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DEPARTMENT OF COMMERCE ★ UNITED STATES OF AMERICA ★

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Scott D. Woodruff, Editor

Environmental Sciences Group
Boulder, Colorado
July 1986

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noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION / Environmental Research Laboratories

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**UNITED STATES
DEPARTMENT OF COMMERCE**

**Malcolm Baldrige,
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NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION

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Proceedings of a COADS Workshop
Boulder, Colorado
January 22-24, 1986

Abstract

The proceedings of a workshop held January 22-24, 1986, in Boulder, Colorado, are presented. The workshop was organized to discuss the Comprehensive Ocean-Atmosphere Data Set (COADS), the most complete set of global surface-marine data available for the period 1854-1979. A compilation of scientific papers and technical material presented or contributed to the workshop is provided, together with reports from its Scientific and Technical Working Groups, and a list of participants. Scientific papers are grouped according to Data evaluation, and Analysis and applications.

Introduction

During January 22-24, 1986, the Climate Research Program of NOAA/ERL (National Oceanic and Atmospheric Administration/Environmental Research Laboratories) hosted a workshop in Boulder, Colorado. The workshop was held at the suggestion of the Equatorial Pacific Ocean Climate Studies (EPOCS) Advisory Committee, to stimulate use of the recently completed Comprehensive Ocean-Atmosphere Data Set (COADS) and to discuss needs for future updates and modifications of these data. Other goals of the workshop were to: 1) acquaint users with data processing procedures; 2) discuss work done to date on COADS data evaluation; and 3) present the results of scientific research based on COADS in order to get a feel for the number of applications already in progress, as well as to share the results of such work.

COADS is the most complete set of global surface-marine data now available for the period 1854-1979. Individual ship observations are available from the National Center for Atmospheric Research (NCAR) or NOAA's National Climatic Data Center (NCDC), and monthly summaries for 2^{o} latitude x 2^{o} longitude boxes and other products are available from NCAR. Parts 1 and 2 (COADS Overview and Marine Data Processing Overview) give further background on COADS, including an update to extend the period of record through 1985 planned for completion by 1987.

Invitations were extended to many scientists and organizations, both in the United States and abroad, and the list of participants is given by Appendix A. Participants were encouraged to each give a brief presentation, and Part 3 is a compilation of scientific papers that accompanied the talks or were contributed to the workshop. These papers are organized under the topic of Data evaluation or Analysis and applications.

After the plenary sessions of the workshop, the participants divided into a Scientific and a Technical Working Group. Reports from these two working groups are given in Part 4, and a summary of the major workshop recommendations and findings follows this introduction.

Workshop Summary

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The following are the principal recommendations and findings of the workshop.

1. The number of marine observations (of sea surface temperature, air temperature, surface wind and a few other basic variables) taken by the principal fishing fleets (Japan, Korea, Taiwan, U.S.) may exceed by a factor of five or more the number of observations taken by the merchant fleets (though the latter take more complete observations according to WMO practices). Greater efforts should be made to obtain access to these observations.

Some contact has been made individually (e.g., Jim Sadler at Hawaii) and through certain institutions (e.g., Forrest Miller, Inter-American Tropical Tuna Commission) to obtain these data, but they have met with minimal success. NOAA representatives will look into the available alternatives. A possible alternative is distribution of monthly summaries (and number of observations) for 2^o boxes, which may be more acceptable to the fishing community than making available individual observations.

2. Some data are going to countries such as the USSR and India, which despite WMO agreements for international exchange, are not being sent to the U.S.

All data collected by the world's merchant fleets regardless of nationality or where the observations are taken should be sent to all the appropriate national archives. The National Climatic Data Center has information regarding receipts of data by responsible country. This problem has been brought to the attention of U.S. representatives to the World Meteorological Organization. Some steps are being taken through the WMO as well as in bilateral negotiations. However, this problem is likely to take some time to be resolved.

3. Studies are needed of the environmental buoy data so that it can be properly integrated into COADS.

Probably more data come from these fixed buoys than from the U.S. merchant marine. Since hourly buoy observations could negate the influence of passing ships on statistics for 2^o latitude x 2^o longitude boxes, the workshop recommends that only 3-hourly buoy data be included in future COADS monthly summaries. Quality problems with individual buoys could lead to serious contamination of summaries. It appears from the work of Wilkerson, Earle and Quayle that winds may be the most affected, but further investigation is needed. A proposal to TOGA may be appropriate.

4. Long-term stations are needed for calibration of ship data.

Historical series for sea surface temperature and other elements observed by island or shore stations would be valuable for calibration of ship records, as would observations from surface-level bathythermographs and buoys along ship lanes.

5. COADS should be formally updated every 5 years, with interim products available yearly.

A Memorandum of Agreement has been signed between the Environmental Research Laboratories and the National Climatic Data Center to update COADS in 5-year increments. Additionally, interim marine data products are planned on an annual basis in support of EPOCS.

6. There are two major data gaps in the COADS record for the Twentieth Century: World Wars I and II encompassing the years 1913-1919 and 1939-1946. Approximately 17-18 million ship reports are available for inclusion in COADS.

The workshop recommends that these data be digitized and added to the archive as soon as feasible. This could possibly be accomplished through the U.S./India Bilateral or through other means. The approximately 932K unpunched forms comprising this data set (each form contains approximately 18-20 reports) must first be microfilmed as they are unique and deteriorating. Cost: $120K-140K. Unless the keypunching could be covered under a bilateral agreement with minimal costs to NOAA, costs could exceed $2 million.

7. A new Cray X-MP computer is slated for installation at NCAR around September 1986. During an acceptance period after installation, "free" time may be available for COADS processing.

Perhaps the current 1980s updating can be carried out during acceptance. Reprocessing of the 1970-79 period to include OSV upgrade data, GATE Project data, FGGE drifting buoy data, and Russian or Indian international exchange data may also be necessary.

In addition, the workshop endorsed the assessing of inhomogeneities in the data record. For example, some large trends in the air-sea temperature difference over time spans of 10-20 years suggest changes in observing practices or other non-climatic bias as the source. Wind speeds appear to be quite sensitive to spatial as well as temporal coverage and statistical tests need to be carried out to assess these effects.

Part 1. COADS Overview

Available COADS Data

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1. Introduction

For several years starting in 1982, NCAR, ERL, CIRES (Cooperative Institute for Research in Environmental Sciences), and NOAA's National Climatic Data Center (NCDC) have worked together on a cooperative project to clean up several existing large files of world ship data and to merge files into a consolidated data set with duplicates eliminated. Release 1 of this Comprehensive Ocean-Atmosphere Data Set (COADS) covers 1854-1979 (Fletcher et al., 1983; Woodruff, 1985; Slutz et al., 1985). Release 2, updating COADS through 1985, is planned for availability by 1987 (Woodruff and Lubker, 1986).

The major component files were the "Atlas" data set from NCDC that was used in the construction of marine atlases (e.g., U.S. Navy, 1977) and the Historical Sea Surface Temperature (HSST) Data Project files for about 1861-1960 that were prepared under the auspices of the International Decade of Ocean Exploration (IDOE) and involving several countries (especially Federal Republic of Germany, Netherlands, and the United States). In addition, all available ship reports from 1961-79 exchanged under WMO Resolution 35 were included. About 9 other smaller files were also merged in. This included buoys and sea surface temperature from XBT reports.

About 100 million ship reports were processed, resulting in 72 million after duplicate elimination. There were 53.19 million reports output for 1854-1969 and 18.68 million for 1970-79. Monthly summaries of acceptable observations within each 2^o latitude x 2^o longitude box give 14 statistics for each of 19 observed and derived variables. The processing steps to clean-up the data, run sort/merges, and calculate statistics took many hours on the CRAY computers at NCAR. Additional time was spent on NOAA computers.

The volume of data is often rather high for the whole world ocean, but many products are organized by 10^o boxes so that part of an ocean basin can be studied without volume problems. Figures 1 and 2 are illustrations of data coverage in time and space. There are additional products such as decade-month summaries and report inventories; for more information, the reader should refer to the overall COADS text (Slutz et al., 1985). Fortran 77 software is available to read all of the packed binary products (Woodruff et al., 1986).

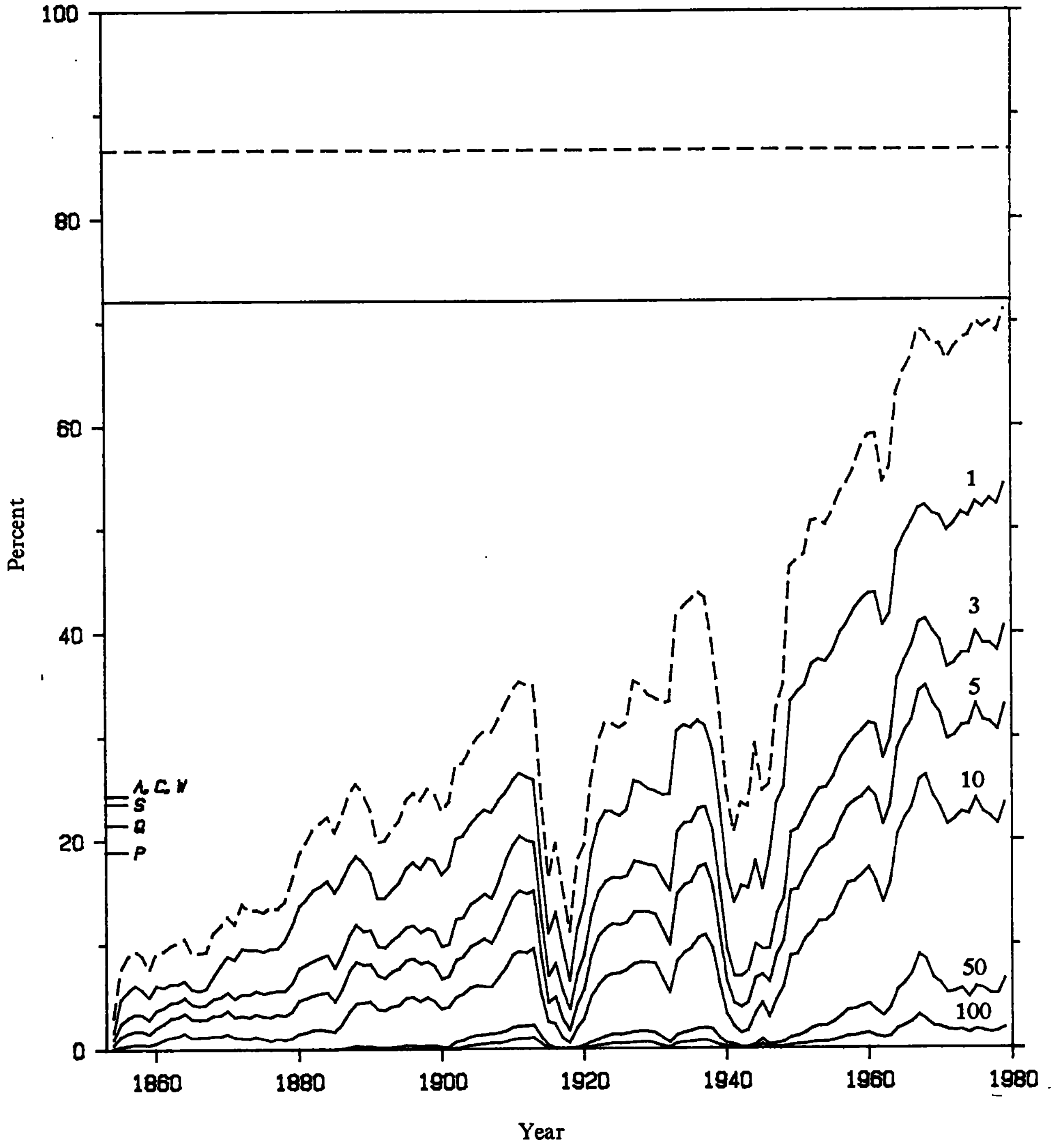
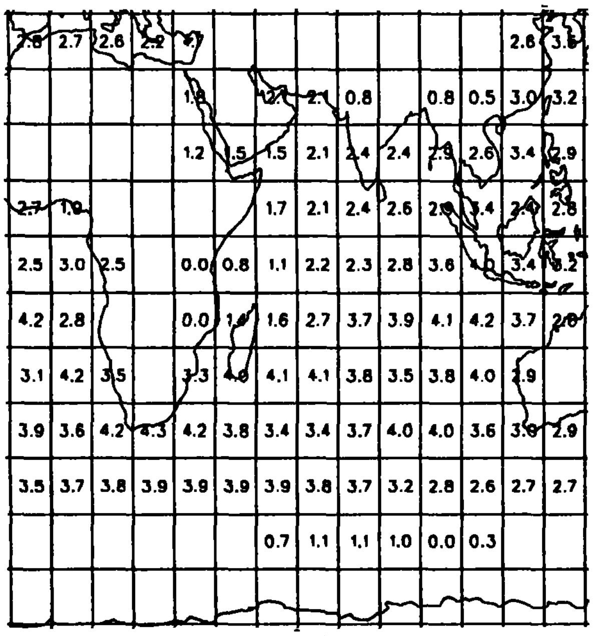
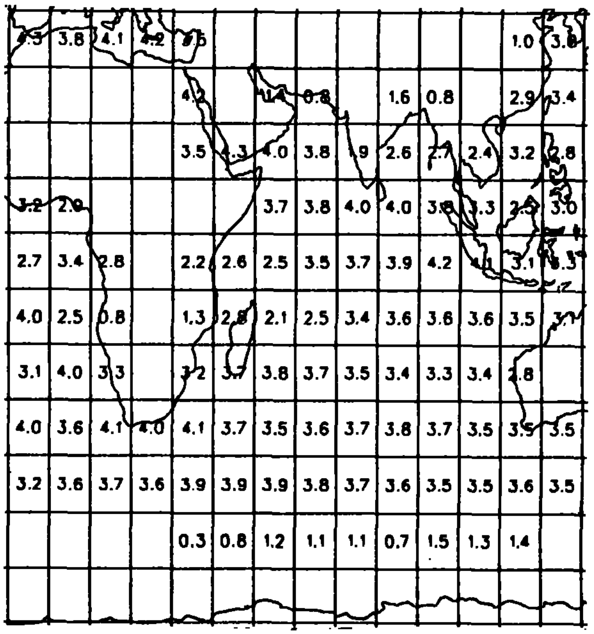


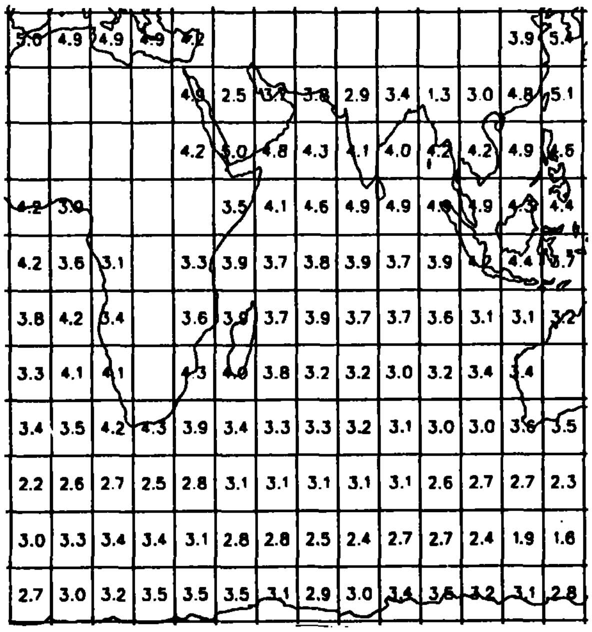
Figure 1. Global percentage of possible (sea or coastal) year-month-2 degree boxes per year containing at least the indicated number of observations of sea surface temperature, subject to trimming (solid curves). The dashed curve is for the equivalent area covered by 2 degree boxes containing at least 1 observation. Horizontal lines represent an approximate upper-limit on the number of boxes (solid) or area (dashed); they are positioned at 100% minus the percentage of boxes or area poleward of 60 degrees N or S. Letters are ordinates of the 126-year-average percentage of 2 degree boxes containing at least 1 observation of variables: *S* = sea surface temperature, *A* = air temperature, *W* = wind, *P* = sea level pressure, *C* = total cloudiness, *Q* = specific humidity.



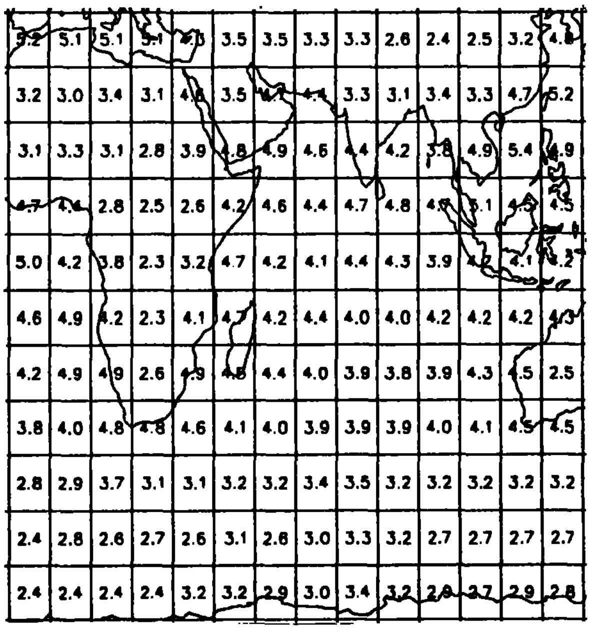
1860-69



1880-89



1930-39



1970-79

Figure 2. Indian Ocean region log base 10 of reports (LMR) in 10 degree boxes for selected decades.

The basic data products are described in the following.

2. Basic ship synoptic reports

Product 19. All 72 million reports (including buoys and surface level XBTs) in TD-1129 character format, 148 characters each report. This product is located at NCDC, Asheville. The volume is about 84.6 Gbit* for the world, 1854-1979.

Product 1. Basic binary data set of Long Marine Reports (LMR) at NCAR

This set has all of the basic data, and data check information. It retains the original form of observations that were modified during processing. For example, a temperature with erroneous alphabetic characters would have been set to missing, but the original information was kept in an attachment. Essentially identical duplicate reports were eliminated, but this data set retains some near duplicates not kept in product 19. It also has a little more report status information. This product was nearly completed through 1979 by about June 1983. The volume is about 39.5 Gbit.**

Product 10. Abbreviated binary data set of Compressed Marine Reports (CMR) at NCAR

This has nearly all of the basic data in observations, but little of the status or QC information. The information dropped includes wave, swell, ship call sign, source ID, and QC flags. Trimming flags are included from the statistics program signifying whether data were outside of 2.8 or 3.5 ("trimmed" from statistics) estimated standard deviations about the smoothed median applicable to their 2° box, month, and 56-, 40-, or 30-year period (1854-1909, 1910-1949, or 1950-1979). Each report is 192 bits long. Total volume is 13.7 Gbit.

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*Number of tapes: Most of the data are stored on 6250-cpi tapes which can hold 10^9 bits (1 Gigabit) each. A 1600-cpi tape holds about 0.3 Gbit and an 800-cpi tape about half that.

**Note: We probably will prepare a 24 Gbit version of product 1 that has ship ID, and most information but not all flags and supplementary data. This may later be sorted into synoptic order (all the world together for one data time), but we will do this large task only if several people need it.

3. Trimmed monthly summaries (MST)

Monthly summaries for each year were calculated containing 19 variables, 14 statistics each. Any year-month-2° box having one or more acceptable observations caused the entire batch of statistics to be produced. To make related elements easier to access, we have separated these trimmed monthly summaries into 5 group files with 4 variables and a reduced set of statistics for each (given in sec. 5).

Caution: These are basic statistics derived from all acceptable observations within a year-month-2° box. Wild observations were "trimmed", but statistics for adjacent boxes for the same month may still be quite different due to different numbers of samples, times of samples, and some data errors. Thus, the raw statistics will need to be further analyzed and smoothed in space and time for many uses. We will also offer and potentially work on some of these analysed products to help make them available.

Product 15.	Basic trimmed statistics (in synoptic sort: all the world at one data time is together). In the whole 1854-1979 period there were 4,470,346 year-month-2° boxes with data, 3,712 bits each. Thus, the volume is 16.6 Gbit.
Product 16.	This is the same as product 15 except that it is sorted by 10° box, 2° box, year, month. This sort is useful for studies that concentrate on a small area.

4. Untrimmed monthly summaries (MSU)

These data do not have as many variables as the trimmed set. (Variables such as surface stress components are not included.) Very wild values were excluded from use, but questionable data were included that were excluded from the statistics in products 15 and 16. Most users will want the trimmed data.

5. Group files

The seven group files are relatively compact alternatives to the full monthly summary trimmed (product 15) or untrimmed format, intended for studies using only eight primary statistics (as given in the following). The trimmed group files are the most commonly used version of year-month summaries. Statistics for each of four related variables are grouped together in each file, sorted into synoptic order (all the world at one data time is together). Thus five files are needed to represent all 19 trimmed variables and two files are needed to represent all eight untrimmed variables.

The statistics were chosen to bring together information which can be used to analyze the variability of the data and inhomogeneities of their distribution in time and space. The following statistics are available for each variable in a trimmed group:

3/6 sextile (median)
mean
number of observations
standard deviation estimate
mean day-of-month of observations
fraction of observations in daylight
mean longitude of observations
mean latitude of observations

The volume of each group of 4 variables is 1.72 Gbit, on 2 tapes, 6250-cpi. NCAR will develop selection routines so that statistics for a given latitude-longitude region can be selected from the whole set. Sort is by year, month, 2° box. The first tape of each trimmed group has statistics through 1945. The second has 1946 through 1979.

Product 18. Monthly Summary Trimmed Groups (MSTG). To distinguish the trimmed groups from the two untrimmed groups which were created first, they are numbered 3-7. The following shows how the variables are grouped together.

Group 3 variables:

S	sea surface temperature
A	air temperature
Q	specific humidity
R	relative humidity

Group 4 variables:

W	scalar wind
U	vector wind eastward component
V	vector wind northward component
P	sea level pressure

Group 5 variables:

C	total cloudiness
R	relative humidity
X	WU
Y	WV (X-Y are wind stress parameters)

Group 6 variables:

D	S - A = sea-air temperature difference
E	(S - A)W = sea-air temperature difference x wind magnitude
F	Q_s - Q = (saturation Q at S) - Q
G	FW = (Q_s - Q)W (evaporation parameter)

Group 7 variables:

I	UA
J	VA
K	UQ
L	VQ (I-L are sensible and latent heat transport parameters)

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Fletcher, J. O., R. J. Slutz, and S. D. Woodruff, 1983: Towards a Comprehensive Ocean-Atmosphere Data Set. *Trop. Ocean Atmos. Newslett.*, *20*, 13-14.

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U. S. Navy, 1977: *Marine Climate Atlas of the World, Vol. II (Rev.), North Pacific Ocean*. NAVAIR 50-1C-529, U.S. Government Printing Office, Washington, D.C., 388 pp.

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Distribution of COADS 1854-1979

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1. Introduction

Thirteen COADS data products (Slutz et al., 1985; Jenne and Woodruff, 1986) are available for distribution from NCAR in packed binary formats, or individual ship reports are available from NCDC in an ASCII-character format (TD-1129). This paper describes some of the distribution of packed binary COADS products that has been accomplished by NCAR. Distribution by CIRES/ERL to the Peoples' Republic of China and to Japan are also described, which involved a new packed binary format for possible future distribution of monthly summary data.

2. Usage of Packed Binary Data

The computational efficiency and volume reductions that can be achieved by using packed binary instead of traditional character-based formats are discussed by Jenne and Joseph (1974). COADS packed binary data products were carefully designed to maximize these advantages across a wide range of computers. The packing technique takes floating-point data coded as positive integers, and packs the resultant binary bit-strings into bytes of the smallest convenient length. Reconstruction of floating-point data requires that the byte length and two other characteristics of each field, the base and units*, be externally specified. Once a given field has been extracted into a coded value, the floating point true value can be reconstructed as follows:

$$\underline{\text{true value}} = (\underline{\text{coded}} + \underline{\text{base}}) \times \underline{\text{units}}$$

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*"Units" gives the smallest increment of the data that has been encoded. Thus a change of one unit in the integer coded value represents a change in true value of one of the units given.

To simplify the usage of packed binary data, COADS includes a machine-transportable Fortran 77 program for each product, which is designed to reconstruct floating point data. These programs, plus auxiliary software, are available from NCAR on a "software tape" (Table 1). Changes may be required to install the software on different computer systems (given certain minimum machine requirements), but those modifications are few and well defined (discussed in supp. H of Slutz et al., 1985). Among the requirements are the two low-level and generally machine-dependent capabilities of 1) transferring a binary block into memory and 2) then extracting into INTEGER variables the bit strings whose lengths are specified. The Fortran 77 programs assume that subroutines GBYTES or GBYTE are available as the second of these capabilities. NCAR has versions of these (Joseph, 1985) for the following computers:

Cray 1 (COS)
CDC (6600, 7600)
IBM (360/370, 43xx)
DEC (VAX, 1170)
UNIVAC (1100)

Because of the complexity of packed binary formats, with some simplicity sacrificed in order to achieve machine efficiency, it is essential that a verification file, preferable machine readable, be provided with the data at distribution time in order to verify proper program implementation. Thus a completed COADS data set ideally will consist of three files: 1) program, 2) verification file, and 3) data. There would seem to be no obstacle to positioning all three on one magnetic tape, provided the binary file (data) follows the two ASCII files (program and verification file). That way if it is inconvenient to switch from coded to binary mode mid-tape, it should be possible to treat the two ASCII files as binary, or conversely disregard the binary file when reading the characters.

Another useful assurance of integrity in COADS packed binary files is the checksum stored in each record. Generally, this is the sum of all the (other) positive coded integers in a record before translation back to floating point true values, modulo $2^n - 1$, where n is the byte size. In the group files the group number (3-7 for the trimmed groups) must be entered into the sum prior to the modulo. Users are strongly encouraged to have their program recompute the checksum and compare the result with the stored checksum. Any discrepancy indicates that an error has occurred in storage or transmission of the data, or more likely that there is a software error.

3. Distribution by NCAR

Table 2 lists COADS distribution performed by NCAR as of January, 1986; Table 3 is a summary of requested data products (see Slutz et al., 1985, for an explanation of products).

Table 1. User Software Tape. The 21 files reside on one 6250-cpi, unlabeled, 9-track, ASCII tape. Records are length 130 blocked 27.

No.	File	Level	Description
1.	BOXLIB	.01J	tools for working with 2, 4, and 10 degree boxes, or MSQ's
2.	QI9	.01G	read and print MSU.2
3.	QI12	.01D	read and print CMR.4
4.	QI21	.01D	read and print MSUG.1 group 1
5.	QI22	.01D	read and print MSUG.1 group 2
6.	QI24	.01C	read and print DSU.2
7.	QL14	.01C	read and print MST.3
8.	QL16	.01C	read and print TRP.1
9.	QL21	.01C	read and print CMR.5
10.	QL28	.01C	read and print MSTG.1 group 3
11.	QL29	.01C	read and print MSTG.1 group 4
12.	QL30	.01C	read and print MSTG.1 group 5
13.	QL31	.01C	read and print MSTG.1 group 6
14.	QL32	.01C	read and print MSTG.1 group 7
15.	RDINV	.01B	read and print INV.3
16.	READER	.01B	read landlocked file LLN2F1
17.	LLN2F1	4/85	landlocked file
18.	QI27	.01A	read and print LMR.5
19.	QL8	.01C	read and print DSUL.1
20.	QL47	.01A	read and print DST.3
21.	GBYTES	5/85	NCAR's GBYTES package with EOF's converted to "/EOR"

Table 2. COADS distribution by NCAR.

Date	Data products*	Sent to
01/13/86	3,6	CSIRO, Australia
01/15/86	3,4	Nicholson/O'brien, Florida State University
11/18/85	3-7	Tubbs, Scripps
10/30/85	CMR ('70s sel)	Bosart, State U. of N.Y.
10/25/85	CMR	Hori, U. of Hawaii
09/20/85	3,4	Wu, Taiwan U.
09/27/85	3	Grotch, Lawrence Livermore
08/31/85	3 (tape 1), 4	Dickerson, Climate Analysis Center
08/31/85	3, 4, 5 (tape 2)	Hseih, U. of B. C.
08/16/85	3-7	Ohio State U.
08/21/85	3, 4, CMR ('70s)	Gryalva, Mexico (Solar Environmental Sciences)
08/14/85	3, 4	Mohanty, India
07/31/85	3	Suppiah, U. of Tsukuba, Japan
07/29/85	3, 4	Flohn, Germany
08/08/85	3-7 (tape 2)	Han, Oregon State U.
05/29/85	3, 5, 6, 7	Rhodes, NORDA
05/28/85	3, 4, 5	Jones, UK Met Service
04/23/85	3	Handler, U. of Illinois
04/19/85	4	Rhodes, NORDA
04/05/85	MST	Cardone, Ocean Weather Inc.
03/21/85	3	Mu, NASA Goddard
03/14/85	3, 6, 7	Schroeder, U. of Hawaii
02/25/85	CMR (1978)	O'brien, Florida State U.
01/28/85	3-7 (tape 2)	Ropelewski, Climatic Analysis Center
01/27/85	3	Walsh, U. of Illinois
12/31/84	4, 5	Hori, U. of Hawaii
01/02/85	3-7	Oort, GFDL
11/16/84	5	O'brien, Florida State U.
11/09/84	3 (tape 2)	Barnston, Climate Analysis Center
11/09/84	4, 5	Schott, RSMAS, Miami
07/27/84	MST (box 279)	Duchon, U. of Oklahoma
03/26/84	MSU	Storch, Germany
12/29/83	MSU ('60s & '70s)	Krishnamurti, Florida State U.

*A number 3-7 indicates one of the trimmed group files (MSTG); in some cases only one of the two tapes that make up a group file was supplied. Other abbreviations: CMR (Compressed Marine Reports), MST (Monthly Summaries Trimmed), MSU (Monthly Summaries Untrimmed).

Table 3. Data request summary
(requests overlap, see Table 2).

Data Products	Requests
MSTG (any group)	26
group 3	22
group 4	16
group 5	11
group 6	8
group 7	7
MST or MSU	4
CMR	4
TOTAL	33

4. Distribution to the Peoples' Republic of China and to Japan

As part of a China/U.S. project administered jointly by TOGA and PRC's National Bureau of Oceanography (NBO), in 1985 R. Slutz delivered COADS data to the Marine Data Center of NBO and to the Institute of Atmospheric Physics of the Academia Sinica. Both individual observations in the form of Compressed Marine Reports (CMR), and trimmed monthly summaries in a new PS (packed simple) format (see sec. 5) were provided, together with Fortran 66 software to help read and analyse the data. At least one of the Chinese machines could not read magnetic tapes at 6250-cpi, so 86 1600-cpi magnetic tapes were supplied to each organization, 172 tapes in all.

In addition to delivery of the tapes, a series of four 2-hour lectures (including translation time) on COADS was delivered at both organizations, plus a large number of lectures on related topics, and additional time was spent working with Chinese programmers on installation of the software used to read the COADS data. A User's Guide for the PS format was also prepared in both Chinese and English (Zhang and Slutz, 1985).

In accordance with reciprocal agreements made by J. O. Fletcher, in 1985 the same COADS data were sent to T. Nitta of the Japan Meteorological Agency (JMA). The trimmed group files (MSTG) were sent in addition to the PS version of the monthly summaries, and Fortran 77 software was provided to read each product. By all indications, the Japanese had no difficulty in using the COADS data and the software required only slight modifications to make it work on JMA computers.

5. PSLIB

The new PS (packed simple) data format, accompanied by a Fortran 66 or 77 version of the software library PSLIB, was supplied to both China and Japan. This format is a useful alternative to the standard MST (Monthly Summaries Trimmed) or MSTG (groups derived from the MST).

Like other COADS data formats and software, PS files and PSLIB were designed with careful attention to machine portability, but with several enhancements. Data in a PS file are sorted by year-month (timesort). Each year-month contains a global map, with land areas marked, whose 2^o latitude bands are available as separate logical records. This has advantages to applications that perform sequential analyses on the globe, or major portions of it, at each year-month separately. Each of the 19 MST variables x 14 statistics has been separated into its own PS file (266 files total). Analyses that require many related statistics and variables together might find the group files more useful, or analyses that concentrate on a limited area (e.g., 10^o or 2^o box) through time will probably find the MST in "boxsort" (10^o box, 2^o box, year, month) advantageous instead.

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Part 2. Marine Data Processing Overview

Marine Data Processing Procedures at the National Climatic Data Center

Richard S. Cram

Surface marine data arrive at the National Climatic Data Center (NCDC) from numerous sources: digitized data from over 40 countries are received through exchange agreements; the NOAA Data Buoy Center (NDBC) provides monthly tapes of data from U. S. buoys and from the Coastal Marine Automated Network (C-MAN); telecommunicated reports are received from the National Meteorological Center (NMC) and the U. S. Navy; approximately 1800 ships in the U. S. Voluntary Observing Ship (VOS) program of the National Weather Service (NWS) mail manuscripts which are digitized at NCDC; and data from oil drilling platforms in the Gulf of Mexico are provided by Louisiana State University semi-annually. The data are received in several different formats, converted to the standard NCDC format (1129), processed through various steps and archived in an area-sorted magnetic tape file.

1. DATA RECEIPT AND PROCESSING CYCLE

Figure 1 shows the date of data receipt and the steps used to complete the monthly processing cycle. Processing of marine data is completed approximately 3 months (80 days) after the data month, e.g., January data are processed and archived by the 20th of April.

Telecommunicated reports are received on 5 magnetic tapes each month from NMC and generally arrive by the 20th of the month following the data month. Buoy data are provided on 3 tapes about 45 days after the data month. Telecommunicated data from U.S. Navy shipping are provided on one tape, called AUTODIN. The data arrive near the end of the processing cycle and are generally included in the following month's processing as delayed receipts. Manuscript data from the NWS VOS program are received from a few days to several months after the data month, depending on when the ships reach port and deliver the forms to the Port Meteorological Officer (PMO). Twenty to twenty-five thousand reports are received before digitizing for the specific data month must be stopped. The hatched areas in Figure 1 indicate that additional data for the data month are received late and are included in the following month as delayed data. Receipt of foreign data is delayed from one to several years and arrives at intermittent times. These data are included with the delayed receipts.

2. PROCESSING OVERVIEW

Manuscript data are reviewed by a meteorological technician. A computer program checks the data for internal consistency, illegal characters and suspect values and lists the questionable observations. The meteorological technician checks the forms

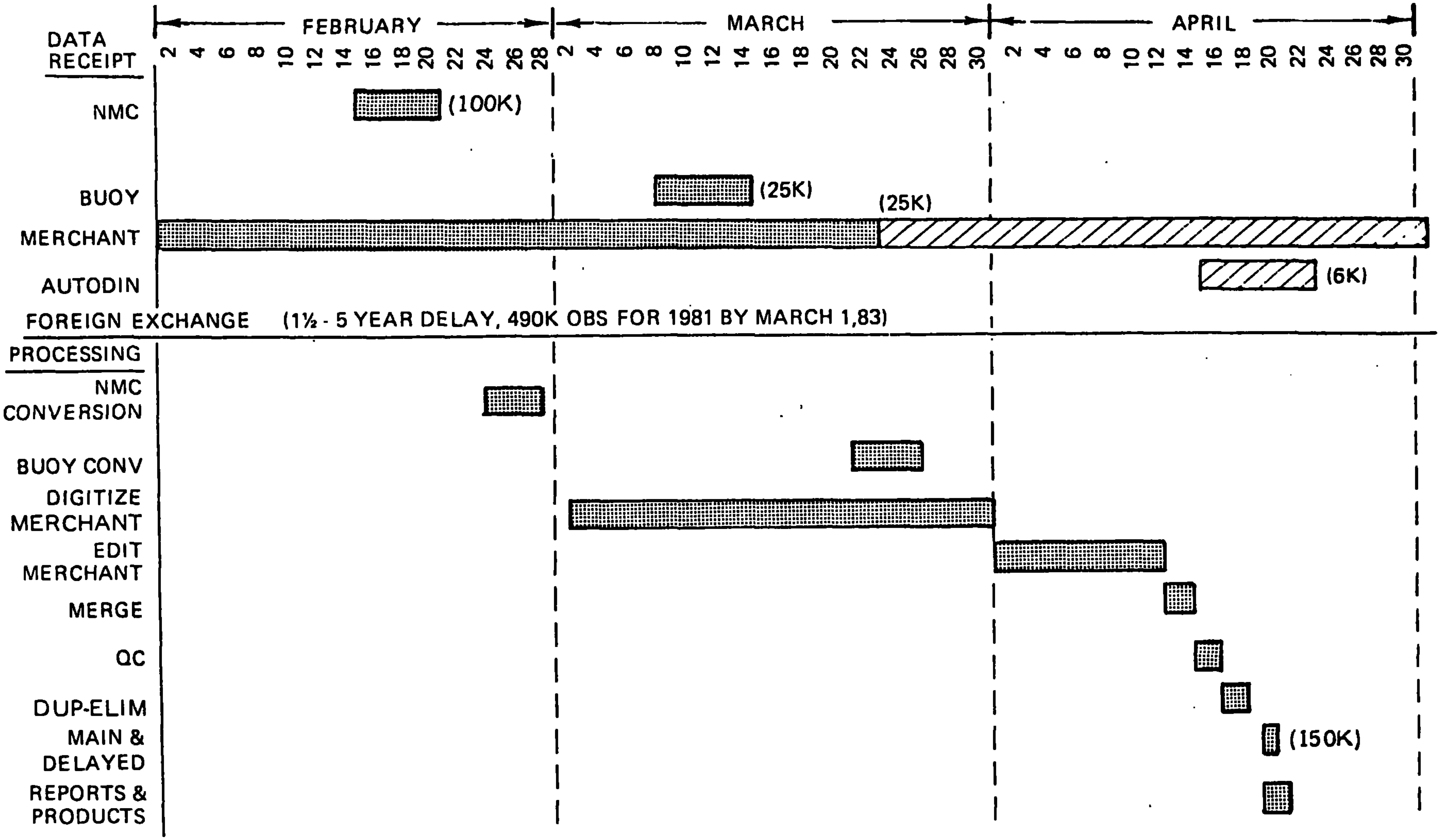

Fig. 1. Marine data processing schedule (January data month).

against the listing and corrects digitizing errors and obvious observer entry errors. If there is any doubt concerning the correct value, such as a temperature that appears to be several degrees too low, the value is not changed. In other words, element values are not estimated and substituted for recorded values. Once the keyed data are corrected, the data are converted to the standard NCDC format and merged with data from the other sources.

The merged data are processed with a quality control program that assigns flags to the data elements of each report. The data are then separated into product files:

1. Main data file - containing the current processing month's data from all sources.

2. Delayed data file - containing all data received for previous months.

3. Buoy data file - containing U. S. buoy and C-MAN observations from NDBC.

4. Gales files - containing reports of high winds and waves in the North Atlantic and North Pacific for publication in the Mariner's Weather Log (MWL).

5. Great Lakes data file - containing all Great Lakes data used to produce annual summaries for the MWL.

6. WMO file - containing manuscript data received from U. S. ships and foreign ships through WMO exchange agreements.

Duplicate data are removed from the main file and the remaining observations are stored in the data base to service customers. The delayed data are also stored in the data base.

Several products are generated from the six files. The main and delayed files are used to create several reports for the MWL, and the NWS. The buoy file is used to create a separate tape and microfiche listing of buoy observations, an inventory, and a summary of buoy observations. The gales and Great Lakes files are also used to produce summary reports for MWL. The WMO file contains the U. S. and foreign manuscript receipts that are exchanged with 7 WMO member countries on an annual basis.

3. FILE MANAGEMENT

In order to provide data to customers in the most economical way posssible, the monthly and delayed data files are merged into quarterly, annual and period-of-record (POR) files. By continually merging the data files and removing duplicate data when practical, the users services section is able to select requested data from fewer tapes and the cost to the customer is much less. The data are stored in area sort by Marsden square.

If, for example, a customer requested data for 1980-85 in the equatorial Pacific, the users services section could select the data from one or two POR tapes. Without the continuous merge process, the users services section would have to select data from 24 tapes each year for the six year period (144 tapes) and charge the customers accordingly.

4. QUALITY CONTROL AND TRACK CHECKING

Marine quality control schemes at NCDC have continued to evolve over the years. The basic data sets have been processed with two separate major procedures, the pre-70's and the present system. Pre-70's data were processed in preparation for the U. S. Navy Climatic Atlas. Quality control performed during the atlas processing included internal consistency checks which allowed for some elements to be changed or eliminated. Composite observations were created from duplicates when certain elements were not reported in both observations. Although the Atlas file was originally intended to be an applications data set, not a primary archive, it became the most frequently accessed data base.

The pre-70's atlas data are included in the COADS data. The data were reprocessed with current quality control procedures. Current data management policy dictates that original data should not be changed. The present quality control scheme was designed to assign quality flags to data elements without altering the data. Figure 2 shows the flags assigned to an element based on the type of error and its severity. Algorithms designed to check the elements and assign flags were developed from quality control procedures used in Britian and the Federal Republic of Germany. Most of the atlas data are flagged with S (missing) or R (accepted as valid) because nearly all of the inconsistencies were removed during the first edit.

In the present system, each flag is assigned a value (see figure 2). In checking an element for exceeding a reasonable value, climatic data consisting of means and standard deviations were derived using 5° squares of latitude and longitude which contain 25 observations or more. If a value lies outside $\pm 4.8\sigma$, it is flagged "suspect". If a value lies outside $\pm 5.8\sigma$, it is flagged "erroneous". If an element contains a flag and is flagged again as a result of a second test, the flag indicating the greatest severity is retained. A flagged element is not used in determining if another element should be flagged. The sum of the values for the elements in the observation provide a relative quality code. The code is entered in the archive record and is used in current processing to select the highest quality observation when duplicate data are encountered.

The present quality control scheme has remained essentially the same since the early 1970s, except that track checking of certain elements was added in 1973, when ships could first be identified by a call sign. In the late seventies additional checks were incorporated for the cloud fields and after the 1982 code change,

ERROR TYPE	SYSTEMATIC OR BIAS ERROR	SUSPECT	ERRONEOUS
		4.8σ	5.8σ
ILLEGAL CODE	A		M
INTERNAL CONSISTENCY	B	J	N
TIME CONTINUITY		K	
EXTREME VALUE		L	Q

A - CLOUD TYPE, HEIGHT, TOTAL AND/OR LOW CLOUD AMOUNT HAVE FAILED INTERNAL CONSISTENCY CHECK.

R - VALUE ACCEPTED

S - VALUE MISSING

QUALITY CODE VALUES

R	0
A B	1
J K L	2
N M Q S	3

Fig. 2. Quality control flags.

minor modifications were made.

Track checking is presently conducted on reports when the interval between reports is less than 24 hours. Based on call sign, sequential observations are compared to check that the net change of position, pressure and temperatures do not fall beyond certain limits. Whenever a limit is exceeded, a flag is assigned. The limits currently used are:

Latitude	0.7°/hr.
Longitude	0.7°/hr., 0 - 40° latitude
	1.0°/hr., 40°-50° latitude
	1.4°/hr., 50°-60° latitude
	2.0°/hr., 60°-70° latitude
	2.7°/hr., 70°-75° latitude

Pressure	5.0 mb/hr
Dry-bulb temperature	5.0°/hr
Dew-point temperature	5.0°/hr
Sea surface temperature	3.0°/hr

5. DUPLICATE ELIMINATION

Locating and eliminating duplicate observations from different sources is not a simple task. Rarely do duplicate observations ever exactly match. Several duplicate elimination procedures have been used since the early seventies. Positions have been compared to 1° or to an exact match of 0.1°. Date and time have been compared exactly or have been allowed to vary by one day or several hours. Elements between duplicate observations have been examined for the maximum number present and/or the quality. Comparing call signs to save observations from individual ships and comparing quality codes or source decks as evidence of the most correct duplicate have been used. Figure 3 shows which duplicate identifiers were used during certain periods of processing.

In 1982, processing procedures were modified in an attempt to reduce costs. Duplicate elimination was completed before the quality control program was run. This procedure reduced the number of observations required to be sorted and processed through the QC program. Since no flags had been assigned or quality code calculated, the system relied on source deck as an indication of quality. The system was modified in 1985 to complete quality control first, allow for ± 0.1° variation in position and determine that the observation was from the same ship. Quality code is used first to determine which observation is saved. If the codes are the same, the highest source deck identifies the duplicate retained.

6. PRESENT HOLDINGS AND FUTURE ADDITIONS

The NCDC archives currently holds both the pre-70's COADS data and the Atlas files. The COADS data are more complete because more

	1970 1977	1978 1981	COADS	1982 1985	AUG 85 Present
LAT-LONG (WITHIN 1°)			X		
(WITHIN 0.1°)	X	X		X	
(WITHIN + 0.1°)					X
YEAR-MONTH	X	X	X	X	X
DAY - HOUR (EXACT)	X	X		X	X
(WITHIN 1)			X*		
8 ELEMENT EQUIVALENCE	X	X			
7 ELEMENT EQUIVALENCE			X		
CALL SIGN		X			X
QUALITY CODE		X	X		X
NUMBER OF ELEMENTS		X			
SOURCE DECK		X		X	X

ELEMENTS

WIND DIRECTION (EXCLUDED IN 7 ELEMENT EQUIVALENCE)
WIND SPEED
VISIBILITY
PRESENT WEATHER
PAST WEATHER
PRESSURE
AIR TEMPERATURE
SEA TEMPERATURE

*Procedures for the pre-1970s and the '70s were different; no day-cross was allowed in the '70s.

Fig. 3. Duplicate elimination procedures.

data sets were added during the COADS development. The 70's COADS data will replace the current 70's DECADE data in the NCDC data base. Several errors in the 70's DECADE data were removed during COADS processing and additional data receipts were added.

To enhance the present data holdings and improve future receipts, several proposals are underway or being considered. The Maury collection containing about 1 million observations from 1820 to 1860 are being digitized by India. The possibility of digitizing manuscript records for the periods of the two World Wars is also being investigated. Thanks to the COADS effort, NCDC can determine the total receipts of foreign exchange data by year and request data for the missing periods from countries participating in the WMO. NCAR may receive data from USSR shipping. Efforts are continuing through the WMO to standardize marine quality control procedures among countries and to improve data exchange.

7. DATA DISCREPANCIES

Errors and discrepancies in the marine data base are present because of varying quality of input sources, changes in observing practices, coding practices and data processing procedures. Users of marine data should examine the element flags and be aware of known discrepancies in certain source decks before selecting observations for research projects. Whenever possible or economically practical, known errors have been corrected in the COADS and 1980's files. The following discrepancies remain which users should consider when working with marine data:

1. Duplicate Observations

Duplicate data will always be present in the data files because of the different duplicate elimination schemes used and the different definitions of duplicates. For example, two identical observations from different ships are not considered duplicates by NCDC because a customer may want all available observations for a certain ship. Researchers, on the other hand, interested in the data at a given point and time, might consider the observations as duplicates. Duplicate data will also remain in the files because of the expense of continuously removing them and the many years over which duplicates may be received.

2. Location

Data from deck 555 (Monterey telecommunicated data), 1970-June 1973 and deck 889 (Global Weather Central telecommunicated data), June 1973-1979, were added to the COADS data files. All observations from these sources that were located north of 80° N latitude were placed in incorrect Marsden squares near the equator during one of the NCDC updates. The observations were relocated to the proper Marsden square during COADS processing, but position and element flags were not changed. Element flags and quality code should be ignored for these observations.

An erroneous test data file was included in the 70's data provided to COADS by NCDC. The data were missing the 100ths position of longitude and were located in the wrong position. An observation at 130° W , for example, would be located in the test file at 30° W. The erroneous observations were duplicates. The correct data were located in the correct position. The test data were for the Feb-July 1975 period and involved only deck 927 (keyed merchant data). The erroneous duplicates, 36,867 total, were recently removed from the COADS files at NCDC. There was some speculation that the erroneous data may have eliminated some genuine observations during a duplicate elimination procedure. Examination of the corrected data, however, does not indicate that a significant number of genuine observations was lost.

3. Time

NMC source data (deck 890) are arranged in synoptic time blocks, 00Z, 06Z, 12Z and 18Z. Time is reported in hundredths of hours. The 00Z block contains data from 20.50 on the previous day to 02.49 hours on the current day. The day is given in a separate header record at the beginning of each block.

When the NMC data conversion programs were written at NCDC, data reported in whole hours at 2100, 2200, and 2300 hours were assigned to the previous day. Beginning about 1980, off-hourly observation times from buoy, coastal marine automated stations (C-MAN) and occasionally research vessels were entered in the NMC records. Observations for hours 20.50 through 20.99 were located in the 00Z time block and were truncated on conversion to 2000 hours (hour 20 in 1129 format). Since the hour was before 2100, the day in the header was not decremented. The result is that any observation from NMC with a time between 20.50 and 20.99 will have the wrong date, one day later than the correct date, and the wrong hour, 20Z instead of 21Z.

In October 1985 the conversion program was changed to round the time to the nearest hour before assigning the correct date. Data prior to the August 85 data month will have the 20Z observation misplaced by one day for deck 890, if the original input time was 20.50 to 20.99. Ship observations from all other sources reported at 20Z will have the proper day and time.

4. Sea Temperature Indicator

The sea surface temperature method indicator, bucket or intake, for U.S. ships was not well documented prior to April 1973. The indicator is available only for manuscript reports and is frequently left blank. Beginning in 1986, the WMO code is used and the indicator is 0 = bucket, 1 = intake, and blank = unknown. Between 1982 and 1986, blank = intake or unknown and B = bucket. Prior to 1982, B = bucket and I = intake or unknown. The only practical use of the sea temperature indicator is to consider B to indicate bucket and I or blank to indicate unknown for any data prior to 1986. If the indicator value is numeric, the 1982 WMO code will be correct. Since intake or injection temperatures may be taken several meters below the surface depending on the size and load of the ship, the temperature may vary from the actual surface temperature.

5. Temperature

From 1966-1973 the only available telecommunication source for marine data was the Monterey data, deck 555. Comparison of data from this deck with manuscript sources shows that temperatures are frequently .5°C to 1.5°C higher than temperatures from other sources. Investigation of other weather elements in deck 555 are incomplete but limited reviews indicate that other elements in deck 555 may be questionable. Data from deck 555 should be used with caution.

From 1973-1979 temperatures from deck 888 (Global Weather Central - GWC) were converted from Kelvin in the original data to centigrade using a 273° conversion factor. In April 1977, GWC changed the factor to 273.2° without notifying NCDC. Temperatures in deck 888 were stored in the data base 0.2 degrees higher than the actual value until the problem was discovered. During one of NCDC's later marine updates, some original GWC data from the pre-April 1977 time period were converted with the 273.2° factor, causing the pre-April 1977 temperatures to be 0.2° too low. These data have been corrected in the NCDC data base but not in the original COADS files.

6. Weather Indicator, i_x

In January 1982 the WMO initiated a new code for marine observations. The new code includes a weather indicator (i_x). If the value of i_x is 2 or 5, the present and past weather fields are not reported because there was no significant weather to report, i.e., the weather was good (weather codes 00-03).

As of January 1, 1984, the i_x indicator is archived in position 148 of the 1129 format and as of March 1, 1985, i_x is entered in position 79 of the IMMT format. The i_x weather indicator is missing from January 1982 - October 1984 for manuscript data and from January 1982 - March 1985 for foreign exchange data. The i_x indicator for NMC data is missing from January 1982 - December 1983 because of formatting problems on the NMC input tapes.

7. Wave and Swell

WMO code changes were initiated for these fields in July 1963 and January 1968. Some countries made the appropriate changes on the effective date while others continued with the old code for indefinite periods. Conversion procedures assumed that code changes were made as specified when they may not have been made. Period of wave and swell should be considered questionable, particularly for foreign exchange data during 1964-65 and 1968-69.

The NMC decode program searches the transmitted report for group identifiers to locate swell direction (3) swell period and height (4) and secondary swell (5). If any of the groups is missing the decode program may locate a special phenomena group such as 333, 444 or 555 and assume it to be the swell group. Combinations of swell direction, period and height, and secondary swell that contain the digits 33, 44, and 55 respectively are erroneous data. This problem has existed since the 1982 code change and was corrected for the November 1985 data in the NMC files.

8. Foreign Fixed Buoy Data from NMC

NMC data were included in the operational processing in 1980. Programs were written to remove fixed buoy data, identified by a code of 561, from the NMC data so that the more correct NDBC data would be entered into the data base without duplication. The NDBC tape contained corrected data from U. S. buoys while NMC contained data from both U.S. and foreign buoys. The conversion procedure has eliminated all foreign fixed buoy data from the data base since 1980. Procedures were changed to correct the problem for July data in October 1985.

COADS 1980-85 Update

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1. Introduction

The fourteen data products now available in Release 1 of the Comprehensive Ocean-Atmosphere Data Set (COADS) provide a unique resource for studies of the global boundary between ocean and atmosphere, over the period 1854-1979 (Fletcher et al., 1983; Slutz et al., 1985; Woodruff, 1985). A limited subset of COADS products for 1980-85 is planned for availability by 1987 as the result of a continuation project, and these data will comprise COADS Release 2. Existing software under modification to handle data in the 1980s will be used to generate the 1980-85 equivalent of the following products (see Slutz et al., 1985; hereafter Release 1) for distribution by NCAR, or solely by NCDC in the case of product 19:

product 1.	Long Marine Reports (LMR)
product 2.	Inventories (INV)
product 10.	Compressed Marine Reports (CMR)
product 15.	Monthly Summaries Trimmed Timesort (MST.T)
product 18.	Monthly Summary Trimmed Groups (MSTG)
product 19.	NCDC Result (TD-1129)

This report describes progress toward COADS Release 2, including an interim product 10 containing currently available data from the NOAA/National Climatic Data Center (NCDC) for 1980-84. The Compressed Marine Report (CMR) format contains 28 frequently used elements stored in packed binary, including individual observations of sea surface temperature, air temperature, wind, pressure, cloudiness, and present weather. Conversion to CMR has the advantage of reducing data volume to one-sixth that of the input 148-character TD-1129 format received from NCDC.

2. Input Data

Data input to the interim processing consisted of 20,249,378 surface marine reports obtained from NCDC in TD-1129 format on 50 magnetic tapes (Table 1), containing annual merge files and delayed data that reached NCDC during the years 1980-84. Delivery of the 1985 annual merge files and delayed data is expected by July, 1986. Annual merge files contain data received during the data month; delayed data were received subsequently (Cram, 1986).

Table 1

Input TD-1129 Tapes

#	Name	Description	Received	Processed	TD1129	SRUS
1	D2ZZ01	DBA01 1980 MSQ 001-081	85/11/05	85/11/20	375746	12004.290
2	D2ZZ02	DBA02 1980 MSQ 082-126	85/11/05	85/11/25	365113	11544.253
3%	D2ZZ03	DBA03 1980 MSQ 127-156	85/11/05	85/11/22	393617	12577.361
4	D2ZZ04	DBA04 1980 MSQ 157-216	85/11/05	85/11/25	414423	13080.873
5%	D2ZZ05	DBA05 1980 MSQ 217-938	85/11/05	85/11/23	348221	11019.227
6	D2ZZ06	DBA06 1981 MSQ 001-060	85/11/05	85/11/23	181102	5791.726
7%	D2ZZ07	DBA07 1981 MSQ 061-109	85/11/05	85/11/26	308490	9825.748
8*%	D2ZZ08	DBA08 1981 MSQ 110-146	85/11/05	REPLACED BY #42		
9	D2ZZ09	DBA09 1981 MSQ 147-180	85/11/05	85/12/04	354082	11073.168
10	D2ZZ10	DBA10 1981 MSQ 181-216	85/11/05	85/12/04	223186	7056.605
11	D2ZZ11	DBA11 1981 MSQ 217-956	85/11/05	85/11/27	333152	10564.851
12	D2ZZ12	DBA12 1982 MSQ 001-081	85/11/05	85/12/04	302828	9570.846
13	D2ZZ13	DBA13 1982 MSQ 082-126	85/11/05	85/11/27	350574	10937.888
14	D2ZZ14	DBA14 1982 MSQ 127-156	85/11/05	85/12/05	340441	10674.535
15	D2ZZ15	DBA15 1982 MSQ 157-216	85/11/05	85/12/11	377534	11829.886
16	D2ZZ16	DBA16 1982 MSQ 217-999	85/11/05	85/12/11	320216	10033.650
17	D3ZZ01	DBA17 197101-198212	85/11/05	85/12/13	59466	1915.595
18	D3ZZ02	DBA18 198202-198312	85/11/05	85/12/19	11243	392.374
19	D2ZZ17	1983 MSQ 001-081	85/11/19	85/12/05	330130	10415.712
20&	D2ZZ18	1983 MSQ 082-126	85/11/19	85/12/12	374552	11678.838
21	D2ZZ19	1983 MSQ 127-156	85/11/19	85/11/29	407321	12804.045
22	D2ZZ20	1983 MSQ 157-216	85/11/19	85/12/02	408697	12732.005
23	D2ZZ21	1983 MSQ 217-999	85/11/19	85/12/06	369955	11514.026
24	D2ZZ22	1984 MSQ 001-081	85/11/19	85/12/02	380408	11933.631
25	D2ZZ23	1984 MSQ 082-126	85/11/19	85/12/03	538323	16749.756
26	D2ZZ24	1984 MSQ 127-156	85/11/19	85/12/03	570718	17727.340
27	D2ZZ25	1984 MSQ 157-216	85/11/19	85/12/06	549257	17253.225
28	D2ZZ26	1984 MSQ 217-999	85/11/19	85/12/06	454417	14114.597
29	D3ZZ03	DBA19 DELAYED IMMT 1-146, 1969-1979	85/11/25	86/01/06	465799	14833.501
30	D3ZZ04	DBA20 DEL 147-999, 1968-1979	85/11/25	85/12/10	391929	12356.740
31	D3ZZ05	DBA21 DELAYED IMMT 1-146, 1980-1981	85/11/25	85/12/09	351319	11395.630
32	D3ZZ06	DBA22 IMMT 147-999, 1980-81	85/11/25	85/12/13	389483	12395.305
33	D3ZZ07	DBA23 DELAYED MARINE 1980	85/11/25	85/12/14	229378	7296.055
34	D3ZZ08	DBA24 DELAYED MARINE DATA 1981	85/11/25	85/12/10	448160	14117.018
35	D3ZZ09	DBA25 DELAYED MARINE DATA 1982	85/11/25	85/12/16	398532	12617.219
36	D3ZZ10	929 OBS 1970-83	85/11/25	85/12/14	252183	7924.700
37	D3ZZ11	929 OBS 1978-83	85/11/25	85/12/16	133086	4227.617
38	D3ZZ12	929 OBS 1975-4/84	85/11/25	85/12/10	140039	4423.993
39	D3ZZ13	929 OBS 10/78-5/84	85/11/25	85/12/21	411274	12927.871
40	D3ZZ14	DELAYED MARINE 1984	85/11/25	85/12/17	391530	12436.179
41	D3ZZ15	DELAYED MARINE 1985	85/11/25	85/12/23	1013250	32059.595
42*	D2ZZ08	SURFACE MARINE OBS, ANNU	85/12/10	86/01/09	426936	13625.203
43	D3ZZ16	926 MSQ001-041&042-081	85/12/16	85/12/18	667143	21220.579
44	D3ZZ17	926 MSQ082-101&102-126&127	85/12/16	85/12/17	711365	22584.144
45	D3ZZ18	926 MSQ145-156	85/12/16	85/12/20	492420	15285.029
46	D3ZZ19	926 MSQ157-216	85/12/16	85/12/18	478231	15064.851
47	D3ZZ20	926 MSQ217-400&401-999	85/12/16	85/12/20	690097	21791.722
48&	D3ZZ21	IMMT 1973-81 #1	86/01/27	REPLACED BY # 51		
49*&	D3ZZ22	IMMT 1973-81 #2	86/01/27	REPLACED BY # 52		
50	D3ZZ23	IMMT 1973-81 #3	86/01/27	REPLACED BY # 53		
51	D3ZZ21	BOULDER #1	86/03/31	86/04/04	499876	15995.822
52	D3ZZ22	BOULDER #2	86/03/31	86/04/11	621875	19944.952
53	D3ZZ23	BOULDER #3	86/03/31	86/04/10	595627	18804.379
54	D3ZZ24	BOULDER #4	86/03/31	86/04/09	606634	19148.505

• tape with block unreadable
& tape not terminated by an EOF
% tape hub broken

It should be noted that the annual and delayed files were acquired separately, rather than NCDC's period-of-record (POR) merge, in order to retain the maximum number of duplicates. This will permit setting a duplicate check flag in later processing to indicate the presence of a GTS (Global Telecommunication System) and logbook duplicate, thus providing location verification.

3. Conversion into Compressed Marine Reports

As a first stage in the interim processing, each input TD-1129 report was converted into CMR (format shown in supp. D of Release 1; in the following, other supplements are also referenced). Table 1 gives processing statistics for each input 6250-cpi magnetic tape, including the dates it was received and processed, and the number of system resource units (SRUS) used at P4 priority on the Department of Commerce Consolidated Scientific Computing System CDC Cyber 180/840 in Boulder, Colorado.

In general, any field outside the legal range for TD-1129 or outside the true value range of Table D0-1 in supp. D was interpreted as blank during the process of conversion and set to missing in CMR. The following procedures were followed for individual fields (numbered per Table D0-1):

6) HOUR

For any occurrence of an hour of 24, one was added to the day (and month/year if applicable) and hour changed to 00.

10) BI bucket indicator

TD-1129 bucket indicators of B, I, 0-9 were accepted, with B and I considered equivalent to 0 and 1, respectively, and translated into CMR as follows (illegal codes 8-9 were translated into "unknown"):

TD-1129	CMR
0 = bucket thermometer	1 = bucket
1 = condenser inlet (intake)	0 = unknown
2 = trailing thermistor	0 = unknown
3 = hull contact sensor	0 = unknown
4 = through hull sensor	0 = unknown
5 = radiation thermometer	0 = unknown
6 = bait tanks thermometer	0 = unknown
7 = others	0 = unknown
8 = (illegal)	0 = unknown
9 = (illegal)	0 = unknown
blank or "-"	missing

12) DP dew point depression

Any $-0.5 \le DP < 0$ was changed to zero (see sec. 2.2 of supp. E).

14)	U	vector wind eastward component
15)	V	vector wind northward component

The combinations of wind speed (W) and direction (D) in Table E2-1 of supp. E for which (U, V) result (ignoring any QC flags) were accepted. For (U, V)=0, a direction indicator (DI) of "-", or D in conjunction with DI having an undefined conversion according to Table F2-1 (of supp. F), was not rejected.

16)	DI	direction indicator

TD-1129 direction indicators of 0-2, blank, or "-" were accepted ("-" considered missing).

19)	C	total cloud amount
20)	NH	lower cloud amount
21)	CL	low cloud type
22)	H	cloud height
23)	HI	cloud height indicator
24)	CM	middle cloud type
25)	CH	high cloud type

Per supp. I (p. I12), if all seven input positions were blank or "-" in any combination, then all seven fields were considered missing. Otherwise, "-" was interpreted as blank in fields where "-" was not legal (C, NH, HI).

26)	ST	ship type

Ship type was set to missing (TD-1129 position 146 was used for input inventory purposes, only).

29)	LF	landlocked flag
30)	SF	sea surface temperature (S) flag
31)	AF	air temperature (A) flag
32)	RF	relative humidity (R) flag
33)	WF	wind (W, U, V) flag
34)	PF	pressure (P) flag

The landlocked flag (LF) was set according to LLN2F1 (see supp. G). All other flags are missing.

It should be noted that any TD-1129 QC flags were ignored in translation, and only those positions that were needed to construct CMR were checked or utilized. A TD-1129 report with an erroneous or inconsistent location or time was discarded as was any resultant CMR without any data.

4. Interim and Update Processing

Figure 1 illustrates processing of the interim CMR data, now available on 5 6250-cpi tapes. Processes b-c (distribution by year and timesort of CMR) organized and compacted 1980-84 data from the 50 intermediate CMR tapes onto 5 tapes (one for each year). The resultant sort is as follows: year, month, 2^o box, day, hour, longitude, latitude (sort useful for calculation of monthly summaries).

To complete Release 2, after receipt of 1985 annual merge and delayed files, all 1980-85 data will be processed according to Figure 2. Note that this will involve reprocessing of 1980-84 data used in interim processing. Possible updates of Release 1 data for 1970-79 or 1854-1969 periods are contingent on a number of factors, including adequate machine and personnel resources, and the availability of Russian or Indian international data that have been proposed for exchange. If the 1970-79 decade is reprocessed, OSV upgrade, GATE Project, and FGGE drifting buoy data should probably be included.

