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MARINERS WEATHER Log

EXPENDABLE BATHYTHERMOGRAPH OBSERVATIONS FROM SHIPS OF OPPORTUNITY

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INTRODUCTION

Personnel of merchant and fishing vessels, who have cooperated for many years in taking and reporting weather observations, are now beginning to make observations of water temperatures below the sea surface to depths of 760 m (2,500 ft). Such observations from freighters, tankers, transports, and fishing vessels are made possible by the relatively new expendable bathythermograph, commonly called the "XBT." Oceanographers call these cooperating nonoceanographic vessels "ships of opportunity."

USES OF SUBSURFACE TEMPERATURE DATA

The primary impetus in the development of the XBT came from the U.S. Navy, whose advances in antisubmarine warfare technology required a subsurface system for recording temperatures that was more accurate and easier to use than the mechanical bathythermograph (MBT). For a dependable observation with the MBT, the ship must slow to 5 kt or less in order to lower and raise the instrument to the required depth (a maximum of 900 ft). This operation usually takes more than 20 min. With XBTs, observations can be made in a few minutes at speeds as high as 30 kt without interfering with the ship's operation.

Although the military need made the development of the XBT feasible, other oceanographic studies of the marine environment also awaited the development of instruments that would economically provide the capability of oceanographic monitoring. By this, we mean the collection of oceanographic observations widely enough distributed in time and space to reveal the week-to-week, month-to-month, and year-to-year differences in a changing ocean. This procedure may be likened to the collection of weather observations that are used to determine storm patterns and forecast weather conditions. Such an oceanwide monitoring system will require observations from many sources, such as buoys, satellites, coastal and island stations, oceanographic research ships, and especially ships of opportunity.

Of the many variables to be observed it seems logical to start with temperature, because it is easily measured and because it is of paramount importance to the following marine biological and physical problems:

1. Marine organisms are affected both directly and indirectly by temperature. One well-known example of harmful temperature changes is the El Niño effect, which occasionally develops along the Pacific coast of South America in the general region of Peru. Here a relaxation of the upwelling of cold water from below the surface and the incursion from the north of much warmer surface water, often accompanied by the bloom of microscopic toxic organisms, cause widespread destruction of coastal fauna. The commercially abundant anchovies (anchovetta) leave the surface layers to avoid the warm water, and the guano birds that normally feed on them emigrate in search of other food or starve in large numbers.
2. Temperature is known to affect migration patterns and group behavior of marine animals. Many nekton (swimming marine organisms) prefer certain temperature ranges. When the albacore, a temperate-water tuna, migrate eastward from the central North Pacific Ocean toward the coast of North America in early

summer, they generally appear in the fishing area where surface temperatures are between 15° and 20° C (59°-68° F).

3. An example of behavior affected by temperature can be found in tropical tunas, which are often fished by purse seine. Statistical studies have shown that when the thermocline (a layer of water separating the warm surface layer from colder deeper water) becomes sharper and is shallower than the bottom of the seine, there is less chance that the tuna will escape by diving below the net before the bottom is drawn together, or "pursed." The tuna tend to avoid passing down through the thermocline.
4. The monitoring of large ocean current systems by direct measurement of currents is difficult and expensive, so oceanographers often turn to the temperature distribution from which many inferences about the circulation can be drawn. Circulation of waters in the sea, including not only horizontal ocean currents but also vertical currents, is extremely important to the inorganic chemical nutrients essential to the growth of phytoplankton (microscopic plants, the first step in the food chain in the sea). In turn, the availability of microscopic food organisms to larvae and juvenile fish, may affect the survival and the ultimate abundance of fish spawned that year. Further, the distribution of heat in the sea, noted next, is very dependent upon the ocean currents.
5. A major physical application of the knowledge of temperature distribution and its changes is related to weather forecasting. Water has a high heat capacity so that the ocean acts as a giant heat reservoir. Not only does it store vast quantities of heat during summer for release in winter, but it may also store a fraction of the heat gained over periods of several years. This abnormal storage, as recognized by monthly temperature anomalies (differences from monthly averages), and the later release of the heat may play a significant role in the modification of large-scale weather patterns. Consequently, a knowledge of the changes in heat storage below the surface of the ocean is necessary to research into long-range weather forecasting.
6. Finally, vertical temperature gradients in the ocean have a large effect on the propagation of sound in the sea. Generally, cooling and deepening of the surface mixed layer increases the detection ranges of sonar equipment used by the Navy and fishing vessels. Conversely, warming

