CO-OPERATIVE OCEANOGRAPHIC OBSERVATIONS PROGRAMME

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1. Concept - The Fleet Numerical Oceanography Center (FNOC) makes global analyses of the ocean's subsurface temperature. To support these analyses FLENUMOCEANEN has developed a Co-operative Oceanographic Observations Programme (COOP) over the past 15 years (Saur and Stevens 1972). The observational programme is now being expanded under a joint Navy/NOAA agreement dealing with ocean observations from ships of opportunity. Various NOAA activities, including National Marine Fisheries Service (NMFS), National Ocean Services (NOS), and the Tropical Ocean Global Atmosphere (TOGA) research programme of Environmental Research Laboratories now contribute to the programme.

Many different types of ships and routes are used to acquire a global coverage of widely spaced "BATHY" observations. Primary emphasis is placed on merchant ships on transocean routes since these navy ships spend much of their time in deep ocean waters. In addition, some Navy and research vessels are recruited and supplied with bathythermograph units when they are transitting sparse data areas between ports or when operating in remote and seas. Fishing vessels (primarily tuna seiners) are also recruited and provide good coverage in fishing areas.

2. Network - The COOP observational network consists of about 100 ships making Expendable Bathythermograph (XBT) observations. Technicians of the US Navy's Meteorological Oceanographic Equipment Programme (MOEP) meet many of the ships. The COOP relies on co-operative arrangements with other oceanographic programmes to meet and service ships. Some of these co-operating programmes are:

1) The TRANSPAC programme of the Scripps Institution of Oceanography in La Jolla, CA.,

2) The SURTROPAC programme operated by the French ORSTOM laboratory in Noumea, New Caledonia,

3) The tropical Atlantic research programme operated by the Deutches Hydrographiches Institut in Hamburg, Germany,

4) The Antarctic/Antarctic Programme of the United States Coast Guard, and

5) NOAA research vessels.

Normally, the shipboard observers space the XBT soundings twelve hours apart and manually encode a CW radio message of the temperature at depth for each sounding. Figure 1 shows an example BATHY observation taken, encoded and transmitted by radio from the containership M/V MEDNIA in the North Atlantic. Position data in reports from fishing vessels are sometimes coded as range and bearing from reference points as the fishermen do not wish to reveal their positions to other fishermen.

Figure 2 sketches the basic architecture of the COOP network. Outlined are routes transitted by ships participating in the COOP and other Volunteer Observing Ship (VOS) programmes that are supported as part of the COOP. Each route is named for the main "parent" compant or VOS programme whose ships monitor that particular area of the ocean. Since most of the observations are in the Northern Hemisphere we are attempting to increase coverage in the Southern Hemisphere to obtain a more uniform global coverage.

3. Hardware - Most of the COOP observations are made using XBT probes and Sippican analog strip chart recorders, although some observations are still made using Mechanical Bathythermograph (MTB) equipment. Deep (760 m) are sometime used to detail the deepened thermocline structure, such as the North Atlantic in winter. Recently Sippican stopped manufacture of the strip chart recorders and thus we must convert to modern microcomputer based hardware. With FNOC and NOAA funding support, we have developed special software for the Hewlett Packard 85 microcomputer and Sippican MK-9 XBT interface for convenient use on merchant ships. We are now installing microcomputer based XBT recorders on other ships.

Figure 3 is an example printout of an automated bathythermograph observation using the HP85 microcomputer system. Temperature readings are automatically stored at one meter intervals on a data cassette as the XBT probe descends to its maximum depth. The temperature values are plotted as a vertical profile and used to compute significant temperature values as a function of depth. The position, time, and significant temperature values are used to automatically prepare a BATHY message for radio transmission to shore.

The NOS of NOAA has purchased about 80 microcomputer based Shipboard Environmental Data Systems (SEAS) for use on NOAA research vessels and in VOS programmes. These systems are similar to the FNOC microcomputer XBT systems but will have GOES satellite radio transmitters for automatic data transmission to shore. Transmission of the report via the GOES satellite can occur within minutes after the observing time and at greatly reduced error rates, relative to present CW radio transmission. Figures 4 and 5 show examples of errors in the data presently received. The figures show data from the Pacific for December 1984. A prime source of present data errors is due to the manual broadcast and handling of the messages.

BATHY (RADIO REPORT)
NAVOCEANO FORM 2080/1 (6-80) 08 0600AUG81

SHIP OF ORIGIN	RADIO CALL SIGN	GROUP COUNT	FILING (DTG) DATE TIME (GMT)	FORWARDED (TOD) DATE TIME (GMT)	RELAYED BY SHORE RADIO STATION CALL SIGN
MEONIA	OXON			08 0940	NAR

Transmit ONLY to a U.S. Government Radio Communication Station authorized to accept the bathythermograph message.

TO: FLENUMOCEANCEN MONTEREY CA JJXX

YYMMJ	GGgg /	QcLaLaLaLa	LoLoLoLoLo	INDICATOR GROUP	ZoZoToToTo
08081	0600/	74611	02851	88888	00206
ZZTTT	ZZTTT	ZZTTT	ZZTTT	ZZTTT	ZZTTT
15200	20190	28180	35170	40165	50168
55155	67150	78146	80143	99901	00143
30140	55138	90136	99902	00135	20134
50132	80130	99903	00128	50125	99904
00120	56115				

(All messages must end with Ship Radio Call Sign) → RADIO CALL SIGN: OXON

DRAFTER: [illegible]
RELEASING OFFICER: [illegible] VIA NMR

Figure 1. Radio log sheet for reporting manually encoded real-time BATHY reports of subsurface temperature. This report was made by the containership M/V MEONIA at 0600Z on August 8, 1981 at 46°11'N, 28°45'W in the North Atlantic. Reports are often normally made by CW in Morse Code by high frequency radio to coastal stations and are relayed by teletype to analysis centers and to the Global Telecommunications System (GTS).

