COADS Project Report 1: Update Plans and Unresolved Issues

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Introduction

Since 1981, a U.S.-funded project has combined international surface marine data, dating back to the inception of routine meteorological observations by merchant ships around the mid-19th Century, into the Comprehensive Ocean-Atmosphere Data Set (COADS).[1] For more recent years, ship reports, either transmitted via the Global Telecommunication System (GTS), or International Maritime Meteorological (IMM) logbook data exchanged under WMO (1963) Resolution 35, have been supplemented in COADS by automated in situ measurements, such as from drifting and moored buoys. This wealth of basic observational data has been edited (quality controlled), and monthly summaries have been calculated for acceptable data falling within 2° × 2° latitude-longitude boxes, for each decade and year of the period 1854 through (presently) 1992.

For reasons of navigation, and thus safety on the high seas, wind direction, and later speed, were among the first weather elements that mariners recorded in ships' logbooks. Partly because wind data extend back to the beginning of the record, COADS wind variables or those derived using the wind are of potentially major importance for climate and global change research. However, wind estimation and measurement practices have varied through time, as have reporting and processing of the data, resulting in data inhomogeneities whose significance has yet to be firmly resolved. This paper is the first of two COADS project reports (with Elms 1995, this volume) designed to provide some background on these and other unresolved issues relevant to COADS wind data, and to set the stage for possible improvements in COADS products.

Update Status and Plans

[1] COADS (Slutz et al., 1985; Woodruff et al., 1987) is the result of a continuing cooperative project between the National Oceanic and Atmospheric Administration (NOAA)—its Environmental Research Laboratories (ERL), National Climatic Data Center (NCDC), and Cooperative Institute for Research in Environmental Sciences (CIRES; Joint with the University of Colorado)—and the National Science Foundation's National Center for Atmospheric Research (NCAR). COADS products are available from NCAR, or individual observations from NCDC

COADS Release 1 (1854-1979), initially supplemented by a set of “interim” products for 1980-91, was extended through 1992 by COADS Release 1a (Woodruff et al., 1993). A variety of data additions was made for Release 1a, including replacement of many GTS ship reports by matching IMM data because of typically higher quality and observational completeness. GTS measurements from drifting or moored buoys were also replaced by quality controlled data from Canada’s Marine Environmental Data Service (MEDS), and from NOAA’s Pacific Marine Environmental Laboratory (PMEL) and its National Data Buoy Center (NDBC). In addition, special fishing fleet data from the Inter-American Tropical Tuna Commission (IATTC) helped improve coverage in data-sparse regions of the equatorial Pacific Ocean.

Release 1a quality controls included duplicate elimination, plus numerous data corrections, such as removal of GTS wind speeds originally reported in meters per second that were doubled due to a U.S. conversion software error (Fig. 1). Two separate sets of 2° monthly statistics were then calculated: (a) To provide compatibility with Release 1 data, the Release la “standard” statistics were restricted as nearly as possible to ship data, and quality controlled using Release 1 (1950-79) limits. (b) To maximize coverage and provide a more accurate representation of extreme climate anomalies such as the 1982-83 El Niño/ Southern Oscillation event (ENSO), the “enhanced” statistics included automated platform types in addition to ships, and were processed using expanded quality control limits.

COADS Release 1b, the next update milestone, is planned for completion in 1995. The main purpose of Release 1b is to provide an update and improvement of the individual observations for the period since about 1947 for use in Global Re-analysis projects (Jenne, 1992). Also as part of Release, we plan to extend the 2° monthly statistics through 1994.

COADS Release 2 is planned as a total re-processing of the record back to 1854 or earlier if possible, using improved methods and incorporating additional data that have been digitized or become available since completion of Release 1 in 1985 (Fig. 2). This large task is now anticipated for completion in the late 1990s because of the timing of historical data digitization efforts by NCDC and other countries including China, Germany, Norway, and Russia, and because of growth in the task of converting and processing all the Release 2 input data relative to available resources (see Elms et al., 1993 and Elms 1995, this volume for further information about digitization activities).

A major element of Release 2 is the planned merger of COADS with existing digital archives that were not included in Release 1 (see Fig. 2):

• A preliminary comparison between COADS and the UK Meteorological Office Main Marine Data Bank (MDB) for selected areas (Woodruff, 1990) revealed more data generally in COADS, but also some reductions and data errors in COADS that hopefully can be resolved by inclusion of MDB data (Parker, 1992).

• Russia has provided its Marine Meteorological Data Set of ship data extending back to 1888 (1980-90 data were used for Release la), and drifting Arctic “ice island” data back to 1950.

• Germany hopefully will be able to provide records from the Seewetteramt Data Archive to replace Historical Sea Surface Temperature (HSST) Data Project reports input to Release 1, because the WMO-defined HSST format (also used as input for

HSST receipts from the Netherlands) lacked some subsidiary weather elements such as present weather and complete cloud fields.

Among possible processing improvements under consideration for Release 2 are proposed increases in the temporal and spatial resolution of statistical summaries for selected time periods, regions, and variables (e.g., ° latitude × 1° longitude/sub-monthly), and separations of statistics to accommodate differences in data from different platform types (e.g., enhanced versus standard statistics) and times-of-day. In addition, improvements in quality control are planned to provide a more faithful representation of climatic extremes (see section below).

