H. L. CRUTCHER

CLIMATOLOGY by MACHINE METHODS for NAVAL OPERATIONS, PLANS, and RESEARCH

PREPARED FOR THE OFFICE OF
CHIEF OF NAVAL OPERATIONS
AEROLOGY BRANCH

WASHINGTON, D.C.
MARCH, 1953

3-17-53-800

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INTRODUCTION

In order to make intelligent decisions regarding any operation, all factors which affect the operation must be considered. Weather is a factor which may have a strong influence upon all phases of naval operations. To produce an appraisal of the weather factor in terms of operational requirements and limitations, a careful analysis of the best available climatic data is necessary. In view of this premise, efforts are being made to increase the amount and reliability of climatic information to be placed at the disposal of the aerologist. This volume represents a partial result of these efforts.

CHAPTER I.

CLIMATOLOGY

A. CLIMATE

The governing factor in the world's weather is the energy received by radiation from the sun. Because the earth is inclined 23 1/2° from the vertical to its plane of revolution around the sun, the angle at which the sun's rays strike a location on the earth varies during the year, causing a corresponding variation in the amount of solar energy received. Latitudinal changes in weather from season to season at any particular location result from the variation in the reception and retention of the sun's energy. The ancient Greeks recognized this association and actually used their word for incline, "Klima", to designate the change of seasons and to signify the history of their weather. Today we use the equivalent word in English, "Climate", for the same purpose.

A rough understanding of the winter-to-summer ranges of climate has served man to advantage since long before he had means for preparing specific climatological records. Besides shaping such fundamentals as his habits of dress and shelter, the march of the seasons dictated his tribal migrations, controlled his food supply, governed the beginnings of his agriculture; and folklore is rich in references to medicine men and seers and chieftains elevated to positions of importance because communities of men believed they could foretell the hardships and blessings of coming seasons. Scientific literature, beginning with that of early Greece and continuing today, abundantly attests to the importance, for many of the needs and actions of civilized life, of an understanding of the nature and variations, the extremes and ranges and persistences, and above all the patterns of recurrence and the dependability, of climate.

Until the invention of meteorological observing instruments and the systematization of efficient and uniform methods for recording weather observations, anything approaching a scientific study and analysis of climate was of course practically impossible; and it is only during the last century that records sufficiently widespread and of really usable detail have been made. A workable collection of such records is now available, however, to which the Navy has direct access and which it is the purpose of this statement to describe to Naval officers and men so that they may take appropriate advantage of it.

Because of the complexity of climate - the variety of its many elements, each one with its own variation pattern - and because also of the tremendous number of data that must be considered in any worthwhile analysis or predictive interpretation of it, the only sensible way to deal with it is by tested and proved statistical methods. Even with these, however, the amount of data involved in any major climatological problem is so great that solution by manual means (pencil and scratch-pad) is impracticable, so that the so-called mechanized or punch-card statistical method must be used.

B. DEVELOPMENT OF THE PUNCHED CARD METHOD IN CLIMATOLOGY

When a situation similar to the above developed in the handling of U. S. census data for 1880, because by manual methods it was no longer possible to analyze and correlate the mass of material gathered in one census before the time for taking another would arrive, punched cards and the machinery to handle the data were devised. Since that time the punched card medium has served continuously and efficiently as a major statistical tool in government and industry in an ever-widening area of application.

The first important application of punched cards to weather data was in the analysis of weather over the oceans. The preliminary task of bringing geographic or chronological order out of the mass of miscellaneous ships' reports is indeed formidable when attempted by manual means. This first attempt at adapting machine methods to the analysis of weather data was made in 1896 by the U. S. Hydrographic Office, in the preparation of climatological data for pilot charts, and in the sorting and filing of data chronologically for the preparation of historical synoptic charts.

About 1920 the Meteorological Office of the British Admiralty began the first successful use of punched cards in extracting meteorological data from ships' logs, processing the cards through the machines to get means and wind roses for 5- and 10-degree squares of ocean surface.

In 1922, the Dutch Meteorological Institute borrowed some of the British card files, and, with these and their own cards, began making their own analyses of ocean weather; Norway and France soon followed suit. By 1927, the Deutsche Seewarte (German Marine Unit) embarked similarly on the analysis of marine climates by the punched-card machine methods.

In the United States, the birthplace of the punched card method, there was continuing interest in the possibilities of mechanical analysis for problems of weather statistics. However, no funds were available for the testing of machine techniques in climatology until the advent of the CWA (later WPA) in the middle thirties.

In 1934, a CWA project under the direction of the Weather Bureau was initiated to prepare a long-needed climatic atlas of the oceans, which was published in 1938. Work was started by the Weather Bureau in 1936, with WPA funds, on punched card compilation and analysis of 20 million surface and upper air (pilot balloon and radiosonde) observations made at about 400 airway weather stations. From these cards, a number of publications were produced, including "Airway Meteorological Atlas", "Normal Flying Weather for the United States", "Temperature Frequencies in the Upper Air", and "Low Visibility Airport Wind Rose Summaries".

Increased demands for weather statistics as a result of World War II gave an impetus to the punched card program. The planners of bombing missions, amphibious landings, task force strikes, and many other operations desired such information as: When will the weather be most favorable at this particular beach for all phases of a complicated landing operation for handling the planes, landing craft, transports, armored vehicles, and personnel? For what temperatures should lubricant and gasoline specifications be calculated? What surface weather and sea conditions make this transport route better than that? What temperatures and humidities will be encountered which will create food-storage problems? Providing answers to these and many other planning problems involved organizing and summarizing quantities of weather data.

We had insufficient prewar information about many parts of the world that now suddenly became important to the national security. We had no information at all about some. Much of the world's "present weather" was blacked out for us. The existing routine summaries were inadequate to answer operational questions. Development of vital forecasting aids required analysis and correlation of climatic information of parts of the world from which weather observations were being obtained with that of areas from which weather observations were not available.

Punched cards and machines proved their value in accomplishing these tasks in much shorter time than would have been possible manually. Early in 1942 the WPA punched card work sponsored by the Weather Bureau was stopped and the entire organization placed at the disposal of the armed forces to help answer some of the questions about weather. The Weather Bureau machine installation, working with Army and Navy funds, together with installations created and supported by the Army Air Force, punched and summarized some 20 million cards prepared from domestic and foreign observations made at weather stations operated by the military services throughout the world. By the end of the war our punched card library contained about 80 million punched cards.

Since 1945 the collection of weather data, punching it in cards, and the increasing capabilities of machines for processing the cards have rapidly expanded the potentiality for producing valuable climatic information. The rest of this pamphlet is devoted to describing (a) this relatively new technique for extracting this information from great quantities of observed data, (b) what climatic records are available to the Navy, (c) the methods by which they may be exploited, and (d) the form in which information may be presented to the Aerological Officer as an aid to answering problems encountered in day to day duties or in preparation for a specific mission.

CHAPTER II.

PUNCHED CARD MACHINES AND PROCESSING OF WEATHFR DATA

To a casual observer of machines compiling weather data, the most impressive operations are the electric sorting, accounting, and computing machines, just as to visitors in a machine shop the operation of large machines, punch presses, milling machines and various types of drills command greatest interest. The punched card is likely to go unnoticed, in the same manner as are the tools and jigs and dies of manufacturing plants. To one interested in the details of operation, however, these seemingly negligible details hold a very real importance. For, just as the forms of dies and jigs determine the shape of a finished manufactured product, so the punched cards control the computing machine and cause it to produce accurate and complete analyses and statistical reports.

A. DESCRIPTION OF PUNCHED CARDS

Punched cards for weather data use are standard IBM cards, 3 1/4 inches wide and 7 3/8 inches long, made of special paper manufactured to strict specifications. Figure 1 illustrates, at actual size, a card in which a marine weather observation has been punched. The cards are divided into 80 columns in each of which holes 1/8 inch long and about 1/16 inch wide can be punched in twelve different vertical positions. In the ten lowest positions of each column, numbered from 0 to 9, weather data observed in numerical units or 10 symbols are recorded. The upper two or OVERPUNCH positions are used for supplementary information. Immediately above the "0" row is the "x" overpunch, used to reduce the number of columns necessary to record certain weather elements. First, the "x" overpunch position provides for explanatory information about the data recorded in the column or columns directly below to eliminate the need for additional columns which would be rarely used. For example, instead of assigning 3 columns to temperature or wind speed to permit the representation of the relatively small number of observations where a value of 100 is reached or exceeded, two columns suffice if the "x" overpunch in column 40 (for temperature) or 45 (for wind speed) is used to indicate that 100 must be added to the values punched in the spaces representing numerical values. In the same way, negative temperatures may be indicated by punching the "x" overpunch in column 39 (see Fig. 1). Second, the "x" overpunch provides the 11th position to allow recording, in only one column, weather data for which 11 possible observing classes exist. The 11 classes of total cloud cover, zero to ten-tenths, can be recorded in one column by punching the "x" overpunch, when the sky is overcast. The 12th punching position, the "y" overpunch, is infrequently used. Since it is mainly for the purpose of control of machine operation rather than representation of weather data, it is not discussed here.

Punching the observed data into cards, the only large-scale manual operation involved, is accomplished on a KEY PUNCH. This has a carriage which holds the card as it is being punched and a keyboard of 12 punching keys, one for each of the 12 columnar positions, 0-9, x, and y. If it is desired to punch a number 6 or 6th code symbol in the column, the number 6 key is depressed. The hole will be punched in the column of the card positioned under the punching dies. As each column is punched, the carriage automatically advances the card from right to left, positioning the next column under the dies. This action is exactly similar to the automatic spacing of a typewriter carriage after a single letter is typed. With two additional keys, a carriage release and a columnar space key, card movement through the punch can be controlled manually.

It will be noted in Fig. 1 that the punched holes have cut out not the numbers they are intended to indicate but the blank spaces immediately below the numbers. This hole-position, which means nothing about the mechanical exactness of the punch itself, is within the accepted printing tolerance for the cards, which allows a variation ranging between the number-space and the blank immediately below it.

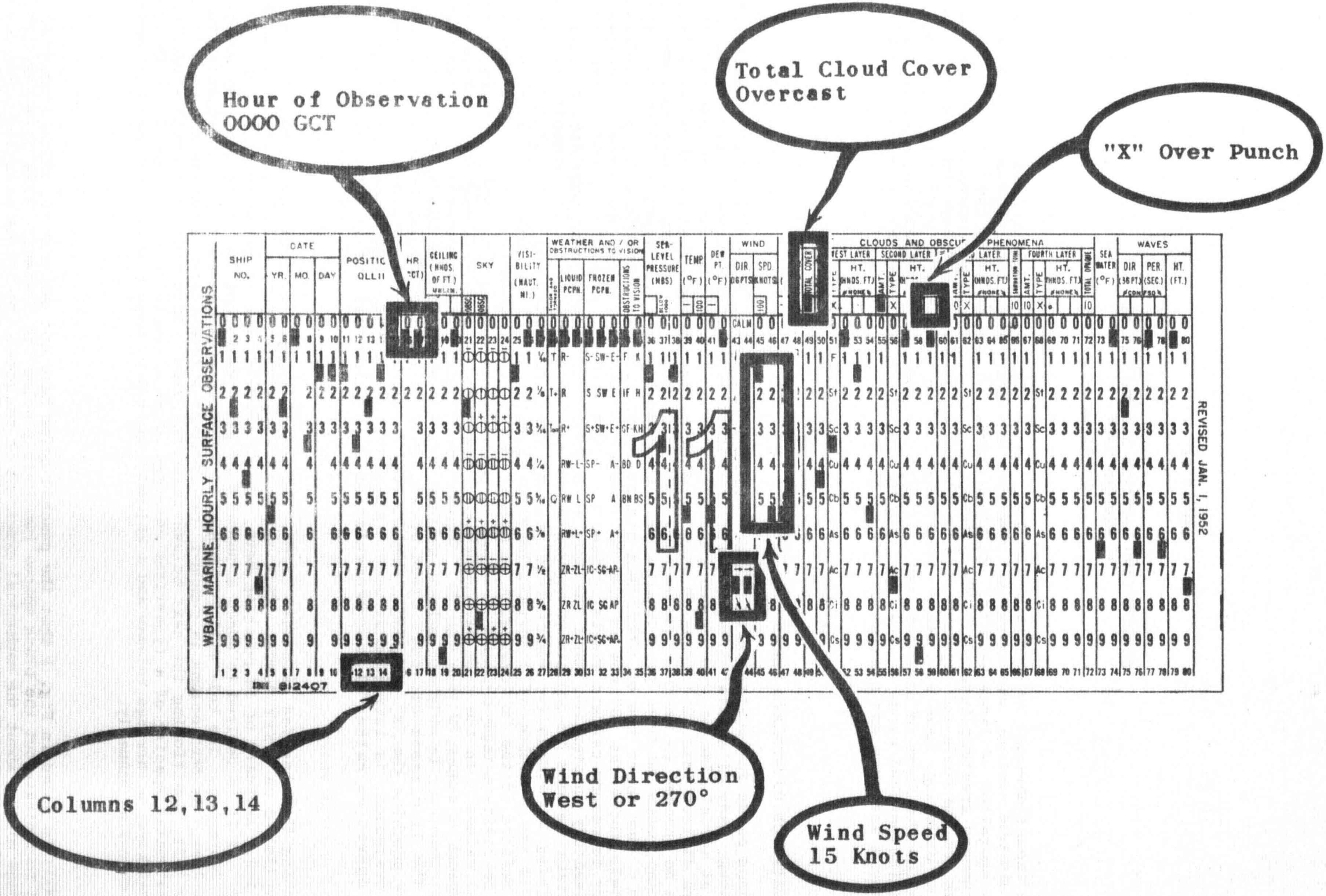


FIG. 1 ILLUSTRATION OF CARD PUNCHED FOR MARINE DATA

ACTUAL SIZE

B. MACHINE PROCESSING OF PUNCHED CARD DATA

The punched card method of recording data by punching holes in pieces of paper results in a unique kind of record which can be used to produce, in machines designed to process the data automatically and rapidly, a wide variety of statistical analyses. The card is actually an electric insulator except in those positions in which holes have been punched. Electrical circuits completed through the punched holes energize electromagnets which control various mechanisms, such as chutes which open, allowing cards to fall into appropriate collection "pockets", or Veeder counters which count the number (a) of cards or (b) of values punched. Singly or in combination the machines can perform the basic operations involved in the analysis of weather data:

1. Arrangement of data into desired sequences or groupings;
2. Interfiling of data into a desired relationship with other data;
3. Comparison of numerical magnitudes of data on two sets of cards;
4. Selection of specific information from large quantities of data;
5. Translation of data into different units of measurement and combining data from several sources;
6. Counting the occurrences of different magnitudes or categories of weather elements;
7. Addition, subtraction, multiplication, and division;
8. Solving equations or parts of equations.

Original data punched into the cards, or the results of any stage of analysis, can be printed on paper by a TABULATOR. The printing unit in this machine, similar in principle to that in a simple adding machine, contains bars or wheels with letters, numerals, and symbols, one for each column on a punched card and extras to permit printing sums or products so that the results of the machine's work come out in the form of a printed tabulation.

