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INTEGRATED GLOBAL OCEAN SERVICES SYSTEM (IGOSS)

SUMMARY OF SHIP-OF-OPPORTUNITY PROGRAMMES AND TECHNICAL REPORTS

This document contains in a consolidated form the national and technical reports on ship-of-opportunity programmes as presented at the Third Session of the Joint IOC-WMO Meeting for Implementation of IGOSS XBT Ship-of-Opportunity Programmes (Hamburg, Federal Republic of Germany, 16 - 20 October 1989). It is intended to complement the Summary Report of the Meeting or to be used separately, as the case may be.

TABLE OF CONTENTS

REPORTS ON NATIONAL ACTIVITIES

ARGENTINA

Although Argentina's priority is the oceanographic investigation of the continental shelf and the national Antarctic Programme, there has been a consistent committment to the submission of data to the IGOSS system.

XBT data taken aboard the ice breaker IRIZAR was discontinued during 1986-87 due to the loss of the supply ship BAHIA PARAISO which sank in the Antarctic. IRIZAR was diverted in order to assume logistical support duties for the Argentine Antarctic bases (1987-88). The Government of Argentina hopes to resume the programme during the next Antarctic summer with an XBT line from Buenos Aires to the Weddell Sea, Drake Passage, and the Gherlache Sea. XBT probes and equipment would come from Argentine sources.

The Argentine Government is willing to expand its role in IGOSS and, to this end, in 1983, submitted the names and callsigns of two merchant ships sailing from Buenos Aires, through the Indian Ocean, with a final destination in Yokohama, Japan. These vessels are still available and could provide monthly coverage on this route. Argentina seeks assistance from interested parties in the form of XBT probes and recording/transmitting equipment for which they have operation and maintenance capabilities.

AUSTRALIA

A - CSIRO XBT SHIP-OF-OPPORTUNITY PROGRAM

Background

The occurrence of widespread drought in Queensland, New South Wales and Victoria is largely controlled by the temperature of ocean waters north of Australia. The largest accumulation of very warm (> 28° C) waters in the global ocean, the planetary heat pool, is located in the tropical eastern Indian and western Pacific Oceans. The geography of this heat pool is characterised by changes in location of its temperature maximum over thousands of kilometres on seasonal and interannual time scales. Details of the geography are known to have statistical relationships to the occurrence of climate anomalies, but the physics underlying these relationships is not well understood. For example, one of the largest pools of 29°C water in the world develops off the North-West Shelf of Australia before the wet season. Qualitatively, the seasonal warming seems to be related to high insolation and low winds prior to onset of the Wet, and temperature is subsequently diminished by cloudiness and stronger winds; but these ideas have not been tested quantitatively and not for interannual time scales. The correlation meteorologists find between sea surface temperature and anomalies of Darwin rainfall is an example of the general tendency for maxima in convective activity to follow maxima in SST, but this idea needs to be documented with high quality oceanographic data and for a long period of time.

Because of thermal inertia, temperature in the planetary heat pool varies relatively slowly, and acts as a memory in the coupled ocean atmosphere system. Consequently ocean temperature can be used as a predictor of rainfall anomalies, either as direct input to statistical models or in the initialisation of numerical/dynamical, coupled general circulation models. In either prediction scenario, model development must be preceded by process studies to identify the physics of ocean temperature change. One aim of the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) research program on ocean/climate interactions is to document temperature in the planetary heat pool north of Australia and to evaluate the relative importance of surface heat fluxes, advection, and mixing processes in the regional thermodynamics. A further aim is to document the variability of major geostrophic currents in the eastern tropical Indian Ocean (South Equatorial Current, South Java Current, Leeuwin Current) on seasonal and interannual time scales, and to evaluate their role in changing sea surface temperature.

Observing Network

A temperature observing network using XBTs launched from volunteer observing vessels provides the primary data base for the research program. The network is operated by CSIRO from a centre in Hobart, with ship-greeting activities in the major ports around the nation. Details about the network including ship names and sampling frequencies are given in Table 1. The routes presently in operation are shown in Fig. 1, and the location of all XBT stations which have been processed, edited and accepted at CSIRO to date are shown in Fig. 2.

The CSIRO activity is closely coordinated with other international programs. Recognising the potential economic and social benefit which could be derived from rainfall prediction, the international agencies of oceanography and meteorology (IOC/WMO/ICSU) implemented a very large program known as TOGA (Tropical Ocean Global Atmosphere), with the goal to establish the scientific basis of global climate prediction. A corner-stone of the TOGA program is the implementation of an observing network, which compliments the already existing atmospheric observing network; and which can provide the observational data needed for process studies and model development. Global coverage of tropical oceans is needed for TOGA, and a coordinated international effort is required to achieve this goal. As a TOGA contribution, the CSIRO network is expected to operate until 1995.

The CSIRO Division of Oceanography has taken a leading role in TOGA since its beginnings; at the planning level in the early 1980's, and in the field program since January 1985. The field program was a very large undertaking, viewed by the Division as a necessity in the national interest, but too large for the Division to accomplish with its own resources. The strategy for funding was from the outset to get resources from several national and international agencies, while maintaining scientific direction and management under the control of research oceanographers. This strategy has proven to be extremely successful, to the point that now over 3500 ocean soundings are made per year.

Support for the network is provided by CSIRO, Australian Research Council, Royal Australian Navy, University of Hokkaido and US National Ocean Service (Table 2).

In addition to the TOGA network, XBTs are dropped in the Tasman Sea and the Leeuwin Current in support of regional studies in Australia, in particular mapping of ocean thermal structure at the RAN's Naval Weather Centre.

Plans for 1989/90

As part of the CSIRO Division of Oceanography's Greenhouse research program, the extent of coverage of XBTs in the Tasman Sea will be increased from the beginning of 1990. Some of these lines will include high density sampling as part of the World Ocean Circulation Experiment (WOCE). High density sampling lines will also be initiated during late 1990 in the southern Indian and Pacific Oceans.

After testing several XBT deck units available on the international market[1], it was concluded that the Sippican MK-9 XBT recorder/processor was the most reliable. Consequently, during 1989/90 CSIRO will be replacing all of its non-Sippican MK-9 units with recently purchased Sippican MK-9/Lap-Top configured XBT systems. These units will also be interfaced with Argos transmitters for the relay of bathymessages onto the GTS. Software will be developed by CSIRO especially for deployment on ships-of-opportunity.

Studies to determine the optimal sampling strategy [2,3,4] were carried out during the past year. These led to the following guidelines for time-series sampling on XBT lines: a) station spacing-one per degree latitude b) repetition rate – 12 to 18 times per year. The sampling strategy for the CSIRO lines will be adjusted accordingly. Repetition rate on the Fremantle–Red Sea line will be reduced from 18 to 14 sections per year, whilst on the Fremantle–Persian Gulf line it will be increased from 6 to 12 per year. Sampling on the Dampier–Japan route will be decreased from 24 to 18 per year.

1 Bailey, R., H. Phillips, and G. Meyers (1989): Relevance to TOGA of Systematic XBT Errors. In Proceedings of Western Pacific International Meeting and Workshop on TOGA/COARE, May 24–30, Noumea, New Caledonia (submitted).

2 Meyers, G., H. Phillips, J. Sprintall (1989): Space and time scales for optimal interpolation of temperature: Tropical Pacific Ocean. *J. Geophys. Res.* (submitted).

3 Meyers, G., J. Sprintall, H. Phillips, J. Peterson and T. Fonesca (1989). Design of an ocean temperature observing network in the seas north of Australia. Part I, Tropical Pacific Ocean: Statistics. CSIRO Marine Laboratories Report No. 204.

4 Phillips, H., R. Bailey, and G. Meyers (1989). Design of an ocean temperature observing network in the seas north of Australia. Part II, Tropical Indian Ocean: Statistics. CSIRO Marine Laboratories Report (in preparation).

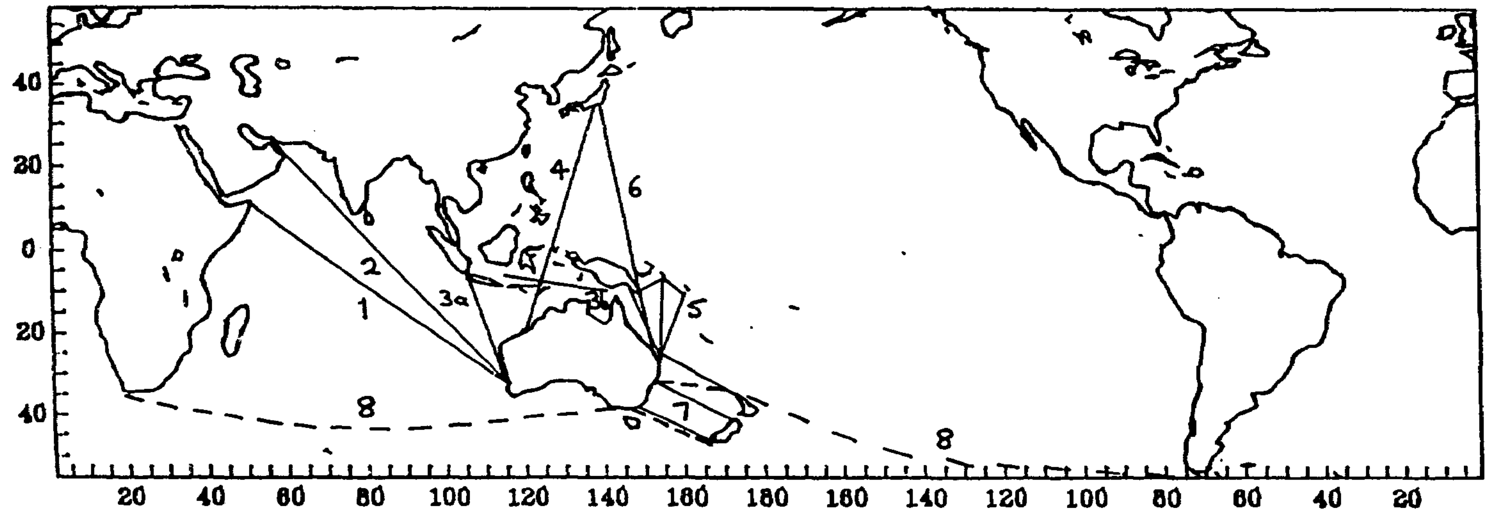
Table 1

XBT USAGE PROJECTION
(May 1989)

Line 1:	Fremantle – Red Sea (Nedlloyd Tasman, Encounter Bay, Flinders Bay)	
	14 Transects/yr 50 XBTs/Transect	700 XBTs/Yr (T–4s)
Line 2:	Fremantle – Persian Gulf (Mahsuri, "Ship")	
	12 Transects/yr 50 XBTs/Transect	600 XBTs/Yr (T–4s)
Line 3A:	Fremantle – Sunda Strait (Swan Reefer)	
	24 Transects/yr 20 XBTs/Transect	480 XBTs/Yr (T–7s)
Line 3B:	Flores Sea – Banda Sea (Anro Australia, Anro Asia)	
	16 Transects/yr 16 XBTs/Transect	256 XBTs/Yr (T–7s)
Line 4:	North West – Japan (Northwest Sanderling)	
	18 Transects/yr 55 XBTs/Transect	990 XBTs/Yr (T–7s)
Line 5:	Coral Sea (Nimos)	
	12 Transects/yr 30 XBTs/Transect	360 XBTs/Yr (T–7s)
Other:	Tasman Sea/Leeuwin Current	200 XBTs/Yr (T–4s)

Total # T–4s	=	1500
Total # T–7s	=	2086
Total # XBTs	**=**	**3586**

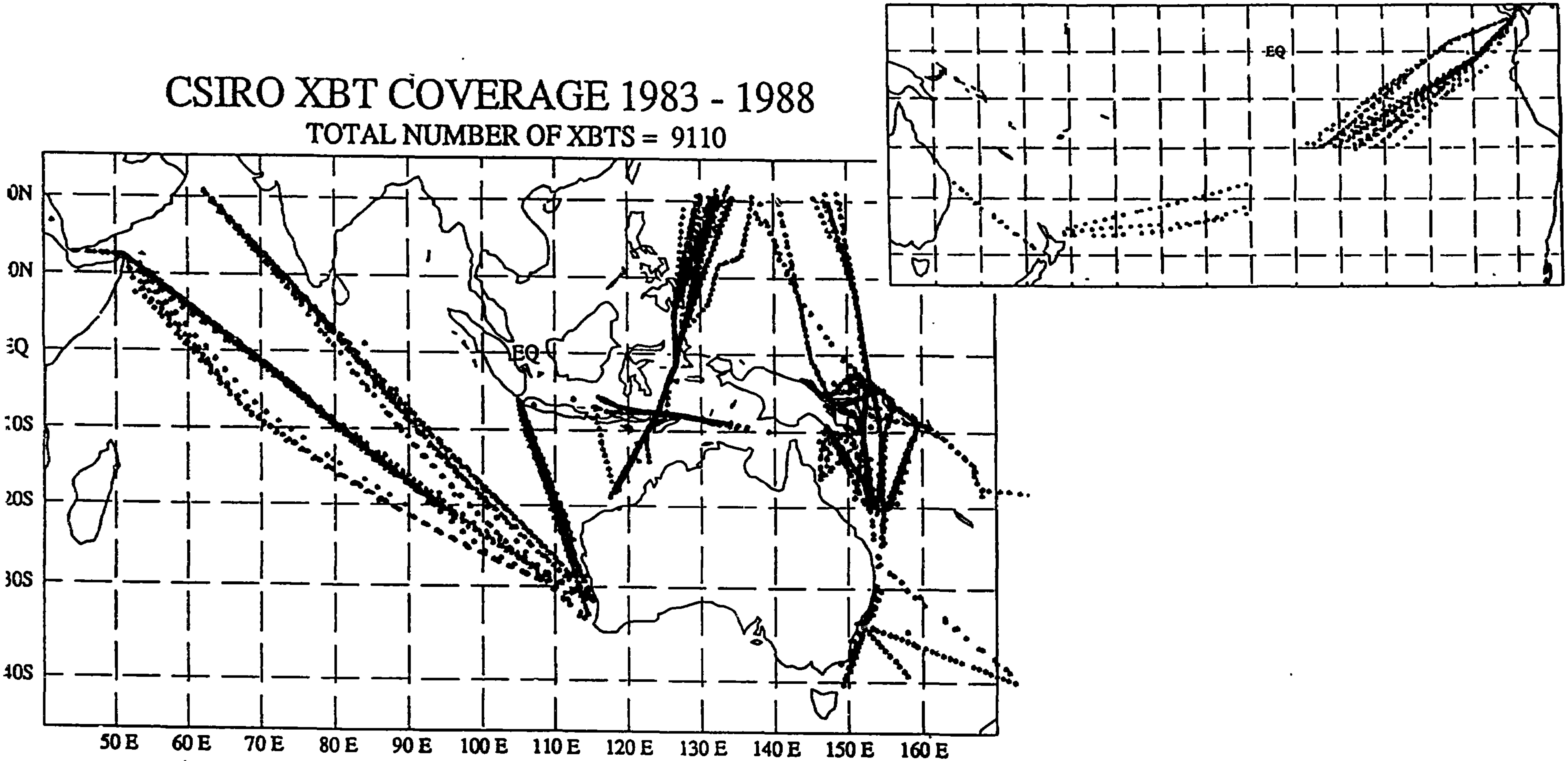
CSIRO XBT Ship of Opportunity Lines



1	Fremantle–Red Sea:	Nedlloyd Tasman, Encounter Bay Flinders Bay
2	Fremantle–Persian Gulf:	Mahsuri, Ship I
3a	Fremantle–Sunda Strait:	Swan Reefer
3b	Flores Sea–Banda Sea:	Anro Australia, Anro Asia
4	Dampier–Japan:	Northwest Sanderling, Australian Progress
5	Coral Sea:	Nimos
6.	Queensland–Japan:	Australian Progress
7	Tasman Sea:	Nedlloyd Tasman, Encounter Bay Flinders Bay, Mahsuri, Ship I
8.	Southern Ocean:	Ship II

Fig. 1. Ship Routes

———— TOGA
- - - - - - Greenhouse/WOCE



PER SHIP			
	ACT 3= 211	ACT 4= 198	ACT 6= 252
	ANRO ASIA= 366	ANRO AUSTRALIA=1057	AUST. PROGRESS=2105
	ENCOUNTER BAY= 460	FLINDERS BAY= 652	MAHSURI= 627
	MERIDIAN= 138	NEDLLOYD TASMAN= 496	NIMOS=1607
	SHEARWATER= 418	SWAN REEFER= 523	

Fig. 2. Successful XBT Stations

Table 2

XBT SUPPLY

	T-4	T-7
Usage	1500	2086
CSIRO		1000
RAN	1500	
U. Hokkaido*		500
NOAA/NOS*		600
Supply	1500	2100

* Proposed May 1989

B - ROYAL AUSTRALIAN NAVY XBT PROGRAM

Royal Australian Navy (RAN) has been collecting XBT data since the early 1970's. In the early 1980's this data was made available to the international community in real time via the IGOSS communications network (GTS). The contribution of the RAN has generally doubled the quantity of XBT data submitted by Australia and this has resulted in Australia being one of the more significant contributors to this important international program.

Since January, 1988 the RAN has deployed over 4,000 XBTs, the majority of which have been transmitted over GTS via the Bureau of Meteorology which is the Australian node for this network. A major effort is being planned by the AODC to increase the number of XBTs deployed in the Australian region. Approximately 600 XBTs will be provided to the CSIRO Ship of Opportunity Program next year in addition to the 1500 already being supplied annually. This will greatly improve the coverage of the Tasman Sea enabling a more detailed and accurate analysis of the complex East Australian Current to be undertaken. The existing weekly analysis products (SST, T250 m and Layer Depth) will be enhanced by increasing the area of coverage and improving the accuracy because of the increased quantity of data that will be available. It is also expected that a larger quantity of XBTs will be deployed by the RAN during the next few years.

The Australian Oceanographic Data Centre (AODC), which forms part of the RAN's Hydrographic Service is now undertaking quality control checks of the near real-time XBT data under the auspices of the Australian Specialised Oceanographic Centre (SOC). The SOC is a cooperative effort between the Bureau of Meteorology and the AODC and is now developing monthly XBT data sets for it's area of interest. The area of interest is approximately 20E to 70W and 30N to 70S, which covers the Indian Ocean and the Pacific Ocean from the tropics to the Antarctic. In the near future, a Bureau of Meteorology communications upgrade will enable the AODC to submit quality controlled data received from Australian Coastal Radio stations directly into GTS. This will assist in improving the quality of the real-time data available to the scientific community.

CANADA

Pacific Ocean

The major Canadian contribution to IGOSS on the West Coast is through the Federal Government research programme on the PARIZEAU, TULLY, RICKER, and ENDEAVOR. The major existing ship-of-opportunity programme is aboard the TANU, an operational fisheries vessel, working within the Canadian 200 mile fishing zone.

Additionally, there are two planned lines that are nearing implementation. The first is a cooperative venture with the USSR and the USA through a research programme aimed at studying the sub-arctic front in the North Pacific. This line, to be repeated twice per year for 5 years, would cover the area between Japan and North America. The research programme would report CTD measurements through IGOSS along a rather complex ship track designed for research purposes. The second line is to New Zealand and would cover the route from Tacoma/Vancouver to Aukland/Wellington several times per year. A vessel travelling along this line has already been instrumented with CO2 sampling equipment; complementary XBT measurements are the next planned stage.

Atlantic Ocean

There are 5 major programmes in the Atlantic that either contribute to the IGOSS data base or use IGOSS data in near-real-time.

1. Study of heat storage in the North Atlantic (Bedford Institute of Oceanography, Dartmouth, NS, Canada)

Objectives:

a. Annual and interannual variability of heat storage;

b. Delineation of the "Polar Front" and the investigation of its behavior;

c. Investigation of the influence of mesoscale eddies on heat transport and the accuracy of heat storage computations.

Methods:

Repeated occupation of three lines over a period of 5 years.

a.	St. John's - Rekjavik	2800 Km	16 Probes	5 times/Yr
b.	Denmark - Cape Farewell	3000 Km	100 Probes per year	
c.	Saglek - Cape Farewell	600 KM		

Line (b) is a collaborative effort with the Naval Hydrographic Office, UK.

2. Collaborative programme with NOAA

This programme is designed to collect temperature profiles from the continental slopes off Labrador and Newfoundland using three Canadian vessels, CAPE ROGER, L. J COWLEY, and the CSS HUSDON which are equipped with SEAS units.

3. Temperature/salinity Monitoring for Fisheries Research

As part of the fisheries research, the Department of Fisheries and Oceans, St. John's, Canada, collects a large quantity of XBT and CTD data. These include data along the NAFO lines as well as from other locations in the Northwest Atlantic. In 1989, the XBT usage will be approximately 150 cases of T10, 130 cases of T6 and 30 cases of T7 probes. The XBT data are transmitted in delayed mode to IGOSS; CTD data will be included once the necessary software is obtained.

4. Trawlers-of-Opportunity

In collaboration with the fishing industry, the programme is designed to collect current and temperature profiles and meteorological data from fishing trawlers. These data are quality controlled and transmitted in near-real-time.

5. Temperature Directed Fishery

This is a good example of how IGOSS data can be used for commercial purposes. In this project, the historical IGOSS data are used to estimate the covariance structure function for an objective analysis scheme. Real-time IGOSS data is then included to generate temperature maps which are transmitted to computers aboard the trawlers.

CHILE

Chile has been participating in IGOSS since 1983. Through the Instituto Hidrográfico de la Armada the tasks have been splited into the three IGOSS component: The IGOSS Observing System (IOS), The IGOSS Telecomunications Arrangements (ITA) and the IGOSS Data Processing and Service System (IDPSS). The most relevant to ship of opportunity program is explained in the next paragraphs.

1) IGOSS Observing System (IOS).

Ships of opportunity:

Chilean merchant vessels have been recruited for the BATHY-TESAC operational program. During intersessional period and through a bilateral arrangement with NOAA, the I.H.A. has installed SEAS III equipment in two chilean merchant vessels; M/N Presidente Gonzalez Videla and O/O Viña del Mar of EMPREMAR. They follow transatlantic and transpacific routes respectively and transmit SHIP and BATHY messages to GOES satellite on real time.

During 1988, 351 XBT observations were performed by the chilean vessels. During 1989 and up to the present the XBT observations reach about 90 probes launched.

It is important to realize that assistance and technical support was necessary only for the installation of the first SEAS III equipment. Chilean personnel performed the four following installations. Maintenance and recovery/supply of data/sensors are performed on chilean ports by I.H.A. personnel. Because of this expertize, NOAA requestrd I.H.A. to solve a technical problem aboard M/N Pacduchess, a foreing ship of opportunity that arrived to Talcahuano, Chile on May 1988. This is an important fact since it reduces NOAA's cost on travel expenses for technicians and therefore it only needs to send the equipment and XBT probes.

In the future, plans include to recruit more chilean merchant vessels, whose routes cross the Pacific ocean, due to the lack of XBT coverage. However, this process will depend on the interest of the Chilean Merchant Companies to continue the cooperation in the program and also on the future supply of such systems through NOAA or other international organization.

FRANCE

A - OVERSEAS OFFICE OF SCIENTIFIC AND TECHNICAL RESEARCH NOUMEA CENTRE

J.R. Donguy

INTRODUCTION

The systematic use of non-specialized ships for collecting meteorological data was no doubt inaugurated by Mathew Fontaine Maury, in 1844. He encouraged ships to record their observations and worked out the "pilot chart" in current use by all seamen.

At the present time, many ships systematically transmit by radio the meteorological data they collect, which are primarily used for the preparation of meteorological charts. These ships transmit, however, only one item which can be used in oceanography: the sea-surface temperature. But, all oceanographers deplore the lack of sea-going facilities made available for their purposes, a lack which is exacerbated by the increasing price of fuel. The use for oceanographic research of the thousands of ships which are constantly plying the oceans would be an invaluable source of data.

1. PARAMETERS

In a somewhat arbitrary manner, two types of parameters can be distinguished: physical parameters and biological parameters. We can also distinguish between the parameters which are already obtained on a routine basis and those which one may hope will be obtained in the more or less near future.

1.1 Routine physical parameters

1.1.1 Sea-surface temperature

This may obtained in several ways:

1.1.1.1 By a usually old-fashioned and poorly calibrated thermometer at the engine cooling water input. This method was used on old-fashioned ships having an engine-room watch. Advantage: ease of use and sampling always carried out at the same place. Drawbacks: frequent reading errors, overheated atmosphere giving rise to errors; calibration difficulties; water intake below the surface.

1.1.1.2 With a thermograph whose sensing unit is usually placed in the engine cooling water intake. Advantage: continuous measurement of the sea-surface temperature. Drawbacks: need for frequent calibration; possible deterioration due to vibrations; variable depth of immersion.

1.1.1.3 With a bucket thermometer. On modern ships, there is no engine-room watch and temperature measurements have to be taken from the bridge. In this case, a bucket thermometer, also known as a plunger thermometer, is used. Advantage: the thermometer is easy to read and to calibrate, so that measurements are accurate. Drawbacks: possibility of breakage and loss due to the increasing speeds of ships and the height of the bridge.

1.1.1.4 On some modern ships, an acquisition unit on the ship's bridge provides meteorological and surface temperature data. The sensor is placed in the engine cooling water intake.

1.1.2 Surface salinity

Salinity is usually calculated on land from bottles filled on board. It is possible, however, to envisage the use of thermo-salinographs which are currently used on research ships.

1.1.2.1 Bottles filled at the engine at the same time as the temperature is read. This procedure was followed on old-fashioned ships which had a continuous engine-room watch. Advantage: ease of execution. Drawbacks: sample sometimes unrepresentative of the outside sea water (stagnation in the piping; contamination by grease; possible faulty liaison with the bridge resulting in position errors.

1.1.2.2 Bottles filled on the bridge by means of a bucket or a bucket thermometer. This procedure is used on modern ships. Advantages: clean water; no transmission errors. Drawbacks: possible falsification of results, if a salt deposit forms in the bucket by evaporation or again, if the bucket contains rainwater; sampling difficulties owing to the height of the bridge and the speed of the ship.

1.1.2.3 Thermo-salinograph. Salinity is measured continuously at the same time as the temperature by an intake fitted to the ship's hull. Advantages: continuous measurement; no handling of samples. Drawbacks: apparatus expensive and fragile; possible breakdowns; difficult to install.

1.1.3 Expandable bathythermograph or XBT

With this apparatus, water temperatures from the surface down to a depth of about 400 m can be recorded without affecting the ship's progress. This recorder is usually placed on the bridge and observations are made by the officers of the watch by means of a hand launcher. The launch must be made from the leeside of the ship, so that the wire stays clear of the ship's hull.

Recordings may be made on paper or on cassette, depending on the type of instrument.

1.1.3.1 Paper recorder. The best known instrument is manufactured by the Sippican Company. Advantage: reliability. Drawbacks: difficult to adjust; need to digitalize the data, so that they can be fed into a computer.

1.1.3.2 Cassette recorder. This apparatus, used by the ORSTOM in the Pacific is apparently not yet on the market. Measurements are displayed on a screen and stored on cassettes. Advantages: flexibility; no subsequent digitalization of data; possibility of using the recorder for other measurements. Drawbacks: maintenance problems.

1.1.4 Surface current measurements

A distinction must be drawn between the estimates customarily used since the last century and the more sophisticated measurements often made by means of radio navigation instruments.

1.1.4.1 Surface current estimates are rather inaccurate data, but useful because they usually integrate the currents and the drift, due to the wind to which the ship has been subjected during 24 hours: this is how the "pilot charts" were prepared.

1.1.4.2 These measurements may be improved in sight of land or by means of a radio-navigation system or by satellite. In 1971-1973, CSIRO studied the East Australian Current by means of ships cruising in sight of land along the east coast of Australia. Many ships are equipped with a satellite navigation system and surface-current estimates may thus be restored to favour.

1.1.5 Visual observations, such as slicks of oil, tar or industrial debris, or the colour of the water.

1.1.6 Bathymetric measurements may also be restored to favour by satellite navigation and by the use, now current, of deepwater sounding apparatus.

1.2 <u>Possible physical parameters</u>

1.2.1 The expendable bathythermosalinograph or XSTD provides temperature, salinity and depth recordings with the same expendable sounding unit. This apparatus, with the recorder, is on the market, but its high price is an obstacle to its routine use.

1.2.2 The expendable current profiler or XCP gives a profile of absolute currents by means of an expendable sounding unit. It operates on the GEK principle, the absolute reference being the earth's magnetic field. The apparatus will shortly be marketed, but the sounding units will obviously be very expensive.

1.2.3 Chemical parameters. It is hard to imagine a ship being asked to carry out chemical analyses. But, certain samples can be kept frozen for a very long time and retain their properties. One might therefore envisage the study of nutritive salts (nitrate, nitrites, phosphate) in the ocean surface, although such a study does not seem to be particularly useful. On the contrary, silicate measurements obtained by the same method of freezing samples would have a certain interest, because silicates can be regarded as tracers of sediments of terrestrial origin.

1.2.4 Surface-current measurements. It would be possible to use the geo-electrokinetograph (GEK) on board merchant ships, if measurements were confined to the cross current. Measurements by the conventional GEK would doubtless be affected by the induced magnetic field of a large steel ship. It would therefore be necessary to study a suitable modification of the apparatus. Moreover, the possibility in the foreseeable future of building large ships in plastic would make it possible for the apparatus to be directly incorporated in the hull of the ship. But, the problem of the stability of the electrodes remains to be solved.

1.2.5 Ocean pollution measurements, when simple methods are developed.

1.2.6 Geophysical parameters. Gravimetric measurements could be obtained on board a ship equipped with a satellite navigation system, by installing a container in the centre of the ship. A technician would also be required on board.

1.3 <u>Routine biological parameters</u>

The biological parameters obtained as a matter of routine by non-specialized ships are less numerous than the physical parameters.

1.3.1 Since 1977, chlorophyll is determined as a matter of routine by the ORSTOM Centre at Noumea. The watch officer filters on board a small quantity of sea water. The phytoplankton is retained by the filter and stored in darkness and, possibly, in the refrigerator. The chlorophyll is determined in the laboratory by means of a reflection fluorimeter on the filters. Advantages: simplicity; temporal variations; overall view of an ocean. Drawbacks: sampling limited to the surface.

1.3.2 The quantity of zooplankton on the sea surface can be determined in several ways.

1.3.2.1 Sampling from the swimming pool. A net is fixed at the seawater intake of the swimming pool of large ships. When the swimming pool is filled, a quantity of zooplankton is collected, corresponding to the volume of the pool. Advantage: simplicity. Drawbacks: discontinuity of measurements; the state of the sample obtained depends on the pumps used. This method has been employed by the ORSTOM Centre at Noumea since 1977.

1.3.2.2 Plankton sampler. This is a small collector of profile plankton fitted with an interchangeable filter that can be towed for a known time by a ship cruising at low speed. Advantages: lightness and simplicity. Drawbacks: discontinuity of measurements; operates only at less than 12 knots; collection limited to the surface.

1.3.2.3 Continuous plankton recorder. This apparatus was designed by Sir Thomas Hardy during the thirties and is at present used by the Institute for Marine Environmental Research, Plymouth, United Kingdom. The apparatus collects a certain quantity of zooplankton, which is then fixed on a roll of gauze plunged in formaldehyde. Advantages: continuous measurements; reliability; can be used at high speed. Drawbacks: the apparatus is expensive and handling delicate; derrick must be constructed on the ship. This apparatus is used on a routine basis on the North Atlantic along 20 shipping routes.

1.3.3 Visual observations of biological parameters - fish, whales, birds, "red slicks" - are always useful and are usually obtained spontaneously.

1.4 Possible biological parameters

1.4.1 Continuous recordings of chlorophyll content may be obtained by the circulation of seawater in a recording fluorimeter. A Continuous Plankton Recorder, to which such a system has been added, has been designed and used at the IMER, Plymouth.

1.4.2 The IMER has also designed a Continuous Plankton Recorder capable of oscillating from the surface to the subsurface, which mitigates the effects of day-and-night cycles.

2. THE RECRUITMENT OF NON-SPECIALIZED SHIPS

When recruiting non-specialized ships for oceanography, the following factors must be taken into account: the type of observation required, the route followed, the type of ship, the officers and crew and the shipping company.

2.1 Type of observations required

The same procedure will not be followed for requesting simple surface observations (e.g., temperature or salinity) and for requesting more complicated measurements (XBT, plankton). Generally speaking, the collection of basic surface observations (T, S) is the first stage. The crew sees that the effort required is minimal and then it is possible to request more complicated operations during subsequent voyages.

2.2 The route followed is a fundamental factor

On the open sea, the most interesting routes are those that cut the surface circulation more or less perpendicularly. Since circulation is mainly zonal, the most interesting routes are those in a meridional direction, the ideal routes following a north-south course. Crossing the equator is also a valuable criterion, because equatorial phenomena are very important in oceanography and climatology.

There are, of course, many special cases: offshore upwellings can only be studied by coastal lines; certain areas may be more interesting than others: The eastern Equatorial Pacific, because of the El Niño phenomenon; the monsoon areas, the Gulf Stream.

2.3 The type of ship is also an important parameter

The most interesting ships are those of average size and speed (100 m, 12 knots). These ships are becoming rare, because they were usually built between 1960 and 1970. The trend towards giant ships and high speeds is for us an unfavourable factor, because ships tend to become automated, engine intake samplings have to be abandoned and the high speed and the height of the bridge make it difficult to take samples overboard. Very recently, however, there are signs of a diminution of speeds due to the increase in the price of fuel. However this may be, the launching of an XBT does not seem to be affected either by the height of the bridge or by the speed of the ship. The function of the ship is also an important factor: the officers of a ship carrying heavy goods (ores, oil) on long sea-routes have more free time than those of a ship carrying goods involving frequent calls: in the latter case, the paperwork (manifests, customs documents, etc.) is unquestionably very burdensome.

2.4 <u>Contact with the officers and, possibly, with the crew: an obvious need</u>

Such contact must be guided by a few simple principles:

2.4.1 The officers are usually co-operative. They are interested in meteorology and oceanography, and some of them are very glad to make a voluntary contribution to science. Others see the measurements as something to do during a tedious watch.

2.4.2 Making measurements must never be regarded as a duty. A request for co-operation must always be presented in the most tactful possible way; above all, one must avoid giving the impression of imposing a task. Although, the captain's consent is indispensable, it is usually not enough and that of the officers of the watch must also be obtained. If the voluntary work is carried out badly or inadequatly, it would obviously be tactless to draw attention to the fact: there may have been special circumstances that interfere with the measurements. And one should not forget that the turnover of crews is usually rapid: this means that the instructions must often be repeated; and also that an unwilling officer will not stay with the ship for ever.

2.4.3 Payment is undesirable: the financial implications for the research institutions would be unpredictable and probably prohibitive. For the crew members, the inevitably small sums paid for making measurements would give the impression of a tip which would give rise to complicated accounting and would generally have disastrous psychological effects. There are grounds for believing that unpaid work is usually done better than paid work.

2.4.4 The most complicated measurements are accepted the most readily. There is something tiresome about sea-surface temperature measurements and salinity sampling; but, more technical and more varied measurements, the expendable bathythermograph (XBT) or the collection of plankton: anything that provides contact with the life of the ocean, is usually welcomed.

2.4.5 There must be some initial motivation. In the first place, one should stress the need for constant monitoring of the ocean, a need which has become manifest during the last ten years. The performance of satellites - an objection that is often raised - is limited and the assistance of seafarers is essential. But, what is the purpose of constant monitoring? There are two: the productivity of the ocean and climatology. The observations requested derive from these two objectives. Reference should be made to certain basic ideas: the ocean is the earth's "central heating system"; the rational management of fish stocks requires a knowledge of their rate of reproduction and of the environment. A comparison with the World Weather Watch is usually well received.

2.4.6 Motivation should be permanent, because the officers change and interest may be lost. Contact with ships should always be conducted by the responsible research workers and technicians. Never send an unqualified person on the grounds that the transport of sample containers is not a researcher's business. Be on the spot as soon as the ship gets in so as to demonstrate your interest in the operation; the worst mistake one can make is to fail to visit a ship that is bringing observation results. Then, the observers must be kept informed about the research carried on with the help of their observations: for this purpose, a visit to the laboratory is usually appreciated.

2.5 Relations with the shipping company are advisable

Some ships' captains agree to collaborate subject to the consent of the company. A letter must then be written describing the operation and emphasizing that the equipment will be supplied and that the measurements will not slow down the speed of the ship. The reply is usually affirmative. Sometimes, contacts go further and the company may grant space in its magazine for popularizing articles (CGM Bulletin). Contacts with the company's local agents or consignees are very important. It is the agent who introduces the researcher to the ship's captain and who keeps him informed of ship movements. He provides excellent advice concerning ships' timetables and routes and perhaps about the character of the officers and captain. There is usually no problem about securing his co-operation.

3. PSYCHOLOGICAL, SCIENTIFIC AND PRACTICAL ASPECTS OF WORK WITH NON-SPECIALIZED SHIPS

3.1 The psychological aspects of collaboration with non-specialized ships has been described at length in the last section. It should not be forgotten that collaboration with any ship can never be taken for granted, so that recruitment has to be continually renewed.

3.2 The scientific aspects are important and cover the frequency of observations, their accuracy and their transmission.

3.2.1 If the ship has been selected for meteorology, it is easy to suggest that the observations (temperature, sampling, XBT) should be carried out roughly at the same time as the meteorological observations, i.e., every 6 hours (0000, 0600, 1200 and 1800 hours GMT), while recognizing that the officer is the sole judge of when he makes an observation. It may be that the circumstances are unfavourable (damage, risk of a collision, difficult passage, bad weather) and that a measurement may have to be postponed or even omitted. A measurement every 6 hours at 15 knots means a measurement every 90 miles, which is acceptable on the scale of the ocean. Some ships take measurements every 4 hours, and others every 3 hours.

Zooplankton samples should be taken at night, because it is at night that the plankton comes up to the surface. Sampling should therefore be requested at a local standard time, e.g., at 2100 hours in the Pacific.

launching of an XBT does not seem to be affected either by the height of the bridge or by the speed of the ship. The function of the ship is also an important factor: the officers of a ship carrying heavy goods (ores, oil) on long sea-routes have more free time than those of a ship carrying goods involving frequent calls: in the latter case, the paperwork (manifests, customs documents, etc.) is unquestionably very burdensome.

2.4 Contact with the officers and, possibly, with the crew: an obvious need

Such contact must be guided by a few simple principles:

2.4.1 The officers are usually co-operative. They are interested in meteorology and oceanography, and some of them are very glad to make a voluntary contribution to science. Others see the measurements as something to do during a tedious watch.

2.4.2 Making measurements must never be regarded as a duty. A request for co-operation must always be presented in the most tactful possible way; above all, one must avoid giving the impression of imposing a task. Although, the captain's consent is indispensable, it is usually not enough and that of the officers of the watch must also be obtained. If the voluntary work is carried out badly or inade-quatly, it would obviously be tactless to draw attention to the fact: there may have been special circumstances that interfere with the measurements. And one should not forget that the turnover of crews is usually rapid: this means that the instructions must often be repeated; and also that an unwilling officer will not stay with the ship for ever.

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3.2.2 Accuracy

It has to be recognized that the accuracy obtained is less than that of the measurements made by a research vessel. Temperature readings on the thermometer cannot have an accuracy of more than ± 0.5. A sample correctly taken in a hermetically sealed flask and analyzed on land gives the salinity with an accuracy similar to that obtained by a research vessel. But, despite all precautions (clean and perfectly dry bottles), faulty measurements are made: the bottles may come open; mistakes in numbering may be made; the water may be contaminated. It can be assumed that 2 to 3% of salinity measurements must be rejected.

Bathythermal measurements are also more difficult to obtain with an non-specialized ship than with a research vessel: the bridge is often very high and the ship cannot slow down or change course. Thus, when there is no wind or a head-wind, the wire falls back against the hull and the measurements are interrupted.

The accuracy of zooplankton sampling is difficult to quantify, but it is obvious that it tends to be less than that obtained on a research vessel: this is due to uncertainty as to the ship's speed and sometimes to the time of measurement and to handling errors on the part of the voluntary observers. On the other hand, the volume filtered when the swimming pool is filled is exactly known.

The comparative inaccuracy of measurements is not in fact a major defect: it is amply made good by the large number of measurements made by non-specialized ships. There has been a change in the attitude of research workers: hitherto, what was wanted was a small number of highly accurate measurements; now, a large number of not very accurate measurements are preferred.

3.2.3 Transmission of data. Most of the data collected by non-specialized ships are not transmitted in real time. When the ship returns to port, it hands in the measurements and samples taken throughout the voyage. The measurements collected may thus be several months old. There are obvious drawbacks about this procedure: risk of losing documents; poor conservation of samples.

It would be an advantage if certain measurements could be transmitted in real time, but many problems have yet to be solved. Laboratories are seldom able to afford the cost of transmission. Most of the time, indeed, laboratories do not work in real time. Although desirable, real time is currently used only in certain special cases, e.g., assistance to fishing or the preparation of a voyage.

3.3 <u>Point of contact</u>

It is worth examining the point of contact between ships and scientists. This is a port in which the ship carries out commercial operations of loading or unloading or administrative operations, such as customs formalities. This is the port in which the personnel in contact with the ship is based, with the laboratory where the data are processed and analyzed in the vicinity.

3.3.1 The representatives responsible for maintaining contact should be of a high level, capable of arranging for the making of observations and of motivating the observers (see paragraphs 2.4.5 and 2.4.6). If there is only one such representative in a port, far from the laboratory, he must have some technical ability and display the greatest scientific honesty. For his relations with officers and crews, he should be the type that makes human contacts easily; and, preferably, he himself should come from a seafearing background.

The use of electronic apparatus (such as the XBT) on board ship calls for a certain competence in that field. The part-time services of an electronics expert should therefore be provided.

3.3.2 The place where the data are processed and analyzed may be the research centre itself if it is not too far away, or some smaller unit. Thus, in Noumea, the ORSTOM Centre is near the port; but, at le Havre, data are collected in conjunction with the Maritime Meteorological Service and are processed on their premises.

3.3.3 Relations with the Meteorological Service

Most of the ships which collect data are selected by the Meteorological Service and their relations with that body are necessary and fruitful. Some data are common to oceanography and to meteorology: oceanography needs concise meteorological data; meteorology collects sea-surface data (surface temperature) and both sciences conduct constant monitoring of the ocean and the atmosphere. The combination of these two types of monitoring forms the basis of the study of hydroclimates.

In some cases, as at Le Havre, oceanographic and meteorological data are collected by the Maritime Meteorological Centre. The ships only fill in a form and the salinity results are acquired with the other meteorological data. This type of organization is obviously to be encouraged, because it avoids the dispersion of effort and the multiplication of papers and files.

3.3.4 Relations with the various port authorities

The port officer must be informed of the existence of the operation and it is usually necessary to get authorization to enter the harbour area and to park a vehicle there. It is also important to have correct relations with the customs authorities. Sample boxes, whether empty or full, must be able to move without excessive formalities between the ship that takes the samples and the laboratory. Authorization must therefore be requested clearly, specifying that the boxes contain scientific samples, of no commercial value, which cannot be subjected to the usual formalities (customs documents, transfer through a forwarding agent). The customs administration is usually very understanding in this matter. If apparatus (XBT, thermograph) are taken on board, free circulation must also be requested, which is usually granted subject, naturally, to inspection.

4. SURVEY OF SCIENTIFIC PROGRAMMES USING NON-SPECIALIZED SHIPS

It may be useful to recall briefly the experiments of this type which, to our knowledge, have been conducted and are now interrupted: we shall refer only to the work that has been done since 1950.

4.1 In the Atlantic, we may mention the work of Berrit (ORSTOM) who, in 1957-1958, collected temperatures and salinities along the African coast, using merchant ships out of Pointe Noire (Congo):

BERRIT G. R., 1961 - Contribution à la connaissance des variations saisonnières dans le Golfe de Guinée - Contribution to the knowledge of seasonal variations in the Gulf of Guinea, Part I: General. Cahiers océanographiques, Volume 13, No. 10, pp. 715-727; Part II: Regional study. Cahiers océanographiques, Volume 14, No. 9, pp. 633-643 and 719-729.

In the Indian Ocean, the ORSTOM Centre at Nosy Be has collected salinity and temperature data along the lines Mascarene Islands-Madagascar and East African coast-Djibouti. This work was interrupted by the closing of the Suez Canal.

DONGUY J. R., 1970 - Observations de surface le long des lignes de navigation dans la partie ouest de l'Océan indien (Surface observations along shipping lines in the western part of the Indian Ocean). Cahiers océanographiques, Volume 22, No. 4, pp. 353-365.

DONGUY J. R. 1974 - Une année d'observations de surface dans la zone de mousson de la partie occidentale de l'Océan indien (A year's surface observations in the monsoon area in the western part of the Indian Ocean). Cahiers ORSTOM, oceanographic series, Volume 12, No. 2, pp. 117-128.

DONGUY J. R. 1975 - Les eaux superficielles tropicales de la partie occidentale de l'Océan indien en 1966-1967 (Tropical surface water in the western part of the Indian Ocean in 1966-1967). Cahiers ORSTOM, oceanographic series, Volume 13, No. 1, pp. 31-47.

In the Pacific, the CSIRO (Division of Fisheries and Oceanography, Cronulla, Australia) carried out, from 1953 to 1960, a study of surface conditions in the Coral Sea and the Tasman Sea (see Oceanographical Station List, CSIRO, Nos. 20, 25, 31, 36, 40 and 50). The ORSTOM Centre at Noumea used the surface data collected in 1959 and 1960 by the ships sailing between Noumea and Sydney.

LEMASSON L., 1966 - Nature des eaux superficielles entre la Nouvelle-Calédonie et l'Australie (Nature of the surface waters between New Caledonia and Australia). Cahiers ORSTOM, oceanographic series, Volume 4, No. 3, pp. 55-76.

In the Central Pacific, the surface sampling of passenger boats sailing between Hawaii, Tahiti and Samoa has been used by Austin (1960) and Hires and Montgomery.

AUSTIN T. S., 1960 - Summary 1955-1957 of ocean temperatures, Central Equatorial Pacific. Rep. Calif. Ocean. Fish. Invest. 7, pp. 52-55.

HIRES R. I. and MONTGOMERY R. B., 1972 - - Navifacial temperature and salinity along the track from Samoa to Hawaii, 1957-1965, J. Mar. Res. 30, pp. 177-200.

4.2 Brief review of current programmes using non-specialized ships

The information necessary to draw up an exhaustive list is at present lacking.

4.2.1 Programmes in the Atlantic

4.2.1.1 NMFS/MARAD Programme (U.S.A.), started in 1970 under the auspices of the National Marine Fisheries Service (NMFS) and the Maritime Administration (MARAD). The programme uses students of the U.S. Merchant Marine Academy to collect bathythermal data (XBT) and sea-surface temperature and salinity on board merchant vessels in the Tropical West Atlantic, the Caribbean, the Gulf of Mexico and the North-West Atlantic. The data are usually disseminated in real time and are mainly used by the Atlantic Environmental Group. The main purpose is the study of the Gulf Stream, the extension of which affects biology, fishing and climate. The data are available at the NODC.

Steven K. COOK - Expendable bathythermograph observations from the NMFS/MARAD Ship of Opportunity Programme, NOAA Technical Report, NMFS SSRF 692, 700, 709, 727, U.S. Department of Commerce.

NODC - Inventory of XBT data along transects in the U.S. Atlantic and Gulf Coastal Waters from NMFS/MARAD Ship of Opportunity Programme for 1978. Key to oceanographic records, documentation Nos. 7, 8 and 9, U.S. Department of Commerce.

4.2.1.2 In 1971-1972, the Max Planck Institut für Meteorologie, Hamburg, regularly obtained surface temperature and salinity data from a thermosalinograph installed on a passenger boat sailing along the north-west coast of Africa. The observations were made by the crew itself and the data were not disseminated in real time. We have no information as to whether this programme is continuing or has been resumed.

TOMCZAK M., 1977 - Continuous measurement of near-surface temperature and salinity in the north-west African upwelling region between the Canary Islands and Cap Vert during the winter of 1971-1972. Deep Sea Research, Volume 24, pp. 1103-1119.

4.2.1.3 In 1930, the Institute for Marine Environmental Research, Plymouth (U.K.) started what is called the "Continuous Plankton Recorder Survey". The programme is primarily biological and uses an apparatus called a "Continuous Plankton Recorder" which, towed behind a ship, continuously collects zooplankton. From 1930 to 1948, the study concerned the southern part of the North Sea; from 1948, it was extended to the North Atlantic, the North Sea, the Norwegian Sea, the Channel, the Irish Sea and the Gulf of Gascony. About 30 ships take part in the operation. Towed at a speed of 12-20 knots, the apparatus samples at a depth of 10 m. Analysis and maintenance are carried out at Plymouth, where the apparatus is then prepared for the next voyage. It seems, however, that the apparatus is taken on board in the ports where the ships call: the transport of the apparatus from Plymouth to the ship, its embarcation and disembercation must present problems. The crew or the ship that tows the recorder receives remuneration in proportion to the work done. The purpose of the operation is to find correlations between the mass of plankton, climatic factors and, possibly, human activities: the information collected is also of prime importance for fishing.

The following bibliography is far from exhaustive, because innumerable publications have appeared since the start of the programme. Bibliography of the Continuous Plankton Recorder, 1926-1971. Bulletins of Marine Ecology, Volume 7, 1973.

COLEBROOK J. M., 1975 - The Continuous Plankton Recorder Survey: computer simulation studies of some aspects of the design of the survey. Bull. Mar. Ecol., Volume 8, pp. 143-166.

COLEBROOK J. M., 1978 - Continuous Plankton Records: zooplankton and environment, North-East Atlantic and North Sea, 1948-1975. Oceanologica Acta, Volume 1, pp. 9-23.

TAYLOR A. H., 1978 - Long-term changes in the North Atlantic current system and their biological implications. Proceedings of the Royal Society of Edinburgh, 76 B, pp. 223-243.

COLERBROOK J. M., 1979 - Continuous Plankton Records: Seasonal cycle of phytoplankton and copepodes in the North Atlantic Ocean and the North Sea. Marine Biology, 51, pp. 23-32.

COLEBROOK J. M. and TAYLOR A. H., 1979 - Year to year changes in sea-surface temperature: North Atlantic and North Sea, 1948-1974. Deep sea research, Volume 26 A, pp. 825-850.

4.2.1.4 The MESTRA Programme, organized by ORSTOM (France). The MESTRA operation "Measurement of salinities and temperatures on Atlantic routes" has been conducted since 1977 by the direction de la Météorologie nationale and ORSTOM from Le Havre under a bilateral agreement on the model of the similar operation carried out in the Pacific from Noumea. The data at present collected are the surface temperature and salinity from 40oN to40oS along the following lines: Le Havre-Gulf of Mexico, Le Havre-West Indies, Le Havre-West Coast of South America, Le Havre-Guyana, Le Havre-East Coast of South America and Le Havre-South Africa. The data are not transmitted in real time. About 20 ships take part in the operation on a voluntary basis.

In future years, it is planned to equip the two transequatorial lines with XBT.

4.2.1.5 Under the SEQUAL Programme, it is planned to install XBT on oil tankers sailing from South Africa to the United States. This programme is a follow-up of the use od XBT on oil tankers in the Indian Ocean. The operation provides for the embarkation of a technician in charge of measurements at Cape Town.

4.2.2 Programmes in the Indian Ocean

4.2.2.1 MESTRA Programme. Although the programme is called "Measurement of salinities and temperatures on Atlantic routes", it comprises the collection of salinities and temperatures on certain Indian Ocean routes: Le Havre-Madagascar-Mascarene Islands via Suez, Le Havre-Far East via Suez and Le Havre-Persian Gulf via the Cape.

4.2.2.2 The Woods Hole Oceanographic Institution has used oil tankers sailing between the Cape and the Persian Gulf to obtain temperature profiles (0-450 m) by means of expendable bathythermographs (XBT). A technician came on board at the Cape and made the return journey. The purpose of the operation was to detect and study the great whirlpools to be found off the Somali Coast.

BRUCE J. G., 1979 - Eddies off the Somali Coast during the south-west monsoon. Journal of Geophysical Research, Volume 84, No. C 12, pp. 7742-7748.

4.2.3 Programme in the Pacific

4.2.3.1 Programme operated by CSIRO, Cronulla, Australia. The initial operation (1953-1960, see paragraph 4.1) was resumed in 1967. At that date, a maximum of 32 ships were taking samples in the whole of the Coral and Tasman Seas. Since container carriers and automated ships came into service, the operation has been reduced in size: at present, eight ships are working between Sydney and New Guinea and between Sydney and West Australia. Originally, salinity was sampled at the engine intake, whereas temperatures were recorded on a thermograph. The thermograph was checked very frequently and measurements attained an accuracy of 0.2°C. Expendable bathythermographs (XBT) have been used between Wellington (New Zealand) and Sydney, but the experiment has been stopped owing to the high proportion of faulty measurements.

The study was used for the plotting of monthly surface temperature and salinity charts and has given rise to a number of publications.

PIIP A 1974 - A critical description of the CSIRO sea-surface temperature and salinity sampling programme from merchant ships. CSIRO, Division of Fisheries and Oceanography, Report No. 57.

ROCHFORD D. J., 1977 - The surface salinity regime of the Tasman and Coral Seas. CSIRO, Division of Fisheries and Oceanography, Report No. 84.

EDWARDS R. J., 1979 - Tasman and Coral Seas: ten-year mean temperature and salinity fields 1967-1976. CSIRO, Division of Fisheries and Oceanography, Report No. 86.

4.2.3.2 TRANSPAC operation

Under the auspices of the NORPAX Programme, the TRANSPAC operation has been using, since 1975, merchant ships crossing the North Pacific between the Far East and North America to obtain temperature profiles at depths of 0-500 m, by means of expendable bathythermographs (XBT).

About 20 Japanese and American ships take part in the operation. Measurements are made on a voluntary basis, either by the crews or by students of the U.S. Merchant Marine Academy. At present, the data are not transmitted in real time, but are collected when the ship arrives in the United States and sent to the Scripps Oceanographic Institution which digitalizes them and feeds them into a computer.

The paper recorders at present in use are now being replaced by mini-computers with recording on cassettes. It is also proposed to transmit the data automatically via satellite.

WHITE W. B. and BERNSTEIN R. L., 1979 - Design of an oceanographic network in the mid-latitude North Pacific. Journal of Physical Oceanography, Volume 9, No. 3, pp. 592-606.

4.2.3.3 Pacific Environmental Group. No information received.

4.2.3.4 The ORSTOM Centre at Noumea has been collecting surface temperature and salinity measurements in the Tropical Pacific since 1969. About 20 ships are participating voluntarily in this programme along the following main lines: New Caledonie-Hong Kong, New Caledonia-Japan, New Caledonia-California, Tahiti-California, New Caledonia-Tahiti-Balboa; many local lines are also operated. The ships usually take samples every 6 hours. Since 1976, this sampling has been extended to biology: the filtering of small water quantities enables the chlorophyll concentration to be evaluated. In addition, the use of a Plankton Indicator on slow ships and of the swimming pool on a number of large vessels gives a meaningful idea of the concentration of zooplankton.

Since 1979, about ten ships have been equipped with an XBT recorder for obtaining temperature profiles as a function of depth along four or five trans-equatorial routes. The operation is financed by ORSTOM and the Scripps Institution of Oceanography, with a view to monitoring the amount of heat present in the equatorial zone. The recorder used is a minicomputer with recording on cassettes; whenever possible, a radio BATHY message is sent after each measurement, but the data are analyzed in deferred time.

DONGUY J. R. and HENIN C., 1976 - Anomalous navifacial salinities in the Tropical Pacific Ocean. Journal of Marine Research, Volume 36, pp. 355-364.

DONGUY J. R. and HENIN C., 1978 - Hydroclimatic anomalies in the South Pacific. Oceanologica Acta, Volume 1, No. 1, pp. 25-30.

DONGUY J. R. and HENIN C., 1978 - Surface salinity fluctuations between 1956 and 1973 in the Western South Pacific Ocean. Journal of Physical Oceanography. Volume 8, No. 6, pp. 1132-1134.

DONGUY J. R. and HENIN C., 1978 - La salinité de surface dans l'océan Pacifique tropical sud-ouest (surface salinity in the Tropical South-West Pacific Ocean). Cahier ORSTOM, Oceanographic Series, 16, No. 2, pp. 107-136.

4.2.3.5 The South-West Fisheries Centre collects the data obtained by tunny fishers working in the Eastern Pacific. This programme started in 1971; about 45 ships take part in it. These are fishing boats and their routes are not fixed; they sail between 5°S and 30°N and between 140°W and the American coast. They make observations, on a voluntary and unpaid basis, which are sent in real time (60%) or collected when the ship returns to San Diego (California), where the equipment is maintained. The ships make meteorological and expendable bathythermogram observations (XBT). In return, they receive facsimile charts of meteorological conditions, charts of sea-surface temperatures and of the depth of the thermocline, which they use in looking for tunny. This highly appreciated service is obviously one of the strong points of the programme. After analyzing the data, the laboratory issues the publication "Fishing information".

EBER L. E., 1976 - Monitoring the ocean environment. Mar. Fish. Rev., 38, 2, pp. 1-9.

5. SHIP POTENTIAL FOR A FUTURE GLOBAL MONITORING OF THE OCEAN

5.1 Ships

The number of non-specialized ships that might be used for making oceanographic measurements may be estimated at 50 000. Of these, some 7 000 have been selected to make meteorological measurements and only 200 for oceanographic work. This is obviously very few. Can the percentage be increased?

5.2 Weak points

Shipping developments show a number of negative aspects: ships go faster and faster, bridges are higher and higher and crews are smaller and smaller. Automation of the engines excludes participation by the engine-room watch. After a small number of voyages, many ships are taken off the line. Lastly, measurements always tend to be made along the same routes; huge areas remain unexplored.

5.3 Strong points

But the picture is not entirely negative. The increasing price of fuel reduces the possibilities of working with research ships, so that there will be a growing tendency to call on non-specialized ships. Moreover, all oceanographers are aware of the need for a continuous ocean watch on the lines of the World Weather Watch.

Technically, the size of ships seems to have reached a maximum: safety problems are now sufficiently great and no one wishes to see them accentuated. Another result of the price of fuel is that many ships cruise at an economical speed, below their possibilities.

Lastly, there are increasing possibilities of co-operation on the part of crews. These are of a remarkably high intellectual level. They are intensely aware of the value of our aims, such as climatology and the protection of the environment.

5.4 Routes

A study of world sea traffic routes shows that the greatest possibilities lie between about 40°S and 50°N, which covers the inter-tropical and temperate zones. These zones are of considerable importance: the inter-tropical zones are those in which solar energy is absorbed and stored for subsequent distribution over the whole globe. The temperate zones are those with the greatest industrial activity on the planet; they are therefore those most threatened by pollution, where nuisance control must be exercised. The coastal areas, where there is usually plenty of traffic, provide a basis for monitoring ocean productivity.

6. FORESEEABLE INSTRUMENT IMPROVEMENTS

6.1 Surface measurements

A cassette recording thermosalinograph, possibly with real-time data transmission using the ARGOS system, is a foreseeable possibility. This would eliminate sampling with heavy and cumbersome bottles and would ensure continuous measurements without the problem of digitalization.

6.2 Subsurface measurements

6.2.1 Recording of cassettes

The replacement of paper recording by cassette recording constituted a major technological advance. There are many different systems which, to my knowledge, have not yet been marketed. There are numerous advantages: it is no longer necessary to digitalize the recordings; the electrical requirements (frequency, voltage) of the apparatus are simple and might be supplemented for the collection of other parameters (e.g., salinity).

6.2.2 Recording of other parameters

Salinity seems to be the most interesting parameter to record. At the present time, it is neglected by the oceanographic community: it is in fact more difficult to observe than temperature, and it is not used by any large industry. It is, however, the natural complement of temperature measurements: a water mass can only be determined by the couple temperature-salinity. Like the thermal balance, the salt balance of the ocean is certainly of great importance for the climate. In addition, it is an indirect method of estimating precipitation. It is therefore to be hoped that, in the near future, technology will enable us to use XSTD systems at moderate cost.

6.2.3 Real-time transmission by the ARGOS system

At the present time, the MESECAR recorders used at Noumea and in the TRANSPAC operation work out a BATHY message derived from the measurement after each launching. Thus, the message has merely to be copied and sent off. A number of problems nevertheless arise. All stations are not authorized to receive these messages. Others, which are authorized, are not accustomed to doing so and do not send it on to the addressee. In any case, telecommunications congestion holds up the transmissions. The automatic sending of BATHY messages by the ARGOS system would obviously be the ideal solution.

6.2.4 Biological observations

It is the Institute of Environmental Research at Plymouth (U.K.) which seems to devote the greatest efforts to promoting biological observations. The latest models of their Continuous Plankton Recorder are equipped with a cassette-recording fluorimeter for determining chlorophyll and a control system enables the apparatus to oscillate between the surface and the subsurface (see paragraph 1.4).

7. WHERE WOULD SUCH PROGRAMMES BE THE MOST BENEFICIAL?

A distinction can be drawn between programmes that would be of benefit to the world as a whole and those of benefit only to a single area or region.

7.1 Programmes of benefit to the whole world

These are programmes involving the monitoring of the ocean's thermal content and, in the near future, of its salt content. Everyone knows that the ocean functions like a thermal machine whose source of heat is in the inter-tropical zone. A knowledge of the ocean's thermal content and of how it is dispersed should enable us to make medium-term climatic forecasts which would be useful for those who live by the shores of the ocean and could be communicated to the whole planet. Such a programme is already in progress in the Tropical Pacific (see paragraph 4.2.3.4) and is planned for the Tropical Atlantic (see paragraph 4.2.1.4). Such a programme should also be envisaged in the Indian Ocean, which is the least known of the three oceans and the one whose shores are the most thickly populated. The ocean doubtless plays a key role in the phenomenon of the monsoon on which the survival of nearly 1 000 million people depends.

7.2 Regional programmes

The monitoring of coastal areas is mainly of interest to fishing and, secondarily, to climatology. It was a programme of this type that was originally put into effect by the IMER, at Plymouth. Such a programme should be implemented along the East African coast, characterized by major upwellings and an alternating monsoon. The El Niño phenomenon in the Eastern Pacific might be monitored by the use of merchant ships off the South American coast.

8. HOW MUCH MONEY AND TIME SHOULD BE DEVOTED TO THE PROGRAMME?

8.1 A surface sampling programme, even on an oceanic scale, does not cost much: a number of such programmes have been launched by laboratories which had no research ships; that was the only way of obtaining observations on the high seas. All that is necessary is to buy recoverable bottles for sampling.

Even a more elaborate programme involving XBTs and biology would, in any case, cost infinitely less than the use of a research vessel, because the floating platform and the observers are unpaid. For this reason, it seems reasonable to suppose that the use of expendable sounding units for recording temperature and salinity would, despite their cost, be far cheaper than the use of a research ship taking up hydrological stations.

It would be unthinkable to use several research ships simultaneously for the continuous monitoring of the oceans, whereas the fitting out of several non-specialized ships with XBT would cause no problem. To give an idea of the orders of magnitude, it can be assumed that the use of an average research vessel (35 m long) costs a total of about US $4 000 a day, whereas an XBT sounding unit costs about US $30.

8.2 For a programme using non-specialized ships, provision must be made for long periods to be spent on the ships in instructing and motivating the observers. There should be no hesitation about spending a whole day with them, inviting them to visit the laboratory or even taking them into the country: in this programme, this time corresponds to that spent in the acquisition of data. The data will be processed - determination of salinity, thermal profiles, etc. - after the ship has left. There remains the interpretation of the data.

At Noumea, two research physicists and two biologists work full time on the programme. Three technicians work full time on processing. In biological work, two difficulties must be mentioned: the need to recruit and train a large number of technicians to sort the plankton; and the considerable observation time required for drawing valid conclusions (several years).

8.3 Operations combining several observing systems

Two basic methods of working must be distinguished in oceanographic research:

- Continuous monitoring over a large area with a small number of parameters, numerous measurements and average accuracy; and
- A study limited in time and space with a large number of parameters, few measurements and high accuracy.

For the first, non-specialized ships are used and, for the second, a research vessel. The first is cheap, the second very expensive. The choice depends on the scientific purpose pursued and the means available.

Other observing systems may be added to these two basic methods, e.g. :

1. Non-specialized ships + drifting buoys + satellites;

2. Research vessel + moored buoys;

3. Non-specialized ships + research vessel;

8.3.1 Non-specialized ship + drifting buoys + satellites.

This is the system applied by a laboratory that does not possess a research ship or has only a ship suited for coastal research. The drifting buoys may be dropped by the latter or even by non-specialized ships if a technician is taken on board. For this operation, it must be possible to stop the ship for an hour. The buoys will give information on the movement of the water masses observed by the non-specialized ships. The satellites will provide data complementary to the ship data.

8.3.2 Research vessel + moored buoys

This is the system applied by a laboratory having a research vessel with highly specialized research workers. The area studied will be small. The research ship will moor and collect the buoys. The sort of laboratory involved might be one studying both sea water chemistry and dynamics.

8.3.3 Non-specialized ships + research vessel

This is the ideal case: this laboratory can thus use both methods of work. The continuous monitoring of the ocean reveals problems that the research vessel can solve. This requires a numerous and varied scientific team.

CONCLUSIONS

A number of conclusions are suggested by this report. It seems inevitable that the work carried out by non-specialized ships will increase: the need for continuous monitoring of the oceans, the cost of research ships, the improvement of data acquisition methods are factors which point to the non-specialized ship as the research vessel of the future.

Moreover, there seems in general to be no problem about securing the collaboration of officers and crews. But, relations with these ships will always involve a psychological aspect and contact with each such ship will always have its specific features.