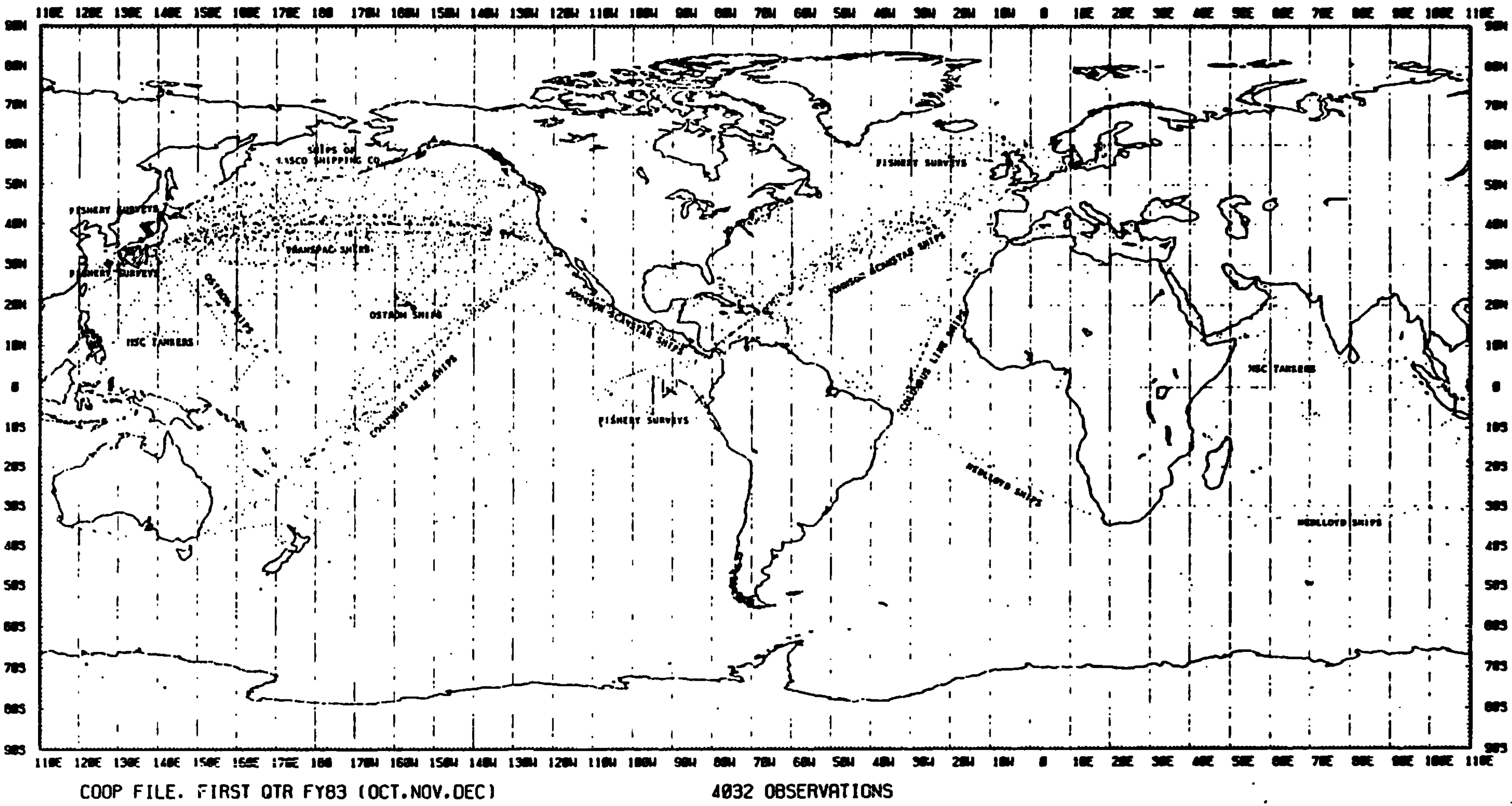


Figure 2. Volunteer observing ship programs and routes in FNOC Cooperating Oceanographic Observations Program. Map shows locations of 4032 real-time radio messages received by FNOC in October to December 1983.

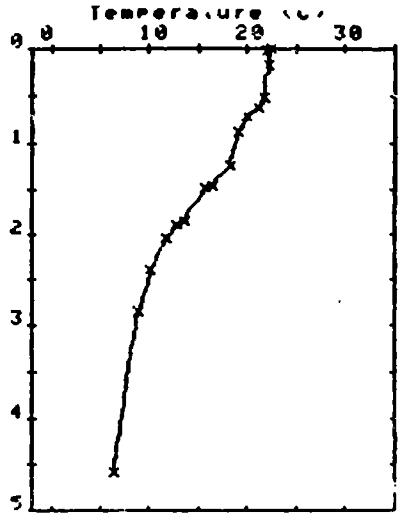
```
              Latitude  24 11 4 N
             Longitude  130 28 8 W
                  Time  14 02
                  Date  06 07 85
  Observer Initials       ROSE

Prelaunch:
Contact = 60.8
Offset  =  6 9 Slope =  .9831
RECORDING XBT    FILE # 2
              Sequence       0002

Since last BT:
     Time (hrs)              24.7
     Course (deg)           233 3
     Distance (n mile)      474.4
     Speed (knots)           19 2

Significant Points:
```

Depth	Temp
0	22 46
3	22.07
17	22.26
52	21.75
62	21.20
72	19 98
89	19.09
125	18 24
146	16.41
150	15 70
185	13.57
190	12 79
205	11.66
235	10 17
285	8.38
459	6 46




```
BATHY MESSAGE:

JJXX  06075 1402/ 72411 13029
88888 00225 03221 17223 52217
62212 72200 69191 99901 25182
46164 50157 85136 90128 99902
05117 39162 85089 99904 59065
DGVK
```

Figure 3. Sample printout from Sippican MK-9 / Hewlett Packard 85 microcomputer digital XBT system programmed by FNOC and NMFS for use on volunteer observing ships. The HP85 program checks that the time and position values entered by the operator are within reasonable ranges; note the latitude value was flagged as out of range and re-entered. The program then computes time, course,distance, and speed since the previous observation and if the speed is negative or unreasonably large, asks the operator to check the time and position. After the XBT cast, the program computes, prints, and plots significant data points and formats a radio message. The actual data values are stored at one meter intervals on a magnetic tape cassette for later archival ashore.