A total of 20,213,853 CMR were output from the interim processing (including pre-1980 data). Figures 3 through 5 show total output CMR distribution by year, month, and card deck, respectively. For 1980-84 there are 16,514,957 CMR.

5. Errors

A number of errors have been detected by NCDC in the data that they sent. Cram (1986) has a detailed list of these errors, indicating which ones have been corrected by NCDC in their period-of-record merge, including instructions on how to bring the annual files into agreement with the POR data.

A number of additional errors were found in the processing of TD-1129 into CMR. One block with an illegal ASCII character (unreadable using standard CDC utilities) was rejected resulting in the loss of 70 reports. A total of 3,570 other TD-1129 were rejected because of erroneous character combinations in geographical location fields as listed in Table 2.

Other elements that were needed to complete translation from TD-1129 into CMR were checked for adherence to TD-1129 code standards. In some cases CMR imposes tighter limits on elements such as sea surface temperature (supp. D). Tables 3 and 4 describe the errors and some of the specific problems that were encountered in translating fields. Many of these errors were found in international exchange data (decks 926-927).

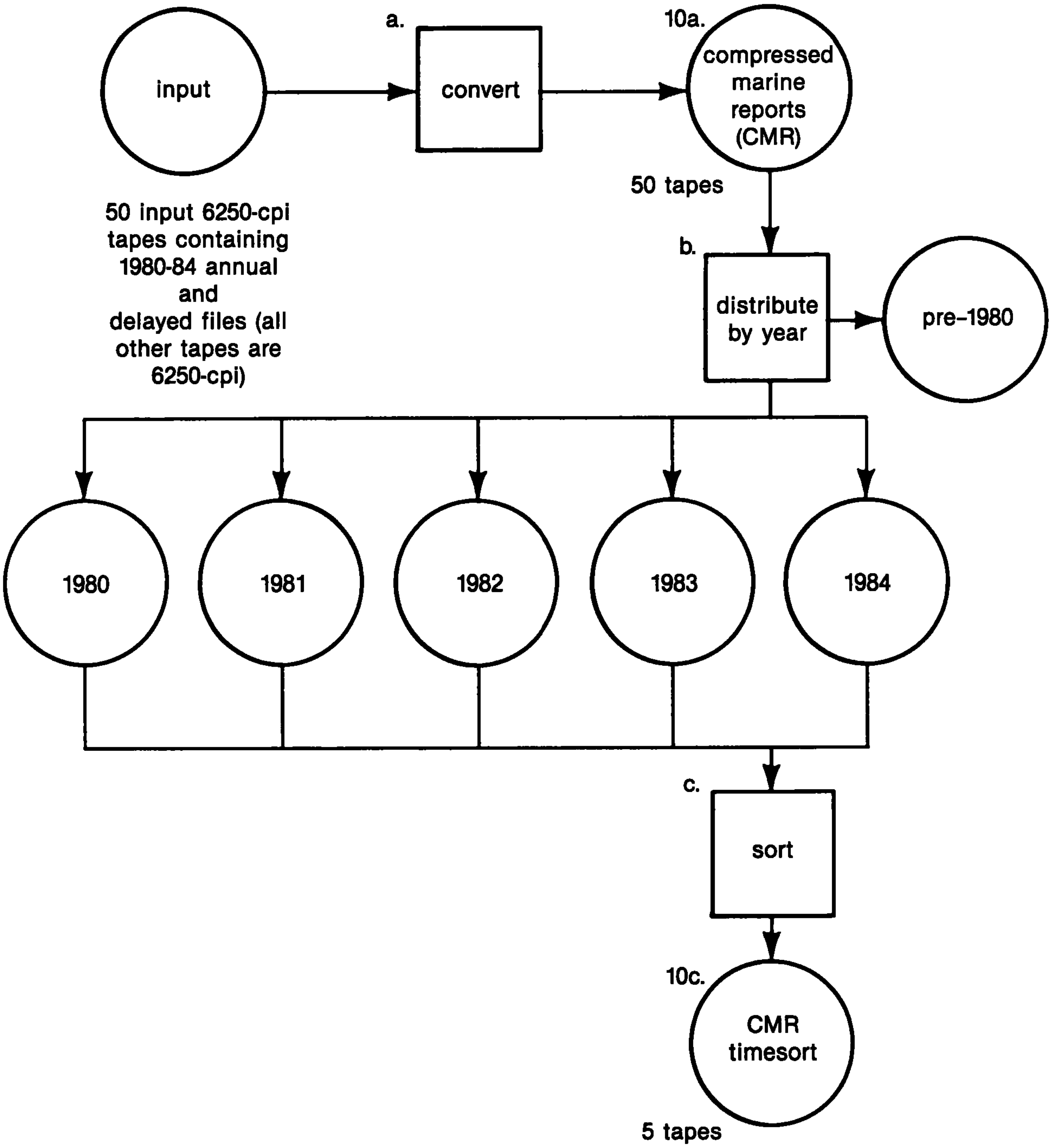

Figure 1. Interim processing. Data products or single intermediate tapes are shown as circles, processes are shown as squares. Process c is a sort by month, 2° box, day, hour, longitude, latitude, performed separately on each of the annual intermediate tapes.

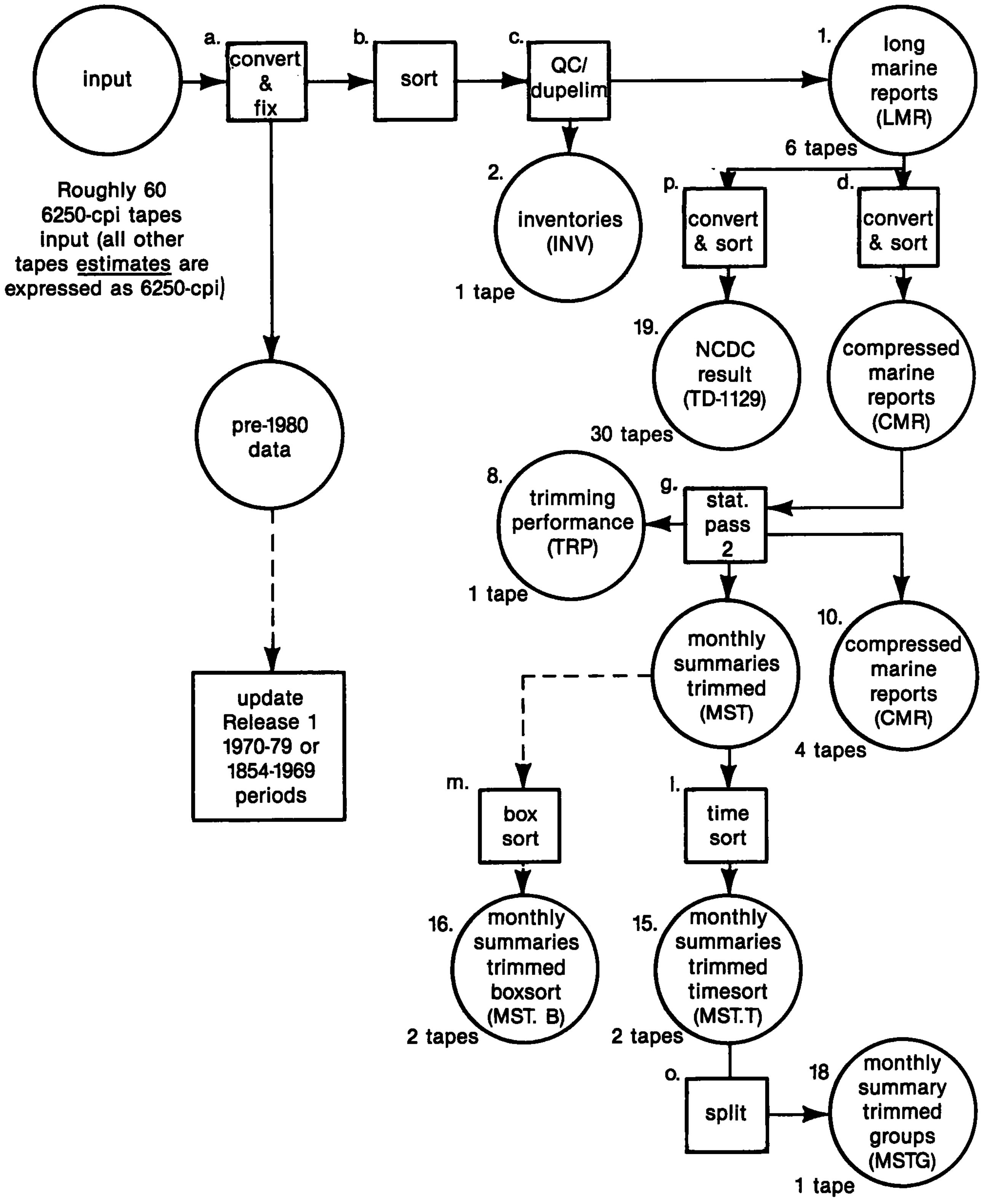

Figure 2. Update processing. Data products or intermediate data (unnumbered) are shown as circles, processes are shown as squares. For detailed information, product numbers or process letters refer to **Release 1.** Dotted lines indicate possible processing, depending on data availability or other conditions.

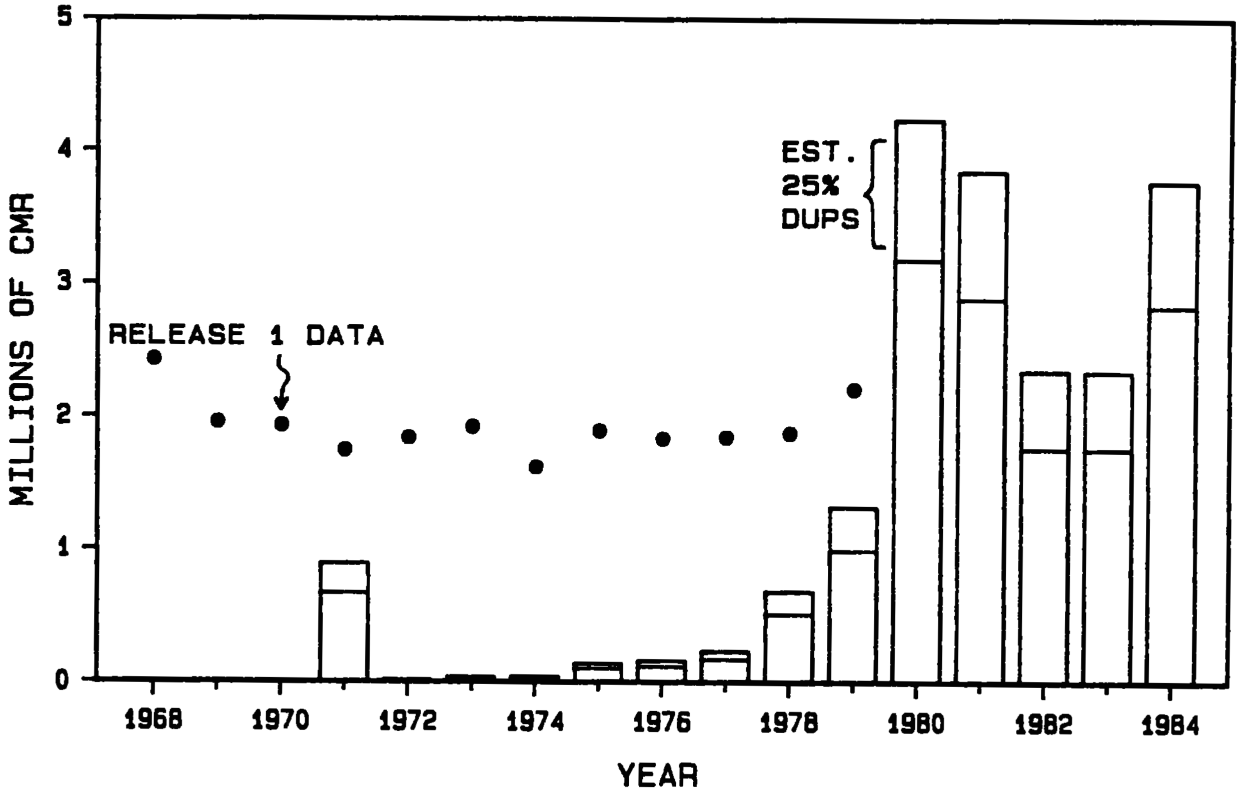

Figure 3. Total interim CMR output by year, conservatively estimating the effect of duplicate elimination on the update CMR data as 25%. (Erroneously dated data within 1871–1991 are not shown.) Dots compare the number of Release 1 (1854–1979) LMR (Long Marine Reports) after duplicate elimination.

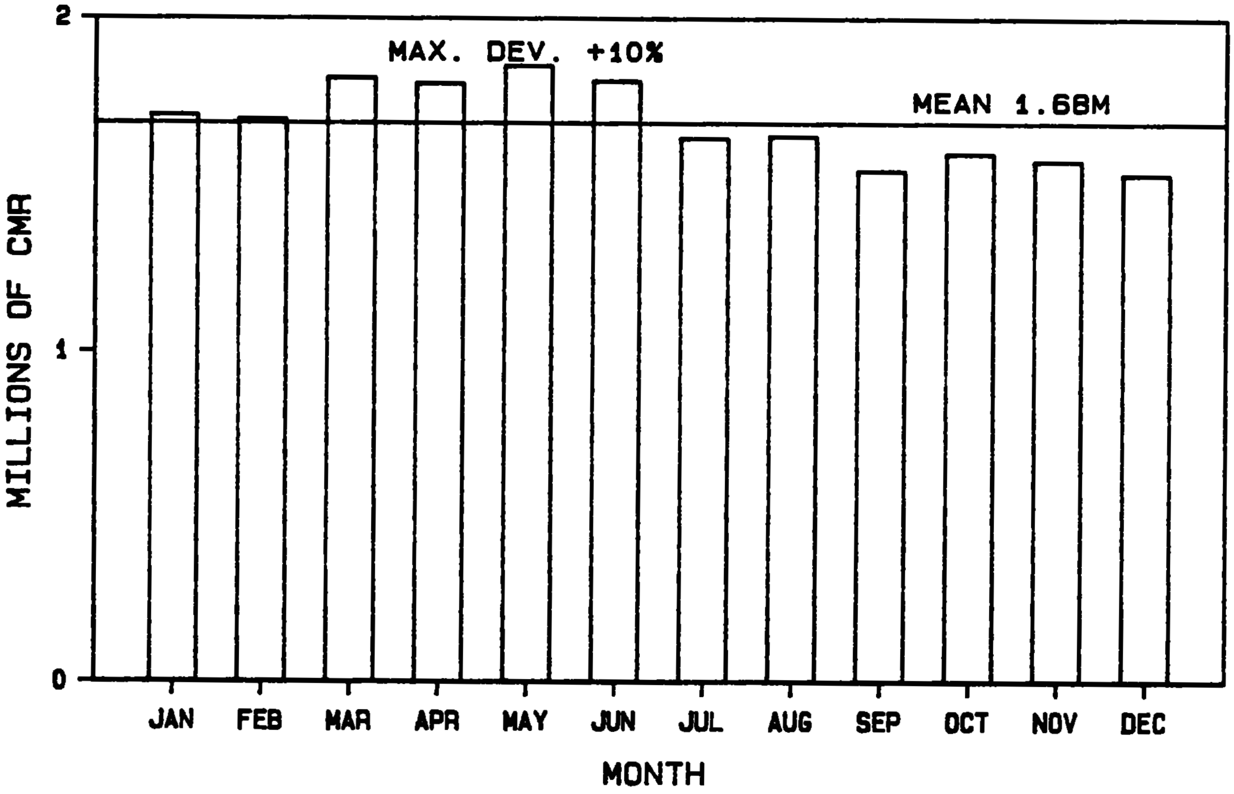

Figure 4. Total interim CMR output by month (summed for all years 1871–1991 [sic]).

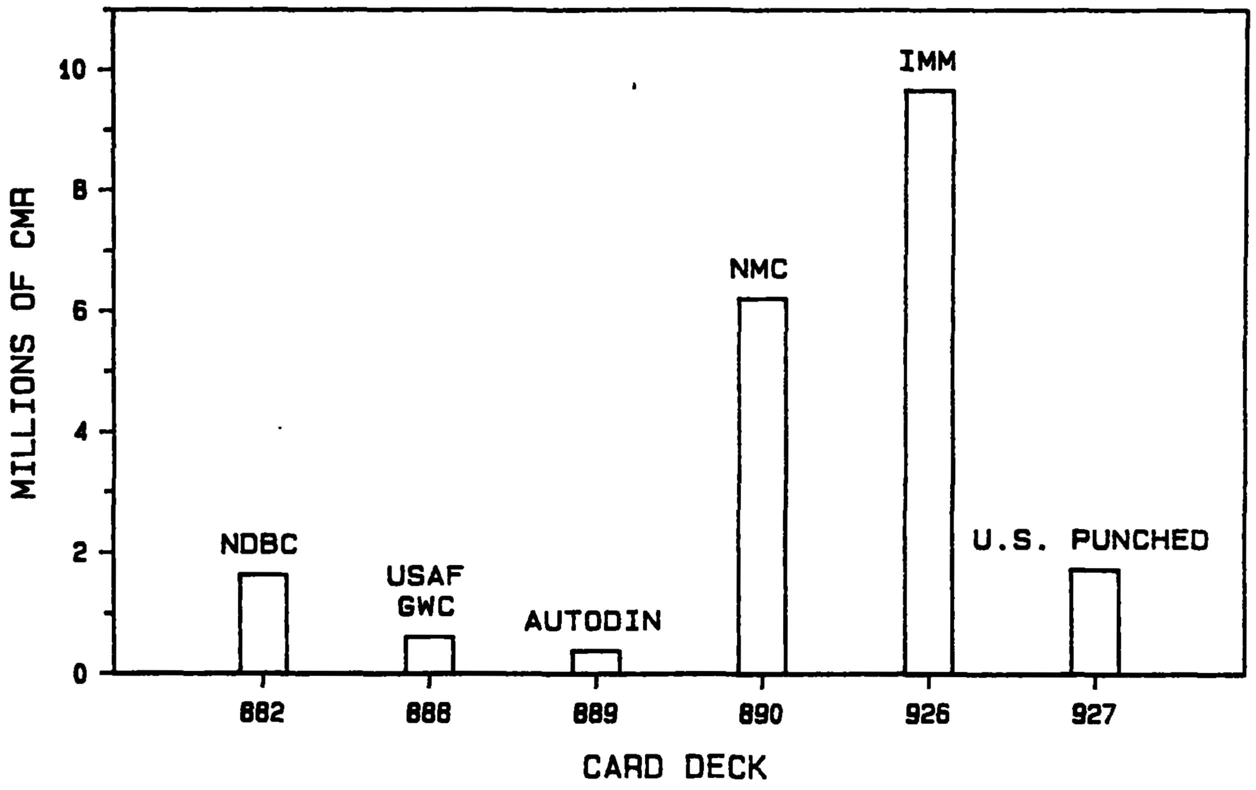

Figure 5. Total interim CMR output by card deck (summed for all years 1871–1991 [sic]).

882	NDBC (NOAA Data Buoy Center)
888*	GWC (U.S. Air Force Global Weather Central)
889*	AUTODIN (Dept. of Denfense Automatic Digital Network)
890*	NMC (NOAA/National Meterological Center)
926	IMM (International Maritime Meteorological) Exchange
927	International Marine (U.S. recruited ships punched in-house)

* GTS deck (from the Global Telecommunication System); all others are manuscript data.

Table 2

Erroneous TD-1129 Location Fields

N	DECK	MSQ	1	Q	LAT	LONG
69		999	00			
731	882	999		1	000	-82
1753	889	***	**	*	***	>1800
3	889	***	**	*	>900	****
4	890	***	**	*	>900	****
356	890	***	**	*	999	****
89	890	***	**	*	***	>1800
163	926	***	**	*	***	>1800
4	926	***	**	*	>900	****
1	927	***	**	*	5—	****
42	927	***	**	*	***	
7	927	***	**	*	***	>1800
2	927	***	**	*	——	———
15	927	***	**	*		****
19	927	***	**	*		0
169	927	***	**	*		
23	927	***	**		***	****
120	927	***				
3570	Total					

* The number of occurrences "N" (out of 20,249,378 reports) of each erroneous input character string spanning the above fields is shown, with "*" denoting any character; alternatively, ">" indicates a numeric value greater than shown. "1" and "Q" represent 1 degree MSQ and quadrant. Blanks within fields are literally blank.

Table 3

Errors in TD-1129 Fields

Field	Erroneous Reports	%*
hour	69	.000
wind direction	3345	.017
wind speed	562	.003
present weather	2	.000
pressure	63601	.314
temperature indicator	27	.000
air temperature sign	7448	.037
air temperature	7708	.038
sea surface temperature sign	122304	.604
sea surface temperature	124193	.613
cloud height	1	.000
bucket indicator	1284	.006

* Percentage out of total input report count (20,249,378).

Table 4

Erroneous TD-1129 Fields with Specific Problems Identified

N	DECK	SLP	SST	BI
1726	890		+410	
79101	926		-**#	
1181	926			J
816	926		-999	
182	926		+999	
42330	926	00000		
58	927			U
3540	927		0———	
838	927		————	
Total		42330	86203	1239

- The number of occurrences "N" (out of 20,245,808 non-rejected reports) of each erroneous input character string spanning a single field above is shown, with "*" denoting any character. Totals do not match Table 3 counts because specific problems were not readily identifiable in all cases. "BI" represents bucket indicator. Blank fields are not under consideration.

References

Cram, R. S., 1986: Marine data processing procedures at the National Climatic Data Center. Proceedings of a COADS Workshop, Boulder, Colorado, January 22-24, 1986, S. D. Woodruff, Ed., NOAA Environmental Research Laboratories, Climate Research Program, Boulder, Colo. (this Volume).

Fletcher, J.O., R. J. Slutz, and S. D. Woodruff, 1983: Towards a Comprehensive Ocean-Atmosphere Data Set. Trop. Ocean. Atmos. Newslett., 20, 13-14.

Slutz, R. J., S. J. Lubker, J. D. Hiscox, S. D. Woodruff, R. L. Jenne, D. H. Joseph, P. M. Steurer, and J. D. Elms, 1985: Comprehensive Ocean-Atmosphere Data Set; Release 1. NOAA Environmental Research Laboratories, Climate Research Program, Boulder, Colo., 268 pp. [NTIS PB86-105723].

Woodruff, S. D., 1985: The Comprehensive Ocean-Atmosphere Data Set. Extended summary, Third Conference on Climate Variations and Symposium on Contemporary Climate 1850-2100, American Meteorological Society, 14-15.

Observations from Fishing Fleets of the Inter-American Tropical Tuna Commission

James C. Sadler

Weather observations from ships of fishing fleets are not routinely available to the meteorological community for various reasons, one of which has been the lack of sufficient priority within the community. The recent interest in tropical air-sea interaction as it relates to climate and climate forecasting has raised the priority, for fishing ships are at present the only potential source of improved surface wind information over vast regions of the tropical oceans. The large potential of the fishing fleets to provide data in the tropical Pacific has been documented by Cutchin (1983).

The Inter-American Tropical Tuna Commission (IATTC) through the efforts of Forrest Miller, Senior Meteorologist, has agreed to make the meteorological observations available from the fishing fleets under their jurisdiction. Through support of the U.S. TOGA Program, the University of Hawaii has contracted with the IATTC (Miller is Principal Investigator) to collect and process the data in a delayed mode and compile them as gridded monthly averages. No individual observations will be supplied. 1980 was selected as the initial year. Figures 1 and 2 show examples of the data distribution over the eastern tropical Pacific for April and August 1980. The number of observations in 2° by 2° squares are shown in large type. The concentrated fishing areas move with seasons to follow the currents and to avoid meteorological hazards. For example, in August the fleet moves westward and concentrates along 10N to avoid "hurricane alley."

Table 1 compares numbers of fishing ship observations with those in the COADS to illustrate the impact such data could have. Note that in the grid square at 126W the number of observations from fishing ships in August 1980 exceeds the number of COADS observations obtained over 80 Augusts from 1900 through 1979.

Table 1. Number of ship observations in 2° by 2° squares centered on indicated latitude-longitude

		Longitude West								
		136	134	132	130	128	126	124	122	120
(a)	10N	32	15	21	76	61	67	51	47	28
(b)	9N	120	141	109	90	102	61	62	73	82

(a) Number of IATTC fishing ship observations during August 1980.
(b) Total number of COADS ship observations for Augusts 1900-1979.

Arrangements should be made to incorporate these data into the COADS data set.

Reference

Cutchin, D. L., 1983: Numbers of meteorological observations by ships in the tropical Pacific. USCD-SIO, La Jolla, CA 92093, SIO Ref. 83-9, 58 pp.

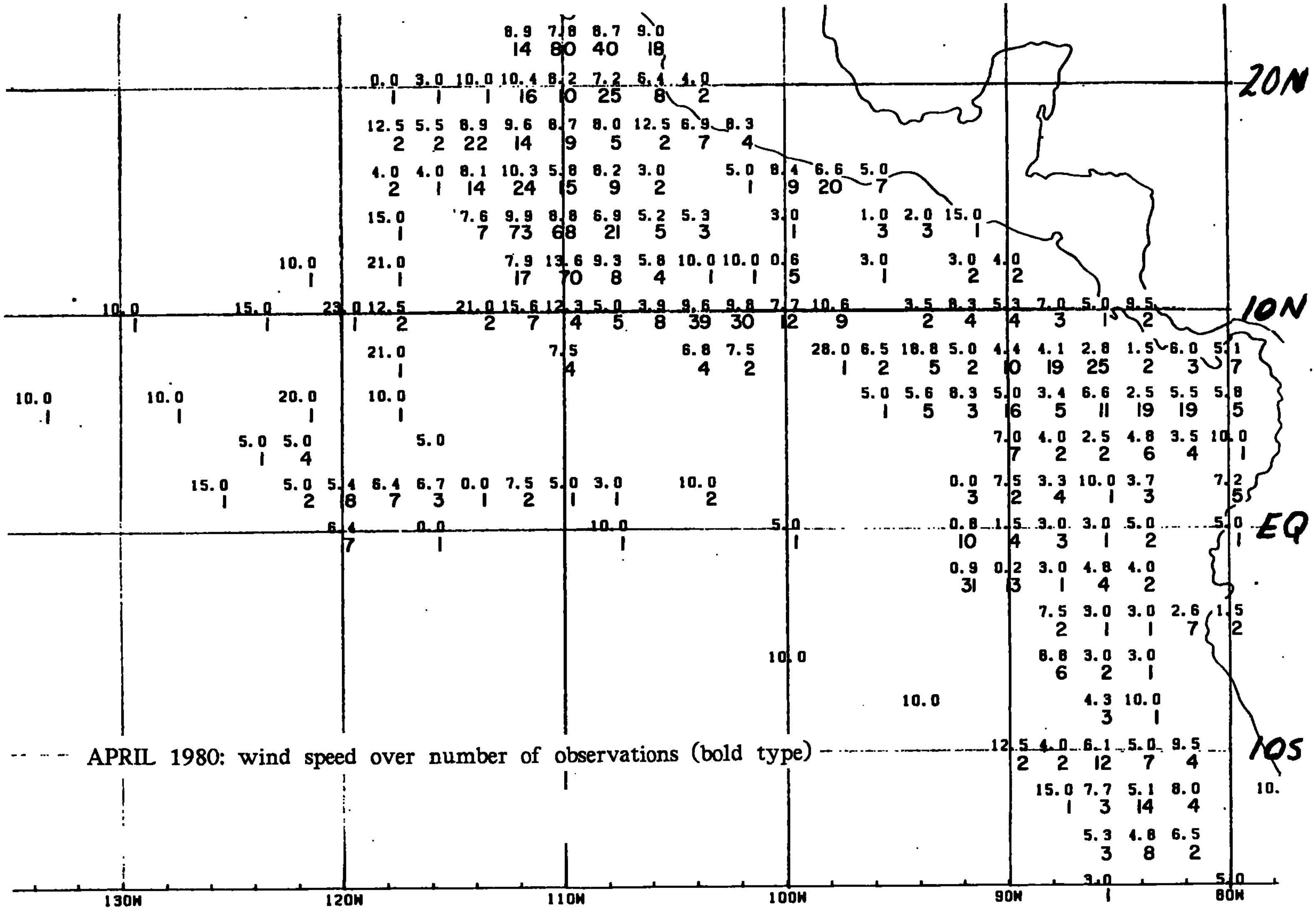

Fig. 1. Distribution of Inter-American Tropical Tuna Commission fishing ship observations in Eastern Tropical Pacific during April 1980. (From F. R. Miller)

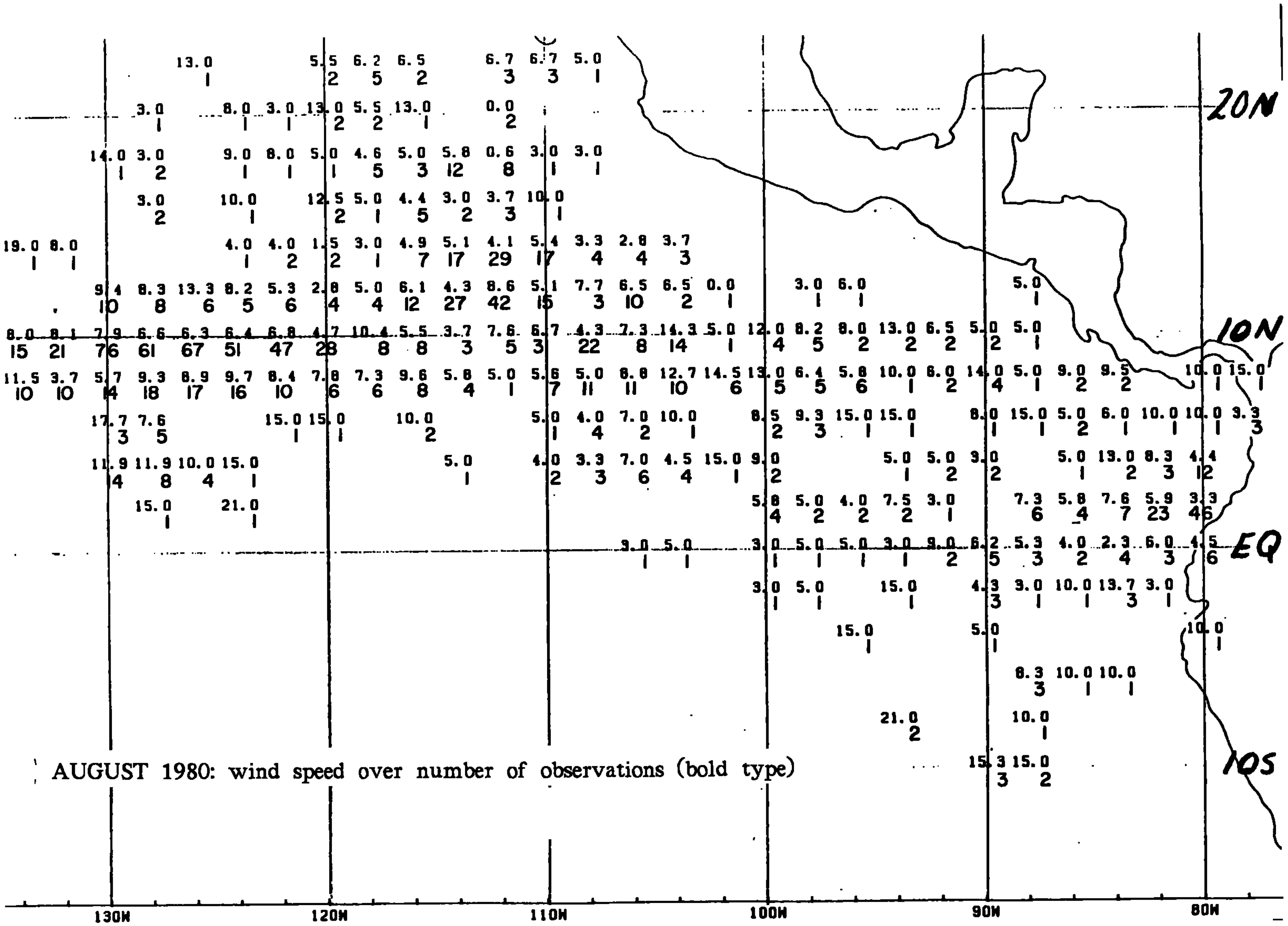

Fig. 2. As in Fig. 1 except for August 1980.

Part 3. Scientific Papers

SOME GROSS ERRORS AND BIASES IN COADS AND THEIR PROBABLE CAUSES

James Sadler, Mark Lander, Arnold Hori
University of Hawaii

Our initial and major interest in COADS was a data source for an improved climatology of the surface winds over the tropical oceans. The long-term mean (LTM) period selected for analysis was from 1900 through 1979. During the subjective analyses some data were conspicuous in not conforming to the surrounding flow patterns. Most seemed misplaced while some were perhaps correct but biased. We, of course, were not in the position to make corrections but did make an effort to identify the suspects and determine their times of occurrence by stratifying the data into 40 year, 10 year and sometimes yearly plots depending on how serious we deemed the problem. The episodes were tabulated and sent to COADS (Mr. Woodruff) where we presume the errors were corrected. Some examples of the data problems follow:

1. A simple but perplexing problem is the isolated error in only one or two grid points for perhaps a single year, yet large enough to overwhelm the 80-year average. Figure 1 illustrates this type at two grid points in the tropical eastern Pacific. These data obviously belong somewhere else. The error belongs to the period 1900-1939 but we pursued it no further.

2. In Figure 2 large batches of ships are mislocated over land and about five grid points in the south Indian Ocean contain misplaced data. Because of the large numbers of data points involved, we isolated the problem down to 1975 for the months of March, April, and June.

3. In February a large number of grid points, but not all contiguous, showed faulty on the LTM chart in the equatorial north Atlantic. The consistent data for 1940-1979 (Fig. 3a, top) placed the errors in the period 1900-1939 (Fig. 3a, bottom). We further stratified the data and found that the errors occurred throughout the period from 1900-1929 (Fig. 3b). They may have also occurred in the 1800's which we did not check.

4. In the LTM for July, August, and September there were some grid points south of Japan with large numbers of observations yet producing noise in what should have been a very smooth flow. Our stratifications placed them into the period of 1940-1979 and then into the period 1940-1949 (Fig. 4). No further stratification was done for we were confident that the observation belonged to 1945 when the large American fleet stood off Japan. This is an example of correct data biasing the data base when a large percentage of the data is taken during a very anomalous year. The data of Fig. 4 (bottom) indicate a rather strong E to ENE flow just south of Japan in July (probably 1945) in contrast to the LTM of light S to SSW winds. Care must be taken with data from recent years due to the increasing number of buoys whose quantity of observations can greatly exceed the numbers of surrounding LTM ship observations, particularly in the tropics.

During visual comparison of the two 40-year period averages, it was obvious that the wind speeds were greater in the 1940-1979 period than in the 1900-1939 period. A quantitative check was made using thirty 2°x2° grid areas over the North Indian Ocean and South China Sea for which there were at least 500 observations per grid box for each 40-year period during December-February.

The speed range was 3.8 to 10.5 m/s with an average of 6.1 m/s for the 60 boxes. The 1940-1979 speeds exceeded 1900-1939 speeds for every grid and the average difference was 1.0 m/s. This bias of greater than 15% may be mostly due to the change from Beaufort scale.

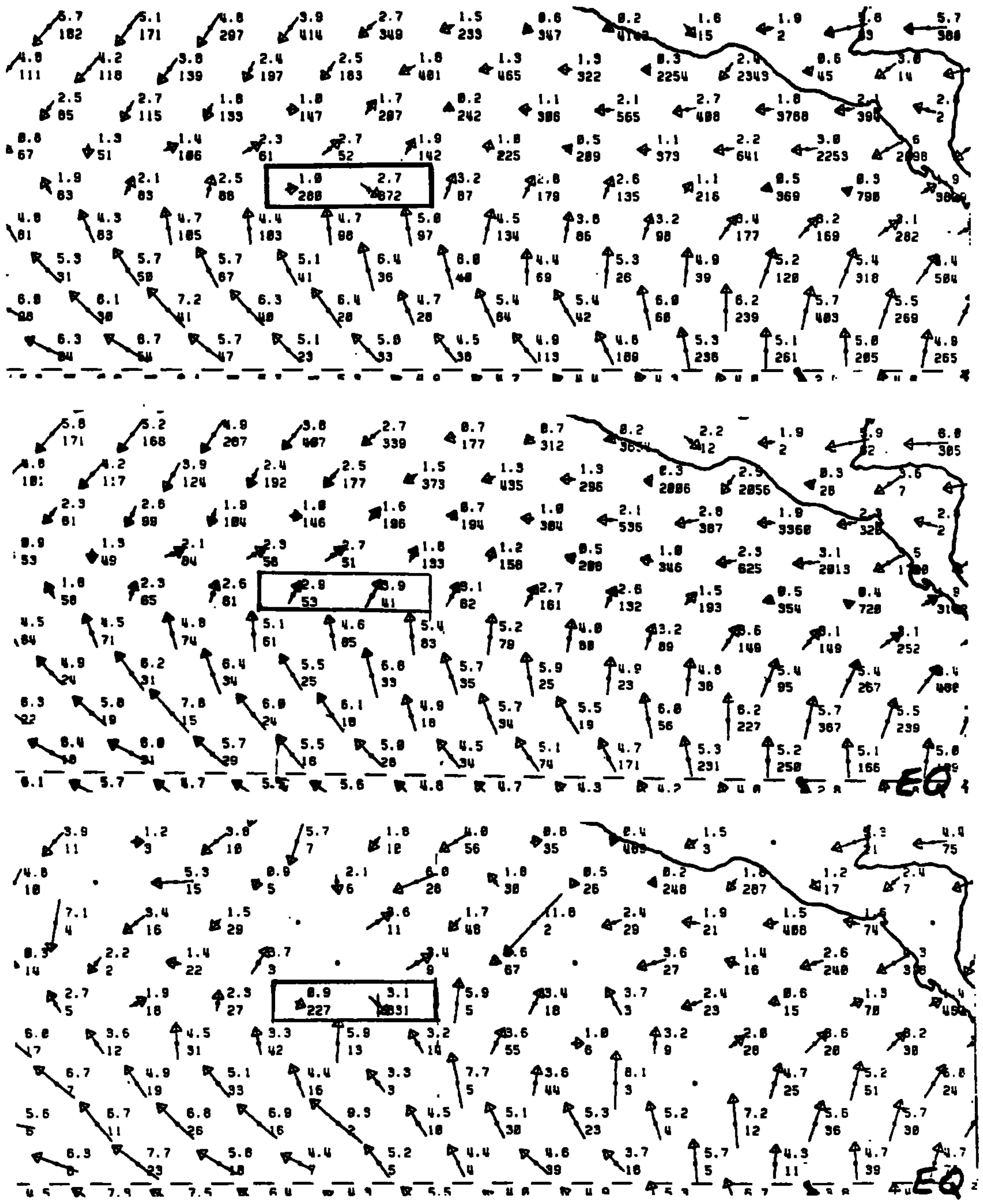

Figure 1. COADS data plots in the eastern tropical Pacific for the periods: Top--July 1900-1979; Center--July 1940-1979; Bottom--July 1900-1939. Data of interest are boxed.

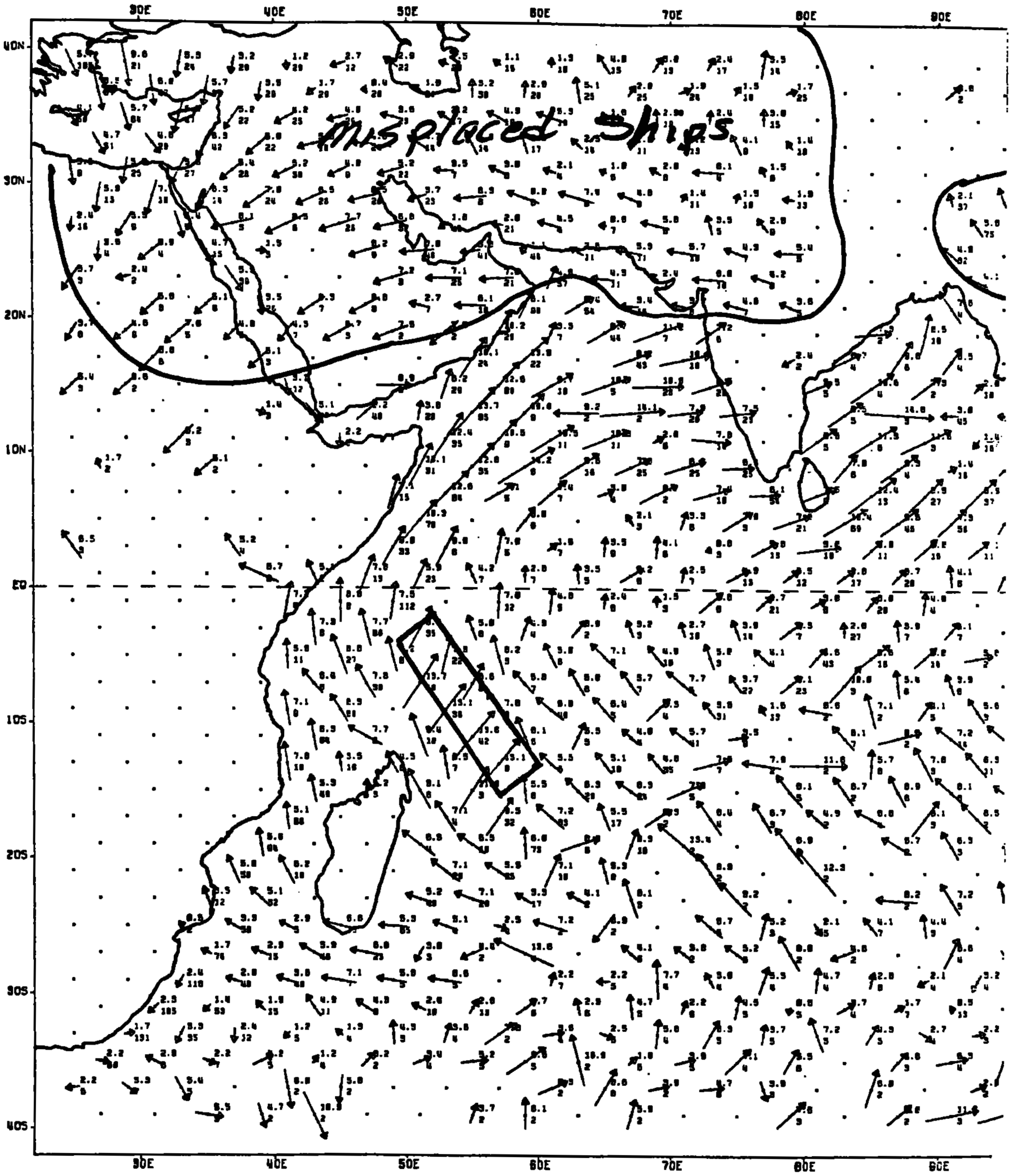

Figure 2. COADS data plot over the Indian Ocean and south Asia for the period June 1975. Data of interest are boxed and encircled.

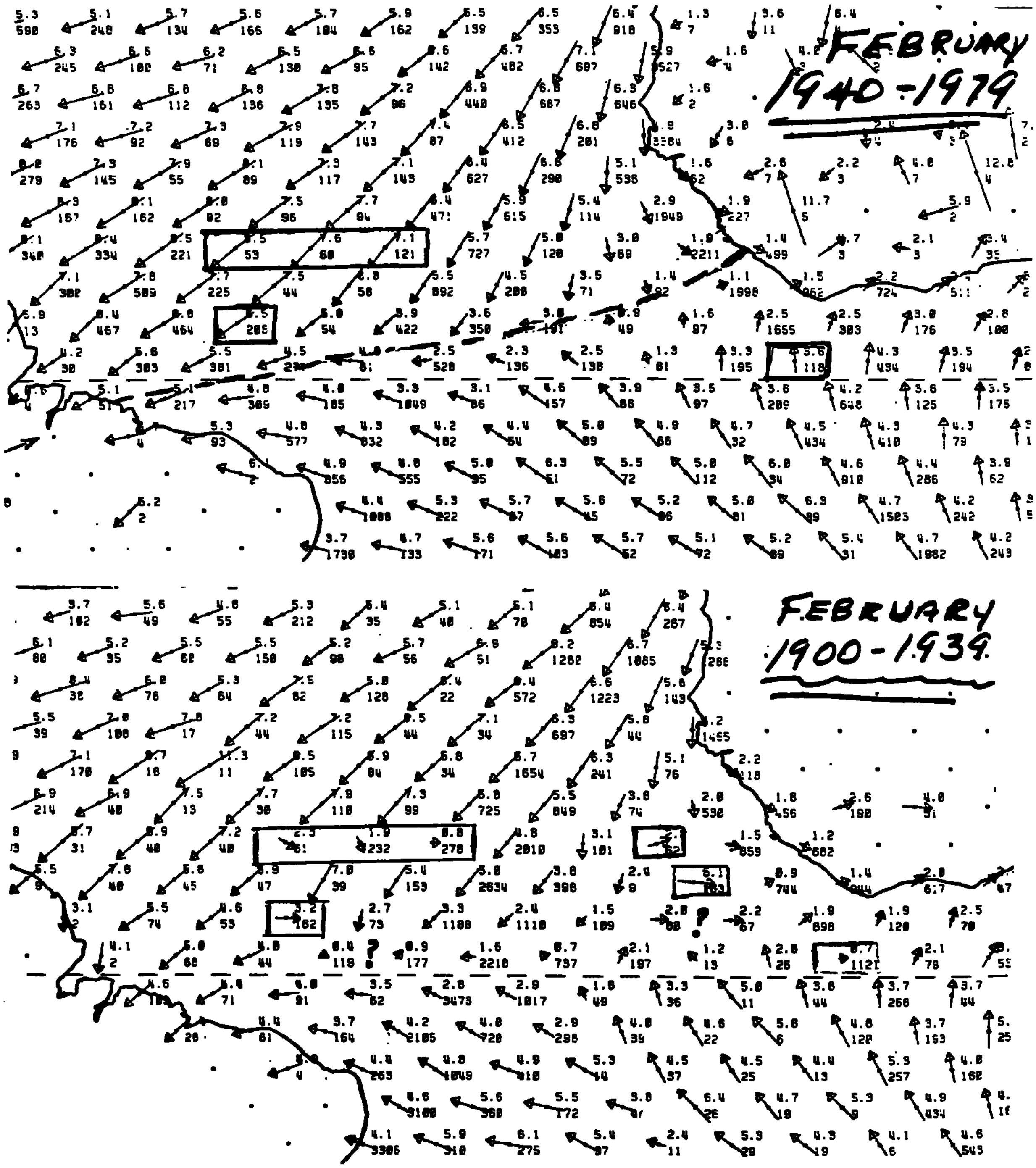

Figure 3a. COADS data plots over the tropical Atlantic for the periods: Top--February 1940-1979; Bottom--February 1900-1939. Data of interest are boxed and question marked.

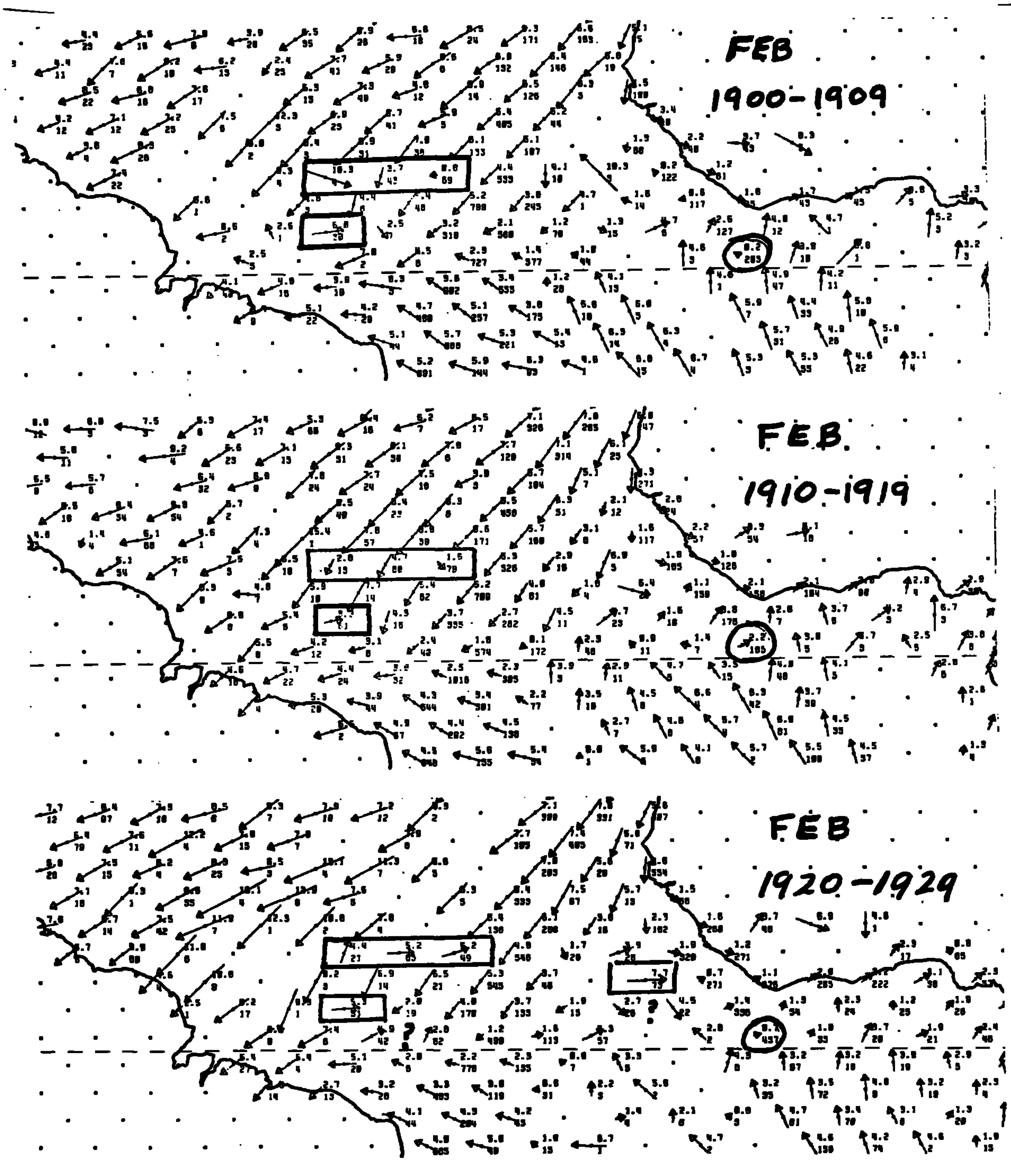

Figure 3b. As in Fig. 3a except for the February periods: Top--1900-1910; Middle--1910-1919; Bottom--1920-1929.

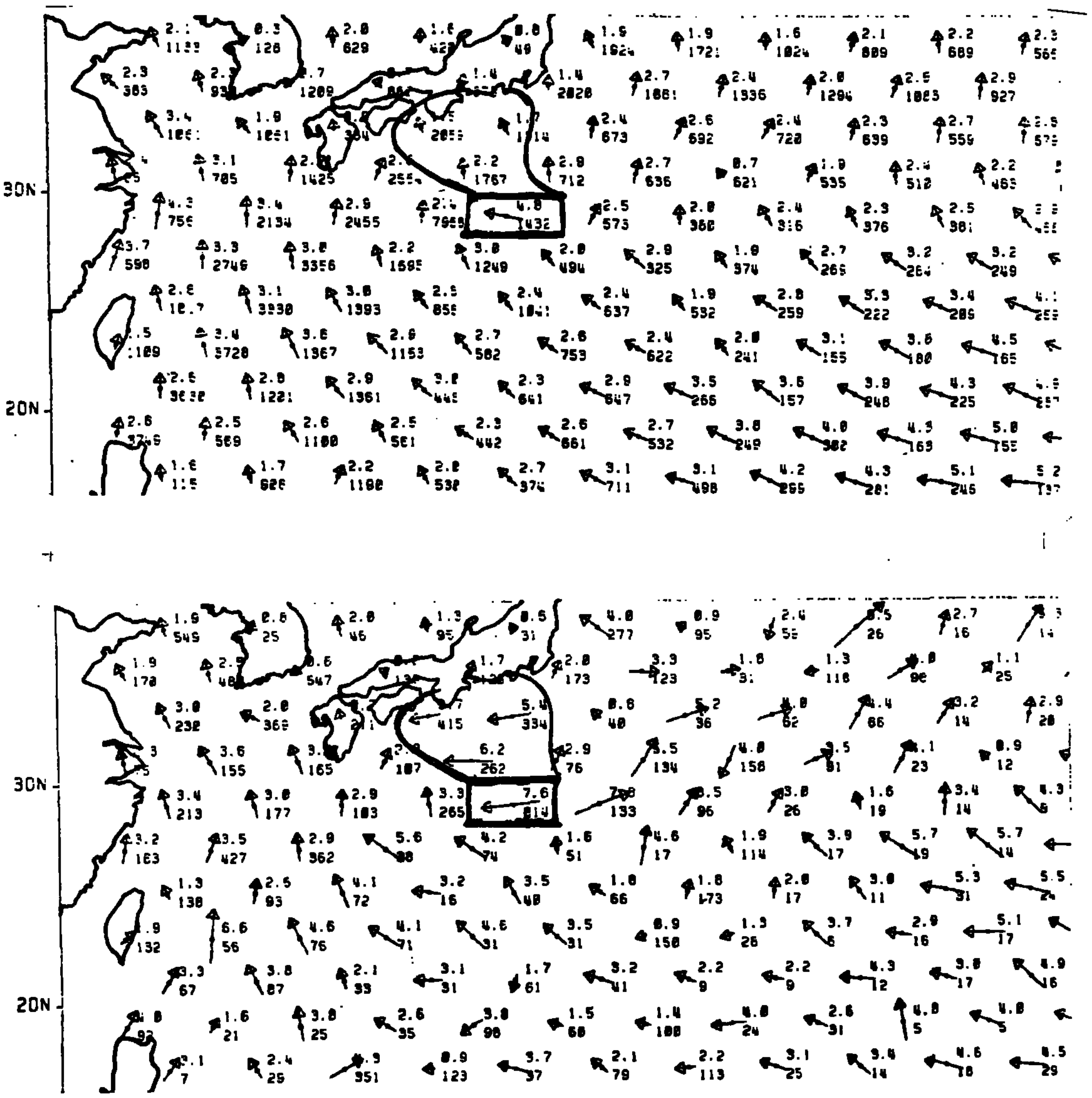

Figure 4. COADS data plots near Japan for the periods: Top--July 1940-1979; Bottom--1940-1949. Data of interest are boxed and encircled.

A DATA GRIDDED SET FOR THE GLOBAL OCEANS, 1854-1979

By

P.B. Wright
and
P.D. Jones

1. INTRODUCTION

Fletcher et al. (1983) have described their compilation of a Comprehensive Ocean-Atmosphere Data Set (COADS). This set will be very valuable for many global and regional studies of atmospheric and ocean surface patterns and their changes. The data comprise monthly mean values of various meteorological fields in 2° latitude by 2° longitude boxes.

The choice of 2° x 2° boxes, rather than larger boxes as used in some earlier ship data compilations, is wise because the data vary in spatial distribution from month to month; if larger boxes were used, a monthly mean would be strongly related to the chance distribution of observations within the box in that month and comparisons between months would not provide reliable estimates of climatic variation, especially in regions where strong gradients occur.

However, use of 2° x 2° data has some limitations for global scale studies. First, the quantity of data is extremely large. Second, in many regions the number of observations in each box is often small or nil, resulting in numerous gaps and in high noise levels due to observational error. Third, the resolution is finer than necessary for most studies, as interest usually focuses on features that span at least some 5° latitude and 20° longitude. Therefore, most users will need to average the data over several 2° x 2° boxes.

If one averages over the squares that are available, the original problem arises again: if some of the squares are missing in some months but not others, biases will arise because the long-term mean is different in different squares.

These limitations can be overcome by averaging not actual values but anomalies. This is because gradients of anomalies are generally much smaller than gradients of actual values and and are more random in incidence. Thus for example, an SST anomaly at 60°N, 40°W is likely to be an acceptable substitute for an anomaly at 55°N, 30°W, whereas the same would not be true for the actual SST itself. Many studies in any case require anomalies rather than actual values. After anomalies have been constructed, actual fields can be reconstituted if desired by adding the appropriate mean field.

We have constructed sets of monthly anomalies for 4° latitude by 10°

longitude boxes, and/or at 5^{o} latitude-longitude gridpoints, for a number of the fields in COADS, for the period 1854-1979. Early stages of the work were undertaken using the untrimmed (partly quality-controlled) COADS and some results using these data have been presented by Wright et al. (1985). The results presented here were undertaken on the trimmed (fully quality-controlled) COADS at the Climatic Research Unit, University of East Anglia, Norwich.

2. METHOD OF ANALYSIS

We first describe the method of analysis of the data set for sea surface temperature (SST). We then describe how our treatment of the other fields differed from that of SST. We describe the procedure for Januaries; identical procedures were performed on the other 11 calendar months.

a) Method for SST and Air Temperatures

i) Generation of a mean field.

For each 2^{o} box, the monthly means for the 30 Januaries 1950 to 1979 were extracted. A value was rejected if the number of observations in each individual January was less than 3, or if the mean date of the observations in that month was 5 or less or 26 or more. The mean of the remaining values was then found. If the number of values used to form the mean was less than 9, the mean was rejected. Values for coastal squares (Appendix 1) were also rejected.

The resulting mean field was smoothed in the east-west direction and subjected to limited interpolation and extrapolation, resulting in a field of smoothed means in 2^{o} boxes for January (to be referred to as 'MEAN-2').

ii) Generation of anomalies.

For each individual January from 1854 to 1979, the following procedure was followed. First, , the monthly mean was extracted for each 2^{o} box, using the same rejection criteria as in i) above. The smoothed mean (from MEAN-2) was then subtracted, to produce a field of anomalies in 2^{o} boxes (ANOM-2).

North-south averaging was now performed on pairs of anomalies. Thus, for example, for each 2^{o} longitude sector the anomalies for 58-56^{o}N and 56-54^{o}N were averaged, the result being accepted if at least one value was present. East-west averaging was then performed on groups of 5 anomalies. Thus, for example, for the zone 58-54^{o}N the anomalies in sectors 30-28^{o}W, 28-26^{o}W, 26-24^{o}W, 24-22^{o}W and 22-20^{o}W were averaged, the result being accepted if at least one value was present. This resulted in a field of anomalies in 4° x 10° boxes (ANOM-4). The 4° x 10° boxes from 78°-74°N to 66°-70°S inclusive and in 10° longitude steps e.g. 0-10°E.

iii) Regeneration of actual values.

The averaging described in the second paragraph of ii) was applied to the field MEAN-2. This resulted in a field of means in 4° x 10° boxes (MEAN-4). The user may regenerate actual SSTs for individual months in 4° x 10° boxes by adding the fields ANOM-4 and MEAN-4.

b) Method for pressure.

i) The same procedures were followed as for SST and air temperatures except for the following differences:

  i) The minimum number of observations was 5.

  ii) Coastal squares were not rejected.

  iii) Smoothing was performed in the north-south direction as well as in the east-west direction.

ii) In addition to a set of data averaged over 4° x 10° boxes, a set of values at 5° grid points was produced. The grid point value was calculated as a weighted mean of all available values in the squares nearest to each grid point. The weights were the reciprocal of the distance between the grid point and the centre of each 2° Square. Some squares are equidistant between grid points. These squares were included for both grid points. 5° grid points extend from 75°N to 65°S inclusive.

3. DATA SETS CURRENTLY AVAILABLE

The following sets are currently available.

i) SST anomalies averaged over 4° x 10° boxes for each month 1854-1979 (SST-ANOM-4).

ii) SST means in 4° x 10° boxes for the period 1950-79 (SST-MEAN-4).

iii) Pressure anomalies interpolated to 5° grid points for each month 1854-1979 (PRE-ANOM-5).

iv) Pressure means interpolated to 5° grid points for the period 1950-79 (PRE-MEAN-5).

v) Air temperature anomalies interpolated to 5° grid points for each month 1854-1979 (AIR-ANOM-5).

vi) Air temperature means interpolated to 5^{o} grid points for the period 1950-79 (AIR-MEAN-5).

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Wright, P.B., T.P. Mitchell and J.M. Wallace, 1985: Relationships between surface observations over the global oceans and the Southern Oscillation. NOAA Data Report, ERL-PMEL-12, 61p, obtainable from JISAO, University of Washington, Seattle 98195, USA.

Appendix 1. Coastal Squares

For some variables, especially SST, there are marked gradients close to many coasts. It was believed that most users undertaking global studies would be interested in values representative of the open ocean rather than of areas close to the coasts. Even if this is not the case, the process of averaging over $4^{o} \times 10^{o}$ boxes would blur the distinction with the risk that the resulting data would not be representative of either. It was also thought desirable to avoid averaging data across isthmuses. Therefore we decided to omit squares that were close to continental coasts. The relevant squares were chosen subjectively to be those containing at least 20% land. We chose not to omit any squares in the following regions: Indonesia and the Carribean. In the following regions we omitted squares identified as ′coastal′ by the COADS authors (Slutz et al., 1985) these having some 80-99% land: Inland seas, Persian Gulf, N of 70^{o}N and S of 60^{o}S.

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PROBLEMS IN USING THE COADS DATA FOR INVESTIGATING SECULAR CLIMATE CHANGE

By

P.D. Jones

1. INTRODUCTION

Long-term changes in global air temperatures are the subject of increasing interest and concern. Such changes are considered to be one of the basic indicators of the state of the climate system. Past variations in global air temperature may indicate the relative importance of the various forcing factors that are thought to affect climate, e.g. CO_2, volcanoes and solar irradiance change.

Early estimates of global mean temperature have relied solely on data from land-based meteorological stations (Wigley et al., 1985). The inclusion of data from marine areas, which represent 70% of the area of the globe, ought to improve the representativeness of area average series. Recently compilations of all marine observations from the so-called ´ships of opportunity´ have been compiled by the United Kingdom Meteorological Office (Folland et al., 1984) and the COADS group (Slutz et al., 1985). Although sources differ particularly after 1960, the U.K. dataset is thought to be a subset of COADS containing roughly two-thirds of the total number of observations. Both datasets offer the opportunity to improve our estimates of global mean temperature. Incorporation of either sea surface temperatures (SST) or marine air temperatures (MAT) with land based temperature estimates is not a simple task because both sets of marine observations are subject to a number of non-climatic factors.

Pre-World War II SST measurements were collected from uninsulated buckets, while more recent measurements come from cooling water intake measurements. These latter readings are considered to be between 0.3-0.7°C warmer than the earlier uninsulated bucket readings (James and Fox, 1972). Increases in ship speeds and size are both thought to have affected air temperatures measured by ships. Many observations in the last century were not taken in the conventional screened locations.

Folland et al. (1984) overcame these problems by making a number of *a posteriori* corrections based on ship sizes for MAT and the bucket/intake difference for SST. Correcting the raw data after the fact is necessary because information on how the measurements were taken was either not recorded or has been lost. The agreement between both Folland et al.´s (1984) marine hemispheric estimates and the hemispheric land-based data of Jones et al. (1986a,b) is reasonable during the present century. During the last century the land and marine series diverge, the marine series (SST and MAT) being between 0.2 and 0.3°C warmer than land estimates.

2. CORRECTIONS TO COADS

Another means of correcting the marine series is to compare estimates for regions where the land and marine data both contain air temperature measurements. For the marine series we use the gridded version of the uncorrected COADS SST and MAT data described by Wright and Jones (this Volume). Fifteen regions were chosen and area averages of MAT and land air temperatures were produced for each region. Also the hemispheric estimates of MAT were compared with land based temperatures from coastal areas. The seventeen (15 regions + 2 hemispheres) difference (land-MAT) series were examined for consistent differences. All areas and both hemispheres exhibit similar differences. The two hemisphere plots are shown in Figure 1.

Some distinct periods can be easily seen, where departures are common to all regions. The periods are 1861-1889, when MAT data appear to be too warm by 0.4-0.5°C; 1903-1941 when MAT is too cold by 0.1-0.2°C. In the recent period 1946-1979 there appears to be no bias. The periods between these are transitional; 1889-1903 exhibiting an upward trend in land-minus-MAT and the war years, 1942-1945 when MAT values are anomalously high. The consistency in these differences between the hemispheres and the regions is remarkable, although the regions show greater year-to-year variability as would be expected.

The consistency of these differences enables correction factors to be made to the MAT series. Having corrected the MAT series it is relatively easy to estimate the SST corrections required to ensure compatibility between MAT and SST. For large regions, Cayan (1980) has shown that trends in MAT and SST must be in agreement. Figure 2 shows the difference between hemispheric MAT estimates (with corrections derived from Figure 1) and hemispheric SST estimates. Figure 3 shows the differences between hemispheric estimates from coastal land areas and SST data. From these figures, corrections for the SST can be inferred. Since all the difference curves are similar between hemispheres, it must be assumed that they reflect non-climatic factors.