Unresolved Issues

This section is a general discussion of other important unresolved issues relevant to COADS winds, as well as other variables, that merit discussion in planning possible data or product improvements.

Spatial and temporal inhomogeneities

Changes in ship propulsion and routing (e.g., construction of the Suez and Panama Canals) account for many large variations since 1854 in global COADS data density (Fig. 2; see also Woodruff et al., 1987). Less well documented, however, are changes in the time of reporting ship observations (Fig. 3). A significant deficiency with the 1912-46 U.S. merchant marine data, which only came to light as the data started to be keyed at NCDC, is that observers were instructed to make logbook entries only once a day at 1200 UTC. Regrettably, corresponding teletype messages that may have been reported more frequently in some areas were discarded at NCDC (Elms et al., 1993).

Scientific measurements from moored and drifting buoys have helped expand spatial and temporal coverage for recent decades, although areas such as the tropical Pacific and the Southern Ocean are still under-sampled. However, combination of ship and buoy data in statistical summaries may also introduce unwanted sampling biases. For example, NDBC moored buoys reporting hourly around the coastal U.S. would likely dominate the statistics for those 2° boxes, except that they were reduced to 3-hourly resolution before inclusion in the Release 1a enhanced statistics.

Changes in instrumentation and observing practices

A survey in this volume of documented procedures for U.S. merchant mariners (Elms 1995, this volume) shows that changes have occurred in procedures for estimating and reporting Beaufort force, or later a wind speed equivalent in knots. For example, the verbal descriptions that accompanied tables for Beaufort force changed (or were even omitted in some years) in gradual transition to the change in estimation of wind speed using sail capacity to that using sea state.

Significant data inhomogeneities also may have arisen from variations in anemometer type and location relative to the evolving size and construction of ships. Compounding all these problems, there is believed to have been a steady upward trend in the ratio of measured to estimated winds (Ramage, 1987). A corresponding positive trend in scalar wind speed, or at least part of that trend, has been widely attributed to such artificial influences (e.g., Ramage, 1987; Wright, 1988; Cardone et al., 1990). These include application of the “old” Beaufort equivalence scale made effective by WMO after 1946, but also applied retrospectively for conversion to knots or meters per second of most winds thought to have been originally reported as a Beaufort force code (e.g., “re bracketing” of HSST receipts; see p. K28 of Slutz et al., 1985).

Cardone et al. (1990) illustrated that different source “decks” (as assigned by NCDC) may exhibit significant differences in wind data, depending on the makeup and processing history of each deck (see also Woodruff, 1990). Based on comparisons for selected areas (see Fig. 1), GTS ship wind speed observations from the former USSR (reported in meters per second) appear to average about 2 knots higher than those from other countries (generally reported in knots). However, more study is warranted before definite conclusions can be drawn from this selective comparison, and separations for other countries might also prove illuminating. Similarly, IATTC fishing boat (estimated or measured) wind speed data have a pronounced bias toward weaker speeds in comparison to the Release la enhanced statistics (Fig. 4). This is probably explained largely by the preference for tuna fishermen to seek out calmer wind areas, plus the effects of an anemometer height of approximately 10 m (F. Miller, personal communication). Thus although the IATTC data appear to reflect actual wind conditions, they were omitted from Release 1a enhanced statistics to avoid calm wind biases.

Introduction of automated platform types into COADS creates new possibilities for data inhomogeneities, applicable to wind data starting about 1970 with the advent of moored buoy measurements (Fig. 5; see also Wilkerson and Earle, 1990; Pierson, 1990; Radok, 1991). Considering for example only the issue of wind averaging period (nominally 10 minutes for ships), two subsets of PMEL data were included in Release a: (a) daily averages from Equatorial Pacific Ocean Climate Studies (EPOCS) moored buoys and low-elevation islands; and (b) Tropical Ocean-Global Atmosphere (TOGA) Program TAO ATLAS moored buoys, with wind averaging periods varying from 1-24 hours (in addition, ATLAS data were not necessarily synchronized on regular synoptic hours, and for earlier instrumentation packages different averaging periods and report times were used for different variables originating from a single buoy).

Similarly, NDBC hourly moored buoy wind data have been averaged over periods of 8-10 minutes, with anemometer heights ranging from 3.7-13.8 m, and either vector or “scalar” averaging depending on the instrument package (Gilhousen, 1987; Woodruff et al., 1991). NDBC and other groups internationally have begun experimentation with wind speed and direction sensors on new drifting buoy designs, and some countries already report these data over GTS. Because of concerns about the experimental nature of this new instrumentation, as well as the size of drifting buoys relative to sea state, wind data from drifting buoys were excluded from the Release 1a enhanced statistics.

Quality control problems

“Trimming” in COADS refers to the process of flagging individual observations that exceed upper and lower quality control limits defined for each 2° box and month, and excluding them from the trimmed 2° monthly summaries (note that the existing summaries have combined wind data without respect either to the original directional compass or to whether the wind speed was estimated or measured; see Morrissey, 1990). For Release 1, the trimming limits were set at the 3.5σ level using three climatological periods (1854-1909; 1910-49; 1950-79). As shown by, e.g., Wolter et al. (1989) and Wolter (1992), the 3.5σ limits have proven overly restrictive for extreme climate anomalies such as the 1982-83 ENSO. For Release la, the 1950-79 trimming limits were expanded to 4.5σ for the enhanced statistics; but 3.5σ was used for the standard statistics to provide greater compatibility with Release 1.

