Dolphin*—(LEE.)

	FATHOMS.									
	300	400	500	600	700	800	900	1000	1100	1200
	INTERVALS.									
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
November 23, 1851	1.30	1.38	1.50	2.10	.....	.....	.....	.....	.....	.....
30, 1851	1.20	1.34	1.46	2.00	.....	.....	.....	.....	.....	.....
December 14, 1851	1.35	1.47	1.56	2.00	.....	.....	.....	.....	.....	.....
January 3, 1852	1.23	1.31	1.45	1.49	.....	.....	.....	.....	.....	.....
6, 1852	1.18	1.30	1.40	1.45	.....	.....	.....	.....	.....	.....
14, 1852	1.09	1.18	1.33	1.38	.....	.....	.....	.....	.....	.....
November 30, 1852	1.21	1.34	1.40	1.56	2.02	.....	.....	.....	.....	.....
December 16, 1852	1.49	1.17	1.58	2.03	2.07	.....	.....	.....	.....	.....
17, 1852	1.30	1.37	1.50	1.59	2.10	.....	.....	.....	.....	.....
January 20, 1852	1.11	1.24	1.18	1.37	2.07	.....	.....	.....	.....	.....
November 28, 1852	.....	1.47	2.00	2.01	2.17	2.15	.....	.....	.....	.....
January 9, 1852	1.16	1.27	1.34	1.43	1.54	2.01	.....	.....	.....	.....
7, 1852	1.18	1.32	1.40	1.47	1.52	1.58	2.08	2.15	2.26	.....
7, 1852	1.15	1.25	1.30	1.42	1.53	1.58	2.10	2.14	2.24	.....
November 30, 1852	1.13	1.34	1.38	1.37	1.52	1.50	2.00	2.03	2.04	2.12
December 16, 1852	1.24	1.41	2.48	1.57	2.42	1.16	2.22	2.33	2.39	2.39
January 13, 1852	1.10	1.20	1.32	1.43	1.48	2.02	2.10	2.17	2.20	2.33
December 15, 1852	1.30	1.40	2.14	1.46	2.16	2.19	2.18	2.27	2.42	2.40
7, 1852	1.31	1.41	1.55	1.47	2.01	2.50	2.21	2.26	2.37	3.37
10, 1852	1.32	1.45	1.53	2.01	2.11	2.17	2.20	2.33	2.40	2.38
November 24, 1852	1.28	1.42	2.15	2.30	2.13	2.27	2.27	2.43	2.40	2.25
December 13, 1852	1.35	1.42	1.53	2.00	2.02	2.17	2.12	2.38	2.35	2.42
January 9, 1852	1.19	1.33	1.41	1.48	1.55	2.10	2.13	2 21	2.31	2.38
December 1, 1852	1.30	1.44	1.58	2.04	2.13	2.23	2.30	2.46	2.49	2.47
January 12, 1852	1.02	1.07	1.13	1.19	1.25	1.28	1.36	1.35	1.41	1.44
November 30, 1852	1.28	1.42	1.53	1.57	2.09	2.19	2.29	2.30	2.39	2.50
January 11, 1852	1.14	1.30	1.40	1.46	1.59	2.03	2.14	2.20	2.29	2.36
19, 1852	1.16	1.24	1.34	1.42	1.52	2.02	2.13	2.19	2.23	2.28
Average interval	1.22	1.33	1.47	1.52	2.03	2.06	2.14	2.22	2.29	2.36
Number of casts	27	28	28	28	22	18	16	16	16	14

	FATHOMS.													
	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600
	INTERVALS.													
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
November 23, 1851	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
30, 1851	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
December 14, 1851	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
January 3, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
6, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
November 30, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
December 16, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
January 20, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
November 28, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
January 9, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
November 30, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
December 16, 1852	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
January 13, 1852	2.41	3.44	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
December 15, 1852	2.46	2.51	3.00	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
7, 1852	.....	.....	3.16	3.21	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
10, 1852	2.52	2.37	2.48	3.05	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
November 24, 1852	2.41	3.11	3.08	3.40	3.25	.....	.....	.....	.....	.....	.....	.....	.....	.....
December 13, 1852	2.49	2.55	3.00	3.06	3.09	3.17	3.28	.....	.....	.....	.....	.....	.....	.....
January 9, 1852	2.47	2.58	2.57	3.00	3.13	3.10	3.17	.....	.....	.....	.....	.....	.....	.....
December 1, 1852	3.06	3.07	3.24	3.22	3.25	3.45	3.39	3.50	3.55	.....	.....	.....	.....	.....
January 12, 1852	1.47	1.48	1.52	1.57	1.56	2.04	2.07	2.10	2.15	.....	.....	.....	.....	.....
November 30, 1852	2.57	3.10	3.12	3.21	3.27	3.29	3.46	3.39	3.47	3.52	.....	.....	.....	.....
January 11, 1852	2.39	2.51	2.56	3.00	3.13	3 12	3.24	3.29	3.29	3.36	3.40	3.40	3.57	.....
19, 1852	2.32	2.38	2.47	2.48	2.58	3.01	3.03	3.12	3.18	3.17	3.23	3.24	3.34	3.43
Average interval	2.41	2.54	2.56	3.04	3.06	3.08	3.15	3.16	3.21	3.25	3.31	3.32	3.45	3.43
Number of casts	11	11	11	10	8	7	7	5	5		2	2	2	1

Table showing the intervals of descent for every 100 fathoms.

DATE.	FATHOMS. 100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100
	INTERVALS.																				
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
October 7, 1852	1.05	1.22	1 38	1.45	1 55	2.09	3.46	2.08	2.28	2.38	....	....	....	....	....	....	....	....	....	....	....
February 2, 1853	1.00	1.00	1.30	1.30	1.55	1.50	2.00	4.35[1]	2.40	2.40	2.50	3.00	3.00	3.00	3.20	3.00	....	....	....	....	....
October 25, 1852	1.00	1.20	1.40	2.15	2.30	1.15[1]	2.10	2.30	1.30[1]	2.30	3.30	3.00	3.30	3.15	2.25[1]	3.00[1]	3.40	3.40	....	....	....
February 9, 1853	0 59	1.09	1.20	1.35	1.51	1.57	2.05	2.20	2.27	2.45	2.41	2.47	3.08	3.11	3.17	3.34	3.32	3.36	3.53	3 49	4.00
January 3, 1853	0.56	1.12	1.25	1.36	1.44	1.52	2.03	2.10	2.17	2.32	2.39	2.46	3.00	3.00	3.06	3.09	3.17	3.28	3.35	3.40	3.45
29, 1853	1.00	1.16	1.29	1.43	1.51	2.01	2.09	2.22	2.38	2.36	3.08	3.01	3.04	3.21	3.09	3.22	3.41	3.44	3.50	4.10	4.00
30, 1853 *a*	1.00	1.15	1.31	1.42	1.57	2.06	2.17	2.23	2.37	2.43	2.47	3.00	3.04	3.18	3.22	3.25	3.31	3.54	3.38	3 45	3.55
February 5, 1853 *b*	0.45	1.00	1.45	1.40	1.50	2.00	2.10	2.40	2.30	2.45	2.50	3 01	3.15	3.05	3.20	3.45[1]	3.35	3.40	3.50	4.20	4.10
October 10, 1852 *c*	1.15	1.28	1.40	1.57	2.00	2.18	2.22	2.30	2.50	2.50	3.45	2.50	3.15	3.30	3.30	3.25	3.25	3.30	3.50	4.05	4.05
January 9, 1853 *d*	0.59	1.18	1.28	1.40	1.55	1.59	2.11	2.20	2.28	2.32	2.49	2.55	2.53	3.23	2.58	3.19	3.18	3.34	3.26	3.30	4.02
February 4, 1853 *e*	0.40	1.00	1.20	1.30	1.50	2.05	2.05	2.30	2.15	2.35	2.30	2.50	2.55	3.00	3.05	3 20	3.30	3.30	3.30	3.40	3.40
January 9, 1853 *f*	0.45	1.15	1.25	1.35	2.00	1.50	2.10	2.10	2.20	2.30	3.00	2.45	2.55	3.00	3.00	3.30	3.00	3.20	3.10	3.25	3.55
October 24, 1852 *g*	1.01	1.34	1.33	1.47	2.00	2.05	2.16	2.20	2.37	2.51	2.53	3.09	3.11	3.19	3.25	3.33	3.43	3.45	3.56	4.02	4.07
9, 1852 *h*	4.03[1]	1.40	2.06	2.08	2.32	2.38	2.47	2.55	3.11	3.23	3.31	3.34	3.41	3.45	3.48	3.47	3.45	3.51	3.53	4.08	4.05
11, 1852 *i*	1.05	1.29	1.40	1.53	2.08	2.19	2.29	2.37	2.42	2.48	2.55	3.09	3.16	3.25	3.23	3.29	3.28	3.32	3.39	3.41	3.49
20, 1852 *k*	1.00	1.00	2.00	1.40	1.50	2.30	2.10	2.30	2.20	2.30	2.30	3.15	2 18	2.27	2.45	2.55	2.20	3.10	3.40	3.40	4.10[1]
February 13, 1853 *l*	....	1.16	1.32	1.31	1.50	2.00	2.22	2.07	2.38	2.39	2.36	3.00	3.00	3.00	3.20	3.30	3.30	3.40	3.50	3.50	3.50
23, 1853 *m*	....	....	1.35	1.45	1.54	1.58	2.10	2.23	2.27	2.30	2.35	2.50	2.55	3.00	3.15	3.09	3.16	3.25	3.28	3.37	3.40
26, 1853 *n*	0.55	1.20	1.40	2.50	2.00	1.48[1]	2.24	2.36	2.37	2.42	2.55	3.03	3.04	3.21	3.13	3.44[1]	3.31	3.42	3.48	4.12	3.58
Average interval....	0.55	1.16	1.35	1.47	1.58	2.06	2.19	2.25	2.33	2.40	2.55	2.59	3.05	3.11	3.15	3.22	3.25	3.35	3.41	3.51	4.03
Number of casts....	16	18	19	19	19	17	19	18	18	19	18	18	18	18	17	15	17	17	16	16	15

[1] The times marked with a small figure ([1]) are omitted in the means, as evidently incorrect.

Time of descent for every 100 fathoms. Two 32 lb. shot;

DATE.	FATHOMS. 100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
	INTERVALS.													
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
August 12, 1853	1.00	1.20	1.33	3.40	2.02	2.12	2.22	2.25	2.38	2.58	2.50	....	....	....
July 24, 1853	1.06	1.26	1.40	1.50	2.00	2.10	2.25	2.30	2.40	2.50	3.00	3.10	....	....
21, 1853	1.00	1.20	1.35	1.45	2.00	2.10	2.20	2.30	2.50	2.45	2.55	3.05	3.15	3.25
20, 1853	1.00	1.20	1.35	1.45	1.55	2.05	2.16	2.26	2.36	2.46	2.54	2.47	3.05	3.15
October 11, 1853	1.03	1.20	1.35	1.44	1.54	....	....	....	....	....	....	....	....	....
August 10, 1853	1.00	1.21	1.39	1.48	1.55	2.07	2.19	2.21	2.38	2.37	2.48	2.57	3.10	3.25
14, 1853	1.00	1.12	1.25	1.37	1.50	2.06	2.08	2.20	2.34	2.48	2.48	2.58	3.00	3.20
June 17, 1853	0.56	1.15	1.27	1.33	1.54	1.57	2.08	2.16	2.31	2.33	2.35	2.45	2.52	3.00
21, 1853	1.19	1.28	1.41	1.51	2.01	2.14	2.28	2.34	2 44	2.51	3.07	3.09	3.16	3.53
August 15, 1853	1.00	1.20	1.35	1.35	1.50	2.00	2.10	2.20	2.30	2.30	2.30	2.45	2.55	3.00
July 4, 1853	0.55	1.15	1.30	1.40	1.50	2.00	2 12	2.24	2.24	2.35	2.45	2.45	2.55	3.05
2, 1853	1.05	1.25	1.35	1.47	1.58	2.13	2.26	2.43	2.33	2.49	2.55	3.00	3.05	3.13
October 2, 1853	1.03	1.17	1.30	1.44	1.56	2.05	2.18	2.27	2.47	2.41	2.52	3.06	3.14	3.30
September 21, 1853	1.00	1.17	1.36	1.47	2.00	2.05	2.13	2.22	2.33	2.50	2.50	3.00	3.10	3.05
July 16, 1853 *a*	1.05	1.20	1.35	1.50	2.05	2.10	2.15	2.25	2.35	2.45	2.45	2.45	2.55	3.05
September 23, 1853 *b*	0.40	1.10	1.20	1.35	1.45	1.55	1.55	2.10	2.20	2 30	2 30	2.40	2.35	3.00
24, 1853 *c*	1.02	1.18	1.30	1.42	1.58	2.08	2.08	2.28	2.38	2.48	2.52	2.58	3.00	3.05
June 10, 1853 *d*	1.13	1.22	1.35	1.45	1.50	1.56	2.09	2.15	2.20	2.27	2.38	2.51	2.54	2.55
24, 1853 *f*	0.58	1.17	1.35	1.42	1.53	2.03	2.14	2.25	2.25	2.38	2.50	3.00	3.02	3.03
7, 1853 *g*	0.56	1.14	1.25	1.40	1.50	1.53	2.02	2.10	2.25	2.25	2.30	2.42	2.43	2.50
October 3, 1853 *h*	1.03	1.15	1.29	1.39	1.42	2.00	2 00	2.08	2.20	2.30	2.35	2.40	2.45	2.50
November 4, 1853 *k*	1.06	1.19	1.37	1.50	2.14	2.12	2.25	2.40	2.48	2.54	3.06	3.21	3.20	3.35
June 14, 1853 *l*	1.14	1.29	1.42	1.53	2.01	2.11	2.18	2.35	2.39	2.42	2.48	2.56	3.00	3.05
Average interval....	1.02	1.19	1.33	1.49	1.55	2.05	2.15	2.24	2.34	2.41	2.48	3.01	3.01	3.10
Number of casts....	23	23	23	23	23	22	22	22	22	22	22	21	20	20

Two 32 lb. shot; small line. From boat Dolphin—(BERRYMAN.)

....	FATHOMS. 2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500
	INTERVALS.																							
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
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....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	3.47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	4.00	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
a.	3.59	4.01	4.15	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
b.	4.10	4.00	4.00	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
c.	4.00	4.00	3.51[1]	4.47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
d.	4.04	3.51	3.49	4.09	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
e.	3.55	4.15	4.00	4.05	4.00	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
f.	3.30	3.40	4.20	3.50	4.10	4.00	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
g.	4.13	4 18	4.30	4.39	4.52	5.08	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
h.	4.15	4.14	4.26	4.49	4.53	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
i.	4.06	4.18	4.18	4.21	4.24	4.23	4.25	4.30	4.36	4.39	4.44	4.46	4.50	....	....	....	....	....	....	....	....	....	....	....
k.	3.00[1]	3.50	4.10	6.20[1]	5.15	2.15[1]	3.30	3.30	7.10[1]	5.50	7.20[1]	4.10	7.00[1]	5.10	4.20	5.05	6.45	7.30	6.50	6.55	5.15	8.00	7.00	6.50
l.	4.00	4.20	4.10	4.10	4.00	4.10	6.00[1]	12.20[1]	9.00[1]	12.20[1]	13.30[1]	13.00[1]	14.15[1]	12.15[1]	....	....	....	....	....	....	....	....	....	....
m.	3.48	3.57	3.52	3.58	4.02	4.13	4.15	4.35	4.30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
n.	3.52	4.00	4.35	4.30	4.25	4.25	4.30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	3.58	4.03	4.12	4.19	4.27	4.28	4.10	4.09	4.33	5.14	4.44	4.28	4.50	5.10	4.20	5.05	6.45	7.30	6.50	6.55	5.15	8.00	7.00	6.50
	14	13	12	10	9	6	4	3	2	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1

small line. From boat Dolphin—(BERRYMAN.)

....	FATHOMS. 1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
	INTERVALS.															
	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.	m. s.
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	3.25	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	3.20	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	3.19	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	3.04	3.14	4.00	....	....	....	....	....	....	....	....	....	....	....	....	....
....	3.33	3.38	3.42	3.50	....	....	....	....	....	....	....	....	....	....	....	....
....	3.00	3.10	3.30	4.10	....	....	....	....	....	....	....	....	....	....	....	....
....	3.05	3.10	3.22	3.22	4.06	....	....	....	....	....	....	....	....	....	....	....
....	3.22	3.33	3.17	3.33	3.42	3.55	....	....	....	....	....	....	....	....	....	....
....	3.30	3.30	3.50	3.45	4.00	3.55	4.05	....	....	....	....	....	....	....	....	....
....	3.15	3.15	3.25	4.00	3.50	3.55	3.35	4.20	....	....	....	....	....	....	....	....
a.	3.10	3.15	3.20	3.25	3.30	3.36	3.47	3 47	3.55	3.55	....	....	....	....	....	....
b.	3.10	3.20	3.20	3.30	3.30	3.45	3.55	3.50	4.00	4.10	4.20	....	....	....	....	....
c.	3.15	3.15	3.30	3.30	3.40	3.50	4.00	4.00	4.00	4.15	4.25	....	....	....	....	....
d.	3.10	3.20	3.21	3.26	3.28	3.32	3.46	3.47	3.52	4.02	4.02	4.08	....	....	....	....
f.	3.12	3.53	3.30	3.42	3.46	3.32	3.45	3.57	4.07	4.01	3.38	4.52	....	....	....	....
g.	3.00	3.05	3.08	3.12	3.20	3.35	3.45	3.50	3.55	3.45	4.00	4.03	4.07	....	....	....
h.	3.55	3.19	3.29	3.21	3.11	3.26	3.50	3.36	3.37	3.45	4.45	4.15	3.45	....	....	....
k.	3.36	3.33	3.56	3.54	4.07	4.17	4.15	4.41	4.27	4.37	4.56	4.40	5.10	4.51	5.15	....
l.	3.10	3.14	3.27	3.24	3.43	3.43	3.48	3.38	3.40	3.50	4.40	4.03	4.40	4.50	4.17	4.17
	3.14	3.18	3.30	3.36	3.41	3.45	3.51	3 57	3.58	4.02	4.16	4.20	4.25	4.50	4.45	4.17
	19	16	16	15	13	12	11	10	9	9	8	6	4	2	2	1

Time of descent for every 100 *fathoms. One* 32 *lb. shot; small line. From boat Dolphin*—(Berryman.)

	100	200	300	400	500	600	700	800	900	1000	1100	1200
	FATHOMS.											
	INTERVALS.											
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
October 22, 1853, *a*................	1:00	1.25	1.45	2.00	2.13	2.21	2.32	2.45	2.55	3.03	3.07	3.27
20, 1853..................	0.53	1.17	1.40	2.01	2.10	2.23	2.26	2.47	2.51	....	....	3.42
23, 1853, *b*	1.11	1.30	1.51	2.09	2.25	2.41	2.50	3.06	3.15	3.24	3.41	3.46
18, 1853, *c*	1.03	1.24	1.44	2.00	2.20	2.32	2.47	2.55	3.04	3.13	3.25	3.37
13, 1853, *d*	1.10	1.27	1.45	2.07	2.24	2.34	2.51	3.03	3.06	3.17	3.25	3.38
27, 1853, *e*	0.55	1.21	1.44	1.56	2.17	2.32	2.35	2.46	2.56	3.04	3.14	3.15
Average interval	1.02	1.24	1.45	2.02	2.18	2.30	2.40	2.54	3.01	3.12	3.22	3.34
Number of casts..............	6	6	6	6	6	6	6	6	6	5	5	6

	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800
	FATHOMS.															
	INTERVALS.															
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
a.	3.37	3.37	3.57	4.02	4.14	4.22	4.13	4.37	4.44	4.47	....	....	....	....	....	....
	3.30	3.27	3.41	....	....	4.10	4.16	....	....	....	4.52	5.15	....	....	....	....
b.	4.06	4.06	4.27	4.28	4.33	4.42	4.49	5.02	5.06	5.12	5.26	....	....	....	....	....
c.	3.46	3.53	4.02	3.57	4.20	4.23	4.22	4.36	4.47	4.30	5.03	5.00	....	....	....	....
d.	4.19	3.57	4.01	4.16	4.24	4.30	5.03	4.35	4.47	5.25	5.02	5.02	5.26	5.29	5.41	....
e.	3.27	3.19	3.29	3.36	4.04	3.51	4.05	4.04	4.13	4.21	4.21	4.25	4.37	4.26	4.38	4.47
	3.41	3.43	3.54	4.04	4.19	4.20	4.28	4.35	4.43	4.51	5.08	4.55	5.01	4.58	5.09	4.47
	5	6	6	5	5	6	6	5	5	5	5	4	2	2	2	1

Average time of descent for every 100 *fathoms. Two* 32 *lb. shot; small line. From mean of soundings by Lieutenants S. P. Lee and O H. Berryman*, 1851, '52, '53.

	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
Mean of soundings—(Lee)........	......	......	1.22	1.33	1.47	1.52	2.03	2.06	2.14	2.22	2.29	2.36	2.41	2.54	2 56	3.4	3.6
Do............(Berryman)..	0.56	1.16	1.35	1.47	1.58	2.06	2.19	2.25	2.33	2.40	2.55	2.59	3.05	3.11	3.15	3.22	3.25
Do..............do....	1.02	1.19	1.33	1.49	1.55	2.05	2.15	2.24	2.34	2.41	2.48	3.01	3.01	3.10	3.14	3.18	3.30
Average interval	0.58	1.17	1.30	1.43	1.53	2.01	2.12	2.18	2.27	2.34	2.44	2.52	2.56	3.05	3.08	3.14	3.23
Number of casts	39	41	69	70	70	67	63	58	56	57	56	53	49	49	47	41	41

	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100	4200	4300	4400	4500
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
Mean of soundings—(Lee)	3.8	3.51	3.16	3.21	3.25	3.31	3.32	3.45	3.43	......	....	...	....	....	...	....	....	....	....	....	....	....	....	....	....	....	....	....
Do (Berryman)	3.35	3.41	3.51	4.03	3.58	4.03	4.12	4.19	4.27	4.28	4.10	4.09	4.33	5.14	4.44	4.28	4.50	5.10	5.20	5.05	6.45	7.30	6.50	6.55	5.15	8.00	7.00	6.50
Do do	3.36	3.41	3.45	3.51	3.57	3.58	4.02	4.16	4.20	4.25	4.50	4.45	4.17	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Average interval	3.26	3.32	3.37	3.45	3.47	3.51	3.55	4.06	4.10	4.26	4.30	4.27	4.25	5.14	4.44	4.28	4.50	5.10	5.20	5 05	6.45	7.30	6.50	6.55	5.15	8.00	7.00	6.50
Number of casts	39	36	33	31	27	24	23	20	16	11	6	5	3	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1

Table showing the intervals of descent for every 100 *fathoms. One* 32 *lb. shot; small line. From mean of soundings by Lieutenants S. P. Lee and O. H. Berryman*, 1851, '52, '53.

	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
Mean of soundings—(Lee)	....	....	1.51	2.09	2.25	2.39	2.49	2.58	3.13	3.24	3.31	3.45	3.45
Do............(Berryman)..	1.02	1.24	1.45	2.02	2.18	2.30	2.40	2.54	3.01	3.12	3.22	3.34	3.41
Average interval..............	1.02	1.24	1.12	2.05	2.21	2.34	2.44	2.56	3.07	3.18	3.26	3.39	3.43
Number of casts	6	6	35	35	35	35	33	32	33	31	27	27	24

	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
Mean of soundings—(Lee)	3.57	4.07	4.13	4.20	4.26	4.31	4.39	4.4	4.48	4.54	5.13	5.01	4.56	5.27	4.30	4.44	4.40
Do (Berryman)	3.43	3.54	4.04	4.19	4.20	4.28	4.35	4.43	4.51	5.08	4 55	5.01	4.58	5.09	4.47	....	....
Average interval	3.50	4.00	4.08	4.19	4.23	4.29	4.37	4.45	4.49	5.01	5.04	5.01	4.57	5.18	4.38	4.44	4.40
Number of casts	24	25	22	22	23	21	17	13	11	10	8	6	5	5	2	1	1

It will be remarked how much more rapidly the line went out from the Albany, than it did to the same weight (one 32 lb. shot) from the Dolphin's boat.

It will be also noted how very uniform is the rate of descent in the last of the Dolphin's tables, and in which two 32 lb. shot were used. This was on her last cruise, when the soundings were intrusted entirely to one officer—young Mitchell—and when the boat's crew had become so *au fait* at the business that they claimed to tell by "the feel" of the line when the shot touched bottom. These results are highly satisfactory; they do Mitchell great credit, and I point to them as a model for others.

It is very evident that a shot will sink at the same rate whether dropped overboard from a ship or a boat. We account, then, for the apparently more rapid rate of descent from the Albany by the greater drift of the vessel; for, of course, as she fell off and gathered headway, she slipped from under the line, which increased its rate of going out. We, therefore, are forced to the conclusion that the Gulf of Mexico and Caribbean Sea are not so deep as, from the Albany's soundings, these two basins were supposed to be.

Indeed, the ocean generally is not quite so deep as this system of deep-sea soundings would represent it. The under currents operate upon the line; it bends to them, and, of course, the sounding reported is rarely, if ever, a true "up and down" measure.

It will be observed how much the waxing of the line increases its rate of descent.

Many of the irregularities in these tables of the Dolphin are owing to changes in the size of the line. Lieutenant Lee weighed his, and found it to vary from 100 to 114 lbs. per 10,000 fathoms.

The human mind delights in the marvellous; and there is no subject which those who cater for it are likely to seize upon with more avidity than upon the reports which are now and then made of the enormous depths to which the plummet has descended in the deep sea without reaching bottom. It is always desirable to prevent error from building up its edifices in the popular mind; for, when truth comes along, it has first to pull these down, and to contend with many difficulties in removing the vast amount of rubbish that falsehood may have made, before it can begin a single structure.

It seems, therefore, the proper time, now that so much has been done with the Atlantic Ocean, in the way of sounding it out, to review the great depths, and the erroneous soundings which have been reported from time to time.

First referring to Plate XI, and the fifth edition of this work, there is the great wire cast of 5,700 fathoms from the Taney. This always, in my judgment, required confirmation, because of the material used. The other soundings, near the same place on the chart, render the probability of any such depth of water in that part of the ocean still more questionable.

I, therefore, in the shadings of this plate, requested Professor Flye, by whom the lines were drawn, not to regard it.

Besides this, there are the soundings of 5,200 fathoms by the Plymouth, in latitude 37° 28′ N., longitude 56° 32′ W.; of 5,070 by the St. Louis, in latitude 36° 16′ N., longitude 46° 52′ 15″ W.; and of 4,000 by the Jamestown, latitude 36° N., longitude 27° 20′ W., all of which are reported without bottom, and all of which were marked as doubtful from the first, owing to the evidence furnished by the official reports which were made with them to this office.

With regard to the Plymouth's sounding, no time except the total was kept. The cast was made from the vessel; and during the operation the wind and sea increased so much, says Captain Kelly, "that I deemed it advisable to part the line and await a more favorable opportunity, not being able to sound with any accuracy."*

In the case of the St. Louis, the sounding was made from a boat; pains were taken to keep the line up and down, but the shot was timed only by the 1,000 fathoms. And though Captain Ingraham reported bottom, the intervals, in my judgment, did not indicate such a depth, and, therefore, the note of interrogation was applied, expressive of doubt, and that doubt remains.*

The Jamestown simply reports no bottom; and on board that vessel the supposition that bottom in any case had been reached, "arose from the fact that the line paying out briskly would suddenly cease, and on being hauled in would for a moment come up very heavily, and then, as though the weight of the shot had parted from it, come up easily."†

It was not supposed that the depth of the ocean could be so great so near the Western Islands; hence the note of interrogation, which I ventured to attach to that sounding; the propriety of which Berryman's soundings seem now to confirm.

I have practically erased the last; and though I doubt the other two, yet, as they are in a part of the ocean where soundings are scarce, and where vessels frequently go, I have left them there with the hope that they would tempt some navigator to get a true sounding, and so erase them, or the mark of doubt.

With regard to the other soundings, which I had no reason, at the time they were made, to doubt, but upon which subsequent results have thrown light sufficient to cause them to be erased entirely, or seriously questioned, I may simply remark, that in this class, among others, is included Captain Barron's sounding of 5,500 fathoms in the John Adams, latitude 32° 06′ N., longitude 44° 47′ W. This cast was made from the ship. The shot was timed by the 1,000 fathoms, but the officers were sure, from "*feeling of the line*," which is no index at such depth, that bottom had been reached. Several good and accurate soundings have been since made near the same place by the Dolphin, and from a boat, which show the depth to be less than 3,000 fathoms. Hence the erasure of Barron's cast. Captain Wullerstorf, of the Austrian exploring frigate Navara, reports in a letter from Rio, August, 1857, a deep-sea sounding made on his way out in latitude, 27°.2 N.; longitude, 27° 7′ W., "with 4,050 fathoms without bottom." He used a Brooke's apparatus, but timed only the 1,000 fathom marks on his line. The 4th thousand occupied more than twice the time in going out that the 2d did, by which I inferred that the shot had reached bottom.

There is a number of other soundings, especially those very great ones which are marked with the sign of "no bottom," to which I have attached notes of doubt (?) on Plate XI.

Though I had no reason to question their accuracy at first, yet subsequent and reliable soundings seem to show that the sea there is not as deep as they indicate it to be.

Since, however, the great wire sounding of Lieutenant Walsh, in the Taney, was made in 1849, and for full details of which see the fifth edition of this work, three others, with a greater length of line out, have been made. They deserve special notice, for I think all of them are in error as to depth.

One of these casts was of 8,300 fathoms, by Lieut. J. P. Parker, of the United States frigate Congress, 4th April, 1852, latitude 35° 35′ S., longitude 45° 10′ W. Another, of 7,706 fathoms, by Captain Denham, of her Majesty's ship Herald, 30th October, 1852, latitude 36° 49′ S., longitude 37° 06′ W. And the other, of 6,600 fathoms, by Lieut. O. H. Berryman, com-

*See Maury's Sailing Directions, page 213, 5th ed. † Ibid.

manding United States brig Dolphin, 12th February, 1853, latitude 32° 55′ N., longitude 47° 58′ W.

The first two casts, it will be observed, were made within 400 miles of each other, and with the same twine; for Commodore McKeever supplied, from the stock on board the Congress, 15,000 fathoms to the Herald. The plummet used by Captain Denham was a 9 pound lead. It is much to be regretted that he did not use a 32 pound shot; for then, his line being the same, his sounding might have been compared with our own with far greater satisfaction.

Captain Denham's last 706 fathoms (from 7,000 to 7,706) went out at the rate of four-fifths of a mile per hour. He had a 9 pound lead as a sinker. Now let us ask any sailor who is familiar with the resistance made by lines when towed through the water, whether, in his opinion, a force of 9 pounds could tow eight miles length of line, three-tenths of an inch in circumference, at the rate of four-fifths of a mile the hour? Moreover, his eight thousand fathoms went out faster than his fifth. Surely, a 9 pound lead would not drag a line 7,000 fathoms long, and upwards, through the water faster than it would drag one out 4,000 fathoms in length.

It is probable that there is in all parts of the deep sea one or more under currents of greater or less velocity. Nature, by her ways, indicates this; reason, with her lights, suggest it; and experiment seems to confirm it. Our experience in deep-sea soundings is now considerable; and seldom, indeed, has it occurred that the line has ceased going out after the shot has reached bottom. And I suppose it is the currents of the sea, coursing through their channels of circulation, that continue to take it out.

Suppose where Captain Denham sounded there had been but one under current, and that that had a rate of only one-tenth of a mile per hour; the line, then, that his 9 pound sinker had to tow through the water, instead of being straight was probably a curve. It may in reality have been a curve of several convolutions; for, for aught we know, there may be in the deep sea several strata of currents, as we know there often are several strata of winds, one above the other, in the atmosphere.

Parker, of the Congress, gives the time of every 500 fathoms, after the first 300 had gone out; Denham, of the Herald, is more systematic: he gives the time of every 100 fathoms from the beginning; Berryman, of the Dolphin, on the contrary, is less so: he gives the time for every 500, for the first 1,500 fathoms, then for every 200, till he reached 2,500 fathoms; then for 400, then for 1,000, then for 100, and so on at irregular intervals, which impairs the value of his results. Denham's is the best in this respect. Now, to compare them fairly, we must have them all for like intervals. I therefore compute Berryman's as far only as is necessary to make them correspond with Parker's times and intervals, arranging Denham's accordingly.

This being done, let us compare the times of the three casts together, referring them also to the average rate of descent determined by actual experiment, (see pp. 140, 141,) that we may see the difference of rate at which the same line will run out, as Parker's and Denham's, to sinkers of different weights, as well as the depths at which all uniformity as to rate of descent begins to disappear.

FATHOMS.	INTERVALS.		
	8,300 fathoms; 32 lb. shot.	7,706 fathoms; 9 lb. lead.	6,600 fathoms: 46 lb. shot.
	Congress.	Herald.	Dolphin.
	m. s.	m. s.	m. s.
From 300 to 800	8 45	14 20	12 06
800 to 1,300	11 00	18 25	12 51
1,300 to 1,800	13 00	19 30	15 07
1,800 to 2,300	15 00	22 00	20 07
2,300 to 2,800	19 00	23 50	24 11
2,800 to 3,300	37 00	28 20	25 53
3,300 to 3,800	51 00	39 20	28 00 } 1,000 fathoms.
3,800 to 4,300	28 00	43 40	34 00
4,300 to 4,800	33 15	42 25	47 22
4,800 to 5,300	34 45	47 50	52 16
5,300 to 5,800	34 00	53 50	64 50
5,800 to 6,300	34 30	55 05	70 32
6,300 to 6,800	21 30	53 55	72 34
6,600 to 7,300	27 00	52 25	....
7,300 to 7,800	38 30	44 14	....
7,800 to 8,300	21 00	....	....

I do not recollect the size of the Dolphin's twine; it is evident, however, that this, as well as all other sounding-twine, requires force to pull it from the reel, and to drag it down through the depths of the ocean; that the deeper the plummet, and the greater the length of line to be dragged down, the greater the resistance, and therefore the slower the rate at which the line goes out.

Hence, we may deduce a rule which, as a general one, may be taken as correct, viz: that when the line ceases to go out at something like a regularly decreasing rate, there is no reliance to be put upon the sounding after the change; and that when the rate of going out becomes uniform—or now fast, now slow—the plummet has probably ceased to drag the line down, and the force which continues to take the sounding line out is due to the wind, currents, heave of the sea, or drift—one, some, or all.

Let us apply this rule to these casts: That of the Congress fulfilled these conditions, as to a tolerably regular decreasing rate, to the 2,800 fathoms mark. The rates after that indicate pretty clearly that, whatever might have been the agent which continued to take the line out, it was not the sinking of the 32 pound shot. There is an appearance of too much uniformity in the rate after that. Therefore, I infer that when the 2,800 fathoms mark went out the shot was probably on or near the bottom; and that, where this sounding was made, the ocean, instead of being some 8,300 fathoms deep, is not more than 3,000.

The Herald's plummet fulfilled the conditions, generally, of a decreasing rate, until the 4,300 fathoms mark went out; and after this the rate becomes of such a character as to justify the conclusion that the 9 lb. sinker used had then ceased, or nearly ceased, to descend, if it were not already on the bottom.

The care with which Captain Denham observed every 100 fathoms mark, and timed it as it went out, enables us to detect, probably, more closely in his soundings than in either of the others, the time when his plummet ceased to sink.

From 100 to 700 fathoms each 100 fathoms mark required between two and three minutes to go out; from 700 to 1,600, each mark required between three and four minutes; from 1,600 to 2,700, each mark required between four and five minutes; from 2,700 to 3,000, each required between five and six minutes. Here the times begin to become irregular; the 3,200 and 3,300 marks each took between six and seven minutes to go out. After this, there is no more regularity as to the increasing times. Every 100 fathoms mark thereafter appears to have a rate of its own, varying from seven to twelve minutes—but now fast, now slow—and in such a manner as to justify the inference that the ocean, where the Herland reports 7,706 fathoms, is probably not more than 4,000 fathoms deep. It was probably the wind, or some agent at the surface, that caused the irregularity as to time, after the 4,300 fathoms mark went out.

The Dolphin had the heaviest plummet and the largest line. The time required with her for each of the first 500 fathoms marks to run out was longer than the Congress, but shorter than the Herald. But after the 4,300 fathoms mark of the Herald went out, then the Herald's line was the swifter; then it assumed, approximately at least, the condition of equal lengths in equal times; whereas, the Dolphin's continued to decrease its rate, and to go slower and slower, till the 6,300 fathoms mark went out. She sent down 6,600 fathoms; the interval, therefore, from 6,300 to 6,800 is computed. The inference, therefore, would be that, if the weight had not reach bottom before, it ceased to go down about the time the 6,300 fathoms mark went out.

But the sounding was not made with the usual care; and, with the lights now before me, no such inference as to depth is admissible.

By aid of the law which a careful examination of the tables, pp. 132–141, will indicate, we can tell very nearly when the ball ceased to carry the line out, and when, of course, it began to go out in obedience to the current and drift alone; for currents sweep the line out at a uniform rate, while the cannon ball drags it out at a decreasing rate.

The development of this law certainly was an achievement, for it enabled us to show that the depth of the sea at the places named (§ 157) was not as great as reports made it. These researches were interesting; the problem in hand was important, and it deserved every effort that ingenuity could suggest for reducing it to a satisfactory solution.

As yet, no specimens of the bottom had been brought up. The line was too small, the shot too heavy, and it could not be weighed. In this state of the case, Passed Midshipman J. M. Brooke, United States Navy, who, at the time, was associated with me on duty at the Observatory, proposed a contrivance by which the shot, on striking the bottom, would detach itself, and send up the line with a specimen of the bottom. See Plates VII and VIII. With this contrivance specimens of the bottom have been brought up from the depth of two miles.

§ 165. We come now to the soundings made by the United States steamer "Arctic," Lieut. O. H. Berryman, in the summer of 1856.

By an act of Congress, approved March 3, 1849, the Secretary of the Navy is directed to assist me in certain researches concerning the physics of the sea. The following is the joint resolution which express the wishes of Congress in the matter:

"SECTION 2. *And be it further enacted,* That the Secretary of the Navy be directed to detail three suitable vessels of the navy in testing new routes and perfecting the discoveries made by Lieut. Maury in the course of his investigations of the winds and currents of the ocean; and to cause the vessels of the navy to co-operate in procuring materials for such investigations, in so far as said co-operation may not be incompatible with the public interest: *Provided,* That the same can be accomplished without any additional expense."

Under this law Lieut. Berryman was sent out in the steamer "Arctic" in 1856, as in 1853 he was sent in the United States brig Dolphin. Much was expected of this cruise of 1856, for it was to be made in a steamer, the first vessel of the kind that had been sent to assist me in these researches; she was provided with the means of hauling up the line by steam, and the main object of her cruise was to throw light upon the discovery that had been made of a submarine ridge or steppe between Newfoundland and the British Islands, which had been named the "Telegraphic Plateau."

A company, profiting by this important discovery, was preparing to lay a submarine telegraph along this ridge; the attention of the world was directed to this enterprise, and, therefore, much interest was attached to the service upon which the "Arctic" was sent, and much was expected of her.

It will be observed that every officer who makes deep-sea soundings is required by regulations (p. 116) and special orders (pp. 116–17) to make them "faithfully," in such a manner, and with such notes and explanations, that the work may be sifted and its accuracy tested at the proper office; that hitherto all the officers had done this, and by this means we were enabled successfully to challenge for accuracy the soundings of the "Herald," the "Dolphin," and the "Congress," *et. al.*, to eliminate error elsewhere and to construct Plate XI. *But on board the "Arctic" no such record was kept;* and every circumstance or fact by which the accuracy of her soundings might be scrutinized and error eliminated was kept back.

These soundings have been the subject of much discussion by those who have had no access to the "Arctic's" journal. I therefore quote all that part of her abstract log which relates to them. It was copied by Lieut. Fillebrown, and includes every entry in the log from the day of leaving Newfoundland for Valentia till the return of the vessel to Newfoundland again, save and except the meteorological observations, such as temperature of air and water at hours other than at noon.

It is the official record which Berryman, both by general orders and special instructions, was required to keep and return to the Navy Department.

Abstract Log of the United States Steamer Arctic, Lieut. O. H. Berryman, commanding. From St. John's, Newfoundland, to Ireland.

[Extracts.]

July 31, 1856.—Wind SW., rate, 4; barometer, 30.50 inches; thermometer attached, 75°; dry bulb, 52°; wet bulb, 51°; form of clouds cir. stra., 0; temperature at surface, 48°; state of the weather, c. During this day cloudy, with misty weather. At 11.15 got underweigh for Valentia Bay. At 6 P. M. commenced our line of soundings in 96 fathoms water; bottom green ooze. At 9 sounded in 180 fathoms water; bottom of the same nature as at 6. At 11 passed a large iceberg.

August 1.—Latitude 48° 46′ N.; longitude 50° 25′ W.; wind SW. 4; barometer, 30.29; thermometer, attached, 66°; dry bulb, 51°; wet bulb, 49°; clouds cir. cu., 0; temperature of water at surface, 43°; weather, c. m.

During the day moderate SW. winds and misty weather. At 1.30, 6, and 10 A. M. sounded in 98, 85, and 120 fathoms water; bottom green ooze, gravel, sand, and mud. At 8.10 discovered an iceberg bearing NE. by E. ¾ E.; passed it about five miles distant. Saw a quantity of sea weed. At 2 P. M. ran out 1,900 fathoms line. In reeling in line, joints of little engine leaked very badly, the reel working very slowly, and sometimes stopping entirely. At 6 a large iceberg in sight, bearing S. ½ W. At 8 finished reeling in line. The lead used was one of Stellwagen's, split at the top, and a 40 pound lead, with an iron bar in the upper part, bolted into the split; weight, 110 pounds. Specimens of bottom, drab colored mud. Dew falling during the latter part of the day. Engineers and gang repairing steam reel.

August 2.—Latitude 40° 03′ N.; longitude 49° 34′ W.; magnetic variation, 3 points W.; wind westward, 4; barometer, 30.14; thermometer attached, 66°; dry bulb, 55°; wet bulb, 56°; clouds, frg. proportion, sky clear, o; surface temperature, 48°; weather, c. Commences with, and during the day, dense fog. At 12.30 ran out 900 fathoms line. At 9 sent port quarter boat to sound; at 11 she returned, reporting bottom at 1,150 fathoms. Filled away. Ends sounded in 1,150 fathoms. Did not recover specimen of bottom. At 11.30 hove to and commenced sounding; passed a small iceberg. During the day and night engaged in repairing steam reel.

August 3.—Latitude 49° 50′ 30″ N.; longitude 47° 30′ W.; currents, no observations; magnetic variations, 3¼ points W.; wind northward and westward, 3; barometer, 30.12; thermometer, attached, 68°; dry bulb, 55°; wet bulb, 55°; clouds, nimbus; proportion of sky clear, o; surface temperature, 53°.

At 12.30 finished sounding, having had 1,600 fathoms of line out. At 9.35 sounded in boat with small line in 1,700 fathoms. Water smooth. Ends repairing steam reel. Furled all sail. Cut with a chisel the 3,000 fathoms line from the reel. At 5 P. M. sounded with boat in 1,250 fathoms line. State of the weather, c. m.

August 4.—Latitude 50° 15′ N.; longitude 44° 40′ W.; magnetic variation, 3 points W.; wind, N.W. 5; barometer, 30; thermometer attached, 72°; dry bulb, 52°; wet bulb, 52°; clouds circum. sa.; proportion of sky clear, 0; surface temperature, 54°; state of weather, c.

Commences; made two attempts to sound with small line and a 100 pound lead with Massey's indicator; lost both leads and indicators and about 3,000 fathoms of line, owing to defect in the line. At 9 hove to under fore and aft sail; drifting to the southward and eastward one knot per hour. Fresh gales during the latter part of the day.

August 5.—Latitude 50° 11′ N.; longitude 43° 45′ W.; current N. 85 E., 59 miles; magnetic variation, 3¼ points W.; wind northerly, 4; barometer, 30.25; thermometer attached, 68°; dry bulb, 53°; wet bulb, 53°; clouds circum. st.; state of the sea irregular; surface temperature, 54; state of the weather, b. c. Weather during the day cloudy and misty. At 9 A. M. turned reefs out of mainsail and set jib; light rain at 11.30. At 8 P. M. commenced sounding and ran out 3,000 fathoms line, having Brooke's apparatus and Massey's indicator attached.

August 6.—Latitude 50° 15′ N.; longitude 43° 08′ W.; magnetic variation, 3¼ points W.; wind northward, 6; barometer, 30.10; thermometer attached, 67°; dry bulb, 55°; wet bulb, 55°; clouds nimbus; proportion of sky clear, 0; sea rough; surface temperature, 53°; weather, o. m.

Weather misty and rainy at intervals. At 12.30 while reeling in line parted it after getting back 500 fathoms. Made sail to mainsail, fore-topsail jib, and fore-topmast staysail. At 1 A. M. stopped engine and banked fires. Hove to under reefed mainsail, fore-trysail, fore-topmast, staysail, and jib. At 8 P. M. stowed jib.

August 7.—Latitude 50° 19′ N.; longitude 41° 52′; current N. 85° E., 29.6 miles. magnetic variation, 3¼ points W.; wind N. by E., 6; barometer, 30.04; thermometer attached, 66°; dry bulb, 56°; wet bulb, 55°; clouds cir. sa.; proportion of sky clear, 0; sea rough; surface temperature, 54°; weather, b. c. Hove to during the day under fore and aft sails. Saw several fin back whales and porpoises during the day. A large number of gulls about the ship.

August 8.—Latitude 50° 03′ N.; longitude 40° 51′ W.; magnetic variation, 3¼ points W.; wind N.NE., 4; barometer, 30.12; thermometer attached, 68°; dry bulb, 55°; wet bulb, 56°; clouds cir. cum.; proportion of sky clear, 0; surface temperature, 54°; weather, c. m. Commences, sea smooth; commenced sounding at 11.30 A. M. from on board; lost a 150 pound lead; ran out 4,500 fathoms line and commenced reeling in. At 6 P. M. brought up spindle; Massey's indicator showing 1,500 fathoms; bottom a soft drab clay, with a gritty substance intermixed. Spoke an English brig bound to St. John's. At 6 set all plain sail, except foretop gallantsail. At 9 took in main topmast staysail; heavy sea from the northward. Water remarkably luminous.

August 9.—Latitude 50° 20′ N.; longitude 38° 51′ W.; current SW. by W. ½ W., 15 miles; magnetic variation, (chart,) 36° W.; wind NE. 5; barometer, 30.13; thermometer attached, 69°; dry bulb, 57°; wet bulb, 56°; clouds nimbus; proportion of sky clear, 2; heavy sea; surface temperature 56°; weather o. m.

Northeasterly winds and thick foggy weather. At 6 A. M. furled sails, and prepared to sound with one hundred pound lead, Massey's indicator and two Saxton's thermometers; one near the lead, the other at 800 fathoms. At 6.18 let go lead. At 8 stopped paying out at 3,000 fathoms line, and commenced reeling up. At 11.15 brought up the spindle with Massey's indicator, showing 1,564 fathoms line; Saxton's thermometers at 800 fathoms, indicating 21°; the one at the lead, 23°. The cylinder of the lower thermometer brought up a quantity of bottom, of drab colored mud and small shells; a few pieces of coal were found on the frame. The thermometer, at 800 fathoms, also contained same, and had apparently been on the bottom. At 11.30 filled away under all plain sail. At mid reduced sail and sounded in 1,600 fathoms. Specimens of bottom of same nature as last cast.

August 10.—Latitude 51° 04′; longitude 36° 33′ W. G.; current, no observation; magnetic variation, 3¼ points W.; wind, N. by W., rate, 2; barometer, 30.02; thermometer attached, 71°; dry bulb, 56°; wet bulb, 57°; clouds cir. cu. stra; proportion of sky clear, 0; temperature at surface, 56°; weather, c. During the day light NW. winds and cloudy weather. At 3.45 finished reeling in line. Thermometer at 800 fathoms below surface, by No. 3 Saxton's thermometer, was + 24°. Black fish around the ship during the day; also a number of sea birds. At 9.30 passed an English propeller standing to the westward. Set port steering sails. At 3.45 commenced sounding, having a Saxton thermometer at the lead, and at 500 fathoms below surface. In reeling up parted the line at 50 fathoms from above the lead, loosing a Saxton thermometer and Massey's indicator. Got another cast; Massey's indicator showing 1,650 fathoms. Temperature at bottom, by Saxton's thermometer, 33°. Water remarkably phosphorescent.

August 11.—Latitude 51° 15′ N.; longitude 34° 08′; wind northward and eastward. Sounding in 1,680 fathoms water; bottom drab colored clay. At 3.20 filled away under all drawing sail. We were much delayed, owing to line parting and shot not detaching.

August 12.—Latitude 51° 49′; longitude 31° 48′ W. G.; current S. 23° E., rate 16¾; variation, 37° W.; wind N.NE., rate 5; barometer, 29.86; thermometer attached, 69°; dry bulb, 57°; wet bulb, 58°; clouds nimbus; proportion of sky clear, 3; surface temperature, 57°; weather o. r. Commences squally. Sounding from 3 to 6 A. M. in 2,070 fathoms water. Specimens obtained, yellowish clay. At 6 P. M. sounded in 2,000 fathoms water; in reeling in a splice drew, and we lost 1,300 fathoms line, Massey's indicator, spindle, and lead. At 8 filled away under all plain sail, and banked fires.

August 13.—Latitude 52° 22′ N.; longitude 29° 05′ W. G.; current SE. by ¼ E., 19 miles; variation, 37° W.; wind northward, rate, 5; barometer, ——; thermometer attached, 69°; dry bulb, 57°; wet bulb, 58°; clouds circum. sa., southward; proportion of sky clear, 3; state of the sea, r.; surface temperature, 57° 5; weather, b. c.

Wind fresh, weather squally and rainy; a heavy swell from northward and northeastward. At 6.20 A. M. commenced sounding from the vessel. At 10 finished sounding; depth 2,000 fathoms; bottom drab clay mixed with sand; filled away. At 10 P. M. shortened sail and commenced sounding; ran out 2,400 fathoms of line, and commenced reeling in.

August 14.—Latitude 52° 23′ N.; longitude 26° 23′ W. G.; current S. 56° E., 22 miles; variation, 37° W.; wind, N.NE., 2; barometer, 30.00; thermometer attached, 71°; dry bulb, 59°; wet bulb, 58°; surface temperature, 59°; weather, 1; light wind and smooth sea. At 1. finished reeling in; Massey's indicator showed 1,830 fathoms; bottom of drab clay mixed with fine sand and shells. At 10 A. M. sounded in 1,920 fathoms, as shown by Massey's indicator; shot was not detached, probably owing to softness of bottom, as specimens came up. At 1.30 furled square sails. Hoisted the coal out of forehold and stowed it in the bunkers.

August 15.—Latitude 51° 59′; longitude 24° 27′ 45″ W.; current S. by E. ¾ E., 15 miles; variation, 37° W.; wind northward and eastward, 3; barometer, 30.10; thermometer attached, 69°; dry bulb, 59; wet bulb, 58°; clouds cir. stra., southward; proportion of sky clear, 2; sea smooth; surface temperature, 59°; smooth sea. Sounded in 1,813 fathoms, bottom drab clay with fine sand. Under all sail and steam. At 5 P. M. double reefed fore-topsail, and furled fore-topgallant sail and main-topmast staysail. Wind increasing towards midnight to fresh gales. Weather squally. Banked fires.

August 16.—Latitude 51° 45′ N.; longitude 22° 52′ W.; variation 34° W.; wind variable, 6; barometer, 30.05; thermometer attached, 69°; dry bulb, 60°; wet bulb, 60°; clouds nimbus, SW.; proportion of sky clear, o; surface temperature, 62°; weather, c. q. r. Commences weather squally. At 7.15 A. M. got up steam. Sounded in 1,650 fathoms water; bottom drab clay. At midnight passed a large ship standing to the westward.

August 17.—Latitude 51° 45′ N.; longitude 20° 45′ W. Current S. 66° E. 22 miles; variation, 33° west; wind NE. 3; barometer, 29.90; thermometer attached, 73°; dry bulb, 60°; wet bulb, 60°; clouds nimbus; proportion of sky clear, 1; surface temperature, 60°; weather, b. c. q. r. At 6 sounded in 1,590 fathoms; drab clay; filled away under steam, and all fore-and-aft sail; at 6 P. M. spoke an English brig bound to St. Johns, Newfoundland; at 8 P. M. sounded in 1,543 fathoms; bottom of drab clay.

August 18.—Latitude 51° 48′ N.; longitude 18° 40′ W. G.; current S. 40° E., 20 miles; variation 32° W.; wind, NE. by N., 2; barometer, 29.92; thermometer attached, 72°; dry bulb, 63°; wet bulb, 61°; clouds circus strà.; proportion of sky clear, 4; surface temperature, 63.5; weather, b. c. Made two unsuccessful attempts to sound from the vessel on account of the line parting at each attempt in reeling in. Sent boat to sound; she was unsuccessful, the line parting as before. The surface of the sea covered with animalculæ; caught and preserved some of them; they appeared to be a minute kind of a squid, triangular shaped, with a hard transparent shell, covering a dark body like that of an insect; they were exceedingly active, moving with great rapidity.

August 19.—Latitude 52° 01′ N.; longitude 17° 07′ W. G.; current S. 84° E., 20 miles;

variation, $2\frac{3}{4}$ points W.; wind S. by E., 2; barometer, 29.83; dry bulb, 65°; wet bulb, 65°; clouds circum., southward and westward; proportion of sky clear, 5; surface temperature, 61°. Made an attempt to sound at 5 A. M.; lead returned with no evidence of bottom; Massey's indicator showing 1,640 fathoms; strong evidence of current in the lower strata during the attempt to sound. Temperature at depth of 20 fathoms same as at surface, 62°. At 1.25 P. M. sounded in 1,905 fathoms; specimens of drab clay. Noticed a number of small snakes in the water. This last cast was made with two parts of large size sounding line from the vessel, and a 120 lb. lead; for time of running see log.

August 20.—Latitude 52° 04′ 30″ N.; longitude 15° 40′ W.; current S. 58° E., 9.5 miles; variation, $2\frac{1}{2}$ points W.; wind, E.NE.; clouds, cir. cum. westward; proportion of sky clear, 6; weather, b. c. At 2 A. M. commenced sounding with three parts of large sized sounding twine. At 5.28 brought back spindle and Massey's indicator; quills full of specimens of bottom of yellow clay; Massey showing 1,518 fathoms. At 5.20 P. M. sounded in 410; bottom drab clay. Banked fires; passed a large ship standing to the westward. Double reefed fore-topsail, and stowed the jib.

August 21.—Latitude 51° 51′ 30″ N.; longitude 13° 31′ W.; current SE., 17 miles; variation $2\frac{1}{2}$ west; wind N.NE., 6; barometer, 29.95; thermometer attached, 67°; dry bulb, 58°; wet bulb, 59°; clouds cir. cum., SW.; proportion of sky clear, 4; sea heavy; surface temperature, 61°; weather, b. c. q. Commences fresh gales and squally weather. Massey's machine, used as a wind gauge, gave 80 miles as the velocity of the wind during the squalls; water deep blue. At 1.30 P. M. sounded in 410, and at 9 P. M. in 717 fathoms of water; bottom bluish mud.

August 22.—Wind N. by W., 3; dry bulb, 61°; wet bulb, 66°; clouds, cir. cum.; proportion of sky clear, 3; surface temperature, 62°; weather, b. c. At 6 A. M. sounded in 114 fathoms water; bottom coarse gray sand; made Skilling lights. At 12 they bore N.NE.; got aloft and set fore-top gallantsail; showed colors to a barque standing to the eastward; spoke a coast pilot boat. At 7 Fasnet light bore, per binnacle compass, NE. $\frac{1}{2}$ E. At 11.20 commenced steaming, wind being very light; coal very low down.

August 23.—At 12.30 passed an English steamer going to the westward. At 8 Kinsale light bore, per compass, NE., distant $4\frac{1}{4}$ miles. At 10 received a Cork pilot. At 12.30 came to in the harbor of Queenstown, in 7 fathoms of water. The American consul visited the ship. Was boarded by an officer from H. B. M. screw ship of the line, Duke of Wellington. Received fresh provisions for.

Abstract Log of the United States Steamer Arctic, Lieut. O. H. Berryman, commanding, from Queenstown, Ireland, to St. Johns, Newfoundland.

September 11.—Wind north, 2; proportion of sky clear, 7; weather, b. c. At 1 A. M. hauled out of dry-dock and made preparations for steaming out. At 1.50 cast off and stood down the harbor under steam. At 3 discharged pilot and made all sail except fore-topmast staysail. At 5.25 A. M. Kinsale light bore NW. by W. $\frac{1}{2}$ W.; during the day standing along the land to the westward.

September 12.—Latitude 50° 56′ N.; longitude 12° 48′ W.; wind northward, 3; dry bulb, 61°; wet bulb, 63°; clouds cir. cum., southward; surface temperature, 62°; weather, c. Reeled 2,000 fathoms line on reel. Unshipped the capstan from the forecastle as it attracted the

the standard compass. At 11.30 furled all sail. At 2 a brig on starboard bow standing to southward.

September 13.—Latitude 51° 52′ N.; longitude 13° 40′ 30″ W.; wind NW. by N. 4. Barometer, 30.46; thermometer attached, 70°; dry bulb, 62° 5′; wet bulb, 63°. Clouds cir. cum., proportion of sky clear, 1; surface temperature, 61°; weather, b. c. Passed a hermaphrodite brig standing to southward. Heavy swell from northward. At 9.45 hove to and got a cast of the lead in 255 fathoms water; bottom blue mud. At 10.15 filled away and set all fore-and-aft sail. At 11 stopped the engine and banked fires. At 10 a large ship passed us standing to the southward.

September 14.—Latitude 51° 21′; longitude 14° 51′ W.; current S. 22°, W. 22 miles; W.NW., 4; barometer, 30.42; thermometer attached, 70°; dry bulb, 62°; wet bulb, 64°; clouds cir. cum., eastward; proportion of sky clear, 2; sea smooth; surface temperature 61°; weather, b. c. At 2.10 A. M. braced around to a breeze from the westward and got up steam. At 9 under all plain sail. At 9 P. M. tacked to the westward.

September 15.—Latitude 51° 31′ N.; longitude 16° 00′ 08″ west Greenwich; wind W.NW., 4; barometer, 30.49; thermometer, 69°; dry bulb, 62°; wet bulb, 62°; clouds nimbus, southward and eastward; proportion of sky clear, 0; state of the sea, b; surface temperature, 61°; weather, c. q. Passed an English brig bound to Bristol. Furled all square sails.

September 16.—Latitude 50° 39′; longitude 17° 37′ 15″; current SE. by E., 12 miles; wind NW. ½ W., 2; barometer, 30.49; thermometer attached, 71°; dry bulb, 63°; wet bulb, 61°; clouds nimbus, eastward; proportion of sky clear, 0; state of the sea, heavy swell; surface temperature 62°; weather, c. Furled sails; passed a ship standing to southward and westward; at 11 set fore-and-aft sails; at 3.30 made all plain sail to northard; banked fires.

September 17.—Latitude 51° 57′ N.; longitude 18° 54′ W.; current SW., 15 miles; magnetic variation, chart, 3¼ points W.; wind W.NW., 5; barometer, 30.15; thermometer attached, 66°; dry bulb, 60°; wet bulb, 60°; clouds nimbus, southward and eastward; proportion of sky clear, 2; surface temperature, 60°; weather, b. c. q. p. d. At 3.30 P. M. braced around to a breeze from the eastward, and took in fore-trysail, fore-topmast staysail; set steering sails and started the engines.

September 18.—Latitude 51° 59′; longitude 22° 43′ 20″ W.; current SW., 15 miles; variation, 3 points W.; wind southward and eastward, 3; dry bulb, 61°; wet bulb, 62°; proportion of sky clear, 6; surface temperature, 61°; weather, b. c. At 8 down jib and squared yards, set all port steering sails, and took in mainsail. 8 P. M. in all starboard steering sails and braced up on port tack.

September 19.—Latitude 51° 56′ N.; longitude 27° 01′ 45″ W.; current W. by S., 17 miles; variation, 3 points W.; wind SW. by W., 3; barometer, 30° 48′; thermometer attached, 71°; dry bulb, 61°; wet bulb, 62°; clouds nimbus NE.; proportion of sky clear, 3; sea smooth; temperature at surface, 60°; weather, c. m. Making and reducing sail as necessary; at midnight banked fires.

September 20.—Latitude 51° 19′ N.; longitude 30° W.; variation, 3½ points W.; winds NW. by W., 5; barometer, 30.20; dry bulb, 59°; wet bulb, 59°; clouds nimbus, S.E.; proportion of sky clear, 7; state of the sea, b; surface temperature, 60°; weather, b. c. q. r. At 7.30 got up steam and went ahead with the engine; going along for the most of the day under single reefed fore-topsail. Passed a barque standing to the southward and eastward.

September 21.—Latitude 49° 38′ N.; longitude 32° 48′ W.; current S. 40° W., 22 miles;

variation, 3 points; wind northward and westward, 4; barometer, 30° 42′; dry bulb, 60°; wet bulb, 61°; clouds nimbus, southward and eastward; proportion of sky clear, 8; surface temperature, 60°; weather, b. c. During the day moderate sea on; under steam and sail for the most part of the day.

September 22.—Latitude 49° N.; longitude 34° 11′ W.; variation, 3½ points W.; wind northward, 4; dry bulb, 63°; wet bulb, 63°; clouds nimbus, southward and eastward; proportion of sky clear, 6; state of the sea, moderate; surface temperature, 61°; weather, b. c. A large number of black fish around the ship. At 3.20 banked fires, and made all sail on the port tack.

September 23.—Latitude 50° 08′ N.; longitude 35° 22′ W.; variation chart, 3½ points W.; wind N.NE., 4; barometer, 30.25; thermometer attached, 68°; dry bulb, 57°; wet bulb, 57°; clouds cum., southward and eastward; proportion of sky clear, 0; surface temperature, 58.5; weather, c. Going to the westward under all drawing sail and steam.

September 24.—Latitude 49° 46′ N.; longitude 39° 43′; variation 3½ points W.; wind southward and eastward, 7; barometer, 30.13; thermometer attached, 72°; dry bulb, 64°; wet bulb, 64°; proportion of sky clear, 1; surface temperature, 62°; weather, c. Going along under sail and steam. Got inboard starboard quarter boat. All starboard quarter steering sails set.

September 25.—Latitude 49° 32′ N.; longitude 42° 51′ W.; variation, 3¼ points W.; wind NW., 2; barometer 30.30; thermometer attached, 71°; dry bulb, 61°; wet bulb, 62°; clouds cir. cum., wetsward; proportion of sky clear, 0; sea moderate; surface temperature, 62°; weather, c. At 8 A. M. furled sail; from mer to mid saw a large number of porpoises. At 10.30 set fore-and-aft sails.

September 26.—Latitude 49° 49′ N.; longitude 44° 40′ W.; current S. 65° E., 9.4 miles; variation, 36° W.; wind westward, 4; dry bulb, 58°; wet bulb, 58°; clouds cir. cum., northward; proportion of sky clear, 1; sea smooth; surface temperature, 60°; weather, b. c. The aurora borealis very brilliant. Passed a large brig-rigged steamer standing to the eastward. At 1 shortened sail and sounded in 1,627 fathoms. Made all fore-and-aft sails.

September 27.—Latitude 49° 49′ N.; longitude 46° 36′ 45″ W. G.; current S. 14° W., 4 miles; variation chart, 35° W.; wind northward and westward, 2; barometer, 30.39; thermometer attached, 66°; dry bulb, 59°; wet bulb, 59°; clouds nimbus, eastward; proportion of sky clear, 6; sea smooth; surface temperature, 56°; weather, b. c. Sounded at 4.30 A. M. in 1,827 fathoms of water; bottom drab clay; also in 1,590 at 1 P. M.; bottom drab clay.

September 28.—Latitude 49° 36′ N.; longitude 49° 05′ W.; variation, 34° W.; wind southward and eastward, 3; barometer, 30.24: thermometer attached, 66°; dry bulb, 55°; wet bulb, 55°; clouds cir., eastward; proportion of sky clear, 0; surface temperature, 56°; weather, f. Sounded in 1,080 fathoms, 732 and 465 fathoms; bottom drab clay and green ooze.

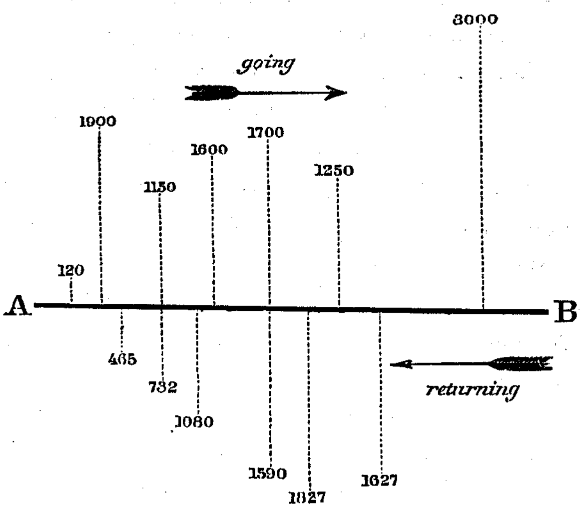
September 29.—Latitude 48° 14′ N.; longitude 50° 02′ W.; variation, 33° W.; wind W. by S., 8; barometer, 30.02; thermometer attached, 64°; dry bulb, 50°; wet bulb, 50°; clouds nimbus; proportion of sky clear, 0; surface temperature, 50°; weather, c. q. Hove to for the most of the day; banked fires; passed several flocks of ducks; lost log reel and line overboard.

September 30.—At 1 made a revolving light on Cape Spear. At 6.15 A. M. let go anchor in St. John's harbor, in 7 fathoms water; veered to 20 fathoms.

The first thing in these notes that strikes one is their baldness—the fact that they make no mention of any experiment to test the several "Massey's indicators" used in sounding. That they all had errors is more than probable, and that some had very large errors is certain, for the soundings made on the homeward passage did not agree with the soundings made on the voyage outward, and the "indicator," even in moderate depths as on the common charts, did not agree with the soundings there given. Thus where the French, in their soundings in the survey of Newfoundland, gave 154 fathoms, Berryman with his "indicator" made out no more than 120.

All the soundings returning from Valentia were made—with one exception and that gave 250 fathoms where the chart of the soundings going showed 760—between the meridian of 43° west, and the 120 fathom cast, which was the last cast on the Grand Banks going out. Between this and 43° west the log shows six casts with bottom going and six returning.

The annexed wood-cut represents these soundings in their order and relative position in profile. The figures above the line A B show the soundings going; those below show the soundings returning. One set is entitled to as much weight as the other, and it is certain that both cannot be right.



The next thing in these notes that strikes attention is the manner in which the record is kept. This vessel was fitted out by law especially to co-oporate with me in perfecting important discoveries.* She was provided with more than ordinary facilities therefor, and yet the work is so loosely done that we cannot search it; nor does her sounding book (abstract log) even give the position of the vessel when the casts were made. It gives the position for noon only, and then simply states they sounded at such and such hours.

This journal in other respects bears upon its face the evidence of great carelessness, to say the least. As an example, the wet bulb thermometer is frequently, I might say generally, recorded as being no lower, or actually higher, than the dry.

Under these circumstances I directed an official examination and report upon the work of the "Arctic:" her abstract log, two manuscript charts, and Berryman's report to the Secretary of the Navy, the result of which is as follows:

NAVAL OBSERVATORY, WASHINGTON, *July* 11, 1857.

SIR: In obedience to your order of the 10th instant, we have carefully examined the report of Lieutenant Berryman of the soundings made by the United States steamer "Arctic," between Newfoundland and Ireland in 1856, with the accompanying charts and the abstract log, and report as follows:

We find that many discrepancies exist between the charts and log, as well as between the charts themselves; and, also, that in some places the report itself differs from both the charts and the log.

The first line of soundings commenced July 31 and terminated August 22. Chart No. 1 purports to show a profile of the bottom according to these soundings. Chart No. 2 purports,

* See law of 3d March, 1849, directing the Secretary of the Navy to assist me with three small vessels (p. 146.) The "Arctic" was sent out under this law.

also, to have been drawn in August, 1856, but gives soundings taken in September on the return passage.

Sounding No. 2, in the report and on the charts, is marked 150 fathoms; in the log as 180.

Sounding No. 6, on chart No. 1, is given as 1,100 fathoms; in the report, and on chart No. 2, as 370; by the log it is 1,900.

Between soundings Nos. 7 and 8 of chart No. 1 the log gives two others of 1,600 and 1,700 fathoms, which are not shown on either charts or report.

No. 7 of chart No. 1 is 1,150 fathoms; on chart No. 2 it is 732 fathoms.

No. 12 of chart No. 2 is marked 1,650 fathoms; in the log and report it is 1,627 fathoms.

No. 13 of chart No. 2, taken by the report on August 6, is marked 1,600 fathoms; on chart No. 1 it is 1,400, and by the log 3,000.

No. 14 of chart No. 2 is 1,590 fathoms; but on chart No. 1, and in the report and log, it is 1,500.

No. 22 is given in the report and log as 1,920 fathoms; and on both charts as 1,930.

No. 27 in the report, and both charts, is 1,750 fathoms; in the log it is 1,640.

No. 31 in the report, log, and on chart No. 2, is 255 fathoms; on chart No. 1 it is 760.

Besides these above mentioned discrepancies, the log also shows others which we are unable to reconcile. We refer, as an illustration, to the remarks on the 11th August. It is, moreover, so meagre and inexplicit that we have often been left in doubt as to its meaning, and were unable to determine whether soundings were obtained or not. It is our opinion, therefore, that the work is unreliable, and that any results derived from such data would be of little value.

Very respectfully, your obedient servants,

R. WERDEN,
Lieutenant United States Navy.
R. AULICK,
Lieutenant United States Navy.
J. S. HUBBARD,
Professor of Mathematics, U. S. N.

Lieutenant M. F. MAURY,
Superintendent U. S. Naval Observatory, Washington, D. C.

It was from such data as this abstract log affords, that Lieut. Berryman constructed and submitted to the Navy Department two charts, each with a profile of the bottom of the Atlantic between Trinity Bay, Newfoundland, and Valentia, Ireland. Neither of these charts agrees with the log; and they differ widely from each other. They give soundings that are not in the log; and the log gives soundings that are not on them. Copies of these charts got into the hands of the Telegraph Company without the knowledge of the Navy Department, or of this office. Not suspecting their accuracy, the company had them lithographed and circulated broadcast.

The depths of the ocean as there given by this company* were received by the world as correct, and published extensively both in this country and Europe.

Thus error has gone forth. It is desirable that truth should overtake it; and hence the necessity of fully exposing it here, and at once.

* *Vide* chart entitled "Profile of the bottom of the Atlantic between Valencia Bay, Ireland, and St. John's, Newfoundland, as sounded by the United States steamer 'Arctic,' Captain O. H. Berryman," on chart entitled "Chart showing the intended telegraphic communication between *Newfoundland and Ireland*, track of steamers between *Europe and America*, and the ice fields in the North Atlantic Ocean, 1856. *New York, Newfoundland and London Telegraph Company.* Directors in New York:

These two profiles of Berryman, reduced by Lieutenant Aulick to a scale of one-fourth from originals furnished by Berryman to the Navy Department and on file in this office, are fairly represented by figs. 1 and 2 on Plate XII. For the sake of comparison, the profile, fig. 4, as furnished by the soundings of Lieutenant Dayman, in her Britannic Majesty's steamer Cyclops, in 1857 is given. It is on a scale of two-thirds the original.* The maximum difference between this and Berryman's No. 2, as to depth, is about a mile. And the maximum difference of depth, as between Berryman's log and Dayman's chart, (fig. 3,) is about two miles, or 1,530 fathoms.

This (fig. 2) is the profile published by the Telegraph Company, and which has been the means of scattering error so far and so widely.

§ 166. The specimens of the bottom, brought up by the help of Brooke's deep-sea apparatus on board the Arctic, proved, however, to be perfect gems.

The following special report to the Secretary of the Navy tells about them and other matters of interest:

Observatory, Washington, *November* 8, 1856.

Sir: The investigations carried on in the Hydrographical Department of this offices possess, in some of their results, an interest not exclusively maritime, but of sufficient public concern to justify a special report to you.

Commander Rodgers, of the North Pacific Surveying Expedition, has furnished a few observations, made on board the United States ship Vincennes last year, on the temperature and specific gravity of the water at the surface, mid way down, and at the bottom of the Arctic Ocean.

These observations are highly interesting. He passed up through Behring's Straits into that sea during the summer of 1855, and, though he remained in it but a few days, he availed himself of the opportunity to try the temperature and specific gravity of the water at various depths and places, and his observations show uniformly this arrangement or stratification in the fluid mass of that ocean: warm and light water on top, cool water in the middle, and warm and heavy water at the bottom.

These observations, if extended, would go far towards the final settlement of the question of an open sea in the Arctic ocean.

In these experiments, Commander Rodgers used as a check upon his two metallic deep-sea thermometers a non-conducting cylinder, of his own contrivance, for bringing specimens of water from various depths. It is well he did so; for the metallic thermometers showed themselves to be incapable of affording the results he sought to obtain; nor did the two agree with each other, nor were the observations of either accordant with themselves.

The thermal observations, which have revealed to us this suggestive arrangement of cool and warm water in the frozen ocean, were made with a common mercurial thermometer upon the water from the several depths, after it had been brought up to the surface in the cylinders. The specific gravity is given for the temperature at which it is observed.

* * * * * * * *

Peter Cooper, esq., Moses Taylor, esq., Cyrus W. Field, esq., Marshall O. Roberts, esq., Wilson G. Hunt, esq., Peter Cooper, esq., president; Cyrus W. Field, esq., vice president; Moses Taylor, esq., treasurer; Professor S. F. B. Morse, electrician; David Dudley Field, esq., counsel. John W. Brett, esq., social manager, London, England. Ambrose Shea, esq., social manager, St. John's, Newfoundland; Frederick N. Gisborne, esq., chief engineer. London, December 4, 1856, compiled, engraved, and published by Day & Son, lithographers to the Queen, 6 Gate street, Lincoln's Inn Fields."

* See admiralty chart No. 2,059, entitled North Atlantic Ocean, for section of the bed of the Atlantic Ocean from Valentia to Trinity Bay, Newfoundland.

It is likely that this warm water went in as an under current; that though warmer, it was salter, and for that reason it was heavier. It was made salter, we conjecture, by evaporation; and while it was subjected to this process it was in some latitude where it received heat while it was giving off fresh-water vapor. This substratum of heavy water was, therefore, probably within the tropics, and at the surface when it received its warmth. Water, we know is transported to great distances by the under currents of the sea without changing its temperature but a few degrees by the way. Beneath the Gulf Stream, near the tropic of Cancer, and in the month of August, with the surface of the ocean above 80°, the deep-sea thermometer of the Coast Survey reports a current of cold water only 3° above the freezing point. That cold current or the water that it bore must certainly have come from the polar regions.

We know of numerous currents flowing out of the polar basin, and discharging immense volumes of water into the Atlantic; we know of but one surface current—and that a feeble one around the North Cape—that goes into this basin. All these out-coming currents are salt-water currents; therefore we cannot look for their genesis to the rivers of hyperborean America, Europe, and Asia, and the precipitation of the polar basin; for all the water from these sources, is fresh water. The salt that these upper currents bring out is sea salt; hence, we should be forced to conclude, were there no other evidence to warrant the conclusion, that there must be one or more under currents of salt and heavy water flowing into the Arctic basin.

A considerable body of water, at the temperature of 40°, rising to the surface there—as come to the surface it must, in order to supply the outgoing upper-currents—would tend mightily to mitigate the severe cold of those hyperborean regions.

This discovery of Rodgers furnishes almost the only link that seems to have been wanting in the chain of reasoning to complete, from known facts, the *theory* of an open water in the Arctic Ocean; and this discovery, taken in connexion with what northern voyagers tell us concerning the migration of animals in those regions; with what Dr. Kane saw and De Haven says; with the fact that harpoons fastened in whales on the shores of Greenland have been taken out of whales along the shores of Kamtschatka and Japan—these facts, taken in connexion with the discovery which my own researches have fully developed, that the right whale of Greenland and the right whale of the North Pacific are the same fish, and that to it the torrid zone is as a sea of flame, which it cannot pass—I say these facts, linked together and taken in connexion with other facts and circumstances, which are set forth at length in the publications of this office, seem to form a chain of almost faultless circumstantial evidence in favor of the existence of an open water in the polar basin.

Could it be explored, there are other circumstances to encourage the expectation that the nursery of the whales would be discovered there, with other sources of wealth to our enterprising fishermen.

Deep-sea soundings, with specimens of the bottom, have also been returned to this office from that expedition. They were taken in the North Pacific with Brooke's apparatus, and have been studied through the microscope of Professor Bailey, at West Point.

They all tell the same story. They teach us that the quiet of the grave reigns everywhere in the profound depths of the ocean; that the repose there is beyond the reach of wind; it is so perfect that none of the powers of earth, save only the earthquake and volcano, can disturb it.

The specimens of deep-sea soundings, for which we are indebted to the ingenuity of Lieutenant Brooke, are as pure and as free from the sand of the sea as the snow flake that falls when it is calm upon the lea is from the dust of the earth. Indeed these soundings suggest the idea that the sea, like the snow-cloud with its flakes in a calm, is always letting fall upon its bed showers of these microscopic shells; and we may readily imagine that the "sunless wrecks," which strew its bottom, are, in the process of ages, hid under this fleecy covering —presenting the rounded appearance which is seen over the body of the traveller who has perished in the snow-storm. The ocean, especially within and near the tropics, swarms with life. The remains of its myriads of moving things are conveyed by currents, and scattered and lodged, in the course of time, all over its bottom. This process, continued for ages, has covered the depths of the ocean as with a mantle, consisting of organisms as delicate as the macled frost and as light as the undrifted snow flake of the mountain.—(*Maury's Physical Geography of the Sea.*)

Wherever this beautiful sounding-rod has reach the bottom of the deep-sea, whether in the Atlantic or Pacific, the bed of the ocean has been found of a down-like softness. The lead appears to sink many feet deep into the oozy matter there, which has been strained and filtered through the sea water. This matter consists of the skeletons and casts of insects of the sea of microscopic minuteness.

The fact that the currents do not reach down to the bottom of the deep sea; that there are no abrading agents at work there, save alone the gnawing tooth of time; that a rope of sand, if stretched upon the bed of the ocean, would be a cable strong enough to hold the longest telegraphic wire that art can draw; these, with other discoveries made in the course of the investigations carried on in the hydrographical department of this office concerning the physics of the sea, and already announced in its official publications and correspondence, are likely to prove of great practical value and importance in submarine telegraphy—a line of business only in the first stage of its infancy, but deeply interesting to the whole human family; for in its bearings and results it touches most nearly the progress of man in the march that is leading him upward and onward. The notion was, that a telegraphic cable must be of great strength to resist and withstand the forces of the sea:—whereupon the conducting wire, after being coated to insulation with gutta-percha, was encased in a wire hawser or cable stout enough to hold the largest "seventy-four" to her anchors.

These cables are very expensive in their manufacture, bulky for stowage, unwieldy for handling, and difficult to lay. It was such a wire-laid cable that the Telegraphic Company lost in the laying between Newfoundland and Cape Breton in 1855; and it is such a one, wire-laid, stiff, and larger than a man's arm, that the French have twice attempted to lay in the Mediterranean and twice lost.

But now we have learned, in the course of these investigations, that all the obstacles interposed by the sea to the laying of submarine telegraphs lie between the surface and the depth of a few hundred fathoms below; and that these are not to be mastered by force nor overcome by the tensile strength of wire drawn ropes, but that with a little artifice they will yield to a mere thread. It is the case of the man-of-war and the little nautilus in the hurricane: the one, weak in its strength, is dashed in pieces; the other, strong in its weakness, resists the utmost violence of the storm, and rides as safely through it as though there were no ragings in the sea.

Therefore, it may now be considered as a settled principle in submarine telegraphy that the true character of a cable for the deep sea is not that of an iron rope as large as a man's arm, but a single copper wire, or a fascicle of wires, coated with gutta-percha, pliant and supple, and not larger than a lady's finger.

[The Atlantic Telegraphic Company did not consider this principle so well settled as I have supposed. They went against it and parted their cable. *November*, 1857.]

A most beautiful system of physical research is this undertaking to investigate the winds and currents of the sea. It was commenced with especial regard to navigation; but it has been most fruitful of useful results in many departments and to many industrial pursuits. Amongst not the least important of these are those which bear upon submarine telegraphy.

The first result bearing upon this subject was the discovery of a telegraphic plateau, which was duly announced in the publications of this office:

"There is at the bottom of this sea, between Cape Race, in Newfoundland, and Cape Clear, in Ireland, a remarkable steppe, which is already known as the Telegraphic Plateau. A company is now engaged with the project of a submarine telegraph across the Atlantic. It is proposed to carry the wires along this plateau from the eastern shores of Newfoundland to the western shores of Ireland. The great circle distance between these two shore-lines is one thousand six hundred (and forty) miles, and the sea along the route is probably nowhere more than ten (or twelve) thousand feet deep."—(*Physical Geography.**)

That company consists of enterprising American citizens and British subjects, who have been furnished with whatever of information this office could afford tending to facilitate their enterprise. With these lights, such as they were, and with their own knowledge, intelligence, and experience to guide them, they have decided upon the electric cord which is to bring the old world into instantaneous communication with the new. They expect to lay the wires over this telegraphic plateau during the next year. The Wind and Current Charts will enable them to select a time for it when the operation will be the least liable to interruption by a gale of wind.

I will, as soon as they are completed, submit for your inspection, and because of their bearing upon this subject, a series of twelve storm charts of the Atlantic—one for each month. Those parts of the ocean with the deepest shading are visited on the average by a gale of wind at least once in every six days; of the next deepest, once on the average in from six to ten days; and in the lightest shading there is a gale once in from every ten to fourteen days on the average. These charts are based on information derived from 265,875 days of observation. They will be prepared by Lieutenants Richmond Aulick and Wm. C. West. They show some of the influences which the Gulf Stream has upon the gales of the North Atlantic. They show that these gales are most prevalent in January and the winter months; least so in July and the summer months. (See Plates for January, February, &c.)

The knowledge which in the course of these investigations we have gained concerning the currents and bed of the ocean justifies the opinion that there is now no difficulty in crossing the Gulf Stream with the magnetic telegraph, and bringing Cuba within the meshes of its net work here, which is soon to be connected with that which embraces both Europe and Asia. There is no current, however strong, no sea, however deep or boisterous, that may not now be spanned with a telegraphic wire; for cable is no longer the word. The limit to the length of submarine lines of telegraph is not to be sought for in the breadth or depths of the ocean, but in the power of insulation and conduction. * * * * * *

* Sailing Directions 6th edition, p 155.

NOTE.—We understand Lieutenant Maury has, in pursuing his investigations, found cause to suspect that the bottom of the deep sea is everywhere protected from the abrasion of currents by a cushion of still water, or at least by a stratum of water so nearly at rest that there is not force enough in its motions to abrade or wear the bottom in the least; and, furthermore, that he has been led to suppose that the strata of running water in the sea do not extend to very great depths—two facts that are of the highest practical importance and value to those engaged with submarine telegraphs.—(*National Intelligencer, December* 18, 1856.)

Professor Morse has recently accomplished the feat of transmitting through an unbroken circuit, upwards of 2,000 miles in length, 270 telegraphic signals in a minute;* and there is reason also to believe that experience will show that the cost of laying a telegraphic wire at the bottom of the deep sea will not be as great, mile for mile, as it now is on *terra firma.* Indeed, Vera Cruz and Brazil, as well as Havana, may now be regarded as fairly within the reach of the submarine telegraph.

Last summer the United States steamer Arctic, Lieutenant O. H. Berryman, was sent on special service, under the act of the 3d of March, 1849, directing three suitable vessels of the navy to be employed in assisting me to perfect the discoveries made in the course of these investigations. Among these discoveries the telegraphic plateau of the Atlantic had claimed a large share of the public attention. Further exploration of it was desired; and the Department, sympathizing with the noble enterprise, set on foot by a company of patriotic and enterprising American citizens, for uniting the people of Europe and America together in the bonds of the magnetic telegraph, directed particular attention to this subject during the cruise of the Arctic. Accordingly she was furnished with steam machinery for hauling up the sounding-rod, and was allowed every facility for the most complete deep-sea sounding equipments.

Other assistance in my researches was also expected from the observations which this vessel was to make. There is the polar current, which, with its icebergs, so much endangers navigation at certain seasons; it underruns the Gulf Stream. Your instructions also pointed to the Gulf Stream; and, from the deep-sea soundings, temperatures, and other observations made on it, I hoped to discover, among other things, the thickness of that sheet of warm water which, as you have already seen, has such a marked, and stormy, and terrible influence upon the navigation between this country and Europe.

The facilities for deep-sea soundings were such that we were encouraged to look for contributions of the highest interest and value to our knowledge concerning the orography of the Atlantic Ocean; for the vessel was a steamer, the first of the kind ever employed on such service, and she could therefore let down Brooke's sounding rod wherever it was desired.

But I have been sadly disappointed. Most, if not all, of the work done in this vessel on this service has to be rejected. Her deep-sea soundings along the plateau, from St. John's, Newfoundland, to Valentia, in Ireland, and back, I regret to say it, come within this category. They were made after plans that were new, with obvious sources of error; but no pains seem to have been taken, either to ascertain the amount of that error, or to afford the means of applying any corrections to the work. I have not been able to reconcile the depths reported by the Arctic with former deep-sea soundings; nor do her soundings going agree with her soundings returning. Their discrepancies are glaring; and it is to be hoped this interesting and important work will be done over again.

We are more fortunate, however, with the samples of the bottom brought up from the telegraphic plateau. They are very precious. Lieutenant Berryman obtained in quills, after the manner of Lieutenant Brooke, specimens of the bottom all the way across by the great circle route between St. John amd Valentia. These specimens are from thirty-four different points along the route.

Immediately on their receipt here they were sent to Professor Bailey, of West Point, for microscopic examination. Though suffering from an attack of illness,† he kindly undertook

* See his letter to Cyrus W. Field, the president of the Submarine Telegraph Company.

† They possess a melancholy interest. That amiable, excellent, and accomplished student of nature, never recovered from that attack; he died during the winter.

the study of them at once. Like all other deep-sounding specimens, they indicate, by their sharp angles and untriturated forms, the total absence of abrading forces at the bottom of the deep sea.

The telegraphic plateau lies across the Gulf Stream, and Professor Bailey says, in a letter concerning these specimens:

"I have no doubt our beautiful ocean river glides along its course in the Northern Atlantic as gently as the current of time, dropping now and then a defunct animalcule into the great sepulchre below, but not wearing or abrading the bottom in the slightest degree."

And again, after further examination:

"I find no evidence of any violent abrasion in any of the specimens. Even in the coarse ones from near the banks the matter has usually sharp angles, and is such as might be dropped quietly from icebergs as they melt without undergoing any subsequent abrasion or transportation."

In a subsequent letter he adds:

"The evidence of want of abrasion of the mineral matter, and the presence of a large proportion of fine calcareous mud, with Gulf Stream forms, continue in all the specimens yet examined."

Thus the remains of these mites of things tell us in their mute way that the ice-bearing current from the North does not reach to the bottom; that the northern edge of the Grand Banks even is below the abrading action of the sea; and that there is no danger to the telegraphic cord even there, except from the grounding of icebergs.

As soon as Professor Bailey's final report upon the microscopic character of these specimens is received I shall have the honor of transmitting it to you.

You will observe that these specimens fully confirm all that other observations had taught us concerning the quiescent state of currents at the bottom of the sea, and that here along this telegraphic plateau, as it is everywhere wherever Brooke's sounding-rod has given us of its treasures, the bottom in the depths of the ocean is so perfectly sheltered from the forces of winds and waves, and running water, that a rope of sand would have strength enough to hold safely to their anchors the submarine wires, were they only lodged there, and that the whole difficulty in stretching the wires of the submarine telegraph across the Atlantic Ocean consists in getting them to the bottom, not in retaining them there.

Respectfully,

M. F. MAURY,
Lieutenant United States Navy.

HON. J. C. DOBBIN,
Secretary of the Navy.

OBSERVATORY, *Washington, November* 15, 1856.

SIR: I have the honor to forward herewith the report of Professor Bailey, of his microscopic examination of the specimens obtained from the bed of the Atlantic by Lieutenant Berryman, in the United States steamer Arctic, alluded to in my report of the 8th instant.

The most noticeable thing here presented is the discovery of volcanic cinders in these specimens. The Gulf Stream seems to have strewed the bed of the ocean for more than a thousand miles across with these "plutonic tallies," as Professor Bailey styles them. They enable us to mark, better than any means heretofore afforded have done, the extreme limits of the annual vibrations made by the channel in which the waters of the Gulf Stream flow.

These fiery tallies were found along the path which is sometimes followed by the European steamers, and the question arose whether they might not be steamboat cinders.

Mr. Manning, of New York, was requested to procure some specimens of these from the ash-pit of the steamers in New York, and send them to Professor Bailey to see. He did so, and the examination leaves no doubt upon the Professor's mind as to the volcanic character of the tallies.

The fact that nothing of the kind has been detected in the specimens brought up by the Coast Survey from the bottom of the Gulf Stream further to the south, seems to indicate that these cinders could not have come from the valcanoes of Central America, which have been known to cast their ashes as far as Cuba. The drift of the ocean would not have brought them from Iceland or any of the British islands, and lodged them where Brooke's lead found them. It appears to be most probable that they came from the extinct volcanoes of the Western islands. The size of the vitreous particles appears to warrant the conclusion that they are too heavy to be carried far by the winds, or to be born long by the water.

It is barely possible they may have come from Ætna and Vesuvius, and been brought out by the under currents from the Mediterranean. Specimens from the deep sea, off the Straits of Gibraltar, would at once settle this question.

Not an angle, or a corner, or a piece of them is broken; nor is there the slightest scratch or chafe upon any of their delicate filagree work. These cinders repeat the story, which the infusorial organisms of the water were the first to proclaim, with regard to the absence at the bottom of the deep sea of all abrading agents.

Respectfully, &c.,

M. F. MAURY,
Lieutenant United States Navy.

Hon. J. C. Dobbin,
Secretary of the Navy.

West Point, *November* 14, 1856.

Dear Sir: I respectfully submit the following as a general report of the results of my microscopic examination of the soundings, made by Lieutenant O. H. Berryman, in his recent voyage, in the United States Steamer Arctic, to Ireland and back.

The specimens submitted to examination were of two series, viz: Those collected in the voyage to Ireland, which will be referred to as series 1, and those made in the return voyage, which form series 2.

The specimens of series 1 were from the following localities:

SERIES I.

	Latitude.	Longitude.		Latitude.	Longitude.
	° ″	° ′		° ′	° ′
1	47 50	52 00	13	52 24	29 16
2	48 00	51 41	14	52 26	27 18
3	48 13	51 20	15	52 26	26 30
4	48 27	50 58	16	52 2	24 51
5	48 40	50 36	17	51 45	22 23
6	48 51	50 5	18	51 45	21 19
7	50 3	40 26	19	51 50	20 12
8	50 20	38 30	20	52 1	17 6
9	50 44	37 15	21	52 5	16 5
10	51 6	35 50	22	52 3	15 2
11	51 15	34 8	23	51 52	13 16
12	51 38	32 20	24	51 54	12 27

In stating the results obtained from these specimens, they will be referred to by the numbers as given in the above table.

Numbers 1 to 4, inclusive, are composed of fine silicious sands, the grains of which are mostly of small size, and with sharp angles. The organic contents are not abundant. Of the calcareous polythalamia there is scarcely a trace, but some of the silicious diatoms may be found in the light parts, which may be rinsed from the sand. Among these diatoms, numerous fragments and some perfect discs of coscinodisci are the most abundant. Some species of chaetoceros were also seen, which are believed to be of northern origin.

Number 5 is a coarse gravel, composed of common and jaspery quartz, with some feldspar, hornblende, &c. It is much the coarsest of all the specimens examined. Some of the quartz grains are rounded by attrition, while a large portion are quite sharp and unabraded. Among the organic contents a very few polythalamia were noticed, with some diatoms and sponge spicules.

Number 6 is a fine calcareous mud, which effervesces briskly with acids, and yields, by this treatment, a large residue of siliceous sand, with some diatoms and spongiolites. This specimen is interesting as indicating the commencement of that great calcareous deposit extending nearly across the Atlantic, which will be alluded to in subsequent paragraphs.

Numbers 7 to 21, inclusive, are fine calcareous muds, which effervesce briskly with acids and abound in the calcareous polythalamia, particularly in species of globigerina. They also contain numerous and very interesting species of the silicious polycistins, diatoms, and spongiolites. The mineral residue, from acids, is usually quite small in relative amount, and consists of minute sharp-angled grains, among which quartz predominates.

Numbers 8 to 21, inclusive, contain, in addition to what is above mentioned, what appear to be well characterized *volcanic ashes*, in the shape of pumice and obsidian crystals of hornblende, single and in groups, with other igneous products penetrated by crystals. These substances generally form but a small portion of the residue left by acids, and may be more readily detected when this residue is examined in water than when mounted in balsam. They are particularly recognizable in number 14.

Number 22 is a fine calcareous mud, with some globigerinæ. It is chiefly noticeable as leaving with acids a considerable amount of fine quartz sand, mingled with microscopic globules of *iron pyrites*. It yielded no recognizable volcanic products, and very few silicious organisms.

Numbers 23 and 24 are very similar in character to number 22, but they yielded no globules of iron pyrites.

Some general remarks on the results of the examinations of the specimens above referred to will now be given.

1. The employment of acid enables me to correct an erroneous statement which I made some time since concerning the deep soundings of the Atlantic. Having at that time only a small portion of the soundings, and being unwilling to destroy a morsel of matters so precious, I did not apply acids, and hence overlooked the portion of mineral matter which, though often very small, is invariably present.

2. The mineral matter in these soundings generally shows no signs of abrasion, the sharpest edges and angles of even the softest minerals being retained. The minute size of the particles and their sharp angular state appear to indicate that they have been quietly deposited from gentle currents and not subsequently disturbed. Even the coarsest and most abraded materials may have been deposited from icebergs.

3. The gradual increase of calcareous matter as the Gulf Stream is approached, and the presence of calcareous organisms from its western margin almost completely across the Atlantic, is in accordance with observations previously made on the Coast Survey soundings of the Gulf Stream obtained further south, which show that calcareous marls, rich in polythalamia, polycistius, diatoms, and spongiolites, form the bed of the Gulf Stream throughout its whole course as far as yet examined, and also occur of vast extent in the Gulf of Mexico.

4. These marls contain a great number of undescribed organisms, both silicious and calcareous. Many species, which occur as far south as Florida and the Gulf of Mexico, are found in the northern soundings above described, while some very remarkable species found in the northern soundings have not been detected at the southern localities, and *vice versa*. The description of the new species is in preparation for speedy publication.

5. Only a few imperfect siliceous *casts* of polythalamia and no well characterized green sand casts have been detected in these northern soundings, while their presence is the rule rather than the exception with regard to the southern soundings above referred to.

6. The occurrence of what appear to be volcanic products in the bed of the ocean for a distance of about twenty-two degrees of longitude, or about a thousand miles, is an extraordinary fact, and one which deserves careful scrutiny. That any one familiar with the microscopic appearance of volcanic ashes, &c., would pronounce the matters to be of volcanic origin I have no doubt. As, however, the ingenious suggestion was made to me that these igneous products might be derived from the fires of the ocean steamers, along or near whose pathway these soundings were made, it became important that these furnace products should also be studied. This I was enabled to do by the kindness of Mr. Manning, the obliging agent of your office, who procured for me from the steamers themselves specimens of such matters as are thrown overboard from the ash-pits of the steamers Asia and Baltic. Careful examination of these

specimens showed that they contained a group of products which could not possibly be confounded with the supposed volcanic matters. In fact there was no relation between the two classes of bodies, except that both were evidently the results of intense heat upon different mineral matters. Among the furnace products of the steamer Baltic were numerous single and aggregated glass spheres of minute, or even microscopic size, which, if they should ever be found in the ocean soundings, would be very puzzling without this clue to their origin.

7. The question of the original source of these volcanic products is one of great interest. How far these plutonic tallies may have travelled and in what directions, whether from the Azores, the Mediterranean, or from Iceland, involves a study of currents and an examination of soundings which have yet to be made.

SERIES II.

The specimens constituting the second series were as follows, viz:

	Latitude.	Longitude.		Latitude.	Longitude.
	° ′	° ′		° ′	° ′
1	49 12	49 42	5	49 49	45 54
2	49 36	49 5	6	49 50	44 43
3	49 40	48 29	7	51 43	13 44
4	49 49	46 43			

They will be referred to by the numbers given in the above table.

Numbers 1 to 6 are calcareous muds, containing much mineral matter and a small proportion of polythalamia. The silicious organisms are also comparatively few, consisting of some large coscinodisci and some spongiolites. No volcanic products were detected.

Number 7 is also a fine calcareous mud, showing but few polythalamia to the naked eye, but rather rich in microscopic organisms, consisting of minute polythalamia, with polysistins, diatoms, and spongiolites. No volcanic products were detected.

Hoping that the above will answer the purpose of a general report upon the character of these soundings, I reserve for subsequent publication the details of the zoological results afforded by these highly interesting series of soundings.

Yours, very respectfully,

J. W. BAILEY.

Lieutenant M. F. MAURY,
National Observatory.

The necessity of doing this work over again, having been thus announced, the English government undertook the task, and last summer Lieutenant Dayman, in her Britannic Majesty's steamer "Cyclops," was sent to accomplish it. Fig. 4, Plate XII represents the vertical section, or profile, as projected at the Hydrographical Office of the Admiralty, according to his soundings. I have seen no account of the plan adopted by him for sounding, and consequently have had no opportunity of discussing the accuracy of his results; nor do I see any reason for challenging it, except to a certain limited extent, and as to which, I have no doubt, his sounding book will set all right. I allude to the remarkable undulations of the bottom midway between Ireland and Newfoundland, and for about one-third the entire distance across. Here the soundings alternate, as deep and shallow, with such remarkably regularity as to suggest the inquiry whether this undulating feature be not referable to an accidental error, or to personal equation among the operators, rather than to physical conformation.

Were the soundings made alternately by day and night? Or alternately by different persons or methods? Any such circumstances might, perhaps, enable one to fill up those remarkable hollows.

If Dayman used the sounding *line* to measure his depths, then we know that they could not be greater than the length of line out, for he brought up "bottom," I believe, in every, or almost every, instance; on the other hand, the depths might be much less than the length of line out would indicate, because the cast, though giving bottom, might not be truly "up and down." There might be "stray line;" therefore, though we may not cut off the ridges by discussion, yet we may perhaps fill up the valleys.

Supposing this undulating feature of the profile to be due to the unavoidable imperfections of the methods used rather than to any actual resemblance in nature between profile and original, we should then have developed in a still more marked extent the middle ground in the midst of the ocean which Dayman's soundings have brought to light.

On either side of this middle ground there is a deep channel way. Thus Dayman gives the deepest water on the sides; while Berryman, in his profiles 1 and 2, makes his deepest water on the top of Dayman's middle ground.

This middle ground is a striking feature. It appears to be in part a submarine projection of Greenland, and in part a deep sea "hook" formed by conflicting currents. Above it no less than three vast currents—two polar and one equatorial—meet and have their places of conflict for the deposit of drift matter.

The polar current, which comes down between Iceland and Greenland, meets on this middle ground the ice-bearing current from Davis' Straits; and these two are met again and crossed by the Gulf Stream. Many a load of earth, rock, and gravel has, we may suppose, in the process of ages, been dropped from icebergs down upon this middle ground. This process has been going on for countless ages. Specimens of the bottom from this middle ground to the north of Dayman's line of soundings might throw additional light upon this subject. At any rate they would be highly interesting.

Plate XI has been altered to the suggestions of Dayman's soundings.

167. The greatest depths at which the bottom of the sea has been reached with the plummet are in the North Atlantic Ocean, and the places where it has been satisfactorily fathomed do not show it to be deeper than twenty-five thousand feet.

The deepest place in this ocean (Plate XI) is probably between the parallels of 35° and 40° north latitude, and immediately to the southward of the Grand Banks of Newfoundland. No satisfactory deep-sea soundings worth mentioning, either in the Pacific or Indian Oceans, have, as yet, been made by those who are co-operating in this admirable plan of research. A few have been made in the South Atlantic, but not enough to justify deduction as to its depths or the shape of its floor.

CHAPTER XII.

THE BASIN OF THE ATLANTIC.*

Height of Chimborazo above the bottom of the Sea, § 168.—The deepest Place in the Atlantic, § 169.—The Utility of Deep-sea Soundings, § 170.—A Microscopic Examination of them, § 171.—Brooke's Deep-sea Lead presents the Sea in a new Light, § 172.—The Agents at work upon the Bottom of the Sea, § 173.—No running water there, § 174.—Is there any life there?—the biotic and antibiotic view, § 175.—How the Ocean is prevented from gorwing salter, § 176.—Knowledge of our Planet to be derived from the Bottom of the Sea, § 177.

168. THE BASIN OF THE ATLANTIC, according to the deep-sea soundings made in the manner described in the foregoing chapter, is shown on Plate XI. This plate refers chiefly to that part of the Atlantic which is included within our hemisphere.

In its entire length, the basin of this sea is a long trough, separating the Old World from the New, and extending probably from pole to pole.

This ocean-furrow was scored into the solid crust of our planet by the Almighty hand, that there the waters which "he called seas" might be gathered together, so as to "let the dry land appear," and fit the earth for the habitation of man.

From the top of Chimborazo to the bottom of the Atlantic, at the deepest place yet reached by the plummet in the North Atlantic, the distance, in a vertical line, is nine miles.

Could the waters of the Atlantic be drawn off, so as to expose to view this great sea-gash, which separates continents, and extends from the Arctic to the Antarctic, it would present a scene the most rugged, grand, and imposing. The very ribs of the solid earth, with the foundations of the sea, would be brought to light, and we should have presented to us in one view, in the empty cradle of the ocean, "a thousand fearful wrecks," with that dreadful array of dead men's skulls, great anchors, heaps of pearl and inestimable stones, which, in the poet's eye, lie scattered in the bottom of the sea, making it hideous with sights of ugly death.

To measure the elevation of the mountain-top above the sea, and to lay down upon our maps the mountain ranges of the earth, is regarded in geography as an important thing, and rightly so. Equally important is it, in bringing the physical geography of the sea regularly within the domains of science, to present its orology, by mapping out the bottom of the ocean so as to show the depressions of the solid parts of the earth's crust there, below the sea-level.

169. Plate XI presents the second attempt at such a map. It relates exclusively to the bottom of that part of the Atlantic Ocean which lies north of 10° south. It is stippled with four shades: the darkest (that which is nearest the shore-line) shows where the water is less than six thousand feet deep; the next, where it is less than twelve thousand feet; the third, where it is less than eighteen thousand; and the fourth, or lightest, where it is not over twenty-four thousand feet deep. The blank space south of Nova Scotia and the Grand Banks includes a district within which very deep water has been reported; but from casts of the deep-sea lead which, upon discussion, do not appear satisfactory.

The deepest part of the North Atlantic is probably somewhere between the Bermudas and the Grand Banks, but how deep it may be, yet remains for the cannon ball and sounding-twine to determine.

The waters of the Gulf of Mexico are held in a basin about a mile deep in the deepest part.

* *Vide* Maury's Physical Geography of the Sea.

THE BOTTOM OF THE ATLANTIC, or its depressions below the sea-level, are given, perhaps, on this plate with as much accuracy as the best geographers have been enabled to show, on a map, the elevations above the sea-level of the interior either of Africa or Australia.

170. "What is to be the use of these deep-sea soundings?" is a question that often occurs; and it is as difficult to be answered in categorical terms as Franklin's question: "What is the use of a new-born babe?" Every physical fact, every expression of nature, every feature of the earth, the work of any and all of those agents which make the face of the world what it is, and as we see it, is interesting and instructive. Until we get hold of a group of physical facts, we do not know what practical bearings they may have, though right-minded men know that they contain many precious jewels, which science or the expert hand of philosophy will not fail to bring out, polished and bright, and beautifully adapted to man's purposes. Already we are obtaining practical answers to this question as to the use of deep-sea soundings; for, as soon as they were announced to the public, they forthwith assumed a practical bearing in the minds of men, with regard to the question of a submarine telegraph across the Atlantic.

There is, at the bottom of this sea, between Cape Race, in Newfoundland, and Cape Clear, in Ireland, a remarkable steppe, which is already known as the telegraphic plateau. A company is now engaged with the project of a submarine telegraph across the Atlantic. It is proposed to carry the wires along this plateau, from the eastern shores of Newfoundland to the western shores of Ireland. The great circle distance between these two shore-lines is one thousand six hundred miles, and the sea along the route is probably nowhere more than ten thousand feet deep. This company, it is understood, consists of men of enterprise and wealth, who, should the inquiries that they are now making prove satisfactory, are prepared to undertake the establishment forthwith of a submarine telegraph across the Atlantic.

It was upon this plateau that Brooke's sounding apparatus (§ 162) brought up its first trophies from the bottom of the sea. These specimens the officers of the Dolphin judged to be clay; but they took the precaution to label them, carefully to preserve them, and, on their return to the United States, to send them to the proper bureau. They were divided; a part was sent for examination to Professor Ehrenberg, of Berlin, and a part to Professor Bailey, of West Point—eminent microscopists both. The latter thus responded:

171. "I am greatly obliged to you for the deep soundings you sent me last week, and I have looked at them with great interest. They are exactly what I have wanted to get hold of. The bottom of the ocean at the depth of *more than two miles* I hardly hoped ever to have a chance of examining; yet, thanks to Brooke's contrivance, we have it clean and free from grease, so that it can at once be put under the microscope. I was greatly delighted to find that *all* these deep soundings are filled with microscopic shells; not a particle of sand or gravel exists in them. They are chiefly made up of perfect little calcareous shells, (Foraminifera,) and contain, also, a small number of silicious shells, (Diatomaceæ.)

"It is not probable that these animals lived at the depths where these shells are found, but I rather think that they inhabit the waters near the surface; and when they die, their shells settle to the bottom. With reference to this point, I shall be very glad to examine bottles of water from various depths which were brought home by the Dolphin, and any similar materials, either 'bottom,' or water from other localities. I shall study them carefully. . . The results already obtained are of very great interest, and have many important bearings on geology and zoology. . . . . .

"I hope you will induce as many as possible to collect soundings with Brooke's lead, in all parts of the world, so that we can map out the animalculæ as you have the whales. Get your whalers also to collect mud from pancake ice, &c., in the polar regions; this is always full of interesting microscopic forms."

I extract from an interesting letter, lately received from Passed Midshipman Brooke, of the North Pacific Exploring Expedition, dated United States ship Vincennes, September 3, 1854:

"* * * * * There has been enclosed to the Department a table of temperatures at various depths, from 100 to 500 fathoms, and two reports of experiments in deep-sea soundings. Several unsuccessful attempts to sound from the ship were made, under the direction of Captain Ringgold, but were considered unworthy of a remark—in which opinion I coincide; for, at considerable depths, one is entirely dependent upon the times of the 100 fathoms. As a general thing, I suppose an hundred thousand fathoms would all be eventually taken from the reel by the drift of the ship. On one of those occasions, a breeze sprung up on the quarter, shooting the ship ahead in such a manner as to render the cast utterly worthless.

"From our experience in the Indian Ocean and Coral Sea, I am inclined to believe that there is no depth from which specimens of the bottom may not be obtained. It will ever be a source of regret that, owing to circumstances beyond my control, we were unsuccessful in recovering the line and specimen after reaching bottom with 7,040 fathoms in the Indian Ocean. Such opportunities are rare in that locality; yet, owing to the current of sixty miles, it will be a difficult matter to determine the absolute depth. That current was not as superficial as one might at first suppose; for it was during the latter part of the operation that the boat experienced its effect, and it would seem that, had the current been superficial, the line would have given indication by tending ahead, whereas it ran *right down*. Moreover, that current was local, which adds to the probability of its depth.

"The cast made in the Coral Sea was satisfactory in every respect; the arming-rod came up with its lower extremity completely coated with what appeared to be a calcareous clay of such adhesive and tenacious character as to preserve the marks of the shot made in slipping off. In fact, we had fallen upon one of those beds which eventually present the characteristic formations of England.

"I fear that the specimen delivered to the chemist of the expedition has been mislaid; but fortunately, I have in my possession ample quantity for microscopic examination, and which will be sent to you by Lieutenant Maury, of the Mississippi."

I am indebted to the politeness of Lieutenant Wm. L. Maury, of the Japan Expedition, for the specimen alluded to. It came from the Coral Sea, latitude 13° S., longitude 162° E., and was brought up by Brooke's sounding rod from the depth of 2,150 fathoms. I am without any further account as to the manner of making the sounding, or the time of running out. The specimen was immediately divided between the microscopes of my friends, Professors Bailey and Ehrenberg. The former reports as follows:

"You may be sure I was not backward in taking a look at the specimens you sent me, which, from their locality, promised to be so interesting. The sounding from 2,150 fathoms, although very small in *quantity*, is not bad in *quality*, yielding representatives of most of the great groups of microscopic organisms usually found in marine sediments.

"The predominant forms are silicious spicules of *sponges*. Various forms of these occur; some long and spindle-shaped, or acicular; others pin-headed; some three spined, &c., &c.

"The Diatoms (silicious infusoria of Ehrenberg) are very few in number, and mostly fragmentary. I found, however, some perfect valves of a coscinodiscus.

"The Foraminifera (Polythalamia of Ehrenberg) are very *rare*, only one perfect shell being seen, with a few fragments of others.

"The Polycistineæ are present, and some species of Haliomma were quite perfect. Fragments of other forms of this group indicate that various interesting species might be obtained, if we had more of the material.

"You will see by the above, that this deep sounding differs considerably from those obtained in the Atlantic. The Atlantic soundings were almost wholly composed of calcareous shells of the Foraminifera; these, on the contrary, contain very few Foraminifera, and are of a silicious rather than a calcareous nature. This only makes the condition of things in the Northern Atlantic the more interesting."

And just as this sheet is going to press, I have received in reply the following letter from Professor Bailey:

"West Point, *February* 18, 1855.

"You ask 'Why do the silicious organisms of the Coral Sea make the calcareous ones of the Atlantic more interesting?' My idea was that they proved that deep water is not *necessarily* underlaid by foraminiferous deposits, and that some peculiar local conditions of temperature, currents, or geological substratum, have made the North Atlantic a perfect *vivarium* for the calcareous forms.

"The chart (Plate XIV) you send is *very* interesting, and combines a wonderful amount of interesting phenomena. I have little doubt that the history of the bottom of the ocean, as recorded by the sediments, would show a close relation to the facts determined for the surface, besides many unexpected relations. I cannot conceive how any intelligent seaman can need *urging* to undertake the task of deep sounding. I feel sure that you can present the matter in a light that would be more attractive to them than I can. I am very anxious to get some soundings from the great ocean current that, as shown in your chart, sweeps *in* through the Caribbean Sea, and along the coast of Mexico and Texas.

"I observe on your chart something which looks like a sargassum sea, SE. of Madagascar. Is it so? Get soundings, if possible, in these sargassum seas. Get soundings *anywhere—everywhere*. Even when they yield nothing, the negative fact is of value."

Here, again, we perceive these little conservators of the sea at work. This specimen comes from the coral regions, and the task of secreting the calcareous matter from the sea water appears to have been left by these little mites of creatures to the madrepores and shell-fish, though they themselves undertook the hard task of getting the silicious matter out. The division of labor among the organisms of the sea are wonderful. It is a great workshop, in which the machinery is so perfect that nothing ever goes wrong.

These little mites of shells seem to form but a slender clew, indeed, by which the chambers of the deep are to be threaded, and mysteries of the ocean revealed; yet the results are suggestive; in right hands and to right minds, they are guides to both light and knowledge.

The first noticeable thing the microscope gives of these specimens is, that all of them are of the animal, not one of the mineral kingdom.

The ocean teems with life, we know. Of the four elements of the old philosophers—fire, earth, air, and water—perhaps the sea most of all abounds with living creatures. The space occupied on the surface of our planet by the different families of animals and their remains, is inversely as the size of the individual. The smaller the animal the greater the space occupied by his remains. Though not invariably the case, yet this rule, to a certain extent, is true, and will, therefore, answer our present purposes, which are simply those of illustration. Take the elephant and his remains, or a microscopic animal, and his, and compare them. The contrast, as to space occupied, is as striking as that of the coral reef or island with the dimensions of the whale. The grave-yard that would hold the corallines is larger than the grave-yard that would hold the elephants.

We notice another practical bearing in this group of physical facts that Brooke's apparatus fished up from the bottom of the deep sea. Bailey, with his microscope, (§ 168,) could not detect a single particle of sand or gravel among these little mites of shells. They were from the great telegraphic plateau, (§ 167,) and the inference is that there, if anywhere, the waters of the sea are at rest. There was not motion enough there to abrade these very delicate organisms, nor current enough to sweep them about and mix up with them a grain of the finest sand, nor the smallest particle of gravel torn from the loose beds of debris that here and there strew the bottom of the sea. This plateau is not too deep for the wire to sink down and rest upon, yet it is not so shallow that currents, or icebergs, or any abrading force can derange the wire after it is once lodged.

As Professor Bailey remarks, the animalculæ, whose remains Brooke's lead has brought up from the bottom of the deep sea, probably did not live or die there. They would have had no light there, and, had they lived there, their frail little texture would have been subjected, in their growth, to pressure upon them of a column of water twelve thousand feet high, equal to the weight of four hundred atmospheres. They probably lived and died near the surface, where they could feel the genial influences of both light and heat, and were buried in the lichen caves below, after death.

172. Brooke's lead and the microscope, therefore, it would seem, are about to teach us to regard the ocean in a new light. Its bosom, which so teems with animal life; its face, upon which time writes no wrinkles, makes no impression, are, it would now seem, as obedient to the great law of change as is any department whatever, either of the animal or the vegetable kingdom. It is now suggested that, henceforward, we should view the surface of the sea as a nursery teeming with nascent organisms, its depths as the cemetery for families of living creatures that outnumber the sands on the sea-shore for multitude.

Where there is a nursery, hard by there will be found also a grave-yard—such is the condition of the animal world. But it never occurred to us before to consider the surface of the sea as one wide nursery, its every ripple a cradle, and its bottom one vast burial place.

The wonders of the sea are as marvelous as the glories of the heavens; and they also proclaim, in songs of unutterable praise, that they too are the work of Holy fingers.

173. On those parts of the solid portions of the earth's crust which are at the bottom of the atmosphere, various agents are at work, levelling both upward and downward. Heat and cold, rain and sunshine, the winds and the streams, all, assisted by the forces of gravitation, are unceasingly wasting away the high places on the land, and as perpetually filling up the low.

But in contemplating the levelling agencies that are at work upon the solid portions of the crust of our planet which are at the bottom of the sea, one is led, at first thought, almost to the conclusion that these levelling agents are powerless there.

In the deep sea there are no abrading processes at work; neither frosts nor rains are felt there, and the force of gravitation is so paralyzed down there that it cannot use half its power, as on dry land, in tearing the overhanging rock from the precipice and casting it down into the valley below.

When considering the bottom of the ocean, we have, in the imagination, been disposed to regard the waters of the sea as a great cushion, placed between the air and the bottom of the ocean, to protect and defend it from these abrading agencies of the atmosphere.

The geological clock may, we thought, strike new periods; its hands may point to era after era; but, so long as the ocean remains in its basin, so long as its bottom is covered with blue water, so long must the deep furrows and strong contrasts in the solid crust below stand out bold, ragged, and grand. Nothing can fill up the hollows there; no agent now at work, that we know of, can descend into its depths, and level off the floors of the sea.

But it now seems that we forgot these oceans of animalculæ that make the surface of the sea sparkle and glow with life. They are secreting from its surface solid matter for the very purpose of filling up those cavities below. These little marine insects are building their habitations at the surface, and when they die, their remains, in vast multitudes, sink down and settle upon the bottom. They are the atoms of which mountains are formed—plains spread out. Our marl-beds, the clay in our river-bottoms, large portions of many of the great basins of the earth, are composed of the remains of just such little creatures as these, which the ingenuity of Brooke has enabled us to fish up from the depth of more than two miles (twelve thousand feet) below the sea-level.

These *foraminiferæ*, therefore, when living, may have been preparing the ingredients for the fruitful soil of a land that some earthquake or upheaval, in ages far away in the future, may be sent to cast up from the bottom of the sea for man's use.

174. The study of these "sunless treasures," recovered with so much ingenuity from the rich bottom of the sea, suggests new views concerning the physical economy of the ocean.

Among the revelations which scientific research has lately made concerning the crust of our planet, none are more interesting to the student of nature, or more suggestive to the Christian philosopher, than those which relate to the physics of the sea.

They not only lead us into the workshops of the inhabitants of the sea—show us through their nurseries and cemeteries, and enable us to study their economy—but they conduct us into the very chambers of the deep. Our investigations go to show that the roaring waves and the noisy billows of the ocean repose, not upon hard or troubled beds, but upon cushions of still water. That every where at the bottom of the deep sea the solid ribs of the earth are protected, as with a garment, from the abrading action of its currents, and the cradle of its restless waves is fended by a stratum of water at rest, or so nearly at rest that it can neither wear nor move the lightest bit of drift that once lodges there.

The tooth of running water is very sharp. See how the Hudson has ate through the Highlands, and the Niagara cut its way through layer after layer of the solid rock. But what are the Hudson and the Niagara, with all the fresh water-courses of the world, by the side of the Gulf Stream and other great "rivers in the ocean?" And what is the pressure of fresh water upon river-beds, in comparison with the pressure of ocean water upon the bottom of the deep-sea?

And why have not the currents of the sea worn away its bottom? The pressure of the water upon the bed of our mightiest rivers is feather-light in comparison with the pressure of the deep sea upon the bottom under it.

Let us see what the pressure is where the sea is only 3,000 fathoms deep—for in many places the depth is even greater than that. It is equal there, in round numbers, to the pressure of six hundred atmoshperes. Six hundred atmospheres, piled up one above the other, would press upon every square foot of solid matter beneath the pile with the weight of 1,296,000 pounds, or 648 tons.

The better to comprehend the amount of such a pressure, let us imagine a column of water just one foot square, where the sea is 3,000 fathoms deep, to be frozen from the top to the bottom, and that we could then, with the aid of some mighty magician, haul this shaft of ice up, and stand it on end for inspection and examination. It would be 18,000 feet high; the pressure on its pedestal would be more than a million and a quarter of pounds; and if placed in a ship of 648 tons burden, it would be heavy enough to sink her.

There are currents in the sea where it is 3,000 fathoms deep, and some of them—as the Gulf Stream—run with a velocity of four miles an hour, and even more. Every square foot of the earth's crust at the bottom of a four-knot current 3,000 fathoms deep, would have no less than 506,880—in round numbers, half a million—of such columns of water daily dragging, and rubbing, and scouring, and chafing over it, under a continuous pressure of 648 tons.

Water running with such a velocity, and with the friction upon the bottom which such a pressure would create, would, in time, wear away the thickest bed, though made of the hardest adamant.

Why, then, has not the bottom of the sea been worn away? Why have not its currents cut through the solid crust in which its billows are rocked, and ripped out from the bowels of the earth the masses of incandescent, molten matter that is pent up and boiling there?