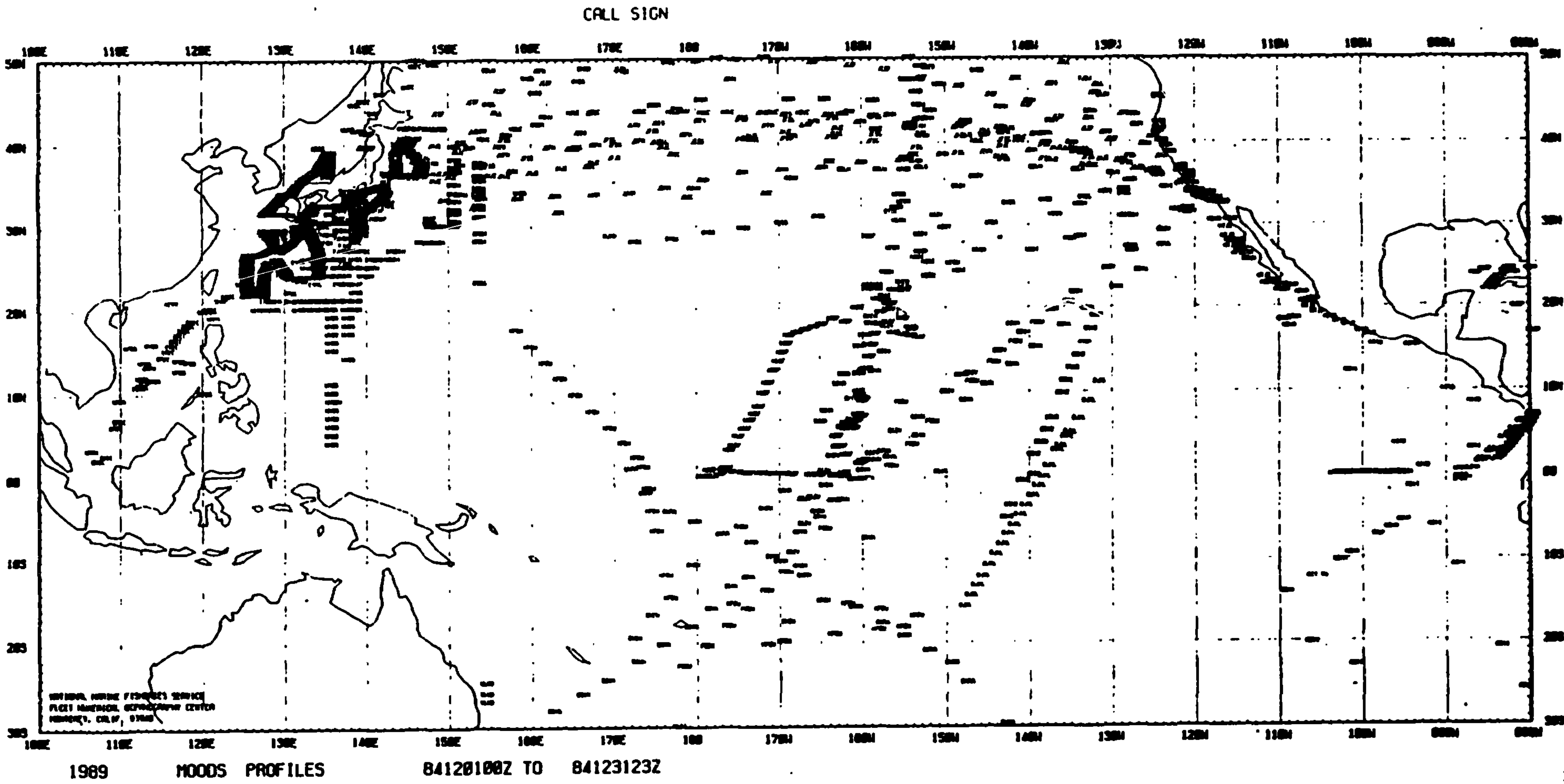


Figure 4. Map of international radio call signs of 1989 real-time messages received by FNOC in Demember 1984 for the Pacific. Call sign maps are very useful in tracking ships and correcting bad position values in real-time message data.

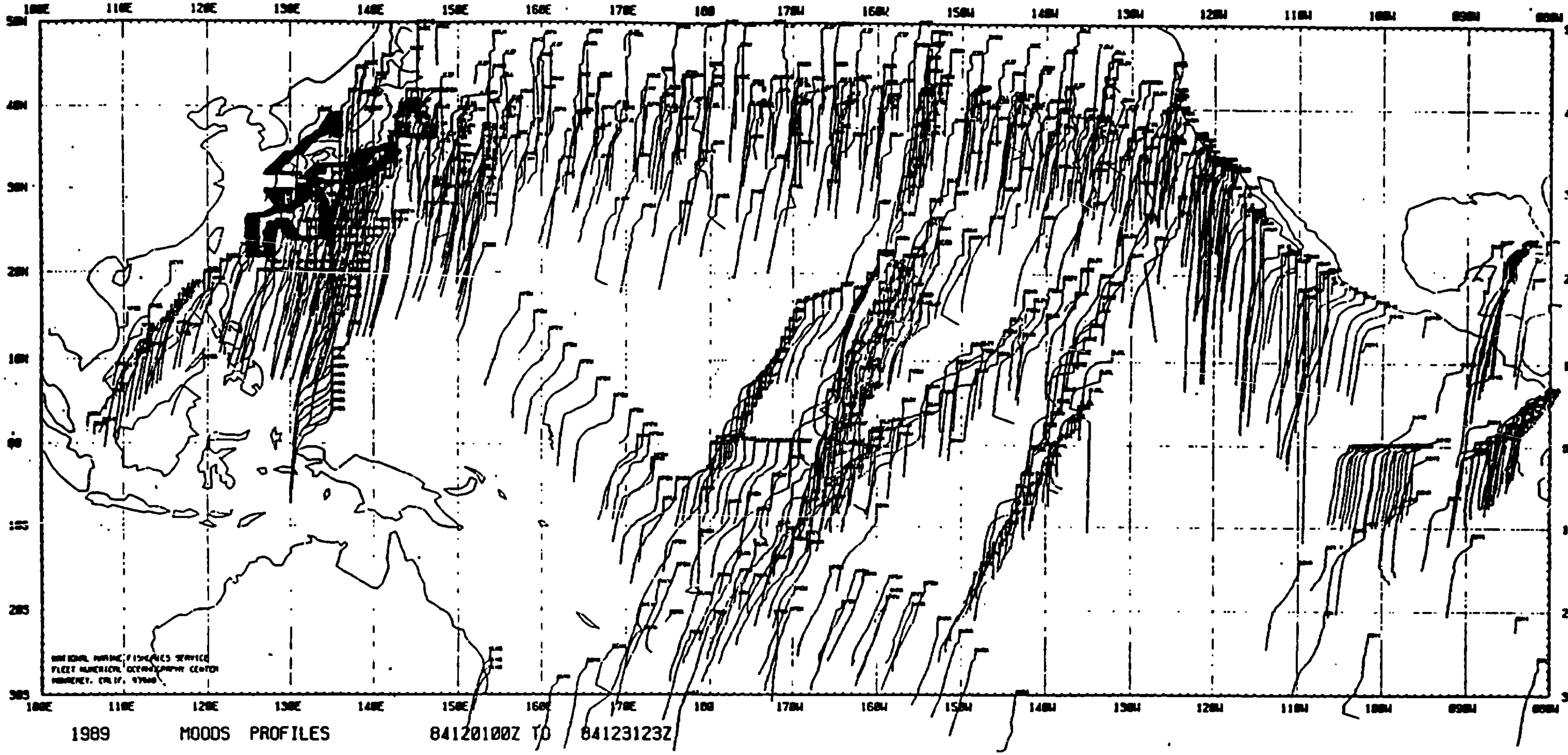


Figure 5. Map of international radio call signs and temperature profiles of same real-time messages as in Figure 4. Profile maps are a very useful quick check on the quality of the data. Note the presence of positive tails at end of some of the profiles and unreal spikes in other profiles.

A major emphasis of the NOS SEAS programme is to increase the number and quality of marine weather reports. All of the SEAS systems will automatically report weather observations and about half will be able to automatically make and digitize XBT observations as well. More and better weather reports will benefit FNOC as well as NOAA.

Recently NOAA and others have developed drifting ocean buoys that make weather reports and which can be instrumented to make subsurface temperature observations. These buoys are based on the US "drifter design" used during the First Global GARP Experiment (FGGE). The new "drifters" have a much longer lifespan (12 to 18 months) than those of FGGE (6 to 12 months). An automated buoy is very cost effective when compared to the present manually observed and transmitted weather reports and XBT soundings from ships. We plan to try to obtain several such drifting buoys in the coming year for use in areas such as the Southern Pacific where shipping and observations are sparse.