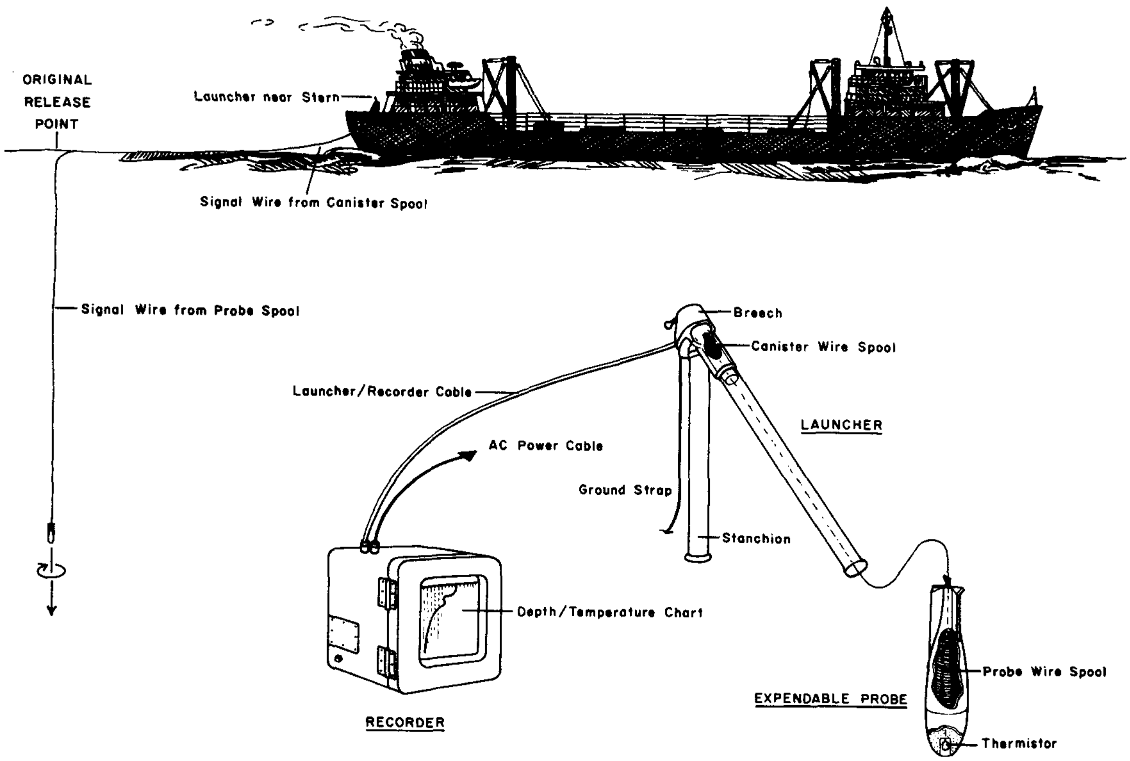


Figure 1.--The expendable bathythermograph system and its operation. Three major components of the system are the recorder, launcher, and canister containing the expendable probe and signal wire. The dual-spooling system for the signal wire permits the probe to sink vertically from its point of entry and the observation to be recorded as the ship proceeds on course.

and a decrease in the depth of the mixed layer reduces the detection ranges of hull-mounted sonar.