The corrections differ markedly from Folland et al. (1984), particularly during the last century. Such a result is not surprising considering the method used to correct the marine series. It is now a relatively easy task to produce global estimates of mean air temperature. Estimates using our 'corrected' COADS series and land data are given in Jones (1986c), together with further details of the method and the exact corrections applied.

3. ACKNOWLEDGEMENTS

This work was funded by the Carbon Dioxide Research Division, U.S. Dept. of Energy, under Grant No. DE-FG02-86-ER60397.

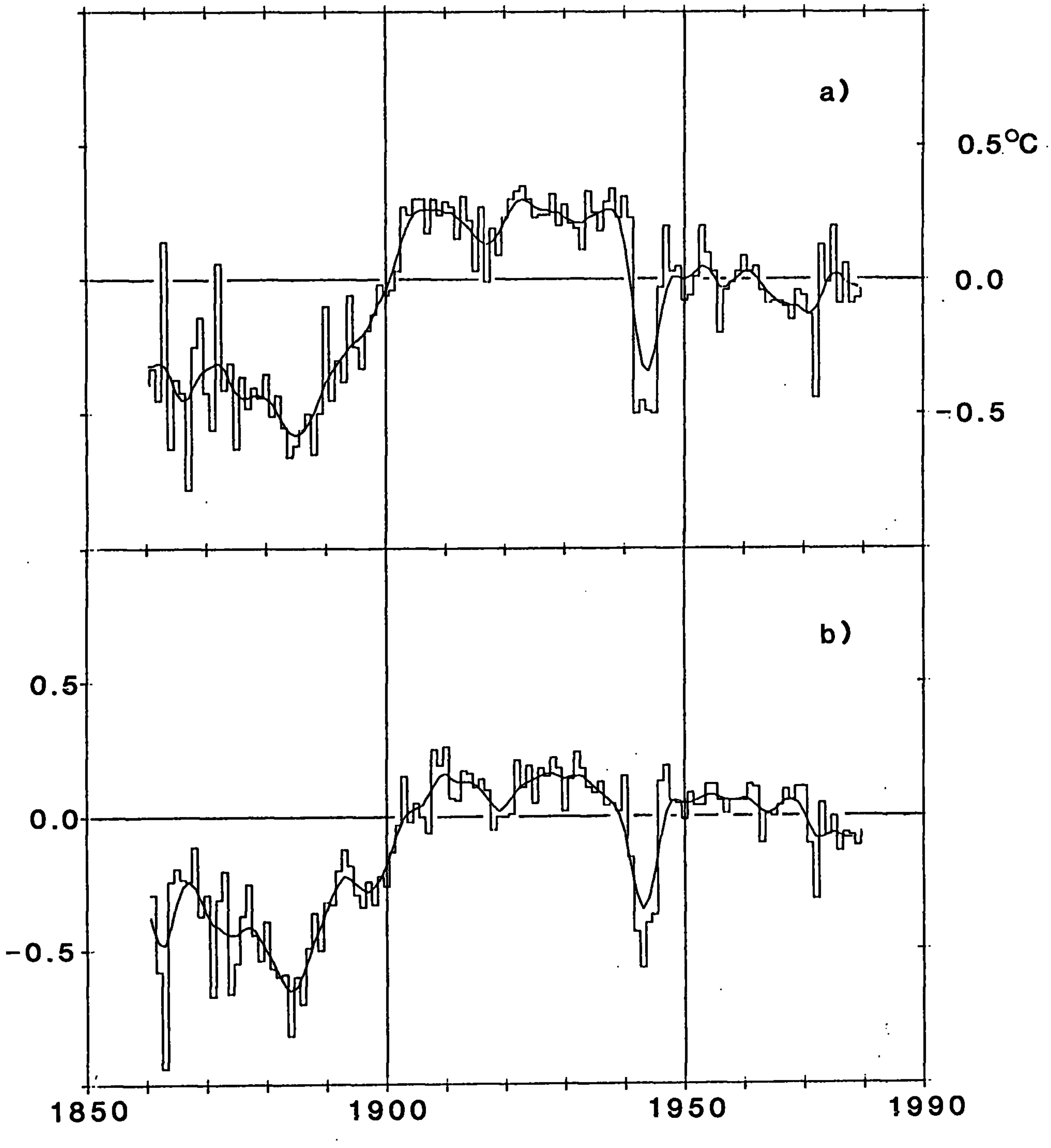

Figure 1: Time series plots of the difference between hemispheric estimates based on coastal land data and estimates based on uncorrected MAT data, 1861-1979. The smooth curve is a 10-year Gaussian filter. a) Northern Hemisphere, b) Southern Hemisphere.

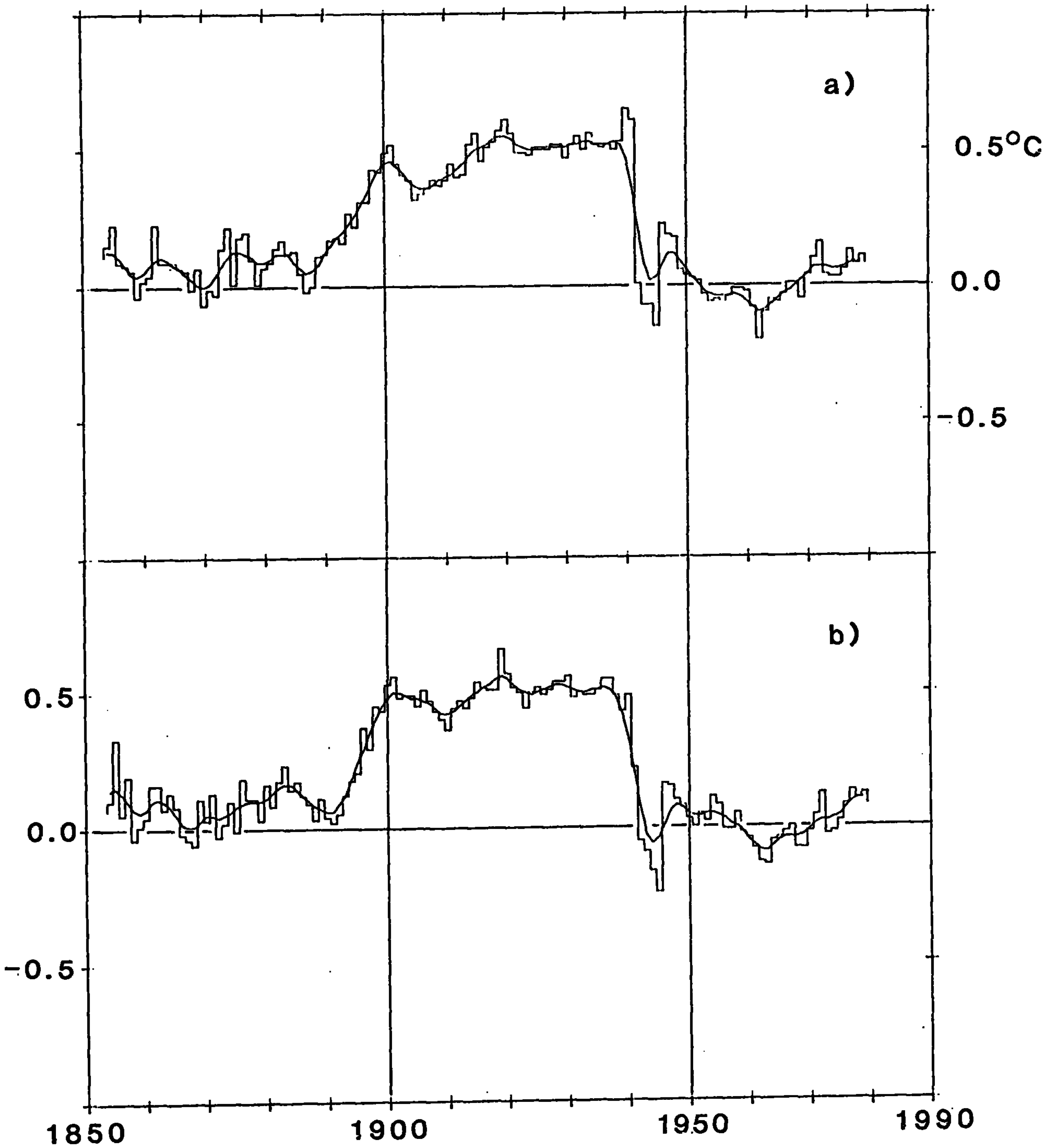

Figure 2: Time series plots of the difference between hemispheric estimates based on the corrected MAT (with the corrections inferred from Figure 1) and estimates based on uncorrected SST data, 1854-1979. The smooth curve is a 10-year Gaussian filter. a) Northern Hemisphere, b) Southern Hemisphere.

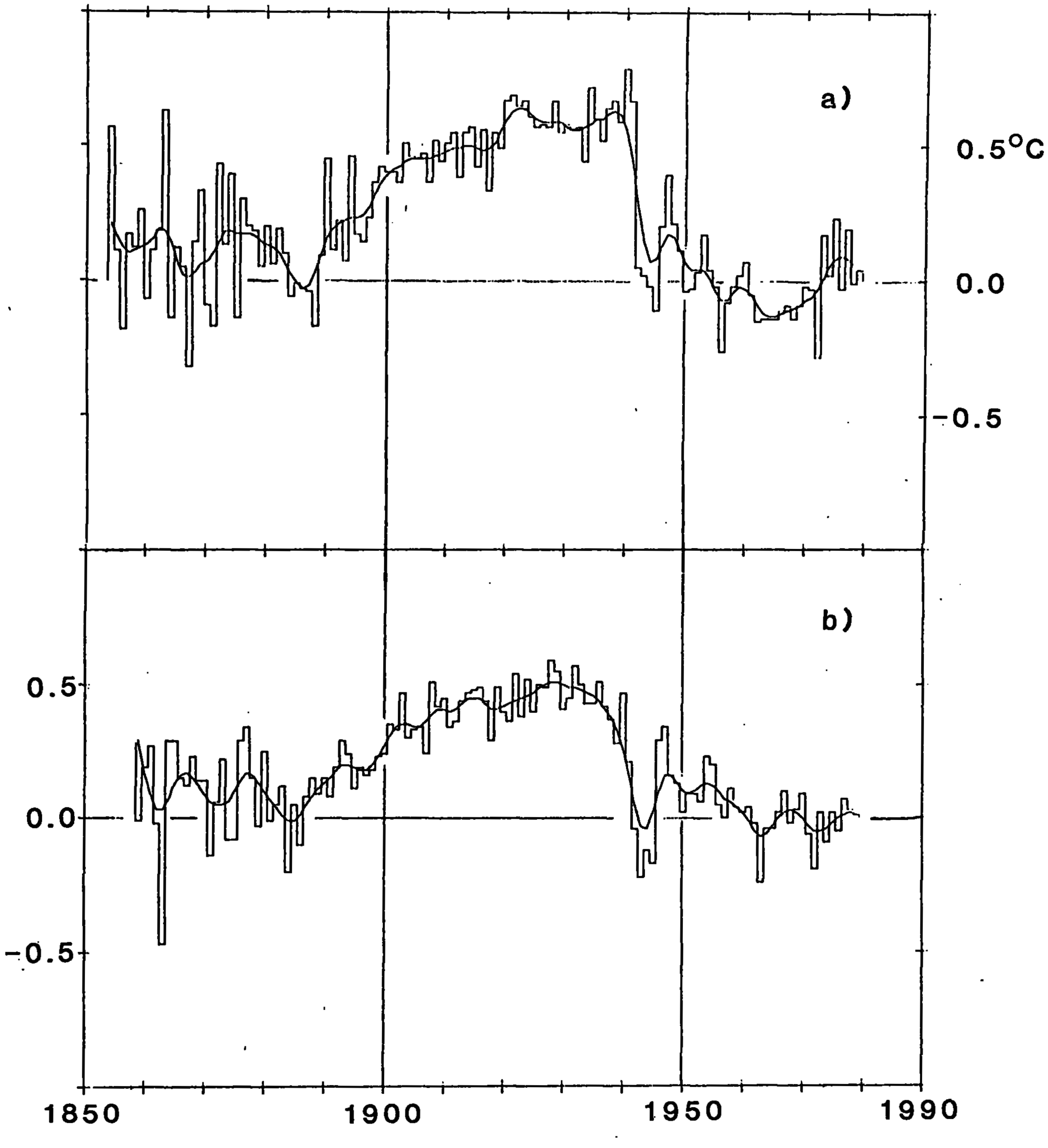

Figure 3: Time series plots of the difference between hemispheric estimates based on coastal land data and estimates based on uncorrected SST data, 1861-1979. The smooth curve is a 10-year Gaussian filter. a) Northern Hemisphere, b) Southern Hemisphere.

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A Comparative Analysis of Marine Weather Records from Ocean Weather Stations and Merchant-Ships

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For the first time marine data are being used in an attempt to detect evidence of secular variation in climate and now, problems that have been relatively unimportant in atlas production, must be tackled. They include non-uniform calibration and changing methods of observation, affecting winds and sea surface temperature, changing heights at which measurements are made and a secular change in the effects of day time ship heating, affecting temperature and moisture measurements.

Although many of these changes occurred prior to and during WWII, one step in deciding how reliable merchant-ship measurements are involves comparing them to ocean station vessel measurements made between 1948 and 1982. OSV's C, M, N and P (Figure 1) have been selected for a start and correlations made between individual monthly averages of meteorological elements measured at each OSV and by merchant-ships in a 2° x 2° box centered on the OSV position. Assuming that OSV's are correct then we would expect the merchant ship data to parallel the OSV data during those years when both operated.

The right-hand column of Table 1 summarizes OSV/merchant-ship correlations for the OSV P area (N=30). These are typical of areas C, M, and N. Air temperature, sea surface temperature and air pressure are well correlated and air-sea temperature differences, dew point depression,wind speed, and cloudiness are poorly correlated. All of the latter are used in bulk aerodynamic calculations of air-sea heat exchange.

All the observations were partitioned into and averaged separately for day and night. Then for January and July, the occasions when year-to-year changes were of opposite sign for the day and night averages were tallied for both merchant-ships and OSV "P" (first two columns of Table 1). Only rarely were the year-to-year opposite changes the same for both merchant-ships and P (column 3) suggesting that when they occurred the data were incapable of detecting interannual change. The correlation between columns 3 and 4 emphasizes the relationship. Even OSV "P" has problems with DP depression, wind speed and cloudiness. Two examples are shown in Figures 2 and 3. In Figure 2, SST for July, the correlation is high and almost all the major features of "P" are reproduced by the merchant-ships. In Figure 3, wind speed for January, one can have little confidence in the merchant-ship data and even some doubts about the OSV data

Finally, the impacts of number of observations and distribution within the month on merchant-ship/OSV correlations were tested (Table 2). Except for the underlined data the results were expected with correlations greatest when merchant-ship observations were most and when they were centered at mid-month. Not surprisingly, wind speed correlations were most sensitive to numbers of observations and to their locations within the month.

CONCLUSIONS

(i) Air temperature, sea temperature and air pressure are the COADS elements most likely to reveal secular changes.

(ii) Air-sea temperature difference, dew-point depression, wind and cloudiness are the COADS elements least likely to reveal secular changes. This goes too for the derived quantity--air-sea heat exchange.

TABLE 1

SHIP P (50^0 N, 140^0 W) AND NEIGHBORING MERCHANT SHIPS

Percent of years in which the year-to-year change in nighttime averages was opposite in sign to the change in daytime averages. January, July combined.

Element	Merchant ships	Ship P	% of opposite changes not duplicated in either set	Avg. r (Ja+Jy)/2
Air temperature	13	0	13	.81
Sea temperature	10	5	15	.85
Air T minus Sea T	17	8	25	.48
Dew point depression	18	10	25	.47
Pressure	8	0	8	.84
Wind speed	22	13	40	.31
Cloudiness	18	18	30	.31
Average	15	8		

r = -0.94

TABLE 2

Correlations between monthly means of merchant ship and ocean station vessel data. The merchant ship data were stratified according to number of observations (A) and period within the month (B).

	Area C			Area M			Area N			Area P		
	<10	11-20	>21	<10	11-20	>21	<10	11-20	>21	<10	11-20	>21
A. Air temperature	.89	.96	.98	.88	.98	.98	.89	.97	.93	.97	.98	.98
Sea temperature	.83	.97	.98	.90	.98	1.00	.95	.96	.83	.98	.99	.99
Wind speed	.44	.73	.90	.32	.84	.93	.11	.69	.80	.64	.72	.67
B. Air temperature	.90	.92	.90	.88	.93	.91	.90	.89	.88	.94	.95	.92
Sea temperature	.91	.94	.90	.96	.97	.97	.82	.83	.80	.97	.98	.96
Wind speed	.53	.62	.60	.60	.68	.66	.53	.56	.50	.51	.53	.54

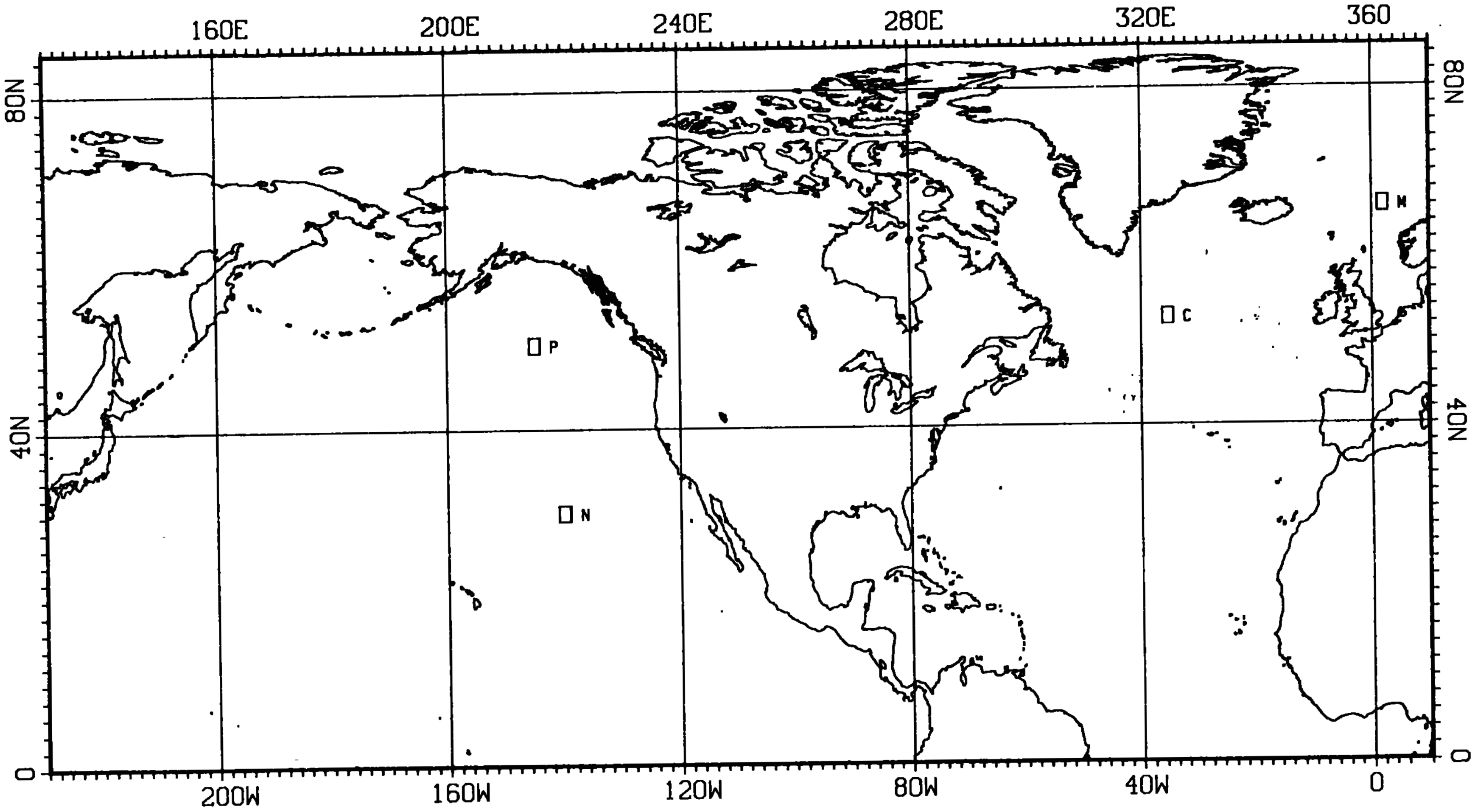

Fig. 1. 2^{o} latitude x 2^{o} longitude study areas centered on Ocean Weather Stations C, M, N, and P.

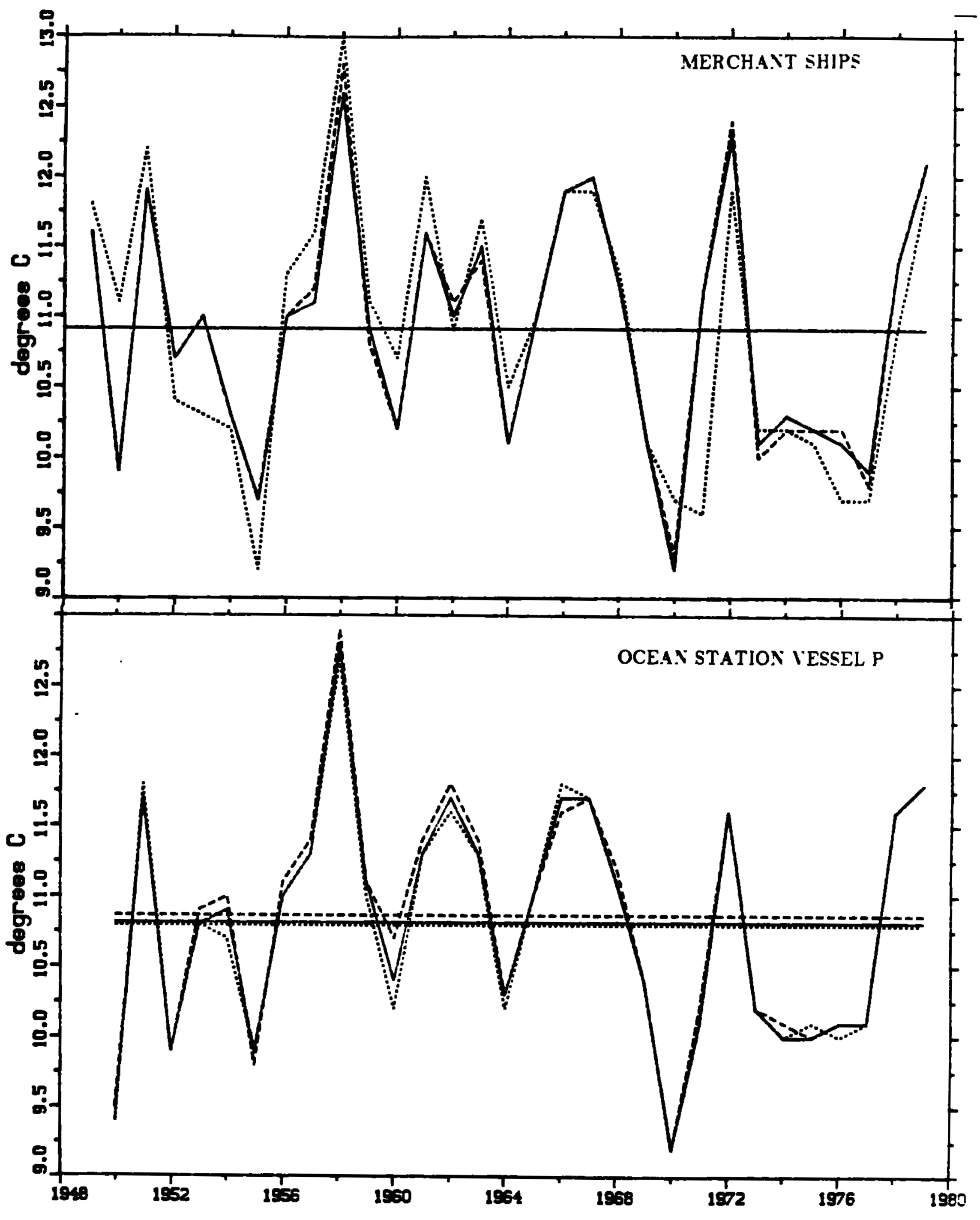

Fig. 2 July sea surface temp. data from Study Area P.
Day hours 18,21,0 GMT dashed. Night hours 6,9,12 GMT dotted, All hours solid. Correlations between merchant-ships and OSV: 0.91 (day), 0.84 (night), 0.90 (all hours).

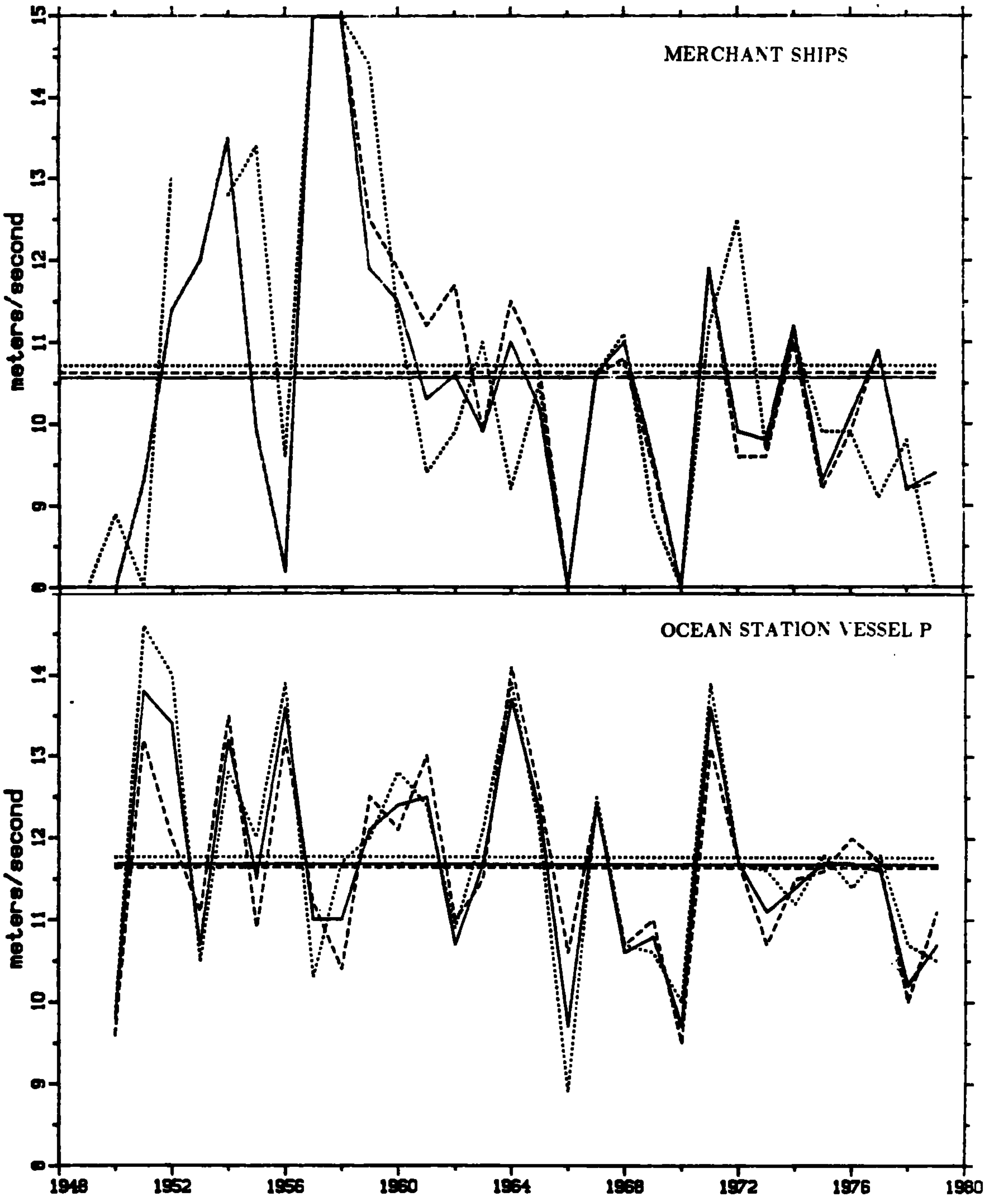

Fig. 3. January wind speed data from Study Area P.
Day hours 18,21,0 GMT dashed, Night hours 6,9,12 GMT dotted, All hours solid.
Correlations between merchant-ships and OSV: 0.16 (day), 0.02 (night), 0.14 (all hours).

How reliable is the COADS sea level pressure data set?

by

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1. INTRODUCTION

Wright and Jones (1986, this volume) have produced from the trimmed COADS 2° x 2° data a gridded version of the sea-level pressure field extending from 75°N to 65°S for each month where possible from 1854-1979. The usefulness of this data set for augumenting the well known gridded pressure data sets will depend mainly on its reliability when compared with station measured data. Because of the nature of the COADS data, each grid point being an average of temporally irregular sampling, the data for certain areas of the world are likely to be more reliable than for other areas. If a data series has high autocorrelation, less observations are generally required to estimate a reliable mean provided the few observations are statistically independent (Parker 1984). For the sea level pressure field this result probably means that the most reliable COADS data will be from areas near the semi-permanent subtropical highs and areas in the tropics.

2. ASSESSMENT AND RESULTS

The Northern Hemisphere north of 20° is likely to be the area where the COADS pressure data will prove least useful because of the high quality of the already available gridded data from operational analyses. Probably the most useful area for the COADS pressure data is the tropics and the Southern Hemisphere. Operational Southern Hemisphere gridded analyses are only available since 1972.

In order to assess the COADS pressure data reliability, 10 mostly island stations have been selected. It might appear that the best means of assessing the COADS gridded pressure data set is to compare it with the well known gridded Northern Hemisphere sea level pressure data. However, this latter source may have used much of the same raw ship's observations and may therefore not be wholly independent. In any comparison it is preferable to use independent station data. The records from these ten stations were compared with the nearest (see Table 1 caption) COADS grid point over the period 1950-79. The locations of the 10 stations and the grid points are given in Table 1. In Figure 1 the annual mean station sea-level pressure minus annual COADS sea-level pressure has been plotted, where available, for

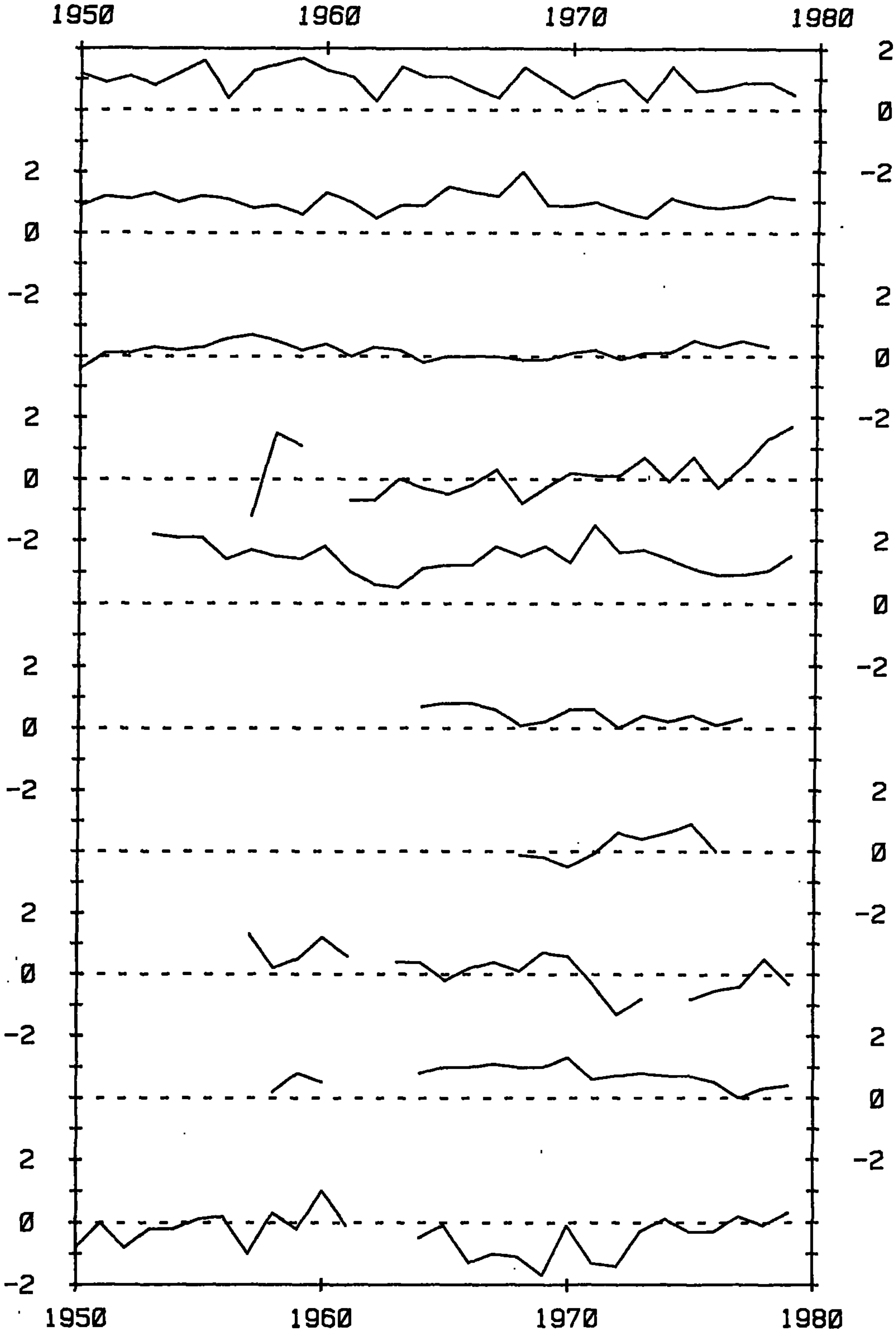

Figure 1: Time series plots of the annual mean sea level pressure difference between station and COADS gridded data at the 10 selected sites. Sites are (from top to bottom), Ponta Delgada (Azores), Bermuda, Honolulu, Juneau, Shanghai, Tahiti, St Helena, Wellington, Mauritius and Buenos Aires. Many of the missing observations in the plots are due to the strict requirement for all 12 month observations to be present. If annual means could be computed from the COADS data with only 9 monthly observations during the year, most of the missing observations would be filled. Note that for Honolulu, station level pressure was used. The correction to sea level would raise the plot by 0.5 mb.

Table 1 The 10 stations and their nearest* grid points

	Station Name	Latitude	Longitude	Latitude	Longitude
1	Ponta Delgada	37.8°N	25.7°W	40°N	25°W
2	Bermuda	32.4°N	64.7°W	35°N	65°W
3	Honolulu	21.3°N	158.0°W	20°N	160°W
4	Juneau	58.4°N	134.6°W	55°N	135°W
5	Shanghai	31.2°N	121.4°E	30°N	120°E
6	Tahiti	17.6°S	149.6°W	15°S	150°W
7	St Helena	16.0°S	5.7°W	15°S	5°W
8	Wellington	41.3°S	174.8°E	40°S	175°E
9	Mauritius	20.1°S	57.6°E	20°S	60°E
10	Buenos Aires	34.6°S	58.5°W	35°S	55°W

* For Juneau, Tahiti and Buenos Aires the nearest grid point had very little data and the next nearest was used.

Table 2

	Station Name	Grid Point	Annual Pressure Difference (mb) (1950-1979) (Station-GP)	Annual Correlation (1950-1979)
1	Ponta Delgada	40°N 25°W	1.0	0.959
2	Bermuda	35°N 65°W	1.0	0.925
3	Honolulu	20°N 160°W	0.6*	0.932
4	Juneau	55°N 135°W	0.2	0.694
5	Shanghai	30°N 120°E	1.4	0.389
6	Tahiti	15°S 150°W	0.4	0.896
7	St Helena	15°S 5°W	0.2	0.226
8	Wellington	40°S 175°W	0.2	0.901
9	Mauritius	20°S 60°E	0.7	0.637
10	Buenos Aires	35°S 55°W	-0.4	0.509

* Station level pressure corrected to sea level by addition of 0.5 mb.

each of the 30 years. For most sites the COADS pressure data is between 0 and 2 mb too low.

In Figure 2 the monthly correlations between the station sea-level data and the COADS pressure data, calculated over available years from 1950-1979, are plotted for each of the 10 sites. The results are generally good, excellent for the Azores station but extremely poor for St. Helena. Overall there is little or no seasonal bias in the results. In order to look at any possible seasonal biases in more detail, Figure 3 shows the long term mean (1950-79) data. Pressure differences appear greater in the winter season, although only for Shanghai is this important. For annual data over the period 1950-79, the correlations and differences between the station sea-level data are listed for the 10 sites in Table 2.

3. CONCLUSIONS

Although this study has only considered 10 areas, the results in some regions, particularly those near major shipping routes of the Southern Hemisphere appear useful. Any reliable information for Southern Hemisphere ocean areas between 1950 and 1972 is a valuable addition, provided the magnitude of any instrumental bias to slightly too low pressure values can be ascertained. Further studies are necessary, particularly of the pre-1950 data. For these 5 Southern Hemisphere sites pre 1950 COADS pressure data is available for parts of the South Atlantic, near to South America and for the Australia/New Zealand region. However, care should also be taken to assess the quality of this early data. For the Azores, Bahamas and Shanghai sites, data pre 1950 is of markedly lower quality than for the post 1950 era. For the Azores the annual corelation over the period 1922-38 is only 0.70 (cf 0.96 over 1950-79).

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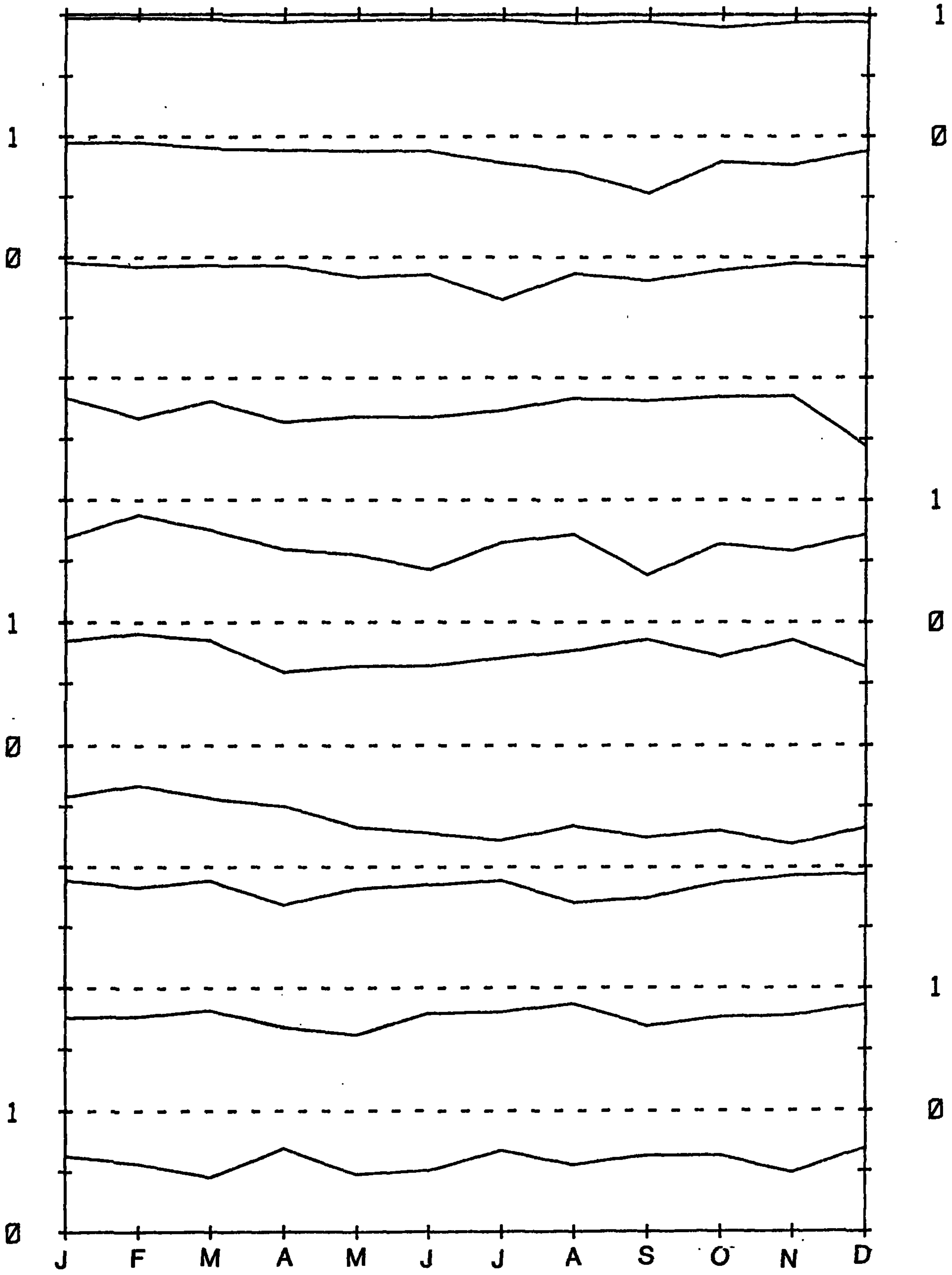

Figure 2: Monthly correlations between station pressure values and COADS grid point values calculated over the period 1950-79. Site order is the same as in Figure 1 and both Tables.

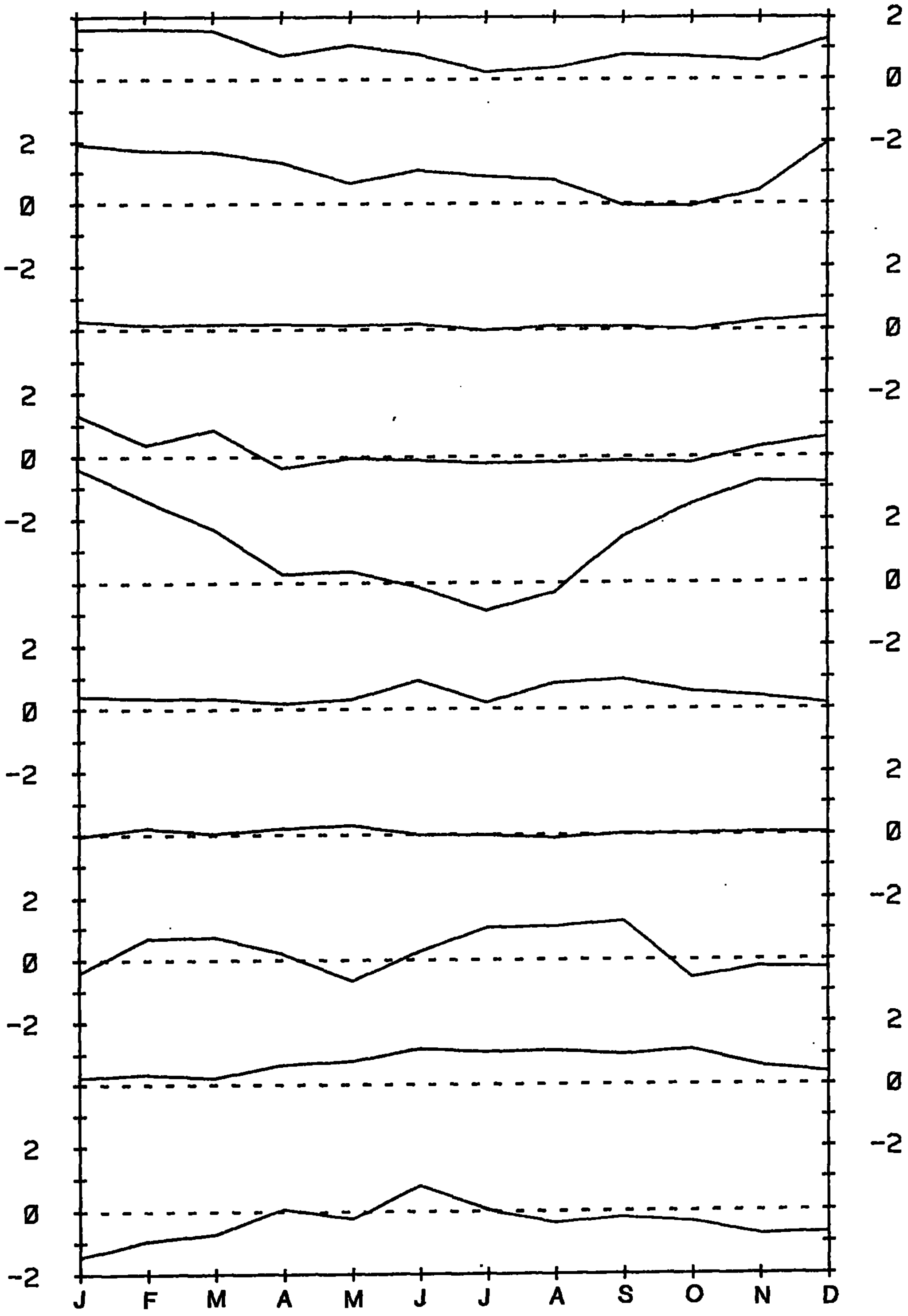

Figure 3: Monthly differences between station pressure means and COADS grid point pressure means calculated over the period 1950-79. Site order is the same as in Figure 1 and both Tables. For Honolulu the plot should be raised by 0.5 mb to correct for sea level.

Data Comparison of Pressure Fields from COADS and Fleet Numerical Weather Central

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As a check on the pressure anomalies derived from the COADS data, a correlation calculation for an upcoming paper was repeated with data from Fleet Numerical Weather Central (FNWC). The FNWC data consist of daily, objectively analyzed pressure fields that have been averaged in time to form monthly means. The comparison of calculations performed with datasets analyzed with two entirely different analysis procedures provides a good test of the COADS pressure data. The correlation coefficients derived from the two datasets show a good agreement over the Northern Hemisphere for the period 1950-1979.

The COADS data for this calculation are the monthly mean sea-level pressure and number of observations for each 2 degree by 2 degree latitude-longitude region of the global oceans from the "untrimmed" version of the data. 2 degree by 2 degree monthly anomalies were calculated for the period 1950-1979 from a smoothed and interpolated monthly climatology (Wright et al. (1985)), and spatially averaged, weighted by the number of observations, into anomalies for 4 degree by 10 degree latitude-longitude regions. A minimum of 6 observations in a month were required to calculate a pressure anomaly for each 4 by 10 region. Note that under this scheme the observations could be evenly distributed throughout the month or all occur on one day. There is mean day-of-month information available in the COADS dataset, but we did not use it. The monthly anomalies were then averaged in time to form 4 by 10 seasonal pressure anomalies for the standard meteorological seasons.

The pressure data from FNWC consist of daily, objectively analyzed sea-level pressure for the Northern Hemisphere (0-90 degrees N) for the period 1950-1979 (Jenne (1975)). The daily data on a 63 by 63 grid have been averaged in time to form monthly averages and then interpolated onto a 2.5 by 5 degree latitude-longitude resolution grid. In contrast to the COADS data, the monthly means derived from the FNWC data are the average of thirty daily values. Also the daily pressure field has been constrained to be dynamically consistent with the temperature and wind fields. A climatology was then calculated for the years 1950-1979, and monthly anomalies produced from it. The monthly anomalies were averaged in time to form 2.5 by 5 degree seasonal anomalies.

The seasonal pressure anomaly fields were correlated with the twelve-month average sea-level pressure anomaly at Darwin, Australia (12 degrees S, 131 degrees E), with the twelve months taken from April of one year to March of the next. Darwin is within the region of large year to year variability associated with the Southern Oscillation, and the choice of the twelve months from April to March maximizes the year to year variability of the index. Figure 1 is a map of correlation coefficients (*10) between December-January-February pressure anomalies derived from the COADS data and the simultaneous value of the Darwin index. Ten out of the thirty years were required to contribute to calculate a correlation coefficient. 4 by 10 degree regions with fewer than ten years of anomalies are presented as blanks, and correlations weaker than 0.25 have only their sign plotted (+ or -). In this season, the SLP correlations show a two-lobe pattern over the western equatorial and subtropical Pacific corresponding to above normal pressure during an ENSO event. The correlations over the subtropical Pacific are as high as 0.8. The eastern Pacific has weaker negative correlations corresponding to below normal pressure during an ENSO event. This pattern is strongest over the climatological south Pacific high and also on the equator on the extreme eastern Pacific. Figure 2 shows contours of the correlations derived from the FNWC data overlaid on the values derived from the COADS data. The agreement between the two sets of statistics is very strong over the Pacific in both magnitude and shape. The agreement is not as good over the Indian Ocean where the correlations are of the same sign, but the FNWC derived correlations are a factor of two weaker. In other seasons (not shown), the correlation statistics are in good agreement over both the Pacific and Indian Oceans. This positive comparison with results from a dataset analyzed with a totally different analysis scheme yields confidence in the usefulness of pressure anomalies derived from the COADS data.

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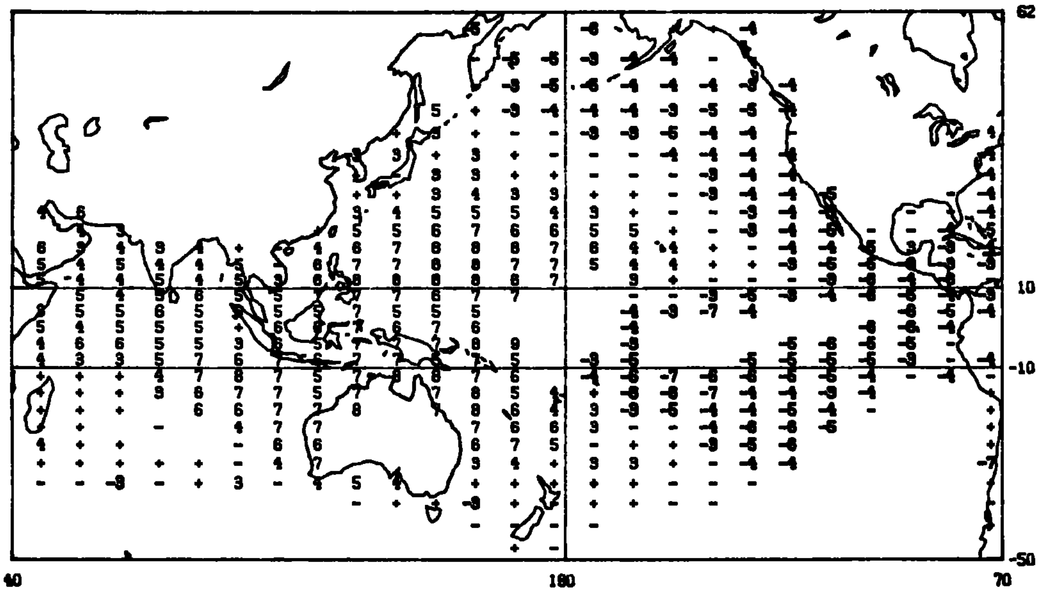

Figure 1. Correlation coefficients (*10) of DJF pressure anomalies derived from COADS data with the Darwin index.

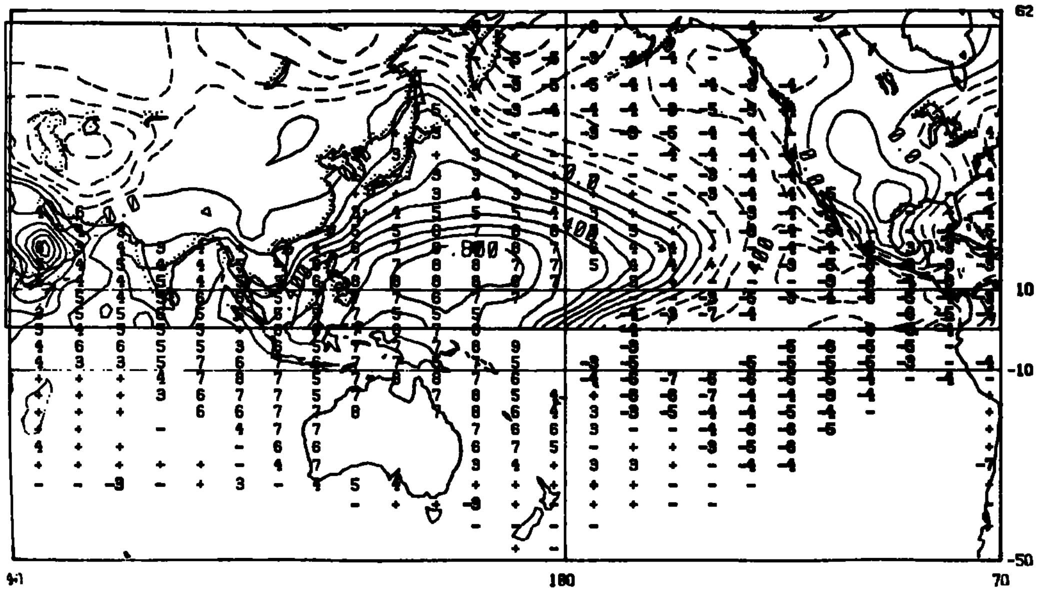

Figure 2. The gridpoint values are the correlation coefficients (*10) of DJF pressure anomalies derived from COADS data with the Darwin index, and the contours are for correlation coefficients of DJF pressure anomalies derived from FNWC data with the Darwin index. The contour interval is 0.1.

Observed and Geostrophic Ship Winds

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1. Introduction.

The Comprehensive-Ocean Atmosphere Data Set (COADS) of historical ship observation presents important quality problems. These have been addressed both by historical research on the ways in which some of the data observations were made at different times over the last 130 years (Ramage, 1982), and by analyses of consistency of physically related data, such as sea surface and air temperatures (Ramage 1984). In this paper another pair of physically related variables is examined - the components of observed wind vectors and those of the geostrophic winds derived from the surface pressure observations. In particular, the main problem we address is the extent to which the agreement between observed and geostrophic winds in long-term averages is degraded for shorter-term averages - specifically seasonal means of winds and pressure gradients.

Clearly the physical link between the surface and geostrophic winds is not nearly as strong as that between air-sea temperatures. The curvature and acceleration of the airflow and surface friction all combine to make the surface wind differ from that balanced by the pressure gradient. There would be little sense therefore in attempting such a comparison for individual ship wind observations.

However, space and time averages of wind and of pressure gradients are a different matter, and their consistency as reflected in the principal wind belts is one of the basic tenets of climatology. It may therefore legitimately be asked whether seasonal averages of winds computed over areas of the order of Marsden squares reflect the year-to-year changes in the principal features of the surface pressure field, similarly averaged. A strong relation would lend additional weight for example, to systematic sequences of surface pressure anomalies in middle latitudes of the southern hemisphere. Certain of these sequences have been tentatively interpreted as precursors of El Niño events (J.O. Fletcher, personal communication).

2. Data

The experiment here reported used ship wind and surface pressure observations during the months June through August in the years 1947 through 1982. The observations were taken from the operational data set collected by the Naval Postgraduate School in Monterey, CA. The creators of COADS deliberately did not incorporate the Monterey data as such because they believed that most of its observations had come to COADS from other sources. A limited comparison of the COADS and Monterey observed winds shows that they agree well, particularly in the more recent years of the period. Like COADS, the Monterey set suffers from substantial inhomogeneities in spatial and temporal data density.

The Monterey data were seasonal averages in 5 ° ×5 ° squares covering the area between latitudes 20 ° N and 40 ° S and longitudes 40 ° E to 140 ° W. The observations of four such 5 ° ×5 ° squares were used to calculate mean values for the 10 ° ×10 ° Marsden squares shown in Fig. 1 (summarized by Fig. 2).

3. Analysis

Fig. 3 shows the long-term mean wind vectors derived from direct observations (thin arrow) and from pressure gradients (heavy arrows). These agree in their broad features - the low-latitude easterlies of the Pacific and summer westerlies of the Indian Ocean, and the small resultant vectors showing the variable winter flow regime in the southern middle latitudes. Major differences between observed and geostrophic vectors occur in the equatorial belt; differences in a few extratropical squares can be attributed to small numbers of observations. The systematic direction differences in the 10 ° -20 ° latitude belt arise from the frictional deflection of the very persistent surface winds.

A more detailed comparison of wind *components* (Figs. 4 and 5) shows that the boundaries between easterlies and westerlies coincide in the observed and geostrophic winds. The mean observed meridional flow is almost uniformly directed towards the summer hemisphere. The mean pressure distribution gives rise to several regions of southward geostrophic flow. The tropical areas simply reflect the lack of geostrophic control but the flow patterns in other areas arise from variations in the semipermanent high-pressure cells over the oceans. These variations appear also in time plots of the observed winds in key squares. Fig. 6a shows such a plot of the meridional wind component in square 431 located near southern Australia, while Fig. 6b illustrates the shifting boundary between low-latitude easterlies and westerlies as reflected in the winds of square 23.

The agreement between the mean winds derived from direct observations and from the observed pressures varies markedly with the data density and is described by the correlation coefficients in Fig. 7. Consistently high positive correlations in the zonal component are found in the data-rich regions near Australia and China, but some substantial correlations also occur in the tropical belt where they must be due to chance. Their statistical appraisal raises the problem familiar from other meteorological contexts - that the usual significance levels lose their straightforward meaning when a multitude of correlation coefficients need to be considered jointly. In such cases it is the *distribution* of correlations that provides the answers.

In the present case it can be expected that the correlations will be statistically insignificant in the tropical belt, and that their significance will systematically increase with latitude. To test this expectation the correlations of Fig. 7 were divided into three groups, covering the latitude belts 10°N-10°S, 10°-20°N and S, and 20°S-40°S, respectively. Fig. 8 shows the cumulative frequency distributions of the "transformed correlations" (Fisher, 1921):

$$z = \frac{1}{2}\ln\frac{1+r}{1-r} \qquad (1)$$

which are expected to be normally distributed with standard deviations

$$S = (n - 3)^{-1/2} \tag{2}$$

where n is the effective number of independent correlated value pairs. The coordinate system of Fig. 8 ensures that normal distributions appear as straight lines. To aid the eye, linear regression lines have been calculated to fit each set of eleven points representing the cumulative proability from 5% through 95%.

The least squares fit to the plotted points is very close in each case. As expected, the means of the correlations (the intersections with the 50% line) increase systematically with latitude from near zero for the tropical belt to values between 0.25 and 0.3 for the latitude belt 20 ° S-40 ° S. The slopes of the lines provide a measure of the standard deviations:

$$S = z_{84.3\%} - z_{50\%} \tag{3}$$

which in view of equation (2) indicate the effective number of observations:

$$n = s^{-2} + 3. \tag{2'}$$

The values of n appear near the straight lines in Fig. 8. They mostly are about one half the actual number of value pairs used. No more definite statement is possible since the actual numbers vary from square to square, between 35 and 11, a characteristic difficulty facing statistical analyses of ship data.

4. Conclusions.

The results presented in this note prove the basic consistency of the ship winds and pressures in the long term mean. However, for individual seasons the link appears to account for at most 10% of the total variation. Thus data gaps in the winds in general cannot be closed by means of pressure or vice versa, except in regions of high data density. More generally, the analysis exemplifies the information that can be deduced from temporally and spatially inhomogeneous data sets such as COADS.

References.

Fisher, R.A. 1921. On the probable error of a coefficient of correlation deduced from a small sample. *Metron, 1* (4), 1.

Ramage, C.S. 1982. Observations of surface wind speeds in the ocean climate data set. *Tropical Ocean Atmos. Newsletter, 13*, 2-4.

Ramage, C.S. 1984. Can shipboard measurements reveal secular changes in tropical sea-air heat flux? *J. Clim. Appl. Meteor. 23,* 187-193.