4. <u>Data Processing</u> - COOP XBT observations provide ocean thermal structure data in two modes, real-time and delayed. The real-time radio messages are sent from the ship to a shoreside communication station, then on to FNOC and the National Meteorological Center (NMC) in Washington, D.C. An example data bulletin (shown as Figure 6) was received in FNOC at 0811Z on 8 August 1981, and is composed of BATHY messages from three ships participating in the COOP, the containerships M/V FALSTRIA and the tanker USNS COLUMBIA. After receipt, the BATHY messages are edited manually but this is a laborous and error-prone process. To speed editing and to reduce errors, NOS and TOGA are funding Compass Systems, Inc. (CSI) to develop software for Zenith microcomputer systems to edit radio messages at both FNOC and NMC using interactive graphic displays. At FNOC, the radio messages are archived on magnetic tapes each month and are eventually merged with other subsurface temperature sets. NMC collects the radio messages during a specified time period, assembles them into bulletin formats, then enters the bulletin onto the circuits of the Global Telecommunications Systems (GTS) and stores copies of the radio message bulletins for the National Oceanographic Data Center (NODC).

At the end of each ships voyage, the XBT strip charts and log book position data are mailed to either FNOC or NODC for delayed mode processing. At each center, the strip charts are manually digitized and the data archived on magnetic tapes. Tapes are exchanged on a regular basis between NODC and FNOC. With NOS and TOGA funding, CSI is programming Zenith microcomputers to digitize XBT strip charts at both FNOC and NODC. The new systems use GTCO digitizing tablets and replace obsolete Calma and Altec digitizing tables at both centers. The systems will allow sharing of software between NOAA and the Navy, and will insure comparability of strip chart digitizing between NODC and FNOC.

Digital data cassettes from SEAS type system are read at FNOC using an HP85 microcomputer, quality checked and archived. We are co-operating with NODC in cassette reading by providing them with the software to read and edit cassette data. In the next year, we will work with NODC to expand the capabilities of the cassette read software to read all four formats of cassettes (original Sippican MK-9, FNOC one meter data, NOS Sutron SEAS, and NOS Bathy Systems SEAS).

```
a4414
NNNN
 ****TSCREEN MSG  16 UNCLAS                    (  BG     A                              )00

PTTUZYUW RULGSGG1928 2200940-UUUU--RUWJAGE.
ZNR UUUUU
P 080600Z AUG 81
FM SS MEONIA//OXON//
TO RUWJAGE/FLENUMOCEANCEN MONTEREY CA
BT
UNCLAS
JJXX  08061 0600/ 74611 02854 88888 00206 13200 20190 28180 35170
40165 50148 55155 67150 78146 80143 99901 00143 30140 55138 90136
99902 00135 20134 50131 60130 99903 00128 50125 99904 00120 56115
OXONS
BT
a1928
NNNN
 ** *TSCREEN MSG  17 UNCLAS                    (  BG     A                              )0C

PTTUZYUW RULGSGG1933 2200945-UUUU--RUWJAGE.
ZNR UUUUU
P 080100Z AUG 81
FM SS FALSTRIA//OYBG//
TO RUWJAGE/FLENUMOCEANCEN MONTEREY CA
BT
UNCLAS
JJXX  08081 0004/ 72441 11219 88888 00215 10162 15167 20162 35160
50157 60150 70143 80140 99902 10141 99904 30142 OYBGS
BT
a1933
NNNN
 ****TSCREEN MSG  21 UNCLAS                    (  BG     A                              )0(

PTTUZYUW RULSSGG7474 2201046-UUUU--RUWJAGE.
ZNR UUUUU
P 081017Z AUG 81
FM USNS COLUMBIA
TO RUWJAGE/FLENUMOCEANCEN MONTEREY CA
BT
UNCLAS //N03160//
JJXX 08081 0800/ 74040 04816 88888 00243 20 40 30231 40211
50183 90187 99901 50178 60163 80160 99902 10160 20150 90140
99903 50179 90172 99904 50170 NCFX
BT
a7474
NNNN
   END OF BT72FIL   MESSAGES, 8108081:                 11022
```

Figure 6. Printout of FNOC programme TSCREEN of received BATHY messages from containerships M/V MEONIA and M/V FALSTRIA and tanker USNS COLUMBIA.

Data from both strip charts and cassettes are processed by the same software and quality control procedures. The ship's course and speed are computed between adjacent XBT drops to check the reported position and time data. Figure 7 is a plot of the cruise track that is produced by the software that commutes the speeds between observations. The data are plotted semi-automatic DISPLAY plots are seen in Figures 8 and 9 using data from the voyage of the containership M/V COLUMBUS VICTORIA between the US westcoast and Australia. Figure 8 is computed from day/time and consecutive latitude and longitudes, each number along the route identifies an XBT station. Also shown are the corresponding sea surface temperature observations along the ship track. The southbound leg of the voyage is shown on the left while the return leg is on the right. The validity of the temperature data are visually checked by computer plotting each profile and then contouring the vertical temperature sections (Figure 9).

Data digitization from the cassettes is faster, cheaper and more accurate than manual digitization of strip charts. We estimate that 6.0 hours are needed to manually digitize and quality control 46 traces as compared to 3.25 hours for automated digitization of 61 traces.

All subsurface temperature profiles are stored at FNOC as the Master Oceanographic Observations Data Set (MOODS, Bauer 1985). MOODS tapes are co-housed at both FNOC and at NODC. The MOODS contains merged records of both the radio messages and the delayed mode observations, not only from the COOP but also other contributors such as the Integrated Global Ocean Station System (IGOSS). The programme that merges the real-time and delayed mode data files checks for duplicate records and duplicate records exist, the delayed mode observation is considered the primary observation and its radio message counterpart is flagged as a duplicate.

The MOODS format was developed for the COOP to store ocean profile data in an efficient manner. Three primary criteria for the design of the MOODS format were:

1) allow storage of large ammounts of subsurface profiles in a very compact form to minimize number of magnetic tapes to be handled,

2) be sortable using standard sort software (on Control Data computers), and

3) be easy to update.

All COOP data have been converted to MOODS format and all available other data have been converted and added to the MOODS data set. All available files from NODC, Japanese, British, French, Australian, and other sources were used. The combined MOODS data set has been merged and sorted by month, latitude and longitude. This data set has been in use for several years by the COOP. The MOODS format and data set are used operationally by other FNOC programmes for handling of real-time BATHY messages and for climatological purposes. In addition, the MOODS format and data set are being considered for use