However, a more complex set of quality control problems applies to wind data, including a lower-bound of zero on wind speed, than to univariate quantities such as temperatures and pressure. COADS wind trimming is currently performed by testing both the u and v components (calculated from individual observations of wind speed and direction) against upper and lower limits for u and v. If either u or v exceeds its limits, the wind components (and speed) are flagged and omitted from monthly summaries. The feasibility of a bivariate test for trimming wind is under consideration for Release 2, as well as possible general improvements in the procedure for all variables (e.g., checks for consistency with respect to "local," as well as climatological, conditions in time and space).

Metadata from individual marine reports

This section discusses wind-related metadata (information about data) available in individual marine reports (the next section describes metadata available from external sources, and issues arising in attempting to join the two metadata sources).

a) Wind direction indicator

NCDC's (1968) Tape Data Family-11 (TDF-11) formed the core of COADS Release 1 data for 1854-1969. TDF-11 contained a wind direction indicator specifying the original compass code: 36-point, 32-point, 16 of 36-point, or 16 of 32-point. Additional wind direction indicator values have been defined in COADS to accommodate HSST 8-point data and high resolution automated measurements.

b) Wind speed indicator (i_w; WMO code 1855)

Modem ship GTS and IMM data contain i_w, which indicates whether wind speed was estimated or measured, and whether it was reported in meters per second or knots (the reduction in precision from reporting winds in whole meters per second, as recommended by WMO, instead of whole knots, should be noted; see Woodruff et al., 1991). Only starting in 1982 was i_w included in its present form in WMO's IMM formats. Although i_w may have been standardized in GTS data after 1963 (Cardone et al., 1990), its availability also depends on the date on which individual GTS receiving centers started saving that information. For example, the units part of the i_w information was apparently omitted from basic GTS data collected by NOAA's National Meteorological Center (NMC), the primary GTS source for COADS since 1980, until 9 May 1984.

Many of the early card decks included in TDF-11 contained little or no explicit information about wind speed observing method or reporting units, although we may be able to estimate indicator settings from documentation (e.g., the earliest decks clearly consist only of Beaufort estimates). Since it was designed after the 1963 IMM format, the TDF-11 wind speed indicator had only two settings: blank for "not measured" and 0 for "measured," such that the former also includes the meaning "unknown." Unfortunately, this ambiguous indicator is still in use in the current NCDC archival format (TD-1129), which is also the COADS format currently distributed by NCDC, although it has been supplemented by an "original wind speed units indicator" whose presence presumably allows reconstruction of i_w when reported. Additional wind indicator flag settings have been defined in the current Long Marine Report (LMR.6) format for COADS individual observations in an attempt to provide users with a single indicator that incorporates both historical and modem information (Table 1).

c) Automated report metadata

As discussed above, wide differences have existed in instrumentation and reporting by US. moored buoys (e.g., PMEL and NDBQ; internationally, even greater differences may exist. Similar to the situation with ship data, the availability of metadata from buoy reports may vary depending on the source and age of the data. Using NDBC moored buoy reports for example, anemometer height is included starting February 1985, and about 1988 fields were added for anemometer method (scalar or vector) and wind averaging period.

Linkage with metadata from external sources

WMO Publication 47 (1955 and later) describes many characteristics of individual ships participating in the WMO Voluntary Observing Program (VOP); unfortunately, WMO Pub. 47 is available only in paper form until 1973 (P. Dexter, personal communication). In addition, NOAA's National Weather Service (NWS) maintains some ship information, and other sources of information may exist (e.g., insurance companies).

At least in its current form, WMO Pub. 47 (and presumably the NOAA ship list) can be linked to individual ship reports only by matching the ship radio call sign. Due possibly to ship call sign errors either in the external lists or the individual ship reports, Wilkerson and Earle (1990) found that many ships apparently participating in the VOP were neither in WMO Pub. 47 nor in the NOAA list. In fact, a variety of format and data source problems impacts the availability of call sign or any form of platform ID in individual marine reports (Fig. 6). In addition, some countries have elected to include a national ship number instead of the call sign in IMM reports (see Woodruff et al., 1992). Figure 6 also illustrates the availability of report metadata indicating the recruiting country or flag nationality of each ship report, which could facilitate Intercomparison of national observing and reporting practices.

For drifting and moored buoys, WMO has expanded its *Operational Newsletter* for the World Weather Watch and Marine Meteorological Services to include some general information about the parameters reported by individual buoys. However, the *Operational Newsletter* currently lacks instrumentation details (e.g., anemometer types and heights). In addition, NDBC periodically updates a publication (NDBC, 1993) that lists instrument packages used aboard each of its moored buoys (and other platform types). As suggested by Woodruff et al. (1991), an internationally sanctioned repository of metadata for automated platform types appears to be highly desirable in digital form (WMO and

NDBC metadata for automated platform types apparently are not yet available in digital form, in contrast to WMO Pub. 47 since 1973).