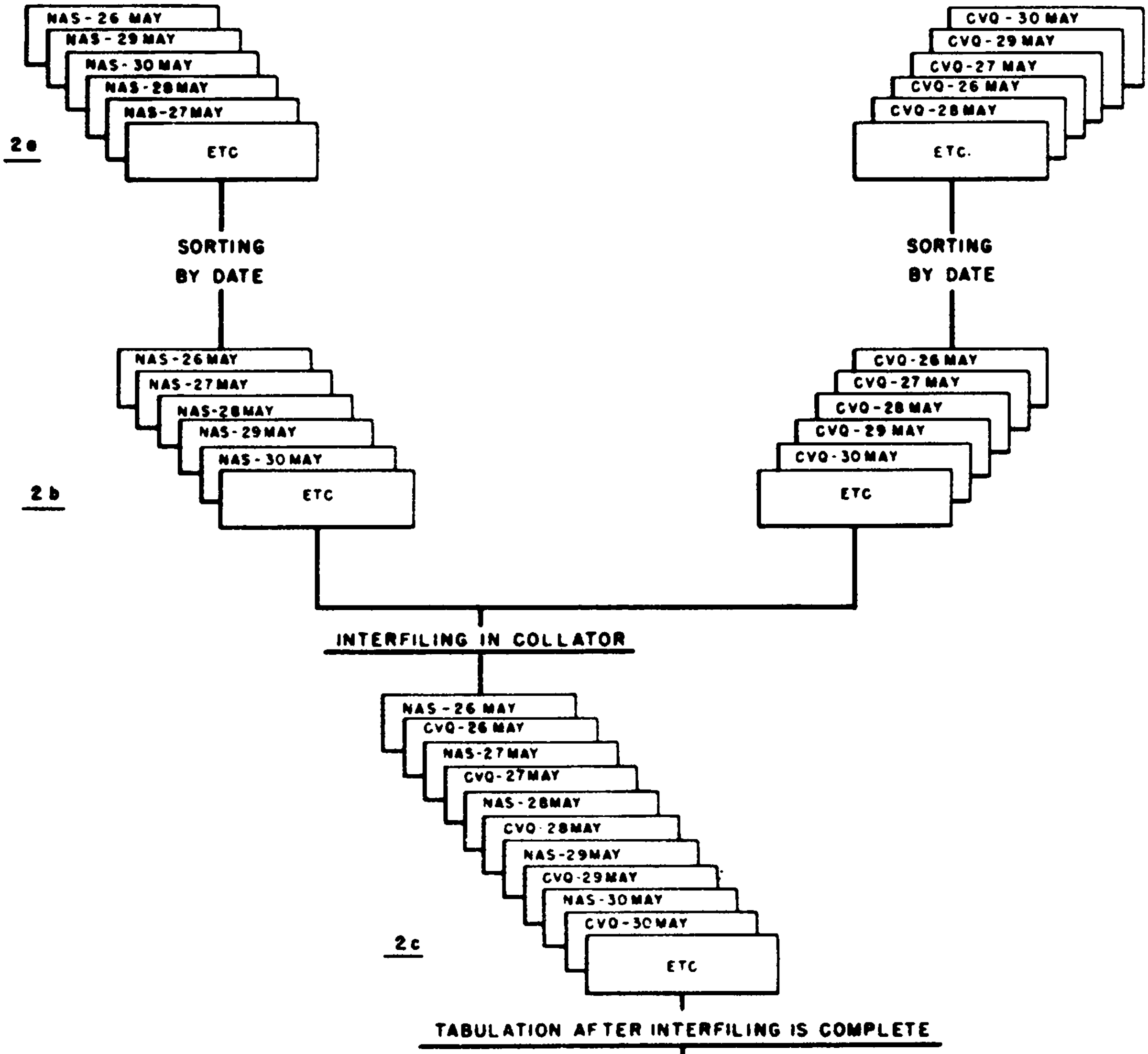
Whenever large volumes of data are involved, manual processing of data is slow and costly, and the great importance of punched card techniques and machines is the speed and economy with which they can do the work that takes so long and costs so much when done by hand. There is nothing magical about them; they do not think; the apparent "intelligence" they display is produced entirely by the technicians who operate them. The machines run cards through, process the data punched into them, and print the desired results electrically, but only in strict accordance with the directions wired into them. What they do is determined by a control panel or "plugboard", which resembles a complicated telephone switchboard. A technician might, for example, wire a plugboard to cause a machine to proceed as follows: separate all the cards with a ceiling of less than 1,000 feet from a set of cards representing ten years of record at a station; separate the cards with less than 1,000 foot ceilings thus obtained into two groups, one containing cards with north winds and the second containing cards with other wind directions; and finally, cause the date of each observation or card with less than 1,000 foot ceiling and a north wind to be printed in chronological order on a sheet of paper.

In the following pages each of the basic operations in analysis of climatic data is illustrated. While the attempt here is to emphasize results of a punched card analysis, a simplified explanation of a machine accomplishing each type of analysis has also been included to show machine capabilities and limitations. Most operations can be accomplished by more than one type of machine, but each has been designed for a few special functions and in that role operates most efficiently.

1. **ARRANGING DATA INTO DESIRED SEQUENCES OR GROUPINGS** is a common preliminary step in preparing data for analysis. Analytical requirements dictate the specific pattern of data arrangement. The sequence may be chronological, numerical for a specific weather element, and so on. Grouping large quantities of values into classes is usually the first step in any statistical study.

The machine used for arranging cards into any kind of desired sequence or separating them into groups is the SORTER. It has 13 pockets, 1 for each of the 12 punching positions in a column, and a thirteenth for cards with no punch in the column being sorted. This machine sorts only one column of the card at a time, at a rate of from 450 to 650 per minute, splitting the file of cards into a maximum of 13 separate groups on each sort, resulting in a numerical sequence for the column sorted. Figure 2a schematically illustrates cards from two stations, NAS and CVQ, in jumbled date-order for each station. Figure 2b shows the cards arranged in order by date after they have been run through a sorter twice; separated first by the column containing the units digit of the date and then a second by the column containing the tens digit.

The cards can be sorted on as many columns as desired, and thus arranged into a great variety of groups. Several columns representing one weather element can be successively sorted to organize the values into classes; several columns representing different weather elements can be successively sorted to provide groups containing combinations of values. Wind speeds in knots, as recorded on marine observation punch cards, can be grouped into Beaufort-force order by sorting into unit values, from zero to the highest, and removing cards from the pockets in groups equivalent to each Beaufort force.



2d

STATION	DATE	VISIBILITY IN NAUTICAL MILES
NAS	26 MAY	2
CVQ	26 MAY	3
NAS	27 MAY	4
CVQ	27 MAY	6
NAS	28 MAY	2
CVQ	28 MAY	10
NAS	29 MAY	1
CVQ	29 MAY	3
NAS	30 MAY	2
CVQ	30 MAY	3
NAS	31 MAY	5
CVQ	31 MAY	8

FIG. 2 SCHEMATIC ILLUSTRATION OF SORTING AND INTERFILING OF CARDS AND TABULATION OF SELECTED DATA

2. INTERFILING OF DATA INTO A DESIRED RELATIONSHIP WITH OTHER DATA is also an important form of organization. Weather records filed chronologically for each station must be interfiled to organize data for a day by day study of an area. Although the sorter can be used for interfiling, a machine more specifically designed for this purpose is the COLLATOR, which performs such a task at a rate between 240 and 480 cards per minute. Fig 2c illustrates the result of collation of the two sorted sets of cards of Fig. 2b.

Arrangement of data and interfiling are what might be called "punched card manipulation" prior to presentation or statistical analysis. Data so organized can be printed (listed) by the tabulator. Fig. 2d illustrates a listing made by a tabulator which has been set up to print station designator, date, and visibility from cards sorted and interfiled into the order desired in the final listing. An actual tabulation of sorted and interfiled radiosonde data, prepared for Northern Hemisphere Historical Weather maps, is shown in Table I.

3. COMPARISONS OF NUMERICAL MAGNITUDES ON TWO SETS OF CARDS is an operation for which the collator is also well adapted. It compares magnitudes of values either between observed data and constants or between sets of observed data. For example, the latter could be utilized in a comparison of 0630Z temperatures for each day at station NAS with the corresponding day's 0630Z temperatures at Station CVQ, resulting in separation of the cards for station NAS into three groups: one with NAS temperatures higher than the corresponding temperatures at CVQ, one with those lower than at CVQ, and the third with those equal to CVQ's. See Fig. 3b. The two sets of cards are placed into the collator simultaneously and as each corresponding pair is scanned the paired cards are directed to the appropriate group (Fig. 3b). Tabulation of differences (Fig. 3c) will be considered in par. 7.

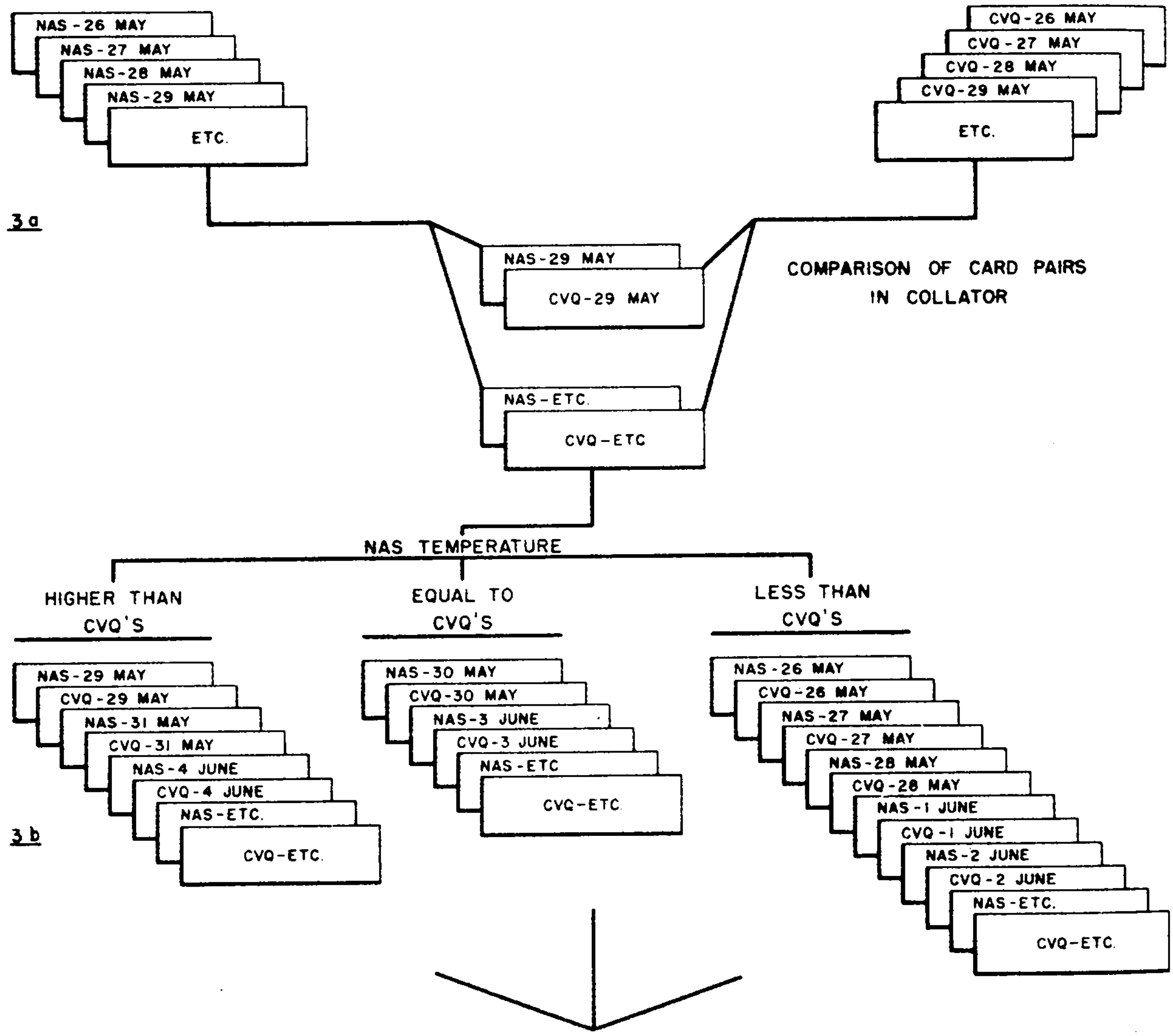
Comparison of a set of data with constants is applied to edit observation records for validity or reasonableness by establishing standards within which valid or reasonable data should fall. Air temperatures over 80 degrees Fahrenheit at Chicago in February would obviously be questionable, as would temperatures of -40°F. These values might be determined as limits of the acceptable range for observed temperatures for that station and month. The questionable cards, representing either a dubious observation or an incorrectly punched card, will then be rejected by the collator. In actual practice, the ranges and relationships set up in the machines for selection of questionable data are much more restrictive and complex than the simple example given above, and have been determined as a result of experience and meteorological knowledge. Usually the interrelationships of several elements are critically examined at the same time. Thus dew-point may be checked against observed air temperature and wet bulb temperature. All Navy weather records are machine edited for accuracy and consistency of observed data.

4. SELECTION OF SPECIFIC INFORMATION FROM LARGE QUANTITIES OF DATA is, so far as the machines are concerned, a matter of comparing each card with values or combinations of values upon which the selection is to be based. In a simple case, selection of the number of times in a 20-year record when three conditions, (rain, east wind, and dewpoint between 55° and 60°) occurred together can be performed in a collator by establishing the given values as standards. Any card whose data for wind, precipitation, and dewpoint fits these standards, that is, has an east wind, rain and dewpoint between 55°F and 60°F, will be directed into one pocket: all other cards will go to another pocket.

Whereas Table I shows a listing of all data from every available card, Table II is a listing of selected data from cards pulled out from a complete set. A study was to be made of storms passing through the area 40° to 50°N. and 50° to 60°W., east of the New England coast and south of Newfoundland. This area is designated as Marsden Square 150, according to a system of numbering 10° squares of latitude and longitude which is explained in the fourth chapter on page 34. Investigation was to be made of the difference between air and sea-water temperatures for storms on the 13th, 14th, and 15th of September 1904. The electrical circuits of the collator were so wired in the plugboard that any card bearing one of those dates and any value of air-sea water temperature difference would be selected out. A tabulator then listed desired data from those selected cards.

As the collator can perform as many as 32 independent or related comparisons at a time, complicated combinations of criteria may be established for a process of selection.

5. TRANSLATION OF DATA INTO UNITS OF MEASUREMENT better suited for the particular study being made is a useful capability of machine punched card processing. By properly wiring the plugboard of a tabulator, a technician can cause it to print a wind direction, though it is punched in numerical or symbolic code, as N, SE, etc.



