NOAA Technical Report NMFS SSRF-709

Expendable Bathythermograph Observations From the NMFS/MARAD Ship of Opportunity Program for 1974

Steven K. Cook and Keith A. Hausknecht

April 1977

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NOAA TECHNICAL REPORTS

National Marine Fisheries Service, Special Scientific Report—Fisheries

The major responsibilities of the National Marine Fisheries Service (NMFS) are to monitor and assess the abundance and geographic distribution of fishery resources, to understand and predict fluctuations in the quantity and distribution of these resources, and to establish levels for optimum use of the resources. NMFS is also charged with the development and implementation of policies for managing national fishing grounds, development and enforcement of domestic fisheries regulations, surveillance of foreign fishing off United States coastal waters, and the development and enforcement of international fishery agreements and policies. NMFS also assists the fishing industry through marketing service and economic analysis programs, and mortgage insurance and vessel construction subsidies. It collects, analyzes, and publishes statistics on various phases of the industry.

The Special Scientific Report—Fisheries series was established in 1949. The series carries reports on scientific investigations that document long-term continuing programs of NMFS, or intensive scientific reports on studies of restricted scope. The reports may deal with applied fishery problems. The series is also used as a medium for the publication of bibliographies of a specialized scientific nature.

NOAA Technical Reports NMFS SSRF are available free in limited numbers to governmental agencies, both Federal and State. They are also available in exchange for other scientific and technical publications in the marine sciences. Individual copies may be obtained (unless otherwise noted) from D825, Technical Information Division, Environmental Science Information Center, NOAA, Washington, D.C. 20235. Recent SSRFs are:

649. Distribution of forage of skipjack tuna (*Euthynnus pelamis*) in the eastern tropical Pacific. By Maurice Blackburn and Michael Laurs. January 1972, iii + 16 p., 7 figs., 3 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

650. Effects of some antioxidants and EDTA on the development of rancidity in Spanish mackerel (*Scomberomorus maculatus*) during frozen storage. By Robert N. Farragut. February 1972, iv + 12 p., 6 figs., 12 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

651. The effect of premortem stress, holding temperatures, and freezing on the biochemistry and quality of skipjack tuna. By Ladell Crawford. April 1972, iii + 23 p., 3 figs., 4 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

653. The use of electricity in conjunction with a 12.5-meter (Headrope) Gulf-of-Mexico shrimp trawl in Lake Michigan. By James E. Ellis. March 1972, iv + 10 p., 11 figs., 4 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

654. An electric detector system for recovering internally tagged menhaden, genus *Brevoortia*. By R. O. Parker, Jr. February 1972, iii + 7 p., 3 figs., 1 app. table. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

655. Immobilization of fingerling salmon and trout by decompression. By Doyle F. Sutherland. March 1972, iii + 7 p., 3 figs., 2 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

656. The calico scallop, *Argopecten gibbus*. By Donald M. Allen and T. J. Costello. May 1972, iii + 19 p., 9 figs., 1 table. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

657. Making fish protein concentrates by enzymatic hydrolysis. A status report on research and some processes and products studied by NMFS. By Malcolm B. Hale. November 1972, v + 32 p., 15 figs., 17 tables, 1 app. table. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

658. List of fishes of Alaska and adjacent waters with a guide to some of their literature. By Jay C. Quast and Elizabeth L. Hall. July 1972, iv + 47 p. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

659. The Southeast Fisheries Center bionumeric code. Part I: Fishes. By Harvey R. Bullis, Jr., Richard B. Roe, and Judith C. Gatlin. July 1972, xl + 95 p., 2 figs. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

660. A freshwater fish electro-motivator (FFEM)-its characteristics and operation. By James E. Ellis and Charles C. Hoopes. November 1972, iii + 11 p., 2 figs.

661. A review of the literature on the development of skipjack tun fisheries in the central and western Pacific Ocean. By Frank J. Hest and Tamio Otsu. January 1973, iii + 13 p., 1 fig. For sale by th Superintendent of Documents, U.S. Government Printing Offic Washington, D.C. 20402.

662. Seasonal distribution of tunas and billfishes in the Atlantic. B John P. Wise and Charles W. Davis. January 1973, iv + 24 p., 13 figs., tables. For sale by the Superintendent of Documents, U.S. Governme Printing Office, Washington, D.C. 20402.

663. Fish larvae collected from the northeastern Pacific Ocean an Puget Sound during April and May 1967. By Kenneth D. Waldro December 1972, iii + 16 p., 2 figs., 1 table, 4 app. tables. For sale by th Superintendent of Documents, U.S. Government Printing Offic Washington, D.C. 20402.

664. Tagging and tag-recovery experiments with Atlantic menhade *Brevoortia tyrannus*. By Richard L. Kroger and Robert L. Dryfo December 1972, iv + 11 p., 4 figs., 12 tables. For sale by the Superinte dent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

665. Larval fish survey of Humbolt Bay, California. By Maxwell Eldrige and Charles F. Bryan. December 1972, iii + 8 p., 8 figs., 1 tab For sale by the Superintendent of Documents, U.S. Government Print Office, Washington, D.C. 20402.

666. Distribution and relative abundance of fishes in Newport Ri North Carolina. By William R. Turner and George N. John September 1973, iv + 23 p., 1 fig., 13 tables. For sale by the Superinte dent of Documents, U.S. Government Printing Office, Washington, D. 20402.

667. An analysis of the commercial lobster (*Homarus america*) fishery along the coast of Maine, August 1966 through December 1970 James C. Thomas. June 1973, v + 57 p., 18 figs., 11 tables. For sale by t Superintendent of Documents, U.S. Government Printing Offi Washington, D.C. 20402.

668. An annotated bibliography of the cunner, *Tautogolabrus adspers* (Wilbaum). By Fredric M. Serchuk and David W. Frame. May 1973, ii 43 p. For sale by the Superintendent of Documents, U.S. Governme Printing Office, Washington, D.C. 20402.

669. Subpoint prediction for direct readout meterological satellites. L. E. Eber. August 1973, iii + 7 p., 2 figs., 1 table. For sale by th Superintendent of Documents, U.S. Government Printing Offic Washington, D.C. 20402.

670. Unharvested fishes in the U.S. commercial fishery of western La Erie in 1969. By Harry D. Van Meter. July 1973, iii + 11 p., 6 figs., tables. For sale by the Superintendent of Documents, U.S. Governme Printing Office, Washington, D.C. 20402.

671. Coastal upwelling indices, west coast of North America, 1946- By Andrew Bakun. June 1973, iv + 103 p., 6 figs., 3 tables, 45 app. fi For sale by the Superintendent of Documents, U.S. Government Print Office, Washington, D.C. 20402.

Continued on inside back cover

NOAA Technical Report NMFS SSRF-709

Expendable Bathythermograph Observations From the NMFS/MARAD Ship of Opportunity Program for 1974

Steven K. Cook and Keith A. Hausknecht

April 1977

U.S. DEPARTMENT OF COMMERCE
Juanita M. Kreps, Secretary

National Oceanic and Atmospheric Administration
Robert M. White, Administrator

National Marine Fisheries Service
Robert W. Schoning, Director

For Sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402 Stock No. 003-017-00397-3

CONTENTS

Figures

Tables

Appendix Figures

Gulf of Mexico Transects

Western Atlantic Transects

Expendable Bathythermograph Observations From the NMFS/MARAD Ship of Opportunity Program for 1974

STEVEN K. COOK and KEITH A. HAUSKNECHT[1]

ABSTRACT

Results of the fourth year of operation of the NMFS/MARAD Ship of Opportunity Program (SOOP) are presented in the form of vertical distributions of temperature and horizontal distributions of sea surface temperature and salinity. Operational and data management procedures also are discussed. Included are descriptive analyses of the most dynamic transects showing the Yucatan, Loop, Florida, and Gulf Stream currents and related eddies. Also, characteristics of the cold cell of bottom water on the Atlantic continental shelf are discussed.

INTRODUCTION

In midyear of 1970 a cooperative expendable bathythermograph (XBT) program was initiated between the National Marine Fisheries Service (NMFS) and the Maritime Administration (MARAD) of the U.S. Department of Commerce (Cook 1973, 1975, 1976). The program, conducted in support of the Marine Resources Monitoring Assessment and Prediction Program (MARMAP) of the NMFS, involved the use of maritime cadets from the Kings Point Maritime Academy to collect XBT data on board merchant ships operating along the east and Gulf coasts of the United States. The objective of this cooperative program was to identify and describe seasonal and year-to-year variations of temperature and circulation in the major current regimes of the western tropical Atlantic, Caribbean Sea, Gulf of Mexico, and western North Atlantic, utilizing merchant ships as relatively inexpensive platforms for the collection of data.

AREAS OF STUDY

Ship routes were selected to obtain regular sampling in the most dynamic areas of the Gulf of Mexico and western North Atlantic. The features of principal interest were the Yucatan Current, Loop Current, Florida Current, Gulf Stream, Shelf Water-Slope Water front, and a cold-water cell in the Middle Atlantic Bight.

DATA ACQUISITION AND PROCESSING

The Ship of Opportunity effort for 1974 consisted of a total of 34 cruises—18 sailing from New Orleans, 12 from New York, and 4 from Norfolk. Fifty-three transects of subsurface temperature observations and associated surface data were obtained. A total of 739 XBT's were launched; of these 514 (70%) were considered of sufficient quality to be incorporated into the transects presented.

Subsurface temperature data were obtained by use of Sippican XBT systems. At the same time, surface water samples were collected with bucket thermometers for salinity determination ashore using a Beckman inductive salinometer calibrated with standard (Copenhagen) water at least once every 30 samples.

The XBT traces were submitted to the National Oceanographic Data Center (NODC) where they were digitized, key punched, and quality controlled. Finally, these processed data were listed in printout form and machine plotted. The plots produced by NODC were essentially camera-ready and needed little hand correcting. The few corrections necessary were made by discarding anomalous XBT observations that could not be supported by other associated data such as sea surface temperature or other nearby XBT observations. Consequently a vertical section plot may have one or two missing observations, resulting from the deletion of inaccurate subsurface data.

The fourth year of operation of the NMFS/MARAD Ship of Opportunity Program (SOOP) was enhanced by the inclusion of Coast Guard cutters as ships of opportunity. The Coast Guard cutters that occupy Ocean Weather Station HOTEL (OWSH) (lat. 37°N, long. 71°W) began taking hourly XBT observations between Norfolk, Va., and OWSH in August. This transect was occupied monthly while OWSH was being maintained, usually from August through April. We plan to resume this section when OWSH is again occupied.

Approximately 225 XBT drops and associated surface data are not included because the observations were much too widely separated in time and space to be useful in the analysis. All data collected were archived by the NODC and are available to interested persons through the NODC, Washington, D.C. 20235.

[1]Atlantic Environmental Group, National Marine Fisheries Service, NOAA, R.R. 7A, Box 522-A, Narragansett, RI 02882.

Further details concerning the acquisition or processing of data from the cruises considered here can be obtained from the authors.

For purposes of this report all descriptive figures have been included within the text and all vertical temperature sections have been organized geographically and chronologically and included as Appendix Figures.

TRANSECT ANALYSIS

Gulf of Mexico (Fig. 1, Appendix Figs. 1-16)

Loop Current.—In 1974 the Loop Current was crossed on seven occasions (Table 1) by SOOP ships. There were two crossings in March (Appendix Figs. 1, 2), one in April (Appendix Fig. 3), two in May (Appendix Figs. 4, 5), and one each in June (Appendix Fig. 6) and July (Appendix Fig. 8).

Utilizing 20°C at 125 m as the left edge of the Loop Current (G. A. Maul, pers. commun.), the position of the front can be monitored from XBT data. Most migrations of the Loop Current edge ranged between lat. 22°N and 24°N. Movements of more than 1° of latitude in less than 2 wk were not uncommon. One migration of about 90 nautical miles (167 km) occurred within 9 days, between 28 June (Appendix Fig. 6) and 7 July (Appendix Fig. 8).

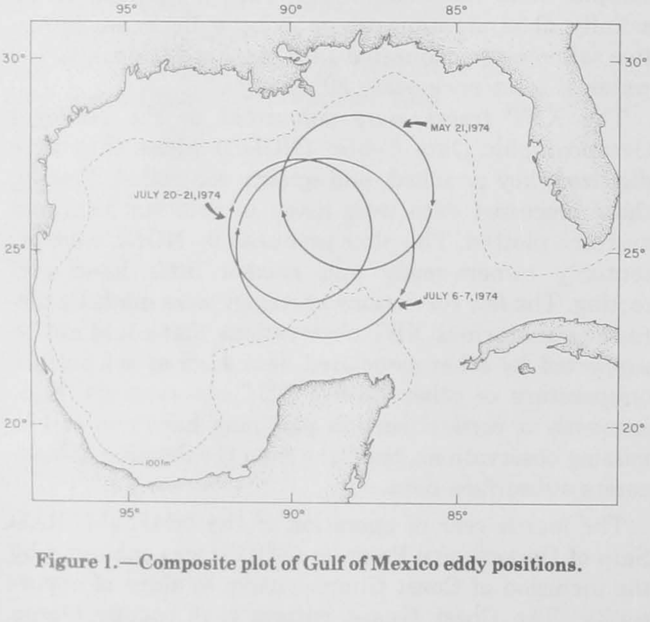


Figure 1.—Composite plot of Gulf of Mexico eddy positions.

Table 1.—Crossings of the Loop Current made by SOOP vessels in 1974.

Appendix figure	Ship	Station no.	Date
1	*Delta Sud*	20-23	8-9 Mar.
2	*Delta Norte*	11-15	21-23 Mar.
3	*Delta Sud*	28-31	15-17 Apr.
4	*Delta Sud*	40-32	21 May
5	*Delta Sud*	22-24	27-29 May
6	*Delta Sud*	9-2	28-29 June
8	*Delta Sud*	17-20	7-8 July

The Loop Current was crossed by the *Delta Sud* on 9 March at lat. 23°15'N at station 23 (Appendix Fig. 1). Again on 23 March at lat. 22°30'N the *Delta Norte* crossed the Loop Current between stations 12 and 13 (Appendix Fig. 2).

In April (Appendix Fig. 3) a crossing of the Loop Current by the *Delta Sud* determined the front to be at lat. 22°N.

In May (Appendix Fig. 4) the Loop Current appeared as a broad flowing current between stations 40 and 32. At this time the front's position had intruded up to lat. 24°N. Again in May (Appendix Fig. 5), the *Delta Sud* crossed the Loop Current between stations 22 and 24. At that time the front had receded back to lat. 23°N.

In June (Appendix Fig. 6) the Loop Current again appeared as a broad flow between stations 9 and 2. The main front (20°C and 125 m) showed up between stations 7 and 8 at about lat. 24°N. Also present at this time was a counterflow around Cuba that showed up between stations 1 and 2.

In July (Appendix Fig. 8), the Loop Current was crossed at lat. 22°30'N between stations 17 and 18.

Eddies.—In 1974 the SOOP ships in the Gulf of Mexico crossed eddies most of which were anticyclonic with warm-cores on 19 occasions (Table 2). Eddies were crossed in March through August and November (Appendix Figs. 1-7, 9-14). The diameters of these eddies where crossed ranged from about 75 nautical miles (138 km) to 335 nautical miles (621 km) and ranged in depth from 200 to 700 m. Some eddies were crossed more than once. One anticyclonic eddy (Appendix Figs. 4, 7, 9) in particular was easy to track because it had a subsurface signature in the form of a peak in the 26° isotherm that was opposite to the rest of the isotherms. This peak also happened to occur at the center of the eddy. This eddy was crossed on 21 May (Appendix Fig. 4), 7 July (Appendix Fig. 7), and 21 July (Appendix Fig. 9) and migrated in position from lat. 26°24'N, long. 87°52'W (Appendix Fig. 4) to lat. 24°55'N, long. 88°55'W (Appendix Fig. 7) to lat. 25°26'N, long. 89°44'W (Appendix Fig. 9). On all crossings the eddy structure extended to depths of greater than 600 m. The eddy moved 140 nautical miles (259 km) in 2 mo in a southwesterly direction or about 2.3 nautical miles (4.3 km)/day (Fig. 1).

Low salinity surface water.—River runoff along the Gulf coast, which forms a plume detectable by low surface salinities $(<34.5^{\circ}/_{\circ\circ})$, sometimes extended great distances offshore (well beyond the shelf break). Nine transects of low salinity water were detected in 1974 (Table 3). Crossings in March, April, May, June, July, and August (Appendix Figs. 1, 3, 4, 6, 7, 9-12) showed large variations in salinity ranges and horizontal extent.

At times the extent of the low salinity surface waters in the eastern Gulf of Mexico seemed to be controlled by the northward migrations of either eddies or the Loop Cur-

Table 2.—Location and characteristics of eddies transected in the Gulf of Mexico by SOOP vessels in 1974.

Appendix figure	Ship	Station no.	Station coordinates (lat., long.)	Date	Depth (m)	Diameter nm (km)
1	*Delta Sud*	12	26°56′N, 91°33′W	8-9 Mar.	>500	170 (315)
		16	25°08′N, 89°21′W		>500	170 (315)
		17	24°56′N, 89°05′W		>500	120 (222)
		20	23°40′N, 87°32′W		>500	120 (222)
2	*Delta Norte*	1	27°52′N, 92°51′W	21-23 Mar.	>600	200 (370)
		5	25°09′N, 89°47′W		>600	200 (370)
		6	24°50′N, 89°28′W		>700	175 (324)
		11	22°55′N, 87°05′W		>700	175 (324)
3	*Delta Sud*	11	27°01′N, 91°51′W	15-17 Apr.	>600	95 (176)
		16	26°00′N, 90°29′W		>600	95 (176)
		16	26°00′N, 90°29′W		>600	290 (537)
		28	22°46′N, 86°30′W		>600	290 (537)
4	*Delta Sud*	40	24°29′N, 86°51′W	21 May	600	245 (453)
		49	28°09′N, 88°48′W		600	245 (453)
5	*Delta Sud*	4	27°28′N, 92°16′W	27-29 May	>600	120 (222)
		9	26°10′N, 90°48′W		>600	120 (222)
		9	26°10′N, 90°48′W		>600	300 (556)
		22	23°10′N, 86°55′W		>600	300 (556)
6	*Delta Sud*	9	25°41′N, 87°08′W	28-29 June	>500	175 (324)
		17	28°08′N, 88°52′W		>500	175 (324)
7	*Delta Sud*	4	27°17′N, 91°44′W	6-7 July	>600	335 (621)
		14	23°30′N, 87°18′W		>600	335 (621)
9	*Delta Norte*	8	27°48′N, 92°44′W	20-21 July	>600	140 (259)
		13	26°17′N, 90°54′W		>600	140 (259)
		13	26°17′N, 90°54′W		>700	195 (361)
		22	24°17′N, 88°17′W		>700	195 (361)
10	*Mayaguez*	1	29°01′N, 88°44′W	17-18 Aug.	>600	165 (306)
		7	27°22′N, 86°41′W		>600	165 (306)
11	*Mayaguez*	19	24°24′N, 82°39′W	25-26 Aug.	>700	240 (445)
		24	26°54′N, 85°53′W		>700	240 (445)
12	*Mayaguez*	1	28°44′N, 88°26′W	28-29 Aug.	>600	140 (259)
		6	27°19′N, 86°27′W		>600	140 (259)
		6	27°19′N, 86°27′W		>200	150 (278)
		9	25°37′N, 84°22′W		>200	150 (278)
13	*Delta Sud*	10	25°37′N, 87°33′W	2 Nov.	>600	[1]75 (139)
		13	26°42′N, 88°06′W		>600	[1]75 (139)
14	*Delta Sud*	21	27°36′N, 87°36′W	6 Nov.	>600	160 (296)
		26	26°07′N, 85°21′W		>600	160 (296)

[1]Only about one-half of this eddy was transected.