THE EXPENDABLE BATHYTHERMOGRAPH SYSTEM

The expendable bathythermograph system, which was engineered and developed by Sippican Corporation,* of Marion, Mass., has three major components (fig. 1). Two components, the launcher and recorder, small and light enough to be carried aboard ship by hand, are mounted semipermanently on the ship. The third and expendable component, one of which must be used for each observation, is the canister (fig. 2), which contains the expendable probe and signal wire.

The temperature sensing element is a rapid-response thermistor. It is mounted in the nose of the ballistically shaped expendable probe (fig. 1), which is about 22 cm (8.7 in.) long, 6 cm (2.4 in.) in diameter, and weighs about 700 g (under 2 lb). The dual-spooling system, see figures 1 and 2, for maintaining an electrical connection between the thermistor and shipboard recorder during the recording cycle is basic to the expendable design. As the ship proceeds on course, the fine (3.5 mm) insulated two-conductor signal wire is payed out freely on the water from the canister spool, which remains in the launcher. During the same period, the spool in the probe pays out wire freely from its finned tail and allows the probe to descend vertically from its point of entry at the surface of the ocean. The probe, which is spin stabilized and carefully weighed in manufacture, has a calibrated rate of fall, so that the depth is determined from the time interval from its entry into the water.

*Use of company name does not imply endorsement of the product by the U.S. Government.

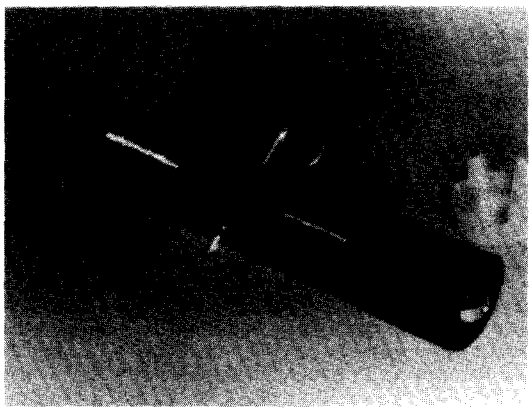


Figure 2. --Cutaway view of canister (35 cm long and 6 cm in diameter) reveals the two spools which together hold about 1.8 km (1.1 mi) of signal wire. The thermistor for sensing temperature is mounted very near the nose of the probe (at right) in the tubular opening extending along the axis of the probe. Release pin and protective cap are also shown.

The recorder operates automatically. When the release pin is pulled, the probe slides out of the launcher by gravity (fig. 3)--no explosive or propulsion device is involved--and the recording cycle is triggered by entry of the probe into the water. The temperature-depth trace is recorded as the probe descends. When the signal wire is expended, it breaks and the probe is lost. After a fixed recording period, the recorder automatically stops and returns to a standby position, ready for the next observation.