If the currents of the sea, with this four-mile velocity at the surface, and this hundreds of ton pressure in its depths, were permitted to chafe against the solid matter of its bed, the Atlantic instead of being two miles deep and 3,000 miles broad, would, we may imagine, have been long ago cut down into a narrow channel that might have been, as the same ocean, turned up on edge, and measuring 2 miles broad and 3,000 deep. But had it been so cut, the proportion of land and water surface would have been destroyed, and the winds, for the lack of area to play upon, could not have sucked up from the sea vapors for the rains, and the face of the earth would have become as a desert without water.

Now there is a reason why such changes should not take place, why the currents should not uproot nor score the deep bed of the ocean, why they should not throw out of adjustment any physical arrangement whatever in the ocean; for in the presence of everlasting wisdom a *compass has been set upon the face of the deep; its waters were measured in the hollow of the Almighty hand; bars and doors were set to stay its proud waves; and when He gave to the sea His degree that its waters should not pass his command, He laid the foundation of the world so fast that they should not be removed forever.*

The currents of the deep sea are, therefore, so adapted and arranged that they should not wear its foundations away. Its bed is protected from abrasion by a cushion of still and heavy water. There it lies—that beautiful arrangement—spread out over the bottom of the deep, and covering its foundations as with a garment, so that they cannot be fretted. If the currents chafe upon it now here, now there, as they sometimes probably do, this protecting cushion is self-adjusting; and the moment the unwonted pressure is removed the liquid cushion is restored, and there is again compensation.

If our labors had been attended by no other results than those contained in this discovery touching the depths of the sea, it alone would have been, in the eyes of all great and good men, an exceedingly rich harvest for the time and labor expended.

This discovery suggests that the streams of running water in the sea play rather about its surface than in its depths.

The causes which produce oceanic currents reside at and near the surface; they are changing heat and cold with their powers of contraction and expansion; the winds and sea-shells, with evaporation and precipitation; and none of these agents appear capable of reaching very far down into the depths of the great and wide sea with their influences. They go not much, if any, further down than the light can reach.

On the other hand, the most powerful agents in the atmosphere reside at and near its bottom; so that, where these two great oceans meet—the aqueous and the aerial—there we probably have the greatest conflict, and the most powerful display of the forces that set and keep them in motion, making them to rage and roar.

The greatest depth at which running water is to be found in the sea is probably in the narrowest part of the Gulf Stream, as, from its mighty fountain, it issues through the Florida pass; and the deep-sea thermometer shows that even here there is a layer of cold water in the depths beneath, so that this "river in the sea" may not chafe against the solid bottom.

What revelations of the telescope, what wonders of the microscope, what fact relating to the physical economy of this terrestrial globe, is more beautiful or suggestive than this secret from the hidden paths of the sea?

In my researches I have as yet found no marks of running water impressed upon the foundations of the sea beyond the depth of two or three thousand feet. Should future deep-sea soundings establish this as a fact in other seas also, it will prove of the greatest value in submarine telegraphy.

What may be the thickness of this cushion of still water that covers the bottom of the deep sea is a question of high interest, but we must leave it for future investigation.

In the chapter on the *Salts of the Sea*, I have endeavored to show how sea-shells and marine insects may, by reason of the offices which they perform, be regarded as compensations in that exquisite system of physical machinery by which the harmonies of nature are preserved.

But the treasures of the lead and revelations of the microscope present the insects of the sea in a new and still more striking light. We behold them now serving not only as compensations by which the motions of the water in its channels of circulation are regulated, and climates softened, but acting also as checks and balances by which the equipoise between the solid and the fluid matter of the earth is preserved.

Should it be established that these microscopic creatures live at the surface, and are only buried at the bottom of the sea, we may then view them as conservators of the ocean; for, in the offices which they perform, they assist to preserve its *status* by maintaining the purity of its waters.

Does any portion of the shells which Brooke's sounding rod brings up from the bottom of the deep sea live there; or are they all the remains of those that lived near the surface in the light and heat of sun, and were buried at the bottom of the deep after death? Philosophers are divided in opinion upon this subject. The facts, as far as they go, seem to favor the one conjecture nearly as well as the other. Under these circumstances I am inclined, however, to the the anti-biotic hypothesis, and chiefly because it would seem to conform better with the Mosaic account of creation. The sun and moon were set in the firmament before the waters were commanded to bring forth the living creature; and hence we infer that light and heat are necessary to the creation and preservation of marine life, and since the light and heat of the sun cannot reach to the bottom of the deep sea, my own conclusion, in the absence of positive evidence upon the subject, has been that the *habitat* of these mites of things hauled up from the bottom of the great deep is at and near the surface. On the contrary, others maintain, and perhaps with equal reason, the biotic side of question. Professor Ehrenberg, of Berlin, is of this latter class. The following correspondence presents fairly each side of the question:

Professor Ehrenberg to Lieutenant Maury.

BERLIN, *October*, 1857.

SIR: Already so much indebted to your kindness, I am continually receiving new proofs of your liberality. His excellency Baron Von Gerolt has recently sent me from you the ashes fallen upon an American vessel near Ceylon and the Maldive Islands. I have made a report thereupon to the Berlin Academy, which I hope will not be without interest.

I am much grieved at the death of your competent Professor Bailey, one of the most skillful and zealous observers, and whom I have nominated to our Academy of Sciences as a candidate for its membership, but who has fallen under a fatal malady. His works were always excellent.

As to the great depths of the sea, I propose a general survey for all the seas of the globe, for a continuation of this microgeology which must soon go to press. I should be very happy to receive again some specimens from the great American depths. It is only the scientific efforts of Americans, as yet, which furnish these so interesting materials, and it is especially Mr. Maury, who animates Americans and other dwellers upon the earth to obtain knowledge of the sea. The Atlantic specimens which Professor Morse, of New York, sent to Mr. Von Humboldt, had been already prepared; they were preserved between two glasses. For this reason I have not been able to make any very clear investigations, for which I should have need of the free unaltered material. Perhaps it will be possible for you to send me some, however little, of this unaltered material. I have the honor to join herewith the extract from my printed report.

Of the deep soundings in the line of the projected Atlantic telegraph, which are 29 in number, I know only 5, the same which Mr. Morse sent to Mr. Humboldt, and which are not among the deepest. I know that they have reached soundings of 2,000 to 2,070 fathoms.

In general I know and have examined soundings of the seas of the globe as far as 12,900 feet. But the late Mr. Bailey has examined to 16,200 feet. Will it be possible to regain some small portion from this same locality?

In your memoir published by the Geographical and Statistical Society of New York, I see that you have followed the judgment of the old observers who deny the existence of stationary life at great depths, and who sustain themselves, of late, by the observations of Mr. Forbes. Also Mr. Bailey has of late published similar opinions. I cannot agree with this anti-biotic judgment, after having put it beyond doubt, that the greater part of the small calcareous carapaces is filled with small soft bodies; Mr. Bailey also speaks of his observation of these soft bodies in the *silicious Bacillaria*, which strengthens my own remark. That the great compression prevents putrefaction is an hypothesis, but the existense of the soft bodies is a certain observation.

The other argument for life in the deep which I have established is the surprising quantity of new forms which are wanting in other parts of the sea. If the bottom were nothing but the sediment of the troubled sea, like the fall of snow in the air, and if the biolithic curves of the bottom were nothing else than the product of the currents of the sea which heap up the flakes, similarly to the glaciers there would *necessarily* be much less of unknown and peculiar forms in the depths. The surface and the borders of the sea are much more productive and much more extended than the depths; hence the forms peculiar to the depths should not be perceived. The great quantity of peculiar forms and of soft bodies existing in the innumerable carapaces, accompanied by the observation of the number of unknowns, *increasing with the depth*—these are the arguments which seem to me to hold firmly to the opinion of stationary life at the bottom of the deep sea.

Excuse, sir, this long letter. Saluting you and wishing you best health, I have the honor to be, your very obedient servant,

C. G. EHRENBERG.

Lieutenant Maury to Professor Ehrenberg.

OBSERVATORY, *November* 9, 1857.

The existence of animal life at the bottom of the *deep* sea is fairly an open question. In this aspect the depths of the sea are as yet almost as completely within the realms of conjecture as are the planets with their inhabitability. We have here and there a faint glimmering of light—such as the fact that many of the little shells hauled up thence contain soft matter—but the ray is so feeble that different spectators, occupying, as they often do, different stand points, see differently. Admitting the "soft bodies" to which you refer to be the fleshy parts of the infusoria, brought up for us by Brooke's deep-sea sounding apparatus, the hypothesis that they lived and grew down there will satisfy the fact I admit; but if we expand both hypothesis and fact, then we shall see, I think, that the other hypothesis will satisfy all the facts a little better than this biotic one of yours. You know it is customary with mariners, especially with the masters of the sailing packets between Europe and America, to "corn" fresh meat by sinking it to great depths overboard. If they sink it too deep, or let it stay down too long, it becomes too salt. According to them, this process is so quick and thorough, because of the pressure and the affinity which not only will force the water among the fibres of the meat, but which also induces the salt to leave the water and take to the meat. That the fleshy parts of these microscopic organisms have been exposed to powerful anteseptic agents, is proved by the fact, that they are preserved throughout the voyage, and until the microscopist can examine them. The specimens I now send you from the "Telegraphic Plateau" have been out of the water for more than a year. I should be glad to know if you find any of the fleshy parts still preserved.

Some of these specimens have come from depths where the pressure is equal to that of 400 or 500 atmospheres. Specimens have been obtained by Lieutenant Brooke, in the Pacific, with "fleshy parts" among them, at the depth of 3,500 fathoms, and where the pressure is 700 atmospheres. We have brought up fleshy matter from the deep sea as deep down as we have gone; and we may infer that if we were to go to 4,000 fathoms, we should still find pulpy matter among the dead organisms there.

At that depth, or a little over, common air, according to "Mariotte's *law*," would be heavier than water; and an air bubble down there, if one may imagine such a thing, would be heavy enough to sink. Under such conditions, and with the antiseptic agencies of the sea, the fleshy matter of these infusoria might be preserved at the bottom of the deep sea for a great length of time.

There is another stand point from which the antibiotic view is favored: There is no light at the bottom of the deep sea, "and there was light" before the waters were commanded to bring forth the moving creature that hath life. Light would, according to this authority, seem therefore to be a prerequisite to the existence of animal life. True, the fish in the great cave of Kentucky have no eyes: they live in black darkness, where eyes would be useless if they had them. But there the water itself is fresh from the light, and still within reach of the heat of the sun. Our notion of terrestrial adaptations moreover seem to favor the antibiotic view. I am encouraged to regard these little insects as the conservators of the sea. They secrete its salts, and prevent the accumulation of solid matter among its ingredients. When we look at the coral reefs and islands, at the marl beds, the chalk cliffs, and other aggregations of solid matter that these mites in the ocean have secreted from sea water, we may get some idea of their task. Each one does a part inconceivably small, but the mountain is formed of an inconceivably great number of just such small parts. By considering what these insects of the sea have done, we may form some idea of what they are doing.

Those agents, the winds, light, heat, &c., which disturb aqueous equilibrium near the surface of the sea, cannot reach down into its depths to disturb equilibrium there. Does water once lodged at the bottom of the deep sea, where its currents are not and cannot be felt, remain there forever? Certainly it must so remain if its specific gravity remain relatively unchanged. Our knowledge of the physical economy that has been ordained for the great deep, faint and superficial though it be, suggests the negative in reply to this question. We have an idea of harmony and design in creation, that there is perfect arrangement and adaptation throughout every part in the water beneath as well as the heavens above, in the smallest as well as the greatest.

If the water which now lies on the floor of the deep sea has to lie there forever, why was it made fluid instead of solid? Simply because it is fluid, we suppose it has been at the surface, and may be there again, in obedience to the workings of its system of circulation. Since there are no changes of temperature in the depths of the ocean, and no currents down there, I was at a loss to conjecture an agency by which the water that had once found its way to the bottom of the sea could ever find its way back again. If it went there in consequence of specific gravity, there it must remain until its specific gravity should be altered. Therefore, when the microscopists told us of the soft matter in these trophies from the bottom of the great deep, they discovered to me room for conjecture. By pressure, the flesh of these animalculæ secreted, after death, the antiseptic agents of the deep sea; by pressure, and the virtues of those agents, it was preserved from decay. Thus the salt, which weighed down the particle of water and lodged it at the bottom of the sea, was extracted from it there by this dead fleshy matter; the particle, therefore, having parted with a portion of its salt, became lighter, and rose to seek its place in the aqueous adjustment.

You mention, in support of your views, "the surprising quantity of new forms" that are found in the *deep* sea, and argue from this that they live at the bottom. Let us consider for a moment the difference between the upper stratum of shoal and the upper stratum of deep water that is within the influence of light and heat.

In coming from sea, and approaching soundings, every mariner notices the change in the color of the water. The littoral has, by contrast, a muddy appearance. In the clear blue of the deep sea the transparency of the water is greater than it usually is along the continental shores; therefore the rays of light and heat should penetrate further down in the clear water of the deep sea than in the less transparent littoral sheets; and, consequently, the thickness of the stratum of prolific water ought to be greater out upon the deep sea where the transparency reaches furthest down. Here, then, we have the conditions for many new forms. Suppose the biotic depth to terminate with the transparency of the water, and that we imagine this layer to be divided into habitable strata one fathom thick each:—each stratum in order as we descend would present a new climate, so to speak, differing from the one both above and below as to pressure, as well as to the intensity of light and heat, for the nourishment of its inhabitants. The water along the coasts, moreover, is diluted more or less with river water, which circumstance, as far as it goes, is again calculated to make a difference in form between the littoral and blue water organisms of the sea.

Another circumstance : On soundings, the currents and the agitations of the surface reach to the bottom and sweep off into deep water much matter that would settle near the shore were the depths on soundings more quiet.

Thus we have grounds for the conjecture that the deepest parts of the ocean, like the "pockets" which the gold washer finds in California, ought most to abound in treasures; masses and varieties should both be greater, supposing the bottom of the deep sea to be antibiotic.

By a process of reasoning like this, I have been induced to fancy the antibiotic hypothesis.

Your judgment is better than mine, and with diffidence I oppose your view. I am, however, ready to surrender my version of the case the moment a fact that it will not satisfy shall be presented.

Pray pardon me if I have vexed your patience by this long writing. The interest of the subject, and my respect for your opinions, are offered in excuse.

Very truly,

M. F. MAURY.

It is admitted (§ 105) that the salts of the sea come from the land, and that they consist of the soluble matter which the rains wash out from the fields, and which the rivers bring down to the sea.

The waters of the Mississippi and the Amazon, together with all the streams and rivers of the world, both great and small, hold in solution large quantities of lime, soda, iron, and other matter. They discharge annually into the sea an amount of this soluble matter which, if precipitated and collected into one solid mass, would no doubt surprise and astonish the boldest speculator with its magnitude.

176. This soluble matter cannot be evaporated. Once in the ocean, there it must remain; and as the rivers are continually pouring in fresh supplies of it, the sea, it has been argued, must continue to become more and more salt.

Now, the rivers convey to the sea this solid matter mixed with fresh water, which, being lighter than that of the ocean, remains for a considerable time at or near the surface. Here the microscopic organisms of the deep sea lead are continually at work, secreting this same lime and soda, &c., and extracting from the sea water all this solid matter as fast as the rivers bring it down and empty it into the sea.

Thus we haul up from the deep sea specimens of dead animals, and recognize in them the remains of creatures, which, though invisible to the naked eye, have nevertheless assigned to them a most important office in the physical economy of the universe, viz: that of regulating the saltness of the sea, (§ 105.)

This view suggests many contemplations. Among them, one, in which the ocean is presented as a vast chemical bath, in which the solid parts of the earth are washed, filtered, and precipitated again as solid matter, but in a new form, and with fresh properties.

Doubtless it is only a re-adaptation, though it may be in an improved form, of old, and perhaps effete matter, to the uses and well-being of man.

These are speculations merely; they may be fancies without foundation, but idle they are not, I am sure; for when we come to consider the agents by which the physical economy of this our earth is regulated, by which this or that result is brought about and accomplished in this beautiful system of terrestrial arrangements, we are utterly amazed at the offices which have been performed, the work which has been done, by the animalculæ of the water.

But whence come the little silicious and calcareous shells which Brooke's lead has brought up, in proof of its sounding, from the depth of over two miles? Did they live in the surface waters immediately above? Or is their *habitat* in some remote part of the sea, whence, at their death, the currents were sent forth as pall-bearers, with the command to deposit the dead corpses where the plummet found them?

177. In this view these little organisms become doubly interesting. When dead, the descent of the shell to its final resting place would not, it may be supposed, be very rapid. It would partake of the motion of the sea water in which it lived and died, and probably be carried along with it in its channels of circulation for many a long mile.

The microscope, under the eye of Ehrenberg, has enabled us (§ 41) to put tallies on the wings of the wind, to learn of them somewhat concerning its "circuits."

Now, may not these shells, which were so fine and impalpable that the officers who obtained them took them to be a mass of unctuous clay—may not, I say, these, with other specimens of soundings yet to be collected, be all converted by the microscope into tallies for the waters of the different parts of the sea, by which the channels, through which the circulation of the ocean is carried on, are to be revealed?

Suppose, for instance, that the dwelling place of the little shells which compose this specimen from that part of the ocean be ascertained, by referring to living types, to be the Gulf of Mexico, or some other remote region; that the *habitat* and the burial place, in every instance, be far removed from each other—by what agency, except through that of currents, can we suppose these little creatures—themselves not having the power of locomotion—to come from the place of their birth, or to travel to that of their burial?

Man can never see—he can only touch the bottom of the deep sea, and then only with the plummet. Whatever it brings up thence is to the philosopher matter of powerful interest; for on such information alone as he may gather from a most careful examination of such matter, the amount of human knowledge concerning nearly all that portion of our planet which is covered by the sea must depend.

Every specimen of bottom from the deep sea is, therefore, to be regarded as containing something precious in the way of contribution to the sources of human knowledge.

CHAPTER XIII.

SUBMARINE TELEGRAPHY.

An important discovery, § 178.—The difficulties of laying a submarine telegraph more in the cable than in the sea, § 179.—The sub-Atlantic cable of 1857, § 180.—The route for it, § 181.—The best season for laying it, § 182.—The cable parts, § 183.—A telegraph cable between Cuba and the United States, § 184.

§ 178. All my researches concerning the depths of the sea suggest the idea of quiet and repose there. That the bottom of the deep sea is protected from the abrasion of its currents by a cushion of still water seems more than probable. The deep-sea soundings all tend to confirm this view, for among the specimens which Brooke's sounding rod has brought up thence, there is no indication of any abrading agent such as running water in the recesses of the ocean. Observations, as far as they go, warrant the opinion that the currents of the sea do not extend far down. The agents which beget them reside near, at, or above the surface. In the depths of the ocean there are no variable forces at play, such as those of alternating heat and cold, to alter the specific gravity or disturb the equilibrium of the waters; and the microscope has yet to detect in the specimens brought up from the bottom the first indication of running water beyond the depth of a few hundred fathoms below the surface.

This is a discovery of great importance in submarine telegraphy.

Neverthelesss, the idea that a telegraphic wire being once lodged on the bottom of the deep sea would lie there for an indefinite period with nothing but the tooth of time to fret, or chafe, or gnaw it away, seems to have escaped the notice of those who have projected ocean telegraphs and planned cables for the deep sea. At any rate the fact has been ignored in the construction of what are called the cables. Pecuniary loss, disappointment, and failure have been the consequence. I believe that it will not cost much, if any, more to establish lines of telegraph across the sea, mile for mile, than it does over the land; with this difference in favor of the deep sea, the wire once planted there will have nothing to disarrange or disturb it. The dangers to be guarded against all reside on shore and in shallow water—calling shallow water what seamen usually term "soundings." It is only on soundings, where the seas in their rage, or anchors, icebergs, and drift can reach and fret the wire, that danger is to be apprehended for the cord of the submarine telegraph.

Now, since there are no currents at the bottom of the deep sea; since the forces which play at and near its surface cannot descend but a little way into its depths, what, may we ask, do we want with those tremendous wire ropes called telegraphic cables to hold the conducting wire on the quiet bottom of the deep sea? If there be no currents there; if the bottom of the deep sea be really protected, as observations indicate, from the abrading action of its waves and currents by a cushion of still water, what, I would ask again and again, do we want with telegraphic cables—those massive and expensive iron served ropes—to hold the conducting wire down? Is not the iron casing a needless expense? The conducting wire being insulated with gutta perch made heavy enough to sink, and paid out slack, would reach the great "Telegraphic Plateau" safely just so surely as it is paid out whole into the sea.

Suppose the iron wire were stripped off the cable, figs. 5 and 6, Plate XII, (which are drawings of the Atlantic telegraph, natural size,) and that the conducting wires with the gutta percha coating were of themselves heavy enough to sink, is it not obvious that such a cord might be paid out without difficulty and just as fast as the ship can go, and that if it were so arranged that while the ship was going 10 miles through the water, 12 or 14 miles of telegraphic cord would be paid out, there would, after paying it into the sea, be nothing to try its strength. Suppose this cord, stripped of its iron coat of mail, should be heavy enough to sink at the rate only of one mile an hour, any one part of it would in 15 or 20 minutes, perhaps, after touching the water, be below the currents. Suppose these to be active enough to sweep it in that time a mile or two to the right or the left of the vessel's track, the cord would still pass through the currents without resisting them, and reach the bottom with slack enough to lie there in safety; for if the wire were drifted and landed by the currents 10 miles, all the way across, on either side of the track made by the paying out vessel, the additional length of wire required to reach between the two landings would be very little—not more than a few miles, even in cases where the landings are as far apart as Newfoundland and Ireland.

The same remarks apply to the Mediterranean cables. They are all too large, too expensive, and too difficult to lay, except for shallow water, as across the English Channel, and on soundings. In shallow water and near the shore the cable, for safety, cannot well be too large, as, for the deep sea, it cannot well be too small, provided only it be properly insulated and the conducting wire have the requisite electrical capacity.

Figures 5 and 6, Plate XII, are sections, natural size, of the sub-Atlantic cable, which, in August, 1857, the United States ship Niagara attempted to lay between Ireland and Newfoundland. The attempt proved a failure. It is to be renewed again during the summer of 1858; the company are sanguine of success—no one can wish them good luck more earnestly than I; still the difficulties, especially with such a cable, are formidable.

It is instructive to mark the change which the light afforded by our deep-sea soundings has called for in telegraphic cables for the deep sea. The sea is mighty in its rage, and its forces, when at play, are terrible. The first idea with the telegraphic engineer seems to have been that these forces must be met by force and resisted by might; hence, the first cable proposed and used were immense iron shrouds, large enough to hold a 74-gun ship at her anchors, and, heavy enough to weigh six or eight tons to the mile.

§ 179. Experience, however, proved that the difficulty of planting such cables along the bed of the ocean was really not in the sea, but in the rope itself. It was so large that it could not be handled, and the chief source of difficulty was in getting it overboard. To give it strength sufficient for the sea, as it was thought, they had to give it size and weight; and as these were arithmetically increased, the difficulties of laying it grew in geometrical progress; so that the strength of these cables really made them weak. From this cause the French failed twice in the Mediterranean, and the Atlantic Telegraph Company once, between Newfoundland and Cape Breton. They had to cut the cable to save the ship from foundering. It was, therefore, a great step to be gained at one stride in the march of improvement when the Atlantic Telegraph Company gave up their first Newfoundland cable and resorted to one as per Plate XII, for the Atlantic. The regret is, they did not go far enough. The gutta percha covering of every submarine wire heretofore, except that of the Black Sea, had been wrapped in a casing of iron wire. But in proportion as this wrapping is stout and heavy, so are the difficulties of handling, the risks of paying out, and the danger of losing it.

§ 180. The Atlantic Telegraph Company, therefore, did wisely to attenuate this wire wrapping for their cable; but, had the problem which they had undertaken been considered more attentively in some o f its physical aspects, it would have been perceived that a slack rope, sc long as it is slack, cannot be broken by the winds or the waves, or the currents of the sea; that in its depths all is calm and quiet; and that the cable being slack enough to adjust itself to the inequalities of the bottom, there is no force down there to try its strength. If, I say, these facts and circumstances had been duly weighed, there would have been no need of risking half so much money in this enterprise, grand and noble though it be, or of calling on the two great maritime powers of the world to lend their navies to the work, nor would the cord have broken.

Such a wire as this would answer much better for the Red Sea than for the Atlantic Ocean. In the first place, the Red Sea is a shallow sea. The water at the bottom is flowing outward, as that on the surface flows inward; and its shallow depths do not, it is conjectured, present that scene of quiet and repose which reign over the Telegraphic Plateau of the Atlantic. Moreover, the Red sea cable will lie longitudinally with its currents, not across them.

In the next place, the breaking strain of this Atlantic cable is said to be 4 tons; it weighs about a ton to the mile, and in the deepest parts of its route across the Atlantic nearly three miles of it will be suspended between the ship and the bottom. To say nothing as to its strength, or of the fact that a cord of that sort is no stronger than it is at its weakest part, let us consider this condition: the greater the length out the greater the strain, and the greater the strain the greater the difficulty in paying out. But in the Red sea there would not, perhaps, in the deepest part, be more than half a mile of this cable between the ship and the bottom. Therefore, while practically it is heavy to handle in the Atlantic, requiring breaks to check and machinery to hold back, in the Red sea it would be comparatively light and easy to handle. In one case, it has to bear nearly three miles of its own weight; in the other, it would probably have not over one-sixth of that length with its corresponding weight.

I urge these views here so earnestly because the occasion calls for them, and because I wish to direct the attention of other submarine telegraph companies and men of enterprise to the true character of the physical forces with which they have to contend in carrying out the grand submarine telegraphic schemes of the world.

It has been urged that the wire covering is a protection of the conducting wire against sharks. But the iron coating of the Atlantic cable is intended for no such purpose, I imagine; for a shark could, without difficulty, thrust his teeth between the iron cords and down into the gutta percha. But no danger from sharks is to be apprehended along the Telegraphic Plateau; and in parts of the ocean where danger from them is to be apprhended, it may be eluded by artifice and a much more simple contrivance than an iron shield extending from one line to the other.

The following letter, because of its bearings upon this grand and noble enterprise, is given a place here:

Observatory, Washington,
March 28, 1857.

Dear Sir: Your letter of the 7th instant, covering, for my perusal and suggestions, the copy of a letter from Colonel Everest to the "chairman and directors of the Atlantic Telegraph Company," has been received.

§ 181. The colonel has kindly taken the trouble to give in that letter the co-ordinates for the great circle along which the cable is to lie, with the course and distance for every degree of longitude which each of the two vessels, with the cable on board, will have to sail in order ot keep near the great circle while paying out.

If the termini of the submarine cable be where the colonel supposes them, he has made the "way for the lightning" so plain, that the paying out steamers, taking up their position midway, can be in no doubt as to the courses and distances to be made thence by each to her terminus of the line.

But I understand that the *exact* points of these termini have not yet been finally established, further than that the one to the east is to be somewhere within Valentia harbor, and the one to the west *somewhere* in Trinity bay.

To complete the route for the paying out steamers, I have taken as the termini of the arc of the great circle, near which the cable is to lie, one point in the middle of the entrance to this bay, and the other in the middle of the entrance of this harbor.

The former point according to the French chart entitled, "*Carte de la côte orientale de l'Amérique Septentrionale, comprenant l'Ile et les Bancs de Terre-Neuve, dressée d'aprês les travaux les plus récents, publiée par ordre de l'Empereur, au Dépôt Général de la Marine en* 1853." The latter, or that for Trinity Bay, is in latitude 48° 15′ N.; longitude, 53° 2′ W.; and for Valentia harbor it is in latitude 51° 56′ 30″ N.; longitude, 10° 20′ W., according to the English admiralty chart. "*Ireland, sheet XII, Valentia to Cape Clear, surveyed by Commanders Wolfe and Church, Lieut. Veitch and Mr. George, master*, 1849–'53."

From the point of entrance to the head of Trinity Bay, where the cable is to be landed, is about 50 miles; but the head of Valentia harbor is not more than three or four miles from its point of entrance. Therefore, if the place of meeting for the two steamers be at sea midway between these two points, instead of midway between the points of landing, the western steamer should have on board some 45 or 50 miles of cable more than the other.

At this point of entrance in Trinity Bay the chart shows soundings of upwards of 150 fathoms without bottom, but the depth in mid-channel of entrance to Valentia is only 21 fathoms. Each vessel, on arriving safely at the entrance of her bay or harbor, may be considered to have accomplished her task and to have passed all the dangers of the sea; the cable may then be landed at will and without more ado.

It is now proposed to treat of the great circle between these points of entrance and to give the several courses and distances which the two paying out vessels, after meeting midway and joining cables, will have to make good in order to reach by the shortest practicable distance the mid-entrance each of the haven to which she is bound.

The position of these two terminal points differs from the position of those which Colonel Everest assumed for his great circle, by 3′ 30″ of latitude, and 5′ of longitude, for the eastern one; and by 34′ of latitude, and 23′ of longitude for the western one. The distance between the two points which are herein assumed is one mile seven-tenths less than the distance given by Colonel Everest between the terminal points assumed by him.

The computations herewith submitted were made by Professor Hubbard, and they may be relied on as correct, assuming the figure of the earth to be a perfect sphere.

Paralells of latitude at which the Great Circle between the mid-entrance of Trinity Bay and Valentia harbor intersects the meridian of every fifth degree of intervening longitude.

Longitude.	Latitude.	Longitude.	Latitude.
° ′	° ′	° ′	° ′
10 20	51 56.5	35 00	51 50.4
15 00	52 19.3	40 00	51 10.3
20 00	52 31.1	45 00	50 15.8
25 00	52 30.4	50 00	49 05.7
30 00	52 16.9	53 2	48 15.0

The vertex of this Great Circle is in longitude, 22° 10.9′, and latitude, 52° 32.4′; the bisecting point in latitude, 52° 4.9′, longitude, 32° 32′.

The whole distance between the terminal points is 1,634.3 miles.

The Great Circle route is really impracticable; for no navigator can steer his vessel for any length of time along the arc of this circle. Practically, the vessels employed to lay the cable must be actually steered along the sides of a polygon, and not along the arc of a circle. The shorter the sides and the less the ship will have to change her course in passing from one side to another of this polygon, the less will she deviate from the Great Circle.

Now when we come to take into account false steerage, the uncertainties of drift, of currents, and reckoning, with the errors of the compass, and to consider the teaching of actual experience in navigation we may safely assume that the steamers employed on this work will not be able to make good the courses actually required of them; on the contrary, they will deviate and their deviation will be appreciable. The difficulty of making good the intended course and distance is so well understood that usually at sea navigators do not on long runs, upon single courses, think it worth while to subdivide them further than to the quarter of a point. Let this be assumed as the limit of deviation for this work.

I therefore recommend that the paying out steamers should, after meeting and joining wires in mid-ocean, attempt the *polygonal* rather than the Great Circle route. I give the co-ordinates for such a many sided route, so projected that in passing from one side to the other of the polygon the ship shall change her course ¼ of a point only. And that the difference between the distance by the polygonal route and the distance by the Great Circle route may be a minimum, the polygon is neither an inscribed nor circumscribed figure, but is so constructed that every side shall be trisected, the Great Circle cutting each side twice, and in such a manner that the distance of the middle of the side below the Great Circle shall be in every case equal to the distance between the circle and either end of the same side.

By this means a polygon route has been obtained, which follows the Great Circle so closely that if two ships of equal speed were to set off from Trinity Bay and keep abreast of each other to Valentia harbor, one on the polygonal, the other on the Great Circle route, they would nowhere along the route be out of hail of each other.

Supposing the paying-out ships to meet midway—that is, in latitude, 52° 4.9′, longitude, 32° 32°, to connect their cables, each will be 817½ miles, by the polygonal route, from the point at mid-entrance of her harbor, and steering by ¼ points will have to make good the following courses and distances to reach that point, viz:

The steamer going east.

From—Longitude.	Latitude.	Course.	To—Longitude.	Latitude.	Distance.
° ′	° ′		° ′	° ′	*Miles.*
32 32	52 04.9	E. ¾ N.	31 04	52 12.8	54.1
31 04	52 12.8	E. ½ N.	27 31	52 25.6	130 9
27 31	52 25.6	E. ¼ N.	23 58	52 32.0	130.1
23 58	52 32.0	E.	20 25	52 32.0	130.2
30 25	52 32.0	E. ¼ S.	16 52	52 25.6	130.1
16 52	52 25.6	E. ½ S.	13 18	52 12.7	131.5
13 18	52 12.7	E. ¾ S.	10 20	51 56.5	110.6
					817.5

The steamer going west.

From—Longitude.	Latitude.	Course.	To—Longitude.	Latitude.	Distance.
° ′	° ′		° ′	° ′	*Miles.*
32 32	52 4.9	W. ¾ S.	34 37	51 53.4	78.3
34 37	51 53.4	W. by S.	38 11	51 27.0	135.3
38 11	51 27.0	W. SW. ¾ W.	41 48	50 52.9	140.3
41 48	50 52.9	W. SW. ½ W.	45 27	50 10.6	145.6
45 27	50 10.6	W. SW. ¼ W.	49 8	49 19.5	151.7
49 8	49 19.5	W. SW.	52 52	48 18.5	159.7
52 52	48 18.5	SW. by W. ¾ W.	53 2	48 15.0	6.7
					817.6

Whole distance by polygon .... 1,635.1 miles.
Whole distance by Great Circle .... 1,634.3 "

Thus you observe that each vessel will have only to change her course 6 times, and that the distance by the polygon is only eight-tenths (0.8) of a mile greater than by the Great Circle.

Now suppose that the telegraphic cord were such that it could be laid exactly, and without kinks, along the sides of the polygon, and that you had a windlass on shore, at each end of the route, by which being so laid, the cord could be "hauled taught," and so brought into the plane of the Great Circle, how much slack do you suppose there would be? Each windlass would haul in only about 350 fathoms.

This consideration, and the convenience of running ¼ point courses, make the polygonal, practically, *the* route.

If the cable were stretched across on the surface "taught" by the supposed windlasses and then sunk, it would, by reason of the spherical form of the earth, lie slack if the bottom were even. But what would actually be the difference in length between two lines in the plane of this great circle—one lying on the surface, the other on the bottom of the ocean—is matter of conjecture; for we neither know its depth, nor the configuration of the bottom with sufficient accuracy.

I had hoped that the United States steamer "Arctic," which was sent last summer especially to assist in these researches, would furnish the requisite data for this purpose; but her soundings, so far as depth and configuration are concerned, proved to be of no value.

The "Niagara" and the "Mississippi,"* the steamers employed on the part of this government to assist in laying the wires, will be furnished with sounding twine and Brooke's apparatus. It is hoped that these two ships in going over, and the Mississippi in returning, will run a line of soundings along the proposed route. Two or three casts along each side of the polygon would suffice. Being properly made and true, such soundings would be of exceeding value and importance. Each of these vessels is furnished with a chart like the one with the polygon which I send you.

You ask me, also, to state the best time for laying the cable.

§ 182. As to gales, there is no great choice on that score between the summer months. In this part of the ocean storms are less frequent in summer than at any other season of the year. But of all the months, June is the most foggy; and this fact, without further investigation, seems sufficient to put June out of the question.

The prevalence in this part of the ocean of gales, fogs, and ice has been the subject of laborious investigation at this office. It was commenced in January, 1855, in reference to the lanes† for steamers across the Atlantic. For many years the whole subject of gales, fogs, rains, and lightning, for the entire north and south Atlantic, has been under discussion, and I am just preparing to announce some of the results derived from upwards of 260,000 days of observations.

The investigations to which the chapter at page 308 of the Sailing Directions refers, and which are illustrated by Plate XXI of that volume, (Plate V, vol II,) are based on 46,000 days of observations made along the route to Europe.

I send you, also, a proof impression of each of four plates, illustrating, according to the 260,000 days of observations, the relative frequency of gales for the whole ocean during each of the months of January, June, July, and August.—(See Plates, "Gales in the Atlantic" for each of the 12 months.)

These plates show:

That in the months of January and February that part of the ocean which lies between Europe and the United States is the most stormy sea in the world; that along the telegraphic route there occurs at least five, perhaps ten, gales of wind during the month of January of every year;

That in the summer season the part of the ocean to be traversed by the paying out steamer going west is almost entirely exempt from gales;

That along the eastern half of the route there occurs annually, on the average, not more than two or three gales in the months of June or July; and,

That there is scarcely a liability to a gale in the month of August in any year until you approach the Irish coast, when the chances of encountering one are about as 3 to 30.

Plate V, vol II is the result of a separate and independent investigation, founded, however, on a greater number of observations for this particular region.

It corroborates the above, and enables us to make with more boldness, and somewhat more in detail, the following—

* The Susquehanna was sent in her stead.

† *Vide* p. 308, *et seq.*, 7th ed. Maury's Sailing Directions, a copy of which is herewith transmitted.

Statement showing the relative frequency of gales and fogs that annually occur on the average for every 5° of longitude along the telegraphic route for each of the months June, July, and August.

Longitude.	Gales.			Fogs.		
	June.	July.	August.	June.	July.	August.
Between 55° and 50° W	1	1	1	13	9	6
Between 50° and 45° W	0	0	1	13	9	8
Between 45° and 40° W	0	0	0	6	7	8
Between 40° and 35° W	1	0	0	5	4	2
Between 35° and 30° W	1	4	2	7	6	0
Between 30° and 25° W	1	2	1	6	5	6
Between 25° and 20° W	0	7	0	5	3	1
Between 20° and 15° W	1	0	0	2	2	0
Between 15° and 10° W	3	0	4	2	1	3

You observe now that in summer one side of the ocean is much more liable to storms than the other, and that the tranquil side is the most foggy. Accordingly, the steamer with the western end of the telegraphic cord will be less liable than the other to encounter a gale, but much more liable to be surrounded by ice. Ice is rarely or never seen along the eastern half of the route; the place for the ice is along the western part.

For ice in this part of the ocean, the log-books for 830 summer voyages, between the meridians of Valentia harbor and Trinity Bay, have been overhauled, of which—

26 out of 266, or 1 in 10, report ice in June;
13 " 306, or 1 in 24, " " July;
8 " 268, or 1 in 33, " " August.

If the risks to be avoided were from ice alone, August would be the month. If foggy weather were the only source of danger to be regarded while laying the cable, then one of the winter months would be the most favorable. On the other hand, if storms were the only difficulty, then June would be the month of smallest risk. But we have to regard all three of these classes of phenomena, and select the time which presents the least unfavorable combination of them.

As to the frequency with which gales and fogs and calms occur, we have all the information that one person could give us who had made not less than 1,500 passages between the same two meridians 55° and 10° W, and north of 40° latitude; and as for the information about ice, we have, as just stated, the actual experience of 830 summer voyages. Weighing these data and their dangers, and striking the balance, the result shows that August has in its favor the combination which gives the smallest total of risk—and the time when the risk shall be a minimum is the object of the present inquiry.

When, however, we come to recollect the character of these investigations—that they refer to the month as a *whole*, taking no note as to whether the gales, &c., occur on the first or last day; and, moreover, when we come to note the difference of the weather in May and June, and again in August and September, then we are left in no doubt as to the most propitious time for this undertaking: It is the last of July and first of August.

Almost every year, between the 18th and 21st of July, a remarkable atmospheric wave seems to roll from west to east across this part of the Atlantic.

In looking over the splendid volume just published by the ordnance survey of the United Kingdom of Great Britain and Ireland, which contains 23 years of meteorological observations at different trigonometric stations in Ireland, I was struck with the fact that almost every year there is there a remarkable fall in the barometer about the 20th of July.

DIAGRAM A.

Shoinwg the extreme annual range of the barometer in Ireland for each day from the 15th to 25th of July, from 1829 to 1852.

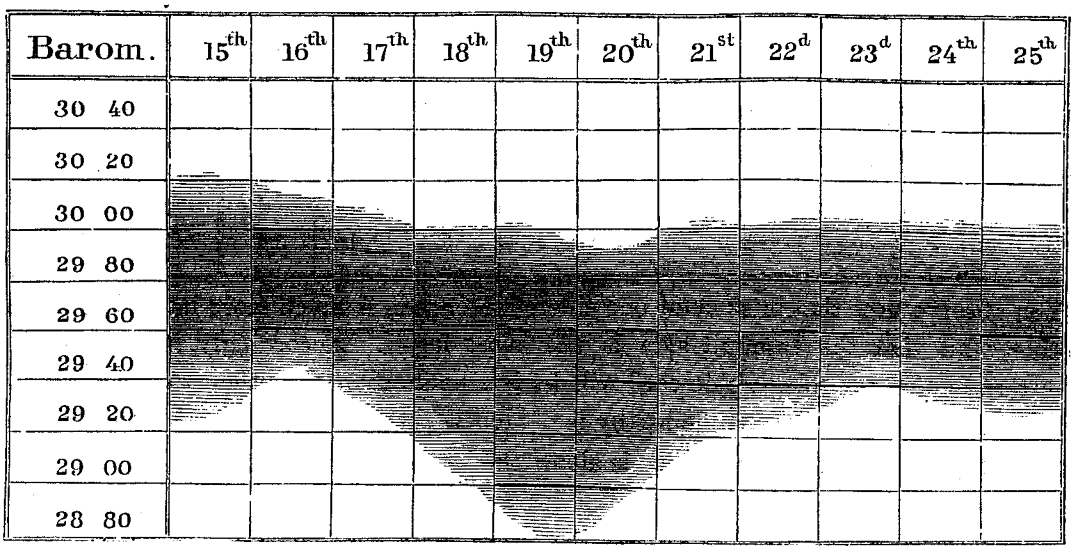
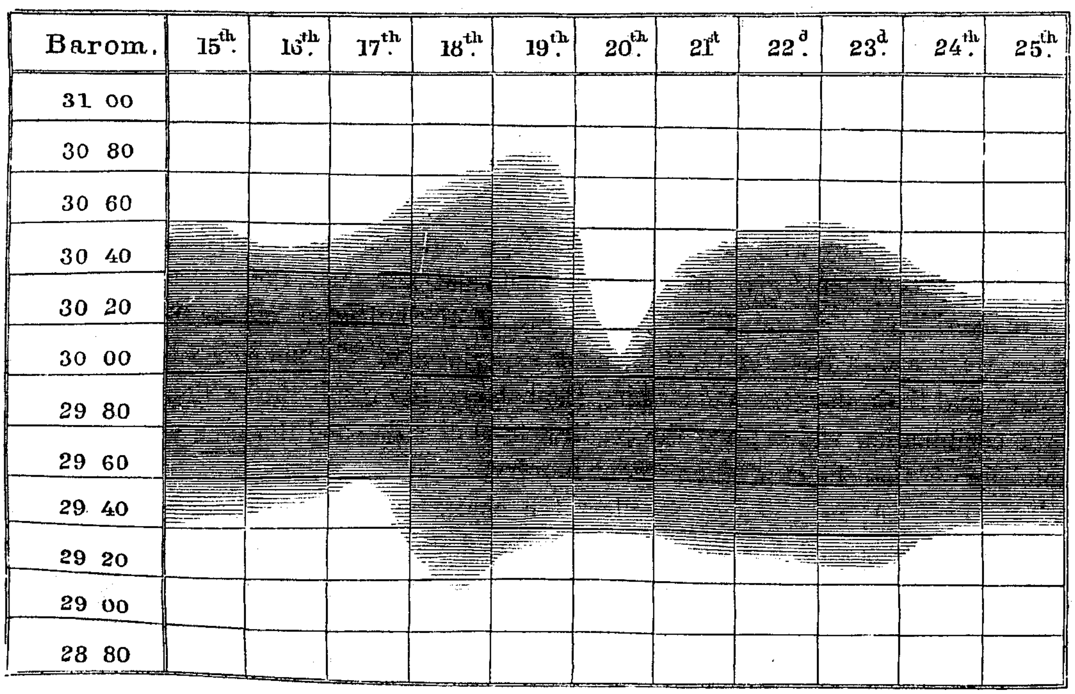


DIAGRAM B.

Showing the extreme annual range of the barometer at sea between Newfoundland and Ireland for each day from the 15th to 25th of July, as determined from the abstract logs of twenty-nine vessels.



The annual curves for the 10 days, from the 15th to the 25th of that month, projected for each one of the 23 years therein recorded, show the range of movement of this sort.—(See diagram A.)

On sixteen out of the 23 years, there was a falling barometer on the 19th and 20th of July—the range of the movements during this period being 1.2 inch; whereas, the mercury was nearly at the same height annually on the 16th and 17th, and again, a week later, the annual range for these days, during the same period, being only 0.8 inch.

Wishing further to pursue this subject with a view to its bearings upon the question before me, Lieutenant Bennett kindly undertook to overhaul the abstract logs of vessels between Newfoundland and Ireland, for the elements of a like curve at sea; and the records of 29 vessels give us diagram B, which shows a steady barometer at sea for the 20th July, annually, but an unsteady one for the preceding and following days.*

I do not know what is the meaning of this. So far as my observations go, this invisible wave appears to have been accompanied by a gale of wind but once or twice. Nevertheless, the enterprise upon which you are engaged is an important one; good weather for it is very desirable, nay, almost indispensible; and these barometric anomalies are suggestive. Perhaps it would be wise for the steamers not to join cables until after the 20th of July. I think between that time and the 10th of August the state of both sea and air is usually in the most favorable condition possible; *and that is the time which my investigations* indicate as the most favorable for laying down the wire.

I recommend it and wish you good luck. Yours,

M. F. MAURY.

CYRUS W. FIELD, Esq.,
New York.

§ 183. The cable, 2,500 miles total length, having been embarked one half on board the United States steamer Niagara, and the other half on board her Britannic Majesty's steamer Agamemnon, those two vessels, accompanied by her Britannic Majesty's steamer Cyclops and the United States steamer Susquehanna, repaired to Valentia about the first of August, 1857. The plan finally adopted was that the Niagara should lay the first half of the cable, the Agamemnon following with the intention of joining her half to that of the Niagara in mid-ocean and proceeding thence with the end of it to Newfoundland.

The eastern end of the cable having been landed on the Irish shore, the squadron proceeded to sea, August 6, the Niagara paying as they went. I quote a single extract from the correspondent of the New York Herald, on board that vessel:

"*August* 11, 1857.—At 3.45 the machinery stopped and the telegraph cable parted in latitude 52° 29′ 5″ N.; longitude, 17° 23′ 2″ W.; 265½ miles made good, and about 380 miles of cable paid out. At 11, Agamemnon sent a boat with a hawser.

"We sent her the end of the cable on board to splice.

"The cable jammed on board the Agamemnon and parted.

**Immense loss of life on the fisheries.*

BOSTON, *August* 5, 1857.—Information has just been received here that on the 22d of July a gale occurred on the north shore of St. John's, accompanied by great loss of life. Sixty boats are supposed to have been lost. Fifty dead bodies have been picked up. It is calculated that there were two hundred boats employed in fishing, and many more disasters are feared. One hundred and thirty American fisherman had put into port at Price Edward's Island for shelter, and a number of fishing boats have drifted ashore.—"*Associated Press.*"

"The Cyclops made a signal she had found bottom at 2,000 fathoms. A heavy swell from the westward.

"At 12.30 received on board the end of the telegraph cable from the Agamemnon; spliced the two ends together, and each paid out several miles. At 3 the Agamemnon made signal that 'the cable has parted.'

"At 3.30 the cable parted near the stern when the ship was stationary. The cable was up and down."

It thus appears that the cable parted several times. The squadron had just fairly got out into deep water, (2,000 fathoms); the sea was right rough, and the cable, at its first parting, was running out quick, and being checked suddenly, parted by its own weight, for about two miles and a half of it were at the time suspended between the ship and the bottom of the sea. So far, also to avoid a strain upon the cable, it had been paid out quite freely, the slack or "stray" cable amounting to 40 per cent. of the distance run. But now the brakes were applied; and, being checked too suddenly, the massive cord snapped asunder; and this it did as often as either or both of the ships tried their hand at paying out in that depth and sea way, and this it is feared will be the result as often as the experiment is made with over massive cables or imperfect machinery in such a depth of water. They had not at the time of this mishap reached the deepest part of the "Plateau."

§ 184. The following letter, written three months before this unlucky failure, to the agent of a Spanish Submarine Telegraph Company, treats of the objections to wire-served telegraphic cords for the deep sea. This letter, the letter of 8th November, 1856, to the Secretary of the Navy, and the circumstances connected with the parting of the cable, all show that the true nature of the difficulties in the way of landing a submarine telegraphic wire safely upon the "Plateau" had not been properly understood. They show that the failure occured by reason of the weight and the *supposed* strength, but *consequent weakness* of the cable. Failure in the Atlantic seems to have damped the Cuban enterprise. This, like the other, is of easy accomplishment. I hope the Cuban company, like the Atlantic, will take courage from failure and resume the enterprise at an early day; good management will insure success.

Observatory, Washington, *May* 7, 1857.

Dear Sir: Last year, following close upon the heels of the recognition of the fact that the bed and bottom of the deep sea are everywhere protected from the abrading action of its currents by a cushion of still water, I had the honor to address a memorial to the government of her Catholic Majesty in relation to the establishing of a submarine telegraph between the island of Cuba and the shores of the United States.

Statements are made in that memorial which bear directly upon the object of the inquiries which in your note of yesterday you address to me, and in which I read with great delight the sententious announcement: "It is intended to lay a submarine telegraph between Cuba and Florida."

In compliance with your request for monographs and unpublished information bearing upon this highly interesting and important problem, I make extracts from that memorial, which sets forth that for the last fourteen years the memorialist has been engaged in researches connected with the physical geography of the sea:—

"That in the course of these researches, facts of great practical value have been elicited, in consequence of some of which certain American citizens and British subjects have been encouraged in the undertaking to establish a submarine line of magnetic telegraph between the old world and the new ;—

"That so much of this line as extends from the United States to Newfoundland has already been constructed, and the company is now actively engaged in making ready for the cable which is to extend from Newfoundland to Ireland, and be thence connected with the lines of the United Kingdom. This submarine cable, it is expected, will be laid next summer, so that before the end of another year, Europe and America may be in instantaneous communication with each other ;—

"That commercially to the people of the United States, and to the government and people of Spain commercially, socially, and politically, it would be a matter of great moment to bring the island of Cuba within this circuit of communication ;—

"That by running a line of telegraph from one of the neighboring States of the south, as Florida, or Alabama, or Geogia, across the Gulf Stream to Havana, and connecting it with the net-work of telegraphic wires in the United States, the island and the people of Cuba would thereby be placed in instant telegraphic communication with all places, both in America and Europe, to which this telegraphic net-work with its marvelous ramifications extends. New Orleans and Quebec, Halifax and Boston, New York, Liverpool, London, and Paris, Washington and Madrid, will all be thus brought within speaking distance of Havana ;—

"That the inconvenience, the losses, and the sacrifices, which all those, both in Spain, Cuba, and elsewhere, who are concerned in Cuban trade and prosperity are called on to suffer, and do suffer, in consequence of the want of telegraphic connexion between that island and the rest of the world are grievous. And while it would be difficult to state the value of this connexion to the commerce of the island, it would be still more difficult to estimate the value to the mother country of having that gem of the Antilles brought so close to her, as to time, that she might hold communication with it daily, transmitting messages and receiving replies, all within the self-same hour. Cuba being brought thus close to the royal council chamber, the captain general might govern it as well from Madrid as from Havana ;—

"The Gulf Stream, it has been thought, would, on account of the great volume, depth, and velocity of its current, render it impossible successfully to span it with a telegraphic cable; but the researches and the discoveries made by the memorialist concerning the currents and the depths of the sea, together with the study which he has given the subject, justify him in asserting, as, with a full sense of the responsibility incurred, he intends by this paper to assert, that the obstacles of the Gulf Stream and its currents have been theoretically surmounted, and that there are no physical difficulties of an insuperable character in the way of throwing over Cuba the meshes of the telegraphic net-work, which is spread out over Europe and America; and the memorialist is willing to risk upon a successful and practical demonstration of this problem whatever of reputation he may possess in the world of science."

You may, therefore, imagine the high satisfaction with which I heard that this beautiful enterprise has been encouraged by the Spanish government and taken up by Spanish capitalists, and that a submarine cord between Cuba and the United States is to be laid during the year.

I proceed to reply to your points of inquiry, treating them in the order in which you propound them.

"Depth of water between Cuba and the United States."

The information upon this subject is meagre; and before any attempt be made to run the telegraphic wire between the two shores, vessels should be specially employed to increase our information and satisfy your interrogatory.

From the soundings made by Lieut. Taylor, in the United States ship Albany, as well as by other officers of the navy who have been co-operating with me in procuring physical statistics from the sea, it appears that the depths of the Gulf Stream, between Cuba and Florida, probably does not exceed 500 or 600 fathoms. The greatest depth to be found in the Gulf of Mexico I conjecture to be about one mile; rather under than over.

"Character of the bottom.?"

Everywhere in the deep sea, wherever the beautiful contrivance of Lieut. Brooke has been sent down for specimens, we learn from the returns that have been received the same story: that in the depths below are deposited all those myriads of organisms which the waters bring forth so abundantly; that for ages the sea has been covering its bed with the microscopic feculences of its water, until they lie there like a mass of lees many feet thick. This fact is very suggestive, for it teaches us that, excepting the volcano and the earthquake, there are at the bottom of the deep sea no forces at play which are capable of trying the strength of even so much as a gossamer, could a thread of it be once safely lodged there.

From a failure to recognize this fact and to appreciate it, great difficulties and drawbacks in establishing submarine lines of telegraph have arisen. The idea was that the submarine telegraph must necessarily be a *cable;* that as the forces of an angry sea are mighty, so the strength of the cable must be great. In giving it strength they gave it also both bulk and weight, thus lending it weakness and insuring failure.

Since the bottom of the deep sea is fended by a cushion of still water from the fury of the terrible forces which are seen raging at and near the surface;—and since the plummet with its specimens has revealed to us the fact that there are no forces at play upon the bottom of the deep sea which have energy enough to drift out of place or to abrade any animal or mineral substance the most delicate, fragile, and light that gravity is capable of placing there;—we perceive that neither massive cables nor heavy anchors are required to hold the electric cord at the bottom of the deep sea;—that having gravity to sink and strength enough to hold together while sinking are, next to proper insulation, the chief, nay, almost the only, requisites.

Near the shore, and in depths less than 100 or 200 fathoms, where there may be danger from the forces always playing, and liable to be called into play there, such as the action of the waves and drift, the accidents of anchors, &c., the telegraphic cord should be heavily coated with a shield of iron, that would give it weight and strength securely to withstand the action of all such abrading or accidental forces.

This is an important point; upon the manner in which it may be met by the company will hinge the success of the enterprise, I shall, therefore, allude to it again.

"How far down do the surface currents of the sea extend?"

In reply it may be said there is upon this point no direct evidence whatever. But I have in the course of my researches come across one or two facts or circumstances which incidentally bear upon this subject, they have induced me to suppose that there is no running water at the bottom of the deep sea, and that its currents do not extend a great way below the surface, probably never so much as a mile, perhaps not more than the quarter of a mile.

In no specimens obtained from the bottom of the sea, where its depth is over 200 fathoms, have any evidences of abrasion or marks of running water been detected. But special inquiry into this subject is of great importance. It deserves particular attention, and is of particular consequence to the successful prosecution of the enterprise which you represent.

To know how deep the currents are is even of more importance in an enterprise of this sort than to know how deep the sea is; for when the strata of currents have been safely passed by the wire all the difficulties, if your cable or cord is of the right kind, may be considered as vanquished. If the cable have specific gravity and strength to carry it through these, it will pass safely through the still water below and finally reach the bottom let it be never so far down.

I shall treat further of this very important and interesting subject of inquiry when I come to speak of the methods and means by which the depths of the surface and the set of the under currents may be determined.

"*The best sounding apparatus to be used?*"

Captain Ingraham, Chief of the Bureau of Ordnance and Hydrography, has been kind enough to direct the commandant of the New York navy yard to place at your disposal, for General Casada, commanding her Catholic Majesty's fleet in the West Indies, one of Brooke's deep-sea sounding apparatus, with the latest improvements upon it, together with samples of the twine used.

These will serve the General for models by which others may be prepared, and here I venture to urge the importance of copying the models with Chinese exactness. The sinker is an eight-inch cannon ball, and the advantage of the Chinese copy is this, viz: We shall then be able to apply to all the soundings to be made by this fleet the checks and tests that I have been able to apply to those made by the American navy.

Lieutenant Brooke has had the kindness to prepare at my request the paper, marked A, for the information of the officers to be charged with the duty of making the deep-sea soundings. This, with the directions given in Chapters X and XI, p. 121, *et seq.*, of the seventh edition of the Sailing Directions, a copy of which is herewith transmitted, for making the soundings will, it is believed, prove all sufficient.

I will, perhaps, be excused for urging the necessity of making the soundings from a boat, and of accurately timing the hundred fathom marks as one after the other they are carried out by the shot, care being taken not to check the line, but to let it go freely as fast as the weight of the shot will carry it out.

It is important, also, both to accuracy and success, that the boat should be kept with the help of the oars as nearly vertical over the shot as possible.

In addition to this mode of sounding I would advise, as the Gulf waters are not *very deep*, the use of the self-registering apparatus which was devised for the "Taney."

Brooke's apparatus and the large twine should be used with this; and when the self-registering method is adopted the soundings may be made from the vessel, and the line wound up on a reel properly fitted, and worked either by steam or by hand.

A description of the reel is not necessary, for the ingenuity of her Majesty's officers employed to make the soundings with this self-register will readily suggest all that is required.

The accuracy of each instrument should be first tested, and its errors carefully ascertained, by sounding several times in moderate depths measured as with lead and line in the common way.

If you decide to have a number of these self-registering instruments made it will afford me pleasure to furnish the necessary plans and drawings therefor.

"The plan adopted by Lieut. Berryman in the Arctic?"

You desire to know what that plan is. It was Massey's patent log attached to the sounding lead. But the whole contrivance was so arranged and manipulated that the results proved utterly worthless. I have not dared to quote them in my works or to use them in my researches, because of their obvious sources of error. The Atlantic Telegraph Company is at this moment really as ignorant as to the depth of the sea where their cable is to lie as they were before the "Arctic" went out with this machine. It is, therefore, needless to say more under this head.

"The lines to be run in order to ascertain the figure of the bottom between Cuba and Florida, an between the meridian lines of 78° *and* 90°*?"*

As the work is to be executed with despatch, and as I understand the Spanish Admiral, moved by enlightened considerations which do honor to himself and reflect lustre upon his flag, is desirous of employing as many vessels of his fleet on this service as may be advantageously employed, I venture to suggest for consideration the following lines:

1*st.*—One from Havana to Key West.

2*d.*—One from Havana to the Tortugas.

3*d.*—One from Havana along the Gulf Stream to Fernandina, in Florida.

4*th.*—One across the Straits of Bemini, with a view to the Bahamas, as a telegraphic station.

5*th.*—One from the Tortugas to Pensacola.

6*th.*—One from Cape San Antonio to the mouth of the Mississippi or to Ship Island.

7*th.*—One from Cape San Antonio to Cape Catoche.

You observe that these lines point to Cuba as the centre of telegraphic communication between Europe and the United States on the one hand, Mexico, the Central American States, the Spanish main, and the West India Islands on the other.

With these lines Jamaica and Panama, perhaps California, but certainly San Domingo, Porto Rico, and all the Guyanas, through the little Antilla chain of islands, would soon be seeking telegraphic communication with Cuba, and extending it from their outposts into Brazil and other South American States. You are aware, perhaps, that a project is already on foot for running a system of wires about Demarara. A newspaper correspondent from that place, April 5th, states that a submarine telegraph was then being laid from Georgetown "to Point Spain and easterly to Surinam, and the connections will be complete, in less than a year, with all the British, French, Spanish, and Danish Islands."

At no distant day the exigencies of the times will probably demand a telegraphic cable across the Yucatan Pass. Hence the suggestion of a line of deep-sea soundings there.

The same may be the case as it regards Cuba and the Bahamas, with other of the English West Indies.

All the other lines recommended to be sounded should be regarded only as is regarded a reconnoissance along different routes for a railway, viz: as a preliminary survey, not to be adopted, indeed, but highly important and essential, nevertheless, to a judicious selection of the best route.

"Mode of determining the depth of currents?"

I promised to return to this subject:

The deep sea thermometer and a block let down to any required depth and buoyed by a float on the surface suggest the best means for this purpose.

Saxton's deep sea thermometer used by the Coast Survey is thought by those who use it on that work the best instrument of the kind. It is made only to order, and I doubt whether you have time for them.

This thermometer, however, can only show the miximum or minimum temperature of the various strata of water through which it may be passed. It cannot be relied on for great depths, and is not always true for moderate depths.

I therefore recommend the use of non-conducting cylinders for bringing up water from any required depth, that its temperature may be taken on deck. With cylinders properly constructed and skillfully manipulated, results of great value may be obtained, and that too at very little cost.

The cylinder wants to be hollow; it should be of wood, and must be rendered, by a woollen coating on the outside, as complete a non-conductor as possible. It should, also, be provided on the inside with a valve near each end, both valves opening upwards, so that when it is going down the valves will open and let it pass down, as it were, over a column of water. On being checked these valves will close, cutting off the column at the depth at which the cylinder happens to be when you commence hauling up. Then hauling in briskly you get a specimen of the water from the very depth required.

In coming up and passing through currents of different temperatures, the temperature of the water within the cylinder may be changed, therefore it should be hauled up briskly and experiments should be made for the purpose of getting a correction for such change.

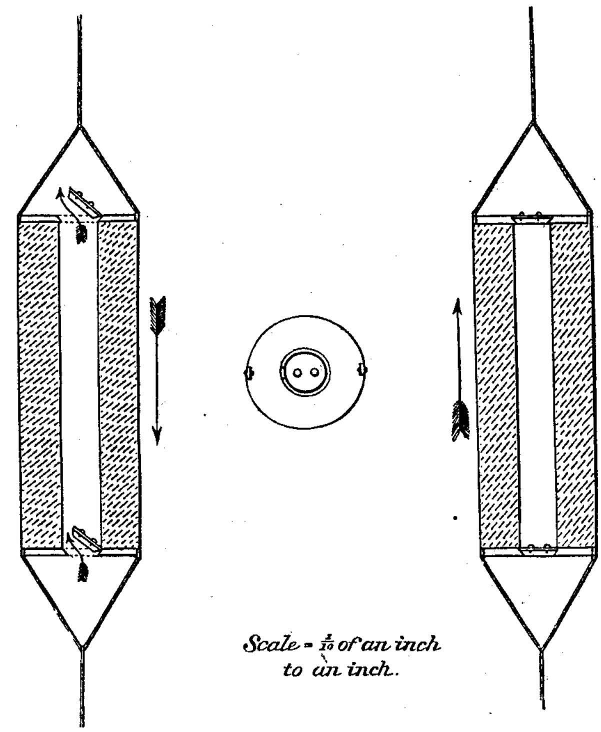
For this purpose, fill the cylinder with sea water 10° or 15° above the water into which you are to immerse it. Having so filled it, immerse, and at the end of every five minutes note the change of the water in the cylinder. Having satisfied yourself as to the law of change, when the warm water is in the cylinder, repeat the experiment with sea water in it 10° or 15° cooler than that into which it is to be plunged. Thus the corrections are obtained.

Then by noting the time employed in a practical way in hauling up the cylinder of water from the depths to the surface of the sea, due corrections may be applied for the change that may have taken place. Thus corrected, the results obtained by this simple contrivance will be accurate enough for present purposes.

See drawings of cylinder P. 196, by Lieutenant Aulick.

To try under currents, take a block of wood about 12 × 12 × 12 inches and load it to sinking. Bend to it, as a buoy rope, 500 fathoms, or as much as you require, of the small size sounding twine. Mark off the depth at which the current is to be tried, and attach a buoy or float just sufficient to retain the block at the given depth.

Thus, after repeated experiments in the Gulf Stream, it will be discovered that when the block reaches a certain depth the surface current will be observed to run past the float. At that depth, also, the temperature of the water should be tried.



Scale = 1/10 of an inch to an inch.

These experiments and observations upon currents and temperatures should be made on board one vessel, while another is running the soundings. The block as well as the cylinder should be tried at various depths and from top to bottom.

"*The most successful mode of conducting this work?*"

Two steamers on each line would insure success; one to sound, the other to try currents and temperatures. These, in the hands of officers who appreciate accuracy in observations and take an intelligent interest in physical research, will be sure to return freighted with the most precious gems that man is permitted to snatch from the sea. Such will be the best mode of conducting the work.

And finally you ask my *good advice.*

Of this I have none to offer that is worth having; but your amiability is large, therefore, with your indulgence I will make, that they may go for what they are worth, such suggestions bearing upon this subject as from time to time have occured to my own mind.

I understand the plan to be to run the wires from Cuba to Key West. Key West is isolated. The magnetic telegraph with its ramifications, has not yet come within several hundred miles of Key West. And that Cuba, after this submarine wire shall be led across the Gulf Stream, may be brought within the meshes of the telegraphic network of this country, a line must be run overland from Key West until it meets with and is joined to other lines.

This would make it necessary for the Florida line to be led for a great distance through a wilderness or sparsely populated country. A line through the swamps of Florida would be liable to frequent interruptions. It would have little or no way business along the Everglades to help keep it in order, and the expenses of keeping it in order, of renewing posts, repairing the ravages of storms, and other accidents would be considerable. In short, communication through it would be frequently interrupted and always uncertain.

The way business of the Everglades would be almost as inconsiderable as the way business of the sea. And if, instead of *via* Key West and the Everglades, the line were to run *via* the Tortugas to Pensacola, or direct from Havana to Mobile or New Orleans, the prime cost would not, I apprehend, much exceed that of the Everglade route, and the line being once laid on the bottom of the sea, it is there for many, many years, without the cost of a quartillo for repairs, without the reach of storms, and almost beyond liability to interruption.

I say, the prime cost by sea would not much exceed the prime cost by Everglades and sea, and I argue that the line, submarine all the way, would be the cheaper in the end, provided the company go to work in the right way, and proceed to make, insulate and lay the conducting wire according to the best lights that the present state of our knowledge concerning the physics of the sea affords.

I prefer the Tortugas route, for reasons which will appear presently.

If it be true that there is in the depths of the sea no running water or other forces at play capable of abrading the shells and detritus that lie on the bottom, or of moving, after it is once lodged there, the microscopic carcass of the most tiny insect that has ever lived and died on its surface; if, I say, this be so, and observations abundantly assure us that it is, of what use at the bottom of the deep sea is a cable served with wire or encased in iron? Does it want strength? My researches teach us that there is no force down there that can try the strength of a gossamer. Is it liable to be chafed? There is no motion down there; but cold obstruction; and my researches show that there is nothing down there, save alone omnipresent time, with its gnawings, that can chafe or fret it in the least. Wrappings of iron wire are no protection for gutta percha against the tooth of time.

Being encased in wire the electric telegraph becomes very costly; it is much more difficult to stow, to manipulate, and to lay than it would be if it were not so heavily mailed in armor.

My own reflections upon this very interesting and highly important subject have satisfied me that the best telegraphic wire for the deep sea should not be a cable-laid or iron bound hawser, but should be a slender cord, consisting of nothing more than a single wire or fascicle of copper wires, properly insulated with gutta percha. Such a cord, without being encased in iron wire, is strong enough, if it be properly managed, to resist the mightiest currents of the sea; for if it be paid over so slack that it will sink through them before they can sweep away the bight, take up the slack and so bring a strain upon the cord, it is safe. But if slack enough be not given for the cord to feed the currents freely and without resistance, no cable, however strong, has strength enough to resist them.

If it be judged inexpedient to make the conducting wires large enough to give the cord the degree of specific gravity requisite for sinking, then let one or two iron wires be stretched along with the cable, not wrapped or twisted about it, but laid parallel with it and "stopped" along it, and thus give it the requisite weight, for strength sufficient it already has.

The cord should be heavy enough only to sink—if a length of it, as a foot or a fathom, for instance, were cut off and thrown into the water—not faster than a mile or two an hour.

Suppose the cable adopted by your company to be heavy enough to sink two miles an hour; that the currents of the Gulf Stream extend half a mile down; that the vessel employed to lay this cord is instructed to "pay and go;" and that while crossing the stream she pays out for every 10 miles of distance run 12 or 15 miles of cable; in 15 minutes any given section of the cord will have sunk below the reach of this current, and, being slack, the cord will then quietly find its way to the bottom and adjust itself gently and without risk to the inequalities thereof.

Of course, when you reach soundings, the cord should be coated with iron, that it may have weight and shield sufficient to withstand the forces that are everlastingly at play there.

The Atlantic Company has not such a cable for their submarine telegraph as I am suggesting for the Cuba company, and because they have not, they have, in my judgment, needlessly multiplied the difficulties in their way, and unwisely added to the expense and risk of the undertaking. By coating their cable so heavily with wire they have greatly increased, instead of lessening, as they supposed, the chances of failure.

There was one advantage, however, which I once thought the cable of this company, with its wire casing, to possess, and that was immunity from sharks. But I was mistaken.

You are aware, perhaps, that these creatures are so ravenous in the West Indies that the mail steamers plying to Aspinwall cannot use their patent log. As often as it is put overboard the sharks bite it off; and this wire coating of the Atlantic cable would, I thought, protect it from their jaws. But I find on a close examination, made yesterday, that the strands of wire coating for this cable can be readily thrust apart with the thumb nail; and if the thumb nail of a man may reach the gutta percha, in spite of its wire armor, surely a shark would have no difficulty in thrusting his teeth between the meshes of the iron wire armor and through the gutta percha to the conducting wire itself. Suppose he could not bite the cord in twain, if he do but touch the copper wire with his tooth, the insulation is destroyed and there is an end to all messages.

Such a cable as the sub-Atlantic cable is, is palpably not shark proof, no more so than it would be without its wire casing; and a cable without the wire casing would probably not cost one-half as much. A cable, therefore, with such a wire casing is, it appears to me, out of the question even for Cuba; and the choice, in my judgment, is between a mere gutta percha cord, with its fascicle of conductors, and a large iron coated cable, like that across the English channel, wrapped with strands so stout and stiff that they may form a shield which it would be impossible for sharks to penetrate with their teeth.

The difference as to cost between two such cables is enormous, and once lodged on the bottom one is as good as the other.

What can artifice do in favor of the less costly plan? From Cuba to Tortugas the distance is 90 miles. That is the most difficult part of the route; it is across the Gulf Stream, and the cable should be laid across it before any other part of the route is attempted. From Tortugas to Pensacola the distance is 415 miles. In that part of the route the greatest depth will probably not much exceed 200 fathoms, and there is little or no current along it. Now may not the sharks be *dodged* by painting the cable black, or blue, or green, and laying it at night, so they shall not see it? A span 125 or 130 miles long would give slack for the Gulf Stream current and length for the distance, and the cheapness of the simple cord is in favor of giving it a trial, at any rate.

One vessel can run easily with this cord from Tortugas to Havana in one night, and then, after so much of the line is down, by putting the rest of the cord on board of two steamers and causing them to join ends half way between Pensacola and Tortugas in the afternoon of a winter's day, they might have the work well-nigh done by the morning.

Mobile and New Orleans are equally within the reach of Havana, and so is Fernandina, on the east coast of Florida. This ancient place is destined soon to be the terminus of an important railway, which will make it a point both of telegraphic as well as of commercial consequence.

Thus you have the result of my reflections hastily uttered. Let it go for what it is worth, no more.

If I can be of any further service towards the success of this enterprise, I beg you will say to the proper functionaries that I should consider it a privilege to be so, and would be most happy to serve them.

Respectfully, &c.,

M. F. MAURY.

M. EUGENIO SANCHEZ Y ZAYAS,
New York.

CHAPTER XIV.

THE CLIMATES OF THE OCEAN.*

Gulf Stream a Milky Way, § 185.—The hottest Months in the Sea, § 186.—A Line of invariable Temperature, § 187.—How the western half of the Atlantic is heated up, § 188.—How the Cold waters from Davis' Straits press upon the Gulf Stream, § 189.—How the different Isotherms travel from North to South with the Seasons, § 190.—The hottest water at ea not at the surface, § 191.—The Polar and Equatorial Drift, § 192.

185. THERMAL Charts, showing the temperature of the surface of the Atlantic Ocean by actual observations made indiscriminately all over it, and at all times of the year, have been published. The isothermal lines which these charts enable us to draw, and some of which are traced on Plate XVI, afford the navigator and the philosopher much valuable and interesting information touching the circulation of the oceanic waters, including the phenomena of the cold and warm sea currents; they also cast light upon the climatology of the sea, its hyetographic peculiarities, and the climate conditions of various regions of the earth; they show that the profile of the coast-line of inter-tropical America assists to give expression to the mild climate of Southern Europe; they also increase our knowledge concerning the Gulf Stream, for it enables us to mark out, for the mariner's guide, the "Milky Way" in the ocean, the waters of which teem and sparkle, and glow with life and incipient organisms as they run across the Atlantic. In them are found the clusters and nebulæ of the sea, which stud and deck the great highway of ships on their voyage between the Old World and the New; and these lines assist to point out for the navigator their limits and his way. They show this *via lactea* to have a vibratory motion that calls to mind the graceful wavings of a pennon as it floats gently to the breeze. Indeed, if we imagine the head of the Gulf Stream to be hemmed in by the land in the Straits of Bemini, and to be stationary there, and then liken the tail of the stream itself to an immense pennon floating gently in the current, such a motion as such a streamer may be imagined to have—very much such a motion—do my researches show the tail of the Gulf Stream to have. Running between banks of cold water, it is pressed now from the north, now from the south, according as the great masses of sea matter on either hand may change or fluctuate in temperature.

* *Vide* Maury's Physical Géography of the Sea; Harper and Brother, New York.

In September, when the waters in the cold regions of the north have been tempered and made warm and light by the heat of summer, its limits on the left (Plate XIII) are as denoted by the line of arrows; but after this great sun-swing, the waters on the left side begin to lose their heat, grow cold, become heavy, and press the hot waters of this stream within the channel marked out for them.

Thus it acts like a pendulum, slowly propelled by heat on one side and repelled by cold on the other. In this view, it becomes the chronograph of the sea, keeping time for its inhabitants, and marking the seasons for the great whales; and there it has been for all time, vibrating to and fro, swinging from north to south and from south to north, a great self-regulating, self-compensating pendulum.

In seeking information concerning the climates of the ocean, it is well not to forget this remarkable contrast between its climatology and that of the land, viz: on the land, February and August are considered the coldest and the hottest months; but to the inhabitants of the sea, the annual extremes of cold and heat occur in the months of March and September. On the dry land, after the winter "is past and gone," the solid parts of the earth continue to receive from the sun more heat in the day than they radiate at night; consequently there is an accumulation of caloric, which continues to increase until August. The summer is now at its height; for, with the close of this month, the solid parts of the earth's crust and the atmosphere above begin to dispense with their heat faster than the rays of the sun can impart fresh supplies, and consequently the climates which they regulate grow cooler and cooler until the dead of winter again.

186. But, at sea, a different rule seems to prevail. Its waters are the storehouses in which the surplus heat of summer is stored away against the severity of winter, and they continue to grow warmer for a month after the weather on shore has begun to get cool. This brings the highest temperature to the sea in September, the lowest in March. Plate XVI is intended to show the extremes of heat and cold to which the *waters*—not the ice—of the sea are annually subjected, and therefore the isotherms of 40°, 50°, 60°, 70°, and 80°, have been drawn for March and September, the months of extreme heat and extreme cold to the inhabitants of the "great deep." Corresponding isotherms for any other month will fall between these, taken by pairs. Thus the isotherm of 70° for July will fall nearly between the same isotherms (70°) for March and September.

A careful study of this plate, and the contemplation of the benign influences of the sea upon the climates which we enjoy, suggest many beautiful thoughts; for, by such study, we get a glimpse into the arrangements and the details of that exquisite machinery in the ocean which enables it to perform all its offices, and to answer with fidelity its marvellous adaptations.

How, let us inquire, does the isotherm of 80°, for instance, get from its position in March to its position in September? Is it wafted along by currents, that is, by water which, after having been heated near the equator to 80°, then flows to the north with this temperature? Or is it carried there simply by the rays of the sun, as the snow-line is carried up the mountain in summer? We have reason to believe that it is carried from one parallel to another by each of these agents acting together, but mostly through the instrumentality of currents; for currents are the chief agents for distributing heat to the various parts of the ocean. The sun with its rays would, were it not for currents, raise the water in the torrid zone to blood heat; but, before that can be done, they run off with it to the poles, softening, and mitigating, and tempering climates by the way. The provision for this is as beautiful as it is benign; for, to answer a physical adaptation, it is provided by a law of nature that when the temperature of water is raised, it shall expand; as it expands, it must become lighter, and just in proportion as its specific gravity is altered, just in that proportion is equilibrium in the sea destroyed. Arrived at this condition, it is ordained that this hot water shall obey another law of nature, which requires it to run away, and hasten to restore that equilibrium. Were these isothermal lines moved only by the rays of the sun, they would slide up and down the ocean like so many parallels of latitude—at least there would be no breaks in them, like that which we see in the isotherm of 80° for September. It appears, from this line, that there is a part of the ocean near the equator, and about midway the Atlantic, which, with its waters, never does attain the temperature of 80° in September. Moreover, this isotherm of 80° will pass, in the North Atlantic, from its extreme southern to its extreme northern declination—nearly two thousand miles—in about three months. Thus it travels at the rate of about twenty-two miles a day. Surely without the aid of currents, the rays of the sun could not drive it along that fast.

Being now left to the gradual process of cooling by evaporation, atmospherical contact, and radiation, it occupies the other eight or nine months of the year in slowly returning south to the parallel whence it commenced to flow northward. As it does not cool as rapidly as it was heated, the disturbance of equilibrium by alteration of specific gravity is not so sudden, nor the current which is required to restore it is so rapid. Hence the slow rate of movement at which this line travels on its march south.

Between the meridians of 25° and 30° west, the isotherm of 60° in September ascends as high as the parallel of 56°. In October it reaches the parallel of 50° north. In November it is found between the parallels of 45° and 47°, and by December it has nearly reached its extreme southern descent between these meridians, which it accomplishes in January, standing then near the parallel of 40°. It is all the rest of the year in returning northward to the parallel whence it commenced its flow to the south in September.

Now, it will be observed that this is the season—from September to December—immediately succeeding that in which the heat of the sun has been playing with greatest activity upon the polar ice. Its melted waters, which are thus put in motion in June, July, and August, would probably occupy the fall months in reaching the parallels indicated. These waters, though cold, and rising gradually in temperature as they flow south, are probably fresher, and if so, probably lighter than the sea water; and, therefore, it may well be that both the warmer and cooler systems of these isothermal lines are made to vibrate up and down the ocean principally by a gentle surface current in the season of quick motion, and in the season of the slow motion principally by a gradual process of calorific absorption on the one hand, and by a gradual process of cooling on the other.

We have precisely such phenomena exhibited by the waters of the Chesapeake Bay as they spread themselves over the sea in winter. At this season of the year, the Charts show that water of very low temperature is found projecting out and overlapping the usual limits of the Gulf Stream. The outer edge of this cold water, though jagged, is circular in its shape, having its centre near the mouth of the bay. The waters of the bay, being fresher than those of the sea, may, therefore, though colder, be lighter than the warmer waters of the ocean. And thus we have repeated here, though on a smaller scale, the phenomenon as to the flow of cold waters from the north, which force the surface isotherm of 60° from latitude 56° to 40° during three or four months.

Changes in the color or depth of the water, and the shape of the bottom, &c., would also cause changes in the temperature of certain parts of the ocean, by increasing or diminishing the capacities of such parts to absorb or radiate heat; and this, to some extent, would cause a bending or produce irregular curves in the isothermal lines.

After a careful study of this plate, and the Thermal Charts of the Atlantic Ocean, from which the materials for this plate were derived, I am led to infer that the mean temperature of the atmosphere between the parallels of 56° and 40° north, for instance, and over that part of the ocean in which we have been considering the fluctuations of the isothermal line of 60°, is at least 60° of Fahrenheit, and upward, from January to August, and that the heat which the waters of the ocean derive from this source—atmospherical contact and radiation—is one of the causes which move the isotherm of 60° from its January to its September parallel.

It is well to consider another of the causes which are at work upon the currents in this part of the ocean, and which tend to give the rapid southwardly motion to the isotherm of 60°. We know the mean dew-point must always be below the mean temperature of any given place, and that, consequently, as a general rule, at sea the mean dew-point due the isotherm of 60° is higher than the mean dew-point along the isotherm of 50°, and this, again, higher than that of 40°—this than 30°, and so on. Now suppose, merely for the sake of illustration, that the mean dew-point for each isotherm be 5° lower than the mean temperature, we should then have the atmosphere which crosses the isotherm of 60°, with a mean dew-point of 55°, gradually precipitating its vapors until it reaches the isotherm of 50°, with a mean dew-point of 45°; by which difference of dew-point the total amount of precipitation over the entire zone between the isotherms of 60° and 50° has exceeded the total amount of evaporation from the same surface. The prevailing direction of the winds to the north of the fortieth parallel of north latitude is from the southward and westward (Plate XV ;) in other words, it is from the higher to the lower isotherms. Passing, therefore, from a higher to a lower temperature over the ocean, the total amount of vapor deposited by any given volume of atmosphere, as it is blown from the vicinity of the tropical towards that of the polar regions, is greater than that which is taken up again.

The area comprehended on Plate XV, between the isotherms 40° and 50° Fahrenheit, is less than the area comprehended between the isotherms 50° and 60°, and this, again, less than the area between this last and 70°, for the same reason that the area between the parallels of latitude 50° and 60° is less than the area between the parallels of latitude 40° and 50°; therefore, more rain to the square inch ought to fall upon the ocean between the colder isotherms of 10° difference, than between the warmer isotherms of the same difference. This is an interesting and an important view, therefore let me make myself clear: the aqueous isotherm of 50°, in its extreme northern reach, touches the parallel of 60° north. Now, between this and the equator, there are but three isotherms, 60°, 70°, and 80°, with the common difference of 10°. But between the isotherm of 40° and the pole, there are at least five others, viz: 40°, 30°, 20°, 10°, 0°, with a common difference of 10°. Thus, to the north of the isotherm 50°, the vapor which would saturate the atmosphere from zero, and perhaps far below, to near 40°, is deposited, while to the south of 50°, the vapor which would saturate it from the temperature of 50° up to that of 80° can only be deposited. At least, such would be the case if there were no irregularities of heated plains, mountain ranges, land, &c., to disturb the laws of atmospherical circulation as they apply to the ocean.

Having, therefore, theoretically, at sea more rain in high latitudes, we should have more clouds; and therefore it would require a longer time for the sun, with his feeble rays, to raise the temperature of the cold water, which, from September to January, has brought the isotherm of 60° from latitude 56° to 40°, than it did for these cool surface currents to float it down. After this southward motion of the isotherm of 60° has been checked in December by the cold, and after the sources of the current which brought it down have been bound in fetters of ice, it pauses in the long nights of the northern winter, and scarcely commences its return till the sun recrosses the equator, and increases its power as well in intensity as in duration.

Thus, in studying the physical geography of the sea, we have the effects of night and day, of clouds and sunshine, upon its currents and its climates, beautifully developed. These effects are modified by the operations of certain powerful agents which reside upon the land; nevertheless, feeble though those of the former class may be, a close study of this plate will indicate that they surely exist.

187. Now, returning toward the south, we may, on the other hand, infer that the mean atmospherical temperature for the parallels between which the isotherm of 80° fluctuates is below 80°, at least for the nine months of its slow motion. This vibratory motion suggests the idea that there is, probably, somewhere between the isotherm of 80° in August and the isotherm of 60° in January, a line or belt of invariable or nearly invariable temperature, which extends on the surface of the ocean from one side of the Atlantic to the other. This line or band may have its cycles also, but they are probably of long and uncertain periods.

188. The fact has been pretty clearly established by the discoveries to which the Wind and Current Charts have led, that the western half of the Atlantic Ocean is heated up, not by the Gulf Stream alone, as is generally supposed, but by the great equatorial caldron to the west of longitude 35°, and to the north of Cape St. Roque, in Brazil. The lowest reach of the 80° isotherm for September—if we except the remarkable equatorial flexure (Plate XVI) which actually extends from 40° north to the line—to the west of the meridian of Cape St. Roque, is above its highest reach to the east of that meridian. And now that we have the fact, how obvious, beautiful, and striking is the cause!

Cape St. Roque is in 5° south. Now study the configuration of the Southern American Continent from this cape to the Windward Islands of the West Indies, and take into account certain physical conditions of these regions: the Amazon, always at a high temperature, because it runs from west to east, is pouring an immense volume of warm water into this part of the ocean. As this water and the heat of the sun raise the temperature of the ocean along the equatorial sea-front of this coast, there is no escape for the liquid element, as it grows warmer and lighter, except to the north. The land on the south prevents the tepid waters from spreading out in that direction as they do to the east of 35° west, for here there is a space, about 18 degrees of longitude broad, in which the sea is clear both to the north and south. They must consequently flow north. A mere inspection of the plate is sufficient to make obvious the fact that the warm waters which are found east of the usual limits assigned the Gulf Stream, and between the parallels of 30° and 40° north, do not come from the Gulf Stream, but from this great equatorial caldron, which Cape St. Roque blocks up on the south, and which forces its overheated waters up to the fortieth degree of north latitude, not through the Caribbean Sea and Gulf Stream, but over the broad surface of the left bosom of the Atlantic Ocean.

Here we are again tempted to pause and admire the beautiful revelations which, in the benign system of terrestrial adaptation, these researches into the physics of the sea unfold and spread out before us for contemplation. In doing this, we shall have a free pardon from those at least who delight "to look through nature up to nature's God."

What two things in nature can be apparently more remote in their physical relations to each other than the climate of Western Europe and the profile of a coast-line in South America? Yet this plate not only reveals to us the fact that these relations between the two are the most intimate, but makes us acquainted with the arrangements by which such relations are established.

177. The barrier which the South American shore-line opposes to the escape, on the south, of the hot waters from this great equatorial caldron of St. Roque, causes them to flow north, and in September, as the winter approaches, to heat up the western half of the Atlantic Ocean, and to cover it with a mantle of warmth above summer heat, as far up as the parallel of 40°. Here heat, to temper the winter climate of Western Europe, is stored away as in an air-chamber for furnace-heated apartments; and during the winter, when the fire of the solar rays sinks down, the westwardly winds and eastwardly currents are sent to perform their office in this benign arrangement. Though unstable and capricious to us they seem to be, they nevertheless "fulfill His commandments" with regularity, and perform their offices with certainty. In tempering the climate of Europe with heat, in winter, that has been bottled away in the waters of the ocean during summer, they are to be regarded as the flues and the regulators for distributing at the right time, and at the right places, in the right quantities.

By March, when "the winter is past and gone," the furnace which had been started by the rays of the sun in the previous summer, and which, by autumn, had heated up the ocean in our hemisphere, has gone down. The caldron of St. Roque, ceasing in activity, has failed in its supplies, and the chambers of warmth upon the northern sea, having been exhausted of their heated water, which has been expended in the manner already explained, have contracted their limits. The surface of heated water which, in September, was spread out over the western half of the Atlantic, from the equator to the parallel of 40° north, and which raised this immense area to the temperature of 80° and upward, is not to be found in early spring on this side of the parallel of 8° north.

The isotherm of 80° in March, after quitting the Caribbean Sea, runs parallel with the South American coast toward Cape St. Roque, keeping some 8 or 10 degrees from it. Therefore the heat dispensed over Europe from this caldron falls off in March. But, at this season, the sun comes forth with fresh supplies; he then crosses the line and passes over into the northern hemisphere; observations show that the process of heating the water in this great caldron for the next winter is now about to commence.

In the mean time, so benign is the system of cosmical arrangements, another process of raising the temperature of Europe commences. The land is more readily impressed than the sea by the heat of the solar rays; at this season, then, the summer climate due these transatlantic latitudes is modified by the action of the sun's rays directly upon the land. The land receives heat from them, but, instead of having the capacity of water for retaining it, it imparts it straightway to the air; and thus the proper climate, because it is the climate which the Creator has, for his own wise purposes, allotted to this portion of the earth, is maintained until the marine caldron of Cape St. Roque is again heated and brought into the state for supplying the means of maintaining the needful temperature in Europe during the absence of the sun in the other hemisphere.

In like manner, the Gulf of Guinea forms a caldron and a furnace, and spreads out over the South Atlantic an air-chamber for heating up in winter and keeping warm the extra-tropical regions of South America. Every traveller has remarked upon the comparatively mild climate of Patagonia and the Falkland Islands.

"Temperature in high southern latitudes," says a very close observer, who is co-operating with me in collecting materials, "differs greatly from the temperature in northern. In southern latitudes there seem to be no extremes of heat and cold as at the north. Newport, Rhode Island, for instance, latitude 41° north, longitude 71° west, and Rio Negro, latitude 41° south, and longitude 63° west, as a comparison: in the former, cattle have to be stabled and fed during the winter, not being able to get a living in the fields on account snow and ice. In the latter, the cattle feed in the fields all winter, there being plenty of vegetation and no use of hay. On the Falkland Islands (latitude 51–2° south) thousands of bullocks, sheep, and horses are running wild over the country, gathering a living all through the winter."

The water in the equatorial caldron of Guinea cannot escape north—the shore-line will not permit it. It must, therefore, overflow to the south, as that of St. Roque does to the north, carrying to Patagonia and the Falkland Islands, beyond 50° south, the winter climate of Charleston, South Carolina, on our side of the North Atlantic, or of the "Emerald Island" on the other.

All geographers have noticed, and philosophers have frequently remarked upon the conformity, as to the shore-line profile of equatorial America and equatorial Africa.

It is true, we cannot now tell the reason, though explanations founded upon mere conjecture have been offered, why there should be this sort of jutting in an jutting out of the shore-line, as at Cape St. Roque and the Gulf of Guinea, on opposite sides of the Atlantic; but one of the purposes, at least, which this peculiar configuration was intended to subserve, is without doubt now revealed to us.

We see that, by this configuration, two cisterns of hot water are formed in this ocean; one of which distributes heat and warmth to western Europe; the other, at the opposite season, tempers the climate of Eastern Patagonia.

Phlegmatic must be the mind that is not impressed with ideas of grandeur and simplicity as it contemplates that exquisite design, those benign and beautiful arrangements, by which the climate of one hemisphere is made to depend upon the curve of that line against which the sea is made to dash its waves in the other. Impressed with the perfection of terrestrial adaptations, he who studies the enconomy of the great cosmical arrangements, is reminded that not only is there design in giving shore-lines their profile, the land and the water their proportions, and in placing the desert and the pool where they are, but the conviction is forced upon him also, that every hill and valley, with the grass upon its sides, has each its office to perform in the grand design.

March is, in the southern hemisphere, the first month of autumn, as September is with us; consequently, we should expect to find in the South Atlantic as large an area of water of 80° and upwards in March, as we should find in the North Atlantic for September. But do we? By no means. The area on this side of the equator is nearly double that on the other.

Thus we have the sea as a witness to the fact that the winds had proclaimed, viz: that summer in the northern hemisphere is hotter than summer in the southern, for the rays of the sun raise on this side of the equator double the quantity of sea surface to a given temperature that they do on the other side; at least this is the case in the Atlantic. Perhaps the breadth of the Pacific Ocean, the absence of large islands in the temperate regions north, the presence of

New Holland with Polynesia in the South Pacific, may make a difference there. But of this I cannot now speak, for the thermal charts of that ocean have not yet been prepared.

189. Pursuing the study of the climates of the sea, let us now turn to Plate XIV. Here we see at a glance how the cold waters, as they come down from the Arctic Ocean through Davis' Straits, press upon the warm waters of the Gulf Stream, and curve their channel into a horseshoe. Navigators have often been struck with the great and sudden changes in the temperature of the waters hereabouts. In the course of single day's sail, in this part of the ocean, changes of 15° or 20°, and even of 30°, have been observed to take place in the temperature of the sea. The cause has puzzled navigators long, but how obvious is it not now made to appear! This "bend" is the great receptacle of the icebergs which drift down from the north; covering frequently an area of hundreds of miles in extent, its waters differ as much as 20°, 25°, and in rare cases even as much as 30° of temperature from those about it. Its shape and place are variable. Sometimes it is like a peninsula, or tongue of cold water projected far down into the waters of the Gulf Stream. Sometimes the meridian upon which it is inserted into these is to the east of 40°, sometimes to the west of 50° longitude. By its discovery we have clearly unmasked the very seat of that agent which produces the Newfoundland fogs. It is spread out over an area frequently embracing several thousand square miles in extent, covered with cold water, and surrounded on three sides, at least, with an immense body of warm. May it not be that the proximity to each other of these two very unequally heated surfaces, out upon the ocean, would be attended by atmospherical phenomena not unlike those of the land and sea breezes? These warm currents of the sea are powerful meteorological agents. I have been enabled to trace, in thunder and lightning, the influence of the Gulf Stream in the eastern half of the Atlantic, as far north as the parallel of 55° north; for there, in the dead of winter, a thunderstorm is not unusual.

190. These isothermal lines of 50°, 60°, 70, 80°, &c., may illustrate for us the manner in which the climates in the ocean are regulated. Like the sun in the ecliptic, they travel up and down the sea in declination, and serve the monsters of the deep for signs and for seasons.

191. The hottest water at sea, particularly in the trade-wind regions is, it should be borne in mind, not at the surface, but a little below. To assist in comprehending why it is so, let us imagine a sheet of cold water from the poles to be brought down and spread out from the tropic of cancer to the equator. As soon as it is so spread, the inter-tropical sunbeam and the trade-wind begin to play upon it with antagonistic forces. The sunbeam with its heat warming it and expanding it to make it lighter; the trade wind with its forces converting it into vapor and making it cooler, while it takes away fresh water, thus leaving it salter and therefore heavier. It continues to grow both warmer and salter, but finally the trade wind force prevails, and it sinks a little way. It is now beyond the reach of the trade wind, but within reach of the sun beam. Here it continues to grow warm, until that at the top has been cooled by evaporation, when the warm comes up to replace it, that in its turn it may grow cooler and salter and then sink again.

Observations show a difference of temperature in the water at the surface and below of about 2°. That below being the warmer.

192. It should be borne in mind that the lines of separation, as drawn on Plate XIV., between the cool and warm waters, or, more properly speaking, between the channels representing the great polar and equatorial flux and reflux, are not so sharp in nature as this plate would represent them. In the first place, the plate represents the mean or average limits

ot these constant flows—polar and equatorial; whereas, with almost every wind that blows, and at every change of season, the line of meeting between their waters is shifted. In the next place, this line of meeting is drawn with a free hand on the plate, as if to represent an average; whereas there is reason to believe that this line in nature is variable and unstable as to position, and as to shape rough and jagged, and oftentimes deeply articulated. In the sea, the line of meeting between waters of different temperatures and density is not unlike the sutures of the skull-bone on a grand scale—very rough and jagged; but, on the plate, it is a line drawn with a free hand, for the purpose of showing the general direction and position of the channels in the sea, through which its great polar and equatorial circulation is carried on.

Now, continuing for a moment our examination of Plate XVI., we are struck with the fact that most of the thermal lines there drawn run from the western side of the Altantic toward the eastern, in a northeastwardly direction, and that, as they approach the shores of this ocean on the east, they again turn down for lower latitudes and warmer climates. This feature in them indicates, more surely than any direct observations upon the currents can do, the presence, along the African shores in the North Atlantic, of a large volume of cooler waters. These are the waters which, having been first heated up in the caldron (§ 176) of St. Roque, in the Caribbean Sea, and Gulf of Mexico, have been made to run to the north, charged with heat and electricity to temper and regulate climates there. Having performed their offices, they have cooled down; but, obedient still to the "Mighty Voice" which the winds and the waves obey, they now return by this channel, along the African shore, to be again replenished with warmth, and to keep up the system of beneficent and wholesome circulation designed for the ocean.

CHAPTER XV.

THE DRIFT OF THE SEA.*

Plate XIV, § 193.—The Polar Drift about Cape Horn, § 194.—How the Polar Waters in the South Atlantic force the Equatorial aside, § 195.—A Harbor for Icebergs, § 196.—Why Icebergs are not found in the North Pacific, § 197.—Drift of Warm Waters out of the Indian Ocean, § 198.—The opinion of Lieutenant Jansen, of the Dutch Navy, § 199.—A Current of Warm Water sixteen hundred miles wide, § 200.—The Pulse of the Sea, § 201.—The Circulation of the Sea like that of the Blood, § 202 —Number of Vessels engaged in the Fisheries of the Sea, § 203.—The Sperm Whale, § 204.—The Torrid Zone impassable to the Right Whale, § 205.

193. I HAVE spoken about currents; but there is a movement of the waters of the ocean which, though it be a translation, yet does not amount to what is known to the mariner as current, for our nautical instruments and the art of navigation have not been brought to that state of perfection which will enable navigators generally to detect as currents the flow to which I allude as *drift*. It arises from changes in the specific gravity of sea water, caused chiefly by the effects of heat. If water, from any cause, commence to flow from the equator towards the poles, it must grow cool by the way; by growing cool, it changes its specific gravity, and when its specific gravity is changed, it cannot any longer be considered as the same mass, for it does not occupy the same space it did before. The great thermal agent of the universe, therefore, is continually disturbing the equilibrium of the sea, and setting its waters in motion by expanding them with heat in the torrid, and contracting them with cold

* *Vide* Maury's Physical Geography of the Sea.

in the frigid zone; consequently, there is a general movement going on to and fro in the sea, in obedience to the forces of heat, which nothing can interrupt. Storms may override, but they cannot arrest this flow. The disturbance created in this mighty and ceaseless flow and ebb, by the agents which produce other currents, is like the eddy which follows in the wake of the steamboat on the Mississippi—it never interferes with the march of the stream in its onward flow.

If we imagine an object to be set adrift in the ocean at the equator, and if we suppose that it be of such a nature that it would obey only the influence of sea water, and not of the winds, this object, I imagine, would, in the course of time, find its way to the icy barriers about the poles, and again back among the tepid waters of the tropics. Such an object would illustrate the *drift of the sea,* and by its course would indicate the route which the surface waters of the sea follow in their general channels of circulation to and fro between the equator and the poles.

Accordingly, the object of Plate XIV is to illustrate, as far as the present state of my researches enables me to do, this normal circulation of the ocean, as influenced by *heat* and *cold,* and to indicate the routes by which the overheated waters of the torrid zone escape to cooler regions, on one hand, and on the other, the great channel ways through which the same waters, after having been deprived of this heat in the extra-tropical or polar regions, return again toward the equator, it being assumed that the drift or flow is from the poles when the temperature of the surface water is *below,* and from the equatorial regions when it is above that due the latitude. Therefore, in a mere diagram, as this plate is, the numerous eddies and local currents which are found at sea are disregarded.

Of all the currents in the sea, the Gulf Stream is the best defined; its limits, especially those of the left bank, are always well marked, and, as a rule, those of the right bank, as high as the parallel of the thirty-fifth degree of latitude, are quite distinct, being often visible to the eye. The Gulf Stream shifts its channel, (§ 143,) but nevertheless its banks are often very distinct. As I write these remarks, the abstract log of the ship Herculean, (William M. Chamberlain,) from Callao to Hamptom Roads, in May, 1854, is received. On the eleventh of that month, being in latitude 33° 39′ north, longitude 74° 56′ west, (about one hundred and thirty miles east of Cape Fear,) he remarks:

"Moderate breezes, smooth sea, and fine weather. At ten o'clock fifty minutes, entered into the southern (right) edge of the Stream, and in eight minutes the water rose six degrees; the edge of the stream was visible, as far as the eye could see, by the great rippling and large quantities of gulf weed—more 'weed' than I ever saw before, and I have been many times along this route in the last twenty years."

In this diagram, therefore, I have thought it useless to attempt a delineation of any of those currents, as the Rennell Current of the North Atlantic, the "Connecting Current" of the South Atlantic, "Mentor's Counter Drift," Rossel's Drift of the South Pacific, &c., which run now this way, now that, and which are frequently not felt by navigators at all.

In overhauling the log-books for data for this Chart, I have followed vessels with the water thermometer to and fro across the seas, and taken the registrations of it exclusively for my guide, without regard to the reported set of the currents. When, in any latitude, the temperature of the water has appeared too high or too low for that latitude, the inference has been that such water was warmed or cooled, as the case may be, in other latitudes, and that it has been conveyed to the place where found through the great channels of circulation in the ocean, (§181.) If too warm, it is supposed that it had its temperature raised in warmer latitudes, and therefore the channel in which it is found leads from the equatorial regions. On the other hand, if the water be too cool for the latitude, then the inference is that it has lost its heat in colder climates, and therefore is found in channels which lead from the polar regions.

The arrow-beards point to the direction in which the waters are supposed to flow. Their rate, according to the best information that I have obtained, is, at a mean, only about four knots a day—rather less than more.

194. Accordingly, therefore, as the immense volume of water in the Antarctic regions is cooled down, it commences to flow north. As indicated by the arrow-heads, it strikes against Cape Horn, and is divided by the continent, one portion going along the west coast as Humboldt's Current, (§ 119 ;) the other, entering the South Atlantic, flows up into the Gulf of Guinea, on the coast of Africa. Now, as the waters of this polar flow approach the torrid zone, they grow warmer and warmer, and finally themselves become tropical in their temperature. They do not then, it may be supposed, stop their flow; on the contrary, they keep moving, for the very cause which brought them from the extra-tropical regions now operates to send them back. This cause is to be found in the difference of the specific gravity at the two places. If, for instance, these waters, when they commence their flow from the hyperborean regions, were at 30°, their specific gravity will correspond to that of sea water at 30°. But when they arrive in the Gulf of Guinea, or the Bay of Panama, having risen by the way to 80°, or perhaps 85°, their specific gravity becomes such as is due sea water of this temperature; and, since fluids differing in specific gravity can no more balance each other on the same level than can unequal weights in opposite scales truly adjusted, this hot water must now return to restore that equilibrium which it has destroyed in the sea, by rising from 30° to 80° or 85°.

Hence it will be perceived that these masses of water which are marked as cold are not always cold. They gradually pass into warm; for, in travelling from the poles to the equator, they partake of the temperature of the latitudes through which they flow, and grow warm.

195. Plate XIV, therefore, is only introduced to give general ideas; nevertheless, it is very instructive. See how the influx of cold water into the South Atlantic appears to divide the warm water, and squeeze it out at the sides, along the coasts of South Africa and Brazil. So, too, in the North Indian Ocean, the cold water again compelling the warm to escape along the land at the sides, as well as occasionally in the middle.

In the North Atlantic and North Pacific, on the contrary, the warm water appears to divide the cold, and to squeeze it out along the land at the sides. The impression made by the cold current from Baffin's Bay, upon the Gulf Stream, is strikingly beautiful.

Why is it that these polar and equatorial waters should appear now to divide and now to be divided? The Gulf stream has revealed to us a fact in which the answer is partly involved. We learn from that stream that cold and warm sea waters, are, in a measure, (§ 143,) like oil and vinegar—that is, there is among the particles of sea water at high temperatures and velocities, and among the particles of sea water at a low temperature, a peculiar molecular arrangement that is antagonistic to the free mixing up of cold and hot together. At any rate, that salt waters of different temperatures do not readily intermingle at sea, is obvious.

Does not this same repugnance exist, at least in degree, between these bodies of cold and warm water of the plate? And if so, does not the phenomenon we are considering resolve itself into a question of masses or momentum? The volume of warm water in the North

Atlantic is greater than the volume of cold water that meets and opposes it; consequently, the warm thrusts the cold aside, dividing and compelling it *to go round.* The same thing is repeated in the North Pacific, whereas the converse obtains in the South Atlantic. Here the great polar flow, after having been divided by the American continent, enters the Atlantic, and, filling up nearly the whole of the immense space between South America and Africa, seems to press the warm waters of the tropics aside, compelling them to drift along the coast on either hand.

196. Another feature of the sea, expressed by Plate XIV, is a sort of reflection or recast of the shore line in the temperature of the water. This feature is particularly striking in the North Pacific and Indian Ocean. Since this plate was finished, I have discovered the same phenomenon in the Gulf Stream. There is a slight bending of its northern edge as it passes the Nantucket Shoals, then there is a curve upwards to indicate the Bay of Fundy. Again, a bending to the south as it passes Nova Scotia, and then a curve upwards answering to the St. Lawrence, and then another sharp turn southward to avoid the Grand Banks, after which its northern edge shoots off to the NE., for the Faroe Islands. The curves representing the mean limits of this edge for 60° in September, and 50° in March, being traced off with a free hand, conform to each other and with the shore-line in the most beautiful and striking manner.

It seems curious that the icebergs should all make for this bend off the Grand Banks, where the Gulf Stream turns sharply to the NE. The prevailing winds are westwardly, and would, were there no counteracting force, drive the ice to the east. Gulf Stream would help them. But the forces of diurnal rotation which are obeyed by the trade-winds, and which are felt by the drift wood of the Mississippi, are present here also to press the iceberg west and force it down into this Great Bend. The peninsula of cold water of which I have so often spoken is in this bend. But let us return to the problems of Plate XIV: The remarkable intrusion of the cool into the volume of warm waters to the southward of the Aleutian Islands, is not unlike that which the cool waters from Davis' Straits make in the Atlantic upon the Gulf Stream. As I write, I receive from Captain N. B. Grant the abstract log of the American ship Lady Arbella, bound from Hamburg to New York, in May, 1854. In sailing through this "horseshoe," or bend in the Gulf Stream (§ 178,) he passed, from daylight to noon, twenty-four large "bergs," besides several small ones, "the whole ocean, as far as the eye could reach, being literally covered with them." "I should," he continues, "judge the average height of them above the surface of the sea to be about sixty feet; some five or six of them were at least twice that height, and, with their frozen peaks jutting up in the most fantastic shapes, presented a truly sublime spectacle."

197. This "horseshoe" of cold in the warm water of the North Pacific, though extending five degrees further toward the south, connot be the harbor for such icebergs. The cradle of those of the Atlantic was perhaps in the Frozen Ocean, for they may have come thence through Baffin's Bay. But, in the Pacific, there is no nursery for them. The water in Behring's Strait is too shallow to let them pass from that ocean into the Pacific, and the climates of Russian America do not favor the formation of large bergs. But, though we do not find in the North Pacific the physical conditions which generate icebergs like those of the Atlantic, we find them as abundant with fogs. The line of separation between the warm and cold water assures us of these conditions.

What beautiful, grand, and benign ideas do we see expressed in that immense body of warm waters which are gathered together in the middle of the Pacific and Indian Oceans! It is the womb of the sea. In it, coral islands innumerable have been fashioned, and pearls formed in "great heaps;" there multitudes of living things countless in numbers and infinite in variety, are hourly conceived. With space enough to hold the four continents and to spare, its tepid waters teem with nascent organisms. "It is the realm of reef-building corals, and of the wondrously beautiful assemblage of animals, vertebrate and invertebrate, that live among them or prey upon them. The brightest and most definite arrangements of color are here displayed. It is the seat of maximum development of the majority of marine genera. It has but few relations of identity with other provinces. The Red Sea and Persian Gulf are its offsets."* They sometimes swarm so thickly there that they change the color of the sea, making it crimson, brown, black, or white, according to their own hues. These patches of colored water sometimes extend, especially in the Indian Ocean, as far as the eye can reach. The question, "What produces them?" is one that has elicted much discussion in seafaring circles. The Brussels Conference deemed them an object worthy of attention, and recommended special observations with regard to them.

The discolorations of which I speak are no doubt caused by organisms of the sea; but whether wholly animal or wholly vegetable, or whether sometimes the one and sometimes the other, has not been satisfactorily ascertained. I have had specimens of the coloring matter sent to me from the pink-stained patches of the sea. They were animalculæ well defined. Quantities of slimy, red coloring matter are, at certain seasons of the year, washed up along the shores of the Red Sea, which Dr. Ehrenberg, after an examination under the microsope, pronounces to be a very delicate kind of sea-weed: from this matter that sea derives its name. So also the Yellow Sea. Along the coasts of China, yellowish-colored spots are said not to be uncommon. I know of no examination of this coloring matter, however. In the Pacific Ocean I have often observed these discolorations of the sea. Red patches of water are most frequently met with, but I have also observed white or milky appearances, which at night I have known greatly to alarm navigators, they taking them for shoals.

Capt. W. E. Kingman, of the American clipper ship the Shooting Star, came across a remarkable white patch in latitude, 8° 46′ S., longitude, 105° 30′ E., and which, in a letter to me, he thus describes:

"*Thursday, July* 27, 1854.—At 7h. 45m. P. M., my attention was called to notice the color of the water, which was rapidly growing white; knowing that we were in a much frequented part of the ocean, and having never heard of such an appearance being observed before in this vicinity, I could not account for it; I immediately hove the ship to and cast the lead; had no bottom at sixty fathoms; I then kept on our course, tried the water by thermometer, and found it to be 78½°, the same as at 8 A. M. We filled a tub, containing some 60 gallons, with the water, and found that it was filled with small luminous particles, which, when stirred, presented a most remarkable appearance; the whole tub seemed to be alive with worms and insects, and looked like a grand display of rockets and serpents, seen at a great distance in a dark night; some of the serpents appeared to be six inches in length, and very luminous; we caught, and could feel them in our hands; and they would emit light until brought within a few feet of a lamp, when, upon looking to see what we had, behold nothing was visible! but, by the aid of a Sextant's magnifier, we could plainly see a jelly-like substance without color; at last, a specimen was obtained of about two inches in length, and plainly visible to the naked

* From Professor Forbes' paper on the "Distribution of Marine Life." Plate 31, Johnston's Physical Atlas, 2d ed. Wm. Blackwood and Sons, Edinburgh and London, 1854.

eye; it was about the size of a large hair, and tapered at the ends; by bringing one end within about one-fourth of an inch of a lighted lamp, the flame was attracted towards it, and burned with a red light; the substance crisped in burning something like a hair, or appeared of a red heat before being consumed. In a glass of the water, there were several small, round substances (say $\frac{1}{16}$ of an inch in diameter,) which had the power of expanding to more than twice their ordinary size, and then contracting again; when expanded, the outer rim appeared like a circular saw, only that the teeth pointed towards the centre.

"This patch of white water was about twenty-three miles in length, north and south, divided near its centre by an irregular strip of dark water half a mile wide; its east and west extent I can say nothing about.

"I have seen what is called white water in about all the known oceans and seas in the world, but nothing that would compare with this in extent or whiteness. Although we were going at the rate of nine knots, the ship made no noise either at the bow or stern; the whole appearance of the ocean was like a plain covered with snow; there was scarce a cloud in the heavens, yet the sky, for about ten degrees above the horizon, appeared as black as if a storm was raging; the stars of the first magnitude shone with a feeble light, and the "milky way" of the heavens was almost entirely eclipsed by that through which we were sailing. The scene was one of awful grandeur, the sea having turned to phosphorus, and the heavens being hung in blackness, and the stars going out, seemed to indicate that all nature was preparing for that last grand conflagration which we are taught to believe is to annihilate this material world.

"After passing through the patch, we noticed that the sky, for four or five degrees above the horizon, was considerably illuminated, something like a faint aurora borealis; we soon passed out of sight of the whole concern, and had a fine night, without any conflagration (except of midnight oil in trying to find out what was in the water.) I send you this, because I believe you request your corps of "one thousand assistants" to furnish you with all such items, and I trust it will be acceptable; but, as for its furnishing you with much, if any, information relative to the insects or animals that inhabit the mighty deep, time will only tell; I cannot think it will."

These teeming waters bear off through their several channels the surplus heat of the tropics, and dispense it among the icebergs of the Antarctic. See the immense equatorial flow to the east of New Holland. It is bound for the icy barriers of that unknown sea, there to temper climates, grow cool, and return again, refreshing man and beast by the way, either as the Humboldt Current, or the ice-bearing current which enters the Atlantic around Cape Horn, and changes into warm again as it enters the Gulf of Guinea. It was owing to this great southern flow from the coral regions that Captain Ross was enabled to penetrate so much further south than Captain Wilkes, on his voyage to the Antarctic, and it is upon these waters that that sea is to be penetrated, if ever. The North Pacific, except in the narrow passage between Asia and America, is closed to the escape of these warm waters into the Arctic Ocean The only outlet for them is to the south. They go down toward the Antarctic regions to dispense their heat and get cool; and the cold of the Antarctic, therefore, it may be inferred, is not so bitter as is the extreme cold of the Frozen Ocean of the north.

198. The warm flow to the south from the middle of the Indian Ocean is remarkable. Masters who return their abstract logs to me mention sea weed, which I suppose to be brought

down by this current, as far as 45° south. There it is generally, but not always, about five degrees warmer than the ocean along the same parallel on either side.

199. But the most unexpected discovery of all is that of the warm flow along the west coast of South Africa, its junction with the Lagullas current, called, higher up, the Mozambique, and then their starting off as one stream to the southward. The prevalent opinion used to be that the Lagullas current, which has its genesis in the Red Sea, (§ 144.) doubled the Cape of Good Hope, and then joined the great equatorial current of the Atlantic to feed the Gulf Stream. But my excellent friend, Lieutenant Marin Jansen, of the Dutch Navy, suggested to me, a few months ago, that this was probably not the case. This induced a special investigation, and I found as he suggested, and as is represented on Plate XIV. Captain N. B. Grant, in the admirably well-kept abstract log of his voyage from New York to Australia, found this current remarkable developed. He was astonished at the temperature of its waters, and did not know how to account for such a body of warm water in such a place. Being in longitude 14° east and latitude 39° south, he thus writes in his abstract log:

"That there is a current setting to the eastward across the South Atlantic and Indian Oceans is, I believe, admitted by all navigators. The prevailing westerly winds seem to offer a sufficient reason for the existence of such a current, and the almost constant southwest swell would naturally give it a northerly direction. But why the water should be *warmer* here (38° 40′ south) than between the parallels of 35° and 37° south is a problem that, in my mind, admits not of so easy solution, especially if my suspicions are true in regard to the northerly set. I shall look with much interest for a description of the 'currents' in this part of the ocean."

200. In latitude 38° south, longitude 6° east, he found the water at 56°. His course then was a little to the south of east, to the meridian of 41° east, at its intersection with the parallel of 42° south. Here his water thermometer stood at 50°, but between these two places it ranged at 60° and upward, being as high on the parallel of 39° as 73°. Here, therefore, was a stream—a mighty "river in the ocean"—one thousand six hundred miles across from east to west, having water in the middle of it 23° higher than at the sides. This is truly a Gulf Stream contrast. What an immense escape of heat from the Indian Ocean, and what an influx of warm water into the frozen regions of the south! This stream is not always as broad nor as warm as Captain Grant found it. At its mean stage it conforms more nearly to the limits assigned it in the diagram, (Plate XIV.)

201. We have, in the volume of heated water reported by Captain Grant, who is a close and accurate observer, an illustration of the sort of *spasmodic* efforts—the heaves and throes—which the sea, in the performance of its ceaseless task, has sometimes to make. By some means, the equilibrium of its waters, at the time of Captain Grant's passage, December—the southern summer—1852, appears to have been disturbed to an unusual extent; hence this mighty rush of overheated waters from the great inter-tropical caldron of the two oceans, down toward the south.

Instances of commotion in the sea at uncertain intervals—the making, as it were, of efforts by fits and starts to keep up to time in the performance of its manifold offices—are not unfrequent, nor are they inaptly likened to spasms. The sudden disruption of the ice which arctic voyagers tell of, the immense bergs which occasionally appear in groups near certain latitudes, the variable character of all the currents of the sea—now fast, now slow, now running this way, then that—may be taken as so many signs of the tremendous throes which occur in the bosom of the ocean. Sometimes the sea recedes from the shore, as if to gather strength for a great rush against its barriers, as it did when it fled back to join with the earthquake and overwhelm Callao in 1746, and again Lisbon nine years afterward. The tide-rips in mid-ocean, the waves dashing against the shore, the ebb and flow of the tides, may be regarded, in some sense, as the throbbings of the great sea pulse.

The motions of the Gulf Streams (§ 143,) beating time for the ocean and telling the seasons for the whales, also suggest the idea of a pulse in the sea, which may assist us in explaning some of its phenomena. At one beat, there is a rush of warm water from the equator toward the poles; at the next beat, a flow from the poles toward the equator. This sort of pulsation is heard also in the howlings of the storm and the whistling of the wind; the needle trembles unceasingly to it, and tells us of magnetic storms of great violence, which at times extend over large portions of the earth's surface; and when we come to consult the records of those exquisitely sensitive anemometers, which the science and ingenuity of the age have placed at the service of philosophers, we find there that the pulse of the atmosphere is never still; in what appears to us the most perfect calm, the recording pens are moving like pulses of the air.

202. Now, if we may be permitted to apply to the Gulf Stream and to the warm flows of water from the Indian Ocean an idea suggested by the functions of the human heart in the circulation of the blood, we perceive how these pulsations of the great sea-heart may perhaps assist in giving circulation to it waters through the immense system of aqueous veins and arteries that run between the equatorial and polar regions. The waters of the Gulf Stream, moving together in a body through such an extent of ocean, and being almost impenetrable to the cold waters on either side—which are, indeed, the banks of this mighty river—may be compared to a wedge-shaped cushion placed between a wall of waters on the right and a wall of waters on the left. If now we imagine the equilibrium of the sea to be disturbed by the heating or cooling of its waters to the right or the left of this stream, or the freezing or thawing of them in any part, or if we imagine the disturbance to take place by the action of any of those agencies which give rise to the motions which we have called the pulsations of the sea, we may conceive how it might be possible for them to force the wall of waters on the left to press this cushion down toward the south, and then again for the wall on the right to press it back again to the north, as (§ 144) we have seen that it is.

Now the Gulf Stream, with its head in the Straits of Florida, and its tail in the midst of of the ocean (§ 173,) is wedge-shaped; its waters cling together (§ 131,) and are pushed to and fro—squeezed, if you please—by a pressure (§ 143,) now from the right, then from the left, so as to work the whole wedge along between the cold liquid walls which contain it. May not the velocity of this stream, therefore, be in some sort the result of this working and twisting, this peristaltic force in the sea?

In carrying out the views suggested by the idea of pulsations in the sea, and their effects in giving dynamical force to the circulation of its waters, attention may be called to the two lobes of polar waters that stretch up from the south into the Indian Ocean, and which are separated by a feeble flow of tropical waters. Icebergs are sometimes met with in these polar waters as high up as the parallel of the fortieth degree of latitude. Now, considering that this tropical flow in mid-ocean is not constant—that many navigators cross the path assigned to it in the plate without finding their thermometer to indicate any increase of heat in the sea; and considering, therefore, that any unusual flow of polar waters, any sudden and extensive disruption of the ice there, sufficient to cause a rush of waters thence, would have the effect of closing for the time this mid-ocean flow of tropical waters, we are entitled to infer that there is a sort of conflict, at times, going on in this ocean between its polar and equatorial flows of water. For instance, a rush of waters takes place from the poles toward the equator: the two lobes close, cut off the equatorial flow between them, and crowd the Indian Ocean with polar waters. They press out the overheated waters; hence the great equatorial flow encountered by Captain Grant.

Thus this opening between the cold water lobes appears to hold to the chambers of the Indian Ocean, with their heated waters, the relations which the valves and the ventricles of the human heart hold to the circulation of the blood. The closing of these lobes at certain times prevents regurgitation of the warm waters, and compels them to pass through their appointed channels.