Conclusions

COADS wind data are impacted by many complex and interrelated issues, such as highlighted in this paper, that will take substantial time and resources to resolve. For example, it is only with the vigorous cooperation of the international community that we can hope to significantly improve spatial and temporal coverage through digitization of historical logbooks. Research into variations in observing practices and instrumentation, not only for wind data but for other variables such as sea surface temperature, should be significantly advanced by easily usable digital files of external metadata for ships and automated platform types; WMO (1955-) Publication 47 and its *Operational Newsletter* should provide starting points for development of such products. For historical data, national and international instructions to mariners through time, such as discussed in the companion paper by Elms (1995) this volume, may need to be made more widely available.

Problems of a more technical or operational nature may also warrant closer attention and better coordination at the international or national level, perhaps through creation of a working group of marine data focal points as discussed in Woodruff et al. (1993). Following are a few such key issues whose resolution should help improve data and metadata quality for future COADS updates, and thus enhance the prospects for research using marine wind data:

• Because of differences between the ship GTS and IMM formats, as well as variations in handling the basic GTS and IMM data by different nations and sources, substitution among duplicates appears critical in order to obtain the best quality data and metadata. For example, ship radio call signs, which are usually included in GTS data, provide the linkage between individual marine reports and external ship metadata (e.g., WMO Pub. 47). However, the call sign was not included in IMM format until 1982, and some countries may still include national ship numbers in their IMM data. Unfortunately, substitution of fields among duplicates is a complicated process because there are frequently multiple duplicate reports, all of which should be compared for differences and relative information quality before creating a single composite report. Thus identification of composite reports and the source of their constituent fields becomes a further issue related to quality control. The simplest solution, in addition to providing report fields indicating when composites have been created, may be to retain the duplicate-rich input for further analysis as needed.

• Similarly, experience has clearly shown that permanent retention of original input data sets before conversion into common data formats is highly desirable. For example, errors have now been found in data converted from the original TDF- 11 card decks, but not all of the original card deck data are available in digital form, and some of these data are probably slated for destruction should ongoing data recovery efforts be derailed.[2]

• The wind speed indicator (e.g., for estimated/measured) and other report metadata fields may need to be improved in usability and reliability. NCDC should ensure that wind speed indicator information is being accurately retained in its archival formats, at least through permanent retention of original input data sets. It should also be noted that questions have been raised about whether observers aboard US.-recruited ships have a clear understanding of how to properly encode the wind speed indicator, since spot checks of US. keyed data archived at NCDC have shown a higher proportion of measured winds, than was expected by the NOAA/NWS marine observations program (V. Zegowitz, personal communication).

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[2] NCDC years ago stored images of punched cards on 16 mm film using the Film Optical Sensing Device Input to Computer (FOSDIC), prior to disposal of the actual punched cards. The FOSDIC was also used to read card images from film and convert them to digital data (i.e., ASCII or EBCDIQ on 1/2” magnetic tape. Unfortunately, the digital tapes were not adequately maintained, as was discovered when attempts were made to migrate them to modem media. However, at the time of this report, 16 mm film and a FOSDIC to read it are believed to still exist, and funding was obtained to recover the film to digital media.

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Table 1: Expanded wind speed indicator (WI) settings as defined in the current Long Marine Report (LMR.6) format, corresponding to available values from TDF-11 ("—" indicates no corresponding information). Also shown are the resultant mappings into WI of corresponding wind speed metadata from original IMM and GTS formats; in many cases these mappings occurred through conversion first into the TDF-11 indicator, and then into LMR.6 (see also Table 6 of Woodruff et al., 1991).

		International Maritime Met. (IMM)			
LMR.6 WI	TDF-11	1963*	1968*	1982(i_W)**	GTS(i_W)***
0=m/s, estimated	–	–	–	6/0	6/0
1=m/s, measured	–	–	–	7/1	7/1
3=knot, estimated	–	–	–	6/3	6/3
4=knot, measured	–	–	–	7/4	7/4
5=Beaufort force	–	6?	6?	–	–
6=est./unknown	not meas.	–	6?	–	–
7=measured	meas.	–	7?	–	–
8=high resolution	–	–	–	–	–

* The 1963 IMM punched card format was defined by WMO (1965) in a standard and a supplementary version ("for exchange of cards with deviating codes or additional data"). For the 1968 IMM format, WMO (1975) revised both the standard and supplementary versions. This table shows the mapping to WI of approximately corresponding fields defined in the two standard versions; additional fields were available in the two supplementary versions. Note that original IMM receipts prior to about 1985 are no longer available at NCDC, thus wind metadata were retained only as converted into the TDF-11 indicator (question marks indicate that the method used to convert IMM metadata into TDF-11 indicator values is not known).
** Two possible mappings, because in some cases i_W (see section 3.4) may have been retained only as converted through the TDF-11 indicator (e.g., "6/0" indicates that the resultant WI was 6 if retained only through the TDF-11 indicator, and 0 otherwise).
*** Two possible mappings, depending on when i_W (see section 3.4) information was available in each GTS source. Using NMC data for example (see discussion in text), "6/0" indicates that the resultant WI was 6 prior to 9 May 1984, and 0 starting on that date.

Figure 1: GTS ship wind speeds averaged for selected 10 Marsden Squares in the North Atlantic, North Pacific, and Mediterranean: 79, 80, 122, 123, 141, 142, 184, 185, 199, 200, 217, and 252. Curves shown for USSR and all other data are displaced possibly due to biases from reporting wind in meters per second versus knots (see text). The effect of a U.S. conversion software error is also strongly evident during February-June 1984.