Table 3.—Low salinity (< 34.5‰) coastal water encountered by SOOP vessels in the northern Gulf of Mexico in 1974.

Appendix figure	Ship	Date	Station no.	Water depth at seaward edge (m)	Offshore extent nm (km)
1	*Delta Sud*	8-9 Mar.	2-4	32	50 (93)
3	*Delta Sud*	15-17 Apr.	1-4	38	70 (130)
4	*Delta Sud*	21 May	49-51	124	70 (130)
6	*Delta Sud*	28-29 June	16-18	>500	90 (167)
7	*Delta Sud*	6-7 July	1-3	144	195 (361)
9	*Delta Norte*	20-21 July	1-11	>800	230 (426)
10	*Mayaguez*	17-18 Aug.	1-3	>800	85 (157)
11	*Mayaguez*	25-26 Aug.	25-27	>800	210 (389)
12	*Mayaguez*	28-29 Aug.	1-6	>800	200 (371)

rent itself. The offshore extent of the low salinity surface water shown in Appendix Figures 4, 7, and 9 apparently was blocked by the presence of one particular anticyclonic eddy. The southwestward migration of this eddy (as discussed above) removed the block and allowed the plume to extend farther offshore. In some instances the low salinity surface waters were entrained into the eddy structure (Appendix Figs. 6, 9, 10, 12). In most cases when this occurred the low salinity water appeared on only the northern side of the eddy. Peaks in the surface salinity (Appendix Figs. 4, 9, 11, 12) indicate the instances where low salinity water was transected, exited, and then transected again, which we interpreted as low salinity surface waters being entrained by the leading edges of eddies. The interaction of coastal water with eddies probably is a significant mechanism for the mixing of the less saline coastal waters with the more saline oceanic waters in the Gulf of Mexico.

Western Atlantic Transects (Figs. 2-10 and Appendix Figs. 17-35)

Specific features that were monitored in the western North Atlantic by the program were the position of the Gulf Stream, variations in temperature and position of the bottom water cold cell on the continental shelf, position of the Shelf Water-Slope Water front, and eddies formed from the Gulf Stream. Where data were available and observations were close enough in time to permit comparison, correlations were made with the National Environmental Satellite Service (NESS) Experimental Gulf Stream Analysis (N-69) charts and *The Gulf Stream Monthly Summary* which show the positions of the Gulf Stream and associated features.

Characteristics of the bottom water cold cell.—In his discussion of temperature patterns in continental shelf water, Bigelow (1933) described a core of cold bottom water that extended from south of Long Island to the mouth of the Chesapeake and was evident throughout the summer months. According to Bigelow, this core was surrounded entirely by warmer water and could receive no replenishment during the summer; thus, he concluded it was formed in wintertime and then persisted throughout the year. Further descriptions of this cold cell have been given by Ketchum and Corwin (1964) and Whitcomb (1970). The data which are presented here show the formation, structure, and modification of this cell during 1974.

Nine observations of the cold cell were made by SOOP vessels in 1974 (summarized in Table 4). For purposes of discussion, the observations have been grouped into three separate geographic areas, chosen because they represent regularly scheduled merchant ship cruise tracks. These tracks have been designated as the MORMAC transect (Fig. 2), *Santa Cruz* transect (Fig. 3), and HOTEL transect (Fig. 4). The MORMAC transect is the cruise track used by Moore McCormack Line ships and closely follows a line between New York and Bermuda. The *Santa Cruz* transect extends from New York to Cape Hatteras, approximately along long. 74°W. The HOTEL transect is the cruise track used by Coast Guard cutters operating between Norfolk and OWSH. In the following discussion, the seasonal characteristics and variations in the cold cell temperature and position along each transect are summarized.

The temperature structure of water on the continental shelf during February (Appendix Fig. 17) should be considered, because the cold cell was formed from these waters and the minimum temperature that could be attained in the cell was dependent upon conditions during the winter months. At this time, cold water (7°-12°C) extended from surface to bottom on the shelf and the structure of the cell had not yet been established by stratification.

Along the MORMAC transect, the first evidence that the cell had formed was obtained on 6 May (Appendix Fig. 21). The characteristic shape of the cell was shown by the outline of the 11°C isotherm in shelf waters. Within this "cell-like" structure, temperatures ranged from less than 9° to 11°C and the cell extended from a minimum bottom depth of 20 m to a maximum of 38 m. The horizontal extent was 65 nautical miles (120 km) and the cell was approximately 20 m thick at the center. When next observed on 14 August (Appendix Fig. 25), temperatures in the cell ranged from less than 9° to 13°C and the bottom depth range of 40-55 m indicated that the cell was migrating into deeper water. The last observation was made on 3 October (Appendix Fig. 30). By this time, temperatures had warmed to 14°C in the outer edges of the cell and it had moved over the shelf break. The depth range extended from 34 to 99 m. These changes in temperature and depth are summarized in Figure 2.

Along the *Santa Cruz* transect the earliest observation of the cold cell was made on 6 May (Appendix Fig.

Table 4.—Characteristics of the bottom water cold cell detected by SOOP vessels in 1974.

Transect	Ship	Date	Appendix figure	Minimum bottom depth (m)	Maximum bottom depth (m)	Depth at center (m)	Approximate thickness at center (m)	Temperature range (°C)	Horizontal extent nm (km)
A	*Santa Cruz*	6 May	20	28	41	35	18	< 8-9	68 (126)
B	*Mormac Argo*	5-6 May	21	20	38	29	20	< 9-11	65 (120)
C	*Santa Cruz*	11-12 June	23	32	49	45	23	< 9-13	100 (185)
D	*Mormac Rigel*	14 Aug.	25	40	55	50	23	< 9-13	53 (98)
E	*Santa Cruz*	3-4 Sept.	27	45	70	50	19	< 9-14	90 (167)
F	USCGC *Taney*	29-30 Sept.	28	40	55	50	15	< 12-15	15 (28)
G	*Export Defender*	1 Oct.	29	40	63	60	22	< 12-16	29 (54)
H	*Mormac Rigel*	3 Oct.	30	34	99	72	30	< 11-14	110 (203)
I	*Santa Cruz*	9-10 Oct.	31	45	70	50	20	< 12-14	75 (139)

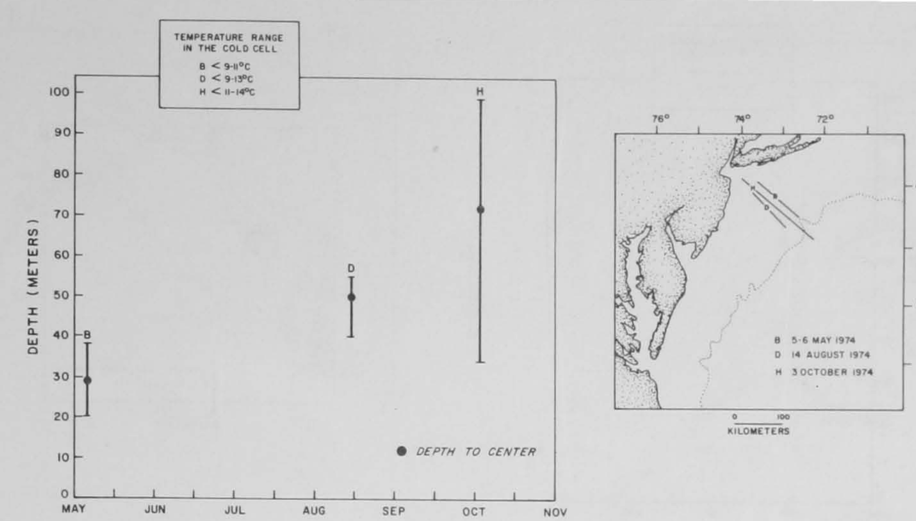


Figure 2.—Variations in cold cell temperature and depth along the MORMAC transect—May, August, and October of 1974.

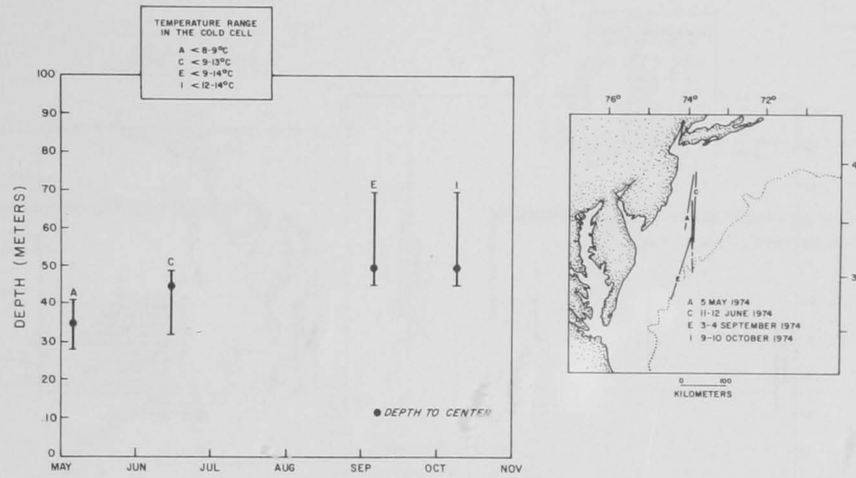


Figure 3.—Variations in cold cell temperature and depth along the *Santa Cruz* transect—May, June, September, and October of 1974.

20). Temperatures in the cell ranged from less than 8° to 9°C. The horizontal extent was 68 nautical miles (126 km) and the cell ranged from 28 to 41 m in bottom depth with a thickness of about 18 m at the center. By 11-12 June (Appendix Fig. 23) the outer fringes of the cell had warmed to 13°C and water with temperatures from 10° to 13°C had begun to move seaward over the shelf break. The bottom depth range at this time was 32-49 m. Within the cell, two separate parcels of water (< 9°C) were present between stations 26 and 30. On 3-4 September (Appendix Fig. 27) temperatures in the cell were in the 9°-14°C range and part of the cell had moved over the shelf break and extended to a depth of 70 m. The tonguelike shape of the 13° and 14°C isotherms showed the initial stages of a process called "calving" by Cresswell (1967) whereby a parcel of water separates from the parent mass and moves seaward. During 9-10 October (Appendix Fig. 31) the calving process was detected in an advanced stage. A mass of water with temperatures ranging from 12° to 14°C had separated from the cell on the shelf and was moving seaward over the shelf break. At this time, the cell extended to a maximum bottom depth of 70 m. These changes in temperature and depth are summarized in Figure 3.

Only two observations of the cold cell were made along the HOTEL transect, and these were closely spaced in time—29-30 September (Appendix Fig. 28) and 1 October (Appendix Fig. 29). Appendix Figure 28 shows temperatures ranging from less than 12° to 15°C in the cell over a bottom depth range of 40-55 m. The horizontal extent was only 15 nautical miles (28 km). Slightly further south, the temperatures ranged from less than 12° to 16° over a bottom depth range of 40-63 m (Appendix Fig. 29). Here the horizontal extent was 29 nautical miles (54 km). The changes in temperature and depth are summarized in Figure 4.

Several generalizations can be made from a composite plot of the changes in cold cell temperature and depth with Figure 5. Minimum temperatures within the cell remained low (8°-9°C) throughout the summer and

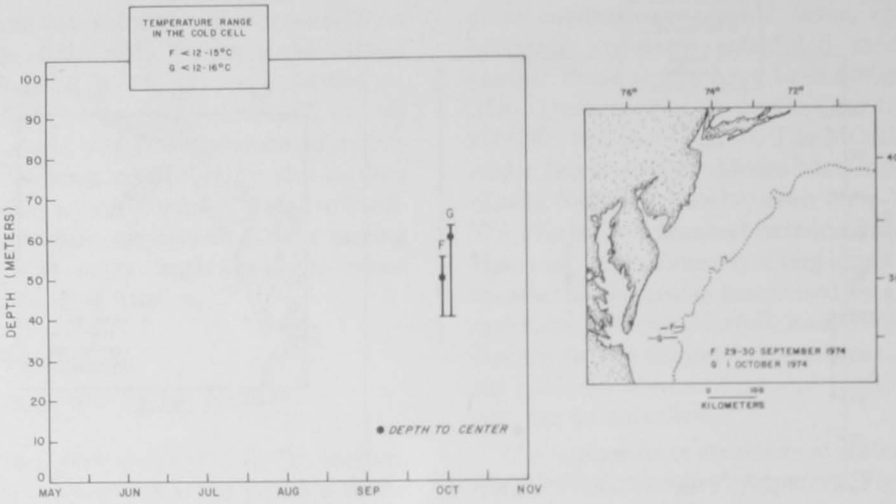


Figure 4.—Variations in cold cell temperature and depth along the HOTEL transect—September and October of 1974.

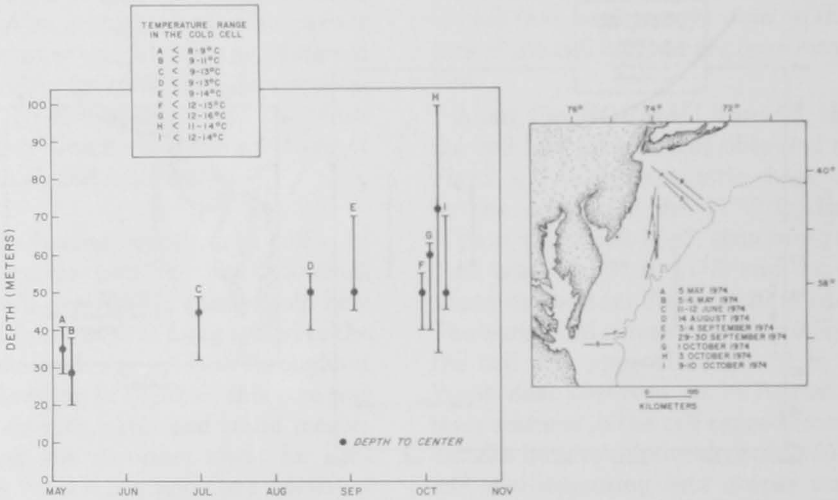


Figure 5.—Composite plot of cold cell temperature and depth—May, June, August, September, and October of 1974.

elevated temperatures were not observed until the end of September. The cold water was found in relatively shallow depths (20-40 m) in the spring, but as warming of shelf waters increased during the summer, the cell moved into deeper water. Observations made in the fall also indicated that the cell covered a greater depth range than in the spring. There seemed to be an increase in the minimum cell temperature from north to south, but there were not sufficient data to separate geographic variations from those caused by seasonal changes. A more detailed analysis would require more frequent observations made at regular intervals.

Gulf Stream.—Considerable attention has been focused on fluctuations in the position of the Gulf Stream. In addition to shipboard observations of temperature and salinity, satellite and aircraft observations of surface temperature are being used to differentiate between water masses. Because the SOOP transects intersect the Gulf Stream at discrete points with considerable spatial and temporal separation, complete coverage of the Gulf Stream and associated features by this means is impossible. However, when correlated with the satellite observations the transect data provide a source of ground truth for the remote sensors, as well as valuable subsurface information for investigators involved in study of the Gulf Stream system and other water masses.

During 1974, SOOP transects crossed the Gulf Stream 12 times. These crossings are summarized in Figures 6-9 and Table 5. Gulf Stream crossings were identified by the strong horizontal gradients shown on vertical temperature sections and positions of the North Wall were determined by using the 15°C isotherm at 200 m (Worthington 1964).

Both *The Gulf Stream Monthly Summary* and the NESS Experimental Gulf Stream Analysis (N-69) charts provide information about fluctuations in the Gulf Stream position. The information provided in these publications gives more complete and synoptic coverage over the entire Gulf Stream system than is possible through

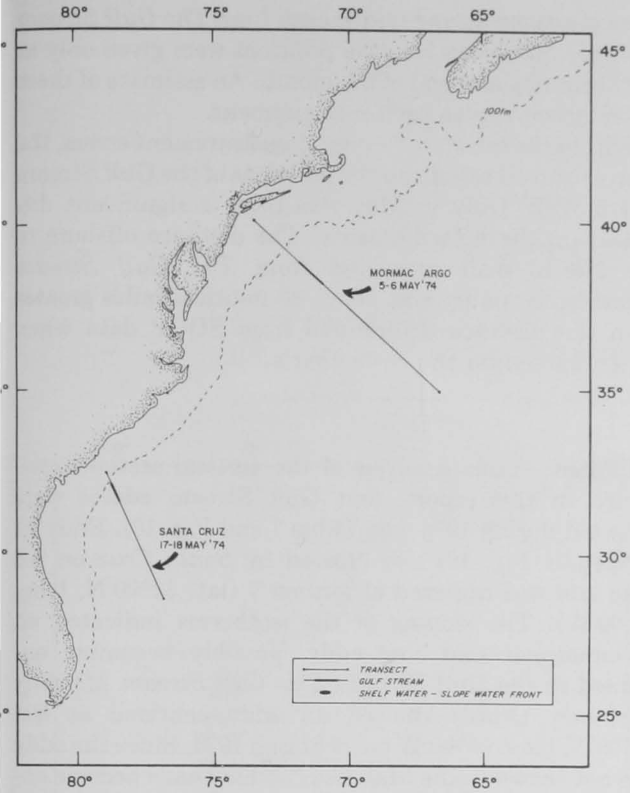


Figure 6.—Gulf Stream crossings—May 1974.

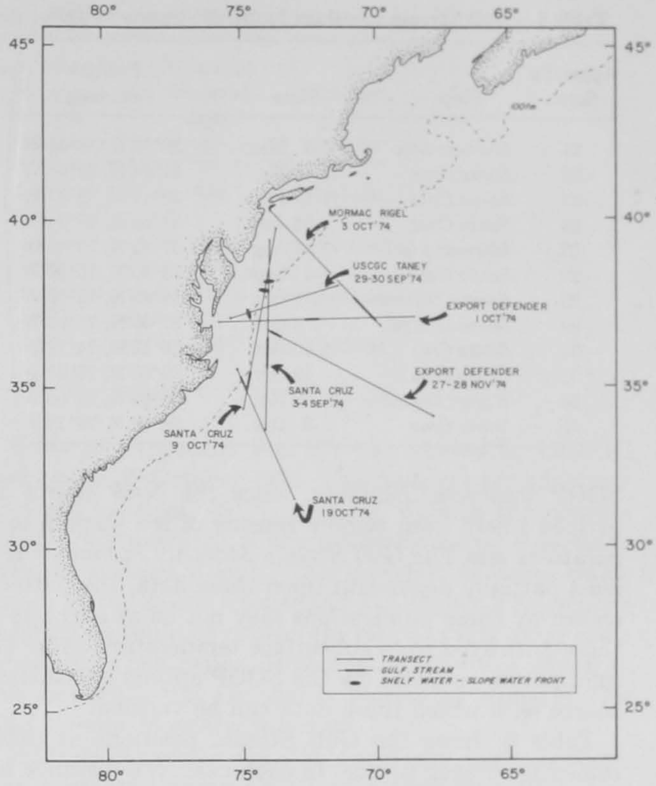
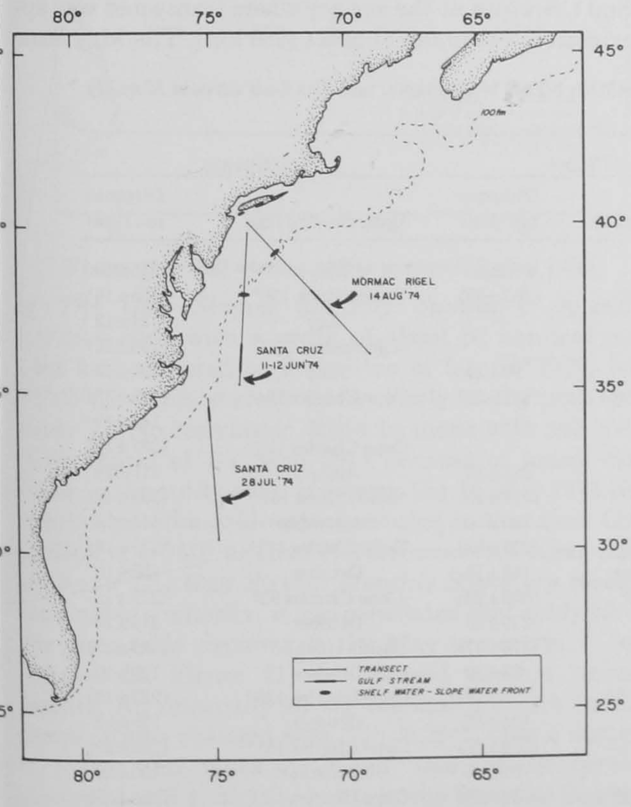


Figure 8.—Gulf Stream crossings and Shelf Water-Slope Water front positions—September-November 1974.



gure 7.—Gulf Stream crossings and Shelf Water-Slope Water front positions—June-August 1974.