From this point of view how many new beauties do now begin to present themselves in the machinery of the ocean! its great heart not only beating time to the seasons, but palpitating also to the winds and the rains, to the cloud and the sunshine, to day and night (§ 174.) Few persons have ever taken the trouble to compute how much the fall of a single inch of rain over an extensive region in the sea, or how much the change even of two or three degrees of temperature over a few thousand square miles of its surface, tends to disturb its equilibrium, and consequently to cause an aqueous palpitation that is felt from the equator to the poles. Let us illustrate by an example: The surface of the Atlantic Ocean covers an area of about twenty-five millions of square miles. Now, let us take one-fifth of this area, and suppose a fall of rain one inch deep to take place over it. This rain would weigh three hundred and sixty thousand millions of tons; and the salt which, as water, it held in solution in the sea, and which, when that water was taken up as vapor, was left behind to disturb equilibrium, weighed sixteen millions more of tons, or nearly twice as much as all the ships in the world could carry at a cargo each. It might fall in an hour, or it might fall in a day; but occupy what time it might in falling, this rain is calculated to exert so much force—which is inconceivably great—in disturbing the equilibrium of the ocean. If all the water discharged by the Mississippi River during the year were taken up in one mighty measure, and cast into the ocean at one effort, it would not make a greater disturbance in the equilibrium of the sea than would the fall of rain supposed. Now this is but for one-fifth of the Atlantic, and the area of the Atlantic is about one-fifth of the sea area of the world; and the estimated fall of rain was but one inch, whereas the average for the year is (§ 35) sixty inches; but we will assume it, for the sea, to be no more than thirty inches. In the aggregate, and on an average, then, such a disturbance in the equilibrium of the whole ocean as is here supposed occurs seven hundred and fifty times a year, or at the rate of once in twelve hours. Moreover, when it is recollected that these rains take place now here, now there; that the vapor of which they were formed was taken up at still other places, we shall be enabled to appreciate the better the force and the effect of these pulsations in the sea.

203. Between the hottest hour of the day and the coldest hour of the night, there is frequently a change of four degrees in the temperature of the sea.* Let us, therefore, to appreciate the throbbings of the sea-heart, which takes place in consequence of the diurnal changes in its temperature, call in the sunshine, the cloud without rain, with day and night, and their heating and radiating processes. And, to make the case as strong as, to be true to nature, we may, let us again select one-fifth of the Atlantic Ocean for the scene of operation. The day

* *Vide* Admiral Smyth's Memoir of the Mediterranean, p. 125.

over it is clear, and the sun pours down his rays with their greatest intensity, and raises the temperature two degrees. At night the clouds interpose, and prevent radiation from this fifth, whereas the remaining four-fifths, which are supposed to have been screened by clouds, so as to cut off the heat from the sun during the day, are now looking up to the stars in a cloudless sky, and serve to lower the temperature of the surface waters, by radiation, two degrees. Here, then, is a difference of four degrees, which we will suppose extends only ten feet below the surface. The total and absolute change made in such a mass of sea water, by altering its temperature four degrees, is equivalent to a change in its volume of three hundred and ninety thousand millions of cubic feet.

204. Do not the clouds, night and day, now present themselves to us in a new light? They are cogs, and rachets, and wheels in that grand and exquisite machinery which governs the sea, and which, amid all the jarrings of the elements, preserves in harmony the exquisite adaptations of the ocean.

205. It seems to be a physical law, that cold-water fish are more edible than those of warm water. Bearing this fact in mind, as we study Plate XIV, we see at a glance the places which are most favored with good fish markets. Both shores of North America, the east coast of China, with the west coasts of Europe and South America, are all washed by cold waters, and therefore we may infer that their markets abound with the most excellent fish. The fisheries of Newfoundland and New England, over which nations have wrangled for centuries, are in the cold water from Davis' Strait. The fisheries of Japan and Eastern China, which almost, if not quite, rival these, are situated also in the cold water.

Neither India nor the east coasts of Africa and South America, where the warm waters are, are celebrated for their fish.

Three thousand American vessels, it is said, are engaged in the fisheries. If to these we add the Dutch, French, and English, we shall have a grand total, perhaps, of not less than six or eight thousand, of all sizes and flags, engaged in this one pursuit. Of all the industrial pursuits of the sea, however, the whale fishery is the most valuable. Wherefore, in treating of the physical geography of the sea, a map for the whales would be useful.

The sperm whale is a warm-water fish. The *right* whale delights in cold water. An immense number of log-books of whalers have been discussed at the National Observatory, with the view of detecting the parts of the ocean in which the whales are to be found at the different seasons of the year. Charts showing the result have been published; they belong to the series of Wind and Current Charts.

In the course of these investigations, the discovery was made that the torrid zone is to the right whale as a sea of fire, through which he cannot pass; that the right whale of the northern hemisphere and that of the southern are two different animals; and that the sperm whale has never been known to double the Cape of Good Hope—he doubles Cape Horn.

With these remarks, and the explanations given on Plate XIV, the parts of the ocean to which the right whale most resorts, and the parts in which the sperm are found, may be seen at a glance.

CHAPTER XVI.

A NEW FIELD.

Insects of the sea—how to capture, § 206.—Beautiful subject for study at sea, § 207.—The climates in the depths of the ocean, with their inhabitants, § 208.—D'Urville and Dana, § 209.—Objects of this chapter, § 210.—Mrs. Toynbee's letter, § 211.—Foster's log, § 212.—Description of the drawings, Plates XX to XXXVII, § 213.

§ 206. "Let the waters bring forth abundantly the moving creature that hath life:"

And God blessed them, saying: "Be fruitful and multiply, and *fill* the waters in the seas."

All who look are astonished to find the waters of the sea so full of life; and when one mounts his microscope to examine the fashion, and to study the organism of these creatures, astonishment is replaced by wonder and delight.

The curious on board ship sometimes amuse themselves by letting overboard, in light winds and calms, a hoop-net of gauze, or other light material, to catch "insects of the sea;" crumbs of bread or other food that will attract them are sometimes placed in it as bait. The hoop is to keep the mouth of the net open and prevent it from collapsing into folds and crushing its spoils as it is hauled up; and these, when they are received on deck, are regarded by all on board with amazed interest and curiosity.

But wait until the microscopist mounts them on his slides, and brings the powers of his instrument to bear. Then every one who looks marvels at the beauty and variety of organic form there presented, and the beholder is at once struck with the extent, the resources, and the richness of the new field of research, into which he has now, it may be for the first time, had the opportunity of casting a look. He fully realizes the idea that the organisms of the sea are as multitudinous as its waves, and as marvelous as its wonders.

§ 207. With such a subject for study and contemplation as these insects afford to all who can use the microscope, let no naturalist who crosses the ocean, and no passenger on board ship, or mariner, who can afford to purchase a microscope, talk hereafter about the monotony of a sea voyage, or the *ennui* of a passage. More varied, strange, and new than the insect life of *terra firma*, the entomology of the sea, if we may so style the families of its little crustaceæ, medusæ and zoophytes, offers quite as profitable and as instructive a field of investigation as does the entomology of the air.

The floating crustacæ of the high seas are classed by naturalists a little lower than the insects of the air, yet, in the scale of being, they rank higher than the worms of the earth. Every one who, with an eye for the microscope, goes to sea may help, with proper drawings and descriptions of what comes to his net, greatly to enrich this field. Not only so, these mites of moving creatures will tell us in their mute way, if we consult them aright, of all the currents, polar and equatorial, that help to regulate the climates of the great deep. They may be regarded as tallies to the water by which the system and channels of oceanic circulation are to be pointed out and made visible, as it were, to the eye of science.

Let us imagine ourselves deep down in the sea—just as far as the most piercing sunbeam with its light and heat can penetrate. The living organisms that dwell there would, we may imagine, be few and low of order. But few or many, pressure, temperature, and light constitute the elements of the climate in which they delight, and on account of these elements there would be genera and species whose *habitat* could neither be above nor below the supposed depth.

Ascending thence to the surface we should pass through layer after layer and climate after climate, each with a degree of light, heat, and pressure, and with races of inhabitants, peculiar to itself. We might expect to find the different depths to constitute a series of *habitats* for the fauna and the flora of the sea, not unlike those which we find as we ascend a high mountain. Those of the steppes on the dry land may have a wider range, but be they of the land or of the water they are all alike the creatures of climate and physical circumstance.

The sea is very wide, and its inhabitants are as numerous as the sands on its shores. It will take many years and many fleets to troll and drag in it, to scoop, and fish up of its treasures, before we shall have collected and described a specimen of every genus, and of all the species, kinds and varieties of organic that abounds in its waters.

Many of those who are helping this work on by their co-operation are well calculated to labor in this field with much profit, and the temptation is very great, for the harvest is abundant.

§ 208. Among the myriads of little insects that swarm in the seas, there are, no doubt, many families of limited and narrow geographical range. In the sea, we may imagine climates superimposed one above the other like so many stratifications. They are also arranged in bands, belts, or zones alongside of each other; they all differ. The inhabitants of these natant climates overlap and intermix with each other; nevertheless, we may suppose that whenever water of an assumed transparency, saltness, and depth is found at a given temperature its microscopic inhabitants are the same. If observation shall approve this conjecture, we may learn much from not only these creatures of oceanic circulation, but of submarine climatology also.

Draw up a bucket of water anywhere within the tropics at sea, and the chances are that something new or beautiful, that hath life, may be found in it. This is not only so at the surface where the forces of light and heat are at play, but even in the depths below, where they reach only with feeble ray. A bucket of water drawn from the wash-deck pump, or from the ship's cock, 15 or 20 feet below the surface, seems to be as well *filled* with sea organisms as one from the surface. So that we have in the sea, it may be imagined, not only zones or belts of insect life reaching across the ocean, and arranged in stripes according to latitude, but laminæ and strata of it also arranged in folds and layers according to the depth, transparency of the sea, its temperature, and the angle of the incident sunbeam.

These mites of marine organisms are fragile of form, and weak in consistency of body. They cannot easily be preserved for the cabinet; they are very perishable, and to be studied and described they must be examined on the spot. And to do this well and wisely a little previous preparation is necessary. But this preparation involves no more labor, expense, or study than every mariner who values aright the accomplishments of the sea may well afford to bestow. He must, to make his contributions in this field valuable to men of science, not only learn to use the microscope, but he must know how to draw and what to draw; he must describe also.

§ 209. The French navy, through D'Urville and others, and the American navy, through Dana, of Wilkes' Exploring Expedition,* have made the most extensive and valuable contributions that the world affords to this department of natural history. These, however, are very costly works, and unfortunately, on that account, are accessible to but few. Many, therefore, of the specimens which those of our corps of observers who may fancy this field will describe,

*See Dana on Zoöphytes, vol. 8, U. S. Exploring Expedition; Philadelphia, Lea & Blanchard, 1848. Dana on Crustacæ, vol. 13, U. S. Exploring Expedition; Philadelphia, C. Sherman, 1852.

thinking them new will be found, in all probability, to have been already described in those works; and if so, the descriptions and drawings will be rendered according to strict scientific rules.

But if an observer now and then finds his specimen already described in those works, let him not be discouraged, for the field is a wide and a rich one; and the waters bring forth most abundantly of moving creatures.—Many of them are strange and new.

Moreover, the works of those accomplished naturalists are, for the most part, sealed books to those who are co-operating with me as observers in this system of research. They are not for us. We have undertaken to convert those who "do business in great waters and see His wonders in the deep" not only into a corps of observers, for the purpose of investigating the phenomena of the winds and the waves, as they bear upon the economy of commerce, but into a corps of Philosophers, also, for the purpose of looking into the physics of the sea, as they bear upon its adaptations and its mechanism, hoping thereby to elevate and improve the sea-faring man, and perchance now and then to add something to the general stock of human knowledge. When we begin to improve we shall find incentives in the hope of making contributions which even those great lights shall hail with joy.

§ 210. This chapter, with its plates and drawings, is therefore not offered to naturalists or to the favored few who have access to the works of Dana, D'Urville, *et al.*, as containing anything that is new or suggestive to them. It is offered to the sea-faring man for his benefit and improvement; it is intended for those who are striving with me to systemize the observations which all navigators are required to make at sea, in order that they may be turned to philosophical and moral as well as to nautical account. This chapter, with its drawings, like its predecessor in the appendix to the 7th edition, is offered simply as an encouragement and as a beginning to other co-operators. It shows what has been gained in this field since the publication of the last edition of this work. In the appendix thereto was Captain Foster's abstract log of the "Garrick." It contained a few pen and ink sketches of marine animalculæ, as seen through the reading glass of his sextant. These little sketches, though of no particular interest to the naturalist, were not therefore valueless; on the contrary, they proved to be highly interesting to mariners and of very great value; for by the example the Gloriana's log has also been greatly enriched. After she had put to sea Foster's abstract attracted the attention of Captain Toynbee of this East Indiaman. There happened to be a microscope on board the Gloriana; hence the drawings that are now presented, and of which Mrs. Toynbee gives the following account:

"SHIP GLORIANA, *en voyage, January,* 1857.

§ 211. "MY DEAR SIR: Your very welcome and kind letter was awaiting us when we landed in Madras last month, for we had left England a day or two before it arrived. I assure you it was with sincere pleasure that Captain Toynbee heard that his logs were likely to be useful to you, for it is a grand thing to contribute even in the smallest measure to your excellent and noble work. The log this voyage will comprise a little further experience of the Indian Seas; for we came up the bay of Bengal in company with a Cyclone, making use of it till the furious squalls and disturbed sea warned us to stop, and most surprised all the passengers were when they heard the order given to heave to, and to learn what it was that we were to avoid. Captain Toynbee had confided his suspicions of our terrible neighbor to me for some days, and most interesting I had found it to watch the gradual changes of wind which were to prove the truth and importance of the circular theory; and when we were the first ship to anchor in

Madras Roads, all that had been there before having been obliged to put to sea, the chorus of praise on this simple but effectual nautical science was universal.

"We have since found that on a night while we had theatricals performing on board in the open air, a ship only 195 miles from us was exposed to all the fury of wind, sea, rain; whilst four ships on shore, and, more dreadful still, the wreck of a vessel's stem, formed into a raft—but with no men on it—completed the horrors of the day; all this, however, is described at length in the log, and that will tell you, too, that the rest of our voyage was rough, rough outwardly, but smooth and pleasant inwardly; for both the passengers and the detachment of the 12th Lancers on board seemed to vie with each other in smoothing over the discomforts of high seas and incessant rain; * * * indeed, we thought that the rough weather seemed just to afford that relief from the monotony and *ennui* of a long voyage, which people in general will not look for in occupation. As for ourselves we have found a new and most engrossing interest in sea life in examining the sea water with the microscope, of the results of which we have since found that you give specimens in the last edition of your Sailing Directions. Unfortunately, Captain Toynbee had not reached the appendix in looking through it before leaving home, else we should have provided ourselves properly for carrying on the search. The surgeon of the Lancers—Mr. Wrench—luckily had his microscope with him, and was enthusiastic and skillful in the use of it, and he and my husband used to spend many hours at first trying to catch these delicate organisms. "Oh", Mr. Wrench sighed, "if I had but a test tube here." A hydrometer had been accidentally broken a few days before and supplied the very thing we wanted, and then all went on prosperously; each day exciting in us more and more admiration for the marvels around us. That rough foaming sea to abound with this minute life, exquisitely colored, and each of the many legs of the little crustacæ beautifully feathered and fringed, seemed a wonder of which we could never tire, and much as we liked Mr. Wrench personally, our regret when he left us was much increased by his *microscope* going with him. He is already at work with it on the fresh water insects in Poonamalee, whilst a kind friend in Madras has lent us his, so that the bucket of water drawn for trying the surface temperature is a perpetual feast. We shall be very much interested in hearing whether the sketches we shall send you resemble those you have had from elsewhere. I fear that I am taking up too much of your precious time with my long letter, but it is a real treat to speak, even on paper, to any one who thoroughly appreciates the grandeur and glory of the sea. What new lights you have thrown upon it in your Physical Geography, and how shall I thank you sufficiently for that charming work? We rewarded Mr. Wrench for his microscopic work by letting him read it, and agrees with us in the dignity and sublimity of its views. * * *

"Believe me your truly obliged, ELLEN P. TOYNBEE.

"I must just add that we crossed the line in the end of September, in longitude 30° W., and passed that terrible bugbear, Cape St. Roque, most successfully."

Tracings of these drawings were submitted to Professor Dana, of New Haven, who, under date 19th December, 1857, writes in reply:

"The drawings you have sent me, and which I herewith return, are evidently by a person of great skill in drawing and nicety of observation. But they lack just that exactness which is necessary to render them available to science. They are not sufficiently detailed to enable me to determine the genus in all cases, and much less the species. If you can obtain access to a copy of my report on crustacæ, you will find in the plates many of the forms figured. I have added names and references to the plates as far as I am able. If the specimens themselves were preserved, the drawings could be identified throughout.

"I think it exceedingly desirable that these animals of the sea should be further investigated. My report would be quite essential to any one who should undertake it; that is, as regards the crustacæ, as it is the only one which gives figures and descriptions of the minute oceanic crustacæ. I wish I could have put a copy into the hands of the accomplished lady who made the drawings on the 'Gloriana.' She has done so remarkably well that but a little more precise knowledge would have given great value to all of her sketches.

"Many of the drawings are of medusa, to which I have paid no special attention; some of them may be found figured in the voyages of D'Urville and others of the French navy."

Captain Toynbee is one of *the men of the sea*, and, like Foster, ranks as a crack co-operator in our wind and current investigations. The Board of Trade in London has awarded him its highest prize for the excellence of his abstract log. His wife, who is a lady of rare accomplishmens, accompanies him on his sea voyages. She is the daughter of Admiral Smyth, R. N. Plates XX to XXXVII are specimens of her handy work. They show what a refined occupation and elevating amusement this new field of physical research is capable of affording to philosophical minds on what has heretofore been considered the most monotonous and tedious of sea voyages; its only variety has been described in the distich:

"Sometimes we see a ship;
Sometimes we ship a sea."

With such resources at hand, let no one who doubles the "stormy capes" hereafter complain of the want of profitable occupation or instructive and wholesome amusement.

§ 212. In 1855, the attention of co-operators was invited to this rich and beautiful field, as per the following paragraph:

"I have added, by way of appendix, a lithographic copy of Captain Foster's abstract log, as an example of what an industrious and zealous observer may do with very simple means. With the glasses or telescope of his sextant, he rigs up a microscope, and sends the most beautiful *colored* drawings of the curious forms of organic life that he finds sporting in the sea. Many navigators have kindly collected and sent me phials of sea water, which they found swarming with animalculæ. But these delicate little organisms soon perished; and when the bottles arrived nothing of their forms could be distinguished but amorphous masses of fetid matter. Captain Foster's drawings, therefore, inasmuch as they are not colored in the lithograph, do not do him full justice. Now, here is a field of research abounding with the gelatinous animalculæ of the sea, and rich with rare and precious gems, which can only be studied at sea. The specimens cannot be perserved long enough for examination. They should be studied, and sketched, and described while alive in the water, and therefore it is hoped that Captain Foster's attempt may stimulate some one to prepare himself with the means of describing such things in a proper and satisfactory manner. Hence the publication of his beautifully kept abstract log. Any one who desires to undertake such description should provide himself with a microscope, and be careful to make his drawings properly. Professor Bailey's microscopic drawings may be taken as a pattern."—P. 863, 7th ed.

Captain Foster has continued regularly to send in his logs. They are always enriched with drawings and sketches of the inhabitants of the sea. He himself thus alludes to them in a letter to a friend:

"Lieutenant Maury informs me he is making a picture chapter of the sea, which must be highly interesting.

"The ocean teems with organic life. On every voyage I discover polypi and medusæ that are strange to me. In my earlier days I was merely an admirer of ocean's wonders. I never took any particular interest in sketching or observing the habits of sea organisms. It was owing to Lieutenant Maury that I became stimulated to action, and to whom, in consequence, I am indebted for many a happy hour when sailing over ocean's solitudes.

"Among other sketches which I send to that gentleman are drawings of various birds which I had captured many hundreds of miles from land. The drawings are correct, but the colorings are very imperfect from the fact that it is impossible to obtain good light in a ship's cabin.

"I am in hopes that the longer I sail on the sea the more opportunities I shall have for capturing the creatures that may be strange, even to naturalists; for this purpose I am having made a properly fitted machine that will enable me to procure in moderate weather many strange individuals which it has been impossible to capture."

Thus it appears that laborers, encouraged by our first step, are already in training for the work that is to be done in this new and beautiful field.

Names and references—see Professor Dana's letter, pp. 220–'21.

PLATE XX.	3.	Euchaeta, (??)
	4.	Calanus, (? M.)
	7.	Hyperia, pl. 67, (Dana.)
XXI.	14.	One of the Acaridae.,
XXII.	16.	One of the Amphipods.
	17.	Probably an Acartia, pl. 79, (Dana.)
	18.	Rhincalanus or Calanus.
XXIII.	21.	Young of a Setella, pl. 84, (Dana.)
	22.	Calanus medius? pl. 73, (Dana.)
	25.	Calanus or Pontella.
XXIV.	27.	Sapphirina, pl. 87 and 88, (Dana.)
	28.	Sapphirina?
	30.	Pontella?
XXV.	34.	Corycaeus pellucidus or concinnus, pl. 86 fig. 67, (Dana.)
XXVI.	32.	Antaria near A. Gracilis, pl. 86 fig. 13, (Dana.)
	38.	Near Polyphemus.
XXVII.	47.	Candace Pachydactyla, pl. 78 fig. 2, (Dana.)
XXVIII.	50.	Near Euphausia, pl. 42 and 43, (Dana.)
	51.	Setella, pl. 84, (Dana.)
	55.	Miracia efferata, pl. 88 fig. 11, (Dana.)
	56.	Orthora, pl. 76, (Dana.)
XXIX.	58.	Rachitia, pl 44, (Dana.)
	59.	Copilia Mirabilis, pl. 86 fig. 14, (Dana.)
XXX.	66.	Harpacticus, pl. 83, (Dana.)
XXXI.	68.	Pontella.
XXXII.	76.	Rhincalanus?
	77.	Synopia? pl. 68, (Dana.)
XXXIII.	80.	Euphausia, pl. 42 and 43, (Dana.)
	81.	Corycaeus or Antaria, pl. 85 and 86, (Dana.)
	83.	Siriella, pl. 44, (Dana.)

XXXIV.	84.	Lucifer (L. Acestra?) pl. 44 and 45, (Dana.)
XXXV.	86.	Of the Caligus family.
	87.	Euchaeta Communis, pl. 77–1.
	89.	Sapphirina S. gemma, pl. 88 fig. 2, (Dana.)
XXXVII.	91.	One of the Amphipods, Genus, (?)

Extracts from the abstract log of the ship Gloriana, Captain Henry Toynbee, from London to Madras, and back, 1856–'57.

PLATE XX, Figs. 1 to 9.

§ 213. *September* 14, 1856, latitude 10° 06′ north, longitude 28° 00′ west; temperature of water at surface 81°. 8 ; specific gravity 1.024.2.

Much yellow matter on the surface of the water; parts of which, when seen through a microscope, looked like longitudinal cells or tubes of vegetable matter placed side by side as in the Pandean pipes; they were transparent and rounded off at the ends.

Assistant Surgeon Wrench of H. M. 12th Lancers has kindly allowed me to copy his description and sketches of this matter as seen through his microscope: "No. 1, vegetable cellular structure; highly magnified."

"No. 2. Flocculent cellular structure, mixed with but not so abundant as No. 1; also visible to the naked eye; here slightly magnified. This did not seem so light as No. 1; in fact, it seemed about the same specific gravity as sea water. The color of No. 1 was orange, of No. 2 straw yellow.

"The water containing them was phosphorescent in the dark, which it lost after standing 24 hours; the luminous points upon agitation seemed to keep near the bottom of the bottle, and gave one the idea that it was emitted by No. 2, which, upon examination by a high power, was evidently of a vegetable structure."

October 23.—Latitude 35° 08′ south; longitude 13° 52′ east; temperature of surface water 60.2; specific gravity 1.027.2.

Found in the freshly-drawn sea water the insect represented in the accompanying sketch, (Fig. 3; Euchaeta ??,) it moved in sudden darts from one side of the bottle to the other. When placed under Mr. Wrench's microscope it bore a strong resemblance to the half digested insect found in the whale bird which was shot some days ago, and what makes it more probable that it is of the same kind is, that there were large numbers of whale birds about the ship to-day. One source of doubt, however, is that the insects taken from the whale bird were quite red, and this had only a few red spots; perhaps their being partly digested may have caused this difference.

October 25.—Latitude 35° 08′ S.; longitude 18° 10′ E; surface temperature, 64°. Found in the freshly drawn sea water a string of similar insects linked by mere adhesion, (5,) for when kept in the bottle for some time they separated, but continued in active motion. They each had a passage for water and ciliae working in that passage, causing a quick circulation which threw out particles in the water with great force. They were transparent and white, except the blue spot, which was even brighter than in the accompanying sketch, (6.) This insect was found at the same time with the above; when magnified, it was seen that each foot was composed of 20 hairs. It moved through the water like an eel.

Fig. 7. This was also found at the same time; its motion seemed to be obtained by a sudden

jerk of the tail under the body towards the head; it will be noticed that the last three or tail feet have more claws than the rest.

3 P. M.—Found this insect (Fig. 8) in the freshly drawn sea water; it was visible to the naked eye, as was also its "sprit-sail yard." It made sudden darts through the water, and the fringes at the ends of its antennae spread out to nearly a right angle with them. The sketch (8) represents it as seen under the microscope alive, and then dead, (8 *a.*)

PLATE XXI, FIGS. 10 to 15.

Monday, October 27.—Latitude 36° 18′ S.; longitude 20° 57′ E.; temperature of surface water 65°.7; specific gravity 1.026.0.

This insect, Fig. 10, which was found in the freshly drawn sea water at 9 A. M., was very beautiful to the naked eye, and still more when seen through the × 9 microscope. It strongly resembled an echinas in shape; the upper part, which was bluish pink, seemed to be the mouth, or the means of exit for the strong current of water which was thrown up from below by the ciliæ, which were very long, and worked most actively from the ribs, which were highly raised. The ciliæ seemed to be thrown upwards and outwards and then moved quickly down with a paddling kind of motion. The whole was transparent.

Fig. 11. This insect was found at the same time. We thought that it might be one of the same kind as those found in a string on the 25th, but in a more advanced stage. It was a beautiful sight; it had the power of contracting its transparent body, which it did by drawing in its side and ends at the same time, sending forth a current of water. When it contracted its body the interior longitudinal passages approached each other. I towed a small net astern for a short time, and its meshes were covered with these insects. It will be noticed that we are on the Lagullas Bank.

November 5.—Latitude 39° 43′ S.; longitude 53° 29′ E.; surface temperature 54°; specific gravity 1.027.3.

Fig. 12. This insect was pumped from the sea by a pump which has a pipe about seven feet under water, and was drawn off into a bath. The large sketch was taken when the insect was lying on its side with its horns under it; but when moving in the water the horns were at right angles with its body; it was very active, and seemed to be fond of standing on the bottom, head downwards. No eyes could be distinguished—perhaps its horns act as feelers—for all the insects that we have found with horns or antennae have not had eyes visible. With a powerful microscope, quick vibration was visible along the back, though no ciliæ were visible; the body was nearly transparent. It much resembled the insect formerly described as the food of the whale bird, but was larger, had longer horns, and much more red about it.

Fig. 13. At 3 P. M. this globular matter was found floating in the bucket of water drawn for the surface temperature; the pinkish ball in the centre seemed to have the power of contraction and expansion; for, when looked at with the × 9 microscope, different parts of its surface seemed concave at times; the exterior film, which was much broken at the edge, seemed to attract and hold by adhesion the particles of dust which floated near it.

November 11.—Latitude 36° 01′ S.; longitude 73° 13′ E.; temperature of surface water 58.8; specific gravity 1.026.8.

Fig. 14. Found in the freshly drawn sea water, the animalculæ represented in the accompanying sketch; very active, with a rapid darting motion. It is here highly magnified, and seen by transmitted light; when seen by reflected light it looked of a pale yellow color, and the body seemed covered by a tuberculated shell.

November 13.—Latitude 32° 42′ S.; longitude 76° 19′ E.; temperature of surface water 62° 1; specific gravity 1.0265.

Fig. 15. Found this insect with horns like the one sketched on the 13th October. Towed the net astern and caught great numbers of acelapha or jelly fish; they floated by in strings, varying from 1 to 4 feet in length; the different individuals united obliquely, the upper ends of one resting on the side of the next. They varied from an inch to eight inches in length. Almost all had one or more scarlet shrimps passing freely about in its hollow body. It progressed by forcibly ejecting the water here seen through the upper horn; the body having been previously filled by the aperture at the other end.

Plate XXII, Fig. 16. This inhabitant of the jelly fish (Fig. 15, Plate XXI) seemed to respire by a quick movement of the hind legs. There was a distinct circulation in the legs of a colorless fluid, containing a few corpuscles, the fluid running down one side of the leg and up the other.

November 18.—Latitude 25° 14′ S.; longitude 83° 47′ E.; temperature of surface water, 72°.3; specific gravity, 1.0260. Mr. Wrench succeeded in getting under his microscope one of the minute insects (Fig. 17,) that have been visible in the sea water almost every day since the 18th of October. (Latitude 36° 49½′ S.; longitude 13° 00′ E.) It was but just visible to the naked eye; it is here given as seen from above, but a side view was very similar to the original blue crustacean sketched on the 23d October, (Fig. 3, Plate XX.)

10. P. M.—The sea phosphorescent; towed the net astern and caught some small specimens of jelly fish, caught on the 13th instant, (Fig. 15, Plate XXI,) but there were no shrimp in them. Found adhering to the net a small crustacean Fig. 18. The beautiful scarlet marks on the back were exactly similar in two specimens examined. They emitted a beautiful phosphorescent light, visible even when a candle was burning.

November 19.—Latitude 24° 16′ S.; longitude 83° 33′ E.; temperature of surface water, 72°.6; specific gravity, 1.0258. Found in the freshly drawn sea a very blue specimen of the blue crustacean and the accompanying very minute specimen of infusoria, (Fig. 19,) which was all but invisible to the naked eye. It was very active, wriggling its long body through the water, and we have frequently spent much time in trying to catch one.

November 22.—Latitude 13° 35′ S.; longitude 81° 57′ E.; temperature of surface water, 79.1; specific gravity 1.0243. Caught the accompanying creature, (Fig. 20, Plate XXIII,) not unlike a small cuttle fish, but wanting the brachiae. Natural length $\frac{2}{12}$ of an inch; on the 28th of November a similar insect was caught having red where this had blue coloring.

November 24—Latitude 10° 34′ S.; longitude 80° 15′ E.; temperature of surface water, 80°; specific gravity, 1.0241. Pumped up the accompanying insect, (Fig. 21,) which progressed by the action of its legs, the thick end of the body being in front; the dark spots very much resembled eyes, and came out when it was dead; also a small crustacæ (cyclops?) with a yellowish green body, and bright yellowish hairs in its tail.

November 25.—Latitude 10° 14′ S.; longitude 79° 58′ E.; temperature of surface water 79.9; specific gravity, 1.0241. Pumped up this crustacean, (Fig. 22,) similiar to yesterday's, (Fig. 21,) but having ova (?) attached to its tail, the hairs at the end of which were miniature feathers. Is this the female and yesterday's the male, the hairs being feathered for the attachment of the ova? (Fig. 23.) Also a crustacean of similar form, (Fig 24,) but some of the legs purple, others and the body marked with scarlet. Later in the day the accompanying blue crustacean, (Fig. 25,) the hairs in the tail were particularly beautiful under the microscope, appearing like little feathers, the insect having the power of contracting and expanding the blade.

November 26.—Latitude 8° 15′ S.; longitude 80° 49′ E.; temperature of surface water, 81°.2 specific gravity, 1.0243. Towed the net astern and caught the accompanying acelapha, (Fig. 26, Plate XXIV,) which is here magnified about 3 diameters; it moved through the water by contracting its umbelliform head. Pumped up the accompanying dark crustacean, (Figs. 27 and 28.) It had a very flexible body, and propelled itself by the action of its tail; its body was too opaque for any of the internal structure to be visible.

November 27.—Latitude 5° 48′ S.; longitude 81° 28′ E.; surface temperature, 80°.2; specific gravity, 1.0249.

3 P. M.—Caught this conical shaped fish, (Fig. 29,) surrounded by four rows of very large ciliae with a pendunculated mouth and an evident stomach.

November 28.—Latitude 3° 25′ S.; longitude 82° 30′ E.; temperature of surface water, 79°.8; specific gravity, 1.0250.

Caught this transparent crustacean, (Fig. 30, Plate XXV,) the body of which is long in comparison with its horns; it kept up a circulation in the water by working its feet and horns.

Also caught the bright one, (Fig. 31,) the color of which seems caused by its food. Also this beautifully colored one, (Fig. 32, Plate XXVI,) peculiar from its short horns and large tail.

November 29.—Latitude 0° 38½′ S.; longitude 83° 39′ E.; surface temperature, 80°.8; specific gravity, 1.0242. Pumped up this crustacean, (Fig 33, Plate XXV,) nearly similar to the one found on the 25th, its eyes are better defined and its tail very remarkable. Caught, also, some crustacae similar in form to yesterday's, but varying in the colors, which were very bright in all.

Fig. 34.—Found on the 25th, latitude 10° 14′; longitude 79° 58′2.

December 1.—Latitude 2° 52′ N.; longitude 88° 05′ E.; temperature of surface water, 81°6; specific gravity, 1.0238 (Fig. 35.) This long backed crustacean was taken from the bucket at 3 P. M.; it swam very heavily in the water, often resting on the bottom, and jumping up perpendicularly, keeping up a motion like treading on the water. The net-work of legs under the fore part of the body retained the appearance given in the sketch, but were in almost constant motion.

December 2.—Latitude 3° 30′ N.; longitude 88° 55′ E.; temperature of surface water, 80°.3; specific gravity, 1.024. Found a small green Holothuria? (Fig. 42, Plate 25,) having very little form but very active motion; it occasionally turned up the upper end, when it appeared bifurcated; when dead something like legs appeared from under its body, but it was of such soft consistency that it went to pieces almost immediately.

Found also this long creature, (Fig. 43, Plate XXVI,) which was very active, and had evident vision, as it avoided any object brought near it; it moved by sudden darts through the water.

December 3.—Latitude 3° 55′ N.; longitude 86° 58′ E.; temperature of surface water, 80°.1; specific gravity, 1.0236. Found something which looks like a piece of sea-weed, (Fig. 36, Plate XXV,) with seed vessels attached by long threads, which threads had the power of very suddenly contracting into a closely packed spiral and then gradually straightening again; this action was kept up constantly. We also found something very much like a joint of this, but it differed in having merely a yellow, rather globular centre, formed of several cells, from which centre hairs shot out at right angles, looking so much like the points of the compass that Mr.

Wrench thought it should be called the compass seed, (Fig. 37, Plate XXVI.) Another seed, something like this  was found in 13° S.

December 5.—Latitude 5° 20′ N.; longitude 87° 13′ E.; temperature of surface water, 80°; specific gravity, 1.0240. Caught these minute infusoria, (Fig. 38 and 39,) which were but just visible to the naked eye.

January 2, 1857.—Latitude 12° 46′ N.; longitude 80° 28′ E.; temperature of surface water, 78°. (Fig. 40.) Two of these were found; under the microscope they appeared like small sheaves of very fine brown fibres with the ends hanging loose; in the centre the fibres must have been connected by some transparent glutinous matter, for the microscope showed them to be closer together in that part; and when, by the motion of the water, the ends were washed first one way and then the other, the centre always kept closely cemented. On carefully examining each fibre they seemed to be semi-transparent, yellow, and cellular. After keeping one for a night in water, each fibre seemed to have lost its distinctness, and was inclined to cling to the rest.

Fig 41. This appeared like a ball of transparent jelly, opaque in the centre, contained in a net of fibres from which spikes protruded; it had no apparent motion.

Fig 32. Latitude 3° 25′ S., 82° 30′ E. Taken, November 28.

January 5.—Latitude 11° 55′ N.: Longitude 82° 31′ E.; temperature of surface water, 78°.5.

Fig. 45, Plate XXVII. This creature moved through the water like an eel, wriggling its body rapidly and using its hairy fins as propellers. It became entangled in some Canada balsam and paper on the slip of glass on which it was placed, and when it disengaged itself had the singular projection from its mouth, shown in the second sketch, (45a,) and died soon after. It very much resembled the one found in the warm water current off the Cape. A few days after, found one of the same species, in which this tongue was visible inside its body near the head.

January 6.—Latitude 12° 54′ N.; longitude 82° 49′ E.; temperature of surface water, 78°; specific gravity, 1.024. Found a small Holothuria, which seemed to move by contraction and expansion, slug fashion. Also this transparent insect, (Fig. 46,) somewhat resembling that found on the 20th November, 1856; it wriggled through the water, keeping its tail in active motion, and when seen under the microscope, there seemed to be a sort of wheel in the centre of its head constantly revolving.

Also several specimens of the sheaves of fibres similar to that found on the 2d, and this circle which seemed to be of the same class. The glutinous matter which held them together was visible in this instance, being yellow and cellular, (Fig. 44.)

January 8.—Latitude 15° 43′ N.; longitude 82° 06′ E.; temperature of surface water, 77°; specific gravity, 1.0232.

Having had my net lined with white bunting, I had it towed for a minute, but finding that the ship was going too fast it was hauled in. On it I found this remarkable crustacean. (Figs. 47 and 48.) The hind legs were large and black and seemed to be used to tread the water, while the fore legs, instead of keeping in a line with its body, moved at right angles to it upwards and downwards.

March 2.—Latitude 3° 22′ N.; longitude 82° 07′ E.; temperature of surface water, 82°.9; specific gravity, 1.0240. Caught, by towing the net, several specimens of this conical shaped fish, (Fig. 49,) apparently similar to the one which was so hurriedly sketched on the 27th November, 1856. They all keep their ciliæ in constant motion, and as soon as the water dries from them they seem to dissolve, so that it is difficult to obtain a correct sketch; some of the specimens had not so many rows of ciliæ, and put me in mind of a trilobite.

January 9.—Latitude 16° 18′ N.; longitude 82° 22′ E.; temperature of surface water, 75°.5; specific gravity. (Fig. 50, Plate XXVIII.) This little fish was caught in the bucket when in about 10 fathoms water. It kept its legs in such rapid motion that it was difficult to distinguish them clearly. Caught another a few hours after by towing the net.

January 25.—Between Coringa and Madras, latitude 15° 32′ N.; longitude 82° 25′ E.; temperature of surface water, 77°. This insect (Fig. 51,) was pumped up from about six feet below the surface; its motion in the water resembled the creeping of a small animal, and the downward tendency of its nose made it appear like an animal seeking food by the aid of that organ.

Figs. 52 and 53. This very small insect was found in the same bucket; its minuteness, length of tail, and delicate feathers, which were of a brilliant yellow, while the rest of the the body was white, made it one of the most remarkable and beautiful insects we have found.

February 28.—Latitude 4° 48′ N.; longitude 82° 20′; surface temperature, 82°.7; specific gravity, 1.0242. (Fig. 54.) This perfectly transparent fish was caught in the net; it moved by darts through the water. When dust or other particles floated near its head it worked its claws rapidly, whereas before they had been stationary, standing up at the side of its head. These claws, which seem to belong to a higher organization, may be a connecting link between it and the crustacæ. Caught, also, a dark sluggish crustacean resembling the one found on the 26th November, (Fig. 26, Plate XXIV,) and another of the same species with a large bunch of purple ova on each side of its tail.

Also this insect, (Fig. 55, Plate XXVIII,) which seemed to creep in the water like the one pumped up on the 25th January. May this be a young one of the same species? Great numbers of both sorts were caught in the net with this one; the colors in each case were identical, so also the legs and the position when dead, with the tail turned up as in the sketch.

March 3.—Latitude 2° 49′ N.; longitude 82° 16′ E.; temperature of surface water, 83°.4; specific gravity, 1.0234. Towed the net and caught several of these minute crustacæ; (Fig. 56,) they were so colorless and transparent that it was difficult, even in a strong light, to make out the legs, horns, and tail with any distinctness.

March 5.—Latitude 0° 11′ N.; longitude 82° 41′ E.; temperature of surface water, 83°; specific gravity, 1.0237. This insect, (Fig. 57, Plate XXIX,) if it may be so called, was caught with many others of its species in the net. I am inclined to think that I saw one of them propelling itself through the water, but cannot speak positively, for in general they lay at the bottom of the tumbler motionless. Several were caught without the long arm, with the thick end, most likely it had broken off. When seen through the microscope its arms seemed to be formed of a thin, hard centre, covered with a transparent gelatinous matter, which, in some specimens, was torn off, in part, probably from towing in the net.

March 6.—Latitude 0° 57′ S.; longitude 82° 50′ E.; temperature of surface water, 82°; specific gravity, 1.0242. Towed the net and caught this fish, (Fig. 58, Plate XIX, and Fig. 63, Plate XXX,) the eyes were very prominent and multiplex, and, as well as the coloring, was similar in two specimens examined.

This insect (Fig. 59, Plate XXIX,) was also found in the net, the striped claw on each horn was very distinct.

Fig. 60. This small crustacean jerked through the water by drawing up its tail towards

its head; the hind feet were kept in such rapid motion that it was difficult to make out more than that they were hairy, decidedly not the clear claws of the front part of the body.

Fig. 61. Latitude 7° 35′ S.; longitude 84° 11′ E. This small transparent crustacean is singular in the shape of its tail; it was caught in the net when the sea was not quite smooth, and as some of the other insects were injured by being towed, perhaps this one may have lost part of its tail.

There was much fluffy matter at the bottom of the bucket in which the net was washed, and, when placed under the microscope, hairs and parts of insects were visible amongst it. I am inclined to think that much of this matter consisted of the insect or vegetable sketched on the 5th, Fig. 57, for, then, when I caught several of them, and left them for an hour or two in a tumbler, nothing was visible except some fluffy matter at the bottom.

The sea had a greenish tinge; may not this have been caused by the abundance of this yellowish matter?

March 12.—Latitude 10° 15′ S.; longitude 79° 31′ E.; temperature surface water, 82°; specific gravity, 1.0235.

Fig. 62, Plate XXIX. This insect, and the one caught November 25, 1856, both seemed to propel themselves by wriggling their bodies, much in the manner that a leech swims, though their movements were much quicker than that of a leech. I fancied that I saw quick motion about the head, but lost it before a more careful examination could be made.

March 9.—Latitude 7° 35′ S.; longitude 84° 11′ E.; temperature of surface water, 80°.4; specific gravity, 1024. (Fig. 64, Plate XXX.) This insect seemed to be of the same species as the one caught on the 25th of October, 1856, in the warm water current off the Cape.

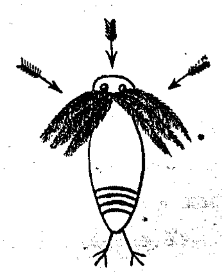
Fig. 65. (Lat. 7° 35′ S. 84° 11′ E.) This moved through the water witha wriggling motion, working its fins rapidly.

March 27.—Latitude 28° 24′ S.; longitude 48° 49′ E.; temperature surface water, 73°.3; specific gravity, 1.0253.

Fig. 66. This insect, which was caught in the net, evidently belonged to the same class as that found on October 25, 1856, (Fig. 7, Plate XX.) It generally remained quiet at the bottom of the tumbler, but, at times, started up and performed several somersaults in the water. In the small microscope it appeared to have a black patch on each side of its head.

March 24.—Latitude 27° 48′ S.; longitude 55° 20′ E.; temperature of surface water, 76°.3; specific gravity, 1.0248.

Fig. 68, Plate XXXI. I watched this insect carefully with a small microscope for more than an hour while it was moving about in a glass tube; its great peculiarity is in that formation which extends from the centre of the body and terminates by all its hairs meeting in a point between the eyes where, I should suppose, is the insect's mouth; these hairs are themselves covered with hairs, and, I am inclined to think, act as gills; for the front feet or fins, (which are well shown in the sketch (Fig. 30, Plate XXIV) taken November 28, 1856, where you look upon the insect's back,) kept up a very rapid motion, throwing the water towards this formation, from whence it passed towards the tail of the insect. I detected the motion in the water by the particles in it; they came in a stream from ahead, as shown by the arrows. May not this also be a provision to catch food from the water as it passes through the sieve, as it may be called? I could not detect that the insect



used its hind legs as propellers, but it evidently used its tail as such. When placed under the microscope it stretched back its hind legs towards its tail. The eyes appeared multiplex, and the circles on them moved regularly to and fro like a piece of machinery. The first specimen of this species was found on the 1st December, 1856, (Fig. 35, Plate XXV ;) we also found some between Madras and Coringa. When the insect was dead, by dividing it carefully with very fine needles, a very distinct view was obtained of its horns; of its two front legs, Fig. 70 and 71; of its third leg or respirator, Fig. 72; and of one of its hind legs. The leg nearest the tail, Fig. 23, was very much smaller than this one.

April 2.—Latitude 31° 20′ S.; longitude 30° 55′ E.; temperature of surface water, 76.5; specific gravity, 1.025.

Fig. 74, Plate XXXII. This minute creature wriggled rapidly through the water, but it died before it was placed under the microscope; it had been left for about a couple of hours in a bottle of water.

April 6.—Latitude 34° 18′ S.; longitude 25° 31′ E.; temperature of surface water, 65°.8; specific gravity, 1.0263.

Fig. 75. Towed the net—and both it and the bucket for trying the temperature were full of these globules; many were examined under the microscope, but only one showed signs of life, by changing from the appearance shown in No. 75 to that in No. 75*a*.

1 P. M. Caught this insect, (Fig. 76 ;) remarkable for the length of its horns, and for its long paddles or fins, with which it kept up a constant action in the water; no eyes were visible, unless the dark spot over the horn may have been one. The long hairs on the horns were scarlet, and the long hairs on the paddles were tipped with scarlet. Another was caught of the same form, rather smaller, and entirely white, excepting the horns, which were seen throughout a deep crimson; had it not been for this coloring, both might have escaped notice, so transparent were they.

April 17.—Latitude 31° 13′ S.; longitude 13° 18 E.; temperature of surface water, 64°.3; specific gravity, 1.0268. (Fig. 77.) This shrimp, as it may be called, was pumped up into a cistern and drawn off into a bath; another was caught in the same manner yesterday but not sketched, supposing it might have been pumped up in Table Bay, but as the cistern has now been several times empty, it seems probable that the northerly current had brought them into the deep sea; the sea was green in 27° south latitude and 9° E. longitude; and in 29° S. latitude and 13° E. longitude we saw large pieces of sea weed, which may also have been the effect of the northerly current. In the magnified sketch, the body is too short; the "natural size" is in better proportion.

April 20.—Latitude 27° 04′ S.; longitude 8° 54′ E.; temperature of surface water, 66°.2; specific gravity, 1.026. (Fig. 78.) This letter acelapha, (which is here given of the natural size,) is one of the most beautiful and delicate we have found; it floated in the water like a balloon in the air, and its little trunk was always in a graceful curve. The outer transparent coat and the outer edge of the convolvulous shaped top of the trunk met in the pink ring, (the upper one,) from which hung down a very thin transparent curtain; this circular curtain kept up a regular contraction and expansion which gave motion through the water.

April 22.—Latitude 24° 36′ S.; longitude 4° 55′ E.; temperature of surface water, 68°.2; specific. gravity, 1.0264. (Fig. 79, Plate XXXIII.) Found this remarkable fish, which very much resembled the one caught near Coringa, on the 9th January, (Fig. 50, Plate XXVIII.)

A finished drawing of the whole was made, but I will only give here those parts which were new to us; the peculiar formation extending from the head where each hair ends in a small hook; the tail; the formation something resembling a hand between the hind and front legs, and one of the front legs highly magnified. The eyes were very large and multiplex; on noticing this we re-examined the Coringa fish, which had been preserved in spirits, and found that its eyes, though shrunk, were evidently multiplex also. The coloring of this fish was exquisite, brilliant scarlet stars, like branches of coral, being strewed over the back and legs.

Fig. 80, Plate XXXIII. This little fish was also taken from the net, but died before it was examined.

April 29.—Latitude 13° 58′ S.; longitude 10° 10′ W.; temperature of surface water, 75°.4; specific gravity, 1.0263. Caught a very active crustacean, similar to the one caught November 29, 1856, (Fig. 33, Plate XXV,) the peculiar fans attached to its tail (of which we have never seen more than three or less than two) by means of some small round flesh colored granules, were very distinct, and have more the appearance of eggs, or something of parasitical growth, than of a part of the tail. Also caught this insect, (Fig. 81,) which was of a delicate sea-blue.

May 1.—Latitude 11° 00′ S.; longitude 15° 00′ W.; temperature of surface water, 77°.3; specific gravity, 1.0262, (Fig. 82.) This insect was found in the bucket of water drawn at 9 A. M. It is peculiar in being the only one of the crustacæ which we have noticed able to walk, both in the water and out of it; in the water it ran along the bottom of the bucket and the side of the tube by which it was caught, and when put on a piece of glass in a drop of water it worked his way out of the water and ran along the glass; the shape of its horns, too, was remarkable. The red spot on its head did not seem to have any structure like that of an eye.

April 8.—Latitude 34° 53′ S.; longitude 22° 38 E.; temperature of the surface water, 64°; specific gravity, 1.0263, (Fig. 83.) Found great numbers of these little fish; the three legs were in such rapid motion that it was difficult to make them out distinctly.

May 8.—Latitude 3° 00′ N.; longitude 27° 02′ W.; temperature of surface water, 79°.3; specific gravity 1.0248. (Fig. 84, Plate XXXIV.)

This insect was caught by towing the net; this may perhaps have weakened them, for among the numerous specimens examined, none seemed to use their remarkable multiplex eyes to avoid the glass tube by which they were caught. They kept up a quick motion with their legs, and something like two short hairy paddles were kept in rapid motion near the part which seemed to be the insect's mouth; quick circulation was visible inside the body near this, and at times it appeared to move something like the two parts of a parrot's beak, but the whole action was too quick to be clearly made out. The front legs, in all the specimens, whether alive or dead, dangled in this nonchalant fashion; and the peculiar formation on the first pair of legs was the same in all. The long front horns projected straight from the head, and are merely curved down in the sketch to save space.

May 9.—Latitude 3° 49′ N.; longitude 28° 02′ W.; surface temperature, 79°; specific gravity, 1.024. (Fig. 85, Plate XXXV.) There were very many of these transparent little barrels in the water; in general the hoops had the twist here shown, and though in some specimens appeared perfect, the whole thing was so delicate that it was difficult to make it out.

This insect (Fig. 86,) was very thin and flat; it looked as if it had a hard shell, which was marked and colored like a tortoise; it was very active, and frequently clung to the sides of the bottle and tube.

Fig. 87. The last two days, when the ship was moving rather fast, we found in the net bunches of blue eggs and insects like the above, but this morning, when it was very nearly calm, we found two specimens with the eggs attached to their tails by an appendage similar to that which had been sketched on the one found near Coringa. The torquoise blue of the eggs was in beautiful contrast to the transparent red and white of the insects; they differed from others that we had found in being all in one plane instead of in a bunch.

(Fig. 89.) This insect was caught by towing the net; it was transparent, but as it turned in the water it shone with all the brightest prismatic colors; never have I seen an insect or bird which showed such a variety of brilliant and delicate colors. It was very active, and each time that it turned it changed its colors; sometimes it looked like the noble opal, then, again, it would shine like the light emitted by phosphorus; but, as it was not visible in the dark, I suppose that it was not phosphorescent. It did not show any difference whether it were placed in sunshine or in shade. The sketch is taken of it lying on its back with its feet curled up under its body; the upper side was exactly the same, except that the feet were even less distinct.

(Fig. 90.) Found in the net many of these Holothuriae, which differed both in shape and color from those we have found before, being of a dirty white with brown spots. When quiet it appeared to be a circular disc, with nearly a globular centre; it moved by working the edges of the disc, and could bring the two sides together, when it resembled the green Holothuria in shape. There were two in the same tube of water, and one, the larger, nearly wrapped itself around the other, so that I am inclined to think that the food is caught by encircling it with the margins of the disc, by which means it is pressed into the globular ball.

When the insect progressed, which it did rather quickly, the little ring at the bottom was always behind it. One remained on a piece of glass till a great part of its margin had melted away, but afterwards it seemed to move nearly as freely in the water as the other.

May 20.—Latitude 30° 00′ N.; longitude 45° 13′ W.; temperature of surface water, 71°.1; specific gravity, 1.0266. (Fig. 91, Plate XXXVI.) This crustacean was found by washing the sargassum, which it much resembled in color. It clung to the side of the bucket with great ease, running along almost as quickly as it swam. No eyes were visible.

Fig. 92. This insect was very active; its motive power seemed to lie in the lower part of its body, the upper part being always kept foremost. It was found in the bucket drawn for trying the temperature.

Fig. 93. This was one of the many insects found by washing the sargassum. The black part was divided into cells very much like a multiplex eye; between this black part and the lobe with a spot on it quick pulsation or circulation was kept up.

Fig. 94. This reddish brown Holothuria was found among the sargassum; in its power of motion it resembled those found in other parts of the voyage.

Fig. 95. On washing some pieces of sargassum in a white bucket of clear salt water, I found hundreds of this little crustacean creeping about the sides of the bucket, some with eggs, as this one, some without; when seen on its side it resembled the insect caught February 28, (Fig. 54, Plate XXVIII.)

May 21.—Latitude 30° 27′ N.; longitude 45° 16′ W.; temperature of surface water, 73°.9;

specific gravity, 1.0269. Fig. 96. This day was very nearly calm, the net was towed for several hours, washing it in a bucket of salt water every hour or so; there was very little sargassum, and none was caught in the net, as it floated too deep, but great numbers of this very minute insect were caught; it looks like a connecting link between the acelapha and the crustacean, for take away its legs and it would be a jelly fish. It seemed to use the horns or fins for propelling itself through the water; besides rapid motion in a straight line it frequently made several quick revolutions.

Fig. 97. This was found amongst the sargassum; the head, which is here sketched, is peculiar, but the general appearance and the divisions on its body were similar to the one found on January 7.

Fig. 99. 31° 39′ N.; 44° 32′ W. The ciliæ of the fish in this little lilac shell worked very rapidly, the effect on the eye being something like that of the twinkling of a star.

Fig. 100. These minute lilac shells were very numerous; one or two were found of a pale straw color.

May 22.—Latitude 31° 02′ N.; longitude 45° 06′ W.; temperature of surface water, 73°.3; specific gravity, 1.027.

Fig. 101, Plate XXXVII. Caught, among many others, this elegant little acelapha, which was in constant motion, contracting and expanding its rays.

Fig. 102. These shells, of an exquisite rose color, were caught by towing the net during a very light air; I suppose that it remained 10 or 15 feet below the surface of the water; each sketch is a distinct specimen; in all, some part of the insect protruded, keeping its ciliæ in rapid motion.

Fig. 103. Caught this little fish, which worked its long front legs with great activity.

May 23.—Latitude 31° 39′ N.; longitude 44° 32′ W.; temperature of surface water, 72°.3; specific gravity, 1.0266. Fig. 104: This beautiful lilac shell was perfect, except in its outer filmy rim, which I am inclined to think extended round the entire outer edge, and probably entered the interior of the shell. The part of the interior marked thus ₢ was in constant rapid motion, and the sucker-like tube outside contracted and expanded, and moved from side to side, as if in search for food. Although these shells have been found in the Sargasso sea, I do not think that they are in any way dependent on the weeds for support, as they were found much deeper than it floats, and none were found when pieces of weed were washed in search of its inhabitants.

May 26.—Latitude 34° 43′ N.; longitude 41° 53′ W.; temperature of surface water, 69°.1; specific gravity, 1.0273. Fig. 105. The body of this insect was blue, the shelly covering yellow; it had the power of drawing up the whole of its hind legs within the shell; the fore legs, or horn, seemed to be supplied with suckers with which to fix itself. It was caught by towing the net in a light breeze.

Fig. 106. This seemed to be a hard conical shell, inhabited by a fish of about the same consistency as a snail. At times it drew its whole body within the shell, at others threw out the feather-shaped parts, shown in the sketch, which it had the power of flapping quickly, bringing them nearly to meet. This I have no doubt is its propelling power.

Extract from the abstract log of the ship Metropolis, Captain R. W. Foster, from Liverpool.
Plates XXXVIII and XXXIX.

September 11.—Departed from the river Mersey. At noon, many varieties of polypi, two of which I have captured, as per drawings.

Fig. 1. This membrane is edged by a delicate fringe, which is in constant motion. Fig. 2 appears to be a conduit, connected with the fringe, and leading to 3, a tough mass of gelatine, which appears to be the seat of life. With the microscope, I discovered a cavity containing a viscid fluid, like unto ropy water. The creature, as seen by me from time time, merely pulsated. This organization, though low in the scale of marine creation, is very beautiful and interesting to contemplate.

Thickest part of gelatine $\frac{1}{10}$ of an inch, and transparent as air.

Fig. 2. Natural dimensions eleven inches and $\frac{3}{10}$ diameter; thickest part gelatine one inch and $\frac{2}{10}$, and very transparent. Fig. d. These pointed ridges adhere firmly to the gelatine, between each is a membrane, Fig b, having an aperture, C, through which the creature draws in its prey. We watched and saw several crustaceans, seven, struggling in vain to avoid being sucked in. These, in the first instance, I had released from the spongy mass, d, by stirring it with a stick.

On the following morning, the creature being still alive, in a deep tin dish filled with salt water, I dissected it, but none of the crustacæ (and there had been many) could be found. A slimy substance, however, floated about in the water. I saw with the microscope a bag-like membrane, which, in all probability, is a stomach. Connected with this, appeared a small gelatine tube, through which, perhaps, the contents of the stomach, after digestion, are ejected. When seen in the ocean, and we saw a great number, the concave side invariably was upwards. At first, we mistook the brown mass for sea weed, adhering to the gelatine. This spongy substance is very tough. The creature takes unto itself several forms—the drawing is perhaps the most graceful.

September 18—Latitude 51° 06′ N.; longitude 9° 00′ W.

Caught a curious polypus, as per drawing. Natural size; concave side; gelatine $\frac{4}{10}$ of an inch thick. The yellow mass, from which the creature, in all probability, throws out slimy filaments, is very poisonous. I touched it with my fingers, and, as long as an hour afterwards, happening to rub one of my eyes, it almost immediately became inflamed.

The deep blue, striped with white, adheres to the gelatine. On dissecting it, I could not discover any substance resembling a stomach. The small round circle is composed of tough gelatine, and contained a watery substance. It possesses no propelling power. In its movements it is merely pulsative. This is a wonderful production of nature.

September 27.—Latitude 42° 04′ N.; longitude 28° 42′ W. The ocean teems with yellow striped medusa; captured one, as per drawing.

Natural size. When first captured it appeared to be, as in fig. d, one distinct animal; it swam about rapidily in the large tin dish, filled with salt water, throwing out behind at each propulsion a considerable jet of water. Taking it out of the water for examination, and throwing it in again with some force, it separated into four individuals and three young ones; these latter were about $\frac{3}{4}$ of an inch in length; I had now a better opportunity of observing their movements. In propelling, the front and hind orifices alternately opens and closes; thus as the front orifice, or mouth, (for it resembles the mouth of a fish,) close, the water is thrown out at the hind aperture, which move forces the creature onward; immediately, on the water being ejected, the latter closes, and the mouth opens to admit the water again. It will be seen from this that the body forms a hollow tube.

The three young ones swam about lively, occasionally they seemed to sport by entering the front orifice of the two old ones and passing out at the rear; later, however, when approaching the old ones they would dart away as if in fear. The old ones, perhaps, had become irritated in their confinement.

The yellow and purple lines magnified exhibit a slimy substance. The circular spots appear to be the vital parts. They contain a juicy matter, and are in constant motion.

These creatures are exceedingly tenacious of life; one which was suspended on the dividers for about fifteen minutes, on being returned into the water, swam about with much animation.

It will be seen that the purple stripes differ in position, may not these be a distinguishing mark between male and female?

The ocean was alive with them, some single and some in clusters.

CHAPTER XVII.

THE SPECIFIC GRAVITY OF THE SEA.

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§ 214. I have the pleasure of submitting the first fruits of the systematic use, according to the plan of the Brussels' Conference, of the hydrometer at sea. These firstlings are derived from the observations of Commodore John Rodgers, in the United States sloop-of-war Vincennes, and of Captain Toynbee, of the English East Indiaman the "Gloriana." I have other observations of the same sort; among them an interesting series by Dr. W. S. W. Ruschenberger, fleet surgeon United States ship Independence, on a cruise to the Pacific; and another by Dr. Raymond and Lieutenant Porter, in the American steamer "Golden Age" from England to Australia. The latter, however, are wanting in value, because not made with instruments that had been compared with the standards at Kew.

Rodgers and Toynbee made their observations with proved instruments. They seem to be most suggestive, and to afford a better representation of the facts and phenomena which this instrument promises to set before us.

Lieutenant Aulick has projected the curves (Plate XVII) from the abstract logs of the "Gloriana" and of Rodgers' North Pacific Surveying Expedition.

Figure 1 shows the thermal and specific gravity curves for the surface water, as found by Rodgers, for every degree of latitude in the Pacific Ocean from the Arctic Sea to Cape Horn. Beginning at the right hand side of the figure the first pair of curves—thermal and specific gravity—commence at 71° N. They go to the equator, and then the character of the lines being changed to denote Southern Hemisphere they go to the parallel of 57° S. By these projections the two pair of curves may be contrasted parallel for parallel.

Fig. 2 shows a similar set of curves for the Atlantic Ocean, also afforded by the observations on board the Vincennes between Cape Horn and the equator, and thence between the equator and New York. The curves of these two figures are projected without regard to longitude.

On the contrary, the curves of Figs. 3 and 4 are projected with especial reference to longitude. The data for Fig. 3 are derived from the logs of Rodgers' squadron, as it went from China to California. Because of the relation between specific gravity and latitude, a curve for that function, the dotted line, is brought in. We thus see by inspection that these specific gravities were obtained in the North Pacific between the parallels of 20° and 66° north latitude.

For the elements of the curves, in Fig. 4, we are indebted to the observations of the admirable Toynbee during the passage, June and July, of the "Gloriana" to Australia, while between the meridians of the Cape of Good Hope and of Melbourne. This figure, consequently, includes the temperature and specific gravity of surface water in a section of the ocean south, while figure 3 relates to the same in a section of the ocean north. The parallels between which Toynbee cast his observations are 40° and 45° south; while Rodgers' observations on his way from China to California range from latitude 20° to latitude 66° north. Both were made in the winter of their hemisphere.

§ 215. These observations for specific gravity are not reduced to a common temperature; they are projected as they were taken; one of the main objects being to show the dynamical force which the ocean derives from difference in the specific gravity of its waters. Whether that difference be owing to difference of temperature or to difference of saltness, or to both, the dynamical effect is the same.

§ 216. The most noticeable feature about the diagrams of this plate is the absence for 30° or 40° of latitude on either side of the equator of any apparent sympathy between curves of specific gravity and the curves of temperature. This is strikingly the case in Figs. 1 and 2. Thus for a thermal change:—

From 82° to 55° in North Pacific	the specific gravity change is	.0005	Fig. 1.
From 55° to 64° ....do	..........do..........	.0010	
From 64° to 42° ....do	..........do..........	.0015	
From 82° to 86° South.....do	..........do..........	.0010	
From 86° to 49° ....do	..........do..........	.0030	
From 82° to 80° in North Atlantic	the specific gravity change is	.0005	Fig. 2.
From 80° to 70°.........do	..........do..........	.0025	
From 82° to 57° South...do	..........do..........	.0015	

Thence onward, on Fig. 3, this pair of curves may be observed marching in accord with each other.

Again, in Fig. 3, for a thermal change from 84° to 50°, North Pacific, the specific gravity change is .0035 ; from 52° to 66°, North Pacific, the specific gravity change is .0005.

Between the meridians of 144° E. and 172° W., the three curves, latitude, temperature, and specific gravity march together ; elsewhere in Fig. 3, and everywhere in Fig. 4, there is scarcely a trace of symmetry between them.

§ 217. These curves appear to have unmasked a fact which may be announced in general terms, thus: Between the equator and the parallels of 30° or 40° north and south, the specific gravity of the water of the open sea does not seem to change with changes of temperature ; whereas, on the polar side of those parallels change of temperature and change of specific gravity are correlatives, so close in symmetry are the thermal and specific gravity curves in polar seas ;—so unlike in seas intertropical.

§ 218. Unwilling to pass, without further investigation, such a physical paradox as is apparently here developed, specific gravity and thermal curves were projected from Ruschenberger's observations; from Porter's and from Raymond's also. They all agreed in showing that between the parallels of 30° or 40° north and south,—for the limits are not well defined,—there is very little change in the specific gravity of sea water, notwithstanding its change of temperature may be considerable. This is curious.

§ 219. I thereupon determined to try the thermal expansion of sea water by a series of special experiments. Rodgers, from his Surveying Expedition to the North Pacific, had sent me specimens of sea water ; and Lee, while co-operating in the Dolphin with me, had collected and brought home numerous specimens from the Atlantic. These were carefully put up in vials, with ground glass stoppers, and had been preserved since his return in 1852.

I sent, April 2, 1857, to Mr. James Green, 422 Broadway, New York, some of the water, returned by Rodgers, with instructions to the following purport:

§ 220. I send you a bottle and a can of sea water, the former marked October 12, the latter as having been taken from the surface in latitude 28° 10′ N. ; longitude 129° 35′ E. ; specific gravity, 1.0264, at a temperature of 68°. Be pleased to make two thermometers, filling one from the bottle, and the other from the box. I want them for the purpose of determining the expansion and contraction of sea water under changes of temperature. You will, therefore, if you please, make the capacity of the bulb large in comparison with the capacity of the tube.

I want to know the capacity of the tubes in relation to that of the bulbs, and unless you can devise a better plan for determining this, I wish you would first fill the thermometers with mercury, and let me know the readings at different temperatures by a standard, say the reading at 32°, 60°, and again at 90°; by knowing this I shall be able to determine, using the expansibility of mercury as the measure, the ratio as to capacity of tube to that of the bulb. After you have done this, and marked on the tube the height of the column at 32°, 60°, 90°, &c., then empty the mercury and fill with sea water. Your tube should be long enough, and your scale upon it sufficient to show the expansion of the water from a temperature of 20° to one of 90° or 100°; of course the larger the bulb in comparison with the capacity of an inch of tube, the more delicate will the instrument be, and delicacy with accuracy is precisely what is wanted. You will make these two instruments, if you please, as early as practicable, pack them carefully and deliver them to George Manning, 142 Pearl street, who will forward safely and promptly.

§ 222. This order was not filled till January, 1858, and then, owing to careless packing, these thermometers were broken on the journey from New York. Two others, B^1 and B^2, were made and placed in the hands of Professor Hubbard, who kindly offered to compare them, and furnish me with the requisite series of observations on the thermal dilatations of sea water, and here is the result:

Observed temperatures and expansion.

Temp. Far.	Thermal expansion.			Observed Temp.	Thermal expansion.		
	B 1.	B 2.	Mean.		B 1.	B 2.	Mean.
From 32° to 33°........	.000024	.000018	.000021	From 40° to 50°	Average for 1°. .000063	.000064	.000064
33 34	12	12	12	50 60	87	88	87
34 35	30	41	35	60 70	113	116	114
35 36	36	35	36	70 80	146	145	146
36 37	42	41	42	80 90	158	160	159
37 38	48	47	48	90 100	181	180	181
38 39	36	53	54	100 110	209	204	206
39 40	42	53	58	110 120	231	238	.000235

The sea water thermometers used in this experiment had a spherical bulb 0.9 in. in diameter; and when it was filled with mercury, a change of 10° in temperature moved the column in the tube through a space of 0.84 in. The same thermal change, when the instrument was afterwards filled with sea water, moved the column of this liquid through a space of 0.63 in., from 40° to 50°, and of 1.80 in. from 90° to 100°. Of course, the expansion of mercury in glass being known, that of sea water may now be readily ascertained.

§ 223. The maximum density of fresh water is assumed to be at 39°.5*; as the temperature descends below that, fresh water expands; not so with sea water, it contracts all the way to 32°, and lower, as appears from the series of experiments above, as well as from others which are to follow.†

These experiments, however, were very far from clearing up the apparent paradox; they only presented it more strikingly.

§ 224. It appears from these experiments that, for a given amount of thermal change, the dilation of sea water is much greater at high than it is at low temperatures. In other words, the waters of equatorial seas at their normal temperature are many times more expansible than the waters of polar seas are at their normal temperature; yet between the parallels of 51° and 71° N. (Fig. 1) the thermal and specific gravity curves are perfectly symmetrical, while they do not appear to have the one to the other any relation whatever, as they march from the equator to 30° N.

Thus far, instead of finding any clue to the paradox in question, investigation seemed only to shroud it the deeper in mystery. Surely the sea water which we have been weighing in our specific gravity scales on the polar side of 51° must be different from that which we have been weighing on the equatorial side of the same parallel. The suggestion here implied would seem to have no force, for the waters of the sea do circulate freely, and there is on opposite sides of imaginary lines no such difference as the above remarks suggest; nevertheless, I looked to see from what part of the ocean the bottle and the hermetically sealed tin cube of water used for

* Hassler makes it 39°.4, and McCulloch in his researches relative to sugars, hydrometers, &c., makes it at 39°.6. I adopt the mean.

† "It has been considered," says M. de La Beche, "that the maximum density of sea water approaches that of fresh water. On this head we have not any good experiments, but it may be supposed that the saline contents of sea-water would have considerable influence on its relative gravity at different temperatures."

these thermometers were taken, but the label on the bottle was simply "October 12," and the tin vessel of the other sample might have changed in some respects the properties of the water contained in it. It came from latitude 28° 10′ N.; longitude 129° 35′ E.

§ 225. In this aspect another question presents itself: What is sea water, *i e.*, what is the saltness and specific gravity of that water we call sea water? And what is the ingredient in it that imparts to it the thermal characteristic of continuing to grow denser and more dense as its temperature descends below that at which fresh water attains its maximum density? Is it one of its salts, or all, that imparts to it this peculiarity?

§ 226. I had other specimens of sea water from various latitudes and depths, and I, therefore, ordered seven other sea water thermometers, for trying its expansion, to be made from the bottles belonging to class Q, p. 241.

These thermometers were taken in hand by Professor Hubbard, and placed with a standard in a vessel of water, glazed on one side with plate glass, so that all the instruments could be read without lifting them from the vessel.

With the instruments thus placed, the water was slowly raised from the temperature of melting ice to 100°, pausing frequently between 32° and 40°; and at the even 10°, above 40°, for readings. At each successive reading the temperature was kept stationary, or nearly so, for some time, in order to be sure that the salt water and the mercury were certainly identical in temperature. The bulbs of the salt water thermometers were larger than that of the mercurial standard, so that to counteract the tendency of the former to lag behind, the water in the glazed vessel, after being heated up for one series of readings, was gradually cooled down from 100° to 32° for another, and thus the readings were repeated on the descending scale.

According to the mean of the readings, "up and down," the following were obtained from these thermometers as the rate of

Sea water expansion for thermal change of 1°. (*Class Q.*)

Thermometer 32° to 34°	.000034	.000037	.000036	.000025	.000031	.000040	.000029
34° to 36°	37	29	36	23	27	29	29
36° to 38°	47	43	47	36	38	40	37
38° to 40°	51	48	55	42	46	55	54
40° to 50°	80	75	78	69	72	75	70
50° to 60°	104	100	105	89	94	99	92
60° to 70°	146	145	146	136	140	141	141
70° to 80°	165	162	162	164	160	163	159
80° to 90°	184	185	184	180	183	178	178
90° to 100°	226	221	218	----------	226	----------	----------

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.
Specific gravity at 60° by Green	1 0287	1.0273	1.0290	1.0248	1.0253	1.0270	1.0269
Expansion for 1 in. on scale =	.000980	.001063	.001096	.000844	.000883	.000839	.000825

An error of one hundreth (.01) of an inch in the reading of the scales would make an error in the apparent rate of expansion of about .00001.

And notwithstanding that these experiments, so far, gave no promise of any clue to the paradox, (§ 218,) I concluded to have a still more delicate instrument made for the investigation. Accordingly, rejecting the water in the tin, I had the four specimens from glass—three from the Atlantic, and one from the Pacific—mixed in equal parts, and a thermometer filled with the mixture. This instrument had a cylindrical bulb 3 + 0.7 inches, and a tube 24 inches long. It was very sensitive. It was read "up and down," and, according to Mr. Hubbard's observations, the following are the average rates of the thermal expansion of sea water in glass, as given by this instrument at the temperatures annexed :

From 32° to 34° average expansion for 1° =	.000029
From 34° to 36° ......do.........do......	34
From 36° to 38° ......do.........do......	42
From 38° to 40° ......do.........do......	53
From 40° to 50° ......do.........do......	76
From 50° to 60° ......do.........do......	110
From 60° to 70° ......do.........do......	149
From 70° to 80° ......do.........do......	173
From 80° to 90° ......do.........do......	000199

With this thermometer, an error of .01 inch in the reading of the scale would produce an error of .0000038 in the apparent expansion of the water.

§ 227. This thermometer had not, owing to an oversight on the part of the maker, been *first* filled with quicksilver and gauged. In trying it at a low temperature, congelation unexpectedly commenced, and produced a crack in the neck. It was returned to the maker, and gauged with mercury. The result was the preceding table for the dilatation of sea water. Fearing the crack might have led to error, a duplicate was ordered ; O, Plate XVIII is a drawing of it.* Its tube was 22 inches long, and being carefully calibrated, the bore was found to be nearly uniform. But since the problem in hand was to determine the dilatation of sea water in glass, as compared with that of mercury in glass, the readings of the mercury, with the corresponding temperature required to move the column in the tube inch by inch along the scale, were observed and noted. They show the tube to be remarkably uniform in its bore, and themselves eliminate all error that could arise from irregularity of bore as to the comparative dilatation of the two fluids. Here are the :

Readings of O, Plate XVIII, when filled with mercury at a temperature of—

° in.	° in.	° in.	° in.	° in.
37.7 = 4	52.8 = 8	68.2 = 12	83.6 = 16	98.9 = 20
41.5 = 5	56.7 = 9	72.1 = 13	87.5 = 17	102.6 = 21
45.3 = 6	60.6 = 10	75.9 = 14	91.3 = 18	106.3 = 22
49.1 = 7	64.5 = 11	79.7 = 15	95.1 = 19	

* Specific gravity of the sea water contained in it, at 60° = 1.0279.

Annexed, also, are the places and the specific gravity of the water used in the other thermometers, with their gauge readings when filled with mercury, and also the readings for dilatation of sea water when filled with that fluid.

§ 228. Of the class represented by P, Plate XVIII, are the thermometers denoted by A 1, A 2, B 1, B 2, and Q. Of those represented by Q, there were originally seven, numbered from 1 to 7; but of those No. 2 was accidentally broken, and No. 3 failed, from some unknown cause, to give reliable indications.

Thermometers A 2, B 2, and Q were filled with sea water from a tin can labeled "surface water; temperature of air 52°; temperature of water 68°; specific gravity 1.0264; latitude 28° 10′ 32″ N.; longitude 129° 35′ 2″ E."

A 1 and B 1 were filled from a bottle which only bore the date "October 12." The water in it came from the North Pacific, and its specific gravity was 1.0252.

Of the thermometers of class Q, the following are descriptions of the contents:

No. 1. "Dolphin, January 23, 1852, 9.30 A. M. Surface water; latitude 4° 6′ 18″ S.; longitude 24° 46′ 45″ W.; temperature 79°." Specific gravity, 1.0287.

No. 2. "Dolphin, January 14, 1852, 4 P. M. Water at depth of 400 fathoms; latitude 3° 42′ 18″ N.; longitude 19° 6′ 0″ W.; temperature 59°." Specific gravity, 1.0273.

No. 3. "Dolphin, January 16, 1852, 4.45 P. M. Water at surface; latitude 3° 3′ 0″ N.; longitude 18° 49′ 39″ W.; temperature 80°." Specific gravity 1.0290.

No. 4. "Surface water; temperature of air 48°; of water 45°; specific gravity 1.026; latitude 68° 39′ N.; longitude 169° 49′ W."

No. 5. "Depth 32 fathoms; temperature of air 48°; of water 40°; specific gravity 1.0272; latitude 68° 39′ N.; longitude 169° 49′ W."

No. 6. "Surface water; temperature of air 64°.2; of water 71°.2; specific gravity 1.0257; latitude 22° 15′ 3″ N.; longitude 122° 25′ 42″ E."

No. 7. "Surface water; temperature of air 64°.2; of water 71°.2; specific gravity 1.0257; latitude 22° 15′ 3″ N.; longitude 122° 25′ 42″ E."

Thermometers I and O were filled with equal parts from Nos. 1, 2, 3, and the bottle, from the North Pacific, labeled October 12.

The following are the readings of the several thermometers of class P and Q when filled with quicksilver and subjected to the temperature of 32°, 62°, and 92°, and, for the first four, of 152° also :

P.	32°	62°	92°	152°
Thermometers.	*Inches.*	*Inches.*	*Inches.*	*Inches.*
A. 1	4.65	6.32	7.96	11.32
A. 2	4.15	5.81	7.45	10.83
B. 1	5.50	8.02	10.55	15.57
B. 2	2.95	5.50	8.01	13.14
2	3.80	6.56	9.32	
Q.				
1	4.09	7.16	10.22	
4	3.83	7.32	10.95	
5	4.20	7.58	11.00	
6	2.89	6.47	10.05	
7	3.75	7.35	11.04	

Thermometer I having been returned to the maker and filled with mercury, it was then found that a change of one inch upon its scale corresponded to a change of temperature of 3°.72.

Assuming the expansion of mercury in glass for a change of 180° to be .018018, according to Dulong and Petit, from these readings, and those given above for thermometer O, was deduced for each thermometer, its co-efficient of expansion, or its change of capacity, as indicated by a change of one inch upon its scale. These co-efficients are—

For I	0.0003714	For 2	0.001088
O	.0003804	1	0980
A. 1	. 001800	4	844
A. 2	. 001798	5	883
B. 1	. 001193	6	839
B. 2	0. 001179	7	0.000824

Being now filled with the sea water and exposed to various degrees of temperature, the following readings were obtained from the mean of many:

THERMOMETER I.

°	*Inches.*	°	*Inches.*
32.0	2.50	50.3	5.45
32.3	2.54	60.3	8.41
34.3	2.69	70.3	12.49
36.3	2.87	80.3	17.13
38.3	3.10	90.3	22.47
40.3	3.40		

THERMOMETER O.

°	Inches.	°	Inches.
25.0	2.362	38.0	2.945
25.5	2.337	39.0	3.075
26.0	2.322	40.0	3.202
27.0	2.312	45.0	4.015
28.0	2.308	50.0	5.075
29.0	2.310	55.0	6.362
30.0	2.332	60.0	7.867
31.0	2.362	65.0	9.620
32.0	2.405	70.0	11.515
33.0	2.490	75.0	13.612
34.0	2.563	80.0	15.822
35.0	2.635	85.0	18.240
36.0	2.725	90.0	20.865
37.0	2.827		

CLASS P.

	B. 1.	B. 2.		B. 1.	B. 2.
°	Inches.	Inches.	°	Inches.	Inches.
23.0	3.53	3.35	37.5	3.61	3.47
24.1	3.51	3.33	38.3	3.65	3.51
25.0	-------------	3.325	39.4	3.675	3.552
25.3	-------------	3.32	40.2	3.66	3.54
25.9	-------------	3.32	40.3	3.715	3.60
26.3	3.50	3.32	40.5	3.72	3.60
26.8	-------------	3.315	42.3	-------------	3.64
27.0	-------------	3.305	43.3	3.85	3.73
27.2	3.45	3.30	45.0	3.90	3.80
27.5	-------------	3.31	45.4	-------------	3.76
28.1	-------------	3.305	48.4	4.26	4.16
29.3	3.475	3.32	48.8	4.20	4.15
30.1	-------------	3.327	49.0	4.13	4.05
30.2	-------------	3.322	50.0	4.28	4.18
30.4	-------------	3.32	50.3	4.30	4.20
32.0	3.482	3.33	55.1	4.67	4.55
32.3	3.49	3.345	57.0	4.85	4.77
32.5	3.50	3.35	60.0	5.14	5.06
33.3	3.51	3.36	60.5	5.20	5.14
34.2	3.52	3.37	62.2	5.38	5.32
34.3	-------------	3.375	70.0	6.28	6.25
35.2	-------------	3.38	80.0	7.70	7.66
35.3	3.545	3.405	90.0	9.27	9.28
35.5	3.54	3.41	100.0	11.10	11.07
35.8	3.50	3.41	110.0	13.08	13.02
36.3	3.575	3.435	120.0	15.36	15.26
36.5	3.57	3.43	130.0	17.76	17.71
37.3	3.61	3.47			

CLASS P—Continued

	2.		2.
°	*Inches.*	°	*Inches.*
25.0	4.175	45.4	4.625
25.9	4.17	46.5	4.94
26.8	4.165	47.0	4.79
27.0	4.155	47.5	4.90
28.1	4.155	48.4	5.13
29.7	4.165	48.8	5.05
30.4	4.168	49.0	4.98
32.3	4.19	50.0	5.11
32.5	4.20	50.3	5.15
33.3	4.21	53.1	5.40
34.2	4.22	54.1	5.45
34.3	4.235	55.1	5.55
35.2	4.205	55.3	5.61
35.3	4.25	55.8	5.60
35.5	4.27	57.0	5.82
35.8	4.17	57.3	5.76
36.3	4.29	60.0	6.07
37.3	4.33	60.2	6.15
37.5	4.33	60.5	6.12
38.3	4.38	62.3	6.33
39.4	4.40	70.0	7.36
40.2	4.35	80.0	8.90
40.3	4.45	85.0	9.87
40.5	4.45	90.0	10.70
42.3	4.50	95.0	11.77
45.0	4.69	100.0	12.71

CLASS P—Continued.

	A 1.	A 2.
°		
130	1.72	1.72
140	3.38	3.37
150	5.12	5.11
160	7.03	6.99
170	9.05	9.01
180	11.11	11.05
190	13.27	13.29
200	15.47	15.59

CLASS Q.

Temp.	1	4	5	6	7	Mean.	No. of obs.
°	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
22.0	3.210	2.557	2.380	2.312	1.750	2.442	10
23.0	3.169	2.486	2.312	2.227	1.669	2.373	24
24.1	3.153	2.452	2.281	2.201	1.640	2.345	30
25.2	3.130	2.430	2.257	2.187	1.625	2.326	20
25.9	3.127	2.412	2.247	2.168	1.608	2.312	15
27.1	3.116	2.379	2.213	2.143	1.578	2.286	25
28.1	3.120	2.370	2.215	2.150	1.575	2.286	5
29.3	3.128	2.369	2.210	2.119	1.570	*2.279	20
30.1	3.134	2.364	2.209	2.152	1.587	2.289	45
32.2	3.180	2.378	2.203	2.170	1.573	2.302	15
34.9	3.250	2.433	2.267	2.255	1.664	2.374	38
36.5	3.355	2.505	2.300	2.385	1.680	2.445	9
38.5	3.450	2.590	2.385	2.480	1.770	2.535	9
40.5	3.560	2.690	2.485	2.600	1.900	2.647	9
50.5	4.380	3.505	3.395	3.495	2.750	3.484	9
60.5	5.440	4.565	4.360	4.670	3.860	4.576	10
70.5	6.935	6.175	5.940	6.345	5.565	6.189	10
80.5	8.615	8.125	7.755	8.290	7.385	8.031	15
90.5	10.495	10.265	9.825	10.420	9.542	10.106	13

In order to deduce more clearly, from the above complex of observations, the thermal law for the dilatation of sea water, as well as to render its march more visible to the eye, the readings as far as 85° were projected as ordinates upon a chart of squares, whose abscissas are represented by temperatures; through and among the points thus laid down, curves were drawn (Plate XVIII) which represent truly the mean of all the observations, and from which we can now determine the required expansions *in glass.* We first obtain from these curves, and, partly from direct observations, the subjoined set of:—

* At this point (29°.3) the contraction of the glass and of the water being equal, the column in the tube has reached its lowest point, though it is obvious that the water has not yet reached its point of maximum density, for as the temperature of the glass is lowered, the bulb of the thermometer continues to contract; its capacity is thereby diminished and the water is forced to rise in the tube; consequently, as soon as the contraction of the water ceases to be sufficient to compensate for this rise, expansion commences, which will continue for several degrees and until the water *does* reach its point of maximum density.

Pouillet, speaking of the maximum density of sea water, says: "It was important to know if sea water has also a maximum density, and at what temperature it is found. Many physicists have made investigations upon the subject; but M. Despretz, taking up again this question, has treated it in the most complete manner, confirming the result at which he arrived for sea water by the results no less remarkable, which were afforded by the solutions of various salts at different degrees of saturation.

"Sea water, specific gravity 1.027 at 68° Fahr.; maximum density 25°.4; freezing point 27°.4; during congelation 28°.6."
—*Pouillet's Elements de Physique Experimentale et de Météorologie, Tome I. p.* 251.

Normal readings.

Temp.	I.	O.	P.	Q.	2	R.
°	*Inches.*	*Inches.*	*Inches.*	*Inches.*	*Inches.*	
22	----------	----------	----------	3.94	----------	----------
23	----------	----------	3.45	3.89	----------	----------
24	----------	----------	3.43	3.85	----------	----------
25	----------	2.35	3.41	3.82	4.18	----------
26	----------	2.32	3.40	3.80	4.15	----------
27	----------	2.31	3.39	3.79	4.14	----------
28	----------	2.31	3.38	3.77	4.13	----------
29	----------	2.32	3.38	3.77	4.13	----------
30	----------	2.33	3.39	3.78	4.13	----------
31	----------	2.37	3.40	3.79	4.15	----------
32	2.50	2.41	3.41	3.80	4.17	----------
33	2.57	2.47	3.43	3.83	4.19	----------
34	2.65	2.55	3.45	3.85	4.22	----------
35	2.74	2.63	3.47	3.88	4.25	----------
36	2.84	2.72	3.49	3.93	4.27	----------
37	2.95	2.82	3.52	3.97	4.30	----------
38	3.07	2.95	3.56	4.01	4.34	----------
39	3.20	3.07	3.60	4.06	4.38	----------
40	3.37	3.21	3.63	4.12	4.42	----------
45	4.27	4.10	3.89	4.48	4.71	----------
50	5.38	5.06	4.22	4.91	5.08	----------
55	6.68	6.33	4.64	5.42	5.53	----------
60	8.30	7.83	5.10	6.01	6.08	----------
65	10.16	9.62	5.65	6.75	6.70	----------
70	12.31	11.51	6.26	7.59	7.39	----------
75	14.55	13.61	6.91	8.46	8.11	----------
80	16.95	15.82	7.68	9.43	8.91	----------
85	19.49	18.24	8.44	10.47	9.81	----------
90	22.29	20.86	9.27	11.51	10.80	----------
100	----------	----------	11.08	----------	12.81	----------
110	----------	----------	13.05	----------	----------	----------
120	----------	----------	15.31	----------	----------	----------
130	----------	----------	17.74	----------	----------	1.72
140	----------	----------	----------	----------	----------	3.38
150	----------	----------	----------	----------	----------	5.12
160	----------	----------	----------	----------	----------	7.02
170	----------	----------	----------	----------	----------	9.04
180	----------	----------	----------	----------	----------	11.09
190	----------	----------	----------	----------	----------	13.29
200	----------	----------	----------	----------	----------	15.54

From these normal readings, and by help of the co-efficients of expansion, we obtain for sea water the following table, in which its dilatation at 60° Fahr. is assumed as unity:

Temp.	I.	O.	P.	Q.	2
°					
22	....	....	....	0.99815	....
23	....	....	0.99804	811	....
24	....	....	802	807	....
25	....	0.99792	800	804	0.99793
26	....	791	798	803	790
27	....	790	797	802	789
28	....	790	796	800	788
29	....	791	796	800	788
30	....	791	797	801	788
31	....	792	798	802	790
32	0.99784	794	800	803	792
33	787	796	802	806	795
34	790	799	804	807	798
35	793	802	807	810	801
36	797	806	809	815	803
37	801	810	813	818	807
38	806	815	817	822	811
39	811	819	822	826	815
40	817	824	826	832	820
45	850	858	857	864	851
50	891	895	896	902	892
55	940	943	946	948	941
60	1.00000	1.00000	1.00000	1.00000	1.00000
65	069	067	065	066	067
70	149	139	137	141	142
75	232	219	215	219	221
80	321	303	306	305	308
85	416	395	396	398	406
90	520	495	494	491	513

Temp.	P.	R.
°		
100	1.00709	....
110	943	....
120	1211	....
130	01499	....
140	....	1.01797
150	....	2111
160	....	2453
170	....	2816
180	....	3185
190	....	3581
200	....	1.03986

§ 230. The constant differences noticed in these determinations are, doubtless, due to accidental errors in the determination of the capacity of the thermometers. The most reliable result, therefore, is that which includes as many such determinations as possible, and that is the mean of the five series where complete. When less than five are given, it becomes necessary to reduce each to the mean of the five, assuming such reduction to be the same for temperatures below 32° as for temperatures between 32° and 40°. These reductions are, for O +.00001; P —.00005; for Q —.00008; and for 2 +.00003. We thus obtain, finally, the following results for the thermal dilatation of sea water.*

Temp.	Dilatation.	Temp.	Dilatation.
°		°	
22	0.99807	50	0.99895
23	801	55	943
24	798	60	1.00000
25	795	65	067
26	793	70	142
27	792	75	221
28	791	80	309
29	791	85	402
30	792	90	503
31	793	100	0716
32	795	110	0950
33	797	120	1218
34	800	130	1506
35	803	140	1804
36	806	150	2118
37	810	160	2460
38	814	170	2823
39	819	180	3192
40	.99823	190	3588
45	0.99856	200	1.03993

Professor Hubbard gave himself up entirely to these experiments for several weeks; patient, careful, and exact, his mode of procedure was,—gradually to raise the temperature of his sea water thermometers, sometimes in the air, sometimes in the water; sometimes by artificial means, and sometimes by exposing them simply to the weather; but always taking care to obtain for the same exposure readings both for a rising and a falling temperature.

It was always tedious and sometimes difficult, by exposing them to the air, or immersing the thermometers in water of varying temperature, to get the mercurial standard and the sea water thermometers all of the same temperature; or, at least, to feel assured that they were.

* This agrees more nearly with Despretz (p. 245) than with Dr. Marcet. The latter states that sea water decreases in weight to the freezing point, until actually congealed. In four experiments Dr. Marcet cooled sea water down to between 18° and 19° Fahr., and found that it decreased in bulk till it reached 22°, after which it expanded a little, and continued to do so till the fluid was reduced to between 19° and 18°; when it suddenly expanded, and became ice with a temperature of 28°. It should always be recollected that a saturated solution of common salt does not become solid, or converted into ice, at a less temperature than 4° Fahr.; and, therefore, if the sea should be, as is sometimes supposed, more saline at great depths, and as it appears to be in the Mediterranean from the experiments of Dr. Wollaston, ice could not be formed there at the same temperature as it could nearer the surface.—(*Vide M. De La Beche, Manual Geology, p. 22.*)

They were, therefore, all occasionally placed in the bulb of one large thermometer, the temperature of the water in it being raised by immersing it in the water that was to be heated or cooled.

This bulb was in the shape of a tin trough $1\frac{1}{2}$ inches wide, $2\frac{1}{2}$ deep, and 24 inches long. The thermometers were placed in it. It was then filled with water two inches deep, and itself placed in the water to which heat or ice was applied. In this manner many observations were made, always giving ample time for the water in the tin bulb to impart its temperature to the bulbs of glass.

The result of all these trials and observations is the determination, already quoted of the thermal dilatation of sea water in glass that partakes of the accuracy with which the expansion of mercury and of glass is known.

§ 231. Still these observations, in their present shape, do not enable us to determine the precise point of maximum density of sea water. Indeed, that depends upon the quantity of salts in the specimens used for experiment. I however diluted several specimens with snow water in different proportions.

They seemed to follow the law developed by Blagden, when he mixed pure salt and pure water in different proportions and froze the mixtures.* Experiments were made with several specimens of three parts of snow water diluted severally with one, four, and five, parts of sea water. These, with a specimen of pure sea water, all in glass vessels, with a thermometer in each, were exposed to the open air, and the temperature noted as the first crystal was observed. As soon as crystalization commenced, the thermometer rose, which was also noted.

Specimen 1. 3 parts of snow and 1 of salt commenced to freeze at 30°.5 and rose to 30°.6.
" 2. 3 parts of snow and 4 of salt commenced to freeze at 27°.7 and rose to 30°.1.
" 3. 3 parts of snow and 5 of salt commenced to freeze at 25°.3 and rose to 29°.7.
" 4. All sea water commenced to freeze at 24°.5 and rose to 28°.

This specimen (4) of sea water was obtained by Lee, of the Dolphin, from the depth of 2,400 feet, in latitude 0° 34′ S., longitude 22° 30′ W.

But by referring to the curves, especially to curve C, Plate XVIII, we shall be led to conjecture, after a little reflection, that the point of maximum density of sea-water is not at the lowest point of the curve, but a little further to the left. For instance, beginning with this curve at 80°, and cooling to 70°, the reading on the scale was changed from 9.52 inches to 7.58 inches. In the cooling the glass contracted; and, so by lessening the capacity of the bulb, the water, had it been insensible to heat, would have risen in the tube by the contraction of the glass. But the water *was* sensible to heat and while the contraction of the glass caused it to rise in the tube, its own contraction caused it to fall; therefore, the readings on the warm side of the point of maximum density show the difference between the thermal dilatation of the glass and water. On the cold side, on the contrary, we have the sum of these dilatations; for the glass, by contracting, causes the water to rise in the tube, and its own expansion sends it up still higher.

The lowest point, therefore, in these curves is when the contraction of the water and glass is the same; after that, though the water continued to contract, it would commence to rise in the glass, because of the contraction of the glass; and when the rise in the tube is more than sufficient to compensate for the contraction of the glass, then we know the water has passed its point of maximum density and commenced to expand. Knowing the rate of expansion for glass and mercury separately, we may approach this point with considerable accuracy.

* Philos. Transactions, Vol. LXXVIII.

The experiments of Dulong and Petit give us the linear expansion of mercury. A change of 100° in the temperature was observed to move the column of mercury 26.24 inches in the tube of thermometer O. According to those savans, a column of mercury 2,622 inches long would expand just 26.24 inches for such a change. Then the mercury in thermometer O was just sufficient to fill a tube, of that bore, 2,622 inches long. According to the observations of Lavoisier and La Place,* a glass rod 2,622 inches long will, for a change of 100°, expand 1.336 inches. According to General Roy,† its expansion for that change would be 1.130 inches. Taking the mean of these, computing the correction and applying it, we find the water, according to the observations with O, (page 243,) to have commenced expanding at 25°.6; while by Q (page 245) we obtain 26°.5 as its point of maximum density. O (p. 243) is entitled to most weight. But all glass is not the same; neither do all specimens of crown or flint probably follow the same law of dilatation. This determination may therefore have a probable error of ± 0°.5.

To vary the experiments on the effect of thermal changes upon the density of sea water and its freezing point, I procured from Green also a glass hydrometer, with a large bulb, and a scale, the reading of which would be varied ½ an inch by a change of .001 in density.

This, with a thermometer, was immersed in a glass cylinder, eighteen inches high and three inches in diameter, filled with sea water. This sea water, like most of that for the thermometers, was of the Dolphin's collection about the equator. The 11th and 12th of February, 1858, were cold; the thermometer in the shade ranging between 15° and 30° from 8 A. M. to 6 P. M. The weather, therefore, was favorable for our experiments.

We had been trying the freezing point of sea water by putting samples of it in phials, inserting therein a thermometer, and subjecting them to refrigeration by exposing to freezing mixtures. The ice commenced to form by coating the sides of the phial, leaving water in the middle always at 28 degrees. The phials were one ounce phials.

The heat of liquefaction, being set free in the act of freezing, went to sustain the water in the liquid state, and, therefore, so long as congelation was going on, the water, as long as any remained, would be kept at or near its minimum temperature. These experiments simply gave us, not the temperature of freezing sea water, because as long as the water remained at 28° no ice would form, but the minimum temperature of liquefaction.

The point of investigation, therefore, assumed the character of an inquiry of this sort: How cold, without confining it, can you make sea water, and how warm can you make sea water ice?

In pursuing these experiments, in the afternoon of February 12, the thermometer in the shade being 23°, I exposed the specific gravity jar and the nine sea water thermometers to the out door temperature. When the thermometer in the jar reached 27°, small crystals of ice, like macles of snow, were observed to form near the bottom, to rise, and to increase as they rose. In truth, the phenomenon was beautiful; it presented a most lovely miniature of a snow storm reversed, for the flakes appeared literally to "fall upward;" and while it was "snowing up" in the jar, covering the top with ice, the water in it rose in temperature from 27°.2 to 28°. Thus showing the maximum density of the water to be not above 27°.2.

The water in the nine thermometers went down to 23°, by the standard, without showing the least sign of crystallization. This experiment was repeated several times, and always with the same result. The thermometers were tapped and jarred by gentle knocks, but no ice formed. The not freezing may, perhaps, be partly owing to that peculiarity which prevents liquids in polished vessels, or in contact with smooth surfaces, from freezing as readily as in rough.

* Schumacher's Jahrbuch, 1837, page 273.

† Philosophical Transactions, Vol. LXXV.

Pressure clearly had something to do with it also; to satisfy myself upon this point, I took two of the Dolphin's phials, filled them full with equatorial sea water, obtained at the depth of 2,400 feet, put the ground glass stopper in one and left it out in the other, and placed both phials out of doors; the water in the open phial commenced to freeze at 24°.5, and that in the closed one went down to 18° without freezing. Hence, we infer that pressure has something to do with it, and may conclude that in polar seas, ice will make faster with a low than it will with a high barometer.

§ 232. The same water and cylinder, that gave us the beautiful miniature of an inverted snow storm, was used for the following series of observations upon the thermal changes of the specific gravity of sea water:

Temperature	Spec. grav.	Temperature	Spec. grav.
27°.1	1.0290	38°.0	1.0287
28°.3	89	43°.5	86
28°.8	91	54°.7	775
29°.0	885	55°.5	77
29°.5	906	62°.5	69
30°.0	885	63°.5	675
32°.0	88	64°.5	665
34°.0	88	80°.5	43
34°.4	89	88°.3	30
35°.2	89	*93°.3	1.0221

For these observations a very delicate hydrometer was procured of Green, of New York. It was made of glass, with a scale divided from .014 to .032, one-half inch on the scale being equal to a change of .001 in specific gravity.

§ 233. The hydrometer shows the maximum thermal density of sea water to be, according to these observations, not above 28–9°. The curve of dilatation, Plate XVIII, shows it to be 2° or 3° lower. It probably gives a more accurate determination. Hence, we may assume, for all practical purposes at present, the point of maximum density of sea water of the torrid zone to be, as before stated, 25°.6.

All these experiments unite in showing that sea water, at equatorial temperatures, is many times more expansible than sea water at polar temperatures; that is, sea water, according to its rate of dilatation, (§ 230,) will expand about seventeen times as much for 5°, when its temperature is raised from 85°, as it will when raised from 28°; and yet, according to Plate XVII, the curves of temperature and specific gravity are symmetrical in polar, non-symmetrical in equatorial seas.

Clearly, there is an agent at work in certain parts of the ocean, which counteracts the effects of change of temperature upon change of specific gravity of sea water. Supposing all parts of the ocean to be equally salt, or, rather, supposing the water, whose specific gravity is given on Plate XVII, to follow the law of expansion, determined by our observations, the specific gravity for a change of temperature from 82° to 55°, Fig. 1, should be .004, instead of .0005; difference .0035.

Here is the suppression of just one-half the thermo-dynamical force of the sea. Let the normal temperature of polar seas be changed to blood heat, and the consequent change of

* Specific gravity at 200° = 0.9908.

specific gravity would be from 1.022 to 1.029. The total change, therefore, of which the sea is susceptible, as to the thermal dilatation of its waters, from their point of maximum density up to their greatest natural warmth, is .007. In this change resides that force whence the Gulf Stream, and those other "majestic rivers in the sea," mainly derive strength for their currents; and here half of that mighty force is held in check by some antagonistic power that seems to have set a watch upon the sun beam.

As we go from the parallel of 30° to the equator, the water grows warm. That is true; but we have here discovered the foot-prints of an agent that prevents it from growing lighter, though it does grow warmer.

Now, what is this agent? The trade-winds travel from near this parallel of 30° to the equator. They evaporate as they go; but can it be possible that they are so regulated and adjusted, counterpoised and balanced, that the salt which they, by evaporation, leave behind is just sufficient to counterbalance the dilatation due the increasing warmth of the sea?

It is the trade-winds, then, which prevent the thermal and specific gravity curves from conforming with each other in intertropical seas! A more beautiful compensation cannot, it appears to me, be found in the mechanism of the universe than that which we have here stumbled upon. It is a triple adjustment: the power of the sun to expand, the power of the winds to evaporate, and the quantity of salts in the sea; these are so proportioned that when both the wind and the sun have each played with its forces upon the inter-tropical waters of the ocean, the residium of heat and of salt should be just such as to balance each other in their effects, and to preserve the aqueous equilibrium of the torrid zone.

Nor are these the only adjustments effected by this exquisite combination of compensations. If all the intertropical heat of the sun were to pass into the seas upon which it falls, it would create a thermo-dynamical force in the ocean capable of transporting water scalding hot from the torrid zone and spreading it, while still in the tepid state, around the poles.

The annual evaporation from the trade-wind region of the ocean is computed, according to the most reliable observation, to be as much as 15 feet, which is at the rate of ½ an inch per day. The heat required for this evaporation would raise 20 such layers of water from the normal temperature of intertropical seas to the boiling point. Such increase of temperature, by its consequent change of specific gravity, would still further augment the dynamical force, until, even in the Atlantic, there would be force enough to put in motion and feed with boiling hot water many Gulf Streams. But the trade-winds and the seas are so adjusted that this heat, instead of penetrating into the depths of the ocean to raise the temperature of its waters, is taken up by the vapor, carried off by the winds, and dispensed by the clouds in the upper air of distant lands. Nor does this exquisite system of checks and balances, compensations and adjustments, end here. In equatorial seas the waters are dark blue, in extra-tropical they are green. This difference of color bears upon their heat-absorbing properties, and it comes in as a make-weight in the system of oceanic climatology, circulation, and stability.

Now, suppose there were no trade-winds to evaporate and to counteract the dynamical force of the sun; this hot and light water, by becoming hotter and lighter, would flow off in currents with almost mill-tail velocity towards the poles, covering the intervening sea with a mantle of warmth as with a garment. The cool and heavy water of the polar basin, coming out as under currents, would flow equatorially with equal velocity. How much, if to any extent, the former warm climates of the British islands and northern Asia may be due to such a warm covering of the sea, may, perhaps, at some future time, be considered whorthy of special inquiry.

The crust of our planet bears record concerning the geological agency of the winds. Is there anything in that ever-instructive tablet concerning the birth of the trade-winds, or the age of marine currents, or the existence of a heavier atmosphere? If so, then may we not look to the currents of the sea and air, instead of to a shifting of the poles, or to internal heat to help us account for the once almost intertropical climates of many now cold countries?

§ 234. Light, as to the various anomalies presented by the several pairs of curves on this plate, seems at last to be beginning to dawn through the mist and darkness in which we have been groping so long. We have already seen that there is something else besides temperature that is at work in effecting changes in the specific gravity of sea water. Whatever increases or diminishes its saltness, increases or diminishes its specific gravity; and the agents that are at work in the sea doing this are sea shells, the rivers, and the rains, as well as the winds. By way of illustration, let us follow the pair of curves (Fig. 2) from the equator to 40° N., near the offings of Sandy Hook. The difference of temperature at the equator and on the parallel of 34° N. is 2°; while of specific gravity, the difference is .0005. Between this last named parallel and 40° the sea water grows suddenly cooler and *lighter*. This seems paradoxical enough; but turning to the track of the vessel that gave us the data for this pair of curves, we find that she was, when this change took place, off our own shores, and approaching New York, from a voyage in the Pacific, and that, when in latitude 34° N., she crossed the inner edge of the Gulf Stream, and then entered the littoral waters, which she found both cooler and lighter than the waters of mid ocean and the Gulf Stream. In this part of the voyage the brine of the sea was diluted with the fresh water from the Chesapeake and Delaware bays, and Long Island Sound; and though it was cooler, the addition of fresh water was sufficient to make the sea water there specifically lighter. The same phenomenon is repeated in Fig. 1, when the observing vessel was between the parallels of 34° and 36° off the shores of Asia, and again in Fig. 3, when she was off the mouth of Canton river.

These instances are not in the open sea. True. But in the open sea, between the parallels of 35° or 40° and the equator, we have an agent continually at work, which keeps in check the effect of changes of temperature upon the specific gravity of sea water.

At sea, between 35° or 40° and the equator, evaporation is in excess of precipitation; at any rate, there is but little precipitation except under the equatorial cloud-ring, (see Storm and Rain Chart, Plate V, vol. II;) and though, as we approach the equator, on either side, from these parallels, the solar ray warms and expands the surface water of the sea, the winds, by the vapor they carry off and the salt they leave behind, prevent it from making that water lighter.

Thus, two antagonistic forces are unmasked, and, being unmasked, we discover in them a most exquisite adjustment—a compensation—by which the dynamical forces that reside in the sunbeam and the trade-wind are made to counterbalance each other; by which the climates of intertropical seas are regulated; and by which the set, force, and volume of oceanic currents are measured.

This compensation is most beautiful; it explains the paradox, gives volume to the harmonies of the sea, and makes them louder in their song of Almighty praise than the music of many waters.

§ 235. Suppose there were no winds to suck up fresh water from the brine of the ocean; that its average depth were 3,000 fathoms; that the solar ray were endowed with power to penetrate with its heat from the top to the bottom; and that, from bottom to top, the seas of each hemisphere, in thermal alternation with the seasons, were raised to summer heat and lowered to winter temperature; the change of sea level from summer to winter, and from winter to summer, in one hemisphere, would, from this cause alone, be upwards of 125 feet; and in its rise and fall we should have, from pole to pole, the ebb and flow of a great thermal tide that would turn with the sun in the ecliptic, and tell the equinoxes by the march of its rising and falling waters on the tide staff.

But difference of level would not be all that would give strength and volume to this tide; difference of specific gravity would lend its weight as so much dynamical force, which difference would create an upper and under annual tide, from one hemisphere to the other. This double disturbance of equilibrium would not give rise to a tidal wave—mere motion without translation—but to a tidal flow and reflow of water from one hemisphere to the other in volumes of vast magnitude, power, and majesty.

This is an exaggerated view of the dynamical force of the sunbeam; but it is presented to show the origin of these thermal tides. The difference between the actual and the supposed thermal tides is one of degree merely; for the sea water that is liable to any considerable change of temperature, instead of reaching from the bottom to the top, is scarcely more than a "pellicle" to the ocean. It forms a stratum or layer which is thickest at the equator, and which comes to the surface near the polar edge of the temperate zones; it then dips again as it recedes towards the regions of perpetual winter.

§ 236. The observations of Kotzebue, Admiral Beechey, and Sir James C. Ross, first suggested the existence in the ocean of this isothermal floor. Its temperature, according to Kotzebue, is 36°. The depth of this bed of water of invariable and uniform temperature is 1,200 fathoms at the equator. It gradually rises thence to the parallel of about 56° N. and S., when it crops out, and there the temperature of the sea, from top to bottom, is conjectured to be permanently at 36°. The place of this outcrop, no doubt, shifts with the seasons, vibrating up and down, *i. e.*, north and south, after the manner of the calm belts. Proceeding, in our description, onward to the frigid zones, this aqueous stratum of an unchanging temperature dips again, and continues to incline till it reaches the poles at the depth of 750 fathoms. So that on the equatorial side of the outcrop the water above this floor is the warmer, but on the polar side the supernatant water is the colder.

By this floor, with its waters of one uniform and permanent temperature, "the ocean," says Sir John Herschel, "is divided into three great regions—two polar basins in which the surface temperature is below, and one medial zone in which it is above 39°.5,* being 80° at the equator; and at the poles, of course, the freezing point of sea water. It will be very readily understood that in this statement there is nothing repugnant to hydrostatical laws, the compressibility of water insuring an increase of density in descending within much wider limits of temperature than here contemplated.

"The physical consequences of this great law, should it be found completely verified by further research, are in the last degree important."

The observations which furnished the data for Fig. 1 were made in the North Pacific, between the months of August, 1855, and April, 1856, and in the South Pacific, during April and May; whereas for Fig. 2 the southern observations were made in May and June, the northern in June and July.

It is well to bear this difference as to season north and south in mind, and to compare these curves with those of the thermal charts; for the two together indicate the existence in the ocean of a thermal tide which ebbs and flows but once a year.

*This remark was made by Sir John, and the supposition, probably, that the maximum density of sea water was at the same temperature as that of fresh, but it is some 12° or 14° lower.

§ 237. By this figure the South Atlantic appears to be cooler and heavier than the northern. The season of observation, however, is southern fall and winter *vice* northern summer.

In January, February and March the waters of the southern ocean are decidedly warmer, as at the opposite six months they are decidedly cooler, parallel for parallel, than those of the northern oceans. Thus periodically differing in temperature, the surface waters of the two hemispheres vary also in specific gravity, and give rise to an annual ebb and flow—an upper and an under tide—not from one hemisphere to the other, but between each pole and equator.

In contemplating the existence and studying the laws of this thermal tide we are struck with the compensations and adjustments that are allotted to it in the mechanism of the sea; for these feeble forces in the water remind one of the quantities of small value—residuals of compensation—with which the astronomer has to deal when he is working out the geometry of the heavens. He finds that it is these small quantities which make the music of the spheres; and so, too, it is the gentle forces like this in the waters which preserve the harmony of the seas.

Equatorial and polar seas are of an invariable temperature, but in middle latitudes the sunbeam has power to wrinkle and crumple the surface of the sea by alternate expansion and contraction of its waters. In these middle latitudes is the cradle of the tiny thermal tide here brought to light; feeble, indeed, and easily masked are its forces, but they surely *exist*.

It may be that the thermometer and hydrometer are the only instruments which are nice enough to enable us to detect it. Its foot-prints, nevertheless, are well marked in our tables showing the thermal dilatation of sea water. The movements of the isothermal lines, marching up and down the ocean, show by signs not to be mistaken its rate and velocity. These movements are well represented on the thermal charts. The tiny ripplings of this feeble tide have, we may be sure, their office to perform in the general system of aqueous circulation in the sea. Their influence may be feeble, like small perturbations in the orbits of planets; but the physicist is no more at liberty to despise these than the astronomer is to neglect those.

The problem that we now have in hand, and which is represented by the diagrams of this plate, is to put the seas in scales, the ocean in a balance, and to weigh in the specific gravity bottle the waters of the northern with the waters of the southern hemisphere.

By Fig. 2 it would appear that the waters of the south Atlantic are decidedly both cooler and heavier, parallel for parallel, than the waters of the north Atlantic; but this difference may be more apparent than real, for the observations were made in the northern summer on this side, and in the southern fall and winter on the other side of the equator.

Had we a series of observations, the converse of this, viz: winter in the north Atlantic, summer in the south, perhaps the latter would then appear to be specifically the lighter; at any rate, the mean summer temperature of each Atlantic, north and south, is higher than its mean winter temperature, and consequently the specific gravity of the waters of each must change with the seasons. A diagram—had we the data for such an one—to show these changes, would be very instructive; it would show beautifully, by its marks, the ebb and flow of this new-born tide of the ocean.

§ 238. By Fig. 1 the south Pacific also outweighs the north in specific gravity; but here again the true difference, whatever it be, is somewhat masked by the time of year when the observations were made. Those north were made during the fall, winter, and spring; those south, during the fall and first winter months of that hemisphere. Nevertheless, the weight of the observations presented on Plate XVII does, as far as they go, indicate that the seas of the southern do outweigh in specific gravity the seas of the northern hemisphere in the proportion of 1.0272 to 1.0262 of specific gravity.* The observations, both for Fig. 3 north and Fig. 4 south, were made each in the winter of its hemisphere. On the average, the thermal curves is about 9° cooler, and the specific gravity curve .0015 heavier, on the southern side (Fig. 4) than the corresponding pair (Fig. 3) on the northern side of the equator. This difference of temperature will account for only about one-half the difference of specific gravity, still leaving an excess of .0007 in the southern scale. Daubeny, Dove, *et. al.*, have pointed out an excess of salt contained in sea water south of the equator, as compared with that contained in sea water north.

These indications, as far as they go, and this view of the subject, whatever future investigations may show to be its true worth, seem to lean in support of the idea advanced and maintained by facts and arguments in Chapter II, viz : that the southern seas are the boiler and the northern hemisphere the condenser for the grand atmospherical engine, which sucks up vapor from the south to feed the northern hemisphere with rains. If it be true—and Dove also thinks it is—that the clouds which supply our fountains with rains for the great American lakes, and with rains for the majestic watercourses of Europe and Asia, Northern Africa and America, are replendished from seas beyond the equator, then the waters of the ocean south should be a little salter, and therefore specifically a little heavier, parallel for parallel, and temperature for temperature, than the waters of cis-equatorial seas.

§ 239. This remark suggest an astronomical view of the subject. I say suggests, because this field has been traversed so little that I do not consider we have as yet begun either to reap or to glean in it. I feel rather as one who is sent to spy it out, and, therefore, as one whose office it is to call the attention of those who are about to enter it as laborers to whatever seems worthy of further special examination. On account of the excess of continental masses in the northern hemisphere, this seeming excess of aqueous specific gravity in the other suggests the idea of an astronomical balance for our planet, a counterpoise in the specific gravity of trans-equatorial sea water tending to match the excess of cis-equatorial land.

We begin to find, moreover, that the hydrometer is bearing testimony in support of the evidence adduced in Chapters II and III, to show that when the trade-winds meet and rise up in the equatorial calm belt, the atmosphere which came there as SE. trade-winds passes with its vapor over into the northern hemisphere. We had not anticipated that this little instrument could throw any light upon this subject ; but if, as it indicates, the sea water of the other hemisphere be salter and heavier than the sea water of this, what makes it so but evaporation, and what prevents currents from restoring its equilibrium but the winds, which are continually sucking up from the brine of trans-equatorial seas, and pouring it down as fresh water upon cis-equatorial seas and land? It is taking out of one scale of the balance, and putting into the other ; and the difference of specific gravity between the sea water of the opposite hemisphere may give us a measure for determining the amount of fresh water that is always in transitu.

Certainly, if evaporation and rains were to cease, if the rivers were to dry up, and the sea shells to perish, the waters of the ocean would, in the course of time, become all of the same saltness, and the only difference of specific gravity in the sea would be due to thermal agencies. After having thus ceased, if evaporation were then to commence only in the other hemisphere, and condensation take place only in this, half the difference, as to saltness of the sea water in opposite hemispheres, would express the ratio in volumes of fresh water, whether as vapor or liquid, that would then be kept in transitu between the two hemispheres. But it

* According to Dr. Marcet, the Southern Ocean contains more salt than the Northern in the proportion of 1.02919 to 1.02757.

evaporates on both sides and precipitates on both; nevertheless, more on one side than on the other, and the difference of saltness will still indicate the proportion in transitu.

If we follow the thermal and specific gravity curves from the parallels of 30°—34° to the equator, figs. 1 and 2, Plate XVII, we see, as I have said, that sea water in this part of the ocean does not grow lighter in proportion as it grows warmer. This is accounted for on the supposition that the effects of the thermal dilatation on the specific gravity is counteracted by evaporation. Now, if we knew the thickness of the stratum which supplies the fresh water for this evaporation, we should not only have a measure for the amount of water which as vapor is sucked up and carried off from the trade-wind regions of the sea, to be deposited in showers on other parts of the earth, but we should be enabled to determine also the quantity which is evaporated in one hemisphere and transported by the clouds and the winds to be precipitated in the other. These are questions which are raised for contemplation merely; they cannot be answered now; they grow out of some of the many grand and imposing thoughts suggested by the study of the revelations which the hydrometer is already beginning to make concerning the wonders of the sea.

§ 240. Returning from this excursion towards the fields of speculation, it will be perceived that these observations upon the temperature and density of sea water have for their object to weigh the seas, and to measure in the opposite scales of a balance, the specific gravity of the waters of one hemisphere with the specific gravity of the waters of the other. This problem is quite within the compass of this exquiste system of research to solve. But, in order to weigh the seas in this manner, it is necessary that the little hydrometric balance by which it is to be done, should be well and truly adjusted.

From these premises it would not be difficult to show that the saltness of the sea is a physical necessity. In some of the aspects presented, the salts of the sea hold the relation in the terrestrial mechanism that the balance wheel does to the machinery of a watch. Without them, the climates of the earth could not harmonize as they do; neither could the winds, by sucking up vapor, hold in check the expansive power of tropical heat upon the sea; nor counteract by leaving the salts behind, the thermal influence of the sun in imparting dynamical force to marine currents, nor prevent the solar ray from disturbing the aqueous equilibrium of our planet. As evaporation goes on from a sea of fresh water, the level only, and not the specific gravity, of the remaining water is changed. The waters of fresh inter-tropical seas would, instead of growing heavy by reason of evaporation between the tropics, become lighter and lighter by reason of the heat; while the water of fresh polar seas would grow heavier and heavier by reason of the cold—a condition which, by reason of evaporation and precipitation, is almost the very reverse of that which nature has ordained for the salt sea, and which, therefore, is the wisest and the best.

The average amount of salts in sea water is not accurately known. From such data as I have, I estimate it to be about 4 per cent., (.039,) and the mean specific gravity sea water at 60° to be about 1.0272. Supposing these quantities to be accurate—and they are based on data which entitle them to be considered as approximations not very wide of the mark—the hydrometer and thermometer, with the aid of the table at page 248, will give as a direct measure for the amount of salt in any specimen of sea water into which the navigator will take the trouble to dip these two instruments.

In order to arrive at this approximate quantity he has only to reduce the specific gravity of the water in question to the temperature of 60°, and then divide it by the decimal .7. Thus, the observed specific gravity 1.027 at 80° being, when reduced to 60°, = 1.030—this rule would give .030 ÷ .7 = .043 per cent. of salt.

§ 241. These specific gravity and thermal curves, as they are presented on this Plate, (XVII,) throw light also on the question of an open sea in the Arctic Ocean. This subject was treated, according to the lights before me at the time, in Chapter VIII of the Physical Georgraphy of the Sea. That open sea is like a boiling spring in the midst of winter, which the severest cold can never seal up ; only it is on a larger scale than any spring, or pool, or lake, and it is fed by the under currents with warm water from the south, which, by virtue of its saltness, (see fig. 2,) is heavier than the cool and upper current which runs out of the polar basin, and which is known as an ice bearing current. It is the same which is felt by mariners as far down as the Grand Banks of Newfoundland, and recognized by philosophers off the coast of Florida.

This upper current, though colder than its fellow below, is lighter, because it is not so salt.

Figure 2 reveals to us a portion of sea between the parallels of 34° and 40° north, exactly in such a physical category as that in which this theory presents the Arctic Ocean. Here, along our own shores, the thermal curve loses 12° of heat ; and what does the specific gravity curve gain in the same interval ? Instead of increasing up to 1.027, according to the thermal law, it decreases to 1.023 for the want of salt to sustain it.

Now, recollect that the great American chain of fresh water lakes never freezes over. Why ? Because of their depth and their vertical circulation. The depths below are continually sending water above 32° to the surface, which, before it can be cooled down to the freezing point, sinks again. Now, compare the shallow soundings in these lakes with the great depths of the Arctic Ocean ; compute the vast extent of the hydrographic basin which holds this polar sea ; gauge the rivers that discharge themselves into it ; measure the rain, and hail, and snow, that the clouds pour down upon it ; and then contrast its area, and the fresh water drainage into it, with the like of Long Island Sound, Delaware Bay, and the Chesapeake ; consider also the volume of diluted sea water between our shore line and the Gulf Stream ; strike the balance, and then see if the Arctic supply of fresh water be not enough to reduce its salts as much as our own fresh water streams are diluting the brine of the sea under our own eyes.