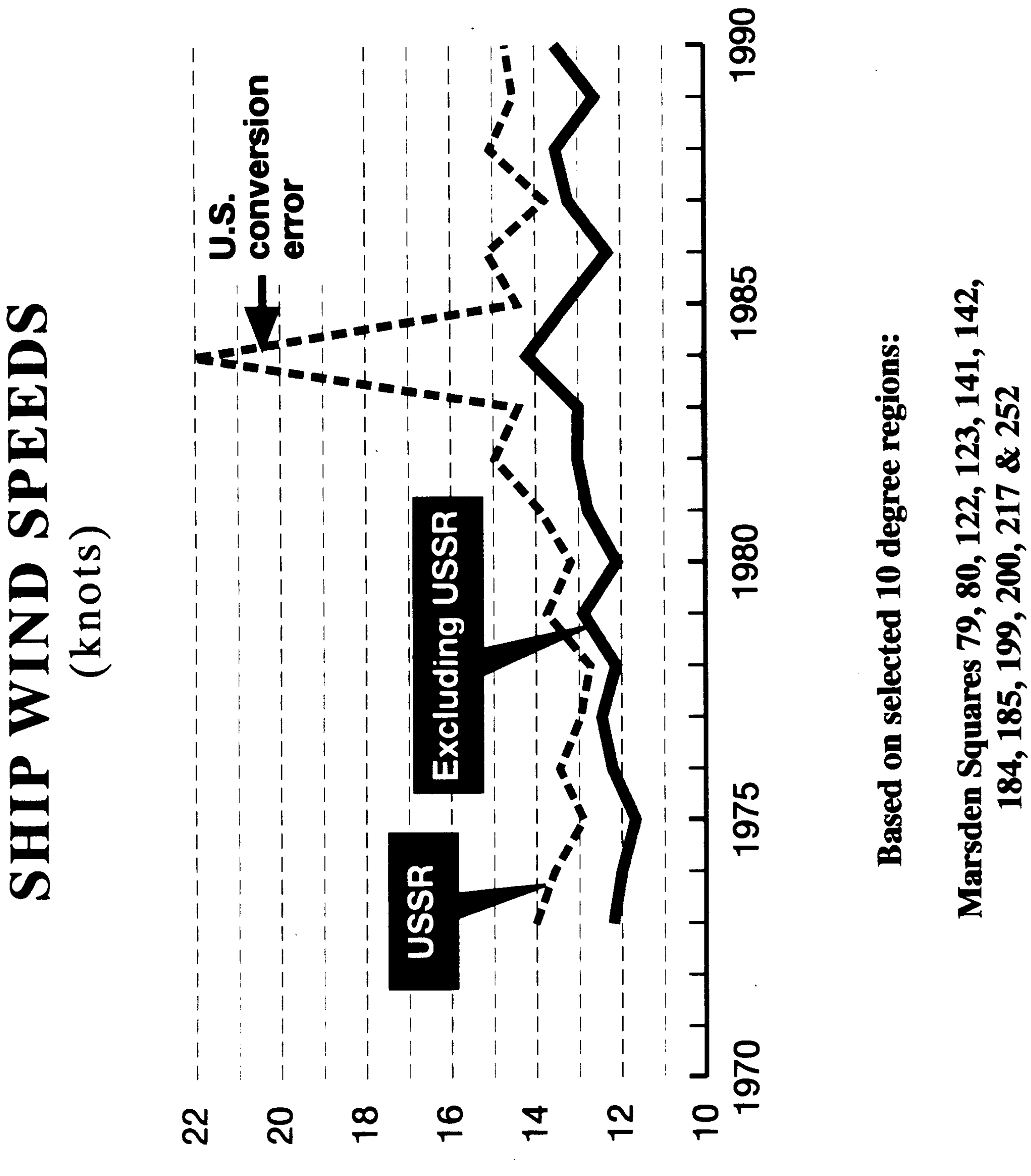

Figure 2: Annual global marine reports after duplicate elimination (curve) for COADS Release 1 through 1979, continued by Release 1a through 1992. Horizontal lines span the time periods for data now being collected and digitized, or proposed for future digitization (*), with the approximate numbers of reports shown in millions (M) or thousands (K) (Elms et al., 1993). Also listed are major existing digital data inputs proposed for inclusion in Release 2 or following Release 2. Labeled ticks along the upper horizontal axis mark the starting years for Release 1a, and those planned for Release 1b (1947) and Release 2 (1854, or earlier).