MARSDEN SQUARE NUMBERS

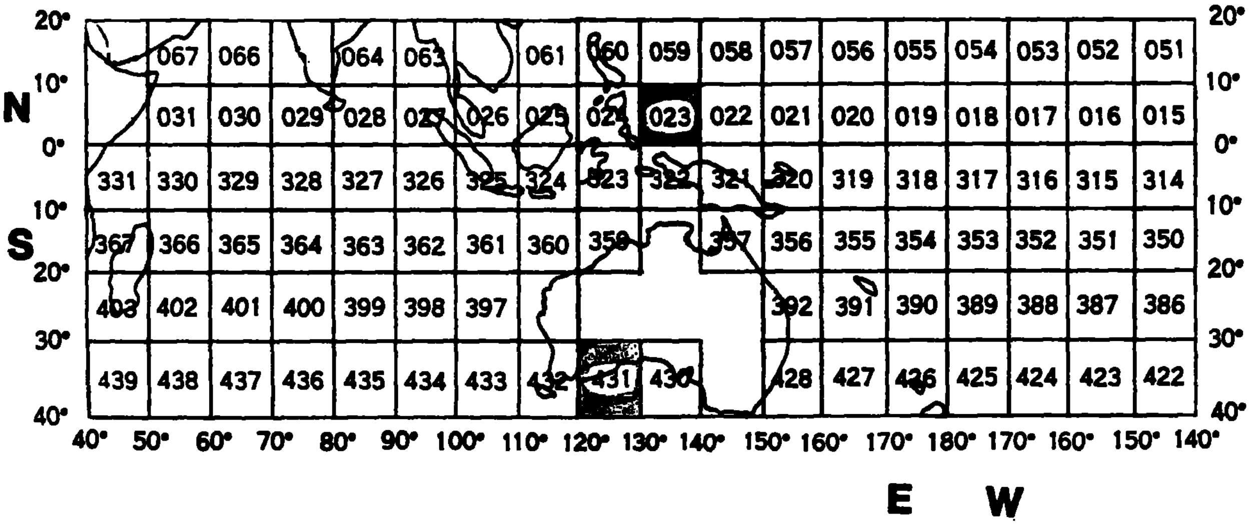
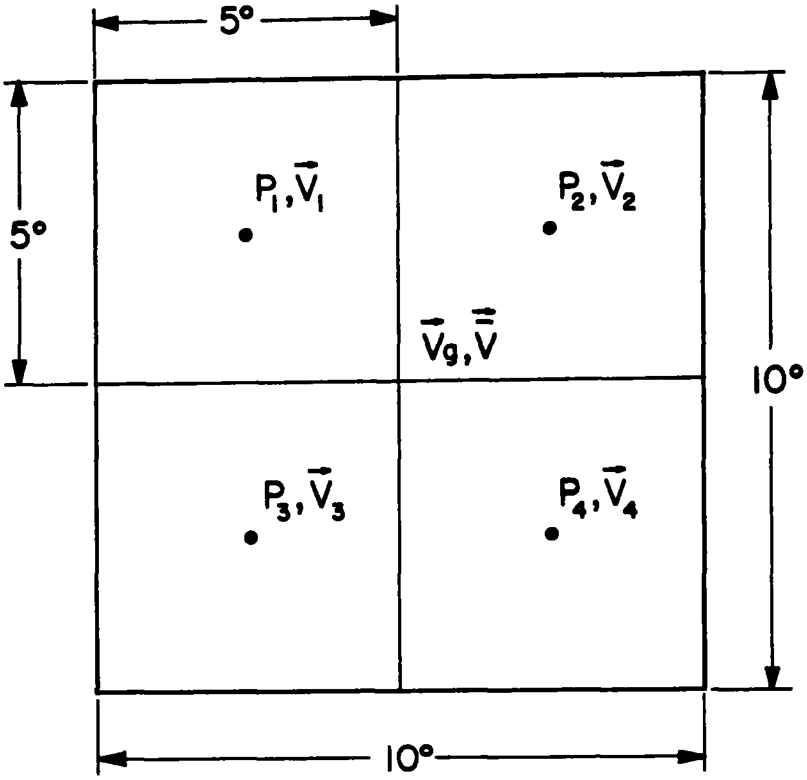


Figure 1

Computation of Geostrophic and Observed Winds in 10 x 10 Boxes



Geostrophic Components

$$U_g = -\frac{1}{\rho f} \frac{\delta P}{\delta y}$$

$$V_g = \frac{1}{\rho f} \frac{\delta P}{\delta x}$$

Observed Components

$$\bar{U} = \frac{1}{4} \sum_{i=1}^{4} U_i$$

$$\bar{V} = \frac{1}{4} \sum_{i=1}^{4} V_i$$

P = Pressure
ρ = Density
f = 2 Ω sin(Latitude)

Figure 2

Long-term Measured (—) and Geostrophic (—) Winds

(JJA, 1947-82)

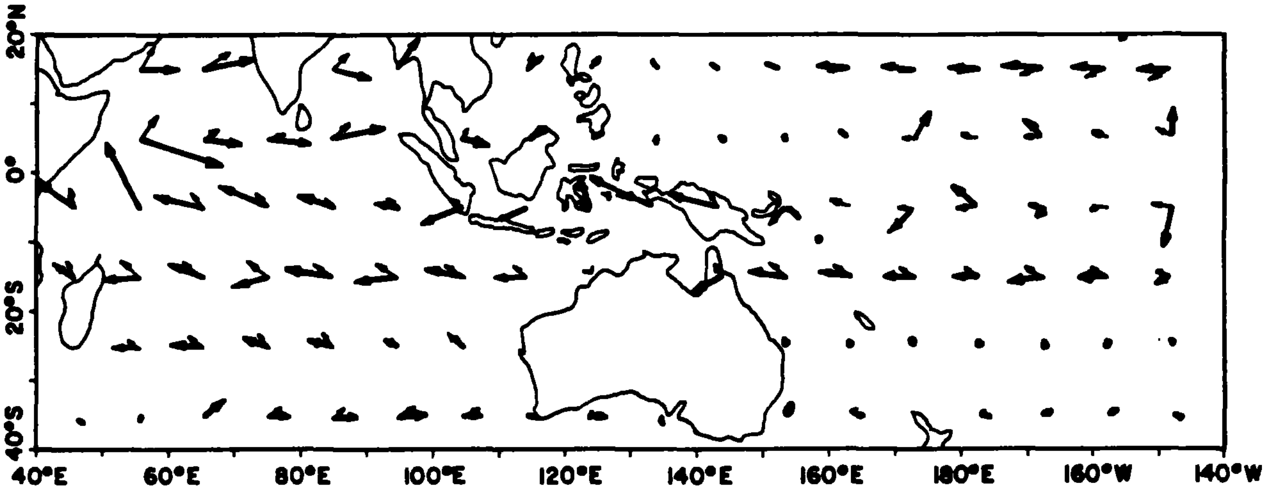
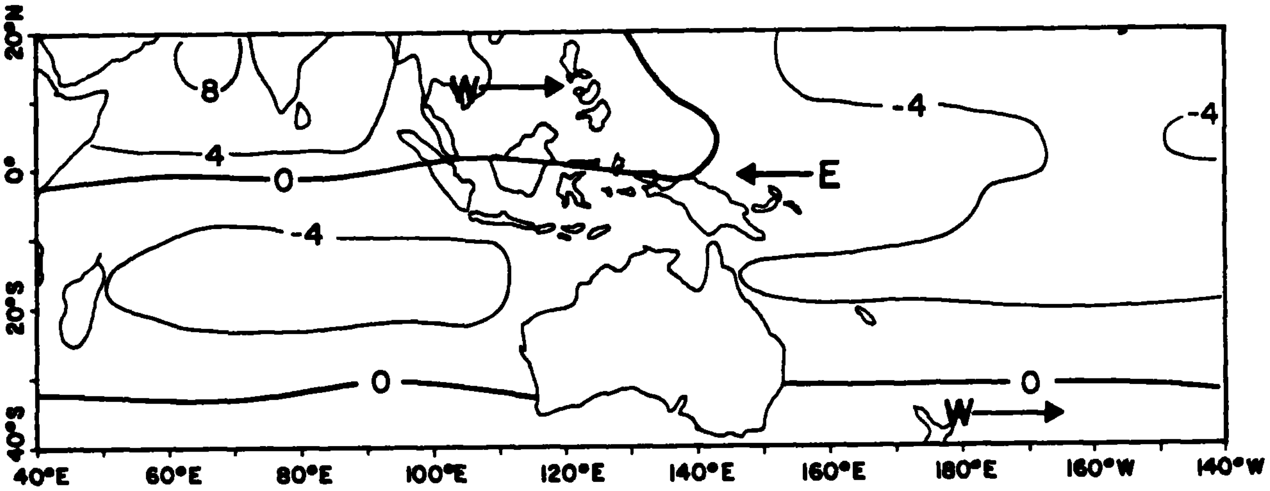
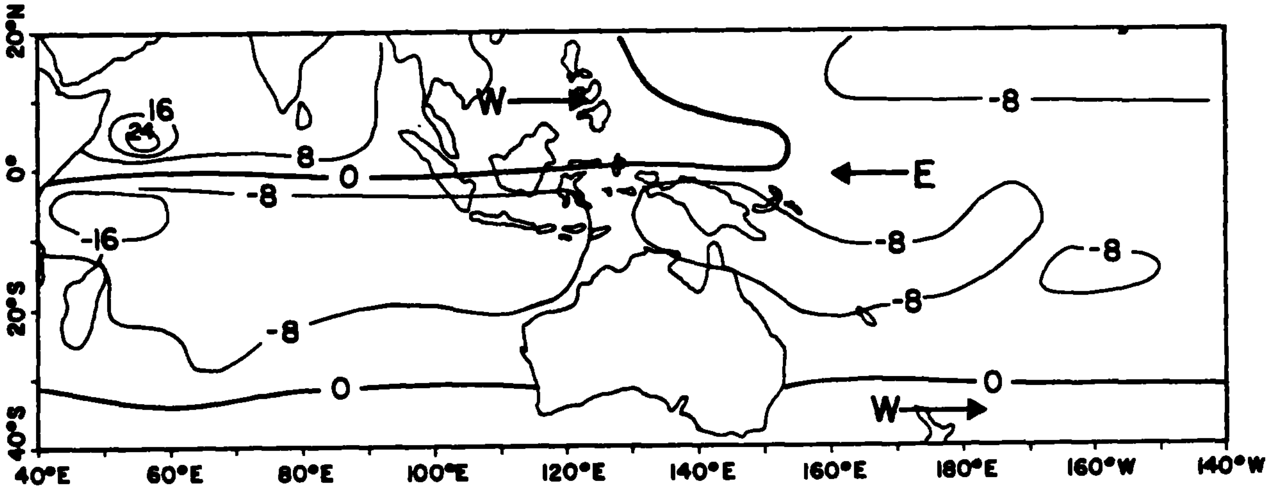


Figure 3



Long-term Mean Observed U Component (JJA, 1947-82)

Contour interval = 4m/sec.

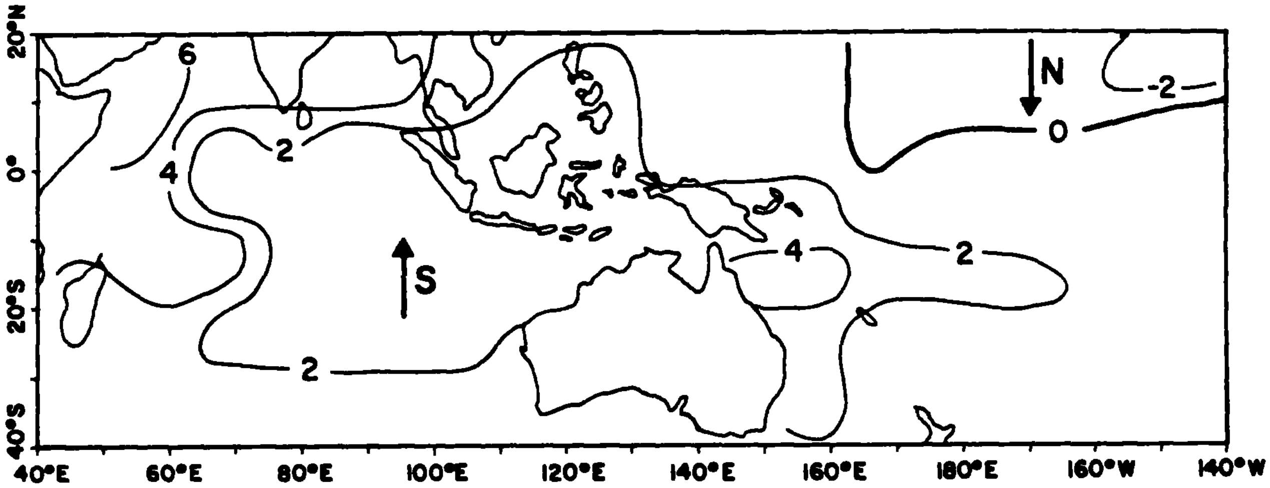


Long-term Mean Geostrophic U Component (JJA, 1947-82)

Contour interval = 8m/sec.

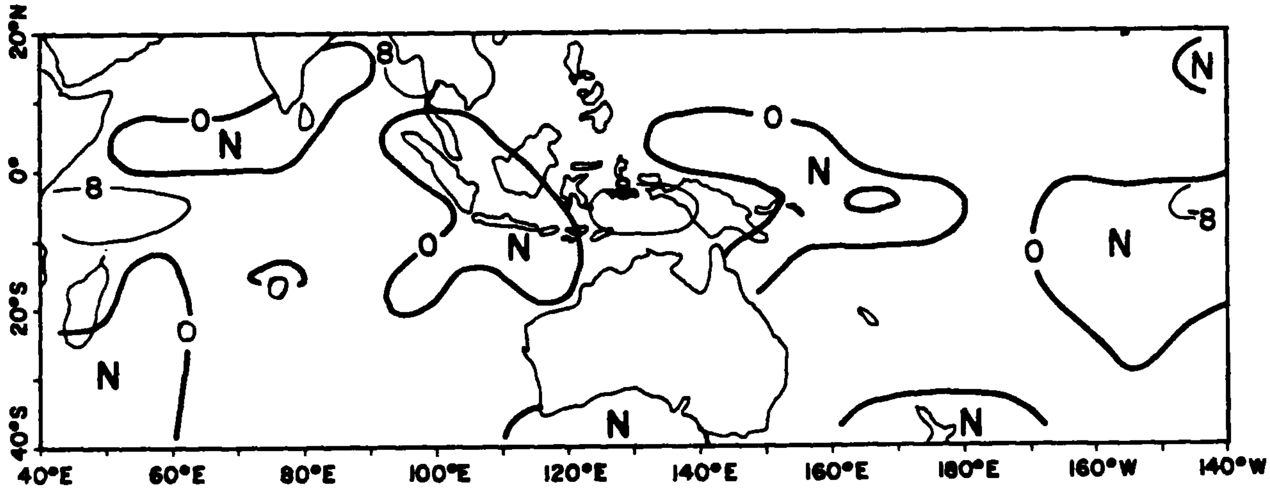
Figure 4

Long-term Mean Observed V Component (JJA, 1947-82)



Contour Interval = 2 m/sec.

Long-term Mean Geostrophic V Component (JJA, 1947-82)



Contour Interval = 8 m/sec.

Figure 5

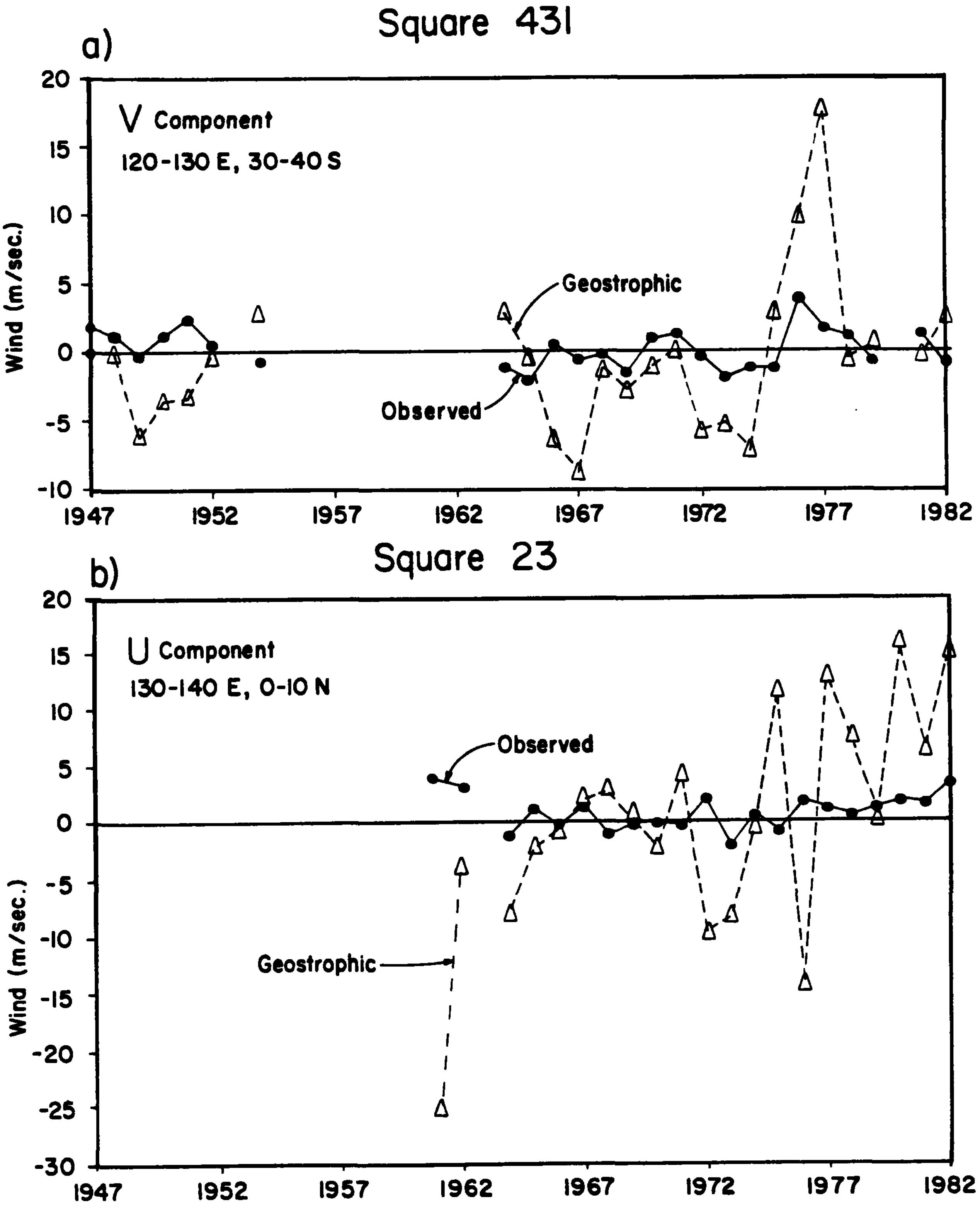
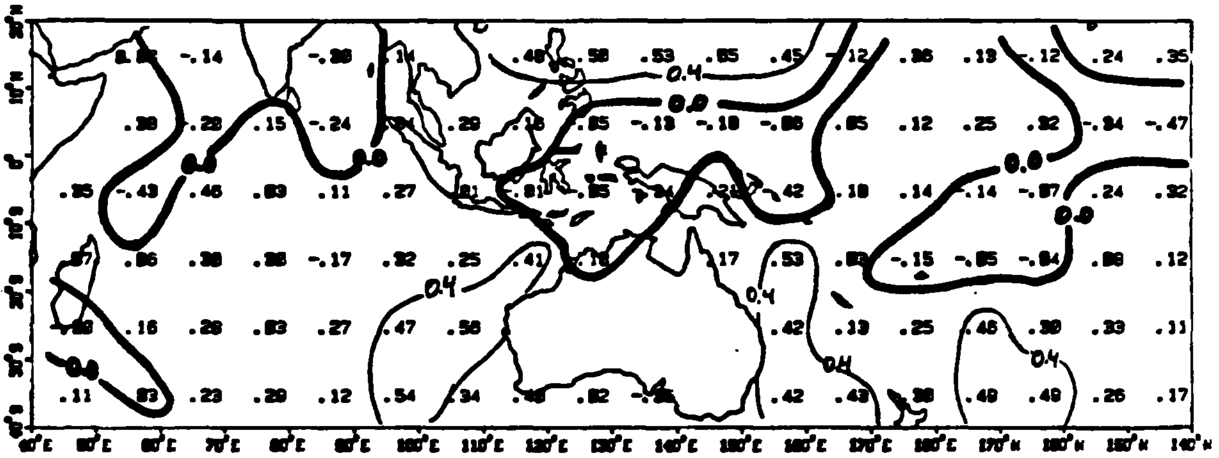
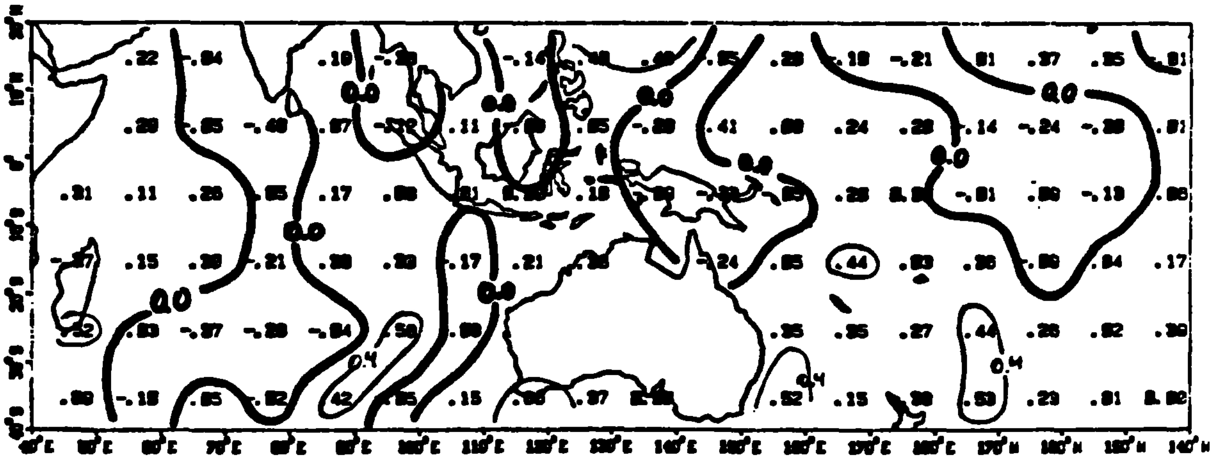

Square 431
a)
V Component
120-130 E, 30-40 S
Geostrophic
Observed
Wind (m/sec.)
20
15
10
5
0
-5
-10
1947
1952
1957
1962
1967
1972
1977
1982
Square 23
b)
U Component
130-140 E, 0-10 N
Observed
Geostrophic
Wind (m/sec.)
20
15
10
5
0
-5
-10
-15
-20
-25
-30
1947
1952
1957
1962
1967
1972
1977
1982

Figure 6

CORRELATION COEFFICIENTS



Observed vs. Geostrophic U (JJA, 1947-82)



Observed vs. Geostrophic V (JJA, 1947-82)

Figure 7

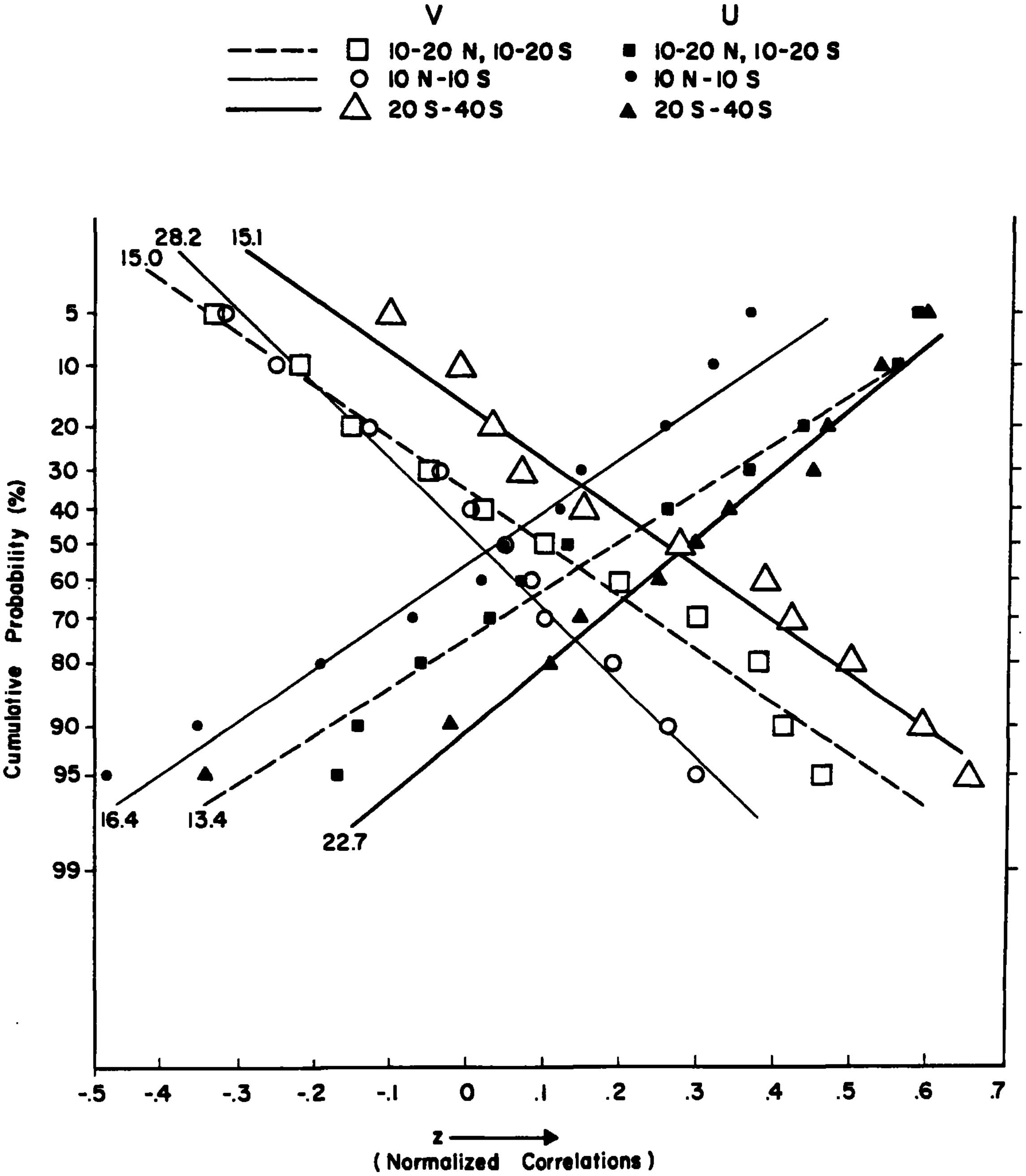

V
U
10-20 N, 10-20 S
10 N-10 S
20 S-40 S
10-20 N, 10-20 S
10 N-10 S
20 S-40 S
28.2
15.1
15.0
16.4
13.4
22.7
Cumulative Probability (%)
5
10
20
30
40
50
60
70
80
90
95
99
95
90
80
70
60
50
40
30
20
10
5
1
-.5
-.4
-.3
-.2
-.1
0
.1
.2
.3
.4
.5
.6
.7
z
(Normalized Correlations)

Figure 8

Roy Jenne
7 Jan 1986

Analysis Strategies and Selected Real Time Data Products

Selected aspects of the data analysis problem are reviewed, especially with regard to the small number of observations that we often are forced to deal with. In addition to the ship statistics that go back many years, there are daily analysis products from operational centers for recent years. A selection of these will be listed.

Sparse Data Sampling

Many of the 2° squares have very few observations during one year-month. From Table 1 we note that the 2° squares off the N. Chile coast, and in another box between Australia and S. Africa typically have no observations during a month, or only one. There are, however, regions of good coverage, such as in the examples off the Spanish coast or in the Gulf of Alaska, where there are usually between 10 and 99 observations in a 2° box each month. This applies to the 1970's decade. For most squares, there were fewer observations in earlier years. During the 1970s, 55% of the ocean 2° squares had at least one observation in a year month; in the whole 1854-1969 period, only 22% of the squares had at least one observation. Tables in the COADS document show the coverage by decades.

Two procedures are commonly used to make year-monthly analyses. The first is to make a direct monthly analysis based on all of the individual observation points taken during the month. The other is to make daily grid point analyses and average them for the month. We first will discuss the preparation of year-month statistics.

Year-Month Statistics

The mean value and variability of pressure, air temperature, and SST at four locations in the world ocean are shown in Table 2. One is for a 2° box off the N. American East Coast at 45°N near Newfoundland. Another is in the region of the Atlantic subtropical high pressure area about 25°N, 50°W. One is in the Gulf of Alaska near 45°N, 145°W. The last one is in the equatorial Pacific near 5°S, 145°W. Table 2 gives the 1 sigma variability of the daily values. it also gives the high and low values permitted to be used for the ship statistics, based on 3.5 sigma. The way that sigma is calculated (based on sextiles) permits the sigma on the two sides of the distribution to be different from each other. (We also note that in NCDC's data checking algorithms, values are flagged as bad if they exceed 5.8 sigma.)

If there is one observation in a square in a month, the error bars on our knowledge of the monthly mean are then 1.0 sigma, where sigma is the daily standard deviation of the variable in that region and month. When n samples are available, the error in the monthly average becomes sigma/$\sqrt{n}$, where we disregard the effect of possible data biases. For example, with 16 samples the error in the monthly mean is reduced to sigma/4. One might think that the standard deviation of all of the full January averages of daily pressure at a point would be (daily sigma)/$\sqrt{30}$, because a monthly average includes all 30 days. However, for variables such as pressure or air temperature, there are usually only about 5 independent samples per month. Thus, the year-to-year standard deviation of monthly values will be about (daily sigma)/$\sqrt{5}$ for this example. If we wish to know a given year-monthly value within 1/4 of the year-to-year monthly sigma, we need about 80 observations within the 2° year-month square for each year.

In order to get a feeling for how the accuracies in the statistics vary with the number of samples, we will extract a few numbers from Table 2:

Gulf of Alaska	*P (Jan)*	*P (July)*	*Air T (Jan)*	*Air T (Jul)*
High value (3.5 sigma)	1036 mb	1039	14.8	19.9
Median	998	1018	9.0	14.0
Low value (3.5 sigma)	954	995	3.1	8.8
Sigma	11.6	6.3	1.7	1.6

Error in year-mo mean equals: $\frac{\textit{long period daily}\ \sigma}{\sqrt{n}}$

$$\text{for 4 observations} = \frac{\textit{daily}\ \sigma}{2}$$

$$\text{for 64 observations} = \frac{\textit{daily}\ \sigma}{8}$$

Also note that for pressure, air temperature, we have:

$$\text{year-mo sigma is about } \frac{\textit{daily}\ \sigma}{\sqrt{5}}$$

Amplitude and space correlation of variations:

Variables like air pressure vary rapidly over periods of 3 to 5 days. In mid southern latitudes it is common to go from 1030mb to 950mb over a 3 day period. A real change of one or two millibars over several decades is a significant climatic change. The errors with sparce sampling are much larger for pressure or air temperature than for variables such as SST that vary over a longer time period (and which have a smaller amplitude).

At any one time, pressure anomalies are correlated to distances of over one thousand kilometers. Thus ships at some distance can contribute information to a local point. This distance is much larger than the size of a 2° box used for statistics. Figure 2 with data correlations at 500 mb is an example.

Data sampling and weighting:

The following aspects of data sampling and weighting should be considered:

— Sometimes most of the samples are in one year or one decade. There have been periods when a certain ocean or atmospheric observing experiment produced many observations.

Methods that weight each observation equally for the whole period may give a result that is dominated by the observations from intensive sampling periods.

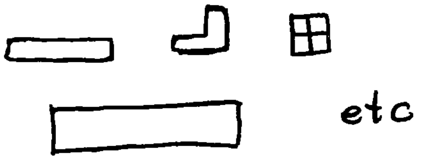
— The problems of unequal sampling can be avoided by making yr-month summaries first, and then smoothing these. However, this can produce a new (sometimes worse) problem if equal weight is given to all summaries, regardless of the expected error in the summary.

- If the error in the monthly summaries is greater than the actual year-to-year variability of the ocean-atmosphere (can easily be true), one must be especially careful about how each month is weighted.

Types of boxes for some past work:

- Wyrtki: 2° Lat x 10° Longitude boxes in equatorial Pacific
- NCDC: 1° boxes with all data for all years weighted equally to make a long period mean
- UK (1979). They wanted yr-mo values each 5°. Data were summarized each 1°, and then analyzed to get a proper center value.
- Atlases: People have used various summary boxes according to knowledge of climate and the number of observations.

Boxes:



A direct monthly analysis of the individual observations as above has some advantages compared to using an average of daily analyses; only real observations are used, thus errors from noisy grid points with no data aren't included. The real monthly atmosphere and ocean has a much smoother monthly mean field than a daily field with its individual intense moving storms. Thus, the monthly space correlations are better and this fact can be used in a procedure to smooth or analyze the year-month statistics.

In many parts of the world (especially before satellites), there was so little data that one can't actually say anything about an individual month, or even a season, or perhaps a decade. With our small 2° Lat-Lon summary boxes in the ship project, the situation appears even much worse (than it actually is) because these small boxes don't directly include the large amount of information from data in adjacent boxes.

The plans to smooth the monthly statistics from box to box (and perhaps from month to month) will bring back some of the space correlation information for fields with space correlations out to 1000 km or more. Any new smoothing process should not reach out to great distances for data if there is enough local information to adequately determine a box average.

In general, one can use appropriate time and space smoothing to reduce the error in an estimated average. If the same filters are used even in cases with enough samples that they are unnecessary, the cost will be truncated time and space resolution.

Daily Objective Analyses

An objective analysis scheme was described by Cressman (1959) that is now known as the "Cressman method". The analysis was done on the northern hemisphere octagonal grid that has a grid spacing of 381 km at 60° N. Observed data out to a distance of several grid distances from a particular grid point will affect its analyzed value. The weighting of an observed data point at the grid point is given by: $w = \frac{N^2-d^2}{N^2-d^2}$

The response of this equation is shown in Figure 1, where d is the distance to the data point and N is the number of grid lengths used in a particular scan (N = 4.75 in scan #1 , 3.60 in scan 2, 2.20 scan 3, N = 1.00 in scan 4 with a constant weight = 1.0). An observed data point that is bad could destroy the analysis. To prevent this, only data within a maximum difference from a first guess are permitted. The procedure used to analyze pressure fields is somewhat more complicated. Suppose that there is only one observation of pressure which is 300 km south of the grid point in question. If there is a strong west wind at the observation point, this indicates a strong pressure gradient, which can be used to modify the pressure as it is extrapolated north to the grid point. Since the sparse observed data tended to produce bumps in the analyses, a smoothing filter was used between analysis scans 3 and 4. This smoother gave a weight to the central grid point of 1/2 and 1/8 to each of the surrounding 4 grid points. Later versions of the method have often used 9-point weighting filters that had a better response.

In summary, the Cressman analysis method first made an analysis by including contributions from observed data that were within 4.75 grid distances of each grid point. This analysis was then used as a first guess, but now only by using the data within 3.60 grid distances. Then there was a smoothing pass, followed by scan 3 using data to 2.20 scan distances, etc.

The Cressman analysis method, the more recent optimal interpolation (O/I) method and others are reviewed by Haagenson, 1982. The O/I scheme is similar to Cressman in many practical respects, but there are perhaps 4 key differences:

1. The data weights versus distance from a grid point, for a particular variable, are derived from the way that the correlation between 2 observations falls off with increasing distance. An observation at a grid point still does not get a weight of 1, because there is some error in the observation. The correlations are prepared from the data each day, or may be done ahead of time for each month of the year. A properly "tuned" Cressman method is probably about the same.
2. The O/I scheme takes account of the relative locations of the observations around the grid point; the Cressman scheme does not. Take an example in which there was one observation of 0°C 100 km south of a grid point and two observations (each is 12°C) that are close together and 100 km north of the grid point. The Cressman method would obtain an analyzed value of 8°C at the grid point, and the O/I method would obtain the more likely 6°C. The smoothers used by Cressman would often remove much of this problem.
3. The O/I scheme is run on the differences from the guess. The real value at a grid point may differ from an observed value 400 km north of it, because the guess is wrong or because there is a gradient in the real atmosphere. The procedure used helps to remove the effects of the latter. This procedure of analyzing anomalies (not whole observed values) could also be easily used with the Cressman scheme, but it usually hasn't been.
4. If the observed data is located right at a grid point, the Cressman method gives it a weight of 1.0. The O/I weight will be less than one, and will depend on the error in the observations, as shown by the way that very close observations are correlated with each other.

Both methods ordinarily use circular weighting functions, and do not vary the weights with the type of synoptic system being analyzed or the location on the earth. The various methods often seem to reduce high gradients somewhat. This is probably because the correlation functions say that high gradients don't happen very often. For example, it appears that temperature gradients calculated from satellite sounder channels are often greater than those in resulting analyses.

In making a daily analysis at a grid point, the observations are given a weight depending on their distance from the grid point and on their expected observational error. If there are enough good (and close) observations, distant data (or the guess) should not be given any weight; most analysis systems don't achieve this. The reason that this would help is that the actual correlation functions at a local point vary markedly from day to day, and the procedures use an average correlation.

Monthly Means of Daily Analyses

Monthly analyses that are summarized from daily analyses should be better than direct monthly analyses in those regions where there is a reasonable coverage of daily data from platforms that cannot be (or aren't) included in the direct monthly analyses. Satellite cloud drift winds, aircraft data, and satellite sea surface temperature are examples of such observations. Thus, the daily data (with its forecast model guess) may be able to preserve some of the statistics better over mid-latitude oceans than other methods. The daily analyses use a knowledge of the space correlations of the data to achieve a reasonably good analysis, even in areas having some data, but not a lot. There were only limited observations in the mid latitudes of the Southern Hemisphere; during the 1957-58 IGY, careful manual analyses of surface and 500 mb Southern Hemisphere conditions were made by paying close attention to backward and forward time continuity of the storms. In the period since satellite pictures became available, the Australians have used these pictures to manually estimate the location and intensity of surface low pressure areas. These are fed into objective analysis programs. Some areas of the Northern Hemisphere oceans also have little data.

A problem arises in making monthly analyses from dailies when there is almost no information going into the daily grids. On the average, the good grid point data from the few days with observations will be swamped by the noise in the grid points on other days. This could be avoided by saving a confidence value with each grid point and using it when preparing the monthly average. I don't know of this ever being done. Note that this is a similar problem to making a decade average from individual yr-months where some months have enough data for good averages, and others are very noisy.

Daily analyses remove the time bias problem such as where there are 50 observations on one day and only 3 on each of 5 other days in a month.

Selected Analyses from Operational Centers

A brief survey of available analyses follows. The Navy products are given more emphasis, because they are not known as well as NMC or ECMWF.

A. Selected Analysis Products from NMC

- NMC global 2.5 degrees. 1 Jul 76 - 10 Dec 84. SLP, sfc T, U, V, T, H 1000-50 mb; humidity in boundary layer and at levels 1000-300 mb. SLP starts 8 Dec 77, sfc P starts 21 Sep 78, SST starts 16 May 79, Boundary layer (U, V, RH & theta) starts 6 June 1980. 71 tapes (all 6250 bpi).

  - A surface subset includes 1000 mb thru June 84, 9 tapes (6250).

— NMC yr-mo SST grids, 40S-60N, Jan 1970 - May 1984, based on ships.

— The daily analyses of SST above use ship and satellite data.

B. Summary of available Navy surface and UA analyses

Some aspects of the Navy analyses are as follows:

— Navy UA (upper air) analyses on hemispheric grids never included wind analyses before 1983. The new UA 2.5° global archives starting Jan 1983 include winds.

— Navy surface archives on hemispheric grids include winds, but these were derived from the pressure field and stability prior to 1974. Real winds were not used before that time. The derived winds appeared to be reasonably good. They were used to make wave forecasts and for other purposes.

— The new 2.5° global archives starting Jan 1983 include wind analyses, which also directly use observed wind data in the upper air.

— A user could prepare global Navy analyses of winds from 1974-on by using global band winds (40S-60N), and blending these with geostrophic winds for the polar areas.

More detailed information about the analyses follows:

1. N. Hemisphere surface analyses (63x63 grid points) 1961 to 1985, and later

   Most grids start about 1961, some before. SLP (from Nov 45), SST (Nov 61), T air (May 65), E air (May 65), N clouds (Jan 68), winds (calc from pressure fields from 1945 until Aug. 1974, then analyzed).

2. N. Hemisphere UA analyses (63x63) 1961 to Jan 1983

   1000 to 100 mb, mostly start about 1961-63. See data lists in NCAR TN/IA-111. (Data Sets for Meteorological Research, 1975, by R. Jenne).

3. S. Hemisphere surface analyses (63x63 grids) July 1973 to 1985 and on

   SST starts 1 Jul 73. Also SLP. By 1983 the data included SST, SLP, Air T, surface vapor pressure. Winds start Dec 1978.

4. S. Hemisphere UA (63x63) Aug 1974 to Jan 1983

   1000, 925, 850...-100mb, start Aug 1974.

5. Global band (40S-60N), Aug 1973 to 1985, and later

   From Aug 1973. SLP, air T, wind, no moisture. The global band surface and UA analyses (40S-60N on 2.5° grids) use reported wind data to make wind analyses. The global forecast model (1983-on) does not use any global band data.

   UA grids up to 200 mb. Information obtained in 1983 said that the global band grids were usually better than hemispheric grids in the tropics; this is still probably true in 1986.

6. "Spherical" 2.5^{o} global surface analyses. Aug 1974 and on. SLP and winds. These global grids used ship and buoy data (pressure, wind, etc. from the time they were started. The other surface analyses (global band and hemispheric grids) were interpolated from these global grids. In the title of the grid, there is an integer count of the number of wind observations used.
7. Upper air 2.5^{o} global analyses. These grids start Jan 1983. NCAR does not have these yet.

C. **Selected Navy Tapes at NCAR (Oct 1985)**

- Navy S. Hemisphere surface and UA analysis (Aug 1974 - June 1983) are on 20 tapes, 6250 BPI. Grids after 17 Jan 83 are interpolated from global 2.5^{o} anal.
- *Global band* (Aug 1973 through July 1984) *and* surface full global "*spherical*" analyses Aug 1974 - June 1983. These two sets are combined on 37 tapes (6250). Global band has grids each 12 hr (49x144 points, 2.5^{o}): SLP; T at 850, 500; U,V at surface, 700,400,250,200 (26 grids/day). Spherical grids are available each 6 hour (SLP and wind) (12 grids/day).
- There are tapes with N. Hemisphere surface grids at NCAR. We do not have the N. Hemisphere UA grids as yet. Or the ocean grids at depth.
- Navy SLP. 63x63 N. Hem. Jan 1946 - Jan 1983. 5 tapes.
- Navy sea level pressure (NMC octagon) extracted from item #3. Jan 1946 - Jan 1983. 1 tape (6250).
- Reanalyses of N. Hemispheric SLP for 1946-75, each 6 hours. Prepared by Manfred Holl working for Monterey. Wind and waves also made, but NCAR did not obtain these. Winds were not analyzed, just geostrophic calculations based on pressure.
- Navy yr-mo SST 63 x 63 N. Hem. Mar 62- Jan 83. 1 Tape.

Note: UA winds are not available in the Navy hemispheric analyses for 1974-Jan 83. They are available in the global band for some levels. These band winds could be used with geostrophic winds at high latitudes to make global winds.

Procedures for Navy Daily Analyses

UA analyses start about 1961 for the N. Hemisphere., 1974 S. Hemisphere:

These were made by using the FIB (fields by information blending) method until August 1982. In the FIB procedure the observed data are first interpolated to a close gridpoint using a short scan radius, with length less than one grid distance. In this process the gradient of the guess is used. At this stage the analysis has some grid points that have been changed, separated by many with no data input. The second part of the FIB process inputs the changed grid points and the gradients of the guess field. It uses calculus of variations methods to obtain a complete analysis. It does not demand any physical constraints (such as height vs wind) in this process. It may also be of interest that S. Africa adopted these procedures and the same S. Hemisphere (63x63) grid for their hemispheric analyses. Later we will describe the global analyses that have been used from August 1982.

More information about the Navy analysis/forecast system is available in Jenne, 1986.

TABLE 1 - Frequency distribution of the number of 2° year-month squares having given counts of observations for statistics. These are given for four different 10° lat-lon boxes, for the 1970's decade. As one goes back in time, more of the boxes will have fewer observations.

	Box 176: 45°N, 15°W, NW of the Spanish Coast		Box 163: 45°N, 145°W, Gulf of Alaska	
Number obs in box,	SST Cases	Pressure Cases	SST Cases	Pressure Cases
0	1	0	0	0
1	1	1	3	1
2	3	1	14	8
3-5	20	9	110	68
6-9	69	34	354	259
10-99	2349	2159	2519	2664
100-999	557	796	0	0
over 999	0	0	0	0

	Box 420: 25°S, 95°W, (off the N. Chile Coast)		Box 438: 35°S between Australia and S. Africa	
Number obs in box,	SST Cases	Pressure Cases	SST Cases	Pressure Cases
0	2093	2067	742	623
1	553	555	745	675
2	210	226	553	585
3-5	127	133	709	824
6-9	16	18	212	256
10-99	1	1	39	37
100-999	0	0	0	0
over 999	0	0	0	0

TABLE 2 — CLIMATOLOGICAL VALUES CALCULATED FROM SHIP OBSERVATIONS
FOR 4 REGIONS, JANUARY AND JULY, AND 3 PERIODS.

THESE ARE PRINTOUTS OF THE DSUL LIMITS (ROUNDED TO THE NEAREST TENTH UNIT) FOR THE CENTRAL BOX2 OF THE BOX10.

BOX10	LOCATION
163	GULF OF ALASKA 45N
172	NEWFOUNDLAND
244	ATLANTIC 25N,55W
343	PACIFIC 5S,145W

STATISTICS ARE:	
G	SMOOTHED MEDIAN
SIG	AVERAGE OF UPPER AND LOWER STD DEV
LOW	SMOOTHED LOWER LIMIT (G - 3.5*SIGLOWER)
UPPER	SMOOTHED UPPER LIMIT (G - 3.5*SIGUPPER)

PERIOD 1854–1909

		PRESSURE (MB)				SEA SURF TEMP (DEG C)				AIR TEMP (DEG C)			
BOX10	MONTH	G	SIG	LOW	UPPER	G	SIG	LOW	UPPER	G	SIG	LOW	UPPER
163	JAN	998.0	11.6	954.4	1035.5	8.5	1.0	5.0	12.0	9.0	1.7	3.1	14.8
172	JAN	1009.8	12.5	965.0	1052.7	3.2	2.0	-3.0	10.8	3.5	3.9	-10.0	17.5
244	JAN	1019.7	3.3	1007.2	1030.6	23.6	.9	20.4	26.5	22.8	1.3	18.4	27.5
343	JAN	1007.3	1.8	1000.6	1013.4	26.9	.4	25.4	28.4	27.3	.9	24.3	30.3
163	JUL	1018.0	6.3	994.6	1038.9	13.9	1.2	10.0	18.2	14.0	1.6	8.8	19.9
172	JUL	1015.1	6.1	993.3	1035.8	13.7	2.3	6.0	21.8	14.9	2.5	6.0	23.6
244	JUL	1020.6	2.0	1013.6	1027.4	26.7	.8	24.0	29.5	26.5	1.1	23.2	30.8
343	JUL	1011.1	1.4	1006.1	1016.1	26.6	.4	25.1	28.2	26.5	.9	23.5	29.6

PERIOD 1910–1949

		PRESSURE (MB)				SEA SURF TEMP (DEG C)				AIR TEMP (DEG C)			
BOX10	MONTH	G	SIG	LOW	UPPER	G	SIG	LOW	UPPER	G	SIG	LOW	UPPER
163	JAN	1008.5	14.4	958.3	1058.8	9.0	1.0	5.5	12.5	8.9	1.7	2.9	14.7
172	JAN	1011.5	12.5	966.8	1054.5	2.9	1.9	-3.0	10.6	1.2	3.9	-12.3	15.1
244	JAN	1019.9	3.3	1007.4	1030.7	23.5	.9	20.3	26.4	22.7	1.3	18.2	27.3
343	JAN	1009.8	1.6	1003.6	1015.1	26.7	.6	24.1	28.5	26.7	.9	23.7	29.8
163	JUL	1022.6	6.3	999.3	1043.6	13.6	1.2	9.8	17.9	14.0	1.6	8.8	19.9
172	JUL	1015.7	6.1	993.8	1036.3	13.3	2.3	5.5	21.3	14.5	2.5	5.6	23.2
244	JUL	1021.1	2.0	1014.0	1027.8	26.6	.8	23.8	29.4	26.5	1.1	23.2	30.8
343	JUL	1010.7	1.5	1005.7	1016.0	27.1	.5	25.6	28.8	26.8	.9	23.8	29.8

PERIOD 1950–1979

		PRESSURE (MB)				SEA SURF TEMP (DEG C)				AIR TEMP (DEG C)			
BOX10	MONTH	G	SIG	LOW	UPPER	G	SIG	LOW	UPPER	G	SIG	LOW	UPPER
163	JAN	1010.8	14.0	960.2	1058.2	8.9	1.4	4.6	14.1	8.5	2.1	.6	15.5
172	JAN	1011.7	12.4	965.1	1051.8	3.8	2.1	-2.7	11.9	2.1	3.8	-11.4	15.3
244	JAN	1019.6	3.7	1005.4	1031.2	23.9	1.1	20.1	27.8	22.8	1.4	17.9	27.7
343	JAN	1009.9	1.5	1004.3	1015.0	27.2	.8	24.2	29.8	26.8	1.0	23.6	30.4
163	JUL	1022.4	7.3	995.2	1046.3	13.8	1.7	7.9	19.8	14.1	2.0	7.5	21.3
172	JUL	1016.7	6.2	993.2	1036.3	13.0	2.4	4.9	21.8	14.5	2.6	5.7	24.1
244	JUL	1021.1	2.0	1013.8	1027.8	27.0	.9	24.2	30.5	26.5	1.0	23.3	30.5
343	JUL	1011.2	1.5	1005.9	1016.2	27.6	.7	25.2	30.4	27.0	.9	24.0	30.0

Prepared for R. Jenne by S. Woodruff, ERL

ECMWF Analyses

Winds, temperature, and moisture is available at 1000 mb and other levels. There are also 10m winds and 2m temperatures in other archives that are harder to access.

References

Cressman, George P., 1959: An operational objective analysis system. *MWR,* Vol. 87, No. 10, pp. 367-374.

Haagenson, Philip L., 1982: Review and evaluation of methods for objective analysis of meteorological variables. *Met. Research,* Vol. 5, No. 2, Rep. of China, pp. 113-133.

Jenne, Roy L., 1986: Navy Analyses. (Appendix B of this volume.)

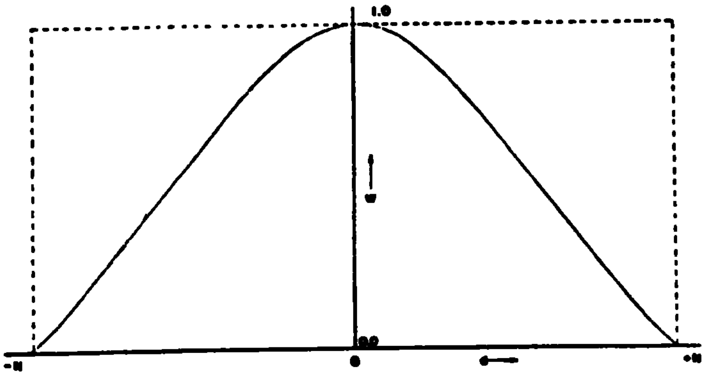


Figure 1:--Curve of the weighting function W vs. distance d.

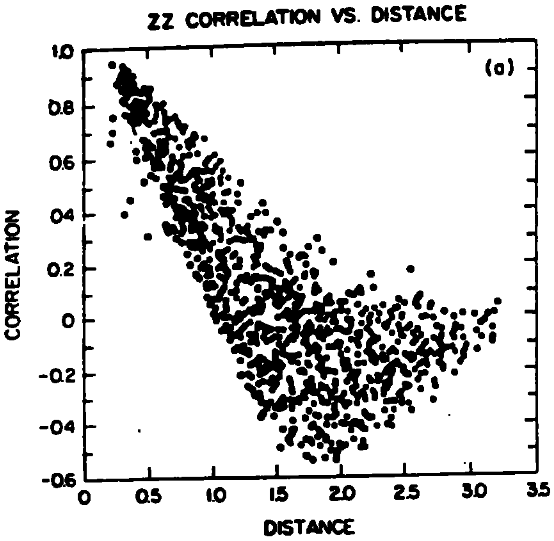


Figure 2: -- 500 mb height correlation with distance. Based on every pair of 50 US raob stations. Distance units are 1000 Km. After Schlatter, 1975. From Haagenson, 1982.

HIGH-LATITUDE COVERAGE AND APPLICATIONS OF COADS

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The existence of coherent fluctuations of sea ice extent over scales of thousands of kilometers has been identified by Walsh and Johnson (1979), Lemke et al. (1980) and Smirnov (1980). Associations between interannual sea ice variability and fluctuations in meteorological fields have been evaluated in varying degrees of detail by model experiments and data analyses. The percentage of variance that may be specified in a hindcast sense from antecedent and/or concurrent meteorological fields appears to be on the order of 10-70%, depending on the region, the temporal resolution, the quality of the ice data and the choice of the meteorological variables.

Commonly cited sources of the "unexplained" ice variance are oceanic factors such as variable ocean currents and sea surface temperature (SST) distributions. The link between SST fields and the high-latitude sea ice distribution can be viewed in the context of Figure 1. The "direct association", in which SST's enhance melting and retard freezing, is to be distinguished from the "indirect association", in which the sea ice distribution is influenced by SST through an SST-induced effect on the atmospheric circulation. Evaluation of the SST-ice coupling from observational data is complicated by the possibility that both coupling mechanisms may act simultaneously.

The summary presented here follows from a preliminary examination of the COADS dataset as a possible tool in studying interannual sea ice variability. The emphasis is on the "direct association" noted above. We report on the spatial distribution of the data available for determinations of ice-SST associations in the marginal ice zones of the North Atlantic and North Pacific, a comparison with the SST data used in a recent study of ice-ocean associations in the Bering Sea, and a preliminary evaluation of North Atlantic SST-ice associations obtained from the COADS data.

Figure 2 shows the location of the marginal ice zone in August and February. The marginal ice zone is defined here as the region bounded by the extreme positions of the 50% ice concentration line over a 25-year period, 1953-1977. Figure 2 is based on monthly fields of ice concentration digitized by Walsh and Johnson (1979).

For the inventory of high-latitude coverage, the 2° x 2° COADS grid cells were consolidated into 4° x 4° cells. Figure 3 shows the distributions of the number of years for which at least one SST report was available for (a) January and (b) July. In both months the availability decreases northward from essentially 100% at the southern boundaries of the oceanic subgrids. While ice cover limits the coverage to less than 100% in the northern portions of the subgrids, the data availability generally ranges from 50% to 80% in the northern ice-free grid cells (e.g., the Norwegian Sea in January and July). A more detailed inspection of the data shows that most of the occurrences of "no data" in ice-free regions are in the first 10-15 years of the 34-year period.

As a check on the interannual variability of the data, the SST values for the COADS grid cell containing the Pribilof Islands (54-58°N, 168-172°W) were compared with Niebauer's (1980) SST's for a 300 km^2 area centered on 57°N, 170°W. Niebauer's values were obtained from the U.S. Navy Fleet Numerical Oceanography Center. Figure 4 shows that a substantial portion of the interannual variability is common to both sets, but that differences of 1-2°C are not uncommon. Niebauer's temperatures are notably colder in 1975, which preceded anomalously heavy sea ice conditions during 1975-76 in the Alaskan waters.

Finally, composite difference fields were constructed in order to compare the SST anomaly fields accompanying the three heaviest and three lightest ice years in the North Atlantic (0°-40°W) during 1953-1977. Figure 5 shows that the SST's are lower when the ice cover is heavy in January, especially to the north and east of Iceland. The differences between the mean January temperatures of the heavy and light ice years exceed 2°C in a number of cells. The pattern and magnitudes of the differences are quite similar in July, although differences of the opposite sign are found south and west of Iceland in the July field. However, the latter region is sufficiently far from the summer ice edge that the sign reversal is not surprising.

Future work will include a systematic comparison of the evolution of the SST and sea ice anomalies in order to assess the nature of any lead-lag relationships in the SST-ice associations. In particular, the spatial progression of large SST anomalies will be examined with a variety of statistical methods and display routines in order to explore the diagnostic and predictive implications for sea ice variability. Statistical relationships between sea ice anomalies and subsequent SST anomalies will also be examined in a search for possible influences of sea ice on the interannual variability of high-latitude SST fields, especially in the region of North Atlantic deep water formation.

References

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Niebauer, J., 1980: Sea ice and temperature variability in the eastern Bering Sea and the relation to atmospheric fluctuations. J. Geophys. Res., 85, 7507-7516.

Smirnov, V. I., 1980: Opposition in ice redistribution in the waters of the foreign Arctic. Meteorol. Gidrol., No. 3, 73-77.

Walsh, J. E., and C. M. Johnson, 1979: An analysis of arctic sea ice fluctuations, 1953-1977. J. Phys. Oceanogr., 9, 580-591.

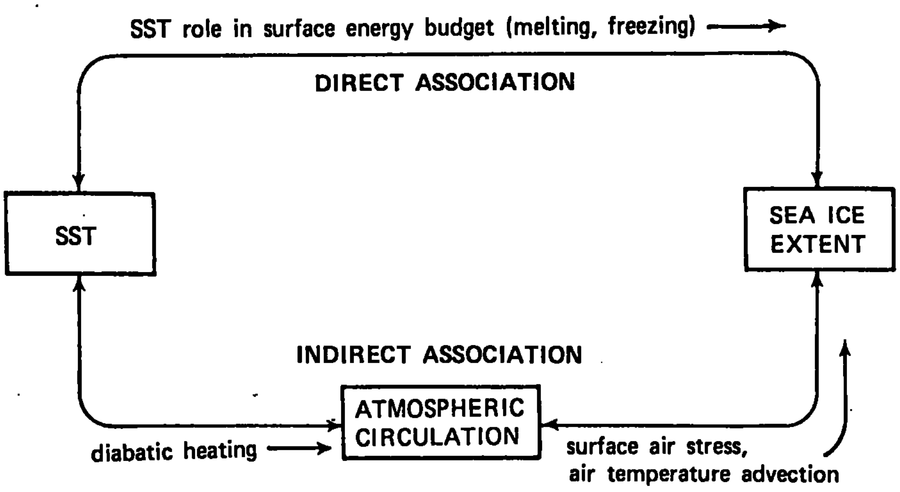
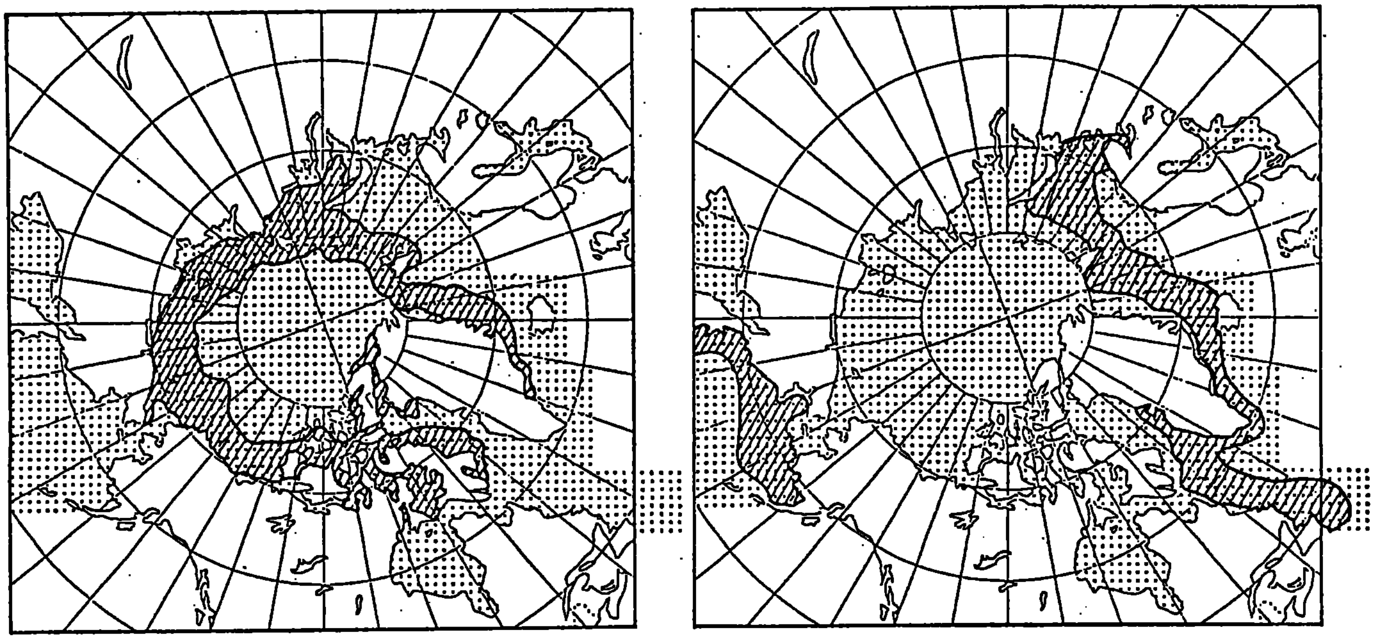


Figure 1. Schematic representation of coupling mechanisms between sea surface temperature (SST) and sea ice extent.

Ice extremes, 1953-1977



(a) August

(b) February

Figure 2. Composite maximum and minimum ice extent at the end of (a) August and (b) February. Heavy lines are extreme positions of 50% ice concentration line based on the 25 August grids and the 25 February grids (1953-1977) of Walsh and Johnson (1979).

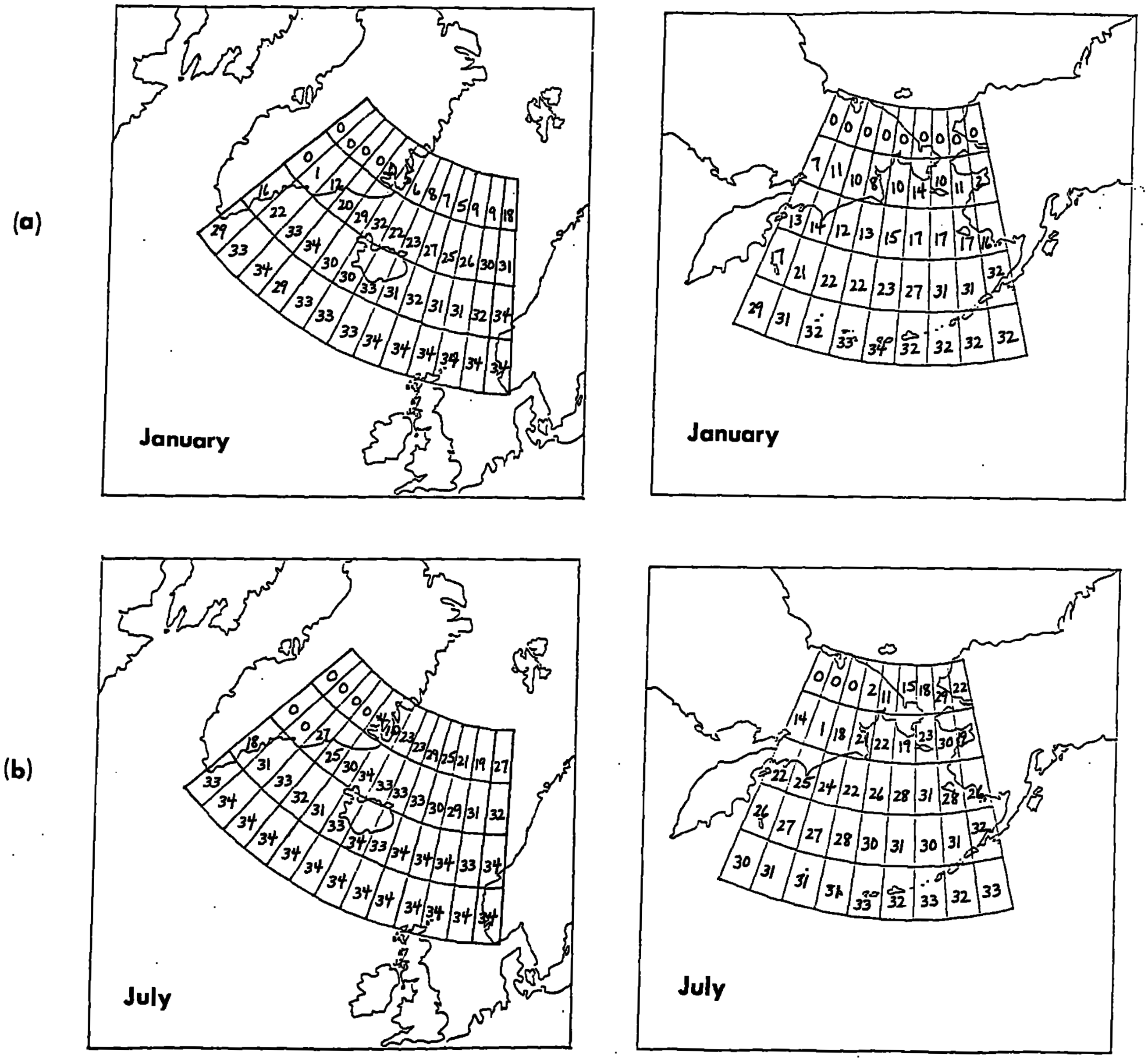


Figure 3. Number of years (of 34) in which at least one SST report was available for 4° x 4° grid cells in North Atlantic and North Pacific during (a) January and (b) July. The period examined is 1946-1979, inclusive.

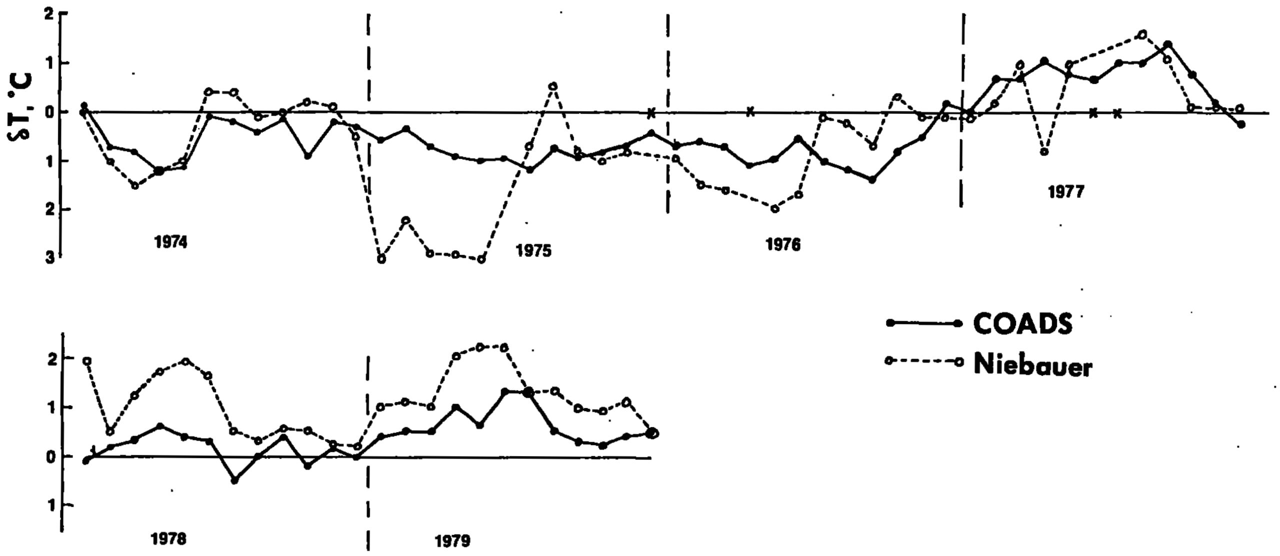
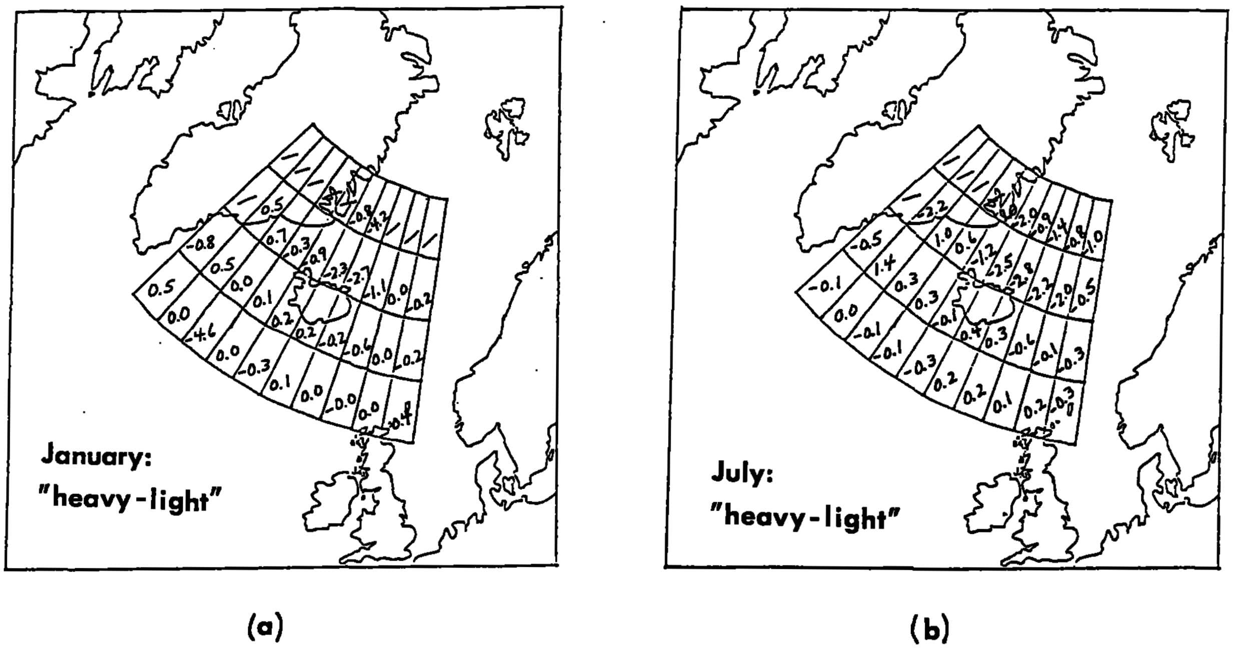


Figure 4. Time series of monthly SST anomalies (°C) in Pribilof Islands region of Alaska. Anomalies derived from COADS are indicated by solid line, anomalies from Niebauer (1980) are indicated by dashed line.