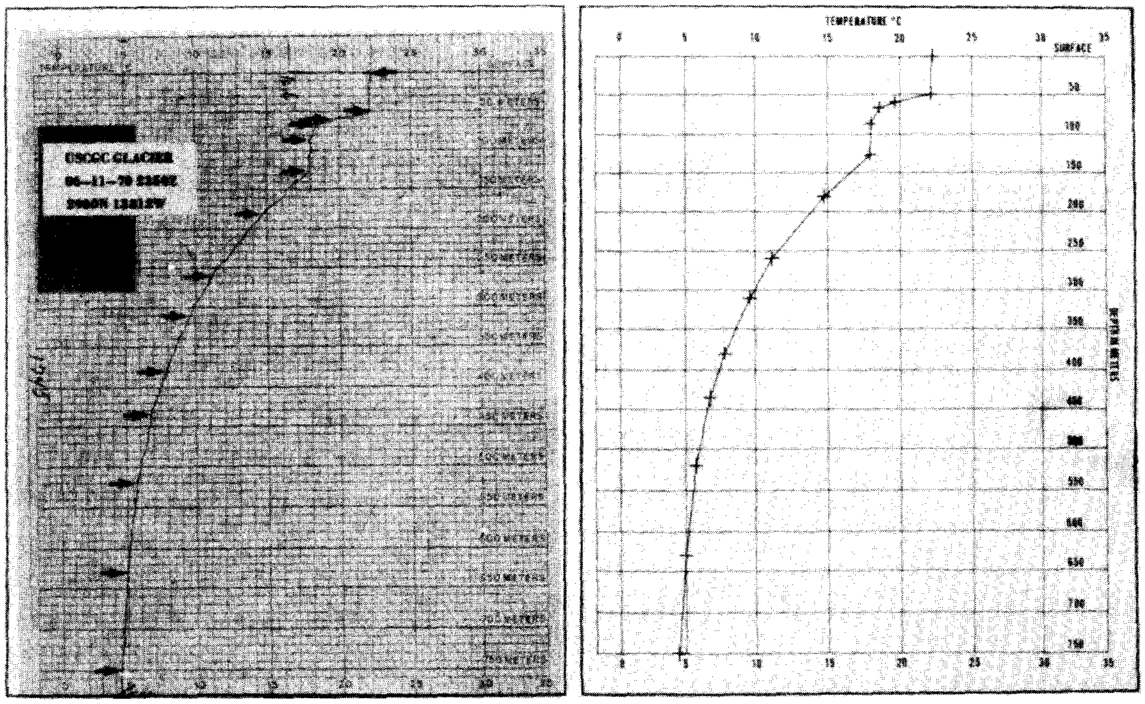
The system records over the normal range of sea temperatures, -2° to 35° C (28°-95° F). Probes are made for two primary depth ranges: (a) to 460 m (1,500 ft) for ship's speed up to 30 kt and (b) to 760 m (2,500 ft) for ship's speed up to 15 kt. The recording cycles last 90 sec and 180 sec respectively.

OBSERVATIONAL PROCEDURES

The work aboard ship at each observational period is neither difficult nor involved.

1. The XBT system is very simple to operate. The loading of the canister into the launcher, the release of the probe, and the recording cycle take less than 4 min.
2. A reference temperature observation is taken and recorded. This observation may be a surface temperature taken with a bucket thermometer or a representative water intake tempera-

Figure 3. --A test drop of an XBT is made from the National Marine Fisheries Service research vessel, DAVID STARR JORDAN. The probe can be seen in midair at lower left, but the signal wire is so fine (3.5 mm) that it does not show up in the photograph.



a. b.

Figure 4.--An XBT observation taken in the eastern North Pacific (29.0° N., 138.2° W.). a) Original trace with arrows designating significant points and standard depths that are read and encoded into BATHY message, b) the computer reconstructs the trace by drawing straight lines between the encoded temperature-depth points.

ture from the engineroom. For the latter, it is preferable to install an accurate electronic thermometer with an easily read meter in the engineroom or on the bridge.

3. Identification information, including observation number, time, location, and reference temperature, is entered on an observation logsheet furnished to the ship for the purpose.
4. A radio message (BATHY report) is encoded by reading the depth and temperature of enough characteristic points to describe adequately the recorded trace (fig. 4). The encoded BATHY message is held until the next regular watch of the radio officer, at which time it is radioed ashore, via the Navy's Fleet Weather Centrals, for the computer analyses prepared at the Fleet Numerical Weather Central, Monterey, Calif.
5. On some ships a sample of sea water is drawn and stored for later analysis ashore to determine the salinity of the near-surface waters. The sample is generally drawn from a sea cock in the engineroom, but some bucket thermometers are designed to collect a water sample of suitable size for this purpose.

The above five steps generally take about 20 min.

On merchant ships, the general responsibility for XBT observations is usually accepted by the chief mate or the watch-standing mates. However, if marine observers of the National Weather Service are aboard to take upper air observations they will make the XBT observations. Also, under a joint program between the Maritime Administration and the National Marine Fisheries Service, cadets from the Merchant Marine Academy make the observations (see page 342 of the November 1971 issue of the Mariners Weather Log for an article describing cadet observations). The ship's captain or navigator usually takes the observation aboard fishing vessels.