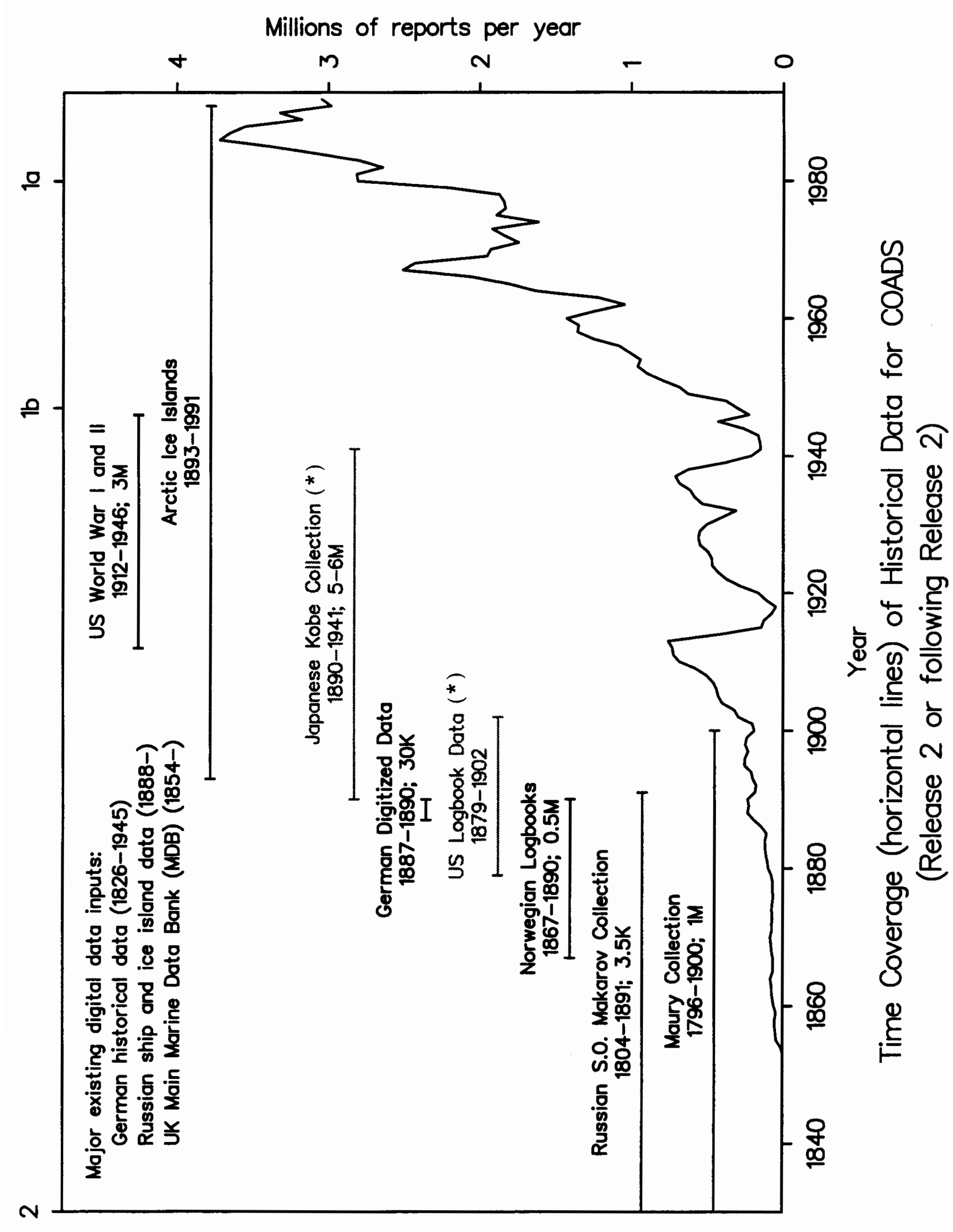

Figure 3: COADS Release 1 (upper) versus the UK Meteorological Office MDB (lower): annual percentages of total ship reports recorded at each UTC hour in 10° box number 200 (Marsden Square 122) west of the U.S. (because the division between two hours corresponds to 25%, a given bar may extend across four such divisions). The concentration of reports in COADS at hour 21 around 1900 has been traced to deck 192 (Deutsche Seewarte Marine), which was excluded from MDB (figure from Woodruff, 1990).