(a)

(b)

Figure 5. Composite differences between mean sea surface temperatures of the three heaviest ice years and the three lightest ice years in the North Atlantic for (a) January and (b) July. Signs correspond to anomalies in heavy ice years.

ANALYSIS STRATEGY FOR THE COADS AND SOME COMPARISON OF PRODUCTS

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Our interests and requirements are mainly in the tropics. The Comprehensive Ocean-Atmosphere Data Set (COADS) is not adequate for the major portion of the tropics even to determine, without many questions, the long-term mean of any parameter. However, it is the best data base available and we use it extensively for both teaching and research. Our primary use at present is for the climatology base required in our methods of producing surface winds and wind stress for the TOGA program. These require grid point data at 2° spacing. Over some high observation density areas such as the midlatitudes of the Northern Hemisphere and the South China Sea the 2° averages of the COADS can be used directly without analysis. However, within the tropics almost all areas require some type of analysis from which the grid point data can be extracted. Our analyses are entirely subjective for there are no objective scheme, to my knowledge, which at present can adequately cope with the highly variable tropical data base.

Subjective analysis permits a variable amount of smoothing over a data base where observations, even in COADS, vary by a factor of 100 between grid points. Subjective analysis also permits the incorporation of other related information. For example in wind analysis useful knowledge comes from observations of pressure, SST, rainfall, satellite cloudiness; models of systems and climatological information and restraints.

I will illustrate by comparing with two recent climatologies whose data bases are comparable to COADS. The first illustrates the lack of sufficient smoothing and violates the first rule--climatological analyses should be smooth. Figures 1 and 2 compare our COADS analyses with those from Hastenrath and Lamb (HL) of the vector wind field and pressure respectively over the Indian Ocean during February. The HL analyses are unreasonably noisey and mask even the major systems and circulation features. In their derived quantities, such as divergence and wind steadiness shown in Fig. 3, the noise is amplified and the data become near useless.

The second illustrates over-smoothing. Figure 4 compares our COADS analysis with that of the Climate Analysis Center (CAC) for the vector wind speed over the tropical eastern Pacific-Caribbean Sea area. The CAC analysis has obviously over-smoothed the data and produced errors of 2 to 3 m/sec in grid point values.

Reference

Hastenrath, S., and P. J. Lamb, 1979: Climatic atlas of the Indian Ocean. The U. of Wisconsin Press.

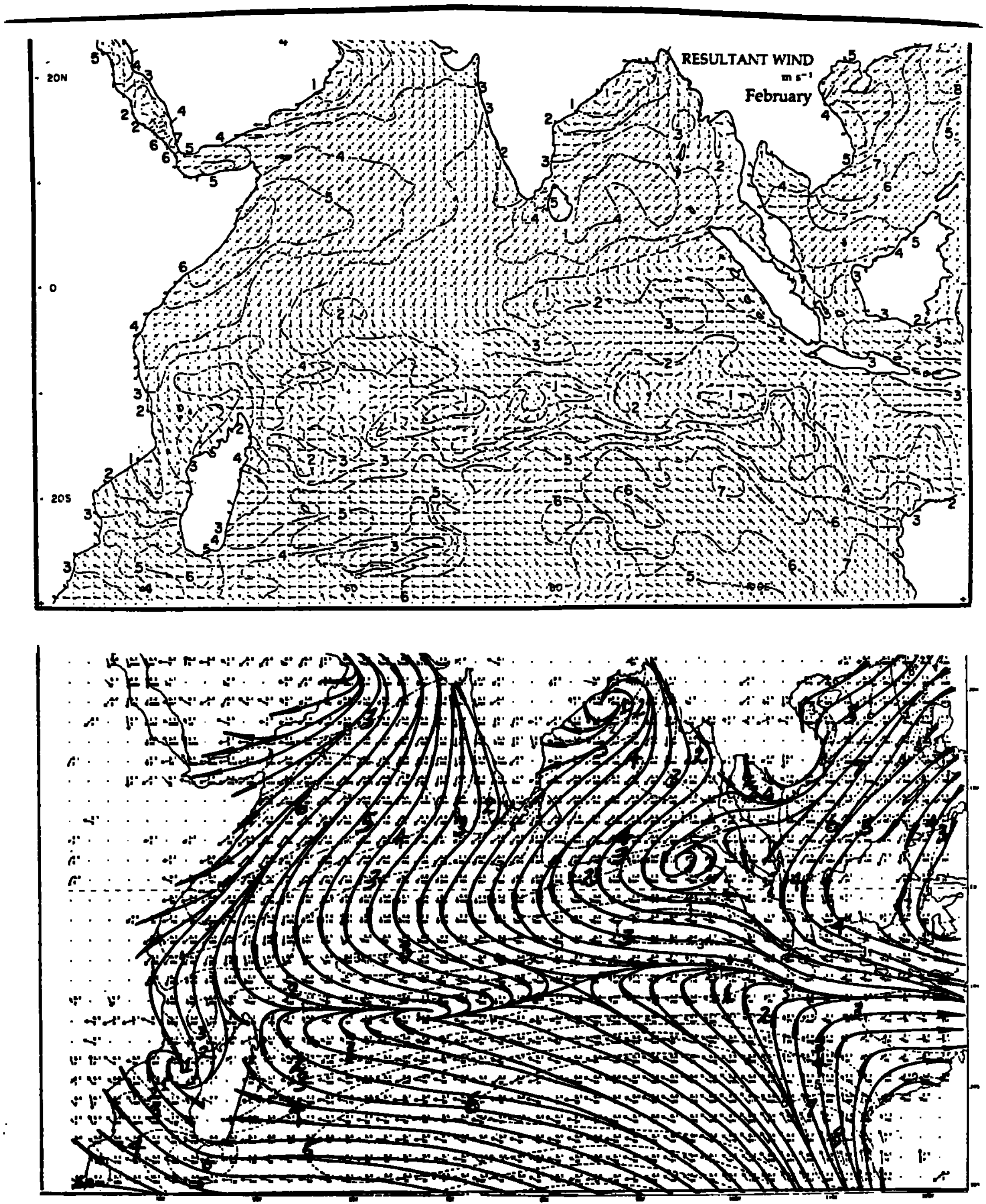

Figure 1. February long-term mean resultant winds over the Indian Ocean: Top--Direction arrows and isotachs (from Hastenrath and Lamb, 1979). Period of record 1911-1970. Bottom--Streamline and isotach analysis of COADS. Period of record 1900-1979.

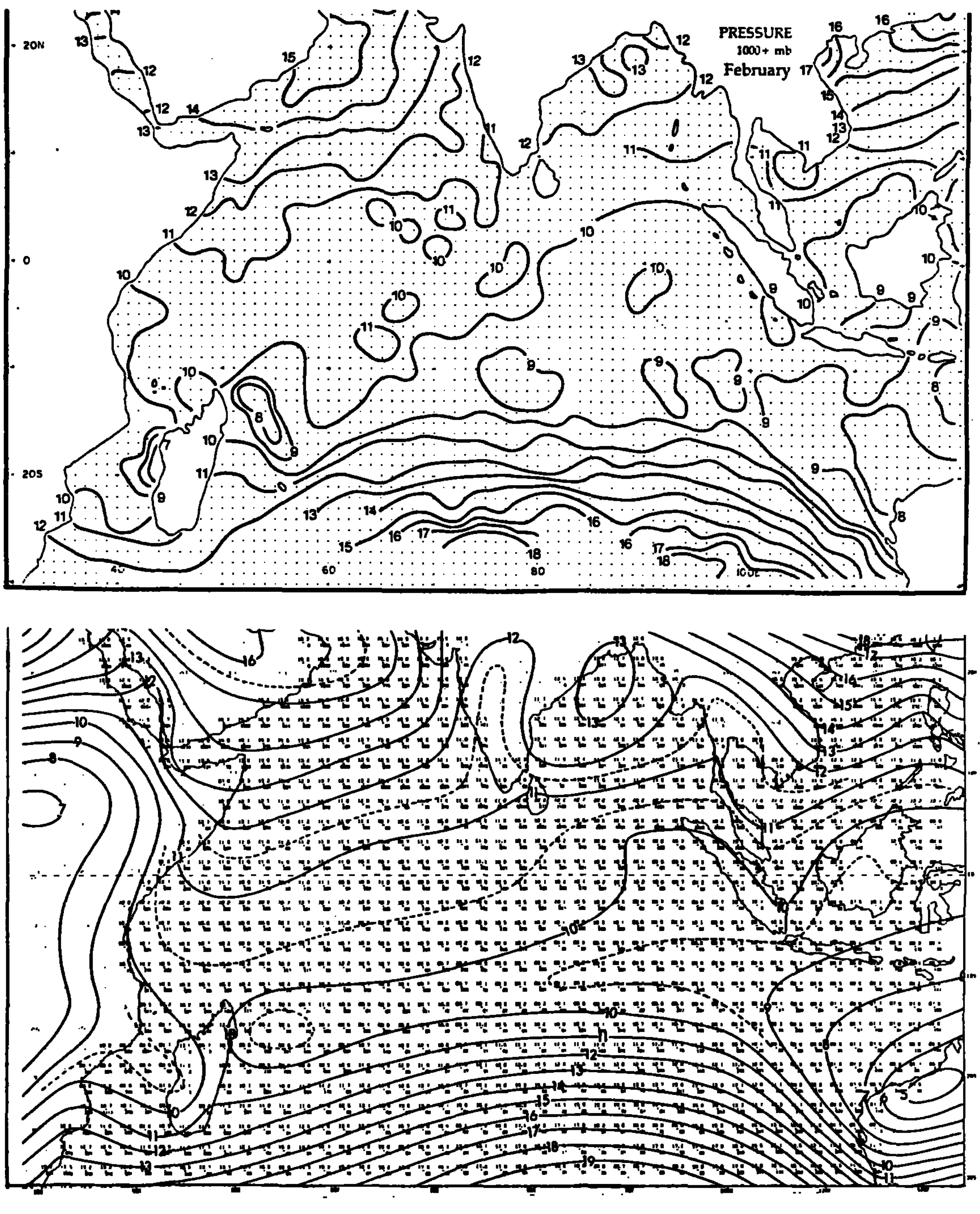

Figure 2. February long-term mean sea level pressure over the Indian Ocean: Top--From Hastenrath and Lamb (1979). Period of record 1911-1970. Bottom--Analysis of COADS. Period of record 1900-1979.

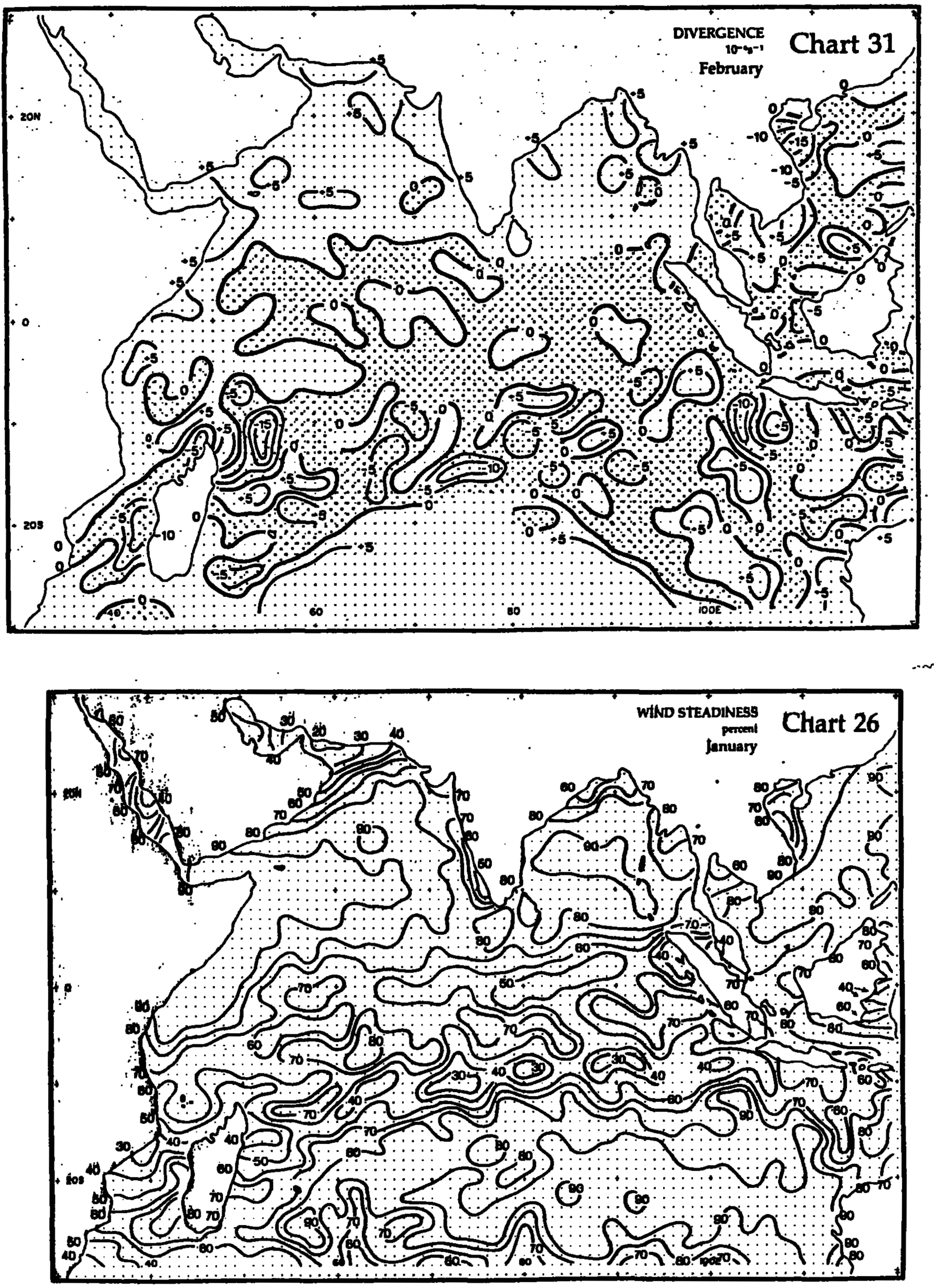

Figure 3. February divergence (top) and wind steadiness (bottom) from Hastenrath and Lamb, 1979.

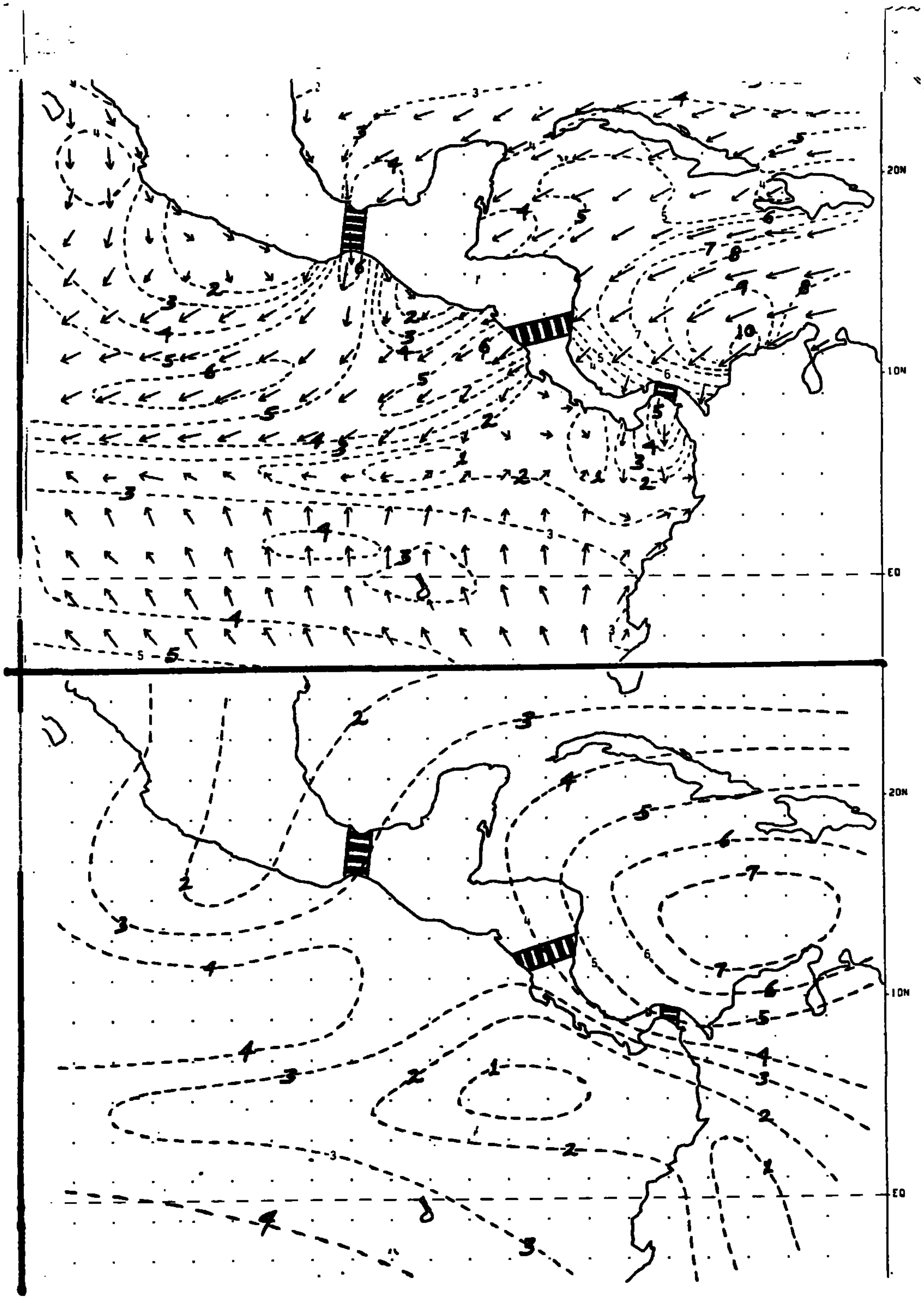

Figure 4. January long-term mean vector wind speed: Top--Our analysis of the COADS (1900-1979); Bottom--CAC climatology by Reynolds.

SURFACE WIND STRESS FROM MONTHLY MEAN WINDS

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The current emphasis on air-sea interaction over the global tropical oceans in relation to climate and climate forecasting has led to another international program of increased tropical observations and monitoring called Tropical Ocean Global Atmosphere (TOGA). A major component of TOGA is the surface wind field for deriving the surface wind stress. There are insufficient observations to determine the wind field over the tropical oceans on a daily or even a weekly time scale. However, a reasonable subjective analysis is possible on a monthly time scale by combining observations from ships, satellites and low-lying islands (Sadler and Kilonsky, 1985). We produce monthly mean wind fields in this manner and from them the pseudowind stress, using simply the mean vector wind speed squared. This paper concerns the search for a relationship to adjust the pseudostress toward the correct stress.

Thompson et al. (1983) developed and tested a formula for calculating the wind stress from monthly mean data knowing the variance of individual data about the long-term mean. This suggested to us that since (1) wind steadiness (ratio of vector mean to scalar mean) is a measure of the wind variability and (2) wind steadiness in the tropics is related to the mean vector wind speed then (3) the ratio of the true stress to the pseudostress would also be related to the monthly mean vector wind--which is available from our routine analyses. Using analyses of the COADS long-term mean (1900-1979) data we first compared the large-scale patterns of wind steadiness and vector wind speed. Figure 1, an example from the Atlantic and eastern Pacific, illustrates the excellent relationship between the two patterns. Next we analyzed the ratio of the pseudostress (which we calculated from the mean winds) and the correct stress (which COADS calculated from the individual observations). Figure 2 (bottom) is the analysis of this ratio for July over the Indian Ocean together with the analysis of the July vector wind speed. Qualitatively the patterns are remarkably similar. We next sought the quantative relation between the two by using the data from 2° by 2° grids between 30N and 30S which contained at least 300 observations. Some 1200 points per LTM month, or about one out of four met these criteria. Table 1 compares the coefficients of determination for the quadratic and exponential regression calculations and the exponential curves for the annual, January and July relationships are shown in Fig. 3.

The excellent correlations sparked a hurried test for the workshop. Two analyses for comparison are shown in Fig. 4. There is very good correspondence between the patterns and the values differ by less than 10% in most areas. Improvements will be made by adjusting the regression curves to better fit the data on the upper and lower ends (see Fig. 3).

Thanks to COADS, we now have a simple method to obtain the surface wind stress from monthly mean winds.

Table 1. Summary of regression calculations

Month	R^2-Coefficient of Determination		Number of Observations
	$Y=A+Bx+Cx^2$	$Y=A+B\exp(Cx)$	
January	0.7964	0.7925	1,238
February	0.7934	0.7919	1,193
March	0.7939	0.7958	1,264
April	0.8686	0.8702	1,192
May	0.9151	0.9148	1,224
June	0.9121	0.9133	1,186
July	0.9018	0.9036	1,242
August	0.8966	0.8897	1,261
September	0.8982	0.8935	1,189
October	0.8762	0.8738	1,215
November	0.8086	0.8043	1,208
December	0.7843	0.7781	1,230
Annual	0.8594	0.8591	14,642

References

Sadler, J. C., and B. J. Kilonsky, 1985: Deriving surface winds from satellite observations of low-level cloud motions. *J. Climate Appl. Meteor.*, 24, 758-769.

Thompson, K. R., R. F. Marsden, and D. G. Wright, 1983: Estimation of low-frequency wind stress fluctuations over the open ocean. *J.P.O.*, 13, 1003-1011.

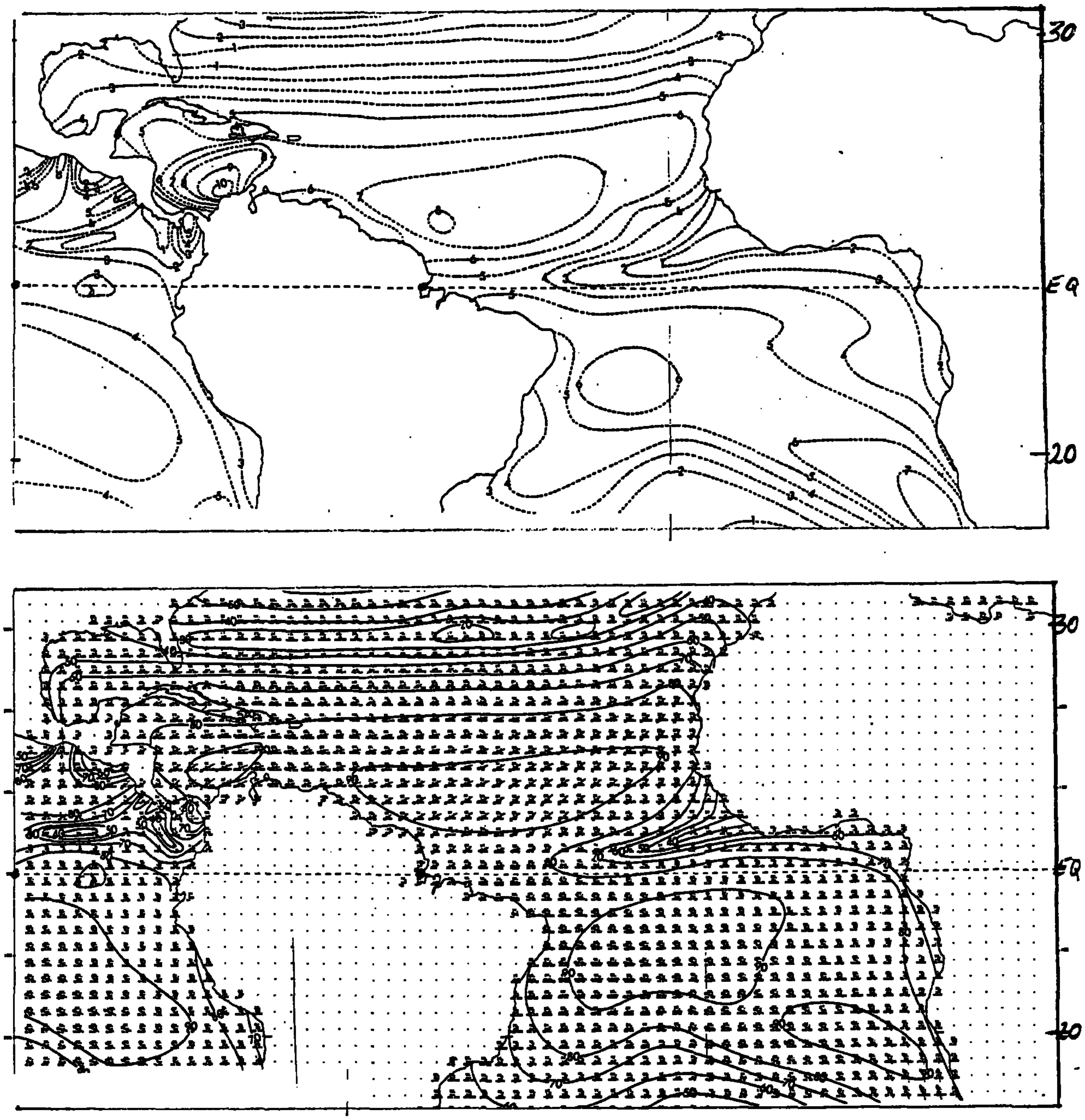

Figure 1. January long-term means (1900-1979) from COADS data. Top: Vector wind speed in m/sec; bottom: wind steadiness in percent.

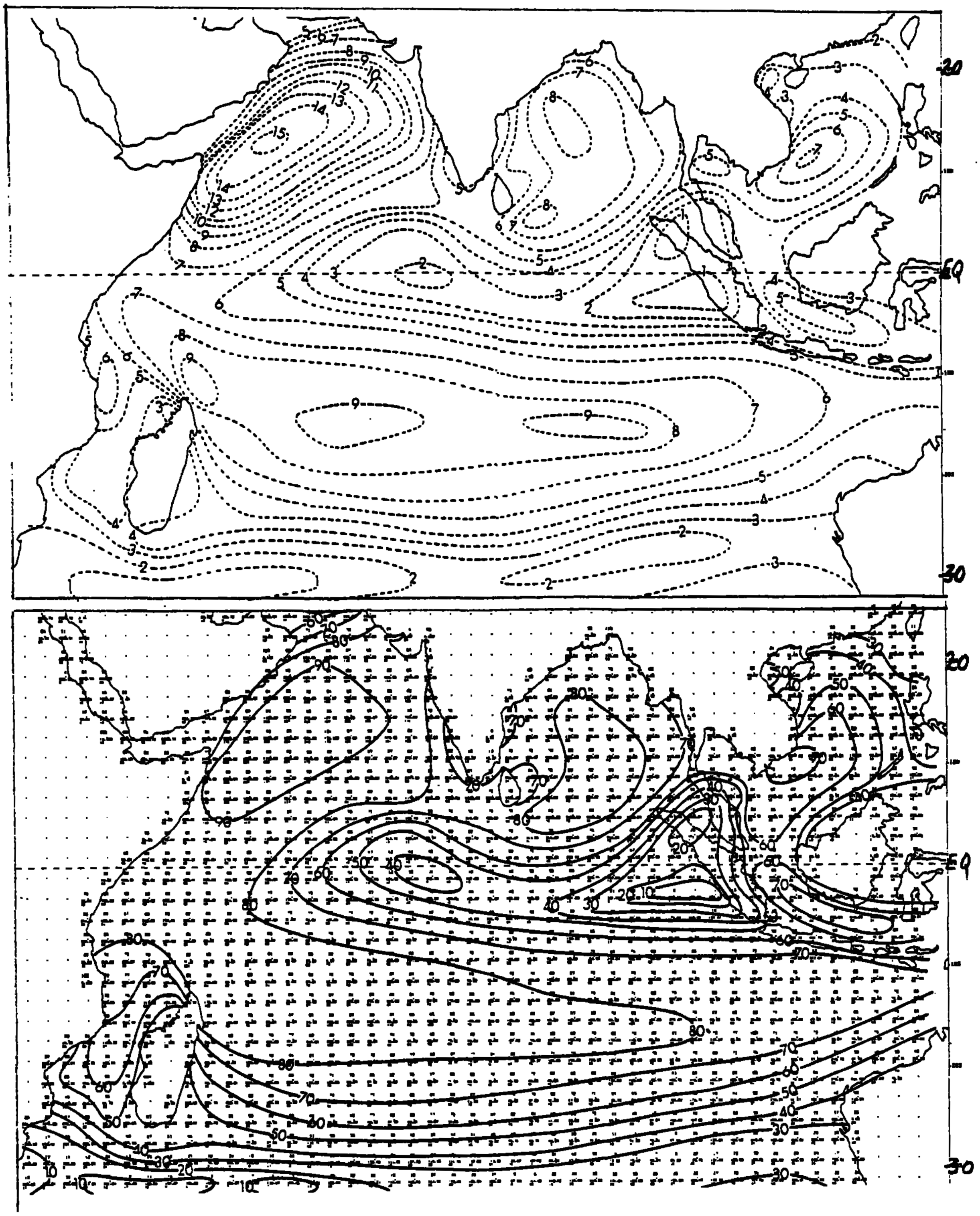

Figure 2. July long-term means (1900-1979) from COADS data. Top: Vector wind speed in m/sec; bottom: wind steadiness in percent.

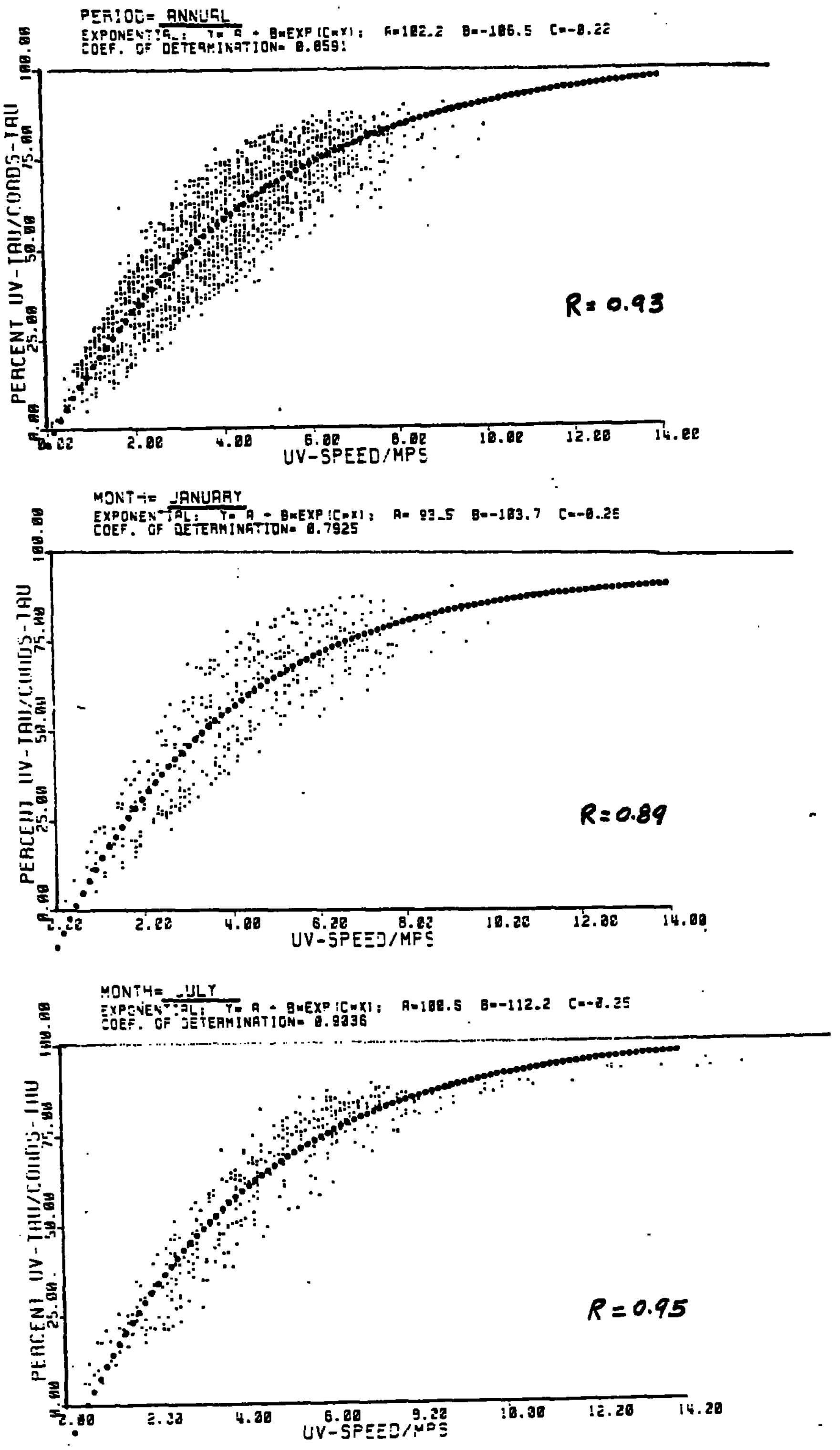

Figure 3. Relationship between mean vector wind speed (m/sec) and ratio of pseudostress to the correct stress. Derived from long-term mean (1900-1979) COADS data using 2° by 2° grids containing ≤ 300 observations. Top: Annual; Middle: January; Bottom: July. Dotted lines are exponential curves of best fit.

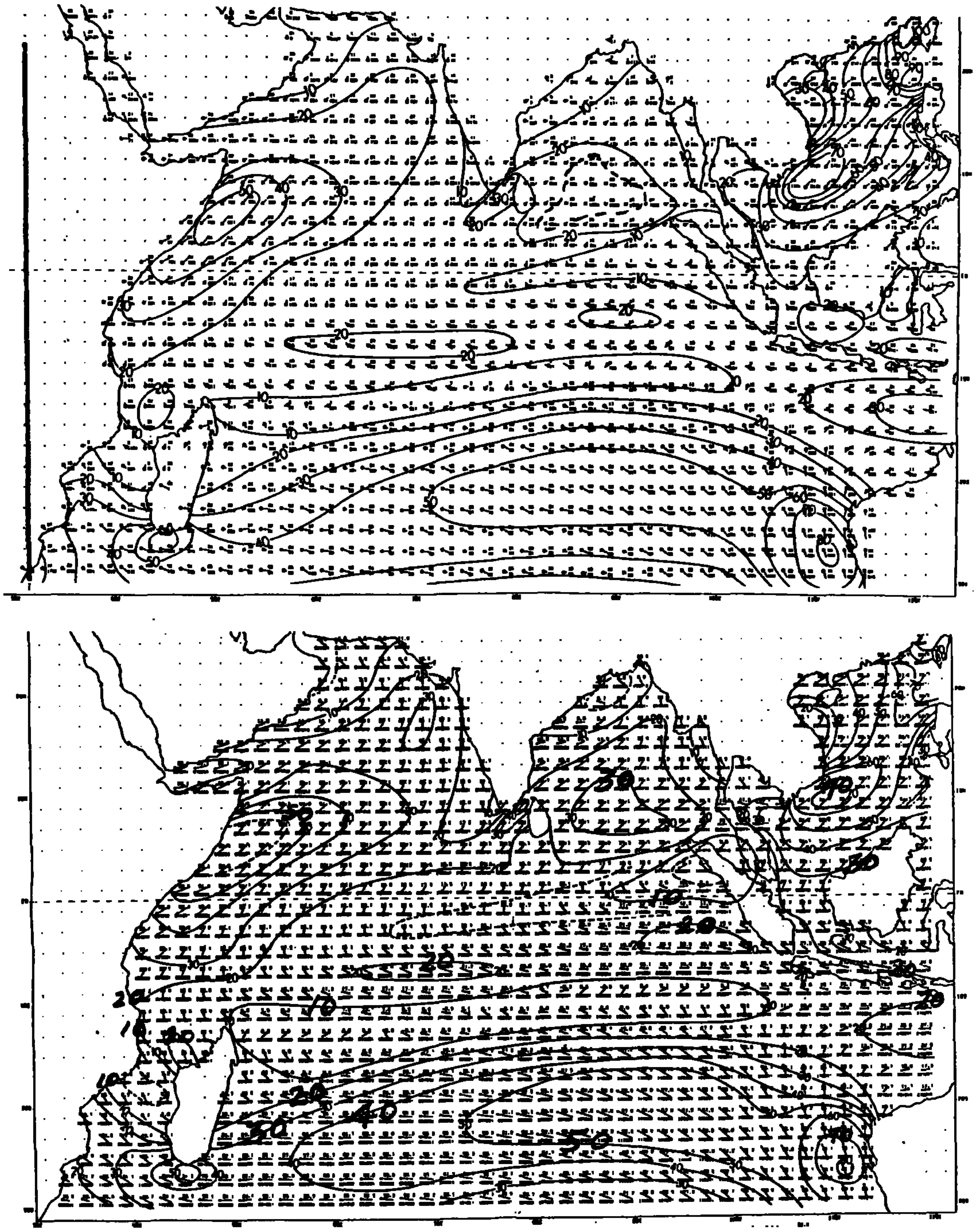

Figure 4. February long-term mean (1900-1979) wind stress. Top: Calculated in correct manner (from individual observations) by COADS; bottom: calculated from LTM winds using the February exponential regression curve similar to that shown in Fig. 3.

COADS:
A Climatological Atlas and Other Uses
at NCAR

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The COADS is being used by scientists within NCAR's Climate Section in a variety of ways. It is being used to derive a global climatological atlas for the period 1950-79, inclusive, and to study precursors to ENSO events. In the near future month-to-month sea surface temperatures (SST's) from the COADS will be used to force NCAR's Community Climate Model (CCM) to study the affect upon precipitation patterns and amounts Africa. Brief summaries of each of these uses will now be presented.

Climatological Atlas

Monthly surface air temperature, precipitation, sea-level pressure and sea surface temperature from two historical data sets are used to derive some statistical estimates of the climate between 40°S and 90°N for the period 1950-79, inclusive. The historical data sets are the Global Monthly Surface Station Data Set (GMSSDS; Shea and Spangler, 1985), primarily based upon observations from land stations, and the Comprehensive Ocean-Atmosphere Data Set (COADS), primarily based upon observations from ships of opportunity. Among the quantities mapped, by objective means, are: (a) the ***mean***, (b) the ***interannual variability***, (c) the skewness, (d) the kurtosis, (e) the difference between the mean and the median, (f) the lag one year autocorrelation coefficient, (g) a robust estimate of the linear trend, (h) the first three eigenvector patterns, (i) the ***annual range***,

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† The National Center for Atmospheric Research is sponsered by the National Science Foundation.

(j) the *amplitude*, the phase and the percent variance explained by the *first* and second harmonics of the mean annual cycle, and (k) the interannual variability about the quantities listed in (j). Items (a) through (h) are presented for all months, the four conventional seasons and on an annual basis. The italicized quantities are presented in printed form while all other quantities are presented on microfiches. The maps included in this atlas should provide useful background fields against which new measurements may be compared and interpreted. In addition, examples of the monthly, seasonal and annual sampling networks are shown.

In order to be a candidate for inclusion in the atlas a time series was required to have a minimum of 10 years of monthly values. Each 2° box monthly value from the COADS was required to have been derived from a minimum of 3 observations before being included in a time series.

Figure 1 shows the distribution of 2° boxes for sea surface temperature (SST) for January. Figures 2, 3 and 4 show derived patterns for the mean, the interannual variability and the annual ranges of SST. Stippled areas indicate areas of sparse or nonexistent data coverage.

ENSO Precursors

van Loon and Shea (1985) used data from the GMSSDS and the COADS to investigate the precursors to the extremes of the Southern Oscillation, called Warm Events (WE) and Cold Events (CE). They demonstrate that, in the fall of the year before a WE,the SST's in the area bounded between 15°S and 45°S and west of $\approx$ 150°W is *consistently* warmer than normal. As there were several instances where this warming does occur and a WE does not, this condition appears to be a necessary but not sufficient in the sequence leading to a WE.

Community Climate Model Experiment

Recently Lau (1985) used observed month-to-month SSTs for the period 1962-1976, between 30°S and 30°N in the Pacific, to force the GFDL general circulation model. The purpose was to asess the capability of that model to simulate relevant ENSO features. An analogous experiment will be made by scientists using the NCAR CCM. The experiment will use month-to-month SST's from the COADS for the period 1970-1984 in the Atlantic Ocean to force the CCM. Particular emphasis will be placed upon analyzing the evolution of precipitation patterns and amounts over Africa.

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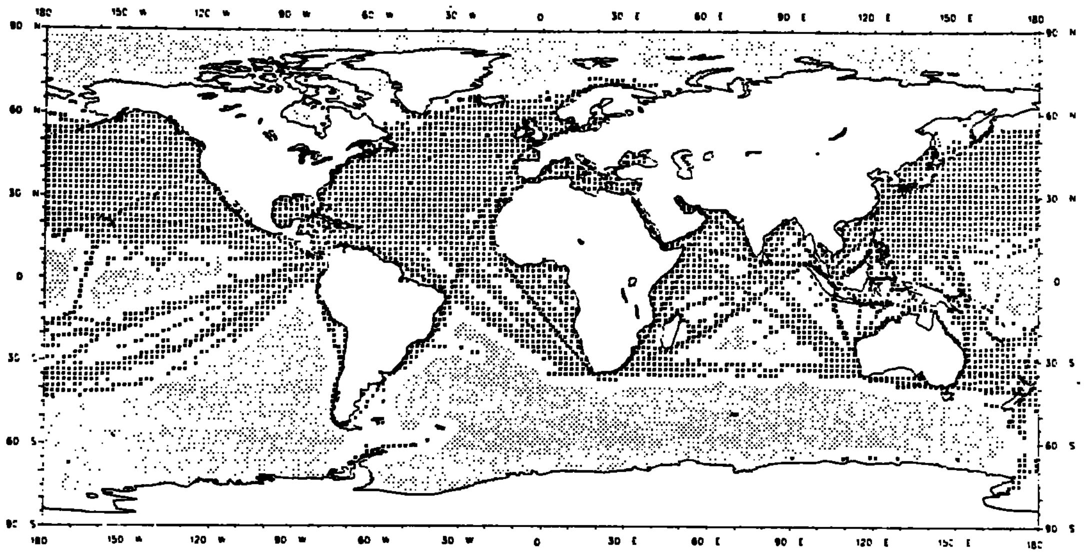
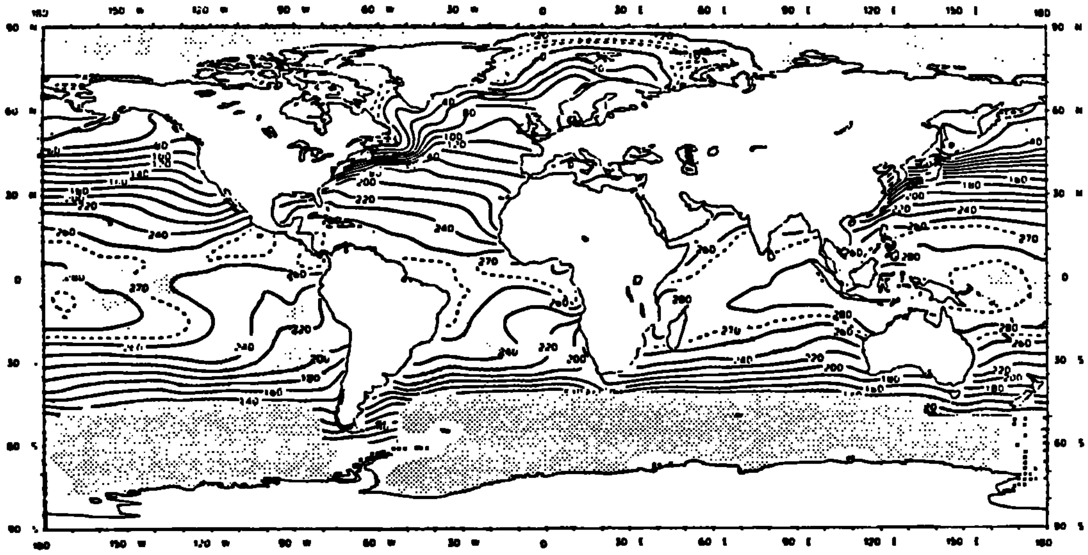
van Loon, H., and D.J. Shea (1985): The Southern Oscillation. Part IV: The Precursors South of 15° S to Extremes of the Southern Oscillation. *Mon. Wea. Rev.,113.* 2063-2074.



JANUARY
LOCATION OF BOXES USED FOR SEA SURFACE TEMPERATURE COMPUTATIONS
1950 - 1979 (10)

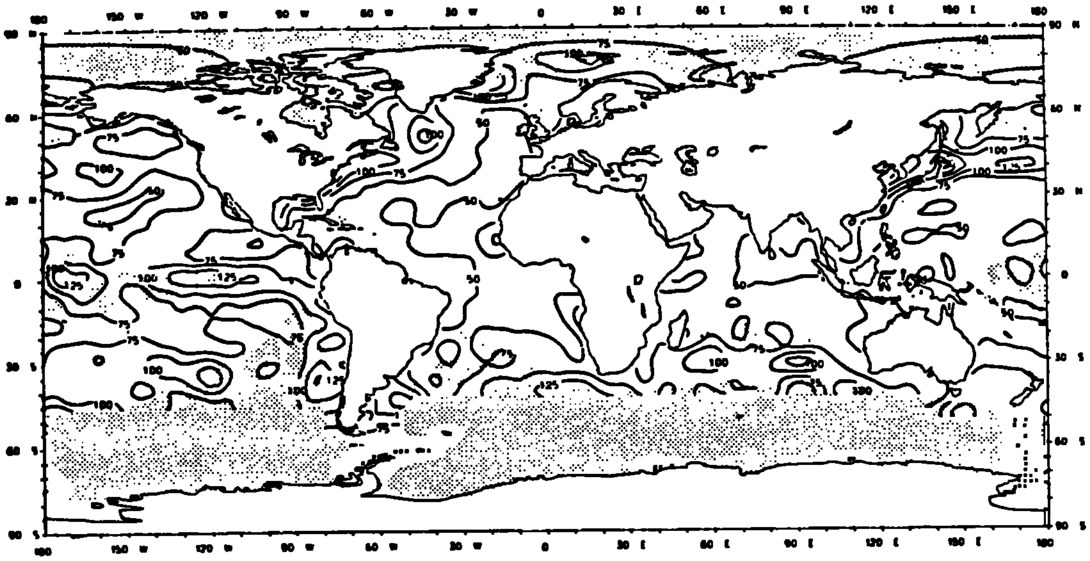
Fig. 1



JANUARY
MEAN SEA SURFACE TEMPERATURE (0.1 °C)
1950 - 1979 (10)

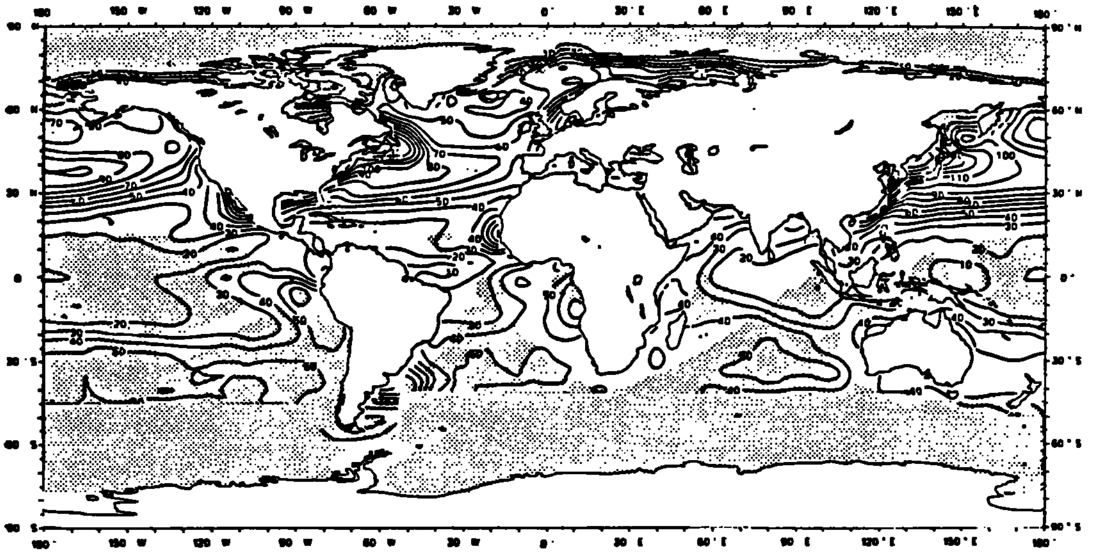
CONTOUR FROM -2.0 TO 40.0 , CONTOUR INTERVAL 2.00

Fig. 2



JANUARY
INTERANNUAL VARIABILITY OF SEA SURFACE TEMPERATURE (0.01 °C)
1950 - 1979 (10)
CONTOUR FROM 0.0 TO 10.0 , CONTOUR INTERVAL 0.25

Fig. 3



JANUARY - DECEMBER
ANNUAL RANGE OF MONTHLY SEA SURFACE TEMPERATURE (0.1 °C)
1950 - 1979 (10)
CONTOUR FROM 0.0 TO 30.0 , CONTOUR INTERVAL 1.00

Fig. 4

Climatology of Ocean Weather Stations

Henry F. Diaz, Colin S. Ramage and Scott D. Woodruff

1. Introduction

The weather observations taken at Ocean Weather Stations (OWS) in the Northern Hemisphere represent one of the best continuous records available over the world's oceans. These data have been taken over relatively fixed areas and by generally trained observers on Ocean Station Vessels (OSV). They therefore represent a valuable source of climate information in regions where the only other source of data comes from traveling ships. Observations were made regularly throughout the day, and hence can be used to study and compare both the diurnal and annual cycles in a number of ocean areas.

Figure 1 shows the location of 2° latitude x 2° longitude "study areas" centered on 17 selected stations; Table 1 summarizes the period of record and number of individual reports available. The number of non-OWS COADS reports in each study area is listed in Table 1 for comparison. In this preliminary report we present a sample climatology for OWS A located in the North Atlantic at 62°N, 33°W. A full compilation for all the OWS will be published as a NOAA/ERL report with support of NOAA's Equatorial Pacific Ocean Climate Studies (EPOCS) Program.

2. Atlas Contents

Following is a sample output from OWS A. Figure 2 gives the number of days per year-month with surface observations. This figure shows that the record is quite complete; for the most part, the number of observations for this OWS is representative of observation frequency for the other stations. The total number of days with observations for the 30 year period 1945-74 is 84% of the approximate total possible (9,203 out of 30 * 365 = 10,950 days).

Figure 3 shows the period of record averages by (three-hourly) synoptic time (GMT on the left, local time on the right). The upper left panel shows mean vector wind and contours of wind steadiness in percent (defined by ($|\vec{V}|$/W) x 100), where $\vec{V}$ is the mean vector wind and W is the scalar mean). The dashed lines delineate daytime versus nighttime hours. Sea level pressure is shown in the upper right and total cloud cover is at lower left. In the lower right panel the percentage frequency of observations reporting precipitation at the station is given. Note the well marked annual and diurnal variations in precipitation frequency.

Figure 4 shows mean air temperature, dew point depression (thus dew point values may be approximated by subtracting this value from the corresponding value of mean air temperature), sea surface temperature and sea-air temperature difference.

Figures 3 and 4 constitute the set of surface parameters to be included in the OWS atlas.

Upper air data are also available from twice daily soundings. They have also been summarized and are shown in Fig. 5. The parameters are mean vector wind, dew point temperature, air temperature and geopotential height. Monthly averages are plotted for selected pressure surfaces (left) at their mean geopotential height. The height scale on the right is based on the annual mean of the twelve monthly values.

Monthly anomalies of selected surface elements are shown in Figs. 6-10. These emphasize the nature of the temporal variations on the annual and interannual time scales at which both the air temperature (AT) and sea surface temperature (SST) anomalies display a significant amount of persistence. The scalar wind anomalies (not shown) do not exhibit as much temporal coherence. Humidity is represented by the dew point depression (Fig. 8); the amplitude of the annual cycle is approximately equal to the magnitude of the interannual variability, and there appears to be some temporal variation at lower frequencies.

As one would expect from this location, the sea level pressure field exhibits a fairly marked annual cycle (Fig. 9). There is also large interannual variance of monthly as well as annual mean pressure. Cloudiness variations (not shown) have a pattern that is fairly random. Sea-air temperature difference (not shown) displays temporal characteristics similar to those of AT and SST. Precipitation frequency (Fig. 10) is highly variable, being punctuated at the annual time scale by a few short periods of much above normal frequency and several years of slightly below normal frequency.

Temporal variations of air temperature at 200, 500 and 700 mb levels, and dewpoint temperature variations at 700 and 500 mb levels will be produced. For OWS A the anomalies (as one would expect) are vertically coherent between the 700 and 500 mb levels but reverse sign at 200 mb. Somewhat less coherence is evident for dew point temperature anomalies between the 700 and 500 mb levels.

Figure Legends

Figure 1	Map showing the location of 2° latitude x 2° longitude study areas centered on the Ocean Weather Stations (OWS).
Figure 2	The distribution by year and month of the number of OWS observations.
Figure 3	Period mean vector wind, sea level pressure, total cloudiness and precipitation frequency. Steadiness contours are shown with the wind graph. Also shown are local and GMT time, and daytime and nighttime hours for the station locations.
Figure 4	As in Fig. 3, except for air temperature, dew point depression, sea surface temperature and sea-air temperature difference.
Figure 5	Upper air averages for standard pressure levels for vector wind, dew point temperature, air temperature, and geopotential height.
Figure 6	Trends of surface air temperature by month and years.
Figure 7	As in Fig. 6, except for sea surface temperature.
Figure 8	As in Fig. 6, except for dew point depression.
Figure 9	As in Fig. 6, except for sea level pressure.
Figure 10	As in Fig. 6, except for precipitation frequency.

Table 1

Comparison of the periods of record for OSV, CLIMAT, and NCAR RAOBS data and the number of reports for OSV and COADS data for OSV Study Areas

OSV Study Area	Period of Record for OSV*	Period of Record for CLIMAT RAOBS	Period of Record for NCAR RAOBS	Number of Reports**	
				OSV	Unique COADS
A	1945–74	1950–73	—	68110	33477
B	1946–74	1950–74	1949–74	67593	31717
C	1945–82	1950–73	1949–73	78939	41376
D	1945–73	1950–73	1949–73	65536	47724
E	1949–73	1950–73	1949–73	64451	48750
H	1945–74	1950–77	1946–77	6462	54166
I	1947–75	1950–75	—	47599	21995
J	1948–75	1950–75	1969–71	64270	58263
K	1949–82	1950–76	1954–70	66523	56937
L	1950–82	1975–82	1949–49	11029	38551
M	1949–82	1952–75	1970–71	73637	68843
N	1946–74	1950–74	1949–74	66363	45996
P	1949–80	1950–81	1946–74 1961–80***	84612	38054
R	1954–82	1958–82	1958–59	6830	38677
T	1948–80	1956–81	1950–70	34262	27245
V	1955–72	1951–71	1951–72	47133	40437
X	1947–53	—	1950–53	15623	987

* Available data at the Study Area location

** After duplicate elimination and from the period of overlap between OSV and COADS data

*** Reports for Ship P are listed under two headings in the NCAR RAOBS dataset — "Ship P" (1946–74) and "Ocean Weather Station P" (1961–80)

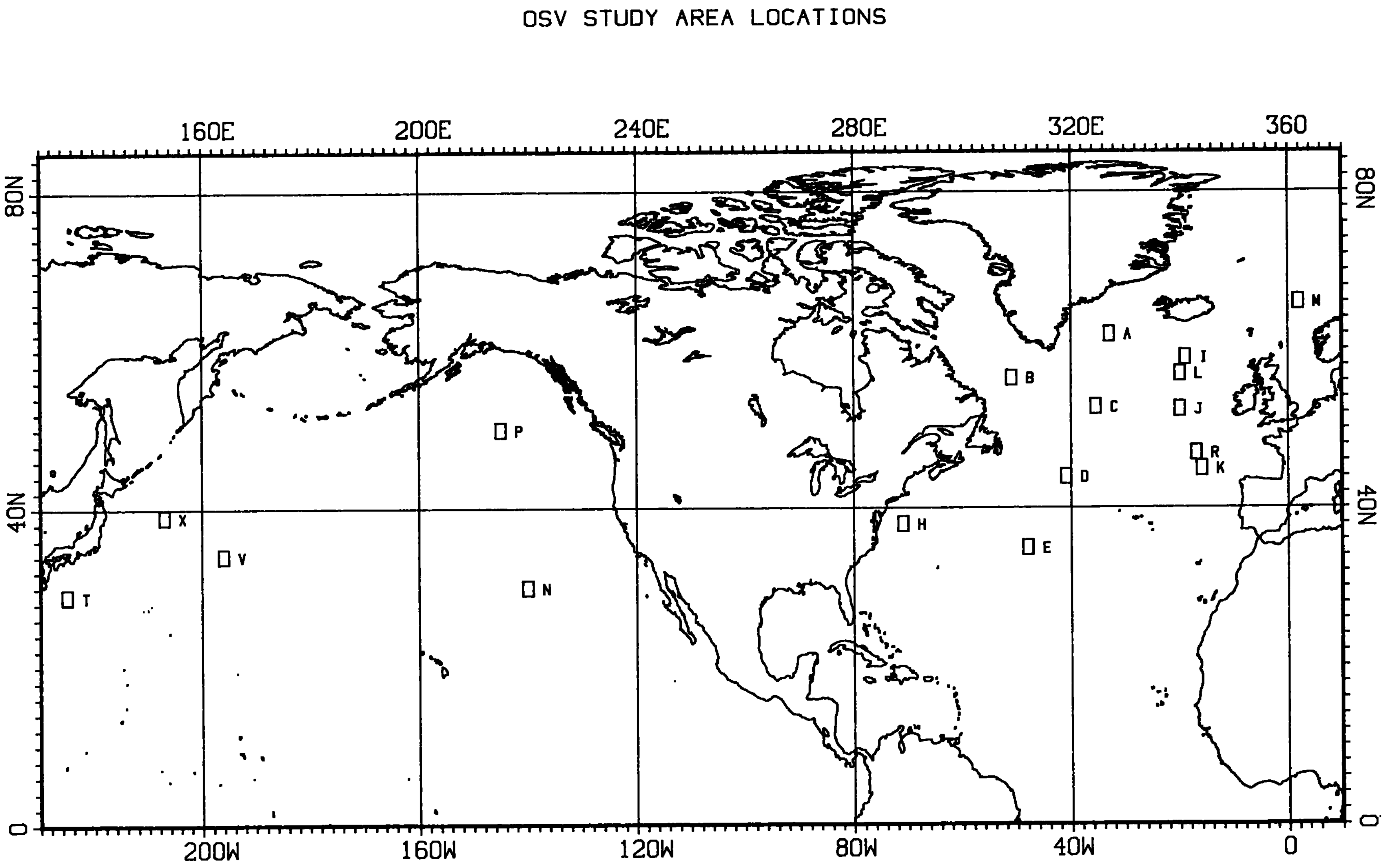

OSV STUDY AREA LOCATIONS
160E
200E
240E
280E
320E
360
80N
40N
0
200W
160W
120W
80W
40W
0
A
B
C
D
E
H
I
J
K
L
M
N
P
R
T
V
X

Figure 1

FREQUENCY OF SURFACE OBSERVATIONS (DAYS/MONTH)

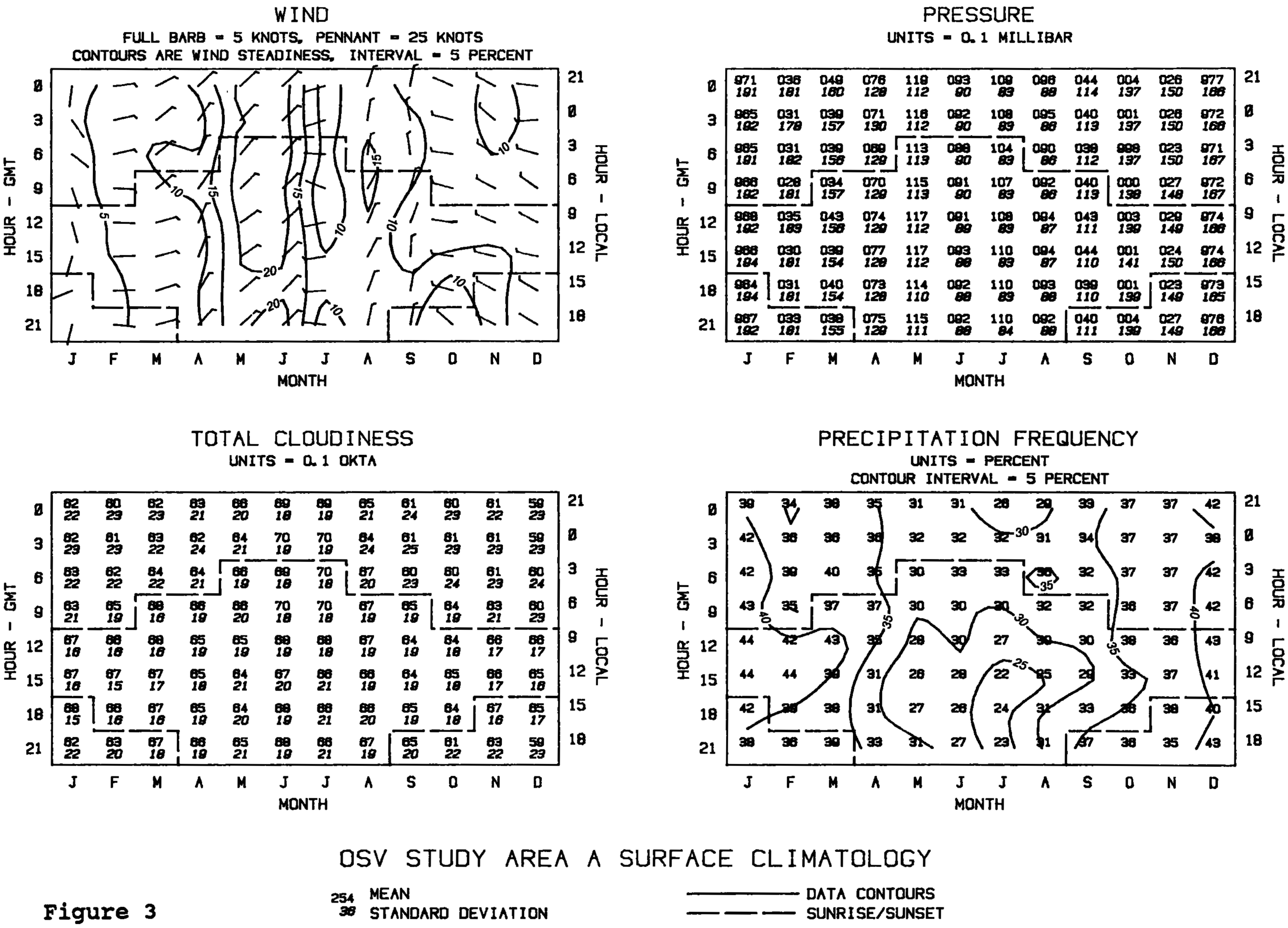
MONTH	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	SUM
J		28 18	31 31	31 31	31 31	31 31	27 27	18 18	11 10	31 31	30 30	29 29	24 23	29 29	30 30	28 28	24 24	31 31	31 31	24 24	31 31	29 29	31 31	28 28	30 30	30 30	31 31	25 25	25 24	5 5	784 771
F		26 19	28 28	29 29	28 28	28 28	28 28	23 23	11 10	28 28	27 27	25 25	28 28	26 26	19 19	25 25	22 22	24 24	28 28	23 23	28 28	27 27	28 28	12 12	27 27	27 27	27 27	9 9	22 17	16 16	699 688
M		31 23	31 31	31 31	28 28	30 30	31 31	31 30	26 25	31 31	27 27	28 28	30 30	28 28	29 29	29 29	30 30	24 24	31 31	31 31	31 31	31 31	26 25	17 17	31 31	31 31	30 30	27 27	27 27	14 14	822 811
A	15 6	29 19	30 30	30 30	30 30	28 28	30 30	30 30	19 18	30 30	29 29	30 30	26 26	26 26	29 29	24 23	30 30	29 29	29 29	30 30	29 29	30 30	30 30	27 27	30 30	29 29	29 28	25 24	22 19	5 4	809 782
M	5 1	16 8	31 31	31 31	29 29	31 31	26 26	17 15	31 30	31 29	31 31	31 31	28 28	24 24	24 24	31 31	31 31	31 31	29 29	29 29	28 28	30 30	31 31	30 30	26 26	28 28	31 31	14 14	16 15		771 753
J		15 12	29 29	30 30	29 28	30 30	30 29	18 18	30 30	30 12	30 30	30 30	29 29	27 27	30 30	30 30	30 29	30 30	30 30	7 7	30 30	30 30	29 29	30 30	30 30	28 28	24 24	20 19	25 25		760 735
J				31 31	31 30	22 22	31 31	31 31	24 10	31 31	30 30	31 31	31 31	29 25	31 31	31 31	30 30	31 31	27 27	31 31	30 30	31 31	31 31	31 31	27 27	27 27	22 22	29 29	15 14		746 726
A		26 10		31 31	31 31	31 31	23 22	28 28	28 22	31 31	27 25	31 31	29 29	31 31	31 31	31 31	31 31	31 31	31 31	31 31	30 30	31 31	30 30	31 31	30 30	31 31	21 19	21 21	7 7		768 738
S		30 22	4 4	30 30	29 29	26 26	20 20	21 4	27 27	30 30	29 29	30 30	28 28	30 30	27 27	30 30	28 28	29 29	30 30	30 30	30 30	30 29	29 29	30 30	30 30	30 30	14 12	20 20	22 22		743 715
O		31 23	29 29	31 31	31 31	21 21	31 27	22 20	31 31	31 31	31 31	31 31	27 27	29 29	29 29	31 31	30 30	31 31	30 30	31 31	29 29	31 31	30 30	31 31	31 31	30 30	25 25	26 26	13 13		804 790
N		30 22	30 30	30 30	30 30	28 28	29 13	30 30	19 18	30 30	25 25	30 30	27 27	30 30	30 30	30 30	21 21	30 30	29 29	30 30	28 28	30 30	30 29	30 30	29 29	28 28	16 14	14 14	5 4		748 719
D	1 1	31 29	31 31	31 31	29 29	2 2	31 31	14 14	31 31	31 31	30 30	31 31	31 31	31 31	30 30	31 31	30 30	31 31	29 29	30 30	30 30	31 31	27 27	31 31	30 30	28 28	14 14	12 12	12 6		751 743
ANN	21 8	293 205	274 274	366 366	356 354	308 308	337 315	283 261	289 262	365 345	346 344	357 357	338 337	340 336	339 339	351 350	337 336	352 352	354 354	327 327	354 354	361 360	352 350	328 328	351 351	347 347	284 277	242 240	211 199	40 39	9203 8969

YEAR

OSV STUDY AREA A (62.0 N, 33.0 W)

Figure 2

EACH OF THE 11 VARIABLES WAS OBSERVED ON 'X' DAYS OF EACH MONTH.
THE UPPER NUMBER IS THE MAXIMUM 'X' FROM AMONG ALL THE VARIABLES.
THE LOWER NUMBER IS THE MINIMUM 'X' FROM AMONG ALL THE VARIABLES.