Figures: 5

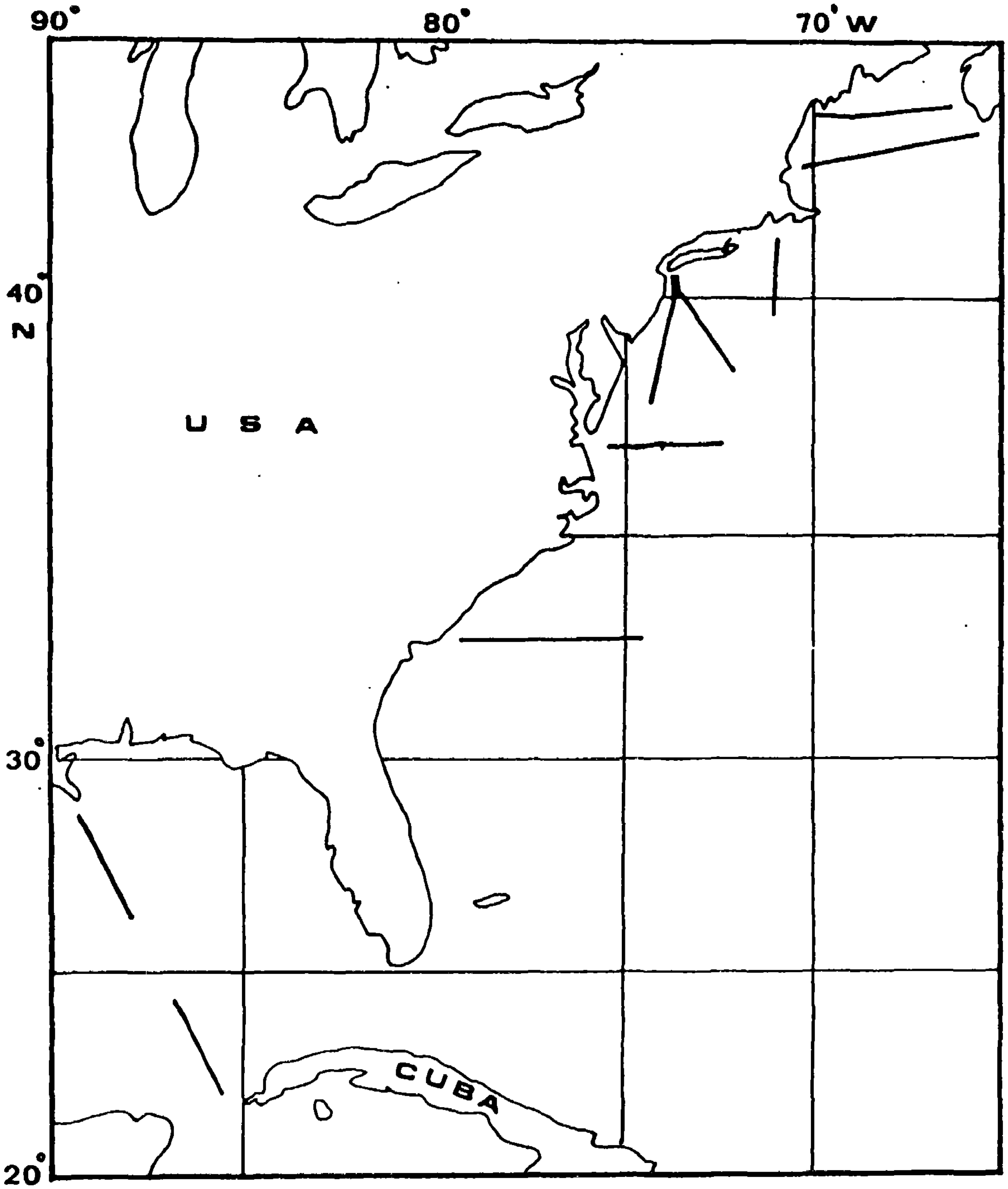


Figure 1 - Routes of ships used by the NFMS/MARAD (U.S.A.) programme

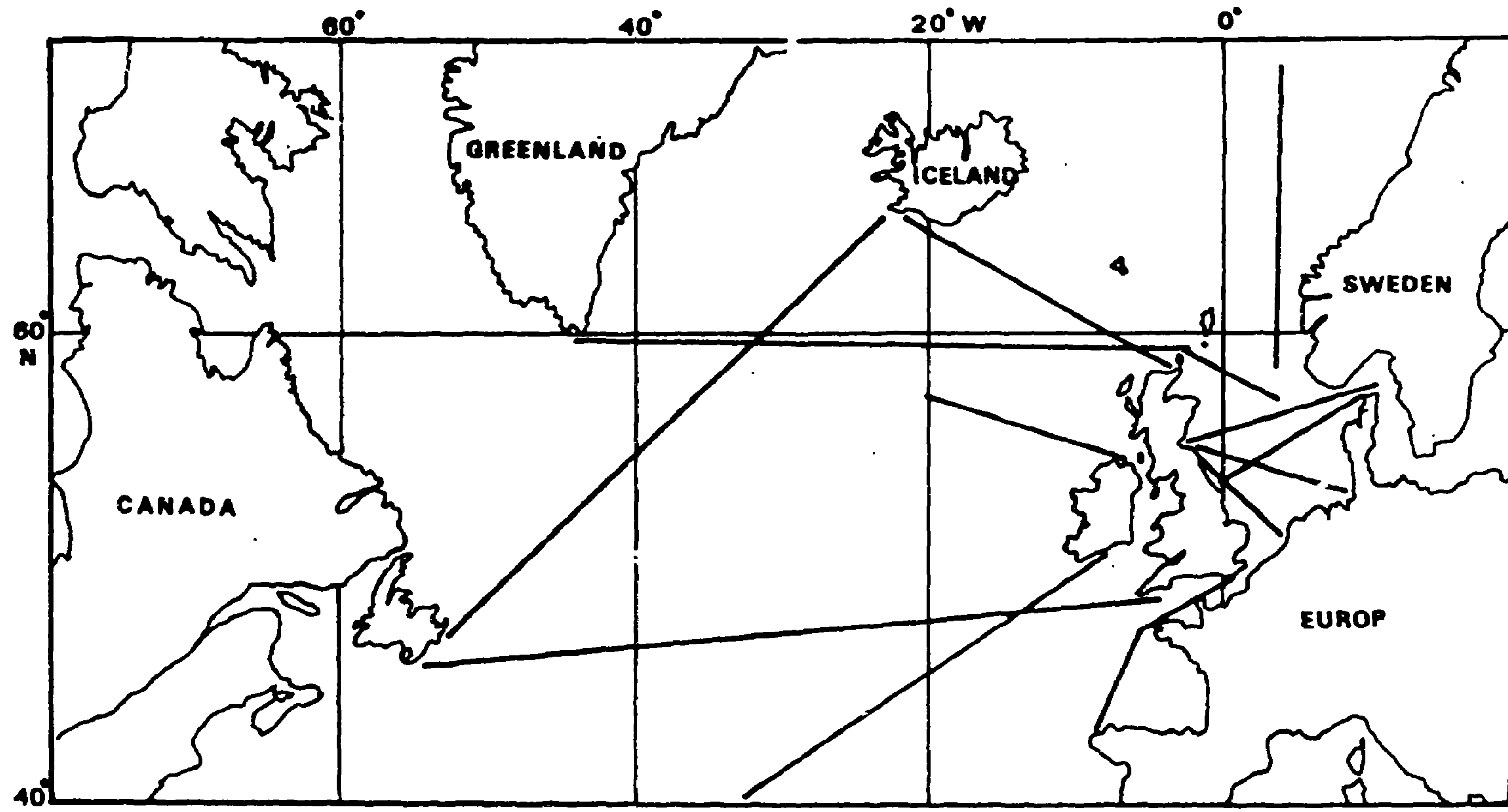


Figure 2 - Routes of ships used by the Institute for Marine Environmental Research (Plymouth, U.K.)

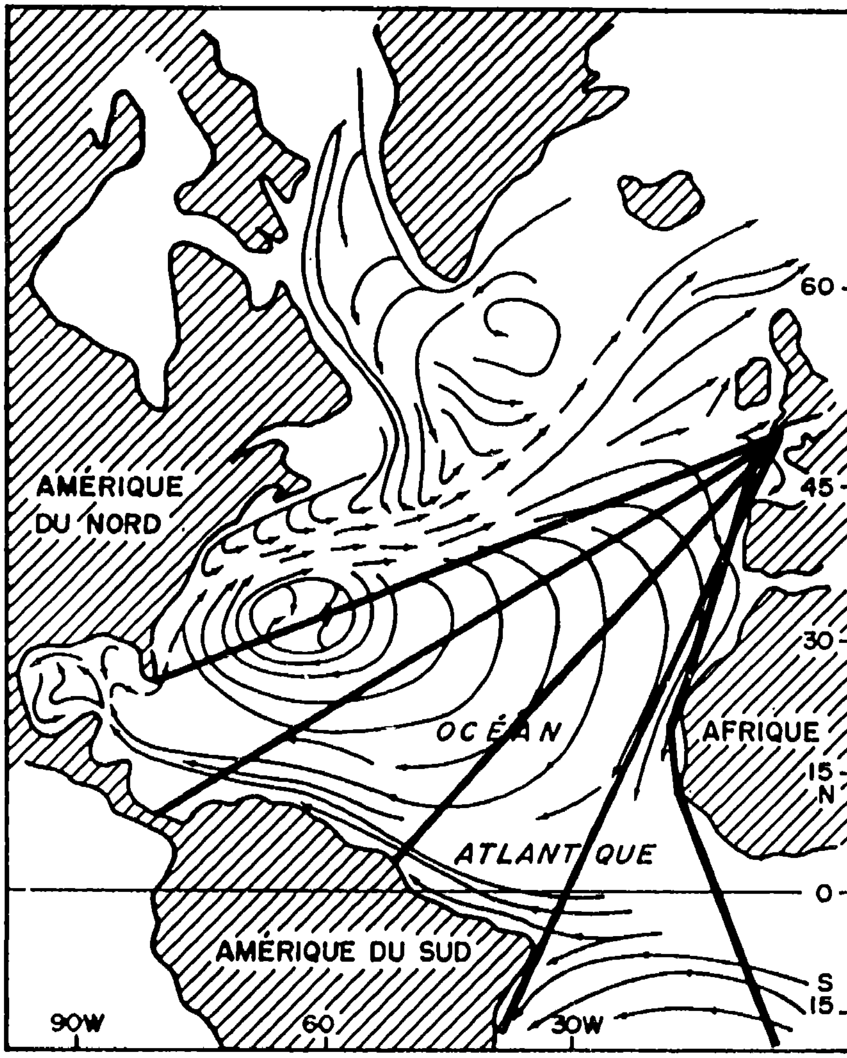


Figure 3 - Routes of ships used by ORSTOM in the Atlantic
(MESTRA Programme)

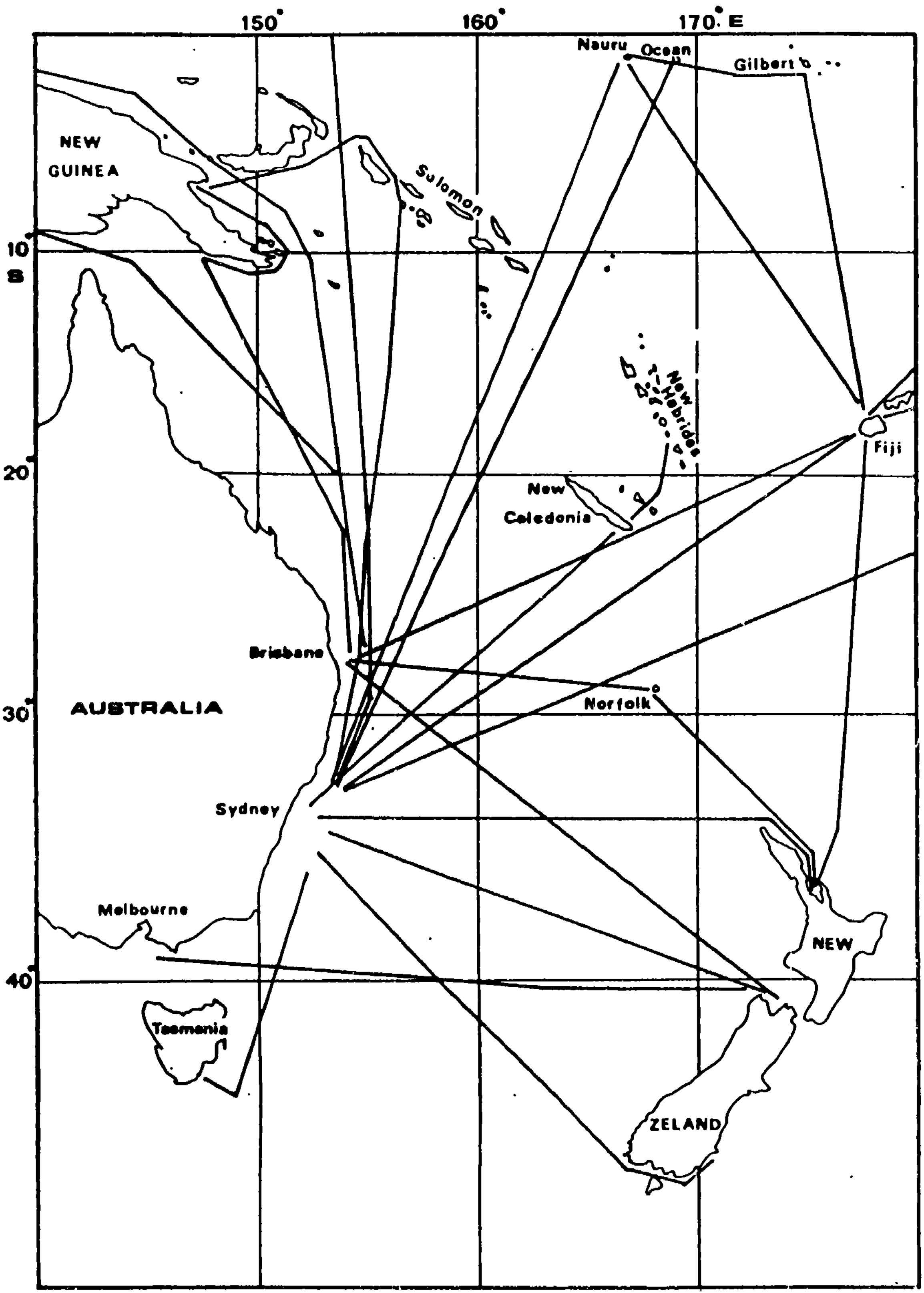


Figure 4 - Routes of ships used by CSIRO (Cronulla, Australiu)

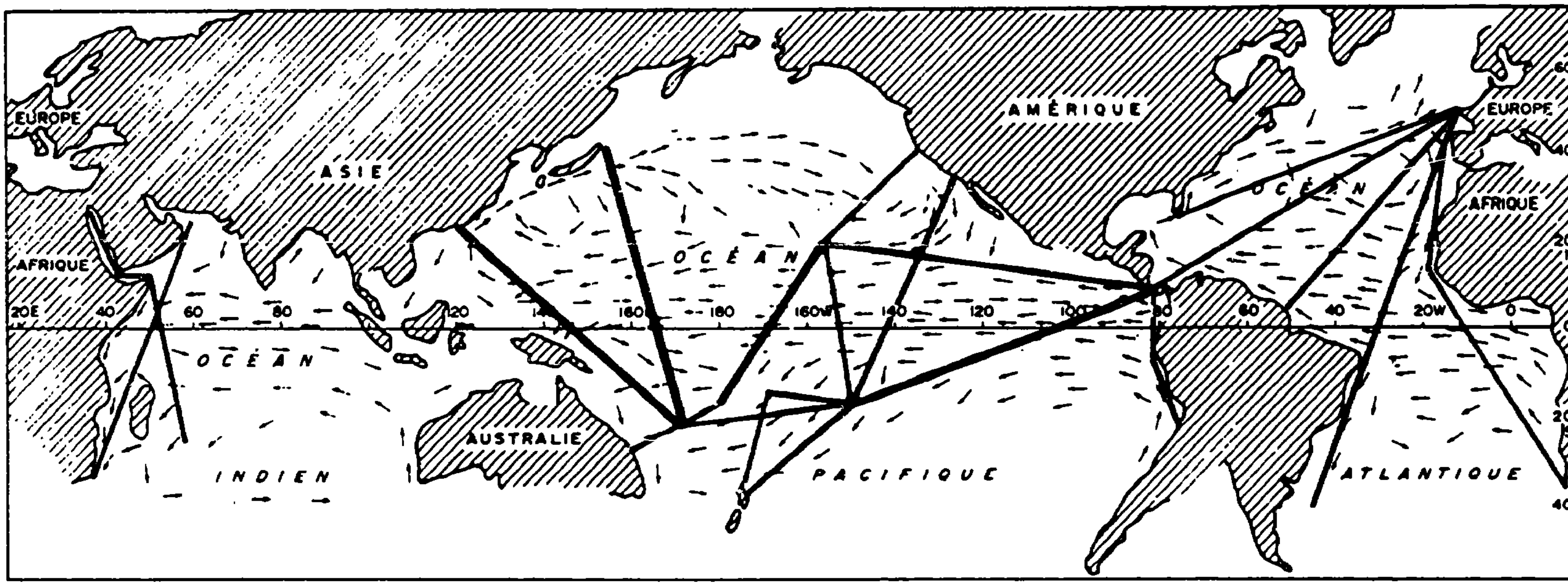


Figure 5 - Routes of ships used by the ORSTOM Centre in Noumea, in the Pacific. Routes on which XBT measurements are made, are shown by heavy lines

EXTRACTS FROM THE WMO GUIDE TO MARINE METEOROLOGICAL SERVICES

5.3 Recruitment of voluntary observing ships

In fulfilling its obligation to recruit voluntary observing ships of national registry, each Member thus contributes to the common objective of obtaining sufficient coverage of meteorological observations over the sea. It would be desirable if uniform coverage could be obtained, but this is difficult to achieve in view of the large differences in the density of shipping traffic over the oceans. This traffic is comparatively dense in the northern hemisphere, but this is not the case in the tropics or in the southern hemisphere. Consequently, greater attention should be given to the recruitment of voluntary observing ships. To satisfy international meteorological requirements for data density from the oceans, the successive plans under World Weather Watch contain estimates of the number of observing ships which should be recruited in the periods indicated. Requirements have shown the need for a continued increase in the number of voluntary observing ships.

Under the common objective of arranging for a sufficient number of observations from the oceans, countries may also recruit ships of foreign registry. This is sometimes done by arrangement between the Meteorological Services of two countries in cases where the home port of certain ships is situated in another country. Prior arrangements are however not strictly required, especially where auxiliary ships are concerned. Selected or supplementary ships thus recruited should, however, visit the ports of the recruiting country sufficiently often to permit regular contact. In order to avoid the entry of duplicate data into the international archiving system, meteorological logbooks from ships of foreign registry should be procured and stored through appropriate arrangements with the Meteorological Service of the country of registry.

Several criteria can be used in deciding whether a particular ship should be recruited as a selected, supplementary or auxiliary ship, to satisfy both national and international needs. Questions which should be examined are whether all the necessary instruments can be installed, whether the ship's officers will have the time available for recording and transmitting the observations and whether the necessary regular contact can be established for the receipt of meteorological logbooks. Generally, shipowners and masters are very co-operative in these matters; however, it is advisable that these questions be thoroughly discussed at the recruiting stage. Account must be taken by meteorological authorities of the normal ship duties of radio and navigation officers and whether they would have sufficient time left over to take observations.

The recruitment of voluntary observing ships is the responsibility of each Member participating in the scheme and for this purpose, Members should establish a suitable organizational unit. Appropriate measures should also be taken for the provision of instruments, instructive material and other necessary documents to ships, for the collection and examination of ships' logbooks, for visits to ships and for the various financial questions involved. In this national unit, a special officer should be made responsible for the recruitment of ships. In addition, it is desirable that, in large ports, a port meteorological office is established.

5.7 Port Meteorological Officers (PMOs)

In recruiting voluntary observing ships and assisting them in their meteorological work, direct contact with ships' officers is often needed to provide them with instructive material and other documents, to inspect meteorological instruments on board ships, to collect back the logbooks of observations and, on an initial check, take such corrective action as is possible by personal contact. For this purpose, port meteorological officers having maritime experience should be appointed at main ports (recommended procedure in WMO Technical Regulations).

Port meteorological officers are representatives of the Meteorological Service of the country as far as the local contact with maritime authorities is concerned. The role of port meteorological officers is a very important one and the efficiency of the voluntary system of ships' observations often depends on the initiative displayed by these officers. They are in a best position to discuss with ships' officers any problems they have encountered and offer suggestions, bring to their attention any changes in procedures that may have taken place and give them the latest information which they may desire. Opportunity should also be taken to explain various meteorological and/or oceanographic programmes whenever observations are specially needed from ships.

The port meteorological officers should also report to the meteorological authorities in their country if the meteorological work done one board the ship has not been found entirely satisfactory. Members should immediately react to these reports; when they concern the work carried out under the authority of another Member, the latter should be informed. If action has to be taken upon complaints, this can best be done through the port meteorological officers who can play a very important role by a tactful approach to the masters and if constructive criticism is expressed in positive terms, goodwill can be maintained all around.

The scope of the work of port meteorological offices depends largely on the importance of the marine traffic in the particular area served. Before deciding to establish a port meteorological office in a given port, a study must be made of the various services which should be provided. As the marine activities develop, a review should be made from time to time to see whether new services should be provided. Guidelines for organizing port meteorological officer (PMO) activities are given in Annex 5-E.

A list of port meteorological officers with their addresses and telephone numbers is also contained in Volume D of WMO Publication No.9, T.P. 4; the list should be provided nationally to ships' officers to facilitate their contact with port meteorological officers.

5.8 Incentive programme for voluntary observing ships

In recognition of the valuable work done by ships' officers in making and transmitting meteorological observations and as an incentive to maintain the high standard of the observations, many maritime countries have established a national award or certificate system. These systems vary greatly from country to country; in some countries the ships receive the awards, while in other countries awards are made to the masters or navigating and radio officers individually. Sometimes recognition for the meteorological work done on board ships is given in the form of books, charts and other documents presented to the ship.

Members, who have not yet done so, are invited to institute a national incentive programme for voluntary observing ships recruited by them, in the most effective way, according to national circumstances.

B - OVERSEAS OFFICE OF SCIENTIFIC AND TECHNICAL RESEARCH
IFREMER CENTRE - BREST

Progress in Real Time Transmission of V.O.S. Sub-surface Data within TOGA

J.P. Rebert

I. Introduction

One of the particular goals of the TOGA programme is to improve or implement new data transmission and management systems oriented towards operational use of subsurface data. After four and a half year of experiment, we can now try to strike a first balance of real time transmission of subsurface data in the TOGA area.

This paper presents an analysis of the real time data sets collected at the TOGA Subsurface data Centre since January 1985. These data sets have been provided by the French IGOSS Centre (Météorologie Nationale) and completed by real time data coming from other IGOSS Centre. We will consider here only the case of the first data set, considered as the "truly available" real time data (the problem of differences between IGOSS Centres data sets will not be examined here). As the results of this analysis can be subject to modifications subsequent to new available informations or enhanced processing (see below), they can be considered only as preliminary. Furthermore the TOGA real time data representing approximately 40% of the global data transmitted, these results cannot pretend to be representative of the complete IGOSS real time transmission.

II. data, principles and method

We will consider here the TOGA real time data set collected from 30°N to 30°S globally, though the examination of each Ocean individually reveals significant differences.

For each vessel having transmitted data, the total number of data transmitted each month is computed and entered in a small data base (vessel, ocean, month, number of data).

The vessels identified as ships of opportunity are then selected. The monthly total amount of data collected by these vessels and number of vessels having transmitted are then computed and transfered in a spreadsheet. This allow to represent the rough time evolution of the transmission for these vessels.

For the simplicity and readability of the graphics only the mean yearly results are presented here.

Checking the efficiency of the transmission is a little more difficult. If one tries to compare what has been transmitted compared to what has been collected, one must first select in the TOGA data base only the vessels for which the delayed mode data sets have already been processed. We create therefore a data base having the same structure than that of the IGOSS data base previously mentionned and containing the monthly number of XBT collected by vessels. Relating these two data bases on call signs allows to compute the differences and ratio of data per vessel.

As previously we will present here only global yearly averages.

III. preliminary discussion

At this stage and before presenting the results, it is perhaps not useless to check the validity of the method. Those who succeeded in understanding the previous paragraph must have noticed that the success of such computations, or at least an assessment of the reliability of their results, are higly dependant on some factors that we will try to discriminate. In fact we found that there are four types of critical issues to be properly solved:

a) ship of opportunity definition and identification

There has never been a clear definition of ship of oppurtunity an one can interpret this term in a strict or loose way. We will consider here only the merchant vessels operating without scientists onboard along regular lines in the TOGA area, irrespective of the programme for which they are collecting data. This precludes in particular the research vessels, even if "opportunely" used.

The second point is their identification. Describing all the shifts used for that would be beyond the scope of this paper. However the major source of reliable information has been since 1987 the IOC IGOSS Officer report distributed monthly. We give at the end of this document the complete list of ship of opportunity used for this study (and available on line on the TSDC catalog on OMNET) for the reader to appreciate its exactness.

b) Relating IGOSS and IODE data bases

The main obstacle put in the way of someone who intends to make a comparison between delayed mode and real time data sets is the difference in IODE and IGOSS data bases structures. Frequently IODE data are organized by cruises, IGOSS data sets by months, ships identifiers differ, prescribing use of cross reference tables which can never be perfectly updated, etc...Most of these studies have therefore been made only on small samples.

Fortunately at the TOGA Centre the two data sets have been assembled in the same data base, which makes their comparison relatively easy, provided the following point has been properly solved

c) Saving and archiving relevant statistics

As the TOGA data base is continuously updated, once the real time data have been replaced by the corresponding delayed mode data, they are definitely lost. This system therefore prescribes to continuously save statistics on IGOSS data as soon as they are loaded. The IGOSS statistics data base is therefore monthly updated since the beginning of TOGA and the data headers archived since one year.

d) Minimize errors

The major source of errors in estimating the amount of data transmitted by vessel (not including the losses in the GTS) is that concerning the vessels identifier. As we mentionned above the IGOSS/IODE data sets are related by their call signs. Many discrepancies and errors can be observed in call signs in both data sets. This tends to minimize the estimate of real time transmission efficiency (or effectiveness).

To overcome this difficulty the data base must be continuously checked for duplicates and erroneous call signs corrected. This has not yet been completely achieved for the two last years, and the results are therefore subject to changes and the real time transmission estimates improved in the future reports.

IV. Results and comments

1. The ship of opportunity network in the TOGA area

The list of ship of opporunity having collected data in the TOGA area is given at the end of the document. Not all of them have transmitted in real time. Though the aim of this study is dedicated to real time transmission only we summarize hereafter their activity since 1985. Last column indicates the number of vessels having reported in real time at least once during the year under consideration.

TABLE 1: Number of VOS having reported data per year

year	OPERATED	STARTED	ENDED	REPORTED in real time
85	54		9	40
86	61	19	10	46
87	73	21	9	70
88	82	16	26	81
89	71	15		69

Apparently both the number of ship of opportunity increased as well as that of those reporting in real time. It seems that nearly all the ships of opportunity are now reporting in realtime. However one must keep in mind that sometimes the dealyed mode data sets are really delayed by several years. So this flattering result may decrease with time.

The second question which arises is that of the importance of ship of opportunity transmission in the global IGOSS data set.

In fact the total number of real time reports for these vessels since 1985 is 25000 out of a total of 57000 reports in the TOGA area, which represents a little less than half of the data transmitted. However the time evolution of this report is interesting

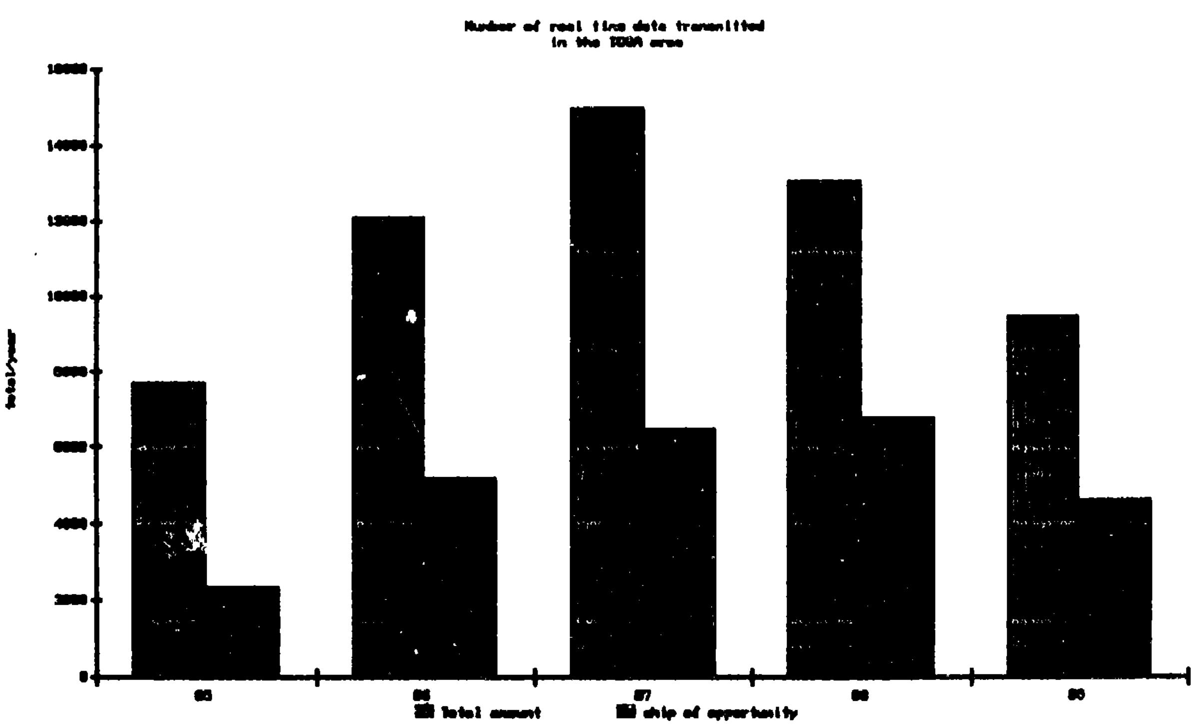


Figure 1: Ship of opportunity real time transmission

Apparently a net increase can be noticed in the ship of opportunity transmission, even in 88 where the total amount of real time reports decreased. As for 89 only 8 months of data are included in the graphic we present below in figure 2 the ratio of ship of opportunity data in the whome data set transmitted in the TOGA area.

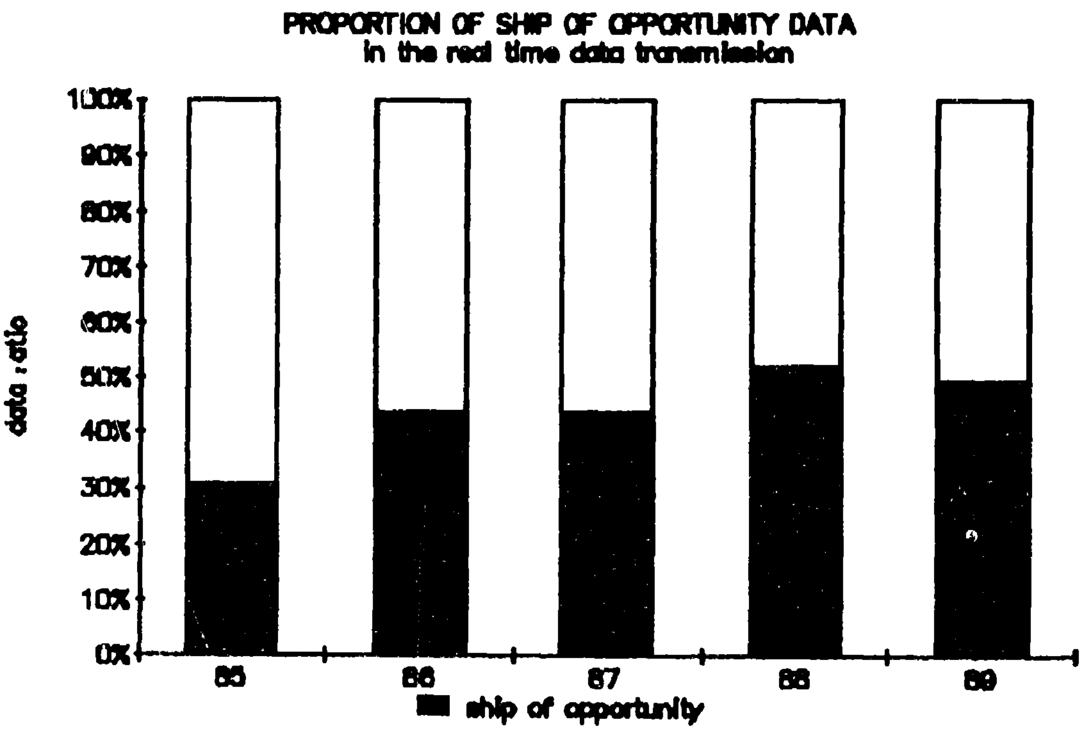


figure 2: ratio of ship of opportunity data

This figure confirms that the participation of VOS in real time data transmission has increased from approximately 30% in 85 to about 50% now.

Finally we present in figure 3 below the five year evolution of the mean monthly number of vessels transmitting their data and the mean monthly number of data received. Comparing this figure to numbers in table 1 can give an estimate of the number of vessels actually in operation which is approximately half of the network fleet.

However these results are very encouraging in terms of achievement of the IGOSS and TOGA goals, as they clearly show the increase both in number of vessels transmitting their data, which has passed from 20 to more than 40 per month and as as well as number of data transmitted

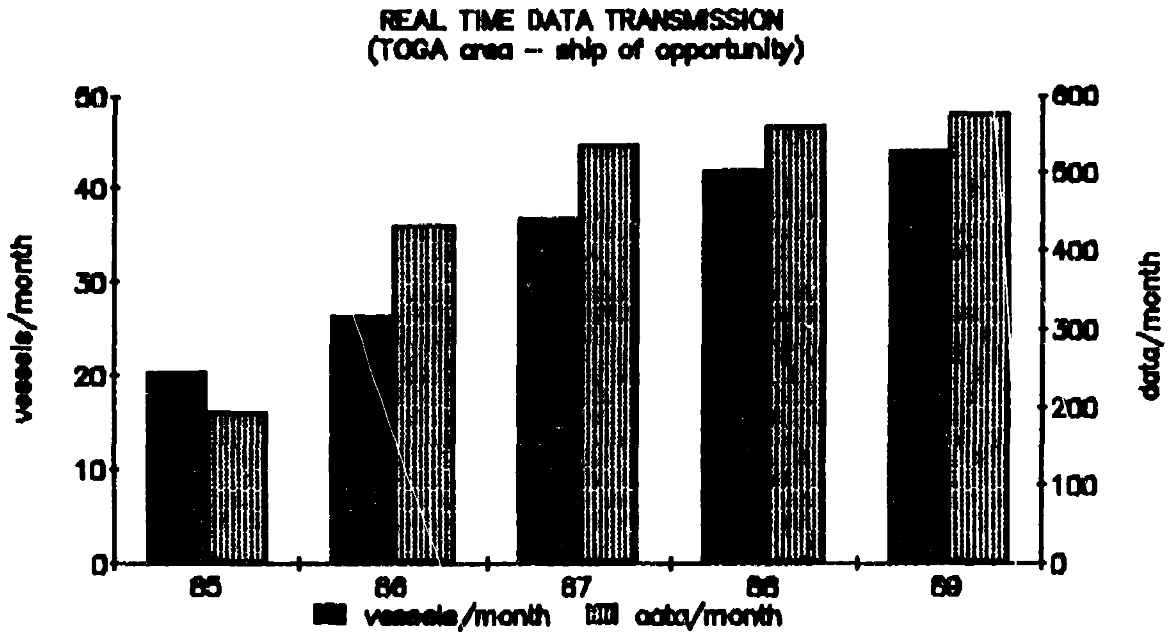


Figure 3: Mean monthly activity of the ships of opportunity

2. Efficiency of data transmission

There are several ways to estimate the efficiency of the real time transmission. An overall estimate would consist of comparing what has been collected to what has been received. Unfortunately a correct assessment of what has been collected is rather difficult, even after several years. Attempts are made within the TOGA Programme to compare what has been used, in terms of probes, to how much has been transmitted. We limit here our study to the presentation of two indices which can give a first idea on the improvement or not of the network efficiency.

The first question which arises is: is the number of data transmitted by these vessels really increasing or is it only the number of vessels which is increasing? The answer is given hereafter in figure 4.

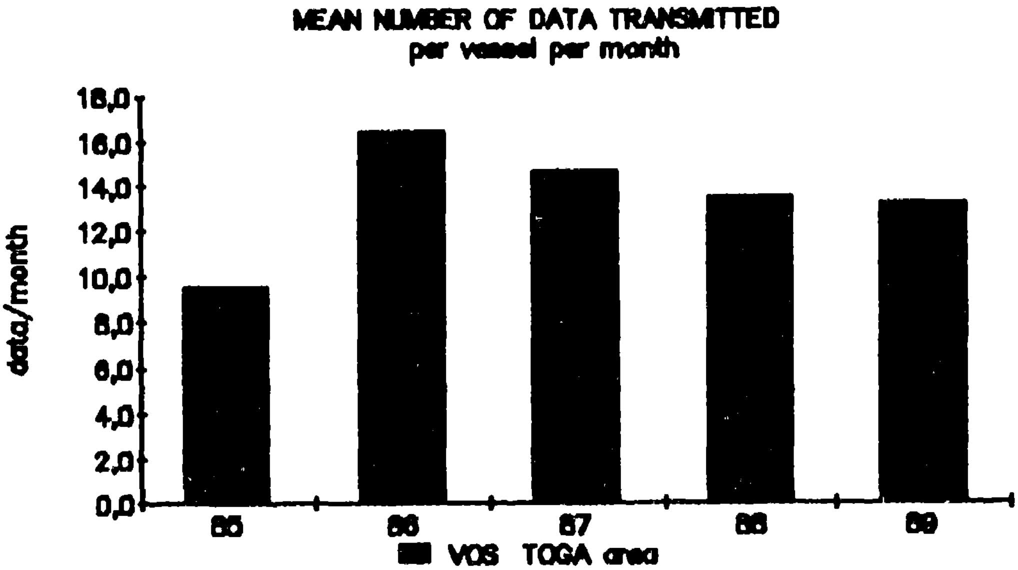


figure 4: mean number of data transmitted per vessel per month

This result is less encouraging with regard to the efforts devoted to the reduction of losses due to transmission by installing satellite transmitting systems. This leads to think that the second hypothesis is the good one, as the mean number of data transmitted seems to stabilize or even to decrease since 86 around an average value of 13 XBT transmitted per vessel each month. However the interpretation of these numbers in terms of transmission must be very careful and can be due to a sampling decrease, shorter lines implementation for the newly equipped vessels, or many other causes or artefacts. In fact inspection of individual results reveals widely variable transmission rates according to the vessel under consideration. This indice is probably not representative of the gain of transmission due to the improvement of the systems, which will be studied in due time.

To try to elucidate a little more this problem it seems simple to compare what is available within IGOSS to what has been collected by the responsible of the network.

This second index is certainly better in terms of transmission but, unfortunately, it is very sensitive to errors mentionned under item III d. The task consists therefore in selecting vessels for which the delayed mode data set has already been transmitted by the operators of these vessels and to compare it to what has been received in real time. This subset has been selected in the TOGA data base until year 88, as in 89 it is too small today to be representative (of course this introduces other kinds of artefacts).

This subset represents about 17000 real time data, corresponding to which 25000 XBT have been transmitted today to the TOGA Centre, which makes this statistic rather comfortable.

The comparison of these two data sets is given below in figure 5.

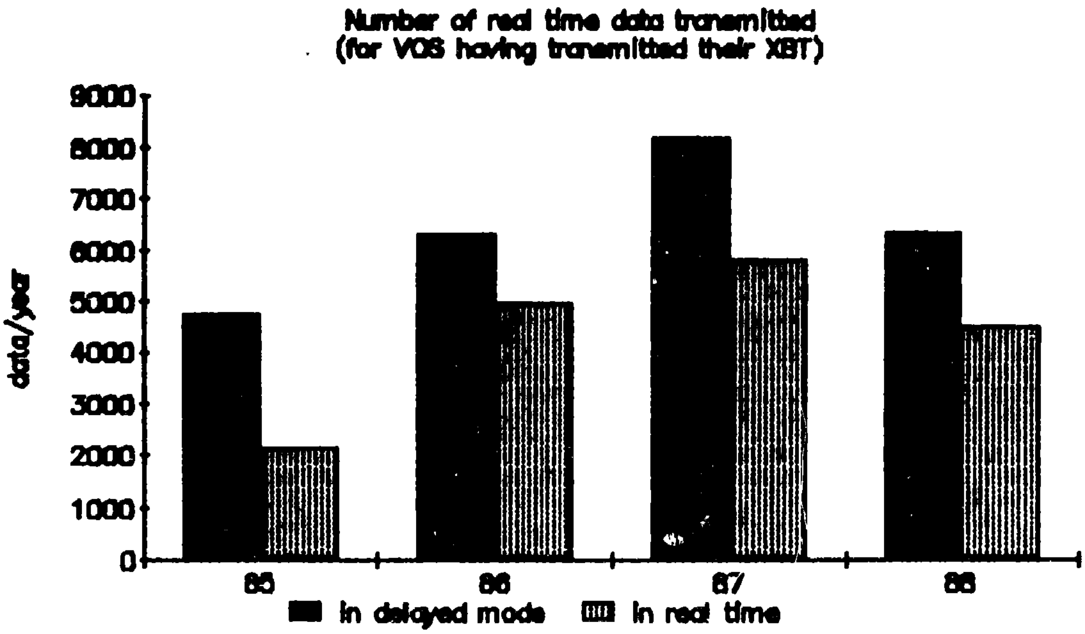


figure 5: delayed mode and real time data sets transmitted
(valid only for vessels having transmitted in real time)

and the ratio of the data transmitted compared to data collected is given in figure 6 herafter.

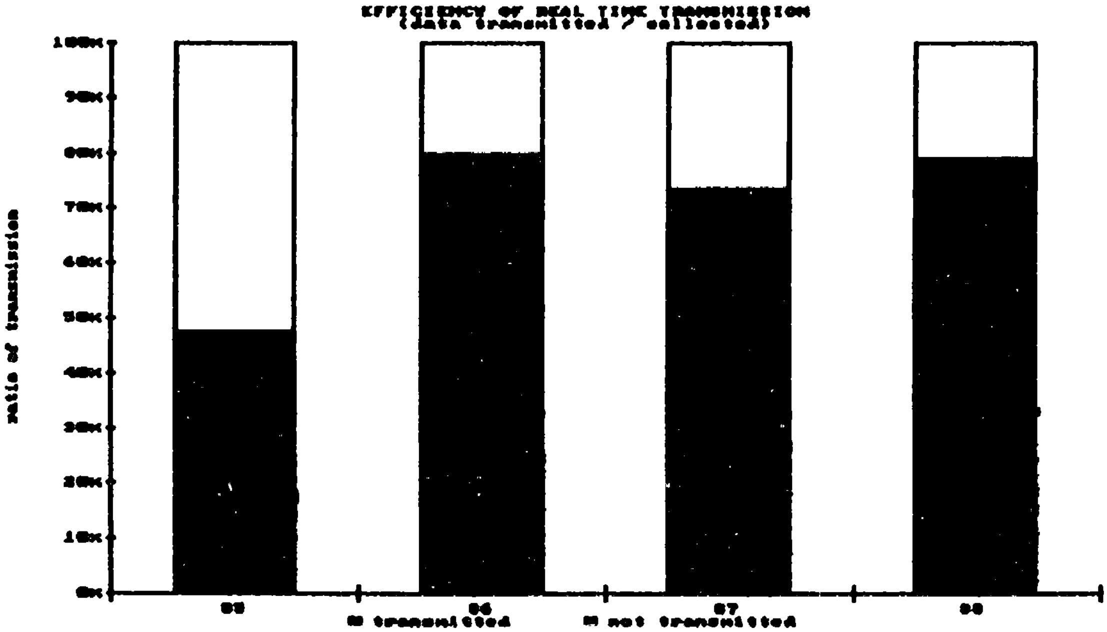


figure 6: For vessels having transmitted in real time

These results, though preliminary, are more encouraging and reveal a net increase, particularly from year 85 to 88. The transmission seems now to stabilize around a rate of success in transmission of 80%. Though the reliability of this result is difficult to evaluate, as different cause of errors can affect it in one way or in the other (errors in call signs tend to decrease the observed ratio, XBT sent in real time but considered as too bad to be transmitted by the operators tend to increase it), it should lie within an uncertainty bar of 5%. But, as already mentionned, this result may vary within wide limits from one vessel to another.

We plan therefore to continue to scrutinize the data and hope to be able to present more refined analysis when the data sets will allow it. At least this analysis will be updated and improved throughout the TOGA period.

V. Conclusions

This first attempt to evaluate the status of the real time transmission in the TOGA area has revealed an encouraging situation.

The ship of opportunity network, based on merchant vessels utilisation to improve the monitoring of the tropical zone, is now tranmitting half of the total amount of the data transmitted in real time in this area. The mean number of vessels participating to this monitoring and the number of data collected each month has more than doubled since 85. It seems that nearly all these vessels are now transmitting in real time, as far as they are correctly declared by the operators.

However the number of data transmitted per vessel as well as the transmission efficiency seem to stabilize since three years. This statement needs confirmation with further and other kind of analysis that we plan to continue to perform if needed.

TOGA SUBSURFACE DATA CENTRE

STATUS OF SHIP OF OPPORTUNITY REPORTS
in the TOGA area (30°N-30°S)

RADIO	VESSEL	TOGA Line	OPERATOR	DATA from	DATA to	Total XBT	Total BATHY	OP.
3ECT5	SHEARWATER	P6	CSIRO	87/7	88/12	4	2	N
3EET4	SEAS EIFFEL (ex EIFF	A1	ORSTOM B.	89/1	89/8	38	60	Y
3EIX2	PRESIDENTE IBANEZ	P22/A8	AOML/CHILE	87/8	89/4	0	59	Y
3EVS	SOUTH ISLANDER		ORSTOM N.	85/1	86/2	313	10	N
3FHI2	MOANA PACIFIC	P18	SIO/ORSTOM	85/11	89/5	747	505	Y
3FXW2	BRESLAU		IFM KIEL	85/9	86/11	111	0	N
5MCB	PACMERCHANT		NOS	85/1	88/9	58	34	N
9VBZ	MAHSURI (ex GXYY)	I1	CSIRO	89/4	89/7	0	34	Y
9VUU	ANRO ASIA	P2/I5	CSIRO	86/7	89/8	214	66	Y
A3BE	COLUMBUS CANADA		NOS	88/11	89/8	0	93	Y
A3BZ	ACT 12	P9	NOS	88/7	89/8	0	133	Y
A8VI	PACDUCHESS		FNOC	85/1	89/8	0	195	Y
C6CV9	LILLOOET	P7	SIO	87/6	88/2	110	43	N
CBAK	ANAKENA	A	AOML/CHILE	87/7	88/4	3	6	N
CBVM	VINA DEL MAR	P16	AOML/CHILE	88/7	89/8	0	46	Y
CXFN	PR. RIVERA	A4/A5	AOML	88/6	89/4	0	107	
D5ND	ST. LUCIA	P14	SIO/IOS	87/7	89/3	23	161	Y
D5NE	MT CABRITE	P14	SIO/IOS	87/4	89/8	77	161	Y
D5NZ	POLYNESIA	P18	SIO/ORSTOM	85/1	89/8	897	546	Y
DDIV	NEDLLOYD VAN DIEMEN			85/1	85/10	0	76	N
DDMA	JEBSEN SOUTHLAND	P5	ORSTOM N.	85/1	87/1	474	17	N
DGCE	CARIBIA EXPRESS		IFM KIEL	85/1	86/11	201	0	N
DGEM	ELBE	P5	ORSTOM N.	86/3	86/8	80	1	N
DGFR	SAXON STAR (COL.CAL)	P7	FNOC/DHI	85/1	88/6	417	258	N
DGLM	MONTE ROSA	A1	DHI	85/1	89/8	277	354	Y
DGPH	PORT HARCOURT		IFM KIEL	85/1	86/8	278	0	N
DGRL	LILLOOET	P9	ORSTOM N.	85/2	87/5	625	33	N
DGSR	COLUMBUS CANADA	P7	FNOC/DHI	85/1	88/10	371	110	N
DGVK	COLUMBUS VICTORIA	P7	FNOC	85/1	89/8	773	294	Y
DGZV	COLUMBUS VIRGINIA	P7	FNOC	85/1	89/8	675	346	Y
DHCW	COLUMBUS WELLINGTON	P7	FNOC	85/1	89/8	634	356	Y
DHEE	ELBE EXPRESS			85/1	85/10	85	0	N
DHJW	ACT 9	P7	SIO/ORSTOM	87/10	89/8	207	451	Y
DHOU	PURITAN		NOS	87/6	89/8	0	281	Y
DILM	ACT 10	P7	SIO/ORSTOM	88/1	88/4	66	3	N
DJKL	SIRIUS		ORSTOM N.	85/1	85/1	21	1	N
DLDE	WESER EXPRESS			85/1	85/4	51	0	N
DNCE	SIERRA EXPRESS		IFM KIEL	85/1	85/4	61	0	N
DZLI	JEBSEN TIMARU	P5	ORSTOM N.	87/1	87/11	96	19	N
ELDM8	SEAL ISLAND	P14	SIO/IOS	86/11	89/8	123	205	Y
ELDW8	SKRIM	P16	AOML/DHNM	86/6	88/10	77	443	N
ELED7	PACPRINCE	A8	NOAA/NOS	87/6	89/8	56	4	Y
ELED8	PACPRINCESS	A8	NOAA/NOS	86/9	89/8	36	23	Y
FNBF	ROSTAND	P12/17	ORSTOM N.	85/1	88/4	712	55	N
FNCW	ROUSSEAU	P12/17	ORSTOM N.	85/1	88/4	873	79	N
FNCZ	LIBREVILLE	A8	ORSTOM B.	89/3	89/8	44	70	Y
FNDT	RENOIR	I4/A3	ORSTOM B.	87/2	87/9	113	5	N
FNDU	ZAMBEZE	A1	ORSTOM B.	86/11	87/9	136	5	N
FNDX	ZEEBRUGGE	A1	ORSTOM B.	85/1	85/2	40	0	N
FNDY	GAUGUIN	P12/17	ORSTOM N.	85/7	87/3	365	0	N
FNDZ	TOULON	A1	ORSTOM B.	87/1	87/10	100	3	N
FNFE	EIFFEL	A1	ORSTOM B.	85/1	85/5	91	2	N
FNFU	ATLAS	A6	ORSTOM B.	86/5	86/11	86	0	N
FNGB	MARION DUFRESNE	I4	LODYC	85/2	89/8	1119	18	Y
FNGS	LA FAYETTE	A1	ORSTOM B.	85/6	89/8	1399	59	Y
FNJT	KORRIGAN	I6	ORSTOM B.	86/7	89/7	205	78	Y
FNOM	ANGO	A3	ORSTOM B.	86/3	89/8	479	91	Y
FNPA	RONSARD	A3/I6/	ORSTOM N.	86/6	89/8	373	230	Y
FNQB	ILE MAURICE	I4/A3	ORSTOM B.	87/2	89/8	336	114	Y
FNQC	VILLE DE ROUEN	I2/I4	ORSTOM B.	87/12	89/8	306	83	Y

FNQM	VILLE DE MARSEILLE	I4/A3	ORSTOM B.	88/3	89/8	287	48	Y
FNXE	RODIN	P12/17	ORSTOM N.	85/1	88/3	763	67	N
FNZO	RABELAIS (ex Lilloet	A3	ORSTOM B.	88/11	89/8	76	52	Y
FNZP	RACINE (ex COSGAREN)	P12/17	ORSTOM N.	88/9	89/8	0	151	Y
FNZQ	RIMBAUD (ex ELGAREN)	P12/17	ORSTOM N.	88/8	89/8	0	231	Y
GOVL	ACT 4	P8	AOML	85/1	89/2	169	105	N
GOVM	DILKARA	P9	ORSTOM N.	85/1	86/9	432	15	N
GOVN	ACT 6	P8	AOML	85/2	89/8	205	80	Y
GQEK	FORTH BANK		ORSTOM N.	89/8	89/8	0	1	Y
GXYY	AUSTRALIA STAR	I1	CSIRO	85/11	88/12	327	91	N
GYRW	ENCOUNTER BAY	I11	CSIRO	86/10	89/8	241	136	Y
GYSA	FLINDERS BAY	I11	CSIRO	86/11	89/8	291	105	Y
GYSE	NEDLLOYD TASMAN	I11	CSIRO	86/9	89/7	192	70	Y
GZKA	ACT 3	P8	AOML	85/3	89/5	189	165	Y
H8DY	CAP ANAMUR	P10	SIO	86/12	88/11	244	295	N
H9BQ	MICRO. INDEPENDANCE	P10	SIO	85/3	89/5	412	257	Y
HCGE	GALAPAGOS EXPLORER	P31	AOML	89/5	89/5	0	3	Y
HCGT	BUCCANEER	P31	AOML/INOC.	85/1	88/10	175	59	N
HPAN	MICRO. COMMERCE	P10	SIO	85/4	89/8	406	130	Y
HPEW	PACIFIC ISLANDER	P5/P4	ORSTOM N.	85/1	89/8	682	296	Y
JBES	YAMASHIN	P1/10	SIO	87/2	87/3	1	1	N
JCDT	AMERICA MARU	US/JAP	SIO	86/10	86/10	0	1	N
JIOW	ALASKA MARU	US/JAP	SIO	87/11	88/4	0	2	N
JJZC	HAKONE MARU	US/JAP	SIO	87/11	88/10	7	15	N
JPJX	HAKURYU MARU	P5	ORSTOM N.	87/11	89/5	181	262	Y
KEOC	EDGAR M. QUEENY	AGM	NOAA	85/5	87/6	0	299	N
KIRH	SEA LAND TRADER	P10	SIO	88/4	89/8	0	97	Y
KIYO	EXXON JAMESTOWN	P20	SIO	85/1	88/2	376	96	N
KRGB	SEA LAND ENTERPRISE	P9/10	SIO	89/4	89/8	0	55	Y
NFKQ	SEALIFT ARABIAN	G.M.		86/1	89/3	6	102	Y
NIKA	SEALIFT ATLANTIC	G.M.		85/5	88/10	28	178	N
NIKL	TAMPA	G.M.	NOS	87/4	88/10	0	155	N
NQST	SEALIFT ARCTIC	P9	FNOC	85/5	89/8	113	169	Y
OWEQ2	MCKINNEY MAERSK	US/JAP	SIO	89/3	89/5	0	4	Y
OXFB2	LEXA MAERSK	US/JAP	SIO	88/11	88/11	0	5	N
OXMD2	LARS MAERSK	P10	SIO	89/5	89/8	0	7	Y
OYBG	FALSTRIA	A8/P20	FNOC	85/1	88/5	51	63	N
P3EU	WILHELM SCHULTE	P10	SIO	88/12	89/8	0	62	Y
PGDF	NEDLLOYD KATWYJK	GLOB	FNOC	86/9	88/12	210	143	N
PGDG	NEDLLOYD KINGSTON		FNOC	85/2	89/8	454	269	Y
PGDS	NEDLLOYD KYOTO	A8	FNOC/DHI	85/5	89/8	69	199	Y
PGDT	NEDLLOYD BALTIMORE		FNOC	88/12	89/8	0	67	Y
PGDU	NEDLLOYD KIMBERLEY		FNOC	85/1	86/12	357	42	N
PGDV	NEDLLOYD BANGKOK	?	FNOC	89/1	89/8	0	51	Y
PGEH	NEDLLOYD BAHREIN		FNOC	89/4	89/8	0	44	Y
PGEM	NEDLLOYD BARCELONA		FNOC	89/3	89/7	0	30	Y
PGOF	NEDLLOYD KEMBLA		FNOC	85/9	89/8	365	187	Y
S6FK	SWAN REEFER	I5	CSIRO	89/1	89/8	0	61	Y
SGNA	PARALLA	P13	ORSTOM N.	85/1	85/6	123	7	N
SGQJ	ELGAREN	P7	SIO/ORSTOM	85/2	88/2	563	124	N
UUYY	MERIDIAN		CSIRO	85/2	86/3	138	0	N
VJBQ	ANRO AUSTRALIA	P2/I5	CSIRO	85/1	89/7	465	172	Y
VJDI	IRON NEWCASTLE	P11	CSIRO	89/4	89/4	0	12	
VMAP	AUSTRALIAN PROGRESS	P11	CSIRO	86/7	89/7	1011	1020	Y
VPGE	SWAN REEFER	I5	CSIRO	87/3	88/9	216	175	N
WCGN	CHEVRON CALIFORNIA		SIO	85/1	89/7	159	43	Y
WNJG	SENATOR	A14		87/7	88/6	0	8	N
WSD362	ROYAL DAWN		NOS	88/12	89/5	0	25	Y
WSG655	IPOKAI		NOS	89/4	89/4	0	10	Y
WUW964	BARBRA H		NOS	89/1	89/3	0	4	Y
WXBR	CHEVRON MISSISSIPPI		SIO	86/8	89/8	44	34	Y
ZCSK	SKEENA	US/JAP	NOAA	88/2	88/2	0	1	N
ZCSL	NIMOS	P3	CSIRO	85/1	89/8	877	283	Y
ZSCT	VICTORY	A3/A5	J. BRUCE	85/1	85/12	111	0	N
*** Total ***								
						26093	13400	

C - STATUS OF THE FRENCH NETWORK

(Atlantic and Indian Ocean oct.88/sept.89)
Sampling 20°N-20°S

EXISTING

IGOSS line	number of ships	vessels names	call sign	number of voyages	mean sampling rate	number of probes/ship	type of probes	equipment/ transmission	line sampling per year	obs.
A9	2	La Fayette	FNGS	7	4/day	48	T7	ARGOS/SAT	14	
		Seas Eiffel	3EET4	5	4/day	48	T4	PET/RADIO	14	1
A6	2	Ango	FNOM	5	4/day	48	T7	ARGOS/SAT	10	
		Rabelais	FNZO	5	4/day	48	T7	PET/RADIO	10	2
A8	1	Libreville	FNCZ	7	4/day	24/36	T4	PET/RADIO	24	
I3	2	Ile Maurice	FNQB	6	4/day	48	T4	ARGOS/SAT	12	
and		Marion Dufresne	FNGB	2	?	120	T4	ARGOS/SAT	4	6
I3/A6	2	Ville de Marseille	FNQM	7	4/day	48	T4	ARGOS/RADIO	14	3
		Ville de Rouen	FNQC	7	4/day	48/60	T4	ARGOS/SAT	14	3
I10	1	Korrigan	FNJT	5	4/day	36/48	T7	ARGOS/SAT	10	

PLANNED

IGOSS line	number of ships	vessels names	call sign	number of voyages	mean sampling rate	number of probes/ship	type of probes	equipment/ transmission	line sampling per year	obs.
A29	1	Ariana	DIDA		4/day		T4	ARGOS/SAT	24	5
I6	1/3				4/day					4

STATUS OF THE FRENCH NETWORK

OBSERVATIONS

1. Since January 89.

2. Will be replaced by the "*RONSARD*" (call sign FNPA) equiped with an ARGOS system end of this year.

3. These two vessels make alternatively a two way trip (Red-Sea, La Reunion) or a round trip (Red-Sea, La Reunion, Cape of Good Hope, Europe).

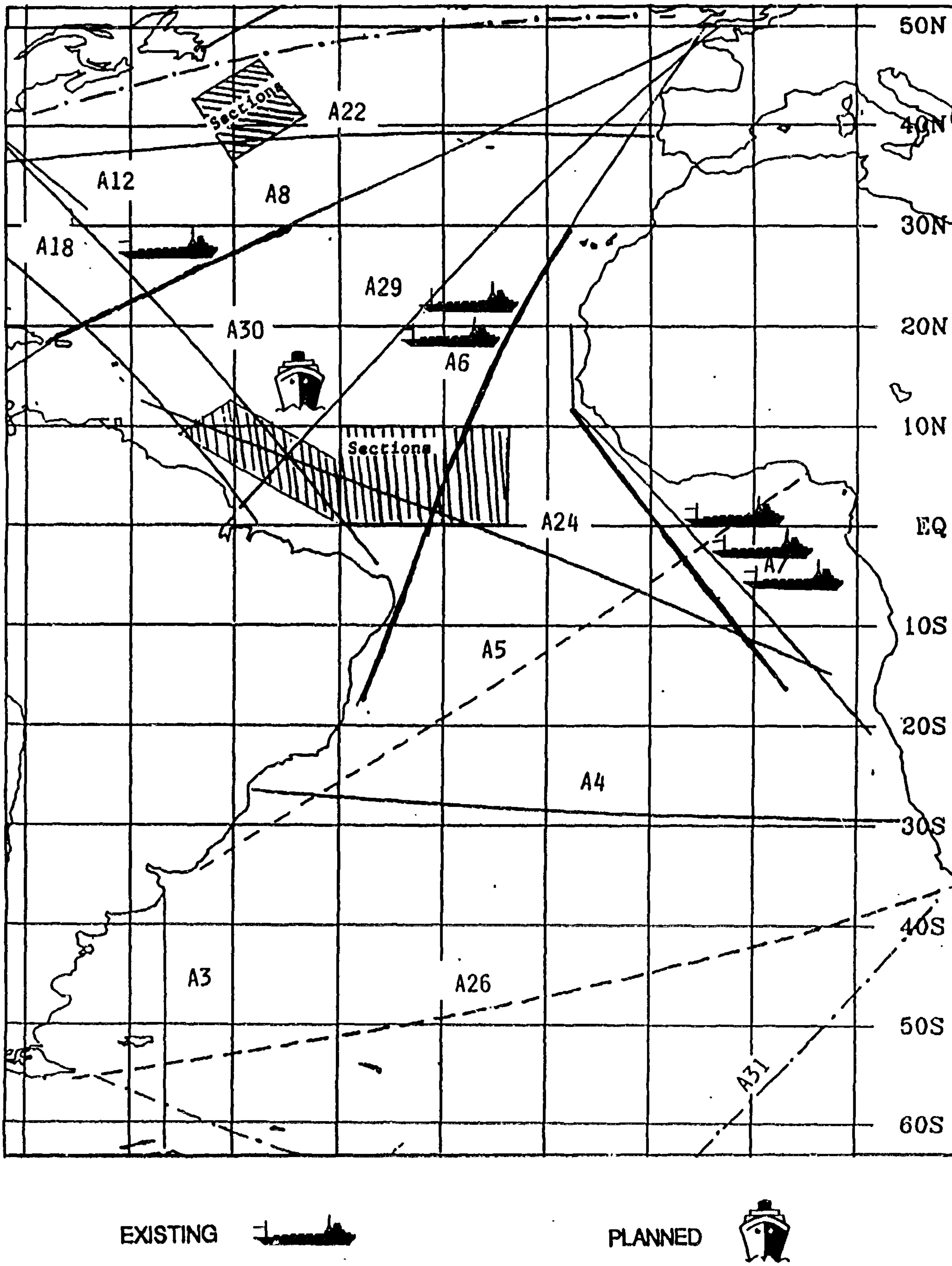
4. Programme achieved in cooperation with Japan (J.M.A.), vessels operated from La Reunion (1 ARGOS equipment available, probes provided by Japan)
No schedule.

5. Should begin in October 89.

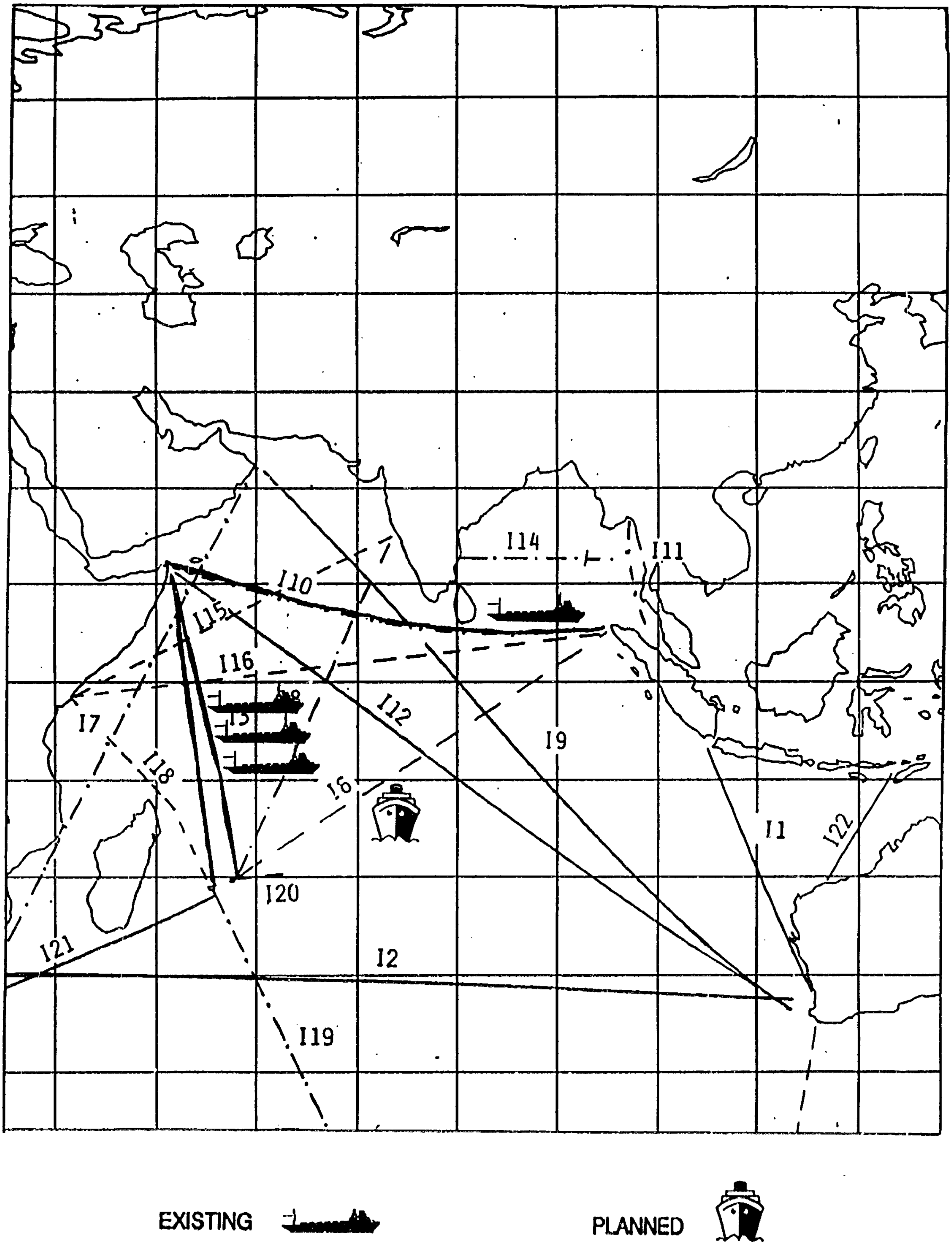
6. Vessel operated by the LODYC group. All the others operated by ORSTOM.

LINES:
A6: Europe - Cape of good Hope
A8: Europe- Panama
A9: Europe - Brazil
A29: Europe - French Guyana

I3: Red Sea - Mauritius/La Reunion
I6: La Reunion - Singapore
I10: Red Sea - Singapore



Atlantic Ocean



Indian Ocean

GERMANY (FEDERAL REPUBLIC OF)

A. Sy, DHI

As announced on the Sidney meeting 1987 the FRG SOOP activities increased significantly during the last two years. Within the framework of WOCE several new lines became operational in 1988 and 1989. Fig. 1 gives an overview on the present FRG XBT network containing all lines managed by FRG agencies as well as lines managed in co-operation with FNOC (USA). Fig. 2 shows the 1989 locations of real-time BATHY reports of this lines, either received from GTS at DHI or inserted into GTS by DHI. Table 1 provides some summarized technical and organizational information concerning these lines. All FRG activities are restricted on the Atlantic Ocean.

The Europe-Brazil line (A6), which has our longest time series and which is one of the longest IGOSS time series anyway, is operated by DHI and provided with T-4 probes by FNOC. This line is part of TOGA and WOCE XBT networks. As already stated at the last meeting (IOC, 1987) some significant improvements should be performed, because this line as it is at present is of limited scientific value only. Certain analyses will suffer from the very poor spatial resolution as can be deduced from a paper published by Emery et al., (1987). Consequently, the TOGA XBT Panel of Experts designed line A6 priority 1, which means measurements with higher spatial resolution (1 sample per degree of latitude), and deeper sampling (T-7) is recommended too (ITPO, 1989). Not only from our point of view, but also according to the TOGA and WOCE requirements (IPO, 1988; 1989), as well as to recommendations adopted by the Seattle meeting (IOC, 1985) a significant improvement of our sampling strategy should take place. In agreement with FNOC, ORSTOM, and DHI appropriate improvements (T7 instead of T4, 60 nm sampling) are planned in 1990. Some hardware improvements are necessary as well, and are planned to be carried out next year by DHI.