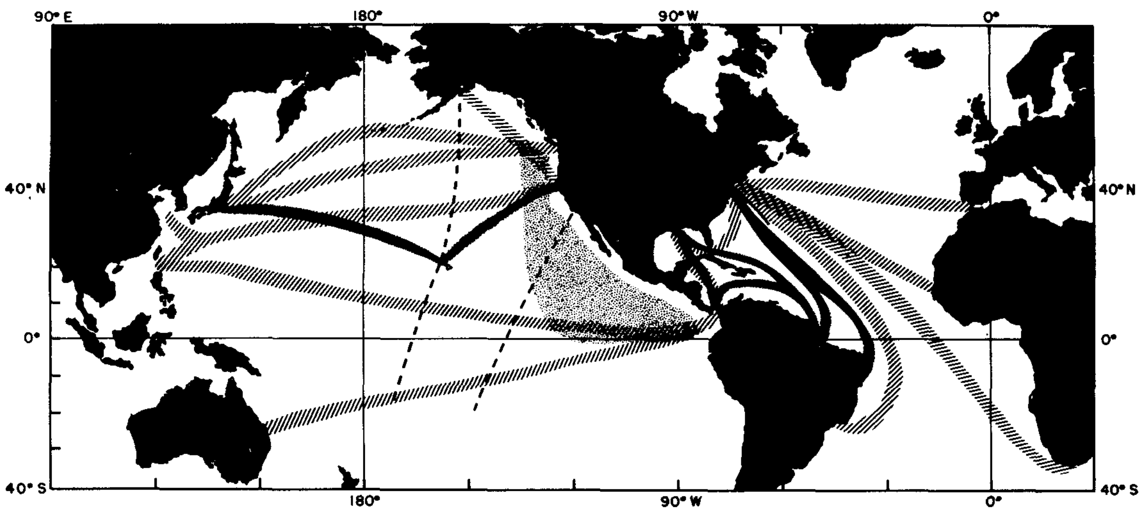
COOPERATIVE OBSERVATIONAL PROGRAMS

Programs for XBT observations on ships of opportunity are almost entirely supported by separate or cooperative projects among several government agencies: the U. S. Navy, National Marine Fisheries Service, National Weather Service, and Maritime Administration.

The U.S. Navy is the major supporter. Under the cognizance of Fleet Numerical Weather Central, Monterey, XBTs have been placed aboard over 30 U.S. commercial vessels, Military Sealift Command ships, and some foreign ships (table 1) which operate primarily on transoceanic routes of the North Atlantic and North Pacific Ocean (fig. 5). Generally two or more observations per day are made under this program.

Table 1. --Ships in Fleet Numerical Weather Central's Cooperative Oceanographic Observation Program

COMMERCIAL - Atlantic		
Farrell Lines, Inc.	SS AFRICAN COMET	SS AFRICAN PLANET
	SS AFRICAN CRESCENT	SS AFRICAN RAINBOW
	SS AFRICAN METEOR	SS AFRICAN STAR
Moore-McCormack Lines, Inc.	SS MORMACALTAIR	SS MORMACLYNX
	SS MORMACBAY	SS MORMACVEGA
		SS ROBIN GRAY
Prudential-Grace Lines, Inc.	SS PRUDENTIAL OCEANJET	
Transmediterrania Company	M/V VILLA de MADRID	M/V CUIDAD de SALAMANCA
COMMERCIAL - Pacific		
American Mail Lines, Inc.	SS ALASKA MAIL	SS JAPAN MAIL
	SS AMERICAN MAIL	SS OREGON MAIL
	SS CANADA MAIL	SS PHILIPPINE MAIL
	SS HONG KONG MAIL	SS WASHINGTON MAIL
Sea/Land Lines, Inc.	SS ELIZABETHPORT	SS SAN FRANCISCO
	SS LOS ANGELES	SS SAN JUAN
MILITARY SEALIFT COMMAND		
	USNS AMERICAN EXPLORER	USNS SHENANDOAH
	USNS FURMAN	USNS SHOSHONE
	USNS MARSHFIELD	USNS VICTORIA
	USNS NORWALK	USNS YUKON



= TRANSOCEANIC ROUTES, FNWC COOPERATIVE OCEANOGRAPHIC OBSERVATION PROGRAM.