TABULATION OF
NAS TEMPERATURE DIFFERENCE FROM CVQ'S

3 c

DATE	°F
29 MAY	+4
31 MAY	+2
4 JUNE	+5
30 MAY	0
3 JUNE	0
26 MAY	-7
27 MAY	-4
28 MAY	-1
1 JUNE	-1
2 JUNE	-5

FIG. 3 SCHEMATIC ILLUSTRATION OF COMPARISON AND TABULATION OF DIFFERENCES

TABLE I TABULATION OF SORTED AND INTERFILED RADIOSONDE DATA

RADIOSONDE AND RAWINSONDE DATA

Oct 10 1960

Index No.	Station Name	1000 mb hhh	1000 mb TTTTT ddx	1000 mb dd	1000 mb ff	850 mb hhh	850 mb TTTTT ddx	850 mb dd	850 mb ff	700 mb hhh	700 mb TTTTT ddx	700 mb dd	700 mb ff	500 mb hhh	500 mb TTTTT ddx	500 mb dd	500 mb ff	Hour GG	Code Type
[illegible]	[illegible]BROOK FLD	038	[illegible]19	00		494	1 111	[illegible]	11	024	08028	18	10	905	59632	17	6	04	1
	BLOCK 91																		
065	MIDWAY ISL	042	[illegible]817	06	17	324	1 139	09	15	060	08049	06	18	950	57694	30	8	03	1
[illegible]	IWO JIMA	043	[illegible]6189	07	6	304	1 026	06	6	035	08994	04	4	930	55995	02	9	04	1
[illegible]	MOKULEIA	043	[illegible]4191	06	12	503	1 115	07	13	034	06563	06	6	910	59688	04	30	03	1
[illegible]	HONOLULU	038	[illegible]6191	06	18	499	1 105	06	10	027	04501	11	1	901	60759	14	9	03	1
[illegible]	HARMON FLD	038				507	1 145	18	6	048	10025	13	8	940	56990	08	16	03	1
[illegible]	WAKE ISLAND	045	27220	09	15	507	1 184	10	[illegible]	043	06503	08	14	930	54995	04	18	03	1
[illegible]	ENIWETOK ATL	042	[illegible]	09	10	509	1 155	08	7	044	05008	05	9	[illegible]	[illegible]			03	1
[illegible]	JOHNSON IS	038	21447	08	17	501	1 149	07	15	038	09681	08	23	927	55991	05	17	03	1
[illegible]	HILO	049	22204	14	8	498	1 137	12	17	039	05033	11	13	909	60645	23	35	03	1
[illegible]	YAP	031	[illegible]	29	4	495	1 876	34	5	042	08998	02	6	[illegible]	[illegible]			03	1
[illegible]	CANTON	030	87215	09	14	493	1 127	11	19	031	10611			923	54994			03	1
	BLOCK 98																		
22[illegible]	LAOAG	039	28241			505	1 151			049	11038			946	84634			03	6
	OCEAN STA																		
[illegible]	[illegible] 350 400	042	21178			496	1 088			019	01688			808	62654			03	1
[illegible]	[illegible] 360 700	042	23810	31	13	503	1 105	23	19	034	07998	22	14	927	58996	24	29	03	1
[illegible]	[illegible] 450 160	133	13089	34	27	450	0 501	34	24	047	00584	29	48	680	63738	30	32	02	8
[illegible]	[illegible] 440 408	046	15093	21	15	490	0 646	41	16	016	05635	24	26	897	59992	22	27	03	1
[illegible]	[illegible] 525 200	004	11105	26	34	340	0 820	20	50	892	54619	20	45	461	69[illegible]			02	8
[illegible]	[illegible] 587 355	002	09085	32	10	439	0 008	26	25	946	54663	26	43	791	69781	27	60	03	1
[illegible]	[illegible] 565 510	015	02808	34	31	436	5 450	36	34	919	09739	34	32	711	67968	34	24	03	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Oct 11 1960

Index No.	Station Name	1000 mb hhh	1000 mb TTTTT ddx	1000 mb dd	1000 mb ff	850 mb hhh	850 mb TTTTT ddx	850 mb dd	850 mb ff	700 mb hhh	700 mb TTTTT ddx	700 mb dd	700 mb ff	500 mb hhh	500 mb TTTTT ddx	500 mb dd	500 mb ff	Hour GG	Code Type
	BLOCK 01																		
[illegible]	JAN MAYEN	035				300	[illegible]			799	64457			[illegible]	[illegible]			03	[illegible]
[illegible]	TROMSO	533				300	80067			[illegible]	[illegible]			[illegible]	[illegible]			03	[illegible]
[illegible]	GARDERMOEN	505				310	50537			[illegible]	[illegible]			[illegible]	[illegible]			03	[illegible]
[illegible]	SOLA	519				310	50501			[illegible]	[illegible]			[illegible]	70813			03	[illegible]
	BLOCK 02 … BLOCK 17, USSR ZONE 1–6	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

RADIOSONDE AND RAWINSONDE DATA – Continued

Oct 10 1960

Index No.	300 mb hhh	300 mb TTTTT ddx	300 mb dd	300 mb ff	200 mb hhh	200 mb TTTTT ddx	200 mb dd	200 mb ff	100 mb hhh	100 mb TTTTT ddx	100 mb dd	100 mb ff	Hour GG	Code Type
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91														
066	181	[illegible]	[illegible]	7	059	06[illegible]	43	11	455	[illegible]			03	1
115	174	[illegible]	34	13	070	04[illegible]1	01	1[illegible]					04	1
165	155	[illegible]	02	43	015	04[illegible]	36	14	39[illegible]	[illegible]	07	18	03	1
182	118	[illegible]	08	10	001	04[illegible]3	33	14	39[illegible]	[illegible]			03	1
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245	170	[illegible]5013	34	40	054	[illegible]	31	39					03	1
250	101	58											03	1
275	177	[illegible]	05	17	108	04[illegible]6	47	10					03	1
285	141	[illegible]43	18	31	041	[illegible]	42	49					03	1
413	101	58											03	1
700	170	[illegible]			054	[illegible]			39[illegible]	[illegible]7			03	1
98														
225	204	[illegible]1901			104	01[illegible]							03	6
[illegible]		OCEAN	STA											
034	1[illegible]4	[illegible]7919			[illegible]	03[illegible]			39[illegible]	[illegible]			03	1
037	155	[illegible]	44	39	037	[illegible]	43	71					03	1
041	[illegible]55	[illegible]1 1			1[illegible]	0[illegible] 1			638	11[illegible]7			02	5
044	124	[illegible]	45	30	008	[illegible]	40	35	387	[illegible]			03	1
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05[illegible]	[illegible]	[illegible]	77	3	[illegible]45	[illegible]							03	1
055	[illegible]	[illegible]	25	[illegible]	735	[illegible]	47	40					03	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Oct 11 1960

Index No.	300 mb hhh	300 mb TTTTT ddx	300 mb dd	300 mb ff	200 mb hhh	200 mb TTTTT ddx	200 mb dd	200 mb ff	100 mb hhh	100 mb TTTTT ddx	100 mb dd	100 mb ff	Hour GG	Code Type
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE II TABULATION OF SHIPS REPORTS, SEPTEMBER 1904, CONTAINING AIR-SEA WATER TEMPERATURE DIFFERENCES IN MARSDEN SQUARE AREA NO. 150.

Marsden square		Time				Wind		WW			Temperature °C						Clouds Type N Nh					Sea		Swell				Pressure Change				Air Pressure		Weather Beaufort & Remarks				
10°	1°	Year	Month	Day	Hour	Direction	Force	Weather	Air Pressure MM (tenths)	Visibility	X	Air	X	Water	X	Difference	C L Low	C M Middle	C H High	Tot. Amt.	Low Amt.	Direction	Force	Direction	Type		Ships Course and speed	Type	1/5 MB	MM	Relative Humidity	MB						Wind Quad.
150	04	04	09	13	66	28	4					248		240		08				3														2				4
150	03	04	09	13	70	30	4					242		258		-16				4														2				4
150	03	04	09	13	54	20	5					209		234		-25								20	3													3
150	03	04	09	13	50	20	4					228		234		- 6				2				20	2									1				3
150	13	04	09	13	58	28	4					252		222		30				5															2	0		4
150	14	04	09	13	62	28	3					248		220		28				5														2				4
150	05	04	09	14	54	2	4					228		253		-25				5														2				1
150	05	04	09	14	50	2	2					245		255		-10				2														1				1
150	06	04	09	14	58	2	3					230		248		-18				5				02	3									2				1
150	06	04	09	14	62	2	4					228		256		-28				5				2	3									2				1
150	07	04	09	14	66	2	4					228		246		-18				3				02	3									1				1
150	07	04	09	14	70	4	3					205		228		-23				2				04	2									1				1
150	08	04	09	15	54	14	4					199		228		-29				3				14	2									1				2
150	08	04	09	15	50	10	3					205		224		-19																						2
150	08	04	09	15	70	20	6					256		254		2				3				20	4									1				3
150	09	04	09	15	58	14	4					254		244		10								14	2													2

Similarly, temperatures punched in degrees Fahrenheit can be translated into their centigrade equivalents (or vice versa), then printed, counted, or used in further statistical study. Therefore it is possible to combine information from cards of several weather-records sources, in which elements have been punched in different units. The United States now has, in addition to its own marine observation records, Dutch, British, and German Marine Observation Card Decks (a "deck" is a set of cards all of one type). Fig. 4 indicates that on the Dutch and German cards temperature is punched in °C while on United States cards °F is used. Furthermore, it will be noted that different columns are used for air temperatures on the United States cards from those on the Dutch and German cards. To obtain the greatest amount of information for climatic summaries over oceans, where observations are relatively few at best, it is necessary to combine all available records, which frequently involves translation into uniform units.

* * * * * * *

The basic operations discussed up to this point are related primarily to preparing quantities of observational information for the more complicated task, in statistical analysis, by which weather records become climatic description. When (a) all data have been checked for accuracy and reasonableness, (b) selection has been made of appropriate information, (c) records from various sources have been translated into the same measurement units, (d) sequenced, and (e) interfiled, they are ready for computation. Of course, this complete succession of the five basic operations represents the maximum of likely preliminaries to further study; but it frequently happens that some of the steps are unnecessary in preparation for any further study; occasionally the cards may be already suitably arranged in their storage files.

Counting, arithmetic summarization, and calculation of equations are functions of punched card computing machines. Like the primarily organizational machines, each is designed specifically for a certain job, in this case some type of computation. However, the newer machines combine both organizing and computing functions and so can produce some form of statistical analysis directly from relatively unorganized decks of cards.

6. COUNTING THE OCCURRENCE OF DIFFERENT MAGNITUDES OR CATEGORIES OF A WEATHER ELEMENT results in a frequency distribution, a form of representation being recognized more and more as a valuable descriptive device for climatic elements. The simplest type of count, where a weather state either has occurred or hasn't, is exemplified by tabulation of number of days per month, or year, on which precipitation, of any kind, was observed. Only those punched cards, from the total for the required period, in which some form of precipitation is recorded, would be counted. A somewhat more detailed picture could be obtained by counting the number of occurrences of individual conditions, such as the number of times each form of precipitation was observed during the period. For those weather elements such as temperatures, whose range is too wide to permit the counting of occurrences by individual units of measurement, enumeration is made by groups of units.

When punched cards have been sorted, and grouped if necessary, counts of occurrence are made by a tabulator. However, both organizing and counting can be accomplished by the ELECTRONIC STATISTICAL MACHINE, which combines some of the operations of sorter and tabulator.

Table III is a one-way frequency distribution of the January daily maximum temperatures for a period of 20 years at Lakehurst, N. J. As the January punched cards containing the summary of each day's weather passed through a (tabulating) machine, maximum temperatures within each of the selected 6-degree temperature groups were counted and the total number in each group printed.

Such an analysis gives a much more complete picture of maximum temperatures than would a single figure, such as the mean, or the mean plus a range. Here the mean is 40°F but the frequency distribution shows that on only 147 January days in 20 years was the maximum temperature in the same 6-degree group as the mean. It can be seen from the distribution, though, that occurrences in that group were about 3 times as frequent as in that from 56 to 61. Accumulating total counts through each class provides further information about a distribution. This operation, a form of counting, is a function of tabulating machines. Accumulated frequencies of occurrence, listed in Table III, indicate that maximum temperatures below freezing have been recorded on 128 January days in 20 years at Lakehurst.

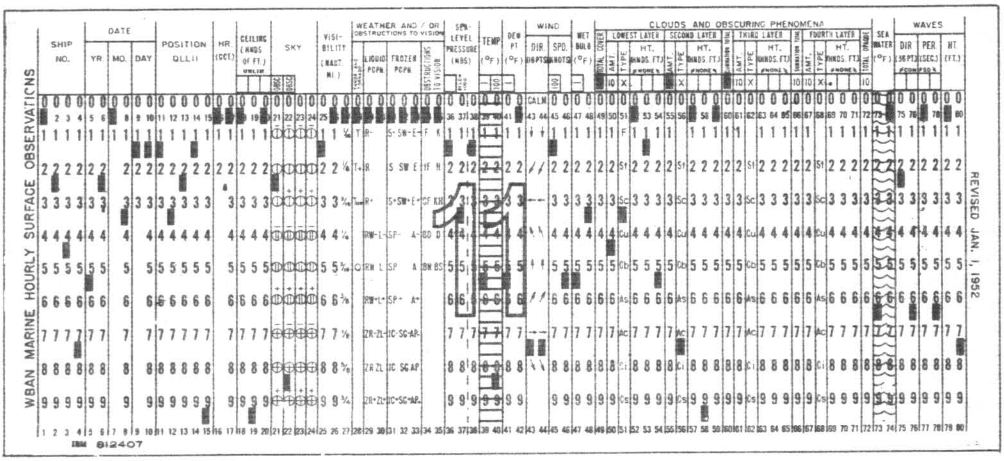
The actual numbers of days mentioned above, 147 and 128, take on different meanings when compared with the total number of January days in 20 years. In making such a comparison, i.e. 147 against 620, one is mentally estimating a ratio or percentage. Or, if the numbers of occurrences in 20 years were divided by 20, average number of days in January with maximum temperature in each 6-degree temperature group could be compared mentally with the total number of days in January. These calculations can be performed and tabulated by machines; but, since they involve division, they are considered under arithmetic computation capabilities of punched card machines in the next section.

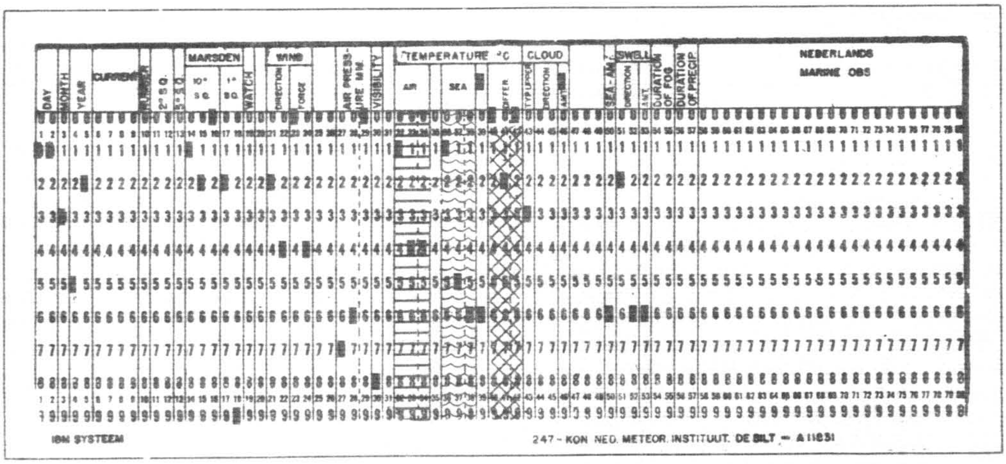
AIR TEMPERATURE

SEA WATER TEMPERATURE

AIR MINUS SEA TEMPERATURE

°F to 1° °C to 0.1°





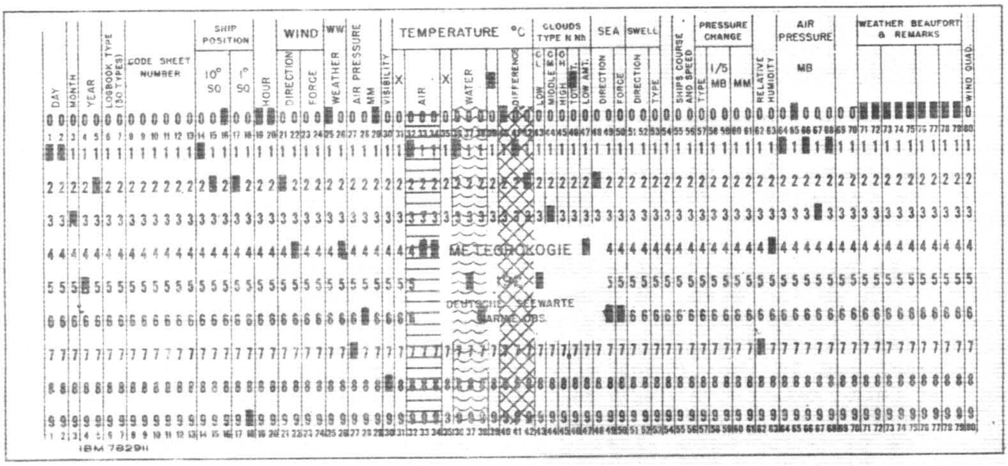


FIG. 4 PUNCHED CARDS
ILLUSTRATING U. S., DUTCH & GERMAN CARDS

TABLE III FREQUENCY DISTRIBUTION OF JANUARY DAILY MAXIMUM TEMPERATURES LAKEHURST, N. J. 1926-1945.