Since May 1988 line A9 between Europe and US East Coast is in operation. The sampling strategy is designed according the WOCE requirements and our own scientific objectives. That is:

1. the investigation of temporal and spatial variability of the North Atlantic Current system and eddy field,
2. the thermal front between Labrador Current and North Atlantic Current,
3. and the deep wintertime convection in the eastern part of the North Atlantic.

That means high temporal and spatial sampling, and profile depths at least down to 1000 m for selected areas. Hence, in 1990 the T-7 will be complemented by T-5 probes. The given selected examples of Fig. 3 verify this strategy. This programme is funded by the FRG Ministry of Science and Technology at least until 1991.

The measurements are carried out by the German container vessel "Köln Atlantic". Size and speed of this ship give rise to some problems concerning the data quality. Thus a more careful processing of the delayed mode data is necessary. This vessel is equipped with a SEAS II unit. Our experience with the automatically encoded and transmitted BATHY messages in case of noisy original (raw) data suggests further improvements of SEAS software. A proposal will be placed before the Third SOOP Meeting concerning a powerful and safe method (Sy, 1985) which could easily be implemented into the SEAS III software to solve a great part of this problem.

To distinguish between data errors and thermal fronts "Köln Atlantic" is equipped with an automatic seasurface thermometer which proves to be very helpful. A Pt100 is fastened to the inside of the ship's hull in a depth of about 6 m and is working as a contact thermometer. These thermometers proved to be reliable on our TRACKOB vessels since years.

The probe failure rate using "Deep Blue" probes only is about 15 %. The overall average satellite transmission failure rate is 18 % but decreased more or less continuously with time. The average rate of the last 6 months is about 10 %. While real-time data are inserted into GTS with a delay of less than 3 days in average the delayed mode data are processed more carefully and thus are much more time consuming. For details of XBT data processing as well as plots of the final data of line A9 it is referred to our data report (Sy and Ulrich, 1989) which will be continued on a yearly basis.

For two Dutch vessels ("Nedlloyd Kingston" and "Nedlloyd Kyoto"), sailing between Europe and the Caribbean (A8) and Europe and the coast of North-East South-America (A29), DHI collaborates with FNOC as a greeting agency in Hamburg. However, this service proved to be more and more difficult due to sudden and often unnoticed cancellations of Hamburg as port of call. Thus, it is suggested to find a greeting agency in the Netherlands, because Rotterdam is a regular port of call for these ships.

In the framework of WOCE two lines planned by IfM Kiel (A4 and the southwards shifted A5) became operational in the South Atlantic this year. Two vessels ("Tilly" and "Paul") with a more or less regular service between Santos/Buenos Aires - Cape Town - Matadi (Zaire) - Rio de Janeiro/Santos are carrying out XBT measurements along the transects between Africa and South America. In case of a service between Abidjan and Santos (A5) it is planned by IfM Kiel to manage this line too. The scientific objective (see Fig. 4) is:

1. to measure the annual and interannual variability of the upper ocean heat storage,
2. and to study the statistics of the eddy activity of the Subtropical Gyre.

This programme is funded by the FRG Ministry of Science and Technology at least for the next two years.

At present the operational status of the new lines in the South Atlantic is that of a testing phase to gain experience with new equipment manufactured by Nautilus Marine Service (FRG), and to solve logistical problems. According the scientific proposal for this programme the temporal and spatial resolution of the two lines should be 6 transects each year with 6 XBT drops per day. From 1990 on it is planned to put only T-5 probes to use. In co-operation with our group real-time data are transmitted via

METEOSAT to Hamburg to be inserted into GTS by DHI personnel. A first test concerning line A4 was carried out successfully last month (see Fig. 2).

Besides SOO observations on a regular service many of FRG research and fishing guard vessels carry out XBT measurements on the way to and in their area of operation, of course, depending on scientific programmes and availability of probes. These activities are very irregular, but they often occur in sparse covered areas. At a first glance, however, it appears that the increase of FRG SOOP is accompanied by a certain decrease of XBT measurements from research vessels. Nevertheless, as a first estimate a significant increase of XBT measurements can be expected during the next 4 to 5 years.

Finally, it is referred to "Recommendation 9" of the last meeting (IOC, 1987) concerning the establishment of the XBT Data Quality Study Task Team. This summer some experiments were carried out at sea and in the laboratory at DHI following the line of this Recommendation. The analysis is not yet finished, nevertheless, first results are available.

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Table 1: Summarized technical and organizational information about FRG XBT activities

	Europe-N.America	Europe-Brazil	E.Coast S.America-Capetown	Zaire-E.Coast S.America	Europe-Caribbean/ S.America
IGOSS #	A 9	A 6	A 4	(A 5)	A8/A29
WOCE #	AX3	AX11	AX17	(AX21)	AX5/AX20
Ship	"Köln Atlantic"	"Monte Rosa"	"Tilly" "Paul"	"Tilly" "Paul"	"N.Kingston" "N.Kyoto"
Callsign	DAKE	DGLM	H8CB HOQT	H8CB HOQT	PGDS PGDG
Programme	WOCE	IGOSS/TOGA	WOCE	WOCE	IGOSS
Start	5/1988	1981	5/1989	9/1989	1988
Finish	1994 ?	open	1994 ?	1994 ?	open
Frequency	12/yr	8/yr	6/yr	6/yr	irreg.
Density	12/d	2/d	6/d	6/d	2/d
Probes	T7/T5	T4	T7/T5	T7/T5	T4
Equipment	SEAS II/III Bathy	Strip	Nautilus PC, DCP	Nautilus PC, DCP	MK9, HP85/PC
Agency	DHI	DHI/FNOC	IfM Kiel	IfM Kiel	FNOC/DHI
Real-time	METEOSAT	Radio	METEOSAT	METEOSAT	Radio

Research vessels carrying out XBT measurements (irreg.):

Meteor	DBBH
Polarstern	DBLK
Gauss	DBBX
Poseidon	DBKV
Valdivia	DESI
Frithjof	DBFJ
Meerkatze	DBFM
Walther Herwig	DBFP
Sonne	DFCG

FRG XBT LINES

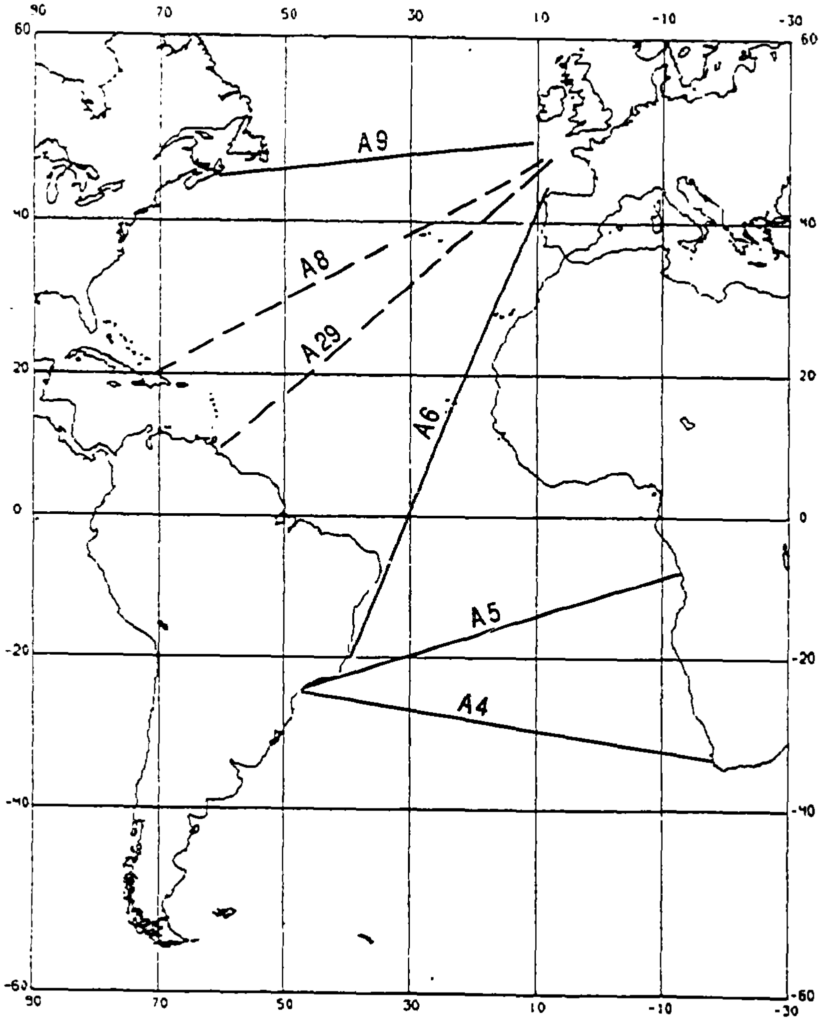
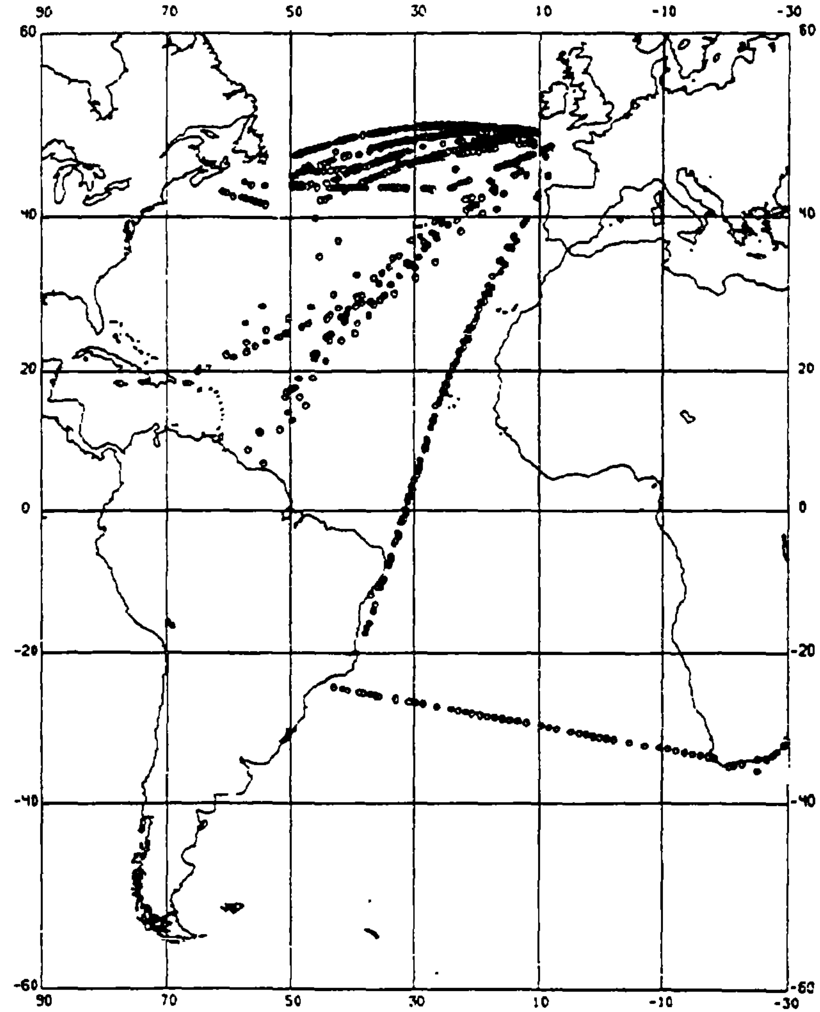


Fig. 1: The FRG XBT network 1989



DHI, H A M B U R G
GEOGRAPHICAL DISTRIBUTION OF OCEANOGRAPHIC OBSERVATIONS
FROM 01. JANUARY 1989 TO 05. OCTOBER 1989

Fig. 2

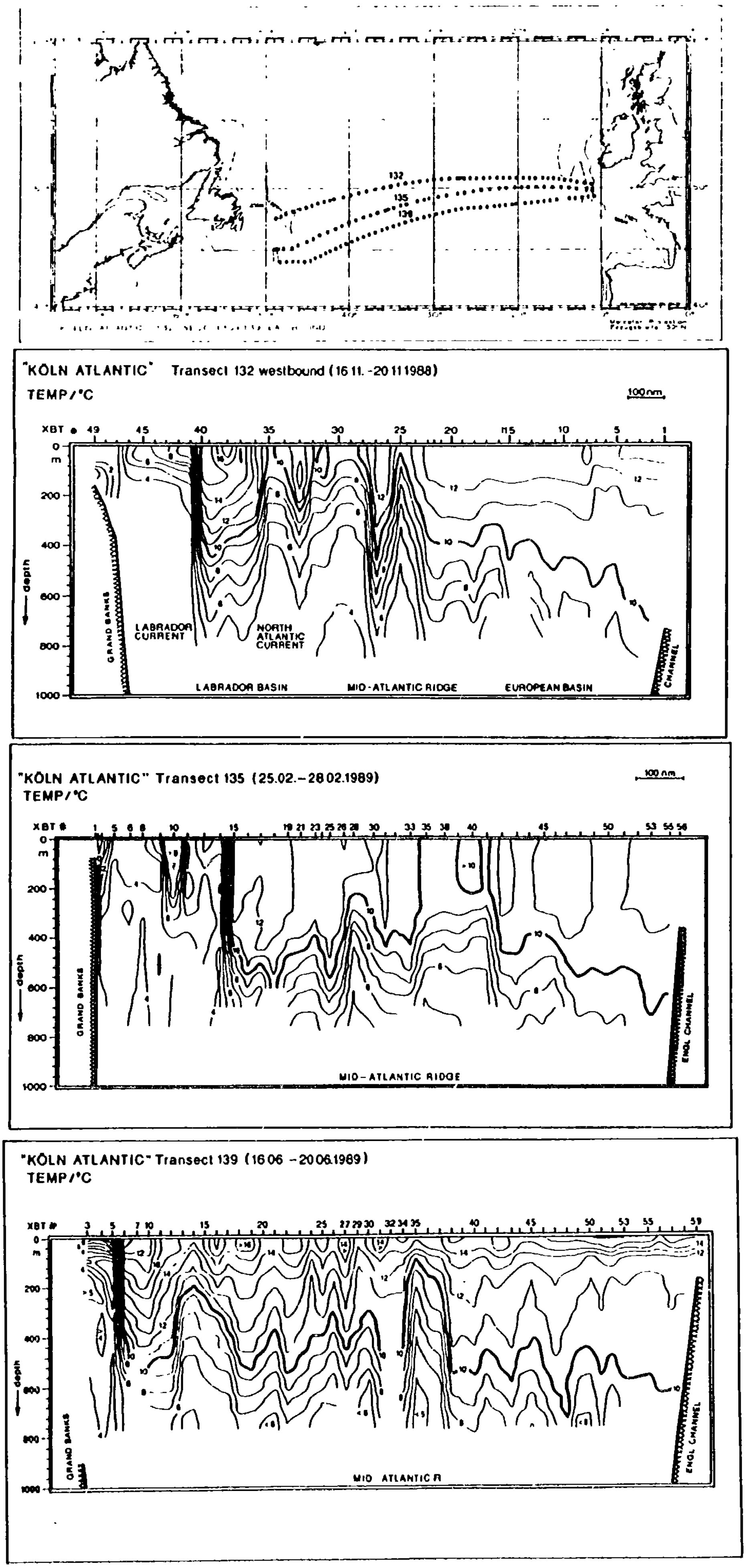


Fig. 3: Temperature sections line A7 of three seasons

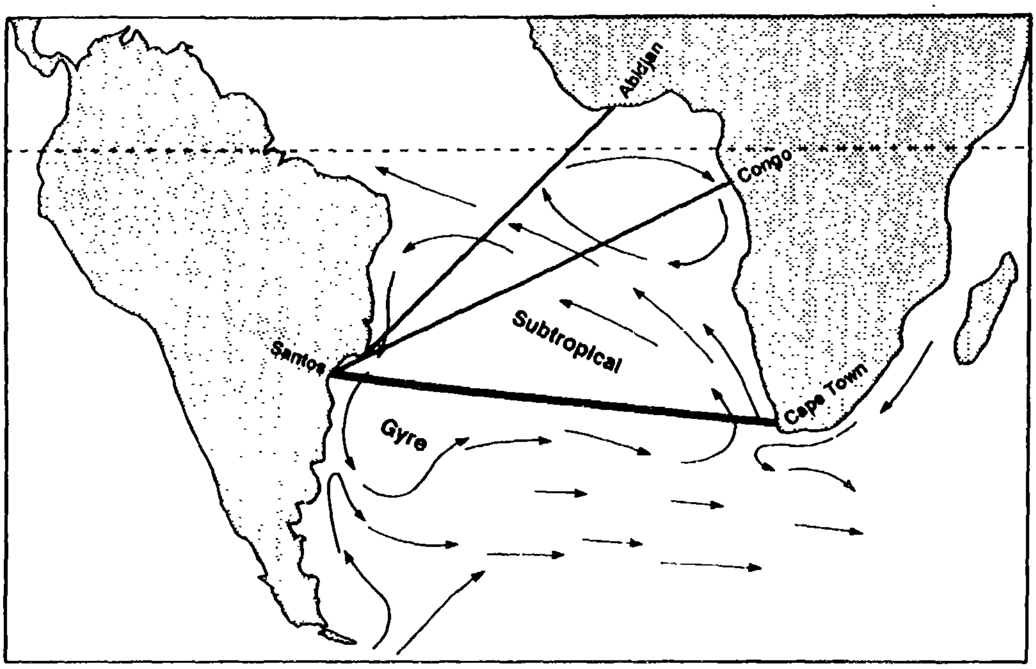


Fig. 4: The Subtropical Gyre and XBT activities in the South Atlantic

JAPAN

AUTOMATED SUB-SURFACE TEMPERATURE OBSERVATION / TRANSMISSION SYSTEM

M. Saiki, JMA

1. Introduction

Since the development and the prevalence of automated systems for the ship and the navigation permit the decrease of number of officers and crew of ship, it is becoming difficult to recruit voluntary ships year by year. And it is recognized that manual observations and data reporting are laborsome and error prone. Sufficient and reliable data provided by the automated system, which will require less time of ship's personel to take and transmit meteorological and oceanographic observation data, are vital to the oceanographic studies related to climate change. From these points of view, automated systems have been expected to be developed.

To realize such expectation, an Automated Subsurface Temperature Observation/Transmission System (ASTOS) has been introduced. This is one of the most automated and reliable systems. It will allow the voluntary observers to collect, store and transmit meteorological and oceanographic data in a more accurate and timely manner. This in turn will improve the real-time acquisition and processing of the data in the analysis centers.

2. System Description

2-1. General Description

This system is a fully automated equipment to add the function of automatic XBT observation to the SEAS (Shipboard Environmental data Acquisition System) which has been developed by the National Ocean Service, US NOAA. Fig.1 displays an outline of operation of the ASTOS and Fig.2 shows the data transmission network for the ASTOS. Subsurface temperature data on the ASTOS platform are automatically coded in BATHY message and transmitted to the Meteorological Satellite Center via the Geostationary Meteorological Satellite (GMS) and put into the Automated Data Editing and Switching System (ADESS) of the JMA. The data are distributed to foreign meteorological centers through the GTS. In the JMA, the data are processed with other BATHY/TESAC reports and domestically exchanged data, and several oceanographic products such as subsurface temperature charts are produced and disseminated via meteorological radio facsimille or by printed matter ("Ten-Day Marine Report"), operationally.

The ASTOS consists of the following components:

- Automatic XBT launcher
- XBT controller
- System controller
- Microcomputer
- GMS transmitter
- Satellite navigation system
- Uninteruptible power supply unit

Fig.3 shows the ASTOS shipboard data collection network.

2-2. Functional Description

2-2-1. Automatic XBT launcher

The automatic XBT launcher can be chambered with 8 XBT probes, and can drop them automatically. Both probe types of T-6 (460m) and T-7 (750m) can be applicable. The overview of the launcher is shown in Fig.4. The mechanism of launching XBT probes one by one is similar to that of a revolver. This automatic launcher weighs about 80 kg. The length (1.3m) and tilt angle (45' from the horizontal place) of the launch tube are designed to ensure the drop of probes with enough separation from the hull of the ship.

2-2-2. XBT controller

The XBT controller has functions to receive a signal for launching XBT probes from the system controller and to select probe types. The front panel of the XBT controller displays the house keeping information of the automatic XBT launcher.

2-2-3. System controller

The system controller has a real time clock and function to command the drop of a probe. This controller amplifies the signal from XBT probe and inputs it into the A/D converter to sample subsurface temperature data every 50cm drop. This has a RAM for data from 8 XBT probes and transmits the data to the microcomputer. Observation intervals are able to be selected from 10 minutes to 24 hours every 1 minute increment.

2-2-4. Microcomputer

The NEC PC-9801 VX21 (16 bits machine) is used to compile automatically XBT data into properly formulated BATHY messages. The PC-9801 has two diskette drive units and 560K RAM. It is equipped with a color display and a dot matrix printer. Temperature vs. depth plots are given on the color display on a real-time basis.

2-2-5. GMS transmitter

This system consists of the following components.

- Master Control Module
- GMS Transmitter Module
- Antenna

The GMS Transmitter Module interfaces with the Master Control Module and has the buffer memories to acommodate a BATHY message, a SHIP message and another message such as a TRACKOB message independently. Each buffer memory can be initialized with a specific channel number, platform identification number and transmission schedule to allow independent self-timed reporting of formatted messages. Each buffer is able to handle a report up 649 characters.

2-2-6. Satellite navigation system

The Navy Navigation Satellite System (NNSS) is introduced for positioning in the ASTOS. This is designed to automatically provide the microcomputer with the position of the observation. The NNSS consists of a satellite signal antenna and a console. This system is also able to provide set-and-drift current data for preparing TRACKOB messages.

3. Software Description

3-1. General Description

The ASTOS Programme consists of a main menu with various sub-menus designed to allow entry of oceanographic and meteorological data for construction of BATHY and SHIP messages. The following command files are located on the ASTOS Programme disk:

1. Initialization of the system controller
2. Initialization of the GMS transmitter
3. Monitoring of the GMS transmitter
4. Read BATHY data from the system controller
5. Input SHIP data
6. Input other message data
7. Usage for a hand-held launcher
8. Delete disk data
9. Input location of the ship

3-2. Software to code a BATHY message

The ASTOS system controller collects subsurface temperature data every 50 cm depth. Based on these data, BATHY is prepared by the algorithm of which a flow chart is shown in Fig.5.

4. Operation of the ASTOS

The ASTOS is in operation on board the container ship "Wellington Maru" (Mitsui O.S.K. Lines) in 1989 on the route between Japan and New Zealand. The automatic launcher is settled on the starboard life-boat deck 20m above the sea surface. The other equipments are located in the navigation bridge.

Fig.6 shows a subsurface temperature profile in the western equatorial Pacific obtained by the ASTOS. Black circles in the profile denote the significant points for the BATHY message. Fig.7 demonstrates the locations of the observation station conducted every 4 hours by M/V Wellington Maru in August and September 1989. About 600 XBT probes will be prepared for the ASTOS every year from 1989 through 1991.

The XBT probe may sometimes fail to make an accurate temperature versus depth profile, when the wire of the probe touchs the ship after launching. The rate of such malfunction is estimated to be less than a few percents. This rate is very small as compared with the false rate of hand-held launching. Consequently, the ASTOS is useful to obtain subsurface temperature data on board a merchant vessel.

Acknowledgements

The present work was financially supported by the Science and Technology Agency as part of Japanese Pacific Climate Study Programme (JAPACS). The author is indebted to the officers and crew aboard M/V Wellington Maru for their cooperation during the field operation.

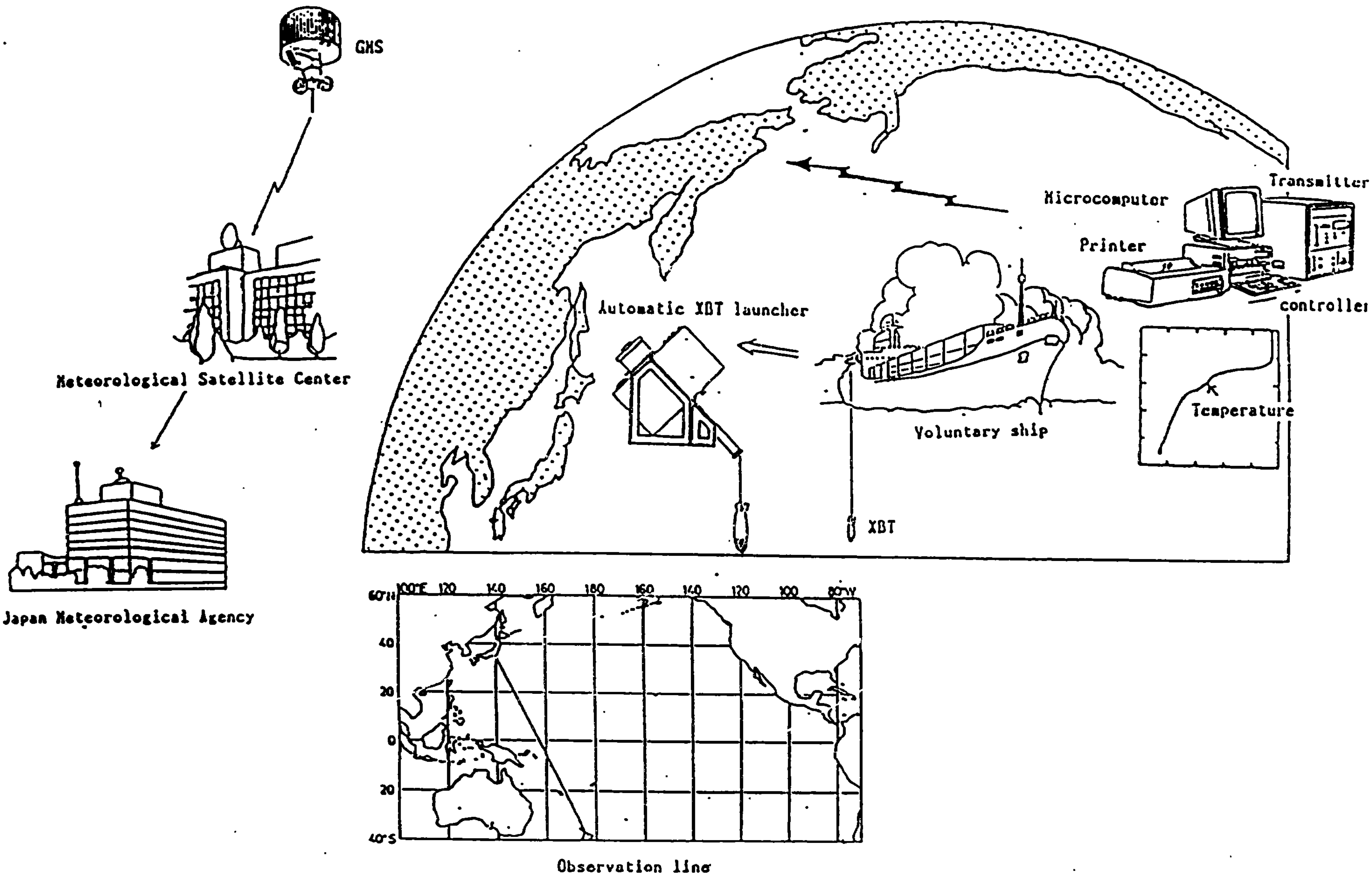


Fig.1 Outline of operation of the ASTOS.

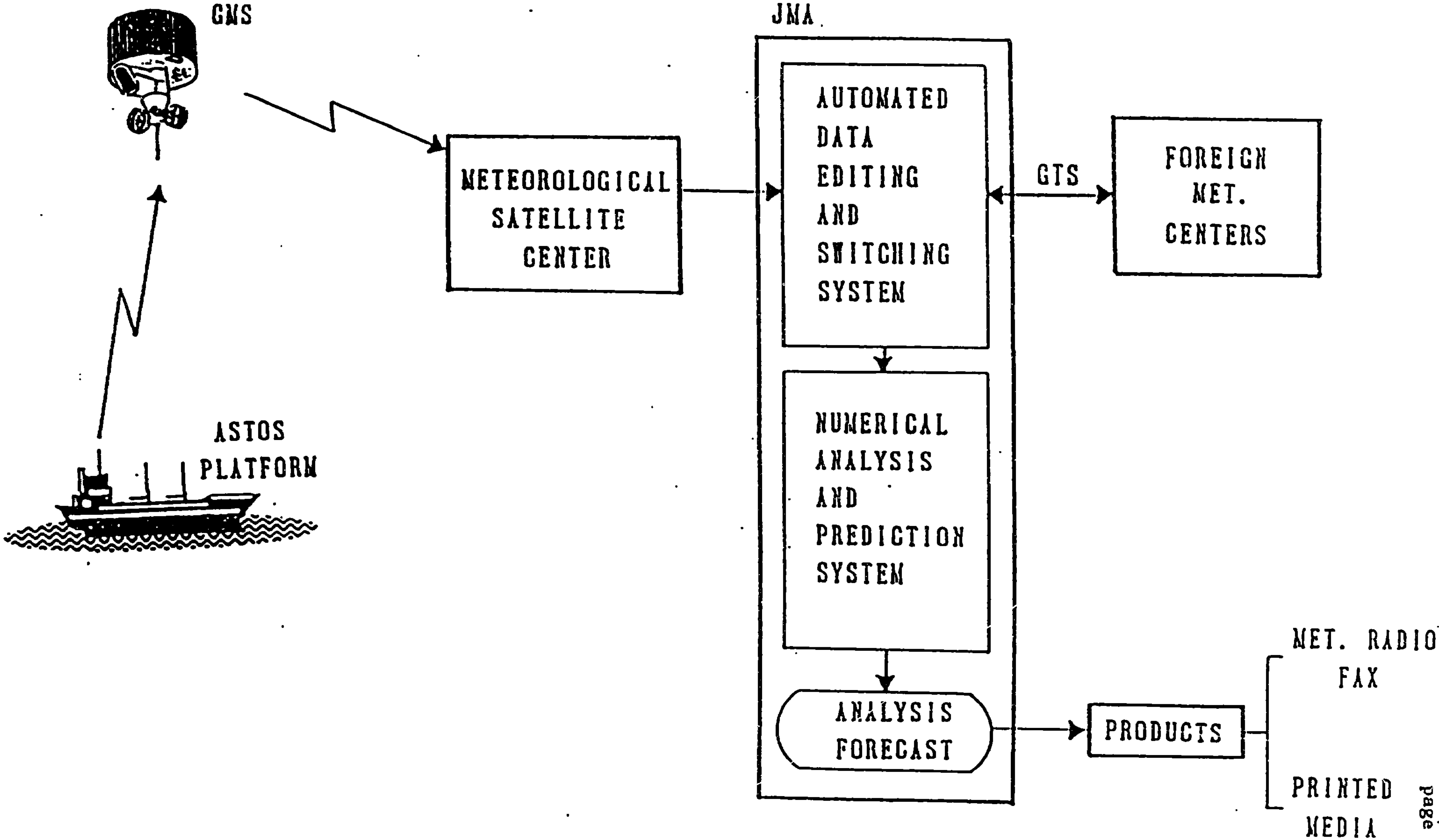


Fig.2 Data transmission network for the ASTOS.

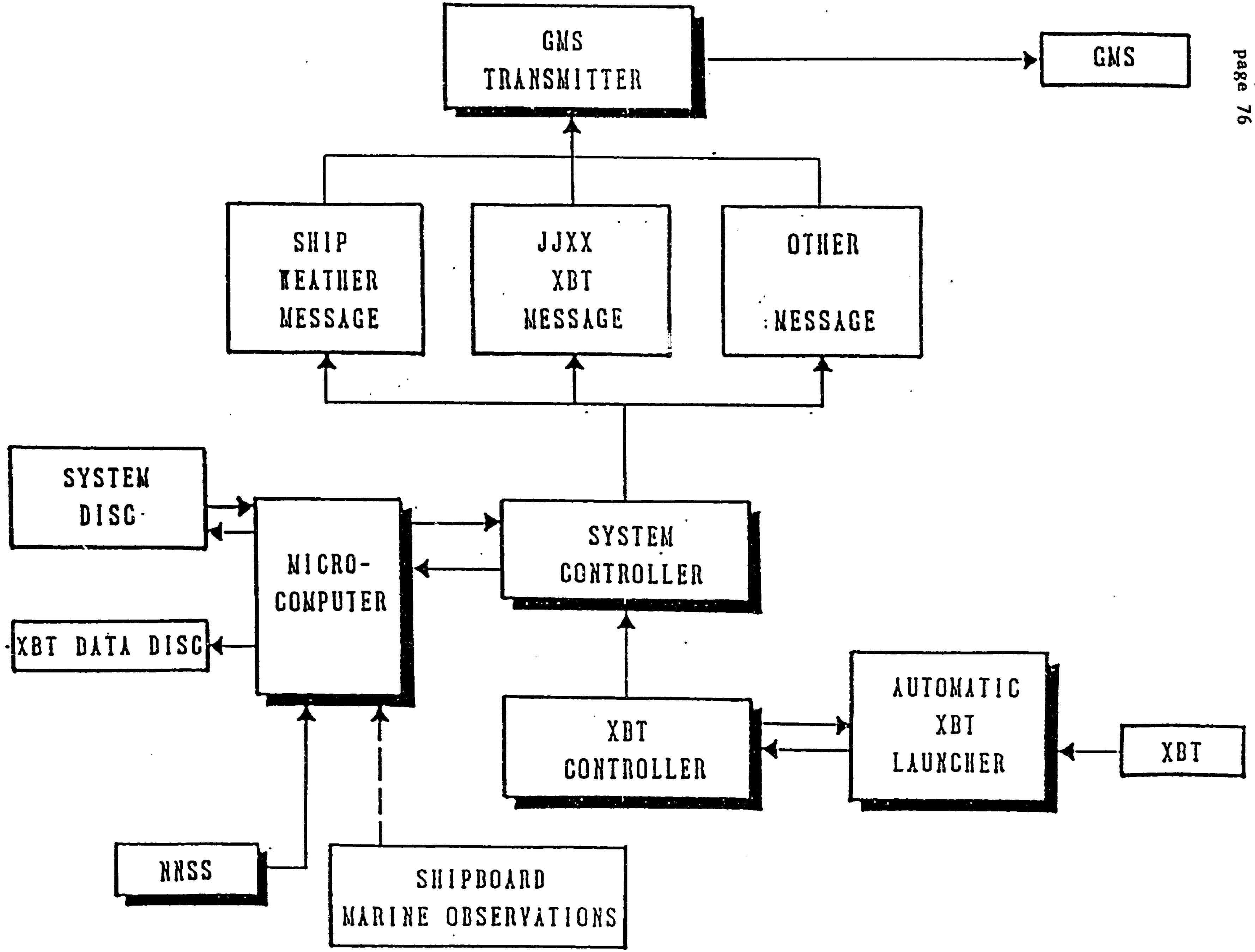


Fig.3 The ASTOS shipboard data collection network.

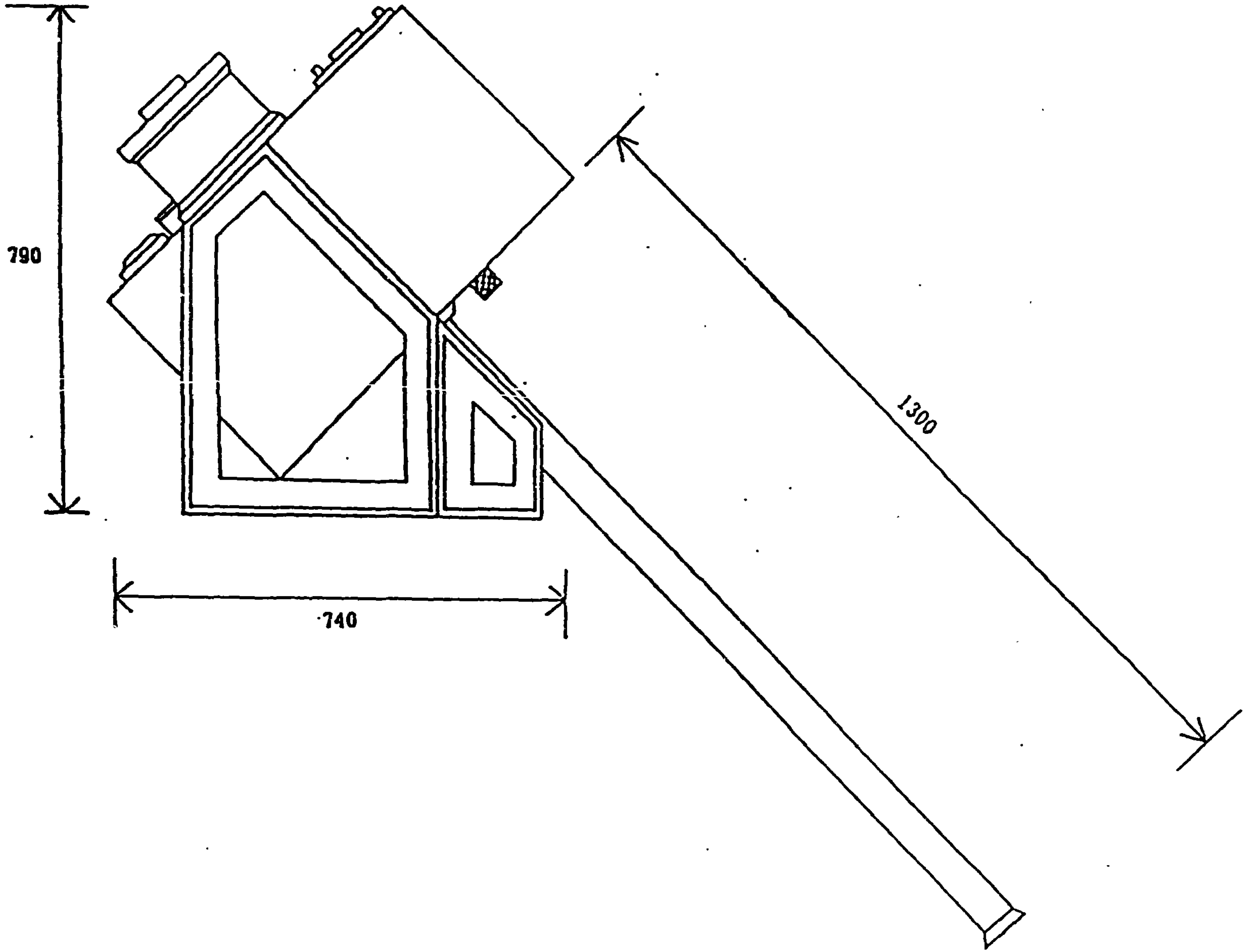
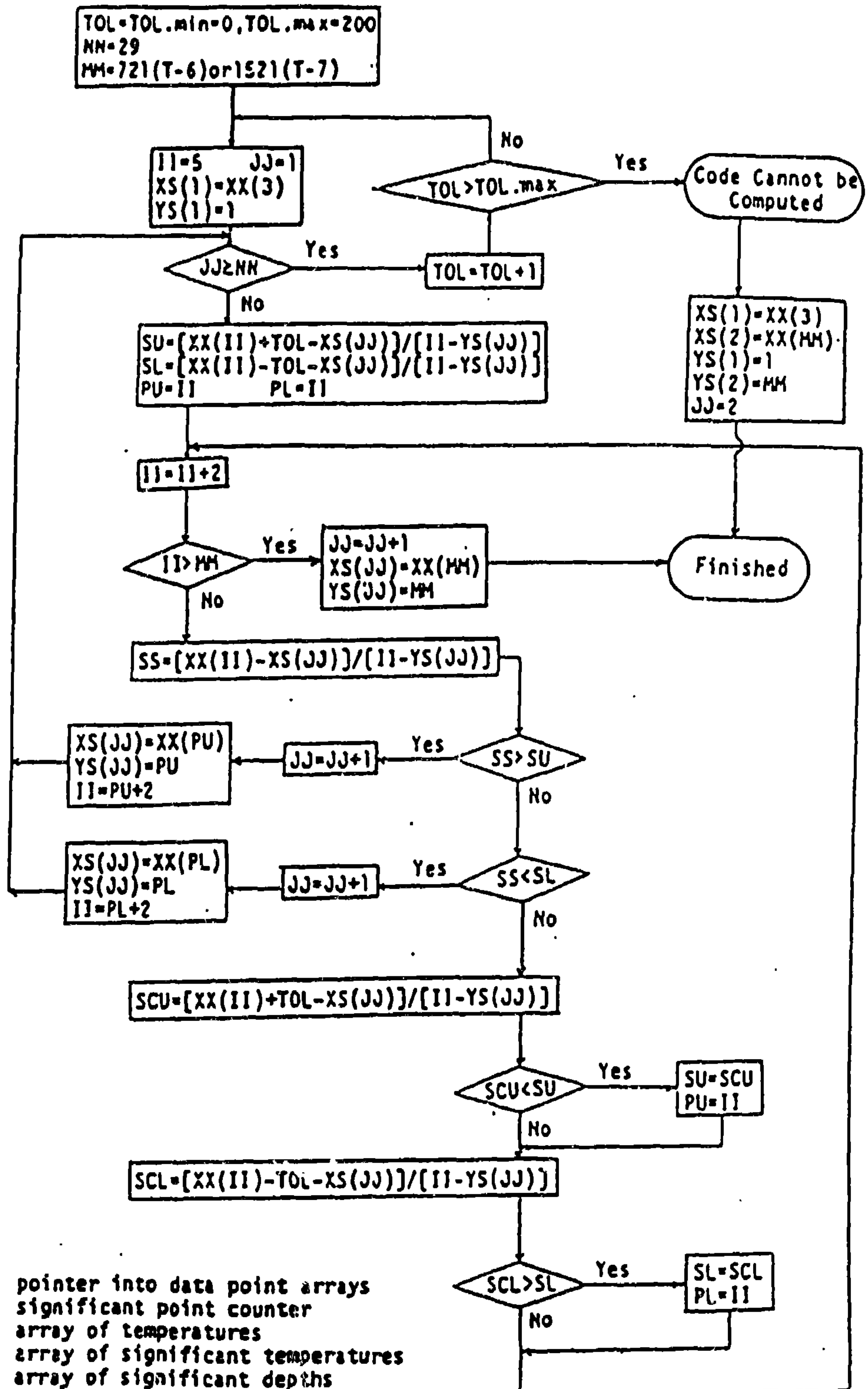


Fig.4 Overview of the automatic XBT launcher. (Numerals denote length in mm)

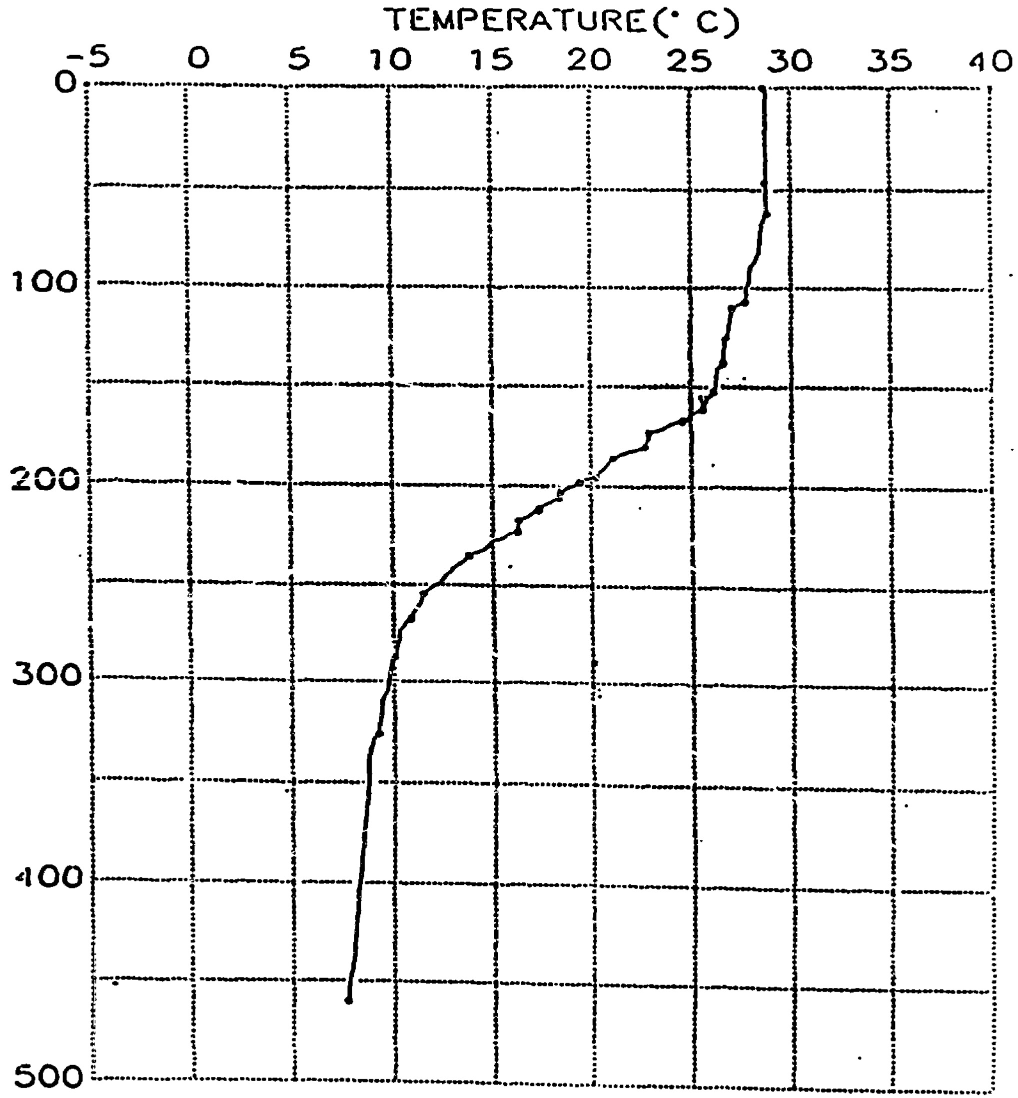


II	pointer into data point arrays
JJ	significant point counter
XX	array of temperatures
XS	array of significant temperatures
YS	array of significant depths
SU	upper slope
PU	pointer to data determining upper slope
SL	lower slope
PL	pointer to data determining lower slope
SS	slope of current point
SCU	upper slope of current point
SCL	lower slope of current point
TOL	deviation allowed
TOL.min	minimum deviation allowed (= 0)
TOL.max	maximum deviation allowed (=200)
NN	maximum number of significant points allowed (=29)
MM	number of data points (=721(T-6)or1521(T-7))

Fig.5 A flow chart of the algorithm for preparing a BATHY message.

<< WELLINGTON-MARU X-BT RECORD >>

0	28.56
1	28.79
2	28.83
3	28.79
4	28.79
5	28.79
10	28.79
20	28.79
30	28.79
50	28.79
75	28.45
100	27.82
125	26.75
150	26.24
200	19.15
250	12.16
300	9.75
350	8.75
400	8.32
450	7.81
460	7.70



FILE NO.29
DATE 89/06/03
TIME 13:00
LAT 03° 00'S
LON 159° 05'E
MLD 100.5M
T100 28.59
T200 26.78
T400 18.86

Fig.6 An example of subsurface temperature profile obtained by the ASTOS.
(June 3, 1989; 1° 00' S, 159° 05' E; Black circles:significant points)

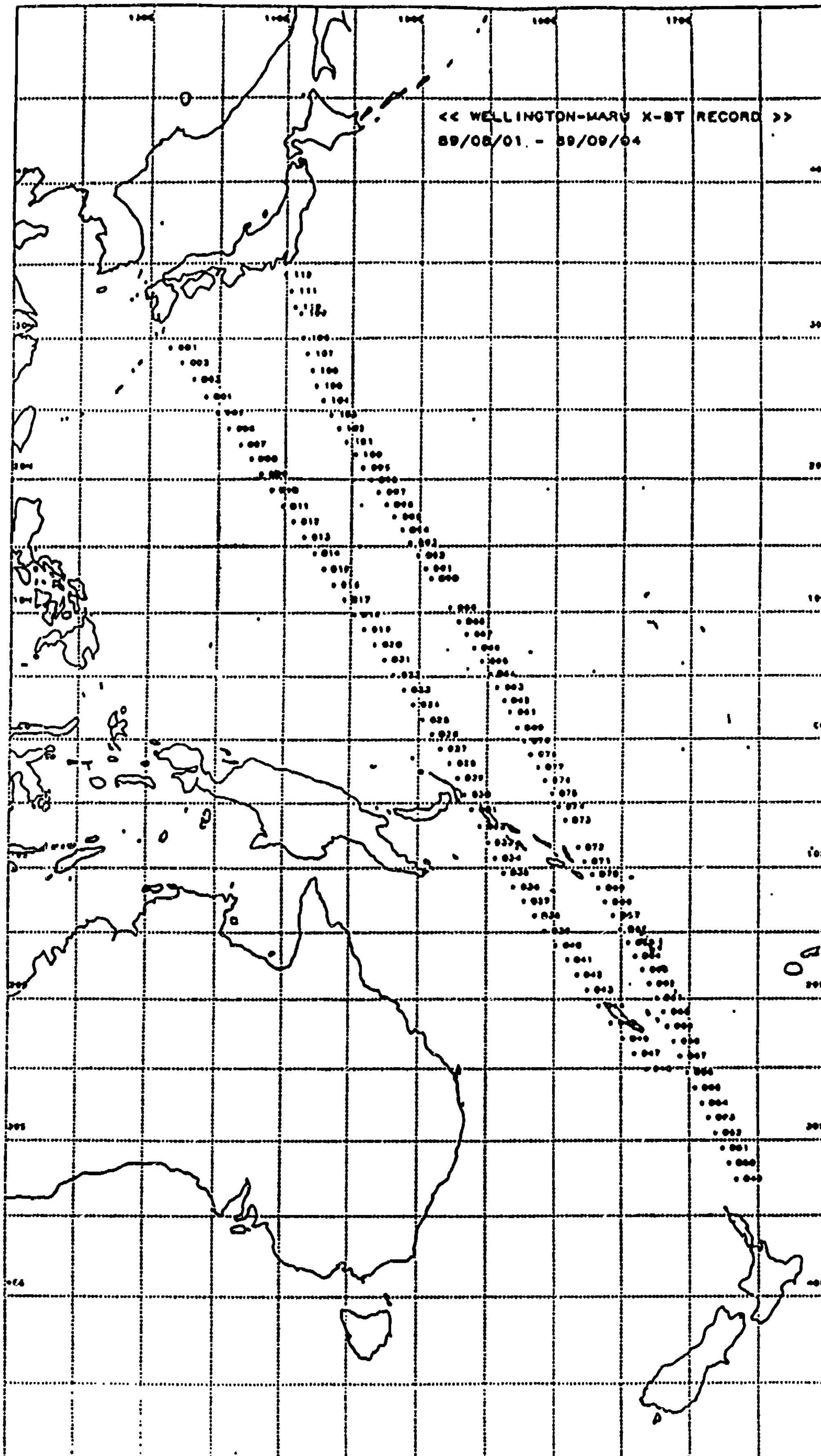


Fig.7 Observation stations occupied by M/V Wellington Maru.
(August 1 - September 4, 1989)

UNITED KINGDOM

The UK Hydrographic Department presently supports 2 full-time Ships-of-Opportunity: the OWS CUMULUS (occupying Ocean Weather Station LIMA) and the M/V POLAR NANOQ (trading operations centred on the Norwegian Sea).

Both ships have recently been fitted with DCPs and arrangements made for bathy messages to be entered on the GTS via Meteosat and the Meteorological office at Bracknell.

"Setting to Work" DCP trials in OWS CUMULUS have identified a number of problems and these will need to be resolved before the second DCP is activated. It is hoped that both ships will be fully operational by January 1990.

In addition to the support provided to the above ships, the Hydrographic Department occasionally supplies XBT T 7 probes to UK Research Ships. At present these Ships transmit their XBT messages by radio but plans are in hand to provide the UK Scientific community with one complete XBT/DCP system which would be maintained by Research Vessel Services (RVS) and moved from ship to ship to ensure maximum usage in areas of high interest.

Regarding further expansion of the UK Ship-of-Opportunity programme, it is hoped to install XBT/DCP equipment in 2 Iceland-based vessels (M/V SELFOSS & M/V BRÚFOSS) both of which operate in the NE Atlantic.

UNION OF SOVIET SOCIALIST REPUBLICS

USSR SOUTHERN OCEAN ACTIVITY REPORT

Every year, 7 to 8 soviet vessels conduct research programmes in conjunction with support operations for Soviet antarctic bases. Of these eight vessels, at least 3 to 4 vessels regularly conduct observations with mechanical bathythermographs and CTD's in support of the Soviet "Southern Ocean" and the new FRG-USA-USSR "AnZone" research projects.

All oceanographic data are transmitted in real time using IGOSS formats BATHY and TESAC.

All three major scientific objectives of the WOCE VOS programs are fully applicable in the Southern Ocean region. Therefore, the role of the Southern Ocean in the world climate system is important and it is important to develop an IGOSS observing system in the Southern Ocean. At the same time there are individual features in the Southern Ocean that limit research activity:

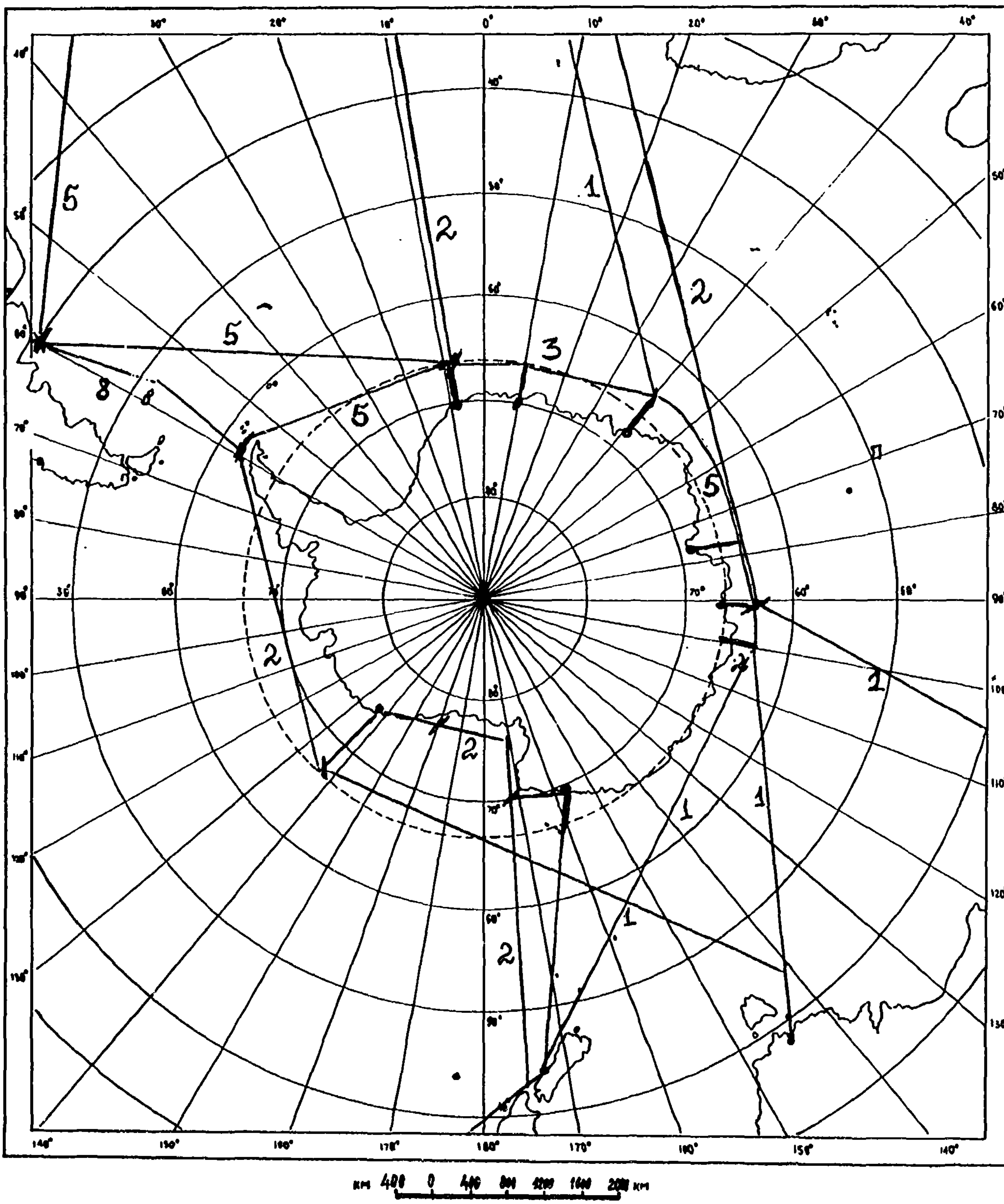
- the seasonality (summer period) of antarctic base resupply operations;

- the variability of the position of the ice boundary and the ice conditions inside the ice boundary;

- the poor weather conditions.

The above reasons prevent the use of the same ship tracks every year. In spite of this, it can be seen from the figure showing USSR Southern Ocean activity for austral summer period (december - april) 1988-89, that some of the lines were repeated from 2 to 8 times. Unfortunately, use of mechanical bathythermographs is severely limited by ice inside the ice boundry. This limitation could be overcome through the use of XBT equipment.

Tracks of USSR vessels in Southern Ocean
Austral summer period December 1988 - April 1989



3 — track position and number of repetitions

UNITED STATES OF AMERICA

A - SCRIPPS INSTITUTION OF OCEANOGRAPHY

Scripps Institution of Oceanography has been operating a scientifically oriented, volunteer observing ship programme since 1975. Historically, the programme has involved an overage of 26 ships but this number has declined in recent years because of a lack of shipboard equipment.

The attached figure shows the positions of bathy messages received from Scripps' ships during the period January - June, 1989. As evident from the figure, Scripps' ships and XBT sampling have been chosen to monitor primarily the large variability of the North and Tropical Pacific. ALL of Scripps' ships are volunteer, merchant vessels which operate on regularly repeated sections throughout the year.

At the bottom of the figure is a list of the ships reporting during January - June 1989 and the individual totals of BATHY messages received from those ships. The total number of good temperature traces produced during this 6 month period was about 2,600. Therefore, the success rate in moving good data from the ships to the BATHY message data base ashore was only about 71%. The rest of the BATHY messages were either not produced or were lost in the very complicated telecommunications processes involved. A major loss of BATHY messages transmitted by the SEAS-equipped ships apparently occurred in the Western Pacific because message data received by the Japanese GMS were not transferred to the GTS.

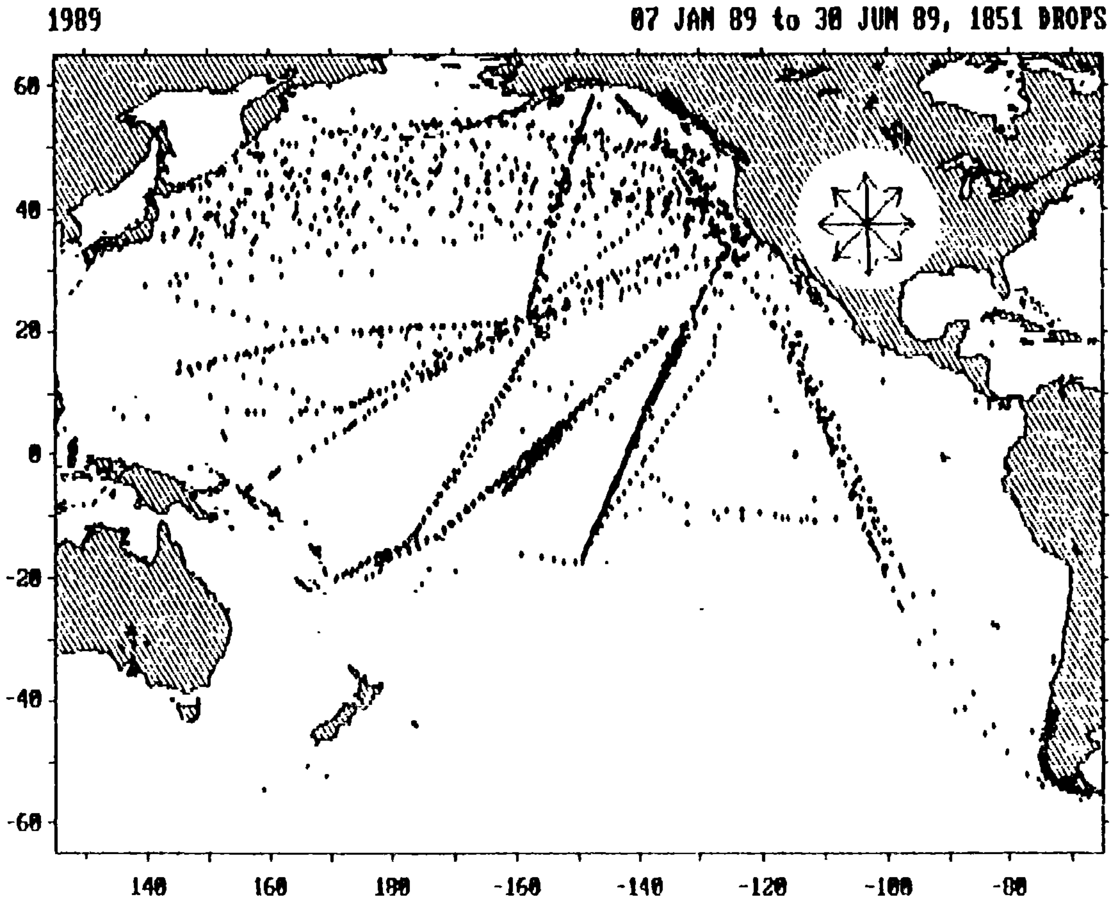
During the period January - June, 1989, SCRIPPS VOS programme loaded 3,344 XBT probes aboard their ships. If this number of probes was expended during this same time period) and the numbers do correspond exactly) this would indicate that about 78% of all probes used resulted in good data traces. An average probe failure rate of approximately 22% is consistent with failure rates determined from other data, but the failure rates for individual ships in different months can vary from as low as 0% to over 50%.

Scripps has developed a computerized data base system for keeping track of volunteer ships by monitoring their BATHY message traffic. Through Scripps own dial-up electronic bulletin board, up to date information is available to field personnel immediately before they visit a ship during a port call.

In addition to dropping XBTs, Scripps volunteer ships make meteorological observations and deploy satellite-tracked drifting buoys.

Scripps also develops specialized instrumentation for the volunteer ships. Among these items are a relatively inexpensive automatic launcher and an acoustic doppler current profiler (ADCP) for use, in "piggy-back" fashion, with existing commercial doppler speed logs already on board.

Scripps' Volunteer Observing Ship Programme is supported by NOAA (National Ocean Service), Fleet Numerical Oceanography Center and the National Science Foundation. Several of the volunteer ships listed on the figure are operated in close cooperation with ORSTOM Noumea.



BATHY MESSAGES RECEIVED IN REAL TIME FROM SIO VOLUNTEER SHIPS

JANUARY - JUNE 1989

3EAB7	CALIFORNIA ZEUSS	45
3EZG5	HIKAWA II	49
3FHI2	MOANA PACIFIC	190
7JOB	SHIN KASHU MARU	120
D5ND	SANTA LUCIA	16
D5NE	MT. CABRITE	107
D5NZ	POLYNESIA	204
DHJW	ACT 9	193
ELDM8	SEAL ISLAND	91
H9BQ	MICRONESIAN INDEPENDENCE	110
HPAN	MICRONESIAN COMMERCE	39
JBRR	JAPAN TUNA II	48
JCDT	AMERICA MARU	35
JCIN	TOKYO MARU	82
JJZC	HAKONE MARU	49
KIRH	SEALAND TRADER	50
KRGB	SEALAND ENTERPRISE	58
OWEQ2	MCKINNEY MAERSK	28
OXFB2	LEXA MAERSK	12
OXMD2	LARS MAERSK	29
P3EU	WILHELM SCHULTE	112
WCGN	CHEVRON CALIFORNIA	74
WXBR	CHEVRON MISSISSIPPI	110

	TOTAL	1851

B - NATIONAL OCEAN SERVICE - VOLUNTEER OBSERVING SHIP PROGRAM

The National Ocean Service (NOS) in cooperation with other Line Offices within the National Oceanic Atmospheric Administration (NOAA) manages and coordinates a Volunteer Observing Ship Program (VOS). The NOS contribution to this VOS network is 120 vessels equipped with Shipboard Environmental data Acquisition Systems (SEAS). The NOS-VOS program also supports and cooperates with other government agencies, other governments, and university VOS programs.

The NOS has provided SEAS installations to 120 vessels. A hundred of these vessels were equipped with the capability to collect and transmit expendable bathythermograph (XBT) and meteorological observations in real-time. The remaining vessels are equipped with meteorological capability only. SEAS data are transmitted via the GOES satellite system in real-time, quality controlled at the Ocean Products Center (OPC), located at the National Meteorological Center (NMC) in Campsprings Maryland, and then inserted on the GTS. Since January 1986 through August 1989, 39,240 XBT's have been collected by SEAS and inserted on the GTS. Of these observations, 5,978 of them were collected from January to August 1989. Figure 1 shows the distribution of the real-time XBT observations from 1986 to August 1989. The goal of the NOS-VOS program is to provide accurate and timely delivery of sea surface meteorological and sub-surface oceanographic observations from the worlds oceans. In addition to providing SEAS units, NOS provides funding, probes, logistic support to other VOS programs. The NOAA VOS XBT probe contribution to the VOS community, managed by NOS, was responsible for the distribution of 13,585 probes in FY 1988 and 16,876 probes in FY 1989, as shown in figure 2.

In addition to the continued NOAA support of the international XBT VOS effort, in FY 1990, the NOAA-VOS program plans to implement additional lines in the Atlantic in support of the Global Change Program. The NOS will also coordinate an investigation into the accuracy of the XBT depth equation which has come under scrutiny within the community. In May 1989, at the TOGA AD Hoc Panel of XBT Experts meeting in Noumea, New Caledonia, the NOS Office of Ocean Services agreed to take the lead in organizing a community wide effort to accurately assess the problem, determine its potential impact and develop suitable recommendations for its resolution.