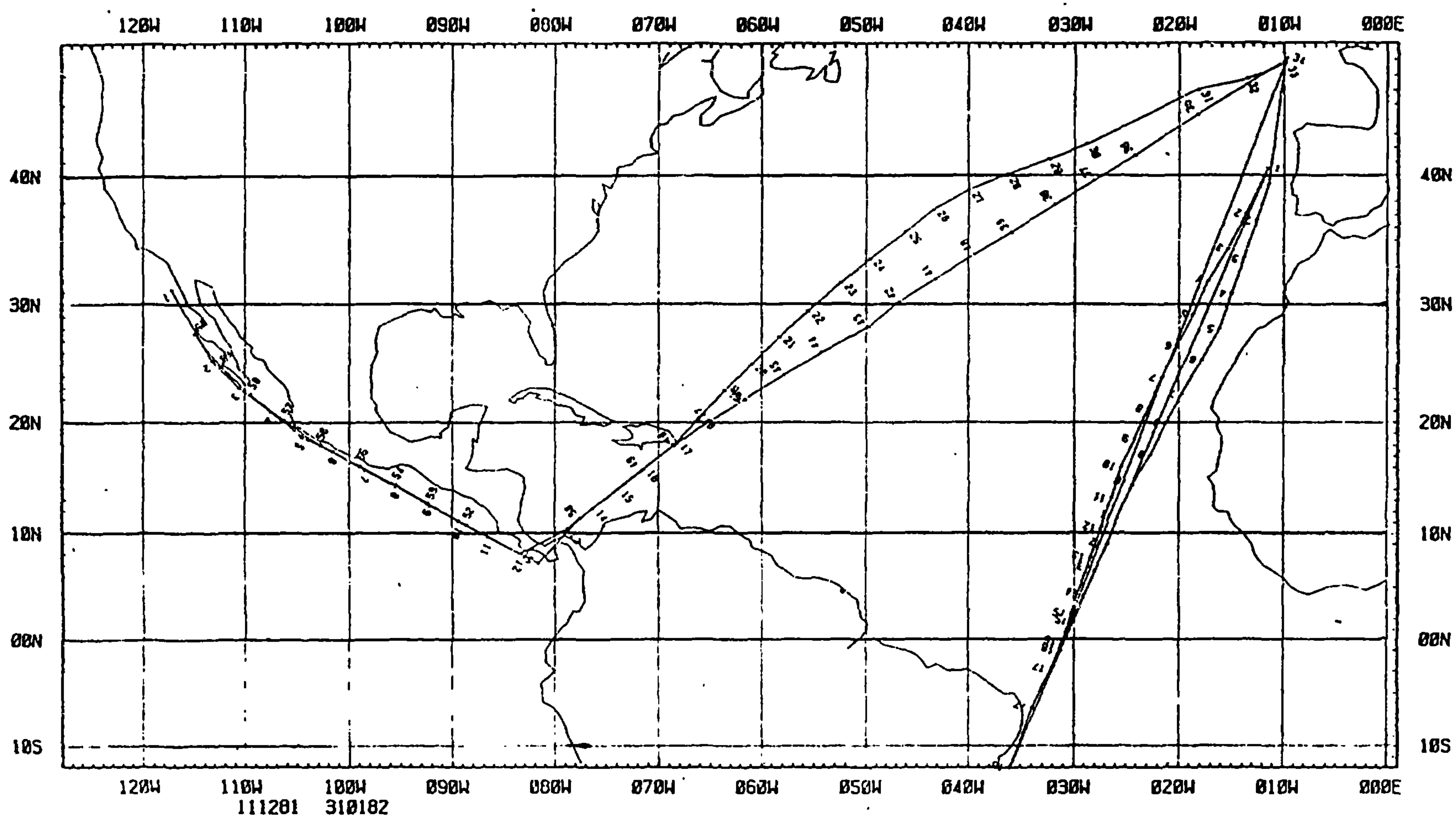


Figure 7. Cruise track plot of locations of XBT drops of ships cooperating in FNOC COOP program. Cruise track plots are computer plotted to check positions of XBT observations. The numbered dots indicate positions where XBT probes were dropped.

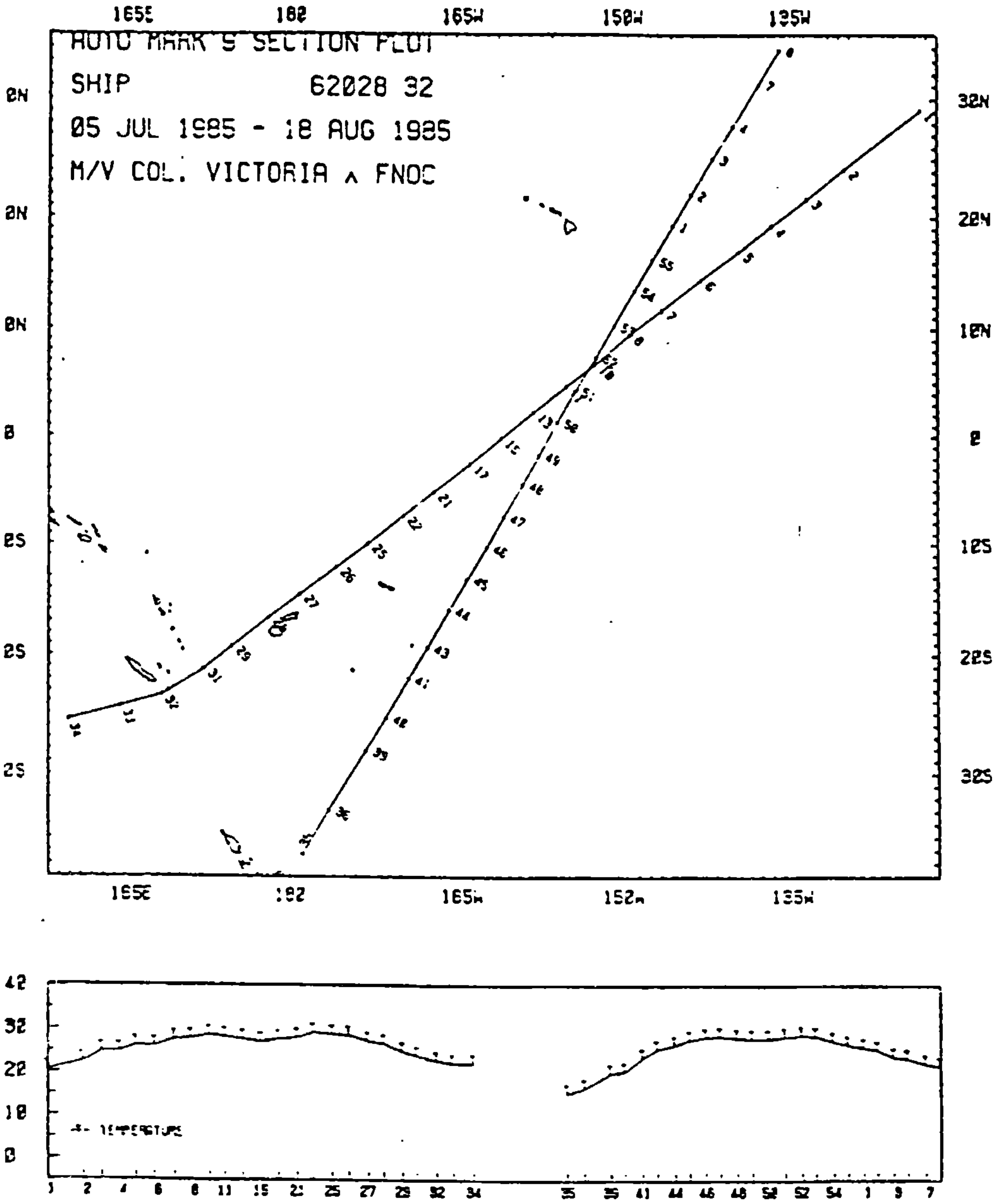


Figure 8. Cruise track and sea surface temperature plots produced semiautomatically by FNOC program DISPLAY from digital XBT cassette data recorded during July-August 1985 on the containership M/V COLUMBUS VICTORIA enroute from US west coast to Australia and return from New Zealand. Lower panel shows the sea surface temperature recorded on this route (southbound leg on the left and northbound leg on the right).