= TRANSOCEANIC ROUTES, NATIONAL MARINE FISHERIES SERVICE - MARITIME ADMINISTRATION.

—— = TIME - SERIES SECTIONS:
[NAVOCEANO] NEW YORK - BERMUDA
[NMFS] HONOLULU - SAN FRANCISCO

- - - - = NEW ROUTES TO BE ACTIVATED UNDER INTERNATIONAL DECADE OF OCEAN EXPLORATION.

NMFS - FNWC COOPERATIVE FISHING VESSELS OBSERVATION AREA.

Figure 5. --Operating areas of cooperating ships of opportunity. Shaded areas indicate major trade routes on which ships take two to three observations per day. Solid lines show two routes where frequently repeated sections of six or more observations per day are taken to investigate time-changes in major currents. Dashed lines show routes selected for development of similar time-series during the International Decade of Ocean Exploration.

Table 2.--Fishing vessels cooperating in the Fishery-Oceanography Observation Program of the National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, Calif.

TYPHOON	QUEEN MARY*
CONQUEST	MARIETTA*
J.M. MARTINAC	GINA KAREN*
SEAQUEST	KERRI M*
ANTONINA C	VIVIAN ANN*
INDEPENDENCE	LOU JEAN II*
SUNRISE**	KATHLEEN*

* XBT systems owned by vessel
** XBT system owned by Oregon Fish Commission

The Fleet Numerical Weather Central also furnishes XBT systems and probes which National Marine Fisheries Service has placed aboard fishing vessels (table 2). Most of these vessels fish for tuna off the west coast of the United States and in the eastern tropical Pacific Ocean. These vessels, which often frequent ocean areas off the normal sea lanes, take one to four observations per day. Radio reports from the fishing vessels are generally channeled to the Fleet Numerical Weather Central through the National Marine Fisheries Service radio station WWD operated at La Jolla by Scripps Institution of Oceanography.

An initial phase of a cooperative program between the Maritime Administration and National Marine Fisheries Service has recently been completed. Cadets from the Merchant Marine Academy undergoing sea training made two to four observations per day on two ships in the Pacific and eight in the Gulf of Mexico and tropical Atlantic (table 3). The routes and areas were selected to contribute information for fishery and oceanographic research projects of the National Marine Fisheries Service, which services the equipment, instructs and advises the cadets, and collects and uses the data. Cadet participation is expected to increase in the future.

The above programs have the general purpose of achieving a widespread coverage of observations throughout the oceans of the Northern Hemisphere. This broad coverage is needed for many quasi-synoptic analyses and forecasts of oceanographic conditions, which are produced every 12 hr on the computers of the Fleet Numerical Weather Central. One analysis which depends almost entirely upon temperature-depth data from XBT observations is that of surface layer depth (fig. 6). Such analyses require that the observational data are coded into BATHY messages and sent out daily by radio from the cooperating ships.

For certain research purposes, it is desirable to have more closely spaced observations, repeated regularly along the same track (time-series sections). In June 1966, the Ocean Research Laboratory,† of the former Bureau of Commercial Fisheries, Stanford, Calif., initiated such a project aboard the SS CALIFORNIAN, a bulk cargo and container vessel of Matson Navigation Company. This ship traveled reg-

†This project transferred to National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, Calif., in July 1970.