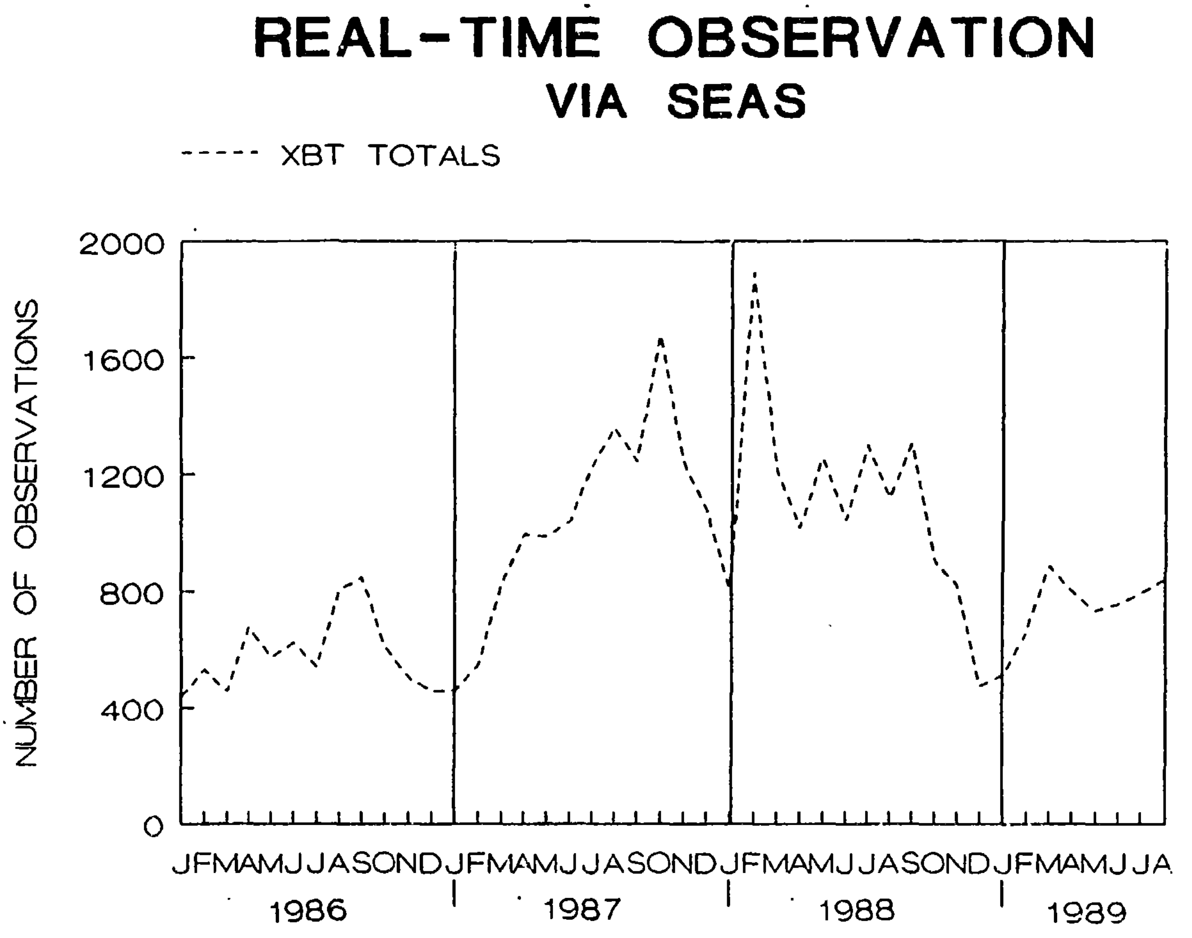
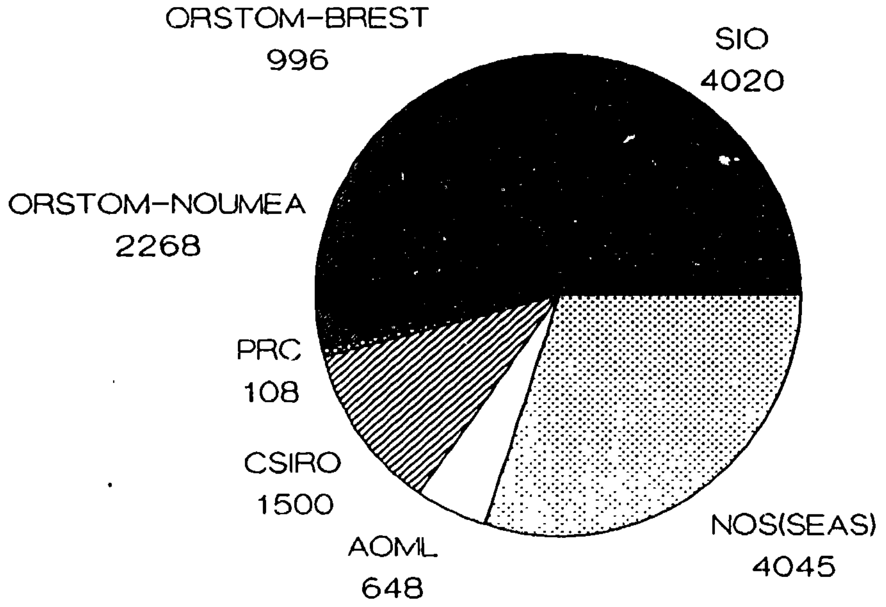

REAL-TIME OBSERVATION
VIA SEAS
----- XBT TOTALS
NUMBER OF OBSERVATIONS
2000
1600
1200
800
400
0
JFMAMJJASONDJFMAMJJASONDJFMAMJJASONDJFMAMJJA
1986
1987
1988
1989

Figure 1

FY-88 XBT PROBE DISTRIBUTION (13,585)



FY-89 XBT PROBE DISTRIBUTION (16,876)

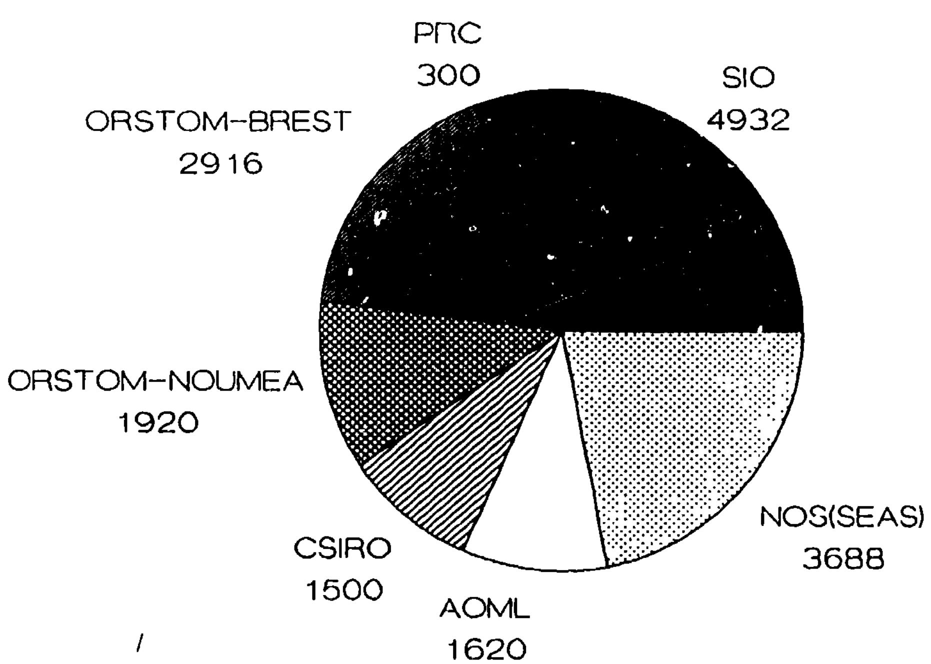
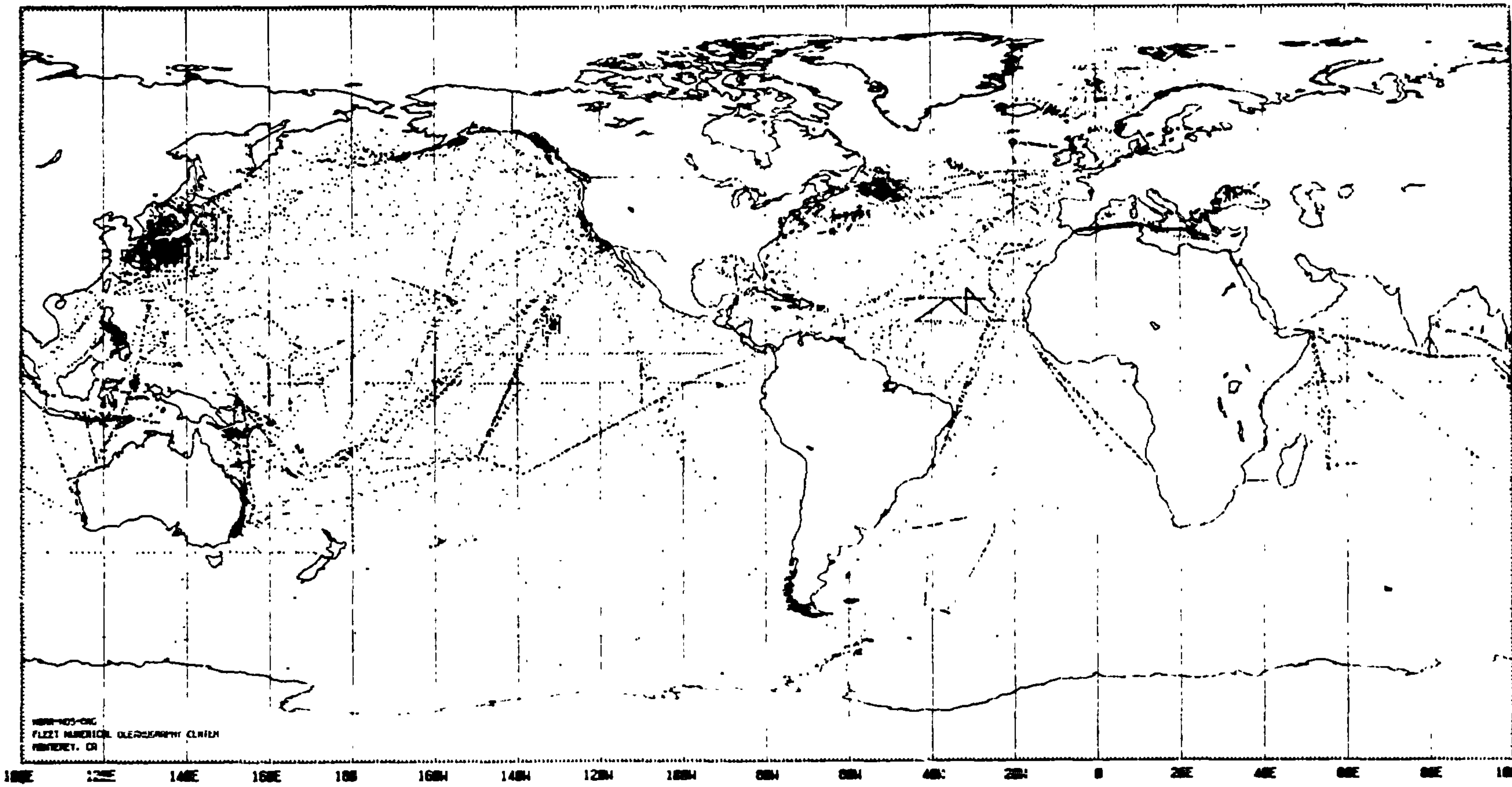


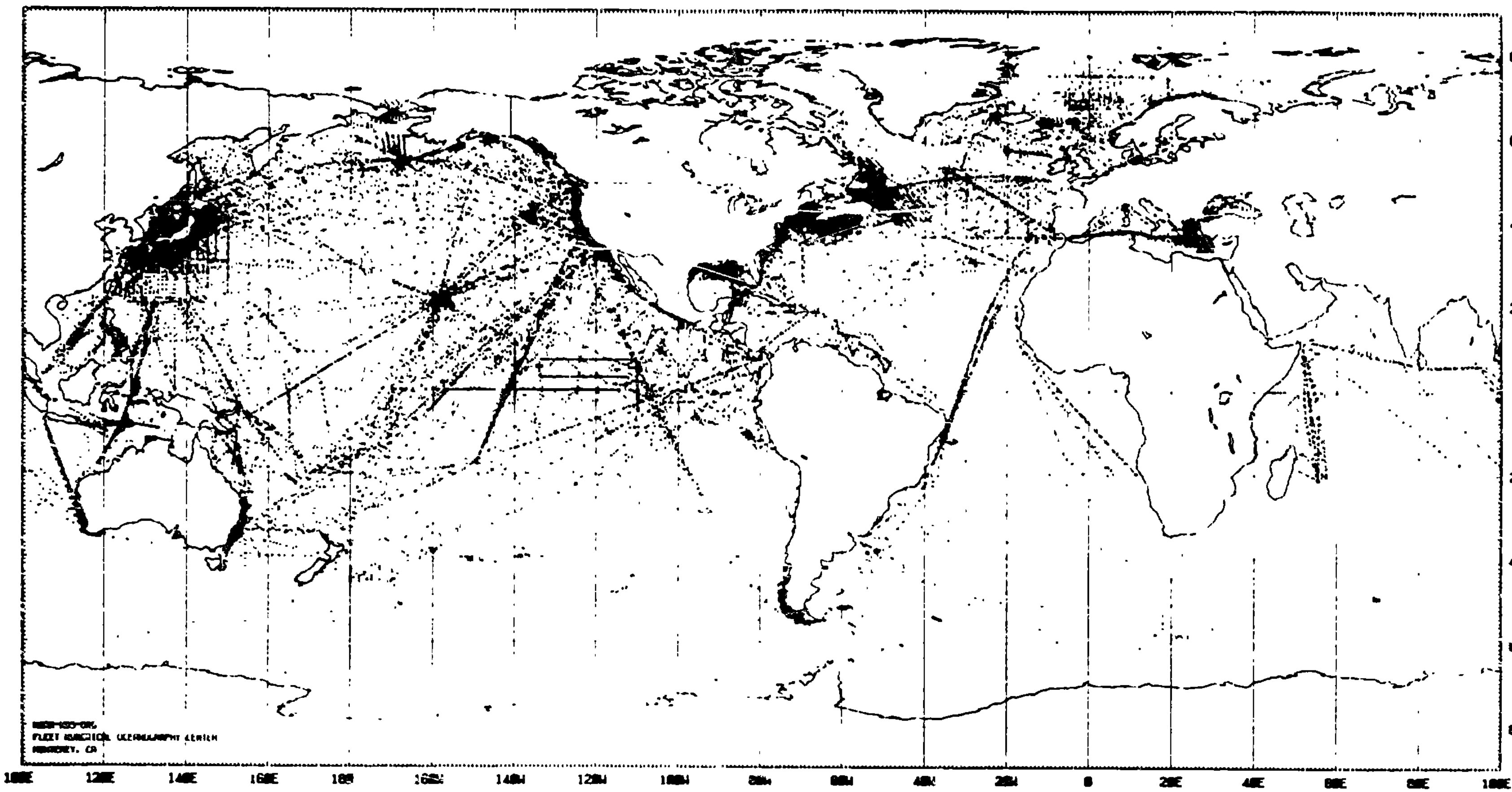
Figure 2

LOCATION



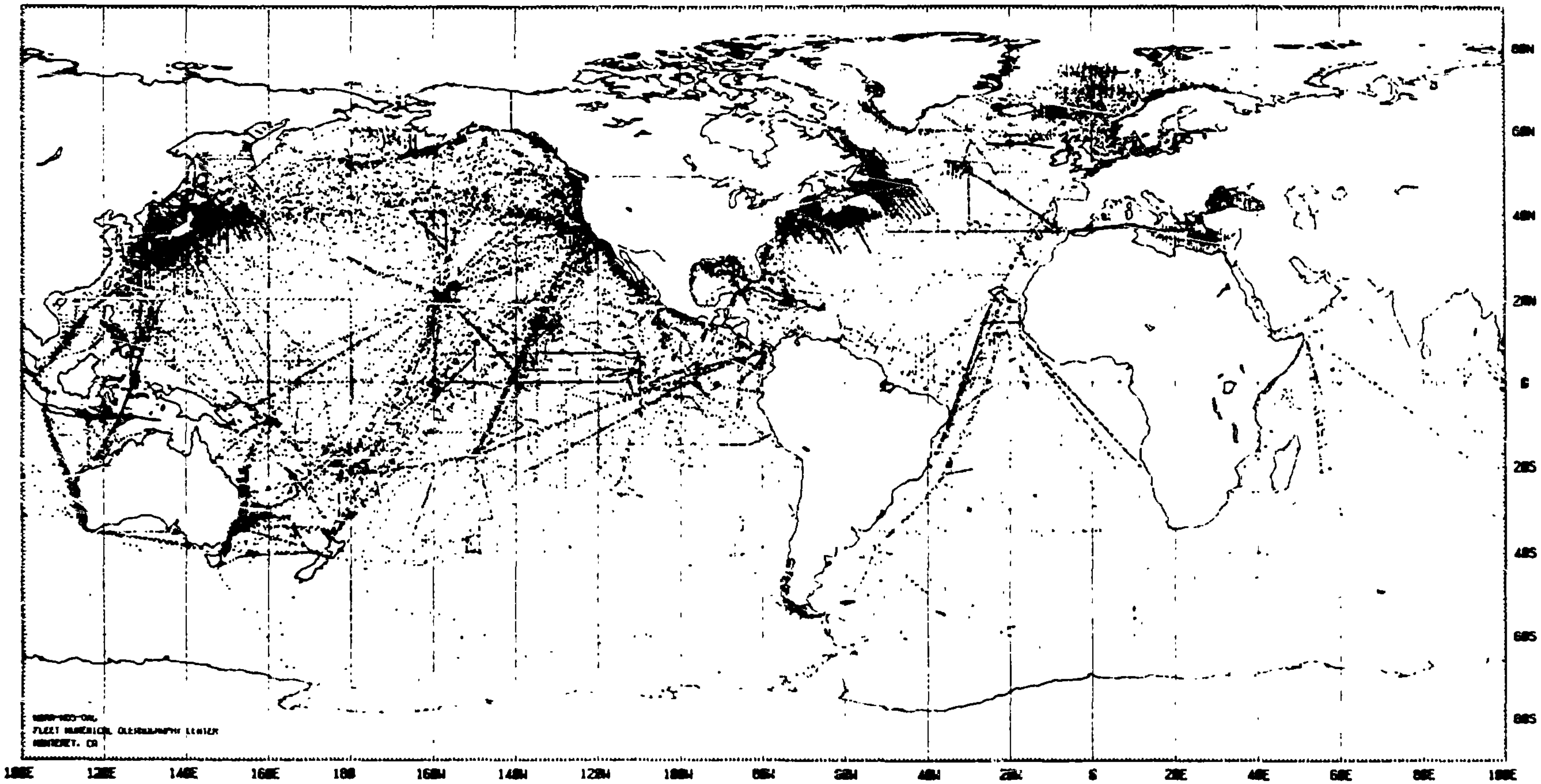
14370 MOODS PROFILES 89010100Z TO 8906[illegible]022Z

LOCATIONS



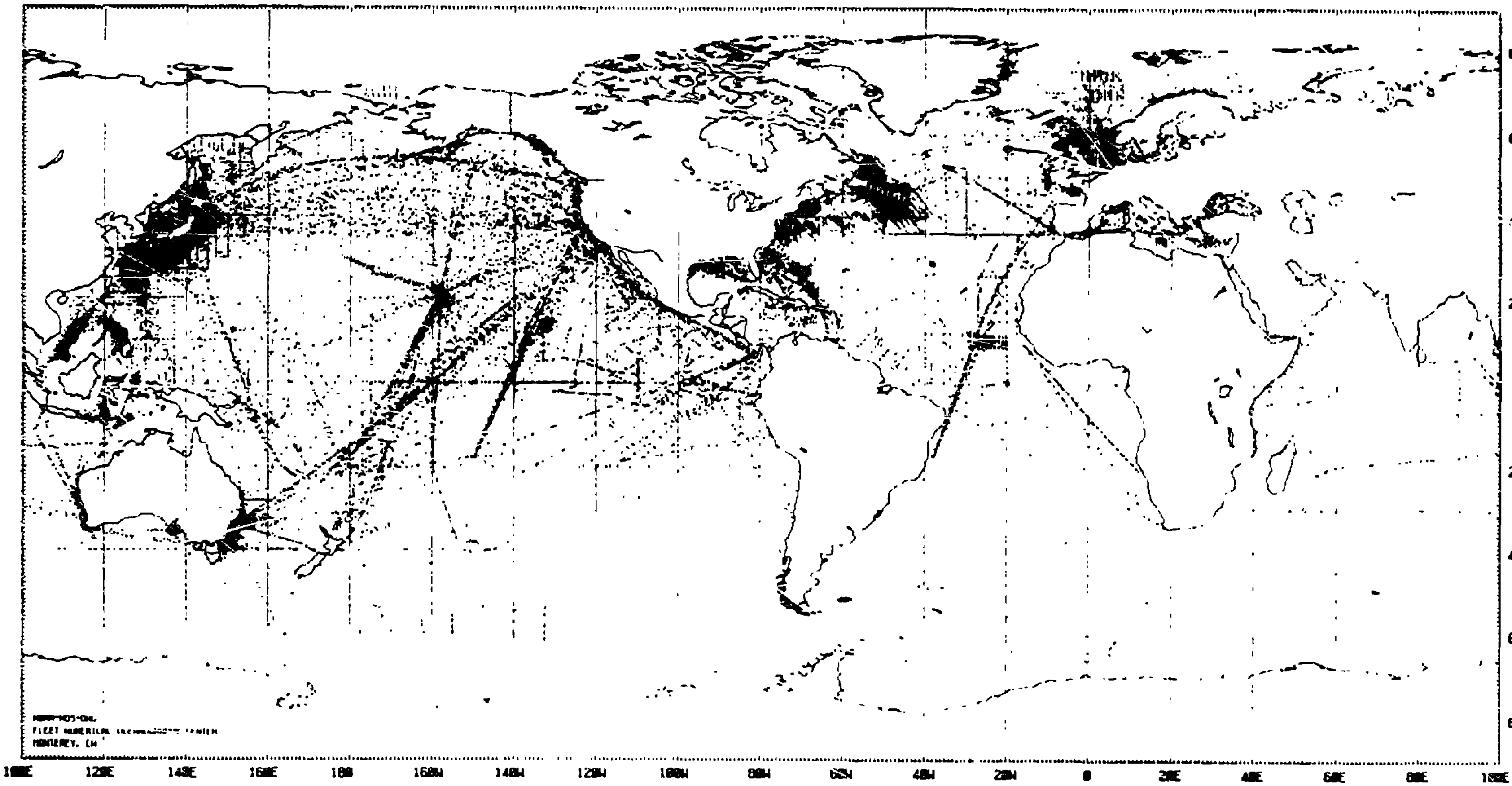
36893 MOODS PROFILES 88010100Z TO 88123123Z

LOCATION.



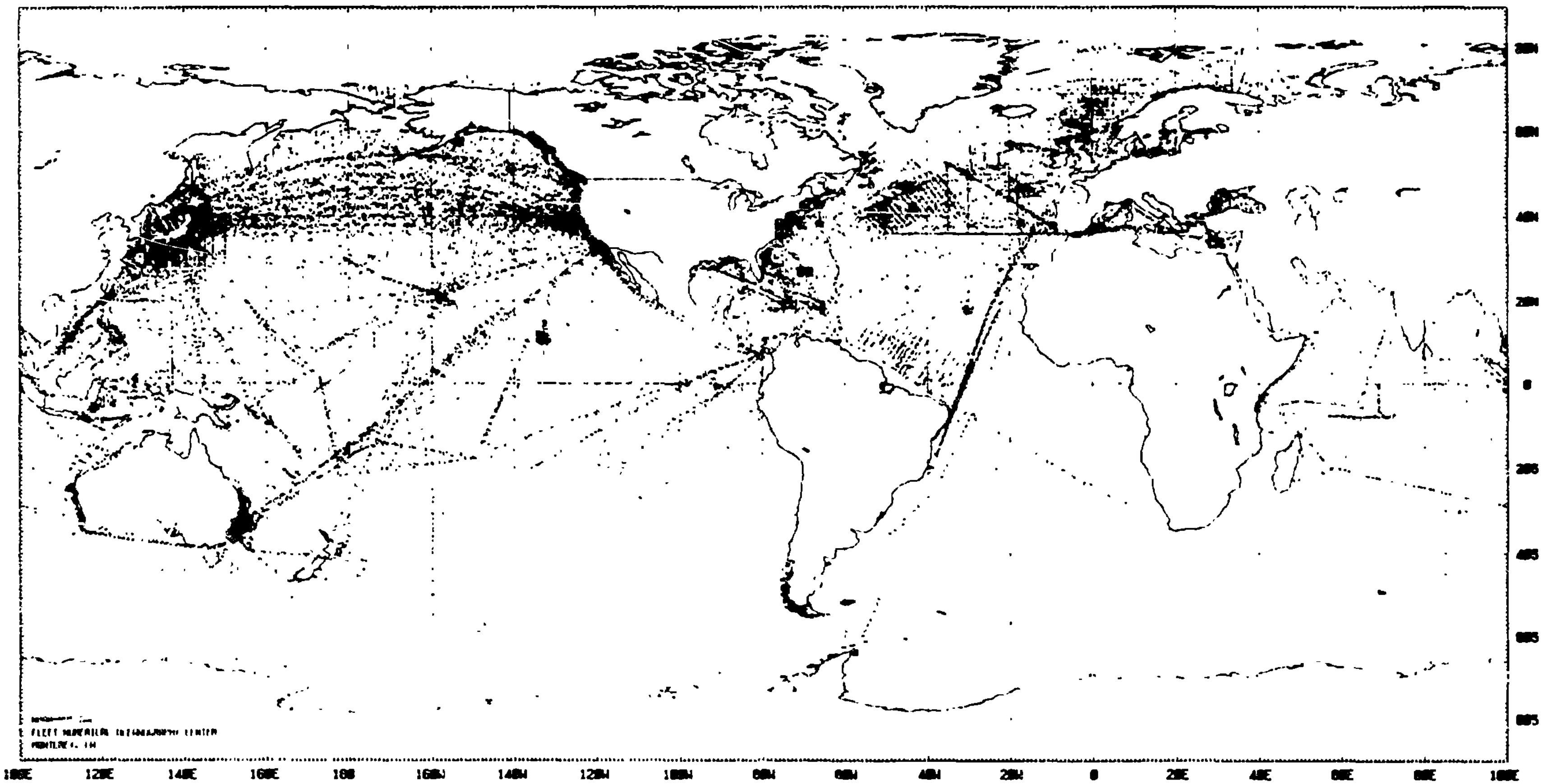
47713 MOODS PROFILES 87010100Z TO 87123123Z

LOCATIONS



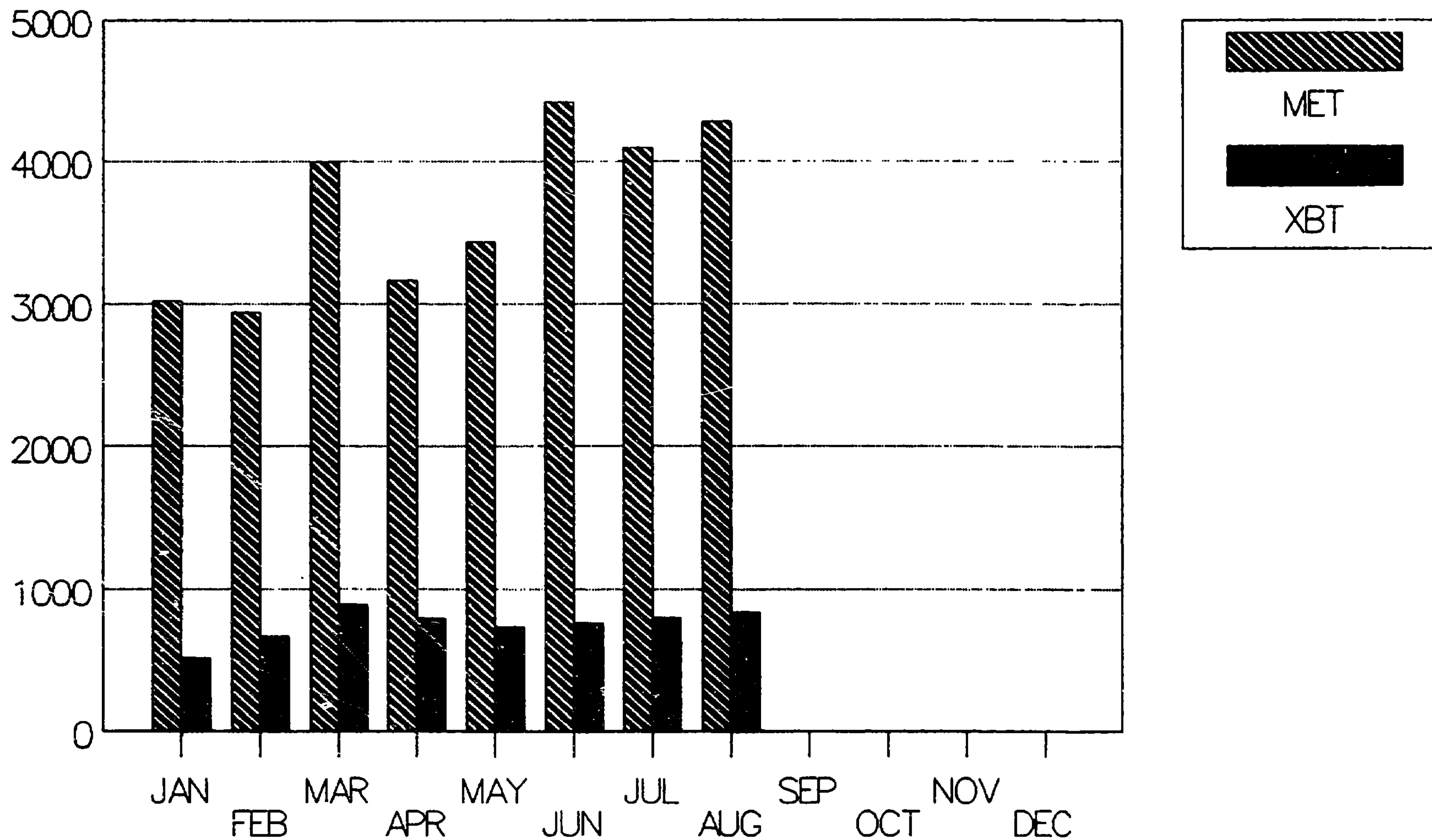
38406 MOODS PROFILES

LOCATIONS



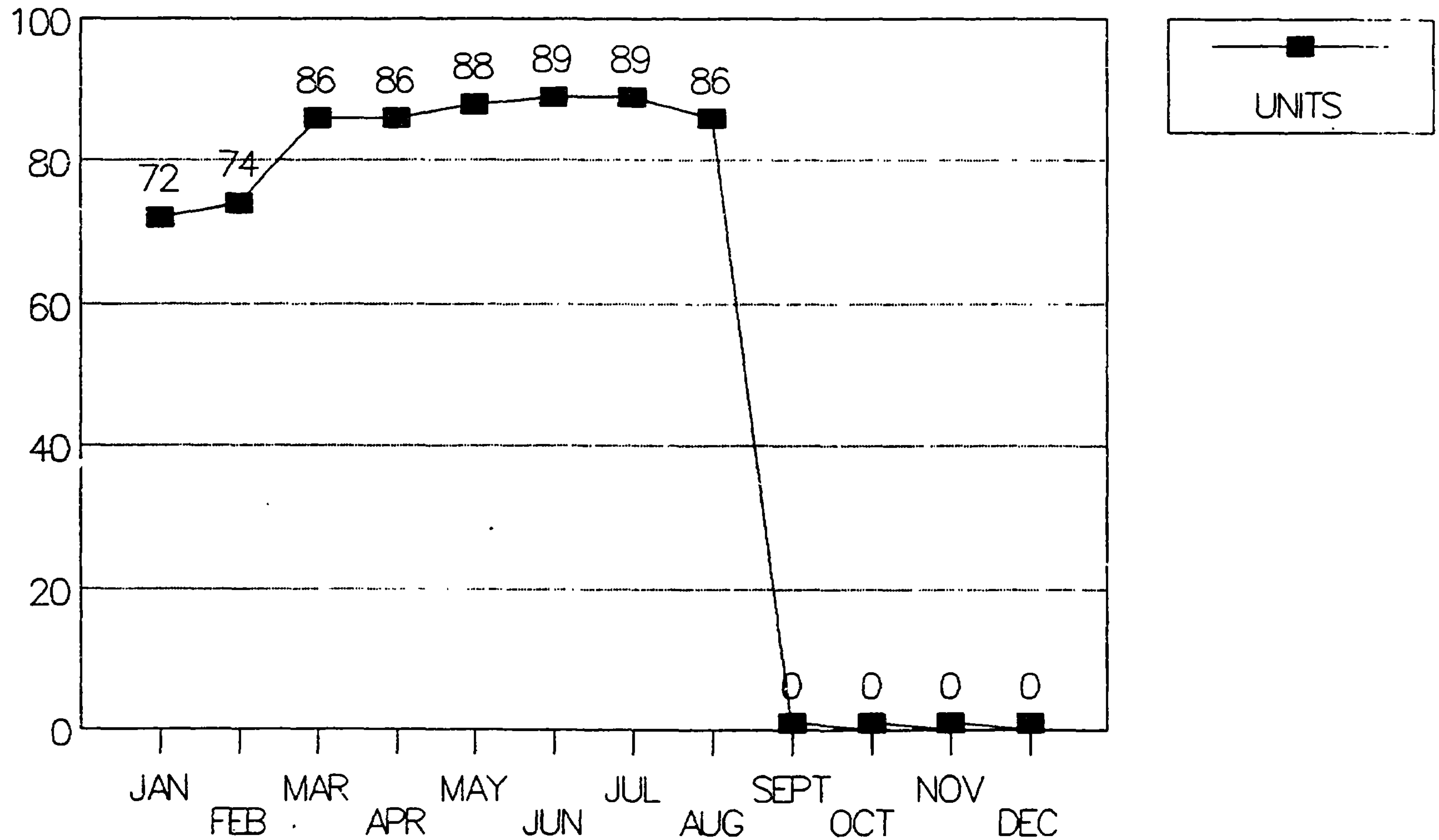
34047 MOORED PROFILES 85010100Z TO 85123123Z

MET AND XBT OBSERVATIONS
JANUARY THRU AUGUST 1989



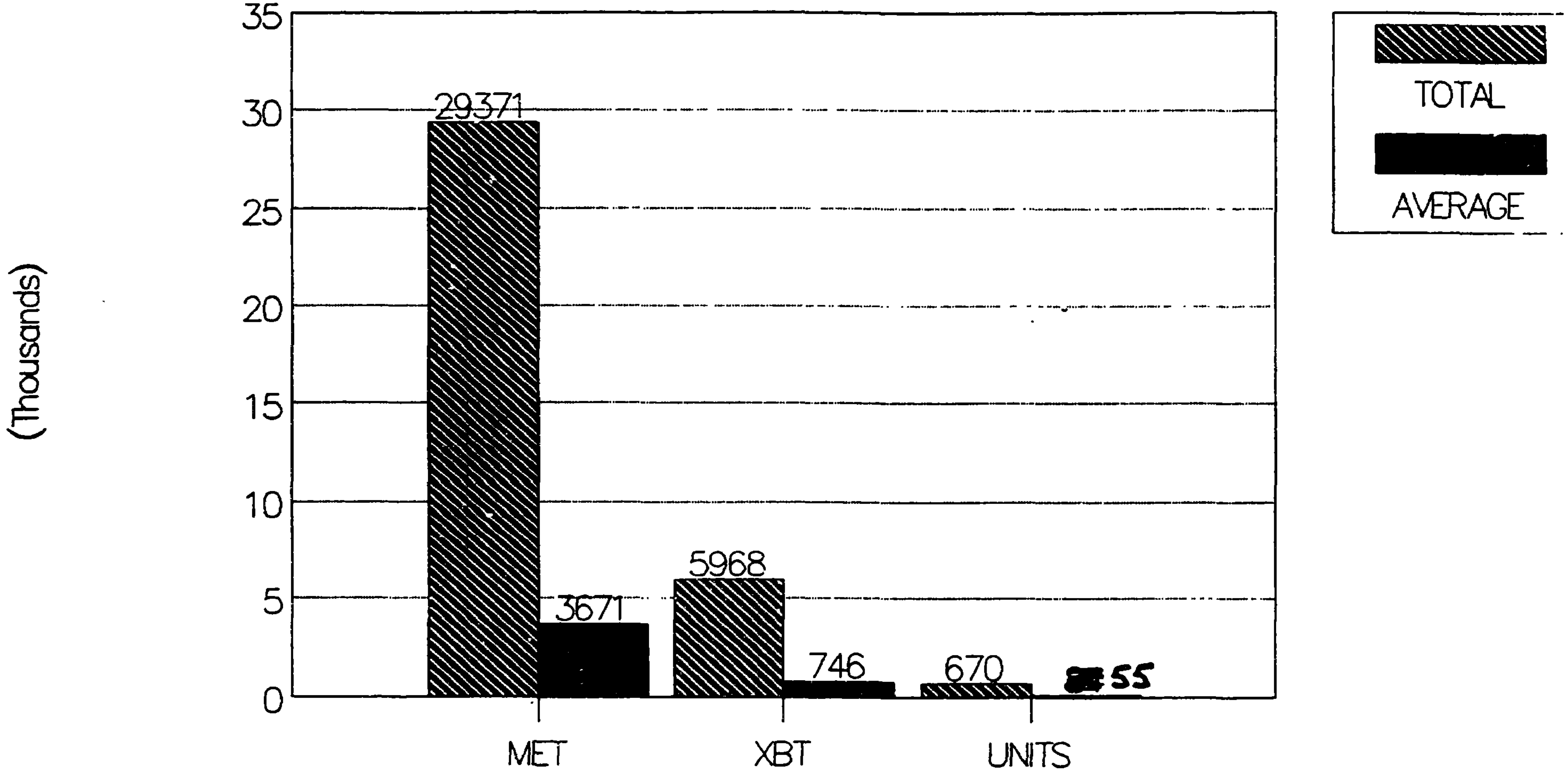
NUMBER OF SEAS UNITS REPORTING

JAN - AUG 1989

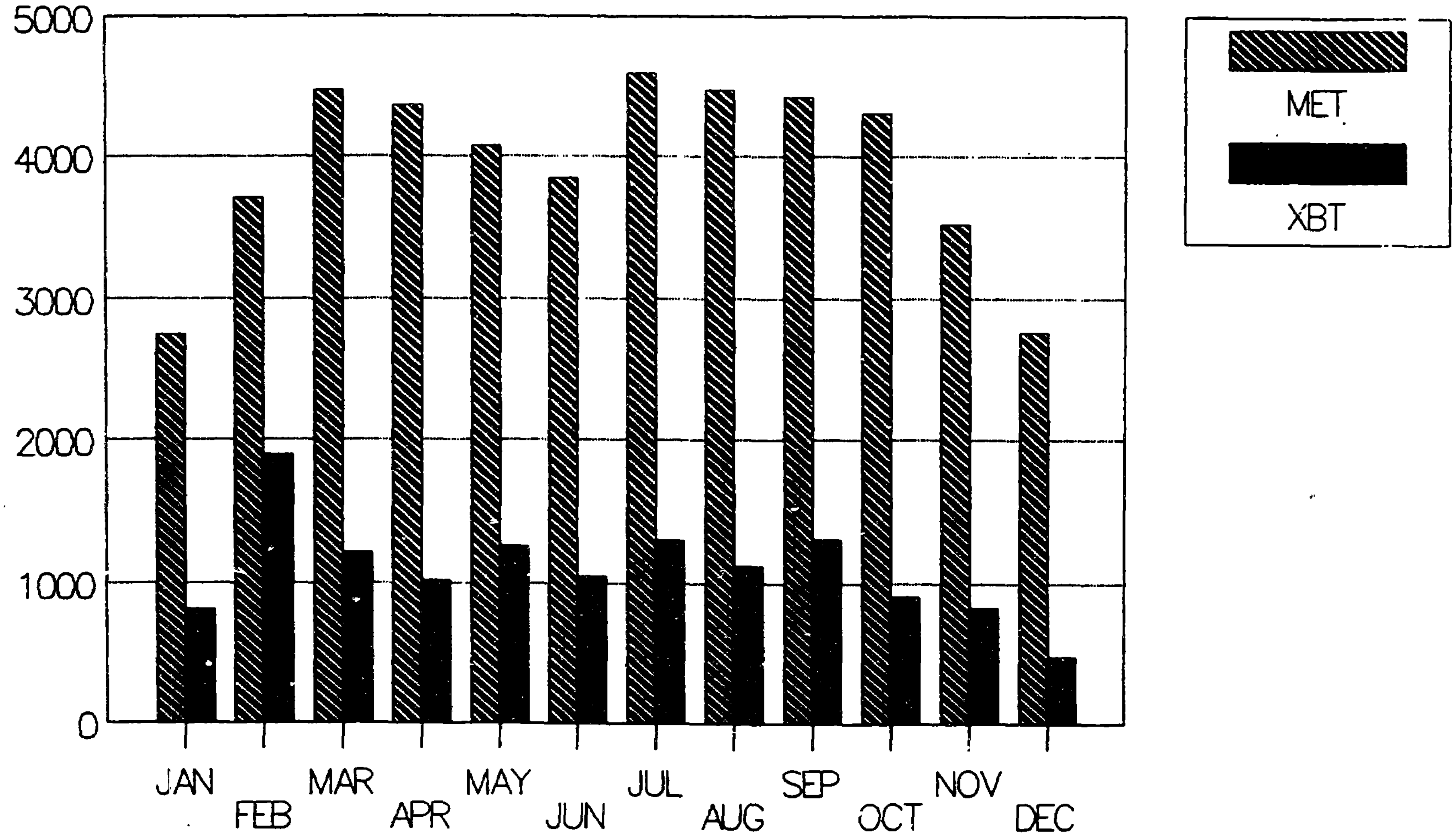


SEAS SUMMARY JAN–AUG 1989

52obs/SHIP/MONTH

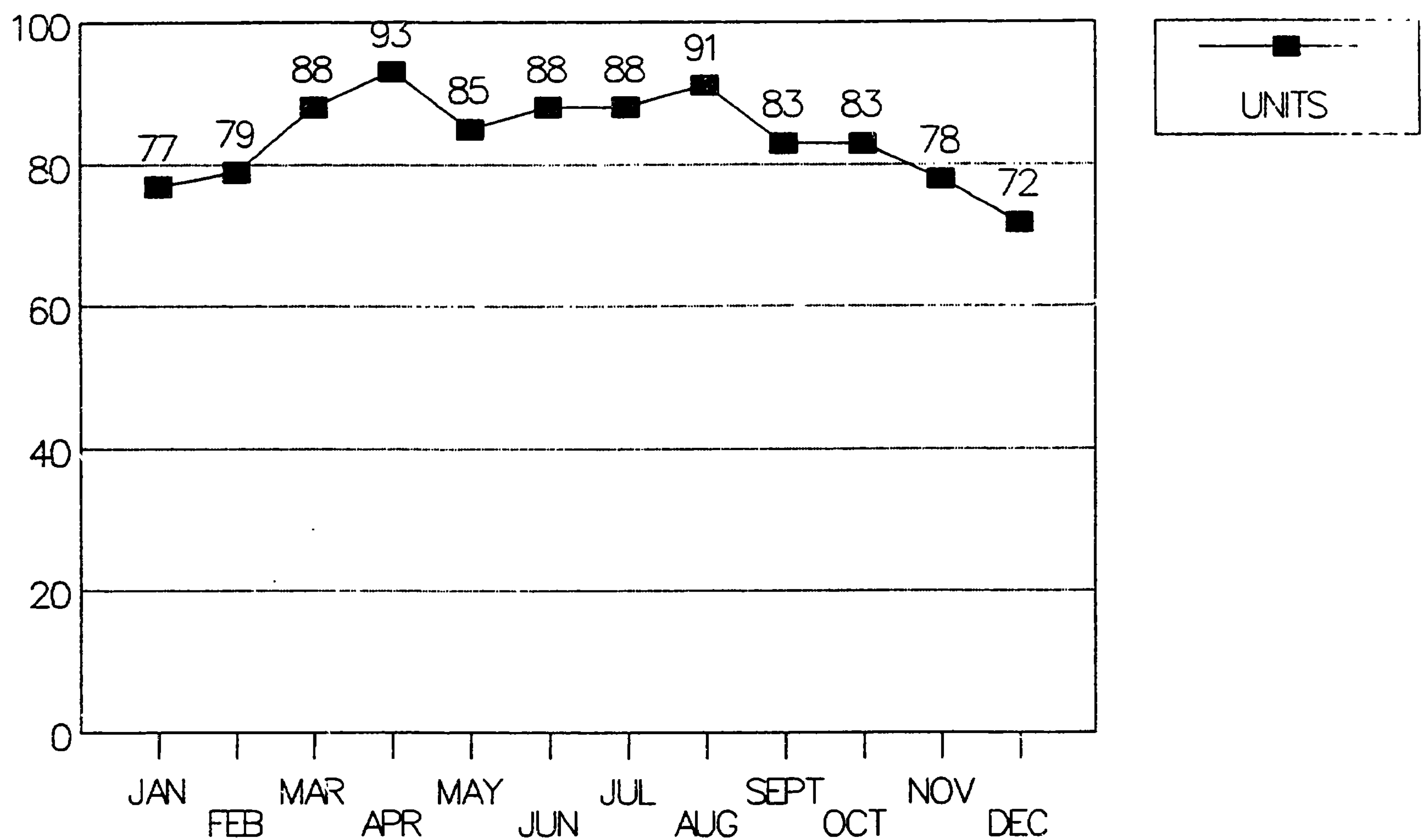


MET AND XBT OBSERVATIONS
JANUARY THRU DECEMBER 1988



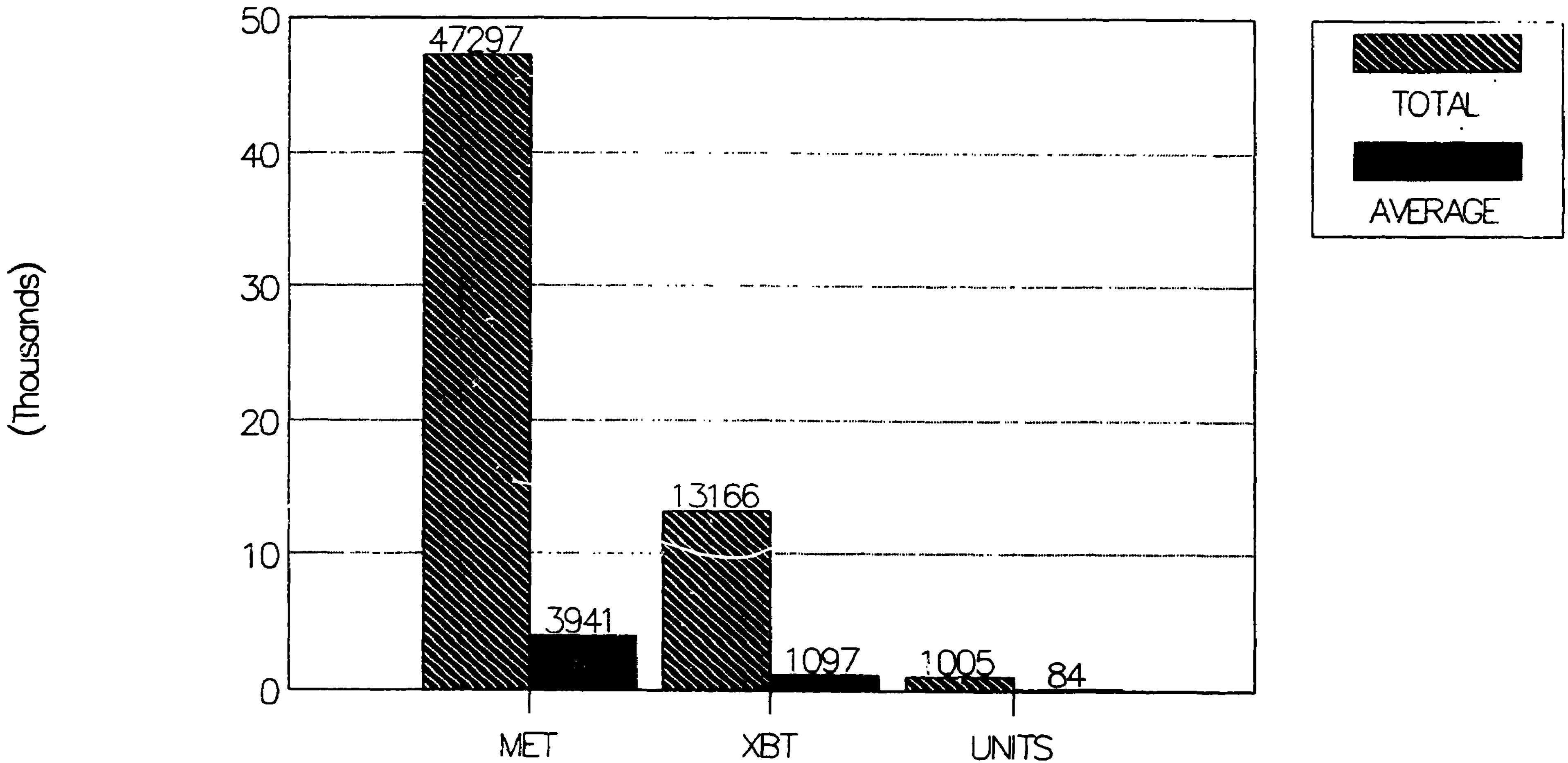
NUMBER OF SEAS UNITS REPORTING

1988

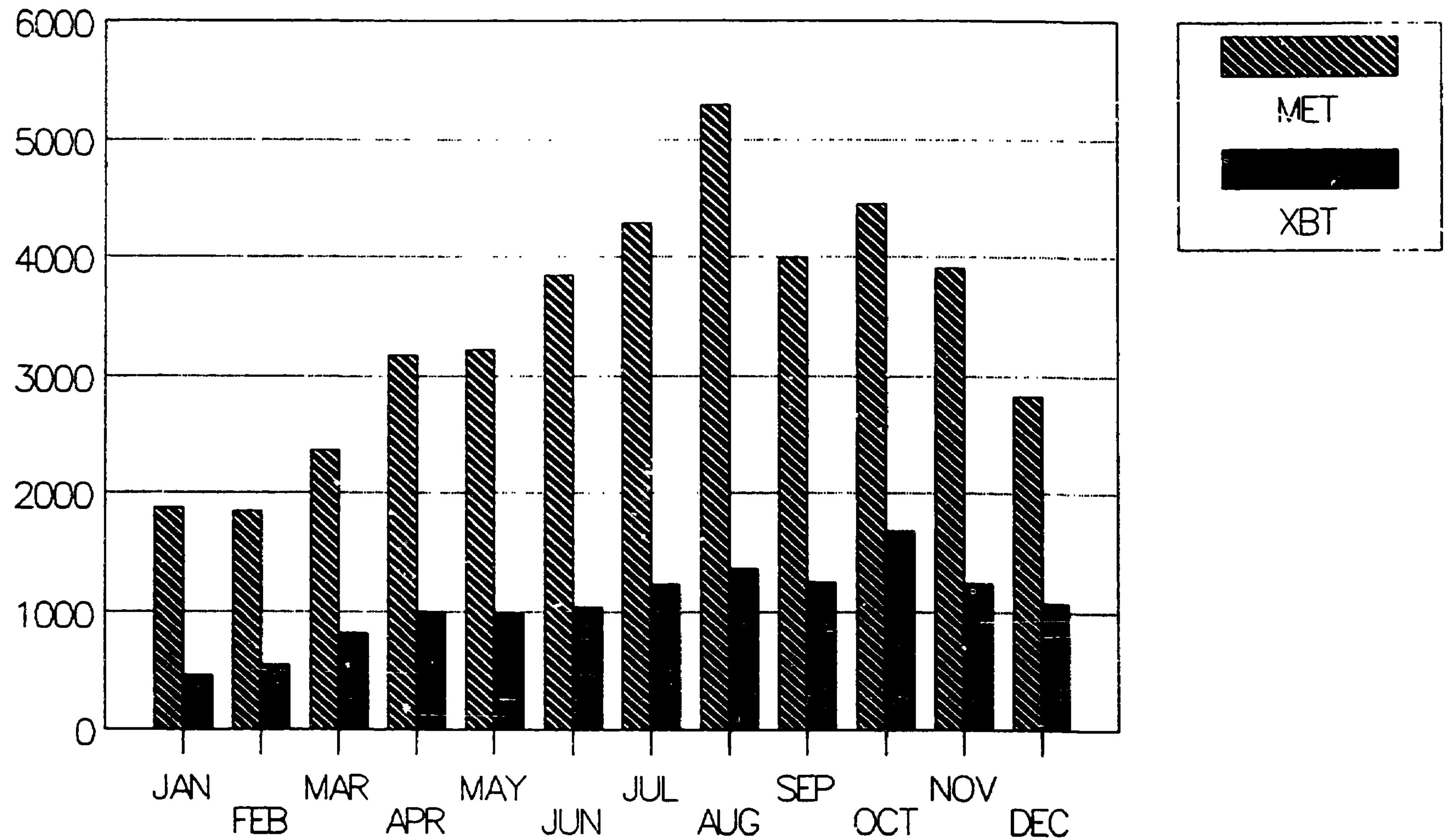


SEAS SUMMARY 1988

60obs/SHIP/MONTH

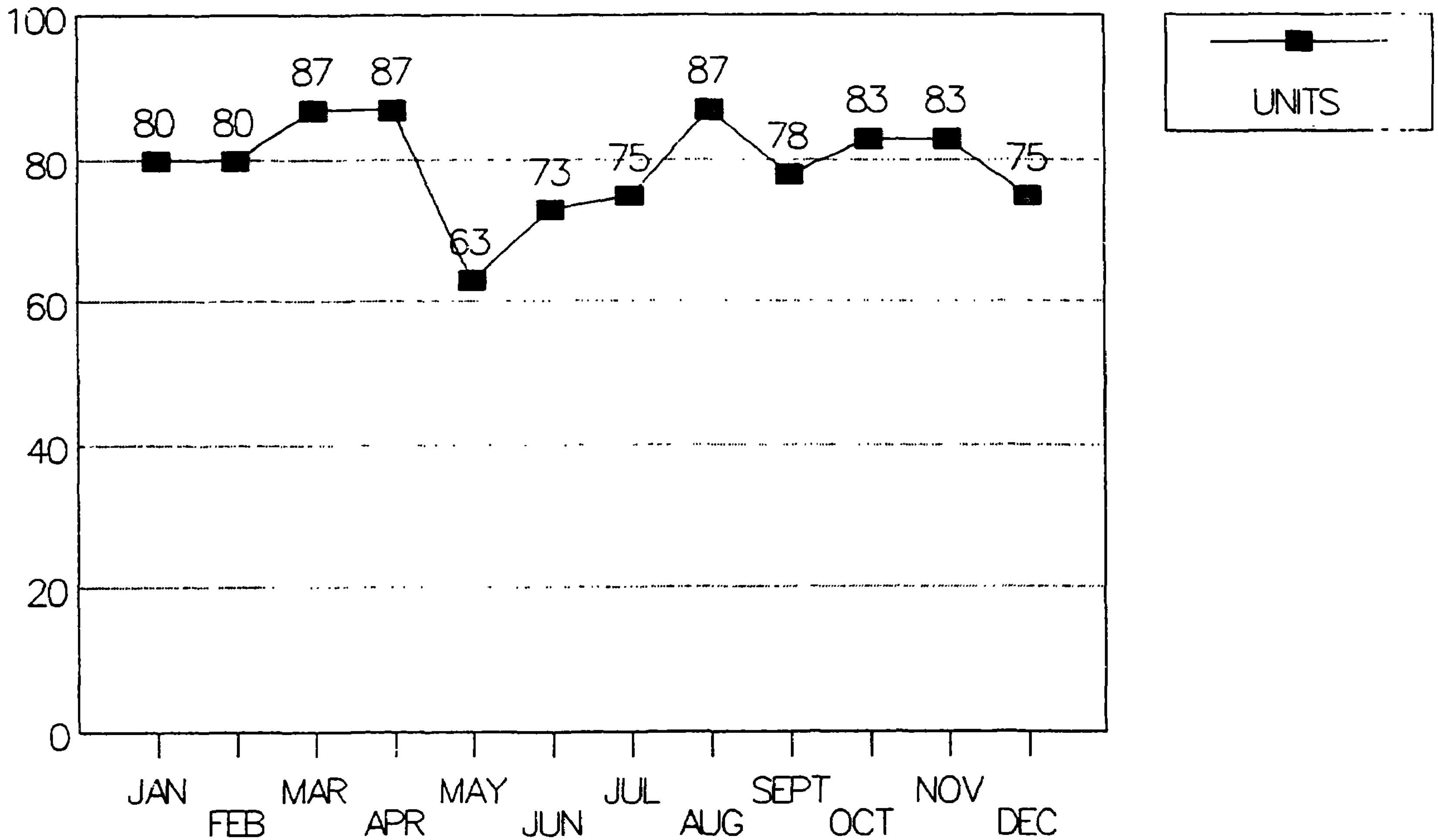


MET AND XBT OBSERVATIONS
JANUARY THRU DECEMBER 1987



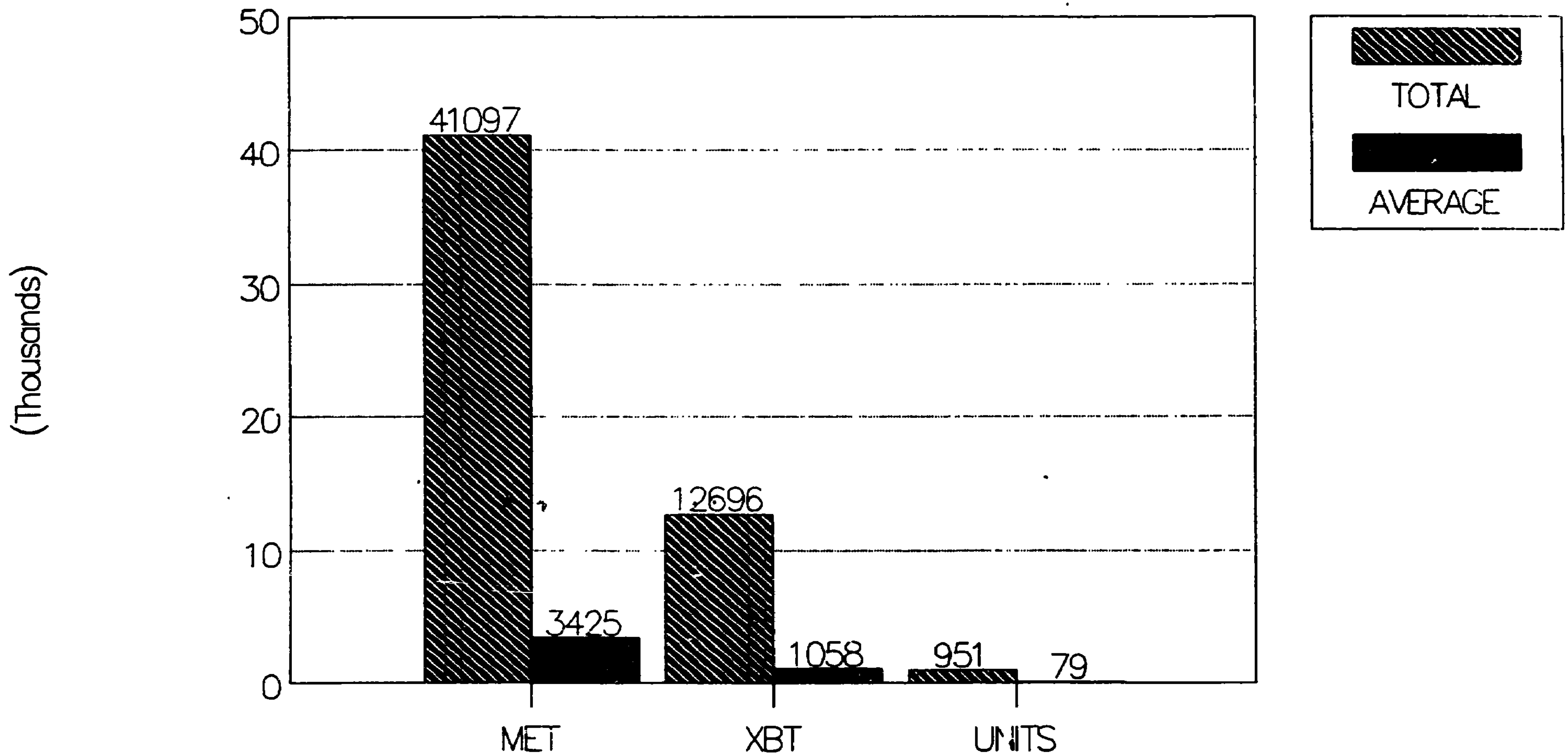
NUMBER OF SEAS UNITS REPORTING

1987

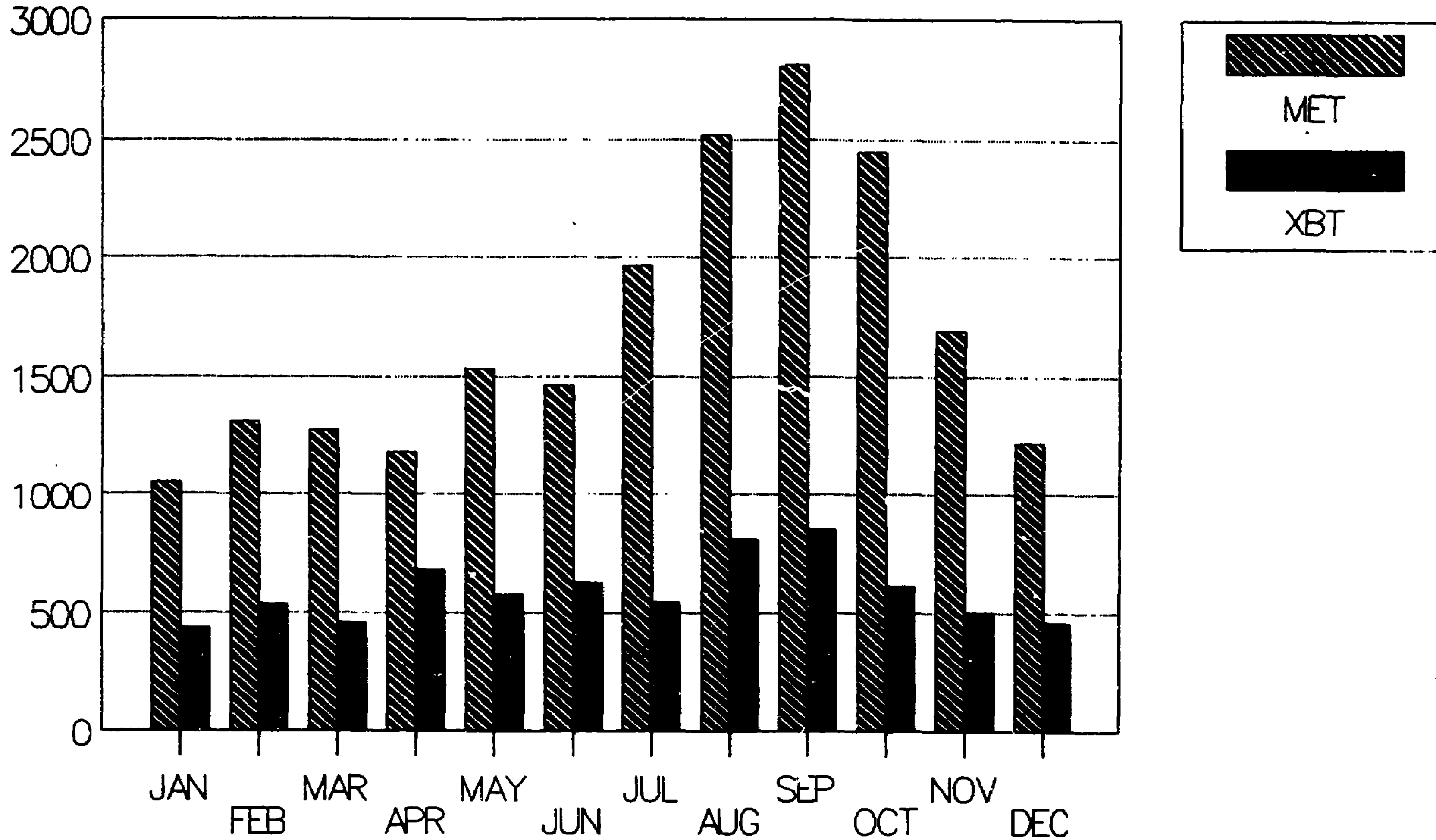


SEAS SUMMARY 1987

57obs/SHIP/MONTH

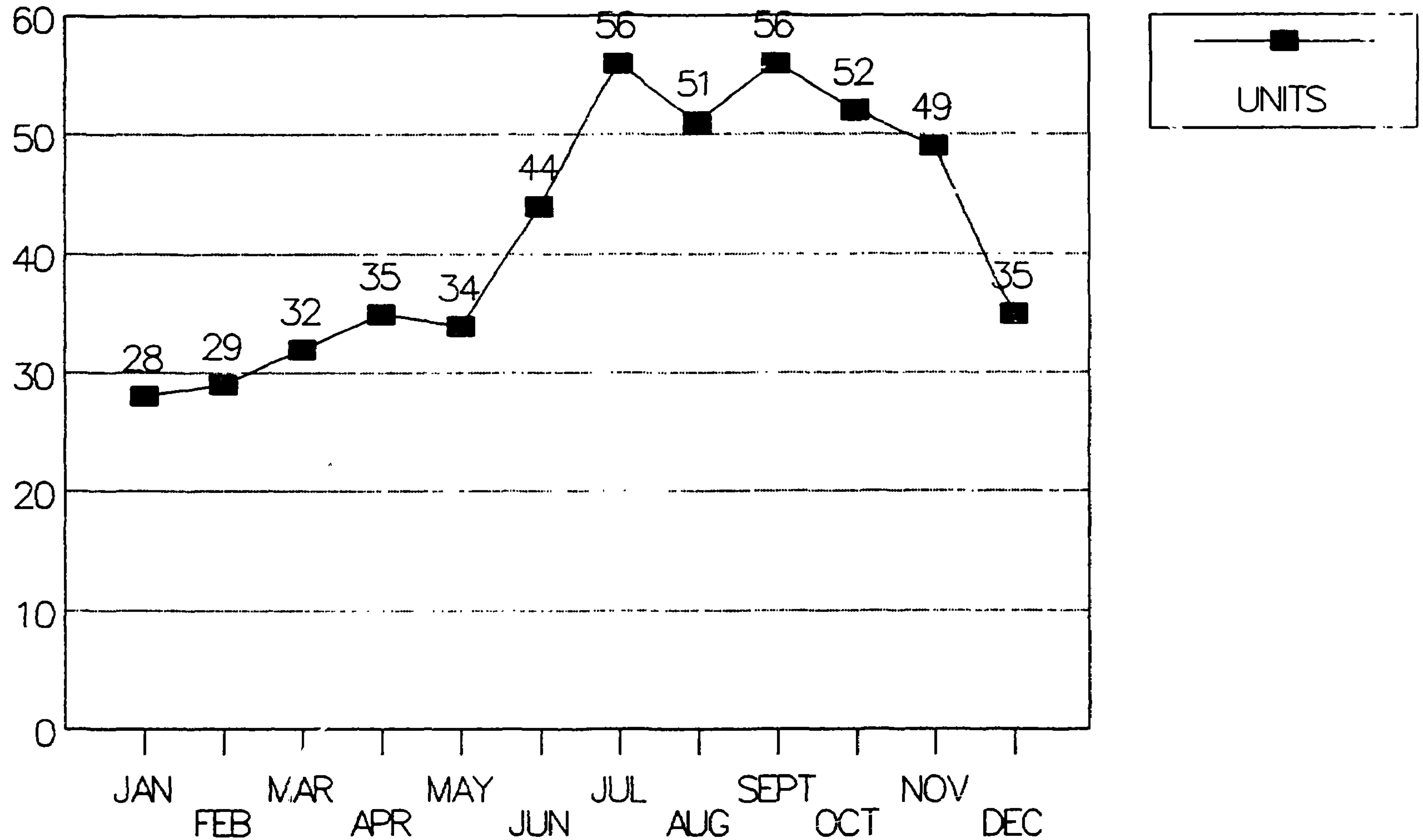


MET AND XBT OBSERVATIONS
JANUARY THRU DECEMBER 1986



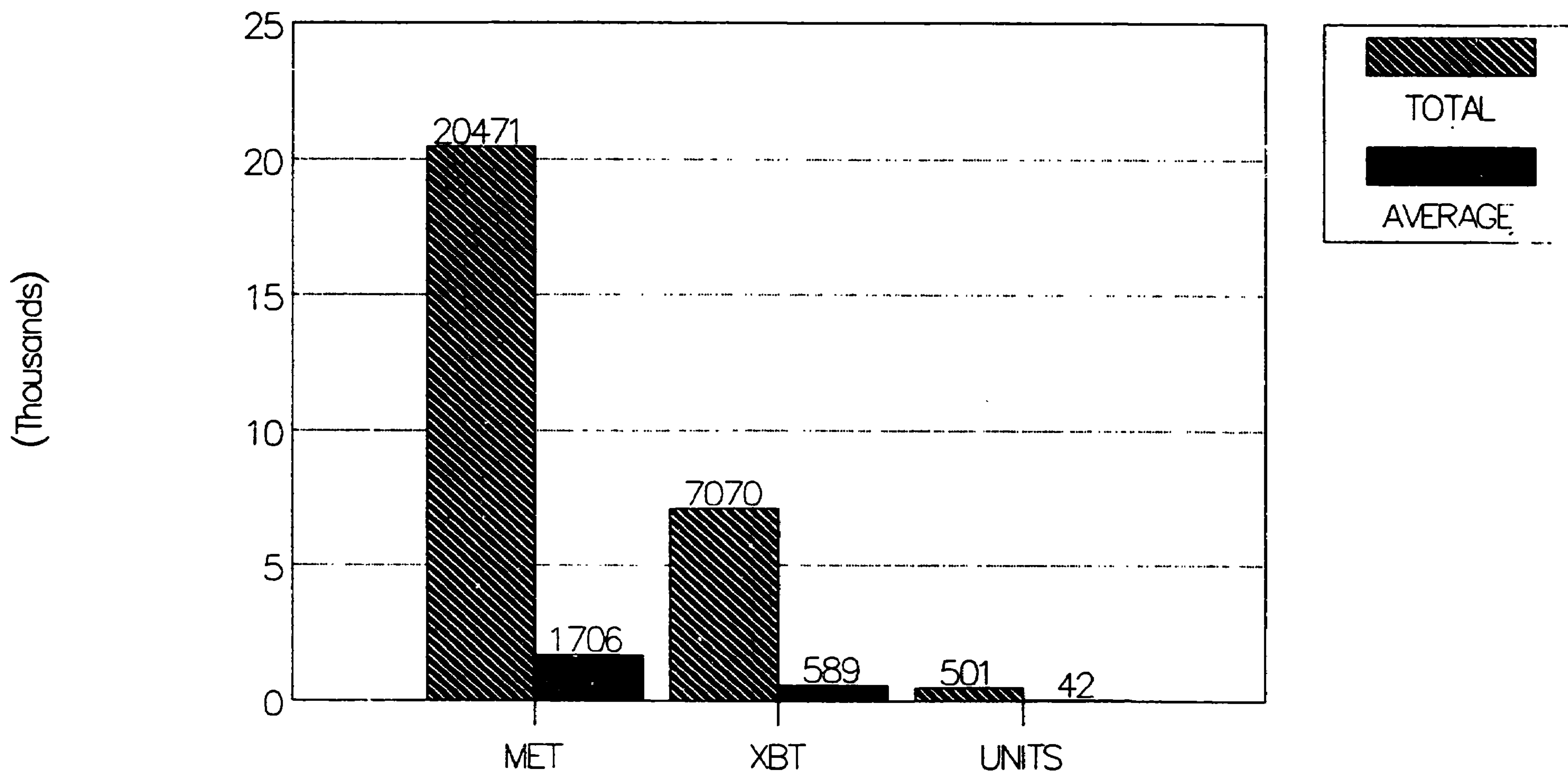
NUMBER OF SEAS UNITS REPORTING

1986



SEAS SUMMARY 1986

55obs/SHIP/MONTH



C - COOP EXPENDABLE BATHYTHERMOGRAPH VERTICAL SECTIONS, 1988

P. Stevens, FNOC
D.R. McLain, NOS
K. Tommos, NODC

The Cooperative Oceanographic Observations Program (COOP) is sponsored by Fleet Numerical Oceanography Center (FNOC) to support of real-time analyses of ocean temperature and other conditions. For this, COOP supports expendable bathythermograph (XBT) observations from merchant and other vessels globally. The observations are often made in cooperative sampling efforts with various ships, laboratories and institutions, both domestic and foreign. These cooperative efforts are mutually beneficial to the ships and institutions and to FNOC because they provide additional observations in a more timely way, with greater quality for less effort and fewer budget dollars than would be possible by separate efforts. COOP's long term objectives are similar to those of many national and international climate programs, that is, long-term monitoring of the upper layers of the ocean in significant ocean areas.