The very Gulf Stream water, which the observing vessel left as she crossed 34° and entered into those light littoral waters, was bound northward. Suppose it to have flowed on as a surface current until it, with its salts, was reduced to the temperature of 40°. Its specific gravity at that temperature would have been 1.030, or specifically 30 per cent. heavier than the sea water of our own coasts. Could two such currents of water meet any where at sea, except as upper and under currents ?

If water that freezes at 32°, that grows light and remains on the surface as you cool it below 39°, is prevented from freezing in our great fresh water lakes by vertical circulation, how much more would both vertical and horizontal circulation prevent congelation in the open Polar Sea, that is many times deeper and larger than the lakes, and the water of which contracts all the way down to its freezing point of 27°.4.

The heaviest water in the sea, uncorrected for the temperature, as shown by the observations before us, is 1.028. This water was found (figs. 1 and 2) off Cape Horn, and (fig. 3) in latitude 48°, (North Pacific Ocean.)

Let us examine a little more closely into the circumstances connected with this heavy water on our side of the equator. It was a specimen of water from the sea of Ochotsk, which is a sea in a riverless region, and one where evaporation is probably in excess of precipitation—Thus fulfilling the physical conditions for heavy water.

The Red Sea is in a riverless and rainless region. Its waters ought to be heavier than those of any other mere arm of the ocean, and the dynamical force, arising from the increase of specific gravity, acquired by its waters after they enter it at Babelmandeb, is sufficient to keep up a powerful inner and outer current through those straits.

§ 242. At the ordinary meeting of the Bombay Geographical Society, for November, 1857, the learned secretary stated that recent observations then in his possession, and which were made by Mr. Ritchie and Dr. Giraud, go to show that the saltest water in the Red Sea is where theory (§ 111) makes it, viz: in the Gulf of Suez; and that its waters become less and less salt thence to its mouth, and even beyond, till you approach the meridian of Soctra; after which the saltness again increases as you approach Bombay.

Its waters, from the mouth of the straits for 300 or 400 miles up, have been found as high in temperature as 95° Fahrenheit. A sea at blood heat! The experiments of Professor Chapman of Canada, which indicated as law:—the salter the water the slower the evaporation—seem to suggest an explanation of this, at least, in part: Evaporation ought to assist in keeping the surface of inter-tropical seas cool in the same way that it helps to cool perspiring animals. And if the waters of the Red Sea become so salt that they cannot make vapor enough to carry off the excessive heat of the solar ray, then, like the dog and the ox, it must get relieved from it by "sweating at the mouth." But for the escape which these highly heated waters are, by means of their saltness, enabled to make from that sea, its climate, as well as the heat of its waters, would be more burning and blasting than that of Sahara. Curious that the waters of a sea should be hotter than the air of the desert.

The specific gravity curves of this plate (XVII) also suggest a greater maze of currents in polar than in inter-tropical seas; and they bring out the fact that the heaviest water of the ocean uncorrected for temperature is found in high latitudes, and not within the trade-wind region, as has been conjectured, though we have nothing yet to indicate that the waters most heavily laden with salts are not to be found where the trade-winds blow.

§ 243. The most comprehensive view that man is permitted to take of cosmical or terrestrial arrangements and adaptations is at best narrow and contracted. Nevertheless, in studying the mechanism which Wisdom planned and the Great Architect of nature designed for the world, we sometimes fancy that we can discover a relation between the different parts of the wonderful machinery, and perceive some of the reasons and almost comprehend the design which Omnipotent intelligence had in view when those relations were established. Such fancies, rightly indulged, are always refreshing, and the developments of the hydrometer which we have been studying point us to one of them. This fancied discovery is, that a sea of fresh water instead of salt, would not afford the compensations that are required in the terrestrial economy, and we also fancy that we have almost discovered a relation between the orbit of the earth and the arrangement of land and water on its surface and their bearing upon climate.

The sun in its annual round tarries 7.3 days longer on the southern than on the northern side of the equator. Our planet passes its perihelion during the southern summer, when it is nearer the centre and source of light and heat by more than three millions of miles than it is at its winter solstice. The consequence is the southern hemisphere would, were its orbit not eliptical, receive more of the direct rays of the sun in its summer than the northern hemisphere does in ours;—but though it does not receive more, it radiates less. The southern hemisphere radiates less in these 7.3 days, because its nights are not so long; and for that reason it should be warmer.

What becomes of this excess of heat, be it annually never so small, and why does it not accumulate in trans-equatorial climes? So far from it, the southern hemisphere is the cooler.

In the southern hemisphere there is more sea and less land than in the northern. But the hydrometer indicates that the water in the seas of the former are salter and heavier than the waters of seas cis-equatorial; and man's reasoning faculties suggest, in explanation of this, that this difference of saltness or specific gravity is owing to the excess of evaporation in the southern half, excess of precipitation in the northern half of our planet.

"When water passes, at 212° Fahrenheit, into steam, it absorbs 1000° of heat, which becomes insensible to the thermometer, or latent; and, conversely, when steam is condensed into water it gives out 1000° of latent heat, which thus becomes free and affects both the thermometer and the senses. Hence, steam of 212° Fahrenheit will, in condensing, heat five and a half times its own weight of water from the freezing to the boiling point."—*McCulloch.*

Now, there is in the southern a very much larger water surface exposed to the sun than there is in the northern hemisphere, and this excess of heat is employed in lifting up vapor from that broad surface, in transporting it across the torrid zone and conveying it to extra-tropical northern latitudes, where the vapor is condensed to replenish our fountains, and where this southern heat is set free to mitigate the severity of northern climates.

In order to trace a little further, in our blind way, the evidences of wisdom and design, which we imagine we can detect in the terrestrial arrangement of land and water, let us fancy the southern hemisphere to have the land of the northern, and the northern to have the water of the southern, the earth's orbit remaining the same. Is it not obvious to our reason that by this change the whole system of climatology in both hemispheres would be changed? The climates of our planet are as obedient to law as the hosts of heaven. They are as they were designed to be; and all those agents which are concerned in regulating, controlling, and sustaining them are "ministers of His."

Johnston, in the Chapter to Plate 18, of his great Physical Atlas, thus alludes to the seas, land, and climates of the two hemispheres:

"The mild winter of the southern hemisphere, plus the contemporaneous hot summer of the northern hemisphere, necessarily gives a higher sum of temperature than the cool summer of the southern, plus the cold winter of the northern hemisphere. The above described relations appear to furnish the motive power in the machinery of the general atmosphere of the earth, in the periodical conversion of the aqueous vapors into liquid form. In this manner the circuit of the fluid element, the essential support of all vegetable and animal life, no longer appears to depend on mere local coolings, or on the intermixture of atmospheric currents of different temperatures; but the unequal distribution of land and sea in the northern and southern hemispheres supplies an effectual provision, from whence it necessarily follows that the aqueous vapour, which from the autumnal to the vernal equinox is developed to an immense extent over the southern hemisphere, returns to the earth, in the other half of the year, in the form of rain or snow. And thus the wonderful march of the most powerful steam engine with which we are acquainted, the atmosphere, appears to be permanently regulated. The irregular distribution of physical qualities over the earth's surface is here seen to be a preserving principle for terrestrial life. Prof. Dove considers the northern hemisphere as the condenser in this great steam engine, and the southern hemisphere as its water reservoir; that the quantity of rain which falls in the northern hemisphere is, therefore, considerably greater than that which falls in the southern hemisphere; and that one reason of the higher temperature of the northern hemisphere is that the larger quantity of heat which becomes latent in the southern hemisphere in the formation of aqueous vapour is set free in the north in great falls of rain and snow.''

In this view of what our little hydrometer has developed or suggested, we trace the principles of compensation and adjustment, the marks of design, the evidence of adaptation between the orbit of the earth and the time from the vernal to the autumnal, and from the autumnal to the vernal equinox; between the arrangement of the land in one hemisphere and the arrangement of the water in the other; between the rains of the northern and the winds of the southern hemisphere; between the vapor in the air, and the salts of the sea; and between climates on opposite sides of the equator. And all this is suggested by merely floating a glass bubble in sea water during a voyage to the Pacific; thus even the little hydrometer, in its mute way, points the Christian philosopher to the evidences of design in creation. That the arrangements suggested above are adapted to each other, this instrument affords us evidence as clear as that which the telescope and the microscope bear in proof that the eye, in its structure, was adapted to the light of heaven. The universe is the expression of one thought; and that it is so, every new fact developed in the progress of our researches is glorious proof.

§ 244. The questions which a study of these plates, XVII and XVIII, suggests are many. They come without bidding. The observations, however, are as yet too few for theory, for further speculation, or conjecture; nevertheless, before we can ascend to these we must catechize the sea more closely, and patiently wait to learn what its waters have to say. Are not its waters very much more salt about the equatorial than they are about the polar regions? And does not the expansibility of the water depend upon its degree of saltness? And the kind of salts held in solution:—are they the same for sea water at all temperatures?

The specific gravity curves of the north Pacific seem to indicate, for high latitudes, not only a different degree of saltness, but a different rate of expansibility for a given change of temperature; at least, if the flexures of these lines do not actually indicate such things, they suggest them to us as points of inquiry to be looked into, investigated, and settled, before we can proceed further.

It remains to be seen whether the hydrometer may not be used to warn navigators of their approach to the eastern shores of the United States, especially to the entrance of our great bays and sounds, as per indications, fig. 2.

There is no instrument of navigation which, after proper and systematic use by co-operators, appears to be capable of affording us more knowledge or instruction concerning the physics of the sea than the little hydrometer, with its companion—the water thermometer. Their general use is commended by another circumstance, they are the cheapest nautical instruments that observers are called on to buy.

CHAPTER XVIII.

GALES, TYPHOONS, AND TORNADOES.

§ 245. Under the head of typhoons and tornadoes, I include all those gales of wind which are known as cyclones. These have been treated of by Redfield, in America; Reid, in England; Tom, of Mauritius; and Piddington, of Calcutta, with marked ability, and in special works. I refer the reader to them.

§ 246. The theory of this school is, that these are rotary storms; that they revolve against the sun in the northern, and with the sun in the southern hemisphere; that nearer the centre or vortex the more violent the storm, while the centre itself is a calm, which travels sometimes a mile or two an hour, and sometimes forty or fifty; that in the centre the barometer is low, rising as you approach the periphery of the whirl; that the diameter of these storms is sometimes a thousand miles, and sometimes not more than a few leagues; that they arise somewhere between the parallels of 10° and 20° north and south, travelling to the westward in either hemisphere, but increasing their distance from the equator, until they reach the parallel of 25° or 30°, when they turn towards the east, or "recurvate," but continue to increase their distance from the equator—*i. e.*, they first travel westwardly, inclining towards the nearest pole; they then *recurve* and travel eastwardly, still inclining towards the pole; that such is their path in both hemispheres, &c.

The question why these storms should recurve, or why they should travel as they do, or turn *with* the hands of a watch in the southern, and *against* them in the northern, hemisphere, puzzled meteorologists and navigators for a long while. The first two questions are still puzzles; but this turning is now regarded as the resultant of diurnal rotation, and of those forces of translation which propel the winds along the surface of our planet. This composition of the forces of the revolving storm, and this resolution of them, are precisely such as to produce opposite rotation on opposite sides of the equator.

§ 247. It can be shown that the path of every wind, like the course of the currents of the sea, is along curved lines. The tendency of winds to move in curve, rather than in straight lines, is beautifully illustrated by the trade-winds, especially those of the southern hemisphere. I say especially those, because the series of observations upon the actual direction of the SE. trade, in various parts of the trade-wind belt, is better calculated to show this tendency here, than any series we are, for a long time, likely to have in the N.E. trade-wind belt. These are the circumstances that make them better: On many of the great commercial thoroughfares vessels have to cross the SE. trade-wind belt of the Atlantic on a bowline, or by the wind; not so in the northeast trades anywhere.

Thus, all vessels bound hence around the Cape of Good Hope, from the time they enter the SE. trade-winds until they lose them, shape their course by the wind; so do those homeward bound from California and the Sandwich Islands; in other words, the course through the S.E. trades, which vessels on these voyages want to make, is S.E. Now, there is no great thoroughfare which, after passing the equator, stretches N.E. through the N.E. trades. The homeward route, both to the United States and Europe, lies from the equator through the N.E. trades; but, for the United States, it is northwest, and for Europe it is north, on account of the western capes of Africa, until this belt be well nigh past. Vessels from the Amazon to Europe, or from the Society Islands to California, would traverse the N.E. trades on a bowline; but they are too few in number to give us the requisite observations.

To determine the path of a particle of atmosphere, which would represent the mean course of the S.E. trade wind as it successively crosses every 5th parallel from 25° S. to the equator, I first determined the crossings of 0°, 5°, 10°, 15°, 20°, and 25°, S., of 310 vessels as they sailed through the S.E. trade-wind belt of the Atlantic, on their way to India and Australia. Having ascertained this, it was easy to compute the course made good from parallel to parallel, and consequently, as all of them were sailing by the wind, we know the average direction of the wind from parallel to parallel.

The average courses made good by the 310 vessels, supposing them to have sailed just six points from the wind, are as follows:

From the equator to 5° S. the course is S. 25° W., and the wind S. 42° E.
From 5° to 10° S. the course is S. 17° W., and the wind S. 50° E.
From 10° to 15° S. " " S. 11° W., " " S. 56° E.
From 15° to 20° S. " " S. 6° E., " " S. 73° E.
From 20° to 25° S. " " S. 23° E., " " S. 90° E.

Thus, a balloon being set free on the parallel of 25° S. in the Atlantic, and supposed to follow the average rhombs of the S.E. trades, thence to the equator, its course—

From 25° to 20° S. would be west with the wind from east.
From 20° to 15° S. would be W. by N. ½ N., with the wind E. by S. ½ S.
From 15° to 10° S. would be N.W. by W., with the wind S.E. by E.
From 10° to 5° S. would be N.W. ½ W., with the wind S.E. ½ E.
From S. equator would be N.W. ¼ N., with the wind S.E. ¼ S.

The S.E. trade winds of the Pacific present a like phenomenon—that is, as you approach the equator from the tropic of Capricorn, the *prevailing* direction of the trades is more and more from the south, thus turning, as far as they go, with the hands of a watch, and showing that their path is along a curved, and not along a straight line.

§ 248. This deflection is in obedience to a simple law, and the rotation of the tornado in opposite directions on the two sides of the equator being admitted, it is easy for the mariner to tell the direction of the centre of the storm from the ship. Thus, suppose we take for example the case of a cyclone in the southern hemisphere. In order to learn how to find the centre, place your watch, face up, on the table, the XII mark to the north, and imagine the wind to be blowing the minute hand around, the wind hauling as the hand goes round, so as to be always blowing perpendicularly against it; now stand with your face to the imaginary wind that is blowing the hand around; the centre of the watch will represent the centre or vortex of the storm, which, you observe, will be always to the left, you facing the wind.

Thus, suppose the hand to be at 15^m, the wind will be north and the vortex west. Suppose the hand to be at 30^m, the wind will be east and the vortex north. Suppose the hand to be at 12^h 45^m, the wind will be south and the vortex east, &c. Now, slide the watch westwardly and towards the pole—*i. e.*, S.W. across the table, and you will perceive how the storm is said to travel over the earth's surface, and to carry its revolving disk along with it. The direction of the wind being given, the following table shows the direction in which, according to the theory, the centre or vortex of the storm ought to be:

If the wind be*—	The vortex of the storm will bear—		If the wind be—	The vortex of the storm will bear—	
	Northern hemisphere.	Southern hemisphere.		Northern hemisphere.	Southern hemisphere.
North	East	West	South	West	East
N. by E.	E. by S.	W. by N.	S. by W.	W. by N.	E. by S.
N. N. E.	E. S. E.	W. N. W.	S. S. W.	W. N. W.	E. S. E.
by	S. E. by E.	N. W. by W.	S. W. by S.	N. W. by W.	S. E. by E.
N. E.	S. E.	N. W.	S. W.	N. W.	S. E.
N. E. by E.	S. E. by S.	N. W. by N.	S. W. by W.	N. W. by N.	S. E. by S.
E. N. E.	S. S. E.	N. N. W.	W. S. W.	N. N. W.	S. S. E.
E. by N.	S. by E.	N. by W.	W. by S.	N. by W.	S. by E.
East	South	North	West	North	South
E. by S.	S. by W.	N. by E.	W. by N.	N. by E.	S. by W.
E. S. E	S. S. W.	N. N. E.	W. N. W.	N. N. E.	S. S. W.
S. E. by E	S. W. by S.	N. E. by N.	N. W. by W.	N. E. by N.	S. W. by S.
S. E.	S. W.	N. E.	N. W	N. E.	S. W.
S. E. by S.	S. W. by W.	N. E. by E.	N. W. by N.	N. E. by E	S. W. by W.
S. S. E.	W. S. W.	E. N. E.	N. N. W.	E. N. E.	W. S. W.
S. by E.	W. by S.	E. by N.	N. by W.	E. by N.	W. by S.

§ 249. Many of the phenomena connected with the storms still remain to be explained; even the facts with regard to them are disputed by some. Professor Espy, after having discussed for many years numerous observations that have been made chiefly on shore, maintains that the wind does not blow *around* the vortex or place of low barometer, but directly *towards* it.

He holds that the place of low barometer, instead of being a disk, is generally an oblong, in the shape of a long trough, between two atmospherical waves, curved with its convex side towards the east; that it is sometimes nearly straight, and generally of great length from north to south, reaching from the Gulf of Mexico to the Great Lakes and beyond, and having but little breadth in proportion; that it travels east, moving side foremost, requiring about two days to go from the Mississippi to St. John's, Newfoundland; that on either side of it, but many miles distant, there is a ridge of high barometer; that the wind on either side of the line of low barometer, in which there is little or no wind, blows towards it, &c., and, in support of these positions, he advances this theory:

"When the air in any locality acquires a higher temperature or a higher dew point than that of surrounding regions, it is specifically lighter, and will ascend; in ascending, it comes

* **Remarks on Revolving Storms, published by the Admiralty, 1853.**

under less pressure and expands; in expanding from diminished pressure it grows colder about a degree and a quarter for every hundred yards of ascent; in cooling as low as the dew point, (which it will do when it rises as many hundred yards as the dew point at the time is below the temperature of the air in degrees of Fahrenheit,) it will begin to condense its vapor into cloud; in condensing its vapor into water or cloud, it will evolve its latent calric; this evolution of latent coloric will prevent the air from cooling so fast in its further ascent as it did in ascending below the base of the cloud now forming; the current of the air, however, will continue to ascend, and grow colder about half as much as it would do if it had no vapor in it to condense; and when it has risen high enough to have condensed, by the cold of expansion from diminished pressure, one-hundredth of its weight of vapor, it will be about forty-eight degrees less cold than it would have been if it had no vapor to condense, nor latent coloric to give out, that is, it will be about forty-eight degrees warmer than the surrounding air at the same height; it will, therefore, (without making any allowance for the higher dew point of the ascending current,) be about one-tenth lighter than the surrounding colder air, and, of cousre, it will continue to ascend to the top of the atmosphere, spreading out in all directions above as it ascends, overlapping the air in all the surrounding regions in the vicinity of the storm, and thus, by increasing the weight of the air around, cause the barometer to rise on the outside of the storm, and fall still more under the storm cloud, by the outspreading of air above; thus leaving less ponderable matter near the centre of the upmoving column to press on the barometer below.

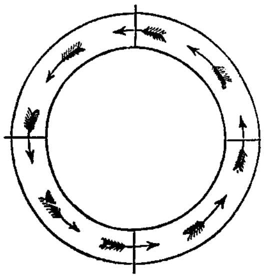
"The barometer thus standing below the mean under the cloud in the central regions, and above the mean on the outside of the cloud, the air will blow on all sides from without, inwards, under the cloud. The air on coming under the cloud, being subjected to less pressure, will ascend and carry up the vapor it contains with it, and as it ascends will become colder by expansion from constantly diminishing pressure, and will begin to condense its vapor in cloud at the height indicated before, and thus the process of cloud forming will go on.

"Now, it is known that the upper current of air in the United States moves constantly, from a known cause, towards the eastward, probably a little to the south of east; and as the up-moving column containing the cloud is chiefly in this upper current of air, it follows that the storm cloud must move in the same direction. And over whatever region the storm cloud appears, to that region will the wind blow below; thus the wind must set in with a storm from some eastern direction, and, as the storm cloud passes on towards the eastward, the wind must change to some western direction, and blow from that quarter till the end of the storm. These are the elements of the theory of storms, which, with the numerical results, are demonstrated proximately in my work on the Philosophy of Storms."*

§ 250. But, returning to the cyclone theory: though the wind be blowing around in spirals against the hands of the watch, yet, from the fact that the centre about which it is blowing is also travelling along, the changes of the wind, as observed by a vessel over which the storm is passing, will not, under all circumstances, be against the sun in the northern, or with the sun in the southern hemisphere. The reason is obvious.

This point is worth studying, and any one who will resort to moving diagrams for illustration will be repaid with edification. Piddington's horn cards are the best, but let those who have them not, cut a disc of paper of any convenient diameter, say $2\frac{1}{2}$ inches, and then cut out a circle of 2 inches from the middle; this will leave you a ring half an inch broad, upon which

* The Fourth Meteorological Report of Prof. James P. Espy; Senate Doc. 65, 34th Congress, 3d session.



to draw arrows representing the course of the wind. Suppose them to be drawn for the northern hemisphere, as in the annexed diagram; lay the paper-ring on the chart; suppose the ship to be in the NE. quadrant of the storm, which is travelling north, the centre will pass to the west, but the wind will change from SE. to S., and so on to the west:—*with the hands of a watch;* though it be revolving about the centre, *against the hands of a watch,* still the rule for finding the direction of the centre holds good: Face the wind, and the centre in the northern hemisphere will be to the right.

§ 251. Suppose that in the case before us, the storm be travelling to the north at the rate of 20 miles the hour, and that the wind be revolving around the centre, also at the rate of 20 miles the hour: when the vortex bears west of the ship, the wind will be south. It is going 20 miles to the north with the body of the storm, and 20 miles around the centre; total force of the wind, 40 miles an hour on the *east* side.

Now, imagine yourself on the other side, that is, that you be in the northwest quadrant, and that the storm be travelling due north, as before; the vortex will pass east of you, when the wind should have changed from NE. to north, turning against the hands of a watch; but when the wind is north it is, in the case supposed, travelling south at the rate of 20 miles an hour around the storm, while the progressive movement of the storm itself is north, at the rate of 20 miles an hour. One motion exactly cancels the other, and there is, therefore, a line of calm and light, or moderate or not so heavy winds on one side of the centre, while on the other side there is a line of violence; in other words, in every travelling cyclone the wind blows harder on one side than the other. This is the case in both hemispheres; and by handling these moving diagrams for illustration, the navigator will soon become familiar with the various problems for determining the direction of the vortex, the course it is travelling, its distance, &c. Therefore, when it is optional with the navigator to pass the storm on either side, he should avoid the heavy side. These remarks apply to both hemispheres.

Captain Toynbee asks if it rains more in one quarter of a cyclone than another? In cyclones that travel fast, I suppose there would be most rain in the *after* quarter; with those that have little or no progressive motion, I conjecture that the rainy quarter, if there be one, would depend upon the quarter whence that wind comes that brings most rain.

The rain in a cyclone is supposed to come from the moisture of that air which has blown its round and gone up in the vortex; then it expands, grows cool, and condenses its vapor, which spreads out at top like a great mushroom in the air, the liberated heat adding fury to the storm.

§ 252. Such, briefly stated, are the two theories. They appear to me, from such observation and study as I have been able to bestow, to be, neither of them, wholly right or altogether wrong. Both are instructive, and the suggestions of one will, in many instances, throw light upon the facts of the other.

That rotary storms do frequently occur at sea we know, for vessels have sometimes while scudding before the wind in them, sailed round and round. The United States brig Perry did this a few years ago in the West Indies; and so did the "Charles Heddle" in the East Indies; she went round and round a cyclone five times.

From such observations as I have been able to obtain upon the subject, I am induced to believe, with Thom, that the wind in a cyclone does not blow round in a circle, but around in spirals. Nay, I go further, and conjecture that it is only within a certain distance of the vortex that the wind gyrates, and that the gyrating column is never *hundreds of miles* in diameter, as the advocates of this theory make it,—I shall allude to this again. The low barometer at the centre is owing, in part, to two causes; one is the condensation of vapor, with its liberated heat, as maintained by Espy; the other is the action of a real centrifugal force, which applies to all revolving bodies.

In weighing the effect of this centrifugal force upon the low barometer, care should be taken not to give it an undue weight. It is not sufficient to cause the air to fly off in a tangent. The lateral atmospheric pressure would prevent that, if the centrifugal force were never so great; and the lower the barometer in the centre, the greater would be the pressure of the surrounding air. The proper weight, therefore, due the centrifugal force I hold to be not very great, though it is appreciable to this extent:—The storm having commenced revolving, the flow of air into the vortex is retarded—not prevented—by centrifugal tendency; and this retardation assists in causing the barometer to stand lower than it would if there were no revolution.

Any one who has watched the little whirlwinds, so often seen during summer and fall, or who can call to mind the whirls or "sucks" in a mill-pond, or at the lock in a canal when the water is drawn off at the bottom, may appreciate the extent to which the *centrifugal tendency* will help to make a low barometer at the centre of a cyclone.

The low barometer, the revolving storm, and the ascending column, require for a postulate the approach by spirals of the wind from circumference to centre. The wind blows towards the place of low barometer; that is admitted by all. It can only reach that place by a direct, or by a curvilinear motion. If by the former, then there can be no revolution; but, if there be revolution, then the air, while as wind it is revolving around the centre, in the gyrations of the storm, is approaching the centre also. Hence we derive the elements of a spiral curve; and the physical necessity for spiral motion is demonstrated, from the fact that there is circular motion and an uprising in the centre. This spiral movement and the uprising may be illustrated by familiar examples:—The angles and corners of the Observatory, and its wings, are so arranged that at a certain place there is, with westerly winds, always a whirlwind. This whirlwind is six to eight feet in diameter; and, when there is snow, there is a pile of it in the centre, with a naked path, in the shape of a ring, three or four feet broad about it. It is the spiral motion which brings the drift snow to the centre or vortex, and the upward motion not being strong enough to carry the snow up, it is left behind, forming a sort of cone, which serves as a cast for the base of the vortex.

If you throw chips or trashy matter into the lock of a canal and watch them, you will see that as they come within the influence of the "suck" they will approach the whirl by a spiral until they reach the centre, when, notwithstanding they may be lighter than the water, they will be "sucked down." Here we see the effects of centrifugal force upon a fluid revolving within itself. The "suck" is funnel shaped. As it goes down, the lateral pressure of the water increases; it counteracts more and more the effect of centrifugal force, and diminishes, by its increase, the size of the "suck."

So, too, with the little autumnal whirlwinds in the road and on the lawn: the dust, leaves, and trash will be swept in towards the centre at the bottom, whirl round and round, go up in the middle, and be scattered or spread out at the top. I recollect seeing one of these whirlwinds pass across the Potomac, raising from the river a regular waterspout, and, when it reached the land, it appeared as a common whirlwind—its course being marked as usual by a whirling column of leaves and dust.

§ 253. These little whirlwinds are, I take it, the great storms of the sea in miniature; and a proper study of the miniature on land may give us an idea of the great original on the ocean.

The unequally heated plain is thought to be the cause of the one. But there are no unequally heated plains at sea; nevertheless, the *primum mobile* there is said, and rightly said, to be heat. Electricity, or some other imponderable, may be concerned in the birth of the whirlwind both ashore and afloat. But that is conjecture; the presence of heat is a fact. In the middle of the cyclone there is always rain, or hail, or snow; and the amount of heat set free, during the process of condensing the vapor for this rain, or hail, or snow, is sufficient to raise more than five times the whole amount of water that falls, from the freezing to the boiling point. This vast amount of heat is set free, not at the surface of the sea, it is true, but in the cloud region, and where the upward tendency of the indraught is still further promoted.

What sets the whirlwind a brewing is another question; but its elements being put in motion, there is a diminished barometric pressure, first, on account of *centrifugal tendency*, next, on account of the ascending column of air, which expands and ascends, ascends and expands on account of such diminished pressure; and next, though not least, on account of the heat which is set free by the condensation of the vapor which forms the clouds and makes the rain. This heat expands and pushes aside the upper air.

Now that the cyclones at sea are ever as broad as a thousand, or as 500 miles, is a question, I conceive, which remains to be proved. That storms do prevail over large areas of sea at the same time is well known; but that it is the *same* cyclone that covers a disk of a thousand miles in diameter, observations have not, I conceive, sufficiently established.

§ 254. Suffice it to say, that whenever I have attempted, with the records of a number of vessels before me, to project the path of one of these storms, I have found a difficulty in reconciling them, upon the supposition that they were all in the same cyclone; and the difficulty is the more marked the further apart the vessels were. If the observations of vessel A be used for the projection, it is easy to mark the centre and march of the storm according to the theory. The case will appear a plain one, for there are no observations to confirm or contradict. But if the records of B, C, D, E and F, which were scattered about also in a storm at the same time, be used for the projection, the chances are that the wind, as actually observed by the other vessels, will not accord with the wind as represented in the diagram. If the other vessels be not very far apart, then the direction of the wind, as observed and as theory would have it, will be more apt to conform.

Referring again to our minature whirlwinds on the land for illustration, we often see a number of them at one and about the same place; and they often appear to skip, raging here, then disappearing for a moment, then touching the ground again, and pursuing the former direction.

Observations have not established that this is not the case at sea; observations are wanting upon this subject. Tornadoes on the land often divide themselves, sending out branches, as it were. It remains to be seen whether cyclones do not the same at sea; and whether in those wide spread and devastating storms that now and then sweep over the ocean, there be only one vortex or several; and if only one, whether the whole storm partake of the cyclone character.

In other words, may there not be a storm within a storm—that is, a cyclone travelling with the storm and revolving in it? I ask the question because the theory does not satisfy all the facts observed.

§ 255. The celebrated Black Sea storm of 1854, which did so much damage to the allied fleet, is still maintained by some to be a true cyclone; and by the observations of some of the vessels a cyclone may be made out. But if we take the observations of all of them, and discuss them upon the supposition that the whole storm was a cyclone, it will puzzle any one to make anything of them. Admiral Fitz Roy, in the Meteorological Papers of the Board of Trade, published diagrams of the winds as observed during that storm on board of various vessels in various parts of that sea. I have not been able to reconcile them with the cyclone theory. Espy maintains that they confirm his.

I call this subject to the notice of co-operators, hoping they will be induced to give it their attention and let me have the benefit each one, not only of his observations, but of his experience and reflections.

The cyclones of the north Atlantic take their rise generally somewhere between the parallels of 10° and 20° north. They take a westerly course until they fall in with the Gulf Stream, when they turn about and run along upon it until their force is expended. The atmosphere over the Gulf Stream is generally well charged with moisture, and in this fact perhaps will be found the reason why the path of the storm is laid along the Gulf Stream.

§ 256. The following table is from Birth's Hand Book of Storms:

Average number of cyclones, or hurricanes, which have occurred in different months of the year, and in various regions.

Locality.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sep.	Oct.	Nov.	Dec.	Total.
West Indies	......	1	2	......	......	4	15	36	25	27	1	2	113
South Indian Ocean	9	13	10	8	4	......	......	......	1	1	4	3	53
Mauritius	9	15	15	8	......	......	......	......	......	......	......	6	53
Bay of Bengal	1	......	1	1	7	3	......	1	......	7	6	3	30
China Sea	......	......	......	......	......	2	5	5	18	10	6	......	46

§ 257. The China Seas are celebrated for their furious gales of wind, known among seamen as typhoons and white squalls. These seas are included on Plate XV as within the region of the monsoons of the Indian Ocean. But the monsoons of the China Seas are not five-month monsoons, (§ 55;) they do not prevail from the west of south for more than two or three months.

Plate I exhibits the monsoons very clearly in a part of this sea. In the square between 15° and 20° north, and 110° and 115° east, there appears to be a system of three monsoons—that is, from northeast in October, November, December, and January; from east in March and April, changing in May; from the southward in June, July, and August, changing in September. The great disturber of the atmospheric equilibrium is situated among the arid plains of Asia; their influence extends to the China Seas, and about the changes of the monsoons these awful gales are experienced.

In like manner, the Mauritius hurricanes, or the cyclones of the Indian Ocean, occur during the unsettled state of the atmospheric equilibrium which takes place at that debatable period during the contest between the trade-wind force and the monsoon force; (§ 56,) which debatable period occurs at the changing of the monsoon, and before either force has completely gained or lost the ascendency. At this period of the year the winds, breaking loose from their controlling forces, seem to rage with a fury that would break up the very fountians of the deep.

So, too, with the West India hurricanes of the Atlantic. These winds are most apt to occur during the months of July, August, and September. There is, therefore, this remarkable difference between these gales and those of the East Indies : the latter occur about the changing of the monsoons, the former during their height. In July, August, and September, the southwest monsoons of Africa and the southeast monsoons of the West Indies are at their height; the agent of one drawing the northwest trade-winds from the Atlantic into the interior of New Mexico and Texas, the agent of the other drawing them into the interior of Africa. Its two forces, pulling in opposite directions, assist now and then to disturb the atmospheric equilibrium to such an extent that the most powerful revulsions in the air are required to restore it.

Captain Toynbee gives, in the abstract log of the Gloriana, a very excellent description of an East India cyclone, and shows how he avoided it according to theory.

Extract from the abstract log of the ship Gloriana, Captain Henry Toynbee, from London to Madras.

"*December* 1, 1856.—Latitude 2° 52′ N.; longitude 88° 05′ E.; current, S. 61° E., 37 miles; wind NW. by W.; force, .2 ; sea very smooth.

"*December* 2.—Latitude 3° 30′ N.; longitude 88° 55′ E.; wind north ; force, 2.4 ; barometer, 29.962 ; sea confused.

"*December* 3.—Latitude 3° 55′ N.; longitude 86° 58′ E.; current, S. 49° W., (in two days,) 51 miles; wind variable, NW.; barometer, 29.960 ; squalls in SW.; NE. and southerly swells.

"*December* 4.—Latitude 4° 34′ N.; longitude 86° 53′ E.; current, S. 71° W., 26 miles ; wind, N.NW., rate, 4.5 ; barometer, 29.898 ; NE. swell.

"*December* 5.—Latitude 5° 20′ N.; longitude 87° 13′ E.; current, S. 88° W., 26½ miles; wind, N.NW., rate, 7.8 ; barometer, 29.835 ; high and confused seas.

"*December* 6.—Latitude 6° 44′ N.; longitude 87° 42′ E.; current, N. 22° E.; wind, W.SW.; force, 7.8 ; barometer, 29.836 ; sea very high and confused.

"*December* 7.—Latitude 9° 58′ 30″ N.; longitude 86° 54′ E.; current, N. 25° E., 22 miles ; wind, SE.; force, 7.8 ; barometer, 29.834 ; sea high and confused ; very heavy rain.

"*December* 8.—Latitude 12° 36′ N.; longitude 83° 56′ E.; current, N. 48° W., 25 miles ; wind, SE. by E., 6.8 ; barometer, 29.862. 3 P. M. hove too, heading from N.NE. to NE.

"*December* 9.—Latitude 13° 37′ N.; longitude 82° 52′ current, W. 4½; wind, E.SE., 6.7; barometer, 29.983. 6 A. M. kept away a straight course for Madras."

§ 258. *December* 23, 1856.—By refering to the above observations, it will be seen that from December 1st to December 4th we had the wind variable from NW. to NE., chiefly north, with squalls and rain of the heaviest kind. About 10 P. M. of the 4th a sharp squall from the NW. split the driver and main-topmast staysail; wore ship and stood to the northward and eastward and then took in the first reefs. During the 4th and 5th we had a high NE. sea, but in the latter part of the 5th it became confused between NE. and NW. From daylight of the 1st to daylight of the 4th the barometer had gradually fallen from 30.00 inches to 29.912, or .030 daily. At 6 A. M. of the 5th we had the wind NW. by N.; force, 6; barometer, 29.850 inches; thermometer, 78°. Dense clouds hanging about the horizon, and great numbers of birds and terns flying about the ship, though we were 320 miles from Ceylon; here I began to suspect that our northwesterly wind was the SW. part of a cyclone, for the wind was increasing and the sea very confused. At 3.30 P. M. close reefed the main-topsail and furled the mainsail; so stood on under very easy sail, the foresail being reefed, and the fore-topsail double reefed; the wind was W. by N.; force 7 to 8, and we made about 3 miles per hour to the northward; this I did, thinking that if the storm were a cyclone, it would, in its easterly course, cross our bow, and the wind would draw to the SW., when we might steer to the northward safely. At 1.30 P. M. of the 6th the westerly wind increased to 8, when we furled the foresail and mizzen topsail, fearing that our progress to the north was too great. At this time the barometer was 29.764; thermometer 76.8; and by 3.45 A. M. it had fallen to 29.734; thermometer 79, which was the lowest barometer we had; the wind remained west until 8 P. M., when it was a little south of west; force 7 to 8. We set the reefed courses and steered N. by W.; then we found the wind gradually drawing to the SW.; so made sure that the gale was NW. of us.

At 8 P. M. of the 6th the wind was south; force 6; barometer 29.864; thermometer 81; the weather fine, but very hazy; made sail to single reefs and top-gallant sails. From noon of the 5th to noon of the 7th steered N.NW.; wind S. to E.; when the barometer remained nearly stationary, and the weather was moderately fine.

At noon of the 7th kept away NW. by W.; barometer 29.834; thermometer 81°; wind SE.; force 7 to 8; the weather very soon became worse; at midnight the rain poured as heavily as possible; the moon lit up different parts of the horizon, as if it was clearing up, but only more rain than ever came, while the wind moaned in a most remarkable manner as it passed over the ship. At 7 P. M. we had treble reefed the main-topsail, and reefed the foresail, we had also furled the mizzen topsail and jib. The remarkable confused state of the sea on the 6th and 7th seemed to prove that the strength of the gale had passed over the part where we then were.

By noon of the 8th we were in 12° 36′ N., within a few miles of the latitude of Madras, and finding that by standing to the westward the gale became worse, I decided on heaving to; so at 3 P. M. of that date we brought the ship to the wind, on the starboard tack, under treble reefs and main-trysail, heading from N.NE. to NE. Here we lay comfortably skimming the sea until daylight, when, at 6 A. M. of the 9th, we kept away, a straight course for Madras. The wind continued a little south of east, and the sea was very much confused, so much so that when, during the evening, the wind fell light the ship rolled as much as I ever knew her to roll.

At 8 A. M. of the 10th, when, by dead reckoning, we were about 25 or 30 miles from Madras, there came on a heavy squall of wind and rain from the eastward; it was so bad that I could hardly see the ship's length before me, and as the sea was a very light green, (though we had failed before in getting soundings,) I though it necessary to stand to the northward and eastward, which we did until noon, when the weather cleared, and having obtained double altitudes, we found our position to be in latitude 13° 19′ N., longitude 81° 00′ E. The barometer was 30.040; thermometer 77°.7. We then tacked and stood in for the land, the wind being light from the south; in the evening we saw the Madras light, and found that there was a strong current setting to the southward; during the night the wind came from the northward and eastward, and at 7 A. M. we anchored in Madras roads.

The only vessel at anchor was the steamer Coromandel, and she came in the same morning; two others came in immediately after us; all the rest had put to sea, and now, on the 23d of December, there are still seven vessels missing.

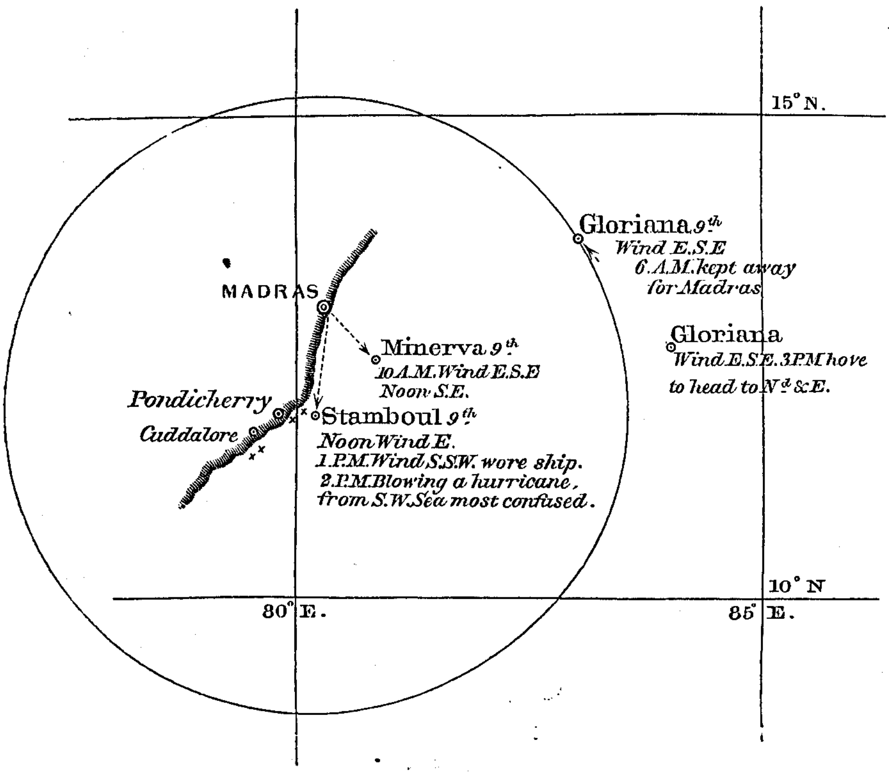
I was able to foretell each change of the wind, always supposing that we were on the outer or eastern part of a revolving storm. I also foretold that there was a gale blowing in Madras; so our being the first ship which came to an anchor after it was very satisfactory. I should like to know if one quarter of these cyclones is more rainy than another; if so, I think we must have been in it.

This is another proof of the advantage to be derived from stopping to allow these dangerous meteors (if they may be so called) to get out of your way. I have no doubt that it helped us some days, for it commenced where we might have had light airs and calms, between the westerly and northeastly monsoons, enabling us to make a run of 200 miles to the north.

Since writing the above, Captain Johnstone, of the Minerva, has favored me with an extract from the log of his ship; and finding an extract from the Stamboul's log in the Madras Spectator of December 29, 1856, I here give the positions of each ship at noon of the 8th and 9th, accompanying them by a diagram.

Gloriana.	Minerva.	Stamboul.
December 8. By observation, latitude 12° 36′ N. Longitude 83° 56′ E. Barometer 29.862; thermometer 78°. Wind E.SE.; force 6 to 8. 3 P. M. Hove to on the starboard tack; head to northward and eastward.	Madras roads. 2 P. M. Barometer 29.94. Wind NE. 3 P. M. Stood to sea under close reefed foresail, on port tack, head to southward and eastward.	Madras roads. 4 P. M. Barometer 29.80. Wind N.NE. 4 P. M. Slipped and put to sea under double reefs; close reefed at 11 P. M.
December 9. Latitude 13° 37′ N. Longitude 82° 52′ E. Barometer 29.988; thermometer 80°. Wind E SE.; force 6 to 7. Sea much confused. 6 A. M. of this date, kept away a straight course for Madras.	By dead reckoning, Latitude 12° 31′ N. Longitude 80° 40′ E. Barometer 29.71. Wind SE. At 9 A. M. had the lowest barometer, 29.68; wind E.SE. Gale raging fearfully; sea much confused; wore ship on the starboard tack; from this time the weather improved, and the barometer rose.	Supposed, by sight of Pondicherry, latitude about 11° 56′ N. Longitude 80° 10′. Barometer 29 40. Wind E., drawing to S of E. 1 P. M. Wind S. SW.; wore ship on the starboard tack. 2 P. M. Blowing a hurricane from SW. The barometer rose suddenly to 29.58, from this time the weather improved. The sea ran from all points of the compass.

I suppose, from the wind changing with the Stamboul from east to southwest in two hours, that she must have been on the north side, but very near the centre of the cyclone, that, she, with her head to the southward, passed along the eastern side and still keeping very near the centre. I am also of opinion that at the same time the Gloriana was on the outer verge of the cyclone, which would give it a diameter of about six degrees and a half.



At 9 A. M. of December 9th the Minerva's log says "gale raging fearfully, and a heavy sea running ; wore ship on the starboard tack;" there the wind was east southeast and the barometer at its lowest ; from the time of wearing ship the weather improved and the barometer rose, because the Minerva was then steering directly from the centre.

With the Stamboul the barometer commenced rising after wearing, though she had very bad weather for some time afterwards ; the wind going from south southwest to southwest, after she got her head to the eastward looked as if the current drifted her round the cyclone faster than she made headway to the eastward. This would lead me to suppose that the centre of this hurricane met the land close to Pondicherry. It will be noticed how immediately these ships improved their weather by going on the starboard tack, which the land prevented them from doing sooner ; in fact, it seems to have been one of those cases where the ships were compelled to close with the centre of the storm."

§ 259. Extra-tropical Gales.—In the extra-tropical regions of each hemisphere furious gales of wind also occur. One of these, remarkable for its violent effects, was encountered on the 24th of December, 1853, about three hundred miles from Sandy Hook, latitude 39° north, longitude 70° west, by the San Francisco steam-ship, (§ 152.) That ship was made a complete wreck in a few moments, and she was abandoned by the survivors, after incredible hardships, exertions, and sufferings. Some months after this disaster, I received by the California mail the abstract log of the fine clipper ship Eagle Wing, (Ebnenezer H. Linnell,) from Boston to San Francisco. She encountered the ill-fated steamer's gale, and thus describes it:

"*December* 24, 1853. Latitude 39° 15′ north, longitude 62° 32′ west. First part threatening weather; shortened sail: at 4 P. M. close-reefed the topsails and furled the courses. At 8 P. M. took in fore and mizen topsails; hove to under close-reefed main topsail and spencer, the ship lying with her lee rail under water, nearly on her beam ends. At 1 30 A. M. the fore and main top-gallant-masts went over the side, it blowing a perfect hurricane. At 8 A. M. moderated; a sea took away jib-boom and bowsprit cap. In my thirty-one years' experience at sea, I have never seen a typhoon or hurricane so severe. Lost two men overboard—saved one. Stove skylight, broke my barometer, &c. &c."

Severe gales in this part of the Atlantic—*i. e.* on the polar side of the calm belt of Cancer—rarely occur during the months of June, July, August and September. This appears to be the time when the fiends of the storm are most busily at work in the West Indies. During the remainder of the year, these extra-tropical gales, for the most part, come from the northwest. But the winter is the most famous season for these gales. That is the time when the Gulf Stream has brought the heat of summer and placed it (§ 151) in closest proximity to the extremest cold of the north. And there would, therefore, it would seem, be a conflict between these extremes; consequently, great disturbances in the air, and a violent rush from the cold to the warm.

§ 260. I have expressed the opinion that a cyclone, *i. e.*, that part of the storm which is revolving, never attains a diameter of a thousand miles, or anything like those great dimensions that are assigned to it by the advocates of the theory. This is conjecture; but those large diameters of the theorists are, also, matters of conjecture, for I have never yet seen the records of vessels that happened to be stationed round in a ring 1,000 miles in diameter, or 500, or even 300, in sufficient numbers, or in such a manner as to prove gyration, all around, at that distance. The wind may change its direction at that distance, as the theory requires, but it is easy to show that such change does not necessarily involve gyration; it may be a mere veering without any circular motion whatever.

It is well understood that the *tendency* of the wind is to blow always from the place of high barometer to the place of low. This is illustrated on a grand scale by the calm belts and trade-winds of the earth. The calm belt of the equator is the place of low barometer; the calms of Capricorn and Cancer of the high; the trade-wind blows from these into that where there is an ascent, an expansion, a cooling, and a perpetual condensation of vapor; here the place of low barometer is a line, a trough, a belt, and the winds blow from either side into it by straight courses; every current of air from the north side, for instance, approaches it on lines that are nearly parallel, so that the conditions of a gyratory motion are wanting in this case. These conditions are a circle or disk of low barometer, with a rush by converging courses and at not less than a certain velocity from all sides towards the middle.

Now, let us picture to ourselves the brewing of a hurricane at sea: the storm fiend commences its work, we know not how, with a low barometer and an upward current of air. If the form of this ascending current be circular, we shall have a rush of circumjacent air from the circumference all around to the centre; but if its form be in the shape of a long and narrow trough or band, as according to the Espy theory it is, then the wind will be directly towards it, and there will be no gyration.

But let us suppose the place of the low barometer to be round or square. Then the air that is nearest the place of ascent will be the first to go up; that which is circumjacent will take the place of this, and there will be a rush from all sides, and the motion, *i. e.* the place at which the air begins to move—will travel outwards like a circle on the water, from centre to circumference, the further from the centre the more feeble will be the rush.

The first rush of the wind being directly for the centre, this motion would not be converted into one of gyration until the centripetal winds from one direction should encounter those from another obliquely and at a considerable velocity. Then the gyration would, if the force of the wind were sufficient, commence, and from that moment the centripetal wind would begin to approach the centre in spirals.

How far from the centre would this spiral motion be commenced—500 miles? It is difficult to conceive such a thing.

On the contrary, it is easy to show that if a large disk of revolving air were put in motion around a centre of low barometer, the disk itself would be broken up by lateral pressure, which would force the revolving air up into the clouds, causing it to flow out at the top as fast as it poured in at the bottom. To illustrate: the low barometer is supposed to produce the centripetal motion of the air, which on its way is diverted by lateral forces into a spiral, centre-seeking, motion. Thus a centrifugal force is created which helps to sustain the low barometer. But this centrifugal force is impressed upon the revolving air as an outward pressure, tending all the while to enlarge the inner circumference of the whirl. On the other hand, the in-rushing air would press the other way and tend to make the outer circumference less; and so, between the two forces, the air of a revolving disk "hundreds of miles in diameter" would be pressed out of the whirling path of the vortex upwards before it could reach the centre; a mile or two of upward motion would get it clear, whereas, by the conditions of the problem, it would have to travel "hundreds of miles" horizontally—to do what? Why, to find a place of escape upwards.

In case of the miniature whirlwinds which we see sporting with the dust of the highways, there appears to be a numerical relation between the size of its vortex and the direction of the whirl, depending upon a dynamical law which remains to be developed. If the column of ascending dust be small, the diameter of the whirl which gathers that dust into the vortex is small; and always the larger the column of dust the greater will be the area about its base from which the dust is drawn in. The same is observed with regard to whirlpools in the water, the radius of the whirl exceeding the diameter of the "suck" a few times only, and the water as shown by the floating straws at a distance approaching the whirl by right lines and slow motion. All these whirls, whether in air or water, are obedient to the same dynamical laws.

§ 261. As we see many of these whirls in troubled waters, so it appears to me we may have several of them in a troubled atmosphere; at least I do not perceive why we should not.

That the cyclone theory, as expounded by its advocates, does not satisfy all the facts of the tornado, as vessels at sea report them, will appear evident to any one who will attempt to project the centre and path of a cyclone from the log-books of a number of vessels that are supposed to have been in one. At least I have never been able to reconcile the observations of such as I have attempted to project, according to this theory. That the theory is not wholly wrong I admit; but that it is perfect I cannot agree.

§ 262. A few days ago I received from an unknown correspondent the anemological record of several vessels that were evidently supposed to be in a cyclone in the China Seas between

Formosa and the "main," in 1856. The record was accompanied by a chart on which the supposed centre, diameter, and path of the storm were projected in pencil. Its diameter, according to that projection, was about 6°, (360 miles,) and its centre on the 30th of October, 1856, passed over the Macclesfield shoals. The storm was at its height on the 29th and 30th, and I copy the records from the 28th to the 31st, inclusive :

Ship "Spirit of the North."

Date.	Position at noon.		Barometer.	Thermom.	Wind.	Current.	Remarks.
	Latitude.	Longitude.					
1856.	° ′	° ′		°			
October 28	19 36	114 46	29.67	74	N.NE. to N.	S. 61 W. 65	In reef topsails, and in top-gallant sails. 29th, 1 a.m. Handed foresail. 7.45. Furled fore topsail. Hove to. 11. Furled mainsail. 2.45. Cut away fore topmast. 4.10. Main ditto. 30th, 2 a.m. Rain. 8 a.m. Cirrus 0. Noon. Cirrus 0.q. Midnight. Cirrus, stratus. 31st. Light fine. Noon. b. c. p. Midnight. Cirrus and nimbus.
29	16 7	114 50	28.84	80	N.NW.	N.NE.	
30	16 0	115 0	29.34	79	S.SW.	W.	
31	16 14	116 36	....	79.5	S.	NW.	

Mail steamer "Singapore."

Date.	Position at noon.		Barometer.	Thermom.	Wind.	Current.	Remarks.
	Latitude.	Longitude.					
1856.	° ′	° ′					
October 28	13 0	112 30	29.90	....	N.NW.	....	Capt. Grainger never having experienced such a heavy sea.
29	14 30	112 41	29.77	....	NW.	....	

Steamship "Min."

Date.	Position at noon.		Barometer.	Thermom.	Wind.	Current.	Remarks.
	Latitude.	Longitude.					
1856.	° ′	° ′					
October 28	17 50	114 15	28.30	....	N.	....	The gale still increasing.
29	18 05	114 10	27.33	....	E. 12 Hurr.	SW.	The jib-boom and fore topmast blown completely out; the mainmast gone; the hands used up; and the engine-room and cabin full of water. Therefore unable to register barometer. 31st. Sea from all directions.
30	18 25	114 6	27.32	....	S.	....	
31	....	....	27.32	....	SW.	....	

Ship "Laughing Water."

Date.	Position at noon.		Barometer.	Thermom.	Wind.	Current.	Remarks.
	Latitude.	Longitude.					
1856.	° ′	° ′					
October 29	8 18	116 20	29.70	....	SW.	W.	
30	10 3	117 26	29.70	....	SW.	....	
31	10 35	118 10	29.70	....	SW.	....	Hot, sultry.

"David Brown."

Date.	Position at noon.		Barometer.	Thermom.	Wind.	Current.	Remarks.
	Latitude.	Longitude.					
1856.	° ′	° ′					
October 28	11 42	112 20	29.68	....	N. by W.	....	Strong wind throughout; gale E.NE.
29	12 25	115 10	29.67	....	W.NW.	....	Opens stronger, with wind N.NW. Stars seen through the night, but very dim. Sky looking very wicked. Hove too to allow storm to pass.
30	13 15	116 30	29.67	....	W.SW.	....	Bore up at 6 a. m.; stood E NE.; weather improving rapidly, but sea as bad as ever, being now in the storm's path; an awful sea.
31	15 46	116 55	29.75	....	W.SW.	....	Weather much improved. Fine to S.SE.

"Cygnet."

Date.	Position at noon.		Barometer.	Thermom.	Wind.	Current.	Remarks.
	Latitude.	Longitude.					
1856.	° ′	° ′					
October 28	15 18	118 20	....	....	....	....	Bare poles; hard rain.
29	17 13	117 20	28.70	....	SE. by S.	....	Hard rain; cross sea.
30	18 23	115 37	....	....	N.NE.	....	Close reefed main topsail.
31	19 42	115 51	....	....	E. by S.	....	Do. do. Heavy sea.

On the 25th the position of the steamer "Min," bound, I judge, to Hong Kong, was in latitude 16° 17′ N., longitude 114° 40′ E. Her position is not recorded again until November 1, when it was 19° 17′ N., and 113° 50′ E. Her position, therefore, on the 28th, 29th, and 30th had to be guessed at. It is supposed that, as she was a steamer, she did not depart far from the straight line between her position on the 25th and 1st. Upon this supposition she is assumed to be on the 28th, 29th, and 30th near the places assigned to her in the table above. At any rate, she had the lowest barometer of them all on these days, and is, therefore, supposed to have been nearest the vortex.

I requested Lieutenant Aulick to project the position of the vortex separately for each one of these records, according to the theory, denoting the direction of the wind by arrows flying with it, and pointing out, for each day, the bearing of the vortex with a hand. The annexed wood cut is the result.

By this it will be perceived that the centre from the "Spirit of the North" (A) bore N.NE. on 29th, W.NW. on the 30th.

David Brown, (B,) N.NE. on 29th, N.NW. on the 30th.

Cygnet, (C,) SW. on 29th, SE. on the 30th.

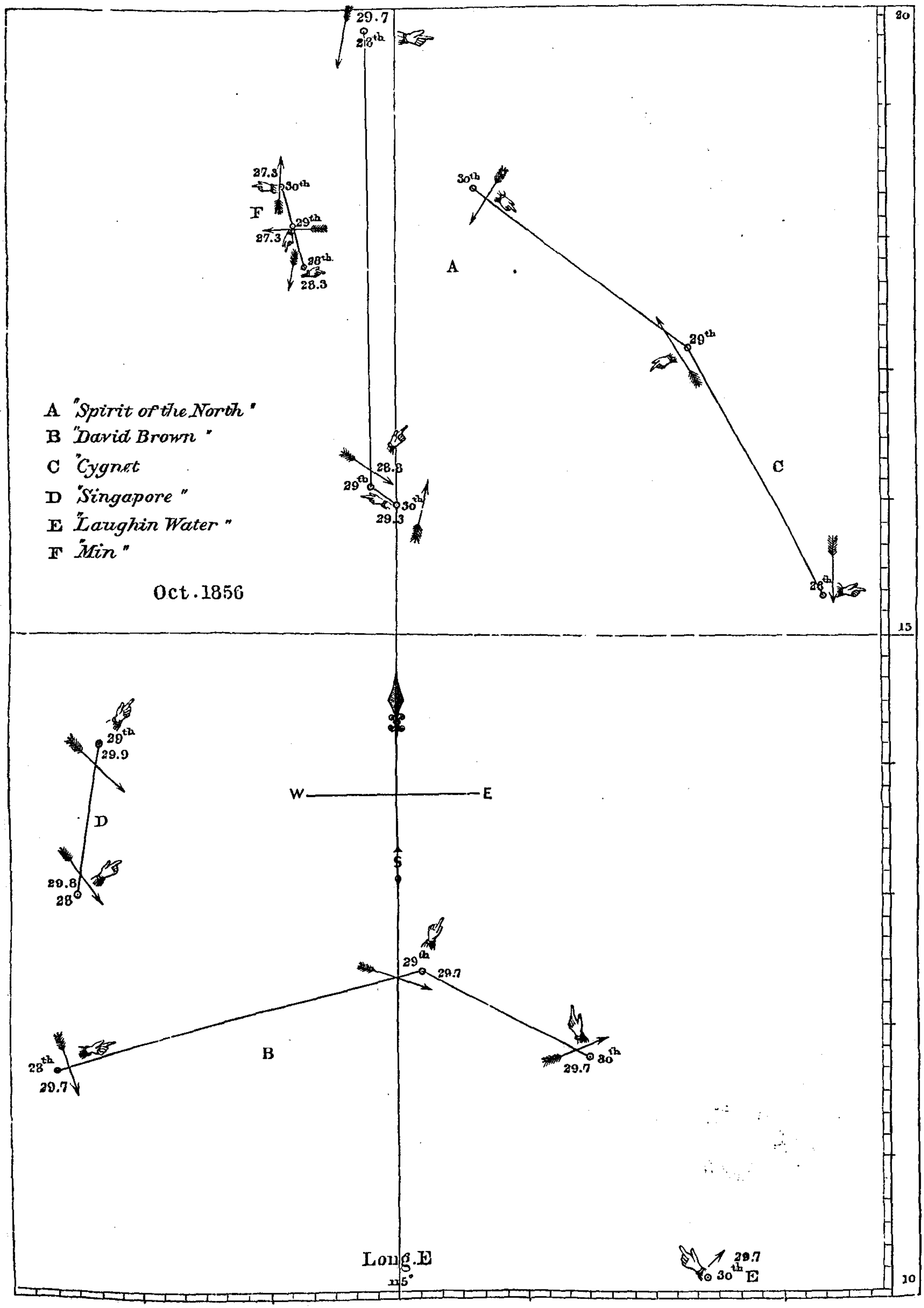
Singapore, (D,) N.NE., (agreeing with A.)

Laughing Water, (E,) NW. on 30th.

Min, (F,) S.SW. on 29th, W. on 30th.

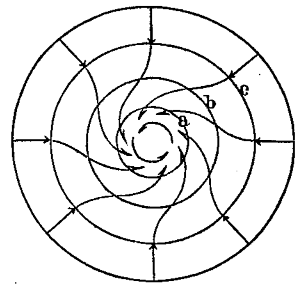
On the 28th, when the storm was rising, the five vessels—barometer with four being 29.7, and of the Min, 28.3—appear to have been west of the centre, for the hands all agree in pointing eastwardly that day. On the 29th none of them point to the Min, but four of them agree in making the centre between A and C, first where the low barometer of the Min shows it not to have been. On the 30th B points to Min as the centre, while A and C point in opposite directions, but neither of them towards the Min.

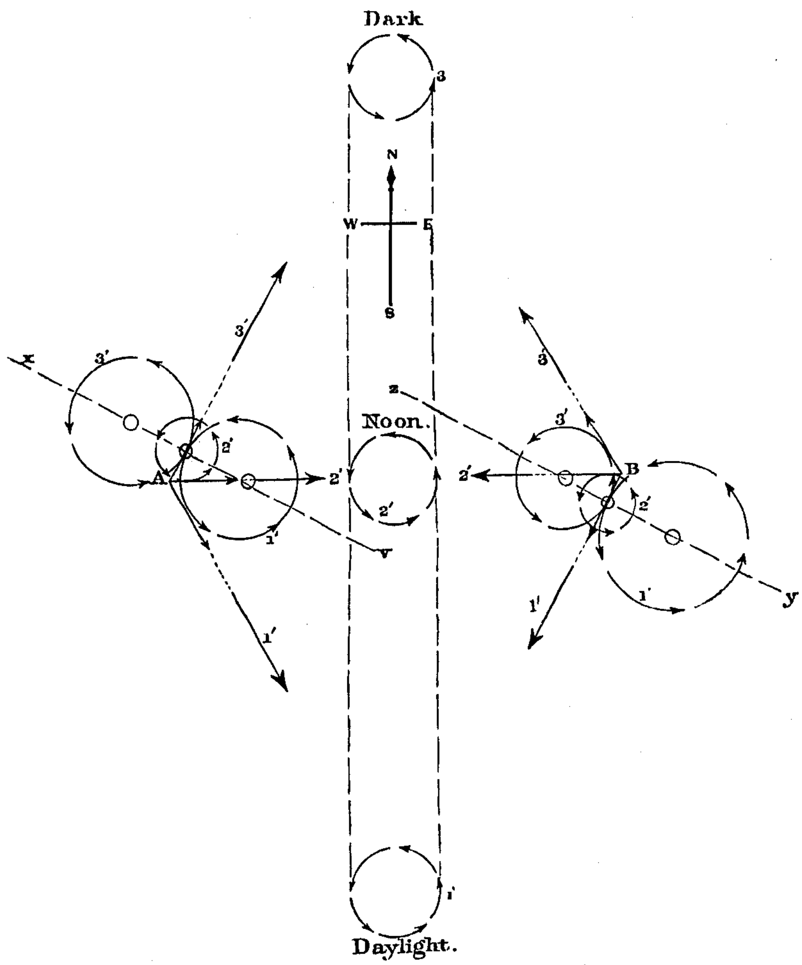
According to the Espy theory, all the vessels on the 28th, instead of being west, were north



of the place of low barometer. But on the 29th and 30th it is all confusion; the facts, as observed, failing to satisfy either theory.

§ 263. Why the wind should blow from a high to a low barometer is clear enough; but why it should blow at right angles with its point of destination, as the advocates of cyclones of large diameter require, is, I must confess, not so clear. Thus, let *a* be the vortex of a cyclone just forming; the air between *a* and *b* will rush in; but, coming from opposite sides with different impulses, the first intention, which is to go straight to the vortex, is defeated and a spiral motion is produced. In the meantime the air between *b* and *c* begins to feel the pressure, and it also takes up its line of march direct for the centre. Now, in order to impart a spiral motion to a fluid seeking a vortex, the in-rushing air must acquire a certain high velocity, and the higher the velocity the larger will be the vortex. This being admitted, we conclude that it is by no means all the wind that a cyclone raises which partakes of the gyratory movement; on the contrary, its veerings at places more than a certain distance from the centre may be accounted for by direct inward motion, instead of circular or spiral motion.





To illustrate this, suppose A and B to be two islands between which the revolving disk of a cyclone passes. It commences at daylight at 1 with its low barometer; the wind, both from A and B, is drawn towards it, as per arrows 1′ 1′. At noon it is at 2; the wind at the shore stations is still blowing towards this moving centre, as per arrows 2′ 2′; and, finally, by dark, it reaches the position 3′, and draws the wind after it, as per arrows 3′ 3′. Now, let us, according to the theory, project the path of this storm from the observations first of A, then of B.

The cyclonist would say, looking at the observations of A, it is the northern hemisphere—the wind gyrated against the sun—therefore, A was in the southwest quadrant of a cyclone; its centre, at the commencement, bore NE., and its path was in the direction of the line *v x*.

Then, looking at B, he would say, here the whirl was apparently with the sun; the observer was, consequently, in the NW. quadrant of the storm, with its centre to the SE., and its path in the direction *y z*. Thus, instead of making the wind blow directly towards the low barometer, he would make it to blow in spirals, as per the arrows, figures 1′, 2′, 3′.

Practically, in such a case as the one supposed, the direction of the wind from the outside stations would be to some point where the vortex *had* been; and the greater the distance the greater the aberration. Thus, a low barometer suddenly occurs at any place, *a;* it takes 10 minutes before the air 10 miles off, and 2 hours before the air 120 miles off, will become aware of it, so to speak, and commence to put itself in motion towards the place of low barometer. But suppose the vortex itself to be travelling at the rate of 30 miles an hour, the wind at the 10 mile station will blow towards a point 5 miles, and the wind at the 120 mile station will blow towards a point 60 miles in the rear of the vortex at any given moment.

The vortex of a cyclone is often and aptly compared to a meteor. I have often observed the paths of such through the forests of the Mississippi valley, and the path has, in no instance that has fallen under my observation, been more than a few hundred yards broad. There the track of these tornadoes is called a "wind road," because they make an avenue through the wood straight along, and as clear of trees as if the old denizens of the forest had been felled with an axe. I have seen trees three or four feet in diameter torn up by the roots, and the top with its limbs lying next the hole whence the roots came. Nevertheless, the passage of the meteor, whose narrow path was marked by devastation, would create a great commotion in the air, and there would be high winds raging for several miles on either side of the "wind road."

Let us consider for a moment the effect of the diurnal rotation of the earth upon one of these revolving discs 1,000 miles in diameter, its height would scarcely be two miles, and its thickness would not be as great, in proportion to its diameter, as half the thickness of this leaf is to the diameter of the circle, (page 279.) Now, the difference in the rate of the diurnal rotation between the northern and southern limbs of the disc would be sufficient, irrespective of the power spoken of, (page 275,) to break it up. Suppose its southern limb to be in 20° N., its northern limb would be 1,000 miles, say 17°, further north, that is in 37°. Diurnal rotation would carry to the east the air in the southern limb, at the rate of 845 miles an hour; but when this same air comes round on the northern limb, diurnal rotation would carry it eastward, at the rate only of 720 miles. Now, referring again to the diagram, page 279, it is plain that neither the observer at A nor at B would know at the time whether the wind with him was blowing around in a circle, or merely hauling in the usual way. I have drawn this diagram to show that *because* the wind hauls in a particular way, it does not follow that it is blowing in a circle, or that the centre of the storm is at right angles to its line of direction.

CHAPTER XIX.

DESCRIPTION OF THE CHARTS.

THE TRACK CHARTS.

The Charts, numbered series A, are the *Track Charts.* Charts of this letter have been published for the North Atlantic, in eight large sheets; for the South Atlantic, in six; for the North Pacific, in ten sheets—sheet one being mostly land, is without tracks; for the South Pacific, sheets one, five, nine, and ten have been published; and ten sheets for the Indian Ocean. The remaining numbers of this series, for the Pacific Ocean, are in process of construction. They are all on a scale 0.8 in. to a degree at the equator.

The different sheets of this series show at a glance the frequented and unfrequented parts of the ocean; they inform the navigator as to the general character of the wind and weather, the force and direction of the currents encountered by those who have preceded him in the same part of the ocean, and at the same season of the year.

This series, as far as published, is the work of Lieutenants Whiting, Humphreys, Porter, Wyman, Balch, Gibbon, Beaumont, Aulick, Welsh, Temple, Wells, Fillebrown, O. C. Badger, and Woolley; and of Professors Flye and Benedict, all of the navy.

THE TRADE-WIND CHARTS.

The Charts of the series marked letter B are illustrative of the trade-winds and the regions of calms and monsoons contiguous thereto. They are constructed according to a peculiar system of engraved squares.

This series, published only for the Atlantic, shows that the NE. trade-winds occupy a belt or zone extending in length from east to west across that ocean, having a variable breadth of from 17° to 35° of latitude. Its average mean breadth is about 23°, and in its extreme range it extends from 3° south to 35° north, according to the season of the year.

This zone makes two vibrations in a year. It reaches its extreme northern declination usually in September. Then returning, and following the sun, it reaches its southern extreme in March and April. Being stationary for two or three months, between 3° and 4° north, it commences to return north, and in the months of August, September and October, its other stationary period, it is seldom or never found to the south of the parallel of 9° N. The parallel of 9° N. may be taken as the mean limit of the equatorial border of the zone of NE. trades.

The SE. trade-winds occupy a similar zone in the South Atlantic, with a like vibratory motion. The mean equatorial limit of this zone, instead of being near the parallel of 9° south, to correspond with the zone of the northern hemisphere, is in about 3° north.

It is a remarkable phenomenon, well brought out in the course of these investigations, that the SE. trade-winds blow with more force than do their congeners of the northern hemisphere. They have force enough to push the latter with their belt back towards the north, intruding occasionally in the late summer, and in the early fall months, as far as the parallel of 9° north. Whereas, out of many thousands of records examined, it does not appear that the belt of NE. trade-winds in the Atlantic, is ever found to cross the parallel of 3° south.

The two zones of winds are characterized by a like difference of strength in the Pacific. The SE. trade-winds of the Atlantic Ocean have force enough to push their equatorial limits over into the northern hemisphere, and to maintain them there during the greater part of the year. The reverse is never the case; the NE. trades have not the force to crowd out the SE. trades, or to maintain themselves for any month of the year in the southern hemisphere.

The mean direction of what are called the NE. trade-winds is, as nearly as the observations which mariners usually furnish enable me to determine, N. 47° E.

By resolving the forces which it is supposed are the principal forces that put those winds in motion, viz: calorific action of the sun and diurnal rotation of the earth, we are led to the conclusion that the latter is much the greater of the two in its effects upon the trade-winds of the northern hemisphere. But not to such an extent is it greater in its effects upon those of the southern. We have seen that those two opposing currents of wind are so unequally balanced; that one recedes before the other; and that the current from the southern hemisphere is larger in volume, *i. e.*, it moves a greater zone or belt of air. The SE. trade-winds discharge themselves over the equator—*i. e.*, across a great circle—into the region of equatorial calms; while the NE. trade-winds discharge themselves into the same region over a parallel of latitude, and consequently over a small circle. If, therefore, we take what obtains in the Atlantic as the type of what obtains entirely around the earth, as it regards the trade-winds, we shall see that the SE. trade-winds keep in motion more air than the NE. do, by a quantity at least proportioned to the difference between the circumference of the earth at the equator and the circumference of the earth at the parallel of latitude of 9° N. For if we suppose that those two perpetual currents of air extend the same distance from the surface of the earth, and move with the same velocity, a greater volume from the south would flow across the equator in a given time than would flow from the north over the parallel of 9° in the same time; the ratio between the two quantities would be as rad. to the sec. of 9°. Besides this, the quantity of land lying within and to the north of the region of the NE. trade-winds is much greater than the quantity within and to the south of the region of the SE. trade-winds. In consequence of this, the mean level of the earth's surface within the region of the NE. trade-winds is, it may reasonably be supposed, somewhat above the mean level of that part which is within the region of the SE. trade-winds. And as the NE. trade-winds blow under the influence of a greater extent of land surface than the SE. trades do, the former are more obstructed in their course than the latter, by the forests, the mountain ranges, unequally heated surfaces, and other such like inequalities.

As already stated, the Charts show that the momentum of the SE. trade-winds is sufficient to push the equatorial limits of their northern congeners back into the northern hemisphere, and to keep them at a mean, as far north as the 9th parallel of north latitude. Besides this fact, our investigations also indicate that while the NE. trade-winds, so called, make an angle, in their general course, of about 43° with the equator, those of the SE. make an angle of 46° or more with the equator. I speak of those in the Atlantic; thus indicating that the latter approach the equator more directly in their course than do the other, and that, consequently, the effect of the diurnal rotation of the earth being the same for like parallels, north and south, the calorific influence of the sun exerts more power in giving motion to the southern than to the northern system of Atlantic trade-winds.

That such is the case in nature is rendered still more probable from this consideration: All the great deserts are in the northern hemisphere, and the land surface is also much greater on our side of the equator. The action of the sun upon these unequally absorbing and radiating surfaces in and behind, or to the northward of the NE. trades, probably tends to retard these winds, and to draw large volumes of the atmosphere, that otherwise would be moved by them, back to supply the partial vacuum made by the heat of the sun—as it pours down with active intensity its rays upon the vast plains of burning sands and unequally heated land surfaces—in our overheated hemisphere. The NW. winds of the southern are stronger than the SW. winds of the northern hemisphere.

The Charts show that the influence of the land upon the normal direction of the wind at sea is an immense influence. It is frequently traced for a thousand miles or more out upon the ocean.

For instance: The action of the sun's rays upon the great deserts and arid plains of Africa, in the summer and autumnal months, is such as to be felt nearly across the Atlantic Ocean, between the equator and the parallel of 13° north. Between this parallel and the equator, the trade-winds are turned back by the heated plains of Africa, and are caused to blow a regular southwardly monsoon for six months.

This monsoon is a circumstance which has been fully and completely developed by the Charts and the investigations connected with them. They (the monsoons) blow towards the coast of Africa, from June to November, inclusive. They bring the rains which divide the season in these parts of the African coast. The region of the ocean embraced by the monsoons is cuneiform in its shape, having its base resting upon Africa, and its apex stretching over seaward till within 10° or 15° of the mouth of the Amazon.

Indeed, when we come to study the effects of South America and Africa (as developed by these Charts) upon the winds at sea, we should be led to the conclusion—had the foot of civilized man never trod the interior of these two continents—that the climate of one is humid; that its valleys are for the most part covered with vegetation, which protects its surface from the sun's rays; while the plains of the other are arid and naked, and for the most part act like furnaces in drawing the winds from the sea to supply air for the ascending columns which rise from its overheated plains.

Pushing these facts and arguments still further, these beautiful and interesting researches seem already sufficient almost to justify the assertion that, were it not for the Great Desert of Sahara, and other arid plains of Africa, the western shores of that continent within the trade-wind region would be almost, if not altogether, as rainless and sterile as the desert itself.

These investigations, with their beautiful developments, eagerly captivate the mind; giving wings to the imagination, they teach us to regard the sandy desert, and arid plain, and the inland basins of the earth, as compensations in the great system of atmospherical circulation. Like counterpoises to the telescope, which the young astronomer at first sight, is so apt to regard as incumbrances to his instrument, these wastes are found to serve as make-weights, giving certainty and smoothness of motion, facility and accuracy to the workings of the machine.

The meteorological and physical researches with which the Wind and Current Charts are connected relate only to the sea. Already, the mariner has felt and acknowledged the importance of them. Commerce and navigation are reaping benefits from them of great moment. The merchants of Bombay, and American navigators, with that regard for the practical and useful which adorns their character and makes them renowned, were the first to come forward and volunteer to co-operate with me in collecting facts for the further prosecution of the work. Nations owning more than nineteen-twentieths of all the shipping in the world,—indeed, I might say every maritime nation of any consequence,—are now engaged in this work; so that more than a thousand ships are daily and hourly occupied in all parts of the ocean in making and recording each a prescribed series of observations upon the winds and the currents, the rains, the calms, the storms, the thunder and the lightning, the fogs, and clouds, and drift; the temperature of the air and water, and all other subjects and objects, facts and phenomena, which are of interest to navigation and to science.

Enough of abstract logs has already been collected at this office to make upwards of four hundred large folio volumes, averaging each from two to three thousand days' observations, and the number is constantly increasing; indeed, the materials increase faster than I have force to discuss them.

When we travel out upon the ocean, and get beyond the influence of the land upon the winds, we find ourselves in a field particularly favorable for studying the general laws of atmospherical circulation.

Here, beyond the reach of the great equatorial and polar currents of the sea, there are no unduly heated surfaces, no mountain ranges, or other obstructions to the circulation of the atmosphere; nothing to disturb it in its natural courses. The sea, therefore, is the field for observing the operations of the general laws which govern the atmospheric circulation. Observations on the land will enable us to discover the exceptions. But from the sea we shall get the rule. On the land, each valley, every mountain range and local district, may be said to have its own peculiar system of calms, winds, rains, and droughts. But not so the surface of the broad ocean.

In this connexion I beg leave to call the attention of meteorologists on shore to the importance of introducing a special column in their journals, to show what are the rainy winds at each station, and for each season of the year.

Upon every water-shed which is drained into the sea, the precipitation may be considered as greater than the evaporation for the whole extent of the shed so drained, by the amount of water which runs off into the sea. In this view, all rivers may be regarded as immense rain-gauges, and the volume of water annually discharged by any one, as an expression of the quantity which is annually evaporated from the sea, carried back by the winds, and precipitated throughout the whole extent of the valley that is drained by it. Now, if we knew the rain winds from the dry, for each locality and season generally throughout such a basin, we should be enabled to determine, with some degree of probability, at least, as to the part of the ocean from which such rains were evaporated. And thus, notwithstanding all the eddies caused by mountain chains, and other uneven surfaces, we might detect the general course of the atmospherical circulation over the land as well as the sea, and make the general courses of circulation in each valley as obvious to the mind of the philosopher as is the current of the Mississippi, or of any other great river, to his senses. That river so abounds with eddies, that it is difficult to tell by regarding small portions of its surface only, which way the water is flowing. But when we come to regard the drift-wood and the whole river, we are left in no doubt as to the onward course of the main stream itself, with all its eddies and whirlpools.

These investigations as to the winds at sea indicate that the vapors which supply the sources of the Amazon with rain are taken up from the Atlantic Ocean by the NE. and SE. trade-winds;—

These investigations show that the trade-wind regions of the ocean, beyond the immediate vicinity of the land, are, for the most part, rainless regions ; and that the trade-wind zones may be described, in an hyetographic sense, as the evaporating regions ;—

They also show, or rather indicate as a general rule, that, leaving the polar limits of the two trade-wind systems, and approaching the nearest pole, the precipitation is greater than the evaporation, until the point of maximum cold is reached ;—

They also indicate, as a *general* rule, that the SE. and NE. trade-winds, which come from a lower and go to a higher temperature, are the evaporating winds, *i. e.*, they evaporate more than they precipitate ; while those winds which come from a higher and go to a lower temperature are the rain winds, *i. e.*, they precipitate more than they evaporate. That such is the case, these Charts indicate ; reason teaches us ; and philosophy tells us it is so.

The results of these Charts, therefore, suggest the inquiry as to the sufficiency of the Atlantic, after supplying the sources of the Amazon and its tributaries with their waters, to supply also the sources of the Mississippi and the St. Lawrence, and of all the rivers, great and small, of North America and Europe.

A careful study of the rain winds, in connexion with the Wind and Current Charts, will probably indicate to us the "springs in the ocean," which supply the vapors for the rains that are carried off by those great rivers.

"All the rivers run into the sea ; yet the sea is not full ; unto the place from whence the rivers come, thither they return again."

Returning now to the trade winds of the Atlantic :—there is, between the two systems, a region of calms, known as the equatorial calms. It has a mean average breadth of about six degrees of latitude. In this region the air, which is brought along to the equator by the NE. and SE. trades, ascends.

If we liken the belt of equatorial calms to an immense atmospherical trough, extending, as it does, entirely around the earth, and if we liken the NE. and SE. trade-winds to two streams discharging themselves into it, we shall see that we have two currents perpetually running in at the bottom ; and that, therefore, we must have as much air as the two currents bring in at the bottom to flow out at the top. What flows out at the top is carried back north and south, by these upper currents, which are thus proved to exist and to flow counter to the trade-winds.

Using still further this mode of illustration ;—if we liken the calm belt of Cancer, and the calm belt of Capricorn, each to a great atmospherical trough extending around the earth also, we shall see that, in this case, the currents are running in at the top and out at the bottom ; here the current from the equator meets, in the upper regions, the current from the poles ; the two descend ; and the atmosphere, which they thus pour into these belts, runs out at the bottom—on one side towards the equator, as the perpetual trade-winds ; on the other, towards the poles, as the prevailing winds of the regions between these belts and the polar circles.

The belt of equatorial calms is a belt of constant precipitation. Captain Wilkes, of the Exploring Expedition, when he crossed it in 1838, found it to extend from 4° N. to 12° N. He was ten days in crossing it, and during those ten days rain fell to the depth of 6.15 inches, or at the rate of 18 feet and upwards during the year.

This belt of calms vibrates up and down the ocean as the belts of the trade-winds do. In the summer months it is found between the parallels of 8° and 14° of north latitude, and in the spring between 5° S. and 4° N.

By this chart the navigator can tell what places within the range of the zone have, during the year, two rainy seasons, what one and what are the rainy months for each locality.

Were the NE. and the SE. trades with the belt of equatorial calms of different colors, and visible to an astronomer in one of the planets, he might, by the motion of these belts or girdles alone, tell the seasons with us.

He would see them at one season going north, then appearing stationary, and then commencing their return to the south. But though he would observe that they follow the sun in his annual course, he would remark that they do not change their latitude as much as the sun does his declination; he would, therefore, discover that their extremes of declination are not so far asunder as the tropics of Cancer and Capricorn, though in certain seasons the changes from day to day are very great. He would observe that these zones of wind and calms have their tropics or stationary nodes, about which they linger nearly three months at a time; and that they pass from one of their tropics to the other in a little less than another three months. Thus he would observe the whole system of belts to go north from the latter part of May till some time in August. Then they would stop and remain stationary till winter, in December; when again they would commence to move rapidly over the ocean, and down towards the south, until the last of February or the first of March; then again they would become stationary, and remain about this, their southern tropic, till May again.

The zone of the SE. trade-winds would present to him its northern edge inclined somewhat to the equator; commencing near the coast of Africa, and tracing the usual outlines of this edge over towards South America, he would discover that it approached the equator at an angle of about 18°; and our supposed astronomer would announce that the equatorial edge of the zone of SE. trades in the Atlantic is inclined towards the equator at an angle of 15°—that it lies W. 15° N., and E. 15° S.

Turning his attention now to the belt of NE. trade-winds, he would observe the equatorial edge of this zone to be somewhat, though not altogether, symmetrical with the equatorial edge of the SE. trade-wind zone of the other hemisphere. On the African side it is furthest from the equator, which it approaches at an angle of about 10°, (W. by S.,) until it reaches the meridian of about 40° west. Here it is deflected to the north, and trends off in the direction of W.NW. Here we begin to experience the effect of the North American continent upon the trade-winds at sea. The rarefaction caused by the lands of northern Texas and the arid plains in that quarter is sufficient in summer to convert the NE. trades of the Gulf of Mexico into a prevailing wind from the southward and eastward.

In the Pacific, and within a certain distance from the land, the NE. trade-winds are, by the same influences, as these researches into the winds and currents of the sea have revealed, converted into a southerly monsoon.

By tracing on a chart the equatorial limits of the NE. and SE. trade-winds, as herein described, it will be perceived that there is left between the two systems a wedge-shaped band, having its broadest part on the African side of the Atlantic. The region of the ocean which the planetary astronomer would observe this band or belt to cover, is the region which is occupied by the equatorial calms and the African monsoons that fall between the systems of NE. and SE. trade-winds. And were the belt which represents these calms different from the rest as to color, the imaginary astronomer would see it as somewhat of an irregular curve, not having the northern and southern edges concentric. The concave side of this curved belt is turned to the E. of N., and has its centre near the shores of Greenland.

As before remarked, the newly discovered monsoons of the North Atlantic Ocean also come within the belt of equatorial calms. They give the peculiar wedge-shaped form to the regions between the two systems of trade-winds.

Having completed the physical examination of the equatorial calms and winds, if the supposed observer from some distant sphere should now turn his telescope towards the poles of our earth, he would observe a zone of calms bordering the NE. trade-winds on the north, and another bordering the SE. trade-winds on the south. These calm zones also would be observed to vibrate up and down with the trade-wind zones, partaking of their motions, and following the declination of the sun.

On the polar side of each of these two calm zones there would be a broad band extending up into the polar regions, the prevailing winds within which are the opposites of the trade-winds, viz: SW. in the northern and NW. in the southern hemisphere.

The equatorial edge of these calm belts is near the tropics, and their average breadth is 10° or 12°. On one side of these belts the winds blow perpetually towards the equator; on the other, their prevailing direction is towards the poles.

These belts, therefore, may also be considered as nodes in the general system of atmospherical circulation.

The atmosphere, which the NE. and SE. trade-winds keep in perpetual motion towards the equator, has for its node the equatorial calms. Here it ascends, boils over, divides, and flows off in the upper regions of the atmosphere, one part going to the northern, the other to the southern hemisphere, to complete the "circuit of the winds," and to supply the sources of the trade-winds with air.

Arrived near the Tropic of Cancer, the northern currents meet, in the upper regions of the atmosphere, the return current, which the prevailing winds of the north temperate zone have carried, as a surface current, to the hyperborean regions of the north. These two currents produce another node or calm region, in which the atmosphere descends, and from which it issues both to the north and the south, assuming, on one side, the character of NE. trades; on the other, the character of the SW. passage winds.

This node has its fellow in the southern hemisphere, where there is a like meeting of upper currents; only from one side of the zone of the calms of Capricorn the wind issues as the SE. trades; from the other as the NW. passage winds of that part of the southern hemisphere which is extra-tropical.—See Plate III, in which the two outer lines, marked A, B, and so on, are drawn to represent the vertical, and the arrows on the shaded ground the horizontal motion of the atmosphere.

Along the polar borders of these two calm belts we have another region of precipitation, though generally the rains here are not so constant as they are in the equatorial calms. The precipitation near the tropical calms is, nevertheless, sufficient to mark the season; for whenever these calm zones, as they go from north to south with the sun, leave a given parallel, the rainy season of that parallel, if it be in winter, is said to commence. Hence we may explain the rainy season in Chili at the south, and in California at the north.

This letter of the series of the Charts will enable any one who consults it to tell to what places the tropical calms bring rain, and in what months the rainy season commences and ends, for any parallel.

To complete the physical examination of the earth's atmosphere, which we have supposed an astronomer in one of the planets to have undertaken, according to the facts developed by the Wind and Current Charts, it remains for him to turn his telescope upon the icy regions of the poles. (For that *we* should complete the examination in this respect, it would be necessary to obtain the log-books of ships in the anti-commercial regions of the ocean, which we cannot do. As the sea is most open near the south pole, the principle of the general law of atmospherical circulation would be better developed probably by observations in the antarctic, than in the arctic regions.)

For the want of such observations, but with the light which these Charts throw on the subject for our guide, let us pursue the SW. passage winds of the northern hemisphere into the arctic regions, and see theoretically, with the imaginary telescope, how they get there; and, being there, what becomes of them.

From the parallel of 40° up towards the north pole, the prevailing winds in the northern hemisphere, as already remarked, are the SW. passage winds, or, as they are more generally called by mariners, the "westerly" winds; these, in the Atlantic, prevail over the "easterly" winds, in the ratio of about two to one.

Now, if we suppose, and such is probably the case, these "westerly" winds to convey in two days a greater volume of atmosphere towards the arctic circle than those "easterly" winds can bring back in one, we establish the necessity for an upper current by which this difference may be returned to the tropical calms of our hemisphere. Therefore, there must be some place in the polar regions at which these SW. winds cease to go north, and from which they commence their return to the south, and this locality must be in a region peculiarly liable to calms. It is another atmospherical node in which the motion of the air is upward, with a decrease of barometric pressure. It is marked P, Plate III.

If we now return to the calm belt of the northern tropic, and trace theoretically a portion of air that, in its circuit, shall fairly represent the average course of these SW. passage winds, we shall see that it approaches the pole in a loxodromic curve; that as it approaches the pole it acquires, from the spiral convolutions of this curve which represents its path, a whirling motion, in a direction *contrary* to that of the hands of a clock; and that the portion of atmosphere whose path we are following would gradually contract its gyrations, until it would finally ascend, turning against the hands of a watch, as it whirls around.

After reaching the upper regions of the atmosphere, through this whirl, its course would be to the southward; or rather, owing to the effect of the axial rotation of the earth, its course would be from the northward and eastward, until it should meet also in the upper regions a like portion from the ascending node, formed in the calms near the equator. This meeting in the upper regions of the atmosphere, as already remarked, takes place in the zone of the calms of Cancer. Here the two currents, the one from the poles, the other from the equator, balance each other, produce a calm, or the descending node for the northern hemisphere, with an increase of barometric pressure.

In the southern hemisphere a like process is going on; only there, the NW. passage wind would, as it arrives near the antarctic calms, acquire a motion with the sun, or in the direction of the hands of a watch.

That such is the case, the investigations that are carried on here do not prove; but they, and a process of reasoning guided by analogy and derived from what they do show, suggest that such is *probably* the case.

The general course of the circulation of the atmosphere, as partly established and partly suggested by these researches and other sources of information, is an upper current from the poles, as far as the tropical calms, towards the equator; thence a descent and a surface current (NE. and SE. trades,) to the equatorial calms. Here an ascent takes place, through which air is supplied for an upper current each way towards the poles, as far as the zone of tropical calms. Here there is a descent, and a continuation towards the polar regions as a surface current (SW. passage winds in the northern, NW. in the southern hemisphere,) until it approaches, in part, the calms of the arctic and antarctic regions. Here it commences to whirl about in the manner already stated, forming the supposed polar calms, in which it ascends, and so commences its return towards the equator by reversing the circuit just described.—(*Vide* Plate III.)

The further my investigations concerning the physics of the sea are carried, the greater is the accumulation of facts and circumstances which seem to indicate that the rivers and fresh water of the northern, temperate, and frigid zones, are, for the most part, evaporated from the south torrid; or, more properly speaking, that they are taken up from sea by the SE. trade-winds. Such, at least, is the indication; and certain facts so tend in their bearings as to convert this indication into a conclusion that does not appear altogether forced.

As a general rule, most of the land is in the northern, and most of the water in the southern hemisphere. But, notwithstanding the absence of evaporating surface in the northern hemisphere, most of the precipitation takes place there, if we regard the waters that are discharged into the ocean by the rivers as an expression of the excess of the precipitation over the evaporation that takes place in the basins drained by these rivers. The basin of the Amazon is in both hemispheres; it is, therefore, common, and should not be counted as peculiar to either. The Rio de la Plata is the only great river, then, in the southern hemisphere; whereas, in the northern, are all the rivers, great and small, which give drainage to Europe, Asia, and America.

The question then comes up: Does the Atlantic afford evaporating surface sufficient to supply all the rivers of Europe and America with rain water; and, if so, by what winds do the vapors that make these rains travel both east and west from the same place?

Very little of America, and no part of Europe, is within the region of the NE. trade-winds; and the trades, because they come from a colder and go to a warmer climate, are eminently evaporating winds. But how is it to the north of the NE. trade-winds, where, on the surface of the earth, the SW. are the prevailing winds? Here, as a general remark, the winds are going from a warmer to a colder climate, and, therefore, ought, it would seem, to precipitate more than they evaporate. Thus, take the isotherm of 60° Fahr. in the Atlantic, as an example; the mean dew-point, we will suppose, along this line is between 50° and 60°, or at any other degree below 60°, suppose 55°, that we may choose for the illustration.

Now, let us proceed still further north in this ocean until we reach the isotherm of 30°; on this line the mean dew-point must be below 30°, how much we cannot say, nor is it material for the illustration that we should say. It is certainly below the mean dew-point of 60°. Now, what becomes of the vapor that has caused the mean dew-point of the isotherm of 60° to change to that which belongs to the isotherm of 30°? It has been precipitated, and the capacity of the air to retain moisture has been lessened proportionably. In thus viewing the case, the question arises: Whence are the vapors taken which supply with rain the sources of the rivers of the north temperate and frigid zones?

I wish to be understood as speaking in general terms, without regard to any of the exceptions caused by anomalies, such as the Gulf Stream, and the like.

Where the NE. and SE. trade-winds meet, they produce what is known as a belt of equatorial calms. This is one of the valves in the great atmospherical machine through which the air that is brought from the north and the south by these trade-winds rises and escapes into the upper regions of the atmosphere, and thence returns to supply the sources of the trades with fresh air to make more winds of.

Now, the question is: Does the air which is brought to this valve by the SE. trades continue on towards the north in the upper regions of the atmosphere, while that which comes down as the NE. trades continues on towards the south, in like manner; or does the air which the SE. trades bring to this calm place rise up and return to the south; or does the air of the two trades intermingle here and go, a part of it indiscriminately, either to the north or to the south, as chance may determine?

I am inclined to favor an affirmative reply to the first of these interrogatories, and for these reasons, in addition to those already alluded to:

1. Winter, late fall, and early spring, are the seasons of our greatest precipitation; and this is the time when the sun is pumping up the vapor with the greatest energy from the southern, and with the least from the northern oceans; and so, too, when the sun is pumping up vapor from the northern hemisphere with all his energies, precipitation is most active in the southern.

2. The belt or band over which the SE. trades prevail is much broader than that over which the NE. trades prevail; consequently, supposing the velocity of each trade wind to be the same, or nearly the same, the SE. trade takes up more moisture, because it sweeps over a broader belt of ocean; and sweeping over a broader belt it remains longer in contact with the evaporating surface, and, consequently, it may be supposed it brings more moisture to the belt of equatorial calms, whence the ascent takes place.

A large portion of this moisture is deposited in the equatorial calms, which we know is a region of constant precipitation. But where is the rest precipitated; in the northern or southern hemisphere? In the former, I suppose; because the rivers and the rain-gauge, as far as it has been observed, tell us that the total amount of precipitation in the northern is greater than that in the southern hemisphere; indeed, it is not necessary to consult the rain-gauge to learn this; the rivers themselves are sufficient rain-gauges for this purpose; for we have only to consider the volume of water annually discharged into the ocean by northern rivers to see in it an expression for an amount by which the total precipitation is in excess of the total evaporation which takes place in the whole extent of valleys drained by such rivers. Search the southern hemisphere for a like quantity, and the search will be in vain.

Seeing, moreover, that the southern hemisphere has more water and less land than the northern, that it has less rain and fewer rivers, it seems as though, in likening the atmosphere to an immense machine, we might call the southern seas the boiler, and the northern continent the condenser for the mighty engine.

There is, perhaps, another point upon which an argument, not altogether without plausi bility, may be turned in favor of this hypothesis.

The grounds for this argument are drawn from probability, and the argument itself rests on the degree of belief and faith we have in the perfection of terrestrial adaptations.

To state the argument in this point of view, we must consider the atmosphere not only as a great condensing machine, but as an immense sewer, in which vast quantities of corrupt animal and vegetable matter are continually being cast for re-elaboration, purification, re-arrangement, and readaptation to the purposes of the animal and vegetable kingdoms.

Notwithstanding the quantity of matter that the plants and animals of the earth are continually taking from the atmosphere on the one hand, and are as continually casting into it on the other, so admirably arranged is it, and so perfect its system of circulation—now across the seas, now through forests, and again over deserts, burning sands, and frozen heights—that its proportions are never destroyed.

In this system of purification and preservation we know that vegetation in active growth has much to do.

Now, then, if we consider that the NE. trade-winds, when they arrive at the equator, ascend, return to the north in the upper regions until they reach the parallel of 30° or 40° north, where they descend to the surface, and are known as what the Germans style the SW. passage winds, if, I say, this be the course of atmospherical circulation, we shall see that the air in our winter time, when vegetation is asleep with us, would probably not be exposed to the process necessary for its purification; and, finally, if such were the system of circulation, the atmosphere of the northern hemisphere would, in process of ages, probably become different from that of the southern hemisphere.*

We have no reason to believe in the existence of any such change in the components of the atmosphere; and I had almost said, *therefore*, in any such partial system of circulation.

On the other hand: If we maintain that the SE. trade-winds flow north, after ascending

* The extra-tropical regions of the north have much more land, and, therefore, it may be supposed many more organs than the south to breathe, consume, and vitiate the atmosphere; consequently, in any given time, as in a northern winter, the demands upon the atmosphere are very unequal on opposite sides of the equator. On one side the animal kingdom is exacting from it in excess; on the other—the southern summer—the vegetable makes the largest demands.

Speaking in general terms it may be said that man, with his retinue of domestic animals, counts in the south but as one in a thousand to his hosts at the north. These myriads of warm-blooded animals in the northern hemisphere, with the fires kindled by man in our winter, leave us to infer that more air is required for animal consumption and combustion on one side of the equator than on the other, especially in the northern winter.

The air thus used loses the proportions of gaseous combinations required to make it wholesome; whence, therefore, is it purified? Not by the vegetation of the extra-tropical north, certainly, for its vegetation is then asleep.

But if we make this air return to the south by the route suggested, it will pass through the NE. trade-wind regions, and be partly replenished by the perpetually active vegetation there. Then rising in the equatorial calms and overleaping, in the upper regions, the SE. trades, it descends to the surface in the extra-tropical south, where it is summer, and where the forces of vegetation are in their most active operation.

Returning in the upper regions towards the north, still more refreshed from this part of its circuit, it first strikes the surface again as the SE. trades, where vegetation is again perpetually active. Being now completely purified, it rises up again in the equatorial calms, overleaps, in the upper regions, the NE. trades, and descends in the extra-tropical north, fresh with supplies in wholesome proportions for breathing lungs and winter fires.

And thus, though we cannot tell the reason why this earth was provided with zones of perpetual summer, alternate winter, and opposite seasons, we may, nevertheless, see through the atmosphere one of the purposes for which this arrangement of seasons, combination of climates, and proportion of vegetable surface was intended to subserve.

In this view we see room for the harmony of nature. We have not a single physical fact going to prove that such is *not* the course of the circulation of the atmosphere about the surface of the earth; but we have many facts and circumstances which, though they do not prove, yet they suggest that such is the course.

Thus, using a figure of speech, we may liken these evergreen places through which the winds go and return, to the lungs of the earth, with their three lobes; one in each of the trade-wind regions, and one now at the north, now at the south, changing from one side to the other, as the summer comes and goes.—M. F. M.

into the upper regions of the atmosphere, through the equatorial calms; and that it is those winds, and not the NE. trades, that in their circuit blow our SW. passage winds; if, I say, we maintain this, we shall see the beautiful adaptation for exposing them to the proper and wholesome vegetable agencies. Our winter is the southern summer; then the SE. trades blow through the southern forests, which are then in their stage of activity.

Arrived at the equator—properly prepared for the use of the inhabitants of the north temperate and frigid zones—they ascend into the clouds; and, after reaching the parallel of 30° N., they descend, and are then felt as the vigorous, wholesome, and healthful SW. passage winds of the northern winter. Continuing on towards the north frigid zone, they perform their office for the inhabitants of those inhospitable climates, and, approaching the polar regions in spirals, they whirl continually around or about the pole in a direction contrary to that of the hands of a watch.

Returning thence in the upper regions towards the south, as unfit for further use, they are next felt on the surface within or near the tropics, where vegetation is again in activity, to fit them for the inhabitants of that region. Reaching the equatorial calms, they ascend, and next appear on the surface in the south temperate zone as the NW. passage winds.

Continuing on towards the south pole, and approaching it in spirals, they whirl about, but in a direction *with* the hands of a watch, and opposite to that which they took about the north pole.

Ascending into the upper regions of the atmosphere, they are next felt on the surface as SE. trade-winds. Reaching the equator, ascending, and coming over into the northern hemisphere, they are again felt to the north of the NE. trades as the SW. passage winds.

Let us suppose that this part of the circuit from the antarctic regions be made in our summer, and of course in the southern winter, when the vegetation here is not so active in its demands upon this atmosphere in motion as it was in the other part of the supposed circuit. But then this same atmosphere, that has been but partially purified for northern use in the southern forests and fields, reaches us in our summer, when vegetation is in full activity, and when, therefore, all disproportions are properly compensated.

I have faith in the "Great First Thought." I believe that the animal and vegetable kingdoms are in exact counterpoise; that throughout the dominions of nature all things are in exact and rigid proportions; that there is not a green leaf too much on one side, nor an insect too many on the other. And because of this belief, I find plausibility and satisfaction in supposing that the general system of atmospherical circulation is as I been endeavoring to represent it.

In this belief I am strengthened by my reading of a text of Scripture (and the Bible cannot any more than Nature be wrong, for the Author of both is One,) which seems to apply to such a system of circulation:—

"The wind goeth toward the south, and turneth about unto the north; it whirleth about continually, and the wind returneth again according to his circuits."

Compare this with what I have already said, which my investigations taught me was the probable course of atmospheric circulation before I remembered me of what Solomon had said, and I think you will find with me, not proof, but grounds to suppose that such may be the system of atmospheric circulation.

That we may pursue a little further some of the thoughts which the study of the winds and the sea in their adaption suggest, let us send the imagination on a voyage of exploration among the great river basins of the world, and listen to the report it brings back concerning some of the physical aspects presented there, and the forces that are at work in them.

The solid portions of the earth's crust are divided off into desert lands and river basins. Every acre of dry land, whether mountain, plain, or valley, belongs to one or the other of these two natural divisions.

The borders of the large river basins are generally fringed with hills, sometimes with very high mountains. Thus the Cordilleras of South America form a magnificent border on the west to the basins of the Amazon and La Plata; while the Rocky Mountains and Alleghanies hedge in the Mississippi on both the west and the east, and give shape to its drainage.

The peculiarities of a river basin impress striking characteristics upon a country. Those of America give very prominent features to our landscapes. The pioneers of the west, with their quick eye and keen perceptions, were not slow in recognizing these peculiarities, and in turning them to practical account; the elevation which divides the waters of one river or stream from the waters of another they called "the divide;" and the slope from which the drainage was collected into a river was termed a "water-shed."

Thus, natural landmarks were afforded for laying out the wilderness into convenient and easily recognizable divisions.

The hydrographic basins of all large rivers, as the Mississippi, are corrugated in every direction with ridges and ravines, which constitute divides and water-sheds for every brook and streamlet that brings down its aqueous tribute to the main stream of the valley.

Hydrographic basin is a term in physical geography, and it is used to express what is commonly meant by the word valley in connexion with river drainage. Thus, the valley of the Mississippi is its hydrographic basin.

There are but ten rivers in the world whose hydrographic basins include an area of more than 500,000 square miles each. These are—

	Square miles.
The Amazon, including the Tocantines and Oronoco	2,048,000
Mississippi	982,000
La Plata	886,000
Yenisei	785,000
Obi	725,000
Lena	594,000
Amoor	583,000
Yang-tse-kiang	548,000
Hoang-ho	537,000
Nile	520,000

These areas are stated in round numbers and according to the best authorities.

The basin of the Amazon is usually computed at 1,512,000 square miles, but such computation excludes the Tocantines, 204,000 square miles, which joins the Amazon near its mouth, and the Oronoco, with a hydrographic area of 252,000 square miles, which, by means of the Casiquiere, is connected also with the Amazon. We think that these three rivers should all be regarded as belonging to one hydrographic basin; for a canoe may pass inland from any one to either of the others without portage.

Of these hydrographic basins, three, including an area of 3,916,000 square miles, are American; six, which contain an area of 3,772,000 square miles, belong to Asia, one to Africa, and none to Europe.

The three largest rivers of Asia, the Yenesee, Obi, and Lena, (2,104,000 square miles,) discharge their waters into the Arctic Ocean, and are therefore out of the reach of the commercial world; consequently they do not possess the interest which, in the minds of men generally, is attached to the rest. The three others of Asia drain 1,668,000 square miles, and run into the Pacific; while the whole American system feed with their waters and their commerce the Atlantic Ocean.

These rivers, with their springs, give drink to man and beast, and with their waters, nourishment to plant sand reptiles, with fish and fowl not a few. The capacity of their basins for production and wealth is without limits. These streams are the great arteries of inland commerce. Were they to dry up, the harmonies of the earth would be destroyed, and that beautiful arrangement, and by which climates are regulated, physical forces adapted to terrestrial machinery, would lose its adjustment and run wild like a watch without a balance.

We see these majestic streams pouring their waters into the sea, but from the sea we know these waters must come again, else the sea would be full. We know, also, that the sunbeam and the sea breeze suck them up again; and it is curious to fancy such volumes of water, as this mighty company of ten great rivers is continually discharging into the sea, taken up by the winds and the sun and borne away through the invisible channels of the air to the springs among the hills, that are the sources of all rivers. This operation is perpetually going on, yet we perceive it not; for few are they who have ever thought much about it.

Let *us* think a moment about it; and that we may be enabled to appreciate the majesty of the forces employed, and to comprehend the magnitude and grandeur of their operations, let us inquire how much rain falls annually upon the water-sheds of one of these streams, as of the Mississippi, how much is carried off by the river, how much is taken up by evaporation, and how much heat is evolved in hoisting up and letting down all this water. At another time we may inquire for the springs in the sea that feed the clouds with rain for these rivers.

If we had a pool of water one mile square, and six inches deep, to be evaporated by artificial heat, and if we wished to find out how much would be required for the purpose, we should be told by those who profess to know that it would require about as much as is evolved in the combustion of two millions and a half of tons of coal. Thus we obtain a unit of measure to help us in our calculation; for if the number of square miles contained in the Mississippi Valley and the number of inches of rain that falls upon it annually be given, then it will be easy to tell how many of such huge measures of heat are set free during the annual operation of condensing the rain for our hydrographic basin. And then, if we could tell how many inches of this rain water are again taken up by evaporation, we should have the data for determining the number of these monstrous measures of heat that are employed for that operation also.

The area of the Mississippi Valley is said by physical geographers to embrace 982,000 square miles; and upon every square mile there is an annual average fall of rain 40 inches deep. Now if we multiply 982,000 by the number of times 6 will go into 40, we shall have the number of our units of heat that are annually set free among the clouds that give rain to the Mississippi Valley. Thus the imagination is startled, and the mind overwhelmed with the announcement that the quantity of heat evolved from the vapors as they are condensed to supply the Mississippi Valley with water is as much as would be set free by the combustion of 6,546,666 times 2,500,000 tons of coal.

Mr. Russell, of Scotland, is our authority for the evaporating powers of 2,500,000 tons of coal; the Army Meteorological Register, published by the Surgeon General's office in 1855, is the authority on which we base our estimate as to the average annual fall of rain; and the annals of the National Observatory show that, according to the observations made by Lieut. Marr at Memphis, the annual fall of rain there is 49 inches, the annual evaporation 43, and the quantity of water that annually passes by in the Mississippi is 93 cubic miles. These observations of Marr are for one place. We shall have to expand them and combine them with others in order to apply them to the whole river and its water-sheds. Thus we obtain data for estimating the value of the quantities we are about to treat of. We shall state our data so much in detail that the reader may go over them himself and make his own calculations.

Since 1819 a regular series of meteorological observations has been conducted at the military posts of the country; and the Army Meteorological Register for 1855 contains a series of rain maps, the best ever published concerning the country. They were compiled by Lorin Blodget from the data furnished by the 36 years of army observations between 1819 and 1855; and according to these maps the mean annual fall of rain in the Mississippi Valley will strike an average of about 40 inches for all parts—in some places it is more, in others less, but the general average for the valley through is about 40 inches.

The water required to cover to the depth of 40 inches, an area of 982,000 square miles, would, if collected together in one place, make a sea one mile deep, with a superficial area of 620 square miles.

Now if we could find out how much of this annual supply is carried off by the river to the ea, swe might ascertain how much is taken up by evaporation and vegetation; or, conversely;—but disregarding the quantity used by the vegetable kingdom as too small an item to enter into a calculation of this sort—if we knew the amount of evaporation for the whole valley, we should be enabled to determine the quantity of water annually discharged by the river into the sea.

These are interesting physical questions which the spirit of research that is abroad cannot ignore.

Among the investigations which are recorded in the annals of the Observatory, there is contained a carefully conducted series of observations and experiments made by the late Lieutenant Robert A. Marr, at the Memphis navy yard; they show, as just stated, that the total annual quantity of water that passes down the Mississippi river opposite that city is 93 cubic miles, and that the annual amount of precipitation exceeds the annual amount of evaporation at that place, by about one-eighth; in other words, that of the 49 inches of rain that annually falls at Memphis, 6 inches run off by the river, and 43 are evaporated up again.

Marr's observations are very interesting and valuable, for he was a very reliable man, and they were carefully and patiently made.

He was a young naval officer of great promise. He was lost in the United States sloop-of-war *Albany*, when that ship went down at sea with all hands on board.

In 1850–'51, being stationed at the Memphis navy yard, he undertook, at my instance, a regular series of daily observations upon the weather and the river.

The observations for the quantity of water that daily passed by in the Mississippi were made in this way: The shape of the bottom and sides of the river, at a convenient place, were carefully ascertained from accurate survey. Then the daily stage of the river was noted, and experiments were made for 365 days consecutively upon the current in the middle and at the sides, at the bottom and at the top, with a view to ascertaining the velocity of the flow; knowing, then, the height of the water for each day, and the area of the cross section from the bottom to the top, he had a very good measure for the quantity of water that daily passed by.

These observations gave 93 cubic miles for that quantity, including the silt. Other tributaries, however, add their waters to the river below Memphis; we estimate these, after deducting for evaporation, to be sufficient to make the total quantity annually discharged by the river into the gulf somewhere between 105 and 109 cubic miles of mud and water.

The first named quantity (105) is obtained by adding one-eighth of the quantity of water passing by Memphis to the quantity that the river receives below that place; but if we allow one-sixth, the whole discharge would be the last named quantity, viz: 109 cubic miles. The actual average discharge is probably somewhere between the two. Let us assume it to be 107 cubic miles.

This, subtracted from the total quantity of rain in the basin, gives 513 cubic miles of water as the quantity which is annually evaporated from the hydrographical basin of the Mississippi. Hence we establish, as a general rule, that about one-seventh of all the rain that falls in the Mississsippi Valley is carried off by the river to the sea.

According to Marr's observations the total evaporation would be 542 cubic miles; but in his experiments a water surface was exposed to evaporation all the time; and the result shows the *capacity* of the climate for evaporation rather than the actual evaporation that takes place; for by reason of droughts, &c., the amount of actual evaporation, or the amount of vapor that rises from the surface of the 982,000 square miles of land in the valley of the Mississippi, must be considerably less than what it would be if that surface, like Marr's, was covered all the time with water.

It appears, therefore, from our most reliable observations, that rain, hail, and snow enough annually fall upon the Mississippi Valley to make, if it were collected into one place, 620 cubic miles of water, and that of this 513 are taken up again, and 107 discharged through the river into the sea. This statement gives in round numbers six-sevenths of the rain for vapor and vegetation, and what vegetation absorbs is ultimately given to the air.

Thus we make another step in our calculations; for if the average annual fall for the whole valley be 40 inches, about 34 will be taken up again, while 6 go to feed the springs and make the river.

The heat which is required to reconvert into vapor these 34 inches of water from our great hydrographic basin is as much as would be set free by a Cyclopean furnace during the consumption of 13,500,000,000,000 tons of coal. Yet the processes of nature are so wonderfully and exquisitely ordered, that the operation of converting this water into vapor and lifting it up is a cooling and refreshing operation, and not a heating or oppressive one. Arrived here in our voyage of exploration, we perceive that we have reached a point from which many new vistas begin to open up before us. Behold now the offices and the adaption of clouds and vapor. They do something more than fetch rain, brew storms, and send down thunder-bolts; they prevent the accumulation of heat on our planet by assisting the earth to send off its surplus caloric into the regions of space.

The amount of heat which is required to lift vapor enough from the sea to make 40 inches of rain all over the hydrographic basin of the Mississippi is more than is bottled away in all the coal fields of the country. The sea and air supplied it; the sun had accumulated it there radiation could not carry it off—so it was given for the conversion of these 40 inches of water into vapor, and when that vapor was reconverted into rain, this immense amount of heat was set free in the clouds, thence to be dispensed aloft, for very little of it comes down to the earth again.

From these statements we infer that there is an annual accumulation of heat in the great hydrographic basins of the earth, which the powers of terrestrial radiation are not sufficient to send away, but which the forces of evaporation are called in to carry off, and that were these forces to be suspended from their offices in any one of these basins, for one year only, as in that of the Mississippi, for instance, it would become like an oven, with a climate so hot and feverish that few could withstand it.

Kind and benignant vapors?—in your marvelous and manifold offices you bring us refreshing showers, and carry away the excessive heat. It is your office to govern the force of the burning ray; but for your wonderful adaptions our magnificent river-basins would not teem with plenty, nor the earth with her increase.

The northern hemisphere is warmer parallel for parallel than the southern, though the southern has so much more water. The hypothesis that the winds which blow the SE. trades do, when they rise up at the equator, cross over into the opposite hemisphere with the vapor for our clouds, receives additional plausibility from this fact. For, upon the supposition that the rains for our rivers come from the southern hemisphere, the heat on that side is bottled away in vapor, to be set free on this side; and that it is so, the hydrometer also (P. 256) suggests.

THE PILOT CHARTS.

Letter C of the series is a Chart of the Winds; it shows the point of the compass from which the wind blows in all parts of the ocean, and for every month in the year. The numbers of this series are called the "Pilot Charts," of which the North and South Atlantic, in two sheets each, and "Coast of Brazil within the Trade-Wind Region," in one sheet; Cape Horn Pilot, in two sheets; the Indian Ocean, in four sheets; five sheets of the North and four of the South Pacific are in the hands of co-operators; leaving to be published only sheet No. 4, North Pacific, and sheets Nos. 3 and 4, South Pacific. These are in hand, and will soon be ready for the engravers. See Plate I, as an illustration of the manner in which the figures for Plate II, are obtained.

The officers employed upon this series from time to time have been Lieutenants Herndon, Dulany, H. N. Harrison, Ball, Forrest, Guthrie, Deas, and Fitzgerald; Passed Midshipmen Davenport, Powell, De Koven, Wainwright, Balch, Roberts, De Krafft, Woolley, Jackson, Murdaugh, Semmes, Johnson and Lewis, Brooke, Wells, Terrett, and Professor Benedict.

The "Brazil Pilot" is on a scale, to the "field," of 2° of latitude by 1° of longitude, and extends from the equator to 23° S.

The rest of the series, except the Cape Horn Pilots, is on a scale of 5° to the "field:" that is, the ocean is divided off into districts or "fields" of 5° of latitude by 5° longitude.

These Charts, perhaps more than any other of the series, deserve a minute description; because, when sailing directions fail, they will supply the navigator with special information as it regards the direction of the winds for any month, and in any part of the ocean. He should consult them daily and diligently; and, that he may do so with facility, this explanation of them is offered.

In getting out from the log-books materials for these Charts, which show in every district of the ocean, and for every month, how navigators have found the winds to blow, it has been assumed that, in whatever part of one of these districts a navigator may be when he records the direction of the wind in his log, from that direction the wind was blowing at that time all over that district; and this is the only assumption that is permitted in the whole course of investigation.

Now, if the navigator will draw, or imagine to be drawn, in any such district, twelve vertical columns for the twelve months, and then sixteen horizontal lines through the same for the sixteen points of the compass, *i. e.*, for N., N.NE., NE., E.NE., and so on, omitting the *by*-points, he will have before him a picture of the "Investigating Chart" (Plate I,) out of which the "Pilot Charts" are constructed. In this case, the alternate points of the compass only are used; because, when sailing free, the direction of the wind is seldom given for such points as N. *by* E., W. *by* S., &c. Moreover, any attempt, for the present, at greater nicety, would be over-refinement; for navigators do not always make allowance for the aberration of the wind; in other words, they do not allow for the apparent change in the direction of the wind caused by the rate at which the vessel may be moving through the water, and the angle which her course makes with the true direction of the wind. Bearing this explanation in mind, the intelligent navigator will have no difficulty in understanding the wind diagram, (Plate III,) and in forming a correct opinion as to the degree of credit due to the fidelity with which the prevailing winds of the year are represented on Plate XV.

As the compiler wades through log-book after log-book, and scores down in column after column, and upon line after line, mark after mark, he at last finds that, under the month and for the course upon which he is about to make an entry, he has already made four marks or scores, thus (| | | |.) The one that he has now to enter will make the fifth, and he "scores and tallies," and so on, until all the abstracts relating to that part of the ocean upon which he is at work have been gone over, and his materials exhausted. These "five and tallies" are exhibited on Plate I.

Now, with this explanation, it will be seen that, in the district marked A, there have been examined the logs of vessels that, giving the direction of the wind for every eight hours, have altogether spent days enough to enable us to record the calms and the prevailing direction of the winds for eight hours, 2,144 times; of these, 285 were for the month of September; and of these 285 observations for September, the wind is reported as prevailing for as much as eight hours at a time: from N., 3 times; from N.NE., 1; NE., 2; E.NE., 1; E., 0.; E.SE., 1; SE., 4; S.SE., 2; S., 24; S.SW. 45; SW. 93; W.SW., 24; W., 47; W.NW., 17; NW., 15; N.NW., 1; Calms (the little 0's,) 5. Total, 285 for this month in this district.

The number expressed in figures denotes the whole number of observations of calms and winds together that are recorded for each month and district.

In C, the wind in May prevails one-third of the time from west. But in A, which is between the same parallels, the favorite quarter, for the same month is from S. to SW., the wind blowing one-third of the time from that quarter and only 10 out of 221 times from the west; or, on the average, it blows from the west only 1⅓ day during the month of May.

In B, notice the great "Sun Swing" of the winds in September, indicating that the change from summer to winter, in that region, is sudden and violent; from winter to summer, gentle and gradual.

In some districts of the ocean, more than a thousand observations have been discussed for a single month, whereas, with regard to others, not a single record is to be found in any of the numerous log-books at the National Observatory.

After all the materials on hand have been exhausted for the investigating sheet, its "scores and tallies" are summed up for each of the 16 points, and separately also for each month, and recorded in Arabic numerals. They are now ready to be transferred to the wind-roses of the Pilot Chart, which, it may be seen by reference to Plate II, consist of a number of engraved squares, without regard to the figure of the earth, and with four inscribed concentric circles in each; and in these circles are radii, drawn so as to represent every alternate point of the compass-card, thus: N., N.NE., NE., E.NE., E.; and so on around the compass. See Plate II.

After all the log-books within reach have been examined, and the observations collated for this letter of the series, as in Plate I, the results are collected for each district, arranged according to months, and entered, each set in its *wind-rose*, Plate II, as the circumscribed square, with its concentric circles and points of the compass, is called. These entries are made in such a manner as to show at a glance the prevailing winds for any month in any part of the ocean. Not only so: the navigator sees at a glance how many days of observation have been discussed for each month in any district; and of these he sees the number of times calms have been found, and the number of times the winds have been reported as coming from each of the sixteen points of the compass.

Thus, in the wind-rose for the district between 5° and 10° N., 15° and 20° W., and marked A, Plate II, he would observe that, in August, 705 observations as to the course of the wind had been made here, and 13 as to calms; *i. e.*, out of $\frac{718}{3}$ days, or parts of days, passed by ships in this district during the month of August of various years, the prevailing condition of the weather for consecutive periods of eight hours' duration each, was found to be calm thirteen times; and the wind was observed to blow from E. 4 times;* E.SE., 17; SE., 5; S.SE., 165; S., 280; S.SW., 171; SW., 23; W.SW., 26; W., 8; W.NW., 2; NW., 1; N.NW., 2; N.NE. 1; and the other points 0.