PRESSURE

UNITS = 0.1 MILLIBAR

HOUR - GMT	J	F	M	A	M	J	J	A	S	O	N	D	HOUR - LOCAL
0	971 191	036 181	049 160	076 128	119 112	093 90	109 83	096 88	044 114	004 137	026 150	977 166	21
3	965 192	031 178	039 157	071 130	116 112	092 90	108 83	095 86	040 113	001 137	028 150	972 168	0
6	965 191	031 182	039 156	069 129	113 113	088 90	104 83	090 86	038 112	998 137	023 150	971 167	3
9	966 192	028 181	034 157	070 128	115 113	091 90	107 83	092 86	040 113	000 138	027 148	972 167	6
12	968 192	035 189	043 156	074 129	117 112	091 89	108 83	094 87	043 111	003 139	029 149	974 166	9
15	966 194	030 181	039 154	077 128	117 112	093 88	110 83	094 87	044 110	001 141	024 150	974 166	12
18	964 194	031 181	040 154	073 128	114 110	092 88	110 83	093 88	039 110	001 139	023 149	973 165	15
21	967 192	033 181	038 155	075 128	115 111	092 88	110 84	092 88	040 111	004 139	027 149	976 166	18

MONTH

TOTAL CLOUDINESS

UNITS = 0.1 OKTA

HOUR - GMT	J	F	M	A	M	J	J	A	S	O	N	D	HOUR - LOCAL
0	62 22	60 23	62 23	63 21	66 20	69 18	69 19	65 21	61 24	60 23	61 22	59 23	21
3	62 23	61 23	63 22	62 24	64 21	70 19	70 19	64 24	61 25	61 23	61 23	59 23	0
6	63 22	62 22	64 22	64 21	66 19	69 18	70 18	67 20	60 23	60 24	61 23	60 24	3
9	63 21	65 19	66 16	66 19	66 20	70 18	70 18	67 19	65 19	64 19	63 21	60 23	6
12	67 16	68 16	68 16	65 19	65 19	68 19	68 18	67 19	64 19	64 18	66 17	66 17	9
15	67 16	67 15	67 17	65 18	64 21	67 20	66 21	66 19	64 19	65 18	66 17	65 16	12
18	66 15	66 16	67 16	65 19	64 20	68 19	68 21	66 20	65 19	64 18	67 16	65 17	15
21	62 22	63 20	67 18	66 19	65 21	68 19	66 21	67 19	65 20	61 22	63 22	59 23	18

MONTH

PRECIPITATION FREQUENCY

UNITS = PERCENT

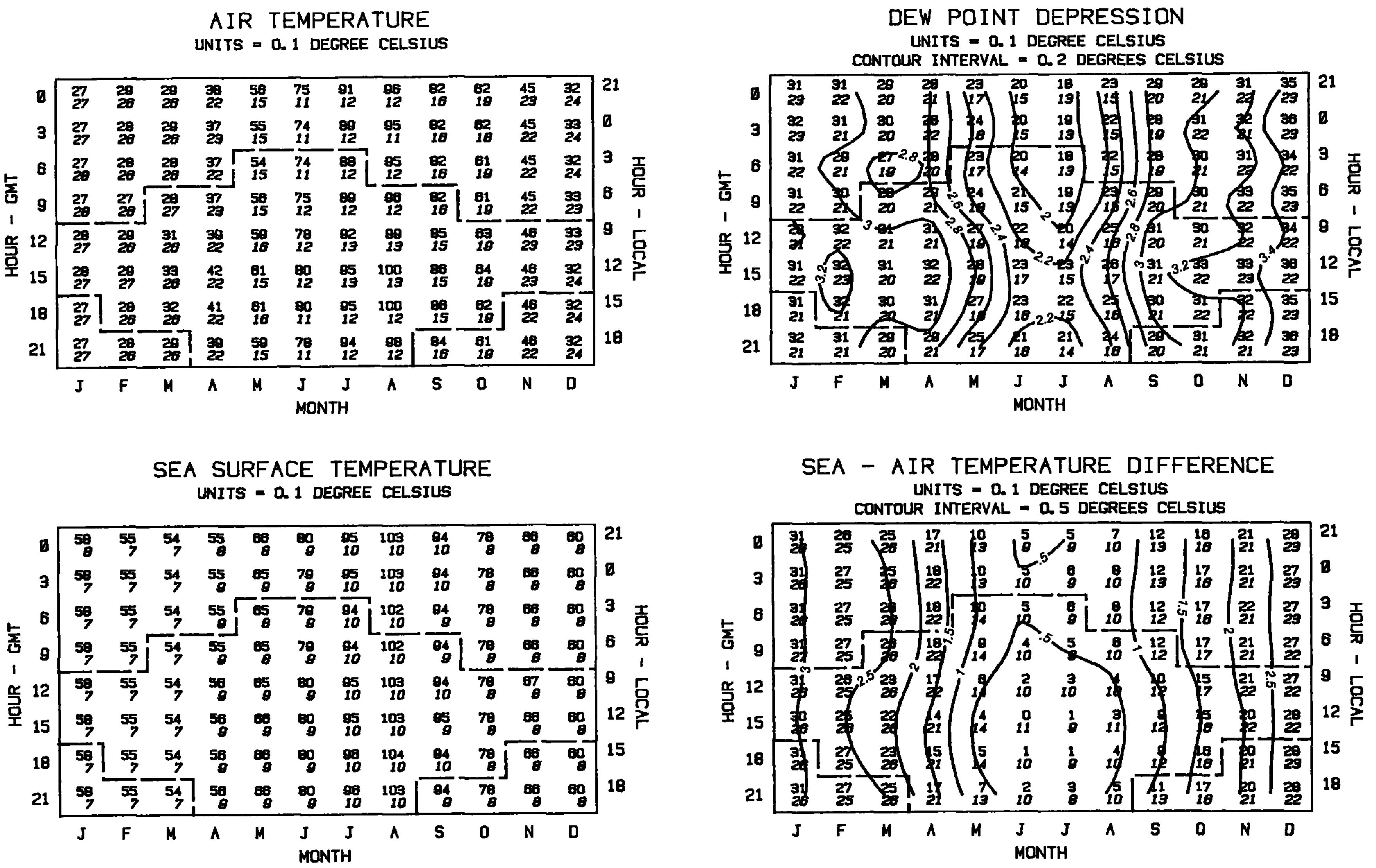
CONTOUR INTERVAL = 5 PERCENT

HOUR - GMT	J	F	M	A	M	J	J	A	S	O	N	D	HOUR - LOCAL
0	38	34	38	35	31	31	28	29	33	37	37	42	21
3	42	36	36	36	32	32	32	31	34	37	37	38	0
6	42	38	40	35	30	33	33	36	32	37	37	42	3
9	43	35	37	37	30	30	30	32	32	38	37	42	6
12	44	42	43	35	28	30	27	30	30	38	36	43	9
15	44	44	39	31	28	28	22	25	29	33	37	41	12
18	42	38	38	31	27	28	24	31	33	36	38	40	15
21	39	36	39	33	31	27	23	31	37	38	35	43	18

MONTH

OSV STUDY AREA A SURFACE CLIMATOLOGY

Figure 3



OSV STUDY AREA A SURFACE CLIMATOLOGY

Figure 4

254 MEAN
36 STANDARD DEVIATION

DATA CONTOURS
SUNRISE/SUNSET

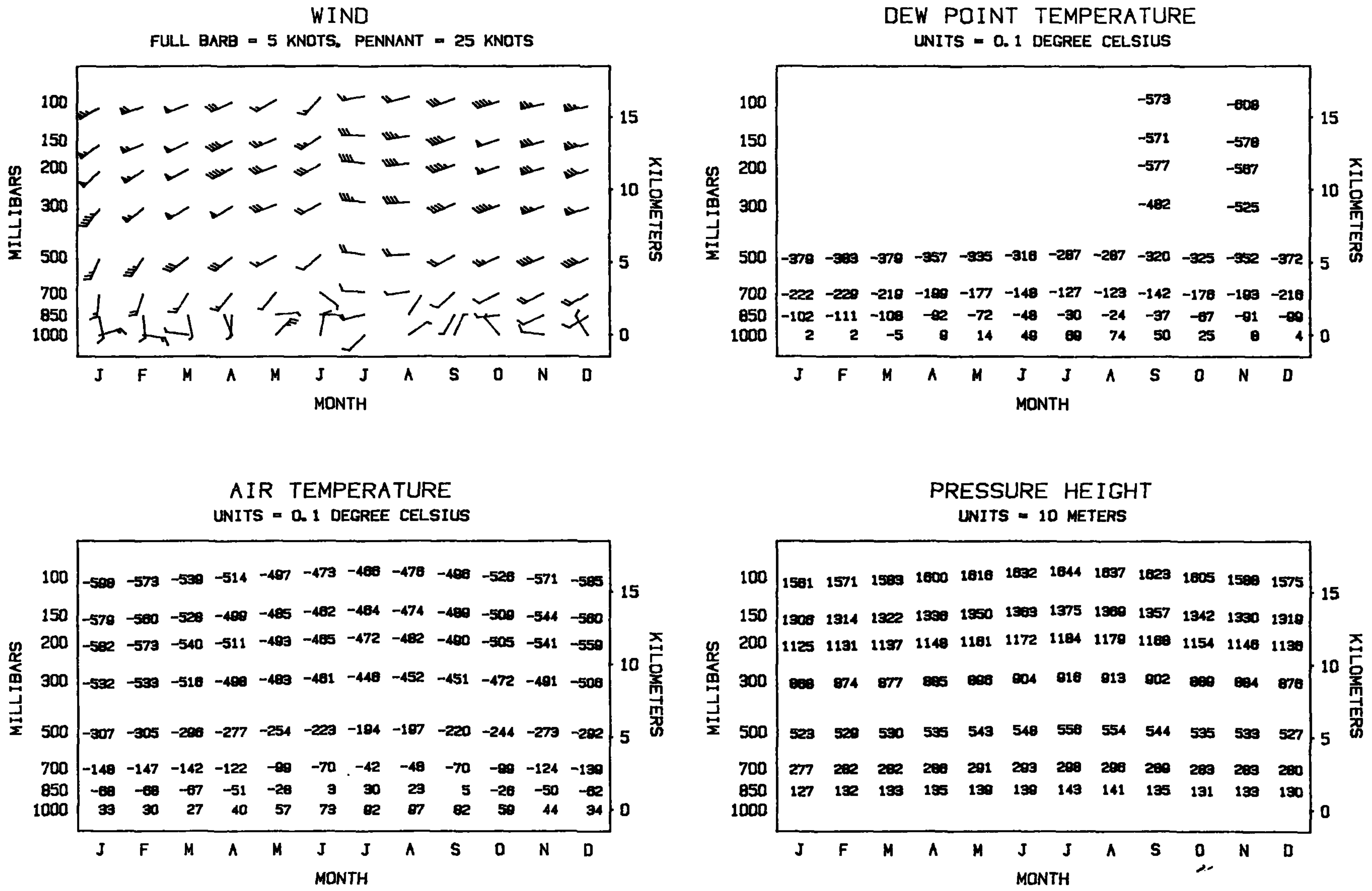


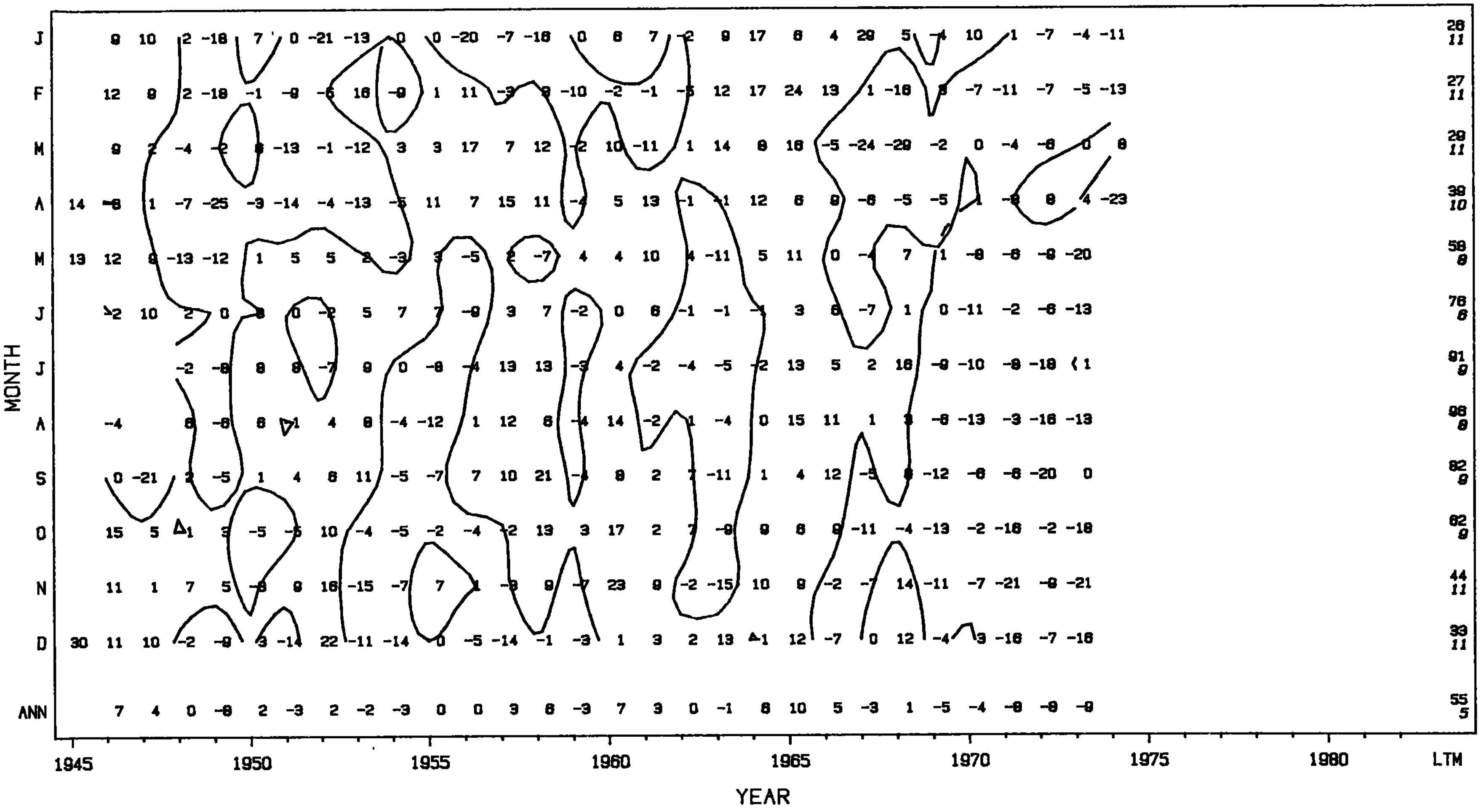
Figure 5

OSV STUDY AREA A UPPER AIR CLIMATOLOGY

MEAN PLOTTED AT ACTUAL HEIGHT

SURFACE AIR TEMPERATURE

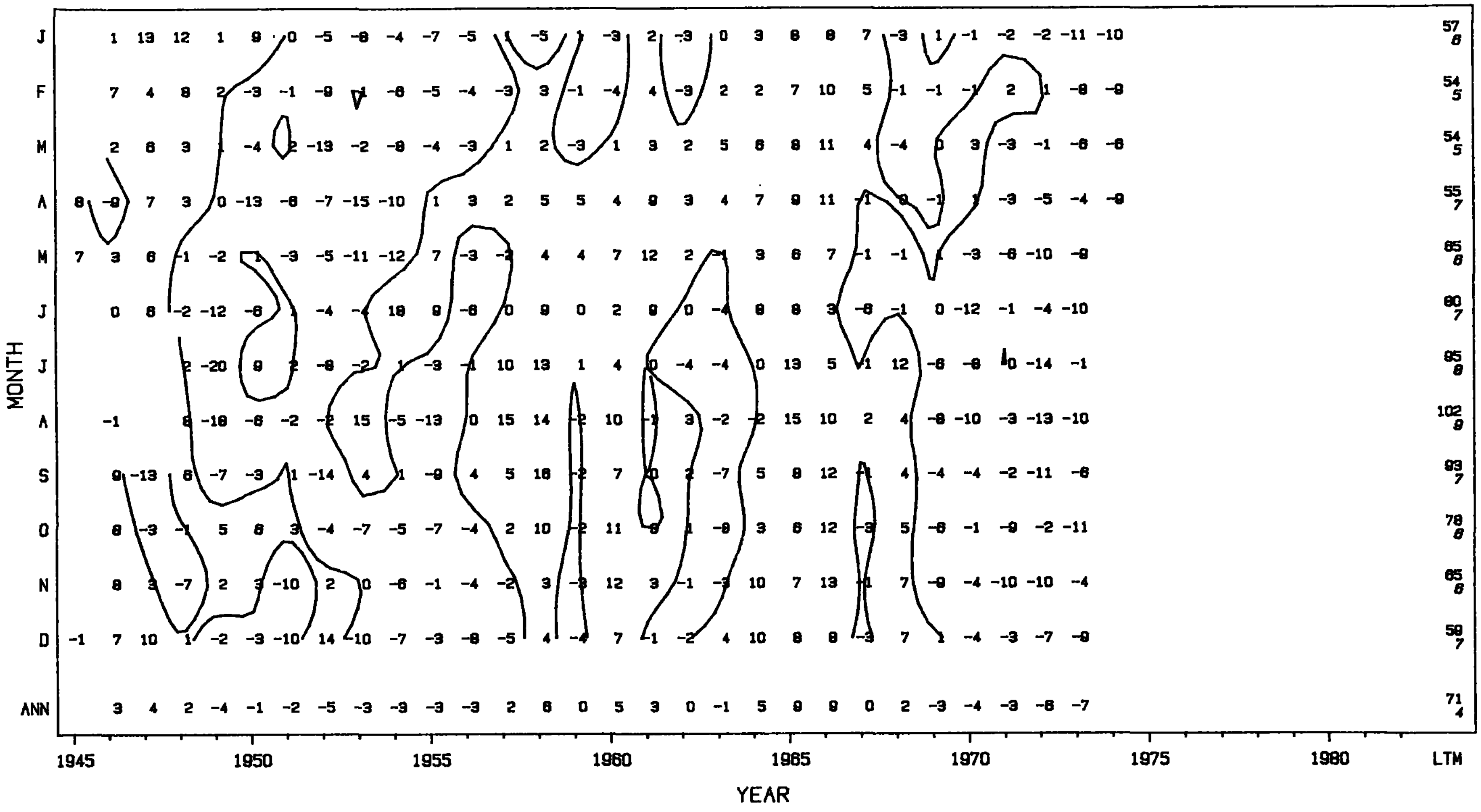
UNITS = 0.1 DEGREE CELSIUS



OSV STUDY AREA A ANOMALIES

——— ZERO-ANOMALY CONTOUR

Figure 6



SEA SURFACE TEMPERATURE

UNITS = 0.1 DEGREE CELSIUS

OSV STUDY AREA A ANOMALIES

——————— ZERO-ANOMALY CONTOUR

Figure 7

SURFACE DEW POINT DEPRESSION

UNITS = 0.1 DEGREE CELSIUS

MONTH	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	LTM
J		-2	-4	-3	-3	-1	7	11	10	7	-2	10	-16	8	-1	-6	-7	5	5	-9	-2	1	-12	3	8	-3	-1	2	-5	2	31 7
F		-1	-1	-7	-6	15	8	4	0	15	3	-12	-7	-1	5	-7	-1	-1	2	-14	-12	-4	-3	8	0	11	-2	2	2	2	32 7
M		-1	10	-4	-9	0	4	1	12	-1	5	0	3	-9	-1	-6	-1	0	1	0	1	-1	4	0	-1	-3	-5	4	-3	-1	30 5
A	-3	2	-3	11	5	6	7	-3	23	6	-13	1	-8	7	-7	-15	-1	5	4	-1	8	2	3	-6	-5	-1	-6	-5	-17	3	30 8
M	-7	-6	-4	6	5	2	-8	11	4	-5	1	-2	-8	9	-3	-7	-1	4	8	-1	-7	7	-6	-1	2	-2	-2	-1	12		28 6
J		13	-1	3	-7	0	-4	1	-3	-2	-1	6	-1	-5	4	5	9	-4	-7	8	-2	0	4	8	-6	-2	-5	-10	-1		21 6
J				-4	-10	-3	-4	-1	7	1	-4	-1	-4	10	-5	2	4	-4	-3	-2	-3	2	7	5	10	7	6	-7	-8		20 8
A		4		-6	-3	1	1	3	5	-5	-7	2	-6	16	-4	-1	-5	0	-2	0	2	6	0	9	-9	-5	5	1	-1		24 6
S		-6	28	6	4	-5	-9	-3	2	5	-7	-4	8	-9	-13	3	-13	2	6	6	3	5	-4	-2	5	5	-1	0	-10		30 8
O		-16	-10	6	-7	7	3	-2	17	10	-3	2	-4	2	-14	-1	-14	4	-7	4	-5	10	0	6	1	3	3	1	2		31 8
N		2	-4	1	1	-4	-1	-6	13	9	-17	-1	-7	3	-3	-1	-6	6	4	-1	2	25	1	-2	8	6	-13	-9	4		31 6
D	-16	-7	-5	-5	11	2	1	-12	3	7	6	-1	9	1	9	11	7	6	-8	7	-9	9	2	-2	-11	1	1	-1	-14		34 8
ANN		-1	0	0	-2	2	0	0	6	4	-3	0	-3	3	-3	-2	-3	2	0	0	-2	5	0	2	0	1	-2	-2	-3		28 3

1945 1950 1955 1960 1965 1970 1975 1980 LTM

YEAR

OSV STUDY AREA A ANOMALIES

Figure 8

SEA LEVEL PRESSURE

UNITS = 0.1 MILLIBAR

MONTH	1945					1950					1955					1960					1965					1970					LTM
J		-128	-83	-88	1	-70	-83	-34	-22	40	100	72	-102	25	181	99	-81	-106	278	71	11	109	101	0	170	-23	27	-138	-124	-204	9953 *111*
F		14	176	-69	-158	-110	-60	94	76	-91	83	72	-25	61	-133	97	-161	22	14	-15	189	-1	-134	139	125	23	-80	-55	-40	-54	10031 *99*
M		-18	94	-136	46	1	126	21	-19	-55	119	-126	16	94	-164	-41	-13	197	-87	-61	50	22	-61	-114	63	120	45	-91	1	-19	10039 *88*
A	26	-10	-90	11	-48	11	63	-69	90	6	-66	69	-4	-28	-19	-35	-47	-40	18	0	-35	-24	-17	58	-31	29	48	85	175	-108	10076 *60*
M	-47	8	-42	35	40	56	4	133	34	27	2	-91	-7	93	-13	-46	18	43	-67	-63	20	-44	41	47	40	-116	-50	-38	-19		10117 *55*
J		16	-25	26	8	-7	55	35	-27	16	8	38	59	35	-10	11	-72	-13	29	-55	-30	-28	-65	-17	-31	-16	98	-21	-13		10091 *39*
J				10	12	-31	-14	8	-6	-9	-76	29	34	50	-30	10	-2	52	10	-72	32	10	3	75	-58	-9	29	-44	-15		10108 *37*
A		14		-3	8	-44	35	59	-34	-9	-76	61	-21	45	12	77	-44	-7	7	73	-23	56	-29	30	-6	5	-68	-47	-70		10088 *44*
S		-13	97	27	60	-54	-13	123	-2	20	-75	18	96	-23	-37	-36	-73	0	-57	49	17	26	-13	13	-15	-14	-104	-25	7		10041 *53*
O		43	10	-9	-5	-42	-30	-51	-48	-41	108	-3	-103	-41	-103	133	-20	-4	-102	16	-21	145	-16	112	-35	57	1	106	-60		9999 *89*
N		37	90	-50	-73	-18	-3	75	-121	-129	52	-44	49	-94	-39	-68	3	51	17	-12	127	64	-14	-25	66	23	47	-139	129		10028 *73*
D	17	-112	72	-49	-17	209	-170	70	-111	-63	-7	-146	3	16	-125	-59	135	40	62	37	-64	-26	53	53	45	137	13	-154	143		9985 *98*
ANN		-13	30	-25	-10	-8	-7	39	-16	-24	13	-4	0	19	-40	12	-30	20	10	-3	23	25	-13	31	28	18	0	-47	8		10048 *22*

1945 1950 1955 1960 1965 1970 1975 1980 LTM

YEAR

OSV STUDY AREA A ANOMALIES

Figure 9

PRECIPITATION FREQUENCY

UNITS = 0.1 PERCENT

MONTH	1945					1950					1955					1960					1965					1970					LTM
J		499	-83	-124	-110	-62	-61	-33	94	-18	-151	45	6	113	-37	-18	21	102	-84	-19	-45	-120	2	7	49	47	70	-37	124	-180	430 125
F		494	-214	-27	84	-55	-54	-77	-72	-14	-92	-73	-65	-61	37	-87	12	133	-1	-97	32	53	101	-118	-125	74	90	28	9	86	395 125
M		553	-241	-77	0	-8	-36	29	76	-37	-42	-65	-84	-88	-1	14	9	-35	56	8	-123	30	15	-45	-26	31	134	33	-24	-36	399 127
A	101	541	-135	-125	137	-124	15	38	-111	-115	8	-2	-80	-91	-37	62	35	-8	-49	-18	-44	31	18	-146	53	-13	89	8	-129	106	361 129
M	888	543	-134	-99	-32	-54	-17	-179	-171	-22	-154	-16	48	-115	-41	88	0	-52	-29	-73	40	22	47	-22	-129	5	13	-8	-105		332 182
J		844	-91	-32	-73	-62	-36	-1	-32	-105	-7	9	-61	23	44	-45	-31	-20	-10	-80	-16	-33	98	-75	18	100	-96	49	-37		320 137
J				-31	37	-62	-39	-3	-44	-73	111	-51	7	-99	44	-112	51	6	2	34	-13	65	-43	-20	47	-6	-104	1	291		278 81
A		285		-138	-80	39	-6	-75	1	32	92	-100	98	-160	-8	-105	84	37	-74	31	14	-81	-17	6	153	27	-93	13	48		318 93
S		473	-230	-185	-75	40	-95	-74	0	-125	-39	-15	-180	74	0	98	21	17	75	29	-23	133	-89	34	18	-14	70	81	-37		333 127
O		379	-5	-182	-92	-92	41	15	-149	-55	-139	-13	8	6	93	-113	-61	74	48	-17	108	-138	-12	54	97	-41	119	-24	91		376 113
N		558	-72	-119	-82	-187	31	-3	-36	-58	9	15	-57	114	65	10	-6	-15	-98	81	75	-28	56	4	-223	29	89	-70	-124		391 137
D	585	511	93	-73	-45	-185	50	-173	-44	-74	-47	-42	-115	-9	-59	27	-188	-13	-148	-35	20	53	31	-11	63	-104	18	3	-87		435 188
ANN		498	-111	-101	-26	-69	-17	-45	-41	-55	-38	-27	-40	-24	10	-17	-3	19	-26	-13	2	-1	17	-28	-1	11	32	7	2		383 100

1975 1980

YEAR

OSV STUDY AREA A ANOMALIES

Figure 10

FOURIER ANALYSIS OF SST CLIMATOLOGIES

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Results of Fourier analyses of objectively analyzed fields of two monthly sea surface temperature climatologies for the world ocean are presented. One of the climatological fields used are the monthly one-degree objectively analyzed fields described by Levitus (1982) which are based on approximately 1.5 million temperature soundings held by the National Oceanographic Data Center (NODC), Washington, D.C. In addition, results are presented from the Fourier analysis of an objectively analyzed sea surface temperature climatology based on a subset of the 70 million historical merchant ship reports (COADS) described by (Slutz et al., 1985).

Our motivation for comparing the data sets was based on three reasons. Firstly, the annual cycle of sea surface temperature is a parameter of prime importance for the study of air-sea interactions and climate. Comparing analyses based on data gathered from different observing systems could yield information regarding the robustness of various features of the annual cycle. Secondly, the much greater data density of the COADS file had the potential to yield information in some areas not observable in the relatively sparse research ship data. Thirdly, by inference, the comparison of the two data sets should yield some information regarding the reliability of the subsurface temperature analyses.

There is excellent agreement of the first two harmonics between the two sea surface temperature climatologies. In the Northern Hemisphere maxima in the amplitude of the first harmonic (Figs. 1 and 2) are found off

Japan (approximately 7.5°C - 8.0°C) and off the east coast of the United States (8.0°C - 9.0°C off Cape Hatteras) and Canada (8.0°C in the Gulf of St. Lawrence). In the Southern Hemisphere open ocean maxima of 3.0°C - 4.0°C are found at latitudes 28°S to 32°S in the Pacific, Atlantic and Indian Oceans. In the tropics of the eastern Atlantic and eastern Pacific maxima appear as tongues extending from the continents to the northwest. Another maximum is observed along the east coast of South America centered at 35°S, 58°W with a value of about 5.5°C.

The results presented are the first global estimates of these quantities and are in agreement with previous results published in the literature for limited ocean domains. A more complete comparison is being prepared for publication which shows the phase of each harmonic and the percent variance of the annual cycle contributed by each harmonic. Agreement between the two climatologies is good for these fields. Disagreement between the two climatologies exists in some regions of the Southern Hemisphere where the NODC holdings are sparse. Most of the disagreement between the two fields occurs in the third and higher frequencies.

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Acknowledgments

The analysis of the COADS observations is being carried out as a joint project with Bram Oort and Mary Jo Nath.

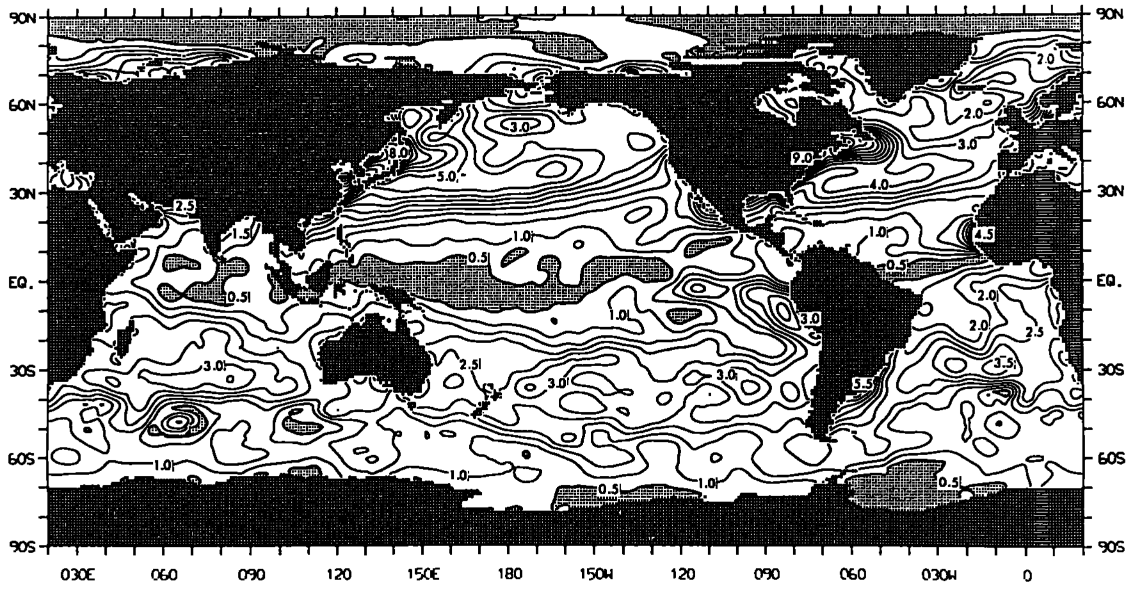

Fig. 1: Amplitude (°C) of the first harmonic of sea surface temperature based on the NODC historical data set. Shading indicates amplitudes less than 0.5°C.

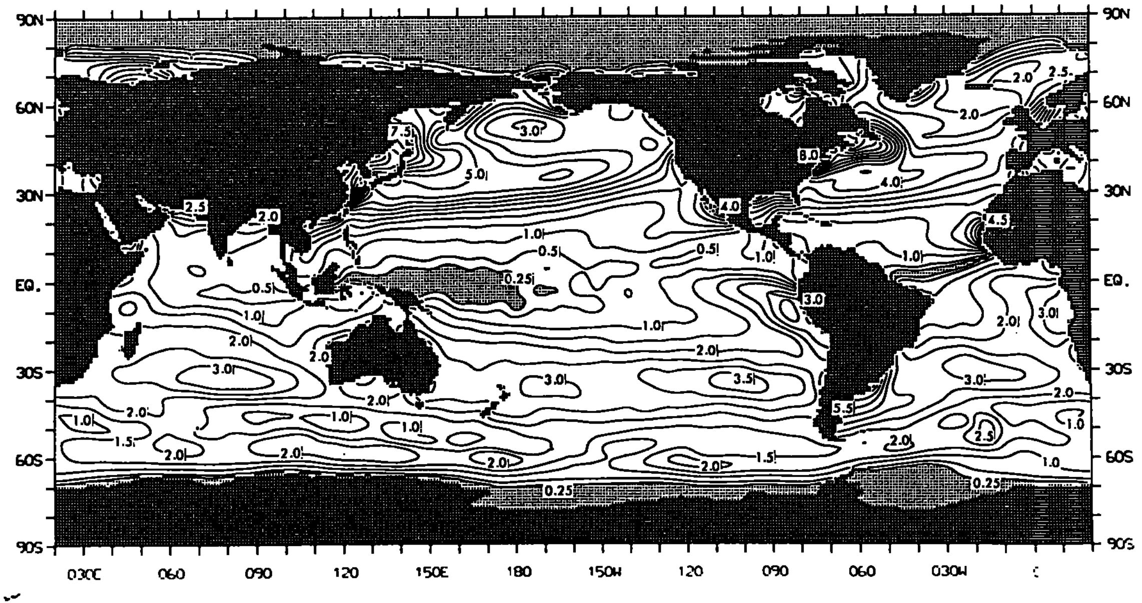

Fig. 2: Amplitude (°C) of the first harmonic of sea surface temperature based on COADS historical data set. Shading indicates amplitudes less than 0.25°C.

Presentation during COADS Workshop
January 22-24, 1986
Boulder, Colorado

Interannual Variability of Surface Marine Fields

by

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Since early 1985 we have made frequent use of the Comprehensive Ocean-Atmosphere Data Set (COADS) for climate research in the Observational Studies Group at GFDL. We have studied mainly the 2° latitude by 2° longitude averaged statistics of sea surface temperature (SST) contained in the Monthly Summary Trimmed Groups (MSTG) as described in the COADS report by Slutz et al. (1985).

The focus in this presentation will be on possible climatic trends in the zonal mean SST anomalies. We chose to study the trends in five 10° latitude wide belts at 50°-60°N, 20°-30°N, 10°S-0°, 30°-20°S and 60°-50°S, where 41, 62, 76, 77 and 99% of the total area is covered by oceans, respectively. The number of input data for the five belts is shown in Fig. 1. North of 30°S there is an apparent steady growth in the number of observations with time except for the deep dips during World Wars I and II. However, in middle and high latitudes the data distribution was actually better in the late 19th and early 20th century than at present, connected with more (whaling and other commercial) shipping in those latitudes around the turn of the century.

To look at the climatic trends a long-term climatology was generated based on the 1950-1979 data north of 20°S and south of that latitude based on all historical data. Then for each month of the 110-year period (January 1870 through December 1979) the SST anomaly fields were analyzed using Levitus' (1982) objective analysis scheme. This project constituted a large computational effort because each analysis required about one minute CPU time on the CDC Cyber 205 system.

The analyzed zonally averaged SST anomalies are shown in Fig. 2. Although no instrumental corrections were applied to the SST data the curves are similar to the most recent estimates by Folland et al. (1985) for the two hemispheres. (A reasonable correction to our data for the change from uninsulated bucket to engine-intake measurements around 1940 might be to raise the pre-1940 tropical values by about 0.3°C. No corrections would be needed in the extratropics; see Folland, et al. 1984; Oort and Maher, 1985).

> We find at all latitudes an early warm period in the SST from 1870 to about 1900, a strong cooling between 1900 and 1910, a cold period between 1910 and 1930, and a heating between 1930 and 1940. Since about 1940 the SST's have been quite warm. Interesting is the tendency for a cooling during the 1960's and 70's in the Northern Hemisphere mid and high latitudes and a heating in the corresponding latitudes in the Southern Hemisphere.

For comparison, we present in Fig. 3 also curves of the zonal mean SST anomalies based on the original, unanalyzed 2°x2° input data. Remarkable is the close correspondence between Figs. 2 and 3, except at 60°-50°S where the number of data points (see Fig. 1) is perhaps below a critical value ($N \approx 400$ or about 30 input values per month in a 10° belt?) Although the unanalyzed curves are somewhat more ragged, the general agreement between the two sets is encouraging in the sense that the method of analysis does not materially affect the results, at least in the case of these zonal averages.

Finally, we present in Fig. 4 curves of the standard deviations showing the level of spatial variability within the 10° latitude belts based on the 2°x2° input data only. The standard deviation estimates are found to be quite stable and steady, hardly varying with time.

Acknowledgments

We thank Syd Levitus, Mary Jo Nath, Mel Rosenstein and Mark Forman for their joint efforts to produce the basic sea surface temperature analyses.

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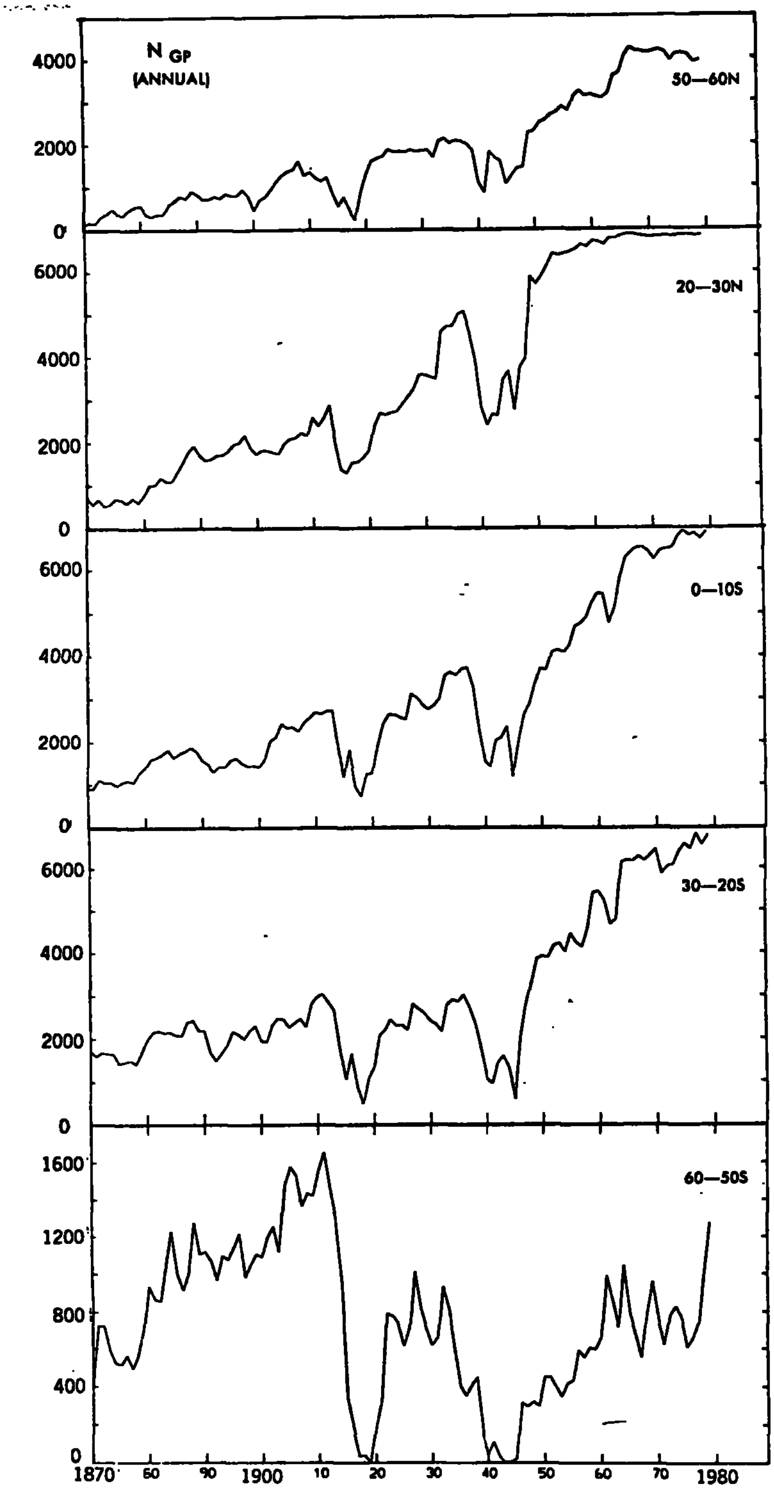

Fig. 1. Time evolution of the number of monthly 2° latitude by 2° longitude boxes containing sea surface temperature data for various 10°-wide latitudinal belts. The plotted values represent sums over individual years (for example, a value of 1200 indicates that there are, on the average, 100 2°x2° boxes with SST data for each month of the year considered).

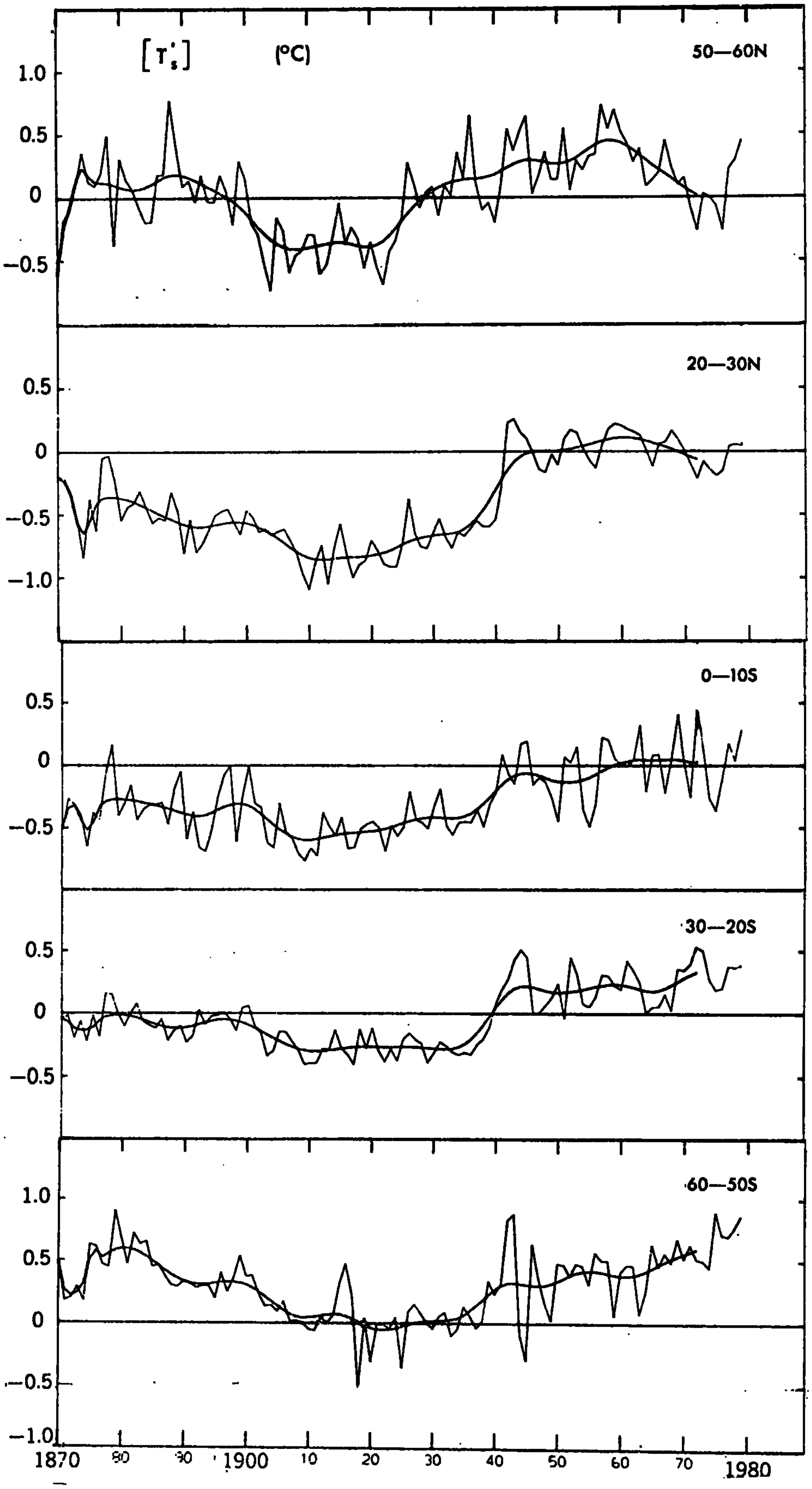

Fig. 2. Time series of the zonally averaged SST anomalies (in °C) based on the objectively analyzed global maps for various 10°-wide latitudinal belts.

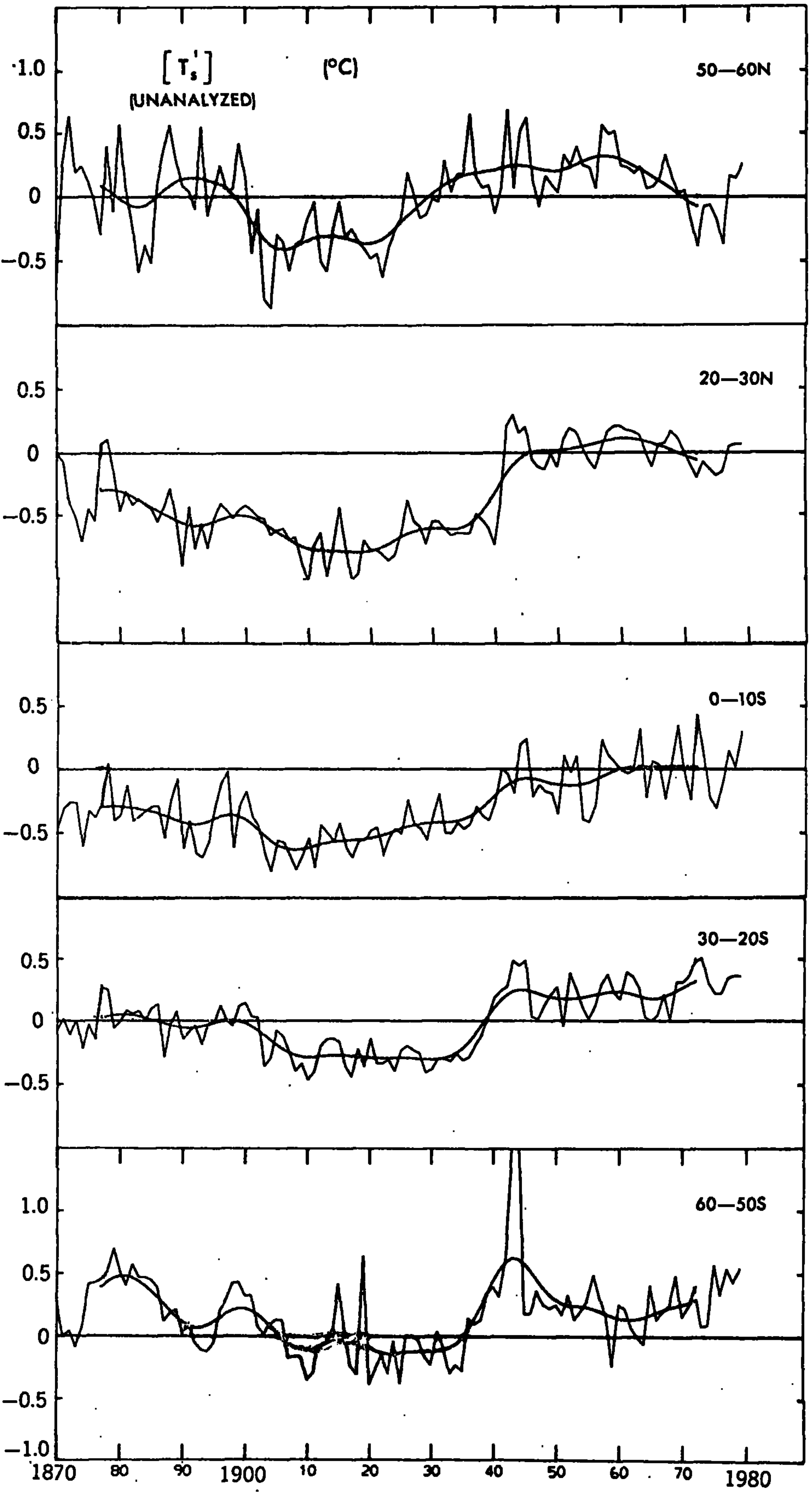

Fig. 3. Time series of the zonally averaged "unanalyzed" SST anomalies (in °C) computed simply as the straight average of all 2°x2° mean SST ship reports in each 10°-wide belt.

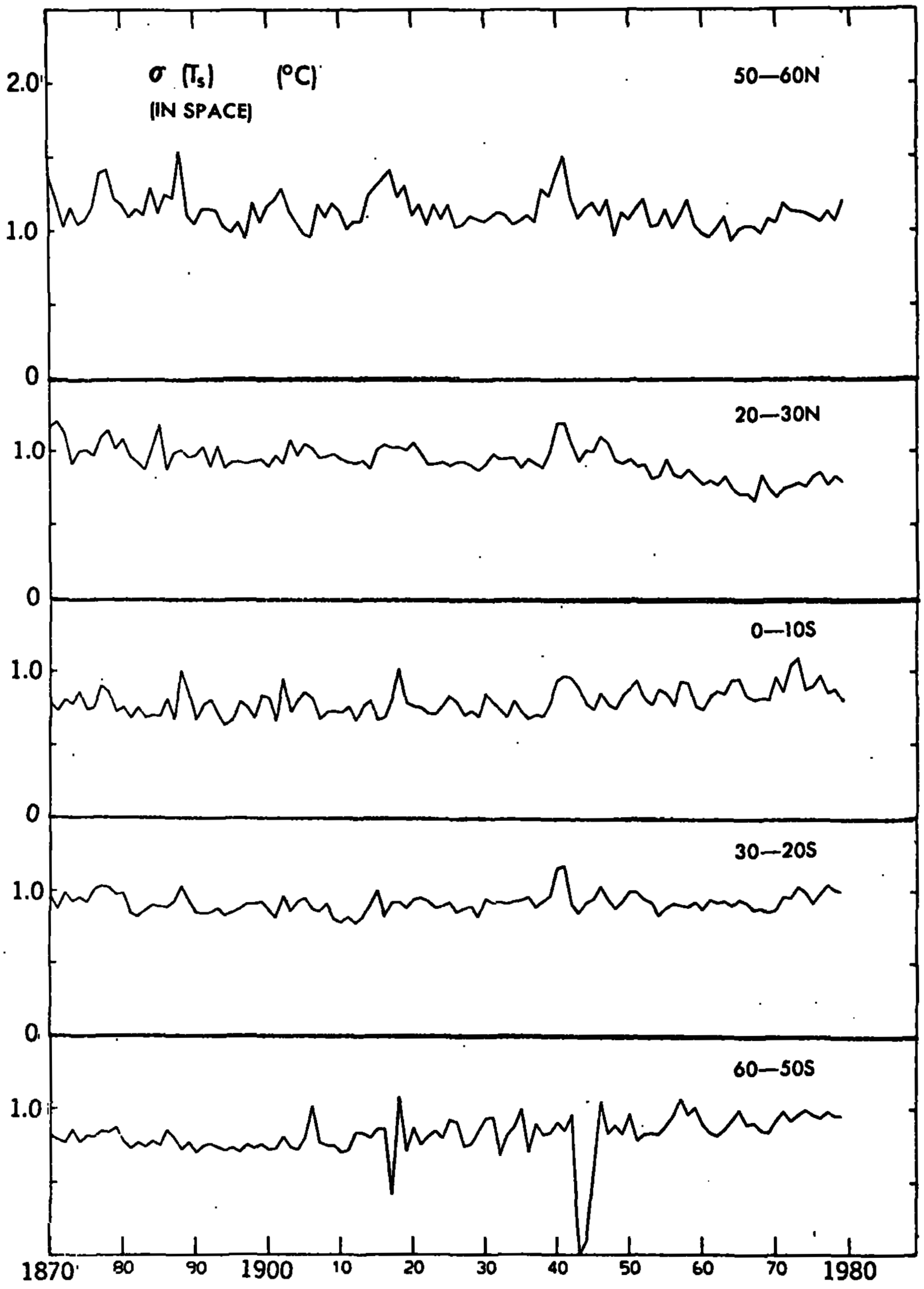

Fig. 4. Time series of the spatial standard deviation of the "unanalyzed" SST anomalies (in °C), compiled as the square root of the variance of all 2°x2° mean SST ship reports in each 10°-wide belt.

Recent Large Scale Variability in the North Atlantic SST Field

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Presented at COADS Workshop
February 1986
Boulder, Colorado

One key to interpreting and calibrating the climate in the long historical record provided by data sets such as COADS is a good understanding of the better sampled contemporary variability, as seen in post-World War II atmospheric and oceanic observations. In this brief report, large-scale SST variability in the northern oceans over the last few decades is qualitatively examined for consistency with selected atmospheric variables.

During the post-World War II period, sea surface temperature (SST) and atmospheric sea level pressure (SLP) have exhibited quite strong interannual variability in both the North Pacific and North Atlantic sectors. A study of decadal scale variations over the North Pacific (Douglas, Cayan, and Namias, 1982) shows a marked cooling north of 20°N for area average SST in the 1969-80 period relative to that of 1947-1966, seen in Fig. 1 (lower). This was associated with anomalously strong westerlies at most midlatitudes, and increased northerly flow in the central and western parts of the basin, averaged over the winters and springs during 1969-80, as shown by mean 700 mb anomalies in Fig. 1 (upper). The general conclusion of this study was that this rather large North Pacific SST decadal variability was qualitatively consistent with that of the atmospheric circulation over this region, as well as downstream over North America.

A comparison of the North Pacific area average SST north of 20°N to that of the North Atlantic over the 1949-1984 period is shown in Fig. 2. Note that both oceans display rather strong low frequency variability, with amplitudes of about 0.5°C in each. Perhaps fortuitously, or perhaps because a common large-scale influence has affected both, the two records are somewhat in phase. It should be noted that inclusion of tropical North Atlantic data (not shown) does not significantly change the shape or amplitude of the area mean record. This is probably due to the small amplitude of interannual SST variability in the tropical Atlantic sector (Servain, et al., 1985), but this conclusion is somewhat uncertain, due to the sparsity of data over much of the tropical North Atlantic (Cayan, 1985a). In contrast, it would seem that the tropical North Pacific would exert a relatively stronger influence on area mean temperature than the North Atlantic due to a stronger interannual anomaly signal. Unfortunately, outside of a very few shipping lanes, the tropical Pacific is poorly sampled, as pointed out by Mobley and Preisendorfer, (1985), and J. Sadler, M. Lander and D. Shea during this workshop. Hence, data sparsity in this region alone would appear to introduce a significant amount of uncertainty in any estimate of hemispheric or global mean surface temperature; this has been emphasized by a number of investigators (e.g., Barnett, 1978; Jones, et al., 1983).

Turning to a more detailed look at the North Atlantic SST, an empirical orthogonal function (EOF) analysis of the low-passed North Atlantic SST shows that the low frequency variability in the whole area mean field is quite well captured by the first EOF (28% of the standardized anomaly variance), whose spatial pattern and time amplitude are shown in Fig. 3. Bunker (1980) also noticed the broad based North Atlantic SST cooling in the 1960s and early 1970s in a record of Marsden Square average ship reports, and found it consistent with bulk formula estimated air-sea flux changes apparently due to shifts in the atmospheric circulation. Unfortunately, the 1949-1985 record is too short to provide a confident statistical characterization of low frequency SST fluctuations. Furthermore, the statistical validation of causal mechanisms of these is impossible with only one or two such "cycles" in this short record. However, a better examination of shorter period fluctuations may provide some insight, and a preliminary examination shows large-scale associations with atmospheric anomalies.

The first EOF of winter-only SST variability (Fig. 4) indicates strongest weighting in the western part of the North Atlantic basin, having a two-celled pattern with the Eastern Seaboard warm and the Carribean region cool, or vice-versa. This pattern is apparently linked to the continental surface air temperature variability over the East Coast, as supported by winter season correlations of Boston surface air temperature with every grid point in the entire North Atlantic SST field, shown in Fig. 5. Looking further, the SST record from "Region 1," centered at about 40°N, 70°W (Cayan, 1985b), is well-related to Northern Hemisphere SLP over the North Atlantic and adjacent continents during winter, as seen in the correlation field in Fig. 6. This atmospheric pattern appears to be strongly related to the North Atlantic Oscillation (Meehl and van Loon, 1979), and weakly related to the Gulf of Alaska–Aleutian Low pattern upstream (see Rodgers, 1984). This evidence, combined with other SLP relationships (not shown) in other seasons and with "Region 2" in the Caribbean area (Cayan, 1985b) reinforce the view that the western North Atlantic SST variability is significantly related to the broad scale atmospheric circulation.

Thus from the COADS data, it should be possible to determine if similar interannual SST variations occur in the pre-World War II record, and if they show the same links to the SLP field. Despite instrumental contamination, the study of strong interannual extremes on a regional scale seems quite feasible, since the natural variability of SST will exceed 1°C for several events. However, Barnett (1984), Folland, et al. (1984)

and the presentation of Jones at this workshop emphasise the importance of removing an apparently large instrumental signal from the historical marine ship observed SST set in determining large area average surface temperature estimates. In order to examine the low frequency (decadal scale) fluctuations over the entire North Atlantic basin, it will be necessary to correct the historical SST record for artificial instrumental variations. This appears to be difficult to achieve the accuracy required to resolve the natural signal, which appears to have an amplitude of about 0.5°C in both the North Atlantic and the North Pacific from inspection of the modern record.

Fig. 7, a comparison of the Boston surface air temperature seasonal anomaly record with that of area averaged SST over "Region 1" shows that both short- and long-period fluctuations apparently contribute to this correlation. The good correspondence of the low-frequency components of surface air temperature with the SST as in Fig. 7 supports the strategy of calibrating long-period ship SST Besides coastal air temperature records, long, high quality shore station records may be useful to untangle the natural signal from the instrumental noise. observations using coastal air temperature records. Coastal monthly SST anomaly histories along the Eastern Seaboard exhibit considerable coherence of the anomaly signal along the coast (see Fig. 8, courtesy of Doug McLain of NOAA Pacific Environmental Group in Monterey, California). Therefore, prospects of using shore station air temperature and SST calibrations to make regional studies of climate variability are quite favorable, especially to examine extreme events where the actual signal is much larger than the instrumental drift.