Temperature °F	8 to 13	14 to 19	20 to 25	26 to 31	32 to 37	38 to 43	44 to 49	50 to 55	56 to 61	62 to 67	68 to 73	74 to 79
Frequency	2	11	40	75	127	147	82	72	47	12	4	1
Acc. Freq.	2	13	53	128	255	402	484	556	603	615	619	620

Unfavorable conditions of several weather elements often limit operations whereas a similar condition of any one element alone might not. A common example is one criterion for visual flight clearance requiring the simultaneous occurrence of at least 1000-foot ceiling and 3 miles visibility. Table IV is a tabulation, for Salt Lake City, made to aid in determining which runway should be lengthened for instrument flight operations. It is one of 16 tabulations (one for each of 16 wind directions) of simultaneous occurrence of various visibility groups with ceilings of 1000 feet and less, and will serve as an illustration of a machine-tabulated multi-way frequency distribution.

7. ADDITION, SUBTRACTION, MULTIPLICATION, AND DIVISION are the fundamental operations of the machines. The basic operations discussed so far have required only the one arithmetic process of ADDITION. Differences, products, and quotients may also be derived through machine computations, even though their identity may be partially obscured by such terms as range, deviation, or rate. Calculation of seemingly more complex statistical summaries of sets of data, such as means, percentages, average frequencies, and so on, amounts to nothing more than combination of several of the fundamental processes in sequence.

Fig. 3c (already shown) represents a listing of numerical differences in 0630Z temperature for corresponding days at NAS and CVQ. Following comparison in the collator and separation into three groups, the pairs of cards were passed through a TABULATOR, which consists of a printing unit, a device to count punched cards, and also an adding-subtracting machine. When processing card pairs in the group where NAS temperatures were higher than CVQ's, the machine was set to indicate possitive difference and the CVQ temperature was subtracted from that of NAS; when NAS temperatures were lower than CVQ's, the machine was set to indicate negative difference and NAS temperatures were subtracted from CVQ's. Speed of calculation, in this case 75 differences per minute, is the main advantage of tabulator processing.

Frequency of occurrence is often more easily visualized, in describing climate, either as a percentage or as an average number for a standard period. Comparing individual frequencies with total number of occurrences, that is, division by machine and tabulation of quotients as percents, produces a percentage frequency distribution. According to Table V, maximum daily January temperature at Lakehurst of 38 - 43°F occurred 147 times in 20 years, which was 23.7 percent of all January maximum temperature observations in that period. From the accumulated percentage frequency it is evident that 128 days with maximum temperature below freezing is equivalent to 20.6 percent of the 20 Januarys considered.

The original frequency distribution can be converted, through division by 20, into average number of days in January with temperature in each group. Such a summary is valuable but can be misleading. Maximum temperature in the 8-13°F group occurred an average of one day in ten Januarys, yet it is quite possible that the 2 readings in 20 years in this group were observed during a cold period in a single year.

Arithmetic operations of multiplication and division, as well as addition and subtraction, are performed on a CALCULATING PUNCH or an ELECTRONIC CALCULATING PUNCH. While the older machines multiply and divide by using mechanical counters, multiplication being rapid addition, and division rapid subtraction, newer machines utilize vacuum tubes and usually bear the descriptive word "electronic" in their names. The term "punch" indicates that computed data can be punched, by a unit in the machine or attached to the machine, into the original card or into a card used to retain the summary of data from many cards. Since these machines have no printing unit, the tabulator must be used for this operation, obtaining data to be printed from either the original or summary cards into which computed data has been punched.

TABLE IV MULTI-WAY FREQUENCY DISTRIBUTION OF CEILING, VISIBILITY, AND WIND SPEED FOR NORTHEAST WINDS, SALT LAKE CITY, UTAH.

(JANUARY 1934 THRU DECEMBER 1941 — JANUARY 1948 THRU DECEMBER 1950)

DIR.	STATION NAME CEIL. GRPS. IN FEET	VEL. GRPS. IN MILES	PERIOD OF RECORD VISIBILITY-MILES 0-1/4	1/4-1/2	1/2-3/4	3/4-1	1-1 1/2	1 1/2-3	3	TOTAL OBSERVATIONS
NE	1000	01-04	1	1	1	2	12	31	848	896
		05-09	1		1	4	4	14	947	971
		10-14				2	2		276	280
		15-30				1			82	83
		30							1	1
		TOTAL	2	1	2	9	18	45	2154	2231
NE	600 thru 900	01-04				1	2	3	1	7
		05-09				2	1		2	5
		10-14					1		1	2
		15-30			1					1
		30								
		TOTAL			1	3	4	3	4	15
NE	500	01-04			1			3		4
		05-09								
		10-14								
		15-30								
		30								
		TOTAL			1			3		4
NE	400	01-04				1			1	2
		05-09								
		10-14								
		15-30								
		30								
		TOTAL				1			1	2
NE	300	01-04	1			1				2
		05-09								
		10-14								
		15-30								
		30								
		TOTAL	1			1				2
NE	200	01-04		1						1
		05-09		1						1
		10-14								
		15-30								
		30								
		TOTAL		2						2
NE	100	01-04	7		1					8
		05-09								
		10-14								
		15-30								
		30								
		TOTAL	7		1					8
TOTAL BY VISIBILITY GROUPS			10	3	5	14	22	51	2159	2264

VELOCITY GROUPS	1-4 MI.	5-9	10-14	15-29	30MI.	CALM
TOTAL BY VELOCITY GROUPS	920	977	282	84	1	
% BY VELOCITY GROUPS	40.6	43.2	12.5	3.7		

TABLE V FREQUENCY, PERCENTAGE FREQUENCY, AND AVERAGE FREQUENCY DISTRIBUTIONS OF JANUARY DAILY MAXIMUM TEMPERATURES FOR LAKEHURST, N. J., 1926—1945

Temperature °F	8 to 13	14 to 19	20 to 25	26 to 31	32 to 37	38 to 43	44 to 49	50 to 55	56 to 61	62 to 67	68 to 73	74 to 79
Frequency	2	11	40	75	127	147	82	72	47	12	4	1
Percentage Frequency	0.3	1.8	6.4	12.1	20.5	23.7	13.2	11.6	7.6	1.9	0.7	0.2
Accumulated Percentage Frequency	0.3	2.1	8.5	20.6	41.1	64.8	78.0	89.6	97.2	99.1	99.8	100.0
Average No. of days in January	.1	.5	2.0	3.2	6.4	7.4	4.1	3.6	2.4	.6	.2	.05

A frequency and percentage occurrence tabulation for simultaneous observation of Low Cloud (L.C.) amounts and specified conditions of sea, wind, and visibility, shown in Table VI, illustrates the fact that multiway distributions can be presented in different forms depending on the use to be made of them. At a glance the percentages of past observations recording predetermined categories of operational conditions are evident. The cards in each Marsden Square were separated into two groups.

(a) Seas 20 feet or less and winds 47 knots or less (Beaufort Force nine) and

(b) Seas greater than 20 feet and winds greater than 47 knots (Beaufort Force nine)

Then the cards of group (a) were separated into three groups of visibilities

(a.1.) Visibility one mile or more
(a.2.) Visibility one-half mile or more but less than one mile, and
(a.3.) Visibility less than one-half mile

The last group was then excluded from the investigation.

Then the cards of group (b) were separated into two groups

(b.1.) Those having visibilities less than one-half mile and
(b.2.) Those having visibilities one-half mile or more.

The latter group was then excluded from the investigation.

The three groups a.1., a.2., and b.1. were then individually separated into groups having 0-5 tenths, 6-8 tenths, and 9-10 tenths cloudiness. These then satisfied the criteria established for conditions I, II, and III, Table VI.

The counts of simultaneous occurrence, automatically punched into summary cards, were divided on a calculating punch by the Grand Total number of observations to obtain the percentages of occurrence. A run of the summary cards through the tabulator then printed the frequency and percentage of occurrence.

A calculating machine can be wired to follow through automatically a sequence of arithmetic operations to a maximum of 40 steps. For example, temperature lapse rate between two pressure levels can be computed from upper-air cards containing observed data of pressure levels, heights, and temperatures. The calculating punch can first find the temperature and height differences between selected levels. Then the temperature difference can be divided by height difference to give the temperature lapse rate.

TABLE VI FREQUENCY AND PERCENTAGE OCCURRENCE OF PREDETERMINED OPERATIONAL CONDITIONS.

Marsden Square Number		Grand Total	CONDITION I				CONDITION II				CONDITION III			
			Total	L.C. 0-5	L.C. 6.8	L.C. 9-10	Total	L.C. 0-5	L.C. 6-8	L.C. 9-10	Total	L.C. 0-5	L.C. 6-8	L.C. 9-10
044	F	7517	7498	6652	625	221	2	1	-	1	17	15	2	-
	%	100.0	99.7	88.5	8.3	2.9	#	#	.0	#	.2	.2	#	.0
112	F	15804	15442	12153	1976	1313	22	3	5	14	340	175	98	67
	%	100.0	97.7	76.9	12.5	8.3	.1	#	#	.1	2.2	1.1	.6	.4
116	F	6636	6473	4929	768	776	20	12	2	6	143	38	44	61
	%	100.0	97.5	74.3	11.6	11.7	.3	.2	#	.1	2.2	.6	.7	.9
147	F	19584	18588	10745	3485	4358	144	25	24	95	852	393	202	257
	%	100.0	94.9	54.9	17.8	22.3	.7	.1	.1	.5	4.4	2.0	1.0	1.3
149	F	13005	11794	6353	2041	3400	207	42	82	83	1004	232	254	518
	%	100.0	90.7	48.9	15.7	26.1	1.6	.3	.6	.6	7.7	1.8	2.0	4.0
151	F	7901	7366	4669	909	1788	87	22	14	51	448	110	55	283
	%	100.0	93.2	59.1	11.5	22.6	1.1	.3	.2	.6	5.7	1.4	.7	3.6

CONDITION I
Number and percentage occurrence of simultaneous observations of sea 20 ft. (Code 6) or less, winds 47 knots (Beaufort 9) or less, visibility one mile (Code 5) or more.

CONDITION II
Number and percentage occurrence of simultaneous observations of seas 20 ft. or less, winds 47 knots or less, visibility 1/2 to 1 mile (Code 4).

less than 1/10%.

CONDITION III
Number and percentage occurrence of observations with seas greater than 20 feet, winds greater than 47 knots and visibility less than 1/2 mile (Code 3).

Producing summaries involving a sequence of arithmetic operations increases the amount of information that can be extracted from a multiway distribution. Thus from Table VII one can read not only the frequency of any simultaneous occurrence of wind force and direction but also:

a. Percentage and accumulated percentage of total number of observations with wind of any force; e.g. Force 3 winds were observed 25.3 percent and winds Force 3 and less occurred 57.4 percent of all observations;

b. Number of observations and percentage of observations with wind from any direction; e.g. SE wind occurred 26 times or 13.7 percent of all wind observations;

c. Total wind force (sum of wind forces) and average force from any direction; e.g. average wind force from E was Beaufort 3.2. (Beaufort Force to tenths may be a new concept to many. It can be translated roughly into average speed in knots by interpolating between the midpoints of the two adjacent whole number Forces)

8. SOLVING EQUATIONS OR PARTS OF EQUATIONS. Since many equations are solved by fundamental arithmetic operations, individually or in combinations, their solutions can be obtained by machine analysis of punched card data. Most complex equations reduce to a series of simple parts, hence can be solved part by part until an integration of the partial solutions gives the solution to the original equation. The rapidity with which the machines work makes them ideal for computing numerous solutions to an equation by substituting different values for variables and following pre-established sequences of the fundamental operations.

The effect of the shearing force of the wind on water surfaces is important in studies of ocean currents and the build-up of heavy seas and swells. An investigation of the stresses usually involves a breakdown into directional components. The equations used for average wind shear or stress in Antarctic waters are:

$$\overline{T}_E = \frac{1}{n} \sum_{i=1}^{n} \left(T_E\right)_i \quad \text{dynes}/\text{cm}^2 \qquad \text{for west-east component} \qquad (1)$$

and

$$\overline{T}_N = \frac{1}{n} \sum_{i=1}^{n} \left(T_N\right)_i \quad \text{dynes}/\text{cm}^2 \qquad \text{for south-north component} \qquad (2)$$

Calculating the AVERAGE stresses reduces to division, by the total number of observations, of the sum of INDIVIDUAL stresses, T_E and T_N.
Equations for the individual stresses are:

$$T_E = K_E\, u^2 \quad \text{dynes}/\text{cm}^2 \qquad \text{for west-east component} \qquad (3)$$

and

$$T_N = K_N\, u^2 \quad \text{dynes}/\text{cm}^2 \qquad \text{for south-north component} \qquad (4)$$

where K_E and K_N are previously determined functions of wind speed and direction comprising the product of a squared drag coefficient, the air density, and a proportionality constant, and u is the observed wind speed in knots. To compute the values of T_E and T_N, all punched cards containing surface wind data were sorted by 5° Latitude and Longitude quadrangles (unit area for which average stresses were to be computed) by months, and separated into sixteen wind direction groups; each wind speed was squared and multiplied by the appropriate value of K_E or K_N obtained from prepared tables. These computed individual stresses were averaged, punched into summary cards, then printed by a tabulator in the form shown in Table VIII.

The separate steps of sorting and separating, squaring (multiplying), multiplying, adding, and dividing, punching summary cards, then printing, might have been done on a series of machines each having one or two special functions. The entire calculation and printing, following sorting and separation, could also have been accomplished, without transfer of cards from one machine to another, by a CARD PROGRAMMED CALCULATOR (CPC), which consists of an electronic calculating punch with which are interconnected, by electrical cables, a tabulator and an auxiliary factor storage unit for holding values until they are needed. The cards pass through the tabulator unit only. Sequences of steps are "programmed" or electrically controlled by special punched cards which contain "instructions", i.e., direct the electrical circuits through the plugboard. A CPC can solve a large variety of relatively complex mathematical and statistical problems.

TABLE VII TWO-WAY FREQUENCY DISTRIBUTION AND STATISTICAL SUMMARY OF WIND FORCE AND DIRECTION IN SUB-SQUARE 2 OF MARSDEN SQUARE 078 FOR SEPTEMBER

SQ.	MO.	SUB SQ.	DIR.	BEAUFORT WIND FORCES 0	1	2	3	4	5	6	7	8	9	10	11	12	NO. of Obs.	% of Obs.	TOTAL FORCE	AVERAGE FORCE
078	08	02	N		1		2										3	1.5	7	2.3
078	08	02	NNE			1	2	5	1								9	4.8	33	3.7
078	08	02	NE			3	8	11	3								25	13.1	89	3.6
078	08	02	ENE		4	6	5	12	8	1							36	19.1	125	3.5
078	08	02	E		7	7	6	4	7		2						33	17.3	104	3.2
078	08	02	ESE			2	3	4	1	1							11	5.8	40	3.6
078	08	02	SE		3	4	11	7	1								26	13.7	77	3.0
078	08	02	SSE			2			5								7	3.7	29	4.1
078	08	02	S		1	1	1		2	1							6	3.2	22	3.7
078	08	02	SSW		1												1	.5	1	1.0
078	08	02	SW		2		3	2									7	3.7	19	2.7
078	08	02	WSW			1	2	1									4	2.1	12	3.0
078	08	02	W				2	1									3	1.6	10	3.3
078	08	02	WNW			4	2	1									7	3.6	18	2.6
078	08	02	NW			2	12										3	1.6	7	2.3
078	08	02	NNW			1											1	.5	2	2.0
078	08	02	C	8													8	4.3		
078	08	02	TOT	8	19	34	48	48	28	3	2						190	100.0	595	3.1
078	08	02	PC	42	100	179	253	253	147	16	10									
078	08	02	ACPC	42	142	321	574	827	974	990										

Note: In order to conserve space, no decimals are indicated in percentage and accumulated percentage figures; e.g., ACPC, 574 under column 3 should read as 57.4%.