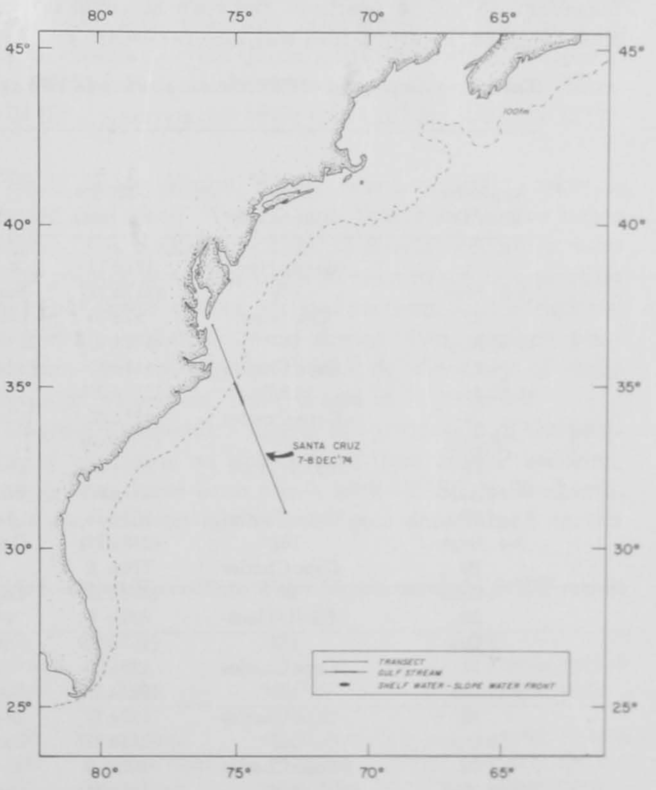


Figure 9.—Gulf Stream crossings—December 1974.

Table 5.—Gulf Stream crossings by SOOP vessels in 1974.

Appendix figure	Ship	Date	Position (lat., long.)
21	*Mormac Argo*	5-6 May	38°30'N, 71°12'W
22	*Santa Cruz*	17-18 May	31°48'N, 79°06'W
23	*Santa Cruz*	11-12 June	38°12'N, 73°57'W
24	*Santa Cruz*	28 July	34°48'N, 75°24'W
25	*Mormac Rigel*	14 Aug.	37°42'N, 70°48'W
27	*Santa Cruz*	3-4 Sept.	35°30'N, 75°00'W
29	*Export Defender*	1 Oct.	36°42'N, 72°18'W
30	*Mormac Rigel*	3 Oct.	37°30'N, 71°00'W
31	*Santa Cruz*	9-10 Oct.	36°12'N, 74°12'W
32	*Santa Cruz*	19 Oct.	35°00'N, 75°00'W
34	*Export Defender*	27-28 Nov.	36°00'N, 74°00'W
35	*Santa Cruz*	7-8 Dec.	36°00'N, 75°18'W

SOOP transects. However, since the N-69 charts are derived solely from remote sensing of sea surface temperatures and *The Gulf Stream Monthly Summary* is at least partially dependent upon these data, the patterns shown by these publications may not be as accurate as those portrayed from subsurface temperature data. The information collected by the SOOP affords an excellent source with which these data can be verified.

Table 6 shows the Gulf Stream positions as determined from each source. In each case, the distance has been measured along identical bearing lines and this distance converted to nautical miles. Several sources of error were apparent. The inconsistent quality of reproduction of N-69 charts and the distortion introduced by photocopying lead to some uncertainty in measurements. In addition, some interpolation was necessary to locate positions between stations on vertical sections. Interpolation was also necessary to determine positions during mid-month from *The Gulf Stream Monthly Summary* because positions were given only at the beginning and end of the month. An estimate of these errors accompanies each measurement.

Within the estimated range of measurement errors, the sources agreed closely on the positions of the Gulf Stream North Wall. Only in May was there a significant difference in the measurements. The distance offshore to the North Wall measured from *The Gulf Stream Monthly Summary* was about 40 nautical miles greater than the distance determined from SOOP data when superimposed on the N-69 charts.

Eddies.—From analysis of the vertical sections contained in this report, four Gulf Stream eddies were detected during 1974 (see Table 7 and Fig. 10). Eddy #1 (Appendix Fig. 19) was crossed by *Santa Cruz* on 5-6 May and was centered at station 7 (lat. 32°00'N, long. 75°00'W). The sloping of the isotherms indicated an asymmetrical cold core eddy, possibly becoming entrained in the Gulf Stream. *The Gulf Stream Monthly Summary* (April) showed an eddy centered at lat. 33°00'N, long. 74°00'W on 30 March 1974. Since the eddy was not shown in the May issue, it may have become entrained during the interval. This eddy was not shown on the N-69 charts.

On 5-6 May (Appendix Fig. 21) *Mormac Argo* crossed a cyclonic, cold core eddy (Eddy #2) that was centered around station 8 (lat. 36°00'N, long. 68°00'W). The structure of the eddy was evident to a depth of about 600 m and the width at the surface where transected was approximately 145 nautical miles (269 km). The May issue

Table 6.—Comparison of Gulf Stream position in 1974 as located by SOOP, NESS N-69 charts, and *The Gulf Stream Monthly Summary*.

Appendix figure/date	SOOP bearing line	Distance nm (km)	N-69 Charts Date/Bearing line	N-69 Charts Distance nm (km)	Gulf Stream Date/Bearing line	Gulf Stream Distance nm (km)
21	Sandy Hook	171±12	4-7 May	155±35	May	235±10
5-6 May	130°	(317±22)	Sandy Hook 130°	(287±65)	Sandy Hook 130°	(435±19)
22	Charleston	87±10	Cloud Cover	—	May	34±12
17-18 May	147°	(161±19)			Charleston 147°	(156±22)
23	Cape Charles	118±15	6-10 June	90±15	June	100±18
11-12 June	124°	(219±28)	Cape Charles 124°	(167±28)	Cape Charles 124°	(185±33)
24	Cape Charles	140±25	Cloud Cover	—	July	144±10
28 July	170°	(259±46)			Cape Charles 170°	(267±19)
25	Sandy Hook	222±15	15-20 Aug.	225±10	August	215±24
14 Aug.	137°	(411±28)	Sandy Hook 137°	(417±19)	Sandy Hook 137°	(398±44)
27	Cape Charles	132±15	4-10 Sept.	120±10	September	115±10
3-4 Sept.	161°	(245±28)	Cape Charles 161°	(222±19)	Cape Charles 161°	(213±19)
29	Cape Charles	174± 6	27 Sept.-1 Oct.	165±15	October	150±10
1 Oct.	95°	(322±11)	Cape Charles 95°	(306±28)	Cape Charles 95°	(278±19)
30	Sandy Hook	225± 6	4-6 Oct.	230±20	October	210±10
3 Oct.	137°	(417±11)	Sandy Hook 137°	(426±37)	Sandy Hook 137°	(389±19)
31	Cape Charles	120±20	11 Oct.	95±10	October	120±10
9-10 Oct.	128°	(222±37)	Cape Charles 128°	(176±19)	Cape Charles 128°	(222±19)
32	Cape Charles	120±10	18-22 Oct.	120±15	October	125±12
19 Oct.	161°	(222±19)	Cape Charles 161°	(222±28)	Cape Charles 161°	(232±22)
34	Cape Charles	102± 6	21-24 Nov.	91±15	November	100±10
27-28 Nov.	140°	(189±11)	Cape Charles 140°	(169±28)	Cape Charles 140°	(185±19)
35	Cape Charles	100±50	5-10 Dec.	135±12	December	121±10
7-8 Dec.	163°	(185±93)	Cape Charles 163°	(250±22)	Cape Charles 163°	(224±19)

Table 7.—Gulf Stream eddies transected by SOOP vessels in 1974.

Eddy number	Appendix figure/ Date	Location of center (lat., long.)	Approximate surface diameter nm (km)	Maximum observed depth (m)	Direction of rotation
1	19 5 May	32°N, 75°W	165 (306)	650	Cyclonic
2	21 5-6 May	36°N, 68°W	145 (269)	500	Cyclonic
3	33 20 Oct.	37°N, 74°W	90 (167)	450	Anticyclonic
4	35 7-8 Dec.	32°N, 73°30′W	150 (278)	660	Cyclonic

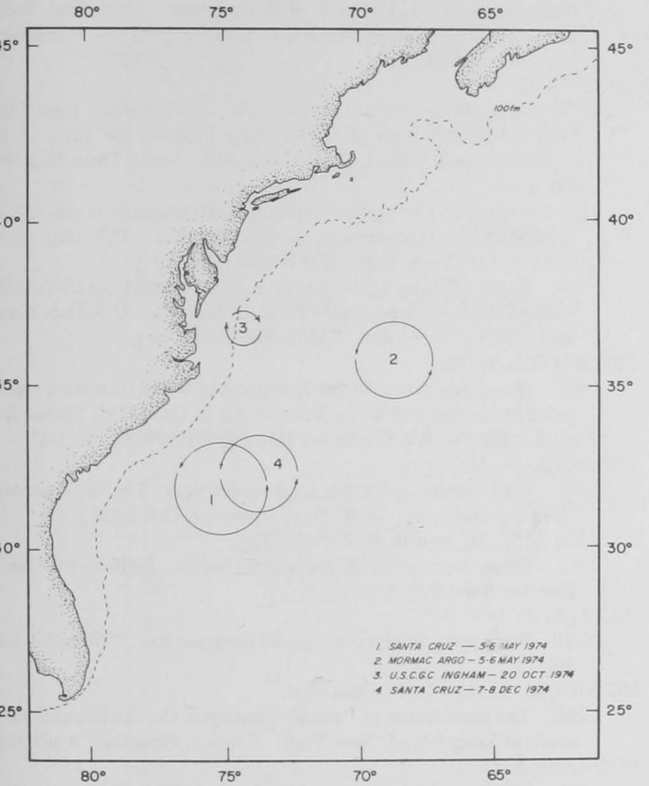


Figure 10.—Gulf Stream eddies surveyed during 1974.

of *The Gulf Stream Monthly Summary* showed a cyclonic eddy with a width of about 80 nautical miles (148 km) centered at a position of lat. 36°30′N, long. 68°00′W, which corresponded closely to the position of Eddy #2. No correlation could be made with the NESS N-69 charts of 4-7 May 1974 because of heavy cloud cover in the study area. However, the 14 May 1974 N-69 charts showed a cold-water intrusion in this area. Comparison of SOOP original XBT traces with other traces shown in *The Gulf Stream Monthly Summary* revealed reasonable similarity; it was concluded that Eddy #2 was the same eddy depicted in the May summary.

Appendix Figure 21 also showed another unusual feature. An unusually strong thermal gradient (surface temperatures changed from 23° to 20°C over a distance of 15 nautical miles or 28 km) was present between stations 3 and 4. Similar fronts in the Sargasso Sea have been described by Katz (1969), Voorhis (1969), and Voorhis and Hersey (1964).

Eddy #3 (Appendix Fig. 33) was located by USCGC *Ingham* on 20 October 1974. This anticyclonic eddy was centered near lat. 37°N, long. 74°W with the characteristic downwarping of the isotherms being detectable between stations 3 and 7. An intrusion of warm water shown on the 23-28 October and 31 October-3 November N-69 charts could have been the result of this warm eddy moving into this region. However, no eddy was shown at this location in the October or November issues of *The Gulf Stream Monthly Summary*.

Eddy #4 (Appendix Fig. 35), a cold core, cyclonic eddy, was crossed by *Santa Cruz* on 7-8 December 1974. The maximum depth observed by XBT was 660 m, while the eddy center was located around lat. 32°00′N, long. 73°30′W (station 14). Sea surface temperatures were as much as 3°C lower than adjacent Gulf Stream waters, but no signature was detectable in the surface salinities. This eddy was apparently the same one that was monitored with neutrally buoyant floats by the U.S. Naval Oceanographic Office and surveyed on 11 December 1974 by P. L. Richardson aboard RV *Trident* (Gemmill 1974; Anonymous 1975; Gemmill and Cheney 1975).

Shelf Water-Slope Water front.—SOOP transects crossed the Shelf Water-Slope Water front five times during 1974. Determinations of frontal crossings were made primarily on the basis of subsurface temperature gradients shown on the vertical sections with additional supporting evidence being drawn from surface temperature and salinity gradients. A summary of these crossings is given in Table 8 and in Figures 6-9.

In order to provide a means of verification of the position of the front as determined from SOOP sections, comparisons have been made with NESS N-69 charts. After the position of the front was determined on the

Table 8.—Shelf Water-Slope Water front crossings by SOOP vessels in 1974.

Appendix figure	Ship	Date	Frontal position (lat., long.)
23	*Santa Cruz*	11-12 June	38°N, 71°48′W
25	*Mormac Rigel*	14 Aug.	39°42′N, 73°W
27	*Santa Cruz*	3-4 Sept.	38°N, 74°W
28	USCGC *Taney*	29-30 Sept.	37°N, 75°W
31	*Santa Cruz*	9-10 Oct.	38°18′N, 73°54′W

Table 9.—Comparison of position of Shelf Water-Slope Water front as detected by SOOP and N-69 charts.

Appendix figure	Date	SOOP bearing line	Distance nm (km)	Date	N-69 bearing line	Distance nm (km)
23	11-12 June	Cape Charles 53°	132±15 (245±28)	13-18 June	Cape Charles 53°	156±18 (289±33)
25	14 Aug.	Sandy Hook 141°	72±15 (133±28)	12 Aug.	Sandy Hook 141°	90±10 (167±19)
27	3-4 Sept.	Cape Charles 53°	108±12 (200±22)	Cloud cover in study area—no measurement possible		
28	29-30 Sept.	Cape Charles 86°	66±10 (122±19)	27 Sept.-1 Oct.	Cape Charles 86°	66±12 (122±22)
31	9-10 Oct.	Cape Charles 53°	132±20 (245±37)	11 Oct.	Cape Charles 53°	102±10 (189±19)

SOOP sections, a bearing line was established to a nearby landmark. The distance in nautical miles was measured with a pair of dividers and an estimate of error was made. The position of the front was then measured along the same bearing line on the N-69 charts. These comparisons are shown in Table 9.

Within the estimated range of measurement error, the positions determined from the two sources agreed closely, suggesting that the methods currently used are reliable indicators of the frontal position.

ACKNOWLEDGMENTS

Appreciation is extended to the Maritime Academy Training representatives M. Chichurel and A. Finley in New York and D. Thompson in New Orleans, La. Their diligent efforts to place midshipmen on board ships that were scheduled to traverse preselected oceanic areas were instrumental to the success of this program. Also, thanks are extended to H. O. Travis and the National Maritime Research Center (NMRC) for their support in expanding the SOOP effort. In addition, thanks are extended to the Moore McCormack Lines and Grace Prudential Lines of New York and the Delta Steamship Company and Sea Land Shipping Lines of New Orleans. Finally, appreciation is accorded to the Marine Science Branch, Commander Atlantic Area, U.S. Coast Guard, and to the officers and crews of the USCGC *Ingham* and USCGC *Taney*.

LITERATURE CITED

ANONYMOUS.
1975. Gulf Stream meandering south of Cape Hatteras. Gulfstream, Natl. Weather Serv. 1(1):6-7.

BIGELOW, H. B.
1933. Studies of the waters on the Continental Shelf, Cape Cod to Chesapeake Bay. I. The cycle of temperature. Mass. Inst. Technol. and Woods Hole Oceanogr. Inst., Pap. Phys. Oceanogr. Meteorol. 2(4), 135 p.

COOK, S. K.
1973. Expendable bathythermograph observations from the NMFS/MARAD Ship of Opportunity Program for 1971. U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Data Rep. 81, 132 p.
1975. Expendable bathythermograph observations from the NMFS/MARAD Ship of Opportunity Program for 1972. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-692, 81 p.
1976. Expendable bathythermograph observations from the NMFS/MARAD Ship of Opportunity Program for 1973. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-700, 13 p.

CRESSWELL, G. M.
1967. Quasi-synoptic monthly hydrography of the transition region between coastal and slope water south of Cape Cod, Massachusetts. Woods Hole Oceanogr. Inst., Ref. No. 67-35, p. 1-47.

GEMMILL, W. H.
1974. Gulf Stream eddy tracking experiment. The Gulf Stream Monthly Summary. U.S. Nav. Oceanogr. Off. 9(10):3-4.

GEMMILL, W. H., and R. E. CHENEY.
1975. Float motions in a translating eddy. Gulfstream, Natl. Weather Serv. 1(3):6-7.

KATZ, E. J.
1969. Further study of a front in the Sargasso Sea. Tellus 21:259-269.