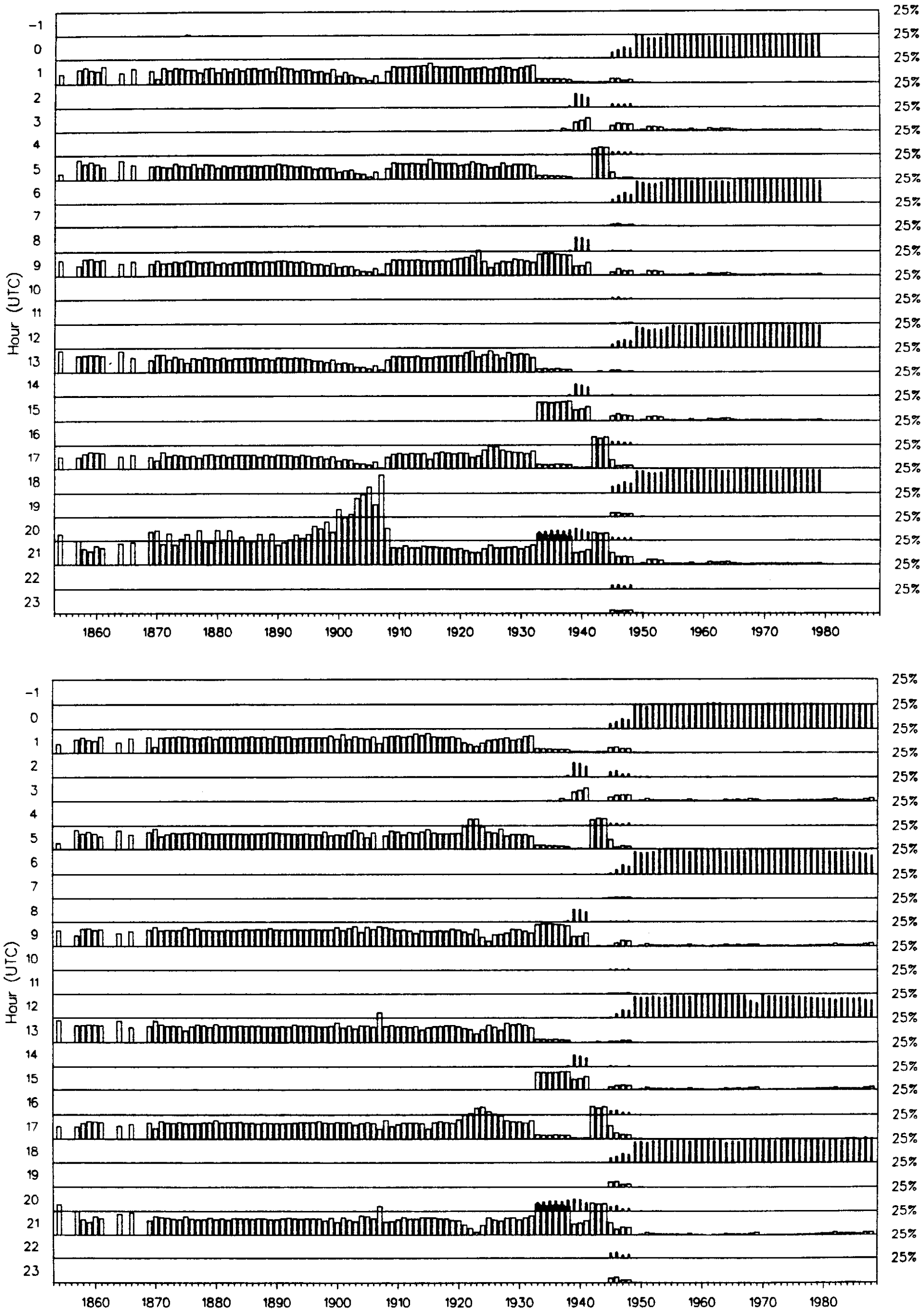

Figure 4: Average of 1980-92 monthly differences between the mean of scalar wind from the Release 1a enhanced statistics, minus that from IATTC special fishing fleet data (meters per second). Note that IATTC wind data were excluded from the Release 1a enhanced statistics.