TABLE VIII ANTARCTIC WIND STRESS COMPUTATIONS

1	2	3	4	5	6	7	8
7	65	25	01	1.10	.87-	9	
7	65	30	01	1.37	.33-	45	
7	65	35	01	1.82	1.02-	47	
7	65	40	01	3.70	1.54-	132	
7	65	45	01	1.54	.20-	236	5
7	65	49	02	6.12	2.59-	1	
7	65	45	12	1.03-	1.27	9	
7	65	50	01	.95-	.32	23	1
7	65	51	02	1.06-	1.26-	9	
7	65	51	12	.58-	.35-	43	

1. Octant of the Globe
2. Latitude
3. Longitude
4. Month of Year
5. $\bar{T}_E$ (West-east stress)
6. $\bar{T}_N$ (South-north stress)
7. n Number of Observations
8. n_c Number of Calms

This section has been limited to a very general discussion of cards and machines because it is not the purpose of this publication to provide technical instructions on the operation and maintenance of machines and the specific and refined procedures which can be applied to machine operation to obtain desired information. Manuals of this latter type are available.

CHAPTER III.

APPLICATION OF MACHINE-ANALYZED CLIMATIC DATA TO ROUTINE TASKS AND SPECIAL PROBLEMS

Records now available of millions of weather observations can provide valuable climatic tools for the aerologist in carrying out routine forecasting and planning tasks and can be helpfully used as supporting evidence in the solution of special problems. Emphasis is placed upon "machine analysis" because only with modern mechanical processing of data could a program of applied climatology be possible for the Navy. Although much remains to be done to take full advantage of climatic information now available, the Navy is progressing rapidly along two general lines in the practical utilization of this information.

A. ROUTINE ANALYSIS AND TABULATIONS constitute the major portion of the work of the National Weather Records Center. Summaries of weather data for each Naval station for which aerological records exist have been prepared as forecasting aids. The first series of such summaries covered the period of record through January 1945 for all stations which had a record of at least one year. This summary of monthly Aerological Records included tabulations of frequencies of occurrence for clouds, ceiling, visibility, wind, precipitation, temperature, and specified flying conditions especially as they influenced flying. Table IX is a page from the #3 S.O.M.A.R. of frequencies of specified ceiling heights at Pensacola, Florida. A new type of summarization, emphasizing the frequency of simultaneous occurrence of weather elements, is being tested and should be in preparation for all stations during the next year.

An important and continuing phase of routine tabulation and analysis is the preparation of statistical summaries for presentation of climatic information in atlases. Of special importance to Naval Aerologists is the compilation of maps of climate elements in marine geographies of operating areas, atlases, and National Intelligence Surveys of marine regions. The principal source of climate information available to the aerologist has been, until recently, the Atlas of Climatic Charts of the Oceans and several collections of climate charts, often reprints of foreign publications, which served needs of World War II, especially in the Pacific Ocean. While these were the best compilations possible at the time they were completed, greatly increased numbers of observation records coupled with increasing knowledge of statistical characteristics and treatment of climatic data have since opened the way to more accurate and detailed summarization. The Atlas of Climatic Charts of the Oceans, published in 1938, utilized roughly 5 1/2 million observations dated mainly between 1885 and 1933. All observations were timed at Greenwich Noon so that a 24-hour local time variation was introduced onto the world charts: mean temperatures in the Atlantic Ocean were for daylight hours while those in the Pacific Ocean were for night hours. A subsequent fourfold increase in the daily number of observations provides adequate data for frequency distributions to supplement mean values and for attempting diurnal variation analyses or at least daily mean values instead of means for one hour of the day. Greater detail in the observation reports of the last 20 years makes possible the charting of simultaneous occurrence of two or more weather elements. The ultimate goal of present climate-study programs is worldwide coverage utilizing available data to the fullest extent to aid the aerologist in daily routine and in planning for special operations.

B. SPECIAL ANALYSES AND TABULATIONS FOR RESEARCH AND PLANNING PROGRAMS are of two types. First, the programs of routine tabulation are new; therefore, for support of operation planners it may be necessary to prepare special studies to provide the climatic information which in time will be available in tabulated summaries and in atlases. Second, research and planning often require specific non-routine combinations of features of several climatic elements or further, in the case of research, special statistical treatment of climatic data. A few of the capabilities of punched card machines have been described and illustrated in Chapter II, emphasizing the tabulated results. Although for some purposes a listing of observation records is desirable, the majority of needs for special analyses and tabulations are answered by frequency distributions of one or more climatic element(s) or of solutions to equations. Each problem requires that special procedures of machine analysis and tabulation be developed. Specifications for information desired must be very clear and exact to insure that the tabulation meets the need of the user. Interpretation of tabulated results of machine analyses and their application to the solution of the problem are carried out by the researcher: machine analysis and tabulation merely organizes and summarizes data to put it in a form suitable for application to a problem. Following are listed, and some discussed briefly, a few problems for which special machine tabulations have been made:

TABLE IX. ONE TABLE FROM THE PRESENT SUMMARY OF AEROLOGICAL RECORDS FOR NAVAL AIR STATIONS.

S.O N.A.R.-3 | AEROLOGICAL SECTION

CHIEF OF NAVAL OPERATIONS

SUMMARY OF MONTHLY AEROLOGICAL RECORDS

3. Frequencies of Specified Ceiling Heights

PENSACOLA FLORIDA (STATION) | 30 21 N (LATITUDE) | 87 16 W (LONGITUDE) | JAN. 1924 THRU JAN. 1945 (PERIOD OF RECORD)

STATION NO.	NO. CODE	HOUR LOCAL STANDARD TIME	CEILING HEIGHT, IN FEET: 0-450 NO. OF OBS.	% OF TOTAL	451-950 NO. OF OBS	% OF TOTAL	951-2050 NO. OF OBS.	% OF TOTAL	2051-3050 NO OF OBS	% OF TOTAL	3051-5250 NO. OF OBS	% OF TOTAL	5251-9750 NO. OF OBS	% OF TOTAL	OVER 9750 NO. OF OBS.	% OF TOTAL	TOTAL OBSERVATIONS
JANUARY (MONTH)																	
235	01	04	6	5	2	2	14	11	3	2	7	6	7	6	85	68	124
		08	28	7	33	8	43	11	12	3	8	2	15	4	255	65	394
		12	11	3	18	5	25	6	13	3	11	3	11	3	307	77	396
		16	7	2	19	5	28	7	9	2	8	2	17	4	310	78	398
		20	9	3	6	2	23	8	3	1	3	1	5	2	229	83	278
		24	7	5	9	6	10	6	5	3	4	3	10	7	107	70	152
ALL HOURS COMBINED			68	4	87	5	143	8	45	3	41	2	65	4	1293	74	1742
FEBRUARY (MONTH)																	
235	02	04	12	15	2	3	5	6	5	6	4	5	1	1	52	64	81
		08	27	8	25	7	32	9	14	4	17	5	18	5	215	62	348
		12	12	4	13	4	20	6	8	3	8	3	11	3	240	77	313
		16	6	2	15	4	17	5	11	3	14	4	24	7	265	75	352
		20	12	5	10	4	17	7	6	3	10	4	13	5	170	72	238
		24	6	7	4	4	5	6	3	3	4	4	3	3	66	73	91
ALL HOURS COMBINED			75	5	69	5	96	7	47	3	57	4	70	5	1008	71	1423
MARCH (MONTH)																	
235	03	04	14	15	6	6	6	7	6	7	4	4	8	9	47	52	91
		08	47	12	30	7	30	7	11	3	6	1	15	4	273	66	412
		12	15	4	17	4	28	7	11	3	2	1	12	3	309	78	394
		16	12	3	15	4	28	7	10	3	5	1	18	4	309	78	397
		20	14	5	5	2	15	5	6	2	3	1	9	3	232	82	284
		24	12	10	7	6	10	8	5	4	3	3	6	5	77	64	120
ALL HOURS COMBINED			114	7	80	5	117	7	49	3	23	1	68	4	1247	73	1698

\# LESS THAN 0.5%

NOTE: THE INFORMATION ON THIS FORM WAS COMPILED BY THE STATISTICS DIVISION, U. S. WEATHER BUREAU, UPON REQUEST OF THE CHIEF OF NAVAL OPERATIONS. ANY REQUEST FOR ADDITIONAL INFORMATION SHOULD BE MADE TO THE CHIEF OF NAVAL OPERATIONS.

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TABLE X PERCENTAGE OCCURRENCE OF WIND IN KNOTS WITH TEMPERATURE IN DEGREES FAHRENHEIT.

		WIND IN KNOTS				
		X	X+5	X+10	X+15	etc.
Temperature in Degrees Fahrenheit	Y°	4	2	1	3	
	Y°+2	1	2	1	4	
	Y°+4	3	1	2	0	
	Y°+6	1	3	0	1	
	etc.					

1. For a study of the effect of high winds (above X knots) together with temperature (above Y°F.) on the path of a projectile (or guided missile), a two-way percentage occurrence distribution of various wind speeds and temperatures at and above the critical values provides climatic guidance in terms of past simultaneous occurrence. Table X illustrates a form which the tabulation could take, the intervals of each class of wind and temperature depending on the units in which the original observations were recorded (i.e. wind may be recorded in Beaufort Force) and the detail needed in the use of the data.

Insofar as the machine tabulations are concerned the processes involved in this problem are identical with most in which a two-way frequency distribution is the result. The major differences from problem to problem are the headings and class intervals. Several other examples of special problems for which a two-way distribution might be made are:

2. Research into correlation of pressure change aloft with changes in surface weather.

3. Tabulation of simultaneous occurrence, by months, of any form of precipitation (including drizzle) with surface temperature 32°F or less.

4. Tabulations of Relative Humidity (X% and above) occurring with temperature (Y°F and higher), to be used in aircraft engine design.

5. Sea state and swell conditions, tabulated in accordance with limits for landing-craft operations.

Two possible ways of tabulating simultaneous occurrence of more than two elements have been illustrated in Chapter II, Tables IV and VI. Several further examples of tabulations are:

6. Simultaneous occurrence of 5000-foot wind direction and velocity with surface wind direction and velocity.

7. Simultaneous conditions of wind, seas, visibility, and low cloud amount.

8. Duration in hours of ceiling below X feet together with visibility below Y miles. Table XI is an example of such a tabulation where in Condition 1, ceiling was 1000 feet or higher and visibility 3 miles or more; Condition 2, ceiling was less than 1000 feet but not less than 500 feet and visibility less than 3 miles but not less than 1 mile; and Condition 3 ceiling was less than 500 feet and visibility less than 1 mile. Under "T" are total number of observations.

Often the most complicated tabulations are derived through solution of equations. An example of solving an equation was given in Chapter II, section 8. Furthermore, there is little similarity among these tabulations, so a typical one cannot be illustrated. Other machine analyses involving solution of equations include:

9. Calculation of Upper Air Density from radiosonde data.

TABLE XI PERCENTAGE OCCURRENCES OF FLYING CONDITIONS FOR INDIVIDUAL MONTHS AACHEN AND FRANKFURT, GERMANY

AACHEN		ALL HOURS				HOUR 14				HOUR 19			
		1	2	3	T	1	2	3	T	1	2	3	T
10407	1	35.2	31.7	33.0	627	39.0	35.2	25.7	210	37.0	26.9	36.1	208
	2	41.9	27.4	30.8	585	42.3	32.0	25.8	194	49.5	25.0	25.5	196
	3	46.9	30.3	22.9	638	46.9	34.7	18.3	213	55.9	28.6	15.5	213
	4	41.0	36.2	22.8	527	39.1	46.0	14.9	174	49.4	33.0	17.6	176
	5	51.7	32.0	16.2	543	52.2	37.8	10.0	180	57.5	34.3	8.3	181
	6	62.2	27.9	9.9	527	61.8	32.0	6.2	178	64.0	30.2	5.8	172
	7	56.0	36.3	7.7	452	53.3	42.0	4.7	150	65.8	29.5	4.7	149
	8	59.9	24.3	15.8	461	64.7	27.5	7.8	153	69.5	26.6	3.9	154
	9	64.4	24.3	11.3	444	65.1	28.8	6.2	146	76.0	18.7	5.3	150
	10	49.8	25.2	25.0	456	53.3	30.0	16.7	150	53.6	23.5	22.9	153
	11	41.5	29.2	29.2	448	48.0	26.7	25.3	150	39.6	30.9	29.5	149
	12	40.4	26.3	33.3	460	46.1	26.3	27.6	152	35.7	26.6	37.7	154
FRANKFURT AM		ALL HOURS				HOUR 14				HOUR 19			
		1	2	3	T	1	2	3	T	1	2	3	T
10412	1	25.0	30.8	44.2	893	29.3	24.3	46.4	304	25.5	35.0	39.5	386
	2	37.1	26.7	36.1	819	46.2	27.6	26.2	279	39.8	27.2	33.0	261
	3	48.9	24.3	26.8	926	52.1	29.4	18.4	309	59.7	22.4	17.9	308
	4	53.6	33.7	12.7	893	51.9	41.7	6.4	295	62.7	32.7	4.7	300
	5	67.1	24.7	8.2	927	64.0	33.1	2.9	308	75.7	21.7	2.6	309
	6	75.3	19.3	5.5	898	70.6	25.8	3.7	299	81.3	16.0	2.7	300
	7	68.6	22.7	8.6	928	68.3	29.4	2.3	309	78.3	19.1	2.6	309
	8	70.8	18.1	11.1	924	74.9	20.8	4.2	307	78.2	18.5	3.2	308
	9	61.8	18.6	19.5	891	66.9	24.0	9.1	296	72.4	17.8	9.8	297
	10	40.5	28.8	30.7	892	47.1	35.3	17.6	306	45.7	26.8	27.5	276
	11	28.0	22.8	49.2	865	32.4	24.4	43.1	299	32.1	24.3	43.7	268
	12	27.1	22.9	49.9	899	32.1	21.1	46.8	308	27.6	24.4	48.1	283

10. Calculation of Radio-climatology data for Electronics Research from radiosonde records.

11. Calculation of cross-wind, head-wind, or tail-wind components at various altitudes on selected air routes.

C. UTILIZING TABULATED CLIMATIC DATA

Results of machine analysis of weather data contained in punched cards are always furnished in tabular form. As illustrated in the preceding pages, these tabulations range in content from listing of arranged observation reports to solutions of complex equations. The format for a tabulation varies with both the character of data tabulated and the use to which the data are expected to be put. Such data can be used directly in numerical and tabular form or be presented for visual impression by a variety of graphical methods.

TABULAR FORM. When a table is to be the final product, the tabulator prints the data on a prepared blank form. A table may be included with graphic presentations of data to provide exact or supplementary information. An illustration of this use is Table I, "Radiosonde and Rawinsonde Data", which is bound in the publication "Daily Series of Synoptic Weather Maps of the Northern Hemisphere". Or, a table may be used as a source of specific information: an aerologist would like to know the percentage of observations during January in which the ceiling was below visual flight rule limits: the first two columns of Table IX would give the answer. The new weather summary table now being tested will list frequency of simultaneous occurrence of specified ceilings with wind direction and speed, and visibility.

GRAPHIC FORM. When the tabulations provide raw data for further analysis on graphic representation they are printed by the tabulator on lined paper and accompanied by a key page explaining the organization of material. Such graphic presentation, of the tabulated data as may be selected or devised by the user, is the best means of emphasizing on maps the relationship of climatic features to their geographical location and the comparison of variation of climatic elements with location; it best achieves emphasis of salient features and trends of tabulated data: and it is often the best approach to problems where direction is one of the variables.

TABLE XII PERCENTAGE OCCURRENCE OF WIND VELOCITIES FOR CEILINGS OF 200 FEET OR LESS AT SALT LAKE CITY, UTAH. (TEN YEAR PERIOD)

	SPEED IN KNOTS						
	Calm	1-4	5-9	10-14	15-30	30	Total
N		5.3	1.5	4.0	1.5		12.3
NE		3.0	0.8	1.4	0.4		5.6
E		3.6	0.8	0.9			5.3
SE		7.3	3.2	2.1			12.6
S		10.5	2.2	1.1	0.4		14.2
SW		10.5	1.0	0.8	0.0	0.6	12.9
W		9.0	2.4	1.0	0.6	0.6	13.6
NW		8.2	3.4	2.8	3.6		18.0
Calm	5.5						5.5
Total	5.5	57.4	15.3	14.1	6.5	1.2	
Accumulated Total	5.5	62.9	78.2	92.3	98.8	100.0	100.0

Analysis of simultaneous occurrence of wind direction and speed with other weather elements is often necessary in dealing with specific problems, such as planning a runway for bad-weather operations. At some airports an Instrument Landing System (ILS) may be used when the ceilings are below 500 but not below 200 feet; when the ceilings are 200 feet or lower a Ground Controlled Approach (GCA) must be used. These landing aids used during low ceiling conditions are usually set up for only one runway because of their expense. From climatic data can be obtained the percentage of low ceilings for each wind direction and speed, information upon which the choice of runway can be based. Allowable crosswind for landing by GCA is a critical factor in choosing the runway. In the illustration Fig. 5, the maximum allowable cross-wind is 14 knots; this value depends upon the physical characteristics of the airport, the handling characteristics of the aircraft expected to use the system, and the ability of the pilots.