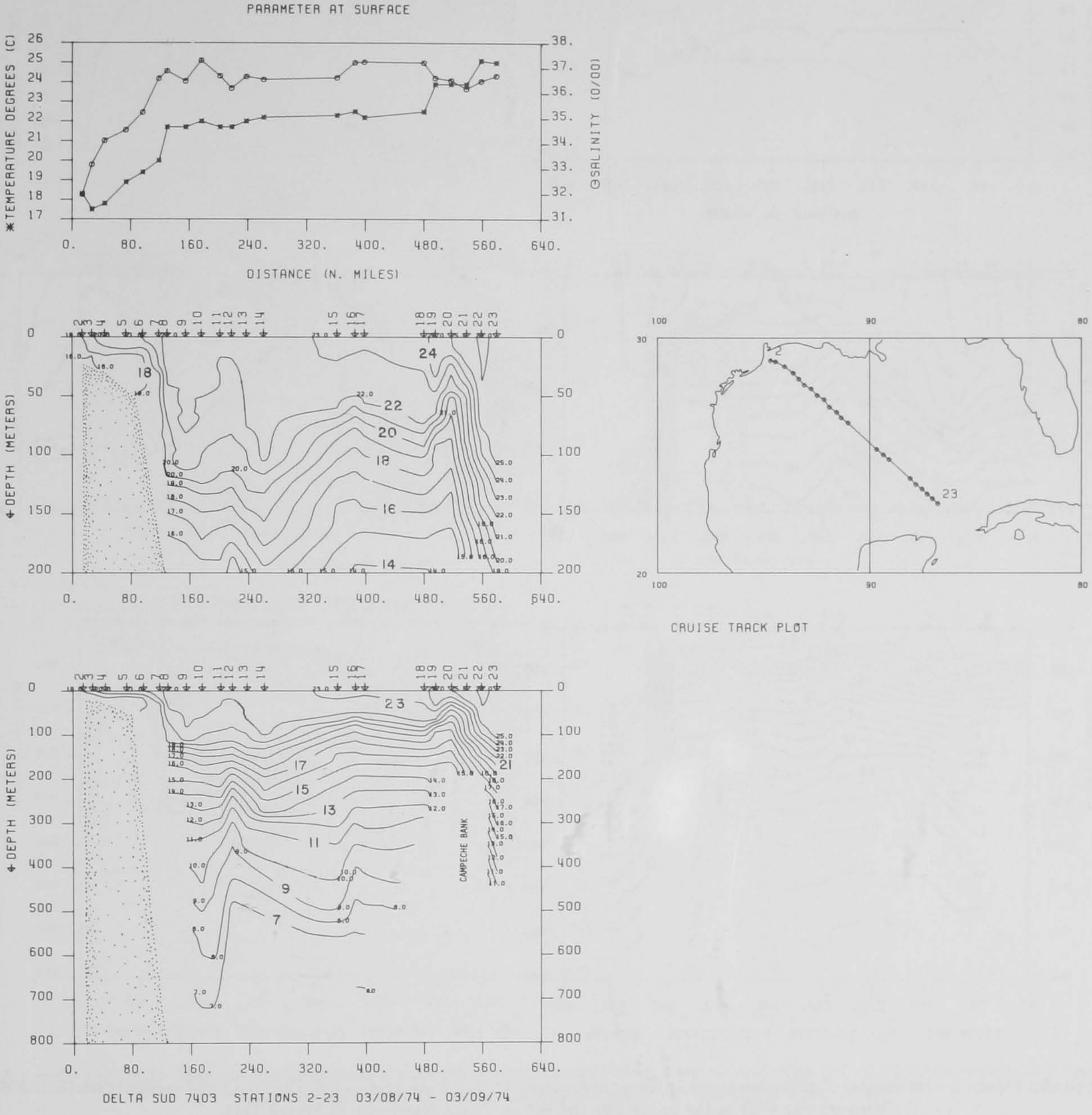
KETCHUM, B. H., and N. CORWIN.
1964. The persistence of "winter" water on the continental shelf south of Long Island, New York. Limnol. Oceanogr. 9:467-475.

VOORHIS, A. D.
1969. The horizontal extent and persistence of thermal fronts in the Sargasso Sea. Deep-Sea Res., Suppl. 16:331-337.

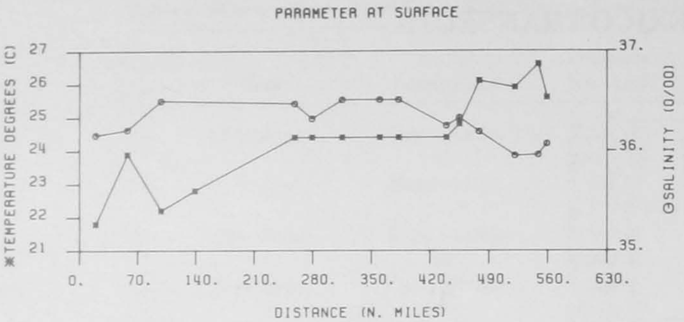
VOORHIS, A. D., and J. B. HERSEY.
1964. Oceanic thermal fronts in the Sargasso Sea. J. Geophys. Res. 69:3809-3814.

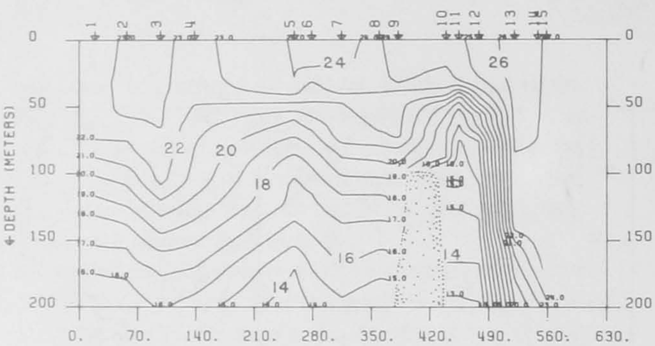
WHITCOMB, V. L.
1970. Oceanography of the mid-Atlantic Bight in supporting of ICNAF, September-December 1967. U.S. Coast Guard Oceanogr. Rep. 35, 157 p.

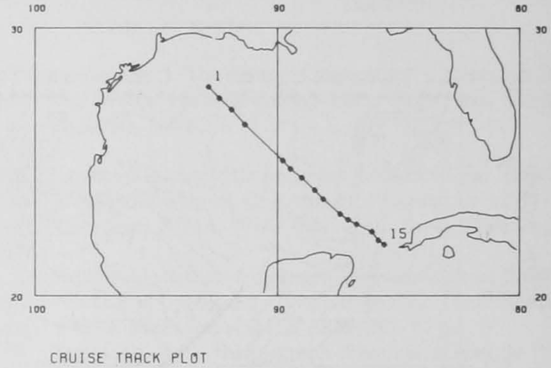
WORTHINGTON, L. V.
1964. Anomalous conditions in the Slope Water area in 1959. J. Fish. Res. Board Can. 21:327-333.

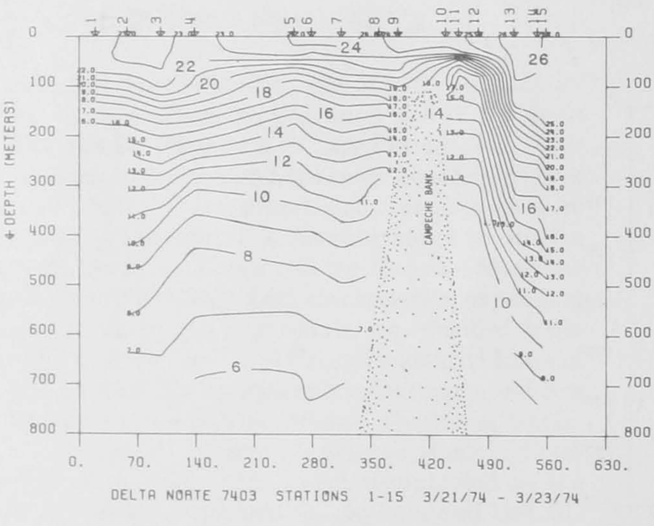


Appendix Figure 1.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—8-9 March 1974.

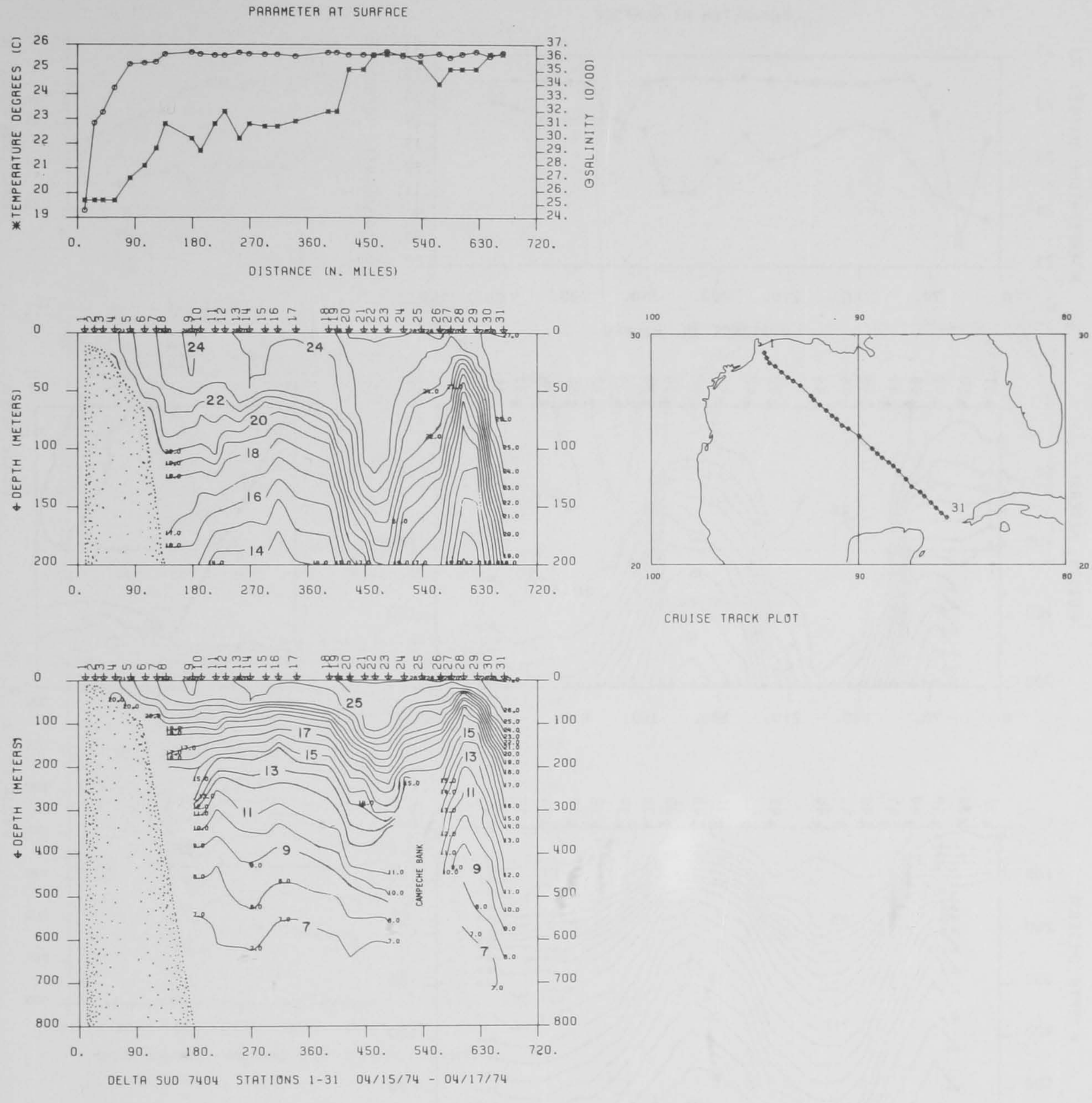




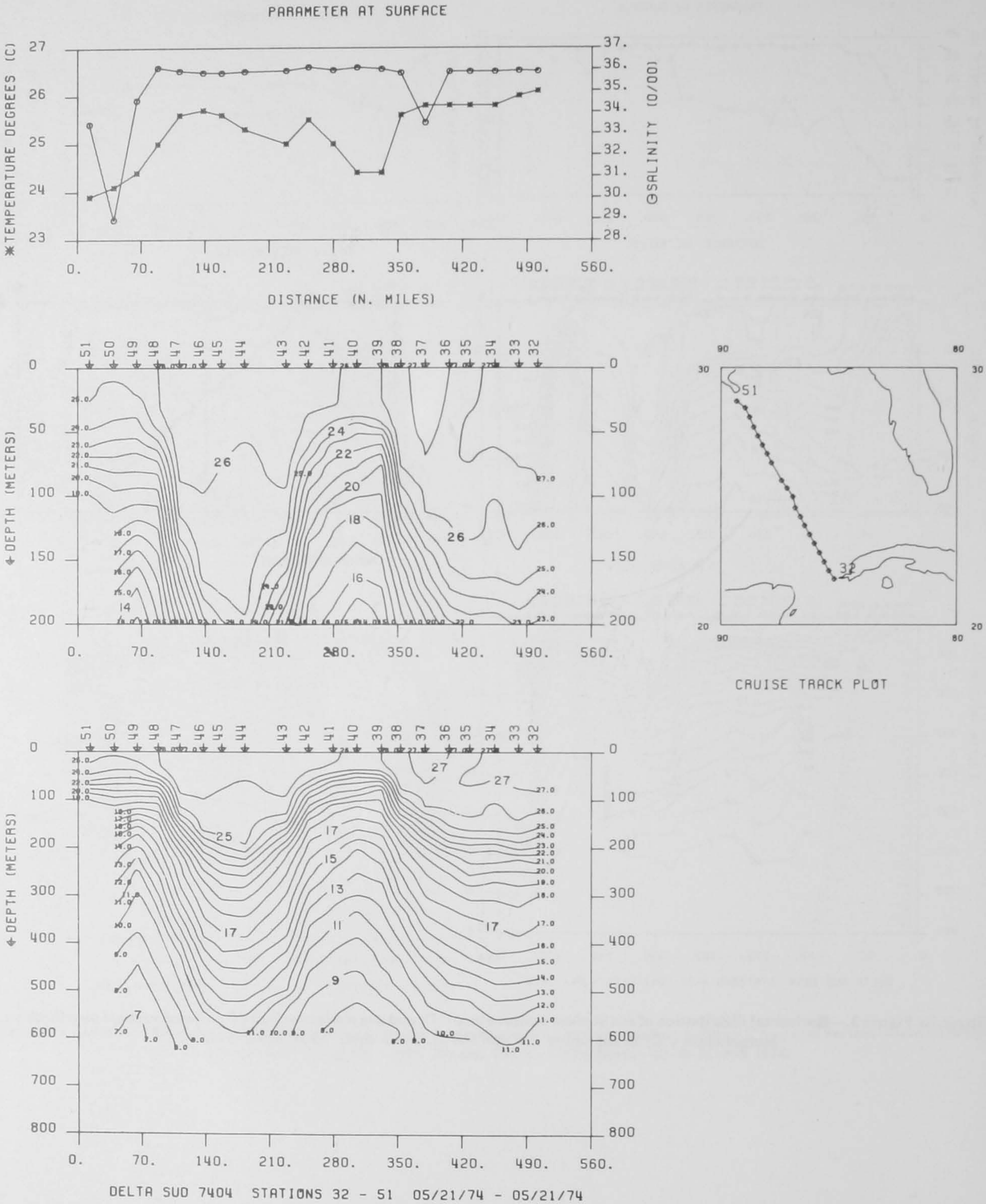




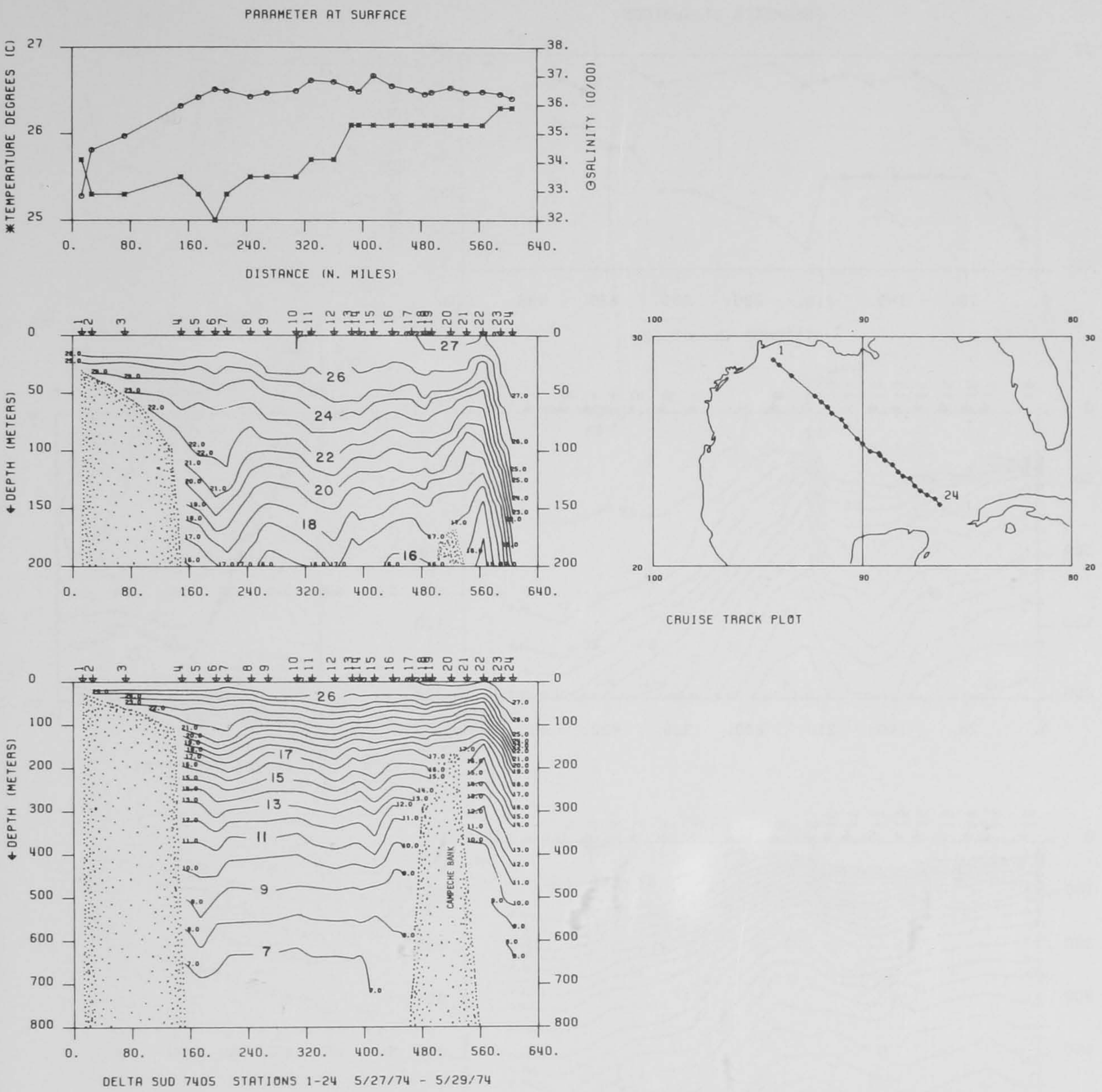
Appendix Figure 2.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—21-23 March 1974.