The object has been to get for these Charts at least one hundred observations for each month in every square of the ocean; this would require for the three great oceans 1,669,200 observations upon the direction of the winds alone.

In some of the wind-roses, or districts of 5° square, we have obtained more than a thousand observations for a single month; whereas, in neighboring districts and for other months, we are left without a single observation—so limited and marked are the commercial paths over the ocean, according to the seasons.

In the South Atlantic, between the route to and fro around Cape Horn, and the route to and fro around the Cape of Good Hope, there is a part of the ocean of immense extent, that is seldom traversed by any vessel. The Pilot Charts, therefore, are silent with regard to the winds there. So are also the Track Charts.

As the wind is found to blow in any part of any given district or division of 5° square, so it is assumed to blow at that time in all other parts of that district.

The Pilot Charts, therefore, give us the number of times that the wind, in any part of the ocean, is found in a given number of times to come from each point of the compass; and consequently, by studying the Pilot Chart, we see the ratio between the number of winds from any one point, and the number of winds from all the other points of the compass.

With such data it is practicable to calculate, according to the doctrine of chances, the track which will give the shortest average passage under canvass from port for any month.

This I have done for the routes generally, between Europe and America; and from the ports of the United States, as far south as the parallel of Rio de Janeiro.

In order to select the best average track, from one place to another, as from the ports of

* Taking "time" to mean a period of eight hours, or three "times" to make a day.

the United States to Rio, or to those of Europe, the Pilot Charts have been discussed in the following manner :

Blank charts on a scale ef 5° to an inch of the equator, Mercator's projection, are constructed and lithographed for the whole ocean, twelve times over, so as to have one complete set for each month.

In every space, of 5° square, a sort of compass-card is drawn, as in Plate I, vol. II.

In the centre of this card are written two numbers—the upper number shows the times—counting 8 hours as "a time"—the winds have been observed in that square, for the given month, which in this case is July, (see A—Plate I, vol. II,) and the lower number shows the per cent. of "the times" in which calms, according to the number of observations made, and the principles of averages, ought to prevail for as much as 8 hours at a time. Thus, in said square A, there have been discussed for the Pilot Charts, in the month of July, 443 observations, and of these, 33 in all, or 7.4 per cent. of the whole, represent calms as the prevailing condition of the atmosphere for that month and part of the ocean.

These two quantities are thus stated in order to enable me, as well as those who take the Charts for their guide, to form some estimate as to the degree of confidence due, or as to the weight to be attached to, the courses recommended and the routes proposed for vessels.

Thus, more weight is attached to a course that should be recommended through square A, than to one through square B ; because, in A, average results are derived from 443 observations ; whereas in B, they depend upon only 21, and calms, it appears, prevail there 14.2 per cent. of the time, which is probably out of proportion.

The object, however, is to show the proportion according to the ratio of per centage, of the winds from each point of the compass, and the per centage by which, according to that showing, a vessel in attempting to sail 100 miles, or any other distance through that square on any given course, would, on the average, have to increase that distance on account of the average prevalence of adverse winds.

Thus, suppose a vessel should wish to sail west though square B in July ; an inspection of the Plate will show, supposing that 21 observations give a fair average as to the winds in that square for that month, that 14.2 per cent. of the winds there are from the west ; that 9.5 per cent. are from W.SW. ; 4.8 from W.NW. ; 14.2 from SW. ; and 4.8 from NW. ; all these winds are adverse for a west course, and consequently they would compel her to turn off from a west course so as to increase the distance required 30 per cent.

In truth, it appears from those 21 observations that 42.7 per cent. of all the winds that blow here in July are between W. and S.SW., inclusive ; that it is calm 14.2 per cent. of the time ; and that, consequently, it is an unfavorable part of the ocean for a vessel to pass through that wants to get from Europe to the United States, *i. e.*, that wants to get to the southward and westward ; it moreover appears that a vessel would have no difficulty, except on account of the calms, in getting to the eastward through this same region.

Again, the square C, which is between the next pair of meridians, affords us the experience of 41 vessels for our guide ; a vessel to make a W.SW. course through this square in July, would have to contend against 53.7 per cent. of winds directly ahead, with the chances of having to increase her distance 92.7 per cent. Here we again see the prevalence of head winds for vessels bound to the United States, and perceive that it is a bad part of the ocean for a vessel so bound to be in, though there are no calms.

It is thus that the Chart for each month, for the whole ocean, is filled up from the Pilot

Chart, with the per cent. of calms and head winds for each month. This is an operation which involves an immense amount of labor.

This being done, the next step in the process is, to find out the best course for a vessel bound in any other direction, to proceed in any given month.

To do this, it is necessary to find out that track, which, with the average per centum of increased distance on account of head winds, and the increase on account of detour, shall give the shortest distance from port to port; for, when that is found, it is called the shortest average route. This route, when thus found, is the route which vessels are recommended, in the Sailing Directions, to take for the several months, to and from Europe to the equator, &c.

This is a tedious operation; for a satisfactory solution of this problem is not to be attained without many trials. For instance, after crossing the meridian of 25° W., bound from Liverpool to New York, it is comparatively easy, in July, as a mere inspection of Plate I, vol. II, shows, to make westing between the parallels of 40° and 45°. But the head winds, and the detour they cause a vessel to make, when she comes to try it, may involve such an increase of distance as to make it better to take the chances by some other route; so that it is not the difficulty of getting through one square alone that has to be considered at a time, but the difficulties of getting through all united.

It may turn out, after this tentative process has been repeated again and again, that, when we come to examine and compare such results, we may find two routes widely differing, yet each requiring nearly the same distance to be accomplished. In that case, each track is traced from port to port; the per centage of head winds and detour is got at carefully for each square through which it passes, and then, in the Sailing Directions, the preference is given to that track which is least liable to calms, to adverse currents, and to other collateral drawbacks, perplexities, and delays; and which track also has in its favor the shortest distance, and the greatest number of chances for fair winds.

The centre figures in each square, Plate I, vol. II, stand, as before remarked, for the whole number of observations, and for the per centum of calms. The next figures, which are arranged along the inner circle, are the per centum of head winds for the courses on which they stand, and the outer circle of figures expresses the number of miles that adverse winds on the average will compel a vessel to turn out of the way, if she attempt to sail 100 miles direct on the course on which these figures stand.

Thus, it will be perceived that no navigator can reasonably expect that the new routes which I recommend are to give the short passages *always*, and in every individual case. They give the shortest passages on the average, and thus offer the best chances for a short passage at all times—that's all. Those chances, as the Charts show, may, and sometimes will, turn up adversely. Thus, a vessel trading to Europe may be told in the Sailing Directions that her best route in July passes through square D, and that her course through it is east. Once in a hundred times, however—and just once in a hundred on the average—the Pilot Chart to which she is referred for a guide tells her the wind in that square comes from the east; and she may find it when she gets there directly in her teeth; she may be the unfortunate hundredth vessel; we cannot tell. All that I pretend to tell the navigator in such cases is where he will find the greatest number of chances in his favor, and what is the best route for him to pursue. In like manner, he may be recommended not to stand W. SW. through C., for then the chances are fifty-four in a hundred that he will have the wind directly in his teeth; still, a vessel may pass through this square seven times, and each time find—as the Chart shows it is possible, though hardly probable, she may find—the wind exactly in the opposite direction.

With this full explanation as to the process by which the new routes here recommended are discussed and discovered, the intelligent navigator who adopts them will perceive that these discoveries and these routes are no matter of opinion with me, but that they are the results of the experience of all the navigators combined, whose observations have been used in the construction of the Charts.

In the European voyages I have found not much room for improvements as to routes, except for the southern or trade-wind route, and on all routes for those shipmasters who are just entering the trade; to them these Charts give all the information as to winds, currents, and routes, that is possessed by the oldest and most experienced "Packet Captain."

When navigators generally shall agree to follow these new routes, the average sailing passage between Europe and America will, it is believed, from what has already been done, be considerably shortened.

But the new routes which these Charts have suggested to the equator, and which lead through parts of the ocean in which the winds and currents were not so well understood as they are along the tracks to Europe, have been attended with more decided advantage, and the most signal success. Practically, they have brought the markets of India and the southern hemisphere many days nearer to our doors.

The route of all vessels bound into the southern hemisphere, whether their destination be the markets of South America, of the Pacific or Indian Ocean, is the same as far as the equator; and these Charts have actually shortened the average passage hence to the equator from two days to two weeks, or more, according to the season of the year; this is shown by the results of actual trial. More than five hundred passages have been made by these Charts, and according to the routes prescribed. The average length of passage for all months by the old route from the ports of the United States to the line is forty-one days. The average passage by the new routes has been, so far, for January, 28.1 days; for February, 26; for March, 26.4; April, 29.4; May, 33.3; June, 34.2; July, 38.3 (by the old route in this month the passage is 48 days;) for August, 35.5; for September, 38.1; for October, 37.3; November, 31.4, and December 29, against 38½ by the old route for December.

The United States ship Saratoga, (Captain Walker,) and the merchant barque Dragon, (Captain Andrew,) sailed at the same time, both in the month of September, 1850; the Saratoga took the old route, went as far as 19° of west longitude, and crossed the equator the forty-second day out. The Dragon took the new route; crossed the equator the thirty-fourth day, and had passed the parallel of Rio de Janeiro in 23° S. before the Saratoga had reached the line; thus making a gain of 1,500 miles upon her competitor, with a saving, that far, of ten days or two weeks on the passage.

Thus, the importance of the undertaking to collect and embody the experience of every navigator as to the winds and currents of the sea, and so to present the results of all this information that each may have the benefit of the experience of all, is brought home to our merchants; they reap benefits from it daily. Encouragement is therefore given for the vigorous prosecution of the work.

Upwards of 210,000 sheets of these Charts have been distributed to friends and fellow laborers, and the demands for them are daily increasing.

The information afforded by the Pilot Charts has been presented in yet another form, as per

Plate XV. The object of this plate, as already explained, is to give a sort of general idea as to the prevailing direction of the winds in different parts of the ocean without regard to exceptions, and to show at a glance the routes between the most frequented ports. It is instructive at least.

THE THERMAL CHARTS.

Letter D of the series designates the Thermal Charts; they show the temperature of the surface water of the ocean, wherever and whenever it has been observed. These temperatures are characterized by colors and symbols, in such a manner that, by a mere inspection of the Charts, the temperatures for any one month may be recognized and distinguished from the rest. The scale is Fahrenheit; and the temperatures are put down just as they are given in each log-book, without any attempt to correct for error of thermometer. The Thermal Chart of the North Atlantic, compiled by Lieutenant Gantt, in eight large sheets, has been published; also that of the South Atlantic, constructed by Lieutenant Gardner, upon the same scale. Those of the North Pacific have been commenced and laid aside for want of material.

The isothermal lines for 80°, 70°, and so on, for every 10° of ocean temperature, have been drawn for each month upon the Atlantic Charts by Professor Flye.

They afford to the navigator and the philosopher much valuable and interesting information touching the circulation of the oceanic waters, including the phenomena of the cold and warm currents; they also cast light upon the subject of the hyetographic and climatic peculiarities of various regions of the earth; they show that the profile of the coast-line of intertropical America assists to give expression to the mild climate of Southern Europe; they increase, to a marked extent, our stock of knowledge concerning the Gulf Stream—that great phenomenon of the ocean—for they show that the waters of this Stream, as it pursues its course to Europe, have a vibratory motion, so to speak, across its course, like a pendulum slowly propelled by heat on one side, and repelled by cold on the other; that it vibrates to and fro with the season, preserving in the meantime a peculiar system of convolutions that calls to mind the graceful wavings of a pennon as it floats gently to the breeze. Indeed, if we imagine the head of the Gulf Stream to be hemmed in by the land in the Straits of Bemini, and to be stationary there, and then liken the tail of the Stream itself to an immense pennon floating gently in a current;—very much just such a motion as such a streamer may be imagined to have, do these Charts show the tail of the Gulf Stream to have.

These Charts were prepared for the press in four sets—each set showing the temperatures for one season—but they are published with the temperatures of all four seasons on the same sheet. A close study of them will reward any student of nature for his labor.

In 1844, I read before the National Institute a paper "On the Gulf Stream and Currents of the Sea." Up to that time but little was known of this "river in the ocean," except that it exists and conveys an immense body of warm water from the Gulf of Mexico through the Straits of Florida into the Atlantic Ocean, thence along the coast of the United States towards the shores of Europe by the way of the Grand Banks. Beyond this* little or nothing was

* "Upon a correct knowledge of the force and set of currents in the ocean often depends, not only the safety of vessel and cargo, but also the lives of all on board; and, owing to the want of this knowledge, hundreds of vessels, thousands of persons, and millions of property are annually cast away or lost at sea.

"I do not intend to occupy the time of the members with a recapitulation here of what we do know with regard to ocean currents; that, indeed, might soon be told, for we know little or nothing of them, except that they are to be met with here and there at sea, many of them sometimes going one way and sometimes another; and that the waters of some of them are known with regard to it. But since the appearance of that paper, attention has been very much directed to the Gulf Stream.* The Coast Survey has been at work upon it, and the information collected by that establishment and the officers of the navy, with regard to it, added to that afforded by these Charts, may be said to exceed in philosophical extent and value all that was previously known about it.

These investigations confirm, to a remarkable extent, the speculations put forth in that paper; they have converted many of the suggestions of theory into philosophical facts, and given increased importance to the views which I had the honor to present in 1844.

In the paper which, as already mentioned, was read before the National Institute fourteen years ago, and repeated, by request, before the Association of American Geologists and Naturalists the same year, it was remarked, with regard to the Gulf Stream and its counter-current, the ice-bearing current from the north:

"The Gulf Stream, as it issues from the Straits of Florida, is of a dark indigo blue; the line of junction between it and the "*roily*" green waters of the Atlantic is plainly seen for hundreds of miles. Though this line is finally lost to the eye as the Stream goes north, it is

colder and of others warmer than the seas in which they are found. That we should have a better knowledge of them, and of the laws which govern them, is not only an important matter to those who follow the sea or make ventures abroad, but it is also a matter of exceeding interest to all those whose enlarged philanthropy or ennobling sentiments prompt in them a desire to diffuse knowledge among their fellows, or in any manner to benefit the human race. The mere fact that this meeting is held at all is evidence ample and complete that it is composed altogether of such. I, therefore, submit it as a question for the consideration of the meeting, whether it be not competent for the National Institute to devise and set on foot a plan for multiplying observations and extending our information upon these interesting phenomena. A subject of vast importance in the business of commerce and navigation, the currents of the ocean seem to me to be altogether worthy the attention of this society; a series of well conducted observations upon them would be in perfect unison with the great objects of usefulness for which it was created and now exists, and for which its distinguished members and guests have been invited, and are here assembled, from all parts of the country.

"Before such an assemblage of mind and intelligence, it is necessary only to mention the meagre state of our information, even with regard to that great anomaly of the ocean, the Gulf Stream; and there will be, there can be, but one mind as to the importance of making further observations, and of multiplying facts with regard to it. In simply reminding the society that all we know of this wonderful phenomenon is contained chiefly in what Doctor Franklin said of it more than fifty years ago, that his facts were collected by chance, as it were, and his observations made with but few of the facilities which navigators now have, I feel that enough, and all has been done that is necessary to be done in order to impress the Institute with the importance of further observation upon it." * * —*Paper on the Gulf Stream and Currents of the Sea; read before the National Institute, April 2, 1844, by M. F. Maury, Lieut., U. S. N.*

* "Linked thus with other geological agents, the currents of the sea cannot fail to present themselves to the mind of the geologists as important and interesting subjects for investigation. How much more so are they in the eyes of the navigator; with him the source of this coast current is a matter of conjecture, and its cause a mystery. And as to its length, its fluctuations, and the laws which govern them, his nautical books are all but silent. Nor has the history of navigation recorded the first series of systematic observations upon it.

"Proceeding further into the Atlantic, we find a vast stream of warm water running counter to this. It is the Gulf Stream bound from the Straits of Florida to the Banks of Newfoundland, and thence to the shores of Europe. What its breadth or depth may be, we know not. We are told, indeed, that, even at the same place, it runs sometimes at the rate of two knots the hour, sometimes at five, and we know that it may always be found within certain broad limits, varying in this, too, at the same place, from 140 to 340 miles. With this our knowledge of it ends; though more accurate information as to it and its offsets would many a time have saved the mariner from disaster and shipwreck, and even now would add not a little to the speedy and safe navigation of the Atlantic.

"Though navigators had been in the habit of crossing and recrossing the stream almost daily for the space of nearly 300 years, its existence, even, was not generally known among them until after Dr. Franklin discovered the warmth of its waters, about 70 years ago. And to this day the information which he gave us constitutes the basis, I had almost said the sum and substance, of all we know about it."—*Ibid.*

preserved to the thermometer for several thousand miles; yet to this day the limits of the Gulf Stream, even in the most frequented parts of the ocean, though so plainly marked, are but vaguely described on our charts. Thousands of vessels cross it every year; many of them make their observations upon it, and many more, if invited, would do the same. But no one has invited co-operation,* consequently, there is no system; and each one that observes, observes only for himself, and when he quits the sea, his observations go with him, and are to the world as though they had not been. * * * * *.

"Supposing the pressure of the waters that are *forced* into the Caribbean Sea by the trade-winds to be the *sole* cause of the Gulf Stream, that sea and the Mexican Gulf should have a much higher level than the Atlantic. Accordingly, the advocates of this theory† require for its support 'a great degree of elevation.' Major Rennell likens the Stream to 'an immense river, descending from a higher level into a plain.' Now, we know very nearly the average breadth and velocity of the Gulf Stream in the Florida Pass. We also know, with a like degree of approximation, the velocity and breadth of the same waters off Cape Hatteras. Their breadth here is about 75 miles against 32 in the Narrows of the Straits, and their mean velocity is three knots off Cape Hatteras against four in the Narrows. This being the case, it is easy to show that the depth of the Gulf Stream off Hatteras is not so great as it is in the Narrows of Bemini by nearly fifty per cent., and that, consequently, instead of *descending*, its bed represents the surface of an inclined plane from the north, *up* which the lower depths of the Stream *must* ascend. If we assume its depths off Bemini to be two hundred fathoms, which are thought to be within limits, the above rates of breath and velocity will give one hundred and fourteen fathoms for its depth off Hatteras. The waters, therefore, which in the straits are below the level of the Hatteras depth, so far from descending, are actually *forced up* an inclined plane, whose submarine ascent is not less than ten inches to the mile!

"The Niagara is an 'immense river, descending into a plain;' but instead of preserving its character in Lake Ontario as a distinct and well defined stream for several hundred miles, it spreads itself out, and its waters are immediately lost in those of the lake. Why should not the Gulf Stream do the same? It gradually enlarges itself, it is true, but instead of mingling with the ocean by broad-spreading, as the 'immense rivers' descending into the northern lakes do, its waters, like a stream of oil in the ocean, preserve their distinctive character for more than 3,000 miles.

"Moreover, while the Gulf Stream is running to the north from its supposed elevated level at the south, there is a cold current coming down from the north; meeting the warm waters of the Gulf midway the ocean, it divides itself and runs *by the side of them* right back into those very reservoirs at the south, to which theory gives an elevation sufficient to send out entirely across the Atlantic a jet of warm water said to be more than three thousand times greater in volume than the Mississippi River. This current from Baffin's Bay has not only no trade-winds to give it a head, but the prevailing winds are unfavorable to it, and for a great part of the way it is below the surface, and far beyond the propelling reach of any wind; and there is every reason to believe that this polar current is quite equal in volume to the Gulf Stream. Are they not the effects of like causes; if so, what have the trade-winds to do with the one more than the other?

"Nay, more. At the very season of the year when the Gulf Stream is rushing in greatest

* The Wind and Current Charts have called forth the co-operation here proposed.

† That the Gulf Stream is caused by the trade-winds.

volume through the Straits of Florida, and hastening to the north with the greatest rapidity, there is a cold stream from Baffin's Bay, Labrador, and the coasts of the north, running to the south with equal velocity. Where is the trade-wind that gives the high level to Baffin's Bay, or that even presses upon or assists to put this current in motion? The agency of winds in producing currents in the deep sea must be very partial.

"These two currents meet off the Grand Banks, where the latter is divided. One part of it underruns the Gulf Stream, as is shown by the icebergs which are carried in a direction tending across its course. The probability is, that this 'fork' *continues on towards the south*, and runs into the Caribbean Sea, for the temperature of the water at a little depth there has been found far below the mean temperature of the earth, and quite as cold as at a corresponding depth off the arctic shores of Spitzbergen. * * * *

"More water cannot come from the equator or the pole than goes to it. If we make the trade-winds to cause the former, some other wind must produce the latter; but these cold currents, for the most part and for great distances, are *submarine*, and, therefore, beyond the influence of winds. Hence, it should appear that *winds* have little to do with the general system of aqueous circulation in the ocean.

"The other 'fork' runs between us and the Gulf Stream to the south, as already described. As far as it has been traced, it warrants the belief that it, too, runs *up* to seek the so-called *higher* level of the Mexican Gulf. * * * * *

"Therefore, this immense volume of water, in passing from the Bahamas to the Grand Banks, meets with an opposing force in the shape of resistance, sufficient in the aggregate to retard it two miles and a half the minute, and this only in its eastwardly rate. There is, doubtless, another force quite as great retarding it towards the north, for its course shows that its velocity is the resultant of two forces acting in different directions. If the former resistance be calculated according to received laws, it will be found equal to several atmospheres. And by analogy, how inadequate must the pressure of the gentle trade-winds be to such resistance, and to the effect assigned them? If, therefore, in the proposed inquiry we search for a propelling power nowhere but in the higher level of the Gulf, we must admit, in the head of water there, the existence of a force capable of putting in motion and driving over a plain, at the rate of five miles the hour, all the waters as fast as they can be brought down by 3,000 such streams as the Mississippi River—a power at least sufficient to overcome the resistance required to reduce, from two miles and a half to a few feet per minute, the velocity of a stream that keeps in perpetual motion one-fourth of all the waters of the Atlantic Ocean.

"But, in addition to this, may there not be a peculiar system of laws not yet revealed, by which the motion of fluids in such large bodies is governed when moving through each other in currents of different temperature. That currents of sea water, having different temperatures, do not readily commingle, is shown by the fact already mentioned—that the line of separation between the warm waters of the Gulf and the cold waters of the Atlantic is perfectly distinct to the eye for several hundred miles; and even at the distance of a thousand miles, though the two waters have been in contact and continued agitation for many days, the thermometer shows that the *cold water on either side still performs the part of river banks* in keeping the warm waters of the stream in their proper channel.

"In a winter's day off Hatteras, there is a difference between these waters of near 20°. Those of the Gulf being warmer, we are taught to believe that they are lighter; they should, therefore, occupy a higher level than those through which they float. Assuming the depth here to be 114 fathoms, and allowing the usual rates of expansion, figures show that the middle of the Gulf Stream here should be nearly 2 feet higher than the contiguous waters of the Atlantic. Were this the case, the surface of the Stream would present a double inclined plane, from which the water would be running down on either side, as from the roof of a house. As this ran off at the top, the same weight of colder water would run in at the bottom; and thus, before this mighty stream had completed half its course, its depths would be brought up to the surface, and its waters would be spread out over the ocean. Why, then, does not such a body of warm water, flowing and adhering together through a cold sea, obey this law, and occupy a higher level? If it did, the upper edges of its *cold banks* would support a lateral pressure of at least 100 lbs. to the square foot; and vessels in crossing it would sail over a ridge, as it were, on the east side of which they would meet an easterly current, and on the west side a westerly current. * * * * * * *

"The maximum temperature of the Gulf Stream is 86°, or about 9° above the ocean temperature due the latitude. Increasing its latitude 10°, it loses but 2° of temperature. And, after having run 3,000 miles towards the north, it still preserves, even in winter, the heat of summer. With this temperature it crosses the 40th degree of north latitude, and there, overflowing its *liquid banks*, it spreads itself out for thousands of square leagues over the cold waters around, and covers the ocean with a mantle of warmth that serves so much to mitigate in Europe the rigors of winter. Moving now more slowly, but dispensing its genial influences more freely, it finally meets the British Islands. By these it is divided, one part going into the polar basin of Spitzbergen, the other entering the Bay of Biscay, but each with a warmth considerably above ocean temperature. Such an immense volume of heated water cannot fail to carry with it beyond the seas a mild and moist atmosphere. And this it is which so much softens climate there. * * * * * *

"May there not exist between the waters of the Stream and their *fluid banks*, always heaving and moving to the swell of the sea, a sort of *peristaltic* force, which, with other agents, assist to keep up and preserve this wonderful system of ocean circulation? * * *

"The line of meeting between the waters of the Gulf Stream and the Atlantic is distinct to the naked eye for several hundred miles. This unreadiness of cold and tepid sea water to commingle has been often remarked upon, and seems to impart to one current the power of dividing and turning others aside. Thus the Gulf Stream bifurcates the Labrador current, one part of which underruns the Gulf Stream, and the other takes a southwestwardly direction along the coast. * * * * * * *

"*It would be curious to ascertain the routes of these under currents on their way to the tropical regions*, which they are intended to cool. One has been found at the equator 200 miles broad, and 23° colder than the surface water. Unless the land or shoals intervene, it, no doubt, comes down in a spiral curve. * * * * *

"What time more fit—what occasion more suitable than the present, for maturing a plan of operations, and for setting on foot a system of observations upon the Gulf Stream, and its kindred phenomena of the sea?"*

* From this question may be traced the origin of the undertaking which has resulted in the "Wind and Current Charts." The Association, appreciating the importance of the subject, and the suggestions connected with it, readily came forward and used their influence in behalf of the undertaking. It was remarked to them then :—

"Gentlemen here, and good men everywhere, can do much to aid in this plan, by giving it their countenance, and using their influence with masters, by inducing them to send to Washington an abstract of their logs, though it contain only the track of the vessel, with the winds and temperatures. Even this would be valuable, and anything additional would be

Thus, by a process of reasoning and argument, it was shown, more than nine years ago, that the Gulf Stream, as far as the Banks of Newfoundland, flows through a *bed* of cold water, which cold water performs to the warm the office of *banks* to a river ;* and which "cold banks," thus pointed out, were discovered with the deep-sea thermometer, by Lieut. George M. Bache, U. S. N., in 1846, while operating in connexion with the Coast Survey. They partake so decidedly of the character of *banks of a river*, that in the annual report of the Coast Survey for 1846, and elsewhere, these banks were likened to a "cold wall;" and by Lieut. Bache, in his report to the superintendent of the survey, to "a bank of cold water against which the the Gulf Stream butts up."†

It was also theoretically shown that the Gulf Stream actually flows up hill ;‡

That its bottom is a bed of cold water ;§

That it bifurcates a cold stream from the north, near the Banks of Newfoundland, and that one fork of this stream pursues thence, on the other side of the Gulf Stream, a *southwestwardly* course as a current of cold water, for the most part submarine ;‖

That it is bifurcated by the British Isles ;¶

And that its surface is a double inclined plane, having the ridge, or line of meeting of the

much more so. Our whalemen do collect, and have it in their power to give much truly valuable information. That which they collect concerns the meteorologist, the naturalist, and others, not less than the navigator and geologist. Indeed, the ocean, with its almost unsealed book of mysteries, presents to the votary of science, whatever be the name of his association, a common highway, upon which each society, like every nation, may make its ventures, and return in vessels laden with treasures to enrich the mind and benefit the human race."—*Extract from a Paper on the Currents of the Sea, as connected with Geology, read before the Association of American Geologists and Naturalists, May* 14, 1844, *by M. F. Maury, Lieut. U. S. N.*

* "The cold water on either side, still at the distance of a thousand miles, performs the part of *river banks* in keeping the warm water of the (Gulf) Stream in the proper channel."—*Paper on the Gulf Stream and Currents of the Sea.*

† "Here, on the left, we have the main currents of the (Gulf) Stream turned to the eastward by Cape Hatteras, and *butting up against a bank of cold water*, which it overflows."—*Report of Coast Survey*, 1846, *Appendix* No. 4, page 50.

‡ "It is easy to show that the depth of the Gulf Stream, off Hatteras, is not so great as it is in the 'narrows,' off Bemini, by nearly 50 per cent.; and that, consequently, instead of *descending*, its bed represents the surface of an inclined plane from the north, up which the lower depths of the stream *must* ascend. If we assume its depth off Bemini to be 200 fathoms,(*a*) which are thought to be within limits, the above rates of breadth and velocity will give 114 fathoms for its depth off Hatteras. The waters, therefore, which, in the Straits, are below the level of the Hatteras depth, so far from descending, are actually forced up an inclined plane, whose submarine ascent is not less than 10 inches to the mile."—*Paper on the Gulf Stream and Currents of the Sea, read before the National Institute, by M. F. Maury, Lieut. U. S. N., April* 2, 1844.

§ "As this" (the warm water of the Gulf Stream made specifically lighter by its temperature) "ran off at the top, *the same weight of cold water* would run in at the *bottom*."—*Paper on the Gulf Stream and Currents of the Sea, read be ore the National Institute, by M. F. Maury, Lieut. U. S. N., April* 2, 1844.

"The Gulf Stream bifurcates the Labrador current, one part of which *underruns* the Gulf Stream."—*Paper on the Currents of the Sea, as connected with Geology; read before the Association of American Geologists and Naturalists, May* 14, 1844, *by M. F. Maury, Lieut. U. S. N.*

‖ "Apparently, in obedience to the laws here hinted at, there is a constant tendency of polar waters towards the tropics, and of tropical waters towards the pole."—*Lieut. Maury on the Gulf Stream.*

"It would be curious to ascertain the routes of these under currents on their way to the tropical regions, which they are intended to cool. One has been found at the equator, 200 miles broad, and 23° colder than the surface water. Unless the land or shoals intervene, it no doubt comes down in a spiral curve ; meeting the warm waters of the Gulf midway the ocean (the cold current,) divides itself and runs by the side of them right back into those very reservoirs of the south."—*Ibid.*

¶ "It finally meets the British Islands. By these it is divided—one part going into the polar basin of Spitzbergen, the other entering the Bay of Biscay."—*Ibid.*

(*a*) Its depth in the Florida Pass has been ascertained by the officers of the United States ship Albany, Commander Platt, acting under the instructions of Commodore Warrington, to be 500 fathoms. That is, bottom has been obtained at that depth. Whether the Gulf Stream water reaches all the way to the bottom, is another question.

two planes, near the axis of the stream—from which the surface water, like the rain from the roof of a house, runs off towards each side.*

Thus most, if not all the conditions which the study of the subject induced me, in 1844, to announce as theoretically to exist, have since, as already remarked, been converted into physical facts by the operations of the Coast Survey, or by the navigators who have been observing in connexion with the Wind and Current Charts.

The observations made in 1846 by Lieut. George M. Bache, U. S. N., for the Coast Survey,† and continued in 1847‡ and 1848,§ by Lieutenants S. P. Lee and Richard Bache, upon the deep-sea and surface temperatures in and about the Gulf Stream, and confirmed, as to the surface temperatures, by these Charts, as well as by the observations of Lieut. J. C. Walsh, U. S. N., while observing in connexion with them in 1850—this mass of careful observations, thus collected—all goes to confirm the theoretical suggestions of 1844, with regard to the *cold banks* and currents of cold water over or through which the Gulf Stream finds its way to the northward.

The officers of the Coast Survey, already alluded to, announced the banks of the Gulf Stream off the coast of North Carolina and Virginia to be a "wall of cold water." They also found, as had already been predicted, the water at great depths to be a very low temperature—38° Fahrenheit.

They also found on the surface of the ocean, east of the Gulf Stream, layers or streaks of warm water. It was inferred by them that this warm water comes from the Gulf Stream—that it sent off a branch in the direction of the Island of Bermuda. It was concluded, therefore, that here was a bifurcation of this stream.

In 1850, Lieutenant Walsh, who was sent out in the United States schooner Taney, to make certain observations which Congress had authorized the Secretary of the Navy to have made, in connexion with my researches concerning the winds and currents of the sea, found like layers or streaks of warm and cold water, and came to a like conclusion as to this bifurcation or "off-set" of the Gulf Stream.

In a letter giving me an account of his cruise, which was unfortunately interrupted by his vessel proving to be unseaworthy, he says: "We discovered the *hot water of the Gulf Stream* extending as far east as 72° 10′, in a latitude so far south as 33° 30′. The column of water temperature in the abstract, from May 23 to 29, while engaged in the search for Ashton Rock, will satisfy you of this interesting and important fact; for you will notice that whenever we reached that longitude, in our various tracks between the latitudes of 33° 30′ and 34° north, we experienced a sudden change of as much as 5° and 6° in the surface temperature—70° to 76°; this must be a branch or off-set from the Gulf Stream." This "discovery" is claimed by the Coast Survey.

* "In a winter's day, off Hatteras, there is a difference between these waters of near 20°. Those of the gulf being warmer, we are taught to believe that they are lighter; they should, therefore, occupy a higher level than those through which they float. Assuming the depth here to be 114 fathoms, and allowing the usual rates of expansion, figures show that the middle of the Gulf Stream here should be nearly two feet higher than the contiguous waters of the Atlantic. Were this the case, the surface of the stream would present a double inclined plane, from which the water would be running down on either side, as from the roof of a house. As this ran off at the top, the same weight of colder water would run in at the bottom; and thus, before this mighty stream had completed half its course, its depths would be brought up to the surface, and its waters would be spread out over the ocean. Why, then, does not such a body of warm water, flowing and adhering together through a cold sea, obey this law, and occupy a higher level?"

† *Vide* Annual Report of the Coast Survey for 1816. ‡ *Ibid.*, 1847. § *Ibid.*, 1848.

Now, these Charts do not show that the temperature of the ocean between these parallels beyond the usual limits of the Gulf Stream is permanently any higher than it is between the same parallels generally, until you approach the coast of Africa. The isotherms of 70° for each month, generally, after leaving the Gulf Stream, stretch off to the eastward, going up as high, in some months, as the parallel of 45°. Recrossing the parallel of 40° north, between the meridians of 15° and 20° W., they then make a sharp turn to the southward and eastward, showing all the surface water between these lines and the equator to be permanently 70° and upwards. It is not probable, therefore, that the Gulf Stream can supply such an extent of ocean with its warm waters; nor is it clear that the warm water of the cool and warm streaks, reported as above, comes from the Gulf of Mexico. The cool water is probably the intruder from below; indeed, these Charts have revealed a natural process of heating and cooling the surface of the ocean which I am not aware has been discovered before. It is exceedingly beautiful, and goes far to explain this phenomenon of the streaks: when the rays of the sun are operating with their greatest intensity in the northern hemisphere, they then raise the temperature of the equatorial surface of the ocean to the highest pitch. Its waters thus becoming lighter, flow to the north in a gentle surface current of warm water; and this current is probably too feeble to be detected by vessels in the ordinary course of navigation.

Thus the isotherm of 80°, for example, will pass from its extreme southern to its extreme northern declination—near 2,000 miles—in about three months.

Being now left to the gradual process of cooling by evaporation, atmospherical contact, and radiation, it occupies the other eight or nine months of the year in slowly returning south to the parallel whence it commenced to flow northward. How natural that in flowing north it should go in layers; and in cooling, that some parts should cool faster than the others; also, that the cool water from below should now and then be forced up through the mantle of warm water with which the heat has covered certain parts of the ocean. When we come down to the lower temperature—the isotherm of 60°, for example—the reverse takes place. In this case the most rapid motion of this isotherm is due to a movement of the waters from the hyperborean regions.

Between the meridians of 25° and 30° west the isotherm of 60°, in September, ascends as high as the parallel of 56°. In October it reaches the parallel of 50° north. In November it is found between the parallels of 45° and 47°, and by December it has nearly reached its extreme southern descent between these meridians, which it accomplishes in January, standing then near the parallel of 40°. It is all the rest of the year in returning northward to the parallel whence it commenced its flow to the south in September.

Now, it will be observed that this is the season—from September to December—immediately succeeding that in which the heat of the sun has been playing with greatest activity upon the polar ice. Its melted waters, which are thus put in motion in June, July, and August, would probably occupy the fall months in reaching the parallels indicated.

These waters, though cold, and rising gradually in temperature as they flow south, are probably fresher; and if so, probably lighter than the sea water; and therefore it may be that both the warmer and cooler systems of these isothermal lines are made to vibrate up and down the ocean by a gentle surface current in the season of quick motion; and in the season of the slow motion, by a gradual process of calorific absorption in the one case, and by a gradual process of cooling in the other.

We have the same phenomena exhibited by the waters of the Chesapeake Bay during the winter.

At this season of the year, the Charts show that water of very low temperature is found projecting out and overlapping the usual limits of the Gulf Stream. The outer edge of this cold water, though jagged, is circular in its shape, having its centre near the mouth of the bay. The waters of the bay, being fresher than those of the sea, may, therefore, though colder, be lighter than the warmer waters of the ocean, and thus we have repeated here, though on a smaller scale, the phenomenon as to the flow of cold waters from the north, which force the surface isotherm of 60° from latitude 56° to 40° during three or four months.

We have, in the making of ice, and in the melting of it again, examples of this irregularity of outline on a still smaller scale. In the freezing of an ordinary pond, the fascicles of ice shoot out, and represent with their spires the jagged edges, or the cold and warm streaks alluded to. They perfectly illustrate, in freezing, the manner in which a gentle current of warm water, overflowing a surface of cold water, may be supposed to send out its couriers or advance streams ahead; and, in melting, the reverse, or the case of the cold water intruding upon the warmer.

Changes in the color or depth of the water, and the shape of the bottom, &c., would also cause changes in the temperature of certain parts of the ocean, by increasing or diminishing the capacities of such parts to absorb or radiate heat.

From these facts, and in the view which I am induced to take of them, I am led to infer that the mean temperature of the atmosphere between the parallels of 56° and 40° north, and over that part of the ocean in which we have been considering the fluctuations of the isothermal line of 60°, is at least 60° of Fahrenheit and upwards from January to August, and that the heat which the waters of the ocean derive from this source, atmospherical contact and radiation, is one of the causes which move the isotherm of 60° from its January to its September parallel.

It is well to consider another of the causes which are at work upon the currents in this part of the ocean, and which tend to give the rapid southwardly motion to the isotherm of 60°.

We know the mean dew-point must always be below the mean temperature of any given place; and that, consequently, as a general rule at sea, the mean dew-point due the isotherm of 60° is higher than the mean dew-point along the isotherm of 50°, and this again higher than that of 40°—this than 30°, and so on.

Suppose, merely for the sake of illustration, that the mean dew-point for each isotherm be 5° lower than the mean temperature; we should then have the atmosphere which crosses the isotherm of 60°, with a mean dew-point of 55°, gradually precipitating its vapors until it reaches the isotherm of 50°, with a mean dew-point of 45°. By which difference of dew-point, the total amount of precipitation over the entire zone between the isotherm of 60° and 50° has exceeded the total amount of evaporation from the same surface.

Now, as a general rule in the Atlantic Ocean, and it may be inferred in the Pacific also, the prevailing direction of the winds, to the north of the 40th parallel of north latitude, is from the southward and westward; in other words, it is from the higher to the lower isotherms. Passing, therefore, from a higher to a lower temperature over the ocean, the total amount of vapor deposited by any given volume of atmosphere, as it is blown from the vicinity of the tropical towards that of the polar regions, is greater than that which is taken up again. How the land may modify this position is another question. I speak of the rule at sea, not of the exceptions on the land.

Now, then, these investigations have brought out prominently before us the fact that there is, near the tropics, both of Cancer and Capricorn, a belt of calms across the great oceans; that on the equatorial side of these belts the winds at the surface of the sea blow permanently towards the equator—*i. e.*, they come from a cooler, and go to a warmer region; thus increasing their capacity for moisture, and consequently taking up more vapor in this part of their circuit than they precipitate down upon it again; and that on the polar side of these calm belts of the tropics the prevailing direction of the wind on the surface of the ocean is toward the poles—*i. e.*, from a warm to a colder temperature; and, therefore, in this part of their circuit, these winds must deposit more vapor than they can take up again.

These facts, though they be not new, yet they are pressed by the Charts so forcibly upon us, that we are led irresistibly to the theoretical conclusion that the trade-wind regions of the ocean are the evaporating regions; and that, as a general rule, in all other regions of the world, except the deserts, and a few others, mostly on the land, the evaporation is less than the precipitation, and that the excess is returned by the rivers and the rains, in the shape of currents, from towards the poles to the evaporating regions of the torrid zone; and that the total amount of rain and river water discharged into the sea, without the limits of the evaporating region, expresses the volume by which the cold currents exceed the warm currents of the sea—designating as cold currents all those which run into the torrid zone; and all those as warm which bring their waters from it.

These Charts indicate that, upon the ocean, the area comprehended between the isotherms of 40° and 50° Fahrenheit is less than the area comprehended between the isotherms 50° and 60°; and this, again, less than the area between this last and 70°, for the same reason that the area between the parallels of latitude 50° and 60° is less than the area between the parallels of latitude 40° and 50°; and they indicate that, *theoretically*, more rain to the square inch ought to fall upon the ocean between the colder isotherms of 10° difference than between the warmer isotherms of the same difference.

Thus, to make myself clear: the aqueous isotherm of 50°, in its extreme northern reach, touches the parallel of 60° N. Now, between this and the equator there are but three isotherms—60°, 70°, and 80°, with the common difference of 10°. But, between the isotherm of 40° and the pole there are at least five others, viz: 40°, 30°, 20°, 10°, 0°, with a common difference of 10°. Thus, to the north of the isotherm 50°, the vapor which would saturate the atmosphere from zero, and perhaps far below, to near 40°, is deposited, while to the south of 50° the vapor which would saturate it from the temperature of 50° up to that of 80° can only be deposited. At least, such would be the case if there were no irregularities of heated plains mountain ranges, land, &c., to disturb the laws of atmospherical circulation as they apply to the ocean.

Having, therefore, theoretically, at sea more rain in high latitudes, we should have more clouds; and, therefore, it would require a longer time for the sun, with his feeble rays, to raise the temperature of the cold water, which, from September to January, has brought the isotherm of 60° from latitude 56° to 40°, than it did for these cool surface currents to float it down.

After this southward motion of the isotherm of 60° has been checked in December by the cold, and after the sources of the current which brought it down have been bound in fetters of ice, it pauses in the long nights of the northern winter, and scarcely commences its return till the sun recrosses the equator, and increases its power, as well in intensity as in duration.

Thus we have here, for the first time, beautifully developed the effects of the seasons, of night and day, of clouds and sunshine, upon the currents of the sea. These effects are modified or marked by the operations of more powerful agents which reside upon the land; nevertheless, feeble though they be, a close study of the Thermal Charts will indicate that they surely exist. The dynamical force brought by the seasons into play upon the ocean, by the summer heating and winter cooling of its waters, is in the aggregate a mighty force. Sea water is much more expansible by heat than mercury, and whether we can perceive it or not, we may infer from this alternate expansion and contraction of the ocean by summer heat and winter cold, that there is a thermal tide that ebbs and flows but once a year. If it were so that the waters from the top to the bottom of the ocean could change their temperatures with the seasons, this thermal tide of which I speak, would become most obvious.

Now, returning towards the south, we may, on the other hand, infer that the mean atmospherical temperature for the parallels between which the isotherm of 80° fluctuates, is below 80°, at least, for the nine months of its slow motion. This vibratory motion suggests the idea that there is, probably somewhere between the isotherm of 80° in August and the isotherm of 60° in January, a line or belt of invariable or nearly invariable temperature, which extends on the surface of the ocean, from one side of the Atlantic to the other. This line, or band, may have its cycles also, but they are probably of long periods.

Theoretically, such a line ought to be found for any given year; but its place for one entire year may not coincide with its place for another, though the motion of such a belt from year to year would probably be very small.

The observations upon which these Charts are founded run through a period of half a century; consequently, they show the temperature for the months only, without regard to the year; and, therefore, they do not enable us to decide satisfactorily as to the existence of such a belt of uniform, or nearly uniform, ocean temperatures for any one year.

Taking the isotherms of 50° and 60° to illustrate the manner generally in which the waters of different temperatures run into each other, we shall find that their line of separation is not smooth, but jagged. The line of junction between the warm and cold waters of the sea is not unlike the sutures of the skull bone on a grand scale. The waters of one temperature are dovetailed and fitted into those of another, in apparently the most irregular manner; but, nevertheless, like the sutures of the skull when they come to be examined closely, these lines of articulation clearly indicate traces of symmetry. They have their laws.

Now a vessel—when waters of marked differences of temperature meet—that sails along near their line of junction, will come across layers or streaks of water at one time warmer, at another cooler. Where a jagged point of warmer water is found in one month to thrust itself up into a body of cooler water, perhaps the next month it will be found that this obtruding of the warm water has disappeared and given place to the intrusion from the cooler water of an articulating surface equally irregular in its outlines. Such layers of cooler and warmer streaks of water are generally to be found along that part of the usual sailing route between New York and the north of Europe, which runs with the Gulf Stream.

There is on this route a peninsula or island of cold water, which hangs down into the Gulf Stream like a curtain dropped from the north. Its position, as well as its dimensions, vary. It often covers several degrees in extent—and it affords instances of the greatest and most sudden changes that are known to take place in the temperature of the surface waters of the sea. It is generally found about the parallel of 45° and the meridian of 50°. Covering frequently an area of hundreds of miles in extent, its waters differ as much as 20°, 25°, 30°, and in rare cases even as much as 35° of temperature from those about it.

These waters, doubtless, come down from the cold regions of the north and are perhaps in the strongest part of that current.

The bottom of the sea in that region—the Grand Banks—assists, no doubt, in forcing this mass of cold waters to the surface; and the fact that they penetrate far down across the usual track of the Gulf Stream, at times almost cutting it in two, as it were, seems to indicate that their momentum here is greater than the momentum of the warm waters of the Gulf Stream, which they push aside; or it may be that this part of the ocean is very shallow. It would be interesting to ascertain as to this with lead and line.

Between this peninsula of cold water and Newfoundland there is a layer or branch of warm waters; perhaps these are brought there by a bifurcation of the Gulf Stream. Here, we have clearly and unexpectedly unmasked the very seat of that agent which produces the Newfoundland fogs. It is spread out over an area frequently embracing several thousand square miles in extent, covered with cold water, and surrounded on three sides, at least, with an immense body of warm. May it not be that the proximity to each other of these two very unequally heated surface out upon the ocean would be attended by atmospherical phenomena not unlike those of the land and sea breezes? These warm currents of the sea are powerful meteorological agents. I have been enabled to trace, in thunder and lightning, the influence of the Gulf Stream in the eastern half of the Atlantic, as far north as the parallel of 55° N.; for there, in the dead of winter, a thunder storm is not unusual.

Reviewing now what has been said concerning the layers of cold and warm water along the European route of the Gulf Stream, and returning to the cool and warm streaks mentioned by Lieutenant Walsh, and claimed by the Coast Survey as the discovery of a "branch" from the Gulf Stream, it appears probable that the warm waters which that survey encountered, and reported as coming from the Gulf Stream, are the warm waters properly due the latitude, and the effect of the South America shore line as far as Cape St. Roque, in sending north its warm waters. The difference of temperature may be partly due, also, to the warm waters of the surface being separated into streaks by the cooler waters of the submarine current, which, by the agitation of the ocean, are here and there brought to the surface though the thin layer of warm surface water.

If we draw a line of a degree or two in breadth from the capes of the Chesapeake and the Delaware Bays towards Cape St. Roque in Brazil, we shall find in this direction, after crossing the Gulf Stream, a remarkable layer of cool water. This layer extends to the equator, and it is more clearly marked at some seasons of the year than at others; so much so, that I have been at a loss to account for it. Like an immense lake, it is surrounded with water of a higher temperature. It cannot, therefore, be brought there by a cold surface current. It is strictly a *layer*, in contradistinction to a current.

The only idea that has suggested itself in explanation of this phenomenon is in the conjecture that there may be, stretching off in this direction, a submerged mountain range or ridge at the bottom of the sea, across which the cold waters of this submarine current, as it forces itself down towards the equator, are brought to the surface by the agitation of the waves.

Standing out like peaks in this range are the islands of Fernando de Noronha, the

Penedo de San Pedro, and the Bermudas. The islands and mountains of Cuba occupy a position which a mountain spur from this sunken range might be supposed to occupy.

Lieutenants Walsh and S. P. Lee were directed to run across this supposed submarine range of mountains a zigzag line of deep-sea soundings, from the equator to the capes of Virginia.—(P. 217 of the 6th edition.) But unfortunately circumstances proved unfavorable, and they each had to abandon this interesting part of his work.

It was announced by Dr. Bache, before the American Association at Cleveland, in 1853, that Lieutenants Craven and Maffit, United States navy, had discovered, to the east of the Gulf Stream, off the shores of the Carolinas and SW. of the region indicated, a remarkable elevation or ridge in the bottom of the sea, thus tending to prove the correctness of this theoretical deduction.

The isotherms of 60°, 50°, and 40° take a northeastwardly direction across the Atlantic, and show the waters of the ocean to be as warm, indeed warmer, between latitude 60° and 65°, off the shores of Europe, than they are on this side, near the parallels of 40° and 45°.

The Gulf Stream *is* roof-shaped; that is, it is higher in the middle and lower at the edges, and has a roof-current running from the middle or axial line to either edge, as suggested in 1844. That it is so has been proved by experiments since made with regard to it by officers of the navy.

Thus, in lowering a boat to try a current, they found that the boat would invariably be drifted towards one side or other of the stream, while the vessel herself was drifted along in the direction of it. Now, were it possible to make a vertical section across the Gulf Stream, the top of it would appear convex, and the bottom concave, unless where the bottom of it reaches the bottom of the sea.

This feature of the Gulf Stream throws a gleam of light upon the *locus* of the gulf-weed, by proving that its place of growth cannot be on this side (west) of the middle of that stream. No gulf-weed is ever found west of the axis of the Gulf Stream; and, if we admit the top of the stream to be higher in the middle than at the edges, in consequence of the expansion due the difference of temperature of the water in the middle and at the edges, it would be difficult to imagine how the gulf-weed should cross it, or get from one side of it to the other.

The inference, therefore, would be, that as all the gulf-weed which is seen about this stream is on its eastern declivity, the *locus* of the weed must be somewhere within or near the borders of the stream, and to the east of the middle. And this idea is strengthened by the report of Captain Scott, a most intelligent shipmaster, who informs me that he has seen the gulf-weed growing on the Bahama Banks. I have specimens of it which he had the kindness to send me, with seed-vessels, plucked from the bottom while at anchor on the edge of the Gulf Stream. Hence we account for the fact that the gulf-weed should be seen on the eastern and not on the western borders of the Gulf Stream.

A study of the Thermal Charts will reward the student with new and better ideas as to system of oceanic circulation. Plate XVI exhibits the mean geographical position of the March and September isotherms for every ten degrees of Fahrenheit from 80° down to 50°. These lines are taken from the Thermal Charts, series D.

Let us take the isotherm of 80° for September as an illustration; the greatest effects of the solar heat is produced upon the land during the month of August; but this Chart shows that it is September before the North Atlantic Ocean is fully supplied with its annual store of heat for the winter.

We see clearly enough, by the monthly isotherm for 80°, that the western half of the Atlantic Ocean is heated up, not by the Gulf Stream alone, as is generally supposed, but by the great equatorial caldron to the west of longitude 35°, and to the north of Cape St. Roque, equatorial flexure, which actually extends from 40° to 2° N., and rises up again to 35° N.— in Brazil. The lowest reach of the 80° isotherm for September—if we except the remarkable to the west of the meridian of Cape St. Roque, is above its highest reach to the east of that meridian. And now that we have the fact, how obvious, beautiful, and striking is the cause?

Cape St. Roque is in 5° S. Now study the configuration of the Southern American continent from this cape to the Windward Islands of the West Indies, and take into account, also, certain physical conditions of these regions: The Amazon, always at a high temperature, because it runs from west to east, is pouring an immense column of warm water into this part of the ocean. As this water and the heat of the sun raise the temperature of the ocean along the equatorial sea front of this coast, there is no escape for the liquid element, as it grows warmer and lighter, except to the north. The land on the south prevents the tepid waters from spreading out in that direction as they may do to the east of 35° W., for here there is a space, about 18° of longitude broad, in which the sea is clear both to the north and south.

They must, consequently, flow north. A mere inspection of the Thermal Chart is sufficient to make obvious the fact, that the warm waters which are found east of the usual limits assigned the Gulf Stream, and between the parallels of 30° and 40° N. do not come from the Gulf Stream, but from this great equatorial caldron, which Cape St. Roque blocks up on the south, and which forces its overheated waters up to the 40th degree of north latitude, not through the Caribbean Sea and Gulf Stream, but over the broad surface of the left bosom of the Atlantic Ocean.

In contemplating the isotherm of 80°, for each month, we are struck with the remarkable bending towards the equator, on the eastern side of the Atlantic. This feature indicates, more surely than any direct observations upon the currents can do, the presence, along the African shores, of a large volume of cooler and running waters.

These are the waters which, heated np in the caldron of St. Roque, in the Caribbean Sea, and Gulf of Mexico, have been made to run to the north, loaded with heat, to temper climates there. Having performed this office, they are obedient still to the "Mighty Voice" which the winds and the waves obey. They are returning by this channel along the African shore to be again replenished with warmth, and to keep up the system of beneficent and wholesome circulation designed for the ocean.

The Thermal Charts abound with beautiful results and instructive facts, all of which are expressed, by the Charts themselves, much more clearly and forcibly than my pen can utter them.

It is proposed to construct from the same journals which have afforded the materials for these Thermal Charts of the Atlantic, which journals give the temperature of the air, also, another set of Thermal Charts, which shall relate to the temperature of the atmosphere over the ocean; though Professor Dové, by means of his valuable Thermal Charts of the atmosphere, has rendered this labor much less interesting than in the absence of his exquisite work it would have been; for it has already been shown by this series of Charts, in connexion with his, that the remarkable bending of his isotherms, as they enter the land along the western shores of Northern Europe and America, is owing, in a great degree, to the manner in which the aqueous curves of equal temperature approach those shores.

These Charts will show very conclusively, and in a manner the most striking, that the mean temperature of the ocean at the surface is higher than that of the atmosphere.

THE STORM AND RAIN CHARTS.

Letter E of the series—Storm and Rain Charts—was commenced for the North Atlantic by Lieutenant Wm. Rogers Taylor, U. S. N.; and in his absence at sea in the Albany, it has been continued by Lieutenant Wm. H. Ball, and in his absence in the United States ship Portsmouth, by Lieutenant George Minor. Those of the South Atlantic have been published also.

The object of these Charts is to show the total number of observations that have been discussed for each month in every space of 5° square in the ocean; and then to show for every square and month the number of days each in which there was rain, a calm, a fog, thunder and lightning, or a storm, and the quarter from whence it blew.

The manner in which these observations are collected from the quarry of log-books, brought together and discussed, and the officers at work upon them, remind one of the sculptor; any single stroke of the chisel, however well directed, does but little towards developing the figure which in due time is to stand out from the rude mass upon which he is engaged. So with these observations; any single one, however accurate, is in itself worth but little. It is only by oft-repeated observations, multiplied and brought together in sufficient numbers to express their own meaning, that satisfactory and significant results can be obtained. Then, like the piece of statuary answering to the repeated touch of the chisel, the Charts speak for themselves, and all at once stand out before the compiler, eloquent with facts which the philosopher never dreamed were lurking so near.

Among the various phenomena presented in the course of these investigations, some have pointed to the moon, and suggested the inquiry: Has the declination of the moon any influence upon the bands of trade-wind and calms, by moving the edges of their zones up and down the ocean, or by accumulating an excess of atmosphere, first in one hemisphere, then in the other, according as the declination be north or south?

The abstract logs will, in the course of time, afford observations enough probably to enable me to answer this question; for it is one of those questions to which a satisfactory reply, either in the affirmative or negative, is equally desirable.

A preliminary investigation of this problem was assigned to Passed Midshipman Matthews, since lost, with all hands, in a boat at sea. His researches related entirely to the Atlantic. Before he had completed it, he was ordered away to sea; and I have not had force since to continue them. But I am apprehensive that the true answer to the question will be so masked by the effects of other causes in moving these trade-wind bands up and down the ocean that its purport will not be perceived.

Perhaps the Pacific Ocean, when there shall be observations enough made in it, will enable me to put this question to rest.

Plate IV is a sample of the manner in which the observations are callaborated for the Storm and Rain Charts.

As with the Pilot Charts, so with these: the ocean is divided out into districts of 5° of latitude by 5° of longitude for these investigations, and whatever phenemenon is reported as occurring in one part of a district is assumed to occur in all parts of that district.

Between each pair of meridians having a space of 5° between them, 12 lines are for the twelve months, always beginning with December, the first winter month; and horizontally between each pair of parallels for each 5° there are 13 lines, eight of which are for gales from the eight semi-quadrants—one for the calms, one for rain, one for thunder and lightning, one for fogs, and the other for the number of observations called days, which have been observed for each month and district. These last expressed in figures, and the other according to the method of "fives and tallies," already explained for other Charts.

Three observations make a day; so, in order to see how many days of observation have been discussed for any month, it is necessary to divide by three the number which stands in the column for the months, and on the line marked "days."

The object of this Chart is to show the exceptions to what may generally be considered the prevailing condition of the weather at sea, and to determine from what quarter storms are most liable to occur for each month in every district.

It may be that mariners do not *always* record in their logs rain, fog, thunder or lightning. They do always mention gales and calms, and the quadrant whence the wind blows. It may, therefore, be probable that both rains and lightning occur at sea more frequently than it would appear by the Charts they do; if so, I have no means of knowing, until I shall have received many thousands of abstract logs faithfully kept according to the form recommened by the Brussels Conference, and now universally used at sea, wherever there is a vessel commanded by a master capable of appreciating his duties, and the importance of a great work like this. But it may be presumed that mariners generally are not more apt to neglect to mention rains, thunder, and fogs in one part of the ocean than another; and that, therefore, the relative frequency with which they occur may be supposed to be fairly indicated on the chart.

But as the Chart is a fair exponent, according to the data from which it is constructed, as to the frequency of the phenomena to which it relates, we are bound to give it as much faith and credit in one respect as in another, and, therefore, to assume, until we have reason to suppose it otherwise, that the occurrence of rain, fogs, and lightning, is fairly represented in point of frequency.

The scores designate not the times that it thunders, or rains, or blows a gale, but simply the number of days on which such phenomena have been reported to occur; as an example, a gale may be accompanied with fog and rain, thunder and lightning, in which case a score would be made in the appropriate places for each.

The districts represented in Plate IV by A, B, and C, extend from 30° to 45° N., and from 55° to 60° W. Those represented by D, E, and F, extend from the equator to 15° N., between the meridians of 25° and 30° W.

This plate also affords matter that is interesting to sailor philosophers.

Examining district F, it appears that rains and calms, and NW. gales, abound from December to May, inclusive; that lightning is never seen, nor thunder heard there, from April to September, inclusive; that in October there is an occasional gale from the eastward; and that from June to September may be called a rainless season, during which period there is rarely a calm, and never a gale nor a thunder cloud to disturb the air.

This is because the equatorial calms and their train of atmospherical disturbances have gone up, as shown per Trade-wind Charts, into district E. The rainy season in E is the dry one of F. It may be said that E has two rainy seasons—one for about two and a half months before August, the other for three months after.

It appears from D that the rains commence before the calms, and continue after them;

that from December to March is a rainless period; and that an electric display from the clouds is a rare occurrence at any time of the year in this district.

Now going to A, the first thing that strikes us is the prevalence of fogs, the regularity of precipitation, the almost total absence of gales in June and July, the scanty rains in the former month, and the abundance of the materials from which these facts are drawn.

Contrasting this with B, we find that July and August are the months which are most exempt from storms and rain, fogs and thunder; that calms rarely occur in January, February, March, April, July, August, October, and November.

In district C storms and rains seldom occur in April, May, June, and July. But it is needless to repeat what the Chart tells so plainly at a glance. Storm and Rain Charts for the Atlantic Ocean, North and South, have been published.

"These Charts are very instructive. They show that that half of the atmospherical coating of the earth which covers the northern hemisphere—if we may take as a type of the whole what occurs on either side of the equator in the Atlantic Ocean—is in a much less stable condition than that which covers the southern.

There are, as a rule, more rains, more gales of wind, more calms, more fogs, and more thunder and lightning in the North than in the South Atlantic. These phenomena at equal distances from the equator north and south, and for every 5° of latitude, have been compared (Plate V)—that is, all the storms, calms, rains, &c., between the parallels of 25° and 30° N., for instance—have been compared with the same between the parallels of 25° and 30° S.; those for January north being compared with those for January south, and so on for each month, between all the five degree (5°, 10°, 15°, &c.,) parallels from the equator to 60° N. and S.

In some places here and there, and in some months now and then, there may be more gales, as in the neighborhood of Cape Horn, in the South than in the North Atlantic; but such cases constitute the exceptions—they are by no means the rule. Cape Horn, in the South Atlantic, and the Gulf Stream, in the North, furnish seats for agents which are very marked in their workings. This plate brings out the fact that, as a rule, rains and calms go together in the tropics; but beyond, rains and gales are more apt to occur at the same time, or to follow each other."—*Physical Geography of the Sea.*

THE WHALE CHARTS.

In 1847, materials sufficient having been collected from the log-books of whalers for an investigation into the habits and places of resort of the whale, Lieutenant Wm. L. Herndon commenced the construction of this Whale Chart F for the whole ocean, excepting the North Atlantic.

The object of these Charts is to show at a glance where this fish has been most hunted; when, in what years, and in what months it has been most frequently found—whether in shoals, as stragglers, and whether sperm or right. The sheets are numbered letter F of the series.

Lieutenant Herndon was interrupted in these highly interesting investigations by orders for sea service. He had proceeded far enough, however, with the Charts to develop some of the first fruits, which, it might be expected, are concealed in a field so abundant with treasures as this may be well supposed to be. But these orders deprived me of the assistance of a most valuable officer, and greatly delayed the work.

The plan of conducting these investigations is by spaces of 5° square, and the observations are so entered as to show at a glance the number of days for each month that vessels have spent searching for whales in each square; the number of days in which whales—and whether they are sperm or right—have been seen; also, the years in which whales of either kind were seen, and the years in which they were not seen, in any given square.

As observation after observation in such an immense field was recorded day after day, with the most untiring industry, and as the oft-repeated process finally began to express a meaning, I was surprised to find the lines for entering the right whales were blanks, through certain districts of the ocean, from one side of the Chart to the other. Finally, it was discovered that the torrid zone is to this animal forbidden ground, and that it is physically as impossible for him to cross the equator, as it would be to cross a sea of flame. In short, these researches show that there is a belt from two to three thousand miles in breadth, and reaching from one side of the ocean to the other, in which the right whales are never found.

Hence the discovery that the fish called the right whale in the northern hemisphere is not the fish which goes by this name in the southern; that the right whale of Behring's Strait and the whales of Baffin's Bay are probably the same animals; and if so, the conclusion is almost inevitable that there is at times, at least, an open water communication through the polar regions between the Atlantic and Pacific Oceans; for this animal, not being able to endure the warm waters of the equator, could not pass from one ocean to the other unless by way of the arctic regions.

The investigations connected with these animals have also assisted to point out the great currents of warm water which keep up the ocean circulation of the Pacific—it might be said, of the globe; for, as we study their habits, these dumb creatures teach us by their instincts that there are continuous currents in the sea, between places the most remote.

After Lieutenant Herndon was called away, the investigations for these Charts were continued by Lieutenant Leigh, for a short time. His duties were soon changed, and I remained without force to resume the work, till late in 1850, when Lieutenant Fleming reported for duty. He was set to work on the Whale Charts, but before he made any progress with them worth the name, he was detached, and ordered on other duty. Passed Midshipman Jackson then took them in hand and completed them.

They show in what part of the ocean the whales "use" in each month, and the knowledge cannot fail to prove of great importance to the whaling interests of the country—an interest which keeps in continual occupation a fleet of 600 sail, manned by 15,000 American seamen, and which fishes up annually from the depths of the ocean property, the real value of which far exceeds that of the gold mines of California.

It is the custom among whalers to have their harpoons marked with date and the name of the ship; and Dr. Scoresby, in his work on Arctic voyages, mentions several instances of whales that have been taken near the Behring's Strait side with harpoons in them bearing the stamp of ships that were known to cruise on the Baffin's Bay side of the American continent; and as, in one or two instances, a very short time had elapsed between the date of capture in the Pacific and the date when the fish must have been struck on the Atlantic side, it was argued, therefore, that there was a northwest passage by which the whales passed from one side to the other, since the stricken animal could not have had the harpoon in him long enough to admit of a passage around either Cape Horn or the Cape of Good Hope.

The whale-fishing is, among the industrial pursuits of the sea, one of no little importance; and when the system of investigation out of which the Wind and Current Charts have grown was commenced, the haunts of this animal did not escape attention or examination. The log-books of whalers were collected in great numbers and patiently examined, co-ordinated, and discussed, in order to find out what parts of the ocean are frequented by this kind of whale, what parts by that, and what parts by neither.—(See Plate XIV.)

Log-books containing the records by different ships for hundreds of thousands of days were examined, and the observations in them co-ordinated for this Chart. And this investigation, as Plate XIV shows, led to the discovery that the tropical regions of the ocean are to the right whale as a sea of fire, through which he cannot pass, and into which he never enters. The fact was also brought out that the same kind of whale that is found off the shores of Greenland, in Baffin's Bay, &c., is found also in the North Pacific, and about Behring's Strait, and that the right whale of the northern hemisphere is a different animal from that of the southern.

Thus the fact was established that the harpooned whales did not pass around Cape Horn or the Cape of Good Hope, for they were of the class that could not cross the equator. In this way we were furnished with circumstantial evidence affording the most irrefragable proof that there is, at times, at least, open water communication through the Arctic Sea from one side of the continent to the other, for it is known that whales cannot travel under the ice for such a great distance as is that from one side of this continent to the other.

But this did not prove the existence of an open sea there; it only established the existence—the occasional existence, if you please—of a channel through which whales had passed. Therefore, we felt bound to introduce other evidence before we could expect the reader to admit our proof, and to believe with us in the existence of an open sea in the Arctic Ocean.

There is an under current setting from the Atlantic through Davis' Strait into the Arctic Ocean, and there is a surface current setting out. Observations have pointed out the existence of this under current there, for navigators tell of immense icebergs which they have seen drifting rapidly to the north, and against a strong surface current. These icebergs were high above the water, and their depth below was seven times greater than their height above. No doubt they were drifted by a powerful under current.

Now, this under current comes from the south, where it is warm, and the temperature of its waters is perhaps not below 32°; at any rate, they are comparatively warm. There must be a place somewhere in the Arctic seas where this under current ceases to flow north, and begins to flow south as a surface current; for the surface current, though its waters are mixed with the fresh waters of the rivers and of precipitation in the polar basin, nevertheless bears out vast quantities of salt, which is furnished neither by the rivers nor the rains.

These salts are supplied by the under current; for as much salt as one current brings in, other currents (§ 113) must take out, else the polar basin would become a basin of salt; and where the under current transfers its waters to the surface, there is, it is supposed, a basin in which the waters, as they rise to the surface, are at 30°, or whatever be the temperature of the under currrent, which we know must be above the freezing point, for the current is of water in a fluid, not in a solid state.

An arrangement in nature, by which a basin of considerable area in the Frozen Ocean could be supplied by water coming in at the bottom and rising up at the top, with a temperature not below 30°, or even 28°—the freezing point of sea water—would go far to mitigate the climate in the regions round about.

And that there is a warmer climate somewhere in that inhospitable sea, the observations of many of the explorers who have visited it indicate. Its existence may be inferred, also, from the well known fact that the birds and animals are found at certain seasons migrating to the north, evidently in search of milder climates. The instincts of these dumb creatures are unerring, and we can imagine no mitigation of the climate in that direction, unless it arise from the proximity or the presence there of a large body of open water. It is another furnace (§ 147) in the beautiful economy of nature for tempering climates there.

Relying upon a process of reasoning like this, and the deductions flowing therefrom, Lieutenant De Haven, when he went in command of the American expedition in search of Sir John Franklin and his companions, was told, in his letter of instructions, to look, when he should get well up into Wellington Channel, for an open sea to the nothward and westward. He looked, and saw in that direction a "water sky." Captain Penny afterwards went there, found open water, and sailed upon it.

The open sea in the Arctic Ocean is probably not always in the same place, as the Gulf Stream (§ 152) is not always in one place. It probably is always where the waters of the under current are brought to the surface ; and this, we may imagine, would depend upon the freedom of ingress for the under current. Its course may, perhaps, be modified more or less by the ice on the surface ; by changes, from whatever cause, in the course or velocity of the surface current, for obviously the under current could not bring more water into the Frozen Ocean than the surface current would carry out again, either as ice or water.

Every winter an example of how very close warm water in the sea and a very severe climate on the land or the ice may be to each other is afforded to us in the case of the Gulf Stream and the Labrador-like climate of New England, Nova Scotia, and Newfoundland. In these countries, in winter, the thermometer frequently sinks far below zero, notwithstanding that the tepid waters of the Gulf Stream may be found, with their summer temperature, within one good day's sail of these very, very cold places.

At the moment of reading proof, I received a copy of the New Bedford Whalemen's List, containing an account of Dr. Petermann's paper, "read some time since" before the Royal Geographical Society, going to show that the whale fishery may be conducted with advantage in the Spitzbergen Sea. My attention has been attracted to the subject for some time, and last fall a gentleman, known as the most enterprising of American whalemen, made me a visit for the purpose of consulting upon that subject. There seems to be no reason why whales should not be as abundant in the Arctic Sea, north of Europe, as they are in the Arctic Sea, north of Asia and America. Physically, my researches have pointed out but one condition in the Arctic Sea, north of Europe, differing from the conditions in the other parts of the Arctic basin. I mean conditions which affect the whales, and that is, the Arctic Sea north of Europe is fed directly by the Gulf Stream ; and these waters, therefore, may not be as favorable to the well-being of the whale, or to the production of their food, as waters are that have been a longer time in the polar basin. I mention this as a *possible* difference, because it is the only perceptible difference, and notwithstanding that whales have been found in those seas, which indicates that there is no real difference so far as the whales are concerned. Nevertheless, the whales that have been found there may have been found in waters that were running out as an eddy to the Gulf Stream.

I have the abstract log of the brig Cyclops, (R. Calhoun,) from Boston to Archangel, and back, in the summer of 1849. That vessel was in the waters of the Gulf Stream all the way, except for two days while passing the Grand Banks; and on the Grand Banks she found the water from twelve to fifteen degrees colder than she did beyond Cape North, on the polar side of the 71° of north latitude. But I see no reason for the conclusion that Gulf Stream water is not as congenial to the right whale as any other water, when reduced to a temperature that affords the climate in which that fish most delights; and being favorably impressed with the probability of finding in those regions a valuable whaling ground, I said all that it was proper to say to encourage this adventurous seaman in his bold enterprise. The regions round about Nova Zembla were thought to be most inviting. He left me, determined to make the attempt in the fishing season of 1855, and I doubt not that by the time these pages reach the public eye, he will be on the ground with his vessel, busily engaged in "cutting in and trying out."

Plate IX exhibits an extract from the Whale Chart.

The object of these charts is to show where the whalemen have hunted, and where they have found their game; consequently, this chart enables us to designate those parts of the ocean where the whales "use," and those parts where they never go, and to tell where in each month this animal is most likely to be found.

The three horizontal lines, Plate IX, marked D. R. S., in the middle column, repeated from parallel to parallel, stand, D for days, R and S for the number of days, each, on which whales, right or sperm, have been seen. The days of search are expressed in figures; the days on which whales are seen are expressed by the system of "fives and tallies," as already explained with regard to the winds.

It will be observed that from 60° north to 60° south, between the meridians of 125° and 130° W., right whales, except in one instance, have never been reported by any of the vessels whose logs have been examined. That sperm whales, except a straggler or two, have never been seen between these meridians, and below 5° S.; between which parallel and the equator they are most abundant. That they are seen between 35° and 50° N.; between the equator and 10° N.; but not between 10° and 35° N.; and the inference is drawn, from the fact of their appearing so frequently between the parallels of 35° and 50° N., that warm water is found there.

The investigations for this chart are so conducted as to show the year in which the whales have been searched for and seen in the various districts of the ocean. These results are the embodied experience of several hundred whaleman as to the best fishing grounds.

Besides the practical advantages which it is conjectured will enure to the whaling interest from these investigations, much information of a highly interesting character will probably be elicited by them for the naturalist and the geologist.

By examining the Whale Chart it will, in its present state, serve to satisfy one at a glance that the favorite haunts of the sperm whale are about the equatorial; of the right, about the polar regions. That near the tropics is a sort of debatable ground, where the pasturage of the one overlaps the pasturage of the other. And that, on either hand, a straggler from the one herd is occasionally found far over within the borders of the other.

I have to request that whalemen, when they come across these stragglers, will observe them closely. Do they appear to be lost? What is their bodily condition, fat or lean; and what the contents of their stomach? Are the stragglers generally male or female, and what is there that is peculiar about them?

The Whale Chart, (series F,) which comprises a chart of the world, Mercator's projection of 10 degrees to an inch at the equator, and which extends from latitude 79° 50′ N. to 68° S., shows three places where the sperm whale is in the habit of leaving the tropical regions and of resorting to higher latitudes. These places are in the South Atlantic, where they have been found in large schools, between the parallels of 30° and 35°; in the South Pacific, between the parallels of 35° and 60°; and in the middle of the North Pacific, as high up as 40°.

I account for their presence up in the North Pacific by the Gulf Stream, which has its genesis in the Indian Ocean, and its exodus in the China Seas. It carries, high up into the North Pacific Ocean, the warm waters and sea climate of the tropics, and the sperm whale resorts there to enjoy it.

The sperm whale, being found in the South Atlantic, has suggested the inquiry as to the temperature of the waters there. Can there be a warm current in that part of the ocean; if so, whence does it come; from the inter-tropical regions of the Atlantic, or from the Indian Ocean, or is it a branch of the Lagullas current?

If it be the temperature of the water which invites the sperm whale into these extra-tropical regions of the South Atlantic, we may, perhaps, obtain from these dumb creatures an answer to the question: By what channel do the waters which the ice-bearing current around Cape Horn, and the cold current from Baffin's Bay, and the waters which the Mississippi River, the St. Lawrence, and all the great rivers of Europe, Africa, and America, bring into the Atlantic Ocean—by what channel do these waters escape and preserve the level of the sea?

These currents bring into the Atlantic water more than enough to supply the waste of evaporation. The brine of the sea is not accumulating or concentrating in this ocean, and we, therefore, *know* that there must be somewhere in this ocean, either in the surface above or in the depths below, a current of large volume running from it. I have searched for it long and patiently. I have looked for it—feeling as certain of its existence as we do of a thing that has been seen and known to exist and is lost—but in vain.

The components of sea water, like the components of the atmosphere, are everywhere the same. It is true that we find a little more salt in this place, and a little less in that; but this is attributable, not to the want of a general system of aqueous circulation in the terrestrial economy, but rather to local causes, such as an excess of precipitation or an excess of evaporation, or the discharges of fresh water from rivers in the neighborhood. If the waters of the sea did not pass from one climate to another, and from one ocean to another, it would not be difficult to conceive why, in the process of time, there should not be as great a difference in the waters in different parts of the great oceanic reservoir of the earth as there is in the waters of the Dead Sea and the Mediterranean, or in the waters of any two seas between which there is no communication.

The chemist analyzes the waters of the Mediterranean and of the Red Sea, and detects the same components. Now, unless the waters of these two seas could intermingle—and I have traced a current from the one to the neighborhood of the other—unless, I repeat, there were an intermingling between the waters of these two seas, what could preserve the same salts in the same quantities in each?

The Red Sea, because it is riverless and rainless, receives no salts from the land on its shores. Whereas, the rivers which empty into the Mediterranean have for ages been filtering "the salt of the earth," taking it up in solution from the soil, and bringing it down with their drainage into this sea.

Now, unless nature had provided some means of process by which the waters of these two seas should regularly intermingle with the waters of the ocean, and, through the ocean, with each other, what would hinder the two seas from salting up their brine with different strength?

No doubt the harmonies of the sea are as beautiful and as sublime as the "music of the spheres." And to what agency, therefore, if not to the agency of currents and the mobility of water, must we ascribe the permanent condition of sea water? For, perhaps, of all parts of creation that are both tangible and visible to us, the waters of the sea are most permanent and stable in their characteristics, proportions, and constituents.

If nature had not provided a general system of circulation for the waters of the sea, what would prevent the waters of the Mediterranean, for instance, from absorbing salts and other constituents through its rivers, and of accumulating them in quantities and proportions which would possibly make a characteristic difference between sea water from the Mediterranean and sea water from the Red Sea?

That the waters of remote seas do not permanently attain different degrees of saltness—that sea water, like the air of heaven, come whence it may, is always the same—may of itself be taken as a proof, if no other evidence could be had, that there is a regular and constant passage, secret and invisible though it be, of the waters from one oceanic basin to another. At least, in the present state of our information upon this subject, we infer that such is the case; and that it is owing to the agency of currents in the depths below and on the surface above, that the waters of one sea are not all brine, of another all fresh, and of another all ice.

Twice, perhaps thrice, as much fresh water is discharged by the rivers of Europe, Africa, and America, into the Atlantic as is discharged by all other rivers into the Pacific. Twice, perhaps thrice, as much fresh water is taken up from the Pacific as from the Atlantic by evaporation. Now, if the waters of these two oceans were never to intermingle—if the waters of the Pacific never found their way into the Atlantic, and if the Atlantic were never to send its waters to mingle with those of the Pacific Ocean in its own basin—what would prevent the great water-sheds that are drained into the Atlantic from filling its basin up, in the process of time, with fresh water? What, too, would prevent the Pacific, which gives more fresh water to the clouds than they restore to it again, from becoming, first, a sea of brine, then finally a bed of salt?

Studying the habits of nature, so to speak, with regard to the air and the sea, I have learned to conjecture that every drop of water now in the Pacific has been at some former period in the Atlantic; and this conjecture, reason teaches me, is as plausible as is the supposition that every breath of air now in the northern hemisphere has at some time or other, in following its appointed paths, coursed its round in the general system of circulation through the channels of the southern hemisphere.

Assuming these principles to be in conformity with the designs of nature, I have been induced to search for a current from the Atlantic Ocean to the Pacific.

Taking its existence for granted, therefore, as I am disposed to do, it can be readily shown that this current does not have its exodus through the Arctic Ocean; for in that case, the precipitation in that ocean being greater than the evaporation, the water of the great rivers of Northern Asia, Europe, and America, being added to its own waters, would create a stream of immense volume and frightful rapidity through Behring's Straits into the Pacific. Whereas, so far from this being the case, the reverse occurs.

The current through Behring's Straits runs generally from, not into the Pacific. I have, therefore, looked to the South Atlantic—to the space between the two stormy capes—as the only place in which this ex-Atlantic current could make its exodus. And if, after all this special and minute investigation; if, after the most accurate, and careful, and patient examination that has been made of log-books here for some evidence of this current; if, after the attention of navigators has been called to it, and they have exhausted all the means which human ingenuity has devised for detecting and measuring currents at sea, and have failed to discover one here; if, after all this labor and research, it should so turn out, when we go there with the water thermometer, that the sea climate is not an extra-tropical one, as its latitude indicates; that it is the inter-tropical temperature of its waters which tempts the sperm whales to gambol there in such multitudes—then the discovery of the fact that the sea water here is a little warmer, and that, therefore, there is a current running hither from the equator, should be regarded as one which is due to the information which the study of the habits of this animal has given us. Plate XIV leaves us to infer it to be an under current.

In the sperm whale region of the coast of Chili and Terra del Fuego we have been taught to believe in the existence of a cold current. Assuming this cold current to be there—that it is not crossed or divided by a warm current—the resort of the sperm whales there must be regarded as an anomaly in the habits of the creature.

These investigations as to the habits and places of resort of the whales have taught me to regard sperm whales as much out of place in cold water as the whalers themselves would regard out of place a wilderness of howling monkeys of the Amazon among the Green Mountains of Vermont.

I take this occasion to say—because some of the whalemen have supposed it unnecessary to continue the abstracts when in sight of land—that it is important to have a complete abstract for ever day they are at sea; that we may know whether they find fish or not, how plentifully, the force and direction of winds and currents, the temperature of the air and water, and that we may glean information as to all other phenomena which they are requested to note in the abstract log,

Plate X is a section taken from the Whale Chart of the world. It is a copy, and nearly a fac simile, except that, in some of the Charts, the right whale curves are colored blue, and the sperm red. Take the square marked A as an illustration and explanation of the Chart. Between the meridians of 45° and 50° W.—as between every fifth pair of meridians—are 12 columns for the 12 months; the first column on the left always standing for December, or the first winter month; the next for January, and so on.

Between the parallels of 35° and 40° are 11 horizontal lines. Beginning always at the south and counting up towards the north, each of the first ten of these lines stands for 10 days, thus making the 10th stand for 100. The scale is then changed; the 11th line stands for 200; and the 12th on the parallel of latitude for 300 days.—(See the figures in the margin.)

Now, by following the curve for the days, and the curve for the whales, right and sperm, for this square, it will be seen that, during different years, whalers have spent in this square upwards of 100 days (125) searching for whales in the month of December; and that, out of this time, they saw right whales on 15 days, sperm on 2; and that during each month they have fished and seen as follows, viz:

Days of search.	No. of days on which were seen—		Days of search.	No. of days on which were seen—	
	Right whales.	Sperm whales.		Right whales.	Sperm whales.
In December.....125....	15	2	In June........12....	....	....
January.......96....	8	12	July.........8....	....	....
February......150....	5	10	August.......28....	....	....
March.........110....	2	8	September...68....	20	....
April..........78....	....	5	October......90....	25	8
May............28....	....	3	November...88....	43	5

It appears, therefore, that from September to December, inclusive, is the best time for whaling in this district of 5° square. In some of its neighboring districts whalers have been more sucessful in other months, as a glance at the Chart will show.

It is worthy of remark that the sperm whale, according to the results of this Chart, appears never to double the Cape of Good Hope. He doubles Cape Horn. Since this fish delights in warm water, shall we not expect to find off Cape Horn an under current of warm water, heavier with its salts? See the limits of the sperm whale ground, as well as of the right, on Plate XIV. These are the approximate limits only of their most usual places of resort.

PHYSICAL CHART OF THE SEA.

There is contained in the abstract logs kept for this office a vast amount of information concerning various phenomena of the air and water.

This information may be called miscellaneous, inasmuch as it relates chiefly to subjects that, though interesting enough, yet do not constitute special objects of consideration; indeed, they are such generally as do not, as yet, come under any one of the various heads of research.

Among these, I may mention observations and remarks concerning gales of wind; notices of driftwood, icebergs, and sea-weed; hail-storms, and tide-rips; flying-fish; and red-fogs; colored water; sea-dust; animalcule, phosphorescence of the sea, and the like.

The officers who are engaged in examining the logs and co-ordinating for them are required each one to keep a memorandum book by him, in which he notes and refers to all such subjects, when mention is made of any of them in the logs.

These little memorandum books have suggested the idea of constructing a physical chart of the ocean, to illustrate some of the principal phenomena and subjects that are visible on and near its surface.

Each officer, as he examines the log for the special object which he has in view, is moreover to keep by him a blank chart, upon which he is to put down by symbols, ice, sea-weed, flying-fish, &c., in the place where the abstracts report them. Thus, it is proposed, should the results, when grouped together, be found sufficient, to construct what may be called, in some sort, a topographical chart of the surface of the ocean.

One of the most curious and puzzling of the many physical aspects presented by the sea, and which seem to belong to its *topography*, is what seamen call "tide-rips." Tide-rips are encountered in many parts of the ocean; they are most frequently mentioned in the abstract logs, between the parallels of 15° N. and the equator and in all seas; but particularly in the Atlantic Ocean.

In the hope of *provoking* others into essays to account for them, I have suggested various explanations, not one of which is at all satisfactory however. Nevertheless, they may suggest something to others, and as the object of this work is not to build up theories, but to advance knowledge, I consider that a step will have been gained in the right direction when I succeed in directing the attention of philosophers to any such phenomenon as the sea presents with its tide-rips.

The appearance thus designated is a ripple in the water, such as is seen in a tide way, or at the meeting of two currents. Sometimes it is a sheet of foam in the ocean, as though the sea were breaking upon a shoal; indeed, tide-rips are often mistaken for unknown reefs and shoals; at other times it is like a boiling and a bubbling from the bottom of the sea. Captain Arquit, of the Comet, in November, 1855, thus describes them:

"*November* 15.—Latitude 7° 34′ N.; longitude 40° 28′ W. Many tide-rips, which we had a good opportunity of observing when becalmed; they came up in ridges, as long as the eye could reach, from all points of the compass, but mostly from east. I examined the ridges very closely, but could not see any fine drift matter of any kind, as you can on the edges of currents in many parts of the ocean. We have had no currents, unless they have been from different directions, and one counteracting the other.

November 16.—Latitude 6° 7′ N.; longitude 40° 5′ W. There has been no time since noon to midnight but that there have been tide-rips either in sight or hearing, mostly tending NE. and SW. in long narrow ridges. From 8 P. M. to 9 P. M. the ocean appeared like a boiling cauldron, which we sailed through for 3 miles. The ship had a very singular motion, like striking her keel on a soft muddy bottom, in a short rough sea-way—the same as I have felt in the harbor of Monte Video. The motion was noticed by all on board. We have had a current of 15 miles, going west. I have often noticed tide rips in this part of the ocean before, particularly when bound home, (for I have never been where I am now, bound out, before,) and have mentioned them in my abstract log, but they were different from what we had last night. The ship would come-to and fall off three points, without any regard to the rudder."

All the information that I have upon the subject tends to show that in these rips there is no current, or, at least, none which can affect the ship. Is the campass effected by them?

These tide-rips are met, most generally, about the region of the equatorial doldrums. They are occasionally seen in other parts of the ocean. But those to which I now refer particularly are those which almost every vessel encounters near the equator, and which are so often mentioned in the abstract logs.

What produces this singular appearance so constantly in this part of the ocean? Vessels sail through these rips and feel no current. How would it be with a boat? for it appears to me that the motion in the water which produces the appearance is a horizontal, not a vertical motion. If the former, the question comes up, can the trade-winds produce it?

I have seen no plausible conjecture in the way of explanation concerning this singular agitation of the water in mid-ocean. The question has been asked: Is there not a breaking up of the water at the meeting of the two systems of trade-winds, and are not these "tide-rips" the surface currents—the crevasses—from this piling up of the water under the equatorial cloud-ring?

In the first place, the barometer stands lower there than it does in the trade-winds on either side; and that *tends* to pile the water up there.

In the next place, the constant and heavy rains from the equatorial cloud-ring would tend still more to pile up; and, in the last place, the northeast trade-wind on one hand, and the southeast on the other, each pressing the water with all its force up into this calm belt, would tend still further to keep up the waters in it. Being so heaped up, and the heaping up force being a variable one, the water might break out here and there, and so produce the phenomenon in question. This, though not satisfactory, seemed to be less objectionable than any other explanation that I have heard suggested. But tide rips are often seen in mid-ocean, far away from the trade-wind regions; so this explanation is not satisfactory.

In what direction do these tide rips appear to run? and though the ship may not feel any current in them, will a boat? and do chips or other light substances thrown overboard show any signs of a current?

Capt. Hanson, of the "Sherwood," has been so kind as to heed this request. I extract from his log:

"*October* 23, 1856.—Latitude 4° 20′ N.; longitude 29° 26′ W.; calms and light winds; in the doldrums yet; strong rips—astonishing; turbulent. These rips are roaring like a cataract.

"I see you refer to the tide rips in and about the doldrums. I am not competent to give any opinion, however. Bound to Valparaiso, two years ago, encountered those rips. I am this time on the same track and again encountered the rips. I was determined if there were any current in them to ascertain, and got me a light skiff or dorg. I tried it first time anchoring it with 20 fathom line to a 25 pound and boatswain's chair, which brought her up, found the current strong enough to lay her broadside to the wind, two knot breeze. Hove a chip about 6 fathoms from the boat, and in 12 seconds it was alongside. The next time took the log-reel and found it to run 1½ knots. Both these times the current was setting NE. by N., this was in one of the rips. Had no opportunity to try the smooth places; each time a smart breeze springing up. I think there is some other besides the meeting of northeast and southeast trades at work causing these rips. May not the SW. monsoons, which blow strong at times, cause a NE. current? I have no doubt the strong rips move towards the NE.; I have noticed it when becalmed. Last summer, bound from Sydney, C. B., to Rio, crossed latitude 30° and longitude 31°; ran down in this longitude until I was in 11° 00′ where I lost the trades in the month of August. Did not encounter such tide rips. Again, about this bugbear of a NW. current off Cape St. Roque, I am thankful to Lieut. Maury for his Sailing Directions. I would follow his route in a flatboat, and the old route in a clipper, and believe the chances would be in favor of the new route."

This is the only trial of the tide rips, for currents, that I have had any account of. Sometimes these tide rips have been observed to swell up into water-spouts. Water-spouts are considered to be due to electrical agencies, and the question presents itself in this aspect: Can tide rips be only the manifestations on the water of those electrical forces at play which give rise to water-spouts, but which are not strong enough to raise the water in columns? These views are presented not because they are, in my judgment, sufficient to account for the phenomena under consideration, but simply because they may remind others of something that will.

Co-operators will remember that these rips have been recommended to them as an object of special inquiry for years, and now that experiments with regard to them have been commenced, it is hoped that attention will not sleep, nor inquiry cease until we arrive at some satisfactory conclusion.

CHAPTER XX.

MARITIME CONFERENCE HELD AT BRUSSELS,

FOR

DEVISING A UNIFORM SYSTEM OF METEOROLOGICAL OBSERVATIONS AT SEA;

AUGUST AND SEPTEMBER, 1853.

THE GOVERNMENTS REPRESENTED AT THE CONFERENCE, AND THE NAMES OF THE OFFICERS WHO ATTENDED, WERE:—

BELGIUM—by A. QUETELET, directeur de l'Observatoire royal, secrétaire perpétuel de l'Académie royale des sciences, des lettres, et des beaux-arts de Belgique; and VICTOR LAHURE, capitaine de vaisseau, directeur général de la marine;

DENMARK—by P. ROTHE, Captain-Lieutenant Royal Navy, Director of the Depot of Marine Charts;

FRANCE—by A. DELAMARCHE, Ingénieur hydrographe de la marine impériale;

GREAT BRITAIN—by F. W. BEECHEY, Captain Royal Navy, F.R.S., &c., Member of the Naval Department of the Board of Trade; and HENRY JAMES, Captain Royal Engineers, F.R.S., M.R.I.A., F.G.S., &c.;

NETHERLANDS—by M. H. JANSEN, Lieutenant Royal Navy;

NORWAY—by NILS IHLEN, Lieutenant Royal Navy;

PORTUGAL—by J. DE MATTOS CORRÊA, Captain-Lieutenant Royal Navy;

RUSSIA—by ALEXIS GORKOVENKO, Captain-Lieutenant Imperial Navy;

SWEDEN—by CARL ANTON PETTERSSON, First Lieutenant Royal Navy;

UNITED STATES—by M. F. MAURY, LL.D., Lieutenant United States Navy.

The sixth edition of this work contained a copy of the proceedings of this Conference. I therefore content myself with an epitome, giving for this edition the results only.

THE CONFERENCE.

The proceedings of the first meeting commenced at the residence of the Minister of the Interior, on the 23d of August, 1853, at half-past eleven in the morning. Present: MM. Delamarche, Hydrographical Engineer of the Imperial French Navy; De Mattos Corrêa, J., Captain-Lieutenant of the Royal Portuguese Navy; Gorkovenko, Captain-Lieutenant of the Imperial Russian Navy; Ihlen, Lieutenant of the Royal Norwegian Navy; Jansen, Lieutenant (of first class) of the Royal Dutch Navy; Lahure, Captain and Director-General of the Belgian Navy; Maury, Lieutenant of the Navy of the United States and Director of the Observatory at Washington; Pettersson, (C. A.,) Lieutenant of the Royal Swedish Navy; Quetelet, Director of the Observatory at Brussels.

The attention of the meeting was first directed to the choice of a president. Lieutenant Maury was requested to direct the proceedings, but he declined the honor; and, at his suggestion, in which other members of the meeting concurred, Mr. Quetelet took the chair.

The President submitted to the meeting the propriety of publishing the discussions of the Conference; expressing, as his opinion, that publicity was one of the best methods of insuring the success of their undertaking; remarking, at the same time, that, independently of the information which would be conveyed to the public through the medium of the press, the minutes of each sitting and the scientific report of the Conference would thus be preserved.

Lieutenants Jansen and Maury seconded this motion.

Captain-Lieutenant Gorkovenko also expressed himself in favor of publicity. He announced to the meeting that he had just been informed that Captain Beechey, appointed by the English Government to take part in the proceedings of the Conference, would arrive at Brussels in the course of the evening.

The President next called upon Lieutenant Maury to explain to the meeting the object of his mission.

Mr. Maury spoke as follows:—

"GENTLEMEN: The proposal which induced the American Government to invite the present meeting originated with the English Government, and arose from the communication of a project prepared by Captain Henry James, of the corps of Royal Engineers, by order of General Sir John Burgoyne, Inspector-General of Fortifications, in which the United States Government was invited to co-operate.

"Nineteen stations had been formed by the English authorities upon a uniform system, and the direction of the observations confided to the immediate supervision of the officers in command of the respective stations.

"In the United States meteorological observations had been made since the year 1816.

"The American Government sympathized with the proposal of the English Government, but said: Include the sea, and make the plan universal, and we will go for it. I was then directed to place myself in communication with the ship-owners and commanders of the navy and mercantile marine, in furtherance of the plan.

"It is from the information extracted from more than a thousand logs that I have been able to prepare the Charts which have been published up to this time, showing the sailing-routes and the direction of the winds and currents.

"With a view, however, of extending still further these nautical observations, the Government of the United States decided upon bringing the subject under the consideration of every maritime nation, with the hope of inducing all to adopt a uniform model log-book.

"In order to place the captains navigating under a foreign flag in a position to co-operate in this undertaking, Mr. Dobbin, Secretary of the Marine Department at Washington, has instructed me to make known that the mercantile marine of all friendly powers may, with respect to the Charts of the Winds and Currents, be placed on the same footing as those of the American Marine; that is to say, that every captain, without distinction of flag, who will engage to keep his log during the voyage upon a plan laid down, and afterwards communicate the same to the American Government, shall receive, gratis, the Sailing Directions and the Charts published.

"It has consequently been suggested to the captains, that they should provide themselves with, *at least*, one good chronometer, one good sextant, two good compasses, one marine barometer, and three thermometers for air and water. I make use of the expression *at least*, because the above is the smallest number of instruments with which a captain can fulfil the the engagement he contracts upon receiving the Charts.

"Foreign flags will thus enjoy the advantage of profiting at once by all the information collected up to this time.

"You will not fail to observe, gentlemen, that the observations made on board of merchant vessels, with instruments frequently inexact, are not to be relied upon in the same degree as those made where the instruments are more numerous and more delicate, and the observers more in the habit of observing.

"The former, however, from the fact of their being more numerous, give an average result, which may be consulted with advantage; but the observations made on board the ships of the navy, although fewer in number, are evidently superior in point of precision.

"The object of our meeting, then, gentlemen, is to agree upon a uniform mode of making nautical and meteorological observations on board vessels-of-war. I am already indebted to the kindness of one of the members present, Lieutenant Jansen, of the Dutch Navy, for the extract of a log kept on board a Dutch ship-of-war, and which may be quoted as an example of what may be expected from skilful and carefully conducted observations. In order to regulate the distribution of the Charts, which the American Government offers gratuitously to captains, it would in my opinion be desirable that, in each country, a person should be appointed by the government to collect and classify the abstracts of the logs of which I have spoken, through whom also the Charts should be supplied to the parties desirous of obtaining them."

The President:—

"GENTLEMEN: I think I shall be anticipating the wishes of the members of this meeting, by proposing to them to pass, in the first place, a vote of thanks to Mr. Maury, and to record our gratitude for the enlightened zeal and earnestness he has displayed in the important and useful work which forms the subject of our deliberations."

All the members in turn intimated their entire concurrence in the proposal made by the President, to express to Mr. Maury their admiration and their gratitude for the eminent services which he has already rendered, and is still endeavoring to render to the science of navigation.

COLUMNS PROPOSED BY THE CONFERENCE FOR THE ABSTRACT LOG.

DATE.—Mr. Beechey proposed to indicate the months by Roman figures, I to XII, begining with the month of January.

Mr. Gorkovenko remarked that Russia did not reckon dates according to the Gregorian calendar; nevertheless, as the object of the meeting was to arrrive as nearly as possible at uniformity, he thought there would be no difficulty in adopting this calendar for meteorological observations.

It was resolved by the Conference that:—

"The time given in the abstract log should be civil time, but if not, mention the time which is given. Instead of writing the names of the months at length, denote them by Roman figures. Thus, for January I, for December XII."

HOURS.—"The Maritime Conference recommends the adoption of the hours inserted in the second column, namely: four in the morning, noon, and eight in the evening, for making observations to be recorded in the first seven columns."

LATITUDE AND LONGITUDE.—"The latitude and longitude should be observed frequently at sea, especially at the hours indicated in the second column, and the result recorded in the log at the hour nearest to those at which the observations are made, so as to determine as exactly as possible the position of the ship at those times. It will be more especially necessary to make these observation when the ship is about to enter or cross any of the great currents or streams of the ocean, (see *Currents.*")

If the longitude be determined by lunar distances, note it in the column with its proper sign ⊙ ☾; if by chronometer, employ one of the following signs: ⊙ or *.

Position by dead reckoning should be deduced from the position by the last observations.

CURRENTS.—"On ordinary occasions the current is to be determined at noon on each day, by the difference between the position of the ship as found by observation and by dead reckoning, and the direction and rate given for the 24 hours; but where the ship is expected to pass through any of the great currents of the ocean, or when any change is anticipated, the position of the ship is to be frequently determined by observations, and the current computed for the intervals."

MAGNETIC VARIATION OBSERVED.—"Enter with the proper sign the variation ascertained, whether by azimuth or by amplitude."

"The variation entered should be what it would have been if, at the time the observation was made, the ship had been in such a position that the local deviation would have been 0. In other words, the variation entered should be corrected for local deviation."

"The variation should be entered in degrees and minutes."

"When the variation is observed by the moon or a star, make after it the sign of ☾ or *."

"It is desirable that every ship co-operating in this system of observations should have a standard compass on board, by which all the observations for variations should be made, and to which a fixed place should be assigned."

"In the selection of a spot for the standard compass, or of any compass intended to be used in making observations on the variation, care should be taken to select a position for the compass, when it is to be used for observation, in that part of the ship, or as near as possible, which is most free from the effects of local deviation, and that it always stand in the same place."

"When no observation has been obtained, the variation which has been used is to be inserted in the variation column, with an asterisk, the quantity having been corrected for the local attraction of the vessel."

DIRECTION OF THE WIND.—The direction of the wind is the magnetic direction, with due allowance for appearances caused by motion of the vessel. It is the direction of the wind which has prevailed for the last eight hours. It should be expressed to the nearest point of the compass.

FORCE OF THE WIND.—The force of the wind should be expressed in figures. The nomenclature of Admiral Beaufort was adopted.

In case of a squall, after the figure indicating the force of the prevailing wind, that of the squall to be entered in a parenthesis.

FORM AND DIRECTION OF THE CLOUDS.—"Howard's nomenclature for the form of the clouds was adopted."

"When, at the same time, there are two currents, an upper and a lower current, they are to be entered one above the other, separated by a line."

PROPORTION OF SKY CLEAR.—"The *proportion of sky clear* to be expressed by figures from 0 to 10, the figures indicating the extent of sky clear."

HOURS OF RAIN.—"The hours of fog, rain, snow, and hail, are to be indicated by a letter for each of these elements, viz: *A* fog, *B* rain, *C* snow, and *D* hail."

[A simple entry in this column is not enough; when there is no entry to make in it, the fact should be noted by the entry of *O;* this shows that attention was awake.]

BAROMETER.—"It will be necessary to place at the commencement of the log-book the corrections of the barometer, or the date for making these corrections, specifying the place where the comparison has been made."

THERMOMETER.—"If it rains at the time of observing the psychrometer, the letter *B* to be placed by the side of observation."

HOURS.—The President expressed the opinion that, in order to ascertain at sea the diurnal variation of the meteorological instruments, it would be convenient to adopt the project of bi-hourly observations, proposed by the Royal Society of London, or at least the project of tri-hourly observations, suggested by Captain Beechey. The first project, more rigorous, would have the advantage to come in the plan of the observations already adopted on land, and to be more convenient for the division of time in the service at sea.

After a discussion on the matter, the following instruction was adopted.

Column 2.—"In this column shall be placed the following hours, viz: 4 A. M., noon, and 8 P. M., when all the observations shall be made and written upon the lines on which those numbers stand, for the columns 3, 3′, 4, 4′, 5, 6, 7, 8, 9, 10, 11, 11′, 12, 12′, and 13. The observations of the 13′, 14, and 14′ columns should be made at least once a day. The observations for the columns 7, 7′, 11, 11′, 12, every two hours, if practicable; and if not, then at 9 A. M. and 3 P. M.

"But with reference to the columns 3′, 4′, and 6, it will be sufficient that the entries in these columns be made at noon on each day, except on such occasions as it may be desirable to detect the limits of any of the great currents of the ocean, or of the trade or other periodical wind, when a more frequent entry should be made, and the ship's place determined, at least at each of the hours specified in Column 2."

Mr. Gorkovenko. "Being perfectly convinced for myself of the great importance, both to science and navigation, of frequent observations, such as are comprised in the columns of our table, being made at sea, I ask permission to put a question with a view of eliciting the opinion of the Committee, viz: To what extent can the Navy comply with these requirements, and are they of opinion that the officers on board, having other duties to attend to, will be able to devote sufficient time to making the entire range of observations with the precision required? For it is to the Navy we must look more for correct than for numerous observations."

Mr. Maury. "I believe it is not only possible but very practicable and very easy. I think these observations may be made with perfect convenience, and with great benefit to science and navigation, by all ships-of-war that are provided with the instruments necessary for safe and proper navigation, more particularly as the whole of these observations are not to be made in person by the officer of the watch. As a general rule, he will appoint one of his subordinates whom he may consider qualified for that purpose. In the United States Navy these observations are obtained without difficulty."

Captain James observed that in the trigonometrical survey of Great Britain non-commissioned officers and privates of the royal sappers and miners were employed in making the observations necessary in determining the latitude and longitude of the trigonometrical stations, and the distances between them; that they used for these purposes the most expensive and delicate instruments, and that the officers superintending the operation of the survey had as much confidence in the observations made by them as they had in the observations taken by the officers themselves; and consequently, he was of opinion that the meteorological observations, which were considered necessary by the Conference, might, under the superintendence of the officers of the ship, be confided to steady persons acting under their orders.

Temperature of the Water at the Surface.—"There is a convenient method, which consists in hauling the water up, in a clean wooden bucket, and placing it in the shade; and after the thermometer has remained in the bucket for two or three minutes, the thermometer should be read, the bulb remaining immersed until the observation is completed."

"Besides the stated periods, occasional observations, made in the same manner, should be entered under the head of Remarks, whenever, for any reason, such as changes in the color of the water, vicinity of ice, shoals, &c., approaches to the Gulf Stream, the mouth of large rivers, or other currents, the temperature of the water be tried."

"The temperature of the water should also be tried during thunder storms, and the heavy display of electrical phenomena."

"The water for surface temperature should be drawn from the quarter boats, in order to get it as far from the ship's side as possible."

Temperature of the Water at certain Depths.—"The temperature *below* the surface of the water to be tried may be taken from any depth that may to the observer seem good, stating in the column the temperature as a fraction, with the depth as the denominator: thus, $\frac{40^\circ}{200}$ fathoms" [*i. e.*, temperature at 200 fathoms, 40°].

"A hollow cylinder of wood, eighteen inches long, about 6 inches in diameter, with a valve near each end opening upwards, will be found, when attached to the deep-sea lead, convenient for bringing up the water from moderate depths."

"It is desirable frequently to try the temperature of the water at the depths of the ship's cock below the surface; before catching the water in the bucket, let it run freely for ten minutes; then put the bucket under, and, when full, let the thermometer stand before reading, as in the case of the surface water."

"Though it is important to have these observations as to temperature made in all parts of the ocean, yet there are parts in which the difference of temperature between the water at and below the surface possesses a peculiar interest; these parts are in the trade-wind regions generally, in the Indian Ocean, Indian Archipelago, and of the Cape of Good Hope, especially in and near Lagulla's Current, near the mouth of large rivers, and in the arctic and antarctic regions."

Specific Gravity of Water.—"The specific gravity, whether of water at or below the surface, should be given without any correction, except such as the instrument used may involve; the object of these two columns being to ascertain the specific gravity of sea water as it actually exists, the temperature of the water at the moment of making the observation should be noted."

"A variety of instruments will probably be used for the purpose of filling this column (specific gravity); it is, therefore, deemed advisable to have the description of the use of the specific gravity instrument at the office from which each navy may be supplied,"

"It may be permitted, however, to express the hope that whatever be the instrument used, a uniform scale will be adopted for all; that is, that the specific gravity of pure distilled water will be adopted as the unity, and that the specific gravity of sea water will be expressed in decimals."

"It will be desirable to know whether the vessel on board of which the observations were made was a steamship, and if so, whether it was steaming or sailing."

"Enter, uncorrected for local attraction, the variation observed, with the time of observation and the direction of the ship's head."

"Frequent mention is made by navigators of tide rips at sea, particularly within the tropics; a close attention to these phenomena is recommended; noting, whenever they are seen, the age of the moon. Enter also sea-weed, drift-wood, and the like."

"It is desirable that navigators compare the phenomena connected with storms, thunder, lightning, &c., in other parts of the world, with the same phenomena in the vicinity of the Gulf Stream."

"When in those regions in which ice is liable to be met with, a frequent resort to the water thermometer is recommended; because in such regions fogs are prevalent, and often conceal the approaching danger. The distance of ice, within several miles, will generally be indicated by the water thermometer, especially when vessels are to windward of the bergs."

"When in the presence of ice, note the direction in which the ice has been drifted, and describe its appearance."

"Mention the time when the dew commences to fall, and, in cases of extraordinary deposits, note the temperature of the air as closely to the surface of the sea as can be done, taking the temperature at the masthead at the same time."

"When considerable differences are found between the temperature at and below the surface, observe also the wet and dry bulb, and enter their readings among the remarks."

"It is desirable that vessels co-operating in this system of observations should, in addition to the thermometer with which ships usually are supplied, have a white and black bulb, and also a bulb of marine blue that is as nearly the color of sea water as may be."

"These three thermometers should be exposed to the sun in clear weather for a few minutes, and observed at 9 A. M., noon, and 3 P. M., and occasionally at night when the dew is heavy, and their readings should be entered in the column of remarks."

"It is desirable that the bulbs of the colored thermometers be painted with water-color."

PSYCHRONOMETER.—"The wet bulb should be observed, after having been wet with *fresh* water of the temperature of the air, and after the instrument has been held in the shade in the open air for some minutes."

"When at anchor, it is desirable that hourly observations with the meteorological instruments should occasionally be taken, and especially at the equinoxes and solstices."

"In the case of storms, tornadoes, and whirlwinds, it is desirable to have a full description of the phenomena, and all the circumstances connected with them: such as the appearance of the sky and clouds; the state of the barometer before, during, and after the event; the electrical displays connected with it; the quantity and time of rain or hail, &c. The barometer should be noted frequently, and the time mentioned at which every variation in it, that amounts to one-tenth of an inch, takes place."

"Also, it will be interesting for the navigator to avail himself of every favorable opportunity for determining the height and velocity of waves, and the distance between them. He should note in this column the results, and describe the method used."

"When land birds and insects are met with at sea, the fact should be noted, and mention made of all the circumstances which are calculated to throw light upon their migration."

"Showers of dust and red fogs are sometimes met with at sea; in such cases a description of the weather and of the appearance of the sky, as well as specimens of the dust, would be desirable."

"Note the direction of the winds which bring the rain, as well as the changes of the wind during and after the rain. By the term *rain*, hail and snow are understood to be included. With regard to hail, describe the stones, and any peculiarity connected with the snow-flakes, being careful to note all the displays of electrical phenomena connected with the hail-storm."

"It would be interesting to know the temperature of the rain, and to have estimates of the quantity of dew."

SOUNDINGS.—"Deep-sea soundings should be made on all favorable occasions; for making these soundings comparable, the uniformity in the size of line used, and the weight of the sinker is a desideratum. The time occupied for every 100 fathoms in going out should be observed, for the discussion afterwards of the soundings. When the sinker is recovered, the specimen of the bottom ought to be carefully labelled and preserved."

"When in harbor, tidal observations should not be neglected; the times of high and low water, with the direction and force of the current at various stages, both on the flood and the ebb, should be noted. Likewise thunder and lightning, the time of their duration, intensity, &c. When marked changes in the color of the water are observed, try the temperature of the water, get a cast of the deep-sea lead if practicable. In the Pacific Ocean, particularly, patches of pink or white-colored water are frequently met with; descriptions of them, with specimens of the water carefully preserved in phials with ground glass stoppers, are desirable."

"Waterspouts: a detailed description; containing the duration, the circumstances of their formation, gyration, motion, form, breaking up, &c."

"Shooting-stars: the number of them observed during a certain time; the point of the heaven (the star or constellation) from which they are emanating and towards which they are converging, in particular about the 10th of August and middle of November."

"Aurora Borealis: duration or time for beginning and ending; its extension, form, tract of the heaven, intensity of light, color, rays, its motions and changes, &c. Note anything that is particular about rainbows, and halos, and meteors of every description, describing their place by reference to stars or the horizon."

"At the commencement of the log-book should be entered: 1. The name of the ship, the nature of materials of which it is built, cargo, captain's name, class of ship, names of ports put into during the period the log has been kept."

"2. Tables showing amount of local deviations observed before departure; stating whethe cargo on board or not at time of observation being made; the method employed to ascertain the local deviation to be minutely described."

"3. Admiral Beaufort's nomenclature for the winds.

"4. Howard's nomenclature for the form of clouds.

"5. The corrections, or the rules for correcting all the instruments employed, more particularly the barometer and thermometer, with the places where the instruments have been compared with the standard.

"6. Description of instruments and methods employed in making observations.

"7. Note down the meridian from which the longitude is reckoned.

"In addition to the observations mentioned in the abstract log, it is desirable that each captain should write at the end any general remarks which his personal experience may suggest, more especially if he has frequently made the same voyage."

GENERAL ORDER.

NAVY DEPARTMENT, *November* 3, 1853.

The form of the "Abstract Log" recommended by the late Maritime Conference at Brussels is hereby approved and adopted for use in the Navy of the United States.

It is recommended to navigators generally, and will be faithfully kept on board of all vessels in the naval service. Commanding officers of vessels are especially charged with the execution of this order, and they will transmit copies of the abstract kept on board to the Chief of the Bureau of Ordnance and Hydrography, at the end of the cruise, and at such other times as he may direct.

J. C. DOBBIN,
Secretary of the Navy

ABSTRACT LOG.

(1).

(2).

(3).

(4).

(5). Local Deviation:

Before sailing.

SHIP'S HEAD.	DEGREES OF DEVIATION.	SHIP'S HEAD.	DEGREES OF DEVIATION.
NORTH . .		SOUTH . .	
N.NE. . .		S.SW. . .	
NE. . . .		SW. . . .	
E.NE. . .		W.SW. . .	
EAST . .		WEST . .	
E SE. . .		W.NW. . .	
SE. . . .		NW. . . .	
S.SE. . . .		N.NW. . .	

When arrived.

SHIP'S HEAD.	DEGREES OF DEVIATION.	SHIP'S HEAD.	DEGREES OF DEVIATION.
NORTH . .		SOUTH . .	
N.NE. . .		S.SW. . .	
NE. . . .		SW. . . .	
E.NE. . .		W.SW. . .	
EAST . .		WEST . .	
E.SE. . .		W.NW. . .	
SE. . . .		NW. . . .	
S.SE. . . .		N.NW. . .	

(1). Enter the class of the vessel, her name, country, and the name of the captain.

(2). *If the vessel is of iron or wood, and mention the quantity of iron, if any, in the cargo.*

(3). Enter the names of the places at which the vessel has called during her voyage.

(4). Name the meridian from which the longitude is calculated.

(5). Give the table of local deviation at the commencement and at the end of the voyage; and state in the log the manner in which it was determined, and if the vessel was loaded with any iron when the observation was made, or whether any iron as cargo was taken on board after the observation was made.

If practicable, the operation should be repeated during the voyage.

ABSTRACT LOG ______________ CAPTAIN ______________

DATE.	HOUR.	LATITUDE BY		LONGITUDE BY		CURRENTS.		MAGNETIC VARIATION OBSERVED.	WINDS.		BAROMETER.	
		Observation.	D. R.	Observation.	D. R.	Direction.	Rate.		Direction.	Rate.	Height.	Ther. attached.
I. 31.	2											
	4											
	6											
	8											
	9											
	10											
Noon.	12											
	2											
	3											
	4											
	6											
	8											
	10											
	12											
II. 1.	2											
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
[a]	[b]	[a]	[c]	[a]	[c]	[a]	[a]	[a]	[a]	[a]	[a]	[a]

ABSTRACT LOG FOR THE

DATE.	HOUR.	LATITUDE.	LONGITUDE.	CURRENTS.		BAROMETER.		THERMOM.		FORMS AND DIRECTION OF CLOUDS.	PROPOR. OF SKY CLEAR.	HOURS OF FOG A. RAIN B. SNOW C. HAIL D.	MAGNETIC VARIATION OBSERVED.
				Direction.	Rate.	Height.	Ther. attach'd	Air.	Water.				
I. 31	4												
	9												
Noon.	12												
	3												
	8												
II. 1.	4												
	9												
Noon.	12												
	3												
	8												
2	4												
	9												
Noon.	12												
	3												
	8												
3	4												

FROM ________________ TO ________________, 185

THERMOMETER.		FORMS AND DIRECTION OF CLOUDS.	PROPOR. OF SKY CLEAR.	HOURS OF FOG A. RAIN B. SNOW C. HAIL D.	STATE OF THE SEA.	WATER.			STATE OF THE WEATHER.	REMARKS.
Dry bulb.	Wet bulb.					Temp. at surface.	Specific gravity.	Temp. at depth.		
										This form is intended more especially for men-of-war.
(14) [a]	(15) [b]	(16) [a]	(17) [a]	(18) [a]	(19) [c]	(20) [a]	(21) [b]	(22) [b]	(23) [c]	(24) [a]

MERCHANT SERVICE.

WINDS.	RATE.	REMARKS.
(Latter part.)		This form contains the minimum of what must be furnished by American merchantmen, in order to entitle them to a copy of Charts and Sailing Directions. It is hoped, however, that many of them at least will be willing to do more, and to fill up the man-of-war log. Forms of this will be given to all who will ask for them.
(First part.)		☞ When the abstract log is filled and returned for one voyage, the master should take care to provide himself with another; for every master who is once supplied with the Charts is expected to *give his co-operation, and keep abstracts as long as they are required for the perfection or completion of the Charts.*
(Middle part.)		A blank chart of engroved squares has been prepared to show the daily march of the barometer with the force and direction of the wind, the hours of rain, &c. This will be very useful to those who will adopt it. Copies of it will be furnished to all who will apply for them.
(Latter part.)		

Describe on a blank page, in the beginning of your abstract, the instruments you have on board, the manner of using them, and of making the observations.

BAROMETER (corrections to) . . . { Index error. Capacity. Capillarity. Mean height above the sea.

Compared by Mr.
with the standard at 185

THERMOMETERS, (correction to.) [Number your thermometers, and state the corrections that are to be applied to the various readings of each, to make them correct.]

FORCE OF THE WIND indicated by numbers, (sailing by the wind.)

0. Calm.
1. Ship has steerage.
2. Clean full 1 to 2 knots.
3. Clean full 3 to 4 knots.
4. Clean full 5 to 6 knots.
5. With royals.
6. Top gallants over single reefs.
7. Double-reefed topsails.
8. Triple-reefed topsails.
9. Closed-reefed topsails and courses.
10. Closed-reefed main topsail and reefed foresail.
11. Staysails.

FORMS OF CLOUDS ARE: cirrus, (*Ci.*;) cumulus, (*Cu.*;) stratus, (*St.*;) nimbus, (*Ni.*;) &c. [See Plate IV, Vol. II.]

The original reports in English and French having been read and signed by all the members of the meeting, the President declared the Conference closed.

QUETELET.

Naval Order.

This abstract log is to be faithfully kept, and at the end of the cruise returned to the Bureau of Ordnance and Hydrography.

It is desirable, nevertheless, to have, from time to time, abstracts of the different passages as they are made during the cruise.

For this purpose loose blank sheets are furnished.

The commanding officer of the vessel is charged with the execution of this order.

The above has been approved by the Secretary of the Navy, and you will please have it printed and pasted in the abstract log before distribution, and take the necessary measures to supply the loose sheets proposed.

C. MORRIS,
Chief of Bureau of Ordnance and Hydrography.

Lieutenant M. F. MAURY,
National Observatory, Washington.
FEBRUARY 9, 1854.

EXPLANATORY NOTES FOR KEEPING THE ABSTRACT LOG.

The name of the *last* place from which the vessel sailed, and the place to which she is going, should be stated in the abstract.

1*st Column.*—THE TIME inserted in the abstract log should be civil time, but if astronomical [or sea] time is inserted, it should be so stated at the commencement of the log. The months should be indicated by the Roman letters from I to XII, January being I, [December XII.]*

2*d Column.*—HOURS; this column contains all the hours at the even numbers, and in addition 9 A. M. and 3 P. M. The hours 4 A. M. and 9 A. M., noon, 3 P. M. and 8 P. M. are printed in larger type, to indicate that it is at these hours that observations are especially required, as will be further explained.

3*d Column.*—LATITUDE OBSERVED.

4*th Column.*—LATITUDE BY DEAD RECKONING.

5*th Column.*—LONGITUDE OBSERVED.

6*th Column.*—LONGITUDE BY DEAD RECKONING.

The latitude and longitude should be observed frequently at sea, and more especially about 4 A. M., noon, and 8 P. M., and the result referred by the log to the hour nearest to which the observations were made, in order that the ship's position may be as accurately determined as possible at those times. This should be particularly attended to, when the ship is expected to cross or enter upon any of the great streams and currents of the ocean, the trade or periodical winds. The position by dead reckoning should be deduced from the last observation for latitude and longitude. If the longitude is determined by lunar distances, note it in the column with its proper sign ☉☾, *☾, and if by chronometer ☉ or *. When in sight of land, and the ship's position is determined by bearings, it is still desirable that the position of the ship should be given in latitude and longitude, in the proper column.

7*th* and 8*th Columns.*—DIRECTION AND RATE OF CURRENTS: on ordinary occasions, the currents should be determined at noon on each day, by comparing the position of the ship as determined by observation, and its position as found by dead reckoning; the direction and rate of the current in nautical miles for the last twenty-four hours should be given, [or, better, for the time during which it has been felt;] besides the daily entry at noon, the rate and direction of currents should be noted at shorter intervals, when the ship is in the vicinity of the great oceanic currents, or when it is supposed that the currents may sensibly vary in the twenty-four hours.

9*th Column.*—THE OBSERVED VARIATION should be entered in degrees and minutes; and when the variation is determined by observation of the moon or a star, the sign ☾ or * should be placed after the entry, thus: 23° 16′ W. ☾.