Table 3.--Cooperative ships in the Joint Maritime Administration-National Marine Fisheries Service Ship of Opportunity Program

Atlantic Ocean and Gulf of Mexico		
Moore-McCormack Lines, Inc.	SS MORMACARGO SS MORMACTRADE	SS MORMACLAKE
Prudential-Grace Lines, Inc.	SS SANTA CRUZ	
Gulf and American Steamship Co.	SS GULF SHIPPER	SS GULF MERCHANT
Delta Steamship Lines	SS DELTA BRAZIL	SS DEL SUD
Pacific Ocean		
States Line	SS IDAHO	SS MICHIGAN

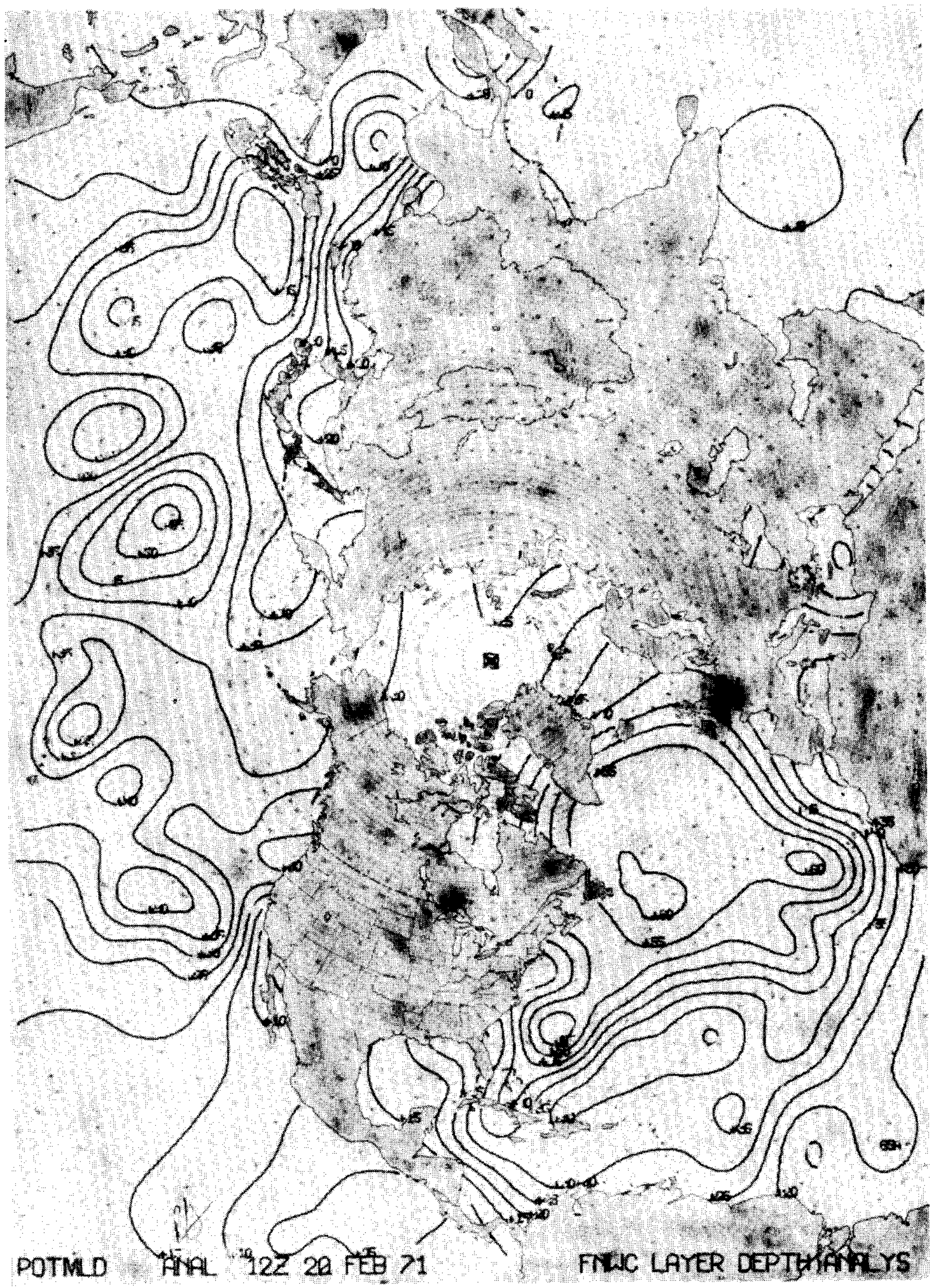


Figure 6.--Chart of layer depth (contours every 5 m [16.4 ft] starting at 20 m [65.6 ft]) is one of several oceanographic analyses produced every 12 hr by the computers at the Fleet Numerical Weather Central.