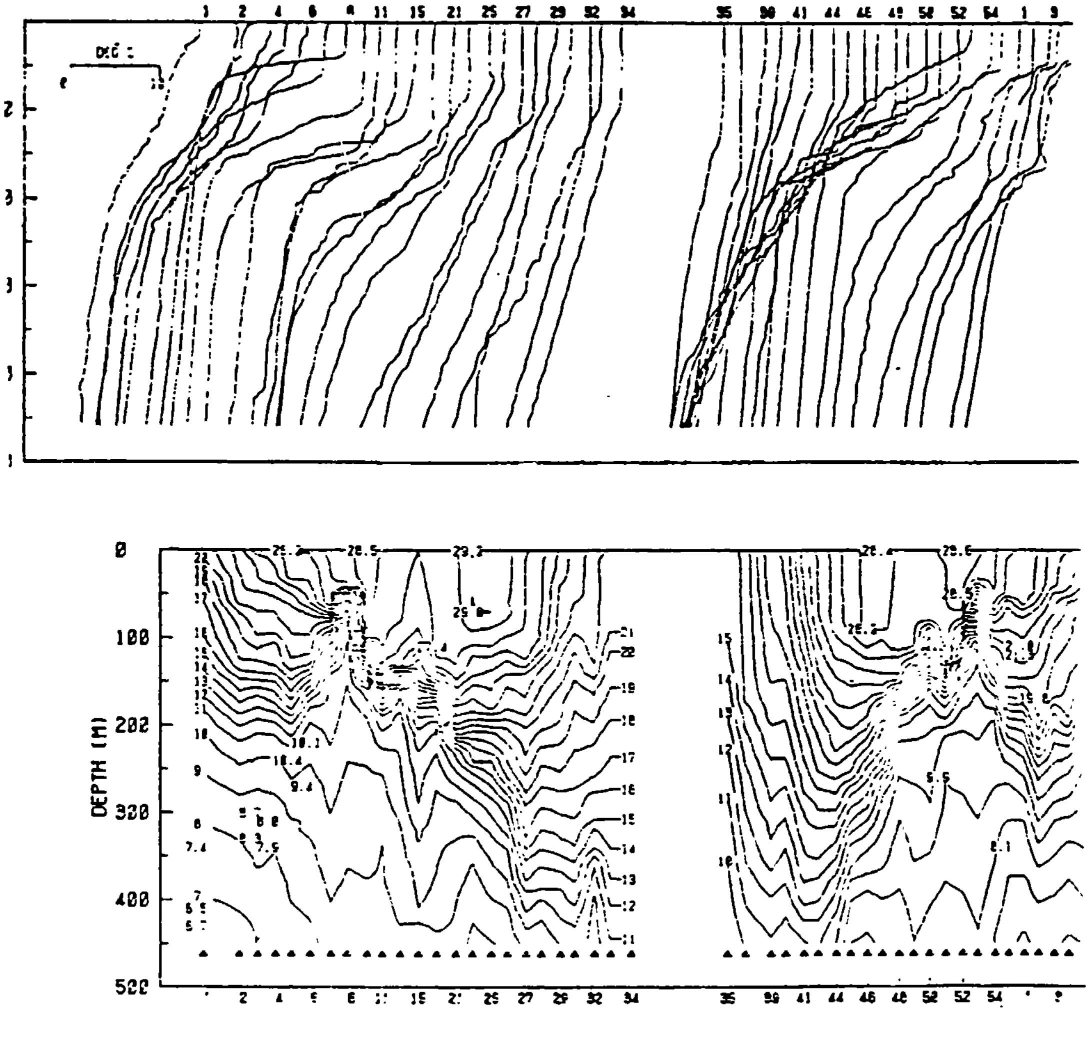


Figure 9. Vertical temperature profiles and contour section of M/V COLUMBUS VICTORIA data shown in Figure 8 and plotted semiautomatically by FNOC program DISPLAY. Vertical profile charts and contour sections are useful to identify erroneous temperature values in XBT section data. Note that the characteristic thermal structures across the equator are reversed in the southbound and northbound legs of the voyage.

as a standard within the Navy for all ocean profile data. Moods software and data files are being used for other laboratories as well, including: NAVOCEANO, NORDA (Teague et al. 1985), Applied Physics Laboratory of Johns Hopkins University (Sinex 1985), NOAA Environmental Research Laboratories in Boulder, CO., Pacific Marine Enviromental Laboratory, Scripps Institution of Oceanography, University of Miami, NOAA Geophysical Fluid Dynamics Laboratory, Pronceton University and Dynalysis Corp.

Much software has been developed to process and display MOODS format data. Figure 10 shows an example of the final result of the data digitization process, using a manual version of programme DISPLAY with data from the rollon-rolloff ship M/V CHANG ZHOU across the North Pacific. The same plots as shown in Figures 8 and 9 are seen in Figure 10 but in a more compact form. We produced a set of DISPLAY plots for VOS equatorial crossings in the 1970's under EPOCS funding (Favorite and McLain, 1982) and hope to produce more in the future under the TOGA programme. Time series changes of subsurface temperature from the MOODS file can be analysed and displayed as in Brainard and McLain (1985).

5. Data Coverage - COOP contributes, as a programme, most of the data contained in the radio message file and a good percentage of the digitized file: 35% for the international message file and about 15% for the digitized file. These percentages are valid only for data disseminated via the circuits of the Global Telecommunications System (GTS).

Figures 11a and 11b illustrate the distribution of data from two files of a five year data set, 1979 through 1984. These files were taken from the MOODS of FNOC. Figure 11a presents the delayed mode (digitized strip chart and cassette data), while Figure 11b depicts the real-time or radio message file. These maps extend only from 50N to 50S because the data were extracted for the TOGA research programme. Note that the radio message file is nearly seven times larger than that of a digitized file at any point in time. Several reasons account for this:

a. Propriatory nature of the original data sets
b. Regulations governing data transmittal to RNODCs
c. Timeliness of data exchanges between RNODCs
d. Priority of processing the original data sets
e. delay in acquiring the original data sets at FNOC

While the number of radio messages received for a given time period is fixed, the number of digitized profiles available for that time period will grow as additional data are required.