The variation should be corrected for local attraction; in other words, the variation

* The remarks contained in brackets [ ] are added by me.—M. F. M.

entered should be what the variation would have been had the ship been heading at the time of observation upon the course in which the local variation would be O.

It is desirable that every vessel should be provided with a *standard compass*, with which all the observations for variation should be made. The position of the standard compass, or of the one used, should be that at which the local attraction is the least, and the compass should always be placed in the same place. When the variation has not been observed, the variation *used* should be corrected for local attraction, and noted.

10*th Column.*—Direction } of the Wind.
11*th Column.*—Force } of the Wind.

The direction and force of the wind should be regularly entered at 4 A. M., noon, and 8 P. M. The force and direction entered should be that which has been most prevalent during the eight preceding hours. The direction should be by compass, and expressed in points. The force of the wind should be indicated by the figures given on page 342; if there are squalls, their force should be given in a parenthesis ( ), opposite the hour at which it takes place.

[Lieut. Vaneéchout, of the French Navy, to whom the task was assigned by his government of translating this work into that language, suggests that fuller explanations should be given as to these two columns. Ready at all times to answer, to the best of my ability, any call for information upon so important a subject as the abstract log, and bearing in mind the distinguished source whence this call proceeds, I have thought I would be rendering the best service to the common cause to give so much of that accomplished officer's letter as relates to the difficulties suggested by him, and of my explanations thereof.

First, he wishes to know if it would be contrary to the plan to make more than three entries a day in columns 10 and 11? To that and his other questions the following is the reply:

It would not be contrary to directions to enter the force and direction of the wind more than three times a day; the observer may enter them for every hour, but he should sum up and give the *prevailing force* and *direction*, according to his judgment, three times a day.

"Must I *always* enter the observations of calm, or only when the calm has been prevalent during the eight hours?"

Answer.—Enter it only when "calm" has been the most prevalent condition for the eight hours.

"I have had one hour of calm, six of north wind, and another hour of calm; what must I enter?"

Answer.—North wind.

"I have had one hour of north wind, six of calm, and an hour of westerly wind; what shall I note?"

Answer.—Calm.

"If I have only an hour or less of calm, must I note it?"

Answer.—It is desirable that you should note it in the column of remarks.

"I have had four hours of N.NW. wind and four of S.SW.; must I enter both, or the resultant—eight hours from the west?"

Answer.—Enter as 8 hours from the west, and call attention to it in your remarks.

"What must I put down for four hours of north wind and four of south wind?"

Answer.—Enter the wind as prevailing from the point from which, in the case supposed, it has been strongest, but note in the column of remarks the fact that it blew four hours from north and four from south.

You remark also, "The instructions issued at Bruxelles are completely silent as to calms, so that many a captain may be tempted to consider them only as the wind zero. I don't think that right." Neither do I. It is seldom that there is such a calm at sea that a vessel moves not for eight hours. There is almost always air enough astir to give her some motion through the water, however slight, during every hour; and the question, therefore, very properly arises what should we call a "calm"?

The more proper classification, perhaps, would have been "light airs and calms," for such I have considered to be the true meaning of the word as used by the Brussels Conference.

In the investigations of this office I have considered and treated as calms not only the absence of wind, but those light baffling airs which are not sufficient to send a vessel more than two knots an hour through the water. Such a classification I consider important and necessary. Perhaps you may differ in opinion with me as to the degree of motion to be classed as a calm; suffice it to say, such is the measure that I have adopted for it, and by this measure all my investigations concerning winds and calms have been conducted.]

12*th* and 13*th Columns.*—THE BAROMETER AND ITS THERMOMETER should be observed, if possible, at all the hours given in Column 2, and at least at 4 and 9 A. M., noon, 3 and 8 P. M. [The thermometer attached to the barometer—and if none be attached, one should be tied to the lower end—should be carefully noted whenever the barometer is observed, for we depend upon it for an important correction for the Bar.]

14*th* and 15*th Columns.*—THE DRY AND WET BULB THERMOMETERS should be observed at the same hours as the barometer. If it rains at the time when the observation with the wet bulb is taken, put the letter B after the temperature. Before reading the wet bulb thermometer, the bulb [or, rather, a thin old linen rag should be tied tightly about the bulb, and then the bulb] should be moistened with fresh water, and allowed to remain a few minutes in the open air, in the shade, and where strong currents of wind from the sails cannot affect it.

All the thermometers ought to have two scales, one that of the country to which the ship belongs, the other the centigrade.

16*th Column.*—THE FORM AND DIRECTION OF THE CLOUDS should be noted at least at 4 A. M., noon, and 8 P. M., and as they appear at the time of observation. The form of the clouds should be indicated by the letters given at page 342. When the clouds are observed to be going in different directions at the same time, the direction of the upper one should be stated above that of the lower, and separated by a bar, thus: $\frac{\text{N.NE. Ci}}{\text{SW. Cu}}$. [Plate IV, Vol. II, shows the form of Clouds.]

17*th Column.*—THE PROPORTION OF THE SKY CLEAR should be indicated by figures from 0 to 10. Thus 8 indicates that $\frac{8}{10}$ of the sky is clear.

18*th Column.*—FOG, RAIN, SNOW, AND HAIL. The number of hours of fog, rain, snow, and hail, in the eight preceding hours, should be noted at 4 A. M., noon, and 8 P. M.

The letter A indicates fog; C, snow;
B, rain; D, hail.

One or two bars placed under the hours indicate degree [intensity or quantity]; thus 3 B, is 3 hours of light rain; 3 $\underline{\text{B}}$, rain; 3 $\underline{\underline{\text{B}}}$, heavy rain.

The direction and force of the wind, &c., before, during, and after the rain, should be stated in the column of remarks.

19*th Column.*—THE STATE OF THE SEA during the eight preceding hours should be stated at 4 A. M., noon, and 8 P. M., by means of the signs given on the second page. [These signs were omitted to be inserted in the original, but I recommend for general adoption those used by Mr. Meldrum, of Mauritius, in his valuable contributions to the meteorology of the Indian Ocean. They are as follows: – for a smooth sea; ∧ for a heavy sea; × for a cross or confused sea; ⌒ for a swell. Put the course after the sign, to designate direction, thus ∧ E. means a heavy sea from the east; ⌓ S., *very* heavy swell from the south.]

20*th Column.*—TEMPERATURE OF THE WATER AT THE SURFACE. For the hours at which the observations should be taken, see directions for the barometer and thermometer. The water should be taken up in a wooden bucket, as far as possible from the ship's side, and placed in the shade on deck; the thermometer should then be placed in the water, and left there for two or three minutes [five], and read afterwards, whilst the bulb is in the water. In addition to the ordinary observations, the temperature of the water should be taken when any particular circumstances may seem to make it desirable, as when there are changes in the color of the water, [or when the vessel is] in the neighborhood of ice, shoals, the gulf or other streams, and at the mouths of great rivers.

The temperature of the water should also be taken during thunder storms, and when any electrical phenomena are observed. [Note also the temperature of the rain.]

21*st Column.*—THE SPECIFIC GRAVITY OF THE WATER AT THE SURFACE OR AT DIFFERENT DEPTHS should be noted at least once a day; when the water is taken from a certain depth, the depth should be entered under the specific gravity, and under a line ($\frac{029}{150}$). The specific gravity is stated without any other correction than that which the instrument employed may require. The temperature of the water should be placed in the 20th and 22d columns. It is desirable that a uniform scale should be adopted in the instruments used in ascertaining the specific gravity; that the specific gravity of distilled water should be the unit, and that of the sea water expressed in decimals. [The hydrometer of commerce, that is, the one of glass, and in the shape of a thermometer with its bulb slightly loaded, used for proving spirits, is the one recommended for the American service.]

22*d Column.*—THE TEMPERATURE OF THE WATER AT DIFFERENT DEPTHS should be taken at least once a day, according as circumstances may be more or less favorable; the temperature [at the surface] should be entered above the specific gravity, and separated from it by a bar ($\frac{54}{30}°$;) the unit of measure in depths is [fathoms of six feet each, English.] In taking water from moderate depths, it may be hauled up in a cylindrical box, 18 inches long and six inches in diameter, having two valves in the ends opening upwards. This box may be either of wood or iron, and attached to the deep-sea lead.

It is desirable, frequently, to try the temperature of the water at the depth of the ship's cock below the surface; the cock should be left open for 8 or ten minutes before the bucket is filled, and the thermometer should be left two or three minutes [five] in the water, as before enjoined, before reading it, and it may be well to note the speed of the ship at the time the cock was open. The temperature of the water at the surface should be observed whenever the temperature at different depths is taken.

When there is a great difference between the temperature of the water at the surface, and at some depth, observe the indications of the wet and dry bulb thermometers, and note them in the column of remarks.

Although these observations are of importance in every part of the globe, still, there are certain regions where the differences between the temperature at the surface and the temperature at certain depths have a particular interest. We may mention the regions of the trade-winds, the Indian Ocean, the Cape of Good Hope, and especially in the Lagullas current, and near the mouths of great rivers.

Column of Remarks.—The column of Remarks will contain everything which the captain may consider useful. We direct the attention to the following points:

1*st.* If the vessel is a steamer, state whether she was steaming or under sail at the time the observations are made.

Tempests, tornadoes, whirlwinds, typhoons, or hurricanes, &c.—Every circumstance connected with these should be stated in great detail, the different changes of the wind, the appearance of the sky and the clouds, of the sea and electrical phenomena, rain, hail, &c. The height of the barometer should be frequently noted, at least as often as there is a change of a tenth of an inch, and the time when the remarks are made [*i. e.* when the phenomena are seen, or when the observations are made] should be stated.

When *waterspouts* are observed, the time of their duration, their successive appearances, their formation, gyratory movement, translation, and breaking up, should be described.

Note the circumstances attending storms, the thunder, lightning, &c.; and when phenomena of this nature are observed by navigators, they should be guided in their observations by a reference to analogous phenomena, which they may have observed in other regions, more especially upon the edge of the Gulf Stream.

It is desirable to have the *temperature of the rain* compared with the temperature of the air.

When it *hails*, describe the *hailstones*, and the electrical phenomena.

Note the quantity of *dew*, the time when it commences to fall, and, in cases of extraordinary deposits, note the temperature of the air as close to the surface of the sea as possible, and at the same time at the masthead.

When *red fogs* or *showers of dust* are met with, describe the weather and the appearance of the sky, and obtain, if possible, specimens of the dust.

Observe the height of the *waves*, the distance between them, and their rate of progress.

Note the *tide-rips* seen, particularly in the tropics, and the age of the moon at the time.

When the surface of the sea is covered with *pink or white patches* of water, as is often the case in the Pacific Ocean, describe them, and preserve specimens of the water in phials with ground glass stoppers; if practicable, get a cast of the deep-sea lead, and take the temperature of the water at the surface, and at some depth.

When *deep-sea soundings* are taken, state the time the lead takes to descend each 100 fathoms, and carefully preserve whatever the lead brings up from the bottom. [Deep-sea soundings should always be made from a boat.]

It is much to be desired, for the sake of comparison, that the same sized line and the same shaped lead, of equal weight, should be used. [For description of those used in the United States Navy, see pages 120–193.]

In places where *ice* may be met with, observe the temperature of the water frequently; these observations are most valuable when there are fogs which may prevent the ice from being seen, as they may indicate its presence even at the distance of 2 or 3 miles, especially when the ice is to leeward.

Note the appearance of the ice, and the direction in which it has been drifted.

In addition to the *thermometers* usually supplied to ships, it is desirable that they should be furnished with others *with white, black, and blue bulbs*, colored with water colors. These three thermometers should be exposed simultaneously to the sun, in fine weather, for some minutes, at 9 A. M., noon, and 3 P. M., and occasionally at night [to the open sky] in time of dew; their indications should be entered in the column of Remarks.

Note the *shooting stars;* their point of departure and the point to which they appear to converge, the constellations which they traverse, their numbers in a given time. They should be especially observed about the 10th of August and the middle of November.

The *aurora borealis*, the time of its appearance and disappearance, extent, form, position, intensity of light, color, its motions, and changes should be described.

Halos, *rainbows*, *meteors*, &c., should also be noted.

Carefully note the appearance of *birds*, *insects*, *fish*, *sea-weed*, *drift wood*, and mention any circumstances which may throw light upon their appearance.

[In light winds and calms keep a small hoop net overboard for catching insects of the sea. This is an interesting branch of natural history. It opens a wide field, and one in which but few laborers have been. Officers of the medical corps, who can use the pencil and the microscope, have a fine opportunity here presented to them of helping to lay the corner stones of almost a new department in natural history.]

When at anchor, *tidal observations* should not be neglected, and the times of high and low water, if possible, should be observed; state the time also of change of tide, the rate and direction of the current at various stages, both on the flow and ebb, and everything relative to this important question. Hourly meteorological observations, especially at the times of the equinoxes and solstices, would be very valuable.

In addition to the observations mentioned in the abstract log, it is desirable that each captain should write at the end any general remarks which his personal experience may suggest, [as to the route pursued, currents, winds, &c., encountered by the way,] more especially if he has frequently made the same voyage."

REPORT OF THE CONFERENCE HELD AT BRUSSELS,

At the Invitation of the Government of the United States of America, for the Purpose of concerting a Systematical and Uniform Plan of Meteorological Observations at Sea.

"In pursuance of instructions issued by the governments respectively named in the margin, the officers whose names are hereunto annexed assembled at Brussels, for the purpose of holding a Conference on the subject of establishing a uniform system of meterological observation at sea, and of concurring in a general plan of observation on the winds and currents of the ocean, with a view to the improvement of navigation, and to the acquirement of a more correct knowledge of the laws which govern those elements.

The meeting was convened at the instigation of the American Government, consequent upon a proposition which it had made to the British Government, in reply to a desire which had been conveyed to the United States, that it would join in a uniform system of meteorological observation *on land*, after a plan which had been prepared by Captain James, of the Royal Engineers, and submitted to the Government by Sir J. Burgoyne, Inspector-General of Fortifications.

The papers connected with this correspondence were presented to the House of Lords on 21st February last,* and have been further explained in the minutes of the Conference. And it is here merely necessary to observe that, some difficulties having presented themselves to the immediate execution of the plan proposed by the British Government, the United States availed themselves of the opportunity afforded by this correspondence, of bringing under the notice of the British Government a plan, which had been submitted by Lieutenant Maury, of the United States Navy, for a more widely extended field of research than that which had been proposed; a plan which, while it would forward the object entertained by Great Britain, would at the same time materially contribute to the improvement of navigation and to the benefit of commerce.

An improvement of the ordinary sea route between distant countries had long engaged the attention of commercial men, and both individuals and nations had profited by the advances which this science had made through a more correct knowledge of the prevailing winds and currents of the ocean. But experience had shown that this science, if it did not now stand fast, was at least greatly impeded by the want of a more extended co-operation in the acquirement of those facts which were necessary to lead to a more correct knowledge of the laws which govern the circulation of the atmosphere, and control the currents of the ocean; and that the subject could not receive ample justice, nor even such a measure of it as was commensurate with the importance of its results, until all nations should concur in one general effort for its perfection. But could that happy event be brought about—could the observations be as extensive as desired, and receive that full discussion to which they were entitled—the navigator would learn with certainty how to count upon the winds and currents in his track, and to turn to the best advantage the experience of his predecessors.

Meteorological observations to a certain extent had long been made at sea, and Lieutenant Maury had turned to useful account such as had, from time to time, fallen into his hands;† but these observations, although many of them good in themselves, were but isolated facts, which were deprived of much of their value from the absence of observations with which they could be compared; and above all, from the want of a constant and uniform system of record, and from the rudeness of the instruments with which they had been made.

The moment, then, appeared to him to have arrived, when nations might be induced to co-operate in a general system of meteorological research. To use his own words, he was of opinion that "the navies of all maritime nations should co-operate, and make these observations in such a manner and with such means and implements, that the system might be uniform, and the observations made on board one public ship be readily referred to and compared with the observations made on board all other public ships, in what ever part of the world. And, moreover, as it is desirable to enlist the voluntary co-operation of the commercial marine, as well as that of the military of all nations, in this system of research, it becomes not only proper, but politic, that the forms of the abstract log to be used, the description of the

* See Parlimentary Papers, No. 115. 1853.

† See Sailing Directions, by Maury.

instruments to be employed, the things to be observed, with the manipulation of the instruments, and the methods and modes of observation should be the joint work of the principal parties concerned."

These sentiments being concurred in by the Government of the United States, the correspondence between the governments was continued, and finally each nation was invited to send an officer to hold a conference at Brussels, on a given day.

And that the system of proposed observation and of combined action might become immediately available, and be extended to its widest possible field of operation, it was determined to adapt the standard of the observations to be made to the capabilities of the instruments now in general use in the respective naval services, but with the precaution of having all these instruments brought under the surveillance of parties duly appointed to examine them and determine their errors; as this alone would render the observations comparable with each other through the medium of their respective standards.

The Conference opened its proceedings at Brussels, on August 23, 1853, at the residence of M. Piercot, the Minister of the Interior, to whom the thanks of the Conference are especially due.

M. Quetelet was unanimously elected President.

Before entering upon any discussion, it was the desire of all the members of the Conference that it should be clearly understood that, in taking part in the proceedings of the meeting, they did not in any degree consider themselves as committing their respective governments to any particular course of action, having no authority whatever to pledge their country in any way to these proceedings.

The objects of the meeting having been explained by Lieutenant Maury, of which the substance has been already given,* the Conference expressed its thanks to that officer for the enlightened zeal and earnestness he had displayed in the important and useful work which forms the subject of the deliberations of the Conference.

In concerting a plan of uniform observation, in which all nations might be engaged, the most obvious difficulty which arose, was from the variety of scales in use in different countries. It is much to be desired that this inconvenience should be removed; but it was a subject upon which the Conference, after mature deliberation, determined not to recommend any modification, but to leave to each nation to continue its scales and standards as heretofore; except with regard to the thermometers, which it was agreed should, in addition to the scale in use in any particular service, have that of the centigrade placed upon it, in order to accustom observers in all services to its use, with a view to its final and general adoption.

The advantages of concert of action between the meteorologist on land and the navigator at sea, were so obvious, that, looking forward to the establishment of a universal system of meteorological observation upon both elements, it was thought that the consideration of scales would, with greater propriety, be left for that or some such occasion.

As to the instruments to be recommended, the Conference determined to add as few as possible to such as were in common use in vessels of war; but regarding accuracy of observation as of paramount importance, the Conference felt it to be a matter of duty to recommend the adoption of *accurate* instruments, of barometers and thermometers especially that have been carefully compared with recognized standards, and have had their errors accurately determined; and that such instruments only should be used on board every man-of-war co-operating in this system, as well as on board any merchantman, as far as it may be practicable.

* See the Minutes of the Proceedings of the Conference.

The imperfection of instruments in use at sea is notorious. The barometer having hitherto been used principally as a monitor to the mariner, to warn him by its fluctuations of the changes in prospect, its absolute indication of pressure has been but little regarded; and makers seldom if ever determine the real errors of these instruments, or, if known, still more rarely ever furnish the corrections with the instruments themselves.

That an instrument so rude and so abundant in error, as is the marine barometer generally in use, should, in this age of invention and improvement, be found on board any ship, will doubtless be regarded hereafter with surprise; and it will be wondered how an instrument so important to meteorology and so useful to navigation, should be permitted to remain so defective that meteorologists, in their investigations concerning the laws of atmospheric pressure, are compelled, in great measure, to omit all reference to the observations which have been taken with them at sea. The fact will, it is believed, afford a commentary upon the marine barometers now in use, which no reasoning or explanation can render more striking.

It was the opinion of the Conference that it would not be impossible, considering the spirit of invention and improvement that is now abroad in the world, to contrive a marine barometer which might be sold at a moderate price, that would fulfill all the conditions necessary to make it a good and reliable instrument; and a resolution was passed to that effect, in order to call the attention of the public to the importance of an invention, which would furnish the navigator with a marine barometer that, at all times, and in all weathers at sea, would afford the means of absolute and accurate determinations."

This call has been met, and navigation is provided with a barometer that leaves nothing more to be desired as to accuracy. To the Kew committee of the British Association, those who delight in physical research, are indebted for this instrument. It is as accurate as a mountain barometer, and as good as any standard. Between the cistern, which is of iron, and the top of the column, but out of sight, the bore of the tube is very small, as in the common marine barometer. It is made so to prevent the top of the column from bobbing up and down with the motion of the ship.

One of the beauties of this barometer is, that it has no corrections except for temperature and index error—the latter is always small, and generally in the third decimal only. A column of mercury 30 inches long varies its length, with a change of 50° of temperature 0.15 inch. But the barometer is of iron and brass; and from the bottom of the cistern to the division mark of 30 on the scale, is 31 inches:—3.2 of iron, 27.8 of brass. The correction is derived from the difference of expansion between a height of 31 inches of metal, as above, and a length of 31 inches of mercury. Thus, suppose the barometric pressure to be 30.00 inches, and that, while the superincumbent air remains undisturbed in its pressure, the temperature of the mercury and the metallic frame of the barometer should change 50°, as from 32° to 82°. On account of this change in the thermometer, the mercury in the barometric tube would expand 0.14 more than the scale, and, of course, the reading would be 30.14 inches.

This beautiful instrument is made in this way: After being constructed and filled with mercury in the usual manner, it is placed, with a standard barometer, under the exhausted receiver of an air pump. The pump is then worked until the standard, corrected for index error and capillarity, stands at 27.50, a reading below which, it is supposed, the barometer seldom falls at sea. The height of the mercury in the new barometer is then marked.

Now air is pumped into the receiver until the standard, corrected as before, reads 31 in.; a reading above which, it is supposed, the barometer never can rise in the open air at sea.

With the standard at this reading, the height of the mercury in the marine barometer is again noted. It is then taken out, and the space between the two marks on the blank scale is then divided into 350 equal parts called tenths of inches, which are, or may be, subdivided into .05. The vernier is then attached, and the barometer is finished. It then may be read to 0.002 inch.

After all this, the barometer may have a small index error. If so, it should be given by the maker when the instrument is purchased of him. To this index error the master may apply the correction for height above the sea level. This correction may be safely assumed to be in the ratio of 0.10 inch to 100 feet; in other words, a barometer will always stand one-tenth of an inch (0.1 inch) higher on a level with the sea than it will 100 feet above the level of the sea. The correction, then, for a barometer that hangs on board ship 10 feet above the water line is + .01. If, with a barometer so hanging, the correction for index error be — .01, then the absolute correction is nothing: one cancels the other. But if the index correction be + .01, then the sum, instead of the difference of the two corrections, must be applied to the observed reading to get at the reading of the barometer, as it would have been, had it stood at the sea level, without an index error.

Supposing these two errors to be treated as a constant, the only correction, which now remains to be applied, is on account of changes of temperature. When philosophers treat of the barometric pressure in certain aspects, they desire to know what it is, or would have been, at the sea level, with the thermometer at 32°. The corrections for temperature are, therefore, to be so applied as to show this.

These corrections, however, are for the navigator rather a matter of philosophical than of practical interest; and he is requested not to apply them to the observations entered in the abstract log, but simply to state, from time to time, in that journal what they are.

In the preceding edition of this work, the hourly mean barometric curves, for every month of the year, were projected for Calcutta, Madras, and Bombay. These curves perfectly illustrate the diurnal fluctuations of the barometer which occur every where within the tropics. About 9½ or 10 A. M. the year round the highest reading of the day takes place; then the barometer falls till about 3½ or 4 P. M., when it reaches its lowest point for the twenty-four hours; such is the rule; there are exceptions to it. It now stands about one-tenth of an inch (.1) lower than it did in the forenoon. It is again high at 9½ or 10 P. M., but generally not *so* high as before, and again low at 3½ or 4 P. M., but generally not *so* low as it was at the low P. M. tide.

This tide in the barometer is an old discovery; but an important one practically as well as theoretically; for about 10 A. M. and 4 P. M.—rather before than after—the mercury day after day, the year through, reaches its highest and lowest reading with such regularity and certainty that the navigator may refer to it as a natural standard for testing, ascertaining the error, and correcting his own barometer.*

* *Extract from Admiral FitzRoy's Report of the Meteorological Department of the Board of Trade,* 1857.

* * * * "Perhaps here reference may also be made to a result obtained from comparison at sea, within the tropics, of a great many reliable Kew model barometers.

"Within certain limits of latitude, near the equator, the barometer varies so little from a normal height now ascertained, that (allowing for its tidal change,) any ship between those parallels may ascertain the error of her barometer, aneroid, or sympiesometer, to nearly three hundreths of an inch, and this without incurring risk by moving the instrument, and without any trouble, beyond making the usual observations.

"By this fact, which could only have been proved by employing such instruments as those recommended by the Kew Committee, a value is given to all barometrical observations made by ships crossing the equator, equivalent to that derivable from comparisons with a standard instrument; and as this applies to past as well as to future observations, it will be the more appreciated." * * * *

The average rise and fall of this tide in the barometer is about one-tenth of an inch. It occurs most regularly between the tropics and away from the land, where the trade-winds blow regularly. Then correcting for index error and capillarity, but not for temperature, the readings of an otherwise correct barometer at 10 A. M. and 4 P. M., would be, in the NE. and SE. trades, nearly as follows for the different months:

	Northeast trades.		Southeast trades.	
	10 A. M.	4 P. M.	10 A. M.	4 P. M.
January	30. 10	30. 00	30. 14	30. 09
February	30. 10	29. 99	30. 16	30. 12
March	30. 09	29. 94	30. 22	30. 13
April	30. 01	29. 86	30. 12	30. 03
May	29. 94	29. 77	30. 14	30. 03
June	29. 85	29. 76	30. 19	30. 10
July	29. 85	29. 78	30. 22	30. 14
August	29. 88	29. 82	30. 23	30. 15
September	29. 97	29. 84	30. 22	30. 13
October	29. 98	29. 85	30. 17	30. 09
November	30. 08	29. 92	30. 15	30. 05
December	30. 07	29. 98	30. 06	30. 00*

In the SE. trades of the Pacific the barometer stands, according to my investigations, about 0.10 inch higher than it does in the NE. trades anywhere, or even in the SE. trades of the Atlantic. The barometer also stands lower in the equatorial calms than it does on either side of them; nor are its readings at a given hour exactly the same all through either system of trades. This varies somewhat with the latitude as well as the season. But if the navigator, while in the trade-wind regions, especially if he be bound accross them,—as vessels are that are going around either of the capes or to South America,—will take the trouble to note accurately, and record the readings of the barometer daily at 10 A. M. and 4 P. M., the mean of these readings, compared with its appropriate mean of the above table, will give him the error of his instrument within one-tenth of an inch, (± 0.1 inch.) And this, if he have an old fashioned barometer, will be a great gain. It is common to find them with an undiscovered error of 0.50 inch.

If every man-of-war, for they are all supplied with this new barometer, would make it a rule whenever they are in the trade-wind region, whether at sea or not, to make hourly observations on the barometer from 8 A. M. to 6 P. M., inclusive, they would soon enable one to give with great accuracy a *standard reading of the barometer* for every trade-wind-parallel of latitude. And they would render a still more acceptable and creditable service if they would make and rcord observations at five minute intervals, about 10 A. M. and 4 P. M. daily, in order to determine the exact time of this high and low tide in the barometer. I appeal especially to the young officers of the service in this matter, and request them to send me their observations separately, according to this form:

* The above table for the SE. trades will give an error, if tried in the Atlantic, a little too large, and a little too small or the Pacific. The observations to which Admiral FitzRoy alludes as in possession of the Board of Trade probably afford data for a more correct table than this.

United States ship ———.

Date.	Latitude.	Longitude.	Barometer at—											Thermometer at—		5 min. readings of the barometer for—	
			8.	9.	10.	11.	Noon.	1.	2.	3.	4.	5.	6.	10 A. M.	4 P. M.	High tide.*	Low tide.

The Conference was also of opinion that an anemometer, or an instrument that would enable the navigator to measure the force, velocity, and direction of the wind at sea, was another desideratum.

The Conference was of opinion that the mercurial barometer was the most proper instrument to be used at sea for meteorological purposes, and that the aneroid should not be substituted for it.

With regard to thermometers, the Conference does not hesitate to say, that observations made with those instruments, the errors of which are not known, are of little value ; and it is, therefore, recommended, as a matter well worth the attention of co-operators in this system of research, whether some plan may not be adopted in different countries for supplying navigators, as well in merchantmen as in men-of-war, with thermometers, the errors of which have been accurately determined.

For the purposes of meteorology, various adaptations of the thermometer have been recommended, such as those which refer to hygrometry and solar radiation ; and accordingly a space will be found in the columns for temperature by thermometers, with dry, wet, and colored bulbs. With these exceptions, the only instrument, in addition to those generally used at sea, for which the Conference has thought proper to recommend a column, is that for specific gravity ; the cost of this instrument is too insignificant to be mentioned.

The reasons for recommending the use at sea of the wet, the white and black bulb thermometers are obvious ; but with regard to the thermometer with a bulb the color of sea water, and the introduction on board ship of a regular series of observations upon the specific gravity of sea water, it may be proper to remark that, as the whole system of ocean currents and of the circulation of sea water depends in some degree upon the relative specific gravities of the water in various parts of the ocean, it was judged desirable to introduce columns for this element, and to recommend that observations should be carefully made with regard to it, both at and below the surface.

With respect to the thermometer having a bulb of the color of sea water, it is unnecessary to say more in favor of its use on board ship, than that the object is to ascertain whether or not such observations will throw any light upon the psychrometry of the sea, or upon any of the various interesting phenomena connected with the radiation from the surface of the ocean.

* The object of these readings is to get the exact turn of the tide.

In bringing to a conclusion the remarks upon instruments, the Conference considered it desirable, in order the better to establish uniformity, and to secure comparability among the observations, to suggest, as a measure conducive thereto, that a set of the standard instruments used by each of the co-operating governments, together with the instructions which might be given by such government for their use, should be interchanged.

The object of the Conference being to secure as far as possible uniformity of record, and such a disposition of the observations that they would admit of ready comparison, the annexed form of register was concerted and agreed upon. The first columns of this form will receive the data which the Government of the United States requires merchant vessels to supply in order to entitle them to the privleges of co-operators in this system of research, and may, therefore, be considered as the *minimum* of what is expected of them. This condition, it may be as well to state here, requires that at least the position of the vessel and the set of the current, the height of the barometer, the temperature of the air and water should each be determined once a day, the force and direction of the wind three times a day, and the observed variation of the needle occasionally.

Every abstract log kept by a merchant vessel should contain *at least* what is here recommended. Anything more would enchance its value, and make it more acceptable.

The remaining columns are intended principally for men-of-war to fill up, *in addition* to those above mentioned; but it is believed that there are many officers in the mercantile navy also who are competent to this undertaking, and who will, it is hoped, be found willing to distinguish themselves in this joint action for the mutual benefit of the service.

In the compilation of this form, the Conference has had carefully in view the customs of the service and the additional amount of attention which these duties will require; and it is believed that the labor necessary for the purpose, at least to the extent specified in the instructions for filling up the columns, is only such as can be well performed under ordinary circumstances, and it has considered it a *minimum*, and looks with confidence to occasional enlarged contributions from zealous and intelligent laborers in the great cause of science.

The directions for filling up the columns and for making certain observations, it will be seen by the Minutes, were limited to such only as seemed necessary to the Conference to insure uniformity of observation. This subject received the benefit of much discussion before the meeting, and it was considered most advisable to confine the matter to *hints;* which, it is hoped, will be found sufficient, when embodied in the instructions which each nation will probably issue with the forms, to insure that most desirable end, uniformity.

The Conference, having brought to a close its labors with respect to the facts to be collected, and the means to be employed for that purpose, has now only to express a hope that whatever observations may be made will be turned to useful account when received, and not be suffered to lie dormant for the want of a department to discuss them; and that, should any government, from its limited means, or from the paucity of the observations transmitted, not feel itself justified in providing for their separate discussion, it is hoped that it will transfer the documents or copies of them to some neighboring power, which may be more abundantly provided, and willing to receive them.

It is with pleasure that the Conference has learned that the Government of Sweden and Norway has notified its intention of co-operating in the work, and that the king has commanded the logs kept by his Swedish subjects to be transmitted to the Royal Academy of Science at Stockholm; and also that, in the Netherlands, Belgium, and Portugal, measures have been taken to establish a department for the same purpose, and that the Admiralty of Great Britian has expressed its intention of giving instructions for meteorological observations to be made throughout the Royal Navy.

The Conference has avoided the expression of any opinion as to the places or countries in which it would be desirable to establish offices for the discussion of the logs; but it is confidently hoped that, whatever may be done in this respect, there will be always a full and free interchange of materials, and a frequent and friendly intercourse between the departments; for it is evident that much of the success of the plan proposed will depend upon this interchange, and upon the frankness of the officers who, in the several countries, may conduct these establishments.

Lastly, the Conference feels that it would but inadequately discharge its duties, did it close this report without endeavoring to procure for these observations a consideration which would secure them from damage or loss in time of war, and invites that inviolate protection which science claims at the hands of every enlightened nation; and that, as vessels on discovery or scientific research are, by consent suffered to pass unmolested in time of war, we may claim for these documents a like exemption; and hope that observers, amidst the excitement of war, and perhaps enemies in other respects, may in this continue their friendly assistance, and pursue their occupation, until at length every part of the ocean shall be brought within the domain of philosophic research, and a system of investigation shall be spread as a net over its surface, and it become rich in its benefit to commerce, navigation, and science, and productive of good to mankind.

The members of the Conference are unwilling to separate without calling the attention of their respective governments to the important and valuable assistance which it has received from the Belgian government. That the Conference has been enabled to draw its labors to so speedy and satisfactory a close, is in a great measure owing to the facilities and conveniences for meeting and deliberating which have been afforded by His Majesty's Government.

Signed at Brussels, this 8th day of September, 1853.

BELGIUM—MM. Quetelet, *President;* Lahure. DENMARK—P. Rothe. FRANCE—Delamarche. GREAT BRITAIN—F. W. Beechey, H. James. NETHERLANDS—Jansen. NORWAY—Ihlen. PORTUGAL—De Mattos Corrêa. RUSSIA—Gorkovenko. SWEDEN—Pettersson. UNITED STATES—Maury."

The Brussels Conference did not pretend to prescribe any series of observations for merchantmen. They are the amateur meteorologists of the sea; their assistance is valuable, and their hearty co-operation greatly to be desired. But inasmuch as the power to compel merchant captains to keep an abstract log, according to the form prescribed, and with proper instruments, is not the same in all countries; and inasmuch as the relations between the merchant captain and his government are both special and peculiar, according to the flag under which he sails, it was deemed wisest and best to leave it to each government to select the columns from the abstract log proposed, which its merchantmen should be required to fill.

Not so with the men-of-war. Here the government has but to command, and it is done.

So, too, with the meteorologists on the land. The great body of them also is made up of amateurs. But governments have their military posts, their light-houses, hospitals, institutions of learning, observatories, and other public establishments answering to men-of-war, where meteorological observations have already been instituted, or where they may be instituted almost without cost.

Meteorological observations, whether made by sea or land, unless they be discussed, properly collated and published, have very little value.

Now, in most governments, there is provision already made for discussing and publishing such observations as are made at government establishments, and it is to governments that we must look chiefly for preliminary discussions and early publications.

The most liberal and enlightened offer on the part of the Secretary of the Navy, to furnish with a set of Wind and Current Charts, every merchant captain, whatever his flag, who will assist in collecting materials for them, secures the co-operation of this most able and efficient class of observers in carrying out the system of observations at sea, as recommended by the Brussels Conference.

A similar offer on the part of each government to its own amateur meterologists, with regard to the observations on the land, would not fail to secure for the proposed universal system the hearty co-operation of this class also.

Meteorological observations which, after being made, remain in pigeon-holes without being published, had almost as well, all will admit, so far as the world is concerned, not have been made. And meteorological observations, though never so well made at an isolated station, and though they be ably discussed and duly published, yet even then they are possessed of comparatively little value, unless they be compared and grouped with others taken under like circumstances in other parts of the world. When this is done, their true value begins to appear.

The whole earth is surrounded with meteorological agencies, which have a direct bearing upon its productions, and climates, and the well-being of all its inhabitants.

They are equally interested in the interpretation of the laws which govern those subtile agencies, and, therefore, it is proper that all nations should unite in one general effort to read them correctly.

So far as the sea is concerned, this has been done. A joint national and indivdual co-operation has been established, and, consequently legislatures have not been called on for additional and heavy appropriations, or any grievous or new imposition of taxes; neither have citizens or subjects been subjected to any new system of taxation to carry on a work which all are willing to support.

Now, so far as the land is concerned, each government may obtain the ready and willing co-operation of its own citizens or subjects engaged observing as amateur meteorologists, and that too at a cost still more trifling than that by which the ocean has been brought regularly within the domains of meteorological investigation.

Every State in Christendom already has one or more meteorological observatories, from which published observations are issued to the world at occasional or stated intervals.

Now, should a universal system be adopted by these States, every government may procure amateur co-operation within its own borders to any extent, and at no greater cost than that of a printed copy of its observations to each of its own citizens, who would provide himself, at his own expense, with the requisite instruments, and who would make the observations according to the prescribed form, and return them to the proper office for discussion and publication.

This is what the United States have done with regard to the observations at sea—two-thirds of the whole meteorological field of the earth. There, the merchantman are the amateurs; and by offering them, for their co-oporation, a copy of the nautical works which their observations help to make, the ocean has become literally dotted with floating observatories, already fitted with instruments, and furnished with observers at private charge.

So, too, any required number of free volunteer co-laborers on the land, may be enlisted in this general field of research, merely by the offer, on the part of their government, to give them a copy of the published works which their observations may help to make.

These amateurs would not, in many cases probably, be able to furnish their observatories with complete sets of self-registering instruments; but as to the ordinary instruments there can be no doubt, and would be no difficulty.

Who shall take up this subject and become its champion?

My field is the sea; and though many of the observations made there suggest, in urgent terms, the importance which corresponding observations on shore, and concert among observers on the land, would be to us in our system of research, yet I am not clear as to the propriety of my taking any very active initiatory part with reference to the assembling of a general meteorological congress, for the purpose of devising a system of observations which, embracing both sea and land, shall be universal. I hope the matter will be taken up by abler and stronger hands by far than mine.

Returning from this review of a general conference among meteorologists, to the proceedings of the Brussels Conference, with regard to the form of an abstract log for merchantmen, it was understood that the powers of the Conference did not extend beyond men-of-war, and that the officers of the various navies therein represented were better judges than the Conference could be, as to what observations, and what part of the man-of-war log, the merchantmen of his country could or would undertake.

These principles and data were, however, laid down as indispensable, viz: 1. Every log of every co-operating merchant man, what everhis flag, must give, at the least, the longitude and latitude of the ship daily; the height of the barometer, and the readings of both the air and the water thermometer, not less than once a day; the direction and force of the wind three times a day:—first, middle, and latter part; the variation of the compass occasionally; and the set of the current whenever encountered. 2. That these observations, to be worth having, must be accurately made, and that, as every thermometer or barometer has its sources of error, consequently every shipmaster, who undertakes hereafter to co-operate with us, and keep an abstract log, should have his barometer and thermometer accurately compared with standard instruments, the errors of which have been accurately determined.

These errors the master should enter in the log; the instrument should be numbered, and he should so keep the log as to show what instrument is in use. For instance, a master goes to sea with thermometers Nos. 4719, 1, 12, &c., their errors having been ascertained and entered on the blank page for the purpose in the abstract log. He first uses No. 12. Let it be so stated in the column of Remarks, when the first observation is recorded, thus: thermometer No. 12. During the voyage, No. 12 gets broken, or, for some reason, is laid aside, and another, say 4719, is brought into use. So state, when the first observation with it is recorded, and quote in the column of Remarks the errors both of Nos. 12 and 4719. Now, with such a statement of errors given in the log, for each of these instruments, according to its number, the observations may be properly corrected when they come up here for discussion.

It is as rare to find a barometer or a thermometer that has no error, as it is to find a chronometer without error. A good thermometer, the error of which the maker should guarantee not to exceed in any part of the scale 1°, will cost in the United States not less than $2, perhaps $2 50.

The errors of thermometers sometimes are owing to inequalities in the bore of the tube. sometimes to errors of division on the scale, &c. Therefore, in comparing thermometers with a standard, they should be compared at least for every degree between melting ice and blood heat.

The hours at which observations are most important are denoted by large figures; and the columns which it is most important for merchantmen to fill up are marked, in the Brussels form, given in the abstract log; (*a*) for those which are indispensable; (*b*) for the next most important; (*c*) for the next, and so on.

We are now about to turn over a new leaf in navigation, on which we may confidently expect to see recorded much information that will tend to lessen the dangers of the sea, and to shorten the passage of vessels.

We are about to open in the volume of nature a new chapter, under the head of MARINE METEOROLOGY. In it are written the laws that govern those agents which the "winds and the sea obey." In the true interpretation of these laws, and the correct reading of this chapter, the planter as well as the merchant, the husbandman as well as the mariner, and States as well as individuals are concerned. They have a deep interest in these laws. For, in the hygrometrical conditions of the atmosphere, the well-being of plants and animals is involved; with its motions, the safety of navies is concerned, and upon its laws the health of armies and the success of campaigns often depend.

The atmosphere pumps up our rivers from the sea, and transports them through the clouds to their sources among the hills; upon the regularity with which this machine, whose motions, parts, and offices we now wish to study, lets down that moisture, and upon the seasonable supply of rain which it furnishes to all cultivated fields, depends the fruitfulness of a country, the prosperity of its inhabitants.

The principal maritime nations, therefore, have done well by agreeing to unite upon one plan of observation, and to co-operate with their ships on the high seas with the view of finding out all that patient research, systematic, laborious investigation may reveal to us concerning the winds and the waves.

Accordingly, every one who uses the sea is commanded or invited to make certain observations; or, in other words, to propound certain queries to Nature, and to give us a faithful statement of the replies she may make thereto.

Now, unless we have accurate instruments, instruments that will themselves tell the truth, it is evident that we cannot get at the real meaning of the answers that Nature may give us.

An incorrect observation is not only useless of itself, but, when it passes undetected among others that are correct, it becomes mischievous; for it vitiates results that are accurate, places before us wrong premises, and thus renders the good of no value.

It is not only necessary that our instruments should be accurate, but it is desirable that they should readily admit of comparison also. Admiral FitzRoy has given in the first number of "The Meteorological Papers of the Board of Trade," an excellent description of the instruments furnished by that office to co-operating vessels. The instruments used by vessels of the United States are of the same sort. The Admiral describes those that are accurate, and, for the benefit of those who wish to procure and use such, I copy from it:

"MEMORANDUM ON THE USE AND ADJUSTMENT OF INSTRUMENTS.

"The instruments chiefly required by navigators are compasses, sextants, chronometers, barometers, or sympiesometers, and thermometers. Those which should be added for special scientific purposes, such as surveying, magnetism, or meteorology, are artificial horizons, theodolites, micrometers, dipping and intensity needles, magnets, hygrometers, or wet bulb thermometers, and hydrometers, besides apparatus for sounding, and other purposes.

"These instruments, except the horizons, theodolites, and intensity needles, may be used afloat, and those which are excepted may be readily carried and used on land near a ship. Rain gauges and anemometers are seldom used where there is not an observatory, either established or temporary, but they are much wanted afloat.*

"Beginning with the COMPASS: So delicate and sensitive an instrument as a well made compass should be most carefully placed, and guarded very vigilantly from the action of any magnetic substance casually within the reach of its influence on the needle. It should be always borne in mind that the local attraction of the iron in a ship affects the compass more or less, by causing the needle to deviate from the position it would have, if suspended above the water or earth, at a distance from any magnetic influence other than that of the earth itself (the terrestrial magnetism;) that this deviation is variable; that lightning sometimes causes sudden changes; and that attraction of iron varies.

"When the ship's head is towards the magnetic north or south, local attraction usually acts on the needle nearly in the same direction as terrestrial magnetism, (though not always,) and, then, compass bearings taken on board that ship are nearly the same as if no local magnetism were influencing the needle.

"And when the ship lies nearly across, or at right angles to the magnetic meridian, the deviation is usually the greatest, the ship's attraction drawing the needle the most out of its correct magnetic position; but in iron ships this does not hold good invariably.

"Terrestrial magnetism causes the needle to incline, or dip, more or less, and in order to keep it horizontal a sliding weight is attached. This must be shifted, when in very different latitude, as the dip varies. It is one cause of the compass card oscillating when the ship rolls, because it gives unbalanced momentum to the needle.

"Compass needles should be deep vertically, but narrow, in order that the direction of magnetism may coincide with their middle line. The centres, supported on steel or jewelled points, should be of agate, or hard metal.

"Spare cards should be kept in pairs, the north and south ends together, or connected by small pieces of soft iron, to preserve their magnetic power.

"If correcting magnets are fixed, their actual effect should be often tested by placing the ship's head to the magnetic north or south (indicated by a compass placed in a position where the ship's local attraction is not sensible, or by a celestial object,) allowing the supposed (if not known) variation of the place.

"A point where the ship's local attraction is not sensible is called neutral, if within her influence, as on deck; but if aloft, as in a top, or other high place where there is no iron, this term is inapplicable, as in such a position the needle is affected by terrestrial or general magnetic influence alone; not by that of the ship.

* No good one has been devised for use at sea, that has yet been proved.

"A neutral point is somewhat difficult to find and preserve in most ships, but the nearer to it a compass can be placed the better it will serve as a standard, or for frequent reference.

"It is necessary not only to guard against iron in or near the compass binnacle, but to prevent the possibility of such a cause of error, as far as possible, by binnacles without doors, and preventing the temporary approach of any magnetic substance within a certain distance.

"The azimuth compass should be placed at a neutral point, if possible and convenient, or at a spot from which bearings can be taken all round, or nearly so, and where the instrument may *always* be placed (as each change of position of course alters the effect of local attraction.)

"The advantage of ascertaining a *neutral point*, (where the local attraction is scarcely felt in *any* direction of the ship's head, owing to the counteraction of opposing influences,) and a neutral line, (in which the ship's length should lie while taking real or correct magnetic bearings,) is well worth the trouble of experiment.

"Generally the centre of magnetic effort exerted by the iron of a ship is before the binnacle, but it may be abaft it if a mass of iron should be very near but abaft the compass. Professor Barlow's correcting plate used to be placed so as to counteract the ship's local attraction—or to double it, and thus show the amount.

"Standard compasses, to which steering compasses are referred, are usually of superior make, and so fitted with prismatic reflectors (for reading the graduated arc) and sight vanes as to answer well for observations in azimuth. The best description have a graduated circle of metal on which the sight vanes traverse. This being horizontal, on account of the compass being suspended in jimbals, affords the means of measuring a horizontal angle like a theodolite. Such a circle is more useful on land than afloat, but it may also be used afloat when there is not much motion. A round of horizontal angles may be taken quickly between terrestrial objects which a sextant would not give without reduction. It is moveable without affecting the card.

"Various experiments have been tried with a view to cutting off or considerably diminishing local magnetic influence on a needle, but hitherto unsuccessfully. Copper bowls,* cases, and screens have been variously adopted, to little or no purpose.

"Whether the needle be in air or in a vacuum is immaterial, it would appear by the investigations made expressly, as the magnetic influence seems to pervade or penetrate through any interposing medium to a certain distance not very different from that of its action when unopposed.

"REFLECTING INSTRUMENTS suitable to the measurement of angles at sea are circles, sextants, quintants, and quadrants or octants, according to their angular measurement. The circle is the most complete instrument, and includes an arc of about 150°, but it is heavy and expensive for common use.

"The quintant is the fifth part of a circle. It measures about 140°, but, if fitted with an extra horizon glass and doubly graduated arc, includes 160°, and is a useful instrument, particularly in low latitudes.

"A sextant is the sixth part of a circle, and measures angles not much exceeding 120°. A quadrant includes the fourth part, or 90°; but this instrument, being in shape the eighth part of a circle, is sometimes called an octant.

"Their principle is similar, but they vary much in construction, material, and price; the best brass circles costing thirty or more pounds; cheap wooden quadrants about two pounds.

* Iron is sometimes present in mixed metal, which becomes magnetic.

"All these instruments should be held carefully, by the frame or handle; not touching the glasses or arc. The adjustment of the glasses is very liable to be injured by pressure; and the arc may be warped or strained by incautious handling.

"They should be very carefully taken from and returned to their boxes. The reflecting glasses or mirrors should be gently wiped when necessary—never carelessly. They should be adjusted as seldom and as cautiously as possible, especially the superior instruments; but the state of the adjustments should be vigilantly noticed always." * * * * *

[The adjustments are explained in the common works on navigation.]

"It is advisable to have brass instruments bronzed, or blacked, not bright. They should not be cleaned beyond careful wiping with a soft substance. A very light touch of sweet oil occasionally is beneficial on the arc and in the joints of glasses.

"Used with care, a really good instrument will not alter much even in years of frequent work.

"Artificial Horizon.—The natural accompaniment to a good reflecting instrument is an artificial horizon, for although the edge of the sea is usually an available horizon, and the mercurial or other substitute for it can only be good on land, it is there invaluable. Such reflecting instruments (sextant and horizon,) and a chronometer, may be considered a portable observatory.

"The artificial horizon is mercurial or of other liquid, or solid. If the former, which is best, it should be placed on a small leaden plate or tripod, (the feet being knobs, about an inch long, rather than points,) the surface perhaps eight inches by six, or less, and covered with coarse cloth. The trough for the mercury should be very low at the edges (shallow,) but high on its base: with a notch for pouring off; and a small wooden scraper for cleaning off dross.

"The Chronometer requires every possible care. It should be kept in one place, and secured in one direction. The outer box bedded in cushions or coarse sawdust, within a fixed frame, near the centre of rolling motion, is an advisable plan. Temperature affects it more than motion. The rate alters more or less with change of temperature, even in the best chronometers; but, generally speaking, those used afloat are not such reliable instruments as they might be if a higher price were given for a greater degree of excellence in manufacture, adjustment, and compensation. Chronometers should not be moved from their fixed position. An inferior timekeeper, or a good pocket watch with a second hand, will suffice for taking time on deck, or even ashore, with an artificial horizon, provided that it be compared with the chronometer immediately after as well as before making observations. Change of temperature should be noticed, and corrections applied to the rate. After ascertaining the daily rate of a well-placed chronometer in any port, the ship may go into a warmer or a colder region, and afterwards into another temperature. Allowance should be duly made for each change. A thermometer should always be with the chronometer, and carefully registered. Erroneous measurements are often made by allowing a rate obtained at one place, in a certain temperature, to be used (without correction) when in a different climate, much warmer or colder; or by using the means of two rates, obtained in nearly equal temperatures, for a voyage, or measurement of longitude (meridian distance rather) made through a temperature higher or lower than that of either place of rating.

"Lunars afford a *skillful observer* the means of checking results of chronometers, and even rating them, as well as ascertaining absolute longitudes within very few miles accurately; but to effect limited exact measurements or meridian distances, such as are required in marine surveying, only chronometers can be employed advantageously, as a general rule.

"Even the best watches should be cleaned and oiled from time to time, as the constant wear of the pivots causes the oil to become thich and clogged. Once at least in about three years a chronometer should be examined by a skillful maker, to insure its accurate performance. Winding up should be regular: daily for two-day watches, weekly for those which will go for eight days.

"As far as may be, the same person should wind and compare them at all times, for the sake of uniformity. They should be wound up to the full extent, on no account taking so many turns only, but always feeling the stop, however gently. Lightning striking a ship, or continued magnetic action of iron, may more or less affect any chronometer—likewise the ship's head being long in one direction.

"THE THERMOMETER is familiarly known to every one. When used as a HYGROMETER, two thermometers should be placed on their stand, in a safe and shaded place. One of the two should have cotton, linen, or muslin rag lightly tied round the bulb, from which a piece of cotton wick or a shred of rag should trail into a small cup or tin of fresh water fixed in the stand below the thermometer [the "wet bulb"] to be wetted. This cup must be kept, as far as may be, from the *dry* bulb, and should be *nearly* covered.

"Another thermometer may be used, in a copper case, as a water thermometer.

"The thermometer scale of Fahrenheit is generally used in England. The space between the points of freezing and boiling is divided into 180 parts; and as it was supposed that the greatest cold was produced by mixing snow and muriate of soda, or common salt, this point was made zero; the point of freezing is therefore 32°, and of boiling 212°.

"In the thermometer of Reaumur, the freezing point is made zero, and the scale between it and the boiling point is divided into 80°.

"In the Centigrade thermometer, the scale between the points of congelation, or zero, and ebullition, is divided into 100°.

"In Delisle's thermometer, the graduation commences at the boiling point, and increases to that of freezing, which is 150°.

"To convert degrees of Reaumur to those of Fahrenheit, multiply by 9, divide by 4, and add 32 to the quotient.

"To convert degrees of the Centigrade to those of Fahrenheit, multiply by 2, divide by 1.11, and to the quotient add 32.

"To convert degrees of Delisle below the point of ebullition to those of Fahrenheit, multiply by 6, divide by 5, and from the quotient subtract 212, or subtract the quotient from 212.

"To convert the degrees of Delisle above the point of ebullition, multiply by 6, divide by 5, and to the quotient add 212.

"BAROMETER.—The principle of the barometer is now so generally known that it need hardly be mentioned here. While the mercury in the cistern falls, or is pressed down by the air, the column rises in the exhausted tube, and the reverse. But the actual length of the column is required (in order to know the weight or pressure of the atmosphere,) as measured from the actual surface of the mercury, which is variable; therefore a correction is required for most instruments on account of the difference from the neutral line or point, namely, that defining the base of the column when the scale attached to it was graduated. In some barometers the graduated scale can be adjusted so that the lower point just touches the mercury, in which case no correction for the relative capacities of the tube and cistern is necessary. In small tubes an error is caused by what is called capillarity and by friction. Unlike other fluids mercury is depressed by capillary action. Other errors to be noticed and allowed for are caused by the expansion or contraction of the mercury by higher or lower temperature than that of the mercury when the scale was graduated, and by the dilatation, expansion, or contraction, of the tube and scale." * * * "Moreover, there are errors in most barometers, occasioned by the variation or the scale, or incorrect graduation, or both, besides that occasioned by air, moisture, or gas in or above the column which affects its height. Some of these may be comprehended as Index Errors, and are so in instruments made on the Kew principle.—(*See* pp. 180, 182.)

"The barometer requires very careful handling, the glass tube being exceedingly liable to fracture. When moved from one place to another the cistern end should be kept uppermost, the instrument having been gently reversed.

"When suspended for use it should hang freely in a vertical position, where neither the sun's rays, nor a fire, nor any local cause of heat or cold, may be likely to affect it. Every observation of the height of column should be accompanied by a notation of the degree of temperature shown by the attached thermometer (which indicates the temperature of the mercury,) as well as by those of the air. In reading off, the edge of the vernier scale should appear to touch (or be a tangent to) the uppermost point of the mercury when the eye is at an equal height and looking horizontally at the tube. A card or a piece of white paper behind or at the side of the tube aids the eye by reflecting light or showing the edge of the quicksilver more plainly.

"The vernier enables one to read off hundreths of an inch, or in most good instruments thousandths. Its principle is the same as that of the sextant—substituting *scale* for *arc*, and divisions of inches for parts of arc. An extreme degree of minuteness in reading is scarcely necessary in marine barometers at sea, which are unavoidably liable to errors exceeding even hundredths, partly from defective construction or adjustment, partly from movement of the ship, which causes oscillation (often called pumping) of the mercury in the tube. To prevent the barometer from acquiring too much motion (from the ship's movement,) from acquiring a momentum which augments its swinging and gives impetus to the mercury, soft cushions, india-rubber straps, or weak springs may be employed.

"As the column rises with increase of pressure by the atmosphere, and descends when the pressure diminishes, it indicates a greater or less accumulation of air, which, like other fluid, such as water, when heaped above its average level or reduced below it (from whatever cause,) will have a tendency to fall or rise till the general equilibrium is restored. An observer may be under the centre of such accumulation or depression, or he may be more or less distant from it, though within the influence of whatever horizontal movement of air may be caused by such temporary increase or diminution of pressure. Hence the barometer shows, and generally foretells, changes of wind; but as complications often occur, and changes are of greater or less extent, affecting or extending through a wider or more limited area, and are accompanied by hygrometric and electrical alterations, it is extremely difficult at times to say beforehand what particular change of weather is to be expected, and at what interval of time; although after the event the correspondence of barometric changes with those of the weather can be readily traced. However, notwithstanding occasional perplexity, the general character of the weather during the next following few days may be predicted by an observer who has watched the barometer in the few immediately preceding days, and who understands the nature and use of the instrument.

"The general peculiarity should be always remembered in endeavoring to foretell weather that the barometric column usually stands higher with easterly than it does with westerly winds, all over the oceans; and with winds from the polar regions also higher than with those from the direction of the equator. Hence the highest barometric columns are observed with northeast winds in northern latitudes and with southeast in the southern hemisphere.

"In middle latitudes there is an average difference (unreduced or observed height as read off) of nearly half an inch, other things being similar. The column ranges from about 28 to near 31 inches in the higher latitudes, but except before or during storms, when it *occasionally* falls below 28 inches, the range in tropical latitudes seldom extends many tenths of an inch above or below 30 inches at the level of the sea.

"As a general rule wind affects the column more than rain* (hail or snow,) but either has influence; and the longer the interval between the alteration of the barometer and the foretold change of the weather the longer that new state of the weather will last, and conversely.

"Moreover, the more gradually the column moves the more settled in character will the weather be, and the reverse; also when the barometric column moves contrary to the natural movement, according to the daily tidal change (however masked,) inferior weather may be expected, and conversely.

"Movements of the atmosphere may be illustrated by reference to the movement of water drawn off from a reservoir by a small opening below, or increased by a gradual pouring in at one point of the upper surface.

"From a slight motion at the commencement, affecting only that portion of the fluid adjoining either of those points of diminution or repletion, gradually all the water becomes influenced and acquires more or less rapid movement. But suppose a long reservoir or canal of fluid which has two such points of exhaustion or two of repletion (as imagined above,) and that one of either is near each end of the vessel, if each aperture be opened at the same moment equal effects will be caused in each half of the fluid towards either end of the vessel, but in the middle there must be a neutral point at which the water falls, but has no horizontal motion. The reverse takes place in raising the level. And in the case of fluid drawn off or diminished in weight at one end while increased by repletion at the other, the whole body of water will move similarly to that in the former vessel, but unequally. Hence it is evident, that before horizontal motion occurs, an augmentation or a diminution of pressure must take place somewhere not very remote, and so it is with the atmosphere, which is a light fluid.

"These considerations show in some degree why the barometric changes usually precede, but sometimes only accompany, changes of weather: and, though very rarely, occur without any sensible alteration in the state of the atmosphere. An observer may be near a central point, towards which the surrounding fluid tends or from which it diverges. He may be at the very furthest limit of the portion of water or air that is so influenced. He may be at an intermediate point, or he may be between bodies of aëriform fluid tending towards opposite directions.

"Cæteris paribus, the column of mercury falls a tenth of an inch for about one hundred feet of elevation near the sea level, and gradually less for each hundred feet as it becomes

* Quere? See Figs. 3 and 4, Plate XIX.—M.

more elevated.* Due allowance, therefore, should be made in correcting or reducing observations for any difference between a fixed limit (usually the edge of the copper sheathing) and the actual water line of the vessel at the time of observation, which should be noted if *considerably* different.

"The tides being so much affected by atmospheric pressure that (according to the observations of M. Daussy on the southwest coast of France) a rise of one inch in the barometer will have a corresponding fall in the tides of about 14 inches; say one foot for each inch (nearly)—here also the barometer proves of service to the navigator—for vessels not unfrequently enter harbors where they have but one foot of water more than their draught: and docking, as well as launching large ships requires the closest calculations.

"The words on scales of barometers are not to be so much regarded for weather indications, as the rising or falling of the mercury, for if it stand at *Changeable*, and then rise to *Fair*, it presages a change of wind or weather, though not so great as if the mercury had risen higher; and, on the contrary, if the mercury stand above *Fair* and then fall considerably, it presages a change, though not to so great a degree as if it had stood lower. From this it appears that it is not from the point at which the mercury may stand that we are alone to form a judgment of the state of the weather, but from its *rising or falling*. Before observation gently tap the barometer near the top, as the mercury will occasionally adhere to the sides of the glass, which would prevent its showing a very slight change that may have taken place in the atmosphere.

"A rail, bar, or frame of some kind should guard the barometer from an accidental blow or displacement; and indeed, generally speaking, the greatest care should be taken of this invaluable monitor.

"The 'Law of Storms' is daily becoming more developed, not only by the investigations of the philosopher, but likewise by the careful observations of some of our intelligent navigators, who, from experience, affirm the truth of the law and the value of the barometer.

"Mr. Redfield said, 'that a whirlwind which sets an extended portion of the atmosphere into a state of rapid revolution diminishes the pressure of the atmosphere over that portion of the earth's surface, and most of all at the centre of the whirl. The depth of the compressing column of air will, at the centre, be least, and its weight will be diminished in proportion to the violence of the wind.' This has been controverted, however, although Sir W. Reid states (p. 19, 'Law of Storms,') that his own observations confirm the truth of the assertion: he likewise observes, that great whirlwinds, by lowering the upper atmosphere, bring down portions of the colder regions of the air, and these mingling with the warmer and moister air at the surface of the sea, form dense clouds. In these gyrations it sometimes happens that the barometer falls as much as two inches, diminishing the atmospheric pressure by $\frac{1}{15}$ part; and it may be expected, as a natural consequence, that very dense clouds should then be formed, such as prevail during a tempest.

[ANEROID barometers, and SYMPIESOMETERS, should not and cannot be used in our researches, and co-operators who rely upon them cannot fulfill their part of the agreement by keeping their "abstract" according to form.]

"The daily movement of the barometrical column may be noted (in a form or table of double entry,) at the hour of each observation, by a dot at the place corresponding to its altitude, and the time of observing; which dot should be connected with the previous one by

* In geometrical ratio, approximately.

a line. The resulting irregular curve or zigzag (as it may be) will show at a glance what has been the motion of the barometric column during the immediately previous days, by which, and not merely by the last observation, a judgment may be formed of the weather to be expected.''

[Expanding this idea, I have added to the blank abstract log a Plate (XIX) of engraved squares, upon which the navigator is recommended to project daily, at sea, his maximum and minimum barometer reading so as to form a belt showing its daily range. He can also mark by arrows the direction and force of the wind for the maximum, also the direction and force of the wind for the minimum barometer when there is a marked difference. With the barometric belt thus projected, the navigator can turn back and see at a glance what winds the barometer would have warned him of if he had have understood its indications—and thus he will ''know better the next time.'' After treating the barometer in this way for a voyage or two, the navigator will understand more about it and its indications than he is likely to do by years of experience in any other way.

Plate XIX is given merely as an illustration. The arrows fly with the wind, and the stronger the wind the longer and broader the arrows.

Fig. 1 shows the belt of barometric range as observed on board the ''Gloriana,'' (Toynbee,) while she was passing from 30° N. to 40° S. in the Atlantic on her way from England to India.

The figures 10°, 20°, 30°, &c., below the belts are given to remind one as to the parallels of latitude between which the observations were made. The observations are not corrected either for temperature or for height above the sea-level, or for any other error. We notice in this figure the fall of the barometer under the equatorial cloud ring, and its steady range in the SE. trade-winds of the Atlantic.

Fig. 2 gives the range as observed by Captain Rodgers on board the United States sloop Vincennes, from 40° N. to 37° S., as he crossed the trade-winds of the Pacific. The arrows are intended to show the prevailing force and direction of the wind for every day, and it will be remarked that he had a change of wind for every change of barometer.

Fig. 3 shows the belt of range around Cape Horn from 39° S. on the Atlantic to 38° S. on the Pacific side. Captain Flye used to be attached to the Observatory as a Professor of Mathematics in the navy. He assisted for a number of years in the construction of Wind and Current Charts. Finally he resigned and went to sea in command of a merchantman. It is from his observations in the ''Edwin Flye'' that the very instructive data for Fig. 3 were obtained. The low barometer off Cape Horn is here quite striking.

The occasional arrows below the belt show the wind for the minimum barometer when there was a marked difference in the wind at low barometer.

The data for Fig. 4 were obtained from the abstract log of the Bremen bark ''Mississippi,'' Captain Carl Gerdes, on a voyage to Archangel.

I have added to these two figures the rain curve, which includes snow and hail. The observations at sea do not enable us to draw this curve for *quantity*. It is drawn so as to show the number of hours during the 24 that snow, hail and rain were falling, and in practice it may be drawn heavy for heavy rain, fast snow, or violent hail. Those days for which no rain curve is drawn, were fair days or rather they were rainless, though they may have been cloudy days.

The diagram (Fig. 3.) illustrates in a striking manner the low barometer off Cape Horn.

In contrast with Fig. 4, "the barometric anomaly" is obvious enough: the barometer when at its maximum height, as observed by Flye, on the polar side of 50° S. is barely as high as it was at its minimum reading by Gerdes on the polar side of 54° N.

It appears, moreover, if we consult these two figures only, that in a given time we have two *rainless* days and two *rainy* hours off Cape Horn, to one rainless day and one rainy hour in the seas about North Cape.

But I will not here go into a discussion of these instructive and suggestive figures. They were constructed from materials taken at random, merely to show the practical advantages which would doubtless inure to those mariners who will take the trouble to project daily at sea their belt of barometric range. However, from this chance projection merely, a rule as to the barometer and the weather is suggested which perhaps has escaped the observation of many close observers of the barometer at sea, but which would not have so escaped for a single voyage had care been taken by any one on board to project in the manner now proposed, the barometric observations as they are usually made at sea.]

"Such a diagram may be filled up by the entries in the register *uncorrected*, its object being to serve as a weather guide for immediate use, not as a record for future investigation. If closely kept up, it will prove to be of material use, and will in some degree reward the trouble of keeping an accurate and regular record.

"Commonly familiar as the practical use of the barometer, as a weather glass, is at sea as well as on land, only those who have long watched its indications, and compared them carefully, are really able to conclude more than that a rising glass USUALLY foretells less wind or rain, a falling column (or glass) more rain or wind, or both; a high column fine weather, and a low one the reverse. But useful as are these general conclusions *in most cases*, they are *sometimes* erroneous, and then deprecating remarks are rather hastily made, tending to discourage the inexperienced.

"By attending to the following brief observations (the results of many years' practice and many persons' experience,) any one not accustomed to use a barometer may do so with less hesitation and with immediate advantage.

"The column of mercury in a good barometer usually stands on an *average* some tenths of an inch higher with or before polar and easterly winds, than it does with or before equatorial and westerly winds (of equal strength and dryness or moisture) in all parts of the oceans. (The terms Polar and Equatorial are used with reference to winds blowing from the *nearest* polar direction, or from the direction of the equator.) This peculiarity causes many mistakes. The glass is high, perhaps, but falling. Wind or rain, or both, are expected in consequence, yet neither follow to any remarkable degree. A change of wind only from one quarter to another takes place. Reversely the glass is low, but rising. Finer weather is expected, yet instead of that a strong wind, accompanied perhaps by rain, hail, or snow, rises from the polar direction.* An impending fall of rain or snow affects the column; wind still more, (having regard to the quarter whence it blows, and the *average* difference.) Electricity in the atmosphere, lightning and thunder, affect Adie's (oil) sympiesometer remarkably, but not the aneroid, or a mercurial barometer, nearly so much.

"Allowance should always be made for the previous state of the column during some days, as well as some hours, because its indications may be effected by remote causes, or by changes close at hand. Some of these changes may occur at a greater or less distance, influencing

* By such changes as these, seamen are often misled, and much calamity occurs sometimes.

neighboring regions, but not visible to each observer, whose barometer feels their effect. Moreover, as a *general rule*, the longer a change of wind or weather is foretold by the barometer before it takes place, the longer the presaged weather will last; and, reversely, the shorter the warning, the less time, whatever causes the warning, whether wind or a fall of rain or snow, will continue.

"There may be heavy rains or violent winds beyond the horizon, and even the view of an observer, by which his instruments may be affected considerably, though no particular change of weather occurs in his immediate locality.

"Sometimes severe weather from an equatorial direction, not lasting long, may cause no great fall of the glass, because followed by a *duration* of wind from polar regions—and at times the column may fall considerably with polar winds* and fine weather, apparently against rule (or law,) because a *continuance* of equatorial wind is about to follow.

"Although wind and its direction affect the barometer more than rain or snow—as certain winds usually bring more moisture than others, the apparent cause of barometric movement is by some attributed chiefly to wind, by others (on land) generally to rain or snow. The hygrometer (or wet and dry thermometer) indications are useful in these cases. It may be repeated here that, as in the higher latitudes the mercury usually ranges from an inch to two, or even three inches; but, in tropical regions, a few tenths of an inch are seldom exceeded, except before hurricanes, or similar tempests, when the quicksilver has been known to fall below 28—even to 27 inches—allowance should always be made, in forecasting weather, for the range in the latitude: and that in the middle, and high latitudes, storms are much more frequent and of longer duration than in tropical or low latitudes, where their fury, though extreme occasionally, lasts only for a short time.

"There is little variation of the barometer between the tropics, because the wind blows generally in the same direction and with equable force, and no contending currents of air cause any considerable change in the density of the atmosphere. For great storms or hurricanes, however, within the tropics, the barometer falls very low, but soon returns to its usual state. It has been observed on some coasts, that the barometer is differently affected by the wind, according as it blows from the sea or from the land; the mercury rising on the approach of the sea breeze, and falling previously to the setting in of the land wind.

"Continued series of observations have proved the inter-tropical diurnal rise and fall of the barometer, the mercury falling from near ten till about four in the afternoon, when it reaches the lowest point of depression; and rising from between three and four till nine or ten, at which time it reaches the highest point of elevation, after which it falls until about three A. M. From this time it rises till past nine o'clock, when it reaches the highest point of elevation. If the mercury moves contrary to this its regular course, comparatively bad weather may be expected, in any inter-tropical region.

"These atmospherical tides depend upon the sun's influence and the rotation of the earth, and do not follow the place of the moon. The rise and fall of the mercury is about 6 or 7 hundredths of an inch. Its regularity is *disturbed by land*, but in the ocean it prevails to latitude 26° north and south; and, in fine steady weather, may be perceived even in the middle latitudes. * * * * * * * * *

* Southerly in North Latitude. Northerly in the Southern hemisphere.

"*Remarks on the Marine Barometer, adopted by Her Majesty's Government and the United States navy—on the recommendation of the Kew Observatory Committee of the British Association for the Advancement of Science.*

"This instrument should be suspended in a good light for reading, but out of the reach of sunshine or heat of a fire or lamp. It should be as nearly amidships, and exposed as little to sudden changes of temperature, gusts of wind, or injuries, as possible. The light should have access to the back of the tube, to admit of setting the index so as to have its lower edge a tangent to the surface of the mercury—the eye being on the same level. White paper or card will reflect light for setting the vernier correctly. The height of the cistern above the ship's water-line should be ascertained, and entered on the register.

"It is desirable to place the barometer in such a position as not to be in danger of a blow, and also sufficiently far from the deck above to allow for the spring of the metal arm in cases of sudden movements of the ship.

"If there is risk of the instrument striking anywhere when the vessel is much inclined, it will be desirable either to put some soft padding on that place, or to check movement in that direction by a light elastic cord; in fixing which attention must be paid to have it acting only where risk of a blow begins, not interfering otherwise with the free swing of the instrument: a very light cord attached above, when possible, will be least likely to interfere injuriously. The small holder on the glass tube is for the purpose of reflection from a card.

"The vernier, as usual in standard barometers, reads to two thousandths (.002) of an inch. Every long line cut on the vernier corresponds to .01 part; each small division on the scale is .05; the hundredth parts on the vernier being added to the five when its lower edge is next above one of the short lines; or written down as shown by the figures on the vernier only, when next above one of the divisions marking tenths.

"In placing this barometer, it is only necessary to fix the instrument carefully as indicated in the above directions, and give a few gentle taps with the fingers on the bottom, to move the mercury. Without further operation, it will usually be ready for observation in about an hour. When replacing the barometer in its case, it will be advisable to allow the mercury to run up to the top of the tube, by holding the instrument for a few minutes inclined at an angle of about 45°, and to bring the vernier down to the bottom of the scale. No other adjustment for portability is required. During carriage, it ought to be kept with the cistern end uppermost, or lying flat, the former position being preferable.

"But if the mercury should not descend at first by a few gentle taps, use sharper (but of course without violence,) by which, and two or three taps with the finger ends on the tube—between the scale and the tangent screw—the mercury will begin to descend.

"ON THE METHOD OF TESTING BAROMETERS AND THERMOMETERS.

"In the year 1853 a conference of maritime nations was held at Brussels, on the subject of meteorology at sea. The report of this conference was laid before Parliament, and the result was a vote of money for the purchase of instruments and the discussion of observations, under the superintendence of the Board of Trade. Arrangements were then made, in accordance with the views of the Royal Society and the British Association for the Advancement of Science, for the supply of instruments properly tested.

"In the barometers now in general use by meteorologists on land, the diameters of the tubes are nearly equal throughout their whole length, and a provision is made for adjusting the mercury in the cistern to the zero point, or the reverse, previous to reading the height of the top of the column. The object of the latter arrangement, it is well known, is to avoid the necessity of applying a correction to the readings for the difference of capacity between the cistern and the tube. At sea barometers of this construction cannot be used. Part of the tube of the marine barometer must be very much contracted to prevent 'pumping,' and the motion of the ship would render it impracticable to adjust the mercury in the cistern to the zero point. In the barometer usually employed on shore, the index error is the same throughout the whole range of scale readings, if the instrument be properly made; but in nearly all the barometers which have till recently been employed at sea, the index correction varies through the range of scale readings, in proportion to the difference of capacity between the cistern and the tube. To find the index correction for a land barometer, comparison with a standard at any part of the scale at which the mercury may happen to be, is generally considered sufficient. To test the marine barometer is a work of much more time, since it is necessary to find the correction for scale readings at about each half-inch throughout the range of atmospheric pressure to which it may be exposed; and it becomes necessary to have recourse to artificial means of changing the pressure of the atmosphere on the surface of the mercury in the cistern.

"The barometers intended to be tested are placed, together with a standard, in an air-tight chamber, to which an air pump is applied, so that, by partially exhausting the air, the standard can be made to read much lower than the lowest pressure to which marine barometers are likely to be exposed; and by compressing the air it can be made to read higher than the mercury ever stands at the level of the sea. The tube of the standard is contracted similarly to that of the marine barometer, but a provision is made for adjusting the mercury in its cistern to the zero point. Glass windows are inserted in the upper part of the iron air-chamber, through which the scales of the barometers may be seen; but as the verniers cannot be moved in the usual way from outside the chamber, a provision is made for reading the height of the mercury independent of the verniers attached to the scales of the respective barometers. At a distance of some five or six feet from the air-tight chamber a vertical scale is fixed. The divisions on this scale correspond exactly with those on the tube of the standard barometer. A vernier and telescope are made to slide on the scale by means of a rack and pinion. The telescope has two horizontal wires, one fixed, and the other moveable by a micrometer screw, so that the difference between the height of the column of mercury and the nearest division on the scale of the standard, and also of all the other barometers placed by the side of it for comparison, can be measured either with the vertical scale and vernier or the micrometer wire. The means are thus possessed of testing barometers for index error in any part of the scale, through the whole range of atmospheric pressure to which they are likely to be exposed, and the usual practice is to test them at every half inch from 27.5 to 31 inches.

"In this way barometers of various other descriptions have been tested, and their errors found to be so large that some barometers read half an inch and upwards too high, while others read as much too low. In some cases those which were correct in one part of the scale were found to be from half inch to an inch wrong in other parts. These barometers were of the old and ordinary construction. In some, the mercury would not descend lower than about 29 inches, owing to a fault very common in the construction of the marine barometer till lately in general use, that the cistern was not large enough to hold the mercury which descended from the tube in a low atmospheric pressure.

"The practice, which has long prevailed, of mounting the marine barometer in wood is objectionable. The instrument recently introduced, agreeably to the recommendation of the Kew Committee, is greatly superior to any other description of marine barometer which has yet been tested, as regards the accuracy with which it indicates the pressure of the atmosphere. The diameter of the cistern is about an inch and a quarter, and that of the tube about a quarter of an inch. The scale, instead of being divided into inches in the usual way, is shortened in the proportion of about 0.04 of an inch for every inch. The object of shortening the scale is to avoid the necessity of applying a correction for difference of capacity between the cistern and the tube. The perfection with which this is done may be judged of from the fact, that of the first twelve barometers tested at the Liverpool Observatory with an apparatus exactly similar to that used at Kew, (whence these instruments were sent by railway, after being tested and certified,) the index corrections in the two pressures of 28 and 31 inches in three of them were the same; two differed 0.001 of an inch; and for the remainder the differences ranged from 0.002 to 0.006 of an inch. The corrections for capacity were therefore considered perfect, and, with one exception, agreed with those given at Kew.

"In order to check the pumping of the mercury at sea, the tubes of these barometers are so contracted, through a few inches, that, when first suspended, the mercury is perhaps twenty minutes in falling from the top of the tube to its proper level. When used on shore, this contraction of the tube causes the marine barometer to be always a little behind an ordinary barometer, the tube of which is not contracted. The amount varies according to the rate at which the mercury is rising or falling, and ranges from 0.00 to 0.02 of an inch. It is thought that, as the motion of the ship at sea causes the mercury to pass more rapidly through the contracted tube, the readings are almost the same as they would be if the tube were not contracted.

"The method of testing thermometers is so simple as scarcely to require explanation. For the freezing point, the bulbs, and a considerable portion of the tubes of the thermometers, are immersed in pounded ice. For the higher temperatures, the thermometers are placed in a cylindrical glass vessel containing water of the required heat; and the scales of the thermometers intended to be tested, together with the standard with which they are to be compared, are read through the glass. In this way the scale readings may be tested at any required degree of temperature, and the usual pactice is to test them at every ten degrees from 32° to 92° of Fahrenheit. For this range of 60° the makers who supply government are limited to 0.6 of a degree as the maximum error of scale reading; and so accurately are these thermometers made, that it has not been found necessary to reject more than a very few of them.

TEST OF HYDROMETERS.

"Hydrometers are tested by careful immersion in pure distilled water; of which the specific gravity is taken as unity.

"In water less pure, more salt, dense, and buoyant, the instrument floats higher, carrying more of the graduated scale out of the fluid.

"The zero of the scale should be level with the surface of distilled water, and rise above it in proportion as increase of density causes less displacement.

"The scale is graduated to thousandths—as far as .040 only—because the sea water usually ranges between 1.014 and about 1.036. Only the last two figures are marked.

"A glass cylinder, on a stand, filled to the brim with distilled water, is used. The hydrometer is kept carefully free from contact with the sides of the vessel, and its scale is read with a lens. The utmost precaution as to dust, oiliness, or (in brass) rust, even the least oxidation, or any dent, is scrupulously observed."

With this exposition to American shipmasters co-operating with me, the results of whose labors are seen in the works of this office, I appeal to their spirit and pride, and leave it for each one to decide what additional instruments he will take with him to sea; what columns of the new log he will undertake to fill, and at what other than the usual hours he will observe.

I leave this to their intelligence and judgment, in the full confidence that, when the next maritime conference meets to compare notes, and discuss new points, he who has the honor to represent our country there, will not be ashamed to lay the contributions of the American merchant marine before the meeting, or to see them compared with the best offerings from other flags.

And that each one may have it in his power to contribute according to his inclination and ability, I have given, on pages 340, 341 of this work, the form of the man-of-war log; and under it, on the same two pages, the form of the abstract log for the merchant service. I call this the "LOG FOR THE MERCHANT SERVICE," because the observations called for in it are a *minimum*. Every merchant captain who wishes to co-operate with us, must, in order that he may be entitled to the Charts, and these Sailing Directions, furnish at least what the blanks of that form call for.

There are many clever men in the merchant service who have been co-operating with me from the beginning; and there are many more who are ready, willing, and competent to give all the information that the most complete man-of-war abstract calls for. To all such, I shall be most happy to furnish man-of-war blanks.

The man-of-war log has already been admirably kept on board the Prussian ships Adler, (A. F. Wegner,) the Lagos, (A. F. Wegner,) and the Pruissi, (H. O. Skarka;) also by Captain Toynbee, of the Gloriana, (English,) and by Captains F. B. Sangston, of the Parana, Rafael A. Bayley, of the schooner Moses Taylor, W. I. Stafford, of the Caselda, Thomas A. Holt, of the Falcon, and by Captain G. Wenke, of the Herculean, Americans all.

Abstracts according to this form are wanted for all parts of the ocean, and for every sea, and particularly for the China Seas, and Indian and Pacific Oceans.

There is a promise of much activity among friends in the East Indies upon this subject, and of many valuable contributions for the construction of charts independently of what American shipmasters may furnish for the purpose. In 1851, a meteorological society was established at the Mauritius, under the especial patronage of the enlightened Governor, Mr. Higginson, and with the indefatigable Meldrum for secretary. This society is rendering most important services to the cause; it has been co-operating with us, making it a regular part of its duties to collect the abstract logs of vessels arriving at that important meteorological station.

I have received from Mr. Meldrum a most valuable collection of abstract logs; they contain upwards of 8,000 days of observations in the Indian Ocean. He has also published a paper under the caption "Contributions to the Meteorology and Hydrography of the Indian Ocean," which is most useful and instructive. It has been republished by the English Board of Trade in No. 1 of their meteorological papers, 1857, and I would ask leave to produce it here but for its length and the size of this volume.

Since 1839, Piddington has been at work in Calcutta, almost solitary and alone, till now. He has, however, collected a vast amount of information concerning storms, from which his cyclonology has sprung.

At Madras, there is a well-founded meteorological observatory, under the charge of Major Jacob, an officer of distinguished merit and high attainments.

Sir Henry Pottinger, and Dr. Ford, the meteorologist, are also in India. Their previous history is a guarantee of sympathy and support from them, in any undertaking to advance science and the good of mankind.

Mr. Fergusson, an officer of the Indian navy, in charge of the Bombay Observatory, has been engaged in collecting materials for, and in the construction of, a set of wind and current charts for the Indian Ocean.

A great step has already been accomplished towards "uniformity" of observations by placing within the reach of co-operators at sea good and accurate instruments, especially barometers and thermometers. Through the kindness and industry of the Kew Committee of the British Association this has been done; and, as it is a matter of no little interest to those who are laboring in this field, I quote a letter from Mr. Gassiot on the subject:

LONDON, *July* 18, 1854.

SIR: I am directed, by the Kew Committee of the British Association, to acquaint you that, after much consideration, they have decided on the barometer which they consider most applicable for marine observations, and that those ordered by Mr. Stevens for the use of the United States navy are of that construction.

In selecting the form of marine barometer best adapted to the purpose of making observations at sea, the Committee have endeavored to combine convenience and economy with accuracy, durability, and simplicity in construction and adjustment.

The barometer proposed by Mr. Adie appears to them to fulfill those conditions in a satisfactory manner. Its action at sea has been tested, under their superintendence, by Mr. Welch,* on two occasions: once in a voyage to Leith and back, and subsequently to the Island of Jersey. The general conclusion arrived at in those trials is that, in order to reduce the pumping of the mercury within convenient limits, it is necessary to have the tube contracted to such an extent, that the mercury will take about twenty minutes to fall from the top of the tube to the height indicating the true pressure of the atmosphere at the time. From comparisons made at Kew with the standard there, it has been found that, owing to this contraction in the tube, the absolute freedom of the mercury is to a small extent interfered with, as the motion of the mercury in the standard barometer is always a little in advance of the marine barometer; that is, when the mercury is rising from increasing pressure of the atmosphere, the marine barometer is a little lower than the standard; and on the contrary, when the mercury is falling, the marine barometer is a little higher. The amount of this retardation is, however, very small—something less than one hundredth of an inch—and, from its being in opposite directions in a rising and falling barometer, will produce no error in the *mean* height of the

* I am indebted also to Mr. Welch for comparing with the Kew standard many hundred thermometers for the navy, none of which have an error exceeding half a degree ($\pm 0^{\circ}.5$) in any part of the scale; generally, their maximum amount of error does not amount to half that quantity.

barometric column; it will, however, to some extent, mask the smaller changes, such as the hourly variations. It should be remarked, however, that the motion of the ship will always tend to diminish the amount of the retardation, and it is believed will, in general, nearly destroy it.

The instrument is constructed by Mr. Adie, of 395 Strand. The price, including cost of packing-case, ten shillings for verification at the Kew Observatory, carriage there and subsequent delivery in London, will be £3 15*s.* 6*d.*, at which price Mr. Adie is prepared to supply any quantity that may be required.

I have the honor to be, sir, your obedient servant,

JOHN P. GASSIOT,

Chairman of the Kew Committee, British Association.

I recommend, therefore, Mr. Adie's MARINE BAROMETER OF KEW, to all shipmasters who are co-operating with me, and who desire to have a really *good* marine barometer—one, the observations with which will be truly valuable, because being made with an accurate instrument, they may be compared with the observations of other standard barometers in all parts of the world, whether ashore or afloat. For such a purpose, observations with the *common* marine barometer are worth comparatively little; and *observations with the* ANEROID, "next to nothing." Therefore, when an Adie or Green's "Mountain Marine," of New York, equally good, is used, please note the fact at the beginning and end of the abstract log for every voyage.

The Meteorological Institute of Utrecht, in Holland, is under the general superintendence of Professor Buys Ballot, who has, by his labors, contributed largely to the science of meteorology. The marine department, however, is under the special charge of a naval officer. In this the admirable Jansen was succeeded by Lieutenant Von Gough, assisted by Lieutenant Andrau. These officers have all worked most zealously, industriously, and efficiently. We have the result of their labors in two neat 4to volumes of sailing directions in Dutch,* bound as wind and current observations. They are devoted chiefly to the route from the English channel to Java Head and the wayside ports. The Dutch marine is peculiarly rich with abstract logs on that voyage.

The contributions made by that office to our knowledge of the winds by the wayside to Java, have already served practically to lessen the distance between *Faderland* and theri East India possessions 10 days or two weeks.† The tables of crossings in their edition are enriched with most of the tables of that work.

A fleet of 250 sail, under the Dutch flag, are co-operating with us. The seamen of Holland are very accomplished—none more so. They are patient observers, and they return admirably kept abstract logs.

The Dutch have also extended their observations landward, and Dr. Kreche has just issued from the Institute of Utrecht the "Nederlandsch Meteorologisch Jaarboek," for 1856; a handsome volume, in which Mr. Buys Ballot claims to have discovered a numerical relation,

* Uitkomsten van Wetenschap en Ervaring Aangaande winden en Zeestroomingen in Sommige Gedeelten van den Oceaan, Uitgegeven Door Het Koninklijk Nederlandsch Meteorologisch Instituut. 2e Omgewerkte Druk. Boekdrukkerij: Kenimk en Zoon Te Utrecht, 1856.

Uitkomsten van Wetenschap en Ervaring Aangaande winden en Zeestroomingen in Sommige Gedeelten van den Oceaan, Uitgegeven Door Het Koninklijk Nederlandsch Meteorologisch Instituut. Utrecht, L. E. Bosch en Zoon, 1857.

† "The Dutch have been hard at work on their own and other materials, and find the Batavia voyages of their ships shortened 15 per cent."—(*Admiral Fitz Roy.*)

of great practical value, between the wind and the difference of barometric pressure at different stations at the same moment. Mr. Ballot's account of this discovery, as stated by himself, is given in the introduction to that work, as an illustration of the importance of extending to the land, according to the plan recommended by the Brussels Conference, this beautiful system of physical research.

There is great activity in that office; as these sheets are going to press I receive from Lieutenant Von Gough the sheets of another most valuable contribution to general navigation. It is in the shape of tables of crossings of no less than 550 tracks of Dutch ships: 1, from Java to the meridian of the Cape of Good Hope; 2, from the Cape to the Line; and 3, from the Line to the English Channel, arranged so as to show the year and the month, the difficult passes, and the time from meridian to meridian, and from parallel to parallel. These highly useful tables are further illustrated by charts and diagrams, that give, for each month, the winds and the weather along the entire route.

The following account of this noble Institute has been kindly furnished by Lieut. Van Gough:

"The Royal Meteorological Institute at Utrecht, in Holland, was established by the Dutch government in January, 1854; it consists of two departments, and has an observatory, provided with meteorological and magnetical instruments, which for the greatest part are self-registering.

"Each department has a special director, under the general superintendence of Professor Bois Ballot, who is the chief of the whole institute.

"The first department of the institute collects and discusses the observations of the land stations.

1°. The observations from the observatory of the Institute at Utrecht, are from the following places in Holland: Assen, Amsterdam, Breda, Groningen, Helder, Hellevoetsluis, Luxembourg, Maestricht, Nymegen, Vlissingen, and Leuwarden.

2°. The observations made in the colonies:

At Amboyna, in the Molucca Archipelago.
Wahaay, " "
Bansermasseng, on the Isle of Borneo.
Banjoewangie, on the Isle of Java.
Bustensorg, " "
Tjilatjap, " "
Padang, on the Isle of Sumatra.
Palembang, " "
Decima, in Japan.
Paramaribo, in the West Indies (Surinam.)
Curaçao. " "

"3°. The observations from the following foreign stations in Europe, &c., are also compiled, reduced, and discussed by the first department of the institute, namely:

"In Sweden and Norway from Stockholm and Christiania.

"In Russia from Dorpat.

"In Denmark from Kiel.

"In England from the Orkney's, Boston, Nottingham, Cheswick, the Shetlands, Aberdeen, and Exeter.

"In France form Paris, Nantes, Toulouse, Marseilles, Dijon, Brest.

"In Germany from Berlin, Dresden, Prague, Muhlhausen, Paderborn, Hamburg, Putbus, Frier, Mannheim, Hanau, Strela, Ittendorff, Munich, Kremsmunster, Cracow, Leipsic, Klagenfurth, Bamberg.

"In Poland from Warsaw.

"In Sevenbergen from Cronstadt.

"In Italy from Parma, Turin, Rome.

"In Spain from Madrid.

"In Portugal from Lisbon.

"In Algeria from Setif.

"In Greece from Athens, and finally

"In Australia from Melbourne.

"Besides those series of observations, the Meteorological Annals of the Institute contain extensive results about climatology, terrestrial magnetism, &c., derived from the above named observations.

"Every year these annals are published and presented to different private individuals and learned societies in the Netherlands and foreign States.

"Professor Buys Ballot and Dr. Krecke, the director of the first department, and also of the observatory, have not only, since 1854, the year of the establishment of the institute, been continually engaged in such a large field, but previously also, for many years, several annals and meteorological papers were published by them prior to 1854.

"To the nautical department of the Meteorological Institute belong the observations made on board of the Dutch men-of-war and trading vessels. It is its duty to see that these observations are made according to the uniform system adopted by the Maritime Conference held at Brussels in August and September, 1853. Also to discuss these observations, and to publish all that will be useful to navigators.

"The special charge of this department, under the superintendence of Professor Buys Ballot, was conferred to Lieutenant M. H. Jansen, of the royal Dutch navy, who had represented the Dutch government at the Brussels Maritime Conference in 1853, and who, being thoroughly acquainted with Maury's method, was authorized to lay down the data from the log-books in the form of Wind and Current Charts, and Sailing Directions for practical use.

"Visiting the United States in 1852, by his acquaintance with Lieutenant Maury, Lieutenant Jansen had originated and prepared the friendly and highly esteemed relations with the American government, as to the promise that the Dutch vessels would be put on a footing with American vessels, and receive the Wind and Current Charts and Sailing Directions; a promise which is accomplished in the most liberal manner.

"Permanent committees were erected in 1854, at Amsterdam, Rotterdam, Dordrecht, &c., for encouraging the co-operation of the ship owners and captains to collect materials, and to distribute Maury's Sailing Directions and Charts to every shipmaster who would engage to keep and return the abstract log.

"Standard instruments were furnished by the committees to verify the corrections of the barometers, thermometers, &c., on board of the different ships. Standard barometers were also placed, by order of the Minister of Marine, at different seaports for better control.

"By public meetings the masters of trading vessels were made acquainted with the method of filling up the man-of-war form of the abstract log.

"Of the royal navy, the co-operation was secured by order of the Minister of Marine of June, 1853. Those of the mercantile marine followed in a most encouraging manner.

"With the beginning of 1854 this department of the Meteorological Institute published explanatory notes about the observations of the barometer, thermometer, &c., and issued ample instructions for keeping the abstract log. Besides some scientifical and theoretical notices about the currents of the air and ocean, (by Professor Buys Ballot,) another volume contained several treatises, for practical use of the Dutch navigators, relating to the arrangement and construction of the Wind and Current Charts; to the trade-winds and calm regions on the ocean; to sailing directions to the equator, and for the passage around Cape Horn; to Panama and from Panama to California on the northwest, and for the route to Australia; all of which were derived from Maury's Sailing Directions, fifth edition; and lastly, a Dutch translation of the report of the Maritime Conference held at Brussels in 1853 was added.

"On the instigation of the institute, numerous log-books were lent that copies or abstracts might be made. Crossing tables for the route to Java and from Java to Europe; investigating charts or "wind leaves" for different parts of the ocean, and for the limits of the trade-winds and monsoons, were projected and filled up as the log-books were received.

"In June, 1854, Lieutenant K. F. R. Andrau, of the royal navy, was assigned to the institute as the assistant of Lieutenant Jansen; and at the end of the first year after the establishment of the institute the co-operation of the Dutch navigators had been so far secured that there were no less than 102 Dutch trading vessels on their voyage to Java, Australia, &c., all provided with Maury's Charts and Sailing Directions, with compared instruments, and observing for the abstract log.

"Much good work was done: the data from many log-books were registered, and the office being duly organized was fairly launched and got under way; and in January, 1855, Lieutenant Jansen was relieved by Lieutenant Van Gogh; and in May, 1857, Lieutenant Andrau by Lieutenant Bowier.

"The year 1854 is memorable in the nautical department of this institute, on account of the important labors of Lieutenant Jansen, as set forth in the aforesaid publications, and the excellent arrangements of many other data to which only a finishing stroke was to be given for publication. The long stay at this institute of Lieutenant Andrau furnished many proofs of his zeal and assiduity.

"Besides his very active participation in all that has been subsequently published by this department, several subjects were exclusively worked out by him. Among others the method of translating the Pilot Charts in figurative form, (wind leaves,) which was his invention, and performed in a most practical manner. Also the description of the Agulhas current, with the different charts and tables, derived by him from the observations on the temperature of the sea, and considered in connexion with the influence on the atmosphere. Those and his further discussions on the sea, the barometer, and the winds and weather in the South Indian Ocean, form a large part of the results published in 1857. Maury's Trade-wind Chart and Pilot Chart of the North Atlantic were enlarged with the data from the Dutch log-books, and applied by his hands as a new edition, while the first results of the observations about the herrings were gathered by him from the fishermen's log-books. In May, 1857, he was relieved by Lieutenant Bowier. This officer has taken up and performed his duties in such a manner that the figurative Monthly Wind Charts of the South Atlantic, and also the Storm and Rain Charts for the neighborhood of the Cape of Good Hope, are now published.

"The first clerk, Mr. Eysbrock, formerly officer of the merchant navy, who received his commission at the nautical department of the Meteorological Institute in 1854, and also Mr.

Ogterox, a captain of the mercantile marine, who volunteered to this office towards the close of 1856, both deserve honorable mention for their accurate and unremitting attention.

"Besides many officers of the royal navy, 240 captains of the mercantile marine are now co-operating in this system of research; they have returned 270 abstract logs to this institute.

"A supply of instruments, charts, books, and a standard barometer has been sent out to Java, with the view of extending the observations in the Indian Archipelago, where the establishment of several meteorological land stations is also projected.

"Many data about wind and weather are already registered, several excellent abstract logs received, and the Institute will publish very soon some notes about navigating in the eastern part of the Indian and China sea.

"All that regards the winds, the currents, the temperature, and the ice of the South Atlantic and South Indian Ocean are gathered from the latest received abstract logs, and will extend the results already obtained.

"Barometric and psychrometric observations are registered in proper books. The simultaneous observations of different vessels, concerning gales, &c., collected, and the observations about some gales of the North Atlantic, will be worked out for different remarkable days, in connexion with the results derived from the land stations in Europe.

"Discussions about the route from Java to Europe are in progress, and the route in the North Atlantic computed, pursuant to Maury's method.

"Monthly sailing directions from Europe to Java were published in July, 1855, and more minutely in October, 1856.

"Fifty ships, using in many respects these Sailing Directions, performed the voyage from Lizard to Java Head in 90.6 *days* on the average. In the *meanwhile* 69 others, also provided with the Wind and Current Charts and Sailing Directions, but relying more upon the old common track, had an average of 99.7 *days*—a difference of 9.1 *days* in favor of the recommended route.

"But this gain is really 10.4 days, as will appear by comparing the mean voyage of these 50 vessels, crossing the equator 3°.7 more to the west, (in 26°.2 longitude;) the meridian of Greenwich 4°.1 more to the south, (in 41°.3 latitude south;) and running to 80° east on a track lying 3° more to the south, with the mean of 421 vessels from the crossing tables, whose average is 101 days.

"Besides the connexion with the Observatory at Washington, whence has flowed so many benefits for the weal of navigators, the institute experienced encouraging interest from the Meteorological Department of the Board of Trade, in England, and may draw much profit, for Dutch navigators, from the important results published by that department, with which the institute has been presented. Exchanges of the books and charts, published by this institute, take place, on a large scale, to the United States and England, and also to other meteorological departments.

"Up to this date, the nautical department has published, in its works, the following papers:

"Suggestive notes about the herrings and the fisheries, in connexion with the temperature of the sea and the weather in the North Sea, deduced from the fisherman's log books of 1856.

"Scientific and theoretical viewings about the general currents of air and ocean.

"Treatise upon Maury's Wind and Current Charts, and their result in connexion with the regions of the trade-wind and calm belts of the Atlantic ocean.

"The Agulhas current deduced from the observations of the temperature of the sea, and its influence on the atmosphere.

"The barometer, wind, weather, and sea, on the South Indian Ocean.

"The ice of the South Atlantic and South Indian Ocean.

"Crossings of Dutch vessels from Europe (Lizard) to Java Head, in four parts, with monthly sailing directions: 1. From Lizard to the equator; 2. From the equator to 0° longitude in the South Atlantic; 3. From 0° to 80° longitude east; from 80° longitude east to Java Head.

"Abstracts of logs on the southern route to India and Australia.

"Crossings of Dutch vessels from Java and Bengal to Europe, in four parts:

"1. From Java Head, Bali or Akyal, to the Cape of Good Hope; 2. From 45° longitude east, round the cape, to 30° latitude south; 3. From the Cape of Good Hope to the equator; 4. From the equator to Lizard.

"Sailing directions from the equator to and round Cape Horn, derived from Maury's Sailing Directions, 5th edition.

"Sailing directions from latitude 50°.5 in the Pacific Ocean to the equator, on the route to California, from idem.

"Route from Panama to California on the northwest, from idem.

"Routes to and from Australia, from idem.

"Crossings of Dutch vessels to Australia and discussion about this route.

"Sailing directions to Australia, and from Australia to Callao, and round Cape Horn, derived from the 7th edition of Maury's Sailing Directions.

"Instructions for the use of the meteorological instruments, and ample directions for keeping the abstract log.

"Reduction tables for the temperature corrections of the barometer.

"Reduction tables for the psychrometer observations.

"Maury's Pilot Chart of the North Atlantic, (eastern part,) enlarged by the observations from the Dutch log-books.

"Maury's Trade-wind Chart of the Atlantic Ocean, enlarged by the observations from the Dutch log-books.

"Figurative monthly wind charts of the *North* and *South* Atlantic, compiled from Maury's Pilot Charts, and from the data of the Dutch log-books.

"Figurative monthly wind charts of the Indian Ocean, (eastern part,) compiled from the data of the Dutch log-books.

"Thermal table, for the whole year, and temperature charts for the months of February, March, and July, of the South Indian and Atlantic Oceans.

"Storm and rain table, for the whole year, and idem monthly charts for the neighbourhood of the Cape of Good Hope."

General Sabine, of the Royal Engineers, as well as the Kew Committee, has been very kind with his powerful aid in behalf of our labors, by assisting me in procuring proper instruments, and in lending a friendly hand in many kind ways. I am indebted also to Mr. Glaisher, of the Greenwich Observatory, to Mr. Welsh, of Kew, and to many other gentlemen in England, for kind services and friendly aid.

The makers who have furnished the best and cheapest thermometers which have fallen under my observation, are Mr. James Green, 422 Broadway, New York, and Messrs. Negretti & Zambra, 11 Hatton Garden, London; Green furnishes also the hydrometers for the navy.

None of the thermometers of either of these makes that have fallen under my observation have errors exceeding a fraction of one degree.

Since, and in consequence of the Brussels Conference, a great improvement has taken place in nautical instruments, especially the meteorological instruments of navigation. Before, there were practically no such things known among navigators as standard thermometers, standard barometers, &c. Now, the errors of almost every instrument at sea are known at this or the other co-operating offices. The Dutch have appointed regular commissioners, consisting of ship-owners and ship-masters, at Amsterdam, Rotterdam, Dordrecht, and Groningen, to see that the ships which receive the Charts have the required instruments on board, and to compare them with the standards.

At Neu-deep, Helvoetsluys, and Flessingen there are standard barometers. At noon, with the time-signal, the reading of the reduced standard barometer is put at the harbor master's office, for comparison.

Every month in winter they had public meetings to promote the researches upon the ocean, and twice a week all the ship-masters were invited to the Zeeman's Hoop, by the indefatigable Jansen, to receive explanations and instruction with regard to the Wind and Current Charts, or abstract log.

In England a Wind and Current Bureau has been established in the Marine Department of the Board of Trade. Admiral FitzRoy has the special charge of it—a sure guarantee that good work is to be done there; for he is already well and favorably known in the nautical world both as a navigator and hydrographer, and is distinguished for the good services he has rendered to the cause of navigation by his admirable charts of South America and other portions of the world.

It is to be very much regretted, however, that the working force of his office is so small. Materials are abundant; the officer in charge, in discussing them, can bring to his aid the lights of professional knowledge and experience of that order, to which the mariner of every nation is wont to pay homage. It is to be hoped, therefore, that a force sufficient to render all those materials available to navigation, forthwith, will ere long be placed at Admiral FitzRoy's disposal. With such a force to assist him, it is not too much to promise that the dangers and the time between Great Britain and India, Great Britain and Australia, India and Australia, Australia and China would be considerably lessened, and that right soon.

This elimination of time and danger from such voyages as these would in a little while remunerate the mother country manifold the expense involved in the mere increase of office force.

That office, however, though so short handed, has, like the one at Utrecht, done good service. It has recast the pilot charts, presenting them to the navigator rather in signs and symbols than in figures, as by this office they are printed. The "first number of meteorological papers published by authority of the Board of Trade" was issued in 1857, from Admiral FitzRoy's office. It is a quarto of 182 pages and 15 large plates. It is a valuable contribution to our researches; I am indebted to it largely, as these pages show.

The Sailing Directions, with the Wind and Current Charts, are sent to the Meteorological Department of the Board of Trade for distribution among British shipping; and to the Meteorological Institute, in Holland, for distribution among Dutch ship-masters.

I have the high satisfaction of announcing to our fellow laborers that France has also joined forces with us—ordered a translation of this work into the French by Leiut. Vaneéchout, who has gone to work with such diligence as to have one volume already (December, 1857) through the press; and that an office, under Captain Le Gras, for the purpose of carrying on this co-operation, has been established in Paris, similar to that in London under Admiral Fitz Roy.

The following letter from the French Minister, in Washington, contains this important announcement:

[Translation.]

LEGATION OF FRANCE IN THE UNITED STATES,
Washington, July 4, 1857.

SIR: Agreeably to the wish expressed to me by the Federal government, I called the attention of the Emperor's government, in the month of April, 1853, to the propositions of Lieutenant Maury, Superintendent of the National Observatory at Washington, made with a view to the adoption, by the great maritime powers, of a uniform system of meteorological observations, propositions which led to the Conference held at Brussels on the 23d of August following, and in which the imperial navy was represented by M. de la Marche, hydrographical engineer.

The more pressing engagements of the period would not allow the conclusions of that conference to be carried immediately into effect on the part of the Emperor's government; but, as soon as it was possible, the Minister of Marine and of Colonies hastened to adopt suitable measures for insuring the co-operation of the imperial navy in an enterprise of such high and universal interest.

At the present time, in pursuance of the orders of Admiral Hamelin, the meteorological journals which are to serve for recording day by day the observations made on board of our vessels are being printed. The merchant vessels will be invited by notices every two months to lend their assistance in the international work in question.

Moreover, M. Le Gras, a captain of frigate, has been directed to collect at the depository of maps and charts the respective observations which France may participate in making. This superior officer must also open a correspondence with Lieutenant Maury. He will receive the meteorological journals from our vessels-of-war and from our merchant vessels, and will send them to the National Observatory at Washington.

I am happy, sir, in having to convey to the knowledge of the Federal government the entire adhesion of the Emperor's government to the propositions which formed the object of the Conference at Brussels, and which were the cause of the mission, altogether special, that has been confided to the captain of frigate, M. Le Gras.

Be pleased to accept, sir, the assurances of my high consideration,

SARTIGES.

Hon. General CASS,
Secretary of State, &c., &c., &c.

Russia and Sweden, Norway, Denmark, and the Holy See, have each also provided for giving the abstract logs kept on board their vessels, both commercial and naval, a discussion; and they, too, no doubt, will from time to time let the commercial world have the benefit of whatever useful results may be developed.

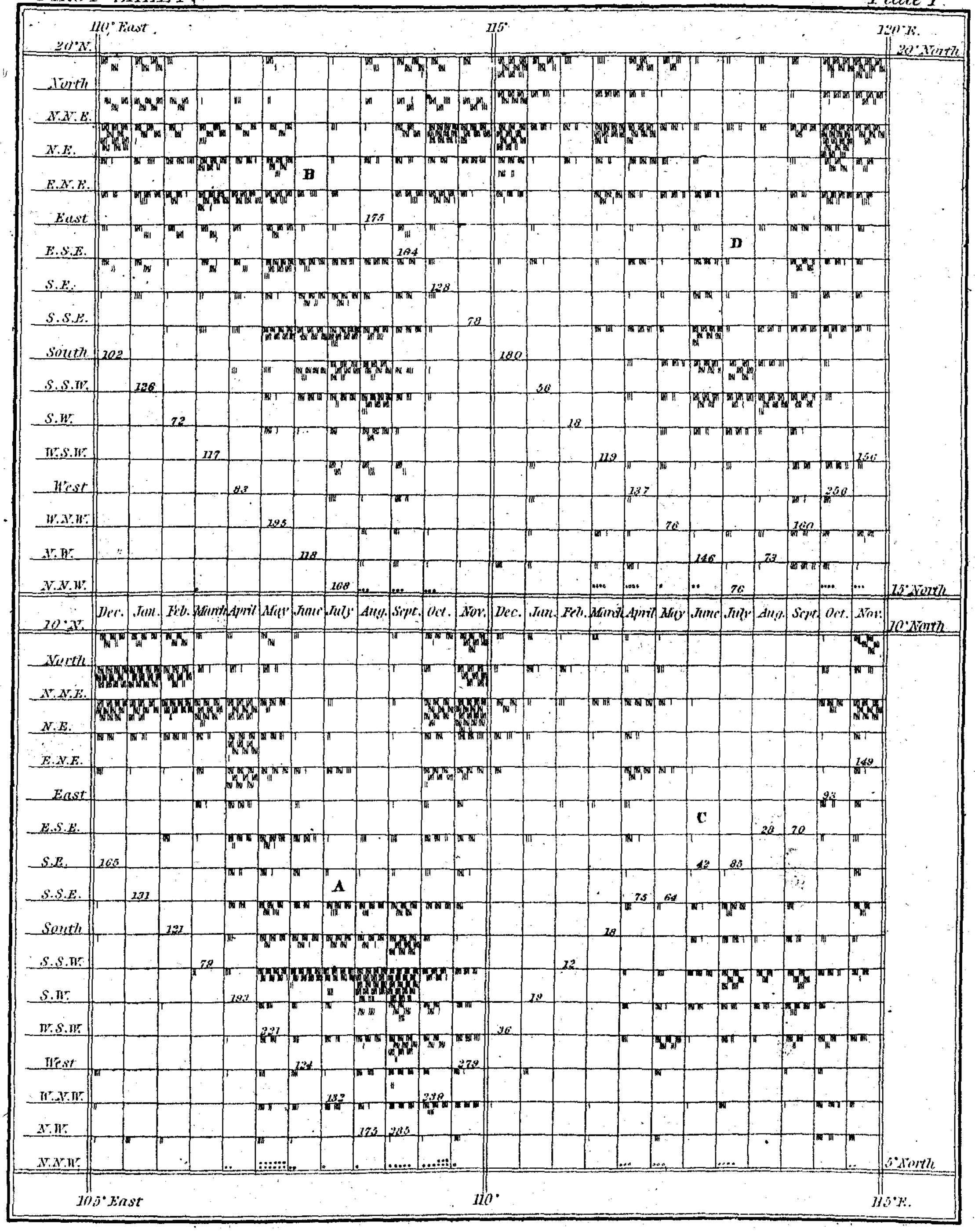
Dr. G. J. A. D. Pegado is at the head of the Wind and Current Bureau in Portugal. He has displayed both energy and zeal in organizing it, and preparing standard instruments for the ships that sail under that flag.

Prussia, Spain, and Sardinia also, are at work in the same way. The Free City of Hamburg, and the Republic of Bremen have each taken steps to have the abstract logs furnished by their vessels properly disposed of, and the results contributed to the common fund of nautical information which has already been developed by these researches. Austria and Brazil receive the charts and use them ; but so far, I am not informed as to the disposition which is made of the abstract logs returned under their flags. I have no doubt but that they will be turned to good account. The progress, therefore, that has been made with this joint work is exceedingly satisfactory, and the future is full of promise ; and I hope those who have been sending their observations to me will derive encouragement from the statement.*

* For further account of the flags that are co operating with us, see Introduction.

END OF VOL. I.

PILOT SHEET. Plate 1.



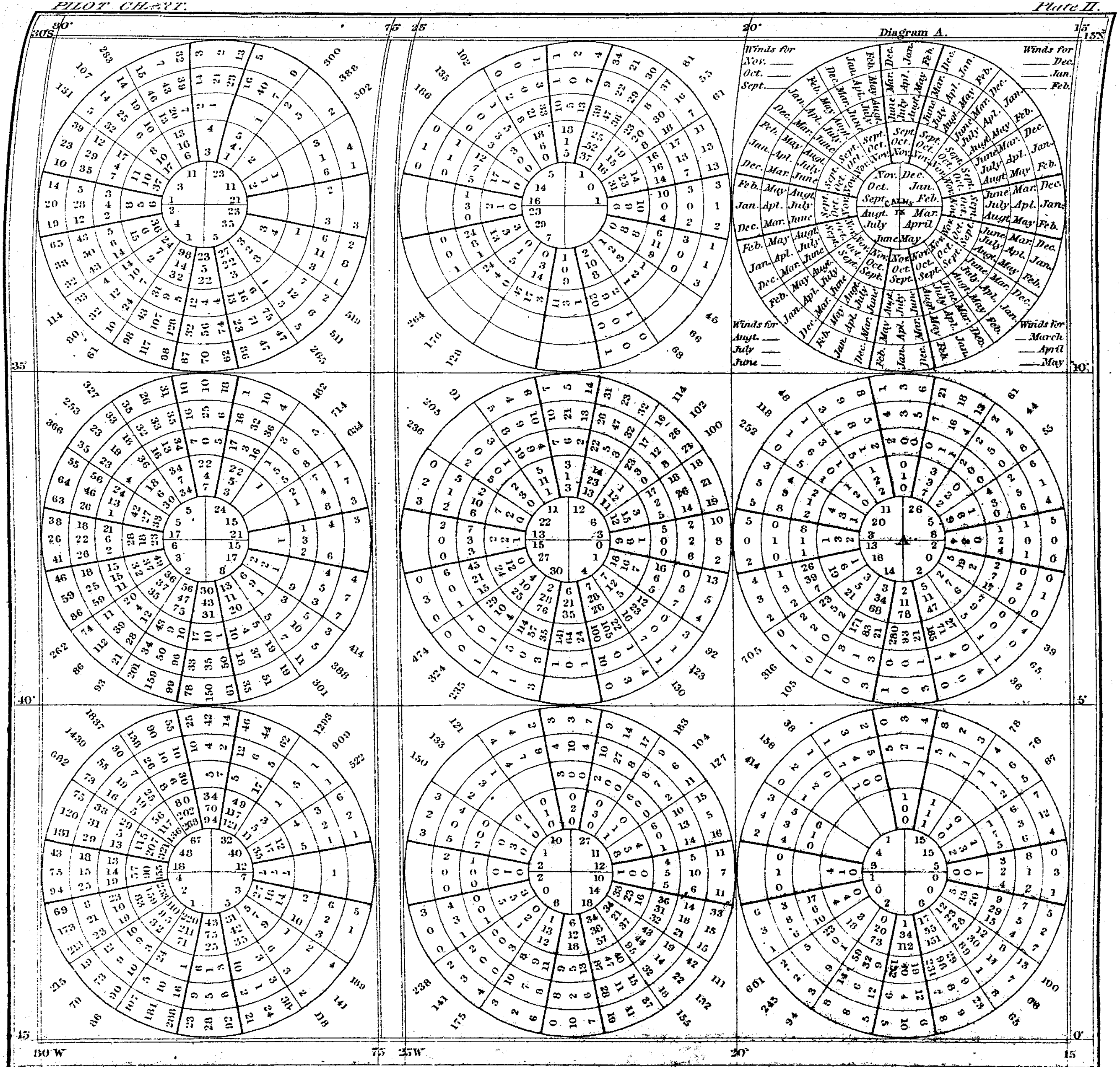
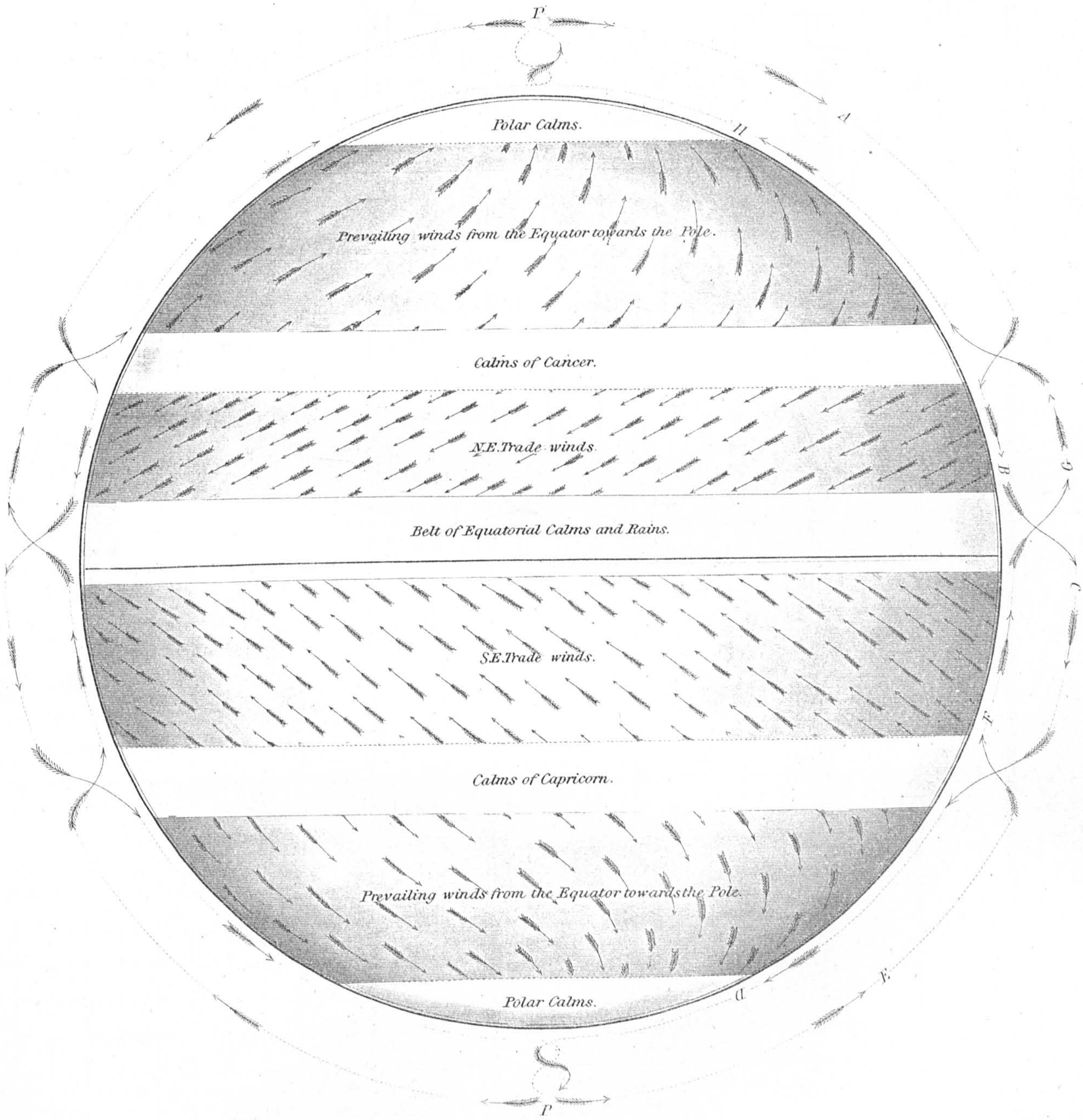
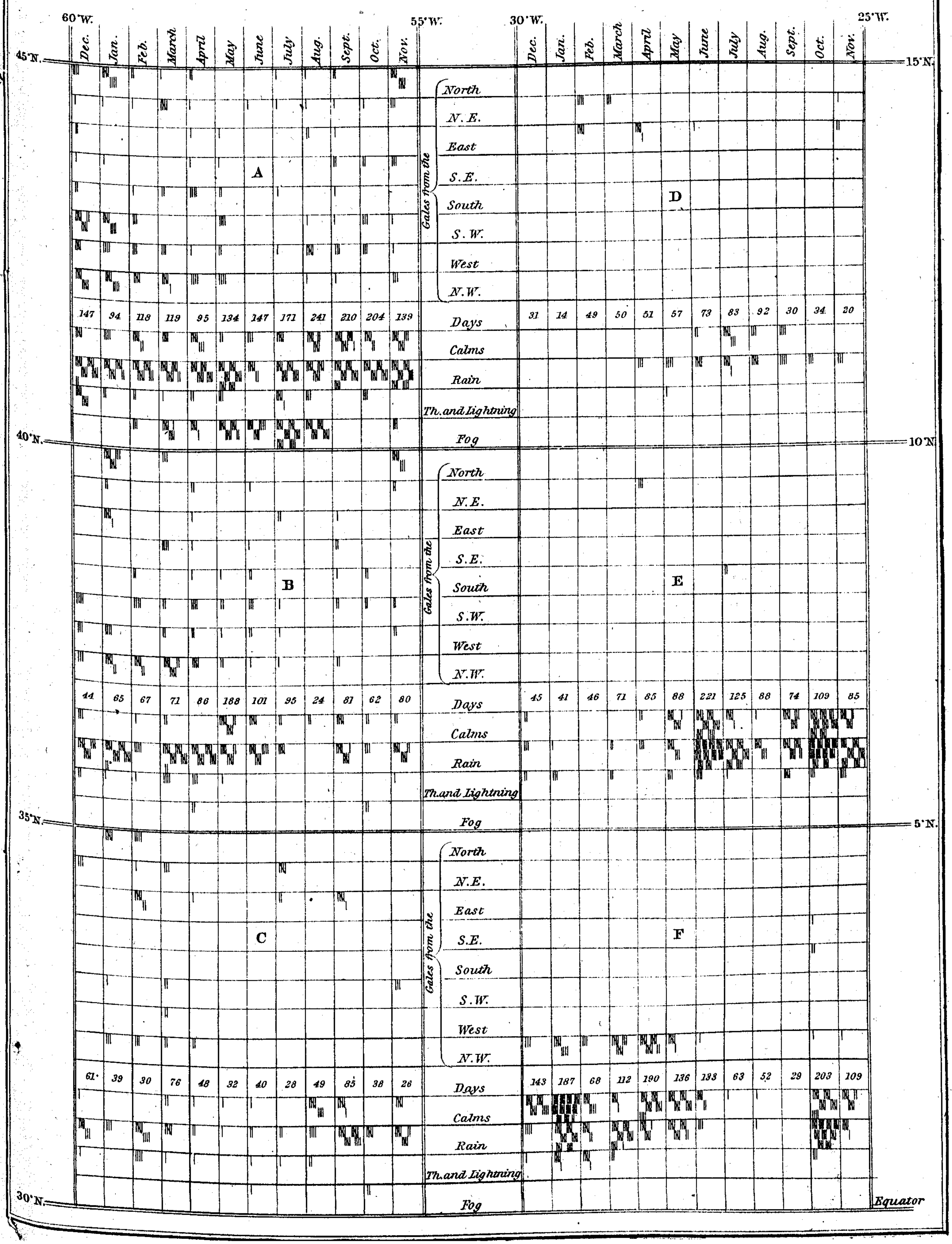
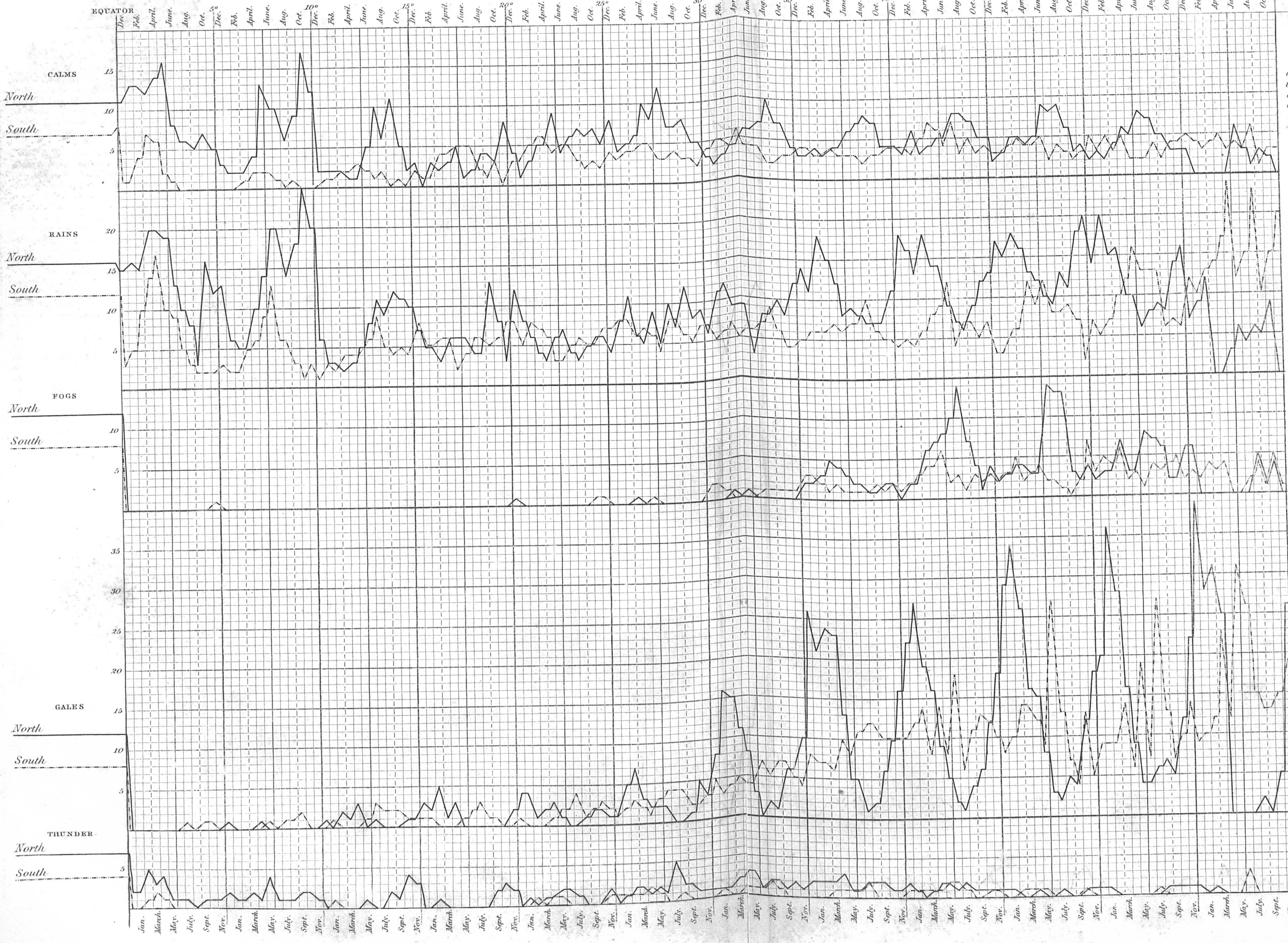


Diagram A.
Winds for Nov. Oct. Sept.
Winds for Dec. Jan. Feb.
Winds for Augt. July June
Winds for March April May
CALMS
30°S
35
40°
45
80° W
75
25 W
20°
15°
15 N
10°
5°
0°


P
A
H
Polar Calms.
Prevailing winds from the Equator towards the Pole.
Calms of Cancer.
N.E. Trade winds.
B
G
Belt of Equatorial Calms and Rains.
C
S.E. Trade winds.
F
Calms of Capricorn.
Prevailing winds from the Equator towards the Pole.
Polar Calms.
D
E
P


60° W.
55° W.
30° W.
25° W.
45° N.
40° N.
35° N.
30° N.
15° N.
10° N.
5° N.
Equator
Dec. Jan. Feb. March April May June July Aug. Sept. Oct. Nov.
Gales from the
North
N.E.
East
S.E.
South
S.W.
West
N.W.
Days
Calms
Rain
Th. and Lightning
Fog
A
B
C
D
E
F
147 94 118 119 95 134 147 171 241 210 204 139
31 14 49 50 51 57 73 83 92 30 34 20
44 65 67 71 86 188 101 95 24 81 62 80
45 41 46 71 85 88 221 125 88 74 109 85
61 39 30 76 48 32 40 28 49 85 38 26
143 187 68 112 190 136 133 63 52 29 203 109

STORMS AND RAINS IN NORTH AND SOUTH ATLANTIC.
(West Indies not included.)