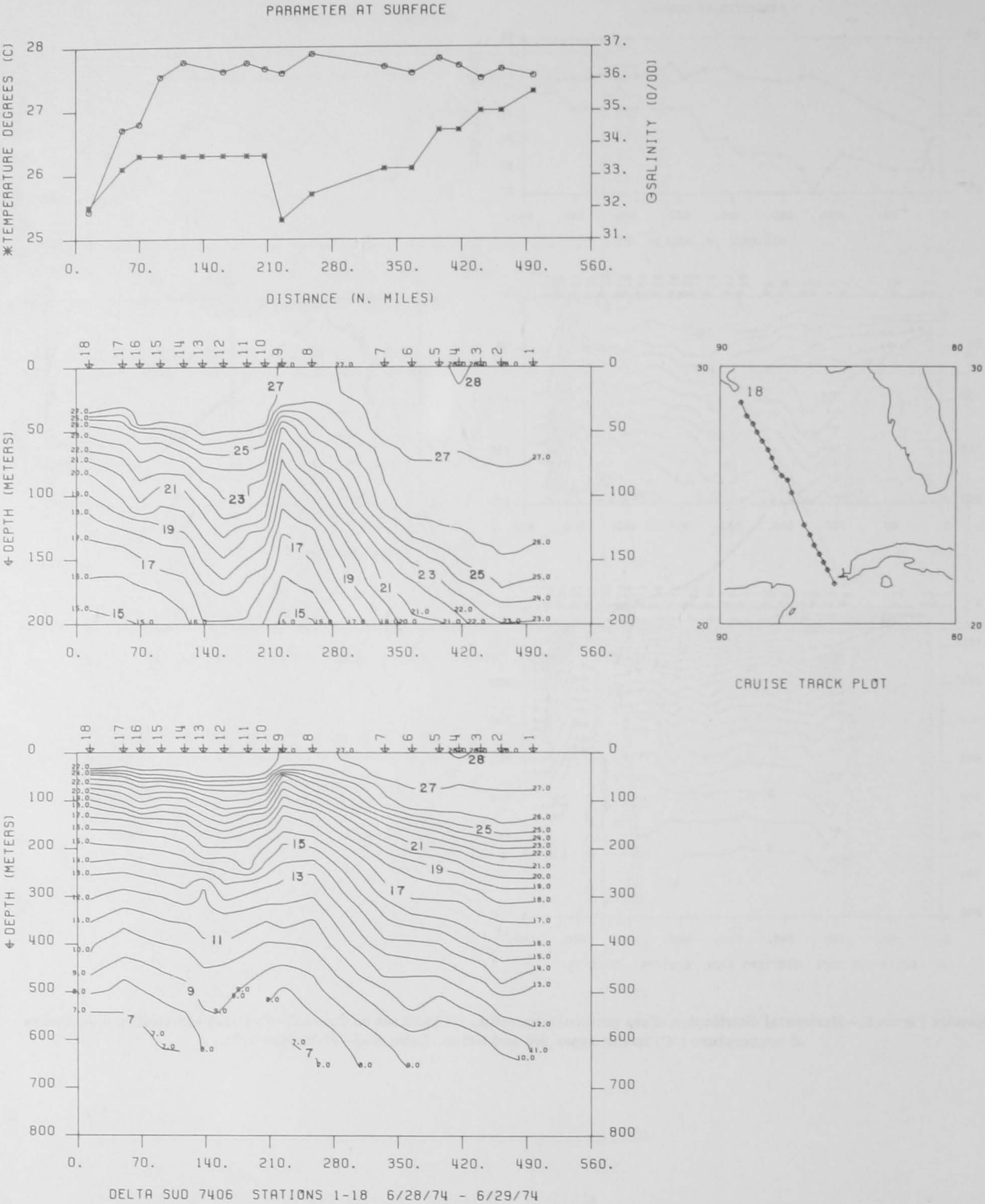
Appendix Figure 3.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—15-17 April 1974.



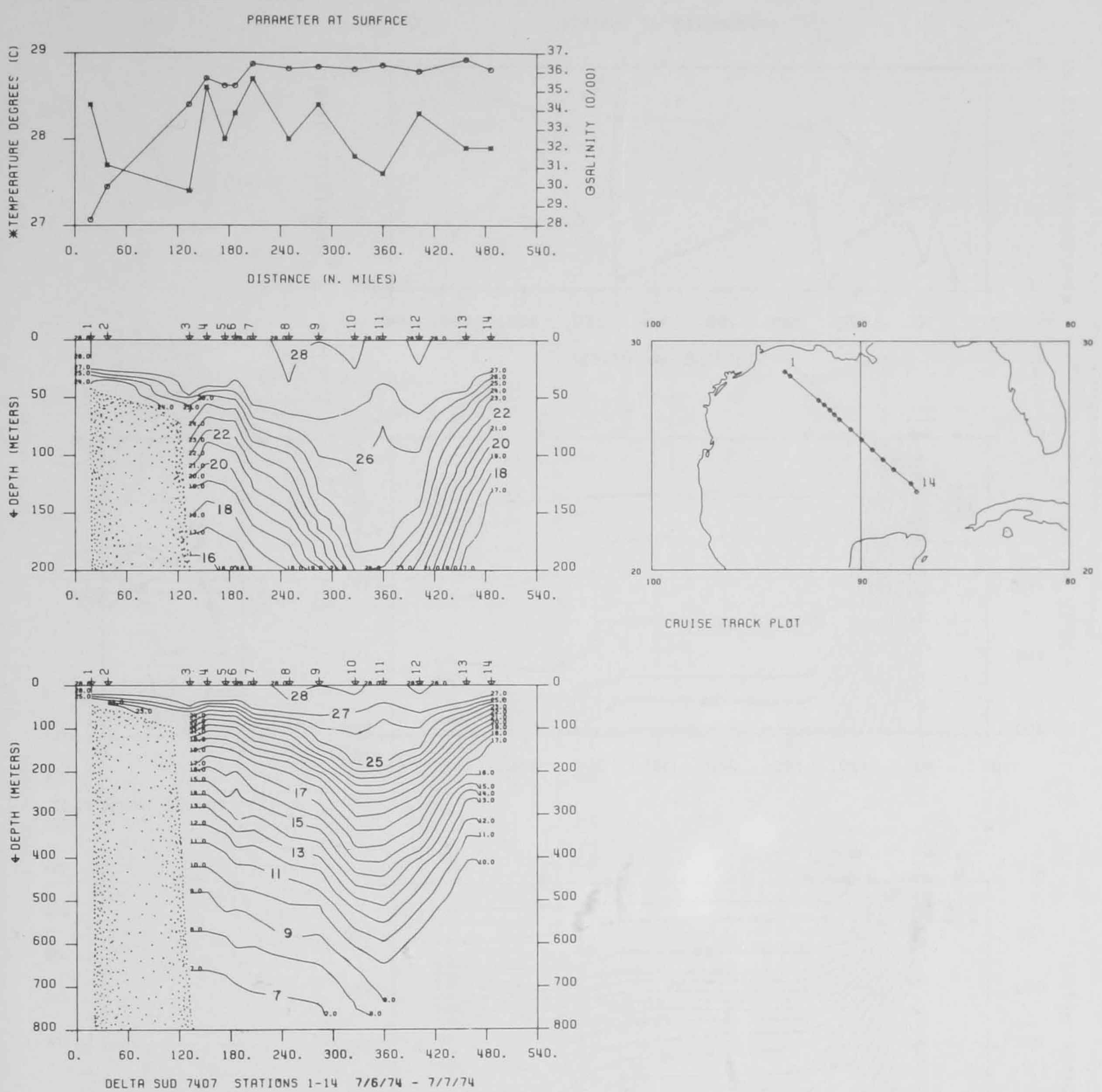
Appendix Figure 4.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—21 May 1974.



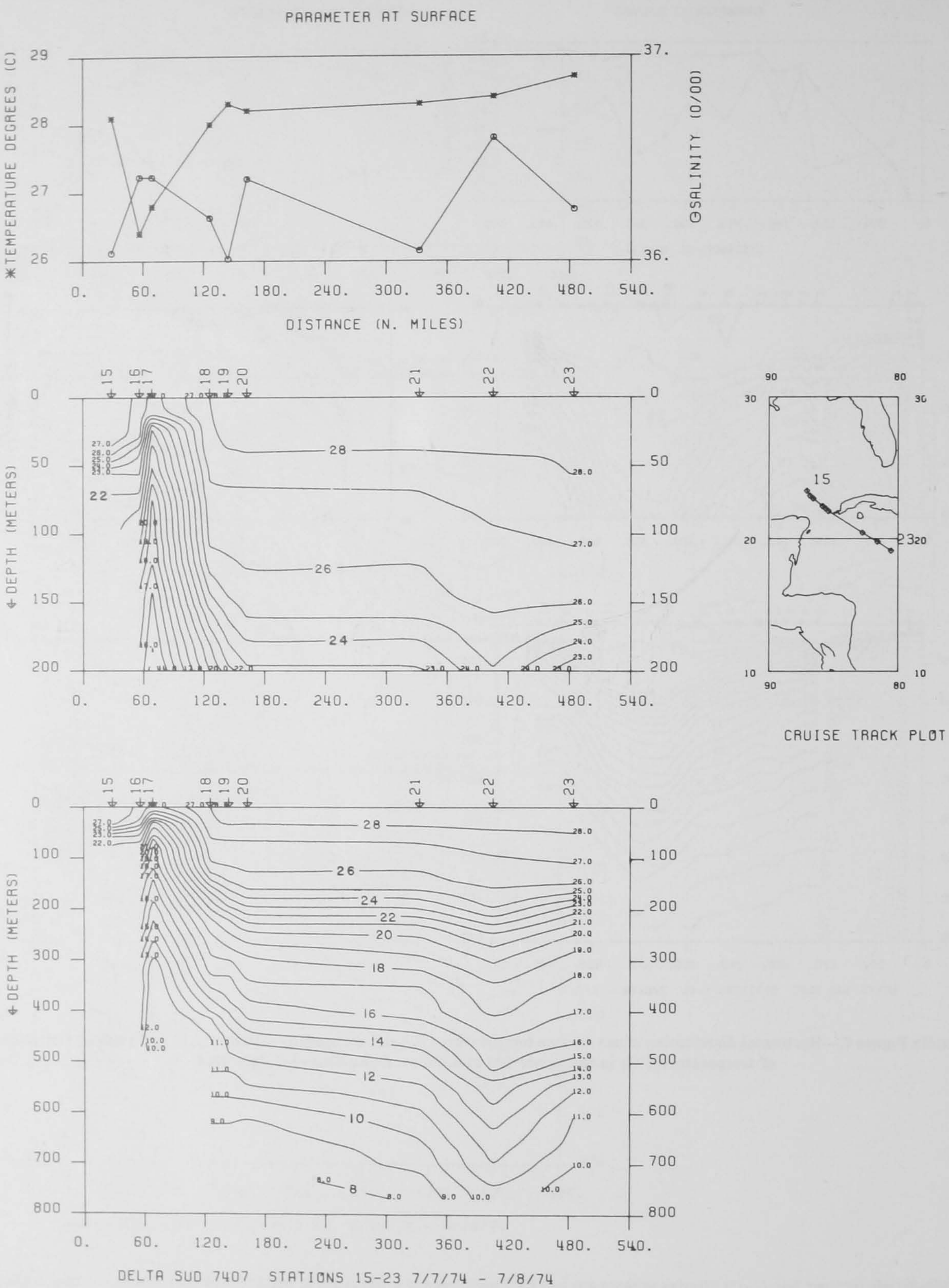
Appendix Figure 5.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—27-29 May 1974.



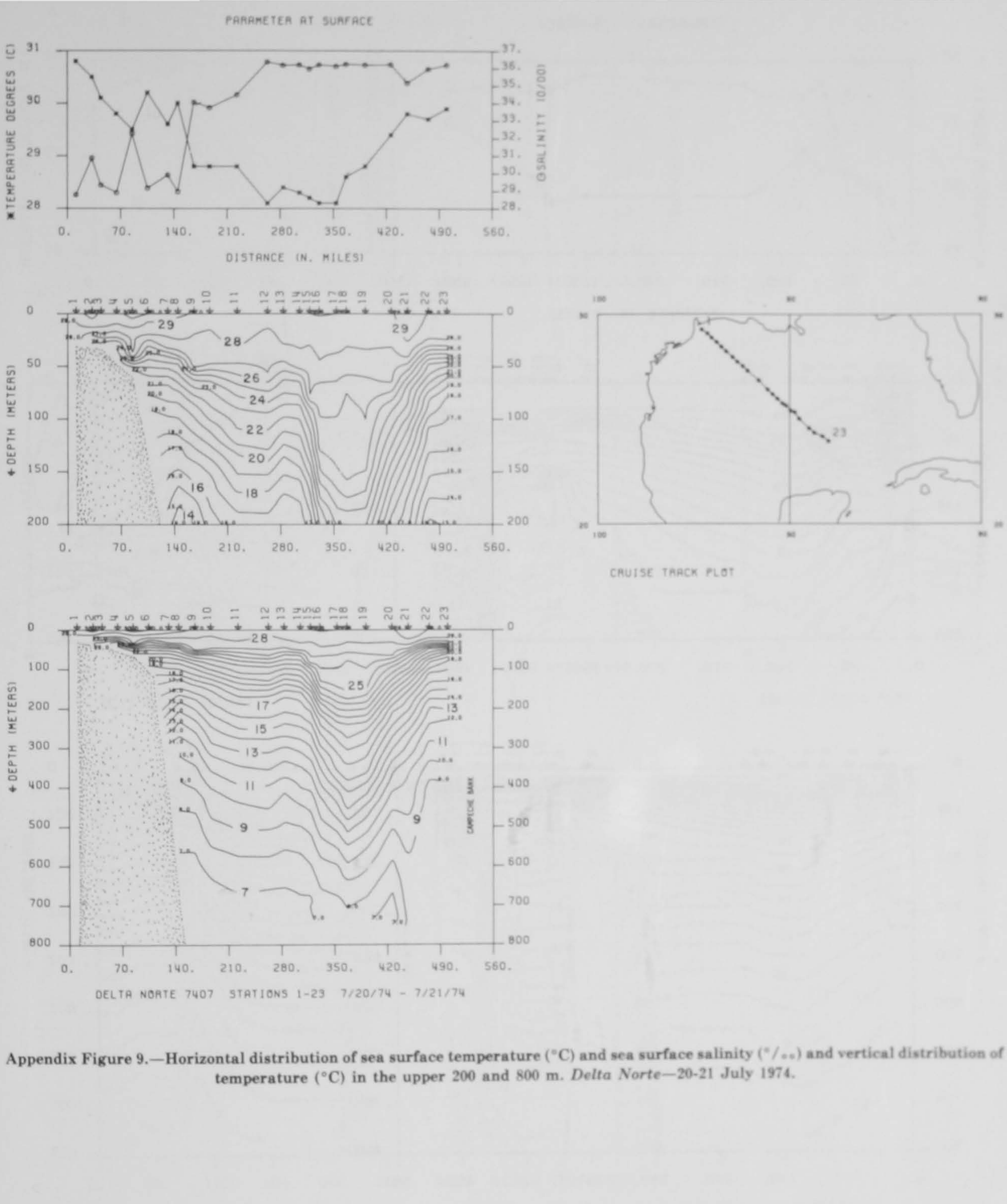
Appendix Figure 6.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/∘∘) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—28-29 June 1974.



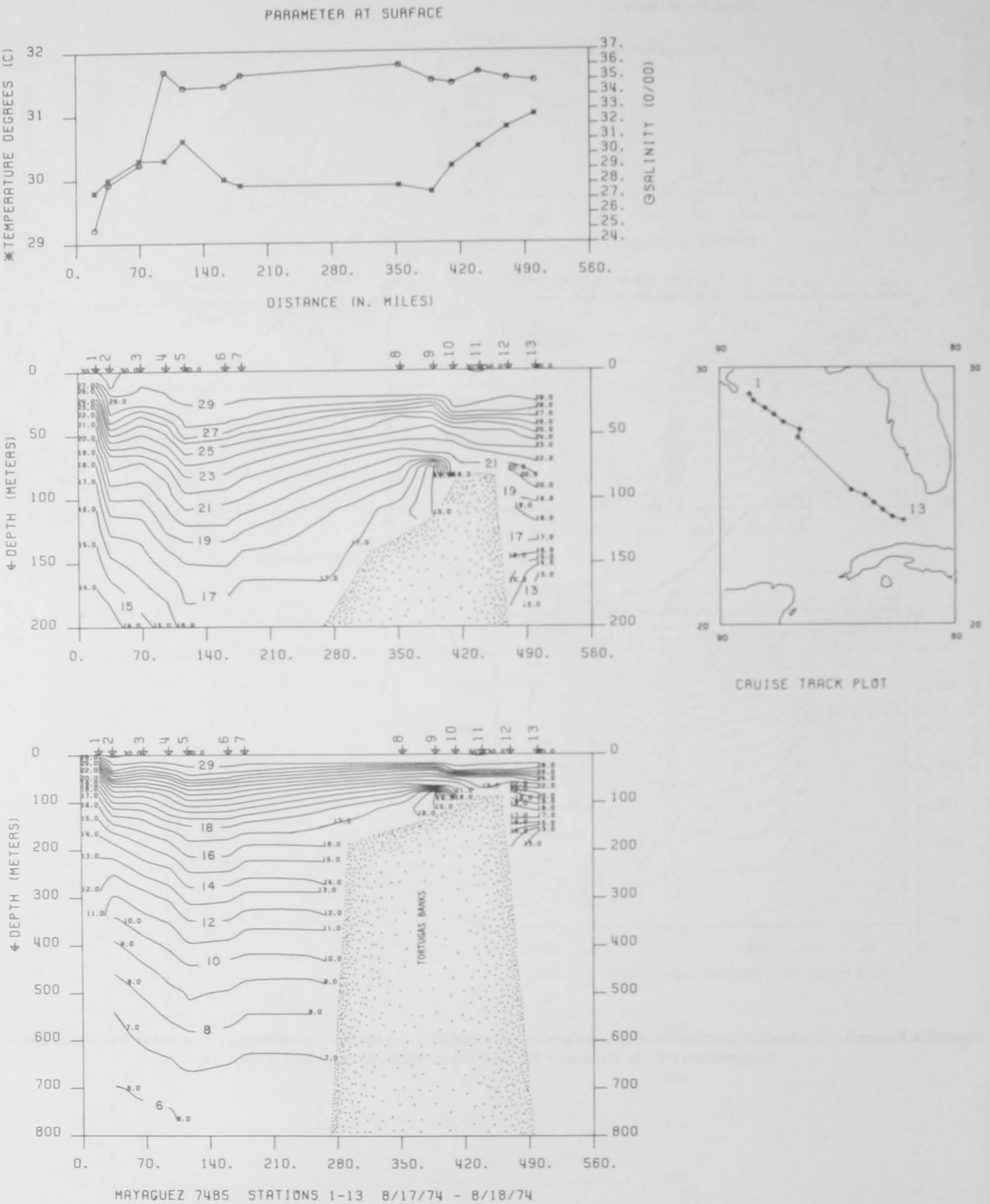
Appendix Figure 7.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—6-7 July 1974.



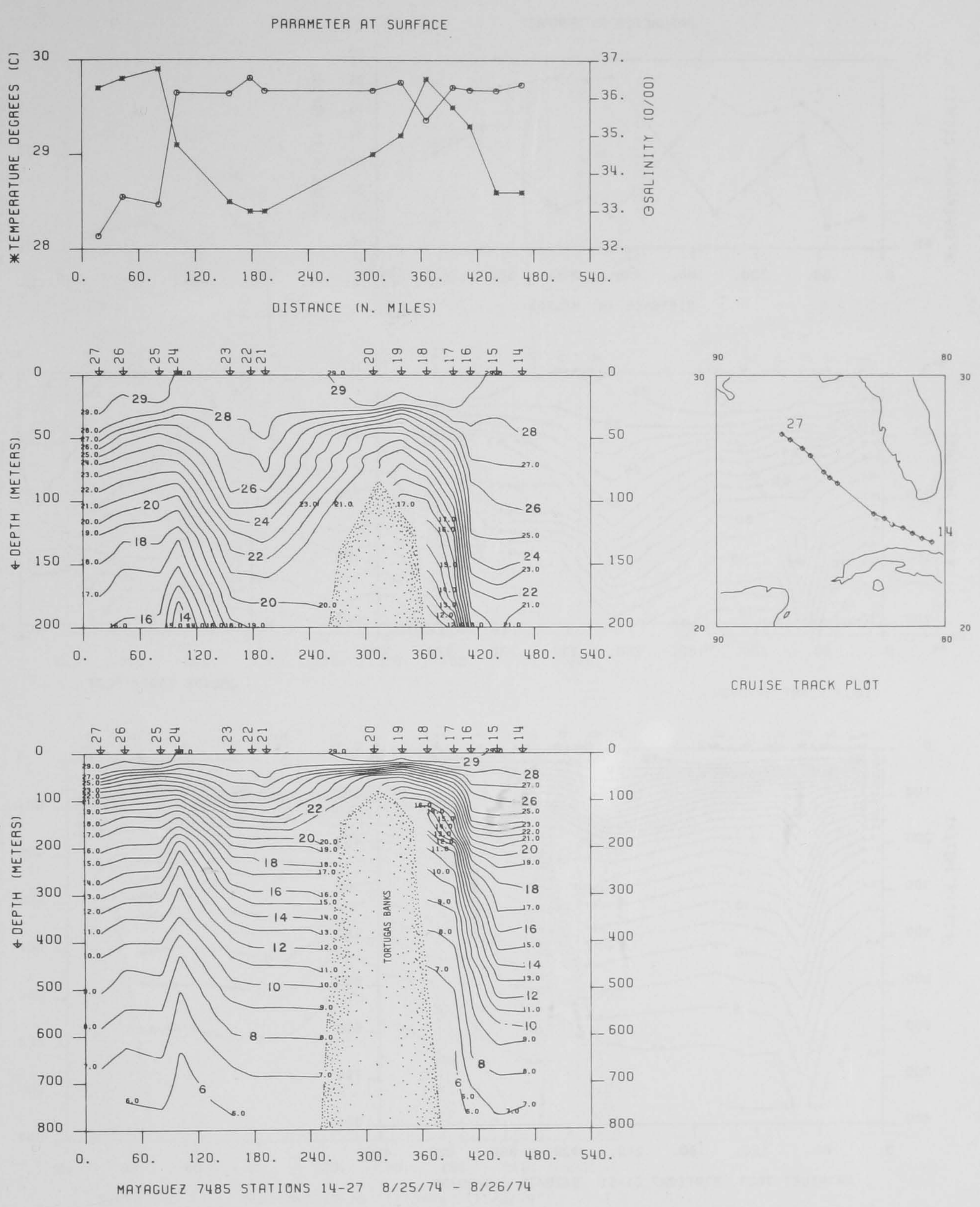
Appendix Figure 8.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—7-8 July 1974.