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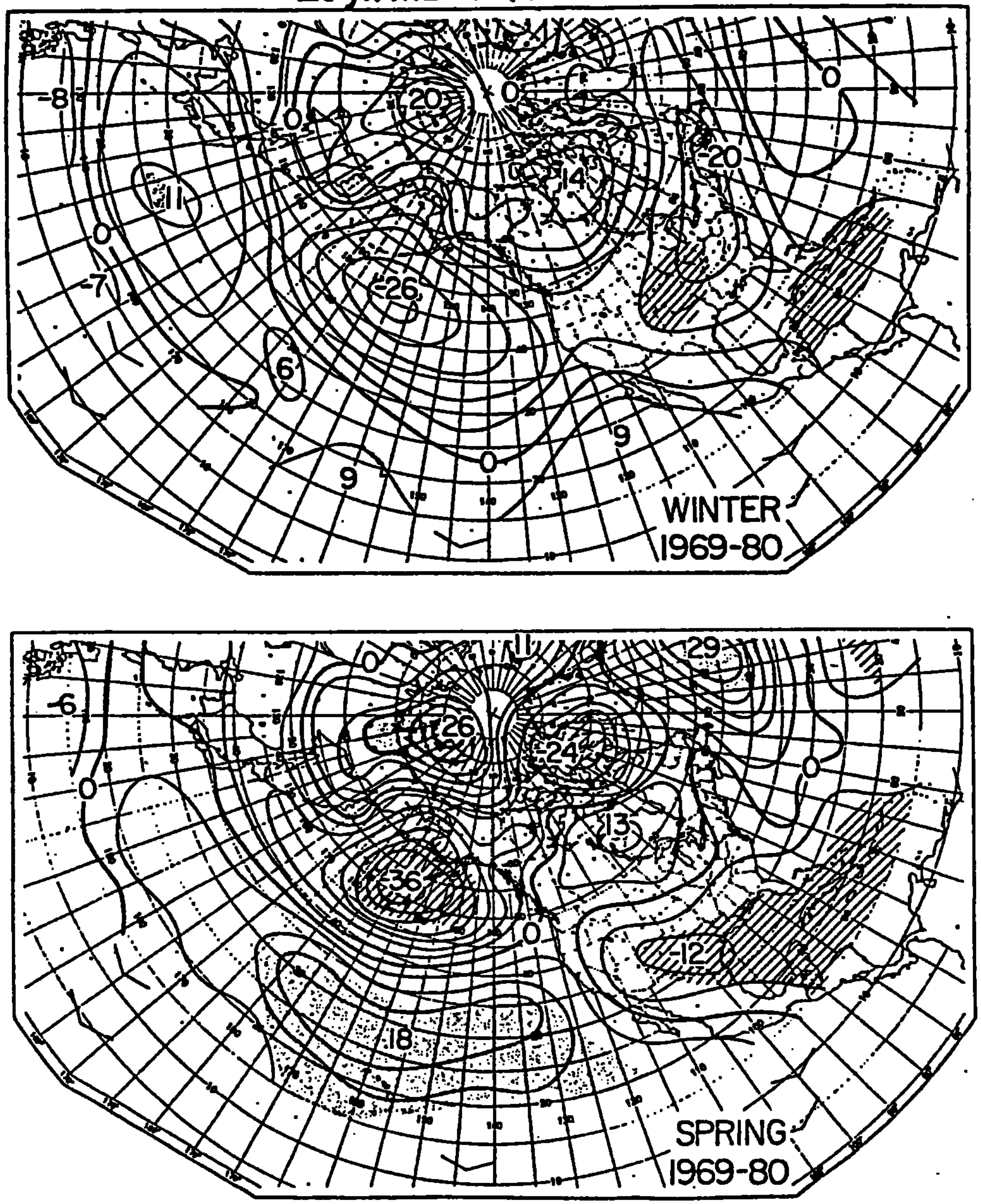
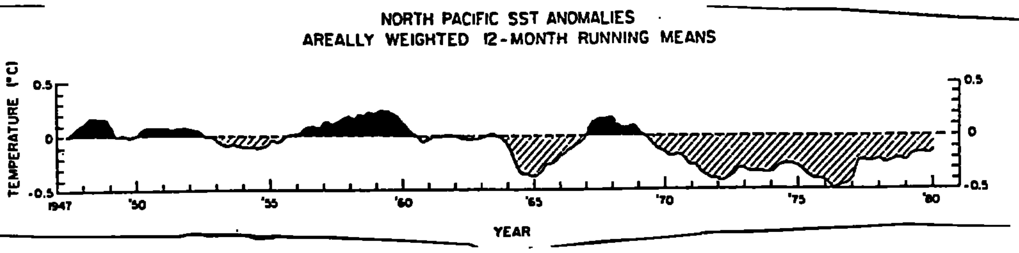
700mb HT ANOMALIES RELATIVE TO 20yr. MEAN (1947-66)



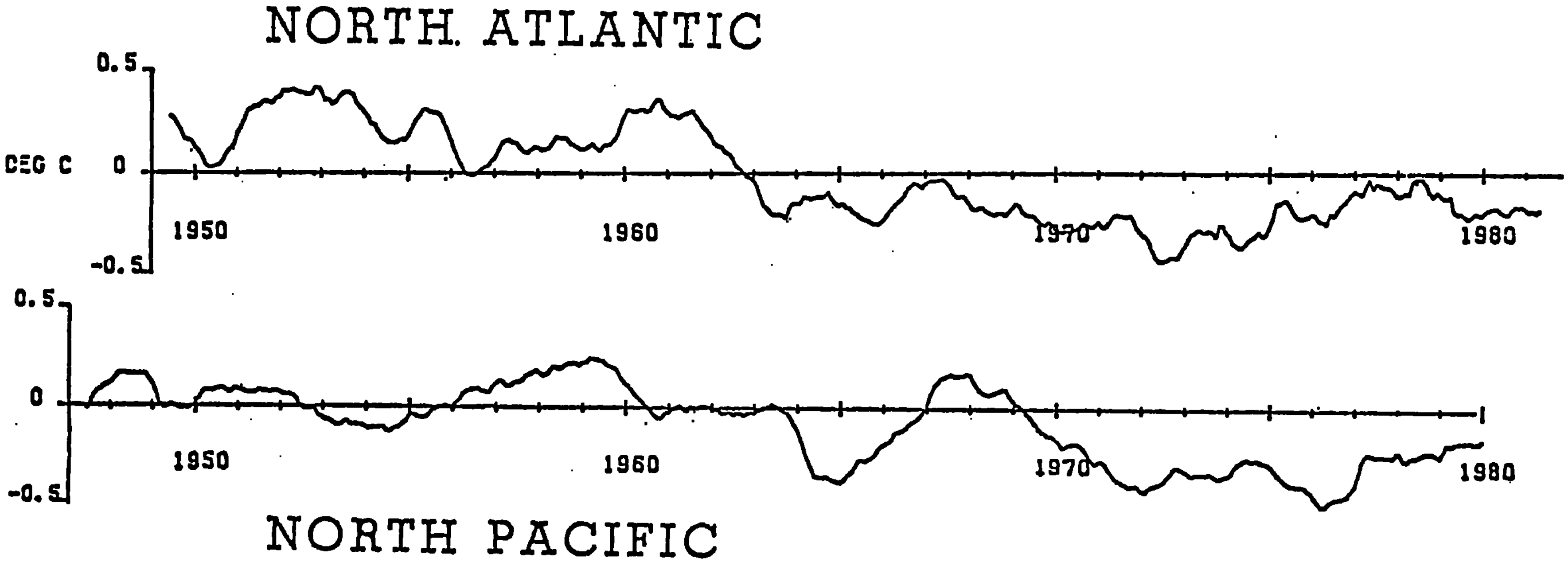
Average winter and spring 700 mb height departures, 1969–80. Shading indicates areas of significant departures at the 5% level. Note that while the departures during the winter over the North Pacific are not significant, a strong anomalous gradient is evident in the vicinity of the oceanic cooling shown in Fig. 2. [Fig. 3 from Douglas, Cayan and Namias, 1982.]



Areally weighted 12-month running mean SST departures for the North Pacific. The means are computed using all available 5° square data from 20 to 60°N. Departures are based on the long term mean 1947–66.

[Fig. 1 from Douglas, Cayan and Namias, 1982.]

Fig. 1 CAYAN



Area averaged SST anomalies (degrees C) for entire North Atlantic (upper) and North Pacific (lower) north of 20 degrees N latitude. 12 month running mean filter has been applied to smooth high frequency variability.

Fig. 2 CAYAN

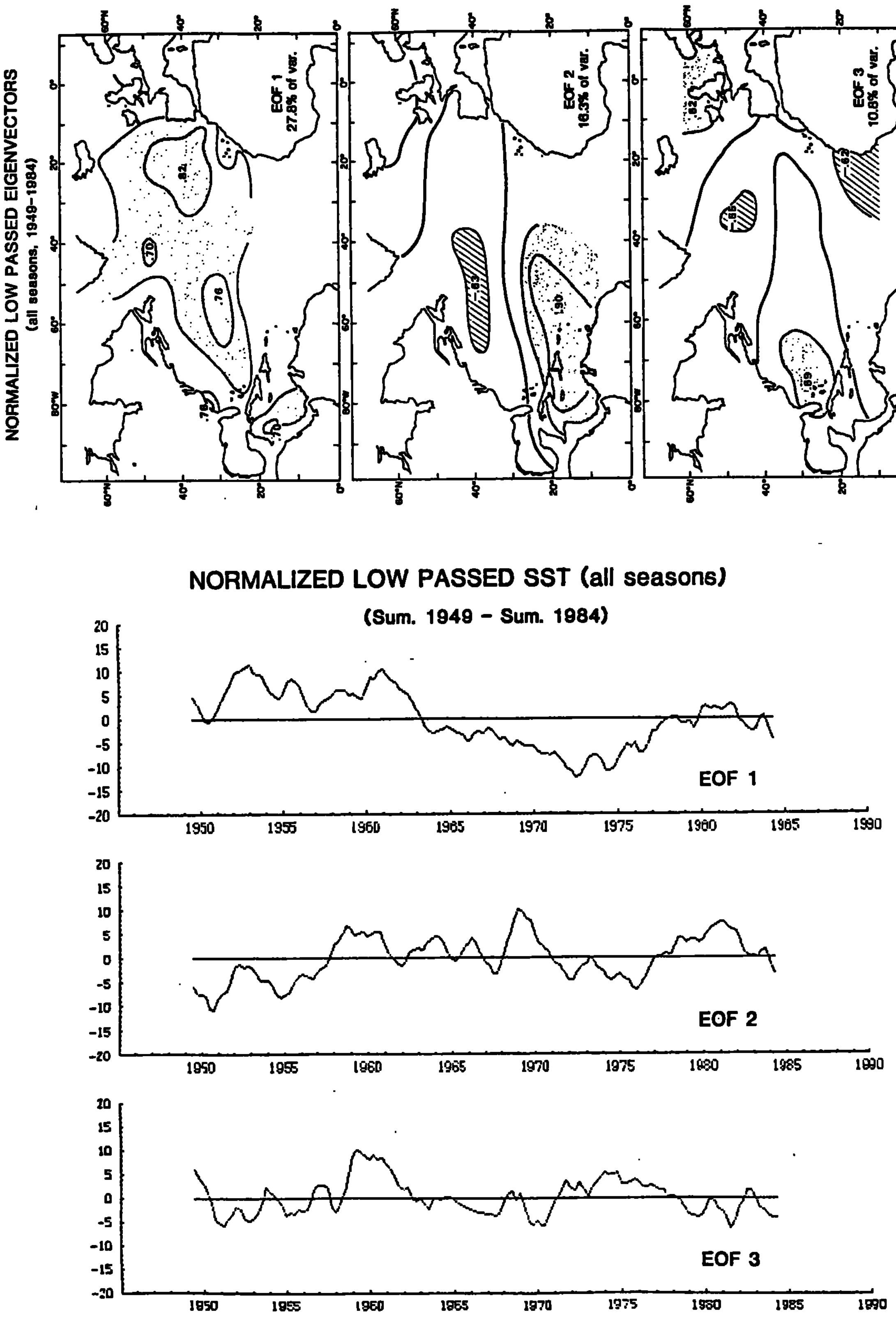

NORMALIZED LOW PASSED EIGENVECTORS
(all seasons, 1949-1984)
EOF 1
27.8% of var.
EOF 2
16.3% of var.
EOF 3
10.8% of var.
.82
.70
.76
.76
-.63
.90
.82
-.66
-.62
.69
60°N
40°
20°
0°
80°W
60°
40°
20°
0°
NORMALIZED LOW PASSED SST (all seasons)
(Sum. 1949 - Sum. 1984)
EOF 1
EOF 2
EOF 3
20
15
10
5
0
-5
-10
-15
-20
1950
1955
1960
1965
1970
1975
1980
1985
1990

Fig. 3 CAYAN

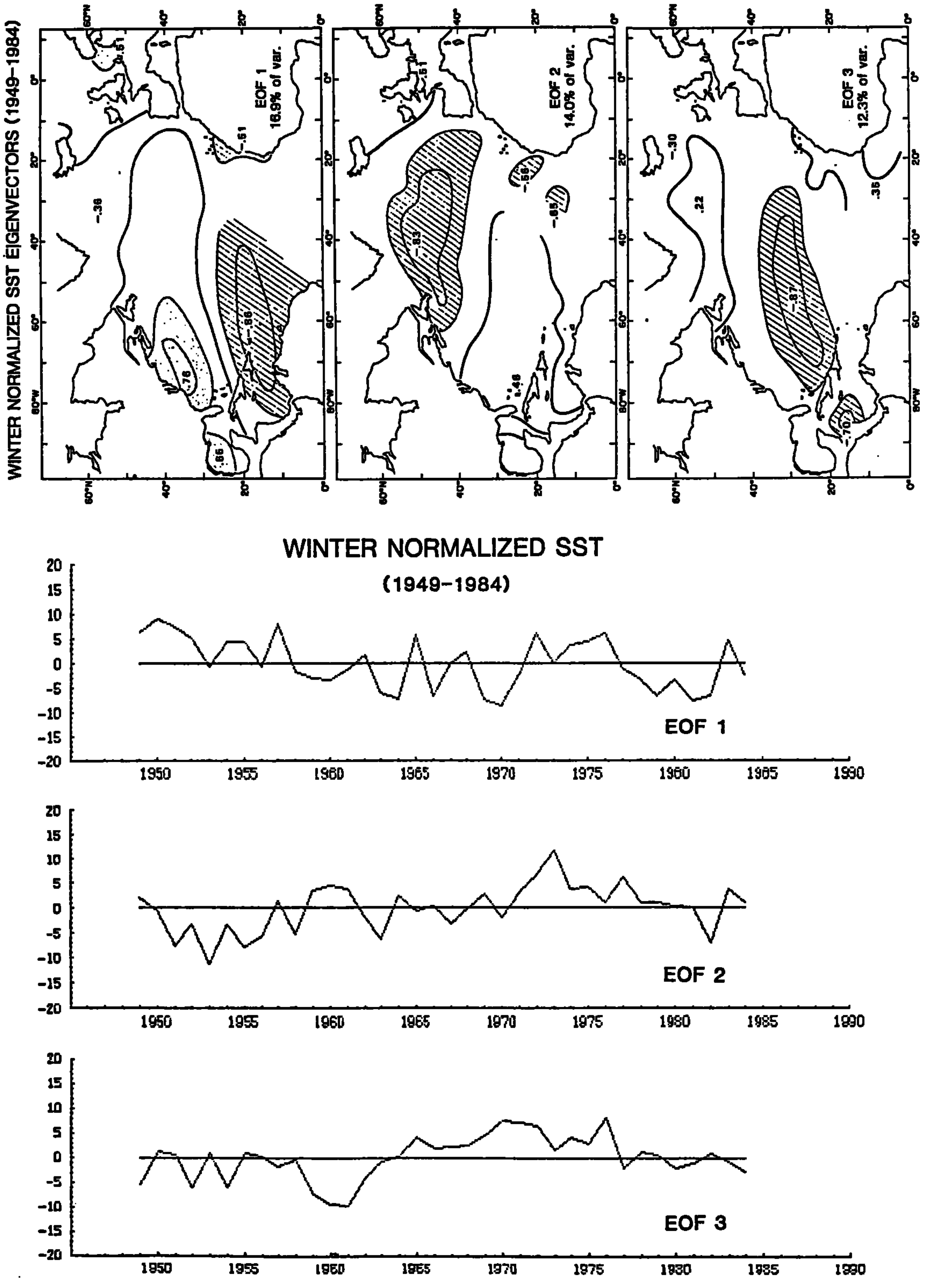
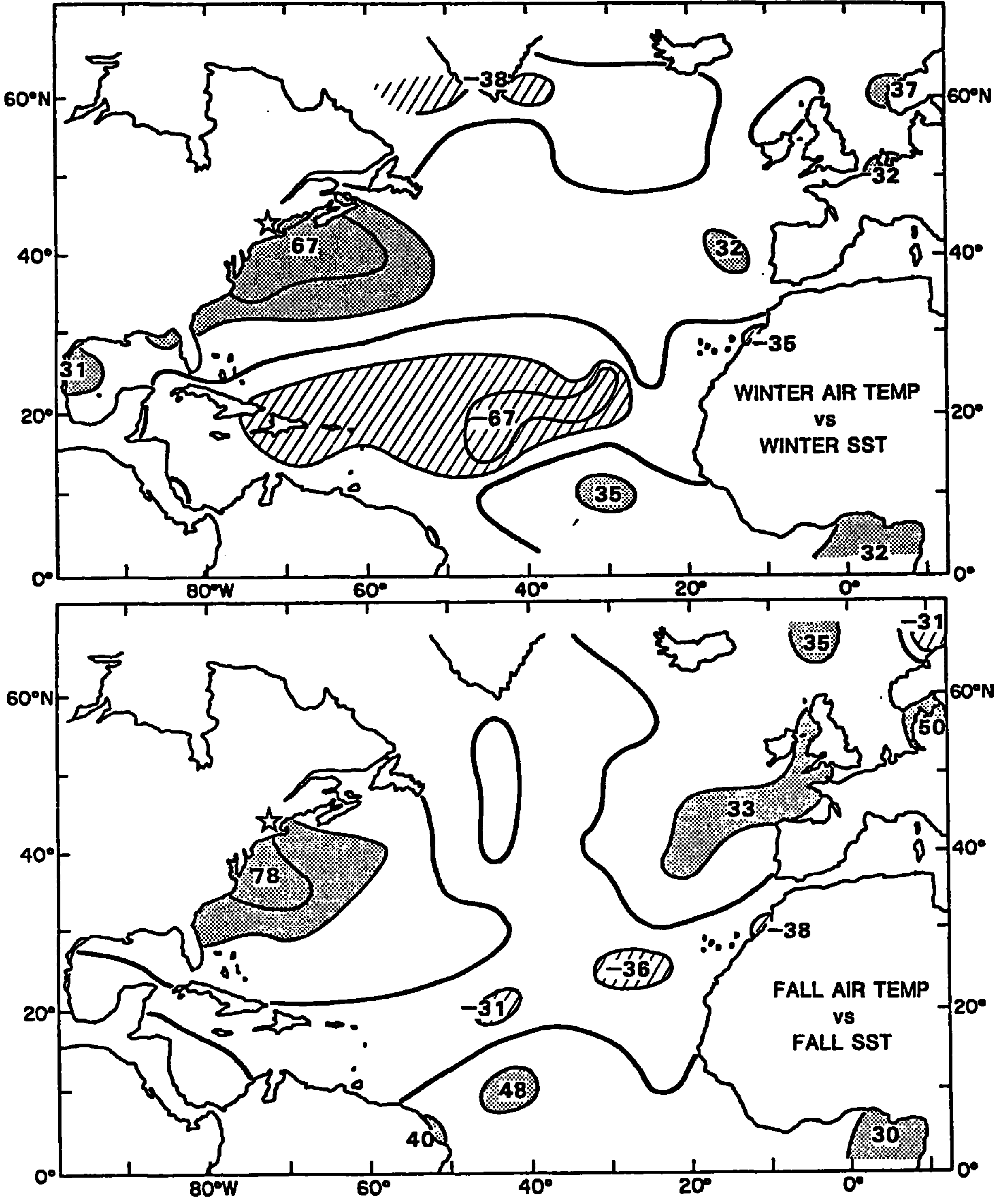

WINTER NORMALIZED SST EIGENVECTORS (1949-1984)
EOF 1
16.9% of var.
EOF 2
14.0% of var.
EOF 3
12.3% of var.
-.38
.76
.66
-.56
-.51
-.63
-.58
-.65
.46
-.30
.22
-.35
-.67
-.70
60°N
40°
20°
0°
60°W
WINTER NORMALIZED SST
(1949-1984)
EOF 1
EOF 2
EOF 3
20
15
10
5
0
-5
-10
-15
-20
1950
1955
1960
1965
1970
1975
1980
1985
1990

Fig. 4 CAYAN



BOSTON AIR TEMPERATURE vs N. ATLANTIC SST
(1949–1981)

WINTER AIR TEMP
vs
WINTER SST

FALL AIR TEMP
vs
FALL SST

Fig. 5 CAYAN

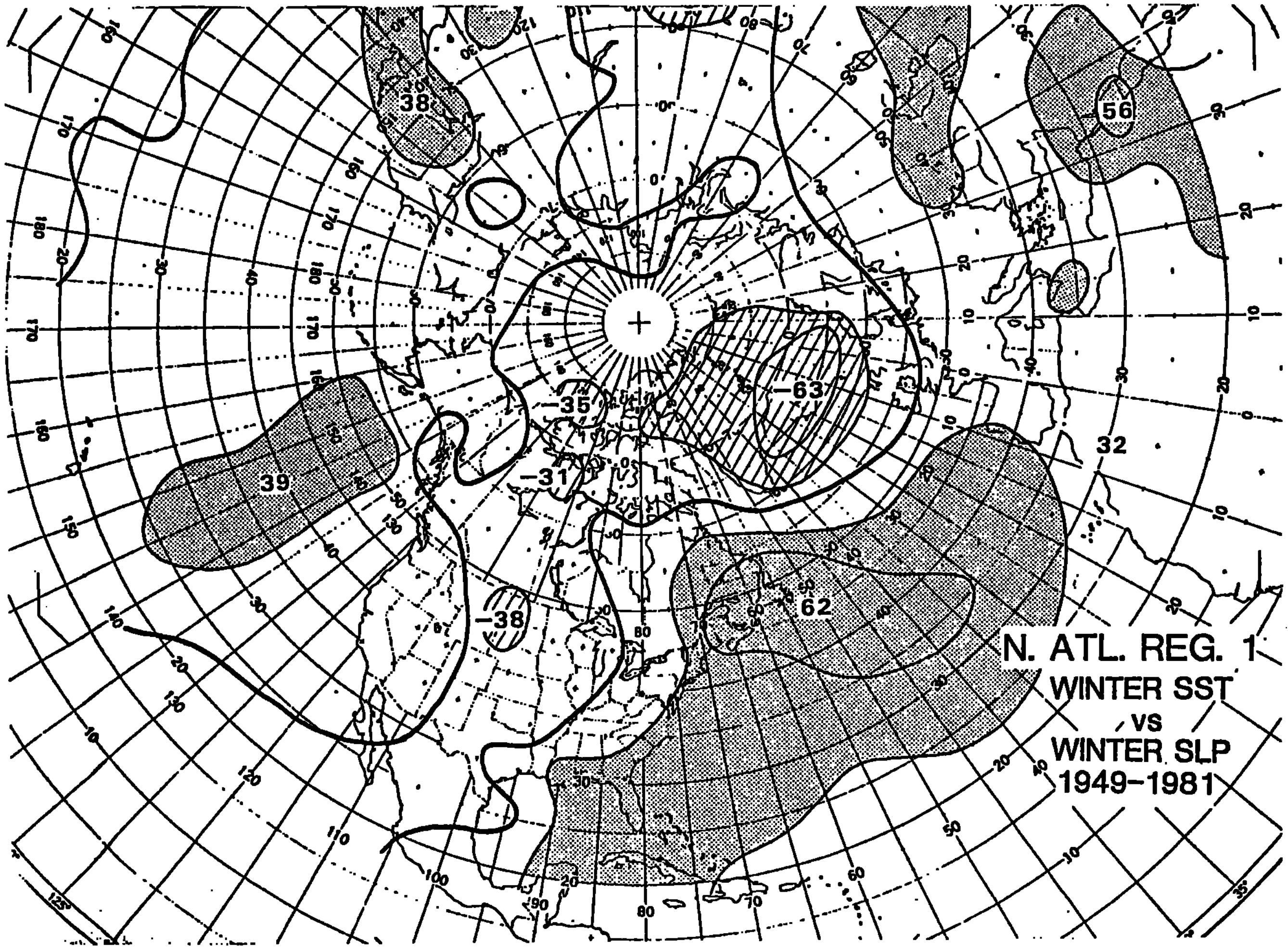

N. ATL. REG. 1
WINTER SST
vs
WINTER SLP
1949-1981
38
56
39
-35
-63
-31
32
-38
62

Fig. 6 CAYAN

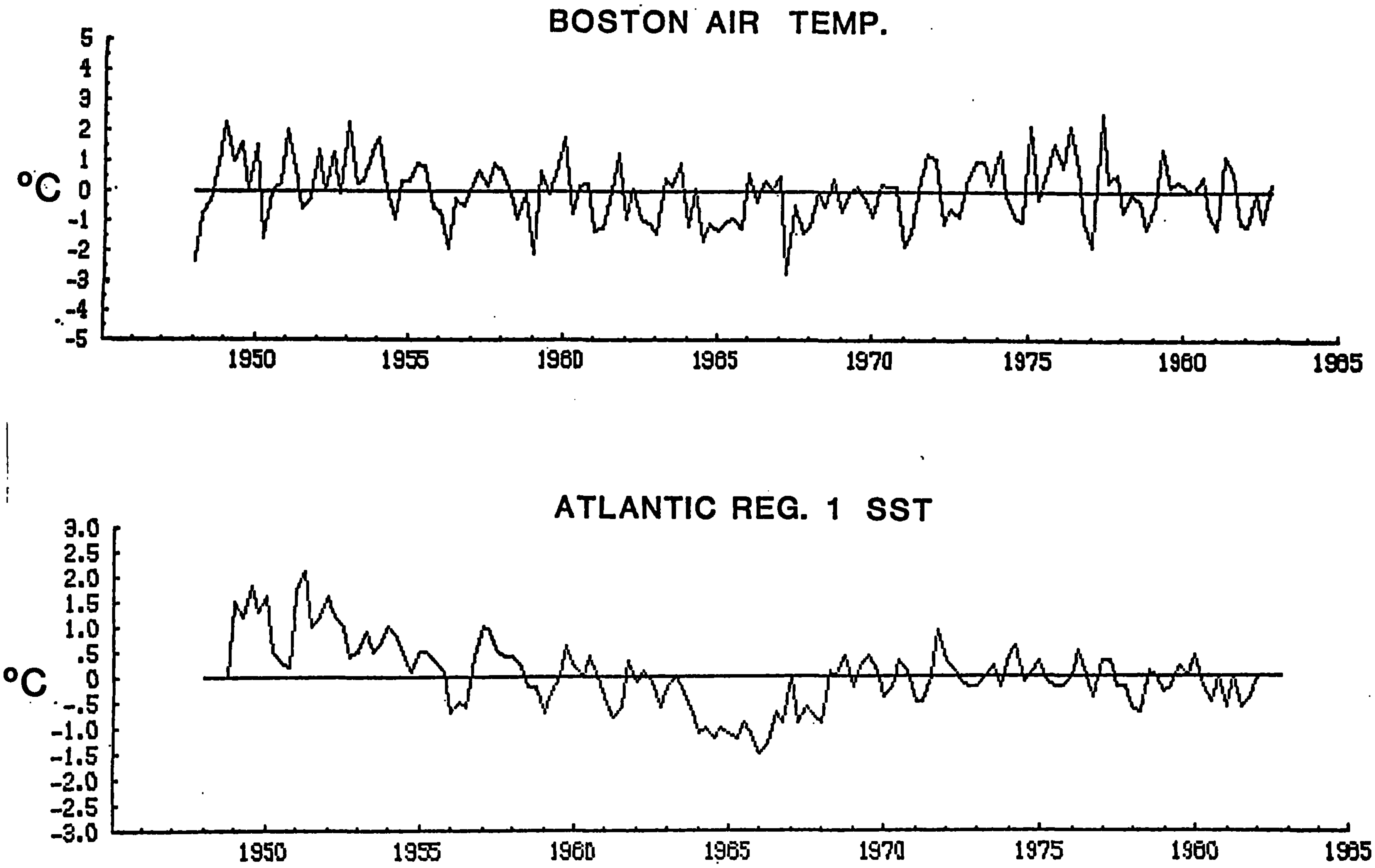
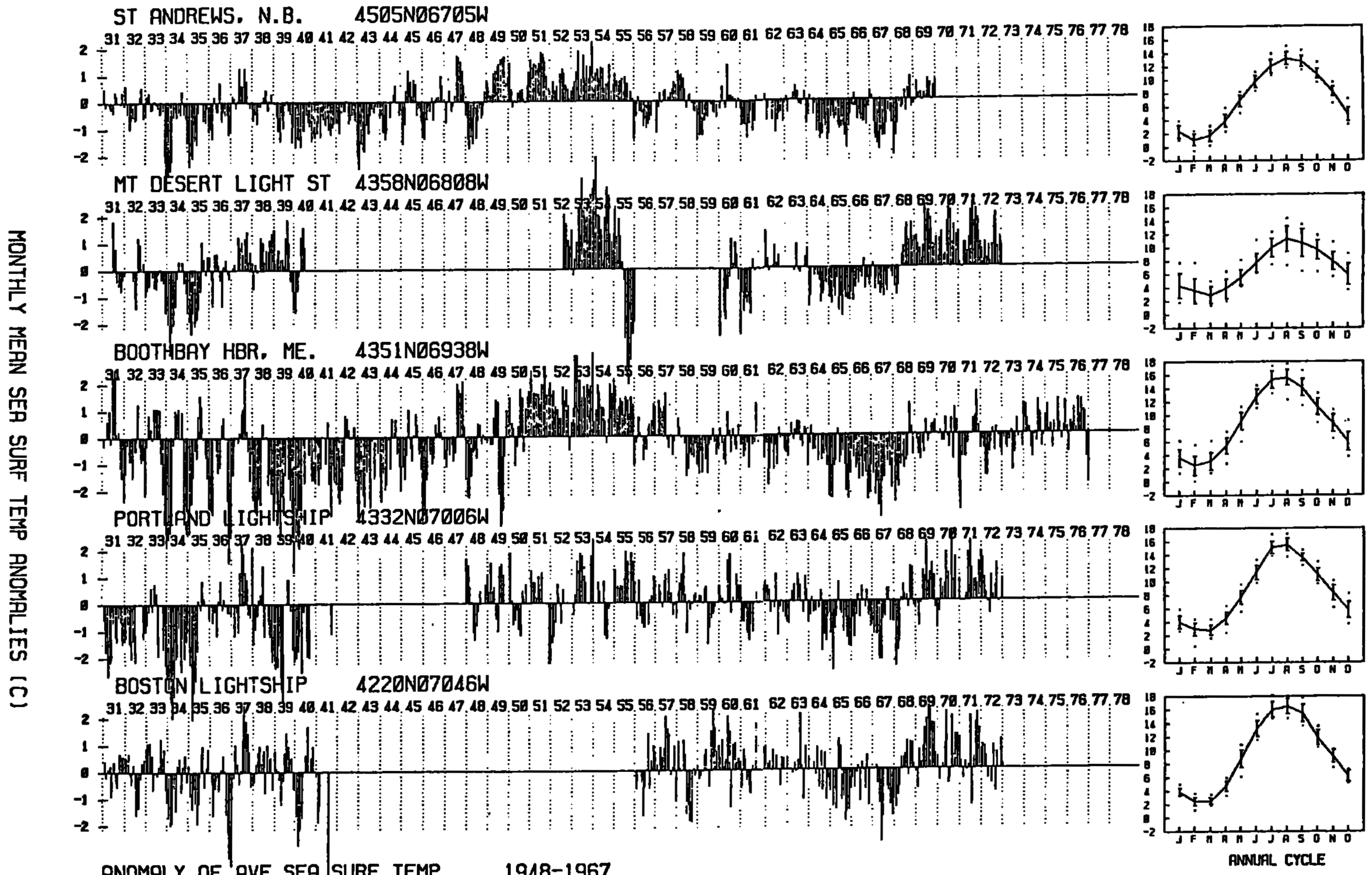

BOSTON AIR TEMP.
°C
5
4
3
2
1
0
-1
-2
-3
-4
-5
1950
1955
1960
1965
1970
1975
1980
1985
ATLANTIC REG. 1 SST
°C
3.0
2.5
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
-2.5
-3.0
1950
1955
1960
1965
1970
1975
1980
1985

Fig. 7 CAYAN



ANOMALY OF AVE SEA SURF TEMP 1948-1967
NOAA-NMFS PACIFIC ENVIRONMENTAL GROUP MONTEREY, CA
(Courtesy of Doug McLain, NOAA)

Fig. 8 CAYAN

REGIONAL SCALE CIRCULATIONS PRODUCED BY THE OROGRAPHY OF CENTRAL AMERICA

James Sadler and Mark Lander
University of Hawaii

The orography of Central America has a large influence on the regional circulation of the eastern tropical North Pacific. The land mass separates the strong and persistent trade wind circulation over the Caribbean Sea and Gulf of Mexico from the seasonally varying monsoon circulation of the eastern Pacific. There is a pressure gradient from the Atlantic to the Pacific which is enhanced by the high topography and wind is forced through the three low-lying passes as illustrated in Fig. 1. The pressure gradient is particularly strong in the winter months (Fig. 2d) and the alternating pattern of low passes and high mountains produces a complex lee wind system of narrow zones of strong winds separated by wide areas of weak and near calm winds (Fig. 2a). The largest pressure gradient (about 1 mb per 25 km) and strongest winds are across the Isthmus of Tehuantepec where the strong northeast surges of gale or hurricane force winds are known as Tehuantepecers.

The steady and persistent wind patterns extend for some 500 to 1000 km offshore and control ocean circulation and thermal structure. The SST pattern in Fig. 2c is dominated by the winds with strong offshore winds producing cold SST's while warm waters are enhanced between the strong wind zones. The large southernmost pool of warm water is called the Costa Rica dome.

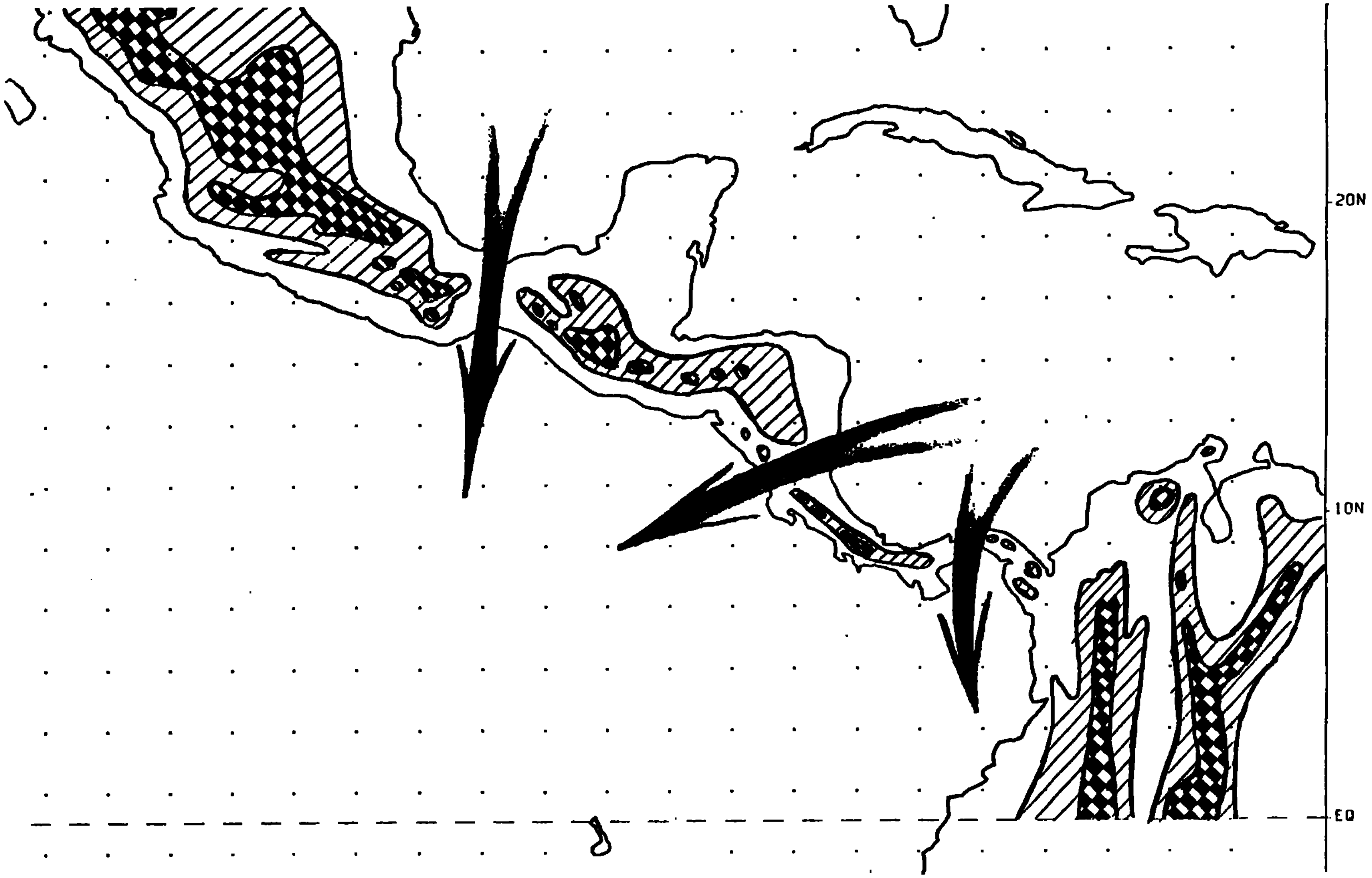


Figure 1. Topography of Central America showing the three main low-lying connections between the Pacific and Gulf of Mexico-Caribbean Sea. Hatched is greater than 2000 ft and checkered is greater than 6000 ft.

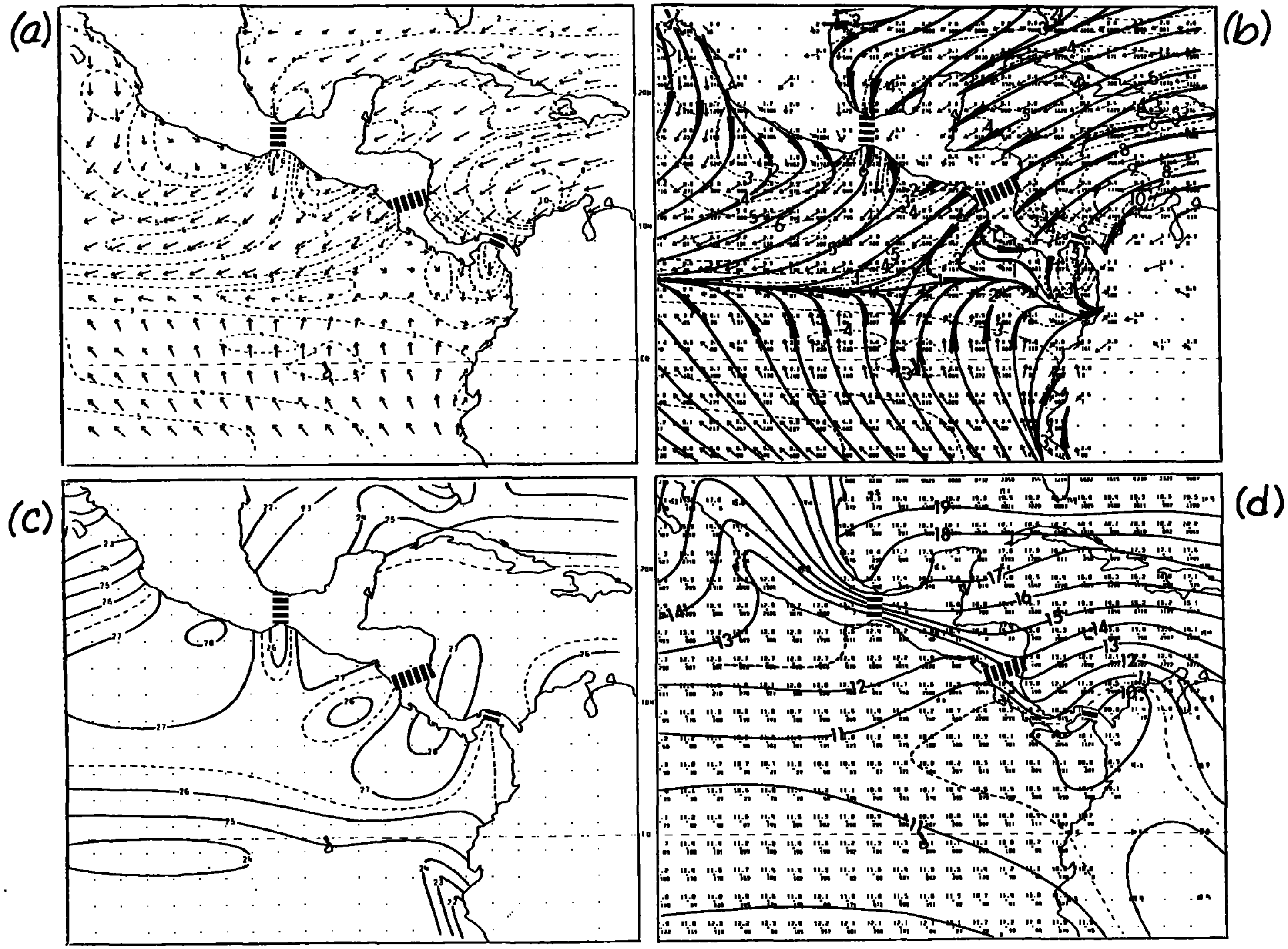


Figure 2. Analyses of COADS mean (1900-1979) data for January. (a) Wind direction arrows and isotachs; (b) Streamlines and isotachs; (c) Sea surface temperature; (d) Sea level pressure. Low-lying valleys from Fig. 1 are shown by wide dashed line.

AN "ANOMALOUS" LONG-TERM MEAN SURFACE WIND PRESSURE RELATIONSHIP IN THE SUBTROPICAL RIDGE AND ITS PROBABLE CAUSE

Mark Lander
University of Hawaii

A very curious relationship exists between the COADS long-term (1900-1979) mean (LTM) surface wind and the LTM surface isobars along large segments of the subtropical ridges, especially in winter. The LTM wind blows through the LTM pressure ridge toward the equator where the LTM pressure gradients indicate poleward geostrophic flow. One may easily be mislead to expect that the LTM wind associated with the LTM pressure in Figure 1 to be light southerly along the ridge axis when, in reality, it is light northerly. *Presumably it is* a feature of the transient disturbances that is responsible for this "anomalous" relationship.

Synoptically one expects the surface wind and the surface pressure to be related in the familiar frictionally-adjusted geostrophic balance. One might further expect the time-averaged wind and pressure also to be related in this way. However, when the wind and pressure are time averaged, a problem arises which is similar to trying to infer the mean of the squares of a series of numbers from the square of its mean. If the synoptic surface wind-pressure relationship is unchanged for all conditions (i.e., the wind always blows across the isobars at a 30° angle and at three fourths the geostrophic speed), then any time-averaged wind and pressure will be related as they are synoptically. However if there is any systematic difference in the wind-pressure relationships for different wind directions or wind speeds, then the LTM relationships need not be the same as the synoptic relations. Considering the conditions in the LTM subtropical ridge, as shown in Figure 1, it seems a reasonable induction that for a given magnitude of the synoptic pressure gradient (in the Northern Hemisphere) that the north wind associated with the negative value is stronger than the southerly wind associated with the positive value. This is observed to be true for some typical synoptic flow patterns.

A typical midlatitude transient disturbance, with effects extending into subtropical latitudes, is shown in the top left and right of Figure 2. The northerly flow behind the sharp pressure trough is a much larger fraction of the geostrophic speed (bottom left of Figure 2) than is the southerly flow ahead of the trough. The cross-isobar angle of the flow (bottom right of Figure 2) also exhibits rather strong regime dependence; the southerly flow ahead of the trough crosses the isobars at about 30° in contrast to the crossing angle of less than 10° in the northerlies behind the trough.

Brown and Liu (1982) developed an Ekman boundary layer model to obtain a derived surface wind field from operational charts of surface pressure. Their modeled wind-pressure relationships exhibited large regime dependences very similar to those shown in Figure 2. The modeled regime dependence is largely due to variations in the stability of the boundary layer which, in turn, are predominantly a function of the wind direction; the north wind is unstable--cold air flows over warmer water, the south wind is stable--warm air flows over colder water. It is proposed that the synoptic regime dependence of the wind-pressure relationship as observed and as corroborated by the Ekman theory is responsible for the "anomalous" LTM wind-pressure relationships observed in portions of the subtropical ridge.

Reference

Brown, R. A., and T. W. Liu, 1982: An operational large-scale marine planetary boundary layer model. J. Appl. Meteor., 21, 261-269.

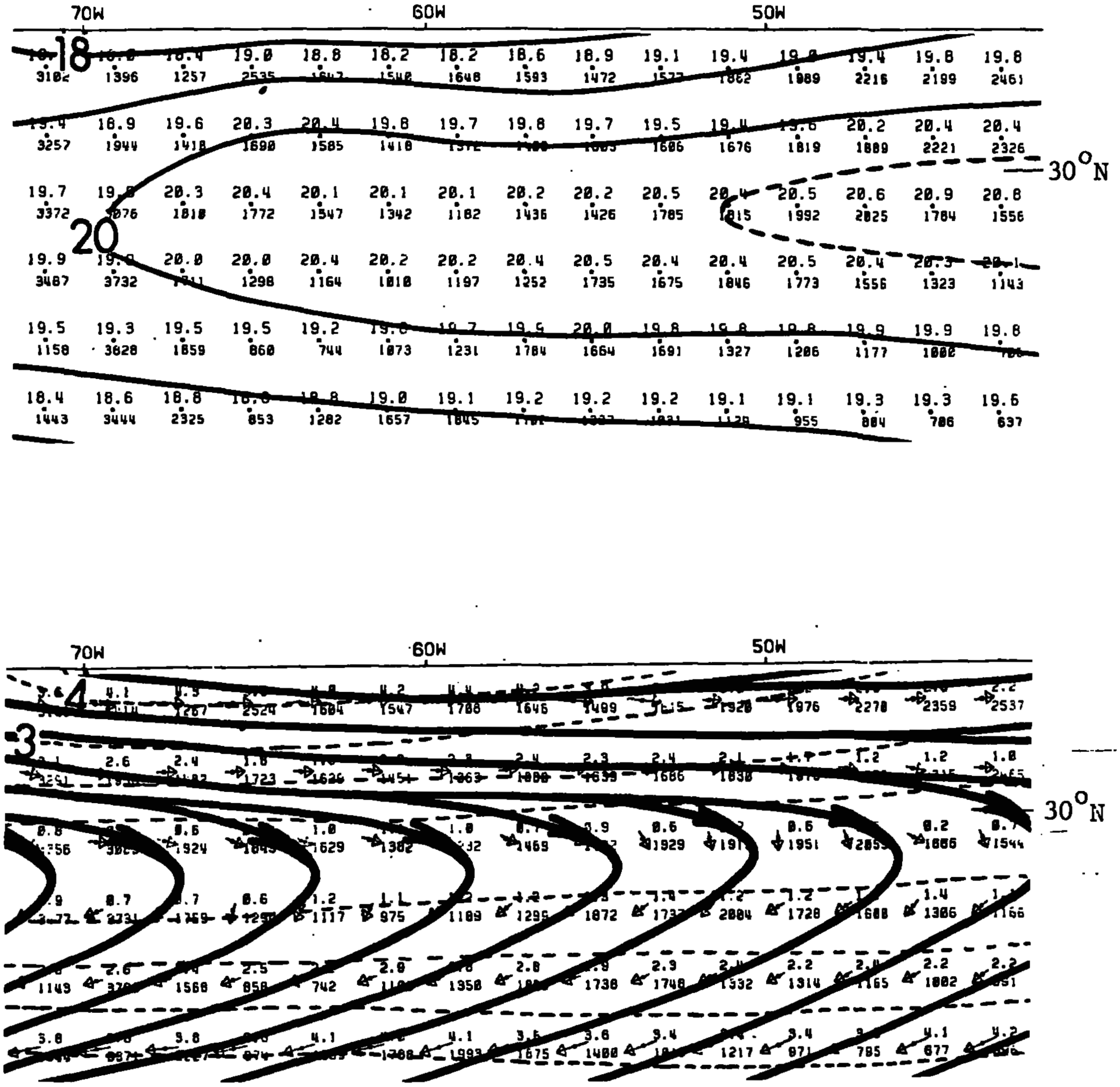


Figure 1. LTM pressures (top) and winds (bottom) in a region of the Atlantic during January.

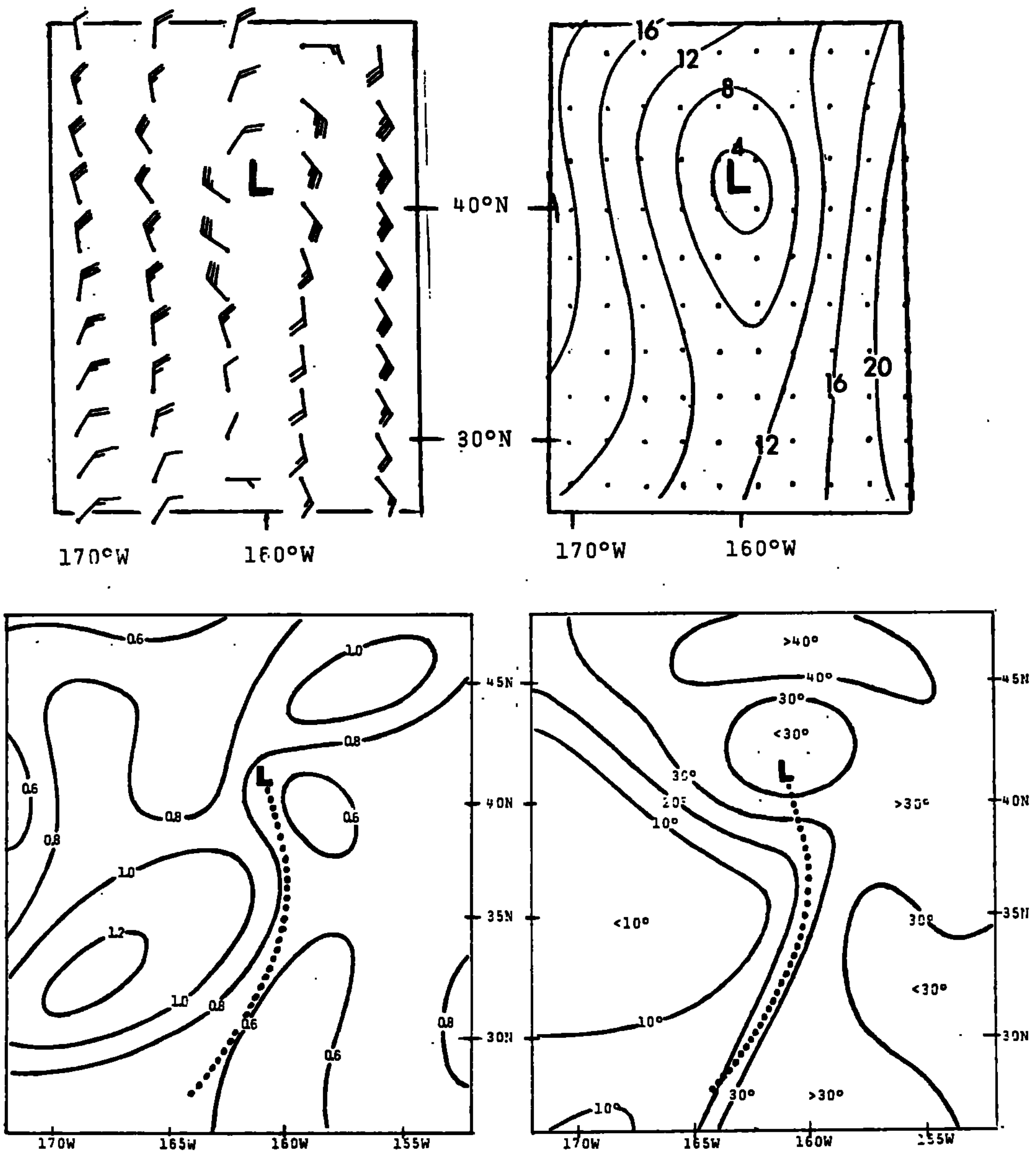


Figure 2. Synoptic conditions in a region of the north Pacific 00Z 09 NOV 82: Top left – Analyzed surface wind (one full barb = 10 kts), top right – analyzed pressure field (mb + 1000), lower left – ratio of surface wind speed to surface geostrophic, lower right – cross-isobar flow angle.

ON THE CONTRIBUTION OF THE SEA SURFACE TEMPERATURE PATTERN TO REGIONAL DIFFERENCES IN THE MARINE BOUNDARY LAYER SHEAR

Mark Lander
University of Hawaii

In the months of July, August, and September the relationship between the long-term mean (LTM) sea-level wind (COADS 1900-1979) and the LTM low-level cloud motion vectors from satellite (sawins) (NESS operational sawins 1976-1982) differs markedly in the northeast and southeast trade regimes of the eastern Pacific. In Figure 1 appropriate data is presented to illustrate the characteristic relationship among the LTM sea-level wind, the LTM sawins, and the LTM geostrophic wind--this last being calculated from the LTM COADS surface pressure gradients. In the northeast trades the sea-level wind crosses the isobars at an angle of about 25-30° while the sawins cross the isobars at about 5°. In the southeast trades both the sea-level winds and the sawins cross the surface isobars at about 25-30°.

It will be assumed that the sawins are representative of the flow at the top of the planetary boundary layer (PBL). Studies by Hasler *et al.* (1977) and others suggest that this is a reasonable assumption. It is further assumed that the trade regimes possess an Ekman PBL. Excluding the thermal wind, the wind at the top of an Ekman PBL is the geostrophic wind as given by the surface pressure gradients; the thermal wind is simply added to this to obtain the total wind.

We hypothesize that: (1) the vector departure of the LTM sawins from the LTM sea-level geostrophic wind is largely a result of the thermal wind, and (2) the LTM thermal wind is controlled by the pattern of the sea surface temperature.

One estimate of the thermal wind is that it is the geostrophic wind calculated from the pressure gradients at one kilometer (our choice of boundary layer depth) due solely to SST-controlled thickness differentials in the PBL. The other estimate of the thermal wind is that it is the vector difference between the sawins and the surface geostrophic wind.

The validity of the two hypotheses made above rests on the closeness of the agreement between the two independent estimates of the thermal wind. Two such estimates, computed from September LTM data in a region of the tropical eastern Pacific, are presented in Figure 2. The two estimates therein seem to be in qualitatively good agreement. Our research continues and we are further looking into the possibility that the SST may govern the thermal wind on shorter averaging intervals, monthly for instance. It may thus be possible to derive the mean monthly sea-level wind field given the mean monthly SST and sawins--the sawins are first corrected for thermal wind effects and then reduced to the surface in accordance with Ekman theory.

Reference

Hastler, A. F., W. Schenk, and W. Skillman, 1977: Wind estimates from Phases I, II, and III of an *in-situ* aircraft verification experiment. *J. Appl. Meteor.*, 16, 812-815.

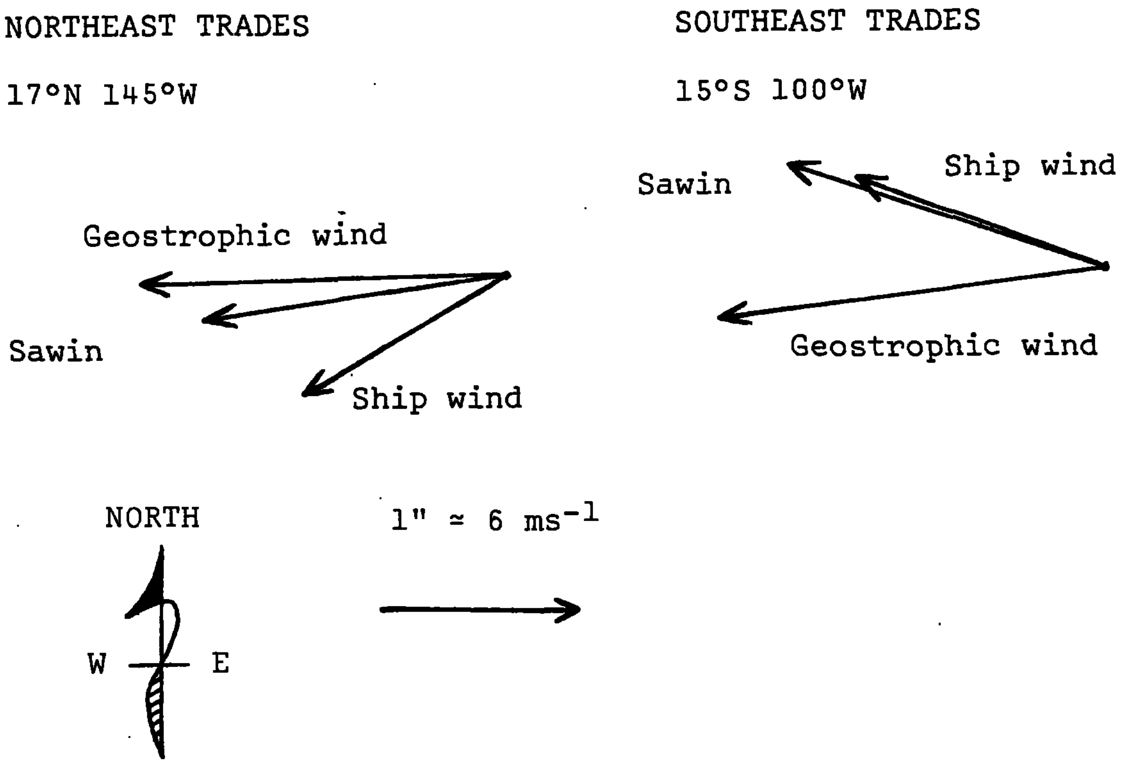


Figure 1. Schematic illustration of the characteristic relationships among the LTM ship wind, LTM SAWIN, and LTM geostrophic wind in the northeast and southeast trade regimes of the eastern Pacific. Data shown are the actual LTM September values at the indicated locations. Data sources:

Ship winds - COADS LTM (1900 - 1979).

Geostrophic wind - From COADS LTM (1900 - 1979) surface pressure.

SAWINS - LTM (1976 - 1982) NESS operational low level cloud motion vectors.

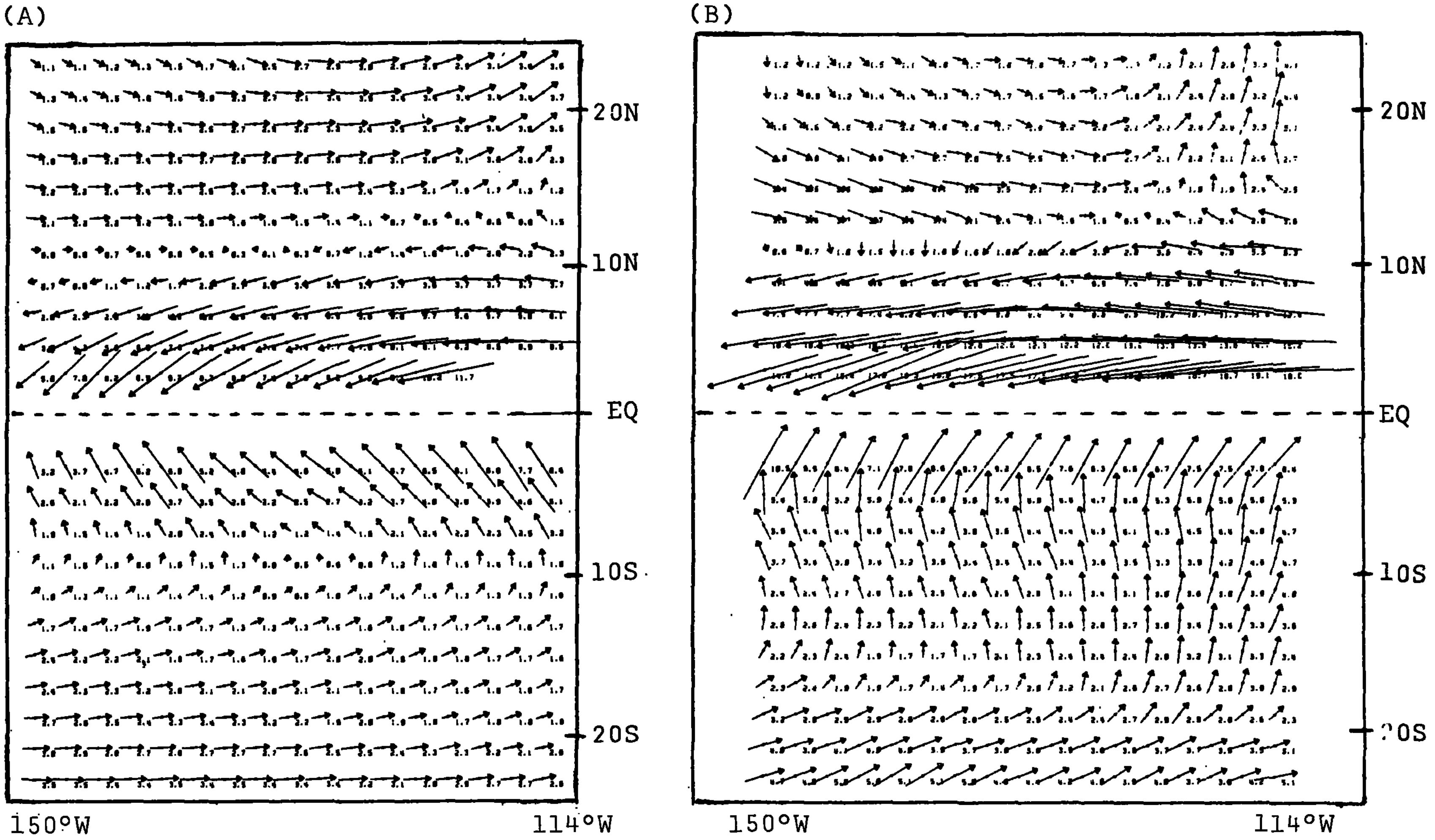


Figure 2. Two independent estimates of the September LTM thermal wind in a region of the tropical eastern Pacific; (A) Geostrophic wind at one kilometer due solely to SST-controlled thickness, (B) Vector difference of SAWINS from the surface geostrophic wind.

Part 4. Working Group Reports

Scientific Working Group Report

C. S. Ramage

We discussed the use of COADS under three headings:

A. Long-term Means. We agreed that COADS is easily the best marine data set ever assembled and could form the basis of an outstanding atlas. However, even over the whole period of COADS there are serious gaps in many areas south of 20° N.

We agreed that the NCDC inventory of unpunched U.S. ship observations should be expanded to include ships of other nations and that back punching priority should be given to WW II and WW I data (both periods included strong Niños).

The group recommended that COADS be updated (including back punching) every five years.

B. Secular Change. We were concerned at the effect of observation and instrumentation changes on the potential of COADS to reveal secular changes, particularly in heat exchange.

P. Jones' finding of an apparently spurious air temperature fall of almost 1°C between 1890 and 1905 must be thoroughly investigated. One way of doing this would be to compare long-term island or windward coastal data to data from adjacent heavily-travelled ship tracks, and to attempt a detailed study of the history of temperature measurements on ships.

C. Stratification. Apart from J. Walsh's demonstration of prior SST anomalies as predictors of North Atlantic sea ice extent, we focussed on El Niño/Southern Oscillation. Using COADS, the groups in NCAR and Hawaii have independently failed to replicate the compositing results of Rasmusson and Carpenter. Although the COADS data are better, the NCAR and Hawaiian composites are much noisier. Once again, lack of data south of 20°N is the problem.

Similar difficulties plague those trying to define error-free fields for model initialization. We agreed that without a major success in obtaining fishing fleet observations, little progress can be made using merchant ship data alone. The group recommended that various surface wind analysis methods be compared with a view to finding the one best suited for oceanographic model inputs.

Technical Working Group Report

Roy L. Jenne

The following is a summary of the major topics discussed by the technical working group. Some additional notes that are referred to follow sec. 11.

1. Problems in COADS Release 1 (1854-1979)

The data set is much cleaner, much more comprehensive, and easier to use than any previous set of ship data. It still has some problems that have not been explained (see also Notes A and B). Examples were shown (Sadler et al., 1986) of a few year-month-2° boxes with bad values in the untrimmed monthly summaries. The original ship data would need to be examined to try and see what the problem is, and the trimmed summaries should be checked to make sure that these bad values were trimmed.

Large amounts of ships mislocated over land were also noted during 1975. A test tape of keyed merchant data (deck 927) containing erroneous longitudes for February-July 1975 was inadvertently included in COADS (Cram, 1986). The problem has been corrected by NCDC in their copy of the 1970-79 TD-1129. NCDC is supplying data so that similar corrections can be made in Boulder when time permits.

Monterey Telecommunication data (deck 555) were the only available real-time source for about 1966-73, containing roughly 4 million reports. Comparisons that NCDC will provide show temperatures (except SST) frequently as much as 1.5°C too high. These errors may have biased the trimmed summaries (deck 555 was omitted from the untrimmed summaries and thus could not contaminate the limits used for trimming). More evidence must be collected before any assessment can be made of the severity of this problem.

2. Errors in the 1980-85 Update Data

Some errors have been discovered by NCDC, primarily in NOAA/National Meteorological Center (NMC) data. Examples are a double conversion of wind speed, improperly decoded data that ended up in swell fields, and switched dew point and wet bulb. All of these errors can be fixed readily, or are confined to limited time periods and will be documented (Note C).

One significant error that cannot be fixed readily is the lack of the weather indicator, i_x, during 1982-83 in data from NMC. This indicator, a part of the 1982 WMO code change, is used to flag the omission of present and past weather fields when no significant (i.e., bad) weather was reported. Without i_x, there is no way to distinguish between missing and good weather (e.g., present weather codes 00-03) after 1982. Unfortunately, there are problems with i_x in other data sets between 1982-84, and the potential exists throughout that time period for serious biases toward good or bad weather (depending on whether missing weather is interpreted as good or bad) in statistical summaries. More study is required to determine how frequently this condition exists and what can be done about it.

Foreign fixed buoys (probably only one or two) are missing prior to July 1985 (drifting buoys are included). This omission could be recovered from the basic NMC tapes when time permits, as with i_x for 1982-83 (see Cram, 1986).