EXPLANATION.

The data for this Plate are furnished by Maury's Storm and Rain Charts, including observations for 107,277 days in the North Atlantic, and 158,025 in the South; collated by lieutenant J.J. Guthrie, at the Washington Observatory, in 1855.

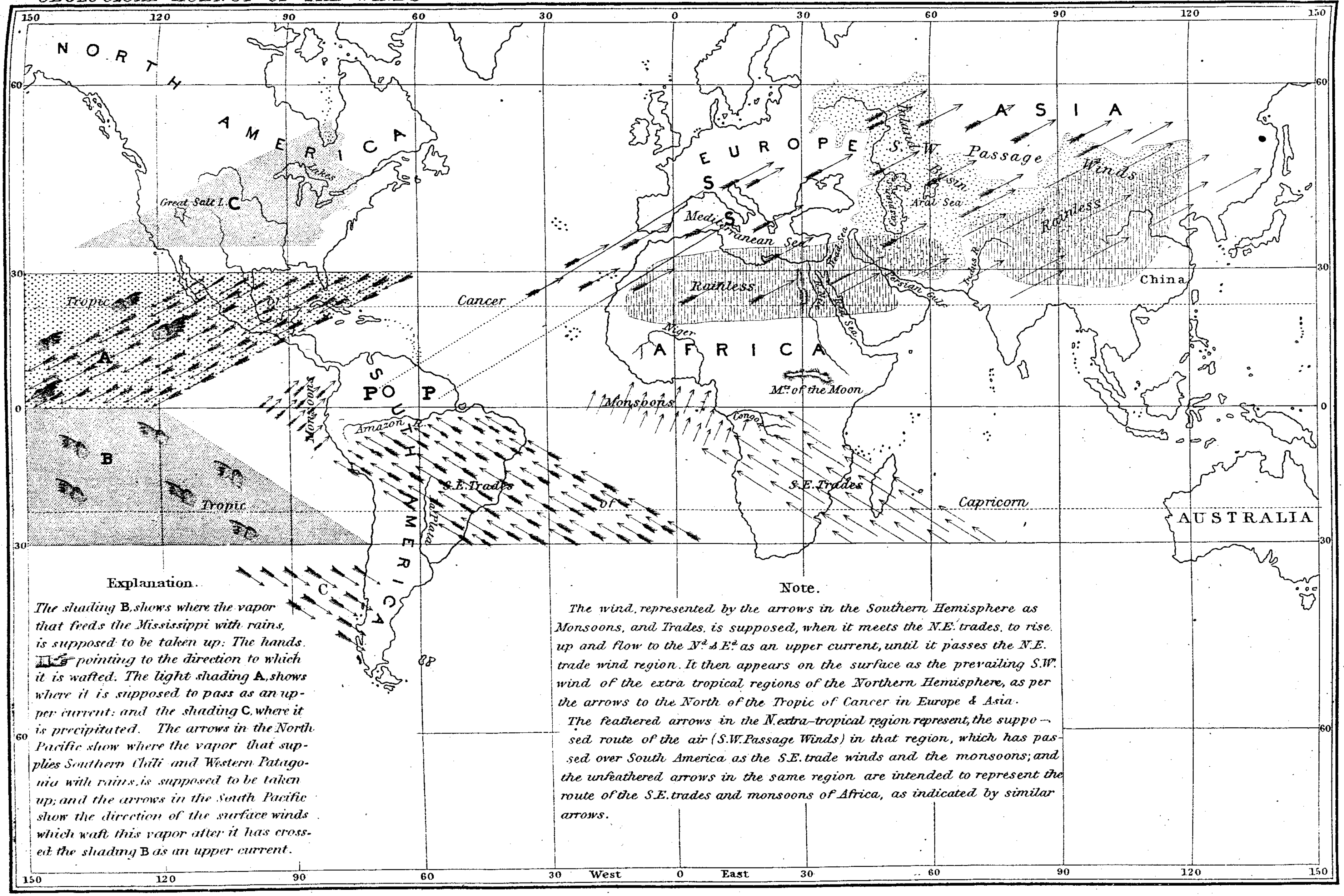
The heavy vertical lines, 5°, 10°, 15°, etc. represent parallels of latitude; the other vertical lines, months; and the horizontal lines, per cents, or the number of days in a hundred.

The continuous curve line stands for phenomena in the North, and the broken curve line for phenomena in the South Atlantic. Thus, the Gales curve shows that in a hundred days, in the month of January, of different years, there have been observed, in the Northern hemisphere, 36 gales (36 pr. ct.) between the parallels of 50° and 55°, whereas during the same time and between the same parallels, in the Southern hemisphere, only 10 gales (10 pr. ct.) have been reported.

The fact is here developed that the atmosphere is in a more unstable condition, in the North than in the South Atlantic; that we have more calms, more rains, more fogs, more gales, and more thunder, in the Northern than in the Southern hemisphere, particularly between the Equator and the 55th parallel. Beyond that the influence of Cape Horn becomes manifest.

M. F. Maury.

Observatory, Washington, 1856.



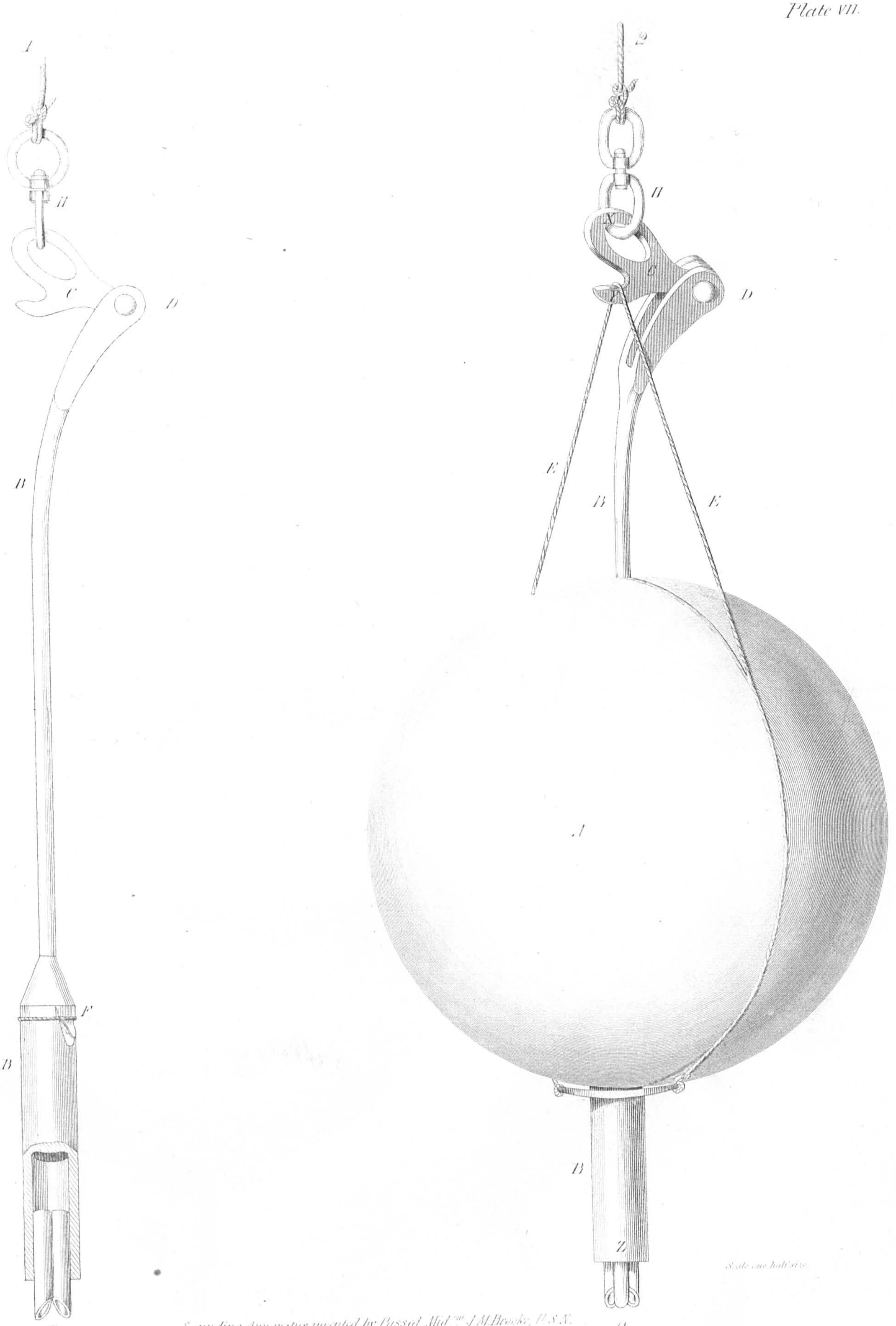
Explanation.

The shading B, shows where the vapor that feeds the Mississippi with rains, is supposed to be taken up: The hands pointing to the direction to which it is wafted. The light shading A, shows where it is supposed to pass as an upper current: and the shading C, where it is precipitated. The arrows in the North Pacific show where the vapor that supplies Southern Chili and Western Patagonia with rains, is supposed to be taken up; and the arrows in the South Pacific show the direction of the surface winds which waft this vapor after it has crossed the shading B as an upper current.

Note.

The wind, represented by the arrows in the Southern Hemisphere as Monsoons, and Trades, is supposed, when it meets the N.E. trades, to rise up and flow to the Nd. & Ed. as an upper current, until it passes the N.E. trade wind region. It then appears on the surface as the prevailing S.W. wind of the extra tropical regions of the Northern Hemisphere, as per the arrows to the North of the Tropic of Cancer in Europe & Asia.

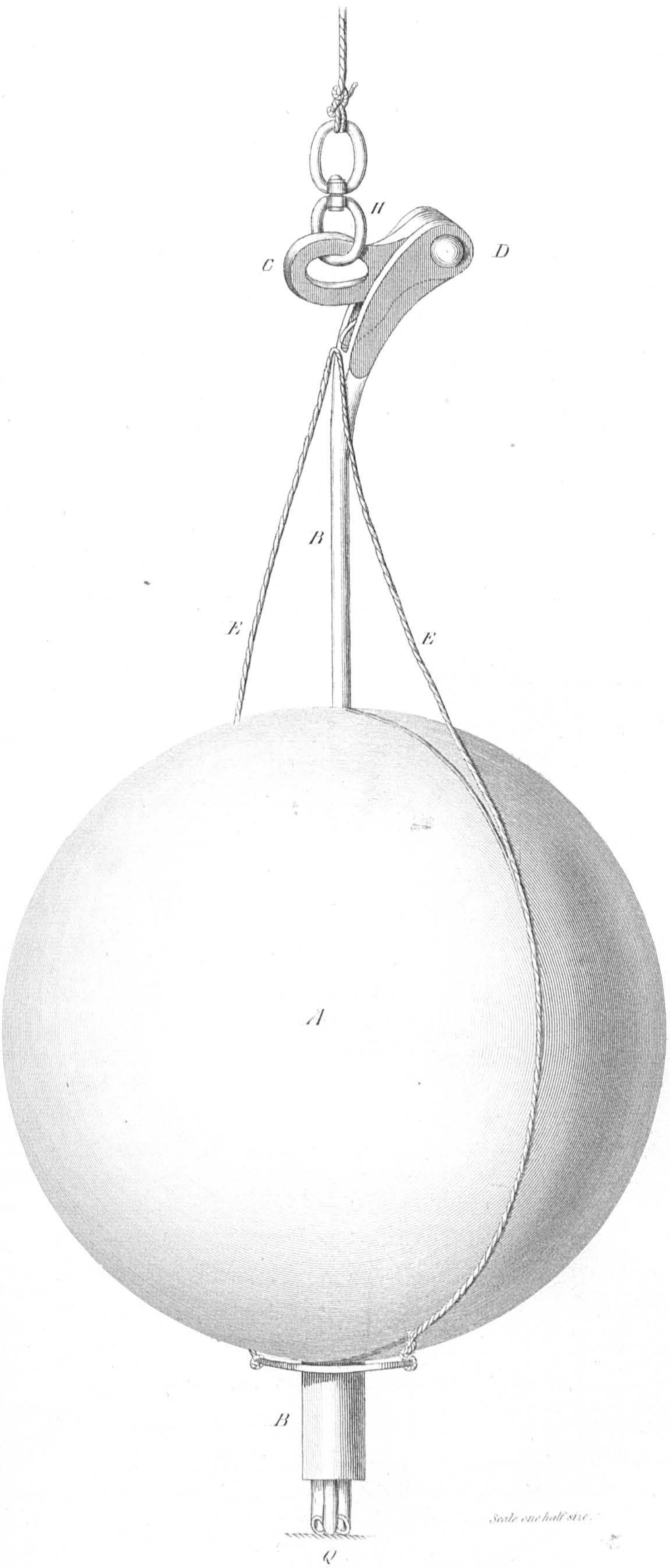
The feathered arrows in the N. extra-tropical region represent, the supposed route of the air (S.W. Passage Winds) in that region, which has passed over South America as the S.E. trade winds and the monsoons; and the unfeathered arrows in the same region are intended to represent the route of the S.E. trades and monsoons of Africa, as indicated by similar arrows.



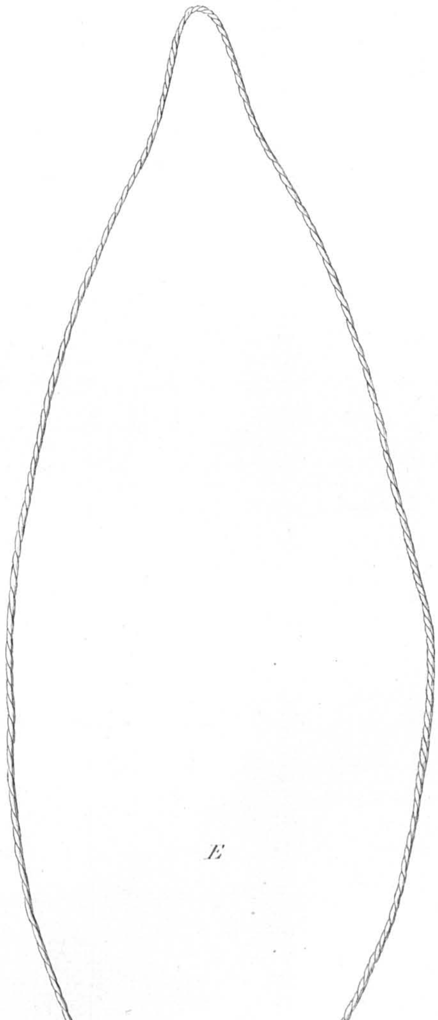
Scale one half size.

Sounding Apparatus invented by Passed Mid.^m J.M. Brooke, U.S.N.

3



4



Scale one half size.

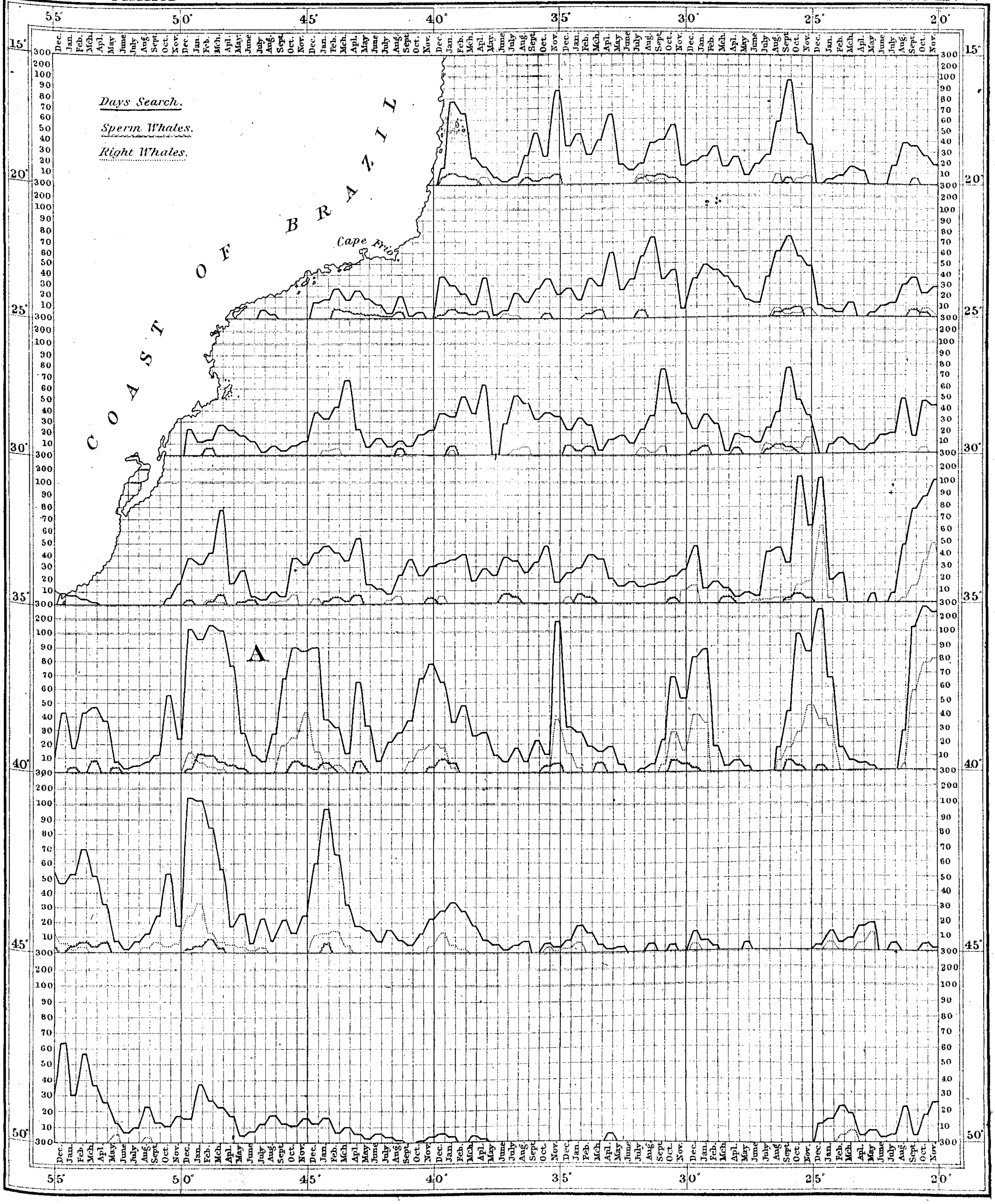
Sounding Apparatus, invented by Passed Mid.^{m} J.M. Brooke, U.S.N.

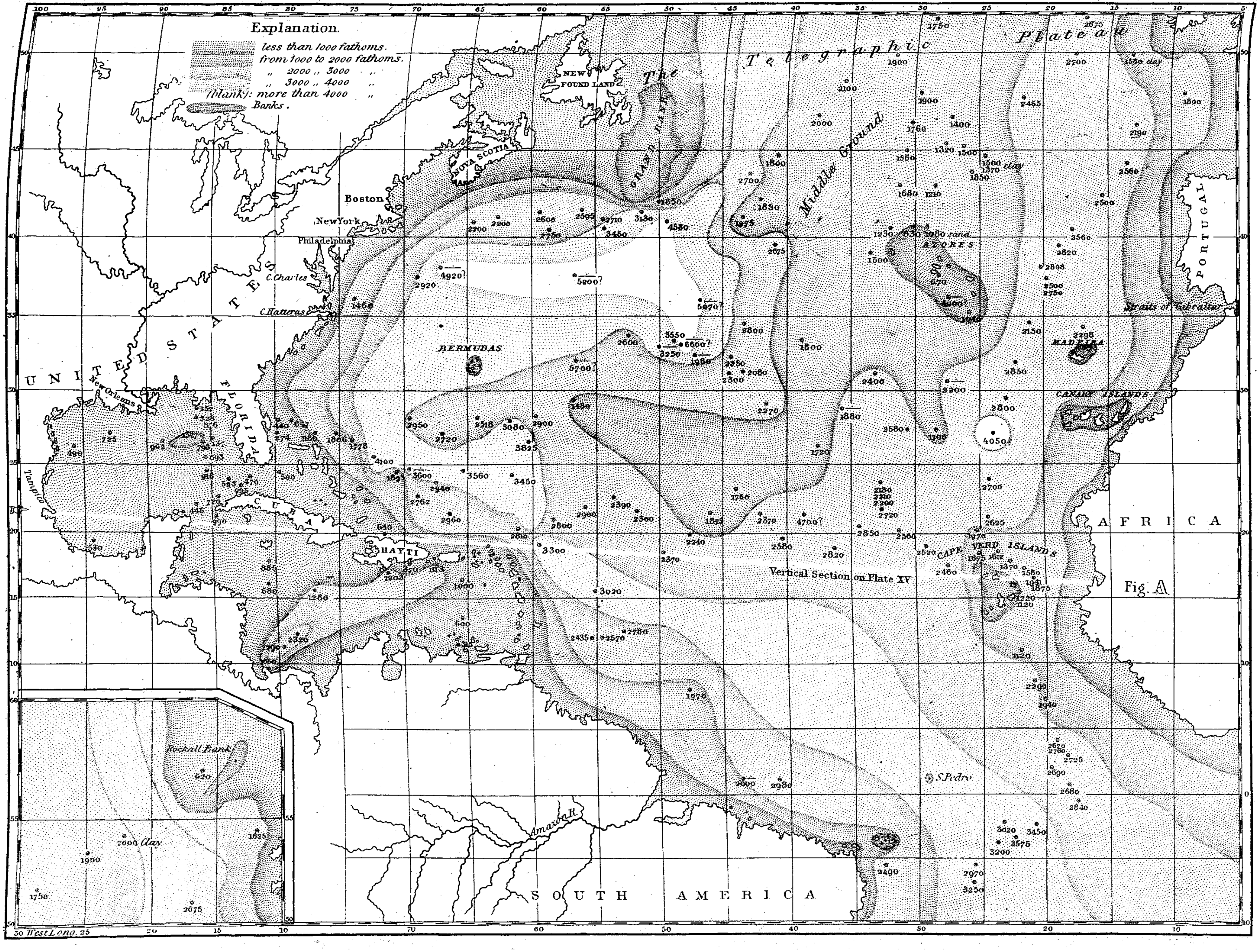
130° W. – 125° W.

Lat. North			Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
60°	Nº days of search	D												
	Nº days on which found whales	S												
		R												
55°	Nº days of search	D									2			
	Nº days on which found whales	S												
		R												
50°	Nº days of search	D							7		13			
	Nº days on which found whales	S							III					
		R												
45°	Nº days of search	D							10	5	17	2		
	Nº days on which found whales	S							IIII	IIII				
		R												
40°	Nº days of search	D							4	7	11	8	4	
	Nº days on which found whales	S								III				
		R												
35°	Nº days of search	D										9	9	9
	Nº days on which found whales	S												
		R												
30°	Nº days of search	D	28	7								4	5	3
	Nº days on which found whales	S										I		
		R												
25°	Nº days of search	D	3		2	5		2	1	3				4
	Nº days on which found whales	S												
		R												
20°	Nº days of search	D	4	5	6	2	5							2
	Nº days on which found whales	S												
		R												
15°	Nº days of search	D	3	3		4	6	2						
	Nº days on which found whales	S	I	I										
		R												
10°	Nº days of search	D	2	7	6	8	4		5	3	6			
	Nº days on which found whales	S	II	I			I				I			
		R												
5°	Nº days of search	D	5	25	25	23	45	37	4		4	6	7	2
	Nº days on which found whales	S		I 卌	II 卌	I	卌	卌						I
0° Equator		R												

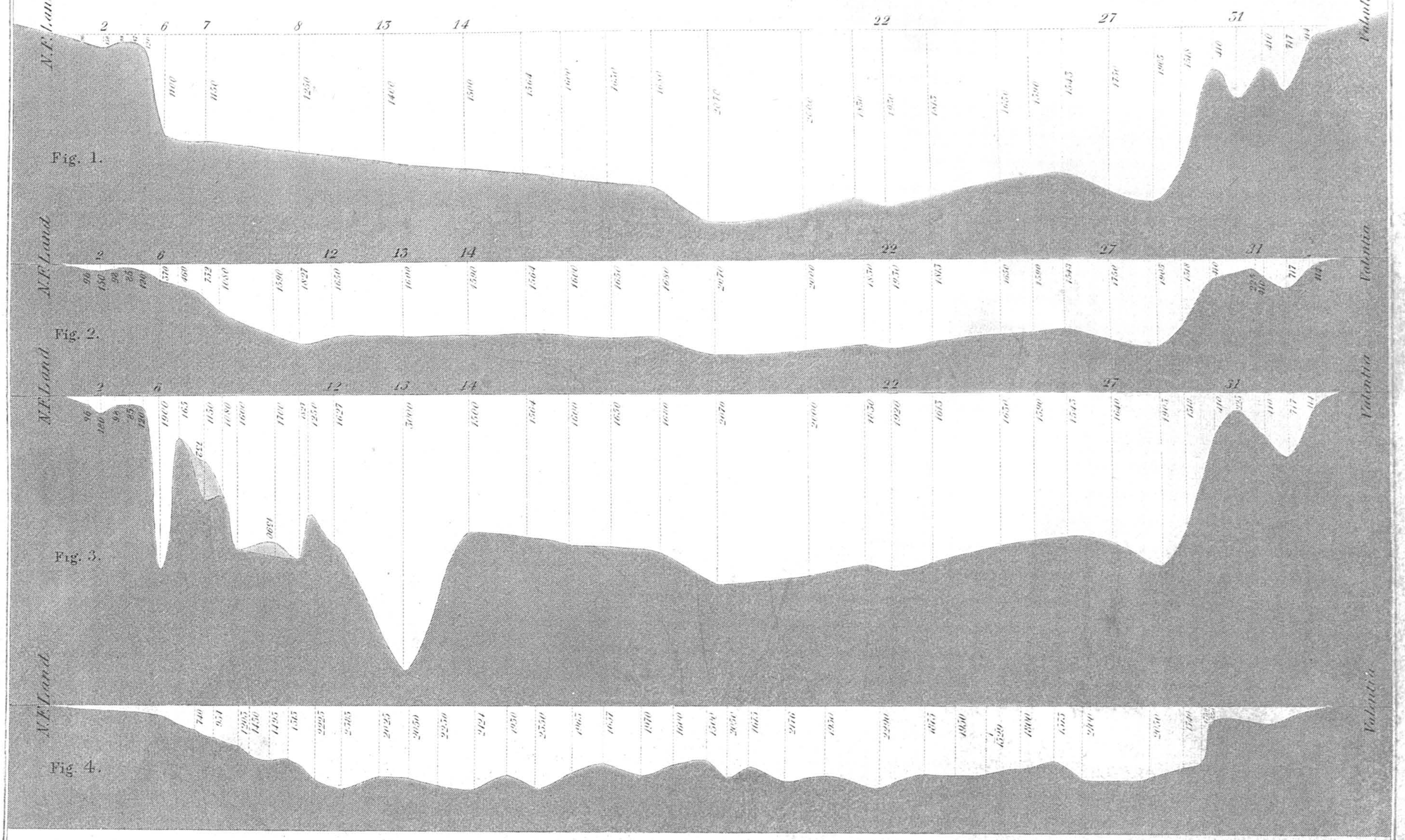
130° – 125° W.

		Dec.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Lat. South
	D	10	89	110	85	44	74	73	82	29	10	13	8	Equator 0°
	S		II 卌	卌 卌I	卌	II 卌	卌 卌 II 卌	III 卌	I 卌	II		I	III	
	R													S. Lat. 5°
	D	3		6	4	4		2			5			
	S													
	R													10°
	D	15			8			2	3	1				
	S				I									
	R													15°
	D	12		2	4		4	3	3	2				
	S													
	R													20°
	D	11	9		8		16		3					
	S													
	R													25°
	D	4	20	14		6	15	4		5				
	S													
	R													30°
	D		16	7			4					2	2	
	S													
	R													35°
	D				3	3		2						
	S													
	R													40°
	D	2	2	9	4			4				3		
	S													
	R													45°
	D	7	9	12	1	1	2	3	2	2				
	S													
	R													50°
	D			4	5							2		
	S													
	R													55°
	D													
	S													
	R													60°


Days Search.
Sperm Whales.
Right Whales.
COAST OF BRAZIL
Cape Frio
A
55° 50° 45° 40° 35° 30° 25° 20°
15° 20° 25° 30° 35° 40° 45° 50°
Dec. Jan. Feb. Mch. Apl. May June July Aug. Sept. Oct. Nov.


Explanation.
less than 1000 fathoms.
from 1000 to 2000 fathoms.
" 2000 " 3000 "
" 3000 " 4000 "
(blank): more than 4000 "
Banks.
The Telegraphic Plateau
Middle Ground
GRAND BANK
NEW FOUND LAND
NOVA SCOTIA
Boston
New York
Philadelphia
C. Charles
C. Hatteras
UNITED STATES
FLORIDA
New Orleans
Tampico
CUBA
HAYTI
BERMUDAS
AZORES
PORTUGAL
Straits of Gibraltar
MADEIRA
CANARY ISLANDS
CAPE VERD ISLANDS
AFRICA
S. Pedro
Amazon R.
SOUTH AMERICA
Vertical Section on Plate XV
Fig. A
Rockall Bank
50 West Long. 25

Figs. 1. 2. 3 are from the same data: therefore they cannot all be right; and Fig. 4 shews them to be all wrong.



PROFILE OF TELEGRAPHIC PLATEAU

Fig. 1 Arctic's soundings by Chart No. 1 Scale 1/4 of Original
" 2 do do do No. 2 do do
" 3 do do by her Abstract Log
" 4 Cyclops' do from Admiralty Chart.

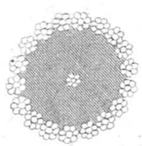


Fig. 5

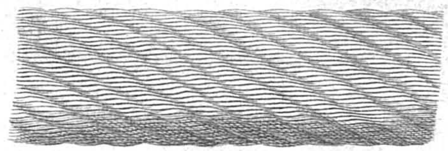
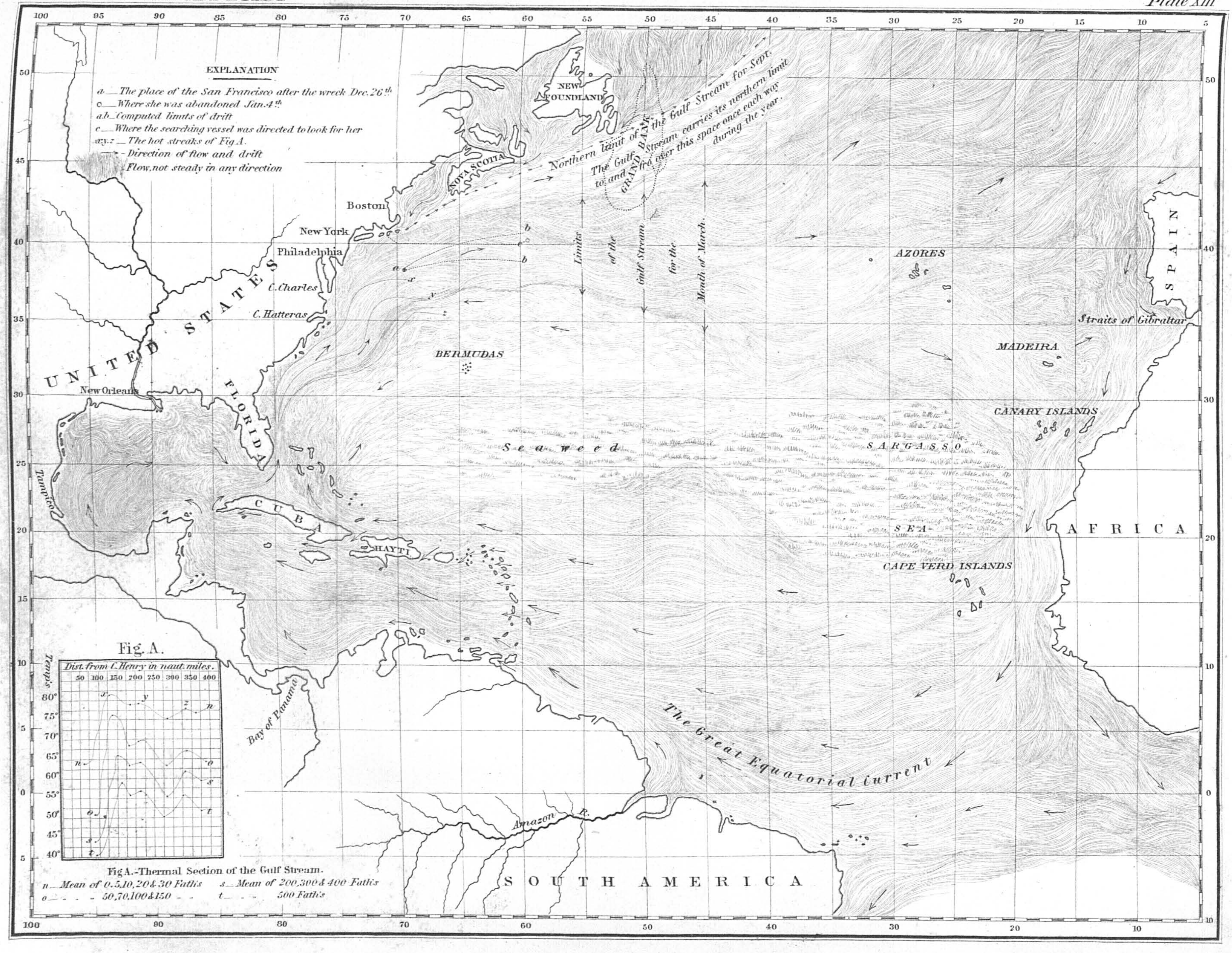
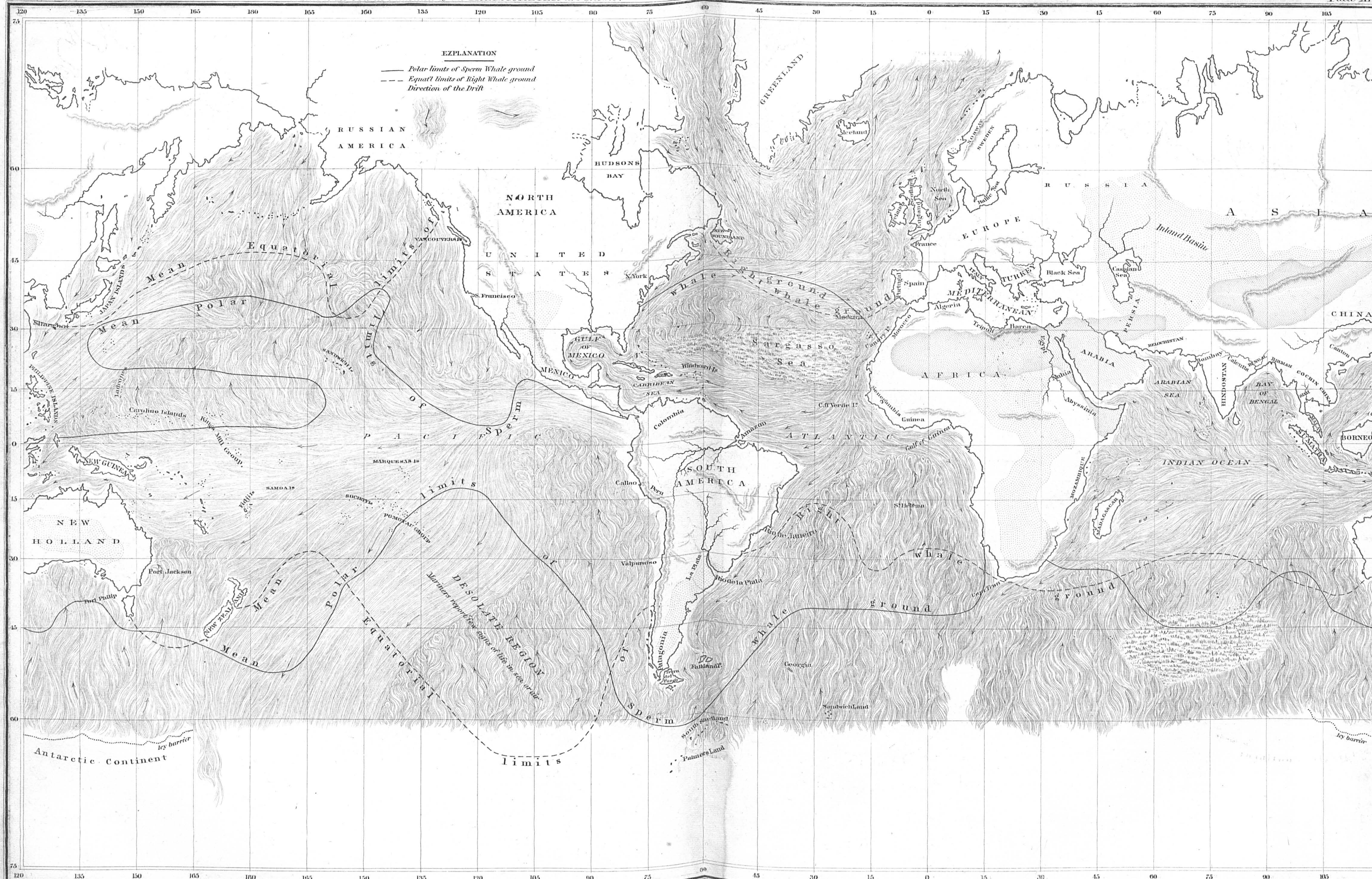
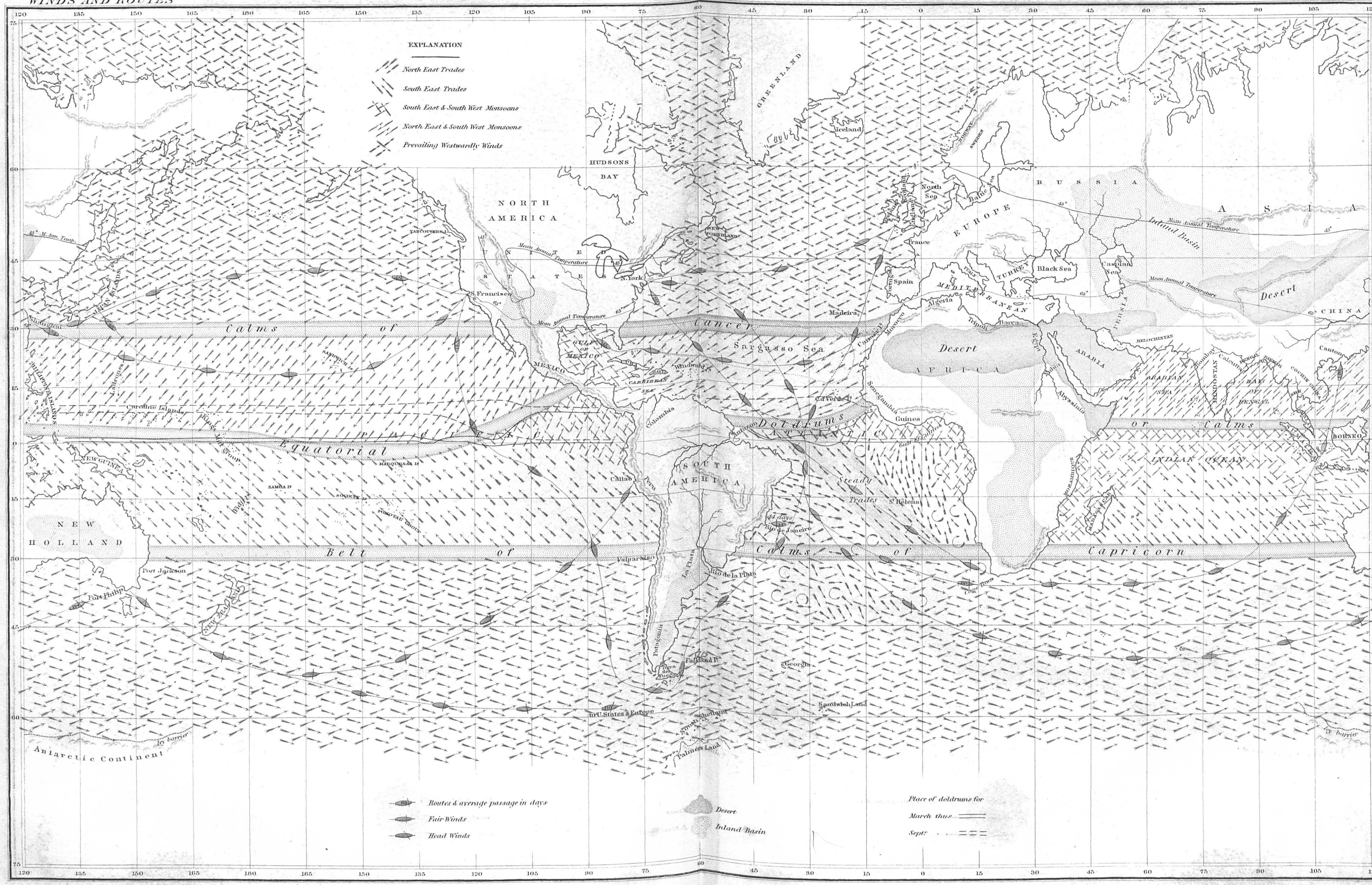


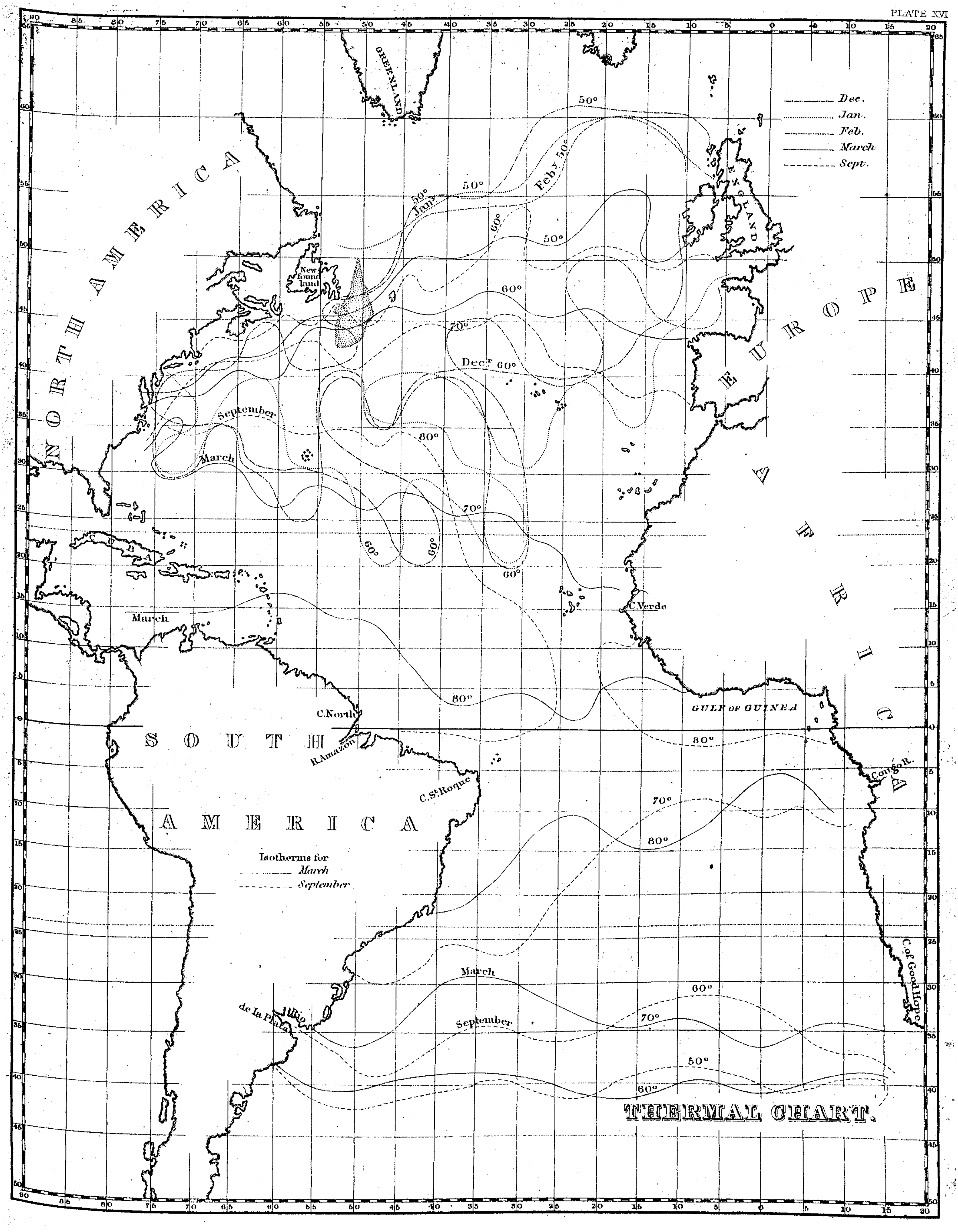
Fig. 6.


EXPLANATION
a — The place of the San Francisco after the wreck Dec. 26th
o — Where she was abandoned Jan. 4th
a.b — Computed limits of drift
c — Where the searching vessel was directed to look for her
x.y.z — The hot streaks of Fig. A.
Direction of flow and drift
Flow, not steady in any direction
NEW FOUNDLAND
NOVA SCOTIA
Northern limit of the Gulf Stream for Sept.
The Gulf Stream carries its northern limit to and fro over this space once each way during the year.
GRAND BANK
Boston
New York
Philadelphia
C. Charles
C. Hatteras
UNITED STATES
New Orleans
FLORIDA
Tampico
CUBA
HAYTI
Limits of the Gulf Stream for the Month of March.
BERMUDAS
AZORES
SPAIN
Straits of Gibraltar
MADEIRA
CANARY ISLANDS
Sea weed
SARGASSO SEA
AFRICA
CAPE VERD ISLANDS
Bay of Panama
The Great Equatorial Current
Amazon R.
SOUTH AMERICA
Fig. A.
Temps.
Dist. from C. Henry in naut. miles.
50 100 150 200 250 300 350 400
80° 75° 70° 65° 60° 55° 50° 45° 40°
Fig A.-Thermal Section of the Gulf Stream.
n — Mean of 0.5,10,20 & 30 Fath's
o — 50,70,100 & 150
s — Mean of 200,300 & 400 Fath's
t — 500 Fath's

SEA DRIFT AND WHALES, on which the movements of the sea as indicated by the THERMOMETER are shewn. *Plate XIV*




EXPLANATION
North East Trades
South East Trades
South East & South West Monsoons
North East & South West Monsoons
Prevailing Westwardly Winds
Calms of Cancer
Sargasso Sea
Equatorial Doldrums
Belt of Calms of Capricorn
Doldrums or Calms
Steady Trades
NORTH AMERICA
SOUTH AMERICA
EUROPE
AFRICA
ASIA
RUSSIA
NEW HOLLAND
INDIAN OCEAN
Antarctic Continent
HUDSONS BAY
GREENLAND
Iceland
Desert
Inland Basin
Mean Annual Temperature
Routes & average passage in days
Fair Winds
Head Winds
Desert
Inland Basin
Place of doldrums for
March thus
Septr


NORTH AMERICA
SOUTH AMERICA
EUROPE
AFRICA
GREENLAND
ENGLAND
New found land
CUBA
C.Verde
C.North
R.Amazon
C.St Roque
GULF OF GUINEA
Congo R.
C.of Good Hope
de La Plata
Rio
Dec.
Jan.
Feb.
March
Sept.
Isotherms for
March
September
Feby 50°
Jany 50°
Decr 60°
September
March
THERMAL CHART.

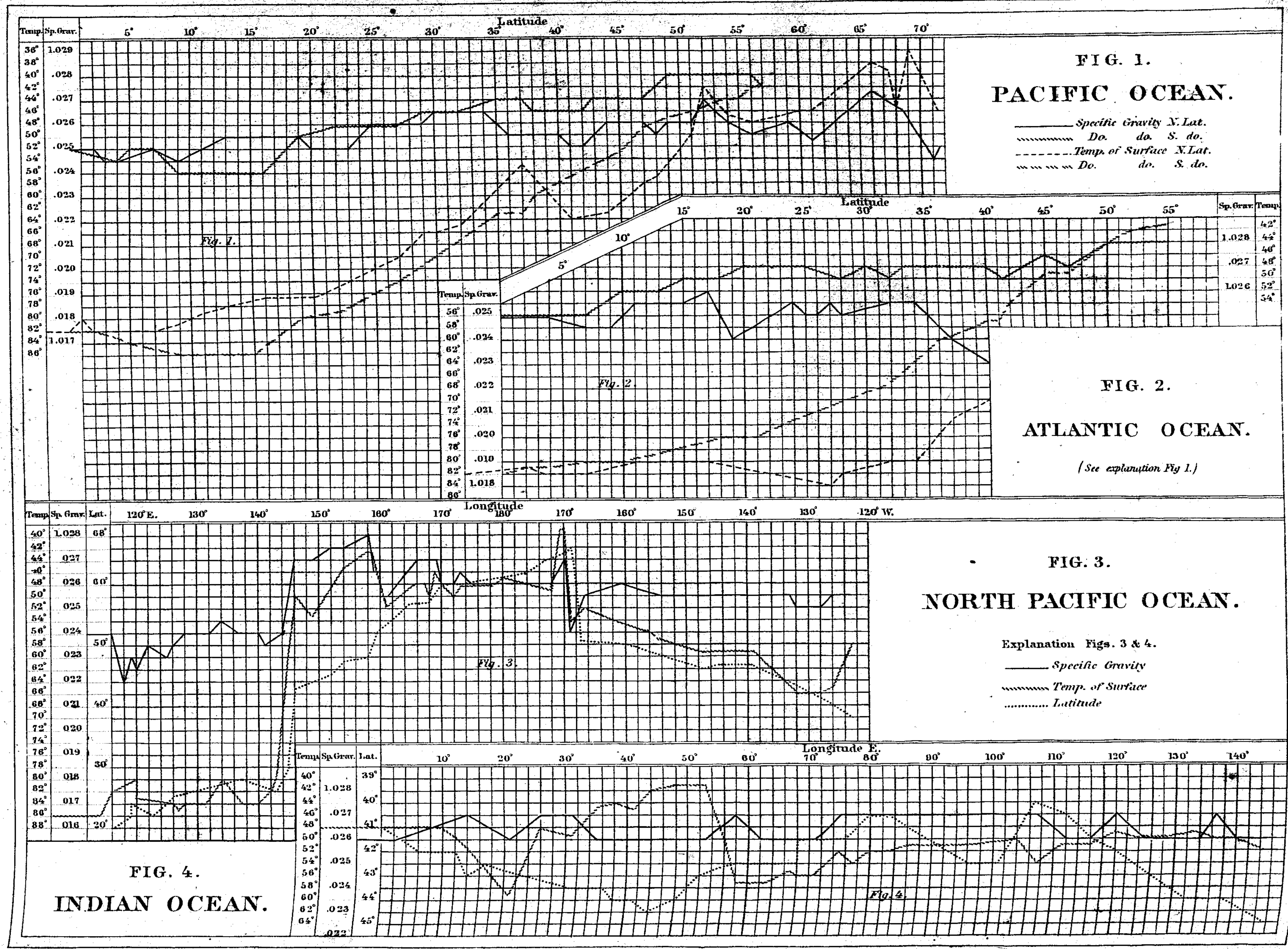
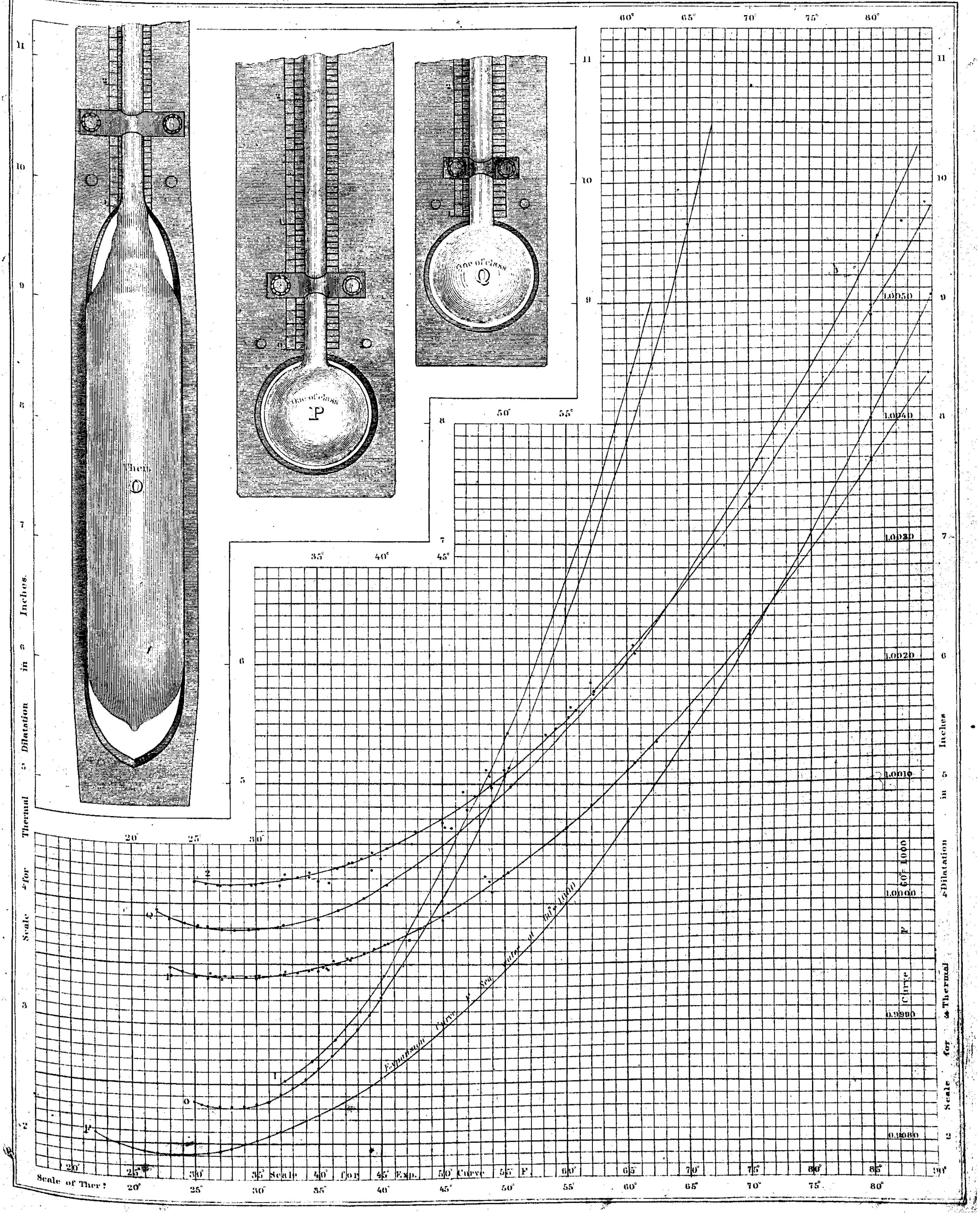


FIG. 1.
PACIFIC OCEAN.
Specific Gravity N. Lat.
Do. do. S. do.
Temp. of Surface N. Lat.
Do. do. S. do.
Latitude
Temp.
Sp. Grav.
Fig. 1.
FIG. 2.
ATLANTIC OCEAN.
(See explanation Fig 1.)
Latitude
Fig. 2.
FIG. 3.
NORTH PACIFIC OCEAN.
Explanation Figs. 3 & 4.
Specific Gravity
Temp. of Surface
Latitude
Longitude
Lat.
Fig. 3.
FIG. 4.
INDIAN OCEAN.
Longitude E.
Fig. 4.


One of class Q
One of class P
Ther. O
Scale for Thermal Dilatation in Inches
Scale for Thermal Dilatation in Inches
Expansion Curve of Sea water at 60° = 1000
Curve F 60° = 1000
1.0050
1.0040
1.0030
1.0020
1.0010
1.0000
0.9990
0.9980
Scale for Exp. Curve F.
Scale of Ther.

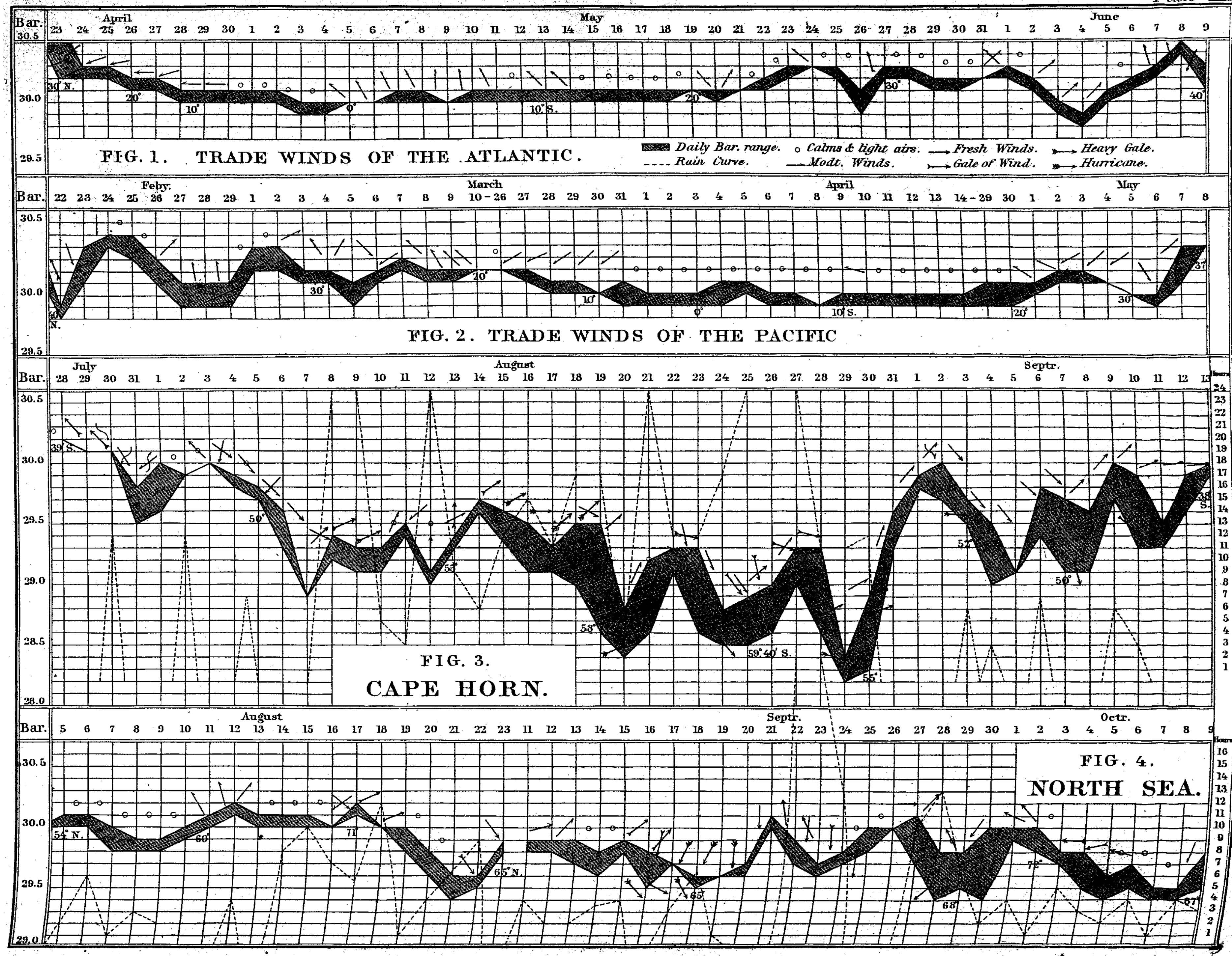
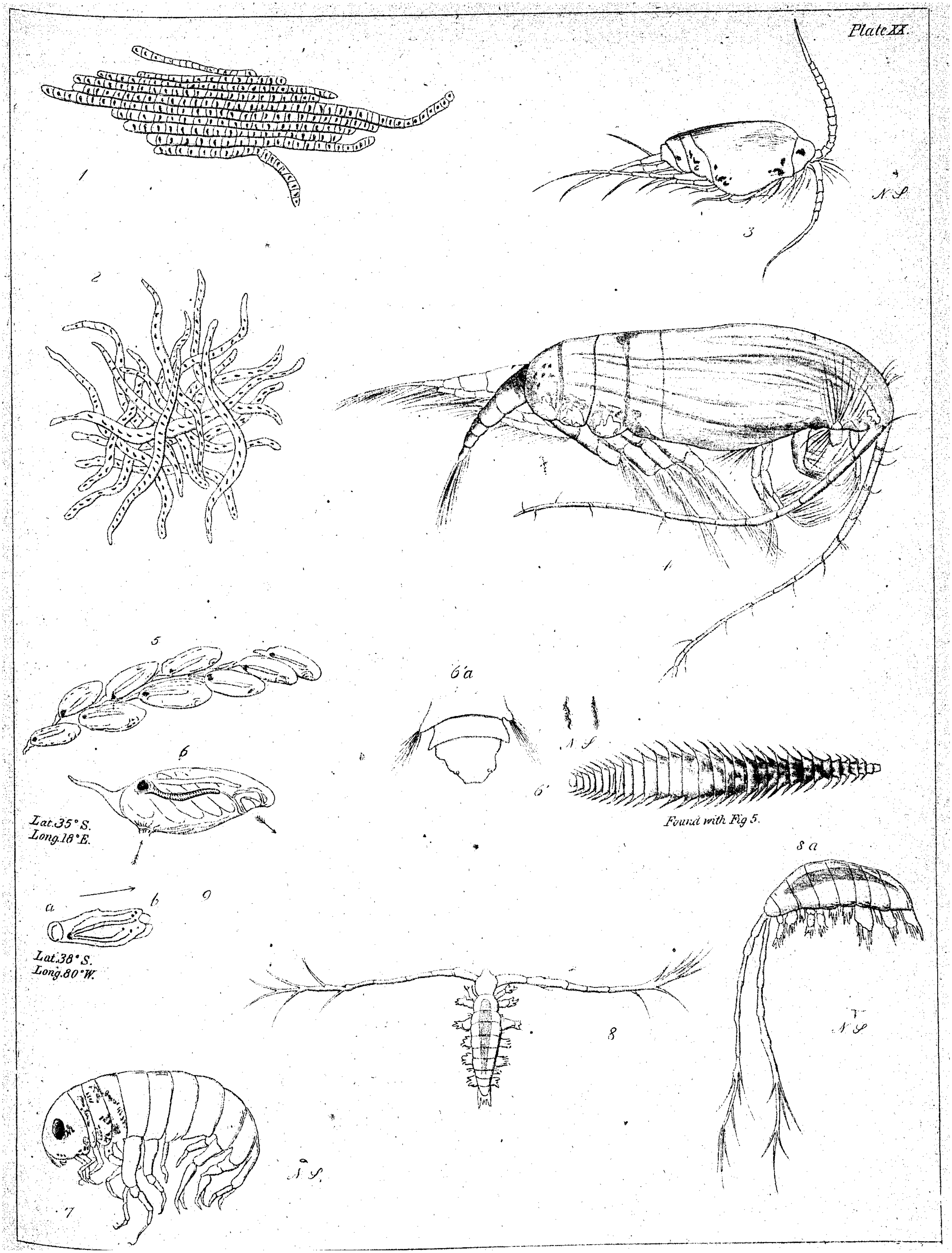


FIG. 1. TRADE WINDS OF THE ATLANTIC.
Daily Bar. range.
Rain Curve.
Calms & light airs.
Modt. Winds.
Fresh Winds.
Gale of Wind.
Heavy Gale.
Hurricane.
FIG. 2. TRADE WINDS OF THE PACIFIC
FIG. 3.
CAPE HORN.
FIG. 4.
NORTH SEA.

Plate XX.



1
2
3
N.S.
4
5
6
6a
6'
N.S.
Found with Fig 5.
Lat.35° S.
Long.18° E.
a
b
9
Lat.38° S.
Long.80° W.
8
8 a
N.S.
7
N.S.

Plate XXI.

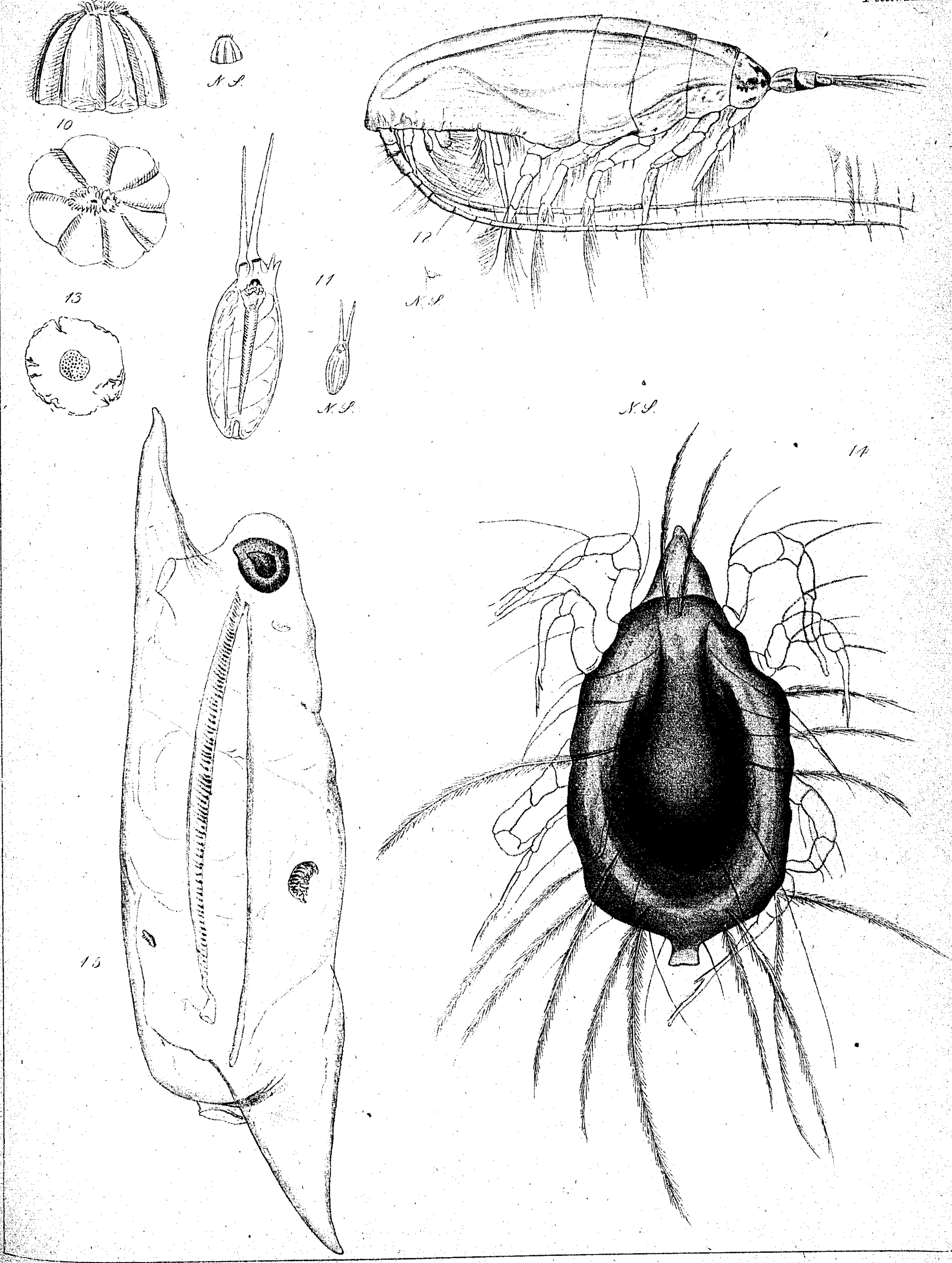


Plate XXII

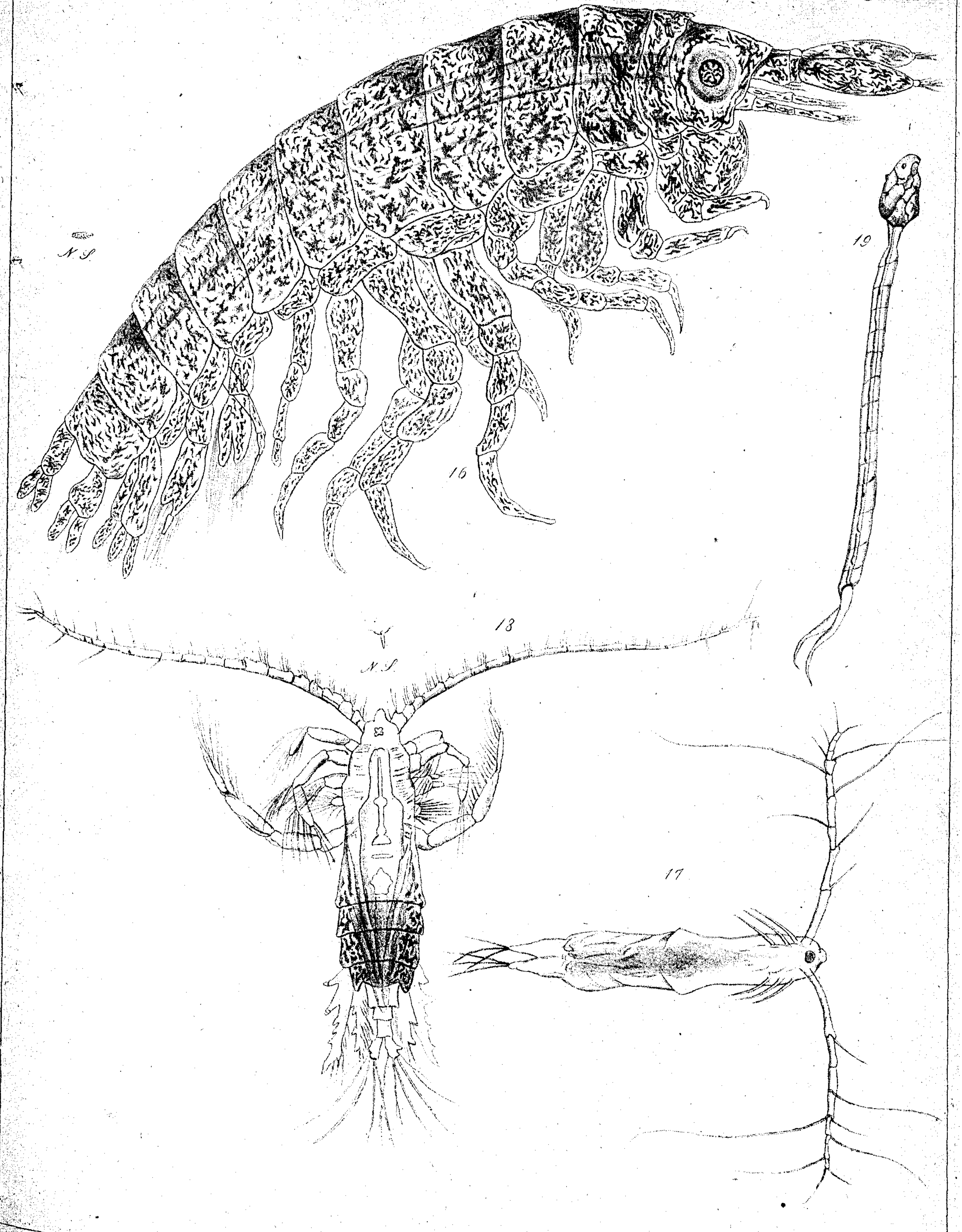


Plate XXIII.

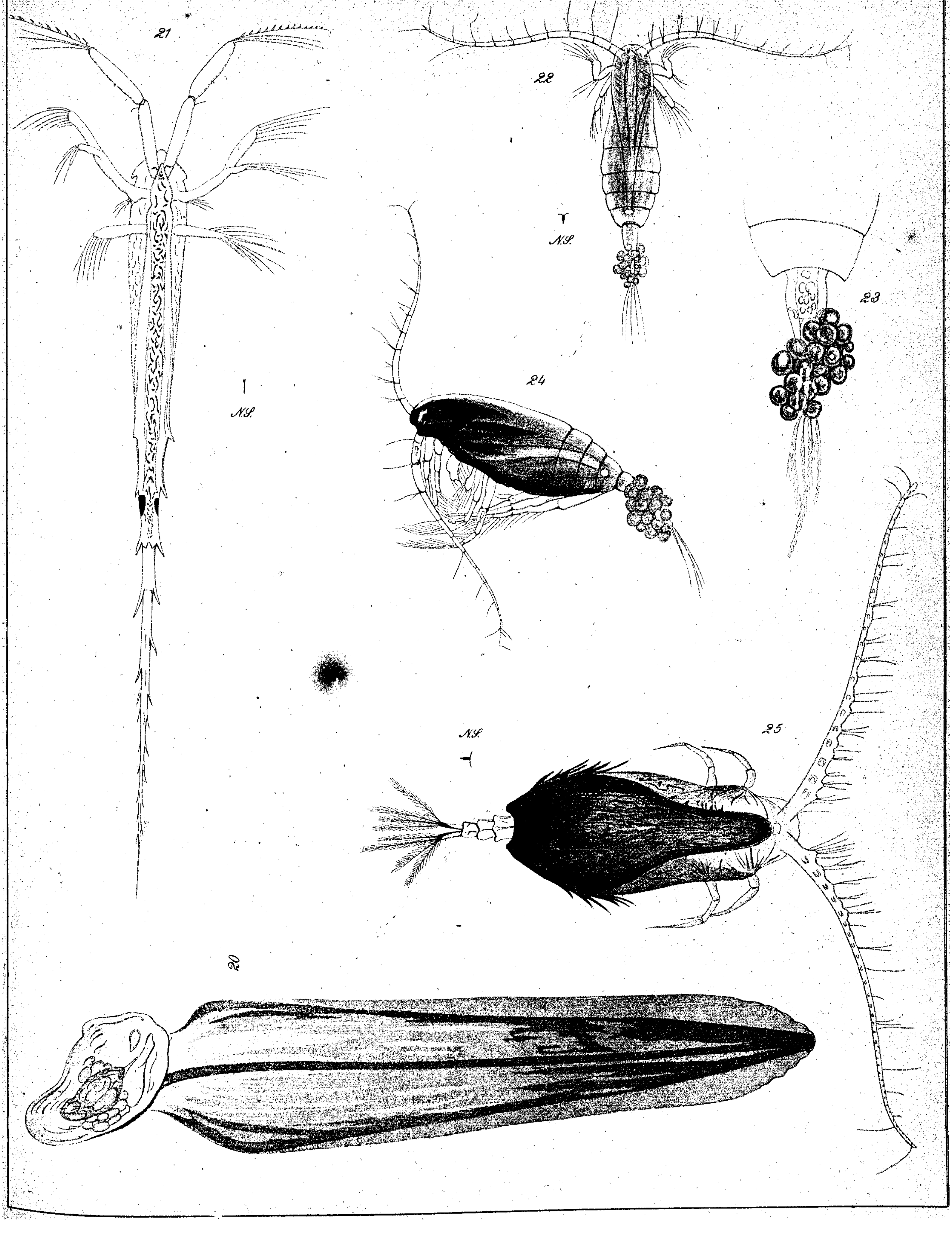


Plate XXIV.

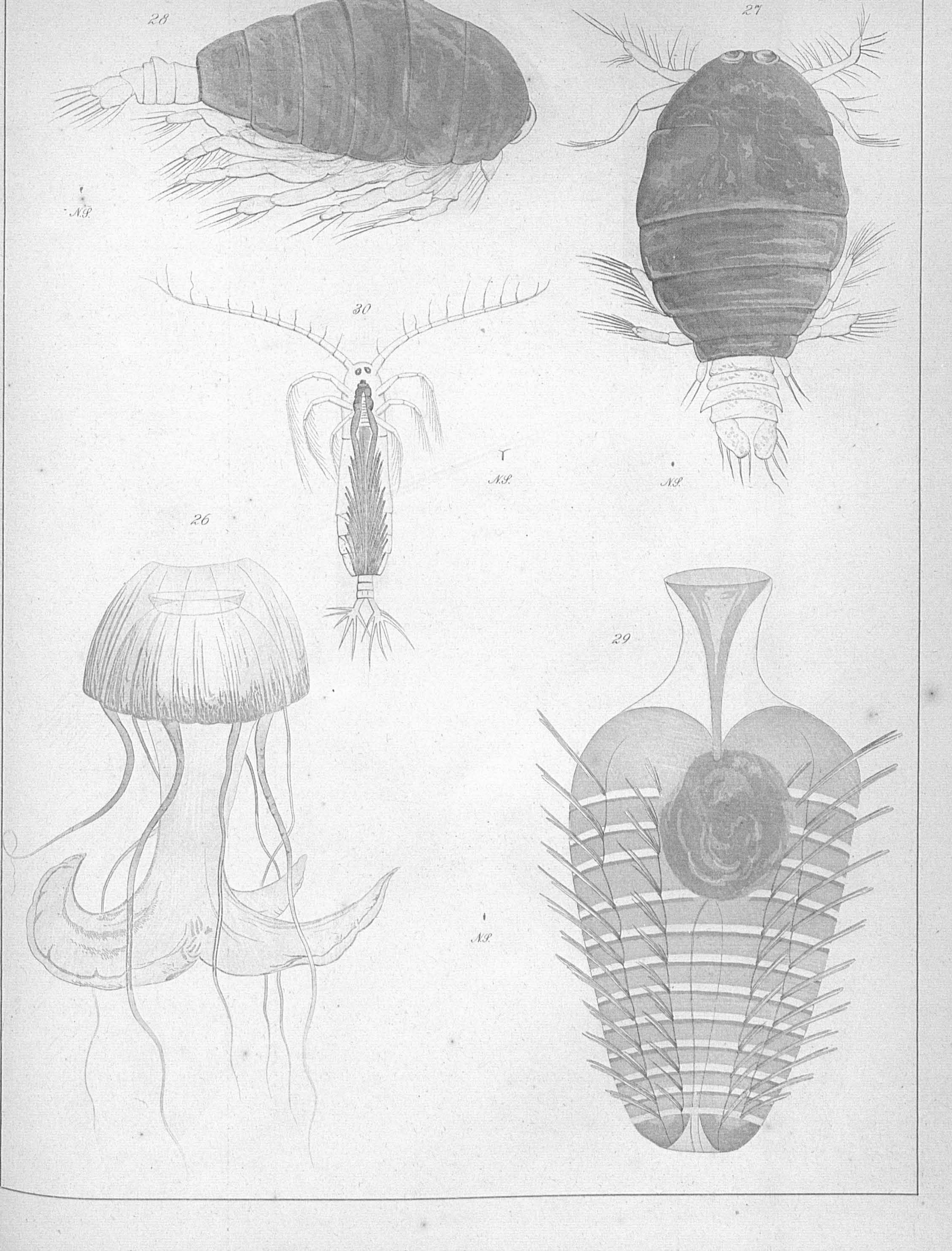


Plate XXV.

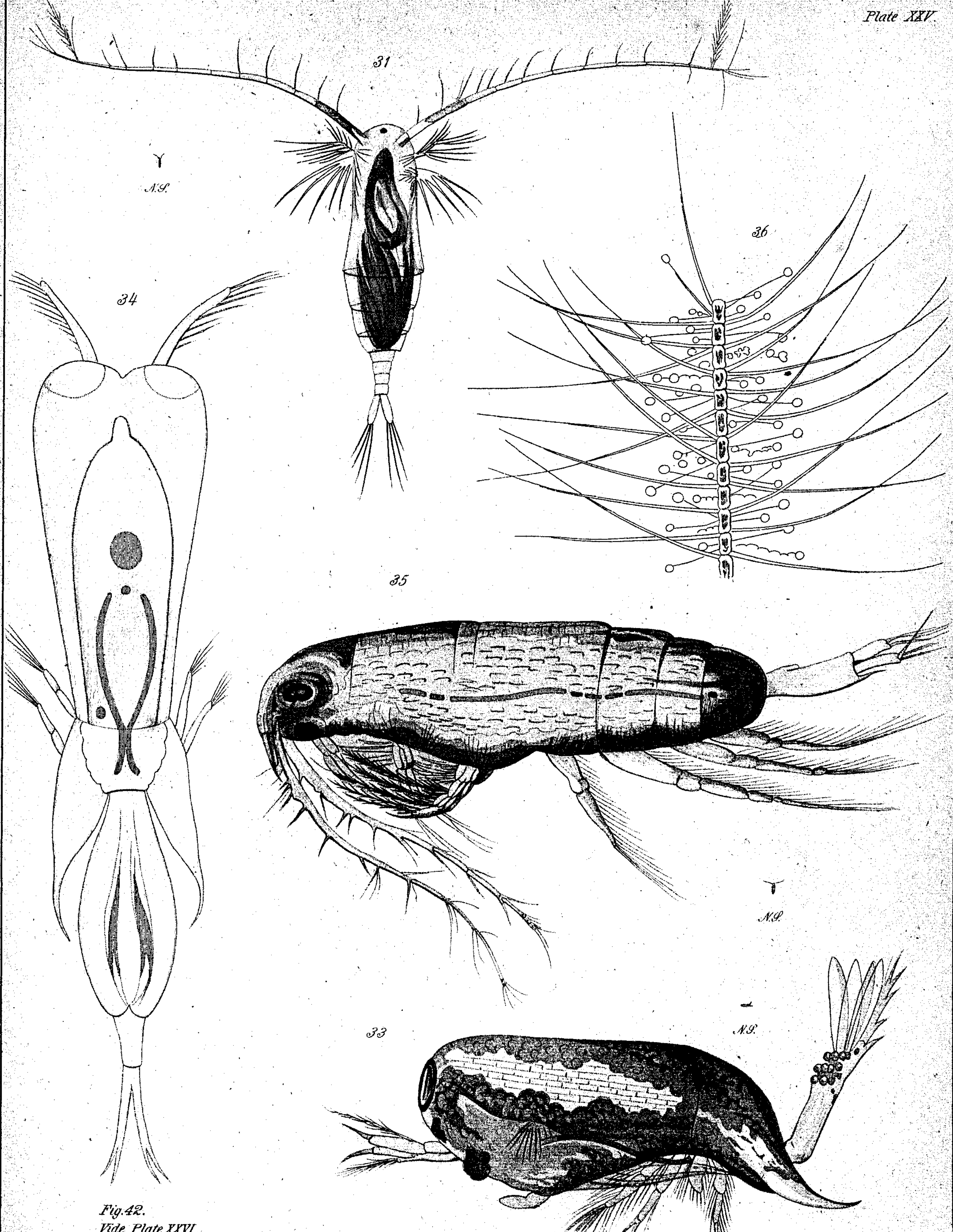


Fig. 42.
Vide Plate XXVI.

Plate XXVI.

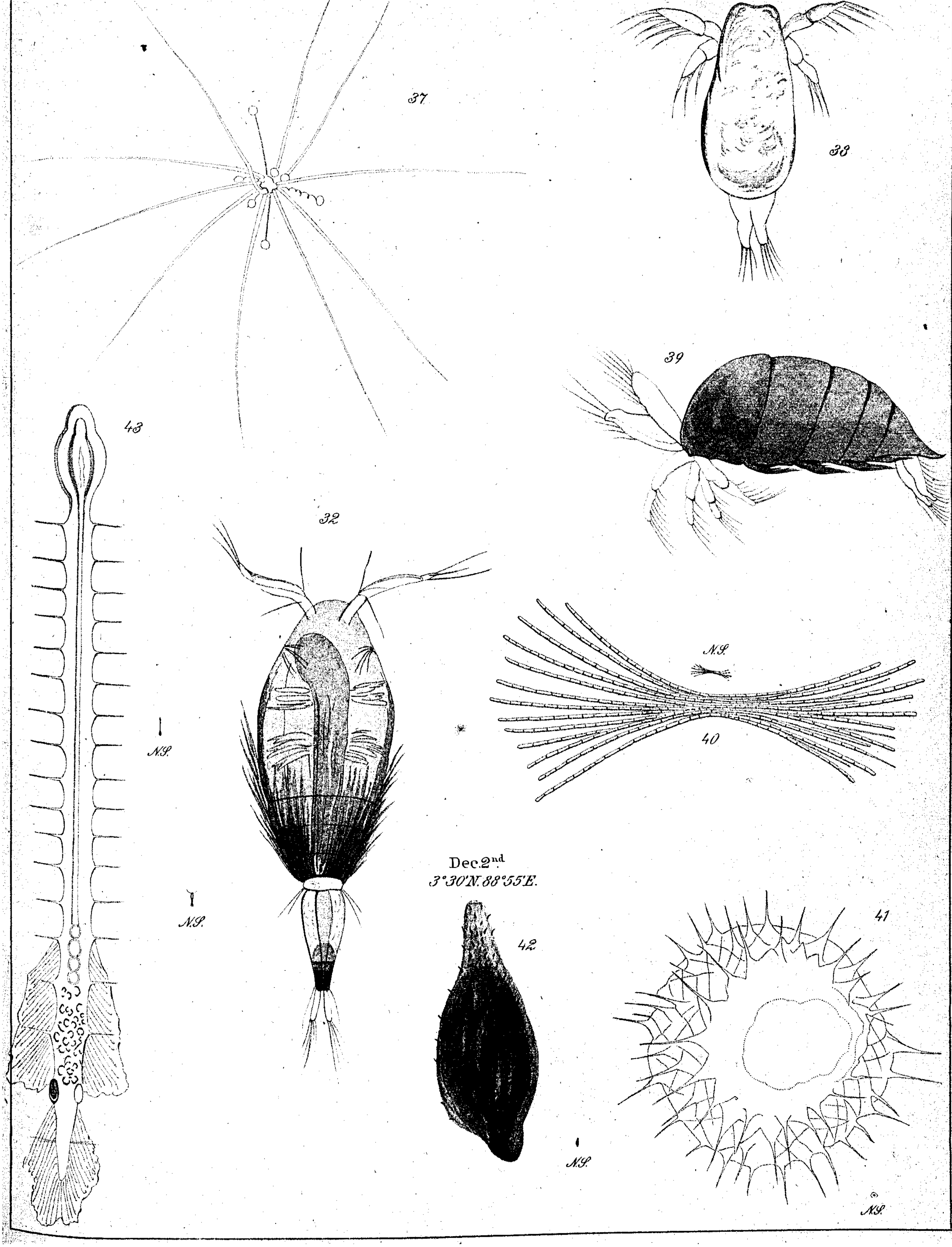
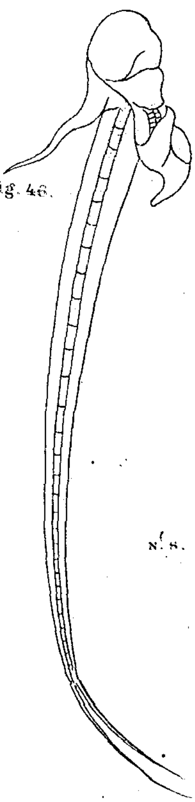
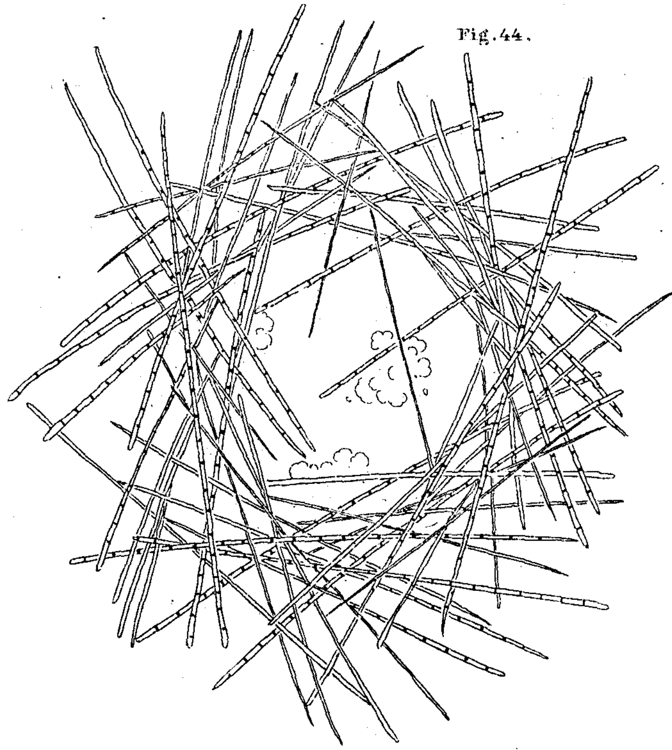


Fig. 46.



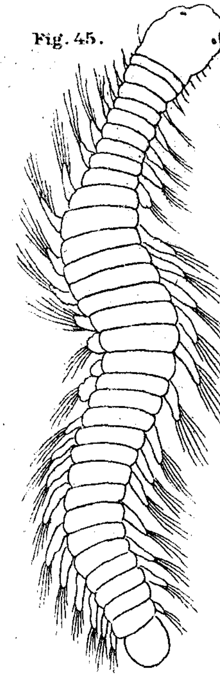
N.S.

Fig. 44.



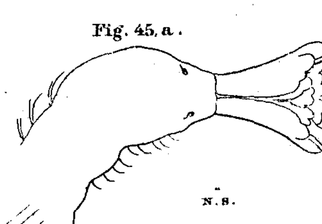
N.S.

Fig. 45.



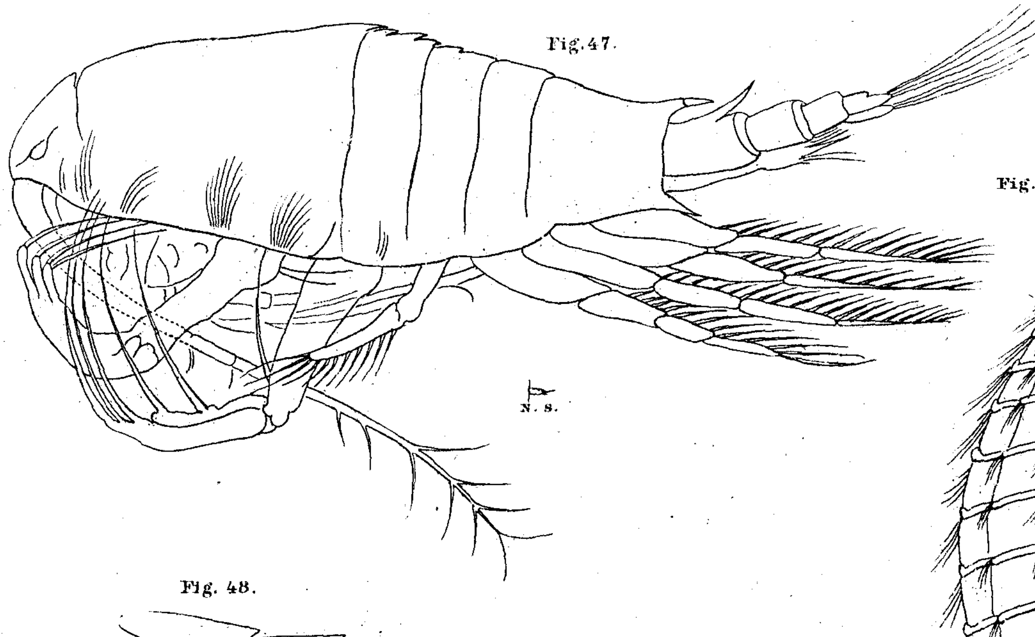
N.S.

Fig. 45, a.



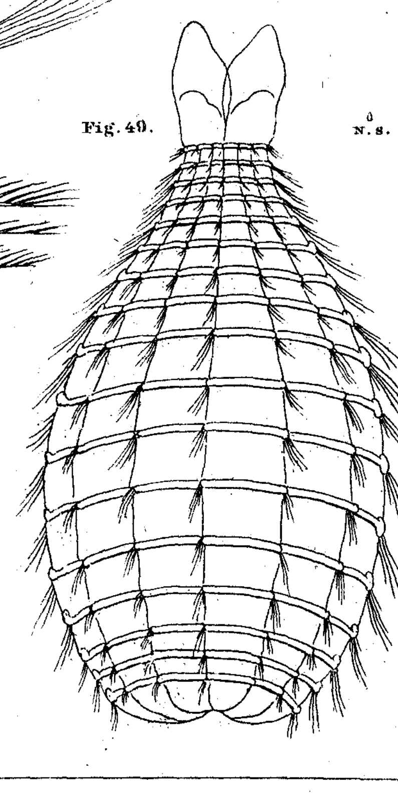
N.S.

Fig. 47.



N.S.

Fig. 49.



N.S.

Fig. 48.

N.S.

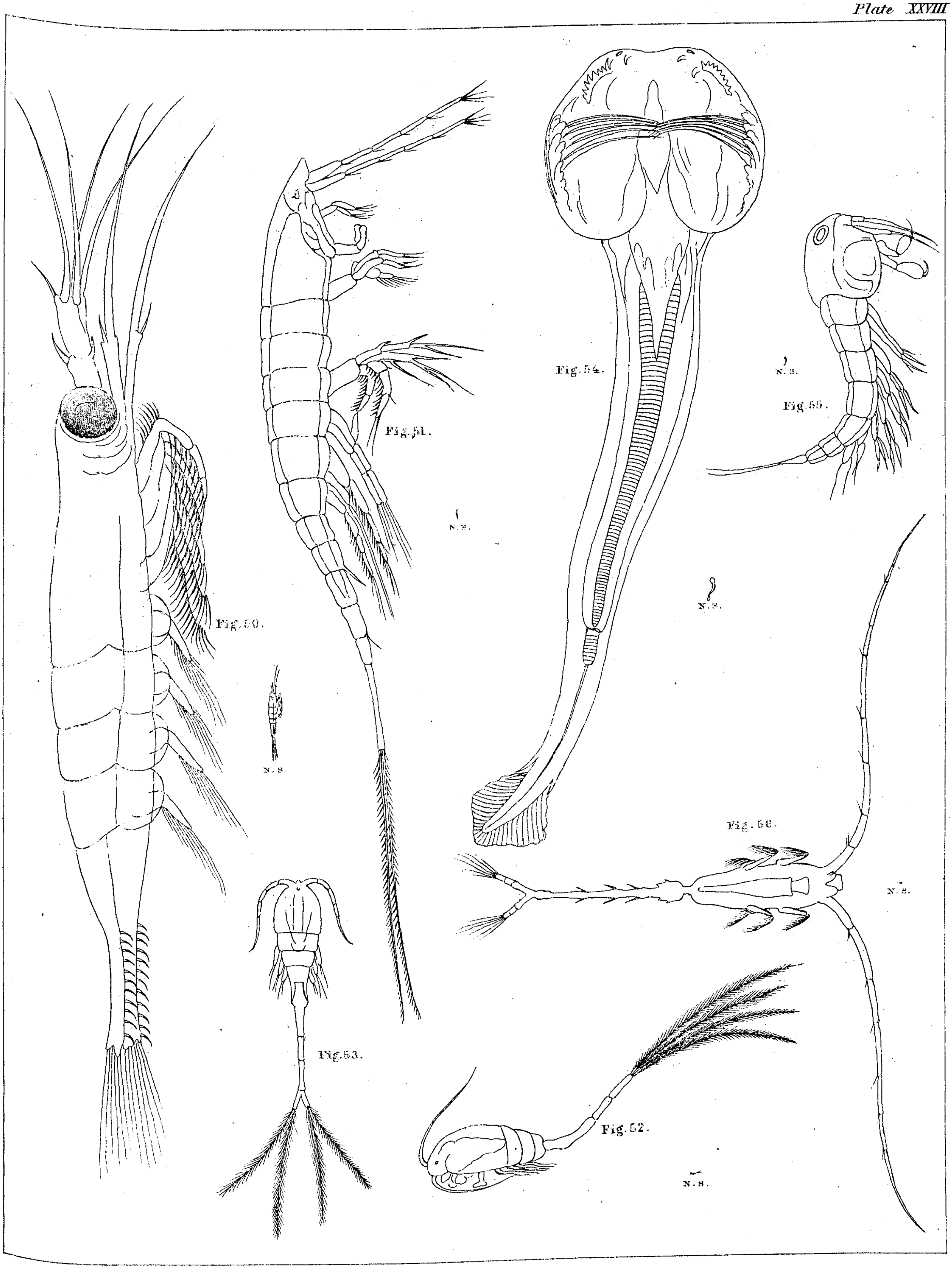


Fig. 50.
N. S.
Fig. 51.
N. S.
Fig. 52.
N. S.
Fig. 53.
Fig. 54.
N. S.
Fig. 55.
N. S.
Fig. 56.
N. S.

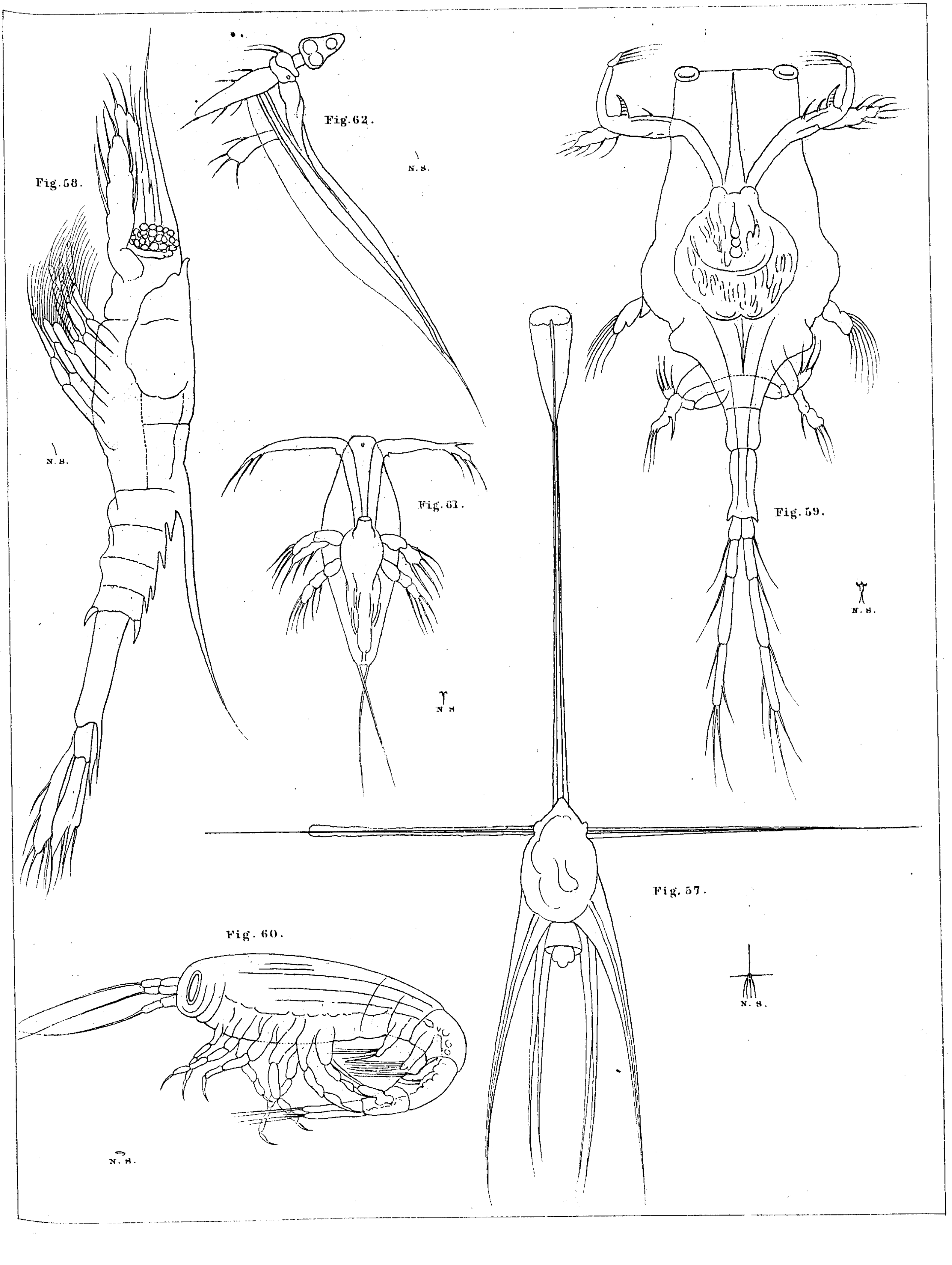


Fig. 58.
N. S.
Fig. 62.
N. S.
Fig. 61.
N S
Fig. 59.
N. S.
Fig. 57.
N. S.
Fig. 60.
N. S.

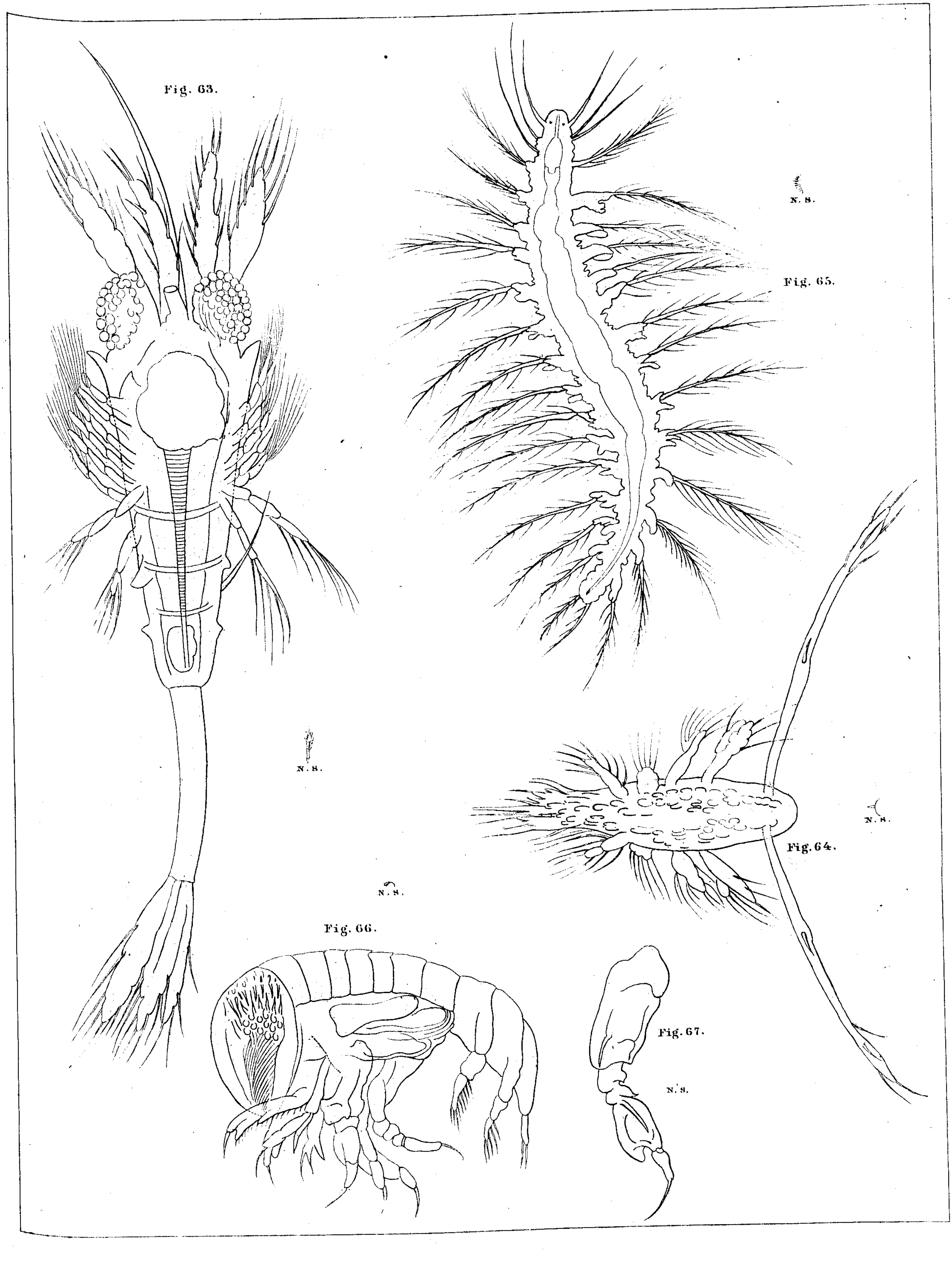


Fig. 63.
N. S.
Fig. 65.
N. S.
N. S.
Fig. 64.
N. S.
Fig. 66.
Fig. 67.
N. S.

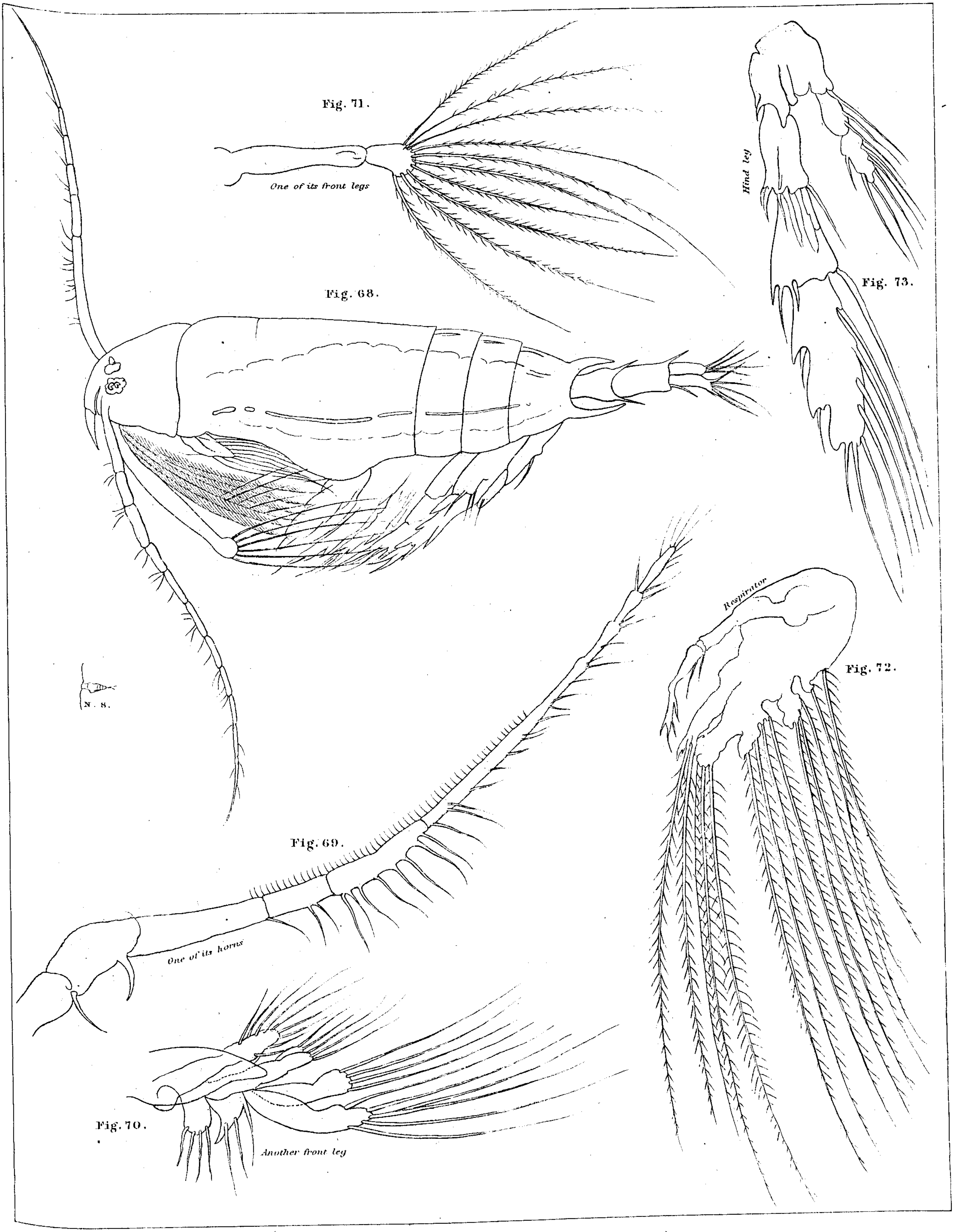


Fig. 71.
One of its front legs
Fig. 68.
Hind leg
Fig. 73.
N. 8.
Respirator
Fig. 72.
Fig. 69.
One of its horns
Fig. 70.
Another front leg

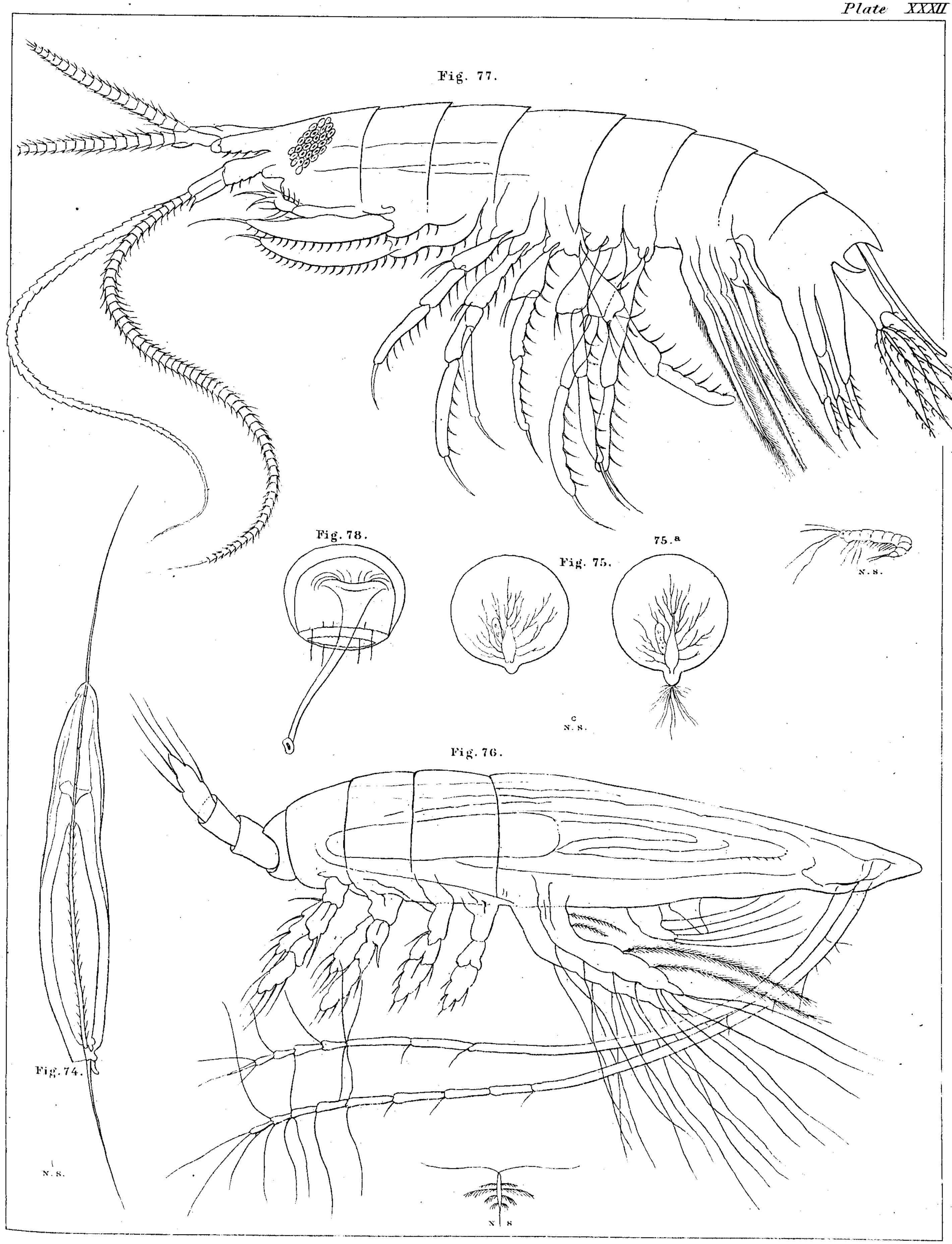


Fig. 77.
Fig. 78.
Fig. 75.
75.a
N.S.
C
N.S.
Fig. 76.
Fig. 74.
N.S.
N S

Fig. 81.

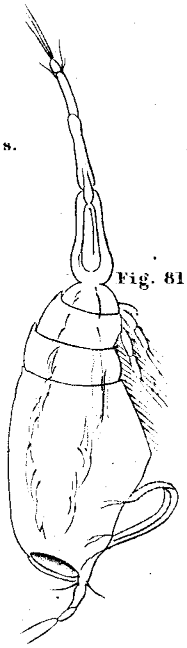


Fig. 80.