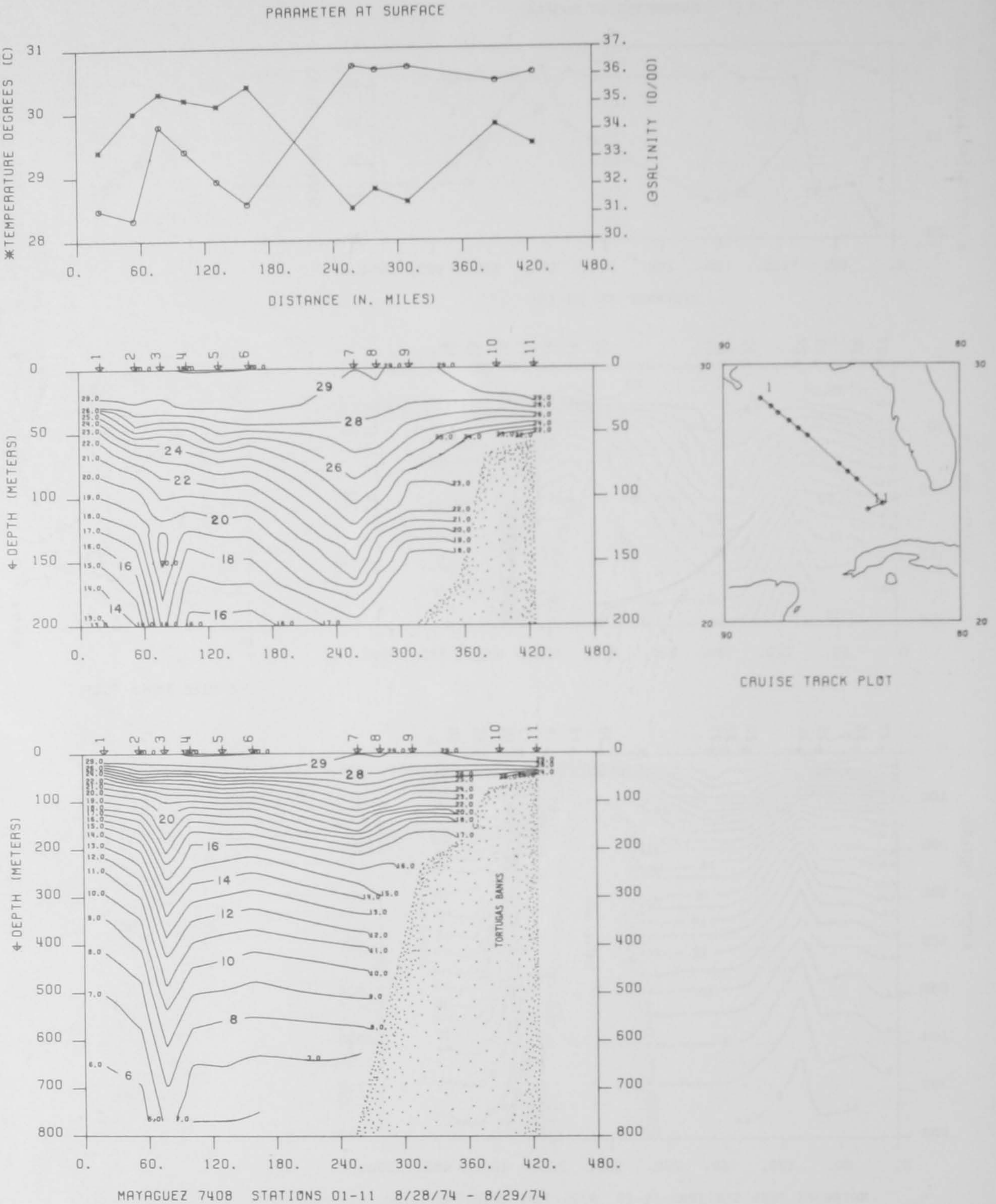
Appendix Figure 9.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—20-21 July 1974.



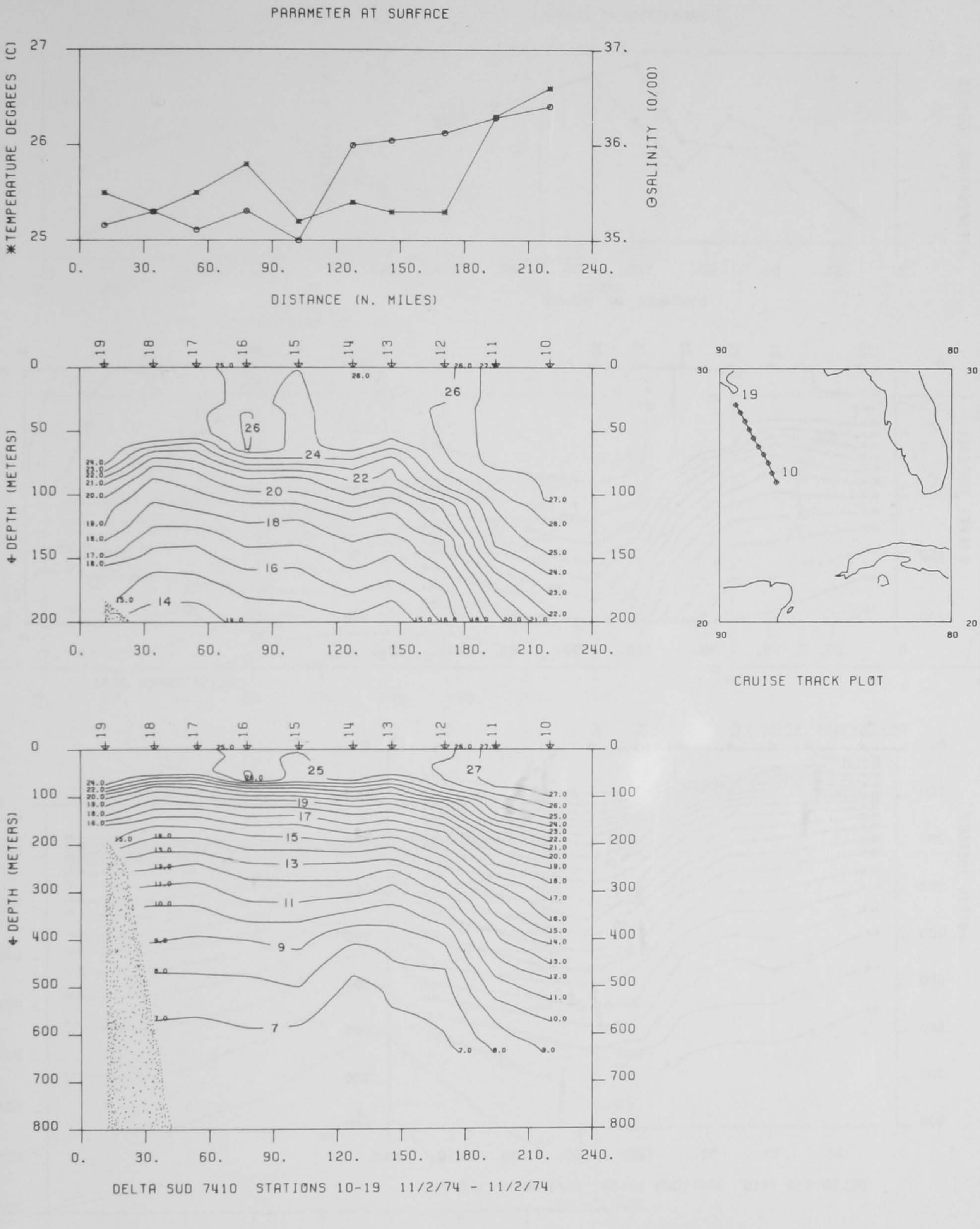
Appendix Figure 10.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mayaguez*—17-18 August 1974.



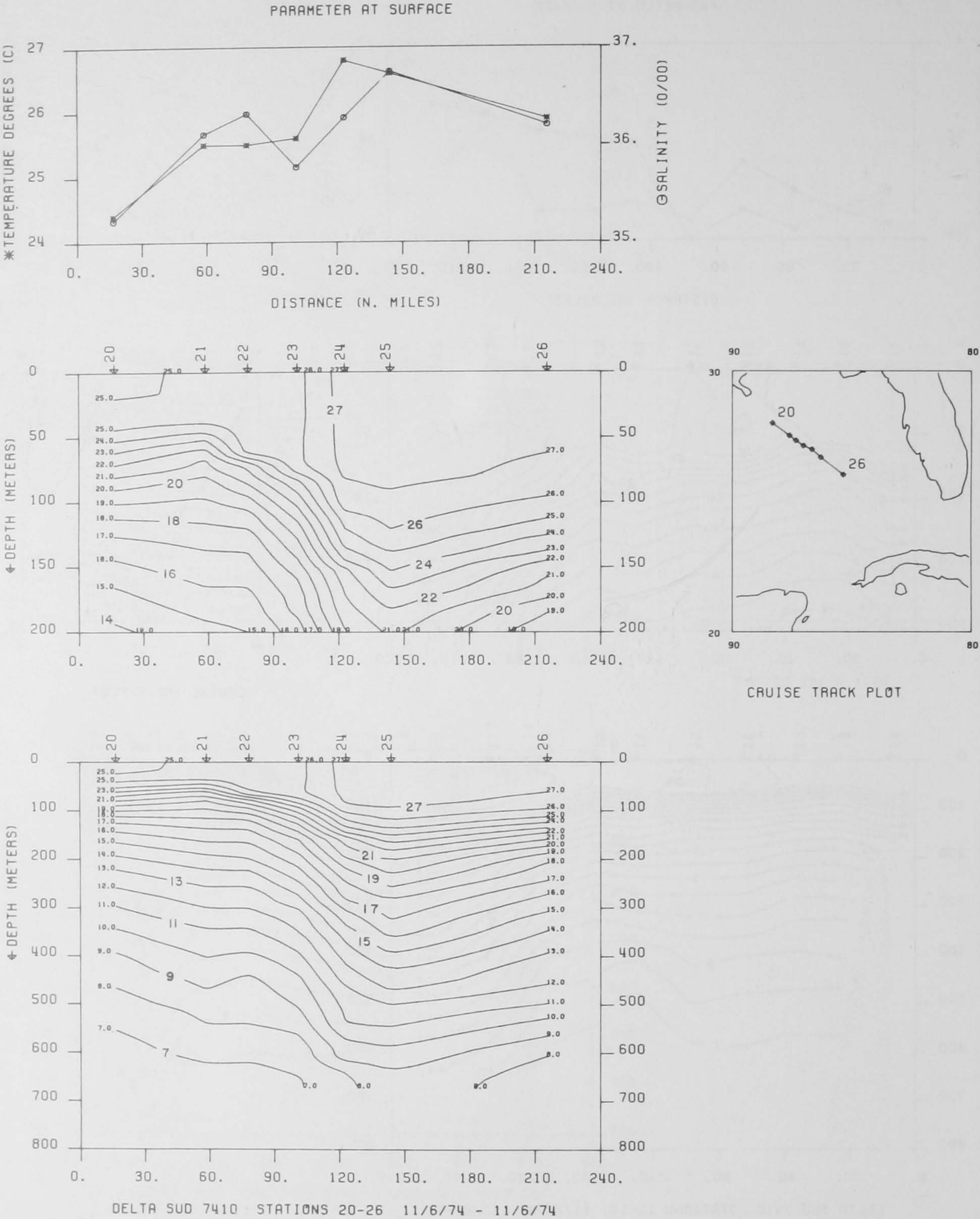
Appendix Figure 11.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mayaguez*—25-26 August 1974.



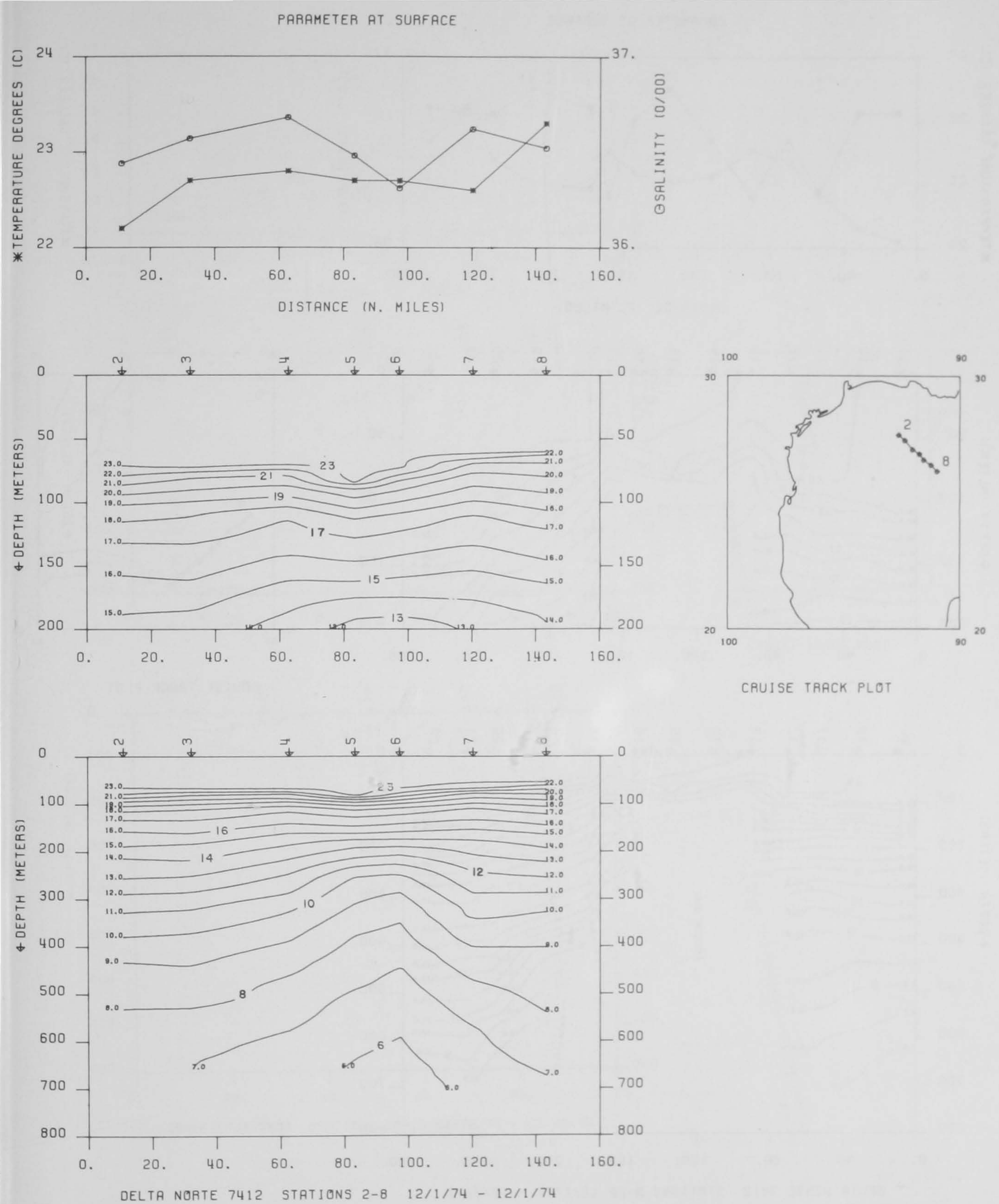
Appendix Figure 12.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mayaguez*—28-29 August 1974.



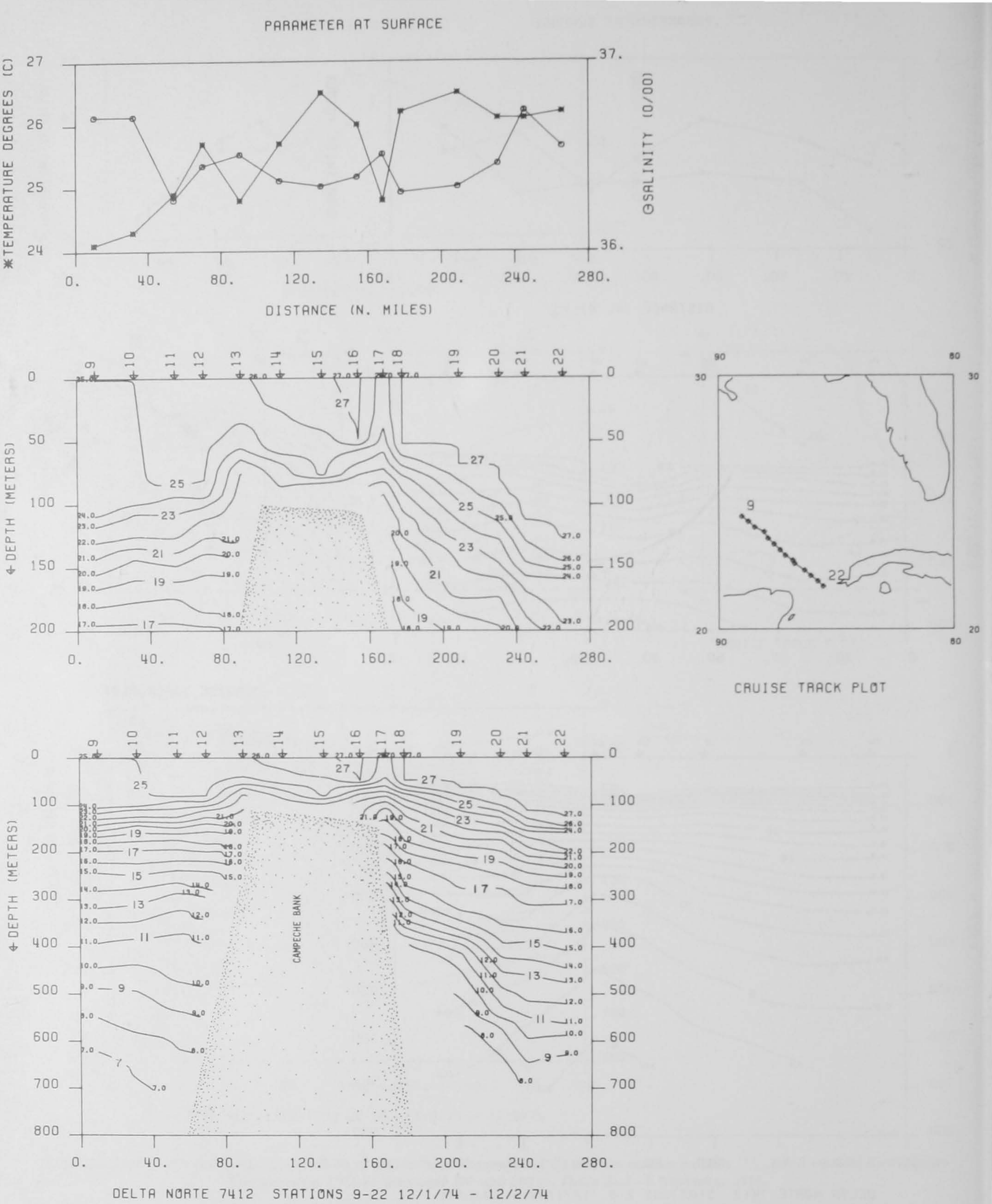
Appendix Figure 13.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—2 November 1974.