For many years, the FNOC through its COOP has supplied XBT recording devices and expendable probes to cooperating ships and institutions. The observations are digitized on board the ship and reported to FNOC as "BATHY" messages for use in twice daily ocean analyses and forecasts. Collectively, there are about 100 ships that participate in COOP; of these, about 45 to 60 are at sea at any one time. On merchant ships, the XBT probes are launched from either the port or starboard bridgewing to allow the mate on the ship to drop the probe from the ship's "leeside".

The XBT hardware on the ships varies and is "tailored" to each particular ship. On many ships, the data are recorded on Sippican strip chart recorders, manually encoded as a BATHY message and radioed to shore using Morse Code CW. Because the manual XBT observations are laborsome and error-prone, the strip chart recorders are being replaced with automated systems. On some ships, a Sippican MK-9 electronic XBT system is used. This system uses a Hewlett Packard HP85A microcomputer for automatic digitizing of the XBT profile, automatic encoding of a BATHY message and recording of the data on a magnetic tape cassette. On these ships, the message is sent to shore by Morse Code CW.

More advanced systems, called Shipboard Environmental data Acquisition System (SEAS, Barozotto and Szabados 1987), are similar but at an appropriate time, transmit the BATHY message to shore via the GOES communication satellite. There are two classes of SEAS: SEAS II with a Hewlett Packard 85B microcomputer and cassette recording and SEAS III with a PC-clone (Televideo XL) microcomputer and recording on a floppy disc.

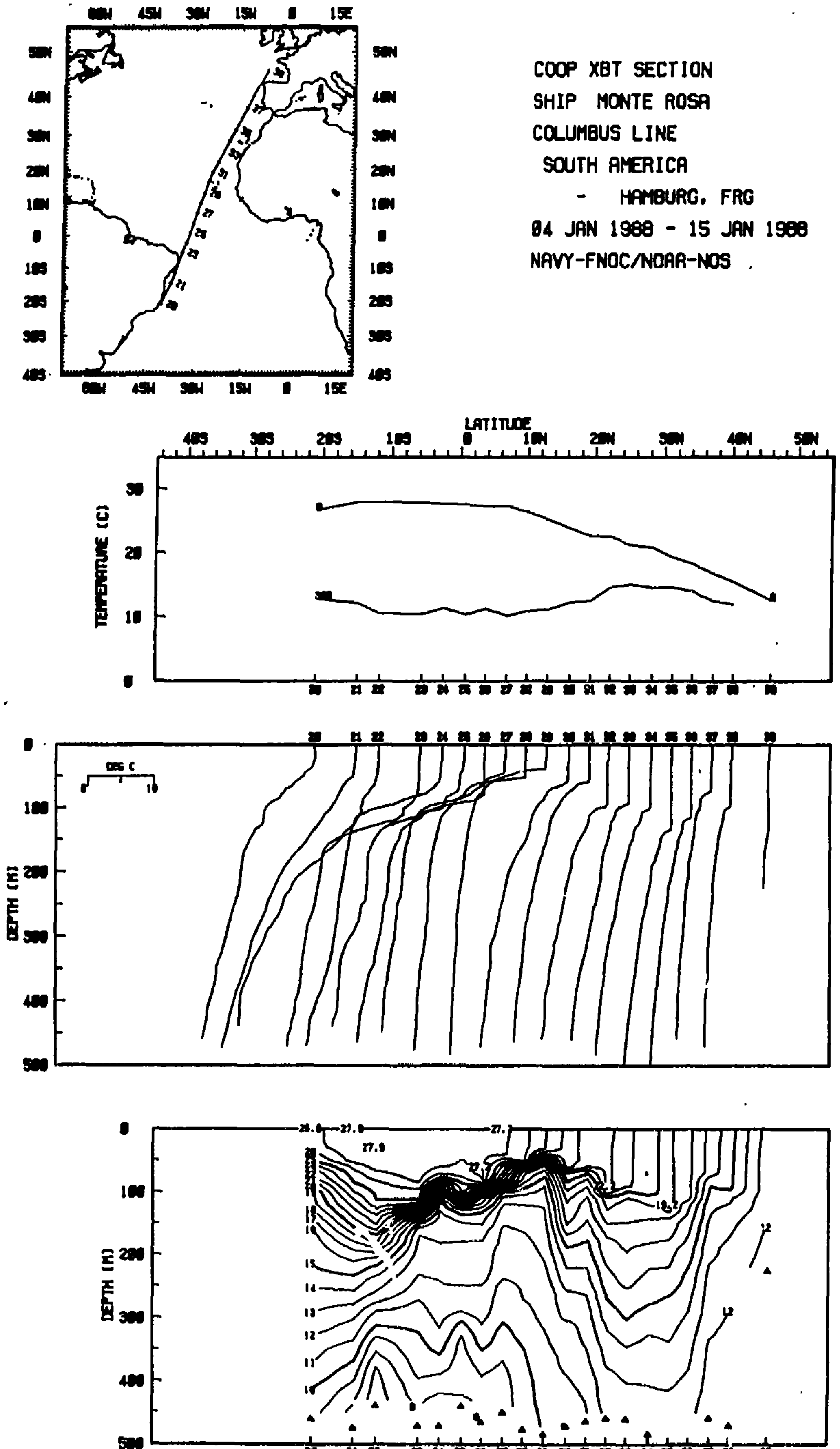
After the ship returns to port, the strip charts or cassettes or floppy discs are recovered for processing at either FNOC or NODC. XBT strip charts are digitized with identical digitizing systems at FNOC and NODC; these systems use a Zenith 120 microcomputer with a GTCO digitizing tablet. The digitized data as well as data recorded on cassettes and discs are sent to the FNOC Cyber mainframe computer for editing. The data are plotted on Varian electrostatic plotters using the FNOC program DISPLAY and are available on magnetic tape from NODC in UBT format.

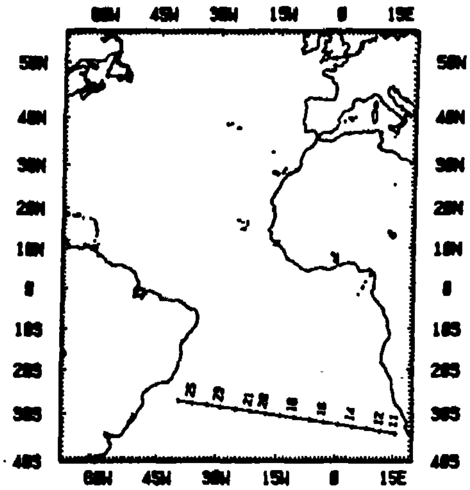
This report contains vertical profiles and contour plots of XBT sections made by ships in the COOP program during 1988 and updates similar reports for 1986 and 1987. The report has three main purposes: 1) provide feedback to the observers on ships to show what data are collected and how they are processed, 2) advertise the availability of the data to interested scientists, and 3) provide a quality control check of the data before submission to the US national archives at the National Oceanographic Data Center (NODC).

Each figure in the report shows the ship track, the times and dates of the sampling, and the name of the ship. The sections are sorted by five ocean areas (Atlantic Ocean, transequatorial Pacific Ocean, other Pacific Ocean, Tasmin Sea, and Indian Ocean). Within each ocean area, the sections are sorted by time. Most of the sections are plotted as a function of latitude although a few are plotted as a function of longitude.

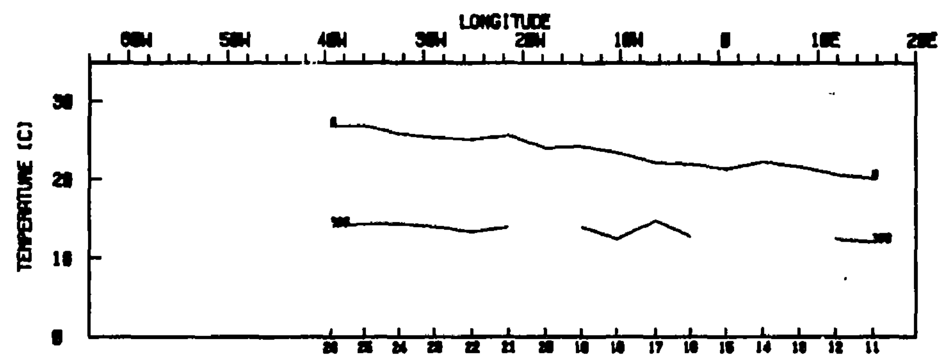
R. Barozotto and M. Szabados. 1987.

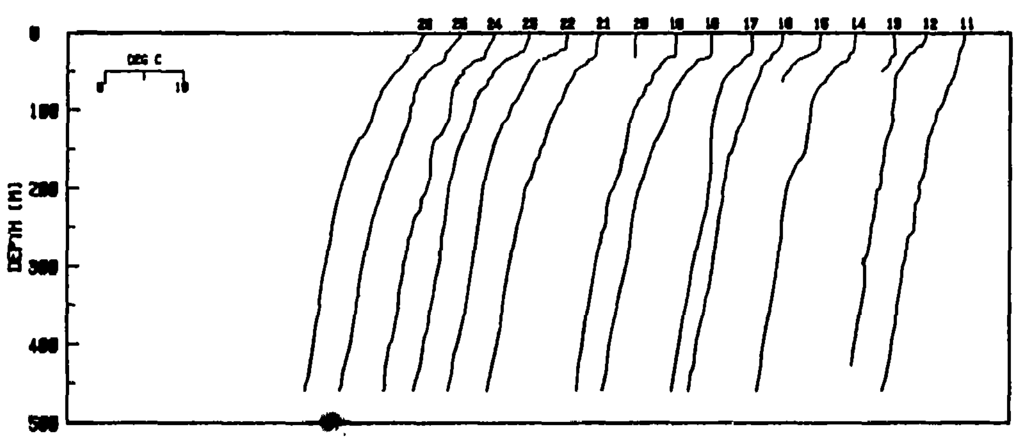
COOP XBT SECTION
SHIP MONTE ROSA
COLUMBUS LINE
SOUTH AMERICA
- HAMBURG, FRG
04 JAN 1988 - 15 JAN 1988
NAVY-FNOC/NOAA-NOS

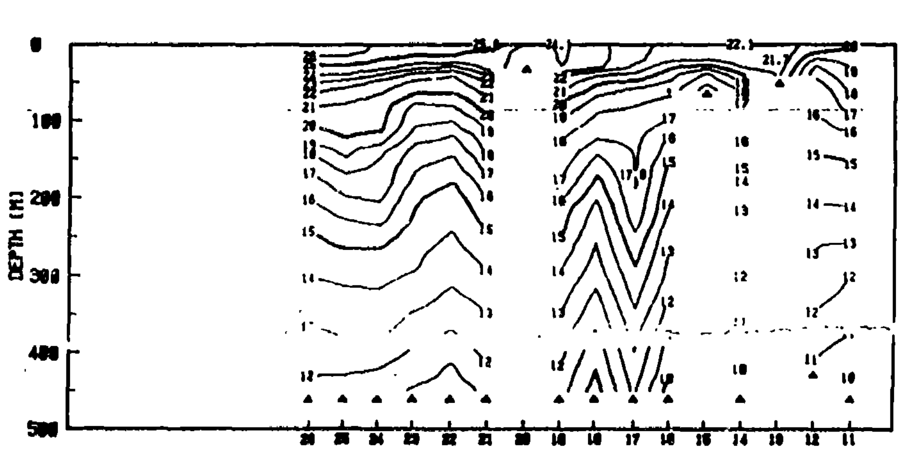




COOP XBT SECTION
SHIP NL KEMBLA
NEDLLOYD LINE
SOUTH AFRICA
- U.S. COAST
16 JAN 1988 - 24 JAN 1988
NAVY-FNOC/NOAA-NOS







COOP XBT SECTION
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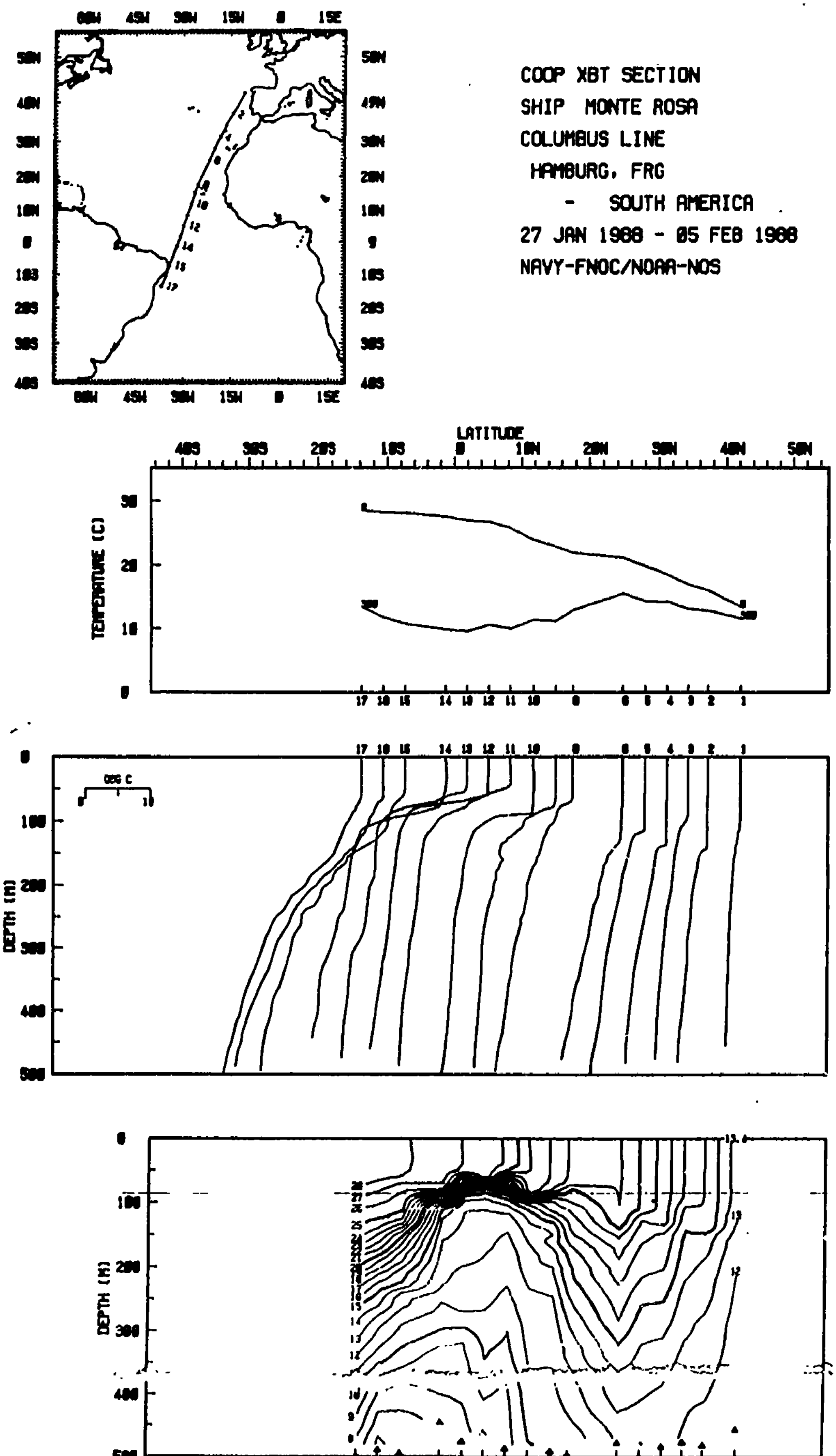
COLUMBUS LINE
HAMBURG, FRG
- SOUTH AMERICA
27 JAN 1988 - 05 FEB 1988
NAVY-FNOC/NOAA-NOS



COOP XBT SECTION
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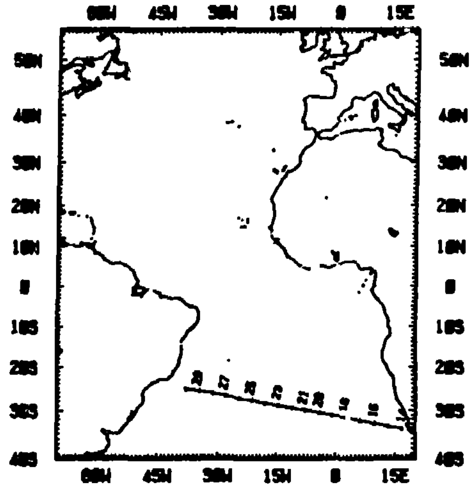
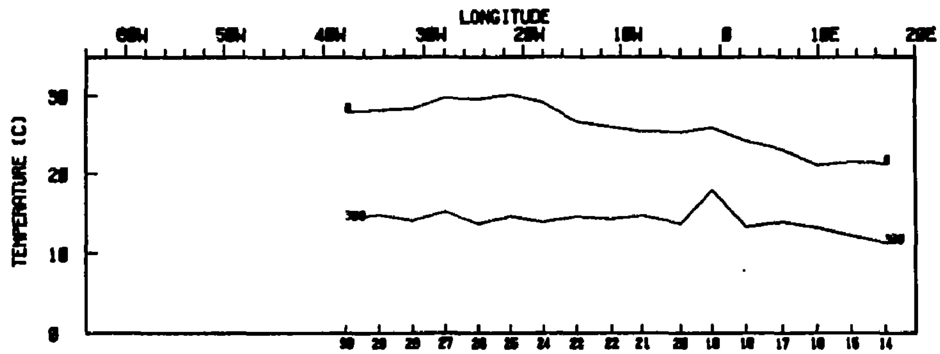
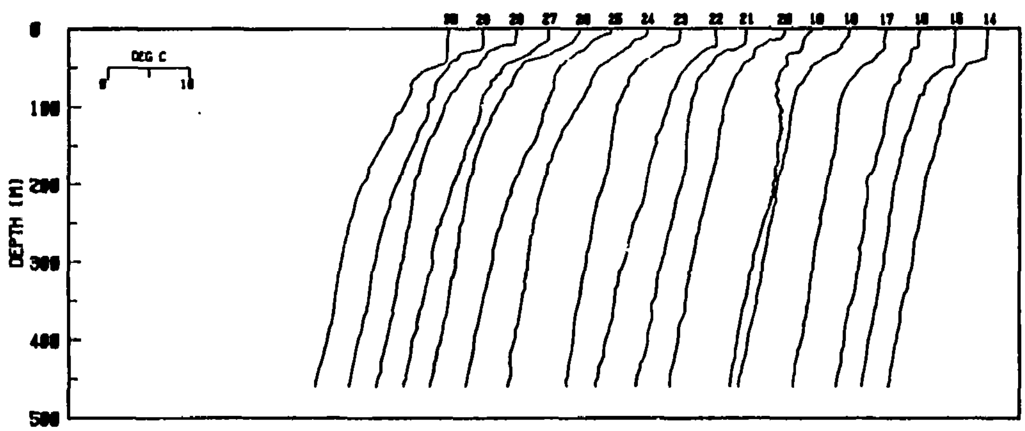
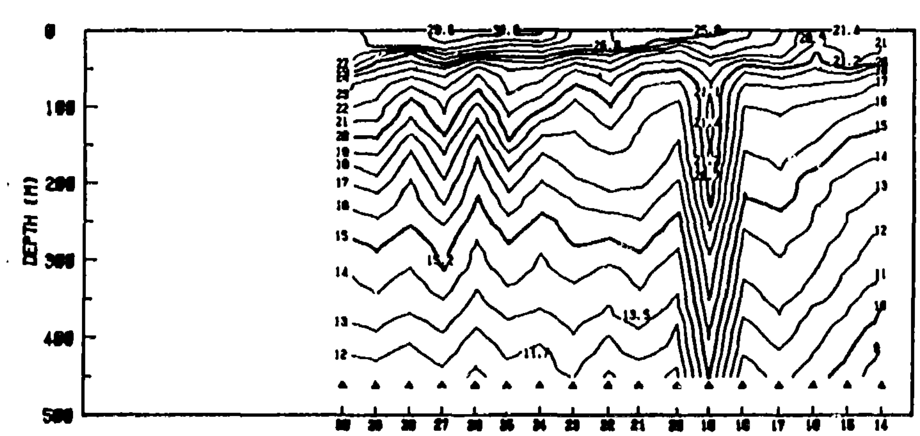
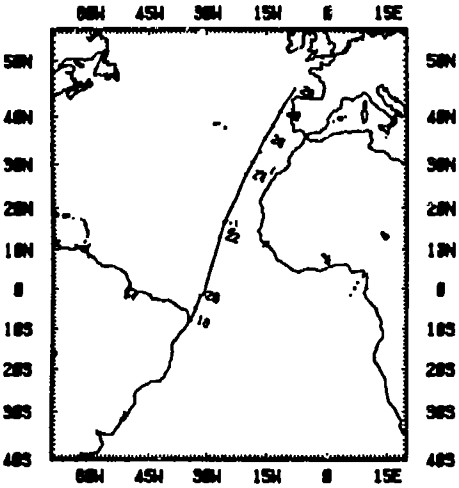
NEDLLOYD LINE
SOUTH AFRICA
- U.S. COAST
08 FEB 1988 - 15 FEB 1988
NAVY-FNOC/NOAA-NOS











COOP XBT SECTION
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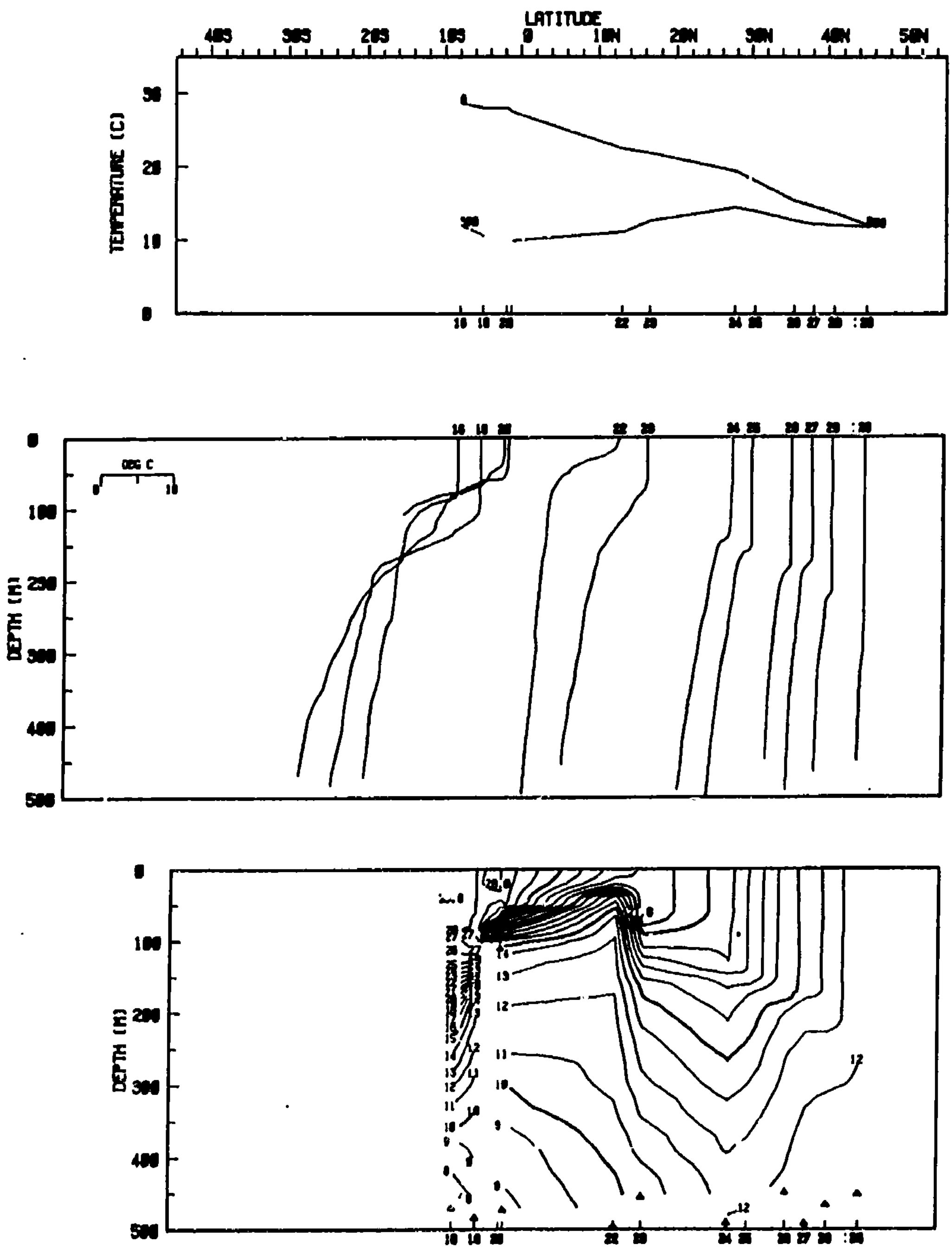
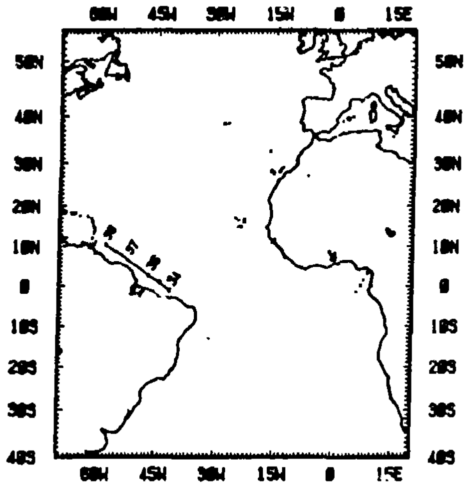
COLUMBUS LINE
SOUTH AMERICA
- HAMBURG, FRG
25 FEB 1988 - 05 MAR 1988
NAVY-FNOC/NOAA-NOS





COOP XBT SECTION
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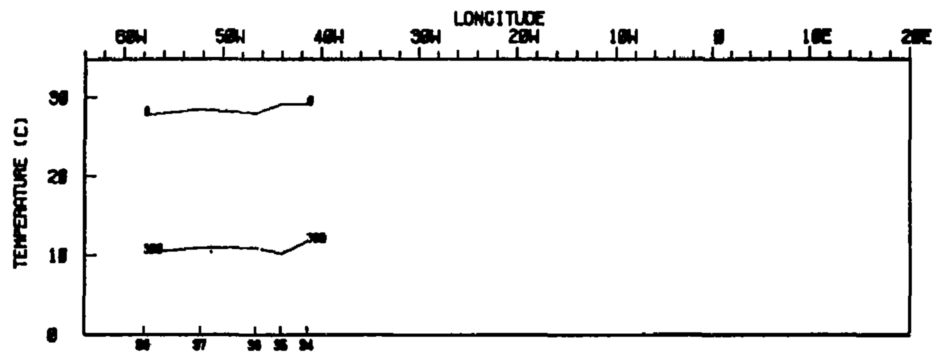
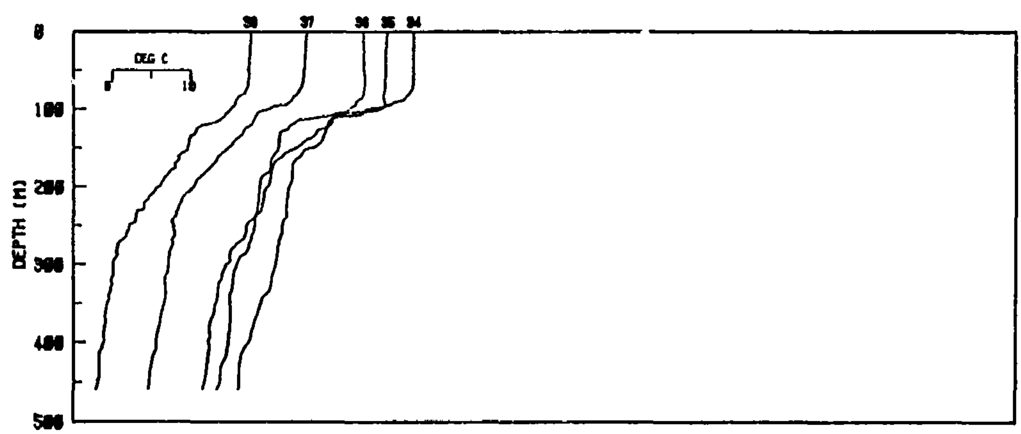
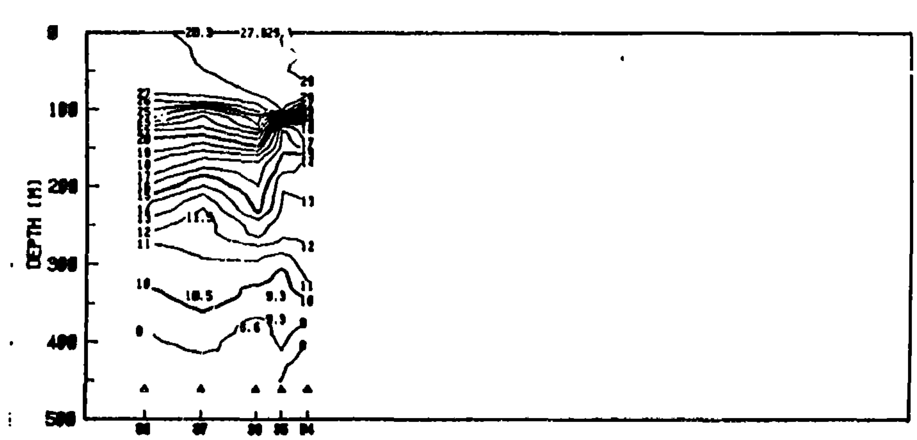
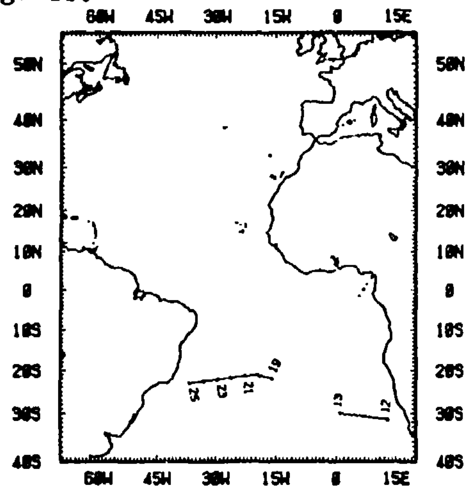
NEDLLOYD LINE
SOUTH AFRICA
- U.S. COAST
27 FEB 1988 - 01 MAR 1988
NAVY-FNOC/NOAA-NOS









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NEDLLOYD LINE
SOUTH AFRICA
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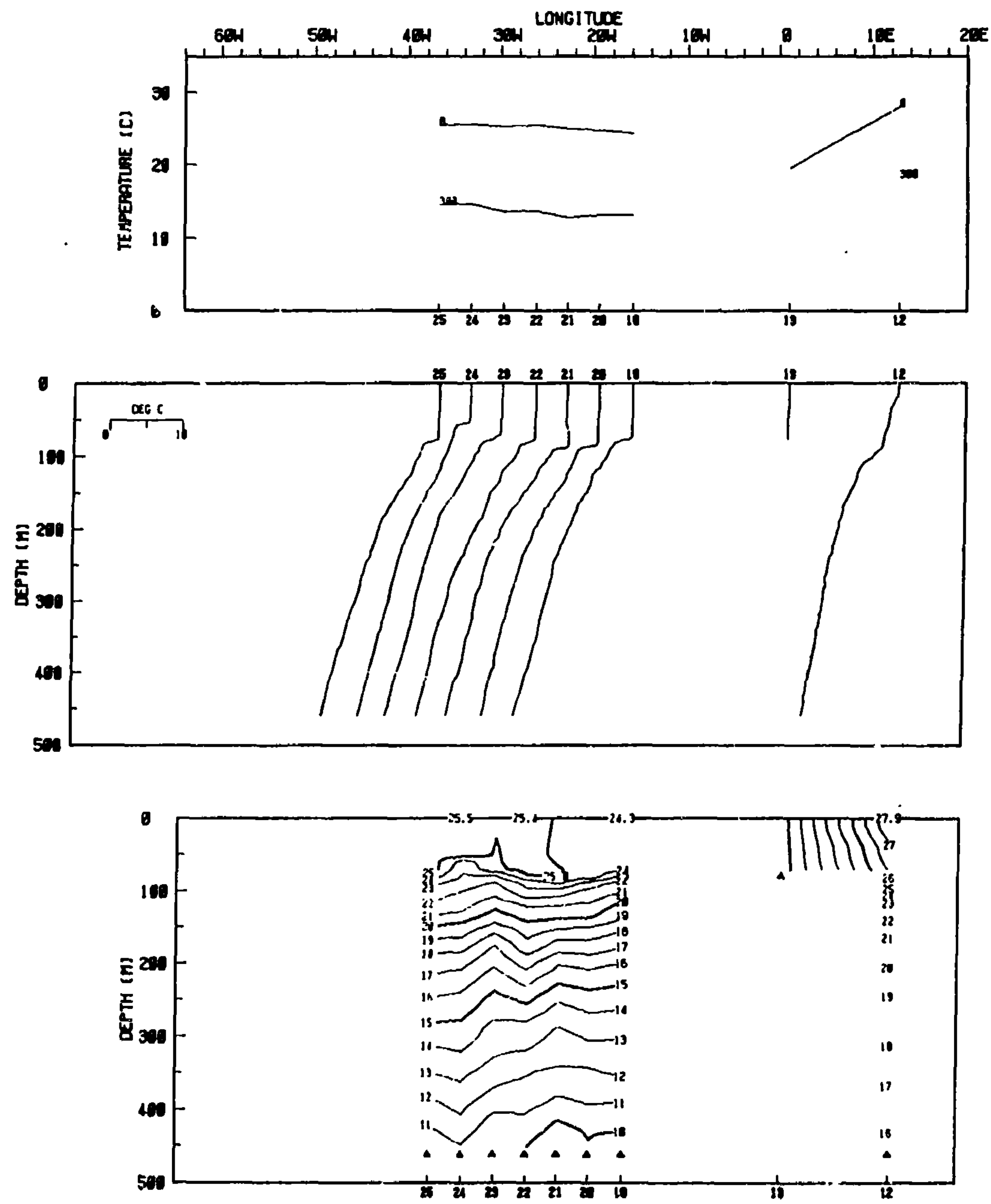
03 JUN 1988 - 10 JUN 1988
NAVY-FNOC/NOAA-NOS



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SOUTH AFRICA
- U.S. COAST
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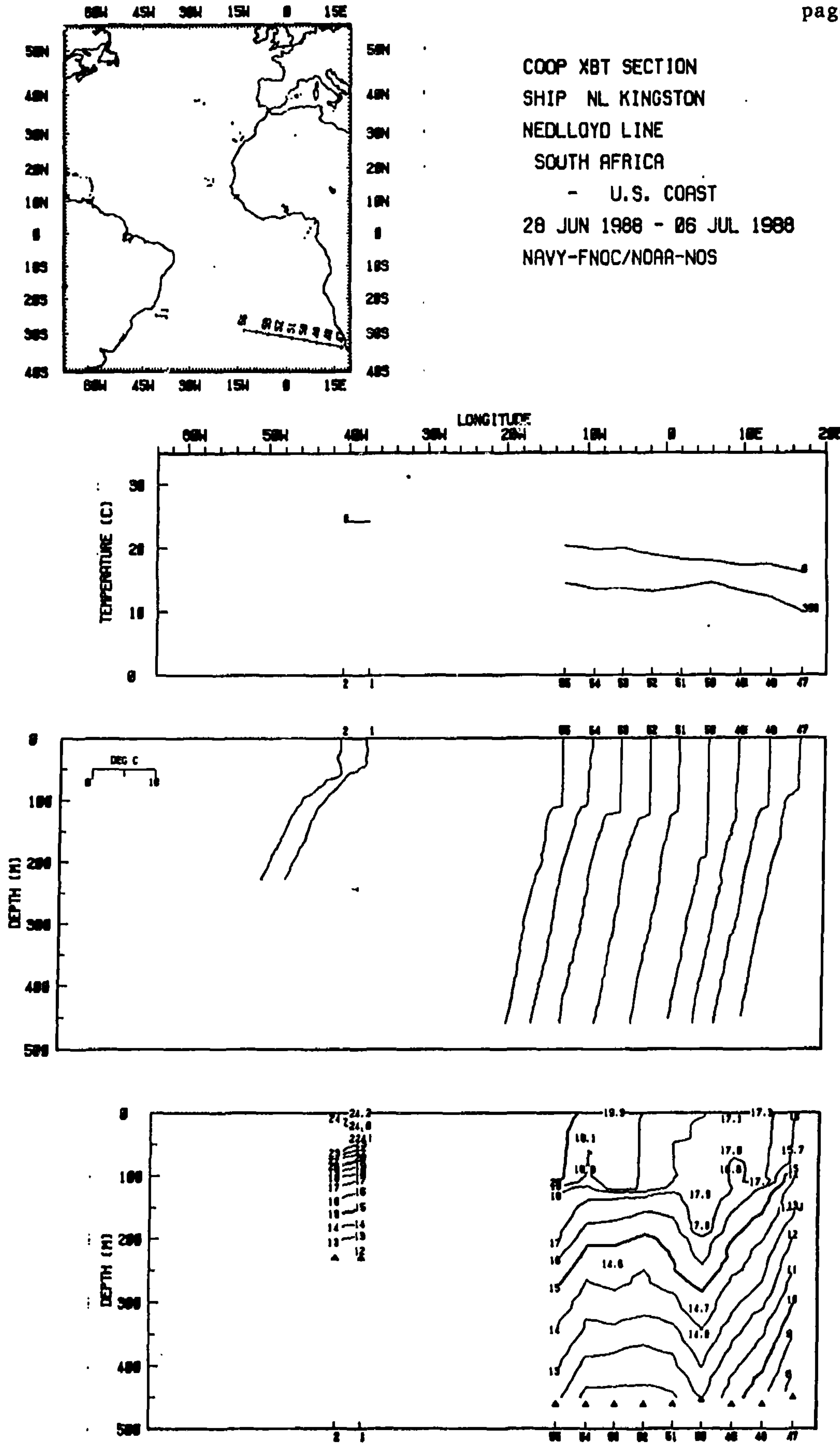
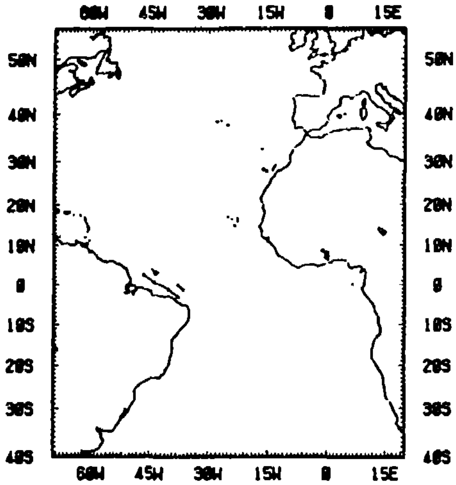
NAVY-FNOC/NOAA-NOS





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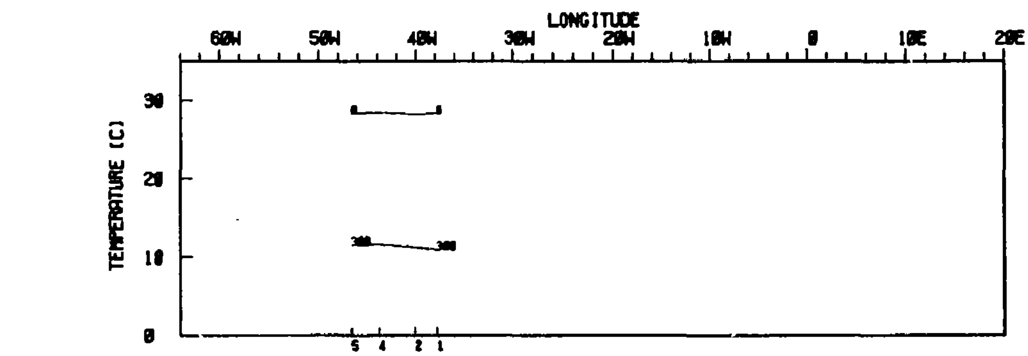
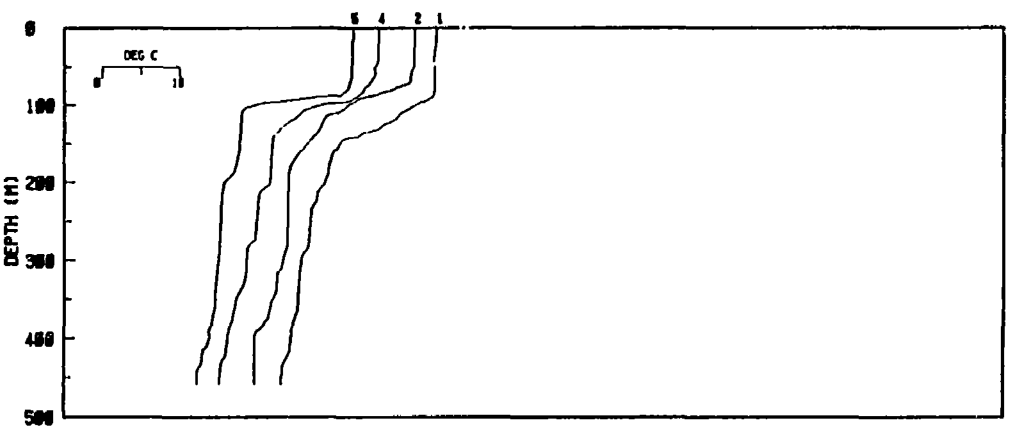
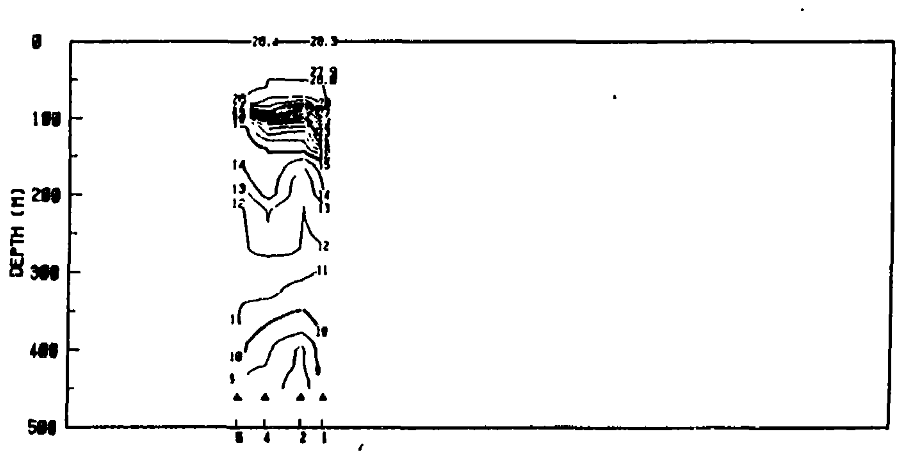
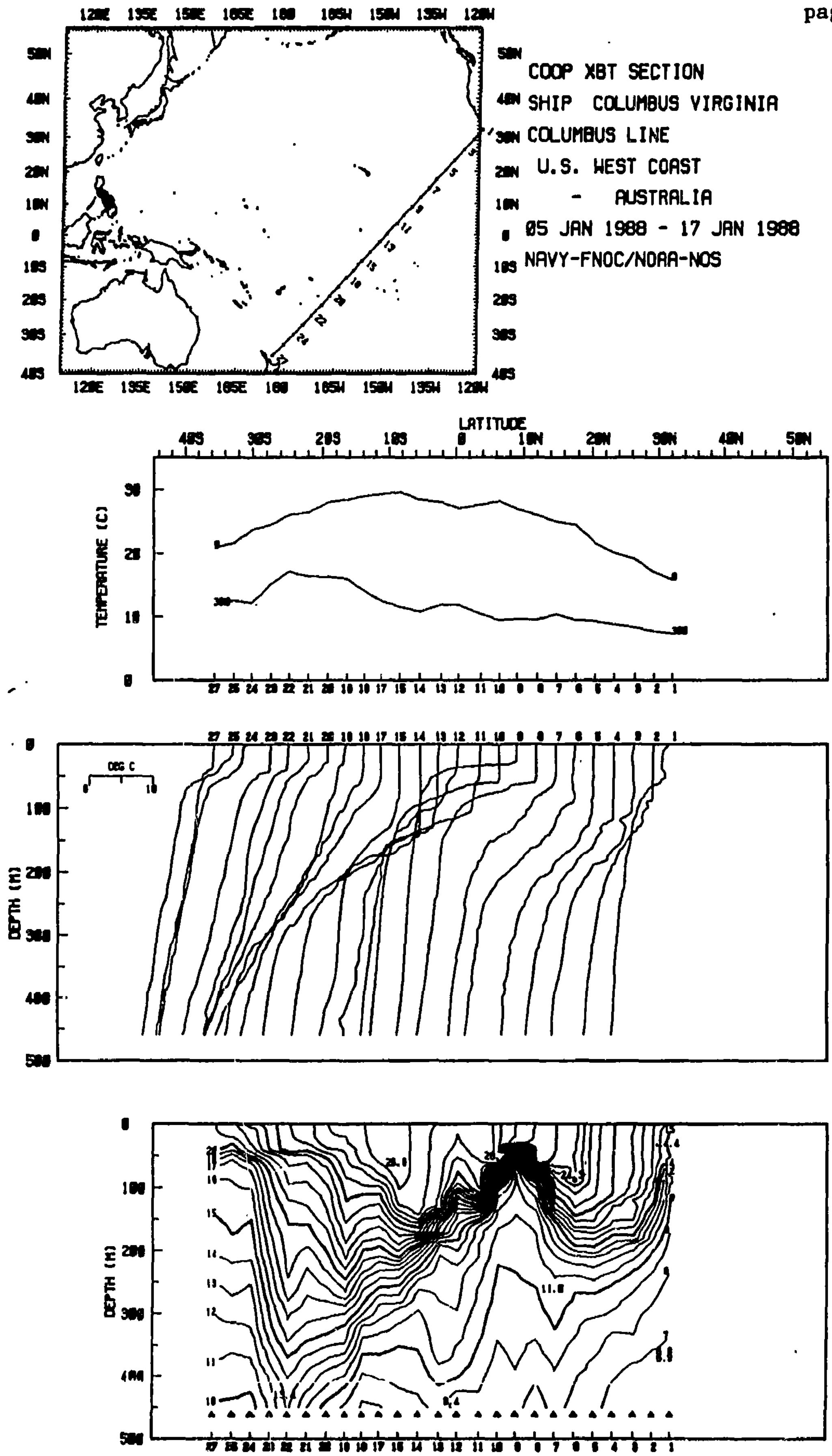
SOUTH AFRICA
- U.S. COAST
29 JUN 1988 - 01 JUL 1988
NAVY-FNOC/NOAA-NOS





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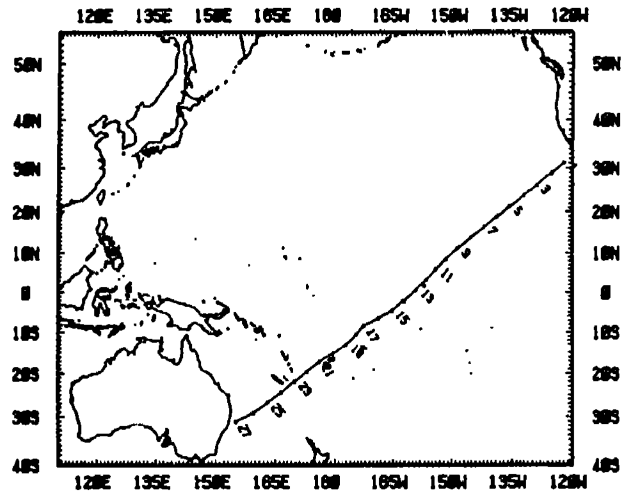
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
05 JAN 1988 - 17 JAN 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C



COOP XBT SECTION
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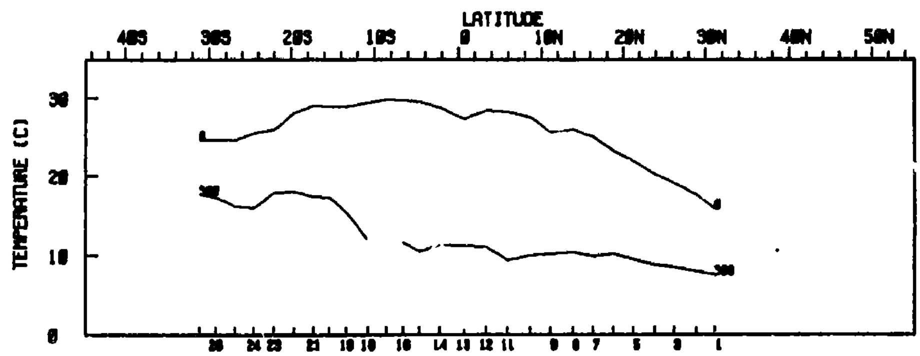
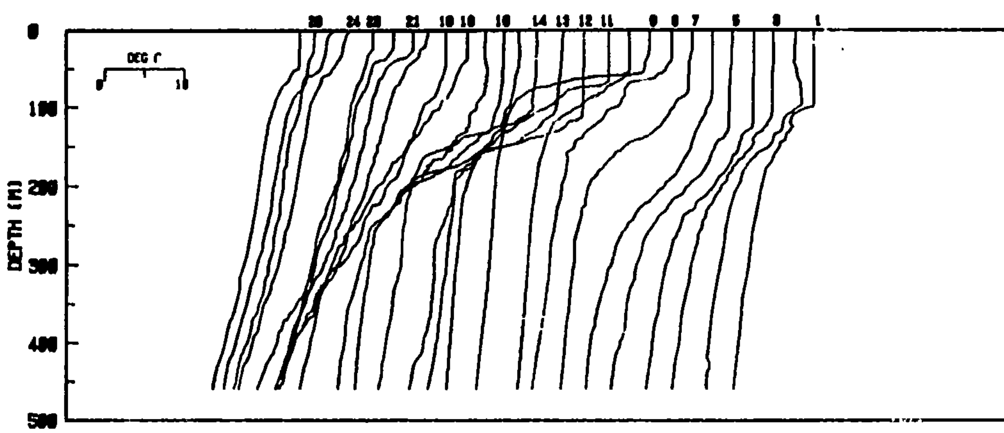
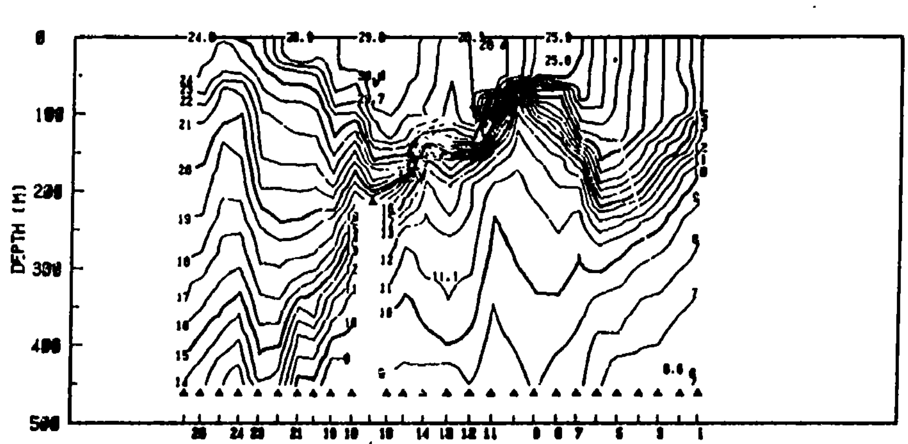
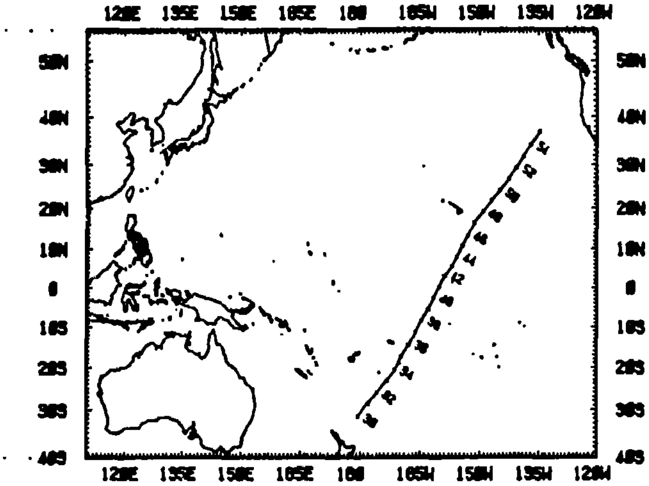
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
13 JAN 1988 - 26 JAN 1988
NAVY-FNOC/NOAA-NOS









COOP XBT SECTION
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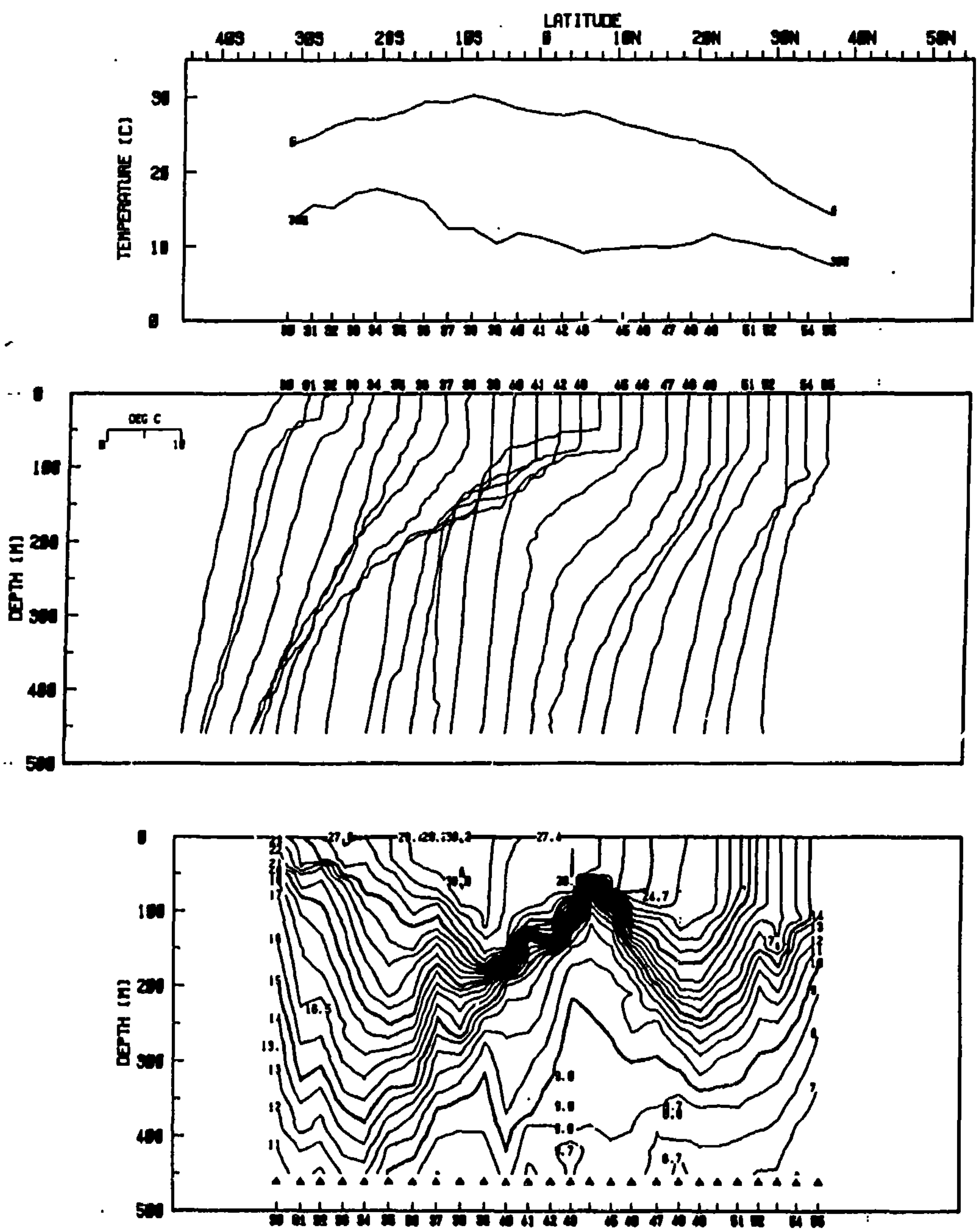
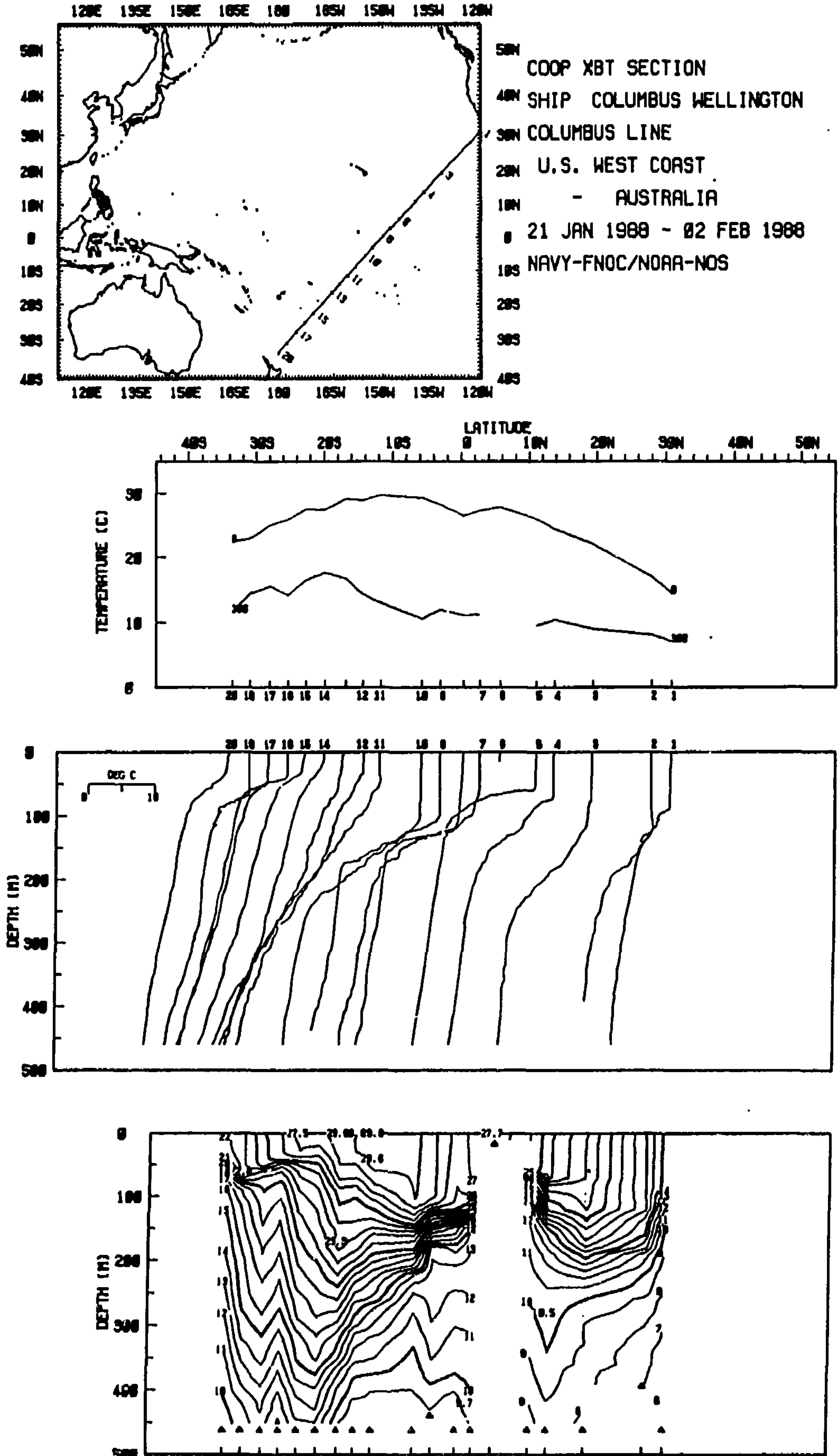
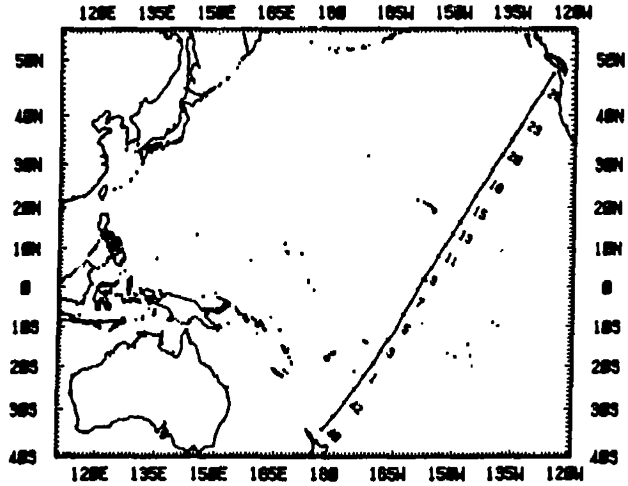
COLUMBUS LINE
AUSTRALIA
- U.S. WEST COAST
19 JAN 1988 - 31 JAN 1988
NAVY-FNOC/NOAA-NOS




COOP XBT SECTION
SHIP COLUMBUS WELLINGTON
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
21 JAN 1988 - 02 FEB 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C