Table XII is a tabulation of the wind-ceiling correlation for ceilings of 200 feet and less. The table immediately shows that any runway will provide an efficiency of at least 92.3%, i.e., the percentage of winds below 15 knots. The runway chosen will then be that on which the highest percentage of the remaining winds produce less than 15 knots cross-wind components, most easily determined by a graphical method illustrated in Fig. 5. It is accomplished in the following manner: On a wind rose consisting of concentric sector areas to eight points of the compass and limited by the class intervals of the table, the percentages in Table XI are placed in their respective areas. Then a transparent template twice the width of the limiting cross wind, 15 knots, is centered for rotation at the wind rose center. Summation of percentages under the template gives the efficiency of a runway having the same orientation as the template. Several summations will permit the selection of maximum efficiency. In fact, integration by eye will often permit a rapid approximation of the desired orientation. In this case maximum efficiency of about 97% will be obtained on a runway oriented in a NNW-SSE direction although it will be only a few percent more than any other runway.

A great variety of histograms and line graphs aid the interpretation of tabulated data, especially in extraction of approximate values interpolated from exact data and in emphasizing trends and distribution by visual impression. Aerologists are all familiar with graphic presentation of climatic information in atlases which show areal distribution by shadings and isolines and month-to-month trends by histograms and line graphs, and could similarly treat tabulated data for their own use.

D. CLIMATOLOGICAL STATISTICS

With increased amounts of observational records and more knowledge of the characteristics of weather elements' behavior, more detailed statistical treatments of climate are possible. Punched cards and machines, performing statistical analysis which time and cost of manual methods had previously made impractical, are opening new channels of understanding and of "applied climatology". Until very recently, climatological statistics consisted for the most part of simple mean values, such as mean monthly temperature and precipitation, and mean number of days of occurrence of fog, thunderstorms, and so on. Mean values provided the basis for early climate classifications, which served to delimit areas of similar mean climatic characteristics but were recognized as only very rough guides in planning and of almost no value in forecasting. Slowly more comprehensive statistical values were added to climatic description steadily encouraging the application of knowledge of climate to specific problems. Frequencies and durations of occurrence, simultaneous occurrence of two or more weather elements, correlation of conditions at several places, and most recently, probability or chance of occurrence now can be statistically reduced where quantity of data is large enough and suitable for such analysis.

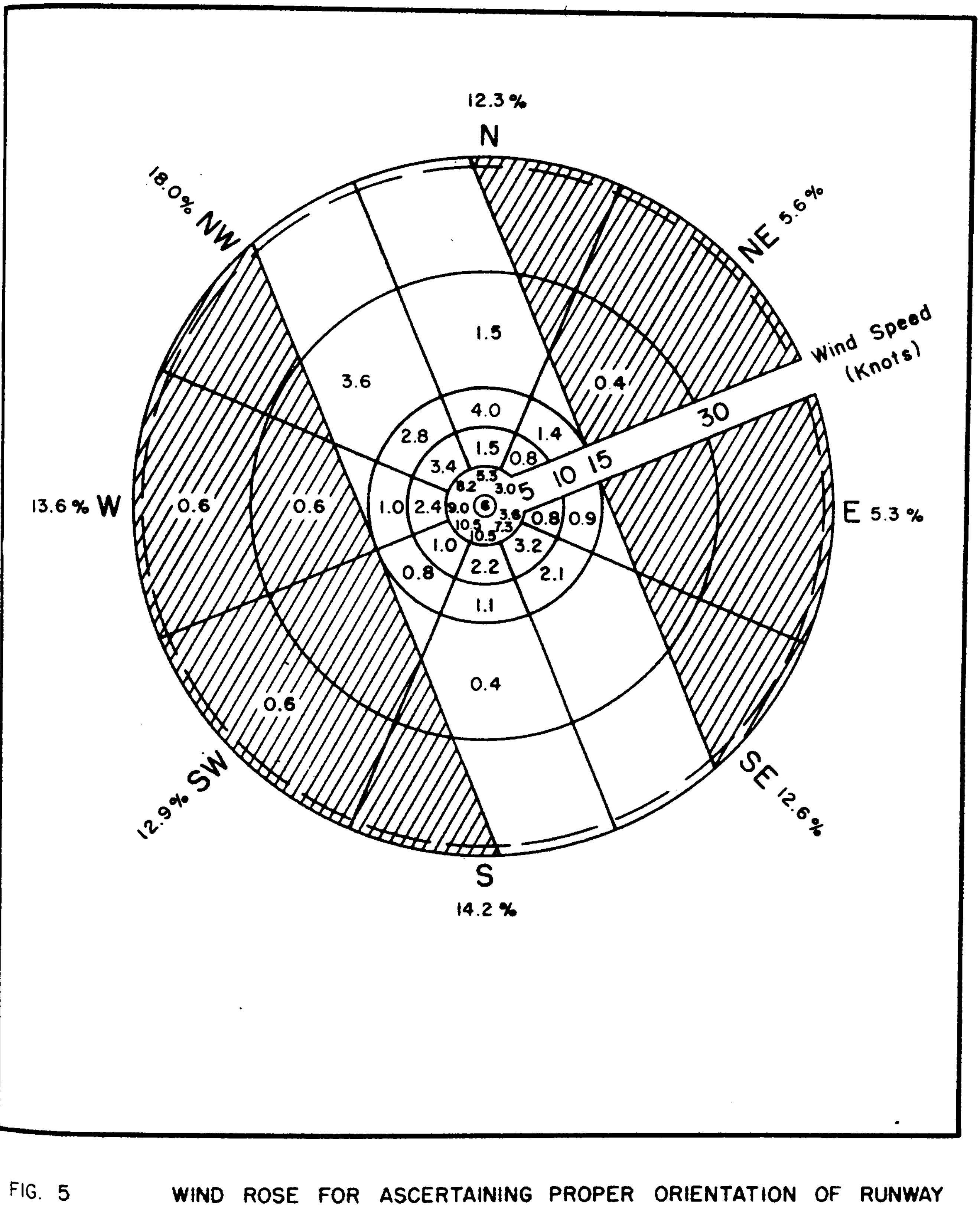


FIG. 5 WIND ROSE FOR ASCERTAINING PROPER ORIENTATION OF RUNWAY FOR WIND VELOCITIES OCCURRING WITH CEILINGS OF 200 FEET OR LESS FOR SALT LAKE CITY, UTAH. PERIOD OF RECORD, 10 YEARS, 1936-1941, 1947-1950.

Thus, for temperature, the following detail of information can be extracted from punched card weather records:

- Monthly mean
- Monthly mean daily maximum
- Monthly mean daily minimum
- Frequency of occurrence of daily maximum and of daily minimum
- Accumulated and Percentage frequency of occurrence of daily maximum and daily minimum
- Frequency of daily range
- Frequency of duration of temp. higher than X°F. or lower than Y°F
- Probability or chance of recording temperature lower than X°F., higher than Y°F., or between X°F, and Y°F
- Frequency of simultaneous occurrence of temperature at A and B

Similar statistical analyses of other climatic elements and their correlations can now readily provide much more complete and usable climate descriptions for application to routine tasks and special problems than has ever before been available.

CHAPTER IV.

THE NATIONAL WEATHER RECORDS CENTER

A. CONCEPTION AND PURPOSE

Preparation of climatic information necessary for planning operations in World War II was hampered by the fact that American weather records were scattered all over the country in files of various Weather Bureau offices, government agencies, private organizations, and each armed service. At that time, the only way different centers could produce climatic summaries was by costly and time-consuming copying and exchange of records. Under the pressure of wartime needs it soon became abundantly clear that if the greatest public benefits were to be determined from these records, for peacetime as well as wartime purposes, they must all be collected and kept at a central location. Following several interim arrangements, final establishment of the National Weather Records Center (NWRC) at Asheville, North Carolina, was completed in May 1952. This center is operated by the U. S. Weather Bureau, U. S. Navy, and U. S. Air Force as a joint activity. The records are maintained at the NWRC by delegation of authority from General Services Administration, National Archives. The purposes of the NWRC are:

1) to assemble and make accessible to users at a central location a complete library of weather records from the United States and from as many foreign sources as possible;

2) to concentrate effort and effectiveness of funds of participating agencies by combining processing facilities to eliminate need for duplication of records, punch card files, and tabulations;

3) to benefit through interchange of statistical methods, processing techniques, and results of machine analysis.

In order to achieve these purposes the National Weather Records Center has initiated a two-fold program for acquisition of weather records: 1) collecting past weather data for periods as long as available, and 2) maintaining and enlarging collections of current observational reports. Both phases involve data in the form of original records, including autographic sheets, microfilm copies, and punched cards. Weather records from the numerous filing centers in the United States have been transferred for centralized filing at the NWRC. All current national records are sent periodically to the NWRC. The Weather Bureau, Air Force, and Navy contribute most while other government organizations, such as the CAA, Soil Conservation Service, and many state, county, and city agencies, and private institutions, notably the airlines, also deposit their records. Foreign records are obtained for the Northern Hemisphere weather map projects and also through the climatic data program of the World Meteorological Organization. Marine weather records are increasing from the Navy, commercial shipping, and foreign sources.

The basic aim of the weather records acquisition program is to have as complete coverage of the world for as long a period as possible. Major gaps exist, some for areas sparsely inhabited or infrequently travelled, others for periods of time. A good example of the latter is the lack of records of marine weather observations made during the years of World War II. To help remove this deficiency the Navy is selecting representative observations from Quartermasters' logs and placing the data in punched cards.

B. RECORDS AT NATIONAL WEATHER RECORDS CENTER

The major portion of records in the National Weather Records Center are original observation forms and microfilm copies. In some cases only the latter are obtainable. When the original records are sent to the Center, some (e.g. all Navy observation forms) are microfilmed as a matter of routine, while microfilm copies of others are made only on request. One of the services of the NWRC is to provide microfilm copies of weather records at cost to those who need the basic observation data.

The most important "working" records are the punched cards. Records from United States stations within and outside the country predominate in numbers, detail, and frequency of observations. Although the longest possible record is desirable for analysis, the volume of current data which must be punched into cards from the original observation forms sent to the Center has made impracticable the transfer of individual data of past years to punched cards. Therefore, except some data which has been punched for special projects, records of observations prior to about 1945 are on punched cards only as summaries of previously performed manual tabulations. Important exceptions are Naval Air Station records placed in punched card form to produce station climatic summaries, Air Force records, marine observations obtained by reproducing British, Dutch, and German punched card decks, and several hundred U. S. Stations prepared for use in the Northern Hemisphere Historical Synoptic Weather Maps series and for special research problems.

In contrast, most punched card records for foreign stations are pre-World War II. Most of these were punched to prepare summaries needed during wartime operations. The only current records from foreign countries being transferred to punched cards are those for about 1000 stations regularly received in the U. S. in conjunction with preparation of Northern Hemisphere Daily Synoptic Weather Maps. After the data have been plotted on the maps, the records are sent to the NWRC for microfilming, punching into cards, and filing.

The punched card library now contains almost 200 million cards in decks including a great variety of combinations of weather elements, surface and upper air. Punched cards of current weather records are increasing the stock at a rate of twenty million a year. WBAN forms 10A and 10B and the punched card containing the first observation of the day are illustrated in Fig. 6. One card represents one observation. A WBAN 20A and the punched cards containing the standard level data from it are shown in Fig. 7. The lower card holds the data from the surface through 11,000 meters and is identified in the machine by the "1" punched in column 19; the upper card is for levels 12,000 through 26,000 meters. Fig. 8 is WBAN 31A with two of the four cards necessary for a radiosonde observation extending to 400 mbs. Corresponding observation records from ships are placed on similar punched cards.

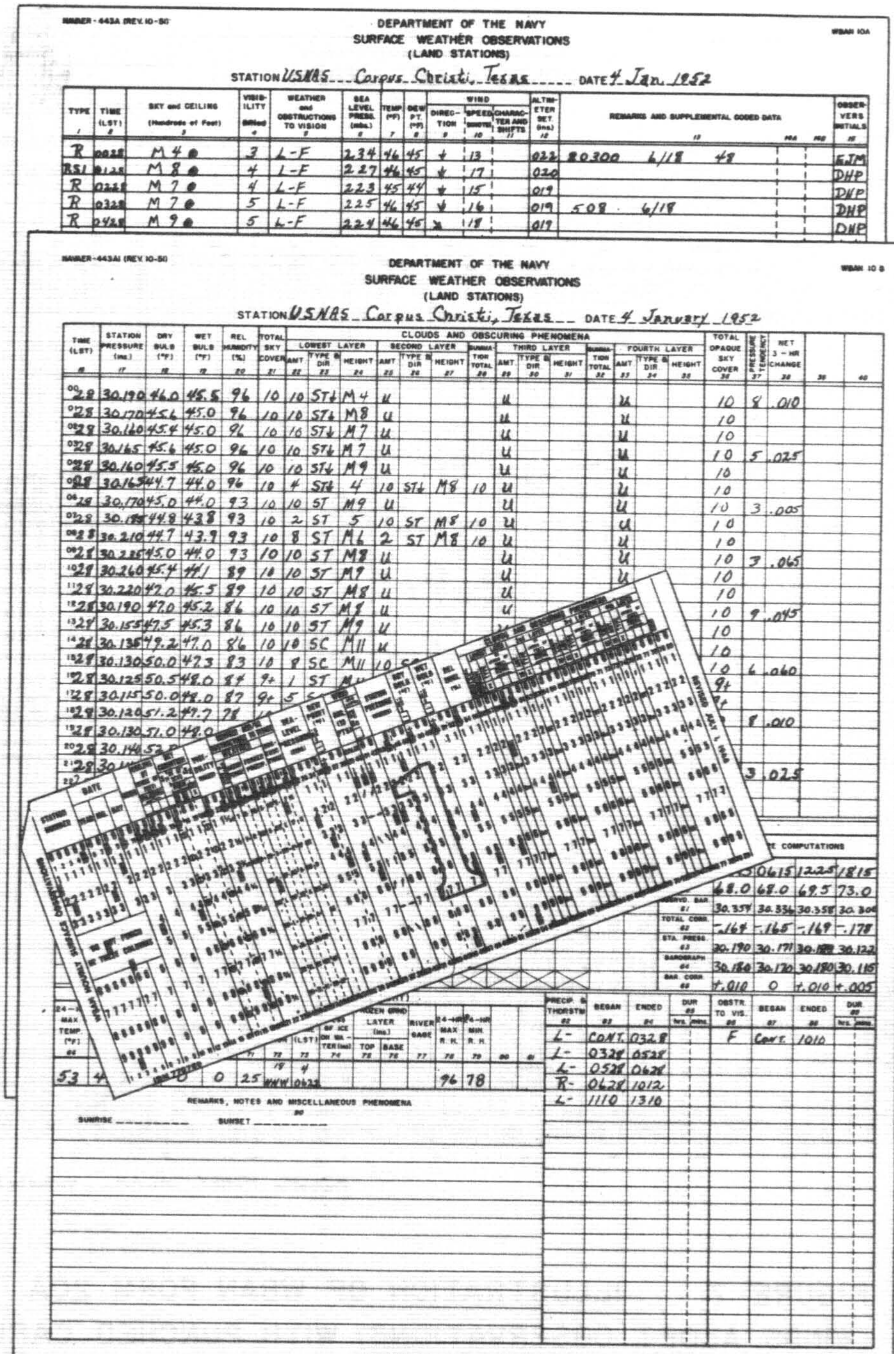
Since much of the climatic analysis done at the NWRC is accomplished by the use of punched cards and machines, emphasis is placed here on the amount and type of information available on punched cards. Some general characteristics and limitations of the data, resulting more from observational techniques and practices than from punched card capacity, need to be pointed out:

1. Records of surface observations make up the greatest amount of data now on punched cards. Of these, the synoptic observations, i.e., the 6-hourly observations, predominate except for the United States for which records of hourly observations will soon surpass in number all other types of cards. Only air temperature, pressure, wind speed and direction, and precipitation are commonly observed and punched; and other elements may be missing for varying numbers of stations, or for any station at varying intervals during the record. Except for the United States, for which summaries of each day's weather are available, such important data as peak gusts of wind are not available. The rapid variation of ceilings, the occurrence of rapid fluctuations of temperatures, the occurrence of more than one phenomenon of present weather, cannot be obtained at the present time without recourse to the original records.