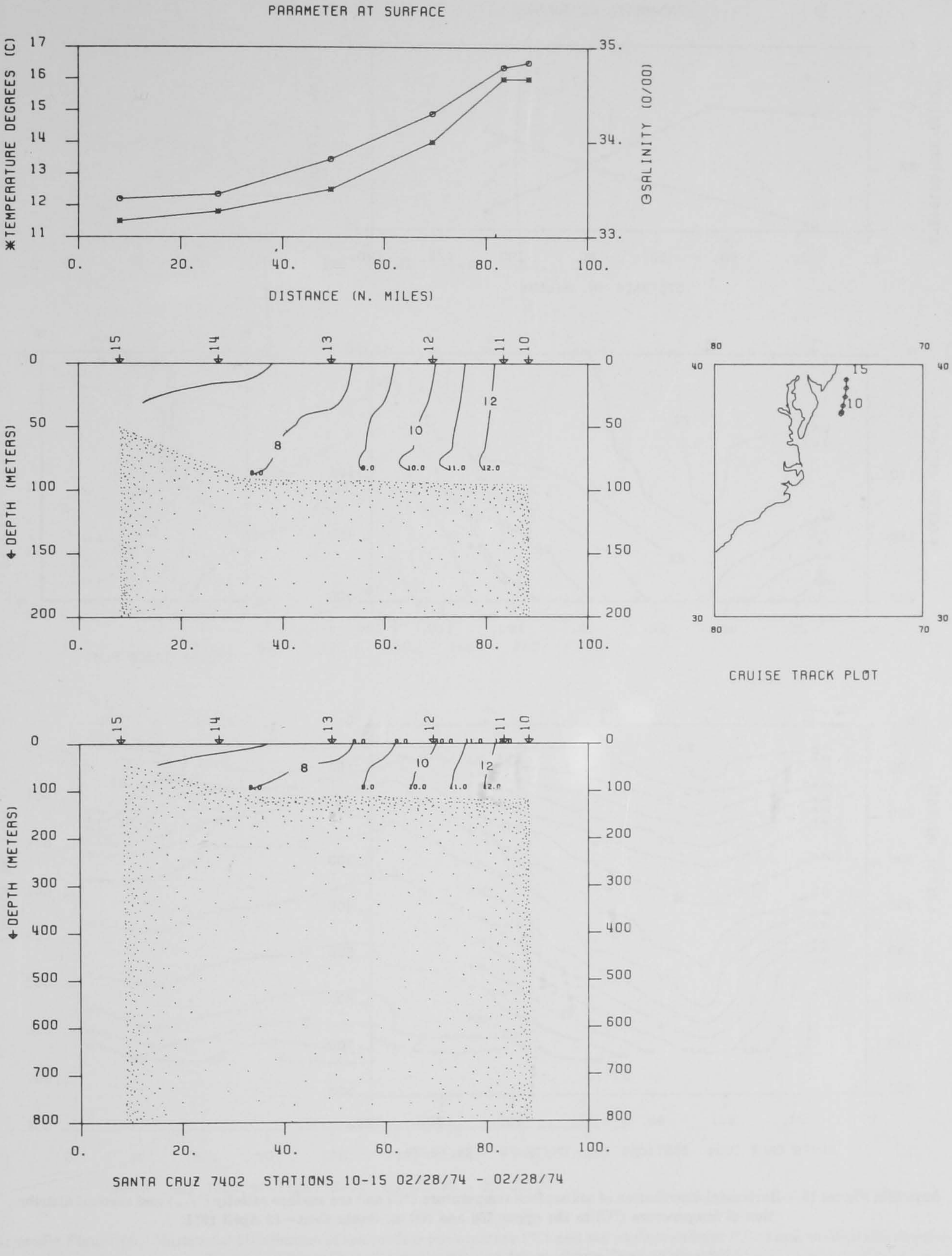
Appendix Figure 14.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—6 November 1974.



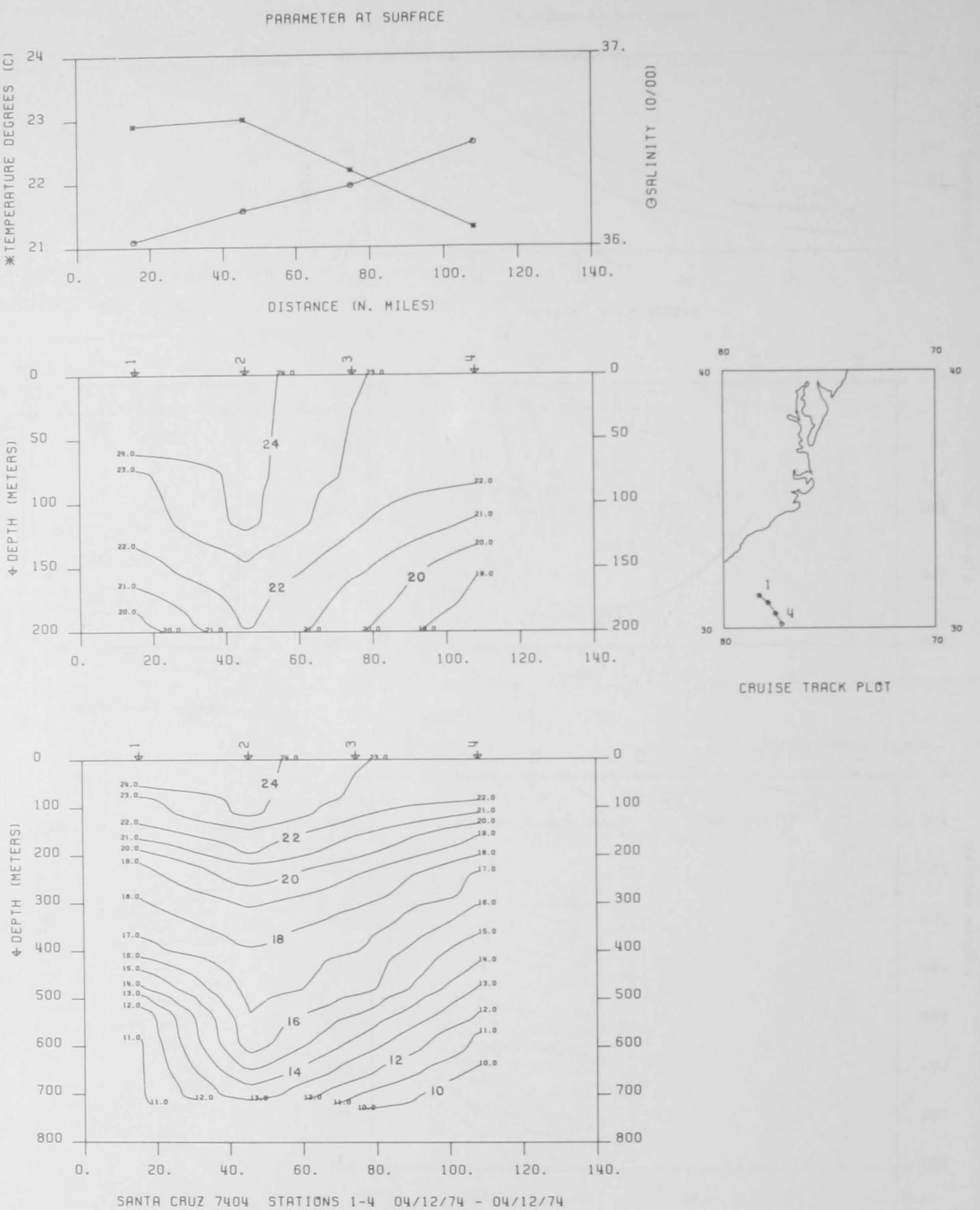
Appendix Figure 15.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 8 00 m. *Delta Norte*—1 December 1974.



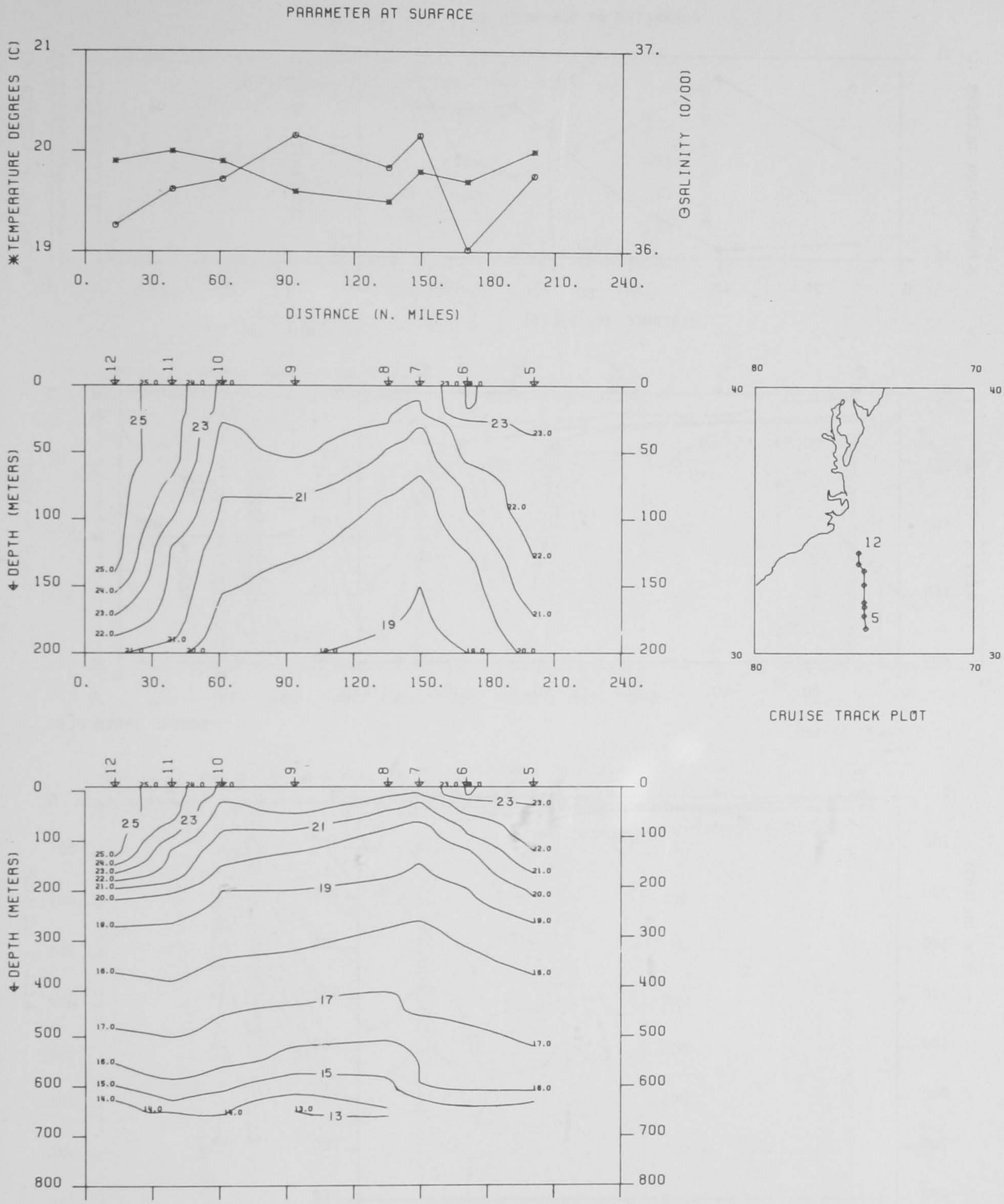
Appendix Figure 16.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—1-2 December 1974.



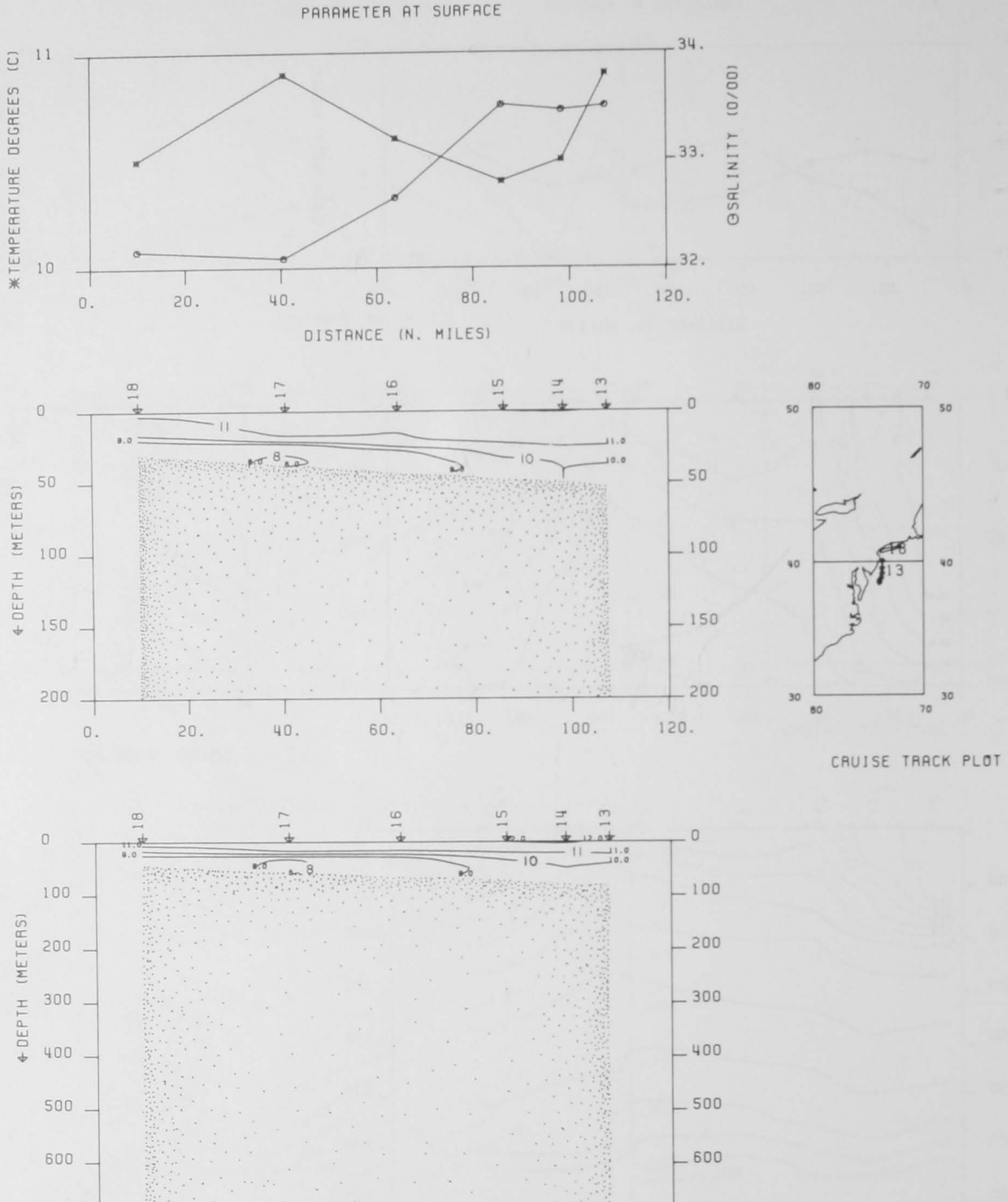
Appendix Figure 17.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—28 February 1974.



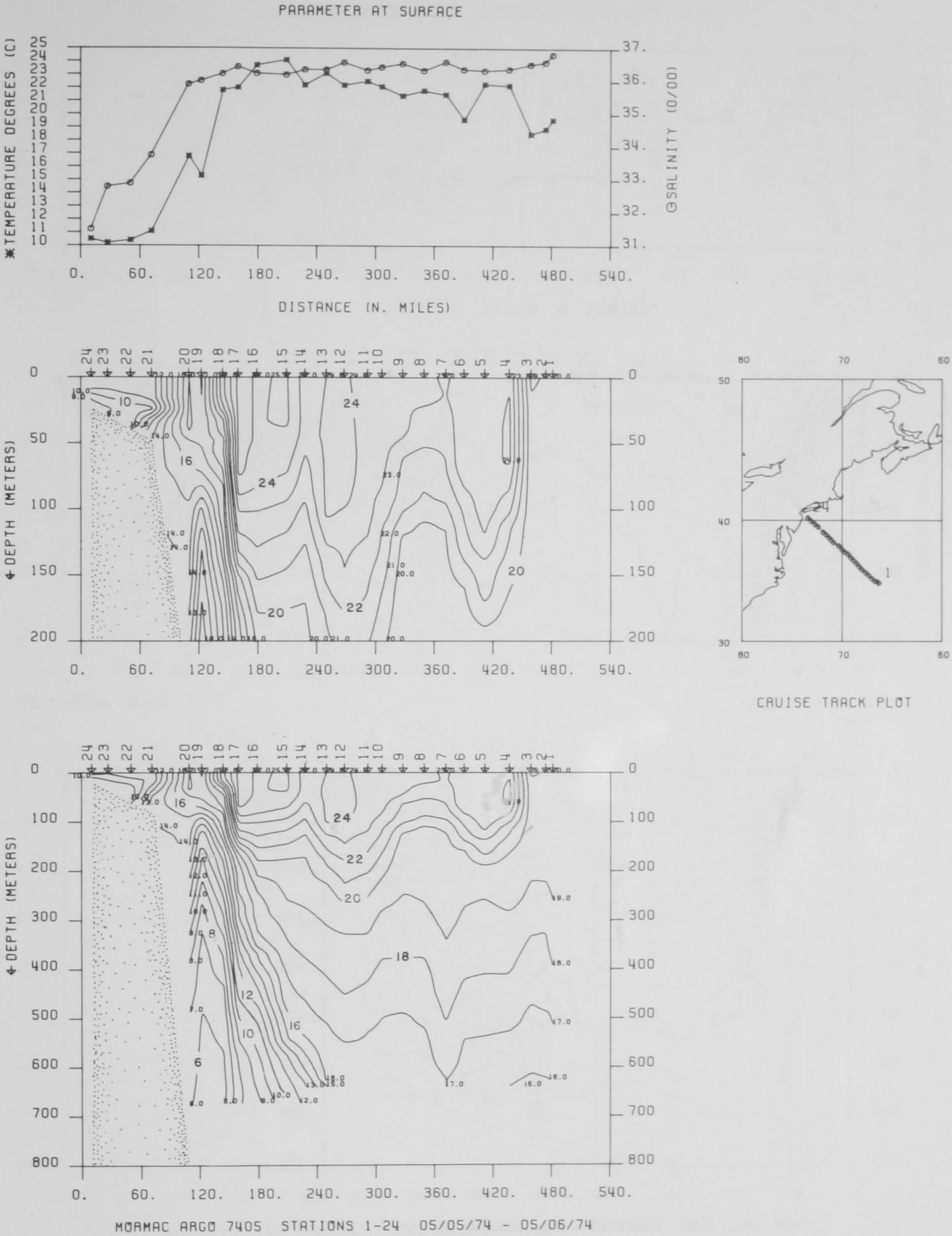
Appendix Figure 18.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—12 April 1974.