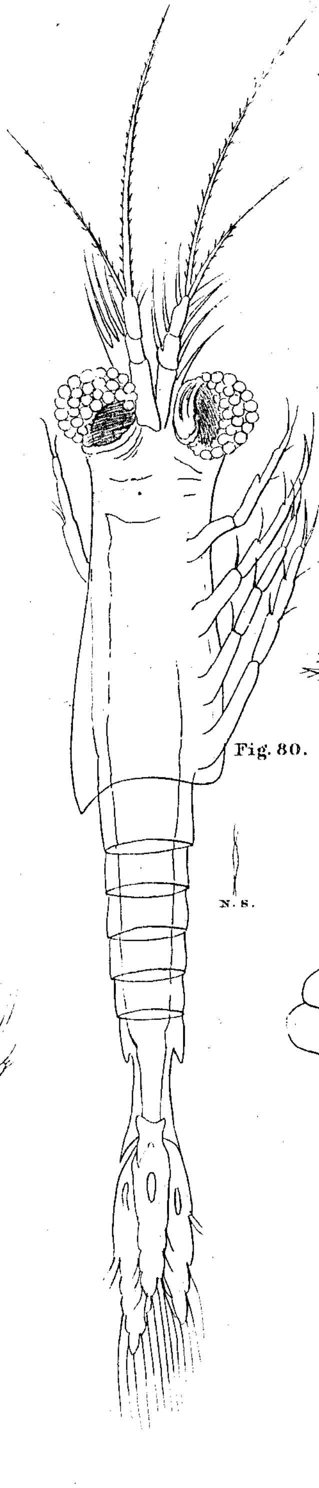


Fig. 79.

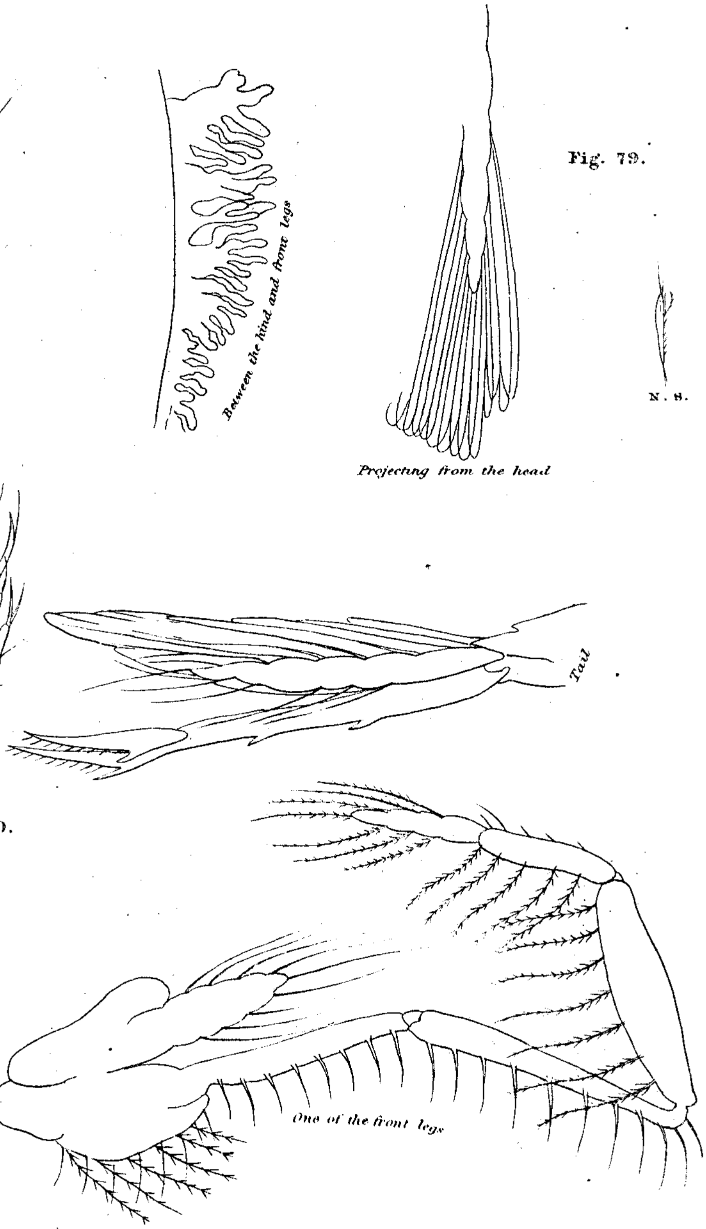


Fig. 83.

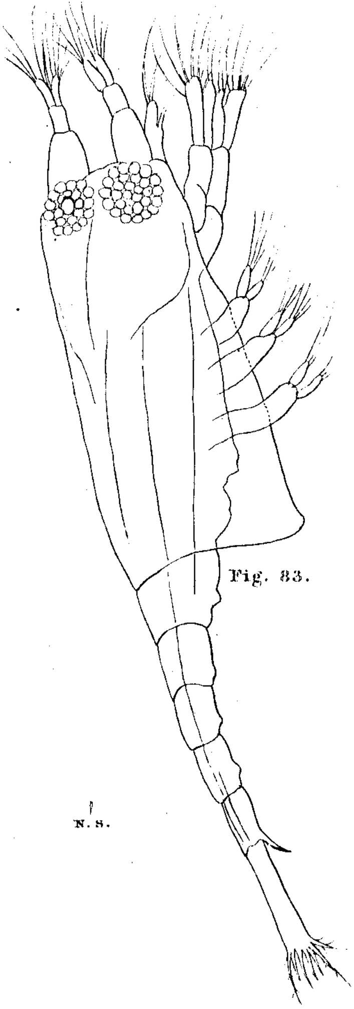
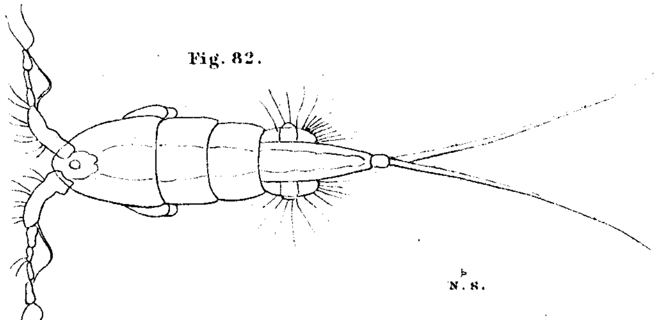


Fig. 82.



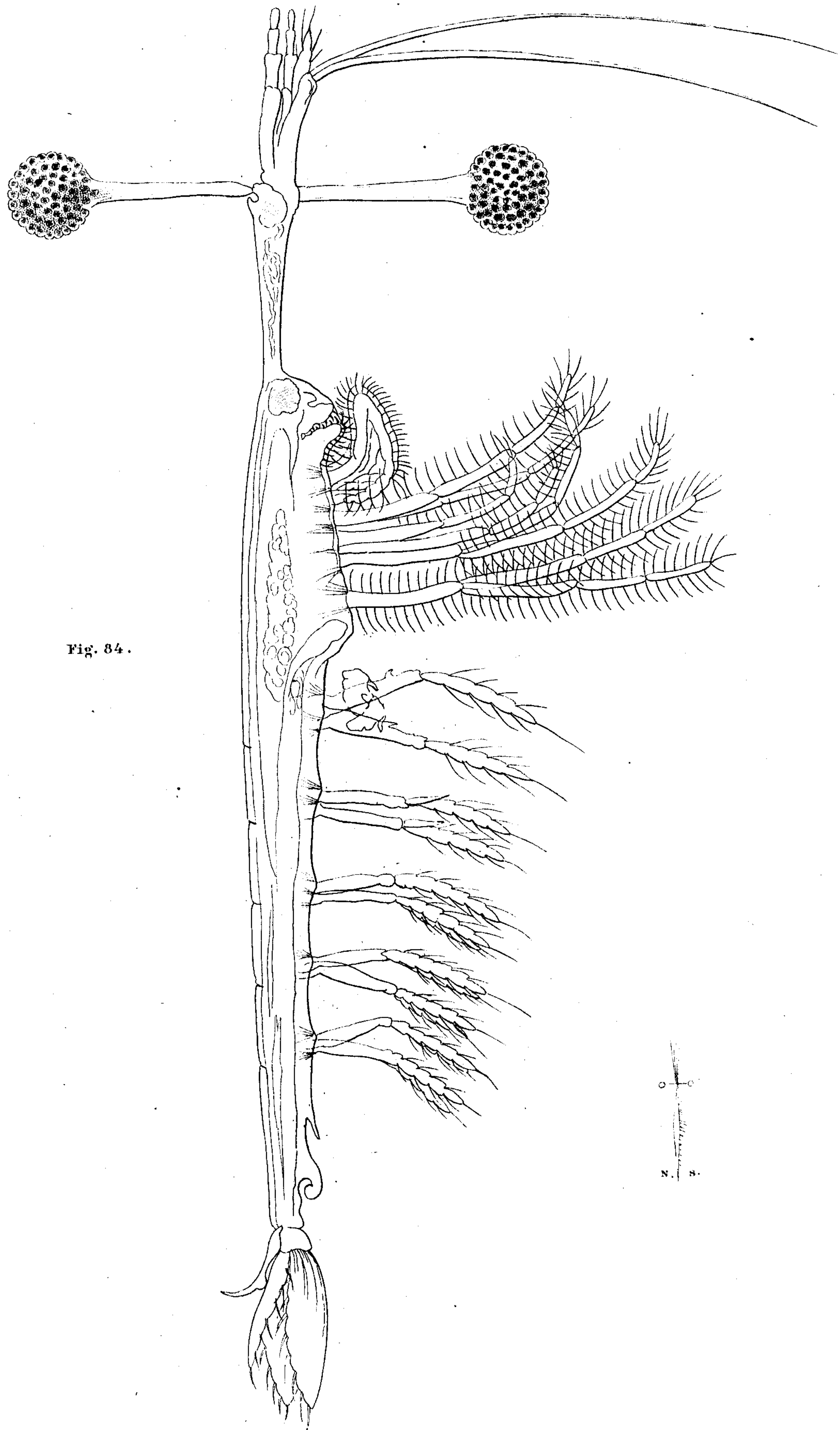


Fig. 84.

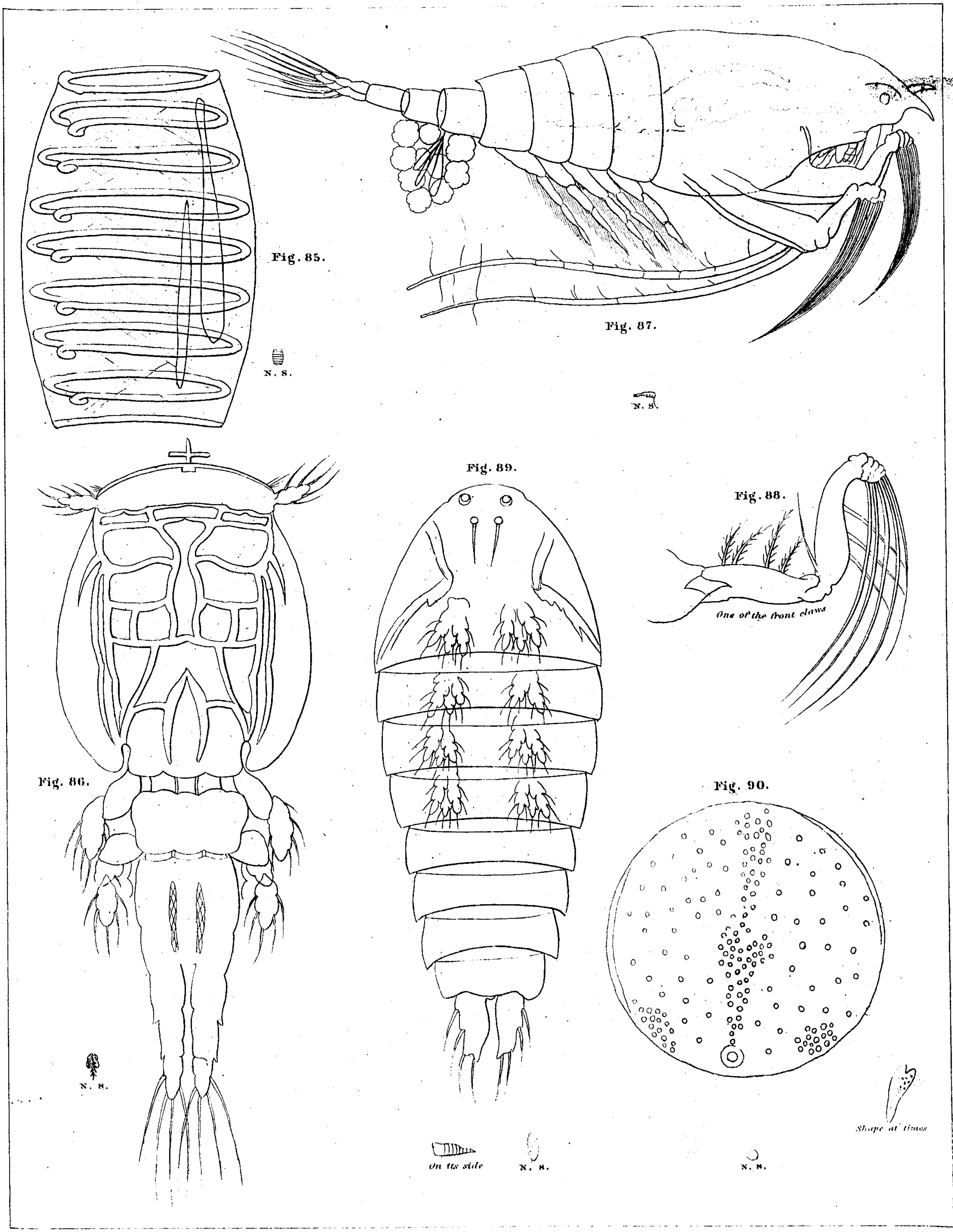


Fig. 85.
N. S.
Fig. 87.
N. S.
Fig. 89.
Fig. 88.
One of the front claws
Fig. 86.
N. S.
Fig. 90.
Shape at times
On its side
N. S.
N. S.

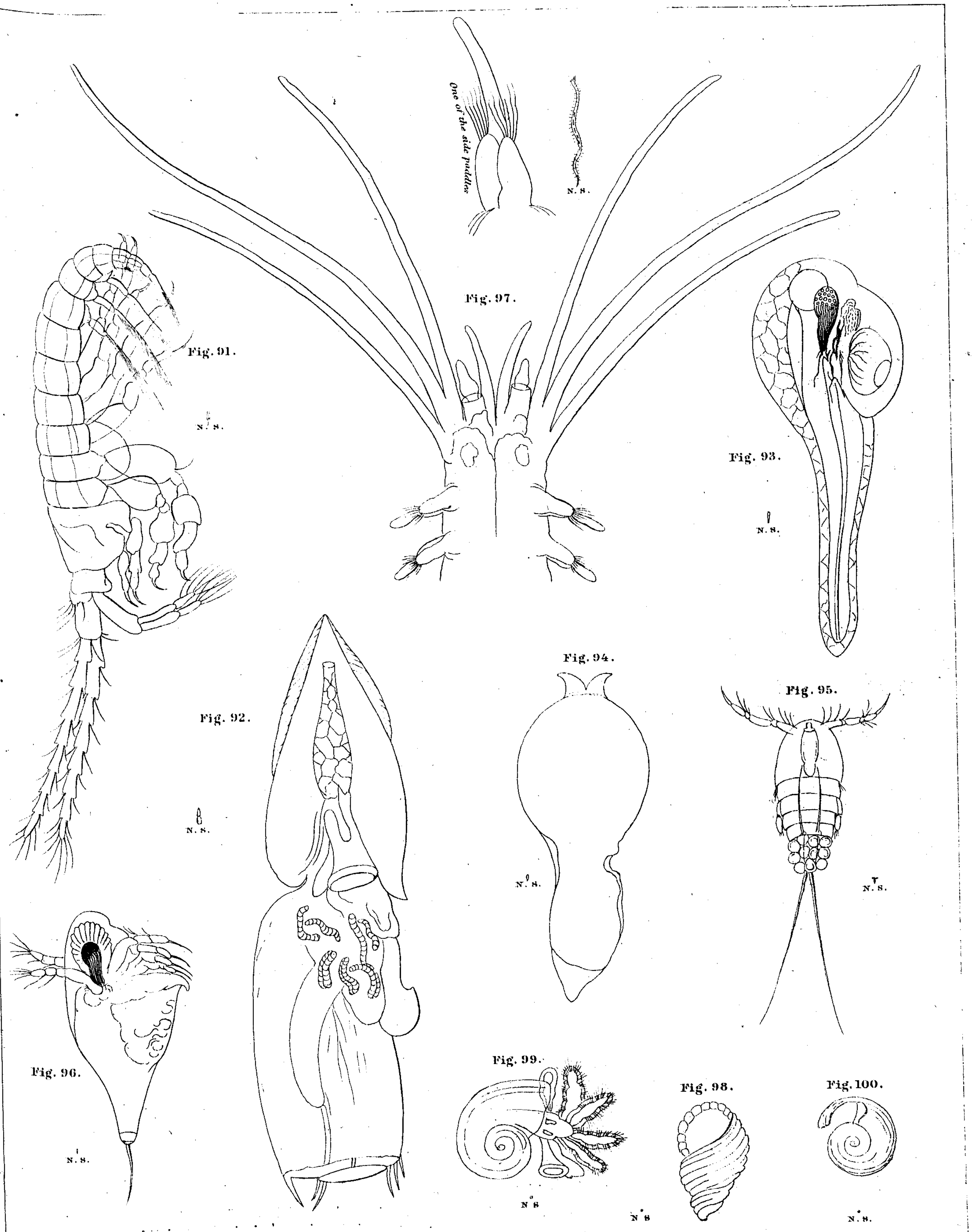


Fig. 91. Fig. 92. Fig. 93. Fig. 94. Fig. 95. Fig. 96. Fig. 97. Fig. 98. Fig. 99. Fig. 100.

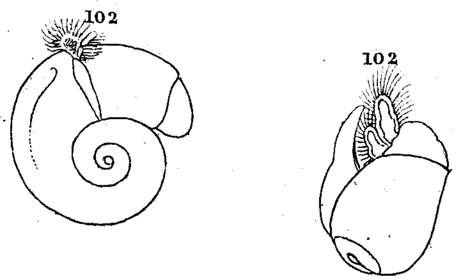
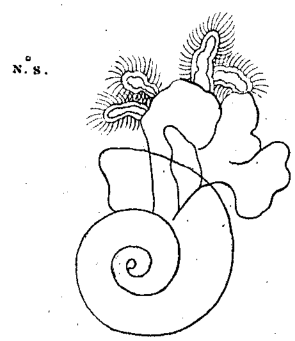


Fig. 102.



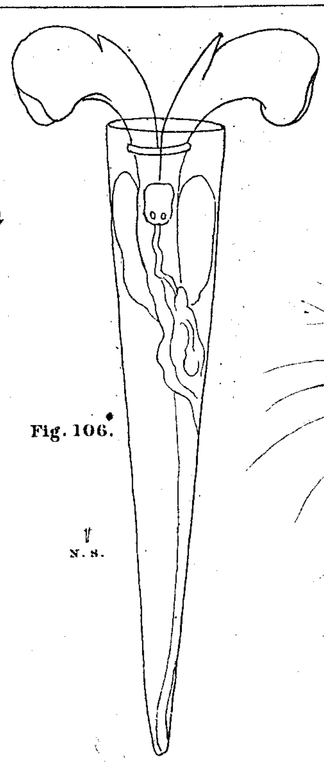


Fig. 106.

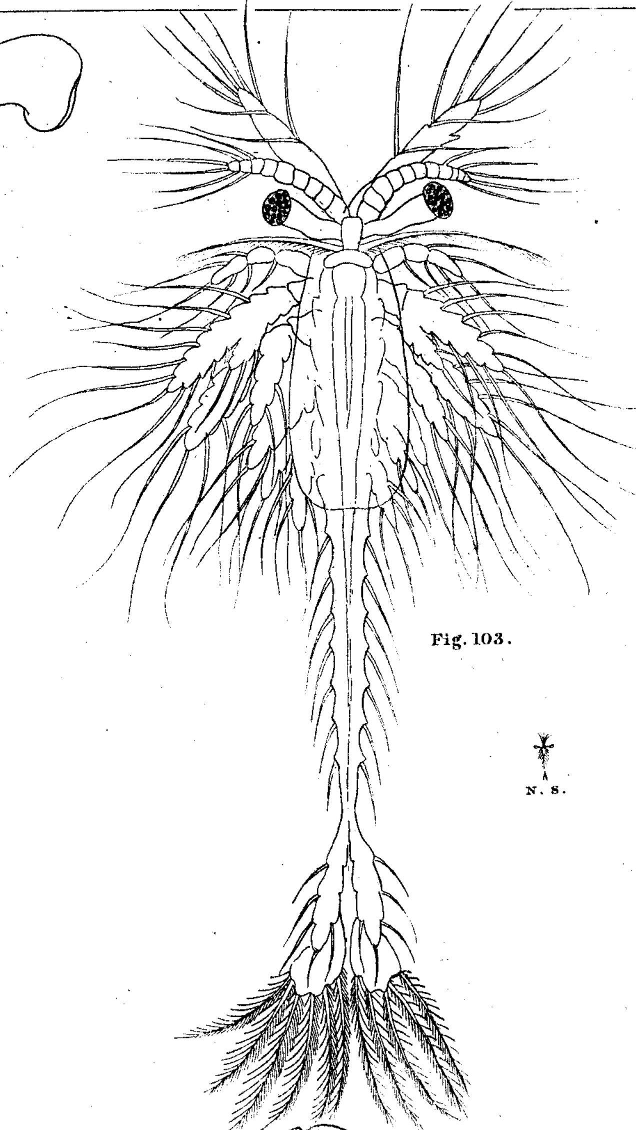


Fig. 103.

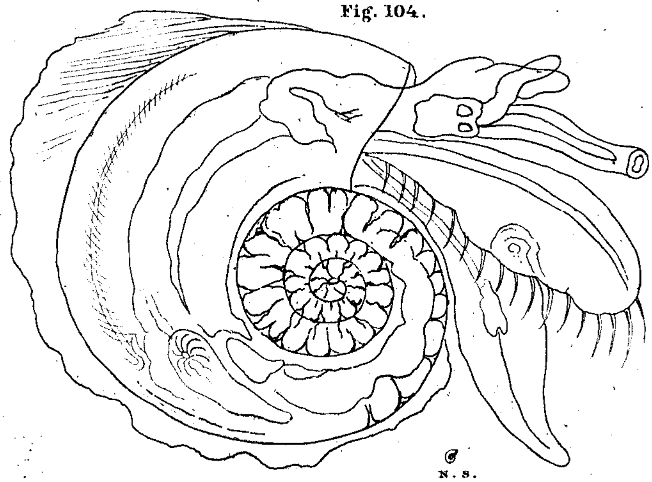


Fig. 104.

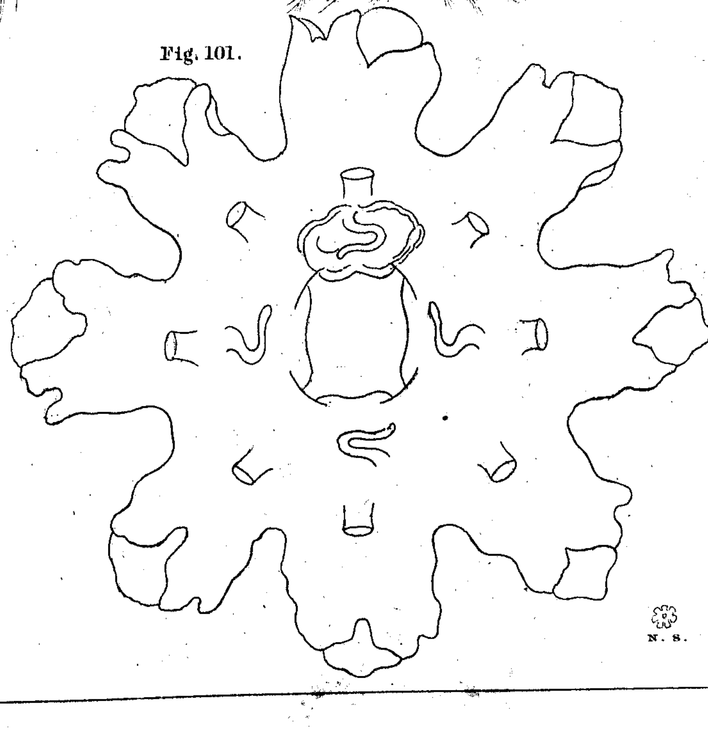


Fig. 101.

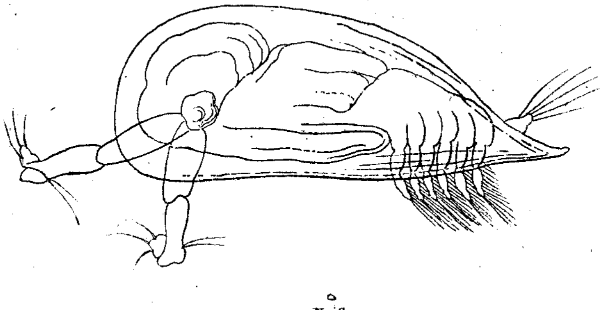


Fig. 105.

Sept. 11th.
(Off the river Mersey)

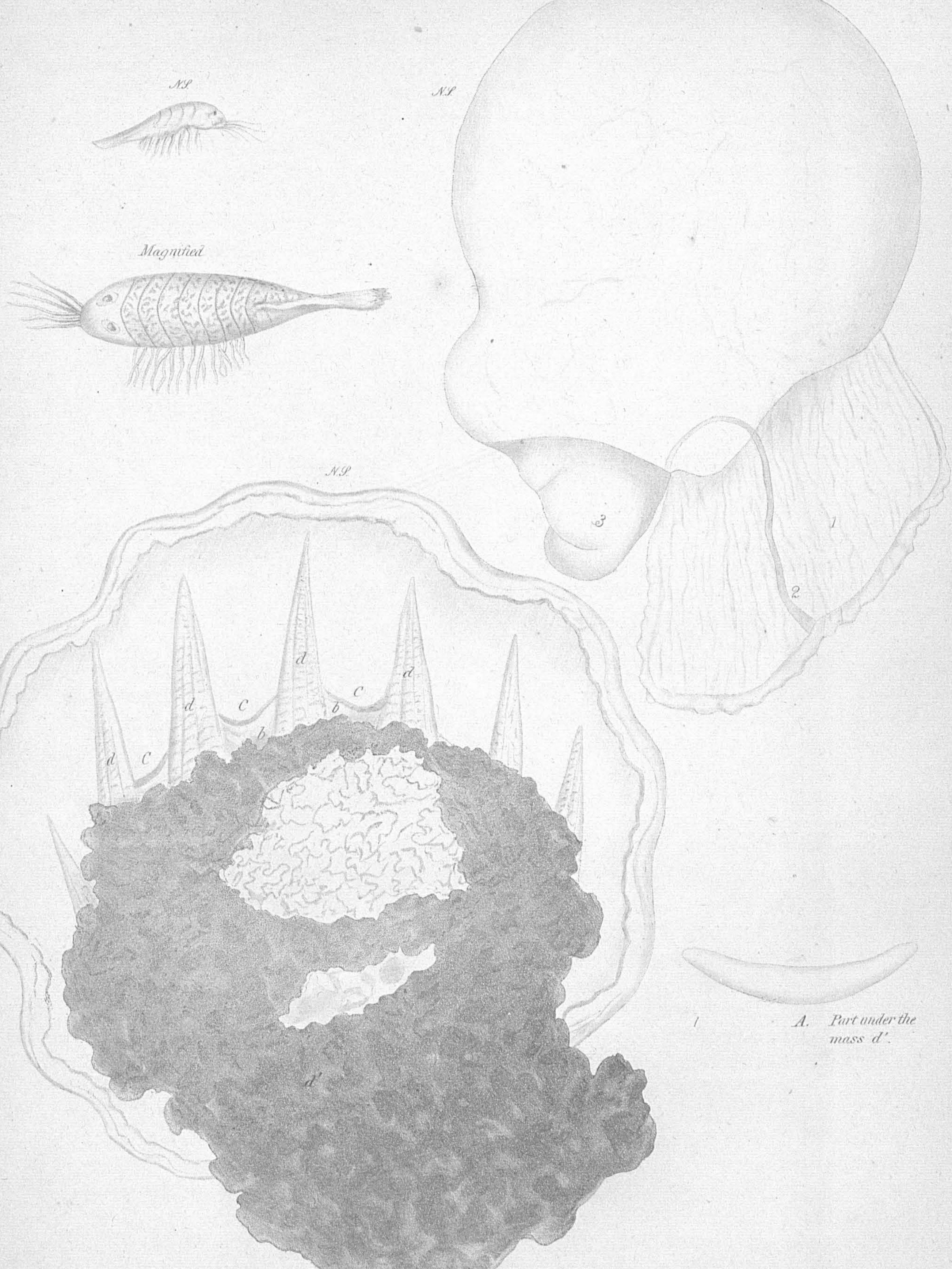
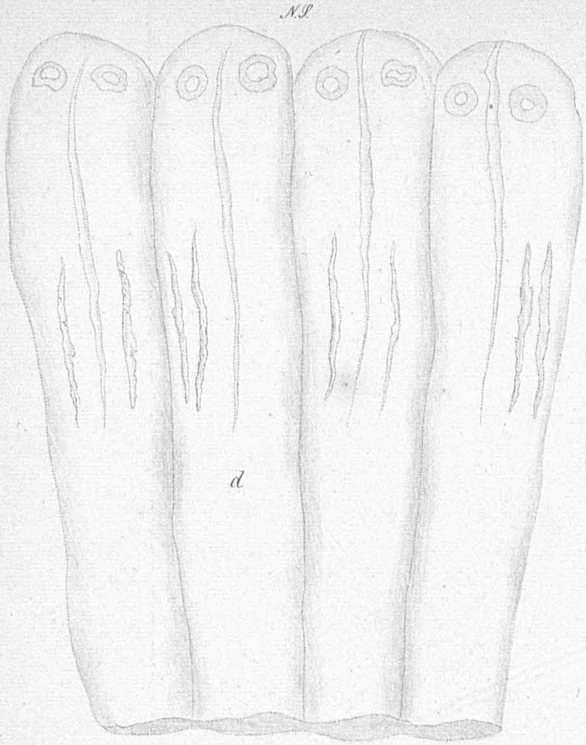
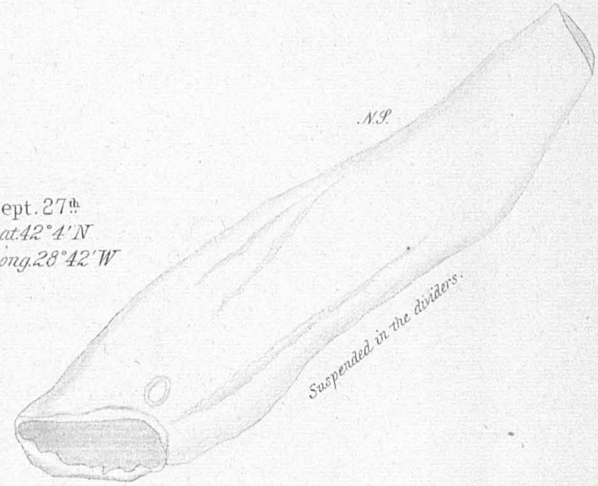


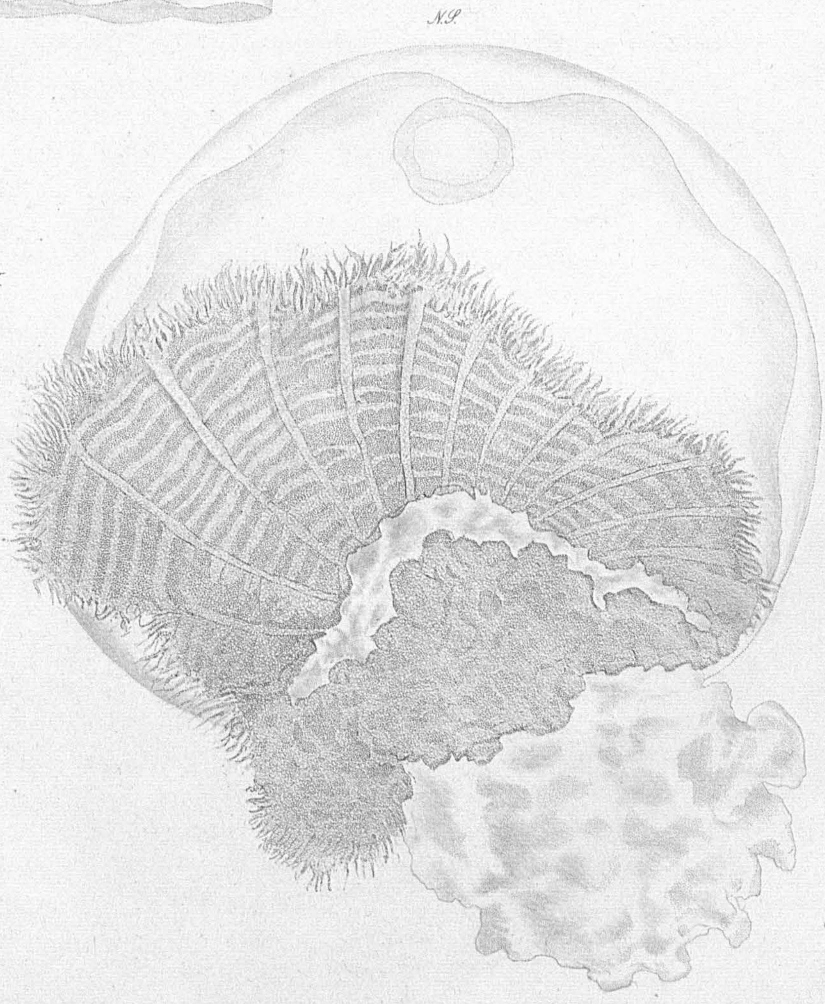
Plate XXXIX



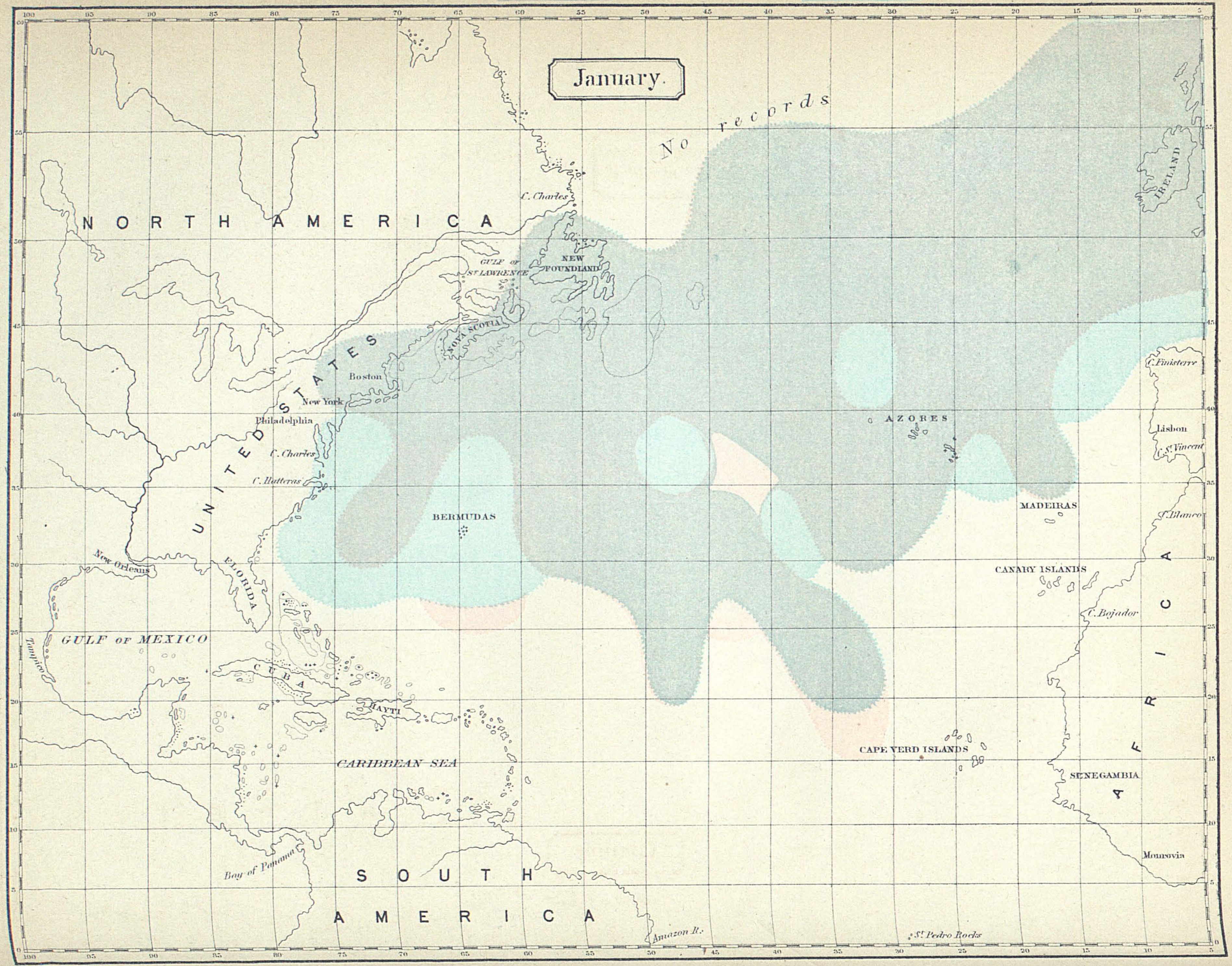
Sept. 27th
Lat.42°4'N
Long.28°42'W

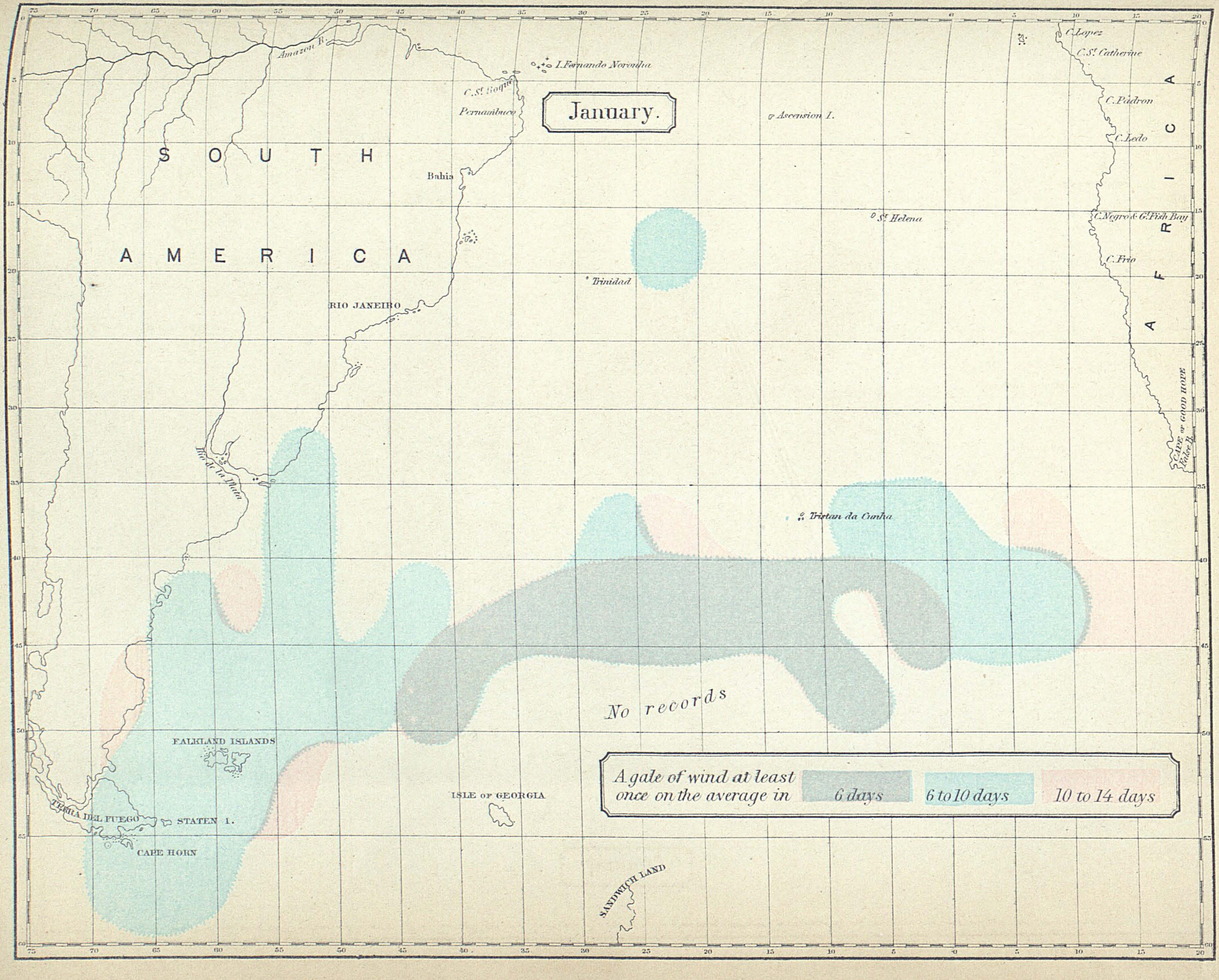


Sept. 18th
Lat.51°6'N.
Long.9°0'W.



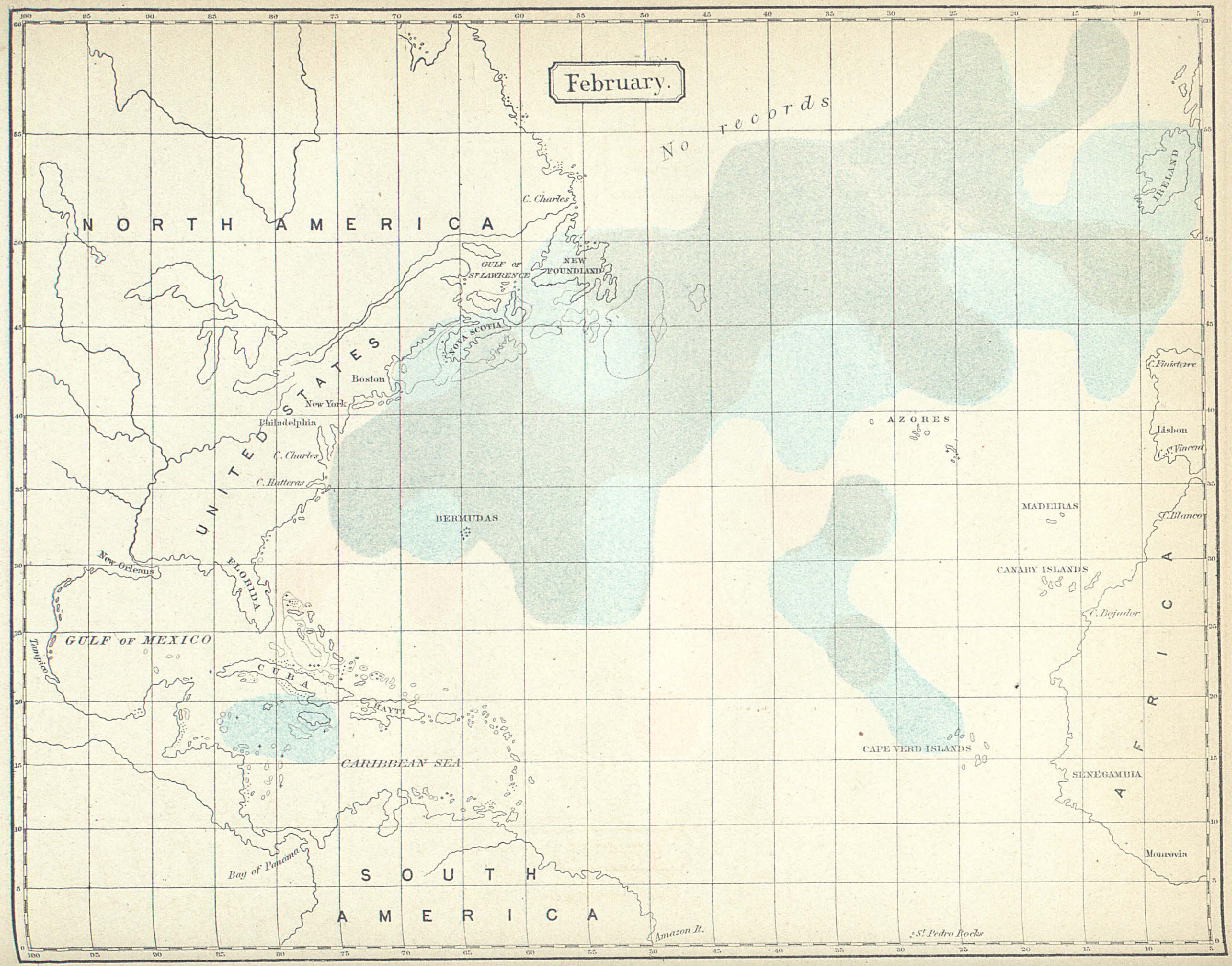
A gale of wind at least once on the average in 6 days — *6 to 10 days* — *10 to 14 days*

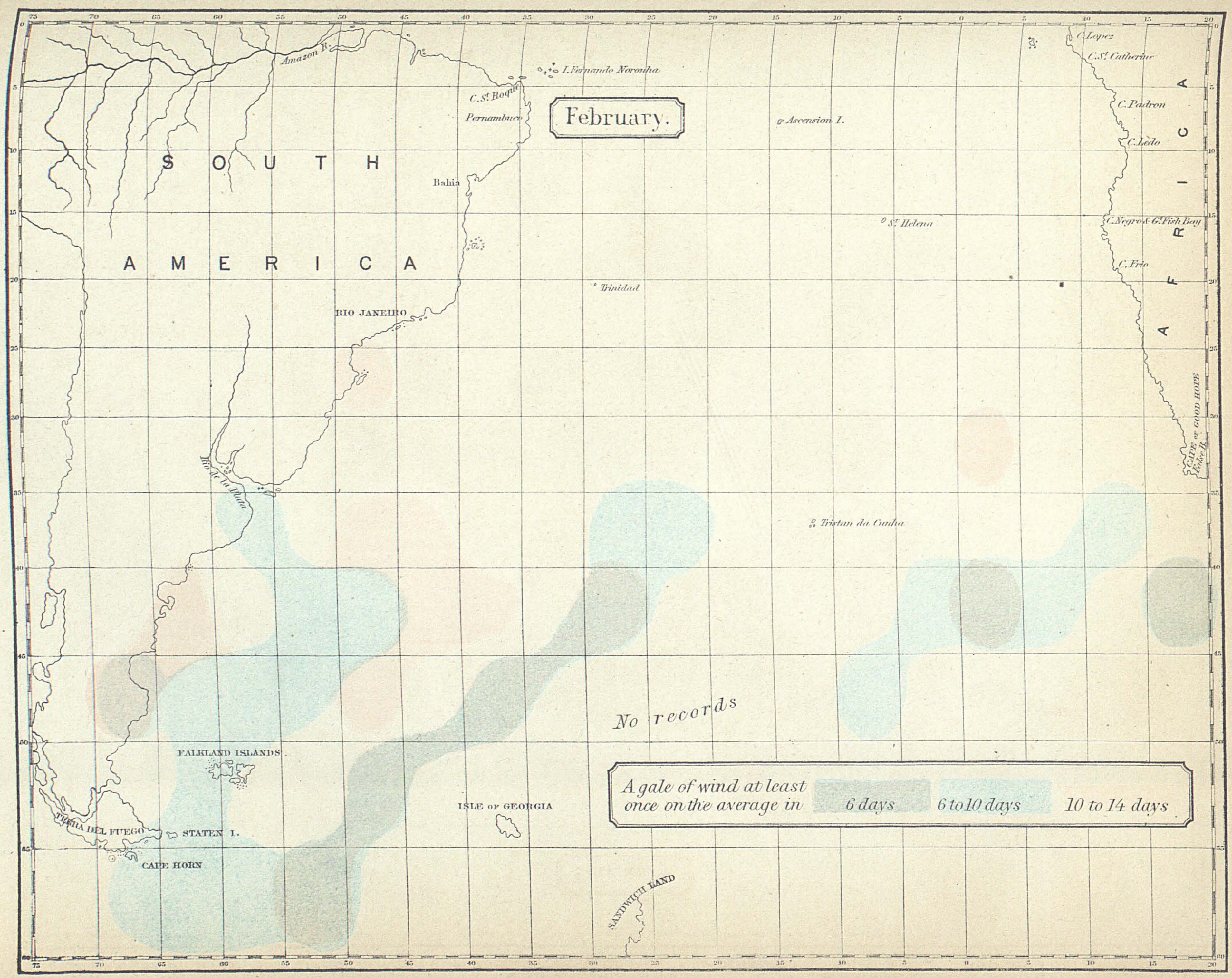




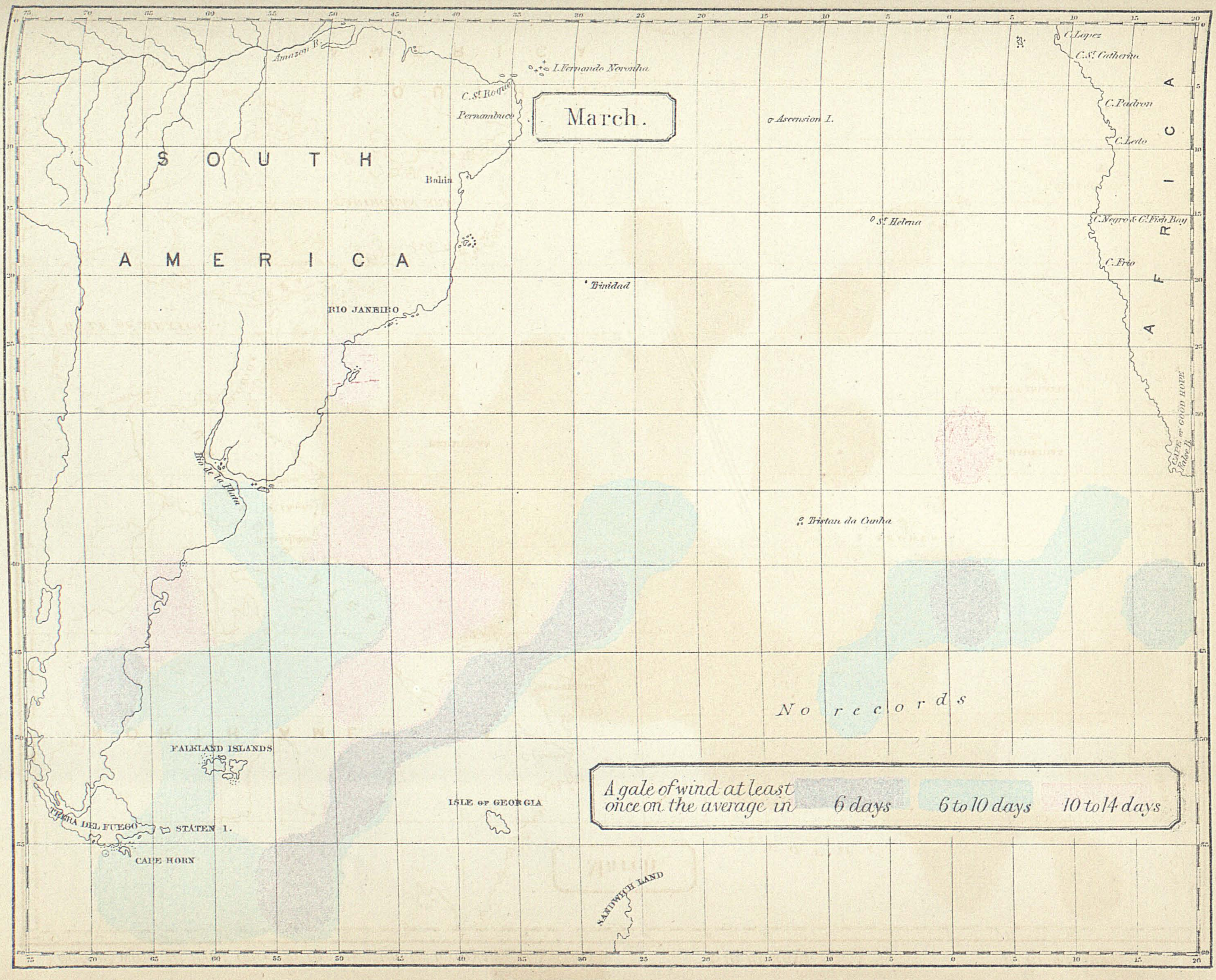
January.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Bahia
RIO JANEIRO
Rio de la Plata
Ascension I.
St. Helena
Trinidad
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE OF GOOD HOPE
False B.
FALKLAND ISLANDS
TERRA DEL FUEGO
STATEN I.
CAPE HORN
ISLE OF GEORGIA
SANDWICH LAND
No records
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

A gale of wind at least once on the average in 6 days — *6 to 10 days* — *10 to 14 days*

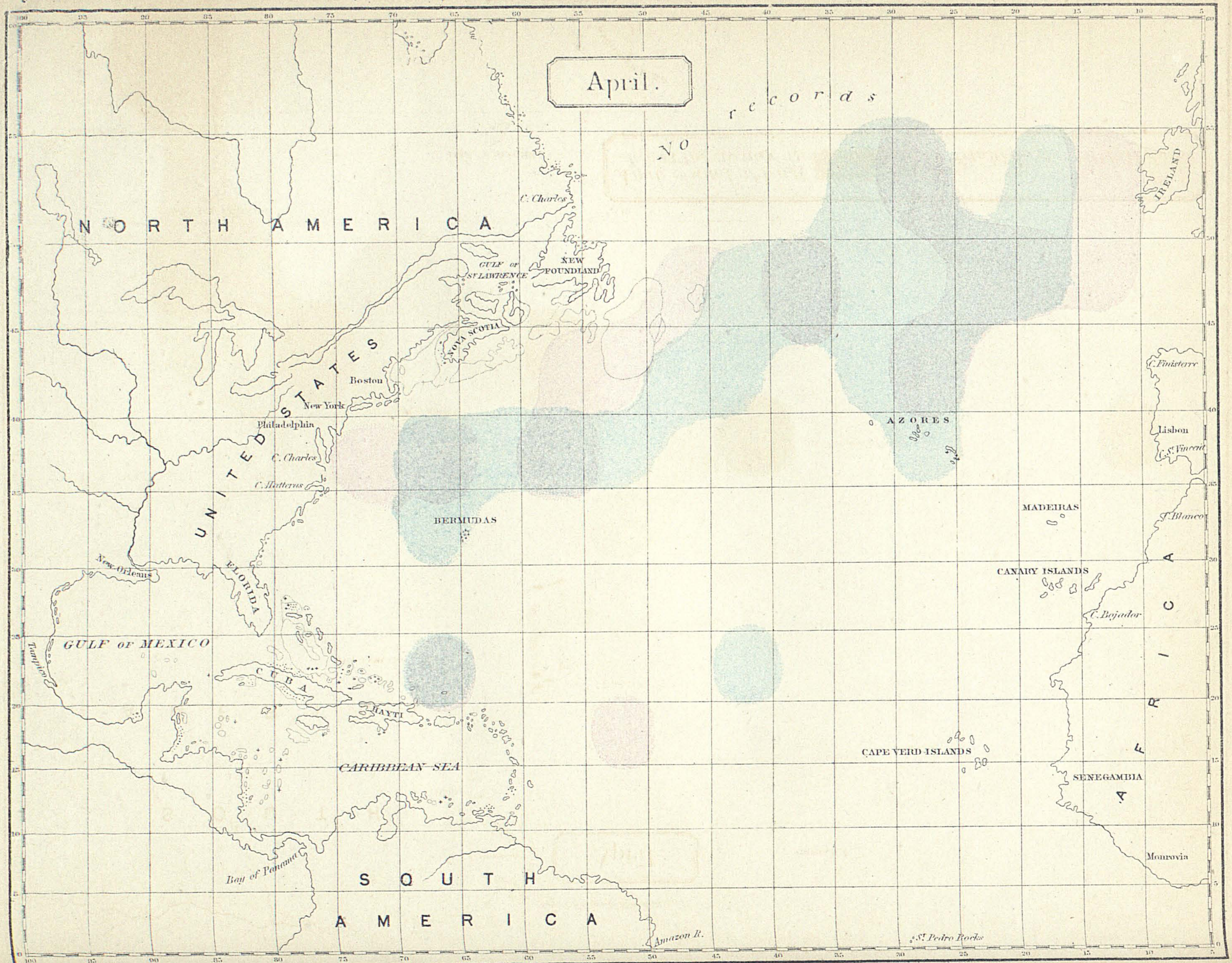


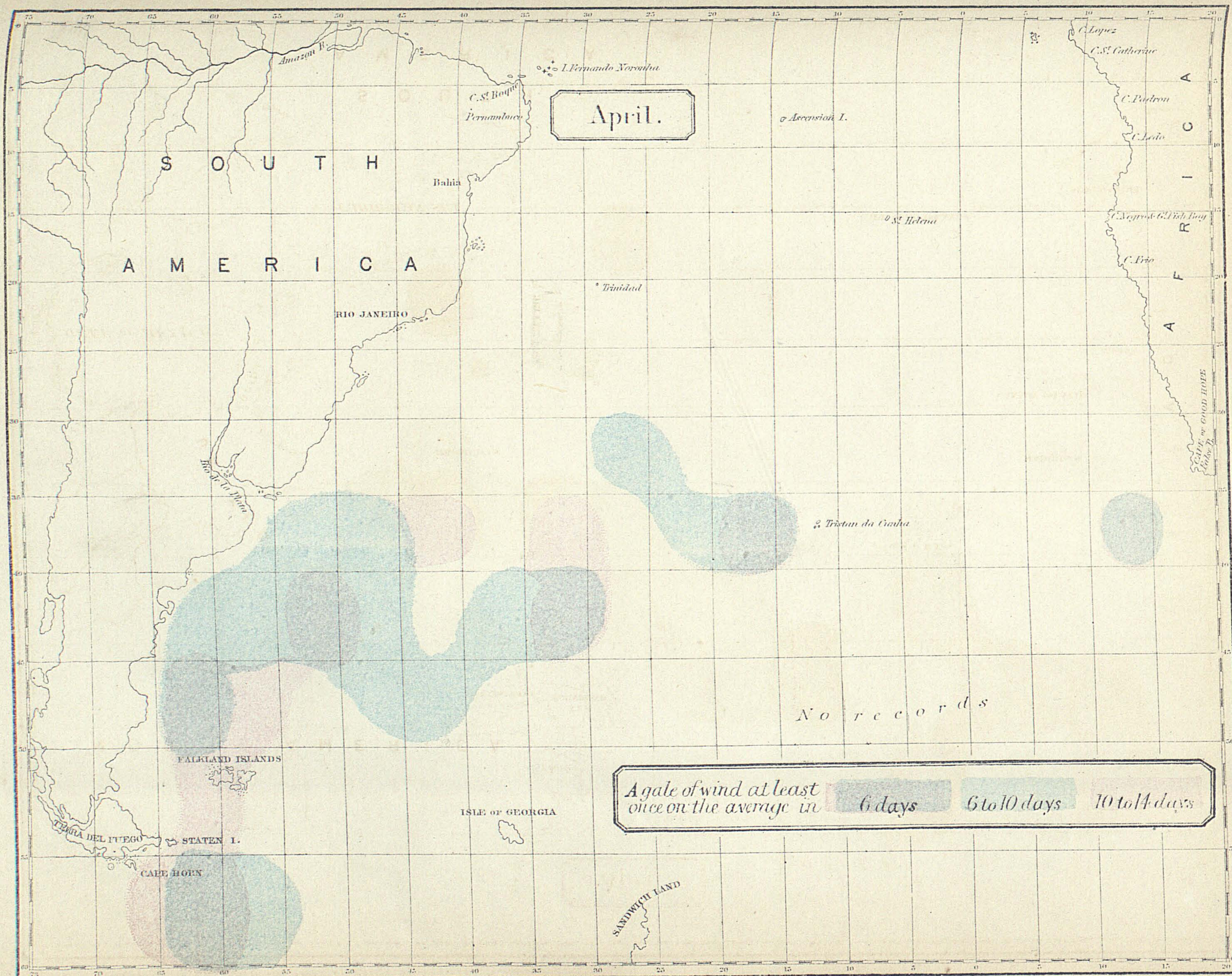

February.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Bahia
RIO JANEIRO
Rio de la Plata
Ascension I.
St. Helena
Trinidad
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE OF GOOD HOPE
FALKLAND ISLANDS
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
ISLE OF GEORGIA
SANDWICH LAND
No records
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

A gale of wind at least once on the average in 6 days — 6 to 10 days — 10 to 14 days

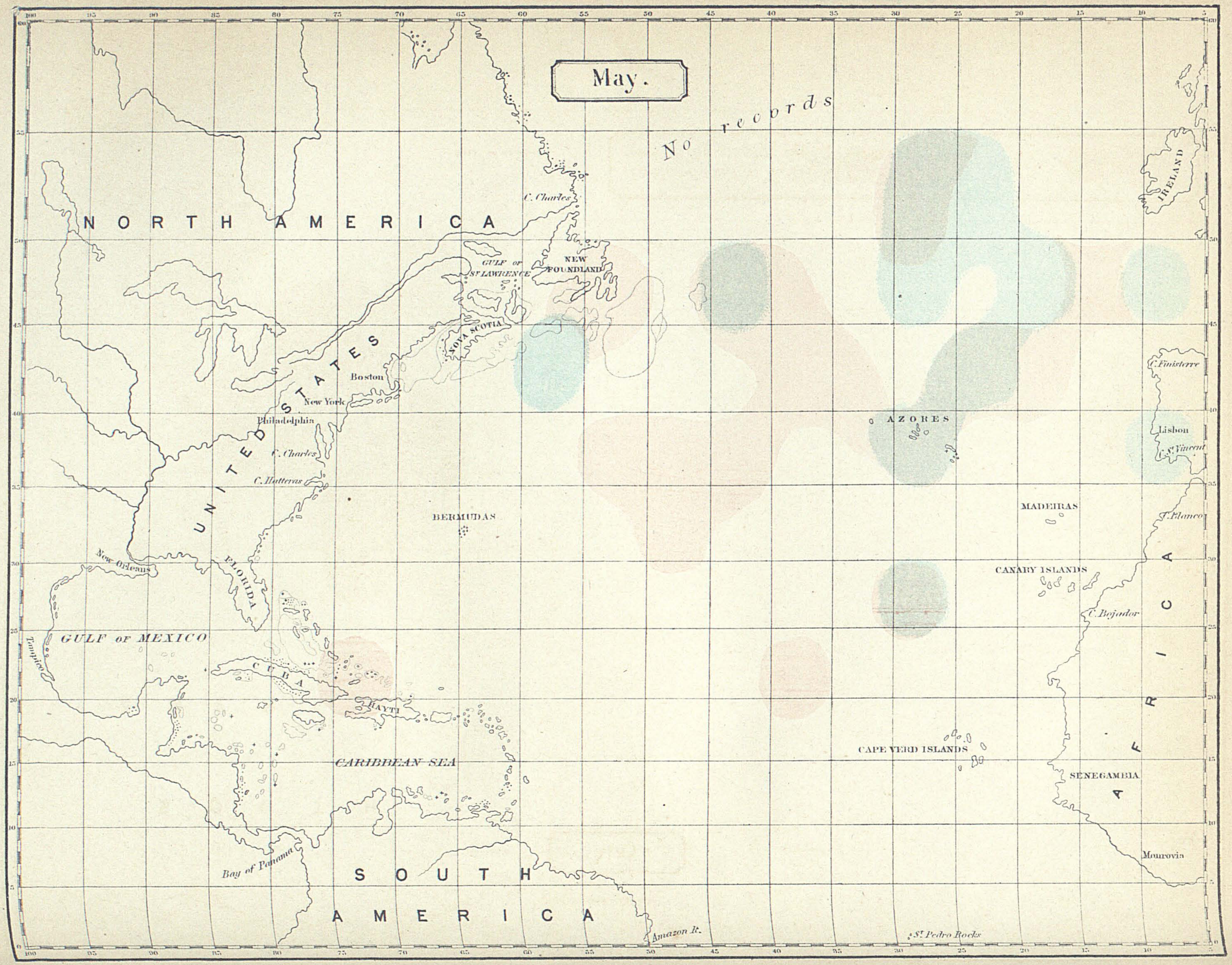

March.
SOUTH
AMERICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Bahia
RIO JANEIRO
Rio de la Plata
FALKLAND ISLANDS
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
ISLE OF GEORGIA
SANDWICH LAND
Ascension I.
St. Helena
Trinidad
Tristan da Cunha
No records
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
AFRICA
CAPE of GOOD HOPE
False B.
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

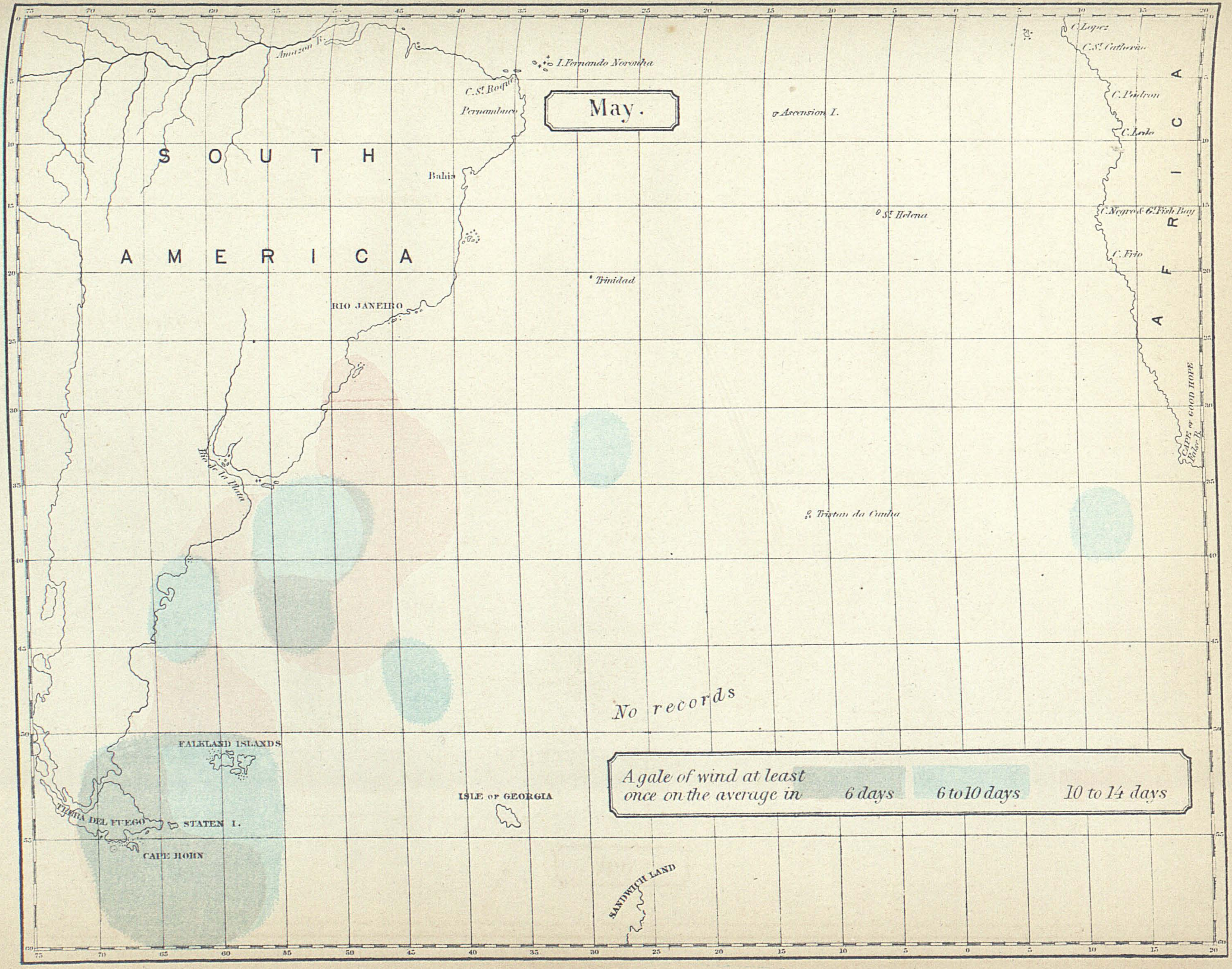
A gale of wind at least once on the average in 6 days   6 to 10 days   10 to 14 days



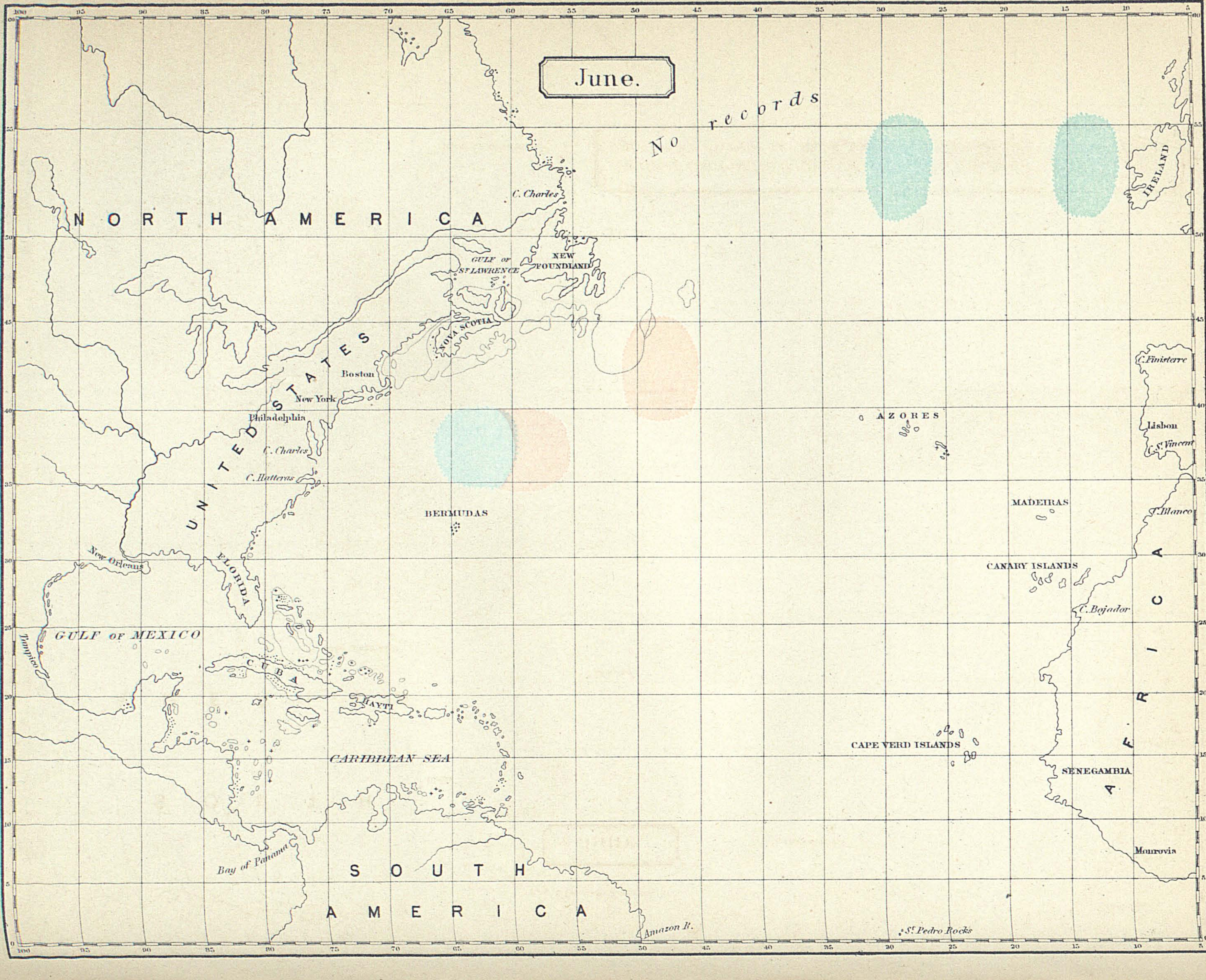

April.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Ascension I.
Bahia
St. Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE OF GOOD HOPE
False B.
No records
FALKLAND ISLANDS
ISLE OF GEORGIA
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
SANDWICH LAND
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

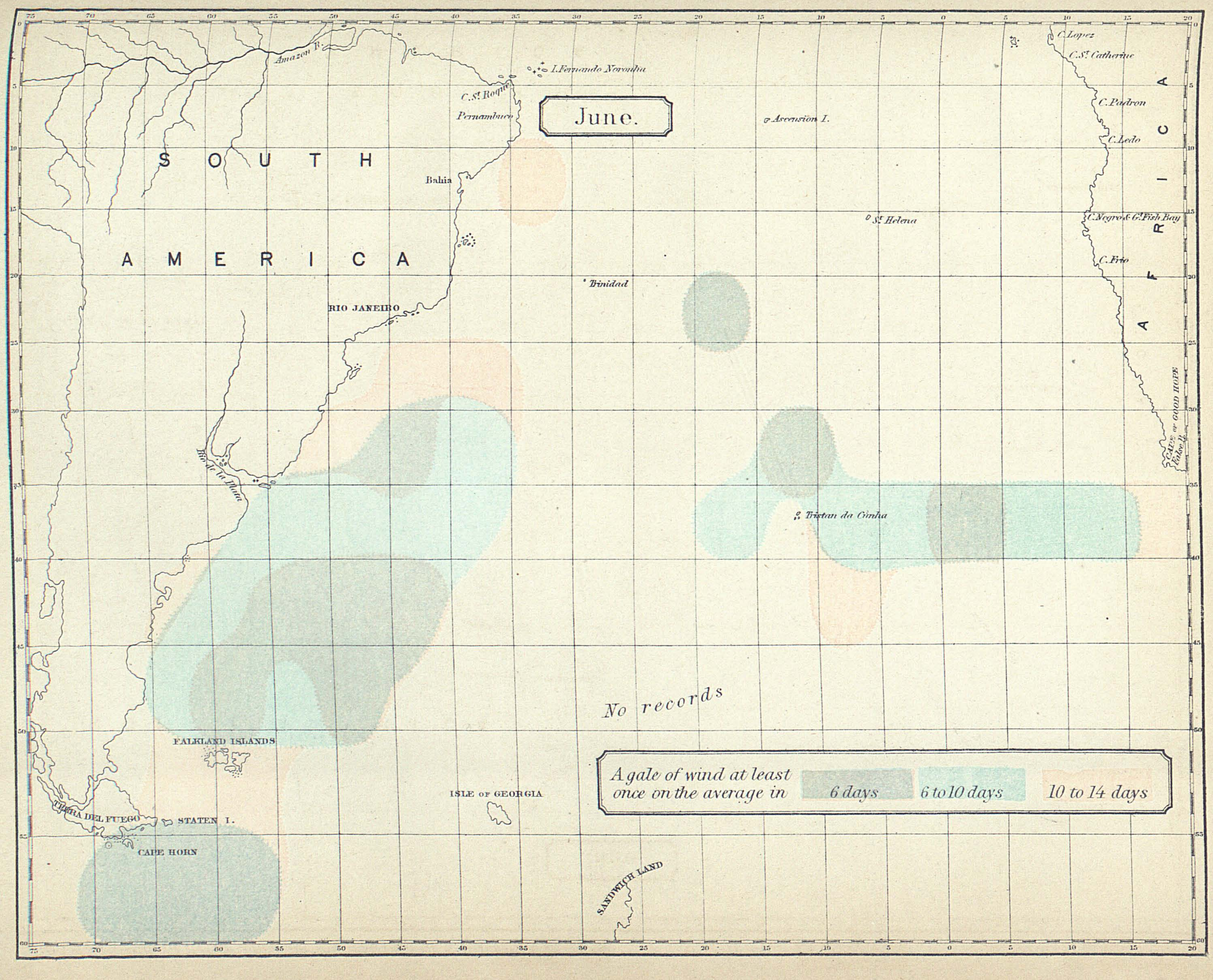
A gale of wind at least once on the average in 6 days — *6 to 10 days* — *10 to 14 days*



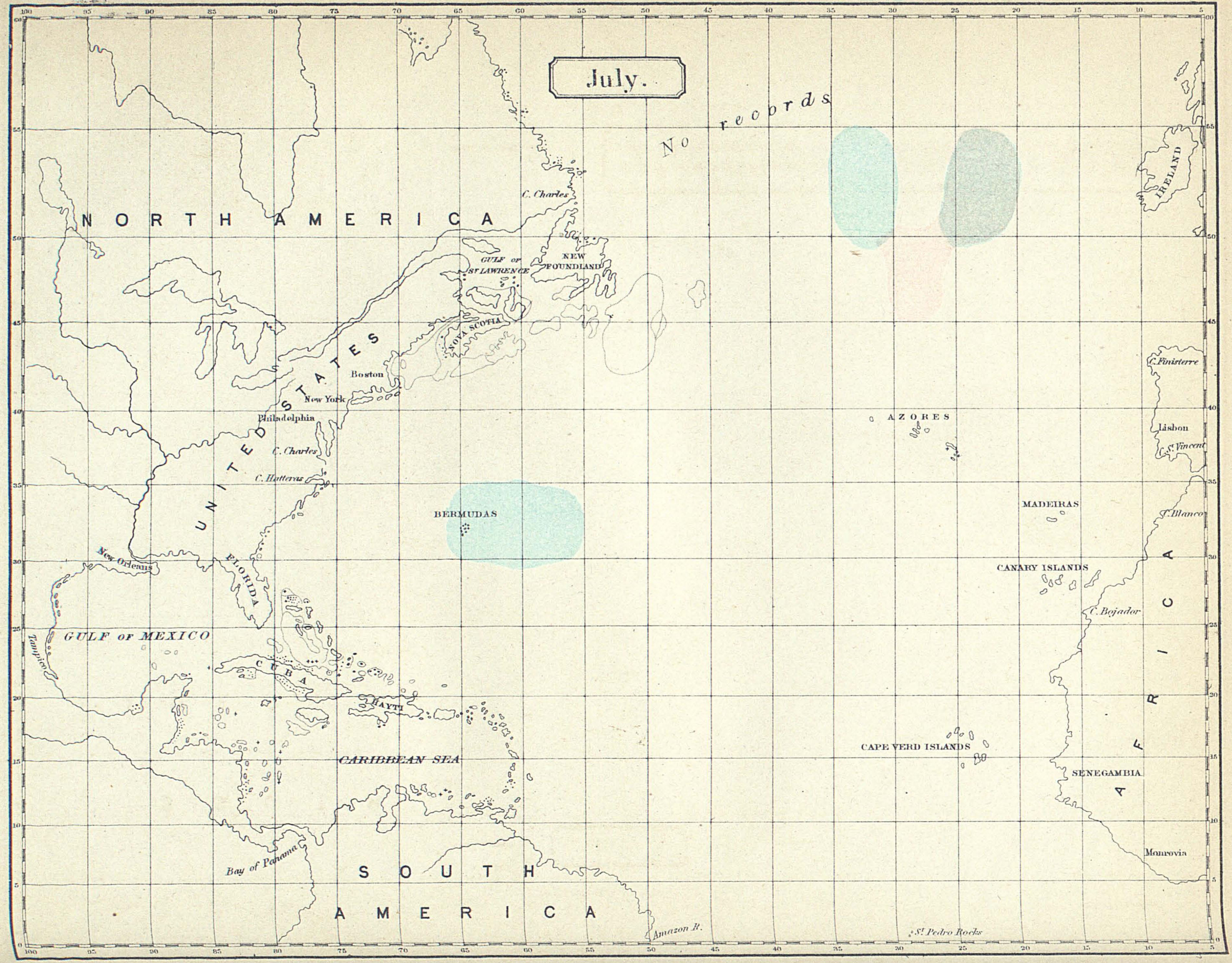

May.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Ascension I.
Bahia
St. Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Negro & Gt. Fish Bay
C. Frio
CAPE of GOOD HOPE
No records
FALKLAND ISLANDS
ISLE OF GEORGIA
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
SANDWICH LAND
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

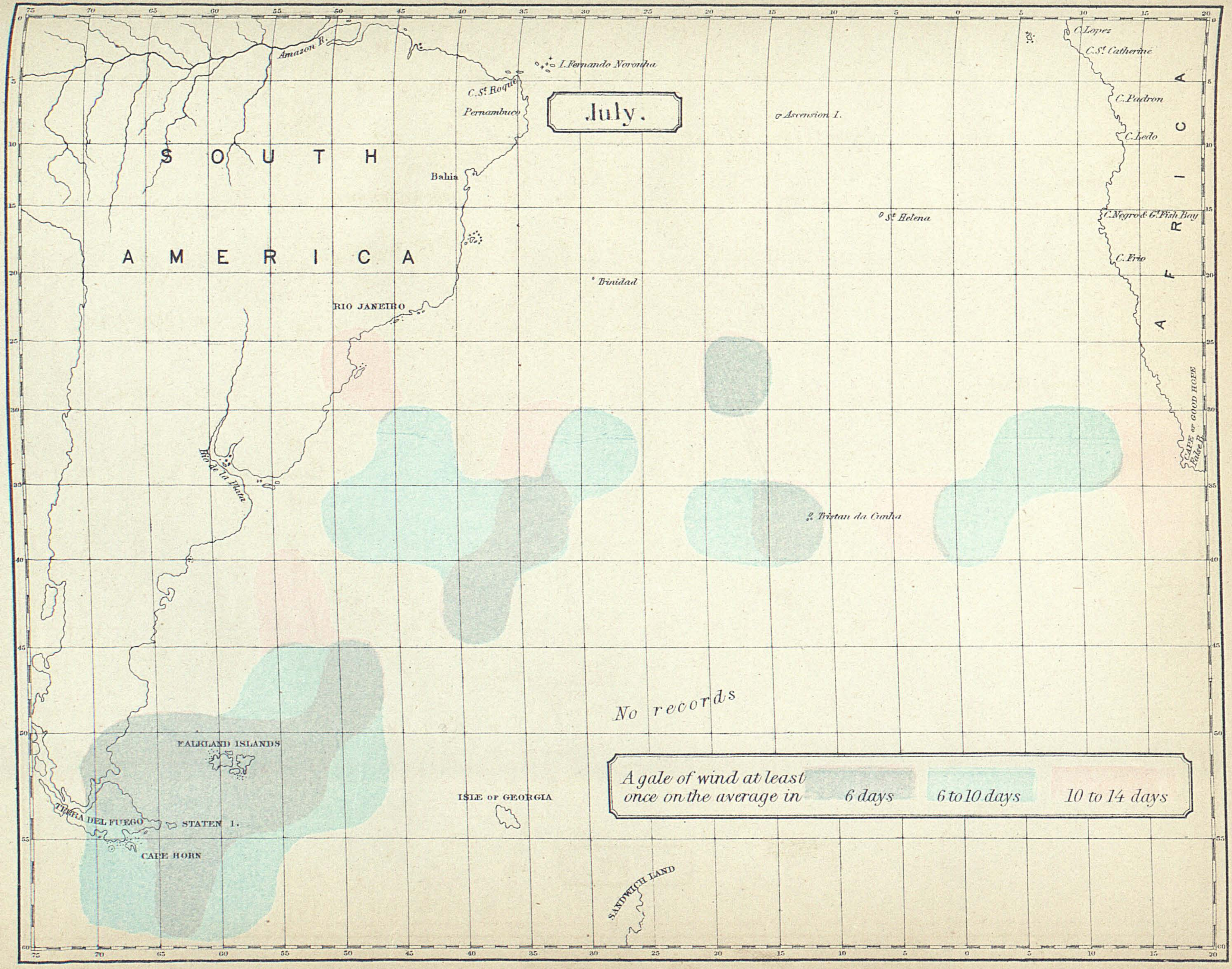
A gale of wind at least once on the average in 6 days — *6 to 10 days* — *10 to 14 days*




June.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Bahia
Ascension I.
St. Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE OF GOOD HOPE
FALKLAND ISLANDS
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
ISLE OF GEORGIA
SANDWICH LAND
No records
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

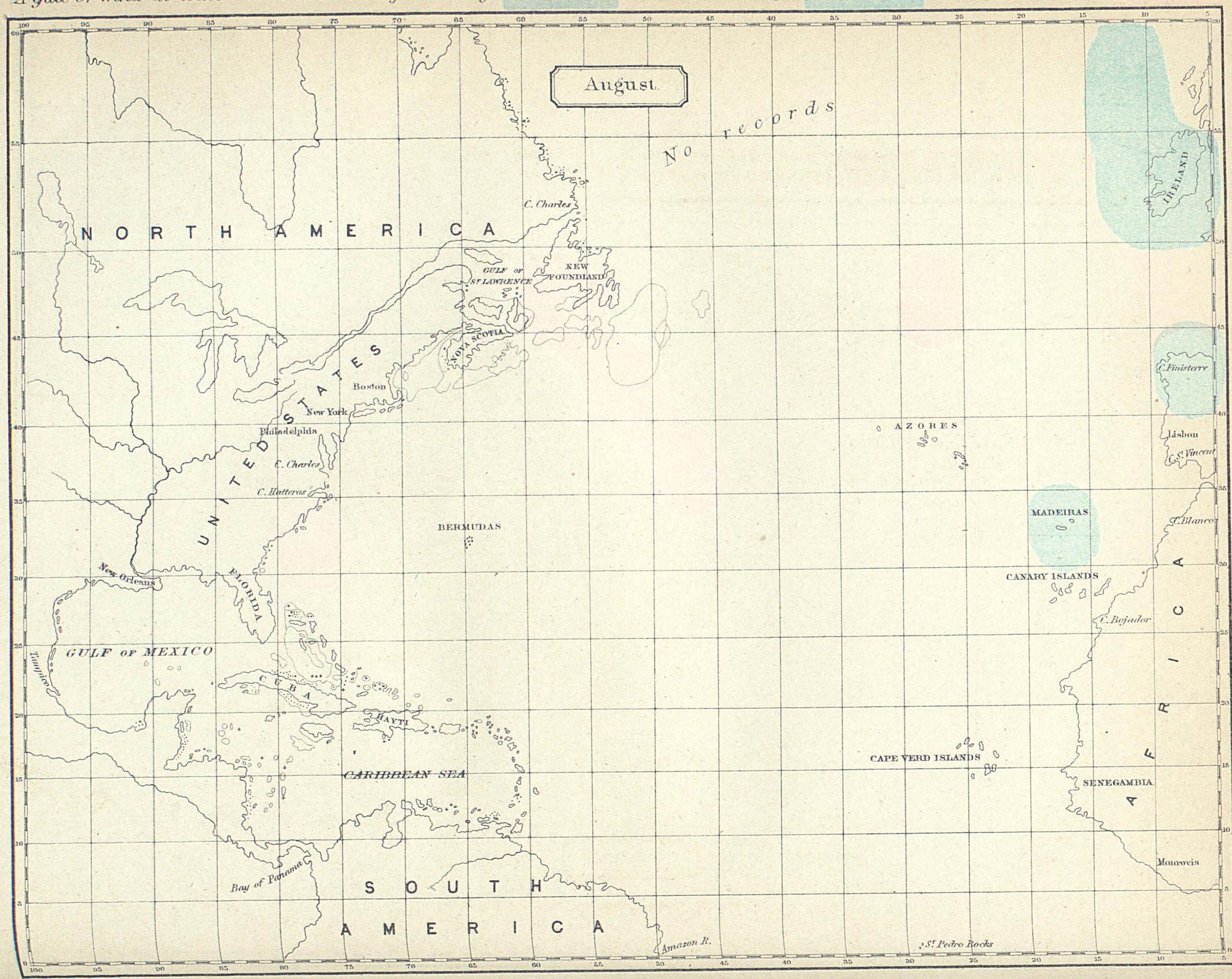
A gale of wind at least once on the average in 6 days | 6 to 10 days | 10 to 14 days

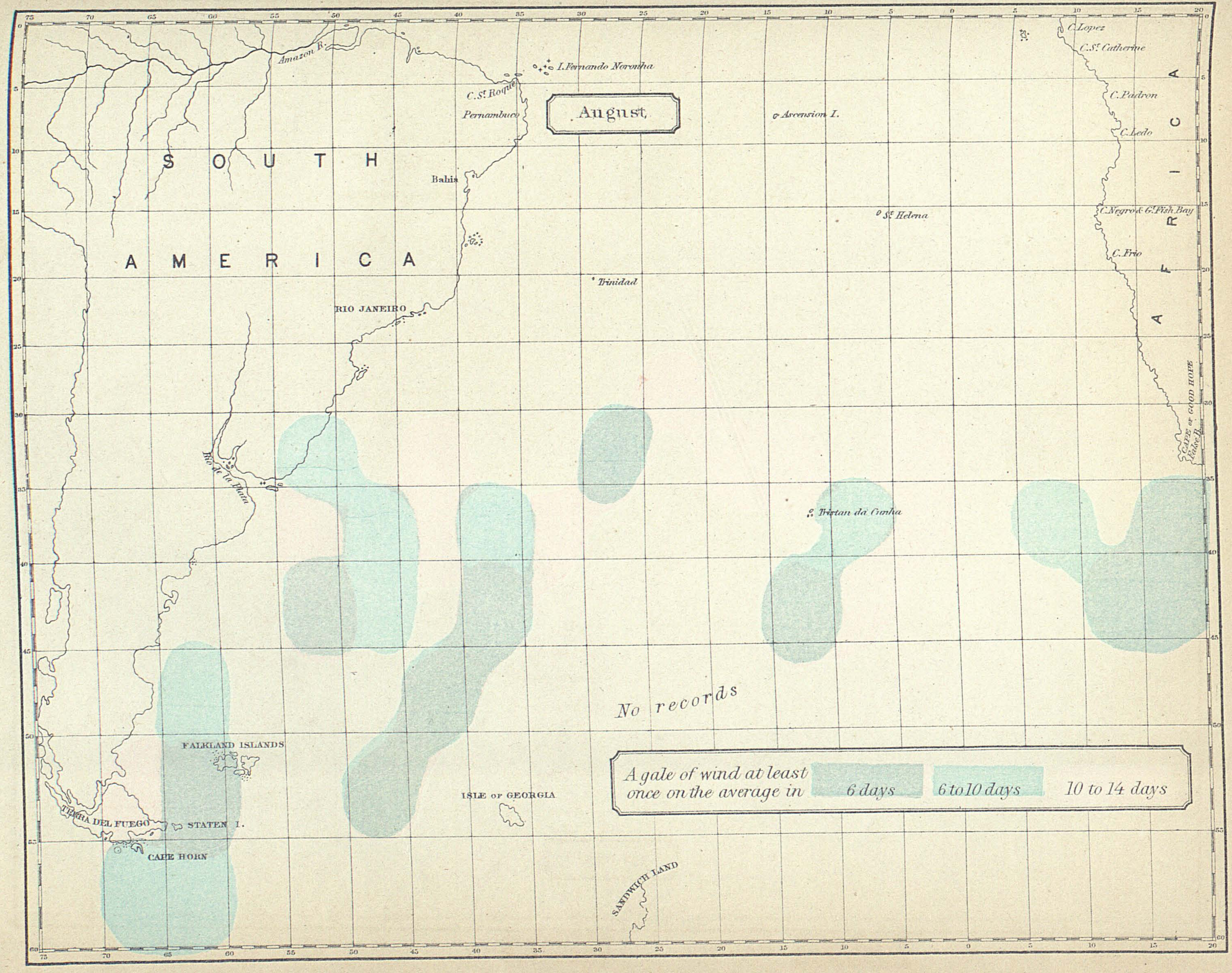




July.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St Roque
Pernambuco
Bahia
Ascension I.
St Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St Catherine
C. Padron
C. Ledo
C. Negro & Gt Fish Bay
C. Frio
CAPE OF GOOD HOPE
False B.
No records
FALKLAND ISLANDS
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
ISLE OF GEORGIA
SANDWICH LAND
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

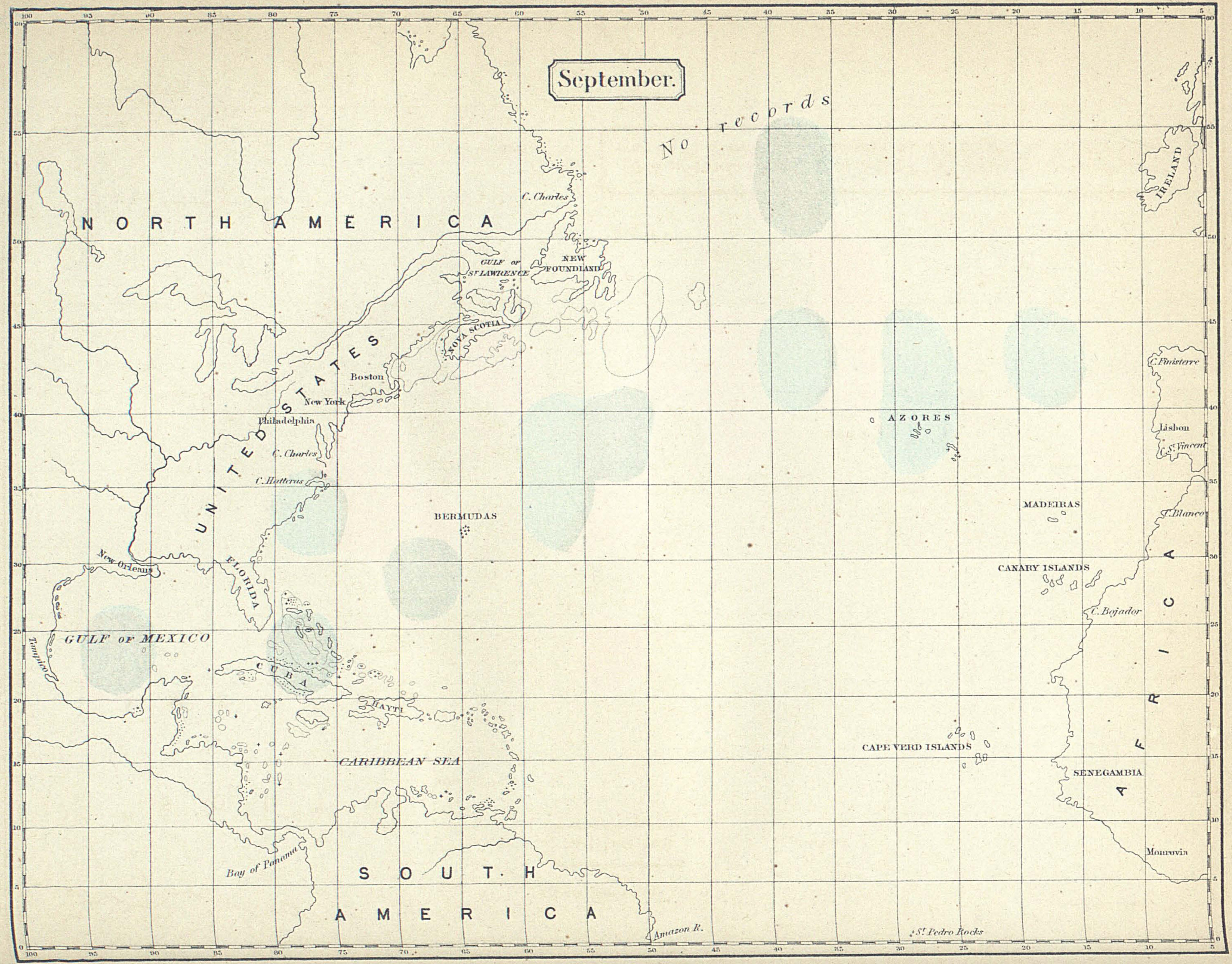
A gale of wind at least once on the average in 6 days *6 to 10 days* *10 to 14 days*

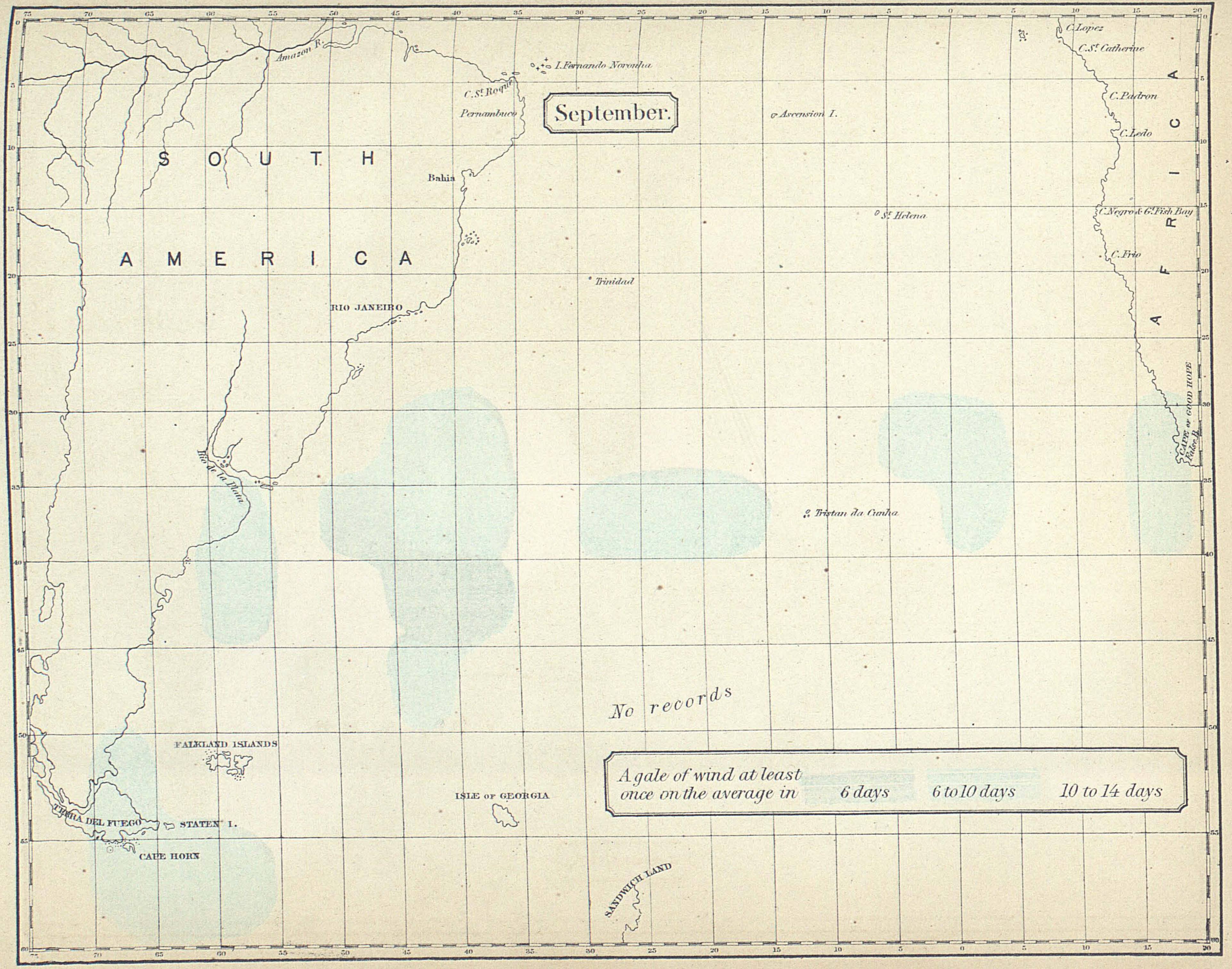




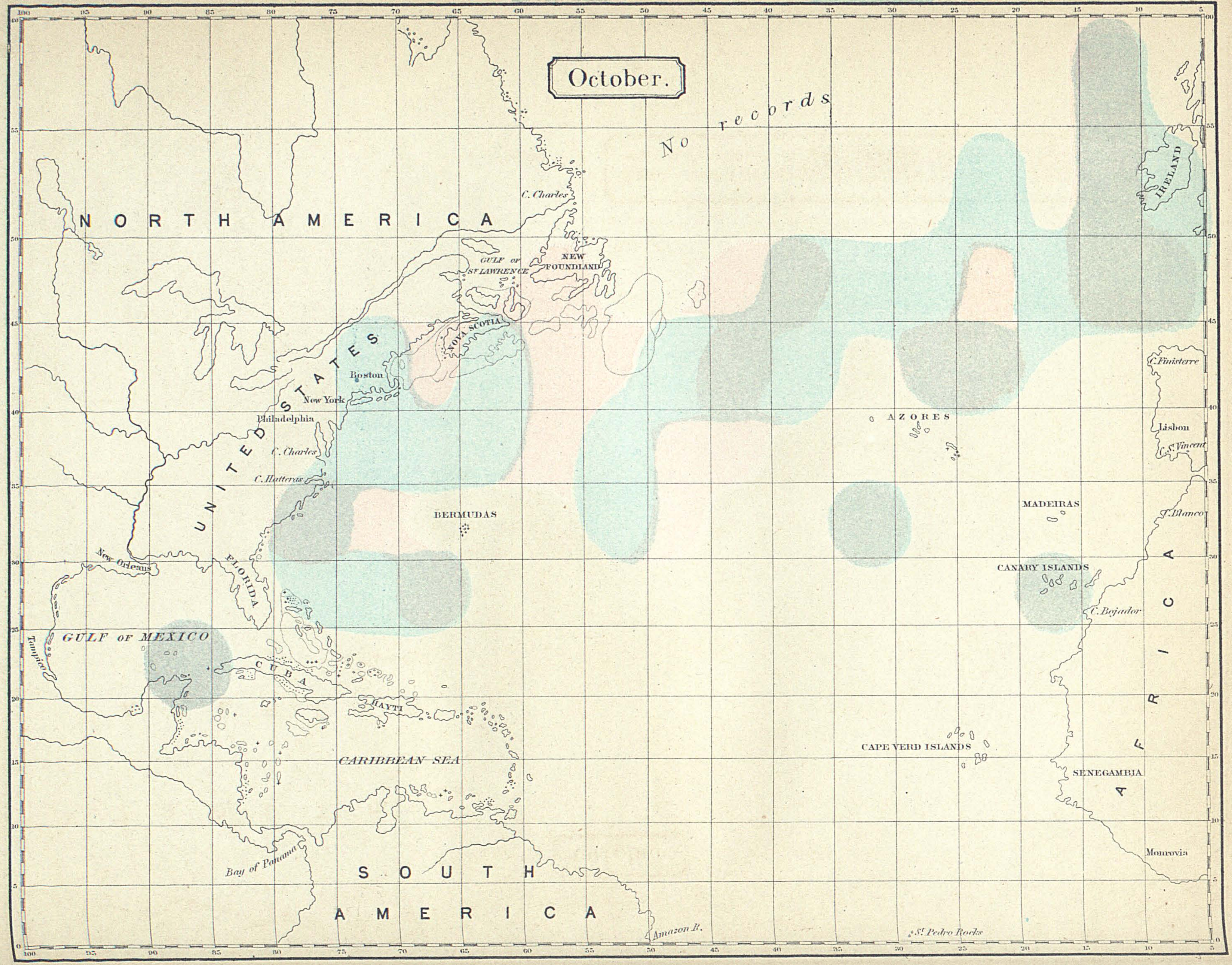
August
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Ascension I.
Bahia
St. Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE of GOOD HOPE
False B.
No records
FALKLAND ISLANDS
ISLE OF GEORGIA
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
SANDWICH LAND
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

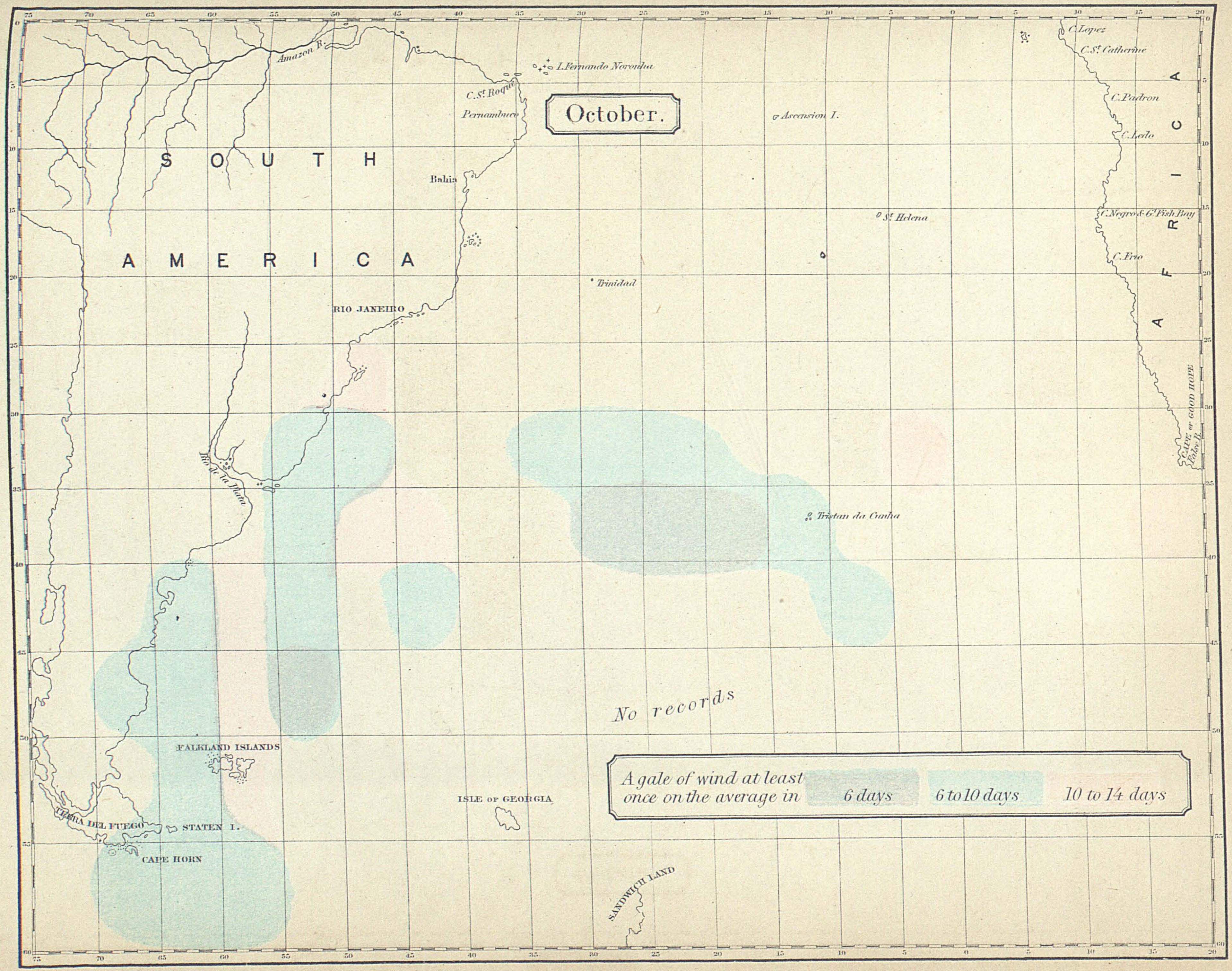
A gale of wind at least once on the average in 6 days *6 to 10 days* *10 to 14 days*




September.
SOUTH
AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Ascension I.
Bahia
St. Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE OF GOOD HOPE
False B.
No records
FALKLAND ISLANDS
ISLE OF GEORGIA
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
SANDWICH LAND
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

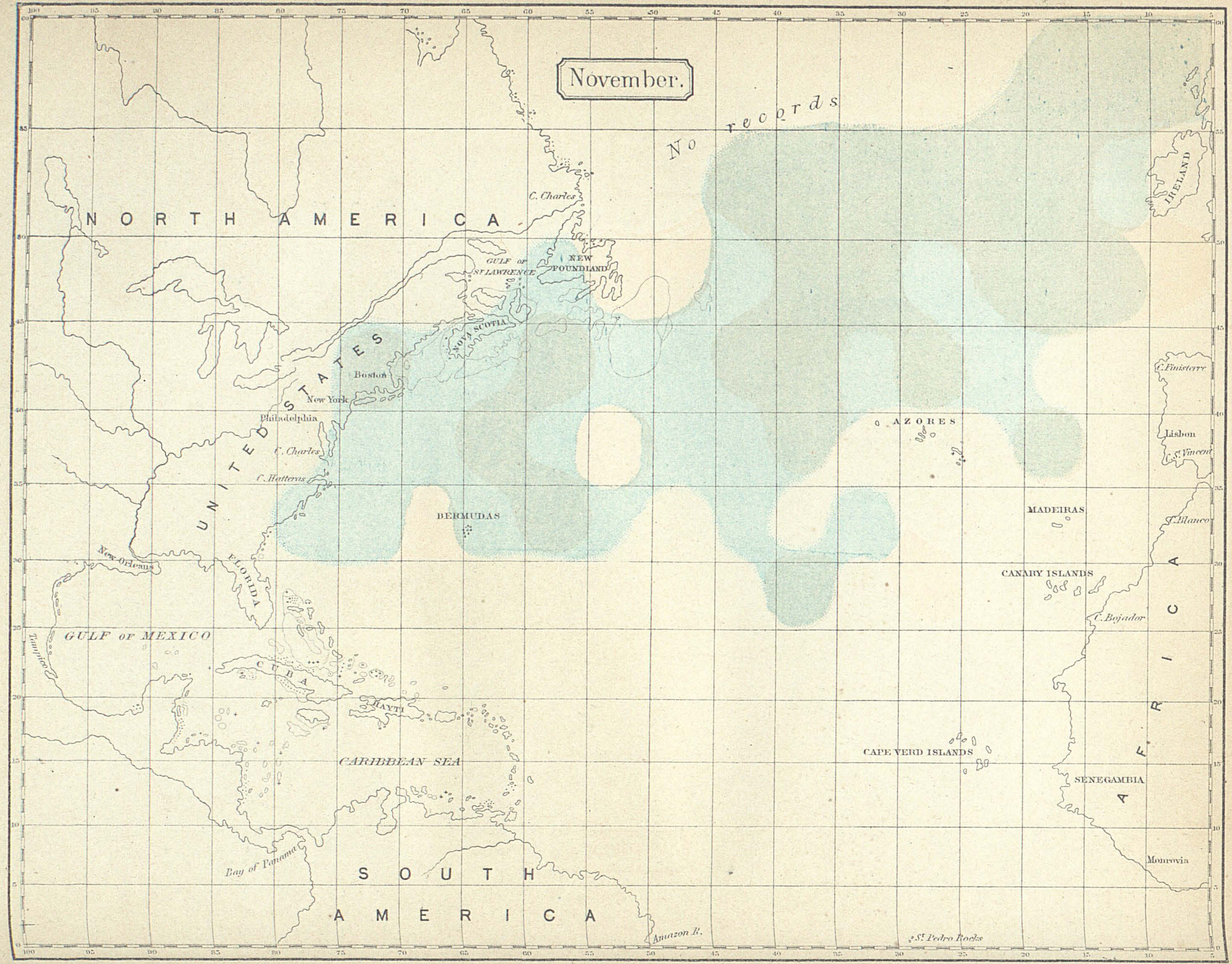
A gale of wind at least once on the average in 6 days — *6 to 10 days* — *10 to 14 days*

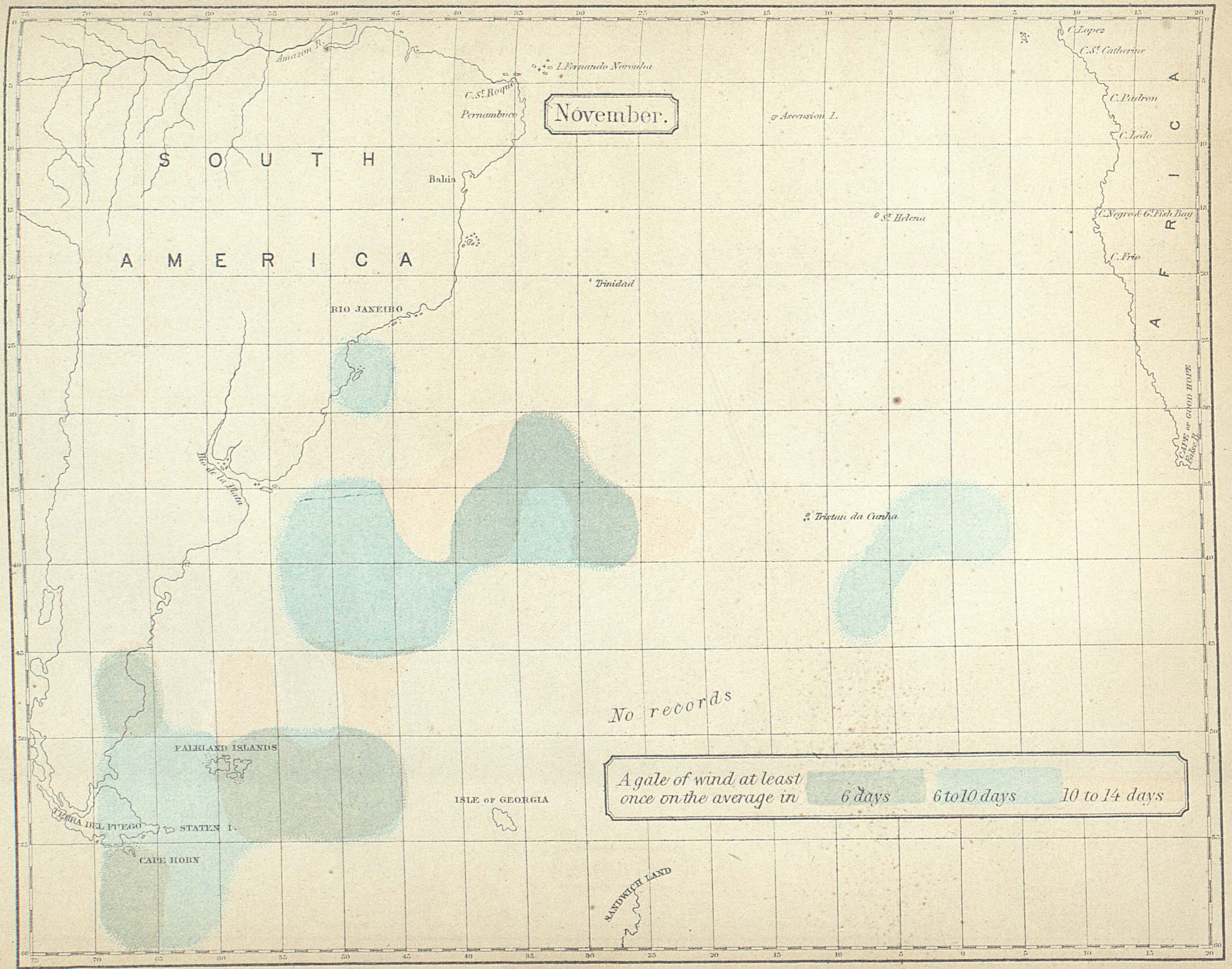


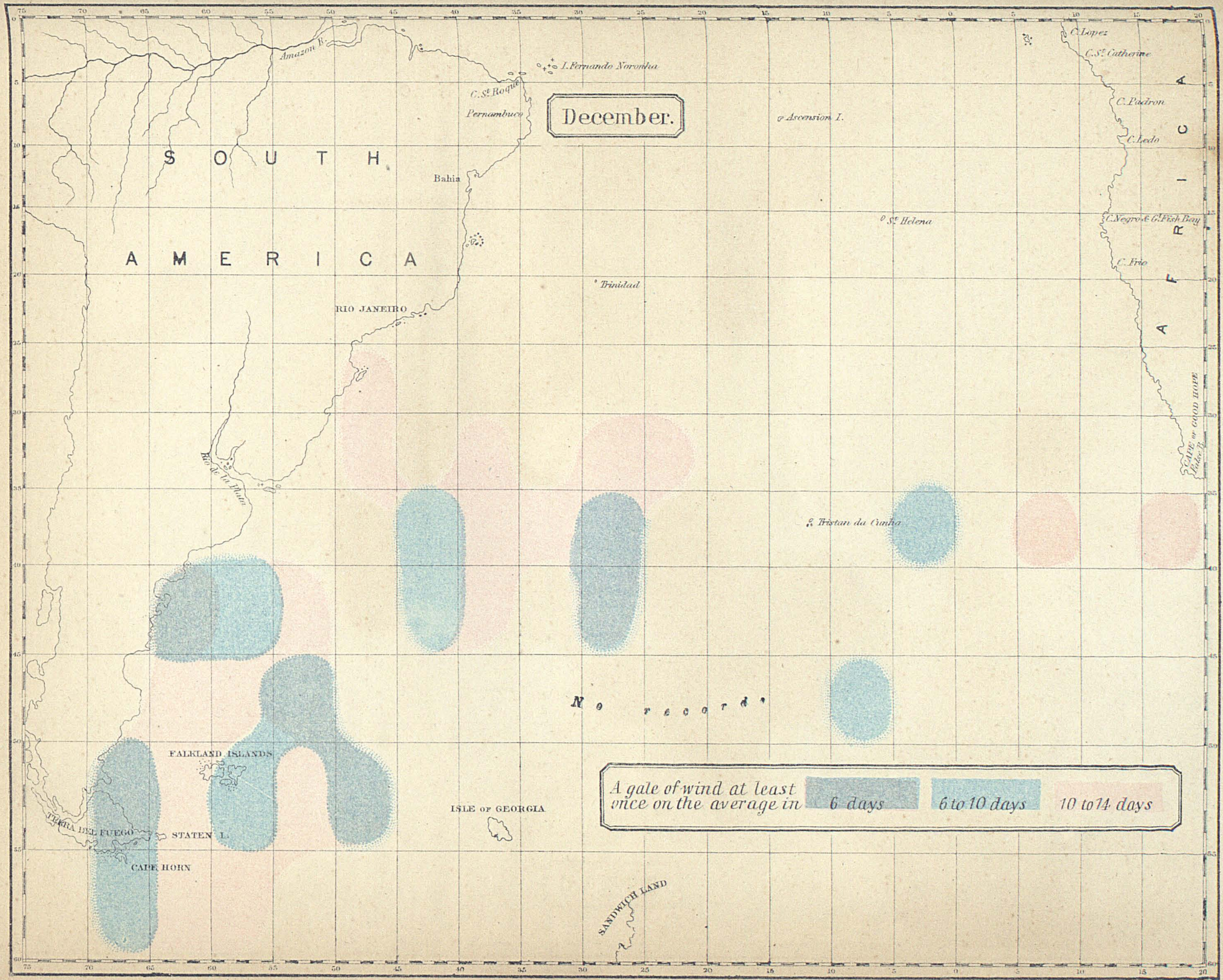


October.
SOUTH AMERICA
AFRICA
Amazon R.
C. St. Roque
Pernambuco
Bahia
RIO JANEIRO
Rio de la Plata
FALKLAND ISLANDS
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
ISLE OF GEORGIA
SANDWICH LAND
I. Fernando Noronha
Ascension I.
St. Helena
Trinidad
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE of GOOD HOPE
False B.
No records
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

A gale of wind at least once on the average in 6 days — *6 to 10 days* — *10 to 14 days*




November.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Ascension I.
Bahia
St. Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE OF GOOD HOPE
False B.
No records
FALKLAND ISLANDS
ISLE OF GEORGIA
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
SANDWICH LAND
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days


December.
SOUTH AMERICA
AFRICA
Amazon R.
I. Fernando Noronha
C. St. Roque
Pernambuco
Ascension I.
Bahia
St. Helena
Trinidad
RIO JANEIRO
Rio de la Plata
Tristan da Cunha
C. Lopez
C. St. Catherine
C. Padron
C. Ledo
C. Negro & Gt. Fish Bay
C. Frio
CAPE OF GOOD HOPE
False B.
No record.
FALKLAND ISLANDS
TIERRA DEL FUEGO
STATEN I.
CAPE HORN
ISLE OF GEORGIA
SANDWICH LAND
A gale of wind at least once on the average in
6 days
6 to 10 days
10 to 14 days

A gale of wind at least once on the average in 6 days — 6 to 10 days — 10 to 14 days