COOP XBT SECTION
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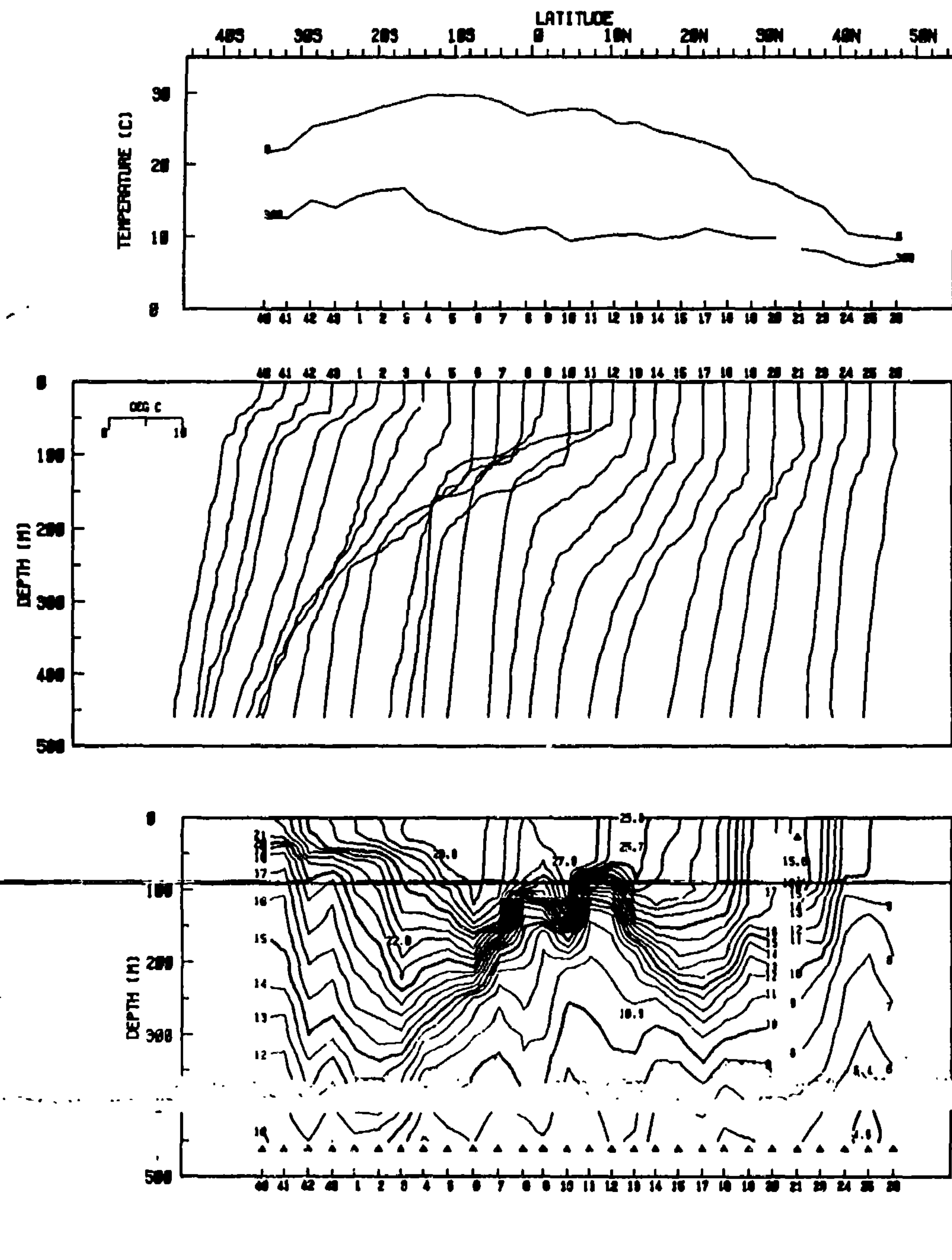
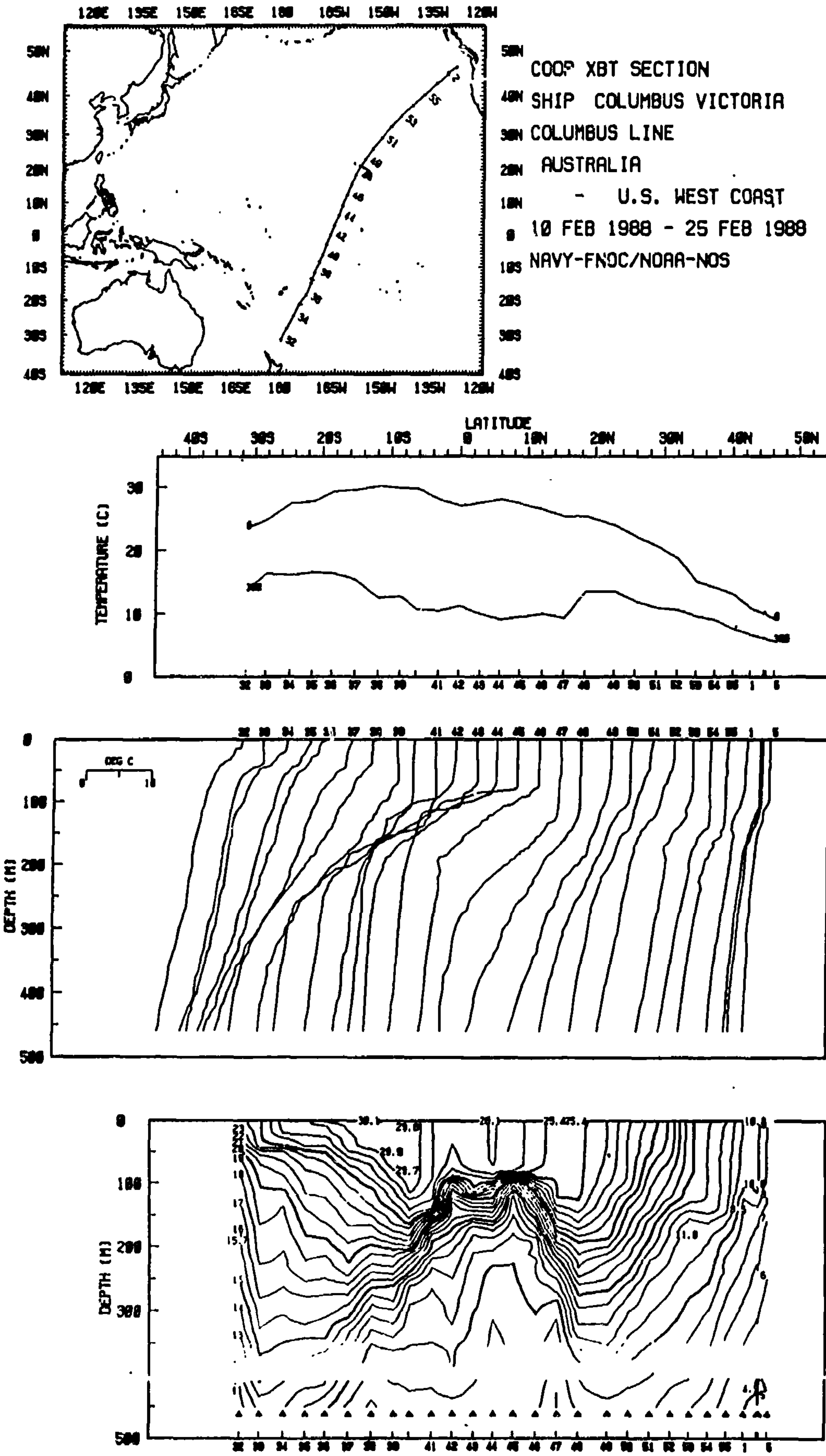
COLUMBUS LINE
AUSTRALIA
- U.S. WEST COAST
03 FEB 1988 - 17 FEB 1988
NAVY-FNOC/NOAA-NOS

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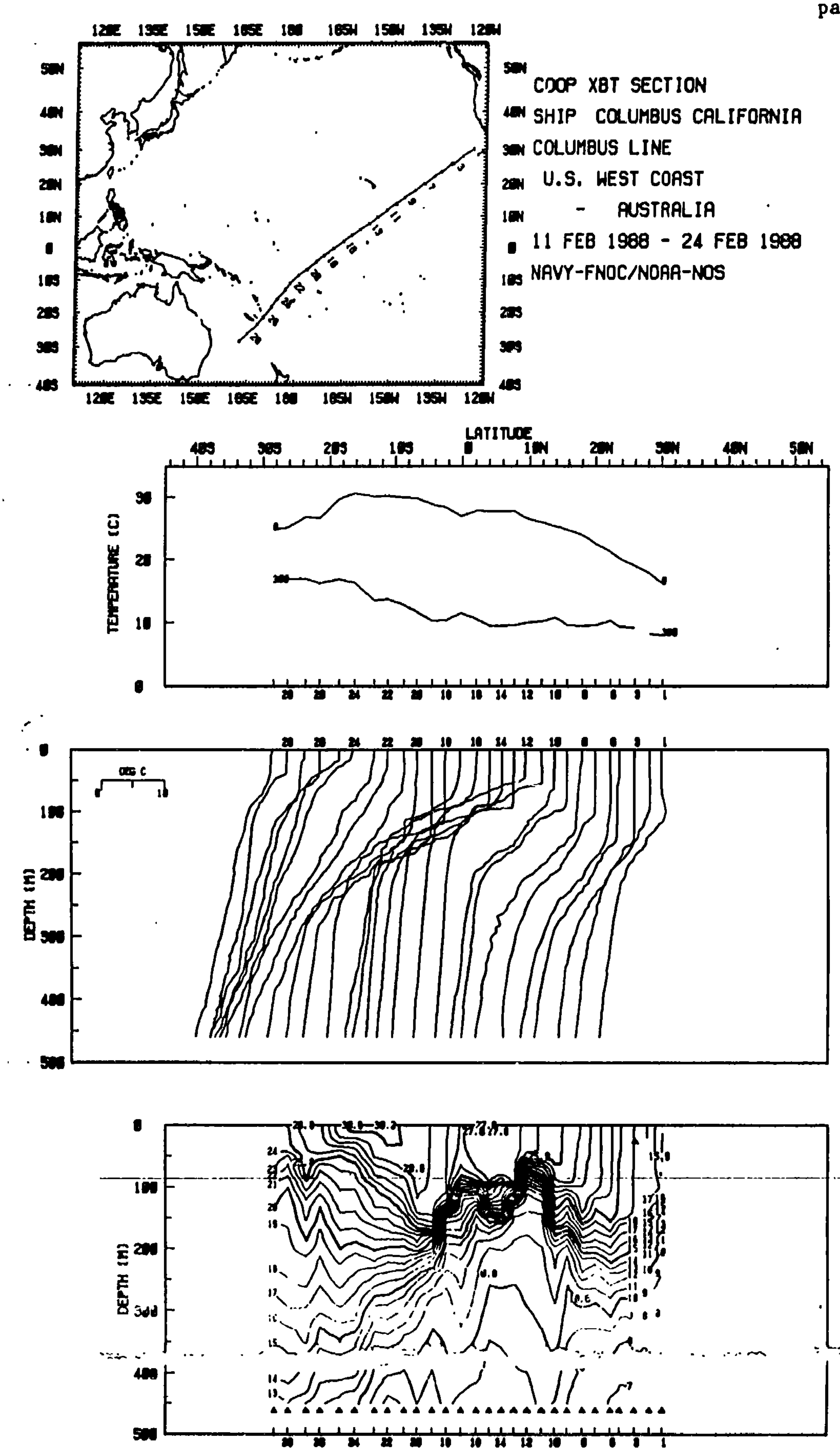
COLUMBUS LINE
AUSTRALIA
- U.S. WEST COAST
10 FEB 1988 - 25 FEB 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C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COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
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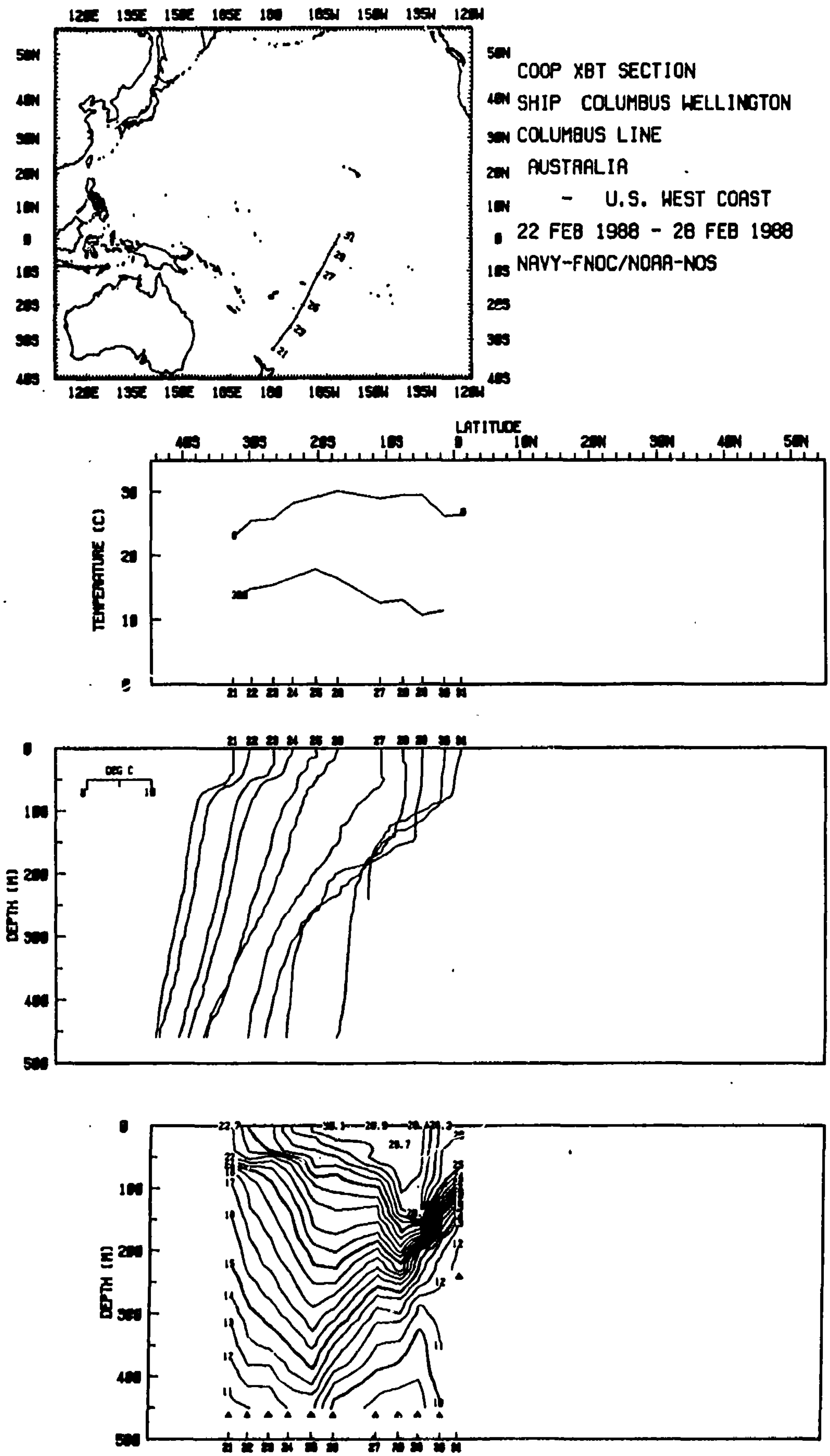
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C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COLUMBUS LINE
AUSTRALIA
- U.S. WEST COAST
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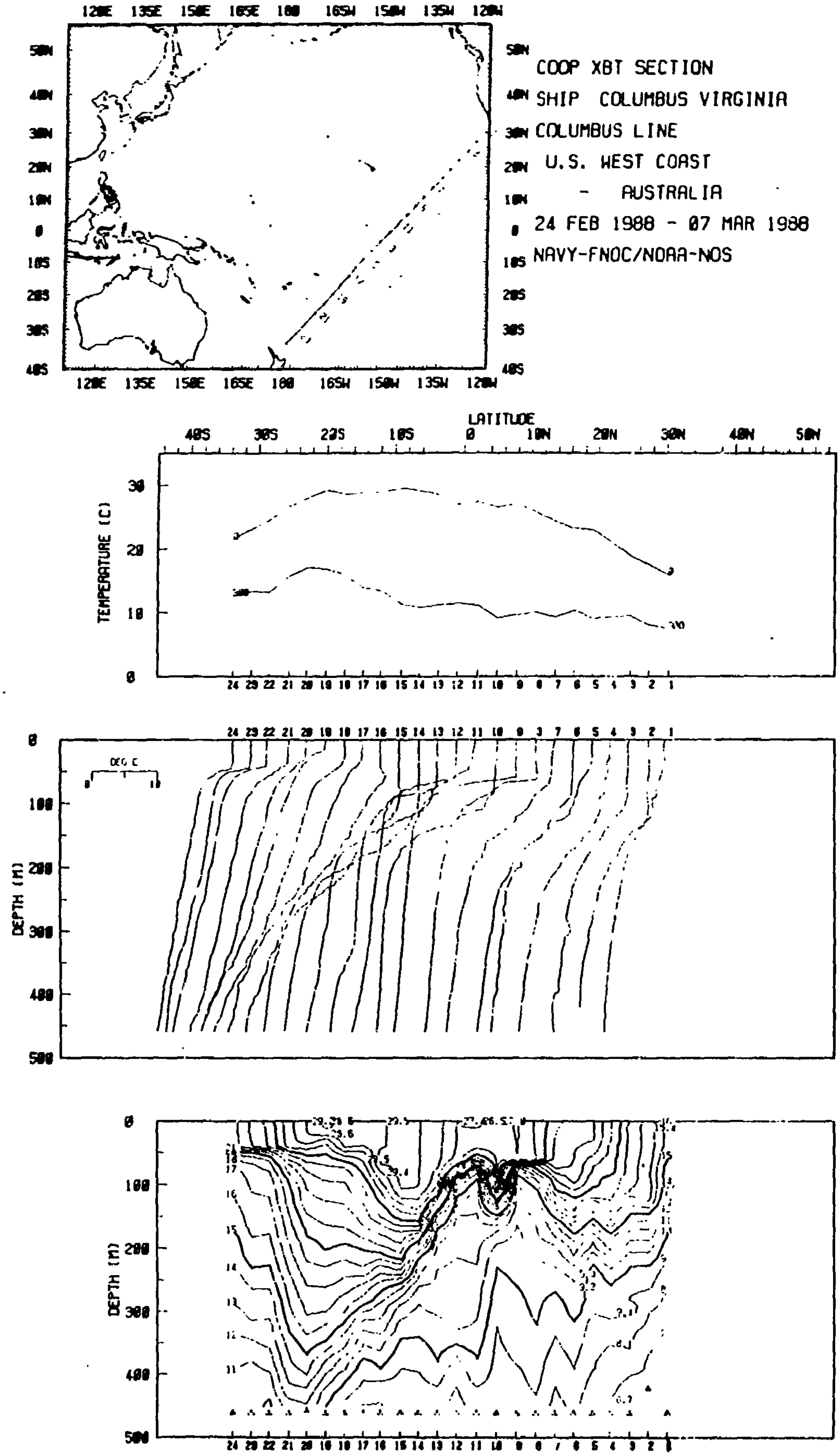
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C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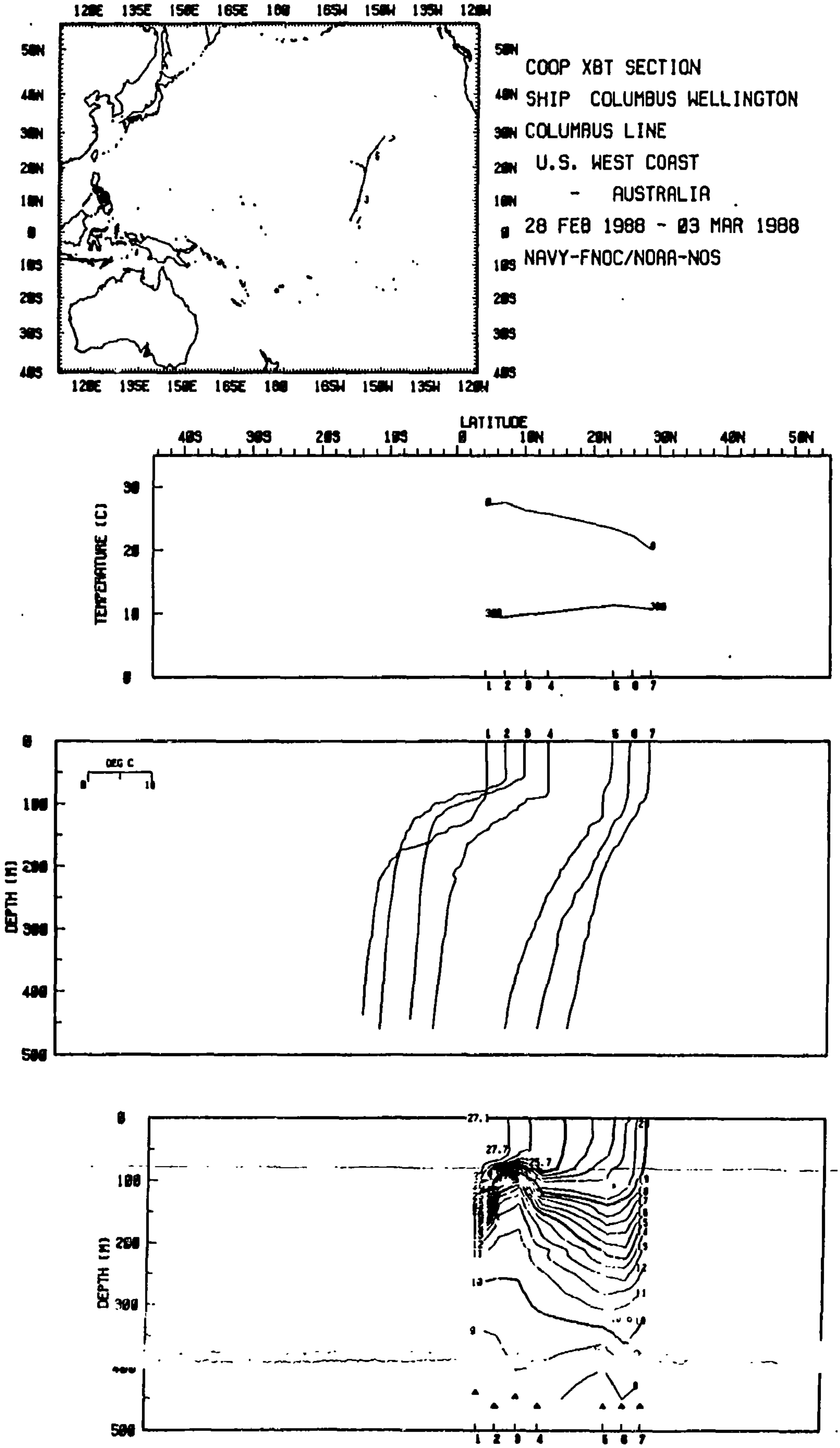
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
24 FEB 1988 - 07 MAR 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C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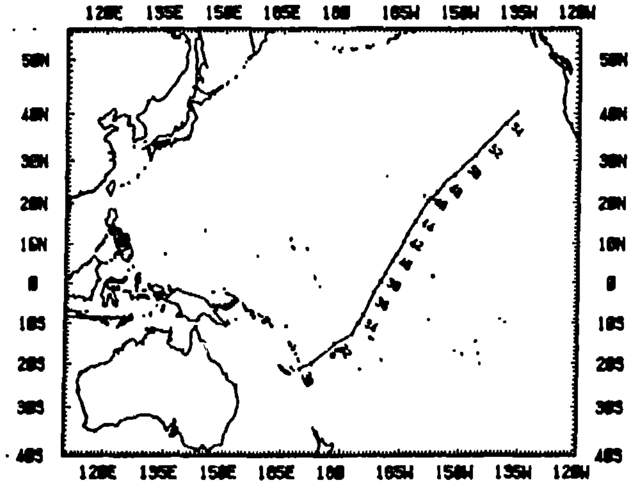
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
28 FEB 1988 - 03 MAR 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C



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COLUMBUS LINE
AUSTRALIA
- U.S. WEST COAST
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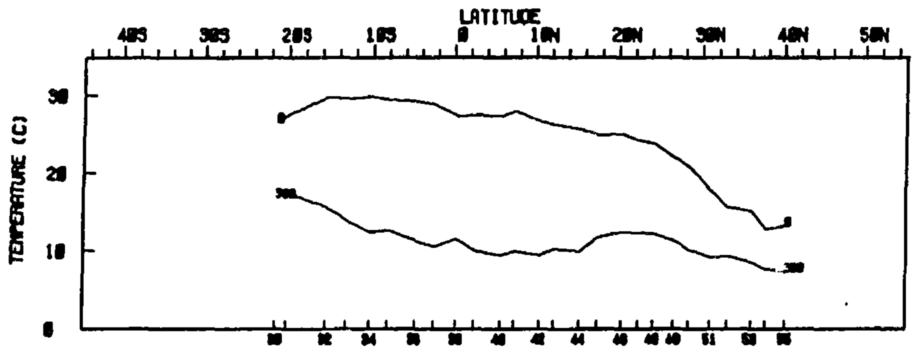
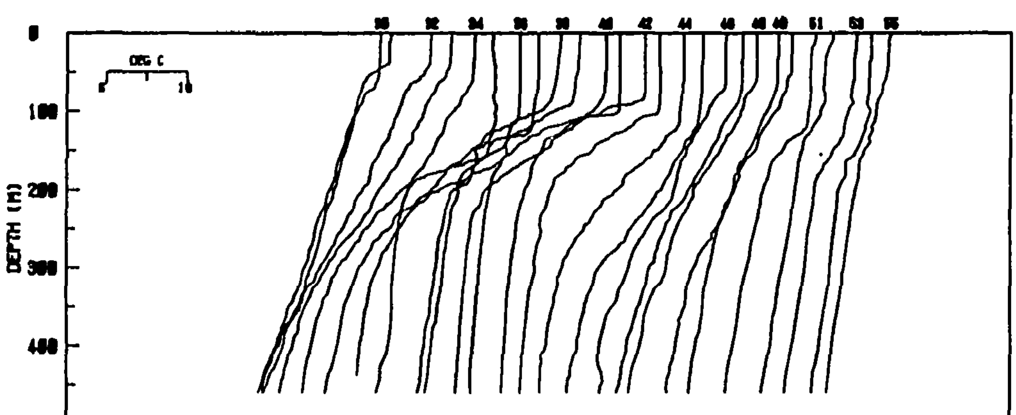
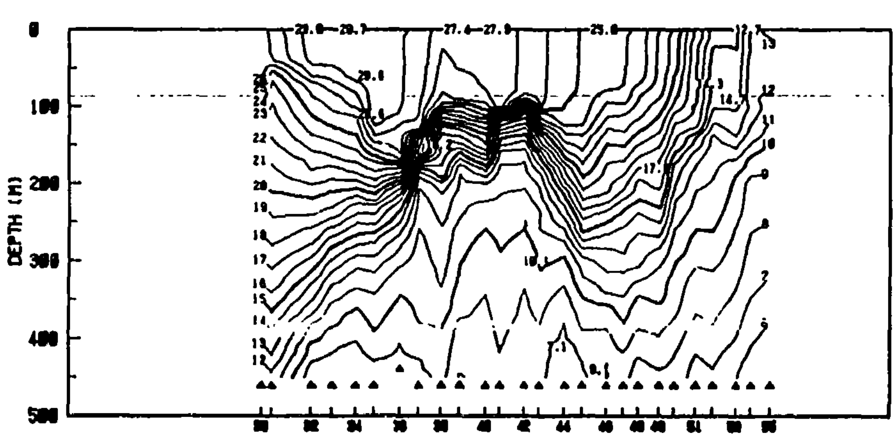
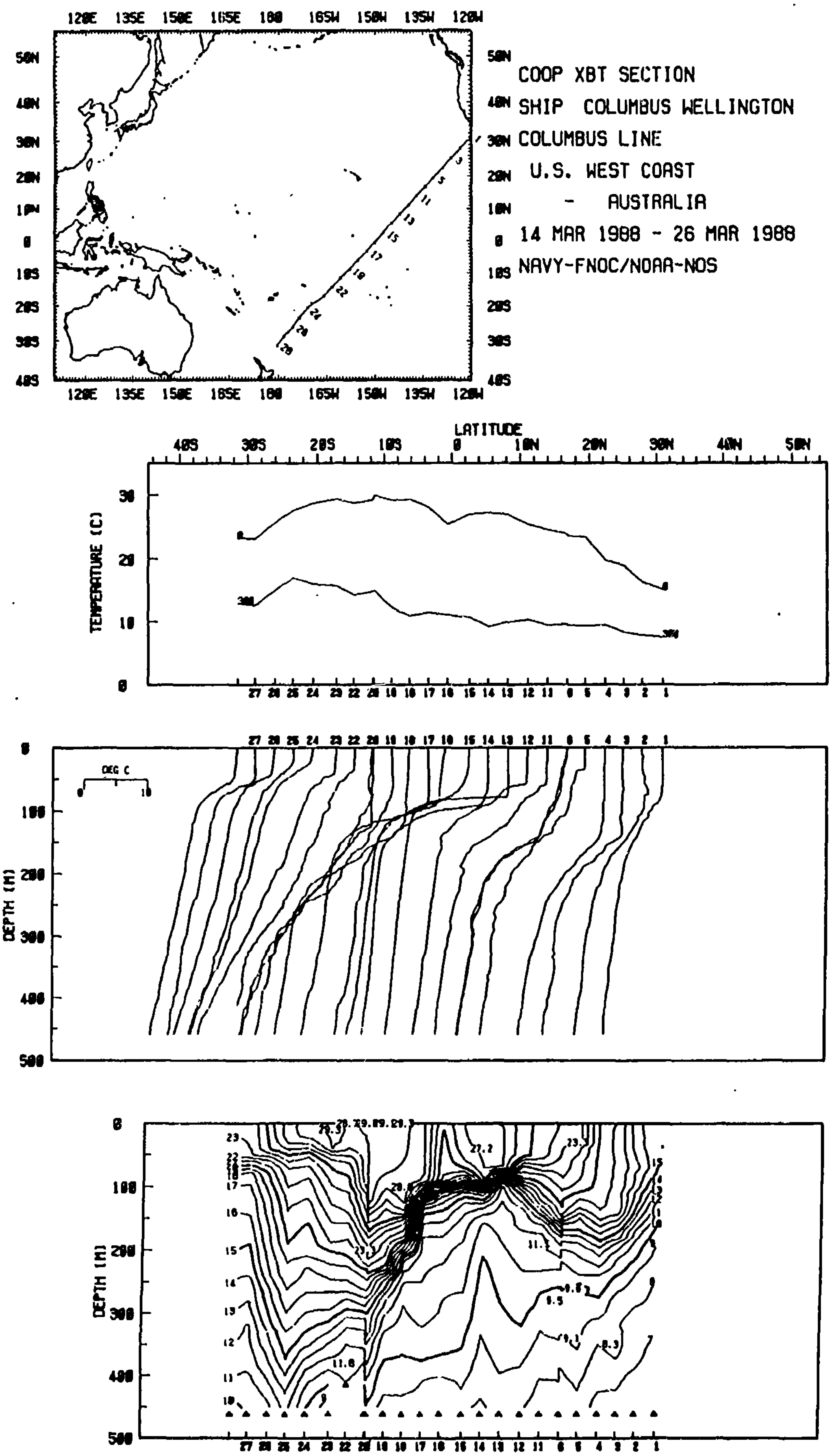
NAVY-FNOC/NOAA-NOS





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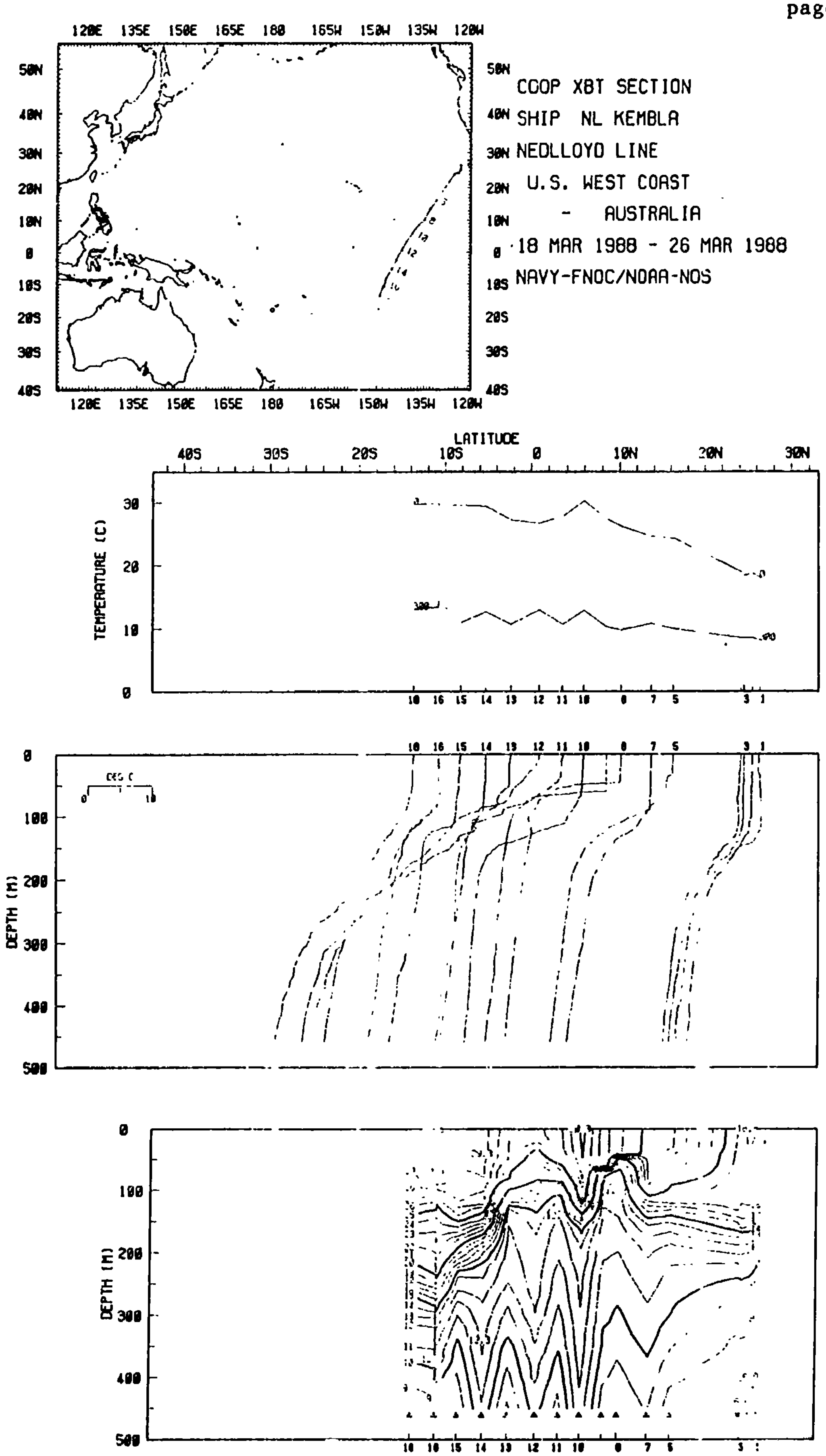
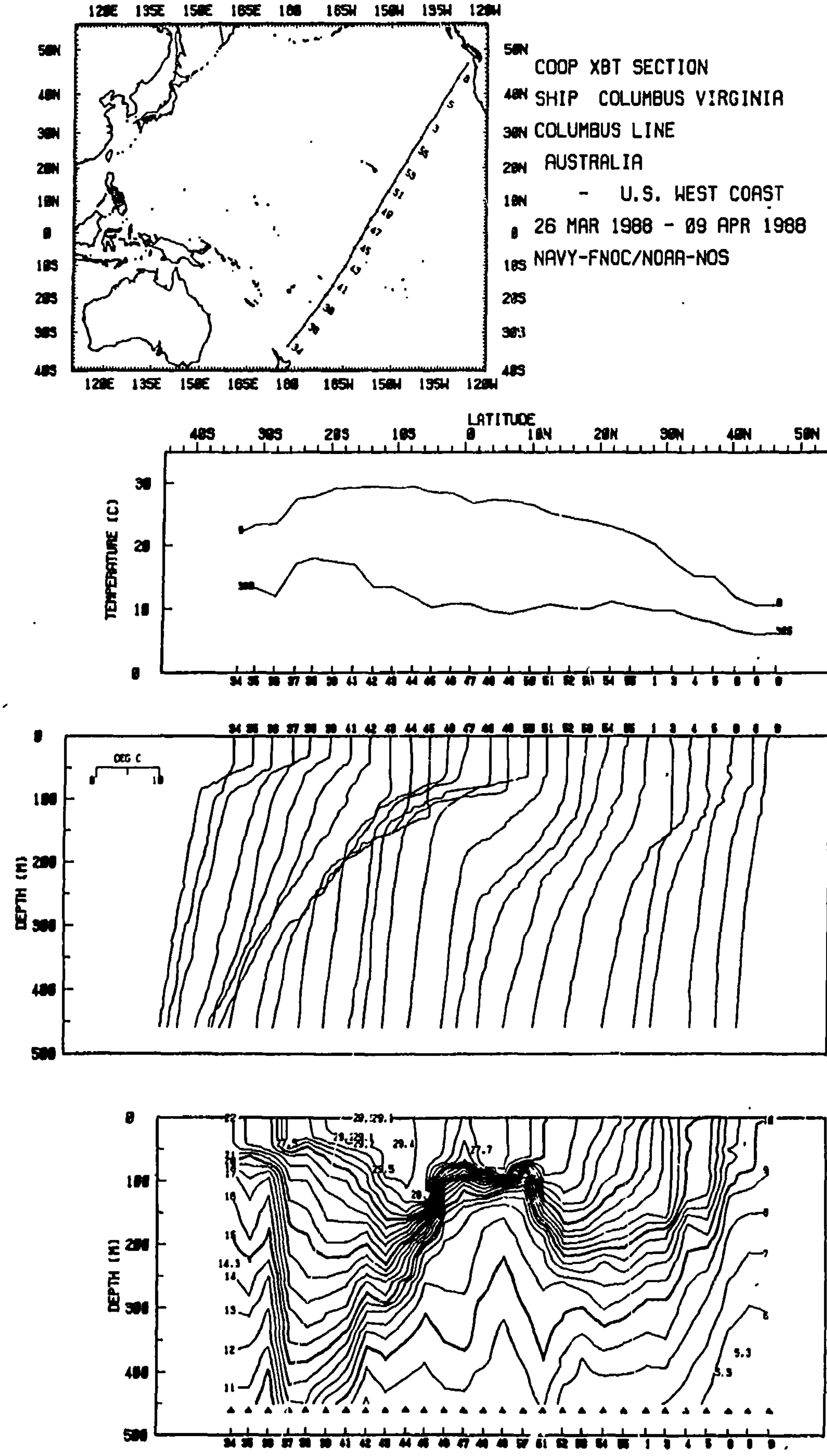
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
14 MAR 1988 - 26 MAR 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C
DEPTH (M)


COOP XBT SECTION
SHIP NL KEMBLA
NEDLLOYD LINE
U.S. WEST COAST
- AUSTRALIA
18 MAR 1988 - 26 MAR 1988
NAVY-FNOC/NOAA-NOS
120E 135E 150E 165E 180 165W 150W 135W 120W
50N 40N 30N 20N 10N 0 10S 20S 30S 40S
LATITUDE
40S 30S 20S 10S 0 10N 20N 30N
TEMPERATURE (C)
DEPTH (M)
DEG C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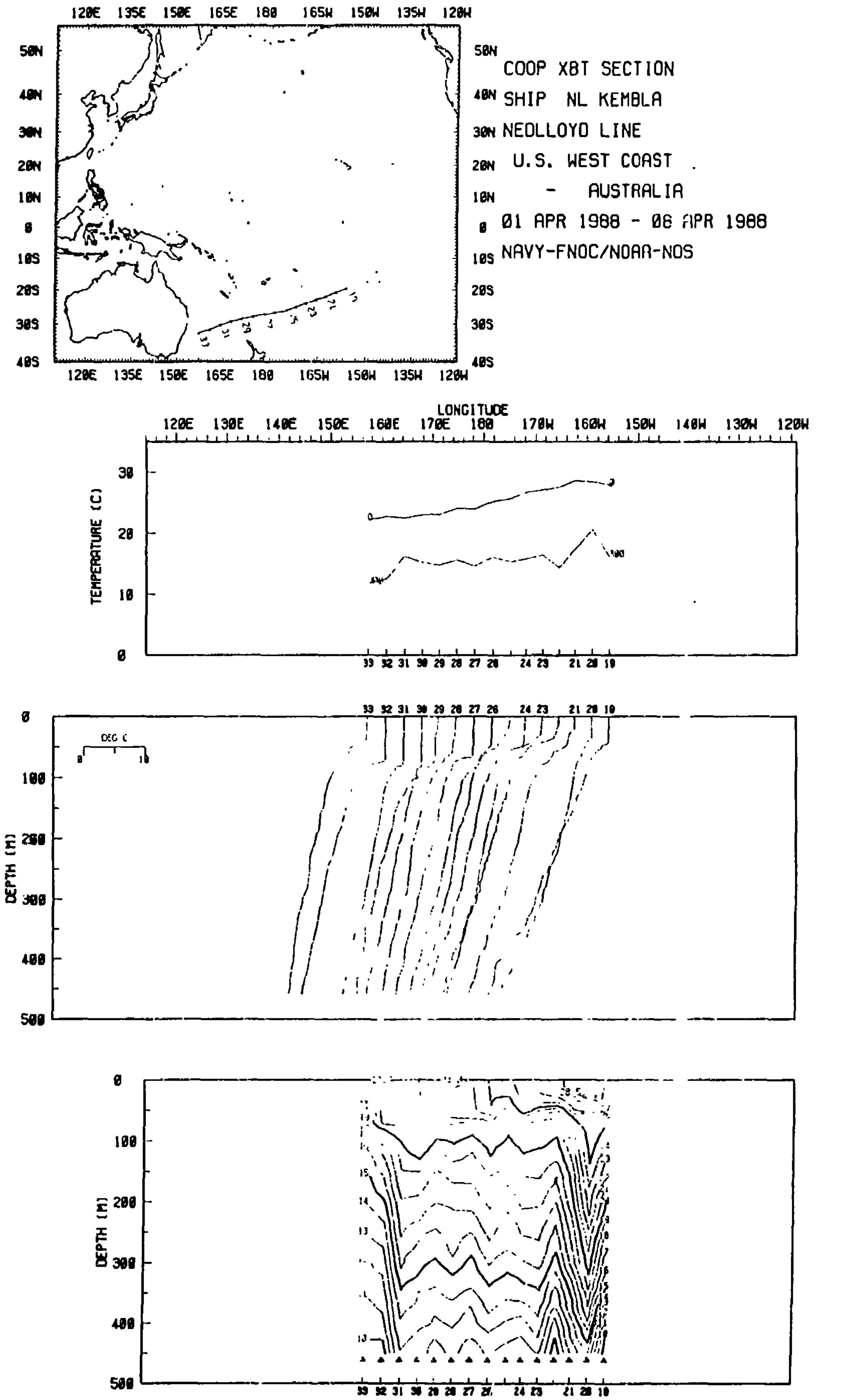
SHIP COLUMBUS VIRGINIA
COLUMBUS LINE
AUSTRALIA
- U.S. WEST COAST
26 MAR 1988 - 09 APR 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C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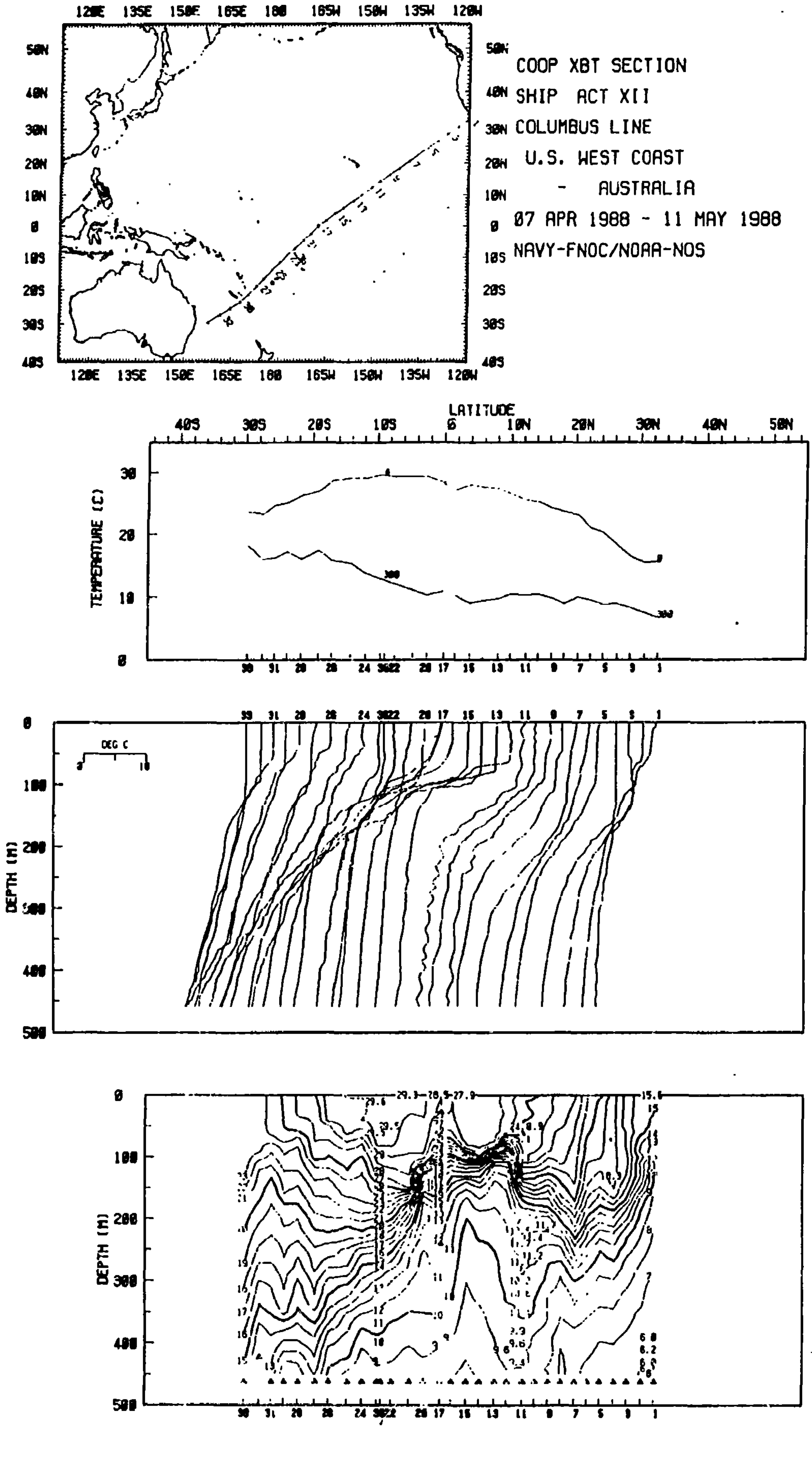
SHIP NL KEMBLA
NEDLLOYD LINE
U.S. WEST COAST
- AUSTRALIA
01 APR 1988 - 06 APR 1988
NAVY-FNOC/NOAA-NOS
LONGITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C


COOP XBT SECTION
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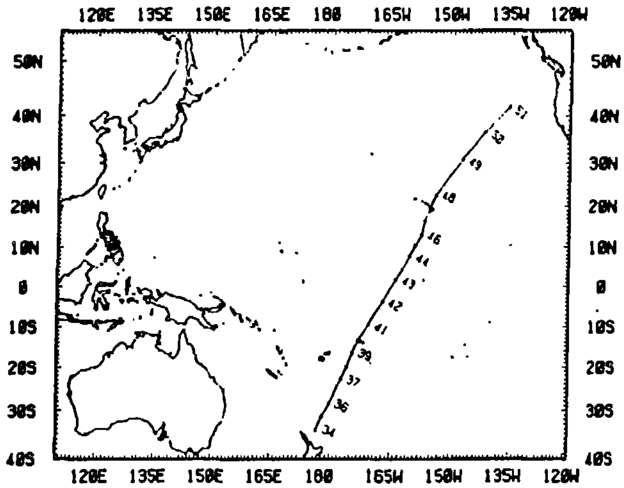
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
07 APR 1988 - 11 MAY 1988
NAVY-FNOC/NOAA-NOS
LATITUDE
TEMPERATURE (C)
DEPTH (M)
DEG C



COOP XBT SECTION
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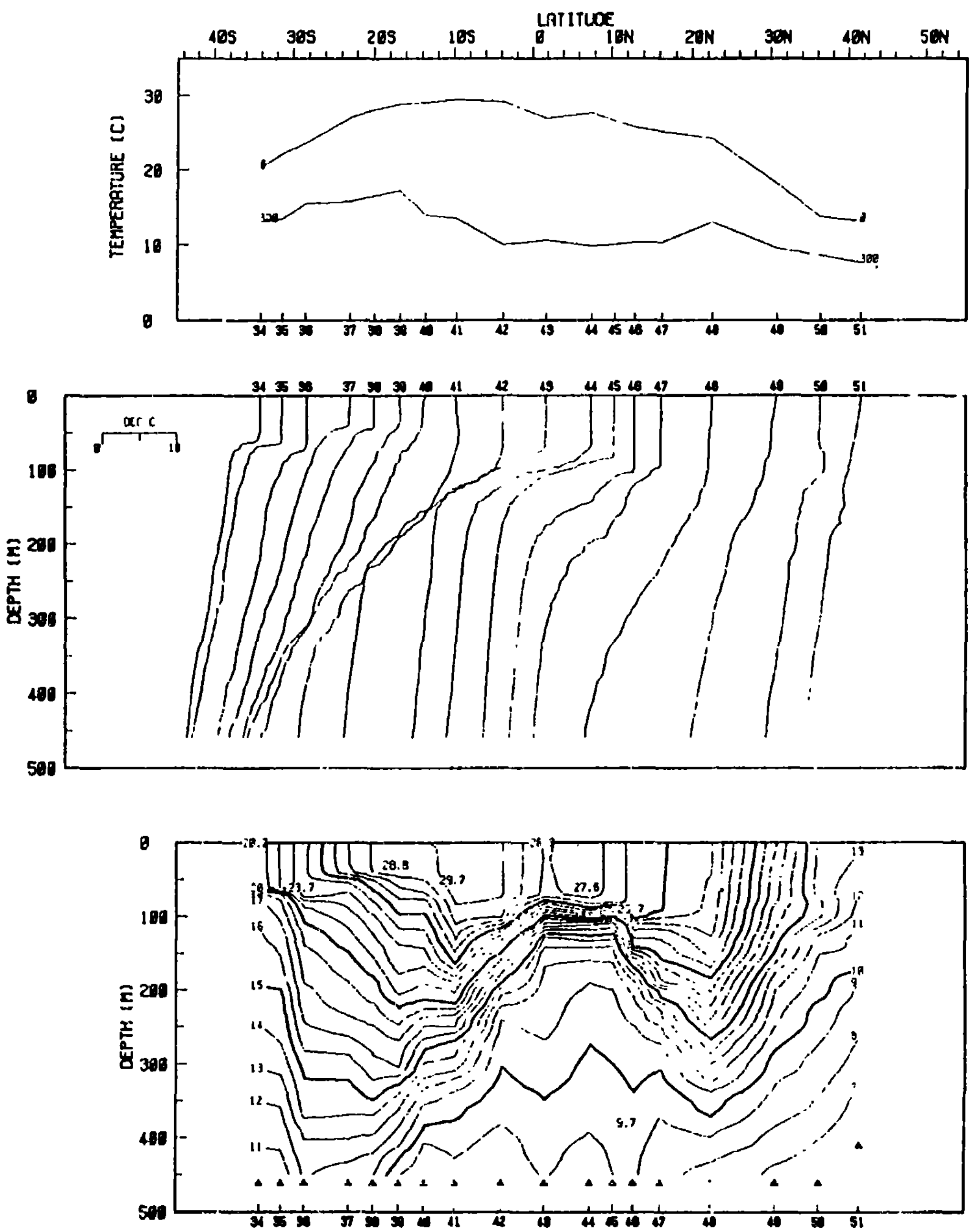
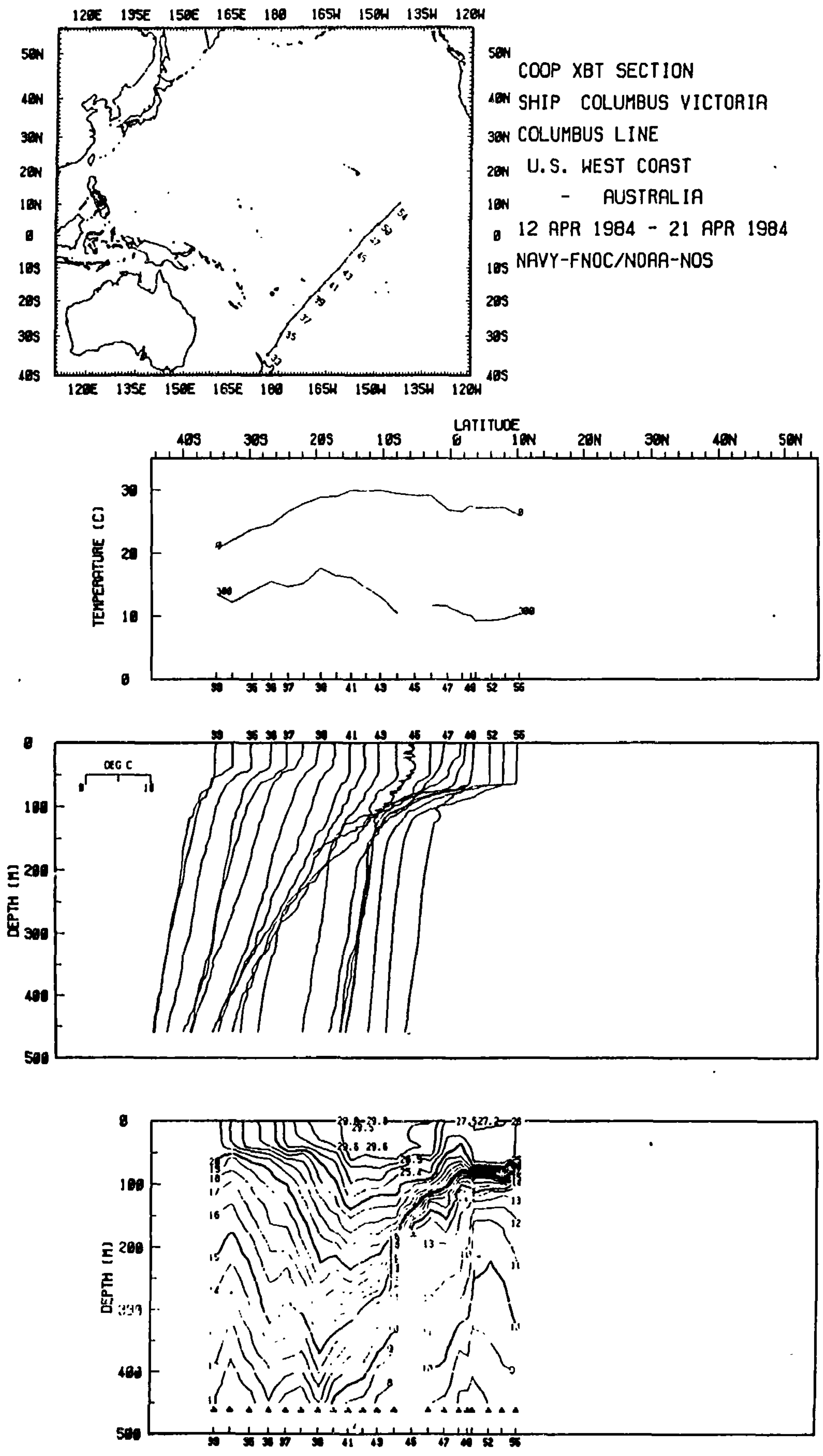
AUSTRALIA
- U.S. WEST COAST
11 APR 1988 - 25 APR 1988
NAVY-FNOC/NOAA-NOS




COOP XBT SECTION
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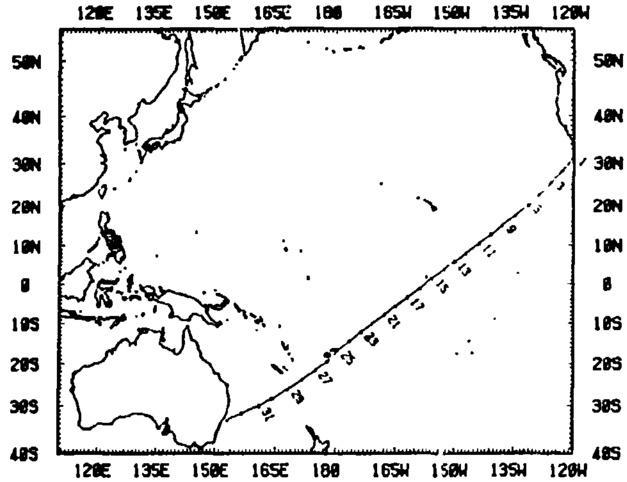
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
12 APR 1984 - 21 APR 1984
NAVY-FNOC/NOAA-NOS
120E 135E 150E 165E 180 165W 150W 135W 120W
50N 40N 30N 20N 10N 0 10S 20S 30S 40S
LATITUDE
40S 30S 20S 10S 0 10N 20N 30N 40N 50N
TEMPERATURE (C)
DEPTH (M)
DEG C



COOP XBT SECTION
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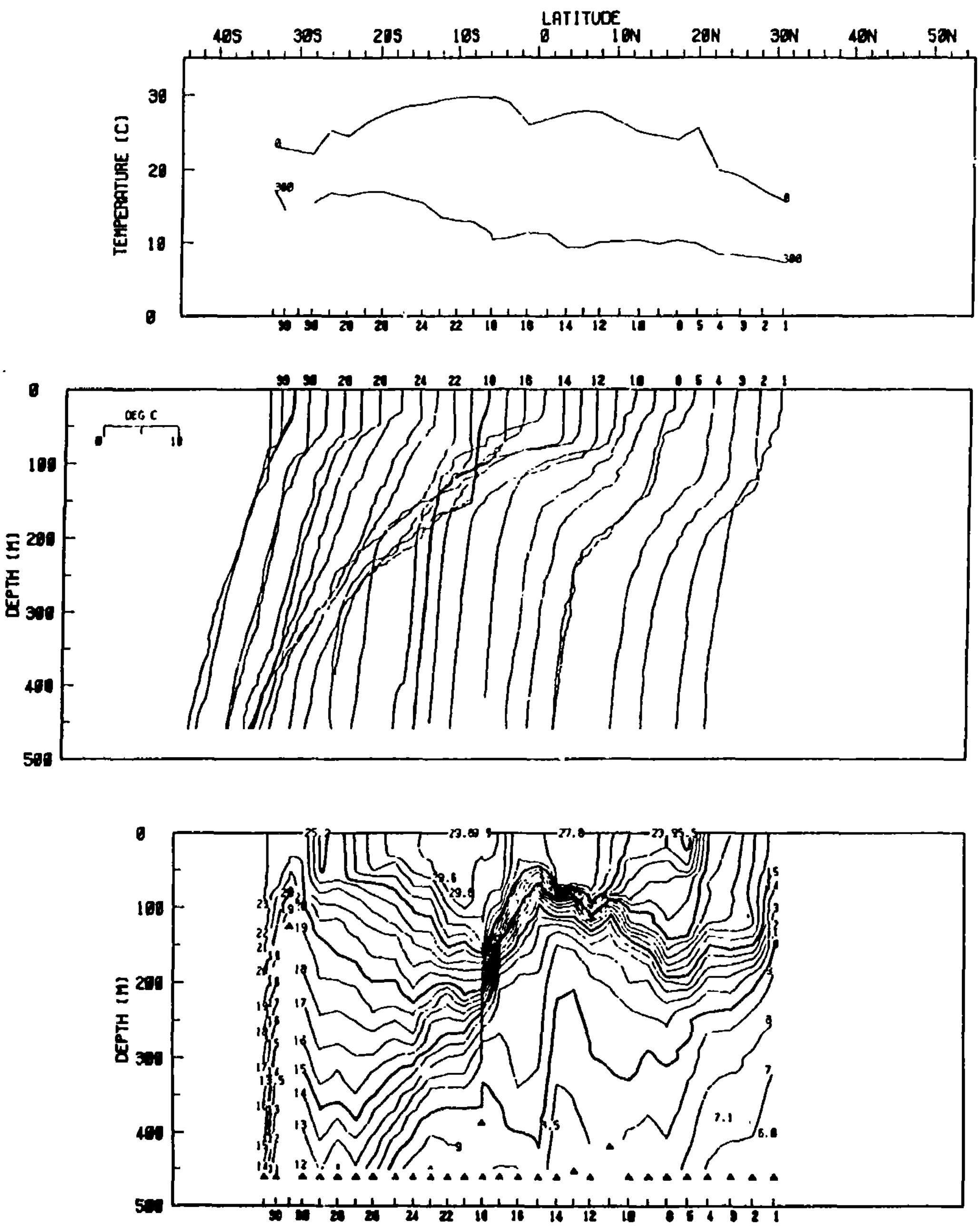
COLUMBUS LINE
U.S. WEST COAST
- AUSTRALIA
15 APR 1988 - 29 APR 1988
NAVY-FNOC/NOAA-NOS



TECHNICAL REPORTS

FIELD EVALUATION OF REAL-TIME XBT SYSTEMS

M. Szabados and D. Wright, NOAA/NOS, USA

INTRODUCTION

The use of XBT's to measure the ocean's subsurface temperature has significantly increased over the past decade. NOAA is actively participating in an international effort to increase the number of subsurface temperature observations in support of global oceanographic and climate studies. NOAA's XBT program currently supports more than one hundred voluntary observing ships (VOS). These vessels are responsible for more than 12,000 XBT observations each year. Determining the field performance of XBT data systems is an importance step in the quality control of these data. The purpose of this field test was to evaluate the performance of four XBT systems under field conditions. The systems evaluated were a SEAS III (Sippican's MK-9), a Bathy Systems' 810 XBT Controller, an ARGOS XBT system, and Oregon State University's (OSU) XBT Data Box. In addition, the capability of both the ARGOS and GOES satellite systems to transmit XBT data in the JJXX format were evaluated. The SEAS III and ARGOS systems were used to evaluate the satellite transmission process for GOES and ARGOS respectively.

METHODS AND PROCEDURES

All XBT data were evaluated relative to a field standard. The field standard used was a Neil-Brown Instrument Systems Mark III CTD. Each XBT system and the Neil-Brown CTD were calibrated before and after the test. A decade box and XBT test canister were used to evaluate the XBT systems over a range of eleven resistance (temperature) values. The results of the XBT calibration check are presented in Table 1. Initially the OSU system failed the calibration test at temperatures below 5 degrees Celsius. The system was returned to the manufacturer for adjustments. The values from the OSU system in Table 1 were taken from a second calibration check of the OSU system after adjustments were made by the manufacturer.

The XBT Field Evaluation took place on board the NOAA Ship WHITING during July 1988. The WHITING was participating in studies of the current and water mass structure in the Southwestern North Atlantic Ocean in the context of the Subtropical Atlantic Climate Studies (STACS) Program. The evaluation occurred during the Barbados-Barbados leg of the cruise when thirty-three CTD casts were taken. Station locations are shown in Figure 1. During each CTD cast, two XBT's were released from each system. One was released during the descent of the CTD and one was released during the ascent of the CTD. Each XBT system was set up for an XBT drop prior to the descent of the CTD. To minimize the influence of internal waves, XBT's were released from each system at the same time when the CTD was located in the thermocline. Similar procedures were repeated during the ascent of the CTD. XBT's released during the ascent of the CTD were used to help indicate the temporal variability of the thermal structure while on station. Only XBT's released during the descent of the CTD were used for the XBT-CTD comparison. A total of 250 XBT's were released during the evaluation. Of these, 126 were released during the descent of the CTD. Table 2 presents the total number and type of XBT probe released for each system during the descent of the CTD. No T-5 or T-10 probes were used with the OSU and ARGOS system since these systems were not programmed with the corresponding depth coefficients.

Table 1. XBT SYSTEM CALIBRATION CHECK
(Temperature in Degrees Celsius)

		XBT System Temp - Calibration temp			
Resistance	(Calibration Temp)	MK-9	BATHY	OSU	ARGOS
3193	(35.55)	0.00	-0.06	-0.05	**N/A
3350	(34.44)	-0.05	0.08	-0.08	**N/A
4024	(30.00)	0.02	0.13	-0.01	-0.03
5000	(25.00)	-0.01	0.08	-0.04	-0.06
6247	(20.00)	0.00	0.06	-0.05	-0.06
7274	(16.66)	0.01	0.05	-0.05	-0.06
9948	(10.00)	0.02	0.04	-0.05	-0.06
12679	(5.00)	0.03	0.04	-0.02	-0.03
16329	(0.00)	0.01	0.00	-0.05	-0.06
17287	(-1.10)	0.00	0.01	-0.06	-0.07
18094	(-2.00)	0.01	0.00	-0.04	-0.05

** - The ARGOS system does not handle temperatures in these two ranges.

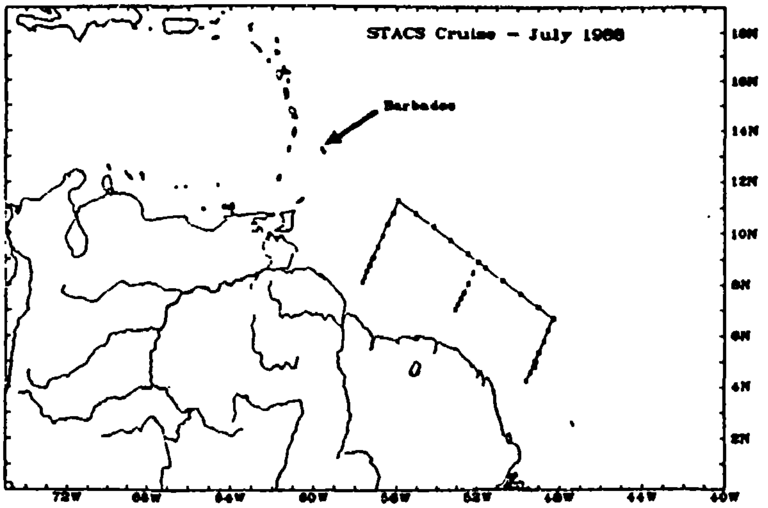


Figure 1. Cruise Track and XBT/CTD Stations

Table 2. PROBE TYPE AND NUMBER RELEASED FOR EACH XBT SYSTEM DURING DESCENT OF CTD

PROBE TYPE	MK-9	BATHY	OSU	ARGOS
T-10	7	7	0	0
T-7	7	7	7	7
T-6	7	7	15	15
T-5	5	5	0	0
T-4	7	7	8	8

Out of the 250 XBT's released, there were a total of five probe failures (2%). A summary of common XBT malfunctions is presented in Kroner and Blumenthal, 1978. The BATHY system had one probe failure, while the OSU and ARGOS systems each had two probe failures. Five software/system crashes occurred with the OSU system. These failures were attributed to incompatibility between the OSU software and the PC clone (televideo XL computer) used. All XBT data collected by the SEAS III and the ARGOS systems were transmitted in real-time contingent on available space in the satellite transmission window.

Before comparing the XBT data to the CTD data, XBT depth-temperature pairs were computed using a linear interpolation scheme so as to have the XBT depth coincide with the CTD depth. Except for the profile plots comparing the XBT and CTD traces, analysis was based on the interpolated XBT data.

RESULTS

Several factors must be considered in the evaluation of XBT - CTD temperature comparisons. Some of the important factors are the methods used to determine the depth of the XBT and the CTD, thermistor errors, and environmental factors such as the stability of the water column. Differences between a temperature measured by the CTD and an XBT can in part be attributed to the computation of the XBT probe depth. The depth of the XBT is determined by using a depth equation based on the fall rate of the probe, while the CTD depth is measured using a pressure transducer. In addition, the XBT descends at a faster rate than the CTD (6.5 m/sec, XBT; 0.5 m/sec, CTD). The XBT and CTD will therefore measure temperature simultaneously at the same depth and time only once. Any changes in the thermal structure of the water column during the descent of the CTD due to internal waves will appear as a temperature difference between the CTD and XBT. Temperature differences between an XBT system and the CTD can also be attributed to the individual thermistor in each XBT probe. While each XBT system and the CTD thermistor were calibrated, the actual thermistor in each XBT probe were not.