2. Since a high percentage of winds-aloft observations have been made by pilot balloon, it is important to emphasize that low clouds, precipitation, dust, and other phenomena often prevent visual observation. Any statistics derived from pilot balloon data, therefore, and probably all winds-aloft summaries, give results biased toward fair weather conditions. In addition, difficulties of balloon observations, such as bad balloons breaking at low altitudes, high winds carrying the balloons beyond low altitude visual and radio range, limited time of observation, or use of balloons having a slow ascent rate largely limit most observations to the altitudes below 12,000 feet. For this reason, adequate summaries for "jet operations" at 30,000 feet are not yet possible, although some guidance may be obtained from the data.

3. The science of radio-sounding of the atmosphere for temperatures, pressures, and humidities aloft is relatively new. The data available cover, with few exceptions, only the past decade and even then are limited to those countries using the radiosonde. Data are almost wholly lacking from the southern Hemisphere.

A brief discussion of the punched cards available at NWRC will give an idea by geographical areas of the present potential (and limitations) for machine climatic analysis. In many areas, not much can be done because the Center does not have adequate punched card records. For large general areas for which considerable data are on file, a survey would probably have to be made to ascertain whether or not specific small-area summaries could be prepared.


NAVAER - 443A (REV. 10-50)

DEPARTMENT OF THE NAVY
SURFACE WEATHER OBSERVATIONS
(LAND STATIONS)

WBAN 10A

STATION USNAS Corpus Christi, Texas DATE 4 Jan. 1952

TYPE	TIME (LST)	SKY and CEILING (Hundreds of Feet)	VISIBILITY (Miles)	WEATHER and OBSTRUCTIONS TO VISION	SEA LEVEL PRESS. (mbs.)	TEMP (°F)	DEW PT. (°F)	WIND DIRECTION	WIND SPEED (KNOTS)	WIND CHARACTER AND SHIFTS	ALTIMETER SET. (ins.)	REMARKS AND SUPPLEMENTAL CODED DATA	OBSERVERS INITIALS
R	0028	M 4 ⊕	3	L-F	234	46	45	↓	13		022	80300 6/18 48	EJM
RS1	0128	M 8 ⊕	4	L-F	227	46	45	↓	17		020		DHP
R	0228	M 7 ⊕	4	L-F	223	45	44	↓	15		019		DHP
R	0328	M 7 ⊕	5	L-F	225	46	45	↓	16		019	508 6/18	DHP
R	0428	M 9 ⊕	5	L-F	224	46	45	↘	18		017		DHP

NAVAER - 443A1 (REV. 10-50)

DEPARTMENT OF THE NAVY
SURFACE WEATHER OBSERVATIONS
(LAND STATIONS)

WBAN 10 B

STATION USNAS Corpus Christi, Texas DATE 4 January 1952

REMARKS, NOTES AND MISCELLANEOUS PHENOMENA

SUNRISE ______ SUNSET ______

U. S. GOVERNMENT PRINTING OFFICE : 1951 O - 910685

FIG. 6 ILLUSTRATION OF WBAN FORMS 10A & 10B (SURFACE WEATHER OBSERVATIONS) WITH PUNCHED CARD.

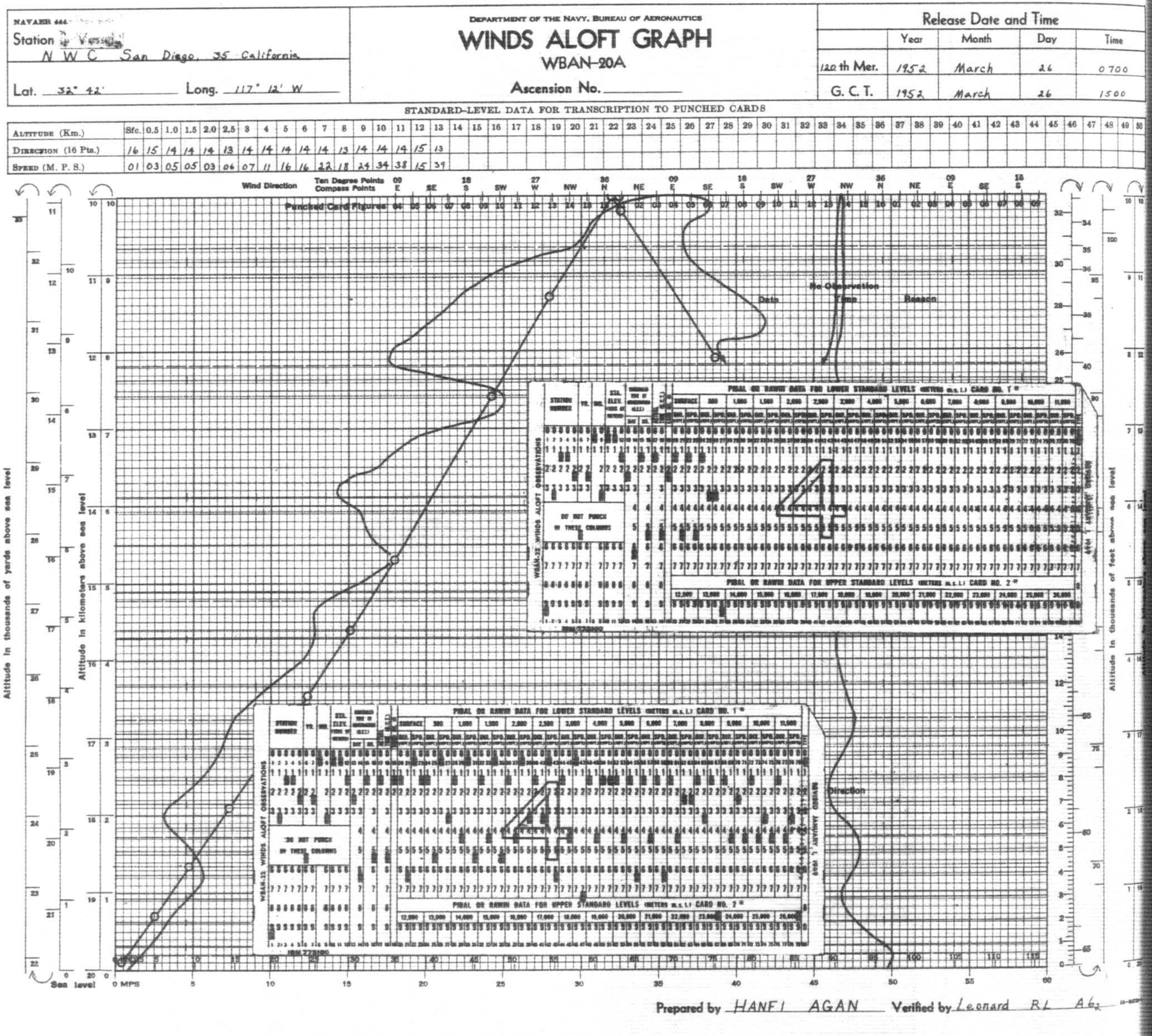


FIGURE 7 ILLUSTRATION OF WBAN FORM 20A (WINDS ALOFT OBSERVATIONS) WITH PUNCHED CARD.

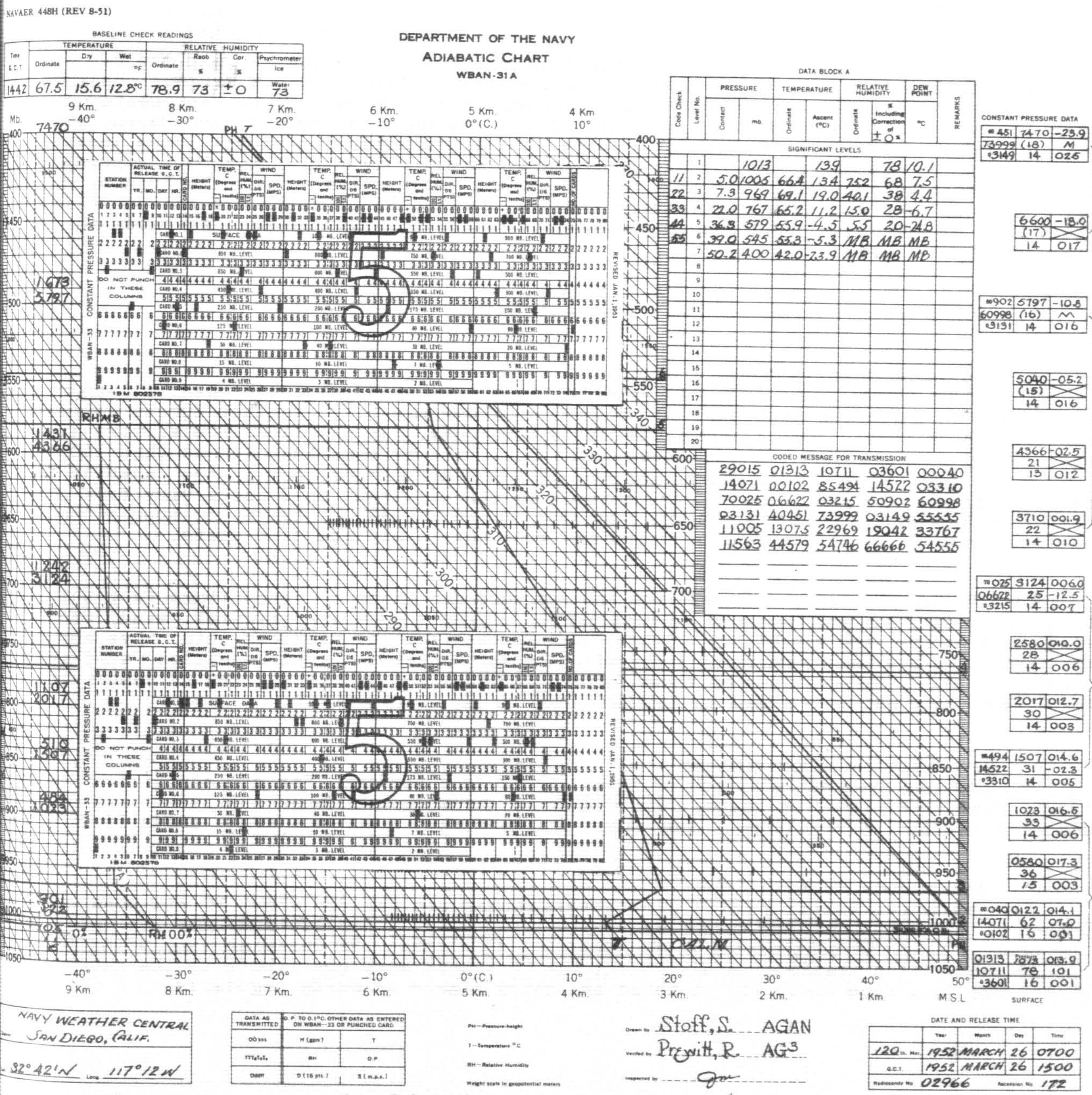


FIGURE 8 ILLUSTRATION OF WBAN FORM 31A (RADIOSONDE OBSERVATIONS) WITH PUNCHED CARDS.

I. PUNCHED CARD DECKS OF LAND STATIONS

1. NORTHERN HEMISPHERE

Card decks of data collected for the Northern Hemisphere weather map project for the periods 1899-1928 and 1945 to the present include nine million 1200 GCT surface observations and three million upper air observations. The same stations may not be represented in each deck in every case; and, it must be pointed out, no quality control procedures have been used to detect and remove errors of observation or transcription except those immediately recognizable by the operators placing the data on cards. The decks have been separated, by origin, into blocks of data, e.g., the English reports are separate from the French, so that cards for any area can be easily removed from the decks. These cards are not duplicated in the files by continent and country, except the one-observation-per-day-cards for U. S. stations since 1945.

2. NORTH AMERICA (INCLUDING CENTRAL AMERICA)

a. Surface Observations.
More than 70 million cards represent an equal number of separate observations coverin about 10,000 observing stations. Over 9000 of these are U. S. Weather Bureau cooperativ stations which record one to three observations per day. In addition, 600 airport and cit stations, including Navy and Air Force, make observations each hour. Less than 100 of th 10,000 are outside the United States and its possessions, most of them in the Canadian Arcti and Greenland. The periods of record covered by the different card decks vary from severa months to 30 years, the majority being less than 10 years. All of the U. S. hourly observin stations have at least one year's record and most have a minimum of 8 years.

The elements most generally observed and recorded are those of temperature (dry bulb, we bulb, dew point, maximum, minimum), precipitation, clouds (types and heights), wind, pressure weather, humidity, and visibility. Other elements observed for stations which have appropriate facilities are measurements of evaporation, solar radiation, soil condition, surf and se condition, etc. Observations of these latter elements are relatively few in number and fo that reason have not been placed on punched cards to any great extent.

b. Pilot Balloon Observations
Observations from 400 stations of this type, 2 to 4 per day, for periods of from 2 to 1 years, have been placed on cards. The number of cards is well over 3 million, representin almost 3 million observations. Two cards are used when a balloon rises above 35,000 feet

c. Radiosonde Observations
A consecutive 4-year period of 2 observations per day for about 80 stations has bee placed on punched cards, and cards for longer periods for a few stations are available. A the present time, 50 continental U. S. stations, 15 Alaskan, 32 Canadian (including Arctic) and 20 cooperative stations in Mexico and the Caribbean area contribute to the records program. The data from about 100 of these are being placed on cards regularly.

3. EUROPE

a. Surface Observations
From upwards of 1000 stations, more than 10 million synoptic observations made prior t 1940 are on punched cards. Recorded in the World Meteorological Organization codes, the cover periods ranging from 4 to 10 years. In general, they were made during daylight hour and vary in number from one to three per day. Information can be extracted from them o cloud cover and height, temperature, wind direction and force, pressure, visibility, stat of sea (for coastal stations), and precipitation.

b. Pilot Balloon Observations
Upper wind observations over Europe, as in the rest of the world, are fewer in numbe than surface observations. A total of about 30,000 observations covering periods of 3 t 5 years' record for 44 stations are available.

c. Radiosonde Observations
Punched cards for roughly 16,000 observations, made at 18 stations over periods of up seven years, have been placed in the Records Center.

4. RUSSIA

a. Surface Observations

Russian observations reduced to punched cards for the Center number about 2 1/2 million. About 350 stations, 100 with a 6-months record, the rest with 6 years of record, have observations for one to three times a day containing data on clouds, weather wind velocities, pressure, air temperature, and relative humidity. About 300 of the stations also observed maximum and minimum temperatures, pressure changes, precipitation, visibilities, state of the ground, snow, and maximum winds, while about 200 had some data on state of sea, height of sea, temperature difference of water from air, and cloud directions. These data have also been placed on the cards.

b. Pilot Balloon Observations

Six years of data for 100 stations totaling about 25,000 observations have been punched into cards.

c. Radiosonde Observations

Eighteen thousand observations are available for 28 stations over the 6-year period 1932-1937, the early years of radiosonde development.