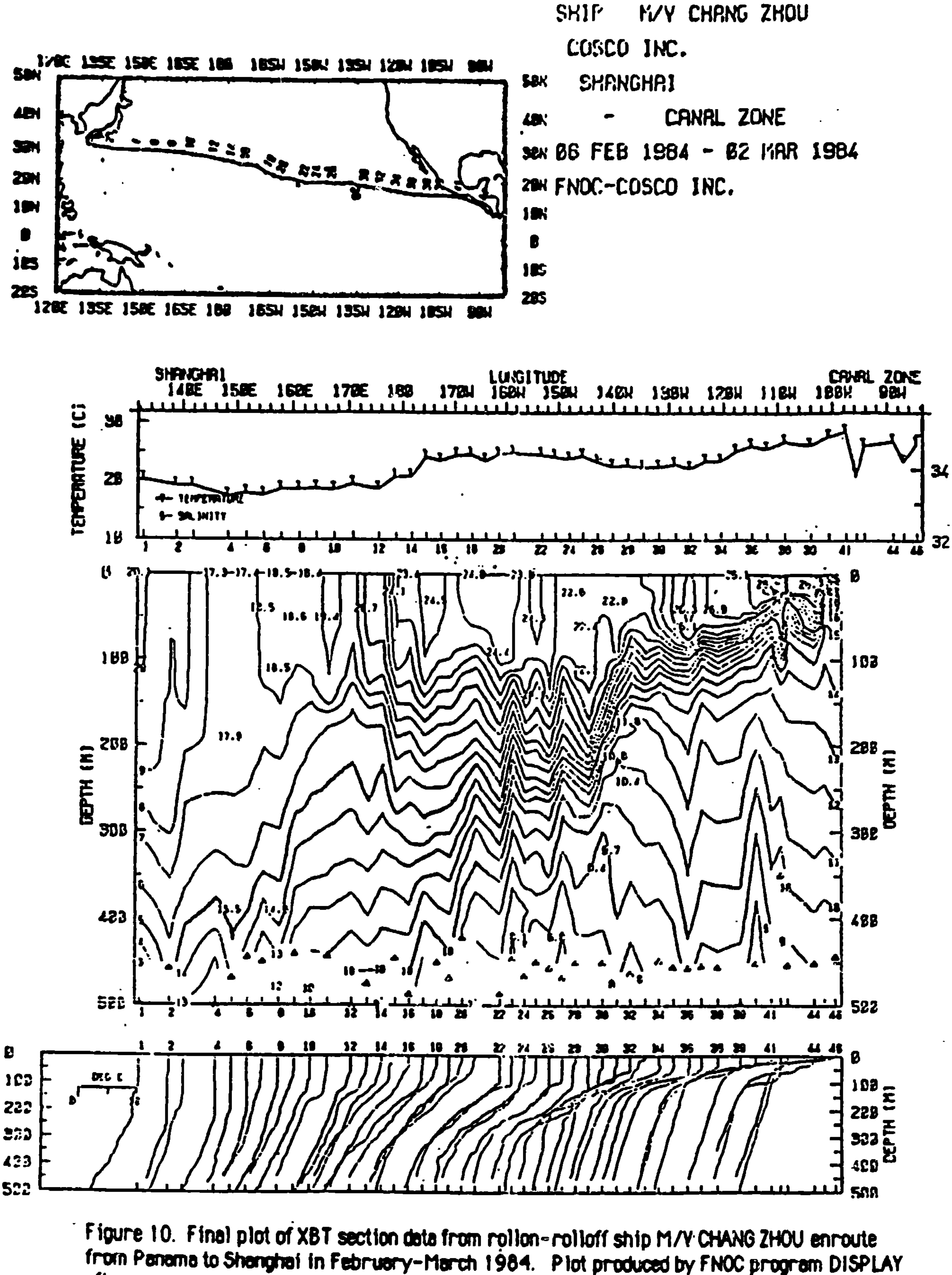


Figure 10. Final plot of XBT section data from rollon-rolloff ship M/V CHANG ZHOU enroute from Panama to Shanghai in February-March 1984. Plot produced by FNOC program DISPLAY after voyages are split into legs and checked for data errors. The upper panel shows locations of XBT drops, the second panel shows the sea surface temperature along the route, the third panel shows the vertical contour section, and the lower panel shows the temperature profiles. Plots such as this represent final product of XBT data digitizing process.

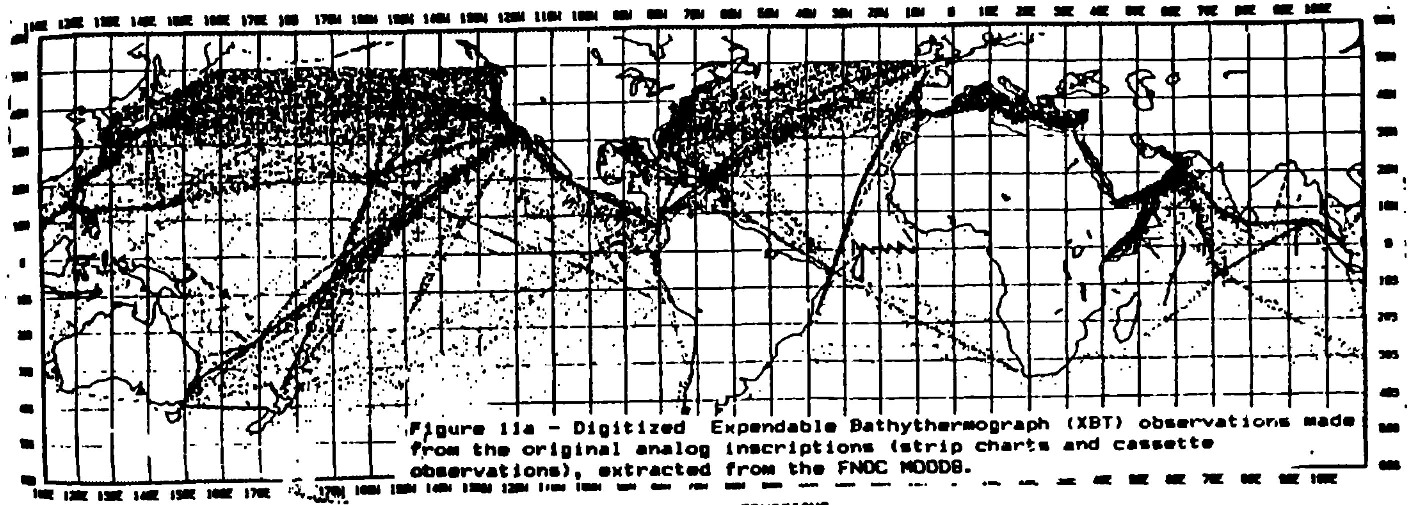


Figure 11a - Digitized Expendable Bathythermograph (XBT) observations made from the original analog inscriptions (strip charts and cassette observations), extracted from the FNOC MOODS.