The mean of the absolute temperature difference between the CTD and each XBT system over the total XBT profile for each probe type is provided in Table 3. These results show differences greater than the +/- 0.15 degree Celsius specification for XBT probes. To interpret these results it is important to identify the factors which contribute to these differences between the XBT and CTD measurements.

Table 3. MEAN OF THE ABSOLUTE DIFFERENCE BETWEEN THE XBT AND CTD TEMPERATURE (Degrees Celsius)

SYSTEM	Probe Type: T-04 Mean	T-04 SD	T-05 Mean	T-05 SD	T-06 Mean	T-06 SD	T-07 Mean	T-07 SD	T-10 Mean	T-10 SD
MK-9	.36	.14	.11	.06	.33	.13	.34	.24	.30	.21
BATHY	.30	.15	.24	.17	.26	.11	.30	.19	.33	.18
OSU	.19	.19			.14	.06	.18	.07		
ARGOS	.38	.22			.39	.11	.42	.33		

To isolate the contributions of the XBT thermistor error to the results shown in Table 3, temperature differences in the isothermal portion of the mixed layers were analyzed. This was done because temperature differences due to depth errors, instrument response, and internal waves would be minimized by these conditions. Thus, as shown in Table 4, when comparing only temperatures in the isothermal portion of the mixed layers, the temperature difference between the CTD and all four systems was reduced by an order of magnitude. The mean departure of the XBT temperature from that of the CTD is well within the XBT specifications. These results also agree well with the XBT system calibration check in Table 1.

Table 4. MEAN TEMPERATURE DIFFERENCES BETWEEN THE XBT AND CTD IN THE MIXED LAYERS (DEGREES CELSIUS)

SYSTEM	MEAN	STANDARD DEVIATION
MK-9	.029	.046
BATHY	.106	.064
OSU	-.074	.083
ARGOS	.016	.055

Errors in XBT depth can also contribute to the differences found between the XBT and CTD temperatures. The temperature profiles in Figure 2 show a depth offset between the XBT and CTD data. To determine the associated XBT temperature error due to an offset in XBT depth, the XBT data was shifted in depth to find a best fit with the CTD data. A best fit of the XBT profile to the CTD was found by shifting the XBT data in 50 meter segments by one-meter increments up and down until the least mean difference between the XBT and CTD temperatures was determined. The depth error was then

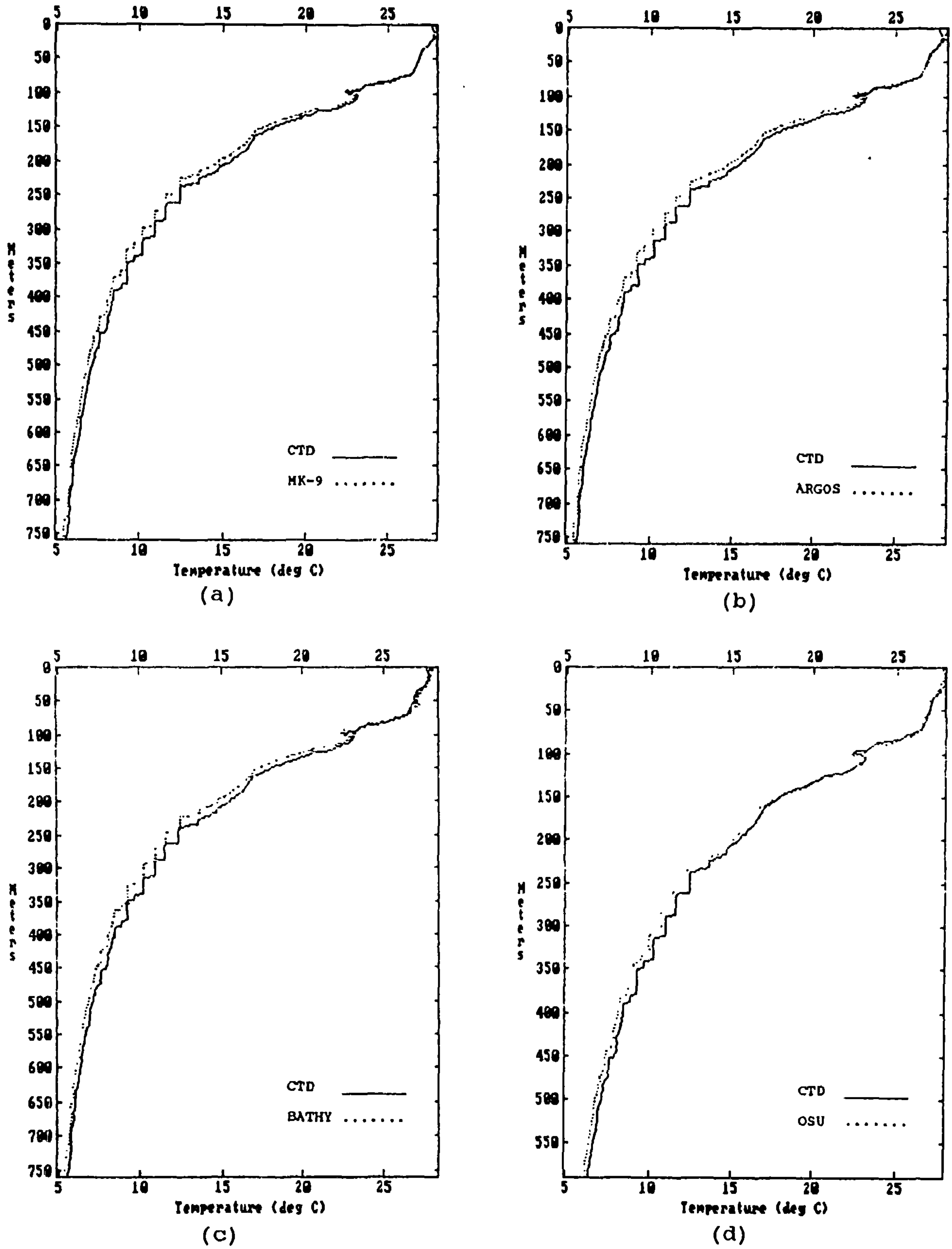


Figure 2. XBT - CTD Temperature Profiles, XBT Drop 25.
(a) MK-9 (b) ARGOS (c) BATHY (d) OSU

computed from how many meters the original XBT data was moved to best fit the CTD data. Table 5 provides a sample output from this analysis. As is shown in Table 5, by shifting the XBT depth the temperature difference between the XBT and CTD can be reduced by an order of magnitude. The mean temperature difference with a depth correction agrees well with the temperature difference found in the mixed layers and those from the calibration check.

For each of the XBT systems, the mean depth error in 50 meter segments is shown in Figure 3 by probe type. While there appears to be some bias between different XBT systems, it is important to note that for all the XBT systems the depth error for probe types T-4, T-6, and T-7 show a similar trend. This trend indicates that these XBT probe types are falling at a faster rate than calculated by the XBT depth equation, using the standard coefficients. The standard depth equation and coefficients are provided in Table 6 (Sippican, 1973). Similarly, the T-10 probes are falling at a faster rate, while the T-5 probes are falling at the proper rate. The OSU system depth error, as shown in Figure 3, was less than the other systems. This resulted in a smaller temperature difference from the CTD data as was indicated in Table 3.

Table 5. BEST-FIT ANALYSIS

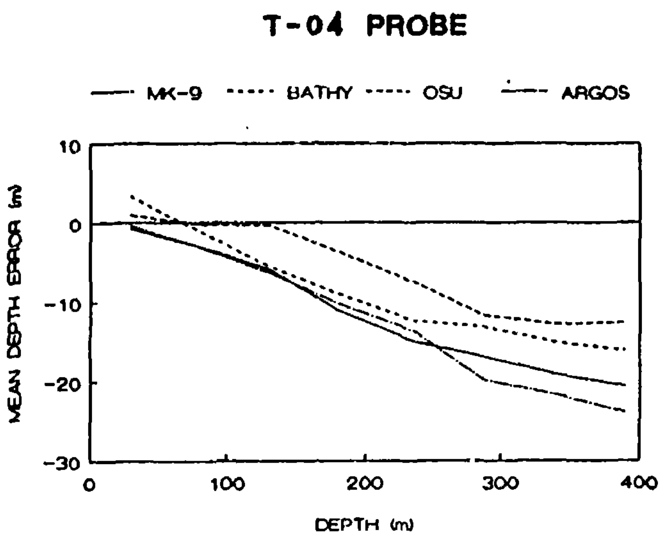
System type: MK-9 Drop Number 27 Probe Type T-07

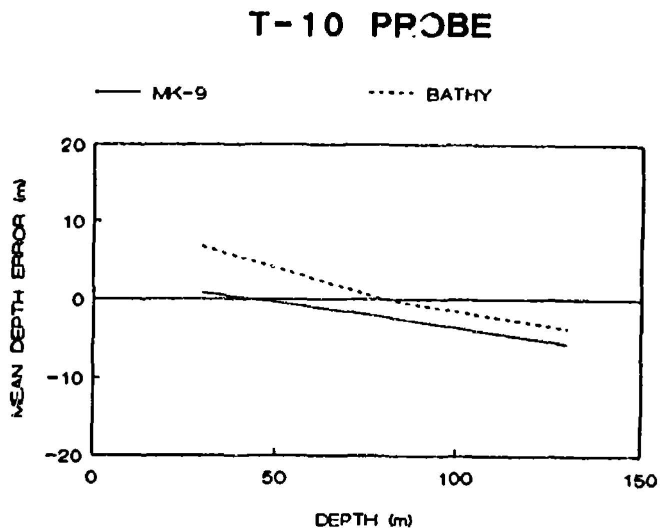
Depth Range (meters)	Depth Error (meters)	Mean Temp. Error w/ Depth Corrected (C)	Mean Temp. Error w/ Depth Uncorr. (C)
5.0 to 52.7	- 0.99	0.05 +/- 0.03	0.07 +/- 0.04
56.7 to 104.4	- 3.98	0.09 +/- 0.05	0.45 +/- 0.10
108.4 to 156.1	- 6.96	0.11 +/- 0.07	0.63 +/- 0.08
160.0 to 207.7	-10.93	0.05 +/- 0.05	0.62 +/- 0.10
211.7 to 259.4	-17.88	0.04 +/- 0.04	0.68 +/- 0.14
263.4 to 311.0	-19.86	0.02 +/- 0.03	0.49 +/- 0.10
315.0 to 362.7	-21.84	0.03 +/- 0.02	0.37 +/- 0.12
366.6 to 414.3	-24.82	0.03 +/- 0.02	0.48 +/- 0.07
418.2 to 465.9	-27.79	0.04 +/- 0.02	0.32 +/- 0.07
469.8 to 517.5	-30.76	0.04 +/- 0.02	0.32 +/- 0.03
521.4 to 569.0	-33.73	0.04 +/- 0.02	0.35 +/- 0.04
573.0 to 620.6	-41.65	0.03 +/- 0.02	0.35 +/- 0.02
624.6 to 672.2	-48.58	0.01 +/- 0.02	0.31 +/- 0.02
676.1 to 723.7	-49.56	0.03 +/- 0.02	0.22 +/- 0.02

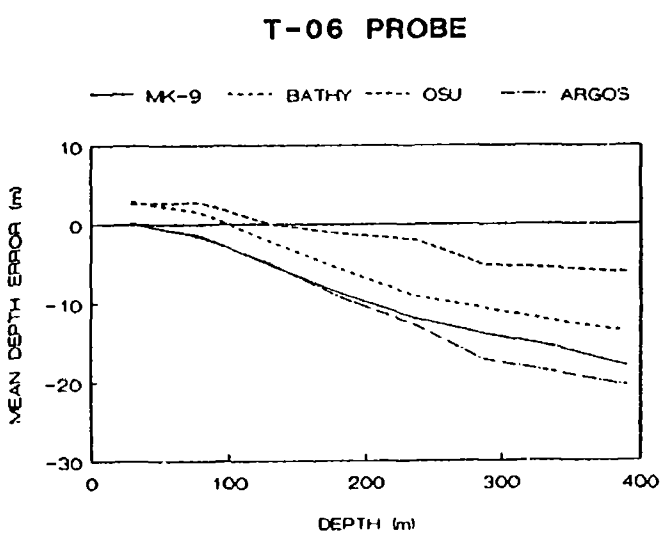
Table 6. STANDARD FORM OF THE DROP EQUATION

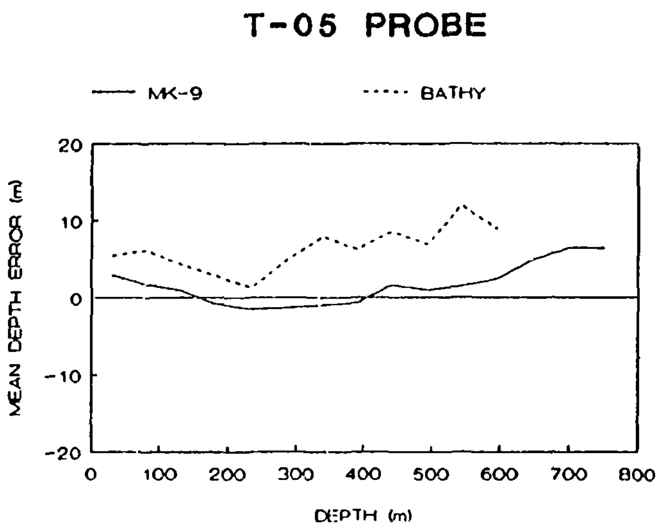
Probe type	Coefficients A	B
T-4	6.472	.00216
T-5	6.828	.00182
T-6	6.472	.00216
T-7	6.472	.00216
T-10	6.301	.00216

$Depth = A*T - B*T^2$ (meters)
T= sample rate * sample no.









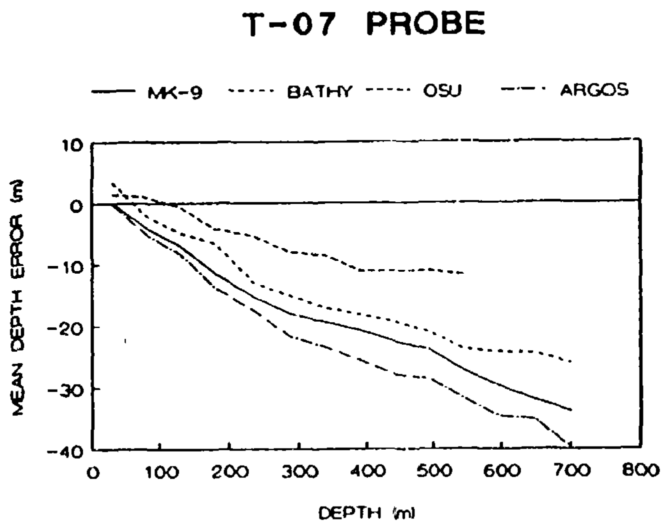


Figure 3. Mean XBT Depth Error

To determine if the XBT depth for the T-4, T-6, and T-7 probes could be corrected by modifying the coefficient in the depth equation, a regression analysis was employed to revise the coefficients using the MK-9 data. This was accomplished by first calculating what the sample interval would have to be to provide the correct depth as determined by the best fit analysis. This sample interval was found to be 0.105 seconds. The actual MK-9 sample interval is 0.1 seconds. The revised coefficients A' and B' were then determined by the following method:

$$A' = (6.472 * 0.105) / 0.1 = 6.796$$

$$B' = (0.00216 * (0.105)^2) / 0.01 = 0.00238$$

New temperature and depth pairs for the T-4, T-6, and T-7 probes using the revised coefficients were then computed. Scatter plots comparing the XBT and CTD using the standard and revised coefficients are presented in Figure 4. As shown in these plots the revised coefficients improve the agreement between the XBT and CTD temperature data. Using the same revised coefficients, the ARGOS and BATHY data had similar results. The temperature profiles that were shown in Figure 2 are replotted in Figure 5 using the revised coefficients. Most of the temperature errors associated with the depth offset (previously characterized by the temperature profiles in Figure 2) are now reduced or eliminated. The exception is the OSU XBT data which has better agreement with the CTD data using the standard coefficients.

To determine the temporal variability of the water column during the XBT-CTD comparison, XBT's were launched from each system during the ascent of the CTD. This provided a measure of the variability on the scale of one hour. Any variability on this time scale is likely a result of internal waves. While a few stations exhibited variability in the thermocline of about 10 meters, typically the variability was less than 2 meters. To quantitatively determine the influence of internal waves on the CTD - XBT comparison, several more XBT drops are required during the descent of the CTD. Although variability of the water column due to internal waves can influence the comparison between the XBT and CTD, it should be minimal since it takes approximately 16 minutes for the CTD to reach 500 meters.

The real-time transmission of XBT data is crucial to the optimum utilization of these data sets by the oceanographic and climatological communities. The alternative is retrospective data submission to national data archives which historically can take months, years or even worse never. During the field test the ARGOS and GOES satellite systems were evaluated for their XBT data transmission capability using the SEAS III and ARGOS XBT systems, respectively. For both these systems, data received was disseminated to the community on the Global Telecommunication System (GTS).

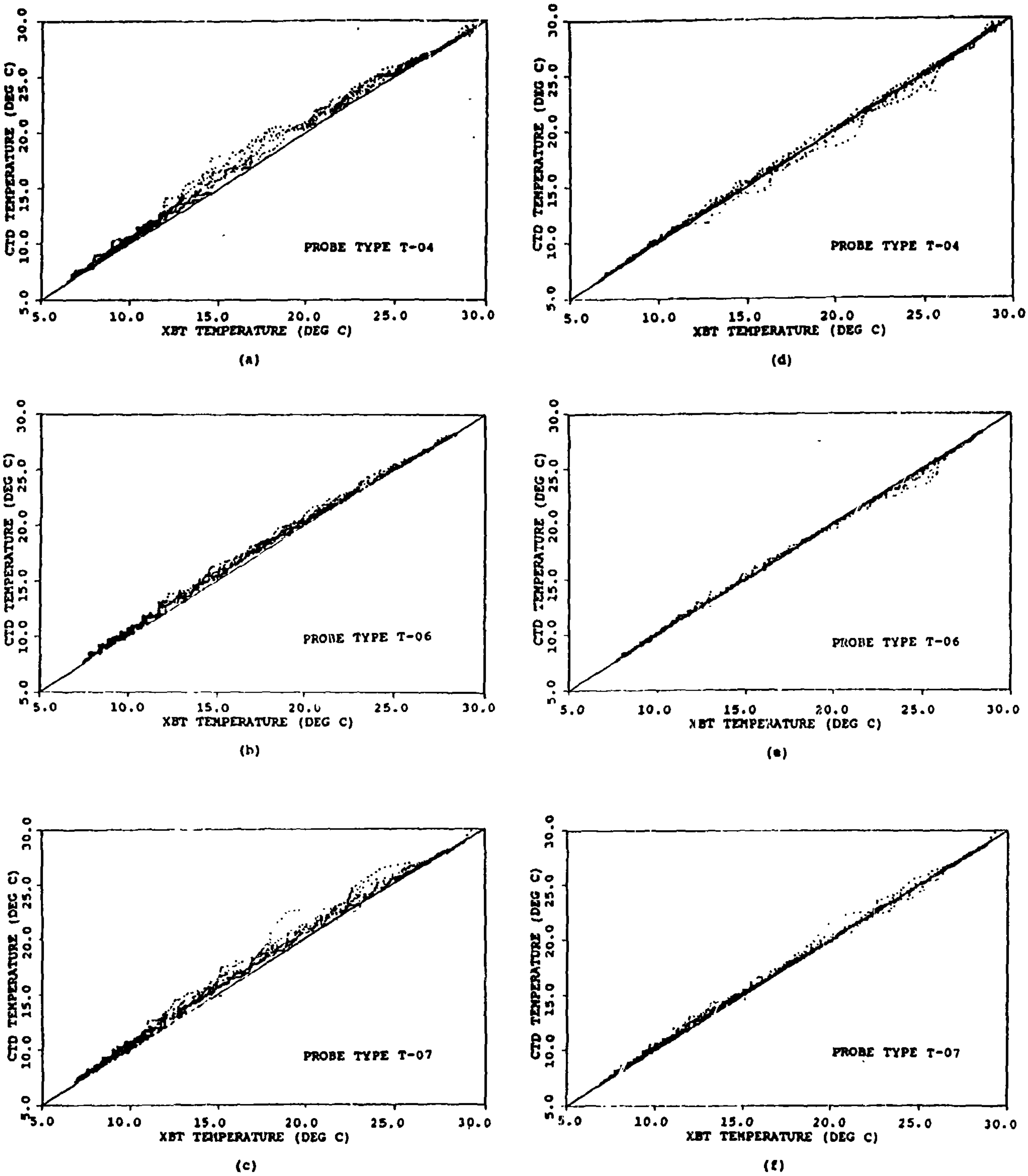


Figure 4. Scatter Plots of MK-9 XBT Data vs. Ctd Data
(a-c) Standard Depth Coefficients
(d-f) Revised Depth Coefficients

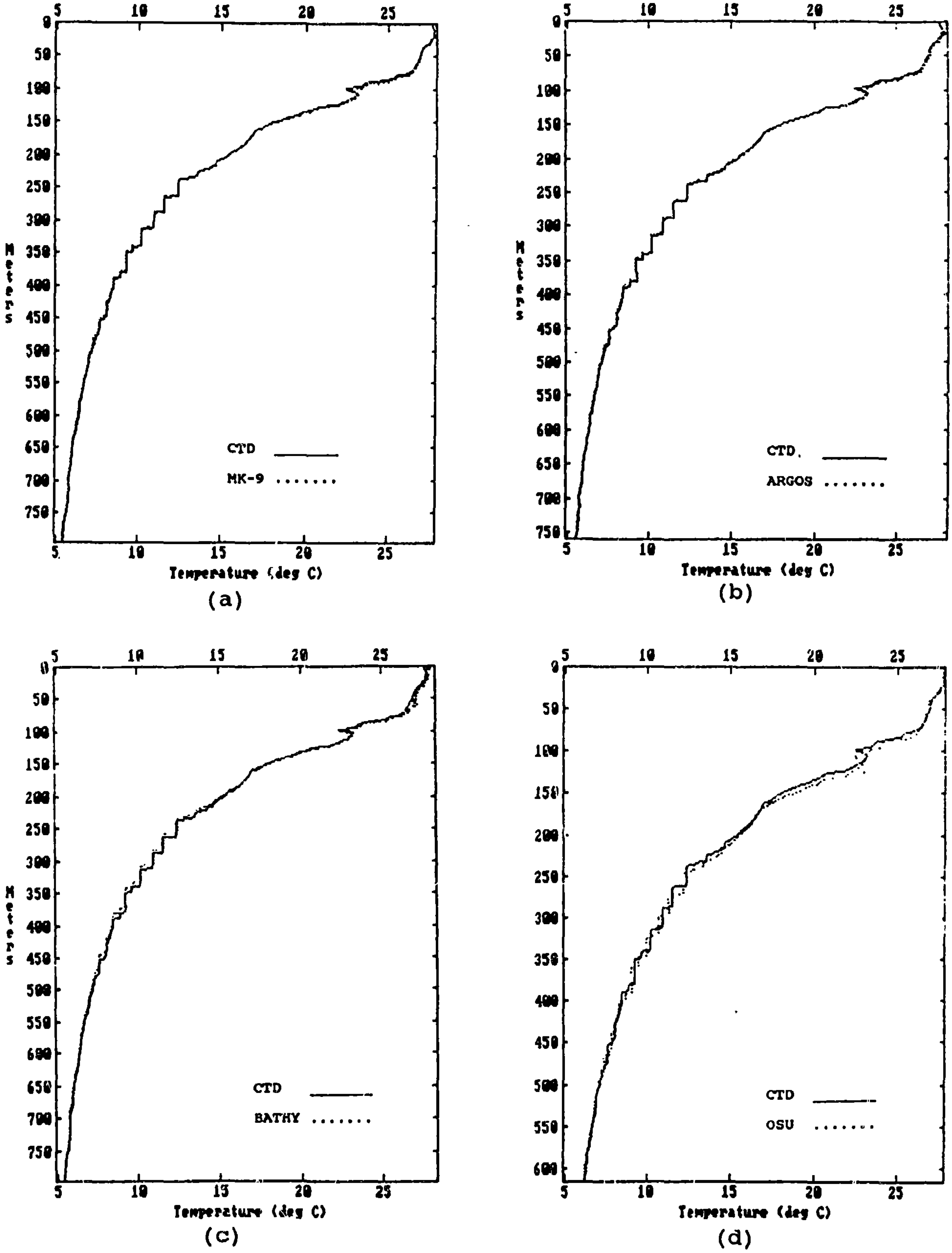


Figure 5. XBT -CTD Temperature Profiles, XBT Drop 25
with Revised Depth Coefficients.
(a) MK-9 (b) ARGOS (c) BATHY (d) OSU

Table 7 summarizes the results from evaluating the real-time data transmissions. Of the 60 XBT's dropped using the ARGOS XBT system, 48 XBT messages were transmitted. Ten were not transmitted because of the 15 iteration limit, imposed by the software in version 1.0, to compute the 15 inflection points. This limitation has been corrected in version 2.0. Two XBT messages were not transmitted because of faulty probes. The high launch frequency, sometimes generating a message every hour, resulted in 11 of the 48 messages not being generated into GTS bulletins. The bulletins were not generated because of the required two transmission receptions not being received. This should not be considered a limitation of the system since most oceanographic surveys do not require the high XBT launch frequency used during this field test. Of the 65 XBT's dropped using the SEAS III system, 58 XBT messages were transmitted and entered onto the GTS. Seven of the XBT drops were not transmitted because of the high frequency of XBT launches. The XBT buffer in the GOES transmitter allows for 3 XBT messages. Since the GOES satellite assignment permitted a transmission every 4 hours, the XBT transmitter rejected seven XBT drops. Again, most oceanographic surveys do not require this high frequency of XBT launches. If necessary, the data can be stored on floppy disk and transmitted at a later time.

TABLE 7 SUMMARY OF REAL-TIME DATA TRANSMISSION

SYSTEM	XBT's DROPPED	TRANSMISSION STATUS	DATA DISSEMINATION STATUS
ARGOS	60	Transmitted - 48	Data Bulletins - 37
		Not Transmitted - 10 (1)	Not Disseminated - 11 (3)
		Not Transmitted - 2 (2)	
SEAS III	65	Transmitted - 58	Data Bulletins - 58
		Not Transmitted - 7 (3)	

(1) Ten XBT messages not generated because criteria for obtaining 15 inflections points were too strict. This limitation is corrected in latest software, Version 2.0.

(2) Two XBT messages not generated because of XBT probe failure.

(3) Eleven from the ARGOS XBT system and 7 from the SEAS III system were neither transmitted or disseminated in real-time because of the high launch frequency during field evaluation.

SUMMARY

This field test evaluated both the performance of XBT systems under field conditions and the capability of the ARGOS and GOES satellite systems to transmit XBT data in the JJXX format. Results show that the mean temperature differences between the CTD and each XBT system over the total XBT profile were greater than the +/- 0.15 degrees Celsius specification for XBT probes. In the isothermal portion of the mixed layer where the temperature differences between the XBT and CTD are minimized due to depth, instrument response, and internal waves, the temperature differences between the XBT's and CTD were reduced by an order of magnitude. From these results, it was determined that temperature error due to the XBT's thermistor is small. The major contributing factor for the differences in temperature is an error in the computation of the XBT probe depth. The error in depth for the T-4, T-6, and T-7 probe types was found to be greater than allowable by the manufacturer's specifications (+/- 5 meters or +/- 2% of depth, whichever is greater). It was determined that these probes are falling at a faster rate than calculated by the standard coefficient of the drop equation. This depth error has been previously identified by Heinmiller et al.(1983) and Seaver and Kuleshov (1982). The depth errors can be reduced by revising the coefficients in the depth equation. While all XBT systems indicated a depth error, there was a system bias among the systems, some showing a greater error than others. This bias among system requires further analysis. Transmission results demonstrated that both ARGOS and GOES satellite based XBT systems provided adequate capability to transmit data in real-time. Together, ARGOS and GOES provide the necessary data communications for a global ocean observation program.

ACKNOWLEDGEMENTS

We would like to express our sincere thanks to Sonny Richardson for help making this evaluation possible and for all his helpful suggestions. We'd like to thank Yvonne Newmen for helping with the data processing and preparation of this report. Also we appreciate the help, suggestions, and support of the following people, Archie Shaw and Mitch Tiger of Argos, Rod Mesecar and Jim Wagner of Oregon State University, Jim Hannon of Sippican, Don Dorson of Bathy Systems, Mike Miyake of the Institute of Ocean Sciences and Bob Molinari of NOAA/AOML.

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PROPOSAL FOR A POWERFUL, SAFE AND EASY METHOD TO IMPROVE THE DATA QUALITY OF REAL-TIME XBT DATA (BATHY MESSAGES)

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There seems to be no doubts: automated XBT systems are a great advantage improving the quality of real-time data (BATHY messages). However, that is not always true. To make the problem perfectly clear, it even may be that the real-time data quality in average will be decreased in a certain degree by automated systems.

The reason for this assertion: good observers are able to correct erroneous strip chart records while encoding the data, automated systems, however, have no powerful tools which allow quality improvement (editing) prior to encoding. Or in other words, automated systems improve the data quality by prevention of encoding errors and transmission errors only. There is no physical control of the acquired data. It has to be emphasized that the method proposed under no circumstances has an effect on the original data stored on tape or disc to be processed later at shore.

A large amount of real-time data distributed via GTS is erroneous caused by noisy/spiky original (raw) data. Due to the fact that the total information of a temperature profile is concentrated on some 20 to 30 inflection points in a BATHY message (which means a nominal data reduction rate of about 97.6 % to 98.4 % for a T7 profile), and thus each inflection point is absolutely independent (i.e. significant), a trustworthy rejection of erroneous inflection points often is not possible or even not allowed. Any quality control prior to GTS insertion is affected by this fact.

An example is given in the Annex of this proposal. This example was picked up from the actual delayed mode data flow obtained from Köln Atlantic at our last visit just four weeks ago. Better examples can be found if necessary. The profile shown is noisy but needs not to be rejected. Due to the noise the software calculated "TOO MANY INFLECTION POINTS" as can be seen on the printed record. The observer has to restart the programme again and again. He was one of the good oberservers. Instead of breaking off this frustrating job as the most would do he finally succeeded in calculating the BATHY message after the eleventh restart. However, looking at the encoded message obviously several wrong values are detectable. This example was taken from the Eastern North Atlantic, an area of simple structured hydrography. In areas with more complex hydrography like the Western North Atlantic sometimes even a specialist cannot tell wright from wrong inflection points. Assuming that the routine quality control of BATHY messages prior to GTS insertion is not carried out by scientists, but by technical personnel as it is in DHI, in many cases erroneous data will be inserted.

It has to be realized that the problem of wrong inflection points due to measurement noise cannot be solved satisfactorily by data quality control of encoded messages. Consequently we have to search for useful methods to be applied before the encoding of data is performed.

There are different spike/noise rejecting methods on the scientific market which should be proved on its applicability for real-time data processing. In most cases serious disadvantages will be found.

The opportunity is taken to place a proposal before the Third IGOSS Ship-of-Opportunity Meeting for a median filter method. The principle is demonstrated in Fig. 2. This powerful and safe method and its application to oceanographic data is described in full detail in Sy (1985). For theoretical background it is referred to Justusson (1981) and Tyan (1981).

In contrast to conventional methods, data editing with the median filter has the following advantages:

1. The number of cycles is not reduced.
2. Gradients and edges are preserved. Optimal results are obtained in regions with monotonic sequences, e.g. for temperature. This advantage is iportant for the proposed application.
3. The profiles are smoothed with only a little blurring of exposed structures within the window (Fig. 2).
4. The method is applicable without the smoothing effect as well.
5. The simple way of handling makes this method suitable for on-line processing.
6. Implementation is very easy, only a data sorting subroutine is needed. (It is recommended to run this filter twice close behind, which can be done in one job).

The disadvantages are:

1. The median filter is a non-linear operation. A general response function cannot be specified because it depends on the actual input signal.
2. Data must be compacted by arithmetic averaging according the window size because of the modified statistical dependence (not relevant for the proposed application to real-time data).
3. There can be a bias due to the occurence of a dense pack of spikes, which are themselves biased in direction (not relevant for the proposed application due to the poor precision of XBT data).

As I know, the experience with this method is good. During my time in Kiel I processed hundreds of CTD profiles, data which are some two orders more sensitive than XBT data. It is a standard method now in Kiel. The group of John Woods used it successfully for on-line pre-processing of hydrographic data in a towed fish. In the last time it became a standard method in DHI, e.g. in a graphic-interactive processing software for timeseries. In the near future the median filter will be implemented in a new designed CTD processing software at DHI.

If it proves to be necessary further quality tests are to be implemented in the BATHY encoding software. For this and for practical experiences with the application of the median filter method implemented the ARGOS XBT encoding software reference is made to Rual (in prep.).

Due to the fact that according the IGOSS Manuals and Guides No. 3 a minimum quality control prior to GTS insertion is recommended, and thus many BATHY messages distributed via GTS are modified by the GTS entry stations anyway, the proposed pre-processing of real-time data should not have any impact on the BATHY scheme. On the other hand it should be kept in mind, that data acquired by mechanical bathythermographs as well as by highly automated and quality controlled ARGOS systems are distributed via GTS, which is not visible in the BATHY messages. Due to this inhomogeneous data quality in principle all BATHY messages have to be treated as modified data in one way or another.

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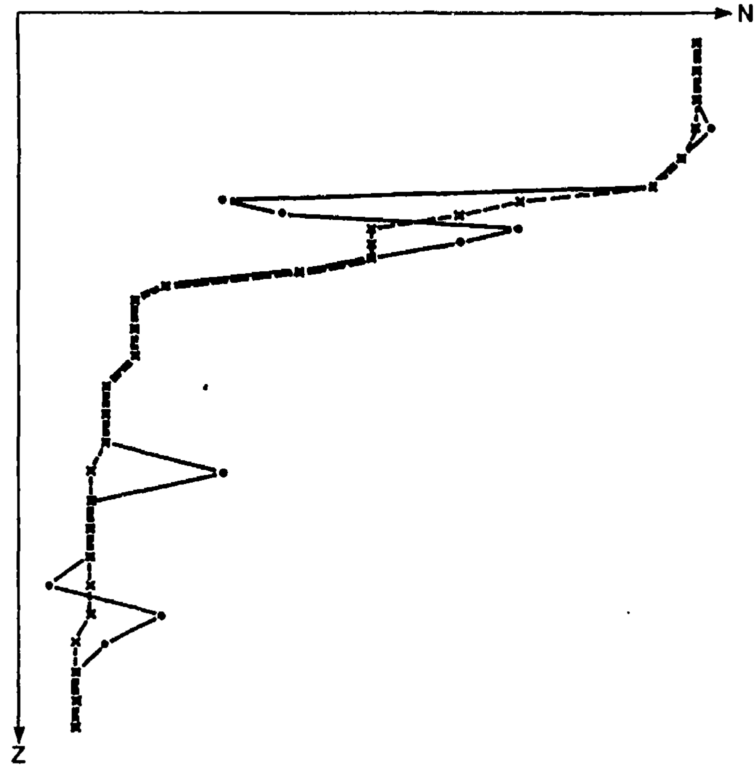


Fig. 4: Illustration of principle properties for a five-point median filter. The solid line is before median filtering. The dashed line is after median filtering.

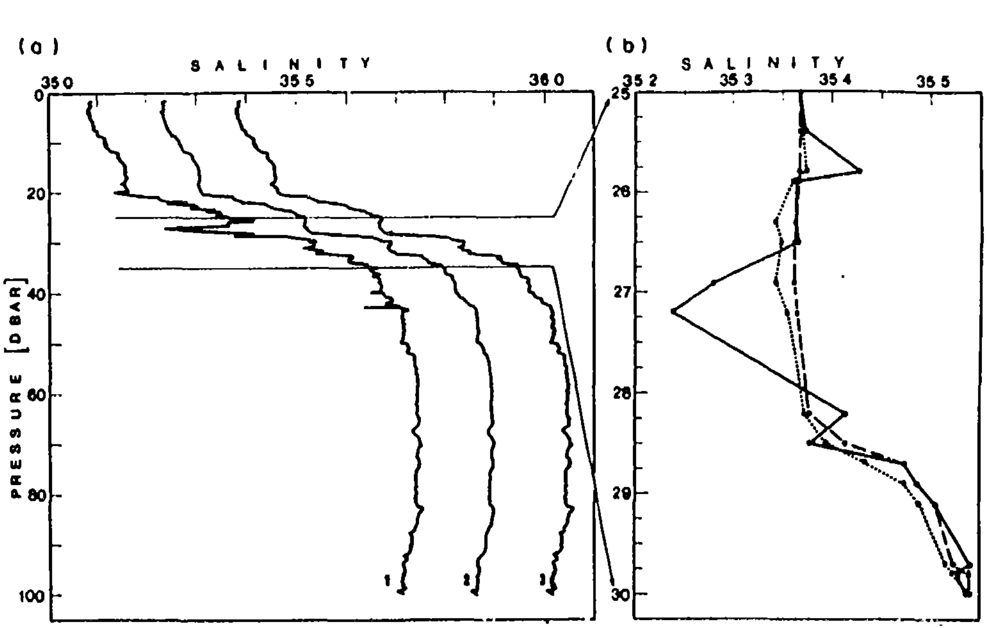


Fig. 2. First example: illustration of principle properties for a seven-point median filter. (a) 100 m cut from a spiky part of a salinity profile. No. 1 marks the initial profile, No. 2 the same profile treated with MEDFIL ($q = 7$); and No. 3 treated with MEDDIF ($q = 7$, $\Delta = 0.01$). (b) Enlarged cut with data point resolution of profiles 1 (solid line) and 2 (dashed line). The dotted line shows the initial profile after moving average filtering for comparison (no equidistant pressure interval, $q = 7$).

Annex: Example showing the influence of noisy data on BATHY messages. The record shown is an actual print out of a Bathy Systems SEAS II unit, and was produced aboard Köln Atlantic (line A9).

***** On-line record *********

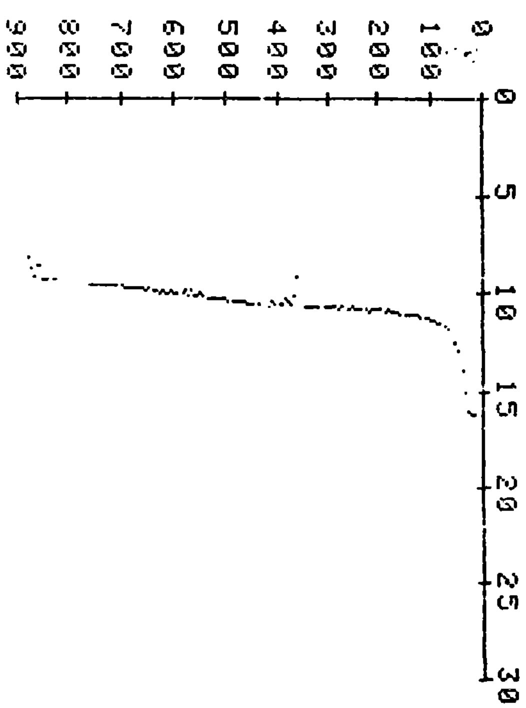
XBT # 44 T- 7 PROBE

TIME 16:00 GMT DAY 255

LAT: 50 DEG 12 MIN 6 SEC (N)

LON: 13 DEG 4 MIN 36 SEC (W)

SA-810 serial # 81
Software Rev. 4-23-87
****



TAPE FILE NAME 744A

****

***** First encoding *********

XBT # 44 T- 7 PROBE

TIME 16:00 GMT DAY 255

LAT: 50 DEG 12 MIN 6 SEC (N)

LON: 13 DEG 4 MIN 36 SEC (W)

SA-810 serial # 81

TAPE FILE NAME 744A

****

TEMPERATURE INFLECTION POINTS

POINT	DEPTH (M)	TEMP (C)
1	0.0	15.93
2	5.2	16.30
3	22.6	16.04
4	23.9	15.77
5	26.5	15.99
6	29.1	16.00
7	33.0	15.55
8	39.4	14.30
9	52.3	12.70
10	65.1	11.91
11	135.6	11.09
12	343.8	10.59
13	345.1	10.61
14	346.3	10.39
15	347.6	10.65
16	348.8	10.62
17	350.1	9.12
18	351.3	8.92
19	352.5	9.27
20	353.8	10.37
21	355.0	9.77
22	356.3	10.17
23	357.5	9.69
24	358.8	9.20
25	360.0	9.80
26	362.5	10.07
27	363.8	10.40
28	365.0	9.70
29	366.2	10.28

TOO MANY INFLECTION POINTS
****

***** Second encoding ********

1	0.0	15.93
2	7.1	16.37
3	26.5	15.[illegible]
4	33.0	15.55
5	39.4	14.20
6	58.7	12.10
7	142.0	11.06
8	343.8	10.59
9	345.1	10.61
10	346.3	10.59
11	347.6	10.65
12	348.8	10.62
13	350.1	9.12
14	351.3	8.92
15	352.5	9.27
16	353.8	10.37
17	355.0	9.77
18	356.3	10.17
19	357.5	9.69
20	358.8	9.20
21	362.5	10.07
22	363.8	10.40
23	365.0	9.70
24	363.7	10.56
25	375.0	10.17
26	377.4	9.85
27	381.2	10.14
28	382.4	7.86
29	383.7	9.71

TOO MANY INFLECTION POINTS
****

***** Eleventh encoding (successful) ******

1	0.0	15.93
2	39.4	14.20
3	103.6	11.30
4	343.8	10.59
5	350.1	9.12
6	381.2	10.14
7	382.4	7.86
8	383.7	9.71
9	413.4	10.98
10	414.7	8.58
11	415.9	11.72
12	418.4	11.46
13	424.6	13.05
14	425.8	11.31
15	480.0	10.40
16	507.0	10.32
17	508.2	7.78
18	510.7	10.08
19	524.1	10.23
20	525.4	14.41
21	526.6	10.17
22	565.6	10.03
23	572.9	10.08
24	574.1	11.59
25	577.8	9.03
26	759.2	9.48

****

JJXX BATHY MESSAGE

227 CHARACTERS

TIME: 1600 GMT

DAY: 12

MONTH: 09

YEAR: 1989

```
JJXX  12099 1600/ 75012 01305
88888 00159 39142 99901 04113
99903 44106 50091 81101 82079
84097 99904 13116 15086 16117
18115 25131 26113 80104 99905
07103 08078 11101 24102 25144
27102 66100 73101 74116 78090
99907 59095 OAKE
```

JJXX MESSAGE TRANSFERRED
TO GOES TRANSMITTER

***** Delayed-mode record *****

XBT # 44 T- 7 PROBE

TIME 16:00 GMT DAY 255

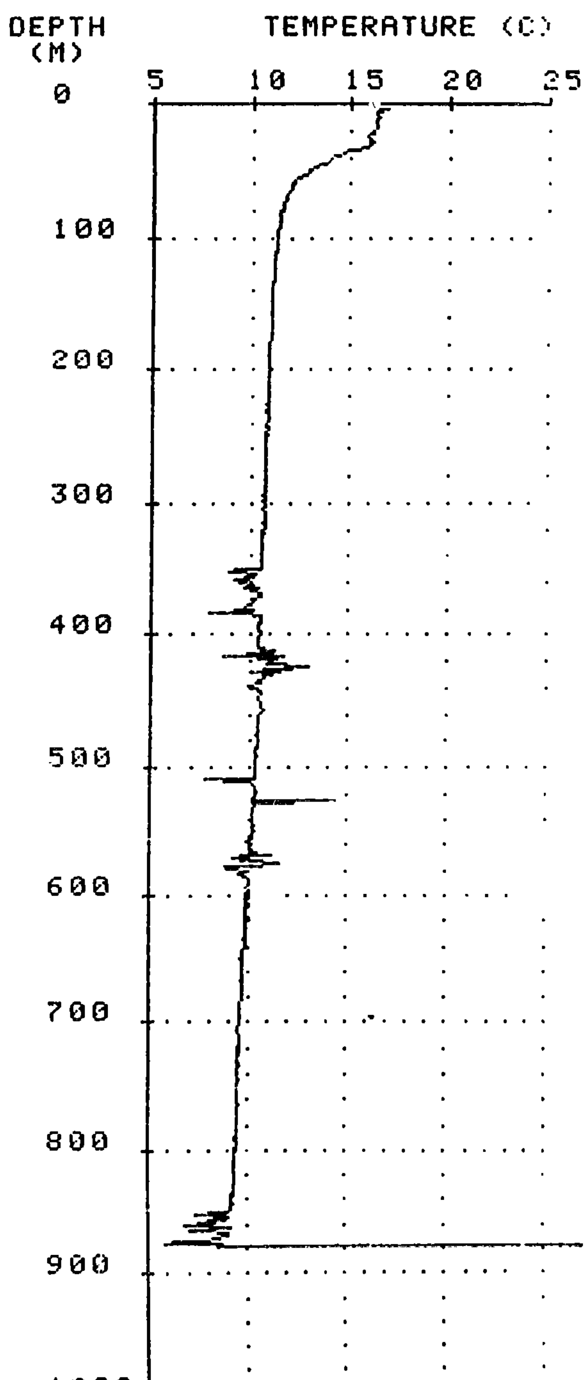
LAT: 50 DEG 12 MIN 6 SEC (N)

LON: 13 DEG 4 MIN 36 SEC (W)

SA-? 0 serial # 81

TAPE FILE NAME 744A

****



****

XBT # 44 T- 7 PROBE

TIME 16:00 GMT DAY 255

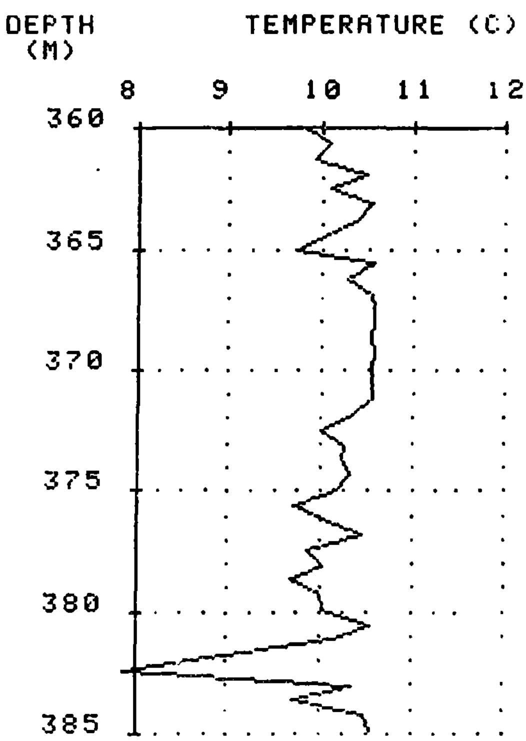
LAT: 50 DEG 12 MIN 6 SEC (N)

LON: 13 DEG 4 MIN 36 SEC (W)

SA-810 serial # 81

TAPE FILE NAME 744A

****



Delayed-mode record and data print out of a 25 m segment

****

XBT # 44 T- 7 PROBE

TIME 16:00 GMT DAY 255

LAT: 50 DEG 12 MIN 6 SEC (N)

LON: 13 DEG 4 MIN 36 SEC (W)

SA-810 serial # 81

TAPE FILE NAME 744A

****

DEPTH (M)	TEMP (C)	MEDIAN $g=7$
360.0	9.80	
360.6	10.07	
361.3	9.90	
361.9	10.47	10.07
362.5	10.07	10.07
363.1	10.55	10.07
363.8	10.40	10.40
364.4	10.07	10.27
365.0	9.70	10.40
365.6	10.58	10.40
366.2	10.27	10.53
366.9	10.53	10.55
367.5	10.56	10.56
368.1	10.58	10.55
368.7	10.55	10.55
369.4	10.56	10.55
370.0	10.55	10.55
370.6	10.53	10.54
371.2	10.54	10.53
371.8	10.34	10.34
372.5	9.99	10.31
373.1	10.26	10.26
373.7	10.23	10.23
374.3	10.31	10.17
375.0	10.17	10.23
375.6	9.70	10.17
376.2	10.03	10.03
376.8	10.45	10.01
377.4	9.85	9.99
378.1	10.01	10.03
378.7	9.69	10.01
379.3	9.99	10.01
379.9	10.04	10.01
380.5	10.55	9.99
381.2	10.14	10.04
381.8	8.99	10.04
382.4	7.86	10.14
383.0	10.33	10.14
383.7	9.71	10.33
384.3	10.48	10.45
384.9	10.54	10.48
385.5	10.48	
386.1	10.57	
386.8	10.54	

RELEVANCE TO TOGA OF SYSTEMATIC XBT ERRORS

R.J. Bailey, H.E. Phillips, G. Meyers
CSIRO, Australia

Introduction

Over recent years expendable bathythermographs (XBTs) have become increasingly relied upon in large-scale oceanographic research programs. An assessment of the accuracy of XBTs, and the systems used to drive them, is therefore essential.

The depth accuracy of XBTs has been the subject of many studies [1,2,3,4]. These studies have proposed alternative fall-rate equations to the one specified by the manufacturer on the basis of the errors observed in the depth of the XBT. Other investigators [5,6] have concentrated on the temperature calibration of the probe thermistors in an effort to improve the accuracy of XBTs.

The aims of this study are to:

- provide further calibrations of XBTs and XBT systems by comparing them with conductivity-temperature-depth (CTD) sensors.
- evaluate the applicability of the various depth-correction algorithms mentioned above.
- examine the implications of the observed depth and temperature errors to a large-scale research program such as TOGA (Tropical Ocean and Global Atmosphere).

Instrumentation and Methods

Two types of digital XBT systems were calibrated against the RV *Franklin*'s Neil Brown CTD Profiler during separate voyages in 1987 (Table 1). Both types of XBT system are used in the CSIRO's Ship-of-Opportunity Program (SOOP). The MK-9 XBT system was used in two configurations for the calibration experiments; with the *Franklin*'s PDP-11 data logging system, and with an HP-85 microcomputer as deployed on ships-of-opportunity. Deep Blue XBTs, from the same batch, were used throughout the calibrations.

The CTD station positions are shown in Fig. 1. Typically, XBTs were dropped 10-20 minutes prior to the descent of the CTD profiler at each station.

The temperature profiles recorded by the CTD Profiler for both voyages are shown in Fig. 2.

Depth and Temperature Errors

(a) Depth Errors

Figs. 3(a) and 4(a) give examples of the average temperature error (T_{XBT}–T_{CTD}) as a function of depth for two of the XBT System/CTD calibration experiments. The characteristic shape of both profiles of temperature error is similar to that found in the experiments of Hanawa and Yoritaka[4]. They found the negative errors in temperature to be mainly due to the errors in depth that result from the XBT falling faster than specified by the manufacturer's fall-rate equation. The largest errors in temperature correspond to the depths of large temperature gradient in the temperature profiles (cf Fig. 2). This is where the depth error due to an incorrect fall-rate has its largest effect.

Figs 3(b) and 4(b) give examples of the average temperature error (T_{XBT}–T_{CTD}) as a function of depth for the same two calibration experiments, however, the depths of the XBTs have been corrected according to the depth-correction algorithm developed by Hanawa and Yoritaka[4]. This algorithm proved to be the most successful at reducing the mean and rms temperature errors for each of the three calibration experiments. The rms temperature error was consistently reduced from above to below the accuracy of the XBT (±0.15°C). The depth-correction algorithm according to Heinmiller et al.[1], on the other hand, actually increased the rms temperature error for each case.

Unfortunately, some errors in temperature still remain at depths corresponding to large temperature gradients, even after the data has been corrected according to Hanawa and Yoritaka[4]. The fall-rate correction of Hanawa and Yoritaka[4] is therefore not totally applicable in the waters of this study, although it does improve the data.

(b) Temperature Errors

Start-up Transients: Large start-up transients in the upper 4 m were observed for the SEAS II XBT System (Fig. 5), and to a lesser extent for the MK–9 XBT System. The mean difference between the first temperature digitisation (0.6 m) and the temperature at 3.9 m (commonly used as the sea surface temperature due to such transients) was –9.50 ± 10.08°C for the SEAS II XBT System, compared to 0.41 ± 0.30°C for the MK–9 XBT System.

SEAS II Mixed Layer Anomaly (Bowing): The need for the comparison of XBT data with a precision CTD sensor was first invoked by the observation of anomalies in the mixed layer temperature profiles recorded by SEAS II XBT Systems deployed in the CSIRO SOOP in the western tropical Pacific. A gradual increase, or "bowing", in temperature was observed as opposed to an isothermal profile. An example is given in Fig. 6. Such anomalies were not present in the data recorded by the MK–9 XBT Systems.

The upper 200 m of the temperature profiles recorded by the SEAS II XBT System and the CTD Profiler during FR0487 are shown in Figs 7(a) and 7(b) respectively. The gradient in temperature in the mixed layer for a single XBT and its corresponding CTD are highlighted to emphasize the "bowing" problem. The corresponding average error in temperature (T_{XBT}–T_{CTD}) in the mixed layer as a function of depth is shown in Fig. 7(c). The mean SEAS II XBT temperature in the mixed layer starts less than and finishes greater than the mixed layer temperature given by the CTD. On examination of each individual XBT/CTD comparison, however, the start and finish temperatures of the SEAS II XBT System were found to be randomly distributed in relation to the CTD mixed layer temperature. In some cases the SEAS II temperature starts above the CTD mixed layer temperature and finishes further above it. In other cases, it may start below it and finish equal to it.

The above results indicate a possible drift problem with the electronics of the SEAS II XBT System. The temperature errors may also extend deeper than the mixed layer. We can only distinguish the problem in the mixed layer where the real temperature gradient is zero.

Implications for TOGA

(a) Isotherm Depth Errors

If we assume the corrected depth (z') from Hanawa and Yoritaka[4] to be the true depth of the XBT, then Fig. 8 shows the depth error (z–z') as a function of depth, where z is the depth of the XBT given by the manufacturer. The depth accuracy of the XBT at any given depth is also shown. A 20°C isotherm depth of 200 m, for example, will be measured by an XBT as occurring at a depth of approximately 192.5 m — an error of 7.5 m. The depth error exceeds 25 m at a depth of 800 m, and exceeds the depth accuracy of the XBT (5 m or 2% of the depth, whichever is greater) at a depth of approximately 135 m.

(b) Dynamic Height Errors

Table 2 shows the mean error in dynamic height ($D_{XBT}–D_{CTD}$) relative to 200 m, 400 m and 700 m for the three calibration experiments. The errors are small both before and after the correction for depth of the XBT. Values range from –0.019 dyn m to 0.001 dyn m. Fortunately, the largest temperature gradients in the tropics are shallow enough for errors in temperature, which affect the dynamic height, to be small. The error in depth, which affects the temperature error, is relatively small at these shallower depths.

The depth correction from Hanawa and Yoritaka[4] successfully reduces the error in dynamic height for the MK–9 XBT System, but increases it for the SEAS II XBT System. The additional positive errors in temperature caused by the "bowing" problem of the SEAS II XBT System are possibly cancelling some of the negative errors in temperature that result from errors in depth. The dynamic height error, which depends on temperature, is therefore reduced for the SEAS II XBT System.

(c) Mixed Layer Temperature Errors

A mixed layer bowing index, defined as the maximum temperature of a profile minus the temperature at 5 m, was used to estimate the typical magnitude and frequency of the mixed layer anomaly recorded by the SEAS II XBT Systems deployed in the CSIRO SOOP. The results for the XBT data recorded in 1987 are given in Table 3. Potentially, 34.4% of the data had errors greater than the temperature accuracy of the XBT (±0.15°C). Some profiles recorded indexes of 0.7°C (Fig. 6) and above.

Fig. 9 shows the error in monthly heat storage rates as a function of the potential error in mixed layer temperature due to "bowing". The errors are shown for two characteristic mixed layer depths (MLD). Given the mean index for 1987 from Table 3 of 0.22°C, the corresponding error in the monthly heat storage rate is approximately 18 W/m^2 for a mixed layer depth of 100 m. This is an unacceptable source of error in heat budget studies.

(d) Sea Surface Temperature Errors

The shallowest depth that should be used to estimate sea surface temperature (SST) from an XBT is 3.9 m due to start-up transients. Large errors in SST will be observed otherwise.

Conclusions

- The depth-correction algorithm according to Hanawa and Yoritaka[4] proved the most effective in reducing the mean and rms temperature errors for this data set. However, as neither this correction nor the other corrections that were applied completely reduced the temperature errors observed between the XBTs and CTD Profiler, further studies on the factors that vary the fall-rate of XBTs between different locations will need to be undertaken before a generally applicable depth-correction algorithm will be found. This will have to be done for each type of XBT probe.

- Temperature errors observed in the mixed layer, due to the "bowing" problem associated with the SEAS II XBT System, are a significant source of error for TOGA. A thorough engineering analysis of the electronics of this system is recommended before future use of the system. On the results of this study, CSIRO has replaced the SEAS II units in its SOOP with MK–9 XBT Systems.

References

1. Heinmiller, R., C. Ebbesmeyer, B. Taft, D. Olson and O. Nikitin (1983): Systematic errors in expendable bathythermograph (XBT) profiles. *Deep-sea Research* 30, 1185–1196.

2. Seaver, G., and S. Kuleshov (1982): Experimental and analytical error of the expendable bathythermograph. *Journal of Physical Oceanography* 12, 592–600.

3. Green, A. (1984): Bulk dynamics of the expendable bathythermograph (XBT). *Deep-sea Research* 31, 415–426.

4. Hanawa, K. and H. Yoritaka (1987): Detection of systematic errors in XBT data and their correction. *Journal of the Oceanographical Society of Japan* 43, 68–76.

5. Georgi, D., J. Dean and J. Chase (1980): Temperature calibration of expendable bathythermographs. *Ocean Engineering* 7, 491–499.

6. Roemmich, D. and B. Cornuelle (1987): Digitisation and calibration of the expendable bathythermograph. *Deep-sea Research* 34, 299–307.

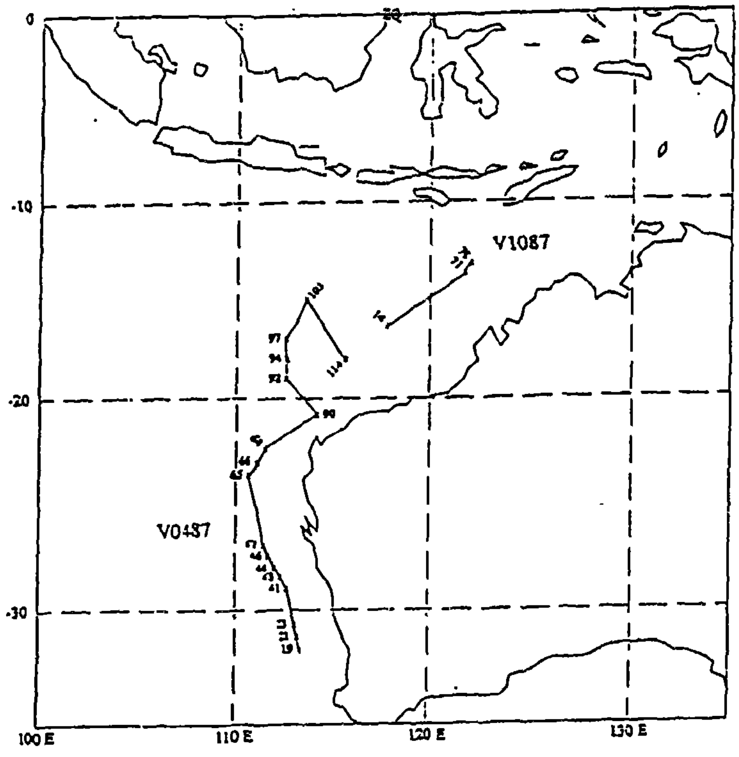


Fig. 1. RV *Franklin* V0487 and V1087 CTD station positions.

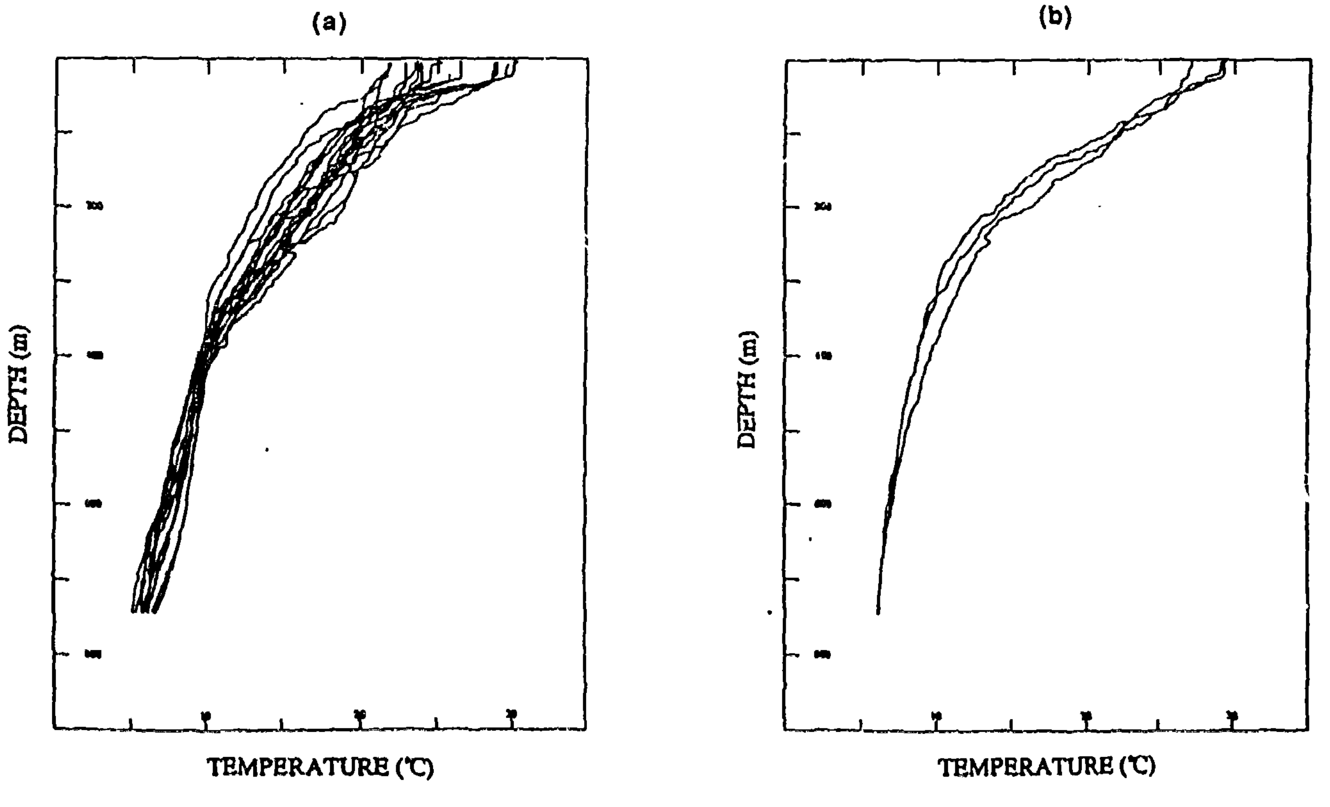
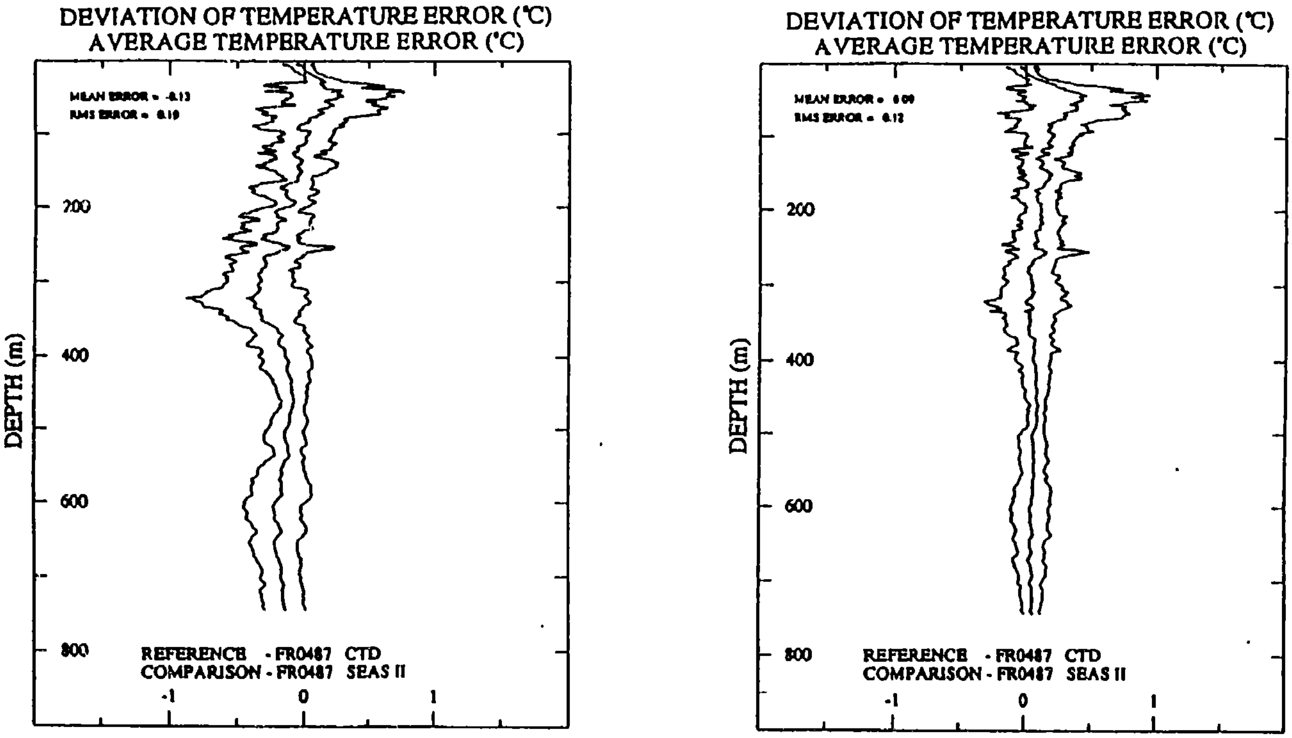
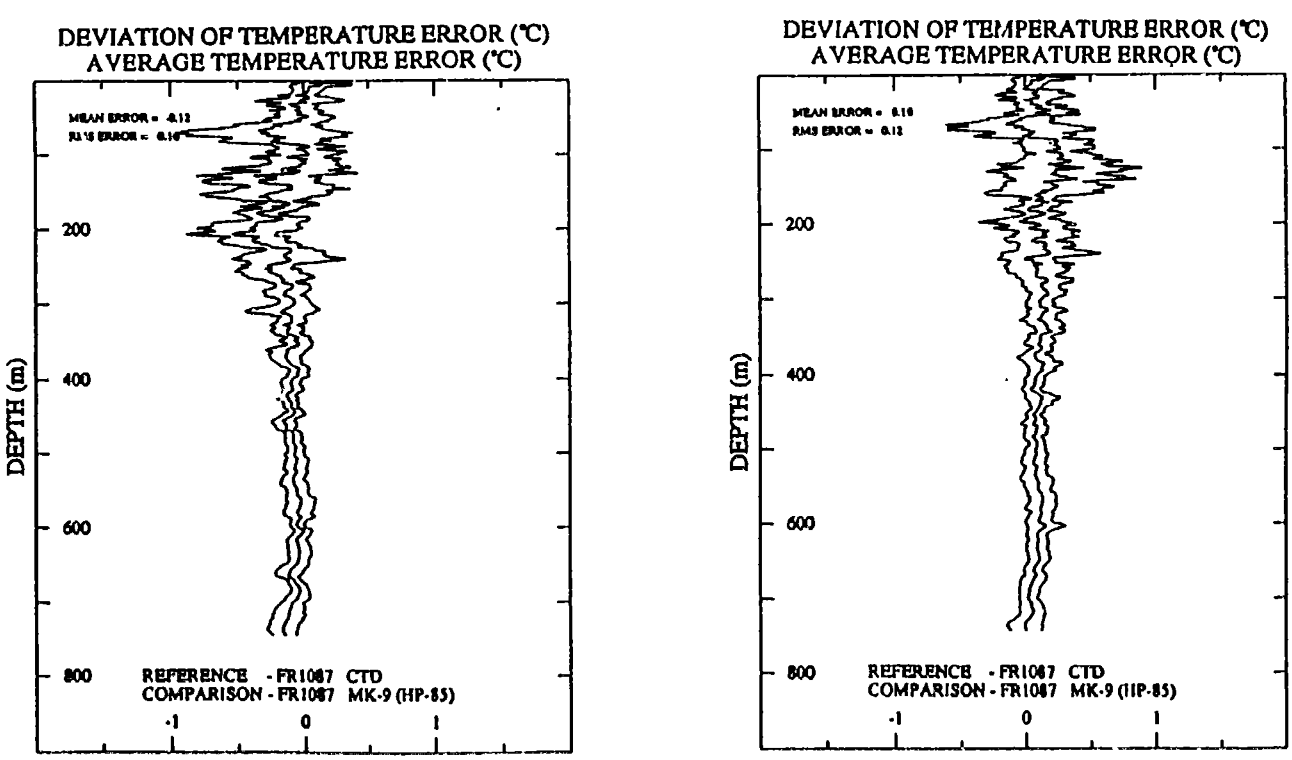


Fig. 2 CTD temperature profiles: (a) FR0487; (b) FR1087.