ularly between San Francisco and Honolulu (fig. 5). Up to six stations per day have provided a comprehensive 4 1/2-yr time-series (June 1966-December 1970) of subsurface temperature sections along this track, averaging about 18 to 20 days apart. The data are being used to study variations of temperature, heat content, and current in the eastern part of the major current gyre in the North Pacific Ocean, particularly the California Current. Observations have recommenced aboard another Matson ship as a part of the International Decade of Ocean Exploration (IDOE) mentioned in the next section.

The CALIFORNIAN Project exemplifies productive cooperation between a civilian agency of the Federal Government, the military, and industry. The project was initiated and supervised by National Marine Fisheries Service; electronic technology was supplied to the project, especially in the initial stage, by the Fleet Numerical Weather Central; and considerable financial support was supplied by the Oceanometrics Division of the Naval Undersea Research and Development Center, San Diego. Above all, the excellent cooperation from the shipping company and from the ship's personnel readily established the feasibility of using XBTs on merchant ships in a manner that has formed the basis for most of the cooperative programs.

Other sections of closely spaced stations have been made in the Gulf of Alaska by tankers of Chevron Shipping Company for the National Marine Fisheries Service and across the Gulf Stream on two passenger vessels (table 4) by the U.S. Naval Oceanographic Office (NAVOCEANO). Sections, from March through November 1970, which have been published in color in the NAVOCEANO monthly publication The Gulf Stream Vol. 5, No. 11, November 1970, show vividly the location and movement of the Gulf Stream.

WHAT OF THE FUTURE?

The development of a full-scale program of XBT observations from ships of opportunity is yet in its early stages. It would be necessary to put XBT systems aboard about 150 to 200 carefully selected ships to provide the minimum time-space coverage in the Northern Hemisphere oceans that would be an adequate base for synoptic oceanographic analyses by computer. Although the use of ships of opportunity is highly cost effective, limitations on funding will demand a slow and orderly growth. Emphasis should be placed on selecting ships and routes for efficient use of capital equipment and expanding observational coverage into sparse data areas. All of this will require the optimum use of ship's personnel.

As a part of the programs for the International Decade of Ocean Exploration, the National Science Foundation has granted funds to National Marine Fisheries Service to obtain time-series subsurface temperature observations on five routes in the Pacific Ocean (fig. 5). The purpose is to identify and describe seasonal and year-to-year changes of temperature and circulation in major currents of the tropical and North Pacific Ocean for further research into their underlying physical causes. Four routes radiate from Honolulu to Japan, Alaska, California, and Samoa, to provide sections across the Kuroshio, the North Pacific Current, the California Current, and the system of equatorial currents, respectively, while a route from California to Tahiti will provide an additional transequatorial section.

Those of us who have been associated with the planning and operation of past and present projects for XBT observations from ships of opportunity appreciate the excellent cooperation we have received from the shipping companies, from ship's personnel, and from fishing vessels. We fully recognize that personnel of cooperating ships will have a key role in the continuing development and success of such programs in the future.

Table 4.--Cooperative ships in programs for time-series sections of closely spaced XBT observations

NATIONAL MARINE FISHERIES SERVICE	
Matson Navigation Co.	SS CALIFORNIAN
Chevron Shipping Co.	SS ARIZONA STANDARD
	SS WASHINGTON STANDARD
	SS IDAHO STANDARD
	SS H. D. COLLIER
	SS J. H. MACGAREGILL
U.S. NAVAL OCEANOGRAPHIC OFFICE	
Cunard Line, Ltd.	RMS FRANCONIA
Greek Lines	TSS OLYMPIA