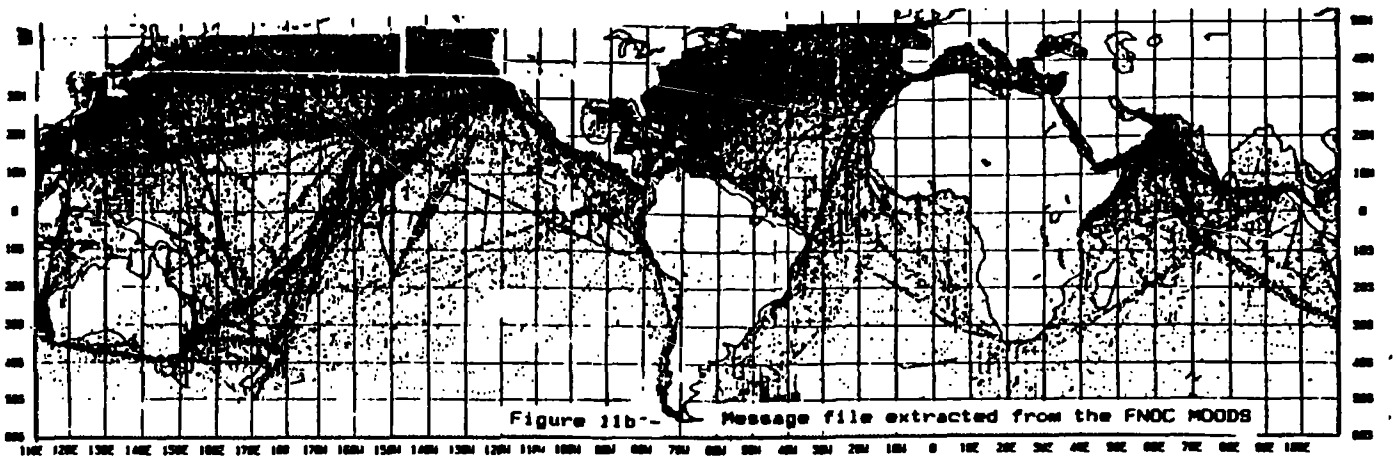


Figure 11b - Message file extracted from the FNOC MOODS

Figure 11

6. Quality Control - Many of the data received in real-time by FNOC have obvious errors such as unreasonable values and unreal gradients of temperature. Some of the errors are due to the XBT probe failure but most are probably due to manual digitizing errors or transmission errors. Reduction of these errors is a major reason for automation of the XBT observations and satellite transmission using the GOES or ARGOS. Currently, a major task is to develop computer software that will further identify and correct other errors that are found in messages. The operational FNOC subsurface temperature analysis and ship tracking programmes reject bad reports but do not save information as to which reports are rejected. Only those reports which fail format tests or do not pass gross temperature and gradient tolerance limits are flagged as bad and edited. The bad reports are manually corrected and re-entered daily into the system using a punch card system. At the end of each month, the profiles are plotted to identify other errors. Figures 3 and 4 show the radio message data for December 1984 in two formats useful for quality control. These are:

a. International Radio Call Sign (IRCS) Maps - Indentifies ships engaged in monitoring along specific routes. Often shows transposition errors of latitude/longitude that might not be detected otherwise.

b. IRCS/Thermal Structure Profile Maps - Visual quality control identifies subtle profile errors, such as spikes or tails on the temperature profile. These errors pass the temperature and gradient test limits in the operational FNOC analysis programmes but are obviously in error. maps.

Many of the errors seen in these maps are being generated by the automated digital shipboard systems. We need to improve the software of these shipboard digital systems to recognize and correct errors before the messages are transmitted as the messages are automatically relayed by NMC globally via the GTS without further editing. Thus any errors present in the messages must be discovered and corrected by each user of the GTS. As an example of automatic message corrections, in the FNOC HP85 software we compute ship speed and course since the previous observation. If the speed of the ship is unreasonable, the programme asks the operator to check the position (Figure 3). Others errors from the digital systems include unreal temperature tails at the end of the profile. Normally the ships' mates delete such tails when manually digitizing a BATHY message, but the software in the digital systems does not recognize the error and the tails are transmitted. Since there are now several different digital hardware and software systems in use (FNOC Sippican-HP, Sippican-HP-Sutron, NOS Bathy Systems-HP-Synergetics, and Scripps-OSTROM Oregon State-Commodore), it would seem desirable to try to develop standard software that could function on all similar hardware (i.e., all HP85-based equipment) that would contain improved error recognition codes.

After receipt of the BATHY messages at FNOC, a number of improved quality control tests could be made. We are beginning to develop some of these now with TOGA and NOS funding Compass Systems, Inc. One scheme is to capture the information in the operational shiptrack and temperature analysis programmes as to which messages were accepted and which were rejected. The rejected messages could then be examined in detail. There is a pressing need to expand the IGOSS-GTS data formats to include data edit flags so that corrected messages can be retransmitted. As an initial step towards this, CSI is developing data edit flags to allow exchange of corrected messages between FNOC and NMC. A second improvement is the replacement of the present manual punch card format editing at FNOC with a microcomputer based system. As mentioned above, CSI will install similar software for Zenith microcomputers at both NMC and FNOC to allow improved editing of messages. Sharing of software by NMC and FNOC will save costs and insure that data editing is comparable at the two centers. Finally, computerized audits of message traffic between FNOC and NMC will be improved to find sources of message loss in transmission.

7. <u>Conclusion</u> - The goal of the combined Navy-NOAA global VOS programme is to provide a comprehensive real-time and historical archive of all available ocean profiles. Salinity as well as temperature is required because of the importance of salinity in determining water density and in defining ocean fronts and boundries. To accomplish these goals, we need to improve our instrumentation, data transmission, editing, archival, and analysis systems. Some possibilities for such improvements include:

(1) Expansion of co-operative agreements with other programmes to increase global coverage,

(2) Use of retrievable mini-STD devices to eliminate XBT probe costs and to obtain salinity as well as temperature profiles,

(3) Reporting of underway surface temperature and salinity along a ship's track to allow better definition of surface features,

(4) Development of standards for digital XBT hardware and software to allow greater commonality between systems and to include improved error correction codes,

(5) Upgrading of all systems to include satellite transmitters for faster and more accurate reporting,

(6) Improvement of editing of historical and real-time profiles,

(7) Improvement of analysis products and data distribution methods.

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Intergovernmental Oceanographic Commission
Reports of Meetings of Experts and Equivalent Bodies

Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes

Seattle, USA, 9-13 September 1985

Unesco

IOC-WMO/IGOSS-XBT/3
Paris, 19 October 1985
English only

In this Series

Reports of Meetings of Experts and Equivalent Bodies, which was initiated in 1984, the reports of the following meetings have already been issued:

- Third Meeting of the Central Editorial Board for the Geological/ Geophysical Atlases of the Atlantic and Pacific Oceans
- Fourth Meeting of the Central Editorial Board for the Geological/ Geophysical Atlases of the Atlantic and Pacific Oceans
- Fourth Session of the Joint IOC-WMO-CPPS Working Group on the investigations of «El Niño»
- First Session of the IOC-FAO Guiding Group of Experts on the Programme of Ocean Science in relation to Living Resources
- First Session of the Editorial Board for the International Bathymetric Chart of the Mediterranean and Overlay Sheets
- First Session of the Joint CCOP (SOPAC)-IOC Working Group on South Pacific Tectonics and Resources
- First Session of the IODE Group of Experts on Marine Information Management
- Tenth Session of the Joint CCOP-IOC Working Group on Post-IDOE Studies in East Asian Testonics and Resources
- First Session of the IOC-UN(OETB) Guiding Group of Experts on the Programme of Ocean Science in relation to Non-Living Resources
- Sixth Session of the IOC-UNEP Group of Experts on Methods, Standards and intercalibration
- First Session of the IOC Consultative Group on Ocean Mapping
- Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes

SC-85/WS/80