(a) (b)

Fig. 3. Average temperature error profiles ($T_{XBT}-T_{CTD}$) for XBT/CTD comparisons on FR0487 using the SEAS II XBT System; (a) depth uncorrected; (b) depth corrected according to Hanawa and Yoritaka[4].



(a) (b)

Fig. 4. Average temperature error profile ($T_{XBT}-T_{CTD}$) for XBT/CTD comparisons on FR1087 using the MK-9 XBT System: (a) depth uncorrected; (b) depth corrected according to Hanawa and Yoritaka[4].

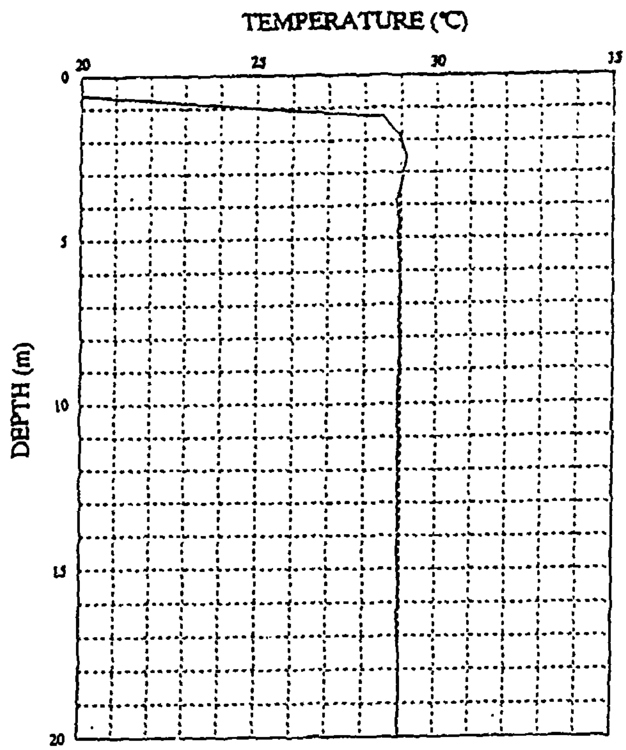


Fig. 5. Example of a start-up transient from a SEAS II XBT System.

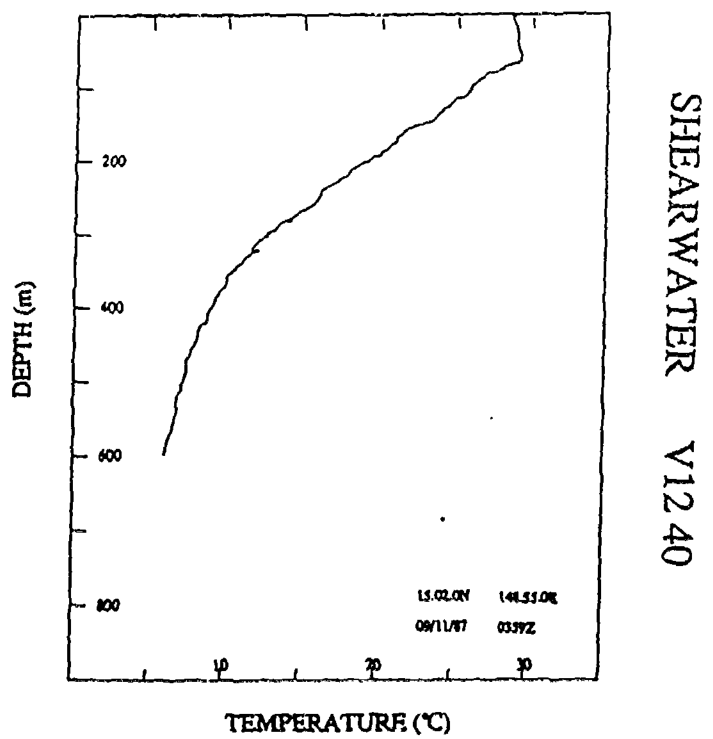


Fig. 6. Example of a mixed layer anomaly recorded by a SEAS II XBT System.

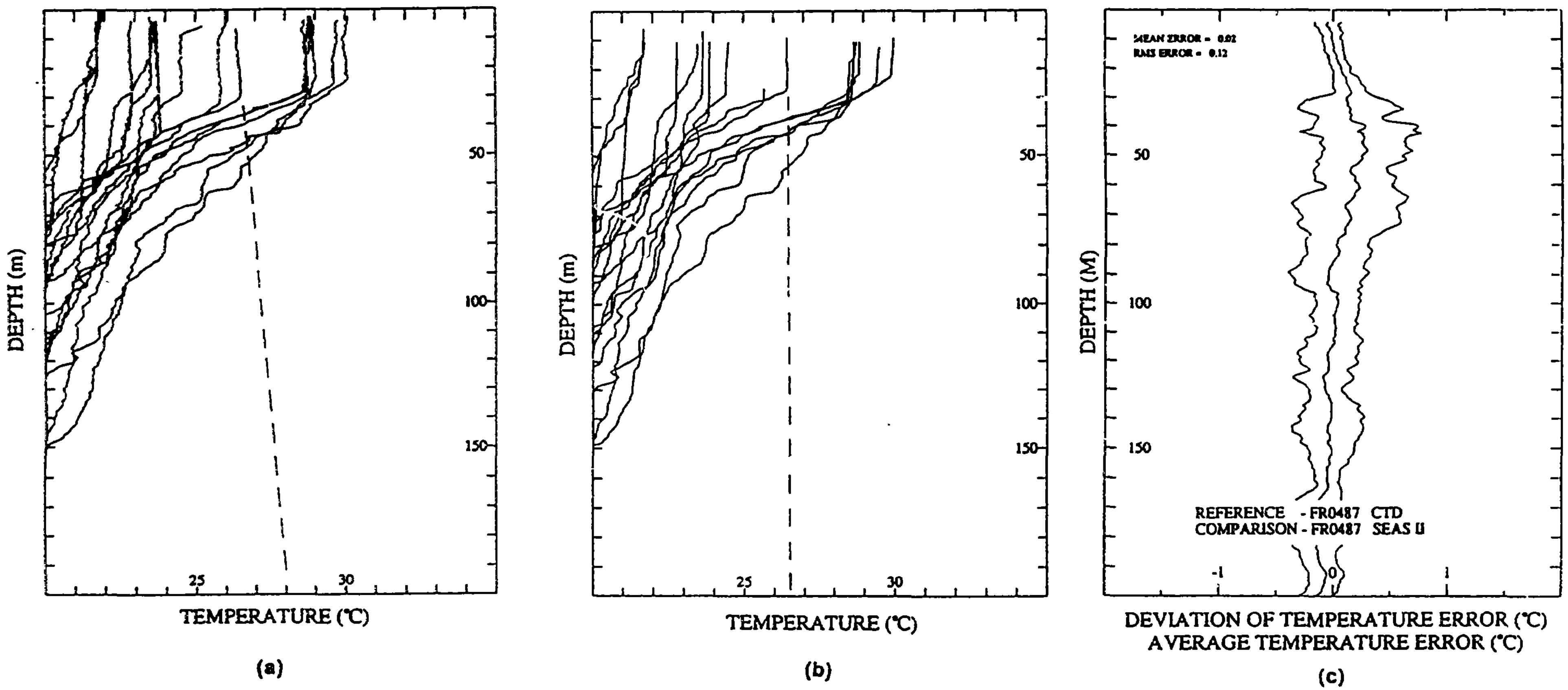


Fig. 7. (a) SEAS II temperature profiles (upper 200 m) for FR0487; (b) CTD temperature profiles (upper 200 m) for FR0487; (c) corresponding average temperature error profile (upper 200 m)

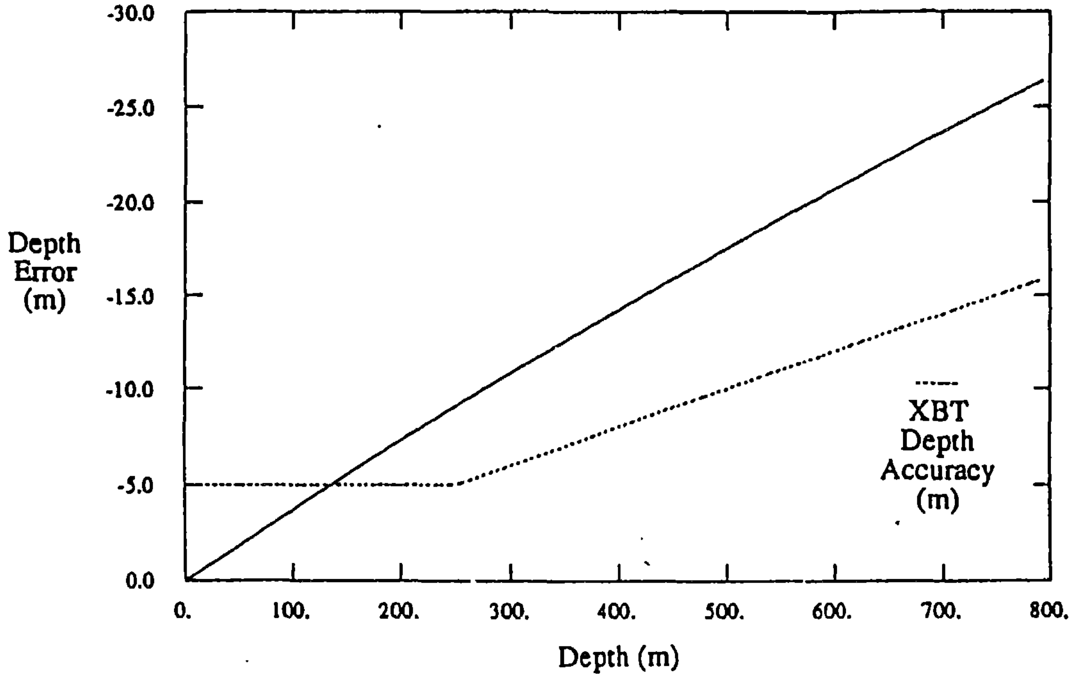


Fig. 8. Depth error of the XBT as a function of depth.

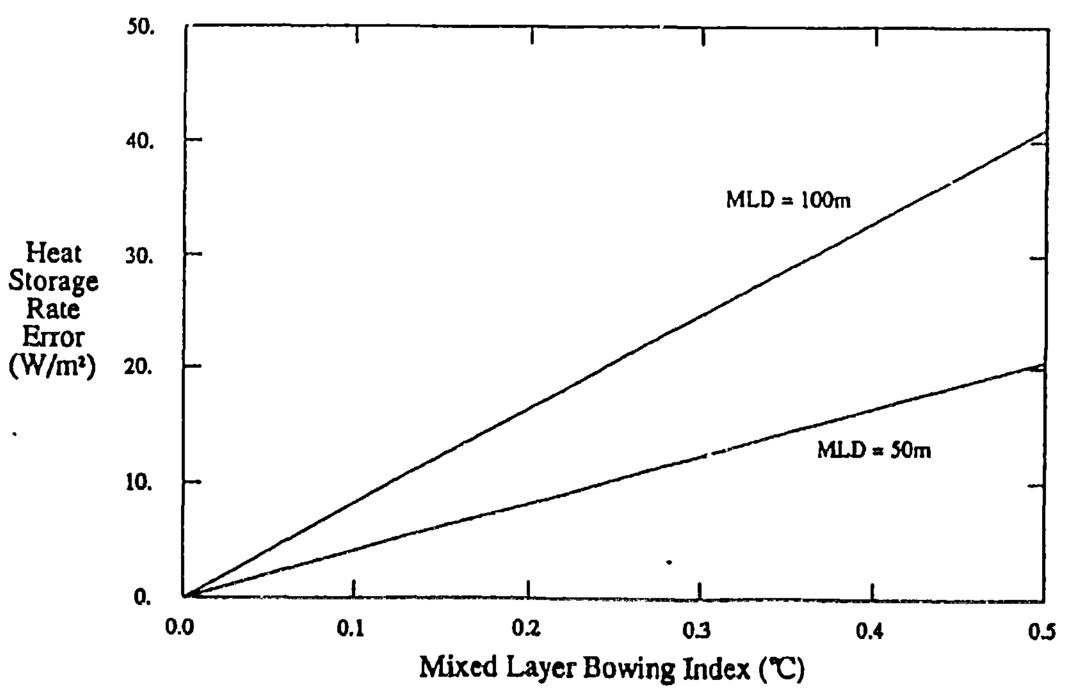


Fig. 9. Error in monthly heat storage rate due to the "bowing" problem of the SEAS II XBT System.

Table 1

Calibration Experiment #	Voyage	XBT System Description	XBT Type	Number of XBTs	Number of Corresponding CTDs
1	FR0487	SEAS II/Bathy Systems SA-810 (HP-85)	Deep Blue	17	17
2	FR1087	Sippican MK-9 (HP-85)	Deep Blue	14	3
3	FR1087	Sippican MK-9 (PDP-11)	Deep Blue	12	3

Table 2

DYNAMIC HEIGHT ERROR

Voyage	XBT System	Error in Dynamic Height Relative to 200 m (dyn m)		Error in Dynamic Height Relative to 400 m (dyn m)		Error in Dynamic Height Relative to 700 m (dyn m)	
		Mean	Standard Dev.	Mean	Standard Dev.	Mean	Standard Dev.
FR0487	SEAS II/Bathy Systems SA-810 (HP-85)	0.001 (0.007)	0.007 (0.008)	-0.009 (0.010)	0.013 (0.013)	-0.012 (0.020)	0.013 (0.014)
FR1087	Sippican MK-9 (HP-85)	-0.011 (0.004)	0.007 (0.006)	-0.012 (0.011)	0.009 (0.009)	-0.016 (0.012)	0.011 (0.011)
FR1087	Sippican MK-9 (PDP-11)	-0.011 (0.003)	0.008 (0.009)	-0.013 (0.008)	0.008 (0.008)	-0.019 (0.009)	0.012 (0.011)

( ) after XBT depth correction according to Hanawa and Yoritaka[4].

Table 3

SEAS II MIXED LAYER ANOMALY ANALYSIS 1987
(Estimate)

Index = $T_{max} - T_{5\ metres}$

Total number of drops = 1739
Total number of anomalous drops = 1223
Mean Index for anomalous drops = 0.22

Index Bin	Index >	Range ≤	Frequency	Percentage of Total Drops
0.1	0.05	0.15	625	35.94
0.2	0.15	0.25	315	18.12
0.3	0.25	0.35	133	7.65
0.4	0.35	0.45	44	2.53
≥0.5	0.45	—	106	6.10
			TOTAL = 1223	TOTAL = 70.34

STATUS REPORT OF THE GROUP OF EXPERTS ON OPERATIONS AND TECHNICAL APPLICATIONS

D. McLain, Chairman

The IGOSS GOE/OTA has dealt with many problems that are of interest to the VOS meeting participants. Some of the problems are as follows. Problems dealt with by the Task Team on Quality Control for Automated Systems will be reported separately by Mr. John Withrow.

I. OBSERVATIONS

A. Lack of Stable Funding for XBT Probes

A fundamental problem for IGOSS is the lack of stable funding for XBT probes for global ocean monitoring. XBT probes now cost about $50 each and many programs are having trouble maintaining their past levels of sampling. As a result, sampling on some ships has been cut from two to one XBT drop per day.

B. Expendable Probes vs. Retrievable Profilers

Expendable probes (XBT's) are now widely used in IGOSS and we're seeing problems with them: 1) cost, 2) ship supply problems, 3) inaccurate calibration (particularly fall rate), and 4) electrical problems ("bowing" etc.) Expendables use separate sensors for each cast -- the sensors are calibrated at the factory but seldom checked in use. In contrast, retrievable profilers use single sensors whose calibration is checked frequently in use. Retrievable profilers (i.e. CTD's) are widely used on research and other vessels that can slow or stop on station but very few of the data are reported to IGOSS in real-time. I feel it's time that IGOSS re-evaluate its dependence on expendable probes and make a real effort to obtain all available reports from retrievable profilers.

CTD profiler data would be very useful in IGOSS as CTD's, in comparison with XBT's: 1) can be inexpensive (if some other program pays for the sampling), 2) measure salinity as well as temperature, 3) measure depth (actually pressure), rather than assuming it from probe fall rate, and 4) use a precision thermometer rather than a poorly calibrated thermister.

Expendable CTD probes are now available commercially and suffer similar problems as XBT's. XCTD probes cost at least $250 each and if we're having problems funding XBT's at $50 each, we can't use XCTD's for IGOSS-style ocean monitoring. Of course, if some other program is paying for the XCTD probes, we should try to get real-time messages of the data.

Mini-CTD's are an attractive source of real-time data as there are several hundred mini-CTD's in use globally. The units are small, inexpensive and reliable. One way to get TESAC messages from mini-CTD's is for mini-CTD manufacturers to include TESAC modules in their standard system software. To this end, TESAC encoding software (from Dr. Mike Miyake at IOS Canada) has been supplied to three mini-CTD manufacturers (SeaBird, Applied MicroSystems, and Ocean Sensors).

C. TESAC Reports

IGOSS must start reporting more salinity data. Although many research vessels measure salinity, few salinity reports are made, with the notable exception of vessels of the USSR and Canada. Salinity data will be emphasized in the GTSPP program, mentioned later.

There should be some discussion at the VOS meeting about how each nation can report research vessel observations in real-time. We should not continue to talk about XBT's and merchant ship lines exclusively.

D. TRACKOB Reports

A few vessels are now making TRACKOB reports (FRG, Canada, etc). Many other ships have underway salinometers that could be interfaced to shipboard microcomputers to encode and report TRACKOB messages. For example, on some US research vessels, Serial ASCII Instrumentation Loops (SAIL) are installed and interfaced to underway salinometers. On these vessels, TRACKOB messages could be encoded automatically by SEAS-type systems from data on the SAIL loop.

E. Military Observations

NOAA has started negotiations with U.S. Navy on the possibilities of release of classified military observations. It appears that the Navy may soon release some of their ship XBT data, after a lapse of several years. If this happens, it will greatly increase the amount of available data in such areas as the North Atlantic.

II. DATA QUALITY CONTROL

Bob Keeley (Canada) and Dieter Kohnke (FRG) have developed a revised and expanded set of quality control procedures for BATHY/TESAC messages. They have incorporated their procedures into a revision of IGOSS Manuals and Guides No. 3 and will submit them for consideration by IODE.

The Quality Improvement System (QUIPS) is a microcomputer system to edit BATHY and TESAC messages. The system is used operationally to edit real-time messages at NMC/OPC in Washington, DC and FNOC in Monterey, CA. QUIPS is also used in non real-time mode by Scripps Institution of Oceanography in La Jolla, CA. to enter BATHY messages that were not sent from a ship in real-time. The original QUIPS was programmed in "C" language for a Zenith 120 microcomputer but has been rewritten to work on PC and AT machines. Demonstration floppy discs of the PC version have been sent to FRG, Turkey and Oman. A similar program (in FORTRAN for an AT) is in use at the Marine Environmental Data Service (MEDS) in Ottawa, Canada.

A new version of QUIPS is now being developed to operate on a microVAX II interactive graphics workstation. In contrast to the microcomputer systems which display a single message and profile at a time, QUIPS2 plots cruise tracks, profile maps and time series so that the operator can see the profile in context of surrounding observations in time and space. The system was initially developed for SHIP weather reports and is operational at NMC/OPC for editing surface pressure data. QUIPS2 is now being extended to operate with BATHY/TESAC reports, NODC UBT data and other data as part of GTSPP.

III. GLOBAL TEMPERATURE - SALINITY PILOT PROJECT

The Global Temperature - Salinity Pilot Project (GTSPP) is a joint pilot project of IGOSS and IODE to: 1) link real-time and non real-time data processing and 2) incorporate salinity as well as well as temperature into ocean analyses. The US, Canada and Australia presently support GTSPP and USSR, France and others may soon join the effort.

A fundamental goal of GTSPP is to link IGOSS and IODE processing using the new technologies of electronic networks and interactive graphics workstations. A key element in this is standardization of data formats and communications so that several data centers can work as a team on quality control without duplication of effort. This requires that flags be generated and saved with the data so that users can know exactly what changes were made previously to the data. Since present data formats do not allow for saving such information, GTSPP will use the new WMO Binary Universal Format for data Representation (BUFR) for data exchange. BUFR is extremely flexible and can store such information, using an extension to WMO's present definition, as will be described later.

Interactive graphics workstations will be the basis of GTSPP. The US QUIPS2 workstation uses BUFR as its internal format and will be used for editing GTSPP data at NODC in Washington, DC and at the Center for Ocean Analysis and Prediction (COAP) in Monterey, CA. MEDS in Ottawa is developing a similar workstation using artificial intelligence (AI) techniques. The rules in the AI system are closely linked to the revised quality control procedures in the new IGOSS Manuals and Guides No. 3. The AI system allows "object-oriented programming", that is, changing the sequence of quality control tests by moving objects on the screen of the workstation.

In GTSPP, BATHY/TESAC messages will be extracted from the GTS at three weather data centers: FNOC, NMC, and AES in Ottawa. All data will be converted to BUFR and routed each day to MEDS for editing. To check on the GTS communications, MEDS will maintain tables of the numbers of observations from the three weather centers. After editing, the data will be sent on SPAN to NODC in Washington for merge with non real-time data and further distribution. NODC will maintain a "continuously updated data set" of GTSPP and other data that will be accessible electronically over a network. Thus the merged and quality controlled profile data in GTSPP can be available within a few days after collection.

All data will be passed to TOGA, WOCE and others. As at present, NODC will send the data for the Pacific on SPAN to JEDA at Scripps in La Jolla for analysis and mapping of Pacific temperatures and anomalies. A JEDA-type data center for Atlantic data has been proposed at AOML in Miami, Florida and may eventaully become part of GTSPP. As at present, JEDA in La Jolla will convert the Pacific data to GF-3 format for relay to the TOGA Subsurface Thermal Data Center in Brest, France. The data will also be sent to COAP in Monteroy for archival, analysis and preparation of near real-time data products.

Bob Keeley of MEDS submitted the following summary to OTA on GTSPP:

"A second ad hoc meeting of the Global Temperature Salinity Pilot Project took place in Ottawa from 25-28 July. There were participants from Australia, the TOGA Subsurface Data Centre, the US, the USSR and Canada. The Project had been adopted as a Pilot Study by IGOSS V held in November last year. It will be proposed to IODE early in 1990. One of its goals is to handle ocean data transmitted in real-time over the GTS, to quality control these data rapidly and to forward them to the IODE system where they will be available quickly to users. MEDS of Canada is taking the lead in handling the GTS data. The data will pass through MEDS in about 7 days, time enough to accumulate some data from each platform and place the data within the context of the cruise. Using telecommunications circuits and BUFR as the format the data will be relayed to the US NODC. There they will be placed in a continuously managed data file with access to all. As delayed mode data are received, the data from the GTS will be replaced. After a few months, all received data will be sent on for scientific quality control and then returned to the NODC to once more update the file. All quality control flags will be retained with the data."

"At each stage in this process, quality control flags will be set. A draft Manual of the quality control procedures is inpreparation. The flag procedures will use the scheme presently used in IGOSS. The latest version of the Manual was reviewed by the meeting and suggestions were made on required changes. An updated version will be issued by November. After the internal review of the Project, the Manual will be sent to OTA, among others for comment."

"A second aspect of importance to OTA is the data monitoring activity being planned within the Project. So, MEDS will be accessing various sources on the GTS to attempt to locate problems in data transfers. They will be assisted by Australia and the USSR. Data transmitted during September to November of this year will be analysed by MEDS to determine the level of duplication and lost messages. Results of this exercise will be made available to interested parties."

IV. DATA FORMATS

A. Binary Universal Format for data Representation (BUFR)

As mentioned earlier, it is vital in IGOSS to save both original and modified data values during editing and processing. Of the available WMO formats, only BUFR is sufficiently flexible to save such information. BUFR has been adopted by WMO for real-time data exchange. In addition, BUFR is both compact and sortable and thus can be used as a data processing format. All major weather forecasting centers (ECMWF, FNOC, NMC, UK Meteorological Office, German Weather Service, and Australian Meteorological Service) are developing BUFR software and plan to develop data bases in BUFR. For these reasons, BUFR is used in GTSPP and in the QUIPS2 workstation.

At a recent BUFR meeting (WMO Commission on Basic Systems, Working Group on Data Management, Subgroup on Data Representation in May in Geneva), two methods were proposed for saving original and modified values for quality control applications. The first method was proposed by the European Centre for Medium Range Weather Forecasts (ECMWF) as a bit table to show which values in a data list are modified. Modified values follow observed values in the data section of BUFR. The second proposed method is the implied descriptor method used in QUIPS2. Both methods have been coded and are in experimental use. The two methods will be discussed at a meeting at ECMWF this winter to look for ways to merge them.

The WMO meeting also dealt with many proposed extensions to the BUFR and GRIB binary data formats. New entries in the BUFR Data Descriptor tables (Table B) were proposed for such parameters as radar precipitation data, atmospheric pollution and radionuclide data and statistical properties of parameters.

One item of particular interest to IGOSS is the need for a character form of BUFR for transmission through telex (non-binary) lines and for display on telex and ASCII terminals. Bob Keeley (Canada) described IGOSS's need for a flexible code for real-time reporting of new types of ocean data (e.g. sea level). Earlier, Bob had proposed a flexible five character code (IGOSS Flexible Code, IFC) for real-time reporting of ocean data, based a combination of the five character codes, BUFR and GF-3. At the WMO meeting, Bob proposed a modified form of IFC, based on ten character groups.

A representative of ECMWF described their proposal for a tabular, character (ASCII) form of BUFR, "BTAB". BTAB is attractive as the meaning of the data is immediately obvious from labels on the column headings but there was disagreement as to the exact labels to be used. Neither IFC or BTAB was formally accepted by WMO and the issue remains unresolved.

B. Linking BUFR and GF-3

It is important that the real-time, primarily meteorological BUFR format be linked with the delayed mode, primarily oceanographic GF-3 format. This would better merge oceanographic and meteorological data collection programs as well as the IGOSS and IODE data exchange programs. As a step towards linking the two formats, in May I visited the Bidston Laboratory at Birkenhead, U.K. to meet with Meirion Jones of the British Oceanographic Data Center and Rex Gibson from ECMWF to discuss how to link BUFR and GF-3. Dr. Jones is one of the originators of GF-3 and Mr. Gibson is one of the originators of BUFR.

I described the need to incorporate IGOSS's oceanographic parameters in GF-3 into BUFR as both formats are table-driven and have related uses. A way must be found to update the data descriptor tables of one format when the other is updated. Not all GF-3 parameters can be incorporated into BUFR, however, as many of the GF-3 parameters are not fundamental parameters but are statistical properties of parameters. But at the least, we have to get sea level into BUFR so that if and when a character form of BUFR is approved, GLOSS sea level data can be sent on the GTS.

V. COMMUNICATIONS

Many of our present communications systems are still cumbersome and error-prone (Morse Code CW, voice, etc). IGOSS must start using newer systems, such as IMARSAT A and C and packet radio. Both INNMARSAT and packet radio offer the possibility of 2-way communications. Both INNMARSAT systems offer reliable, global coverage. INMARSAT A systems are now installed on over 8000 thousand ships and thus are excellent candidates for IGOSS use. The newer INMARSAT C offers very low cost, digital communications using inexpensive terminal equipment.

Packet radio systems are rapidly evolving and provide high data rates at very low cost. Packet radio will provide primarily regional coverage using HF and VHF frequencies. IGOSS must work to maintain the special Ocean HF radio frequencies for use with such systems as packet radio.

VI. IGOSS MONITORING

A. Ship Visit Reports

We need to be able to monitor IGOSS activities both on the 1) ship level of number of XBT probes supplied to a ship and 2) the GTS level of the number of BATHY messages received from the ship. On the ship level, the monthly activity reports that VOS personnel telemail to the IGOSS Operations Coordinator (Mr. Carl Berman) are very useful but we must work toward a consistent format for the reports and for more complete reporting by all VOS programs. The combined ship visitation data should be easily read into database management systems for automated comparisons and analyses of the data.

B. GTS Monitoring

Comparisons on the GTS level of the number of messages available at different locations are more difficult. The GTSPP program will provide automated summaries for three GTS centers, as mentioned earlier. On a simpler level, I can generate a floppy disc of the numbers of reports I receive here from FNOC. The data are stratified by ocean basin and latitude band (90N-30N, 30N-30S, and 30S-90S). Dave Cutchin from Scripps will compare the numbers of GTS messages with the number of XBT probes he puts on ships. Valerie Lee from TOGA may also use the data for monitoring the number of IGOSS reports in the 30N-30S TOGA area.

C. IGOSS Monitoring

A quarterly summary of IGOSS data collection and real-time report is now being distributed by the IGOSS Operations Coordinator. The data are supplied by the French Meterological Service. This report is a useful summary of IGOSS activities.

An excellent start at development of an interactive way of monitoring IGOSS sampling has been made by Dr. Jean-Paul Rebert of the TOGA Subsurface Data Centre in Brest. This is an online system on telemail to summarize data in the TOGA area. IGOSS participants are encouraged to contribute data to the development of Dr. Rebert's system.

VII. DATA DISTRIBUTION

A. NODC CD-ROM

A major new method of distributing marine data is now available with Compact Disc - Read Only Memory (CD-ROM). These discs are very inexpensive and store over 600 megabytes of data. CD-ROM readers are available for PC microcomputers for about $800. Many discs of marine data are becoming available, including one from the US NODC that contains some 1.4 million temperature and salinity profiles for the Pacific. A companion floppy disc includes software to extract and display the data in a variety of ways. The NODC disc is available to IGOSS participants at no cost, only for comments on possible uses of and needed improvements to the data. Other available CD's contain marine bibliographic data (FAO ASFIS), satellite data (NASA JPL) and daily and monthly gridded fields of Northern Hemisphere surface pressure (University of Washington Department of Meteorology).

B. "2-Way SEAS"

IGOSS is presently oriented towards the "big science" programs of global climate and ocean research. To expand our base, we need to get many more "small science" programs and fishery and pollution control applications involved. The data collected by such programs would by primarily coastal in nature and would complement the open ocean, merchant ship XBT data to give greatly increased coverage and resolution for all users.

One way many small marine data collection programs might become involved in IGOSS is development and distribution of "2-way SEAS" software. Such a system could make and report observations and also receive and display data. Recent articles in Sea Technology give examples of available software for ship routing (April 1988, page 47) and fisheries (August 1989, page 10) that could be incorporated in a 2-way SEAS. In oceanography, a 2-way SEAS could display observations made by the system itself in combination with data received from shore (contour maps, etc), from satellites and from data archived within the system (say, on CD-ROM's).

STATUS REPORT OF THE TASK TEAM ON QUALITY CONTROL FOR AUTOMATED SYSTEMS

J. Withrow, Co-chairman

At the Second Joint IOC-WMO Meeting for Implementation of IGOSS Ship XBT Ship of Opportunity Programmes (Sidney, Canada 5-8 August 1987), a task team was formed to study both the systematic and random error characteristics of each component of the [XBT] systems in use such as:

- Instrument Error Characteristics
- System and software performance limitations; and
- Algorithms used to calculate fall rates, temperatures at depth, etc.:

Initially, the group looked at the standardization of equipment and made a preliminary list of the following items:

1. RS-232 port for data input from the XBT system
2. RS-232 port for the Satellite Transmitter
3. MS-DOS 2.x compatability and upward
4. 110 volt or 240 volt/50 Hz or 60 Hz compatability
5. Data file written in ASCII
6. At least one floppy disk drive
7. Graphics capability

However, no one was in favor of standardizing equipment because changing technology mandated that the system remain flexible enough to accommodate the equipment presently in use and configurations in the forseeable future. There was more interest in standardizing the procedures used by the automated system used to handle the data and making the current software available for public distribution.

There was no disagreement concerning writing the files in ASCII and the vertical resolution appeared to be satisfactory. The temperature equation also appeared to fulfill the requirement that the XBT interface be able to resolve temperature to 0.1 degree C. There was an indication of a problem with the equation used by Sippican to calculate the depth of the probe. There was also a separate "bowing" problem associated with a particular SEAS unit.

At this point the group was embarking on an examination of the quality of the observations developed by automated systems. Another problem surfaced with regard to TRACKOB messages. It was possible for a SEAS unit to transmit a TRACKOB message with more than 69 characters per line which was unacceptable from the GTS point of view. The suggestion was made that the software be changed so that one less 5-digit group would be printed in a line. This change would require a carriage return/line feed after every eleven groups instead of every 12.

About this time, at the First Session of the IGOSS Group of Experts on Operations and Technical Applications (Geneva, 30 November - 4 December 1987) a sub group of experts was formed to develop general recommendations regarding standards in equipment and software to be used for IGOSS purposes (particularly in the context of ship-to-shore communications). The sub-group was to take into account existing technological developments and the necessity of facilitating the participation, in IGOSS, of all countries regardless of their level of technological development.

This situation confused the picture for several months since both groups were comprised of many of the same people and were doing essentially the same things. The Chairman of the Group of Experts on OTA rectified the situation by unofficially combining the groups.

The Fifth Session the Joint IOC-WMO Working Committee for IGOSS observed that both groups were "to deal with the quality control of data obtained from automated observing systems" and hence combined the two into a unique Task Team on Quality Control Procedures for Automated Systems, as a subsidiary body of the IGOSS Group of Experts on Operations and Technical Applications. The following terms of reference were noted:

1) to study both systematic and random error characteristics in each component of the automated systems in use such as:

   - instrument error characteristics;
   - system and software performance limitations; and
   - algorithms used to calculate fall rates, temperatures at depth, etc:

2) to recommend to the IGOSS Group of Experts on Operations and Technical Applications possible standards in equipment and software to be used for IGOSS purposes (particularly in the context of ship-to-shore communications);

3) to maintain a close working relationship with IODE experts

in order to ensure consistency between IGOSS and IODE procedures in the field of quality control of data;

The membership of the Task Team is as follows:

Mr. R. Bailey	(Australia)	Co-Chairman
Mr. J. Withrow	(USA)	Co-Chairman
Dr. P. Collar	(UK)	
Mr. S. Cook	(USA)	
Dr. D. Cutchin	(USA)	
Mr. P. Parker	(Australia)	
Dr. M. Miyake	(Canada)	
Mr. T. Saito	(Japan)	
Dr. A. Sy	(FRG)	

After a slow start, the group is now officially constituted and has several items to review.

1. What if anything should be done about the problem with the depth equation?

2. What caused the "bowing" problem and should anything be done about it?

3. Has the problem with TRACKOB messages been corrected?

4. A review of the new quality control procedures adopted by IGOSS V and their application to automated systems.

5. An examination of data losses within the system, namely between the ship and the GTS insertion point.

SUMMARY ABOUT PRELIMINARY RESULTS FROM STUDIES OF DEPTH FALL RATE ERRORS OF "DEEP-BLUE" PROBES

A. Sy, Deutsches Hydrographisches Institut, FRG

Following "Recommendation 9" of the Sidney meeting 1987 some laboratory and seegoing tests were carried out to collect information about errors in the depth fall rate of XBT probes. There is no other way than comparing XBT data against CTD data, and usually differences in temperature readings are interpreted as errors in the depth fall rate. However, this procedure is not quite correct, because the derived depth fall rate error is a function of possibly two erroneous parameters, i.e. of the depth fall rate formula which converts the elapsed time into depth, and the temperature measured by the probe's thermistor.

Consequently, the first step in our test was the calibration of those XBT thermistors which should be used later for the in-situ comparison. The laboratory test should allow to eliminate one of the possibly two error sources. Originally it was planned to compare several ship units as well, however, no hardware except our own Bathy Systems SEAS II units were available.

The laboratory calibration was carried out in the following way:

The controller (Bathy Systems SA-810) was calibrated according the manual's guidelines. As further instrumentation a HP85B computer with original Bathy Systems software, a brand new Sippican Handlauncher, and two insulated water baths about which one was equipped with a calibrated Pt100 thermometer for the reference temperature, and a stirring-propeller to guarantee a homogeneous temperature distribution in the bath.

As a first step the probes were pre-cooled close to the reference temperature in the first water bath. The launch was simulated in the second water bath, and the reading of the PT100 temperature and the depth at the display was taken about one minute after the launch began. During the launch the probe was moved up and down to guarantee a better water exchange through the hole of the zinc nose where the thermistor is located. The probe adoption, in particular that of the zinc nose with a great thermal mass, was necessary in order to allow stable readings. However, the up and down movements caused sometimes noise in the XBT record, possibly due to connecting tolerances of the launcher. For each probe two measurements were carried out each in the range between 1 C and 5 C, 10 C and 11 C, and 19 C and 20 C, and were compared against the recorded temperatures. 36 Sippican Deep-Blue probes were calibrated according this procedure, one box in 1988 and two boxes in 1989. All proves were purchased about a half year prior to the test. In addition, 6 probes XBT-7 manufacured by Sparton of Canada were calibrated in 1989.

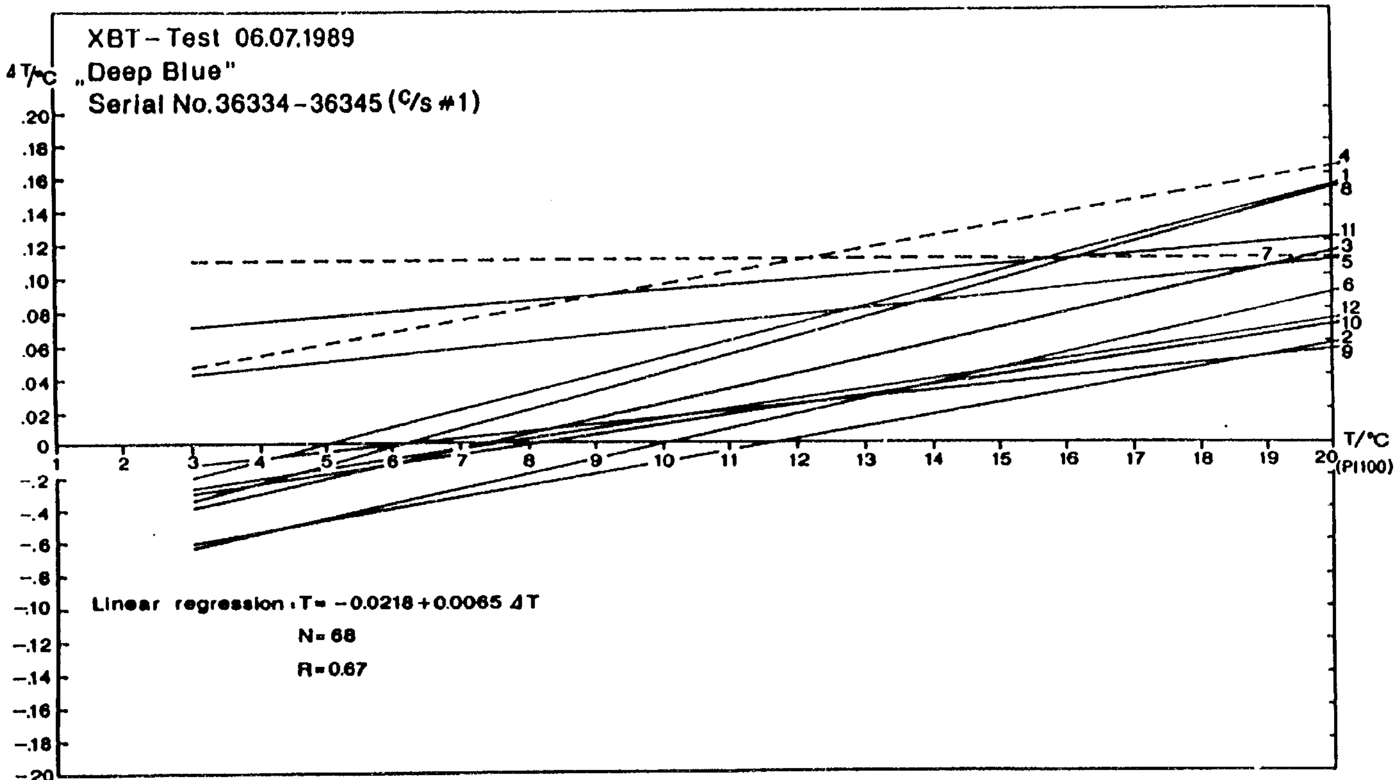
Except for three probes all error functions calculated are significant due to a linear fit and show a positive derivation (Fig. 1a-d). The overall result is that the accuracy given by Sippican as $\pm$ 0.2 K were found to be correct. It is assumed that the positive derivation possibly is caused by the Bathy System controller. If this assumption can be confirmed there are grounds for the assumption that this error is the source for the so called "bowing effect" in the mixed layer observed by several groups. It should be easy to verify or falsify this assumption. According to the results presented a systematic error in the order of + 0.2 K can be expected for measurements in the tropical mixed layer. Fortunately, that is no problem for our North Atlantic activities.

Irrespective of the presumtion that the positive derivation is due to the Bathy Systems controller or not, it is necessary to carry out a careful thermistor calibration at least for three temperature points. However, provided that the calibration procedure itself is of no effect on the probe characteristics (e.g. caused by water remaining in the probe, rusting parts, etc.). Further, it should be usefull to weigh all probe in order to get a first indication of individual differences.

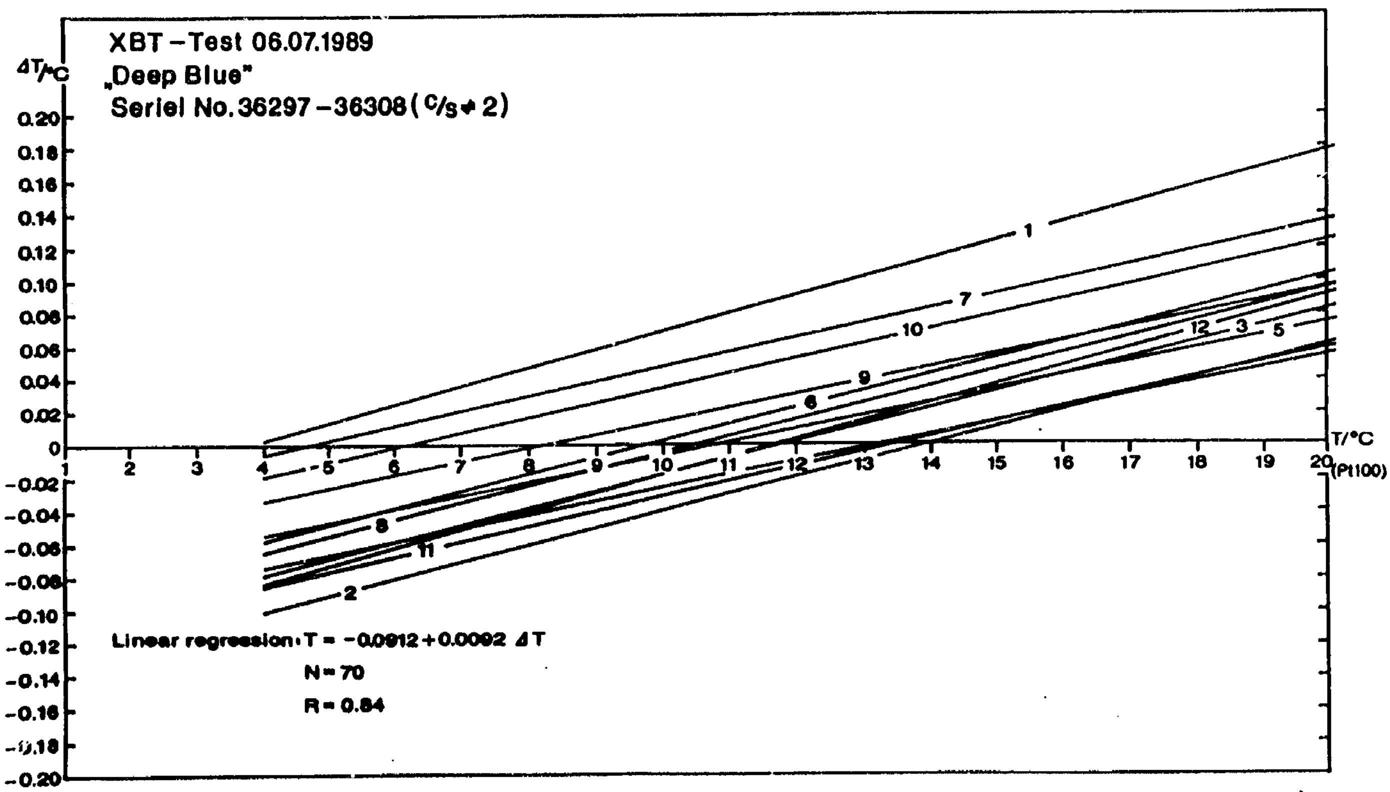
A week after the laboratory tests this summer 12 calibrated probes were used for an in-situ comparison with two CTDs in the Norwegian Trench (water depth 700 m). An autonomous SIS CTD with a self adjusting high resolution pressure sensor was mounted at a NB MkIII CTD. The sensor systems of both instruments were horizontally 30 cm apart. No significant deviation between the profiles of the two CTDs are observed.

First results of this comparison are shown in Fig. 2a-c. The XBT traces are corrected according the calibration results. The depth difference z(XBT) - z(CTD) of 8 XBT traces are negative while that of 3 traces match the CTD trace (solid line). 1 probe seems to be failed (# 9). In the segment of the strongest gradient, which is between 290 m and 440 m, the maximum negative depth difference which can be found is about 14 m (# 10, # 12) at the lower end of this segment. The depth difference of the remaining 6 probes above the CTD trace is below 10 m in average. According Sippican the depth accuracy is given as $\pm$ 2 % of depth, which is $\pm$ 8 m at 400 m depth.

It has to be emphasized that the analysis is not yet finished and the numbers presented are more or less raw estimates, which show a tendency towards negative values. Nevertheless, they indicate that probably no significant depth fall rate error will result from this test - in contrast to results from other groups. This can be due to the weak temperature gradient of less than 0.01 C/m or due to some internal variability which, however, was found to be small. It even may be that the depth fall rate error varies with the area. In addition, it is very likely that different results are caused by some certain differences of the probes (batches) itself and finally, it cannot be excluded that the calibration procedure influenced the depth fall characteristic of the probes. All these points have to be proved and discussed in context with all results of all groups available.

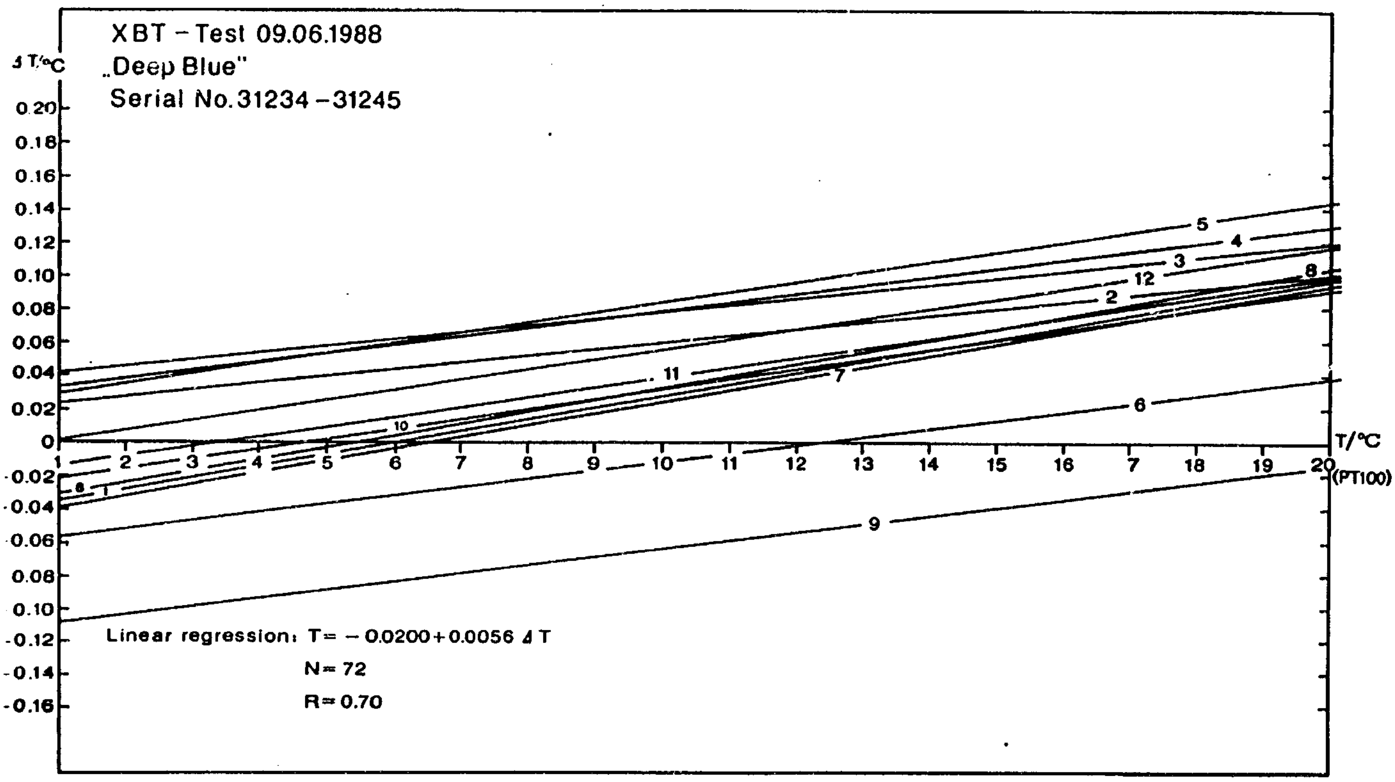


a)

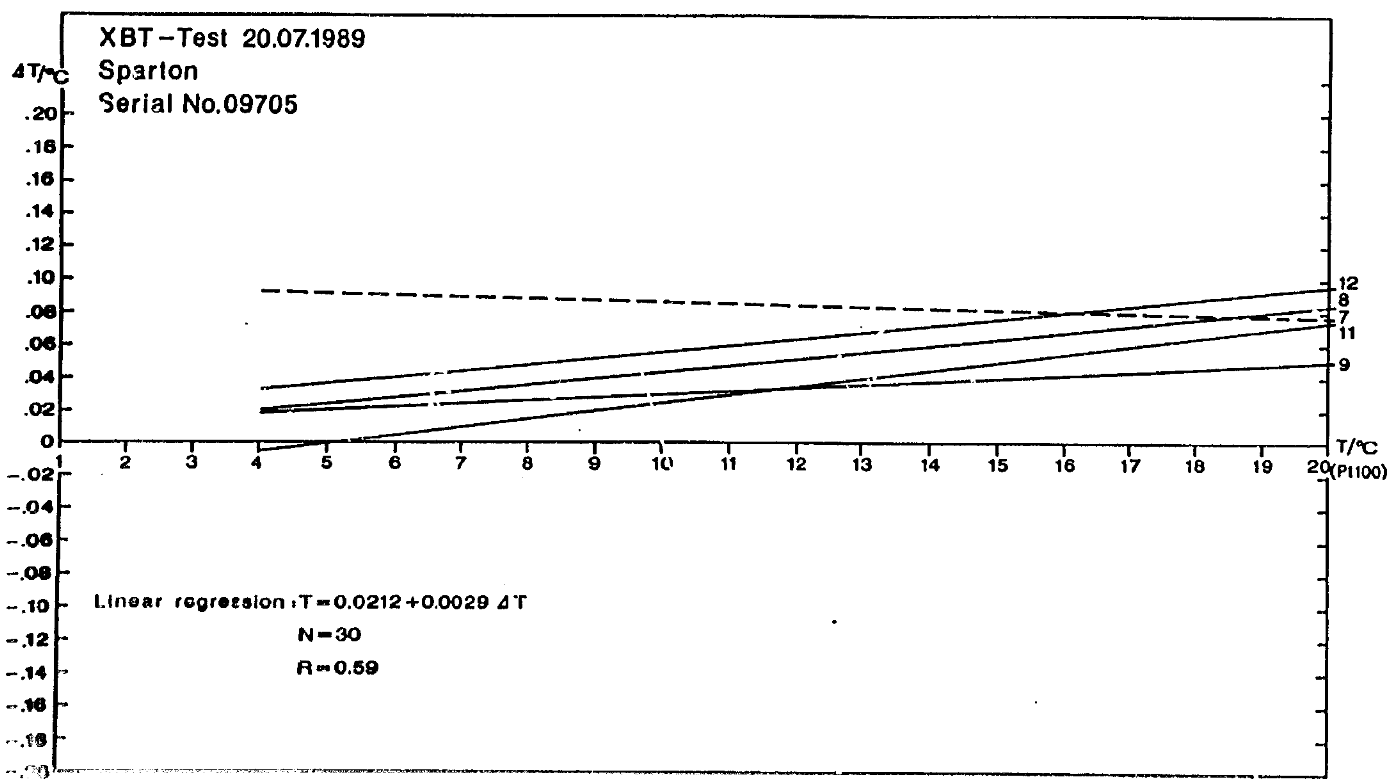


b)

Fig. 1 a-d: Results of laboratory XBT thermistor calibration


XBT - Test 09.06.1988
„Deep Blue"
Serial No. 31234 - 31245
ΔT/°C
T/°C
(PT100)
Linear regression: T= - 0.0200+0.0056 ΔT
N=72
R=0.70

c)


XBT-Test 20.07.1989
Sparton
Serial No. 09705
ΔT/°C
T/°C
(PT100)
Linear regression: T=0.0212+0.0029 ΔT
N=30
R=0.59

d)

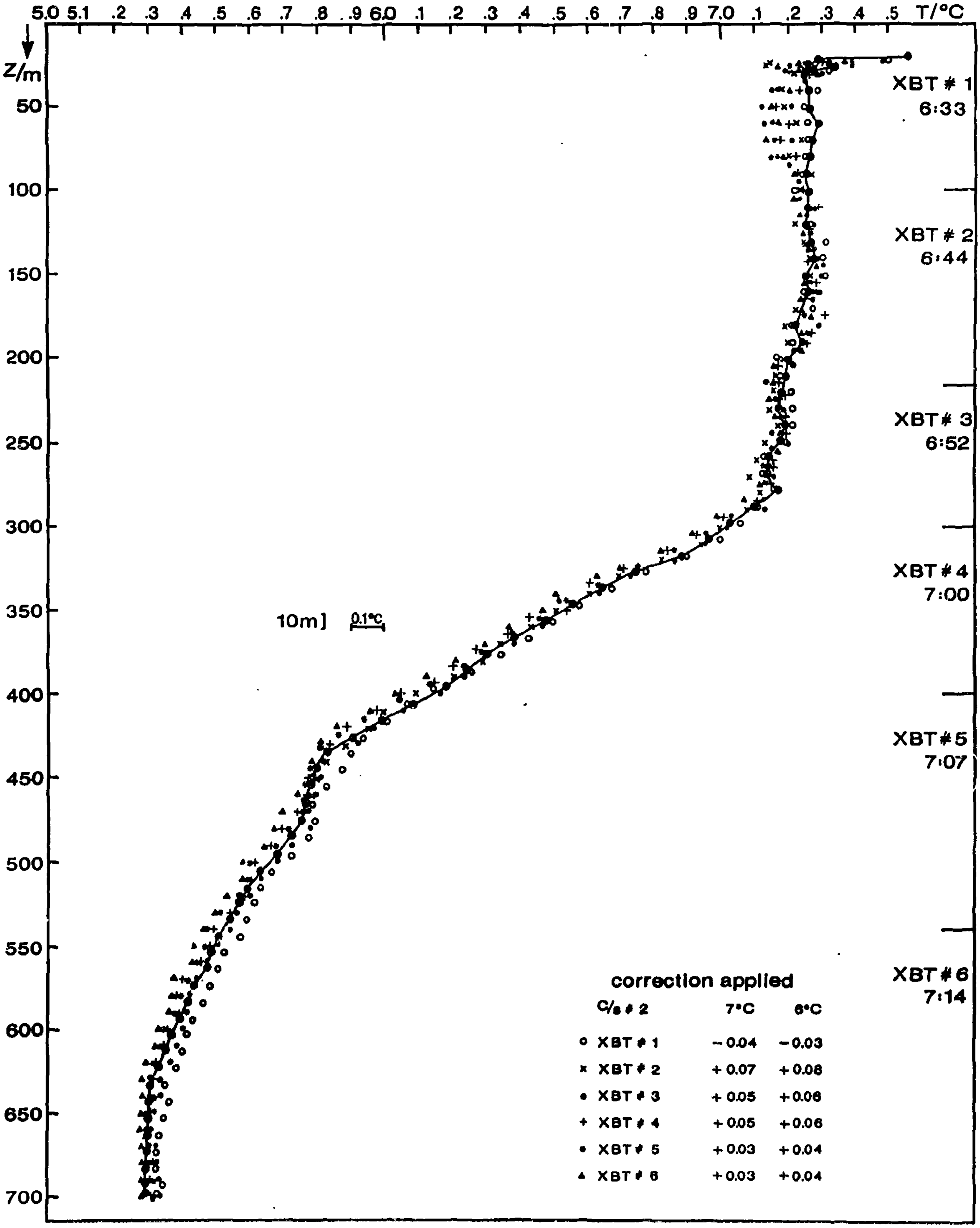
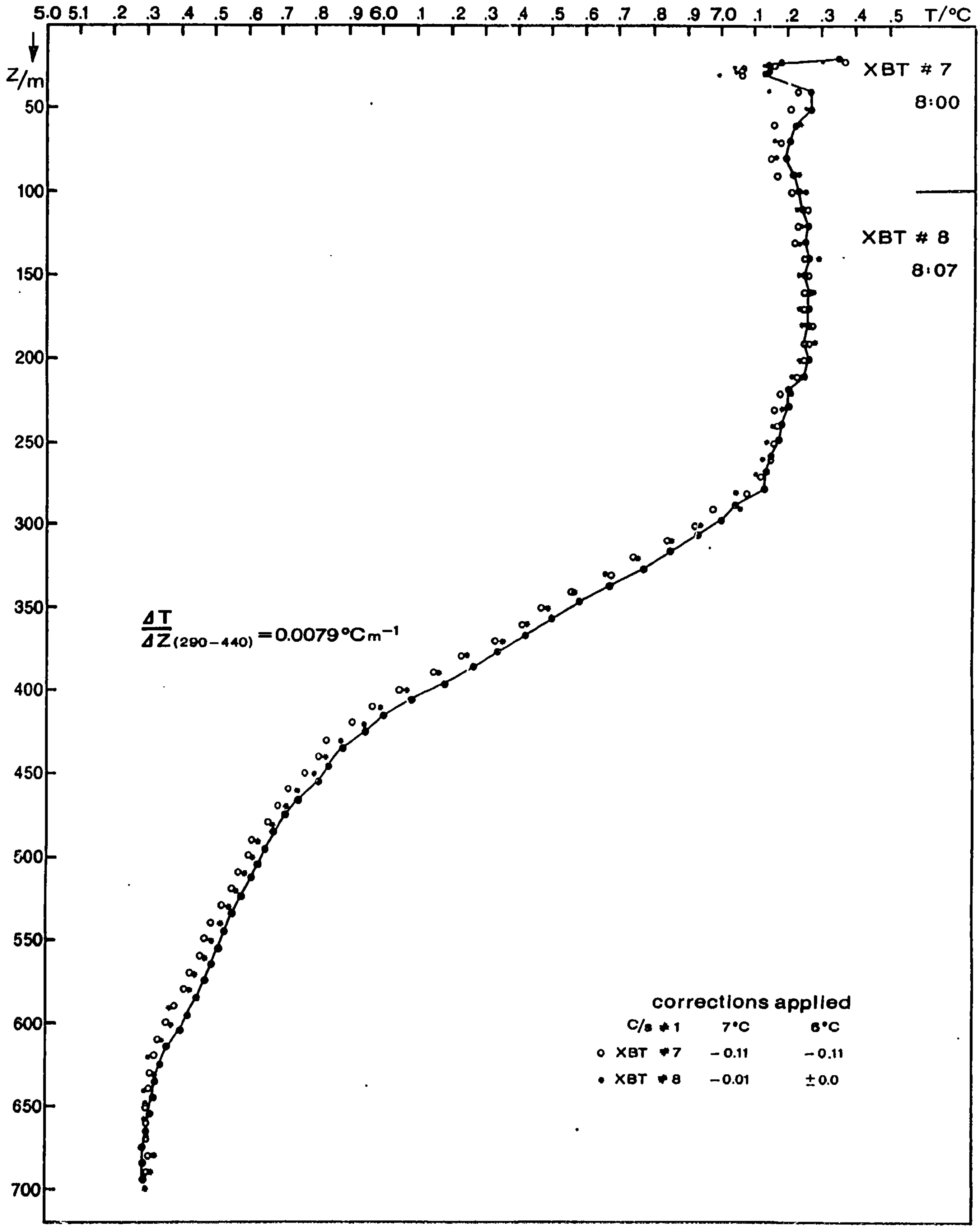
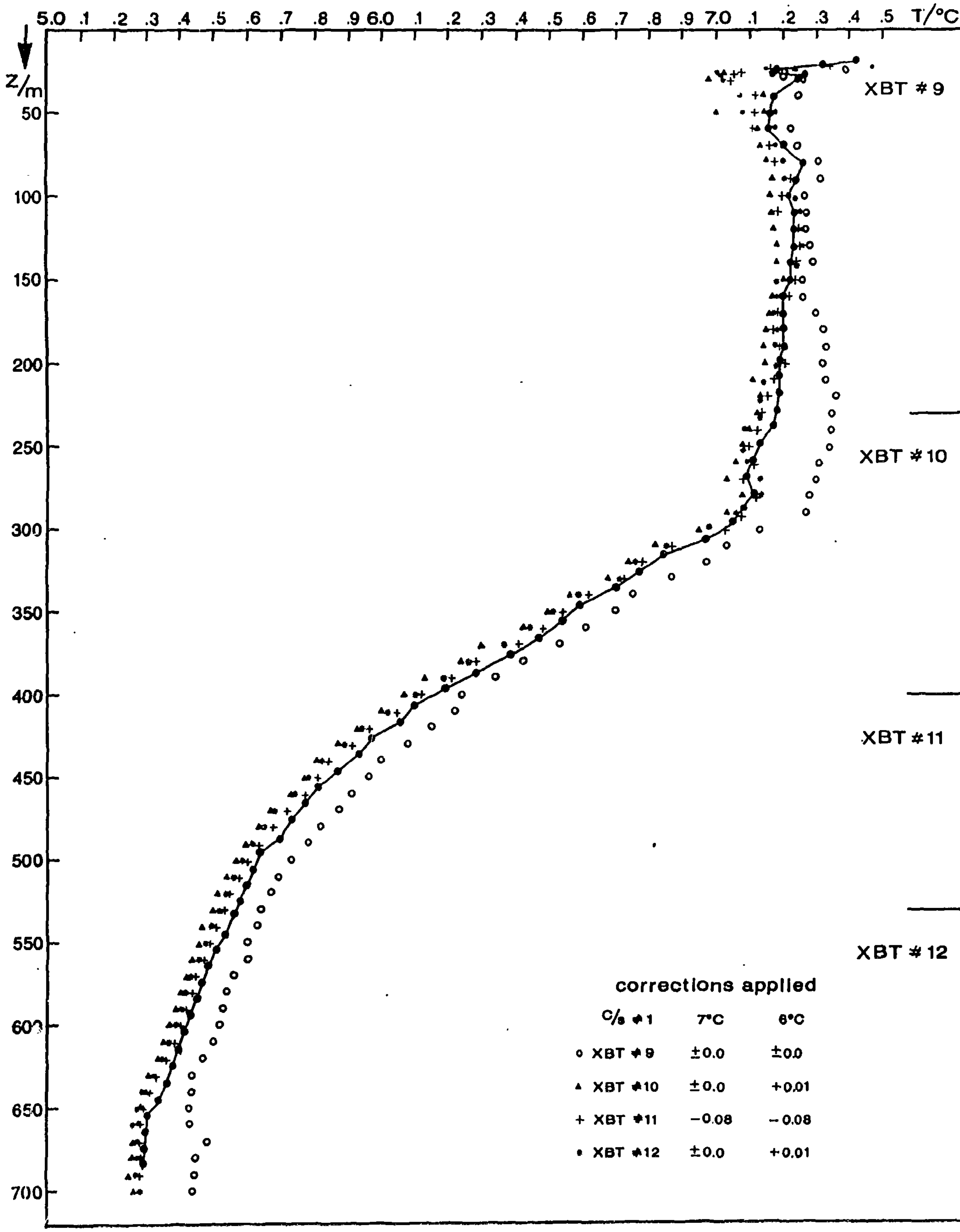


Fig. 2 a-c: Results of XBT-CTD comparisons carried out in the Norwegean Trench, July 1989


5.0 5.1 .2 .3 .4 .5 .6 .7 .8 .9 6.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 7.0 .1 .2 .3 .4 .5 T/°C
Z/m
50
100
150
200
250
300
350
400
450
500
550
600
650
700
XBT # 7
8:00
XBT # 8
8:07
$\frac{\Delta T}{\Delta Z}_{(290-440)} = 0.0079\,°C\,m^{-1}$
corrections applied
C/s # 1 7°C 6°C
○ XBT # 7 −0.11 −0.11
• XBT # 8 −0.01 ±0.0


5.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 6.0 .1 .2 .3 .4 .5 .6 .7 .8 .9 7.0 .1 .2 .3 .4 .5 T/°C
z/m
50
100
150
200
250
300
350
400
450
500
550
600
650
700
XBT # 9
XBT # 10
XBT # 11
XBT # 12
corrections applied
C/s # 1 7°C 6°C
o XBT # 9 ±0.0 ±0.0
▲ XBT # 10 ±0.0 +0.01
+ XBT # 11 −0.08 −0.08
• XBT # 12 ±0.0 +0.01