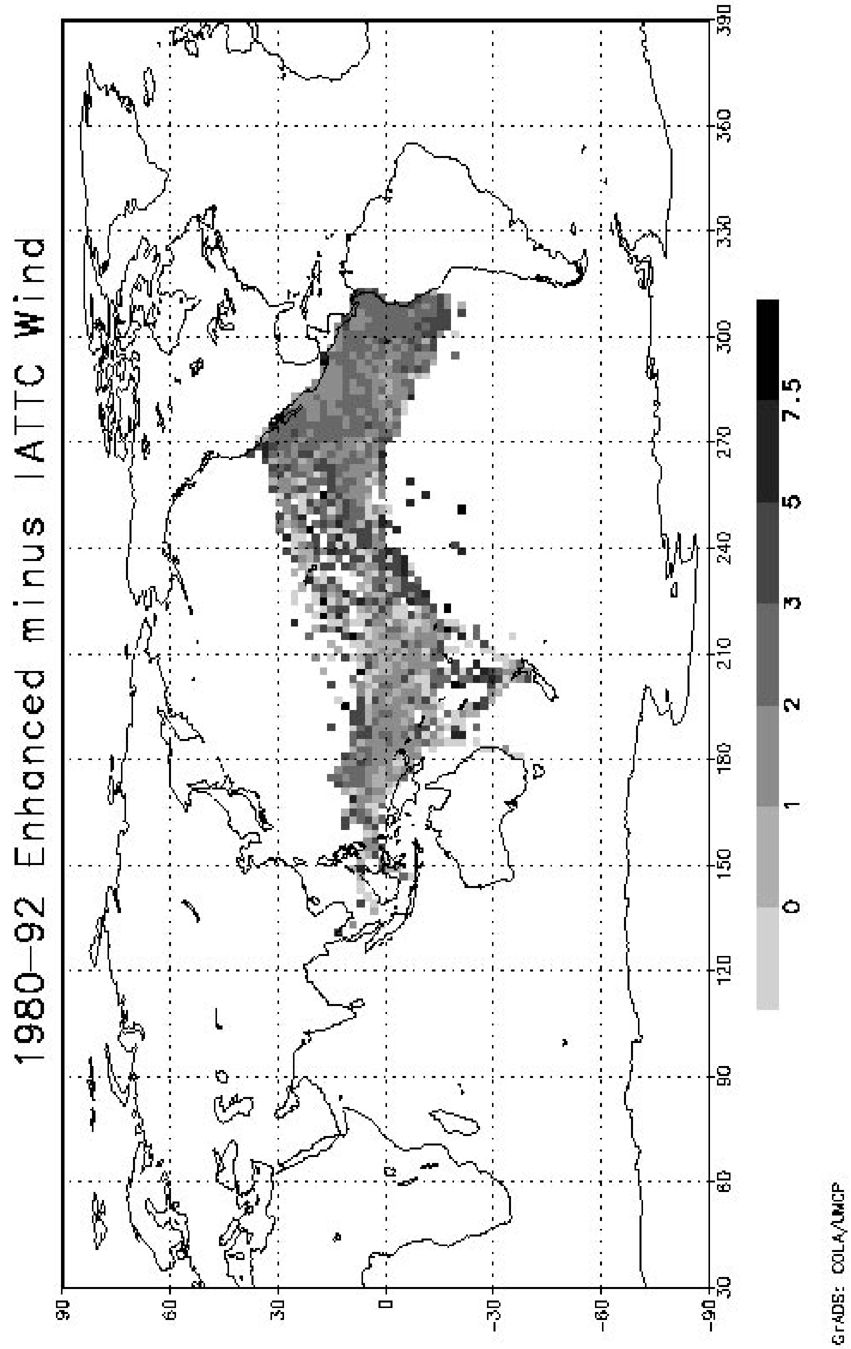

Figure 5: Annual average of 1980-92 monthly average differences between the Release 1a enhanced minus standard mean of scalar wind (meters per second). In many cases, negative differences (> -2 m/s) in 2° boxes around the U.S. coastline and across the equatorial tropical Pacific correspond to NDBC and PMEL moored buoy locations. Positive differences (< 5 m/s, but rarely above 2 m/s) arise from relaxation of the trimming limits to 4.5σ (figure from Woodruff et al., 1993).

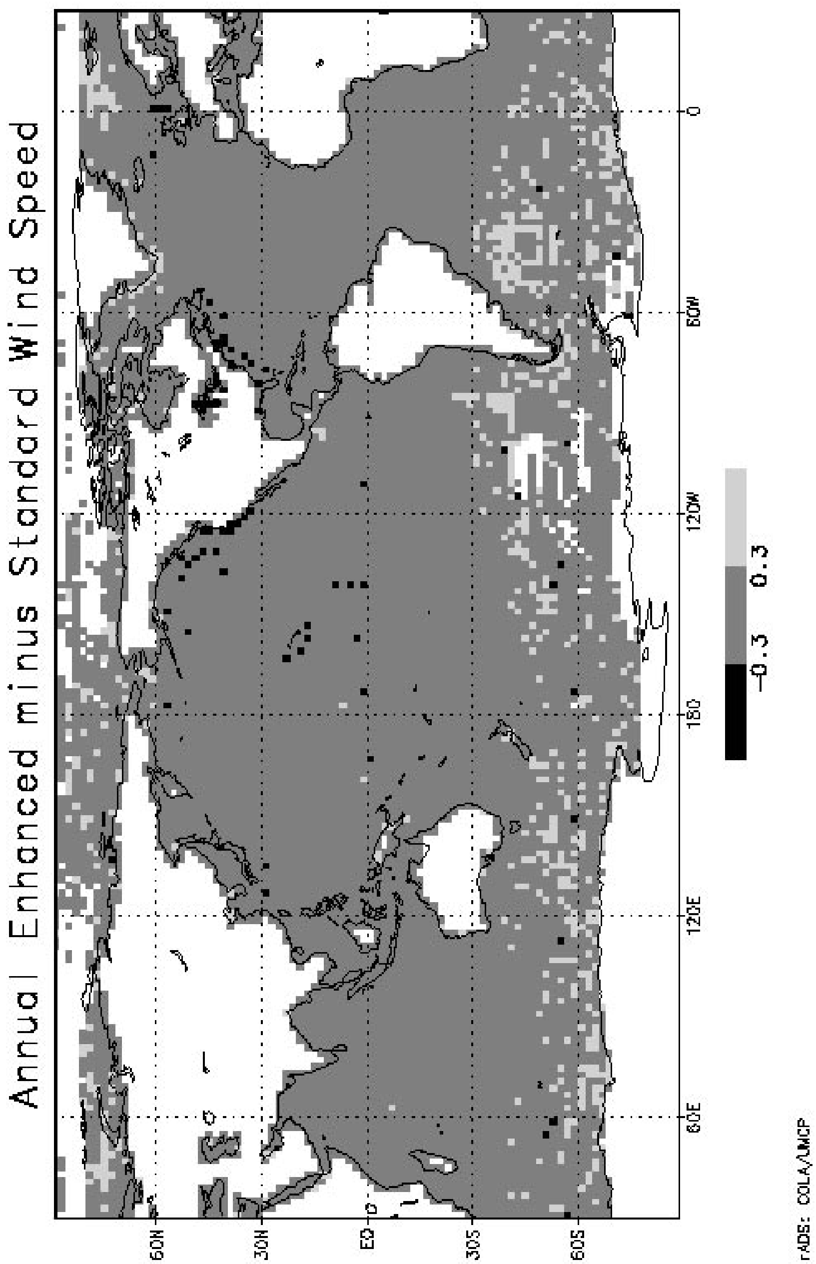

Figure 6: Approximate availability through time of ship radio call sign or other ID information, of wind indicator information (i_W) and of recruiting country code and ship flag nationality, from IMM (logbook) versus GTS data. Also shown is the availability of annual metadata from WMO (1955-) Publication 47. (Note: There were also IMM format revisions in 1987 and 2 November 1994 that did not impact the availability of fields shown here).