5. ASIA

a. Surface Observations

Slightly less than 5 million surface observations from 500 stations in this vast area, and over a 4 to 10 year period, have been placed on punched cards. Approximately two-thirds of the cards contain cloud observations of some type but cloud directions were observed only about once in thirty times. Only two to three observations per day are available, with the exception of those of a few island stations. Provision was made for observation of air pressure, wind, air temperature, humidity, ceiling, and visibility, and in a large percentage of cases these have been placed on the punched cards. Other elements occasionally observed were soil temperature, wet-bulb temperature, vapor pressure snow, precipitation, state of ground, height of sea.

b. Pilot Balloon Observations

Twenty decks for 200 stations for periods ranging from 1 to 7 years contain 300,000 irregularly scheduled observations. A few contain data on type, direction, and speed of the clouds in addition to the wind velocities.

c. Radiosonde Observations

Two decks covering three stations, one for 2 years, the other for 11 1/2 years, are available. The irregularity of operations has kept the overall number of observations very low, between 1000 and 2000.

6. SOUTHWEST PACIFIC AND PACIFIC ISLANDS (INCLUDING AUSTRALIA)

a. Surface Observations

Observations on punched cards for 15 stations for periods ranging from 4 to 10 years number about 300,000. Elements observed in all cases were clouds, wind, air temperature, pressure, and precipitation. Other elements occasionally observed by some stations were pressure tendency, soil temperature, maximum and minimum air temperature, humidity, and visibility.

b. Pilot Balloon Observations

Eight stations for three years produced a limited number of observations which have been placed on punched cards.

c. Radiosonde Observations

One deck for one station for about 7 years with two observations per day provides almost 5,000 observations.

7. AFRICA

Besides those in the Northern Hemisphere card decks, the only punched cards for any type of observation that the NWRC has for Africa, number about 300,000 containing synoptic surface observations at 60 Egyptian and Anglo-Egyptian Sudan stations, and a small number for pibals at 20 stations in the same countries. Maximum length of surface records is 9 years. Temperature, pressure, wind, and humidity were generally observed. A few observations of clouds, maximum temperature, wet-bulb temperature, vapor pressure, precipitation, and visibility were made and are available from the cards.

8. SOUTH AMERICA

a. Surface Synoptic Observations

About 500,000 observations on punched cards have been obtained for South America. The period covered by them ranges from 6 to 10 years for 70 stations. Records of clouds, wind, temperature, humidity, pressure, precipitation, and visibility have been transferred to punched cards for the majority of the stations. In a few cases, ceiling, pressure tendency, wet-bulb temperature, vapor pressure, state of ground, and cloud height are available.

b. Pilot Balloon Observations

A few stations' records have been placed on punched cards, the total number of cards now available (1952) numbering only about 15,000.

c. Radiosonde Observations

A few observations from Talara, Peru, and Barranqilla, Colombia, are available but do not cover any protracted period.

II. PUNCHED CARD DECKS OF MARINE DATA

Since the decade of 1850-60, maritime nations have been recording marine weather observations quite regularly. In the beginning the observations were primarily of value in building up climatological data, but with developing communications they have led to better weather maps and forecasts of direct aid to ships. The observations have been slowly accumulating over the past century; the majority have been collected during the past fifty years. Areas of greatest concentration of data are coastal waters and along the most used shipping routes. Off the shipping routes are some areas where there are few or no recorded observations.

The number of modern IBM punched cards containing observations from U. S. merchant ships since the publication of the Atlas of Climatic Charts of the Oceans has not yet become large. Together with about 1 1/2 million Navy shipboard observations they total about three million. The bulk of marine data on modern punched cards now held by the NWRC have been procured from the British, Dutch, and German Meteorological Services by exchange and purchase. These three decks total nearly 15 million cards.

Filing and analyzing weather data from ocean areas present several outstanding problems. Unlike observations at land stations which have a fixed location, any two at sea are rarely made at exactly the same place. Therefore, shipboard observations must be grouped for an area and treated as though they were made at a single location. Early in the 19th century Marsden of the British Admiralty devised a plan for grouping observations which is now used by Meteorological Services of all countries. This plan called for numbering all the 10° quadrangles of latitude and longitude on a Mercator map. The numbering of these quadrangles, commonly called "Squares", is illustrated in Fig. 9. The smaller numbers shown in each square give the thousands of weather observations in the marine card decks obtained from the British, Dutch, and Germans. Though not shown here, each 10° Marsden Square is subdivided into four 5° squares and 100 1° squares. The smallest area for which adequate data are available is used in preparing tabulations.

While the useful convention of assuming that all recorded observations within a Marsden Square were made on the same spot is statistically imperfect, an even less statistically dependable difficulty exists in the irregularity of the observations. Several ships may pass through a Marsden Square area within 2 or 3 days, then no others for the remainder of the month; many more traverses per month may be made through an area during some years than during others. Quite probably data in different squares are not for comparable periods of years since shipping routes have changed with geographical and economic conditions. For example, because of the opening of the Panama Canal the observations around Cape Horn were reduced after 1910 while those in the approach waters to the canal predominate after 1905.

A valuable marine observation program has been carried out by the maritime nations bordering the Atlantic and Pacific Oceans since 1940. Weather ships, whose primary purpose is to provide continuous observations from limited areas, operate at 10 "ocean station" locations in the North Atlantic and 9 in the North Pacific. Their observations are:

1. a good chronological series of three-hourly data which offers an excellent source for diurnal and duration studies;
2. continuous samples of ocean weather observed by trained personnel which can be used to test reliability of observations from other ships:
3. the only controlled source of upper air data over the oceans.

Most marine observations have included wind direction and speed, present weather, air temperature, pressure, visibility, water temperature, cloud cover, and sea condition. Weather observations were, and are, made every three, four, or six hours. The number of all types of marine observations on punched cards, though small until recently when monthly and diurnal totals are considered, does provide sufficient material in certain areas to provide good representations of climate in those areas.

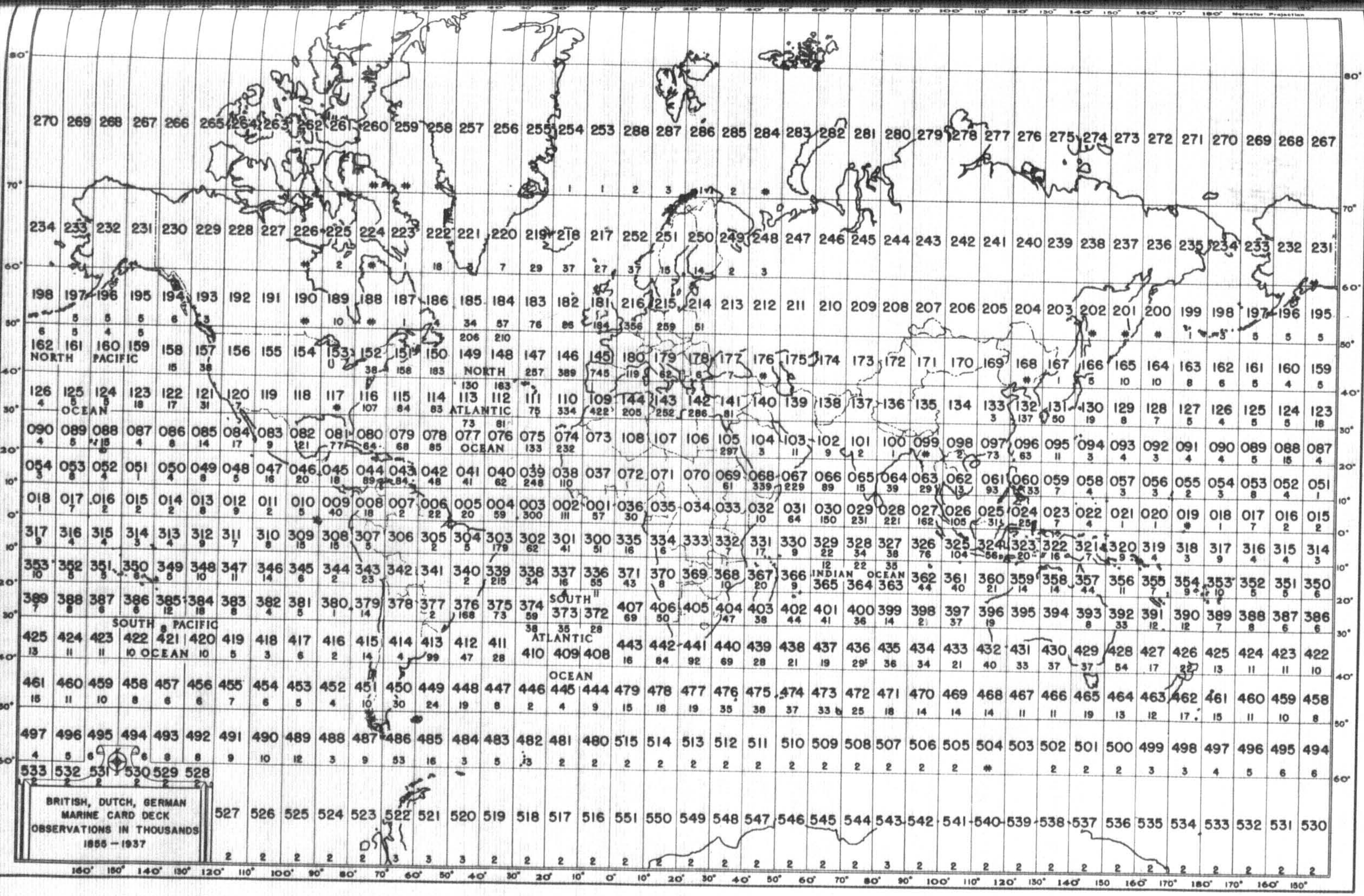


FIG. 9 MARSDEN SQUARE CHART

SHOWING THE NUMBER OF MARINE OBSERVATIONS AVAILABLE IN THE BRITISH, DUTCH, AND GERMAN DECKS; PERIOD (1855-1937)

CHAPTER V.

REQUESTING CLIMATOLOGICAL INFORMATION

A. The main purpose of this pamphlet is to bring the existence of the National Weather Records Center and its potentialities to the attention of:

1. The Aerologist (in the field and in planning units) who may need climatic information for guidance in preparing general forecasts;

2. The Research director, who can call upon the Center for aid in his exploration of large masses of data for his study of the limiting influence of climate and weather on the operational efficiency of personnel, ordnance, many types of equipment, buildings, aircraft, vessels, and vehicles; in the development of forecasting and planning aids; and so on;

3. The Task Group or Fleet Commander to whom the aerologist and the research man convey essential information bearing upon the over-all aspects of planning.

The greater proportion of the present effort by the Navy Machine Unit at the National Weather Records Center is devoted to established projects described as "routine tabulations" in Chapter III. Naval station climatological summaries, atlases, and special area studies usually provide general information for large parts of the world and such detailed information for specific locations as can be processed for all places by mass production methods. Routine tabulations are designed to answer as many problems as possible which may face the Aerologist, the Researcher, and the Commander. Those problems which cannot be answered by these tabulations must be handled individually and may require the development of special procedures to provide the necessary information.

In Chapter II the capabilities of punched card machines were described from the standpoint of results that could be produced. Chapter III translated the general capabilities of machines into actual types of problems for which machines can be utilized. There remains to be described the procedure by which the information can be obtained by the man with the problem: where to send a request, what to include in it, and what will happen to it.

The Office of Chief of Naval Operations controls the Navy participation in the joint activity of the Records Center. Correspondence requesting the utilization of capabilities of the Center and the Machine Tabulating Unit should be addressed to:

Chief of Naval Operations (Op-533)
Navy Department
Washington 25, D. C.

B. When a request is received, the climatology unit of Naval Aerology makes the following preliminary review before work is commenced at the National Weather Records Center:

1. Ascertains if there is an existing tabulation or study which would fulfill this request in whole or in part. From the many tabulations which have been made for routine studies and special projects, occasionally one already accomplished meets the requirements of a new request;

2. Determines if the required data are available to process the desired information. In certain cases, large time or area gaps exist in the weather records of the punched card library, and also certain weather elements may not have been recorded;

3. Studies the recorded unit of measurement of the weather records in question. A variety of units and class limits have been used in taking weather observations. These may not be transposable to the desired breakdown;

4. Estimates an approximate cost of work required to determine if it can be accomplished within allotted funds without interrupting the planned climatological work. The magnitude of Navy participation in the NWRC is based on the known and estimated Naval need for climatological information and on budgetary limitations. The estimated Naval need is based upon the actual requests that have occurred in previous years. After appropriation and allotment of funds for the fiscal year, a continuing basic program of action is developed whereby the known needs can be fulfilled and within which the estimated needs can be met as they arise. Requests may exceed the estimated needs either in number or in magnitude, in which case special funds and arrangements will be necessary. When this cannot be done, priority lists are established and future budget estimates are made so that the work can be done when funds do become available;

5. If necessary, resolves with the requester any question on required modification concerning the request. For requests which will entail extensive machine analysis and tabulation, a pilot project may be set up to examine and test such analysis and tabulation. If the results of a pilot project indicate that the available information and the procedures established will produce adequate answers, arrangements then will be initiated for the entire tabulation, subject to (4) above.

C. As far as possible, every consideration is given to providing timely and adequate results. In order that the most satisfactory results may be obtained, the originator of the request should bear in mind several important points:

1. Requests should be made sufficiently in advance to assure receipt of the tabulations by the time they are needed. (Several weeks to several months will often be required to complete special studies since they generally must be fitted into the schedule of priority work.);

2. Large tabulations and research problems may require conferences and pilot projects to determine feasibility;

3. Large and costly tabulations may require the transfer of additional funds and an increase in machine facilities of the National Weather Records Center to accomplish the work in a reasonable time;

4. Information desired should be clearly described and should include:

a. Place - when an area, boundaries must be specifically defined;
b. Period of record - month(s) and year(s). Non-specific terms like "winter months" should be avoided because several interpretations are possible;
c. Units of measurement - e.g. wind in knots, wind by Beaufort Force, visibility in thousands of yards or air temperatures in °C or °F;
d. Tabulation breakdown - e.g. by months; wind in knots, grouped 0 - 3 knots, followed by 10-knot intervals beginning 4 - 13;
e. Type of summary - e.g. percentage frequency of occurrence of cloud cover in groups 0 - 2 tenths and 6 - 10 tenths, and total number of observations reporting any cloud amount including 0/10;
f. Data to be included - e.g. in a request for "mean zonal wind components" the technician setting up a punched card machine analysis must know whether north and south winds should be omitted in the calculation or considered as having zero zonal components.

5. Care must be taken that all terms used in a request have a definitely understood meaning. This is especially true for research problems where special words, phrases, or notations may have been developed that are not commonly known. In other words, the aim of writing a request should be detail sufficient to obviate the need for any further interpretation of exactly what is desired.

6. Insofar as possible, the use to which the tabulated data are to be put should be included in each request. Thus, if the exact weather records are not available to provide the required tabulation, a substitute may be suggested. Or, if the description of desired information is not absolutely clear in itself the intended use for the data may clarify it.

* * * * *

BECAUSE OF THE RECOGNIZED NEED FOR SUCH INFORMATION IN MANY OF ITS MISSIONS, THE NAVY MAINTAINS FACILITIES AT THE NATIONAL WEATHER RECORDS CENTER FOR PREPARING WEATHER SUMMARIES AND CLIMATOLOGICAL ANALYSES. IT IS INTENDED THAT THE BENEFITS OF THESE PRODUCTIONS SHALL FALL TO THE PERSONNEL WHO PLAN AND ADMINISTER SUCH MISSIONS. THIS INTRODUCTORY APPRAISAL OF THE POTENTIALITIES OF THE CENTER SHOULD AID IN ENLARGING THE FUNCTION OF SUPPLYING INFORMATION NEEDED FOR ROUTINE AND SPECIFIC PROBLEMS, THEREBY INCREASING THE USEFULNESS OF CLIMATOLOGY TO THE NAVAL ESTABLISHMENT.