3. Hourly Data From Fixed Buoys

Hourly data from about 33 buoys have more observations than the U.S. merchant marine (currently, 20 moored U.S. buoys are "offshore," plus 29 within 150 km of shore). It was suggested that only 3-hourly data from buoys should be retained in COADS, with hourly data in a side set. NCDC prefers to keep all observations in COADS (except sub-hourly resolution). In any event, future computation of monthly summaries should exclude off-3-hourly data to increase the influence of passing ship observations on statistics for 2° boxes containing fixed buoys.

Monthly counts of global data received at NCDC for 1980-84 average approximately as follows (see also Appendix C):

source	reports/month
U.S. merchant marine (ready within 3 months)	23,590
International exchange	60,000
NMC (telecommunications data without U.S. fixed buoys)	90,306
U.S. fixed buoy data (hourly)	24,797
NODC surface-level XBTs (not incorporated after 1977)	n/a

(For U.S. observations only, it is estimated that 59% of the NMC data are not duplicated in delayed manuscript sources; conversely, about 72% manuscripts are unique.)

4. Boulder/NCDC Agreement on COADS Update

A batch of data for about 1980-85 will be prepared by continued cooperation between the groups. NCDC will always prepare annual updates. A major cooperative update will be done about each five years (see Note D and Woodruff and Lubker, 1986).

5. Deficiencies in Global International Exchange

WMO's data flow plan is intended to gather ship reports into eight regional centers operated by the following responsible countries: Federal Republic of Germany, Hong Kong, India, Japan, Netherlands, U.K., U.S., and USSR. NCDC tries to obtain a global set by negotiating with countries and regional centers, but where these efforts are unsuccessful major gaps in logbook data are expected.

6. Data Additions

The U.S. hopes to obtain USSR ships via the U.S./USSR exchange. Under the U.S./India Monsoon Bilateral, India may provide us with Indian ships, data in the Indian Region, and key-enter early Maury ship data.

There is very little ship data in COADS during World Wars I and II. About 18 million U.S. observations could be key-entered to fill this gap. It costs Asheville about 10 to 15 cents to key one ship report (60 or more digits) and archive it. Thus the whole task would cost $2 million. Perhaps costs could be decreased by going overseas.

Commercial fishing fleet data often are kept secret. If we can't get the basic observations we should try to get year-month statistics from the companies.

See Note E for more information on data additions.

7. Ship Location Problem

NMC and the Navy have estimated that 6%-8% of the GTS real-time ship reports may have the wrong location. It is hard to believe that the problem is this bad. The Boulder group plans to study the problem (Note F).

8. Ship History Data

Information about ship size, anemometer height, and SST measurement method should be available for individual vessels (Note G). NMC keeps track of barometer biases on each ship, which should be saved or used for recalculation of pressure, probably the latter. If a barometer is adjusted in port, that fact (and the change) should be part of a calibration data set.

9. Exchange of Information About Ship Data

There are plans to obtain a better exchange of information between Boulder, NCDC, and the research community. Periodic notes will be prepared.

10. NCDC Budget and Contract Problems

NCDC has been under heavy budget pressure and there are plans to contract our (under A76) many tasks in computing, key entry, and others (114 people will be contracted out). It is very hard to get any new tasks done. Fifty-two more positions in data operations divisions may be contracted out later. More information about NCDC operations, data, budgets, and these problems can be obtained from NCDC or from notes by R. Jenne at NCAR. A consortium approach has been suggested by some at NCDC to improve marine data flow in which half a dozen institutions would each contribute $50-100K per year.

11. Use of COADS Data

The data (especially the 2^{o} latitude x 2^{o} longitude monthly summaries in group files) have been used in many significant research projects. Some of these are described in this volume. The USSR and India are hoping to obtain the data under exchange agreements.

The data, and regular updates, are needed to support future TOGA research projects as well as other types or research.

Technical Working Group Discussion Notes

Note A. Overlaying QC Flags ('70s)

Reports that had been relocated in processing performed at ERL to translate the 1970-79 decade from TD-1127 to TD-1129 retained QC flags indicating mislocation. When overlaying of the QC flags occurred these flags were output even though the reports were no longer mislocated. A policy of not overlaying flags resulting from different procedures was adopted.

Note B. German HSST Wind Directions

German HSST (source Exchange format) wind directions reported as whole degrees were translated from LMR into TD-1129(M) code by truncation of units (as for 36-point data). Eight-point data, if any, were translated by the same method. Tests could be performed on CMR to determine extent of problem in TD-1129; LMR and CMR are unaffected because direction is stored as whole degrees.

Note C. 1980-85 Data

NCDC has provided a status report on errors discovered in the '80s data (Cram, 1986) with instructions on how to bring the annual tapes into agreement with the period of record (POR) file at NCDC. Most known errors were found in NMC data input to or after processing by NCDC.

Note D. Update Procedures

Quality and duplicate controlled individual marine reports for 1980-current and corresponding 2° trimmed monthly summaries are planned for availability by 1987. We hope to complete processing by the end of calendar 1986, but the uncertain timing of possible major new data additions (e.g., U.S./USSR exchange) requires some flexibility in this time-table because of large computer requirements.

NCDC will determine if the COADS (NCDC specified) QC differs from current NCDC procedures. Existing flag positions and codes will be examined by NCDC to see if there is room for flags indicating whether a report has passed the track checks, and a duplicate check flag. NCDC will also identify portions of the COADS (NCDC specified) duplicate elimination procedures that would need to be changed to meet NCDC's specifications for '80s data. With an adequate duplicate check flag, indicating whether a GTS and logbook duplicate were found, "certain" duplicates would no longer need to be retained.

If a data exchange is agreed upon that necessitates conversions back and forth from binary to characters on an annual basis, these conversions would have the benefits of ensuring information retention, provided TD-1129 output agrees with input, and automatic gross error checking because of tighter bounds in binary.

Current trimming procedures are considered adequate including use of the 1950-79 period limits for '80s trimming.

Note E. Data Additions

Possible additions for different time periods:

- pre-1970

  OSV upgrade (TD-1160)
  U.S./USSR exchange
  U.S./India bilateral (Maury collection,
  Indian ships/area of responsibility)

- '70s

  OSV upgrade (TD-1160)
  GATE project data (June-October 1974)
  FGGE drifting buoys
  delayed receipts
  NODC data (research ships or surface-level XBTs)

- '80s

  delayed files for January-November 1983 (about 200K reports); NCDC will check if these or other data are missing in the annual tapes and possibly available in NCDC's period-of-record (POR) merge.

NCDC will obtain cost estimates from pending contractors, as soon as appropriate, to punch or microfilm 20K or 1 million reports).

Although it was noted that, resources permitting, GWC (U.S. Air Force Global Weather Central) data might supplement NMC by 5% and provide valuable redundancy, possible quality problems and lack of resources preclude this at the present time.

Note F. Ship Location Problems

NCDC will check if there are counters showing how many reports are flagged during track checks.

Note G. Information About Individual Ships

NCDC will pursue archiving and sources of such information.

References

Cram, R.S., 1986: Marine data processing procedures at the National Climatic Data Center. Proceedings of a COADS Workshop, Boulder, Colorado, January 22-24, 1986, S.D. Woodruff, Ed., NOAA Environmental Research Laboratories, Climate Research Program, Boulder, Colo. (this Volume).

Sadler, J., M. Lander, and A. Hori, 1986: Some gross errors and biases in COADS and their probable causes. Proceedings of a COADS Workshop, Boulder, Colorado, January 22-24, 1986, S. D. Woodruff, Ed., NOAA Environmental Research Laboratories, Climate Research Program, Boulder, Colo. (this Volume).

Woodruff, S.D., and S.J. Lubker, 1986: COADS 1980-84, Proceedings, of a COADS Workshop, Boulder, Colorado, January 22-24, 1986, S.D. Woodruff, Ed., NOAA Environmental Research Laboratories, Climate Research Program, Boulder, Colo. (this Volume).

Appendices

Appendix A

COADS Workshop, January 22-24, 1986
Boulder, Colorado

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Appendix B

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Roy Jenne
9 Oct. 1985
Rev. 9 Jan 86

NAVY ANALYSES

A. *General Comments*

- Navy UA (upper air) analyses on hemispheric grids never included wind analyses before 1983. The new UA 2.5° global archives starting Jan 1983 include winds.
- Navy surface archives on hemispheric grids include winds, but these were derived from the pressure field and stability prior to 1974. Real winds were not used before that time. The derived winds appeared to be reasonably good. They were used to make wave forecasts and for other purposes.
- The global band surface and UA analyses (40S-60N on 2.5° grids) use reported wind data to make wind analyses. The global forecast model (1983-on) does not use any global band data.
- The new 2.5° global archives starting Jan 1983 include wind analyses, which also directly use observed wind data in the upper air.
- The initial state for the forecast model does *not* use wind grids at the surface that include the direct use of real winds.
- A user could prepare global Navy analyses of winds from 1974-on by using global band winds (40S-60N), and blending these with geostrophic winds for the polar areas.

B. *Summary of available Navy surface and UA analyses*

1. N. Hemisphere surface analyses (63x63 grid points) 1961 to 1985, and later

   Most grids start about 1961, some before. SLP (from Nov 45), SST (Nov 61), T air (May 65), E air (May 65), N clouds (Jan 68), winds (calc from pressure fields from 1945 until Aug. 1974, then analyzed).

2. N. Hemisphere UA analyses (63x63) 1961 to Jan 1983

   1000 to 100 mb, mostly start about 1961-63. See data lists in NCAR TN/IA-111. (Data Sets for Meteorological Research, 1975, by R. Jenne).

3. S. Hemisphere surface analyses (63x63 grids) July 1973 to 1985 and on

   SST starts 1 Jul 73. Also SLP. By 1983 the data included SST, SLP, Air T, surface vapor pressure. Winds start Dec 1978.

4. S. Hemisphere UA (63x63) Aug 1974 to Jan 1983

   1000, 925, 850...-100mb, start Aug 1974.

5. Global band (40S-60N), Aug 1973 to 1985, and later

   From Aug 1973. SLP, air T, wind, no moisture.

   UA grids up to 200 mb. Information obtained in 1983 said that the global band grids were usually better than hemispheric grids in the tropics; this is still probably true in 1986.

6. "Spherical" 2.5° global surface analyses. Aug 1974 and on. SLP and winds. These global grids used ship and buoy data (pressure, wind, etc. from the time they were started. The other surface analyses (global band and hemispheric grids) were interpolated from these global grids. In the title of the grid, there is an integer count of the number of wind observations used.

7. Upper air 2.5° global analyses. These grids start Jan 1983. NCAR does not have these yet.

C. *Tapes at NCAR (Oct 1985)*

- Navy S. Hemisphere analysis (Aug 1974 - June 1983). 20 tapes, 6250 BPI. Grids after 17 Jan 83 are interpolated from global 2.5° anal.
- *Global band* (Aug 1973 through July 1984) *and* surface full global "*spherical*" analyses Aug 1974 - June 1983. These two sets are combined on 37 tapes (6250). Global band has grids each 12 hr (49x144 points, 2.5°): SLP; T at 850, 500; U,V at surface, 700,400,250,200 (26 grids/day). Spherical grids are available each 6 hour (SLP and wind) (12 grids/day).
- There are tapes with N. Hemisphere surface grids at NCAR. We do not have the N. Hemisphere UA grids as yet. Or the ocean grids at depth.
- Reanalyses of N. Hemispheric SLP for 1946-75, each 6 hours. Prepared by Manford Hall working for Monterey. Wind and waves also made, but NCAR did not obtain these. Winds were not analyzed, just geostrophic based on pressure.

Note: Some grid reformatting will be done at NCAR to simplify IDs. This may change the tape counts somewhat.

D. *Procedures for analyses*

UA analyses start about 1961 for the N. Hemisphere., 1974 S. Hemisphere:

These were made by using the FIB (fields by information blending) method until August 1982. In the FIB procedure the observed data are first interpolated to a close gridpoint using a short scan radius, with length less than one grid distance. In this process the gradient of the guess is used. At this stage the analysis has some grid points that have been changed, separated by many with no data input. The second part of the FIB process inputs the changed grid points and the gradients of the guess field. It uses calculus of variations methods to obtain a complete analysis. It does not demand any physical constraints (such as height vs wind) in this process. It may also be of interest that S. Africa adopted these procedures and the same S. Hemisphere (63x63) grid for their hemispheric analyses. Later we will describe the global analyses that have been used from August 1982.

Robert Seaman, 1977, provides a good description of the FIB procedure: Australian Met. Mag., Vol 20, p. 83-104. This reference is recommended by Monterey.

E. *First guess for hemispheric analyses before 1983*

The above forecast model is now used for the guess for the global analyses. Before this analysis/forecast method started in Aug 82 we will consider what was used for the first guess for analyses. For each of the hemispheres, it was what might be called a "poor man's" forecast model. The tropospheric flow was divided into long waves and short waves. The short wave systems were moved along in the long wave flow at a speed a fraction of the flow.

F. *Adjustment of surface analyses (Aug 85)*

Navy centers around the world also provide some input to the Navy surface analyses. For example, for 00Z data, analyses are made at 01, 02, and 03Z. If, for example, a regional center doesn't like the analysis in its vicinity, they can send bogus points back that will be used in the 00Z analysis made at 02Z. The analysis made at 3Z is the final one for archive, and for input to the UA analyses.

G. *Global band analyses - tropics (Jan 83 - Zuver)*

The global band (40S - 60N) does not use the FIB methods (fields by information blending) that were used for the hemispheric grids. It has SST (interpolated from hemispheric grids), SLP, sfc wind, sfc air T, 850 T, 700 wind, and alternating T, wind through 200mb. No UA height analyses are made. The global band methods use observed winds in the analyses. A global band analysis (2.5°) has 49 x 144 points = 7056 points.

The hemispheric analyses look good down to 20-22°N. Things can get rather bad in the tropics, but these band analyses are good there. The band analyses have a blending zone between 12 and 30° latitude that shifts somewhat with the season. At least by north or south of 30° lat., they are purely hemispheric data. The analysis guess is the hemispheric grid data and a persistence blend with climatology in the tropics. Since persistence is strong there, this seemed to work well.

Jim Miller, Department of Meteorology and Physical Oceanography at Rutgers, Cook College, New Brunswick, NJ 08903 (201-932-9027) used the surface band data and said they look good. (Jan. 1983).

August 85: Global band, with non-FIB methods still being done. In the summer of 1985 the data inputs were modified some to do away with some of the small scale features. The Navy center in Guam that produces tropical cyclone forecasts is not convinced that the present global is as good in the tropics as this traditional global band. Monterey made a study about 1981, comparing various tropical wind analyses including NMC, and concluded that the global band was then best to support the typhoon forecasts. The Navy P.G. School, also preferred the global band. For about two weeks starting 15 Aug 1982 (when the new global analysis started), the global band was interpolated from the new global analyses. Then the regular program was restarted and used since.

H. *Southern Hemisphere analysis archive (info Jan 83 - phone Zuver)*

These start August 1974. Earlier analyses back to 1973 had a problem. Includes grids of SST, SFCT, SLP, sfc wind, sfc moisture, and 850-200mb on 63x63 grids.

For SST, Jim Zuver (Monterey) thinks they got the NESS satellite spot temps whenever available, and used weights between ships, satellite, and climatology. He thinks that a believable report almost overrides climatology. Sub-surface analyses in the ocean have not been made in the Southern Hemisphere.

The archive includes SLP every 6 hours and T, E, U, V, SST every 12 hours. It has Z, T at 1000, 925, 850, 700, 500, 400, 300, 250, 200, 150, 100 mb each 12 hr. Dew Point depression at 1000, 850, 700, 500, 400, 300.

I. *New global Lat-Lon analyses started Aug 1982*

The global analyses were started about 15 Aug 1982. The analyses were interpolated to the standard Hemispheric (63x63 grids) and global band archives. A computer change forced a reversion to old analysis procedures between about 15 Nov 1982 and 4 Jan 1983.

These new programs for UA analyses produce an archive on a global 2.5° Lat-Lon grid with 73x144 = 10,512 points. The grid origin is 90°N, 60E. For 4-17 January 83, the data was interpolated to the old 63x63 grids. On 18 January 1983 the basic archive became the 2.5° grids. Levels surface through 100 mb. This 2.5° archive replaces the UA 63x63 grids for each hemisphere that were previously made.

The method uses a successive correction method on the UA data. It is about like a Cressman scheme (1979). The wind and height fields are analyzed independently. The winds and heights are then forced to be in balance according to the balance equation. In the tropics, winds are changed very little; the heights are changed to achieve balance. Divergence from the forecast guess is then added back into the analyses (starting summer 1983). Before this the analyzed winds were non-divergent.

Recall that the surface analyses are still made by the old FIB procedure (this is written Oct 85). In the UA analysis, the surface is held constant. It is likewise constant during initialization.

The ocean analyses (currents, temperature at depth, sfc heat transfer, etc.) include the above analyses at time zero, and any XBT data. The surface forcing quickly becomes wind, etc. from the forecast model until the next analysis period.

Grids of ocean latent and sensible heat exchange, clouds, and surface net radiaton, are prepared globally. Cumulative precipitation is also archived. They think that the surface grids are reasonably good because they seem to help the ocean thermal structure analyses. Information from Byron Maxwell, Ext. 2383). Zuver says that some fields from the forecast model, such as PBL depth (planetary boundary layer) and stratus clouds, are not archived. PBL should be saved.

Tom Rosemond did some checks of winds in the tropics near the surface (925 mb) from the forecast model and from the global band analysis. He said that the forecast winds have more continuity in time, but tend to drift to an unreal model wind. The global band analyses depend heavily on climatology when there is no data. Thus, if climatology is a good forecast, they are fine; if there is a big anomaly, there is trouble. My note: Persistence is heavily weighted in the guess. We should find out how fast persistence decays to climatology.

Change October 1984

The users complained that the analyses were too smooth. In this change, the analyses (after balancing) were sent through a fast successive correction analysis pass (like Cressman methods) with a fairly narrow scan radius and a tight error tolerance on observed data. Observed winds are applied to the wind analyses; Observed heights, temps are independently applied to those grids. This product is sent to the users, and it is the archived grid. The forecast model still uses the balanced fields as before.

August 1985 Status

Now doing analysis thru 100mb, as before. This winter they will test a new analysis package (that is O/I) surface through 10mb. Perhaps operational in Spring 1986.

J. *Comments*

Forecast Model

The forecast model is a 9-level sigma model, on a 2.4° lat by 3° lon grid. The analyses are interpolated from the 2.5° grid to this one for the forecast. The top of the model atmosphere is 50 mb, the top forecast level is about 60-70 mb. The model is based on the UCLA model (expert is Tom Rosemond, head of section, X2858).

The forecast model has a boundary layer. Uses the Deardorff "bulk method". Handles trade wind inversions, etc. Keeps track of height of inversion over water and land. The depth is a function of mass convergence in the boundary, entrainment of air from above, and convection sucking air out of the boundary. The depth is not more than 150 mb (and not less than 5 mb). This layer depth is not archived.

Monterey (FNOC) compares forecast verification statistics with NMC and ECMWF results. They were on a par with NMC until the NMC statistics improved with new GFDL model physics and better resolution. ECMWF is well ahead of both in verification scores.

Data Inputs

They have used all the satellite cloud winds and thicknesses that they could obtain, going back many years.

Monthly Analyses

Monthly grids of Northern Hemisphere analyses were prepared for many years until Jan 1983. The global band and Southern Hemisphere grids were never summarized.

Notes:

Oct 1985: Sometimes they still can't use the CDC 205 computer and revert back from the global 2.5° UA analyses to the old hemispheric 63 x 63 methods. The hemispheric grids are then archived, but typically have not been used to fill related gaps in the global files.

When a 63 x 63 grid was interpolated from the global 2.5° grid, there was a change in the title section of the ID that gives a different model source.

NCAR TN/IA-111, Datasets for Meteorological Research (Jenne, 1975) describes the history of Navy archives up to that time.

The above information was mostly from Tom Rosemond (408-646-2858), Ed Barker (x2945), and Jim Zuver (x2259). Zuver runs the Navy archives. Rosemond and Barker are in NEPERF (Navy Environmental, Prediction, Research Facility) at Monterey. It reports to the Navy Research Command.

Archives of observed data from FNOC are also kept at NCAR.

Note: Navy grids called TP are dew point depression. T2 grids are 1000 mb temperature.

Data Volume:

Type of Analysis	Grids/Day *1983-85*	Points/ *Grid*	Words/Grid *(64 bit)*	Bits/Yr. *(10^9)*
Spherical (Surface 2.5°)	4x3	73x144	2642	0.741
Global Band (2.5°)	2x13	49x144	1778	1.080
S. Hem. UA	(4x1)+(2x33)	63x63	1006	3.290

Talk with Jack Kitla, Navy, Monterey re Boundary Layer (Dec 1985)

Their wind analyses are for the level of 19.5 meters, which is taken to be the level of the anemometer on most ships. The difference between a 5m wind and one at 19.5m would be about 10 to 15% under neutral stability.

Kitla says that ship winds are used in the global spectral analysis (144 x 73 points) and that the hemispheric winds are just interpolated from this global 2.5° wind. The analyzed wind is less than the ship wind. See the study JAS Oct 78, p. 1488, Carl Friehe. Compare wind to buoy wind. Buoy too large.

Kitla tried using analyzed winds directly in wave model. Results were bad--waves 200% too high. To calculate waves he uses the analysis wind only in the tropics. For the hemispheres he uses his generated winds at time 0. For later times in the forecast period, he uses winds from the forecast model.

The Deardorff scheme is described in 1971 MWR. This is what is in the UCLA model which was used for their present NOGAPS forecast model. They have had some trouble with the fact that the top of the boundary can go up and down through a sigma level. Emphasizes that the boundary layer is in the model, but it is never analyzed using real data. He says, for example, that the tropics and specifically the Somali Jet associated with the Indian monsoon aren't handled well.

They will soon have an article in Bul AMS that compares their new global scheme to buoys. Looks pretty good. His analyzed winds are only somewhat above the average (8-minute) winds from buoys. The winds are better than the opnl hemispheric, though it is supposed to be the same code. He thinks that things got cleaned up better in the code conversion.

y winds are by far the best data that has come along. There are many probnds. He thinks that when people take a ship wind it is biased toward the an average. He says that Pearson (1983) has written a very good article on son talks about the question of what is an average wind.

in the December 1976 MWR where he shows how he has parameterized the obtain the winds that he uses for waves. Neperf is now designing a new scheme.

REFERENCES

Seaman, Robert, 1977: title, Australian Met. Mag., Vol. 20, pp. 83-104.

"An Operational Evaluation of the Navy Operational Global Atmospheric System...", Toll & Clune, MWR, Sep 1985.

Pearson, Feb 1983: Measurement of synoptic scale winds over the ocean. JGR, Vol. 88, pp. 1683-170.

Cressman, George P., 1959: An operational objective analysis system. MWR, Vol 87, No. 10, pp. 367-374.

Appendix C

Marine Data Inventories

Table 1 was compiled from an inventory that NCDC completed by deck, month and year for the corrected '70s COADS and '80s period-of-record tapes (as of 13 February 1986).

Tables 2-5 were compiled from inventories (product 2) described in <u>Release 1</u> (Slutz et al., 1985). Table 2 summarizes duplicate elimination input (I), output (O), and uncertain duplicates (D) for three periods (1854-1969, 1970-79, 1854-1979). The number of Long Marine Reports (LMR) is given for a few general categories and separately for each card deck*. Table 3 gives related percentages with respect to the complete, global LMR file of a particular type (I, O, D) and time period. Table 4 is a similar breakdown for ((I - O) + D)/I and D/O. ((I - O) + D)/I is the fraction of input that was identified as duplicate (certain or uncertain). D/O is the fraction of output that was identified as uncertain. Each fraction is expressed as a percentage with respect to the input or output for a specific category (GTS, etc.) and time period, only. Thus ((I - O) + D)/I in each case is really ((I - O) + D)/I x 100. Table 5 lists thousands of LMR per source ID (see <u>Release 1's</u> Table F1-2, reprinted within Table 2) separately for each year 1854-1979.

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* Global telecommunication system (GTS) data were identified by card deck (see <u>Release 1's</u> Table F1-1, reprinted within Table 2): 555, 666, 849, 850, 888, 889, 999. Non-GTS data comprise all other card decks, as well as identifiable data from the remaining categories: buoy decks 143, 876-882; NODC 891; IMM 926; U.S. IMM 128, 927-928; foreign 118-119, 184-185, 187-189, 192-194, 196-197, 898-900, 902; U.S. 110, 116-117, 195, 281; Historical Sea Surface Temperature (HSST) Data Project 150-156; and other 186, 897, 901. It should be noted that U.S. International Maritime Meteorological (IMM) exchange data (deck 927) include some foreign IMM prior to 1980. Therefore, counts for IMM and U.S. IMM are inaccurate.

26 July 1986

Table 1

SHIP DATA
(thousands of reports per year)

	1970s Ships (1970-79 COADS Release 1 Data)				1980s Ships						
Deck	1970	1975	1979	70-79	1978	79	80	81	82	83	84
555 Navy	348.2			196.1							
888 GWC		830.4	963.1	594.3			410.9	199.7			
889 Autodin		10.0	16.0	15.6		.1	46.8	47.9	44.9	54.8	63.9
890 NMC GTS							616.3	1027.0	1016.5	1280.9	1477.6
891 NODC XBT	71.1	19.9		31.9							
900 Austr.	22.9	12.5	4.0	14.2							
926 IMM	0	15.4	128.5	48.9	119.0	356.2	933.0	932.0	781.0	253.4	34.5
927 US Marine	1452.6	942.5	536.9	873.1	.4	.7	358.7	338.2	209.3	219.7	289.4
928 US OSV	24.8			4.5							
849-850 FGGE			420.3	46.5							
876-881 Buoy		17.1		13.6							
882 NDBC Buoy			124.4	17.6			164.8	224.8	271.9	327.1	499.3

NOTES: 1. Information on 1980s ships is based on an inventory of NCDC's period of record file on February 13, 1986. Each year data is ready by about June of the following year. The update includes older data that came in late, and may contain some duplicates.

2. NCDC shifted from GWC as a primary real-time data source to NMC. The real-time data is always available by the end of the year in question.

Ship Logs

3. Deck 927 (US Marine) has gone sharply down over the years, because it includes earlier IMM Resol 35 data identifiable only by country code.

4. The lag in obtaining IMM data can be seen by looking at IMM data counts in 1982, 83, 84 and by seeing what 1978-79 data arrived during the 1980-84 time period as given above.

5. Buoys: Currently, the NDBC data has hourly data from around 49 buoys and 40 stations from the Coastal-Marine Automated Network (C-MAN). The total number of reports is less than the maximum ((49+40) x 24 x 365 ≈ 780,000) probably because of inoperative periods routinely experienced by buoys or stations, and instances of garbled message transmission. The NMC data includes ships, fixed buoy data, and drifting buoy data (now from about 100 buoys), all as received in real time. The NMC data are collated with the NDBC data to eliminate duplicate NMC reports.

TABLE 2
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D) AS LMR PER CATEGORY*

	1854–1969			1970–79			1854–1979		
	I	O	D	I	O	D	I	O	D
GTS	2402206	1402022	98778	8893700	8549428	23483	11295906	9951450	122261
NON–GTS	72231643	51783897	230455	14923737	10133056	34342	87155380	61916953	264797
TOTAL	74633849	53185919	329233	23817437	18682484	57825	98451286	71868403	387058
BUOY	0	0	0	554047	324725	52	554047	324725	52
NODC	1572431	1334474	2861	337852	320348	1327	1910283	1654822	4188
IMM	2444198	1697902	7800	1062839	497169	7929	3507037	2195071	15729
US IMM	12976703	11691488	63250	12719050	8835422	22463	25695753	20526910	85713
FOREIGN	21385213	20200522	33860	248229	153680	2569	21633442	20354202	36429
US	8494456	8412621	68252	0	0	0	8494456	8412621	68252
HSST	25329850	8419189	54364	0	0	0	25329850	8419189	54364
OTHER	28792	27701	68	1720	1712	2	30512	29413	70
TOTAL	72231643	51783897	230455	14923737	10133056	34342	87155380	61916953	264797

*See text for definition of categories. Tables F1-1 and F1-2 are reprinted from *Release 1* for reference in using Tables 2 through 5.

Table F1-1
Card Deck Assignments (GTS*)

CD	Description	Approximate** output period
110	U.S. Navy Marine	1945-1951
116	U.S. Merchant Marine	1945-1963
117	U.S. Navy Hourlies	1952-1964
118	Japanese Ships No. 1	1930-1953
119	Japanese Ships No. 2	1934-1971
128	International Marine (U.S. recruited ships punched in-house)	1900-1978
143	PMEL (Pacific Marine Environmental Laboratory) Buoy	1975-1977
150	Pacific (U.S. Responsibility) HSST Netherlands Receipts	1939-1961
151	Pacific (U.S. Responsibility) HSST German Receipts	1862-1960
152	Pacific (U.S. Responsibility) HSST U.K. Receipts	1854-1961
155	Indian (Netherlands Responsibility) HSST	1861-1960
156	Atlantic (German Responsibility) HSST	1852-1961
184	Great Britain Marine (194 Extension)	1953-1961
185	USSR Marine IGY	1957-1958
186	USSR Ice Stations	1937-1970
187	Japanese Whaling Fleet	1946-1956
188	Norwegian Antarctic Whaling Factory Ships	1932-1939
189	Netherlands Marine	1901-1959
192	Deutsche Seewarte Marine	1855-1939
193	Netherlands Marine	1800-1938
194	Great Britain Marine	1856-1955
195	U.S. Navy Ships Logs	1941-1946
196	Deutsche Seewarte Marine (192 extension)	1949-1954
197	Danish Marine	1871-1956
281	U.S. Navy MAR (Monthly Aerological Record)	1926-1945
555*	Monterey Telecom.	1966-1973
666*	Tuna Boats	1971-1975
849*	FGGE (First GARP Global Experiment)	1978-1979
850*	German FGGE	1978-1979
876-882	NDBC (NOAA Data Buoy Center)	1972-1979
888*	GWC (U.S. Air Force Global Weather Central)	1973-1979
889*	AUTODIN (Dept. of Defense Automatic Digital Network)	1972-1979
891	NODC (National Oceanographic Data Center) Surface	1900-1977
897	*Eltanin*	1962-1963
898	Japanese	1954-1974
899	South African Whaling	1900-1955
900	Australian	1931-1979
901	FOSDIC Reconstructions (card images from 16mm film)	1868-1963
902	Great Britain Marine (184 extension)	1957-1961
926	IMMPC (International Maritime Meteorological Punch Card)	1956-1979
927	International Marine (U.S. recruited ships punched in-house)	1970-1979
928	Same as 927 including OSV (Ocean Station Vessels)	1970-1974
999*	U.S. Air Force ETAC (Environmental Technical Applications Center)	1967-1969

Table F1-2
Source ID Assignments

SID	CD	Description	Format	Char	Output period
1	mix	Atlas	TD-1100	ebcdic	1800-1969
2	150-2,192	HSST Pacific	TD-1100	ebcdic	1854-1961
3	155	HSST Indian	Exchange	ebcdic	1861-1960
4	156	HSST Atlantic	Exchange	ascii	1852-1961
5	mix	Old TDF-11 Supplement B	TD-1100	ebcdic	1854-1975
6	primarily 128	Old TDF-11 Supplement C	TD-1100	ebcdic	1855-1978
7	555	Monterey Telecom.	TD-1100	ebcdic	1966-1969
8	mix	OSV (Ocean Station Vessels)	TD-1100	ebcdic	1945-1973
9	mix	OSV Supplement	TD-1100	ebcdic	1947-1973
10	mix	MSQ 486 and 105 Omissions	TD-1100	ebcdic	1854-1939
11	891	NODC Surface	TD-1100	ebcdic	1900-1975
12	891	NODC Surface Supplement	TD-1100	ebcdic	1902-1977
13	897	*Eltanin*	TD-1129M	ebcdic	1962-1963
14	898	Japanese	TD-1129	ebcdic	1954-1974
15	899	South African Whaling	TD-1129M	ebcdic	1900-1955
16	900	Australian	TD-1129	ebcdic	1931-1970
17	926	IMMPC	TD-1129	ebcdic	1956-1963
18	mix	'70s Decade	TD-1129	ascii	1970-1979
19	926	IMMPC ('70s)	TD-1129	ebcdic	1970-1979
20	mix	OSV Z ('70s)	TD-1100	ebcdic	1971-1974
21	900	Australian ('70s)	TD-1129	ebcdic	1971-1979
22	?	*Islas Orcadas* ('70s)	n/a	n/a	n/a
23	mix	'70s Mislocated Data	TD-1127	ebcdic	1970-1979
24	143,876-82	Buoy Data	TD-1129	ebcdic	1972-1979

* GTS deck (from the Global Telecommunication System): all others are manuscript data. Decks 849-850 are considered GTS although they may have been mixed.

** Period of record is exact for CMR (supp. D), except that the starting years of decks 156 and 193 are exact for LMR (both start in 1854 in CMR).

TABLE 2 (CONTINUED)
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D)
AS LMR PER CARD DECK

	1854-1969			1970-79			1854-1979		
	I	O	D	I	O	D	I	O	D
DECK 110	676120	652553	2830	0	0	0	676120	652553	2830
DECK 116	7008270	6954754	57348	0	0	0	7008270	6954754	57348
DECK 117	15875	13304	2322	0	0	0	15875	13304	2322
DECK 118	1738110	1729281	2125	0	0	0	1738110	1729281	2125
DECK 119	910008	908485	2362	2	2	0	910010	908487	2362
DECK 128	12976703	11691488	63250	3868856	82447	12895	16845559	11773935	76145
DECK 143	0	0	0	26963	12367	0	26963	12367	0
DECK 150	192643	104557	396	0	0	0	192643	104557	396
DECK 151	986875	600798	264	0	0	0	986875	600798	264
DECK 152	1833708	199597	23258	0	0	0	1833708	199597	23258
DECK 155	5928656	1225254	7547	0	0	0	5928656	1225254	7547
DECK 156	16387968	6288983	22899	0	0	0	16387968	6288983	22899
DECK 184	607424	595171	1303	0	0	0	607424	595171	1303
DECK 185	112357	112298	406	0	0	0	112357	112298	406
DECK 186	18885	18875	11	1720	1712	2	20605	20587	13
DECK 187	11482	11215	66	0	0	0	11482	11215	66
DECK 188	21640	8021	493	0	0	0	21640	8021	493
DECK 189	473541	235431	2263	0	0	0	473541	235431	2263
DECK 192	6659359	6050249	3167	0	0	0	6659359	6050249	3167
DECK 193	6402681	6276721	775	0	0	0	6402681	6276721	775
DECK 194	3713708	3633644	6946	0	0	0	3713708	3633644	6946
DECK 195	603599	601994	3579	0	0	0	603599	601994	3579
DECK 196	176430	176214	982	0	0	0	176430	176214	982
DECK 197	24077	22678	133	0	0	0	24077	22678	133
DECK 281	190592	190016	2173	0	0	0	190592	190016	2173
DECK 555	2344535	1355464	97554	2031386	1967981	6960	4375921	3323445	104514
DECK 666	0	0	0	17825	313	195	17825	313	195
DECK 849	0	0	0	282160	256043	1021	282160	256043	1021
DECK 850	0	0	0	221068	210191	219	221068	210191	219
DECK 876	0	0	0	61718	36359	51	61718	36359	51
DECK 877	0	0	0	7962	4680	1	7962	4680	1
DECK 878	0	0	0	61995	41590	0	61995	41590	0
DECK 879	0	0	0	71538	44065	0	71538	44065	0
DECK 880	0	0	0	12208	8288	0	12208	8288	0
DECK 881	0	0	0	1450	1275	0	1450	1275	0
DECK 882	0	0	0	310213	176101	0	310213	176101	0
DECK 888	0	0	0	6182234	5958378	14999	6182234	5958378	14999
DECK 889	0	0	0	159027	156522	89	159027	156522	89
DECK 891	1572431	1334474	2861	337852	320348	1327	1910283	1654822	4188
DECK 897	1255	614	10	0	0	0	1255	614	10
DECK 898	120828	94220	7573	15851	8719	101	136679	102939	7674
DECK 899	76776	61029	4082	0	0	0	76776	61029	4082
DECK 900	205463	156225	494	232376	144959	2468	437839	301184	2962
DECK 901	8652	8212	47	0	0	0	8652	8212	47
DECK 902	131329	129640	690	0	0	0	131329	129640	690
DECK 926	2444198	1697902	7800	1062839	497169	7929	3507037	2195071	15729
DECK 927	0	0	0	8801018	8707752	9335	8801018	8707752	9335
DECK 928	0	0	0	49176	45223	233	49176	45223	233
DECK 999	57671	46558	1224	0	0	0	57671	46558	1224
TOTAL	74633849	53185919	329233	23817437	18682484	57825	98451286	71868403	387058

TABLE 3
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D) AS PERCENTAGE OF LMR PER CARD DECK

	1854–1969			1970–79			1854–1979		
	I	O	D	I	O	D	I	O	D
GTS	3.22	2.64	30.00	37.34	45.76	40.61	11.47	13.85	31.59
NON–GTS	96.78	97.36	70.00	62.66	54.24	59.39	88.53	86.15	68.41
BUOY	.00	.00	.00	2.33	1.74	.09	.56	.45	.01
NODC	2.11	2.51	.87	1.42	1.71	2.29	1.94	2.30	1.08
IMM	3.27	3.19	2.37	4.46	2.66	13.71	3.56	3.05	4.06
US IMM	17.39	21.98	19.21	53.40	47.29	38.85	26.10	28.56	22.14
FOREIGN	28.65	37.98	10.28	1.04	.82	4.44	21.97	28.32	9.41
US	11.38	15.82	20.73	.00	.00	.00	8.63	11.71	17.63
HSST	33.94	15.83	16.51	.00	.00	.00	25.73	11.71	14.05
OTHER	.04	.05	.02	.01	.01	.00	.03	.04	.02
DECK 110	.91	1.23	.86	.00	.00	.00	.69	.91	.73
DECK 116	9.39	13.08	17.42	.00	.00	.00	7.12	9.68	14.82
DECK 117	.02	.03	.71	.00	.00	.00	.02	.02	.60
DECK 118	2.33	3.25	.65	.00	.00	.00	1.77	2.41	.55
DECK 119	1.22	1.71	.72	.00	.00	.00	.92	1.26	.61
DECK 128	17.39	21.98	19.21	16.24	.44	22.30	17.11	16.38	19.67
DECK 143	.00	.00	.00	.11	.07	.00	.03	.02	.00
DECK 150	.26	.20	.12	.00	.00	.00	.20	.15	.10
DECK 151	1.32	1.13	.08	.00	.00	.00	1.00	.84	.07
DECK 152	2.46	.38	7.06	.00	.00	.00	1.86	.28	6.01
DECK 155	7.94	2.30	2.29	.00	.00	.00	6.02	1.70	1.95
DECK 156	21.96	11.82	6.96	.00	.00	.00	16.65	8.75	5.92
DECK 184	.81	1.12	.40	.00	.00	.00	.62	.83	.34
DECK 185	.15	.21	.12	.00	.00	.00	.11	.16	.10
DECK 186	.03	.04	.00	.01	.01	.00	.02	.03	.00
DECK 187	.02	.02	.02	.00	.00	.00	.01	.02	.02
DECK 188	.03	.02	.15	.00	.00	.00	.02	.01	.13
DECK 189	.63	.44	.69	.00	.00	.00	.48	.33	.58
DECK 192	8.92	11.38	.96	.00	.00	.00	6.76	8.42	.82
DECK 193	8.58	11.80	.24	.00	.00	.00	6.50	8.73	.20
DECK 194	4.98	6.83	2.11	.00	.00	.00	3.77	5.06	1.79
DECK 195	.81	1.13	1.09	.00	.00	.00	.61	.84	.92
DECK 196	.24	.33	.30	.00	.00	.00	.18	.25	.25
DECK 197	.03	.04	.04	.00	.00	.00	.02	.03	.03
DECK 281	.26	.36	.66	.00	.00	.00	.19	.26	.56
DECK 555	3.14	2.55	29.63	8.53	10.53	12.04	4.44	4.62	27.00
DECK 666	.00	.00	.00	.07	.00	.34	.02	.00	.05
DECK 849	.00	.00	.00	1.18	1.37	1.77	.29	.36	.26
DECK 850	.00	.00	.00	.93	1.13	.38	.22	.29	.06
DECK 876	.00	.00	.00	.26	.19	.09	.06	.05	.01
DECK 877	.00	.00	.00	.03	.03	.00	.01	.01	.00
DECK 878	.00	.00	.00	.26	.22	.00	.06	.06	.00
DECK 879	.00	.00	.00	.30	.24	.00	.07	.06	.00
DECK 880	.00	.00	.00	.05	.04	.00	.01	.01	.00
DECK 881	.00	.00	.00	.01	.01	.00	.00	.00	.00
DECK 882	.00	.00	.00	1.30	.94	.00	.32	.25	.00
DECK 888	.00	.00	.00	25.96	31.89	25.94	6.28	8.29	3.88
DECK 889	.00	.00	.00	.67	.84	.15	.16	.22	.02
DECK 891	2.11	2.51	.87	1.42	1.71	2.29	1.94	2.30	1.08
DECK 897	.00	.00	.00	.00	.00	.00	.00	.00	.00
DECK 898	.16	.18	2.30	.07	.05	.17	.14	.14	1.98
DECK 899	.10	.11	1.24	.00	.00	.00	.08	.08	1.05
DECK 900	.28	.29	.15	.98	.78	4.27	.44	.42	.77
DECK 901	.01	.02	.01	.00	.00	.00	.01	.01	.01
DECK 902	.18	.24	.21	.00	.00	.00	.13	.18	.18
DECK 926	3.27	3.19	2.37	4.46	2.66	13.71	3.56	3.05	4.06
DECK 927	.00	.00	.00	36.95	46.61	16.14	8.94	12.12	2.41
DECK 928	.00	.00	.00	.21	.24	.40	.05	.06	.06
DECK 999	.08	.09	.37	.00	.00	.00	.06	.06	.32

TABLE 4
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D) AS PERCENTAGE OF LMR PER CARD DECK

	1854–1969		1979–79		1854–1979	
	((I-O)+D)/I	D/O	((I-O)+D)/I	D/O	((I-O)+D)/I	D/O
GTS	45.75	7.05	4.14	.27	12.98	1.23
NON–GTS	28.63	.45	32.33	.34	29.26	.43
BUOY	.00	.00	41.40	.02	41.40	.02
NODC	15.32	.21	5.57	.41	13.59	.25
IMM	30.85	.46	53.97	1.59	37.86	.72
US IMM	10.39	.54	30.71	.25	20.45	.42
FOREIGN	5.70	.17	39.12	1.67	6.08	.18
US	1.77	.81	.00	.00	1.77	.81
HSST	66.98	.65	.00	.00	66.98	.65
OTHER	4.03	.25	.58	.12	3.83	.24
DECK 110	3.90	.43	.00	.00	3.90	.43
DECK 116	1.58	.82	.00	.00	1.58	.82
DECK 117	30.82	17.45	.00	.00	30.82	17.45
DECK 118	.63	.12	.00	.00	.63	.12
DECK 119	.43	.26	.00	.00	.43	.26
DECK 128	10.39	.54	98.20	15.64	30.56	.65
DECK 143	.00	.00	54.13	.00	54.13	.00
DECK 150	45.93	.38	.00	.00	45.93	.38
DECK 151	39.15	.04	.00	.00	39.15	.04
DECK 152	90.38	11.65	.00	.00	90.38	11.65
DECK 155	79.46	.62	.00	.00	79.46	.62
DECK 156	61.76	.36	.00	.00	61.76	.36
DECK 184	2.23	.22	.00	.00	2.23	.22
DECK 185	.41	.36	.00	.00	.41	.36
DECK 186	.11	.06	.58	.12	.15	.06
DECK 187	2.90	.59	.00	.00	2.90	.59
DECK 188	65.21	6.15	.00	.00	65.21	6.15
DECK 189	50.76	.96	.00	.00	50.76	.96
DECK 192	9.19	.05	.00	.00	9.19	.05
DECK 193	1.98	.01	.00	.00	1.98	.01
DECK 194	2.34	.19	.00	.00	2.34	.19
DECK 195	.86	.59	.00	.00	.86	.59
DECK 196	.68	.56	.00	.00	.68	.56
DECK 197	6.36	.59	.00	.00	6.36	.59
DECK 281	1.44	1.14	.00	.00	1.44	1.14
DECK 555	46.35	7.20	3.46	.35	26.44	3.14
DECK 666	.00	.00	99.34	62.30	99.34	62.30
DECK 849	.00	.00	9.62	.40	9.62	.40
DECK 850	.00	.00	5.02	.10	5.02	.10
DECK 876	.00	.00	41.17	.14	41.17	.14
DECK 877	.00	.00	41.23	.02	41.23	.02
DECK 878	.00	.00	32.91	.00	32.91	.00
DECK 879	.00	.00	38.40	.00	38.40	.00
DECK 880	.00	.00	32.11	.00	32.11	.00
DECK 881	.00	.00	12.07	.00	12.07	.00
DECK 882	.00	.00	43.23	.00	43.23	.00
DECK 888	.00	.00	3.86	.25	3.86	.25
DECK 889	.00	.00	1.63	.06	1.63	.06
DECK 891	15.32	.21	5.57	.41	13.59	.25
DECK 897	51.87	1.63	.00	.00	51.87	1.63
DECK 898	28.29	8.04	45.63	1.16	30.30	7.45
DECK 899	25.83	6.69	.00	.00	25.83	6.69
DECK 900	24.20	.32	38.68	1.70	31.89	.98
DECK 901	5.63	.57	.00	.00	5.63	.57
DECK 902	1.81	.53	.00	.00	1.81	.53
DECK 926	30.85	.46	53.97	1.59	37.86	.72
DECK 927	.00	.00	1.17	.11	1.17	.11
DECK 928	.00	.00	8.51	.52	8.51	.52
DECK 999	21.39	2.63	.00	.00	21.39	2.63

TABLE 5

DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1854	I	13	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21
	O	13	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1855	I	41	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65
	O	41	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1856	I	46	1	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72
	O	46	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1857	I	51	2	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	80
	O	51	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1858	I	52	3	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	82
	O	52	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1859	I	43	3	0	23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69
	O	43	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1860	I	56	5	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	92
	O	56	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	59
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1861	I	65	3	17	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	121
	O	65	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	68
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1862	I	71	2	20	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133
	O	71	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1863	I	72	2	23	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136
	O	72	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1864	I	78	2	24	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150
	O	78	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1865	I	63	1	19	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
	O	63	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1866	I	63	1	19	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119
	O	63	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 5

DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1867	I	63	1	19	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119
	O	63	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1868	I	71	4	22	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	137
	O	71	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1869	I	74	5	22	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	139
	O	73	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1870	I	79	6	25	41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	152
	O	79	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	83
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1871	I	69	7	22	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133
	O	68	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	72
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1872	I	69	8	22	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135
	O	68	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1873	I	64	9	19	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127
	O	64	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1874	I	70	7	23	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136
	O	70	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1875	I	65	12	19	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127
	O	65	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1876	I	61	11	21	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120
	O	60	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1877	I	65	10	24	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	129
	O	65	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	69
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1878	I	64	12	22	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127
	O	63	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	67
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1879	I	72	16	26	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	143
	O	71	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	76
	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

TABLE 5
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1880	I	92	15	32	41	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	181
	O	91	1	1	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96
	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1881	I	98	20	31	43	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	193
	O	97	1	1	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	102
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1882	I	107	19	34	50	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	211
	O	106	1	1	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	113
	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1883	I	111	24	36	48	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	219
	O	109	1	1	5	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	117
	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1884	I	111	25	36	48	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	221
	O	109	1	2	6	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119
	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1885	I	99	22	32	47	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	202
	O	98	1	1	7	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	108
	D	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1886	I	122	25	35	75	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	257
	O	120	1	1	18	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141
	D	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1887	I	132	25	34	124	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	316
	O	130	2	1	57	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	192
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1888	I	133	31	31	162	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	358
	O	131	2	1	98	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	233
	D	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1889	I	129	21	32	164	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	347
	O	128	1	2	93	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	224
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1890	I	123	22	31	172	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	349
	O	121	1	2	106	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	231
	D	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1891	I	113	21	28	130	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	293
	O	112	1	1	69	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	183
	D	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1892	I	102	19	27	127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	274
	O	101	1	1	73	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	176
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

TABLE 5
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1893	I	110	21	28	145	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	305
	O	109	1	1	87	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	198
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1894	I	107	24	31	149	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	312
	O	106	1	1	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	208
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1895	I	118	25	34	190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	368
	O	116	1	2	134	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	253
	D	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1896	I	121	26	33	186	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	366
	O	119	1	1	127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	249
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1897	I	115	28	31	166	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	340
	O	113	2	1	113	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	229
	D	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1898	I	126	29	31	183	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	369
	O	124	2	1	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	248
	D	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1899	I	112	30	32	173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	347
	O	110	2	1	124	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	238
	D	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1900	I	85	28	28	128	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	270
	O	83	2	1	102	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	189
	D	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
1901	I	96	36	30	132	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	296
	O	95	3	3	101	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	202
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1902	I	115	45	56	188	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	408
	O	113	11	25	141	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	294
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	I	113	44	61	212	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	434
	O	111	12	30	163	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	320
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1904	I	149	45	75	275	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	549
	O	148	15	42	192	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	400
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1905	I	170	44	81	293	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	593
	O	167	16	46	192	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	426
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 5
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1906	I	256	56	87	275	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	679
	O	253	16	35	131	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	437
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1907	I	267	53	90	296	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	711
	O	264	16	37	138	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	459
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1908	I	295	57	97	327	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	781
	O	291	18	44	145	0	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	503
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1909	I	303	81	107	366	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	861
	O	299	24	50	197	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	576
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1910	I	408	89	130	429	0	1	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1064
	O	403	22	53	196	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	681
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1911	I	436	96	135	451	0	1	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1125
	O	431	22	51	210	0	1	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	721
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1912	I	454	92	143	449	0	1	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1144
	O	448	22	48	204	0	1	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	727
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1913	I	550	88	154	450	0	1	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1246
	O	542	15	37	155	0	1	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	754
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1914	I	352	37	109	219	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	721
	O	346	3	10	44	0	1	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	407
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1915	I	136	5	58	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	264
	O	133	0	2	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	144
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1916	I	117	5	44	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	224
	O	115	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	127
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1917	I	64	4	14	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	108
	O	64	0	1	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1918	I	39	1	9	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65
	O	39	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 5
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1919	I	103	4	35	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	198
	O	101	0	1	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	115
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1920	I	126	8	45	88	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	269
	O	123	2	3	34	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	162
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1921	I	264	21	87	144	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	519
	O	258	0	2	20	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	283
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1922	I	348	34	104	189	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	680
	O	341	2	4	23	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	373
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1923	I	356	42	113	228	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	745
	O	349	5	13	57	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	427
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	I	373	46	126	250	0	2	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	800
	O	365	7	16	75	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	467
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1925	I	362	44	131	254	0	2	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	796
	O	354	7	21	82	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	469
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1926	I	383	51	132	268	0	2	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	841
	O	374	9	22	84	0	1	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	495
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1927	I	443	62	139	292	0	2	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	942
	O	434	8	18	83	0	1	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	547
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1928	I	458	61	143	300	0	2	0	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	968
	O	449	8	17	79	0	1	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	558
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1929	I	439	58	144	293	0	1	0	0	0	11	4	0	0	0	1	0	0	0	0	0	0	0	0	0	952
	O	430	10	15	79	0	0	0	0	0	11	3	0	0	0	1	0	0	0	0	0	0	0	0	0	549
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1930	I	463	57	110	270	0	1	0	0	0	10	4	0	0	0	1	0	0	0	0	0	0	0	0	0	917
	O	439	4	8	36	0	1	0	0	0	10	3	0	0	0	1	0	0	0	0	0	0	0	0	0	503
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1931	I	375	42	84	219	0	0	0	0	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	732
	O	354	3	5	35	0	0	0	0	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	0	407
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

TABLE 5
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1932	I	297	29	69	156	0	0	0	0	0	6	4	0	0	0	4	0	0	0	0	0	0	0	0	0	567
	O	276	1	3	20	0	0	0	0	0	5	4	0	0	0	2	0	0	0	0	0	0	0	0	0	311
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1933	I	518	30	99	175	0	0	0	0	0	7	7	0	0	0	9	0	0	0	0	0	0	0	0	0	846
	O	494	1	2	17	0	0	0	0	0	7	6	0	0	0	5	0	0	0	0	0	0	0	0	0	533
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
1934	I	564	31	111	194	0	0	0	0	0	9	9	0	0	0	5	0	0	0	0	0	0	0	0	0	923
	O	542	1	2	17	0	0	0	0	0	9	8	0	0	0	4	0	0	0	0	0	0	0	0	0	584
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1935	I	588	25	110	224	0	0	0	0	0	9	12	0	0	0	5	0	0	0	0	0	0	0	0	0	973
	O	570	1	2	16	0	0	0	0	0	8	12	0	0	0	4	0	0	0	0	0	0	0	0	0	613
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1936	I	657	23	122	270	0	0	0	0	0	9	10	1	0	0	4	0	0	0	0	0	0	0	0	0	1095
	O	641	1	2	17	0	0	0	0	0	9	10	1	0	0	3	0	0	0	0	0	0	0	0	0	684
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1937	I	680	18	135	282	1	0	0	0	0	10	11	1	0	0	4	0	0	0	0	0	0	0	0	0	1142
	O	665	1	2	17	0	0	0	0	0	10	10	1	0	0	3	0	0	0	0	0	0	0	0	0	709
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1938	I	525	11	111	314	0	0	0	0	0	6	14	0	0	0	2	0	0	0	0	0	0	0	0	0	983
	O	514	0	35	56	0	0	0	0	0	6	13	0	0	0	1	0	0	0	0	0	0	0	0	0	626
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1939	I	333	9	47	143	0	0	0	0	0	1	14	0	0	0	1	0	0	0	0	0	0	0	0	0	549
	O	326	4	14	22	0	0	0	0	0	1	13	0	0	0	1	0	0	0	0	0	0	0	0	0	382
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1940	I	196	2	17	21	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	247
	O	195	0	0	5	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	210
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1941	I	137	1	10	17	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	174
	O	136	0	0	4	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	149
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1942	I	145	1	3	8	0	2	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	165
	O	144	0	1	4	0	1	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	155
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1943	I	157	1	3	7	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	174
	O	156	0	0	3	0	1	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	166
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1944	I	252	1	4	8	0	1	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	273
	O	250	0	1	3	0	1	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	263
	D	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

TABLE 5
DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1945	I	413	5	5	7	0	1	0	11	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	451
	O	404	1	1	4	0	1	0	11	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	429
	D	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1946	I	120	14	43	69	0	5	0	11	0	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	269
	O	116	6	30	56	0	5	0	9	0	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	227
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1947	I	211	26	58	110	8	13	0	11	1	2	6	0	0	0	3	0	0	0	0	0	0	0	0	0	449
	O	196	6	21	49	1	12	0	10	1	2	6	0	0	0	3	0	0	0	0	0	0	0	0	0	307
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1948	I	274	30	73	164	16	9	0	18	4	3	9	0	0	0	2	0	0	0	0	0	0	0	0	0	604
	O	253	3	18	60	1	8	0	18	4	3	9	0	0	0	2	0	0	0	0	0	0	0	0	0	378
	D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1949	I	516	37	78	165	31	10	0	32	4	3	12	0	0	0	4	0	0	0	0	0	0	0	0	0	893
	O	495	3	19	48	0	8	0	29	4	3	11	0	0	0	4	0	0	0	0	0	0	0	0	0	625
	D	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
1950	I	561	36	78	171	34	14	0	34	4	5	18	2	0	0	5	0	0	0	0	0	0	0	0	0	963
	O	535	2	19	56	1	11	0	31	4	4	17	2	0	0	4	0	0	0	0	0	0	0	0	0	686
	D	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
1951	I	643	44	67	229	32	14	0	35	6	4	20	0	0	0	6	0	0	0	0	0	0	0	0	0	1101
	O	617	1	14	87	0	12	0	31	6	4	19	0	0	0	5	0	0	0	0	0	0	0	0	0	796
	D	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
1952	I	714	50	68	257	34	12	0	36	13	4	25	0	0	0	6	0	0	0	0	0	0	0	0	0	1221
	O	684	1	16	106	0	10	0	33	12	4	24	0	0	0	6	0	0	0	0	0	0	0	0	0	896
	D	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
1953	I	744	25	72	282	34	27	0	37	11	5	30	0	0	0	5	1	0	0	0	0	0	0	0	0	1274
	O	728	2	11	109	0	26	0	34	10	5	29	0	0	0	4	1	0	0	0	0	0	0	0	0	959
	D	4	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6
1954	I	718	11	72	294	36	29	0	36	1	6	31	0	0	0	4	1	0	0	0	0	0	0	0	0	1239
	O	710	2	13	111	0	28	0	36	1	6	30	0	0	0	3	1	0	0	0	0	0	0	0	0	941
	D	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
1955	I	667	27	92	318	11	20	0	34	1	4	36	1	0	2	3	2	0	0	0	0	0	0	0	0	1219
	O	659	13	52	185	0	20	0	34	1	4	35	1	0	1	3	2	0	0	0	0	0	0	0	0	1010
	D	3	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5
1956	I	625	48	92	308	0	16	0	35	1	1	39	2	0	3	0	5	111	0	0	0	0	0	0	0	1285
	O	611	20	68	175	0	15	0	35	1	1	38	1	0	2	0	4	111	0	0	0	0	0	0	0	1082
	D	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
1957	I	750	50	71	318	0	35	0	34	1	1	55	2	0	6	0	4	237	0	0	0	0	0	0	0	1564
	O	720	10	36	121	0	28	0	34	1	1	54	1	0	5	0	4	236	0	0	0	0	0	0	0	1251
	D	4	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	10

TABLE 5

DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1958	I	836	53	81	292	0	45	0	34	1	1	65	1	0	8	0	3	231	0	0	0	0	0	0	0	1651
	O	804	13	41	123	0	33	0	34	1	1	63	1	0	7	0	3	230	0	0	0	0	0	0	0	1355
	D	6	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	11
1959	I	838	56	93	298	0	53	0	34	1	1	61	2	0	12	0	8	222	0	0	0	0	0	0	0	1679
	O	820	20	51	128	0	39	0	34	1	1	60	1	0	9	0	7	179	0	0	0	0	0	0	0	1349
	D	5	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	10
1960	I	898	63	95	294	0	55	0	35	1	1	66	1	0	12	0	7	217	0	0	0	0	0	0	0	1746
	O	880	24	57	132	0	39	0	35	0	1	64	1	0	10	0	7	177	0	0	0	0	0	0	0	1427
	D	6	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	9
1961	I	820	64	0	231	5	49	0	34	1	1	71	4	0	16	0	11	204	0	0	0	0	0	0	0	1512
	O	801	13	0	92	3	39	0	34	1	1	69	1	0	16	0	11	166	0	0	0	0	0	0	0	1248
	D	7	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8
1962	I	728	0	0	0	2	57	0	34	1	1	76	8	1	15	0	15	203	0	0	0	0	0	0	0	1142
	O	712	0	0	0	0	56	0	33	1	1	73	2	0	15	0	15	138	0	0	0	0	0	0	0	1047
	D	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	7
1963	I	668	0	0	0	2	66	0	35	1	1	86	6	1	7	0	19	490	0	0	0	0	0	0	0	1382
	O	650	0	0	0	0	59	0	34	1	1	83	2	0	7	0	19	363	0	0	0	0	0	0	0	1220
	D	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	4
1964	I	1516	0	0	0	0	6	0	34	1	1	80	6	0	8	0	22	0	0	0	0	0	0	0	0	1674
	O	1490	0	0	0	0	6	0	32	1	1	76	3	0	7	0	20	0	0	0	0	0	0	0	0	1635
	D	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	4
1965	I	1686	0	0	0	31	0	0	34	1	1	78	9	0	8	0	21	0	0	0	0	0	0	0	0	1869
	O	1662	0	0	0	25	0	0	32	1	1	76	5	0	6	0	4	0	0	0	0	0	0	0	0	1812
	D	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	6
1966	I	1797	0	0	0	127	6	178	34	1	1	87	6	0	7	0	19	0	0	0	0	0	0	0	0	2264
	O	1742	0	0	0	67	6	108	34	1	1	84	4	0	2	0	4	0	0	0	0	0	0	0	0	2051
	D	5	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
1967	I	1773	0	0	0	294	1	811	34	1	0	65	8	0	7	0	20	528	0	0	0	0	0	0	0	3542
	O	1626	0	0	0	171	0	494	32	1	0	64	5	0	2	0	13	98	0	0	0	0	0	0	0	2508
	D	14	0	0	0	4	0	29	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	50
1968	I	1200	0	0	0	1133	6	915	34	1	0	73	9	0	5	0	23	0	0	0	0	0	0	0	0	3398
	O	1124	0	0	0	671	5	498	29	1	0	71	7	0	2	0	21	0	0	0	0	0	0	0	0	2428
	D	4	0	0	0	5	0	45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55
1969	I	1057	0	0	0	738	48	441	34	1	0	65	12	0	6	0	23	0	0	0	0	0	0	0	0	2425
	O	1014	0	0	0	511	44	255	30	1	0	63	10	0	4	0	22	0	0	0	0	0	0	0	0	1954
	D	3	0	0	0	3	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23
1970	I	0	0	0	0	467	48	0	35	1	0	63	12	0	9	0	27	0	1834	0	0	0	0	0	0	2497
	O	0	0	0	0	9	1	0	2	0	0	62	10	0	3	0	23	0	1820	0	0	0	0	0	0	1929
	D	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	5

TABLE 5

DUPLICATE ELIMINATION INPUT (I), OUTPUT (O), AND UNCERTAIN DUPLICATES (D), AS THOUSANDS OF LMR PER SOURCE ID (1-24)

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
1971	I	0	0	0	0	114	84	0	28	1	0	65	15	0	3	0	0	0	1444	300	1	24	0	0	0	2080
	O	0	0	0	0	2	1	0	1	0	0	62	13	0	2	0	0	0	1409	233	1	19	0	0	0	1744
	D	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	7
1972	I	0	0	0	0	185	139	0	15	1	0	53	13	0	2	0	0	2	1774	3	1	25	0	0	5	2218
	O	0	0	0	0	4	2	0	0	0	0	50	12	0	2	0	0	1	1745	0	1	19	0	0	0	1837
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	4
1973	I	0	0	0	0	382	142	0	5	1	0	33	19	0	1	0	0	3	1868	11	1	19	0	0	13	2498
	O	0	0	0	0	10	3	0	0	0	0	32	18	0	1	0	0	2	1832	5	1	11	0	0	5	1919
	D	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	6
1974	I	0	0	0	0	137	409	0	0	0	0	14	15	0	1	0	0	2	1574	10	0	19	0	0	11	2193
	O	0	0	0	0	3	6	0	0	0	0	14	15	0	1	0	0	1	1552	6	0	12	0	0	4	1614
	D	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4
1975	I	0	0	0	0	12	623	0	0	0	0	3	19	0	0	0	0	36	1859	30	0	27	0	0	18	2627
	O	0	0	0	0	0	12	0	0	0	0	2	18	0	0	0	0	6	1822	10	0	13	0	0	8	1891
	D	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	6
1976	I	0	0	0	0	0	516	0	0	0	0	0	12	0	0	0	0	12	1807	14	0	28	0	0	38	2428
	O	0	0	0	0	0	11	0	0	0	0	0	11	0	0	0	0	3	1770	5	0	13	0	0	18	1831
	D	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	5
1977	I	0	0	0	0	0	398	0	0	0	0	0	1	0	0	0	0	21	1828	28	0	29	0	0	57	2362
	O	0	0	0	0	0	9	0	0	0	0	0	1	0	0	0	0	6	1778	6	0	16	0	0	25	1842
	D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	6
1978	I	0	0	0	0	0	140	0	0	0	0	0	0	0	0	0	0	104	1823	112	0	27	0	0	61	2268
	O	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	15	1756	65	0	15	0	0	18	1871
	D	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	0	0	6
1979	I	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	2138	348	0	9	0	0	126	2648
	O	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	2035	128	0	4	0	0	31	2203
	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0	0	0	0	0	10
SUM	I	38602	2865	5929	16388	3871	3130	2345	859	68	195	1566	189	1	137	77	233	2650	17949	857	4	205	0	3	330	98451
	O	37527	475	1225	6289	1483	578	1355	741	58	189	1504	150	1	103	61	179	1737	17518	458	3	122	0	3	108	71868
	D	120	17	8	23	17	23	98	11	3	0	3	1	0	8	4	1	9	33	7	0	2	0	0	0	387

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