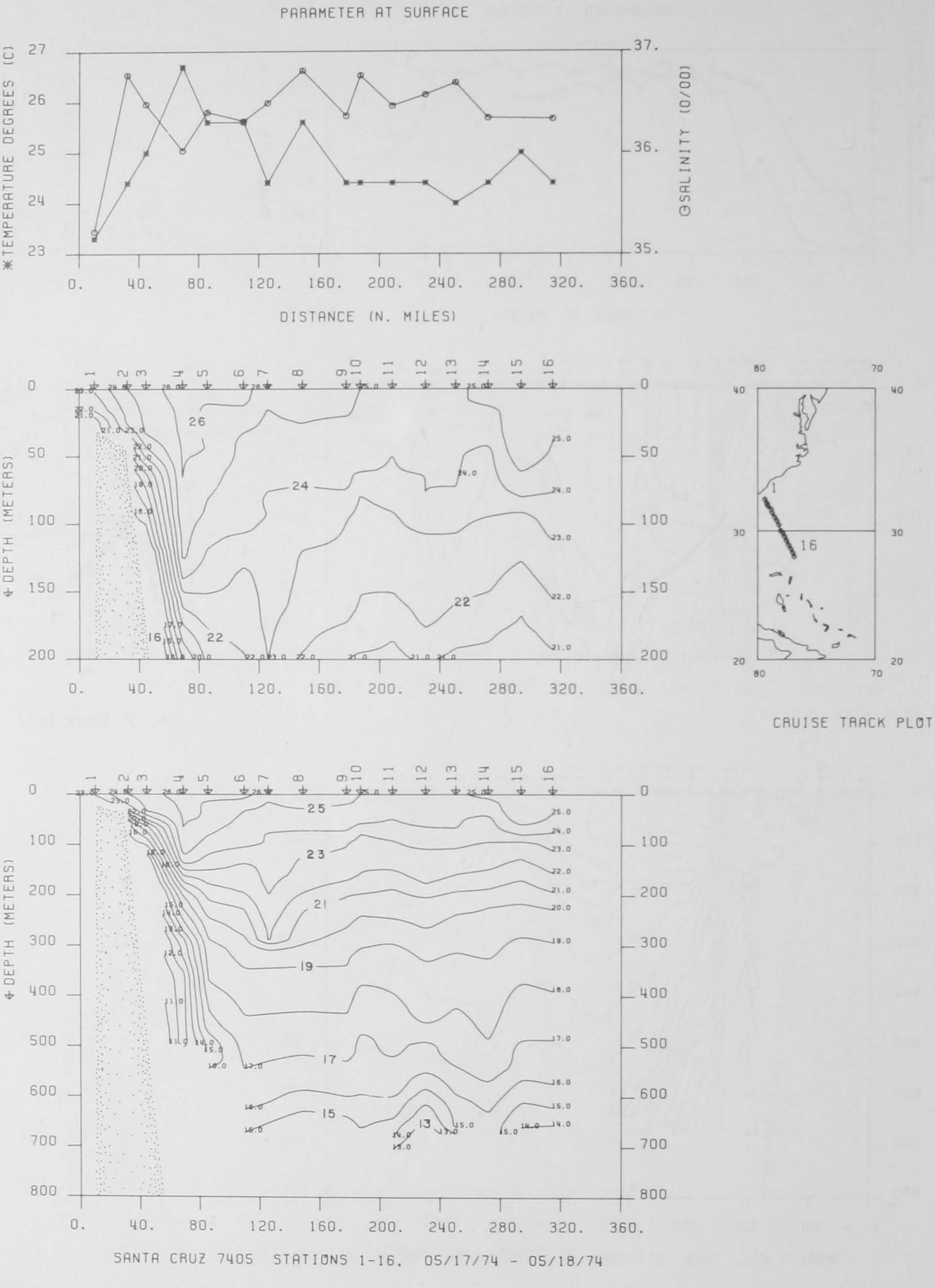
Appendix Figure 19.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—5 May 1974.



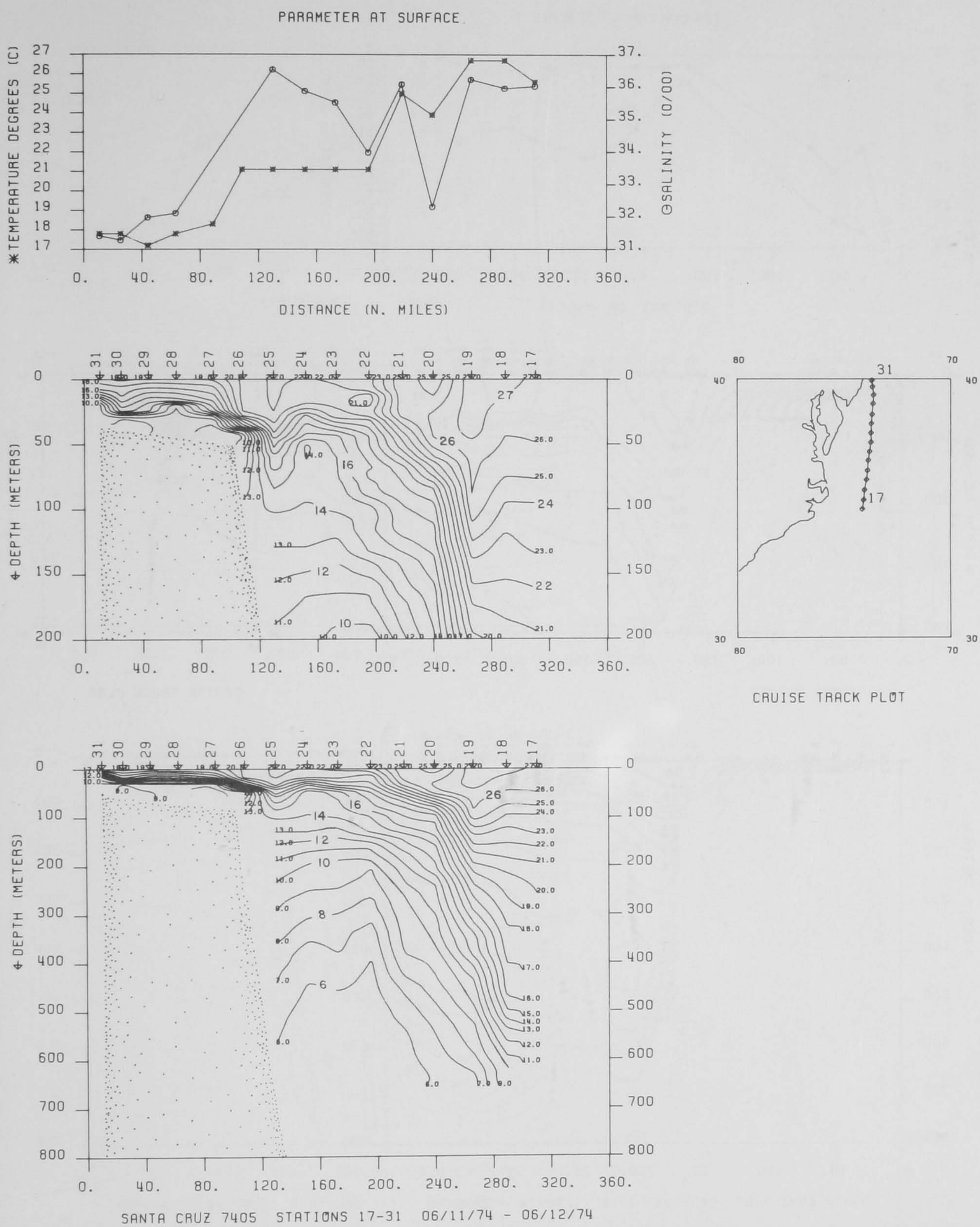
Appendix Figure 20.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—6 May 1974.



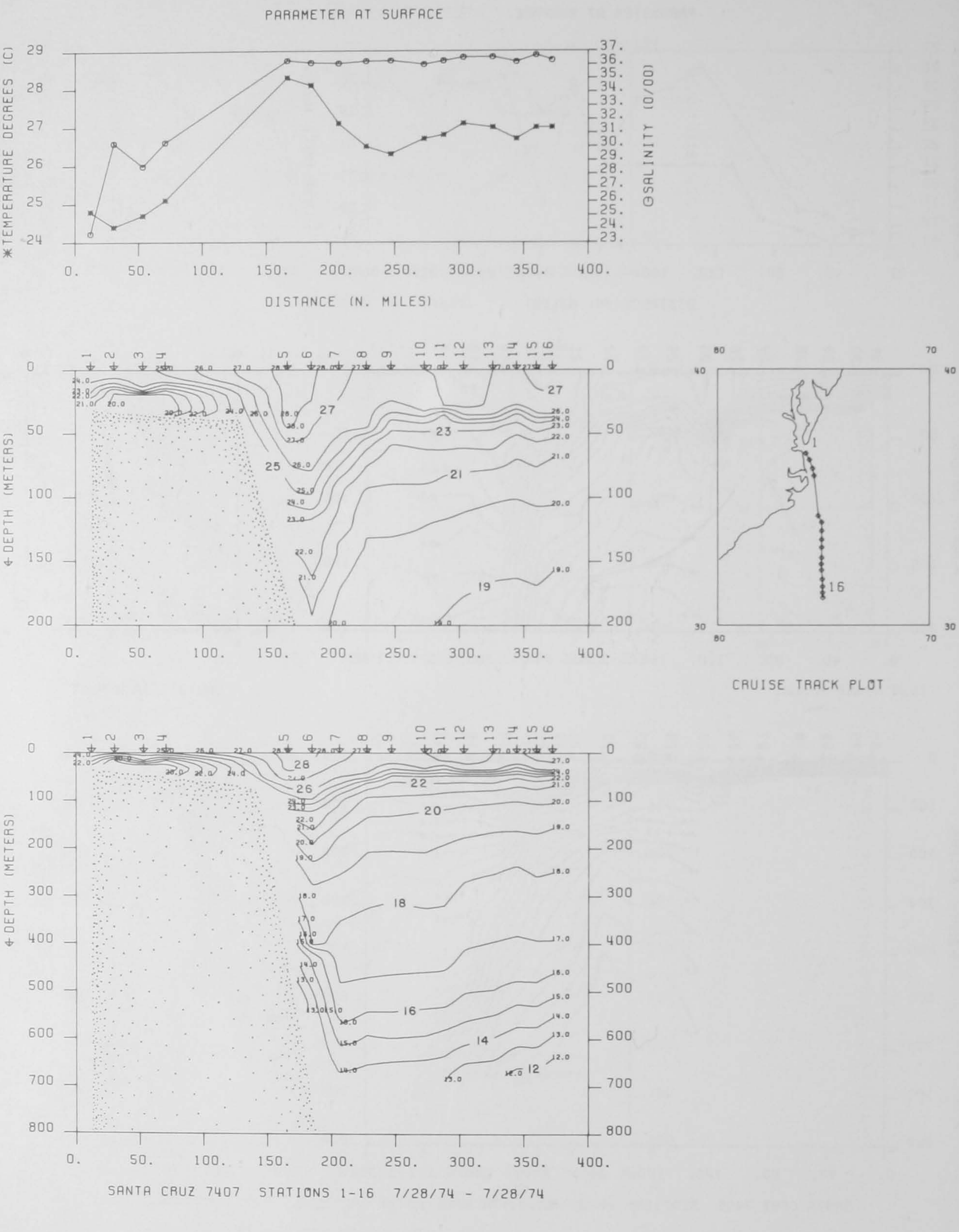
Appendix Figure 21.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Argo*—5-6 May 1974.



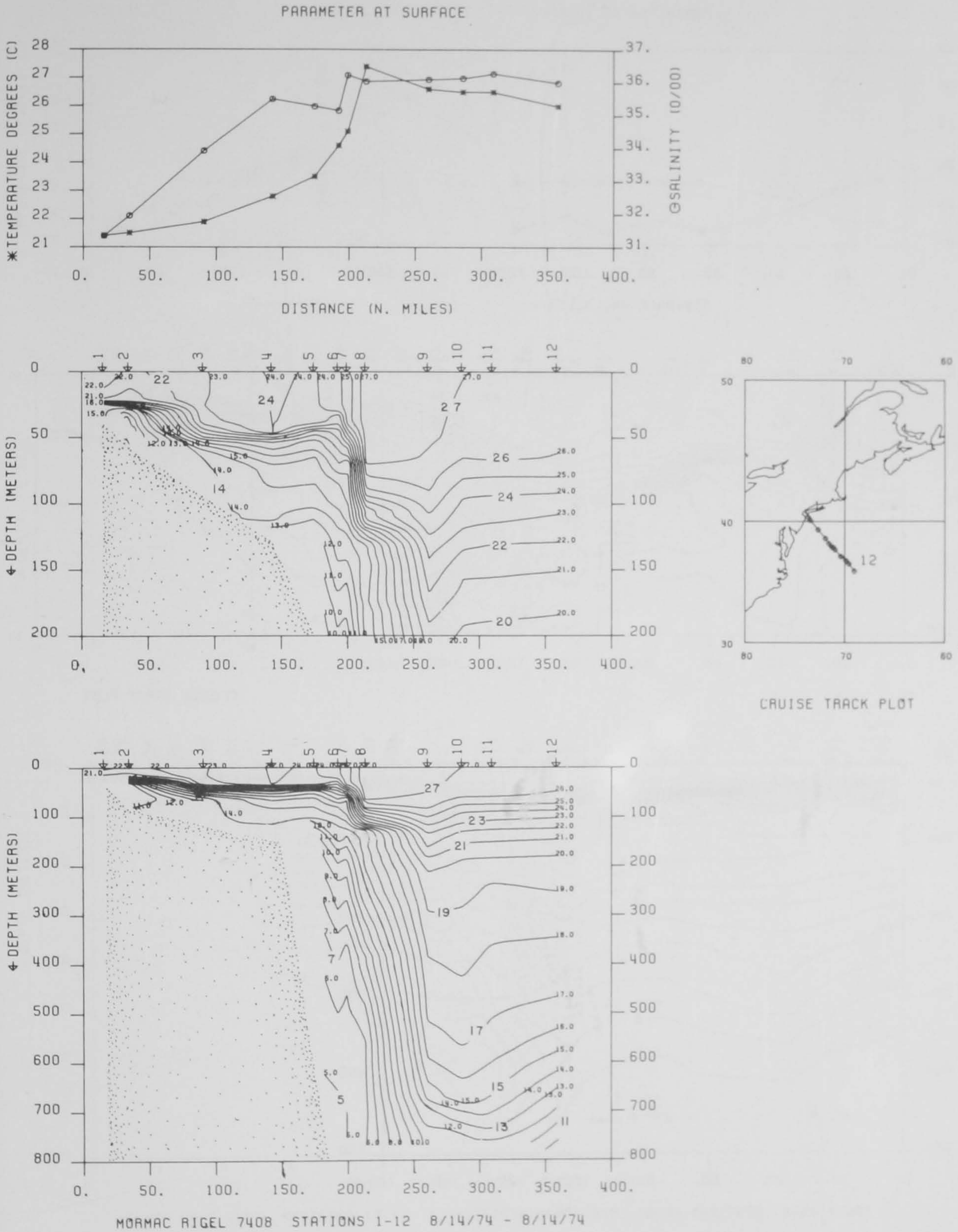
Appendix Figure 22.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—17-18 May 1974.



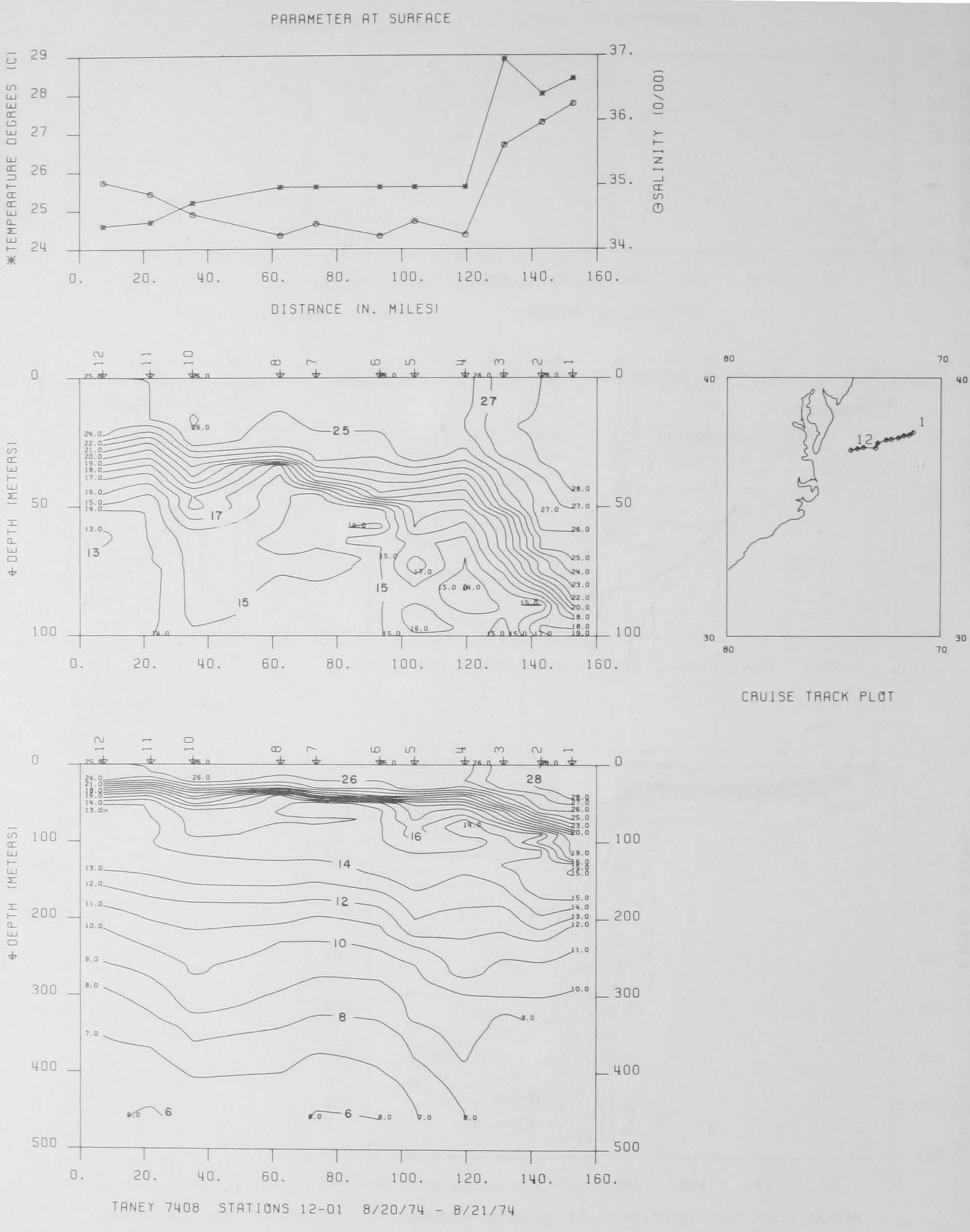
Appendix Figure 23.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—11-12 June 1974.



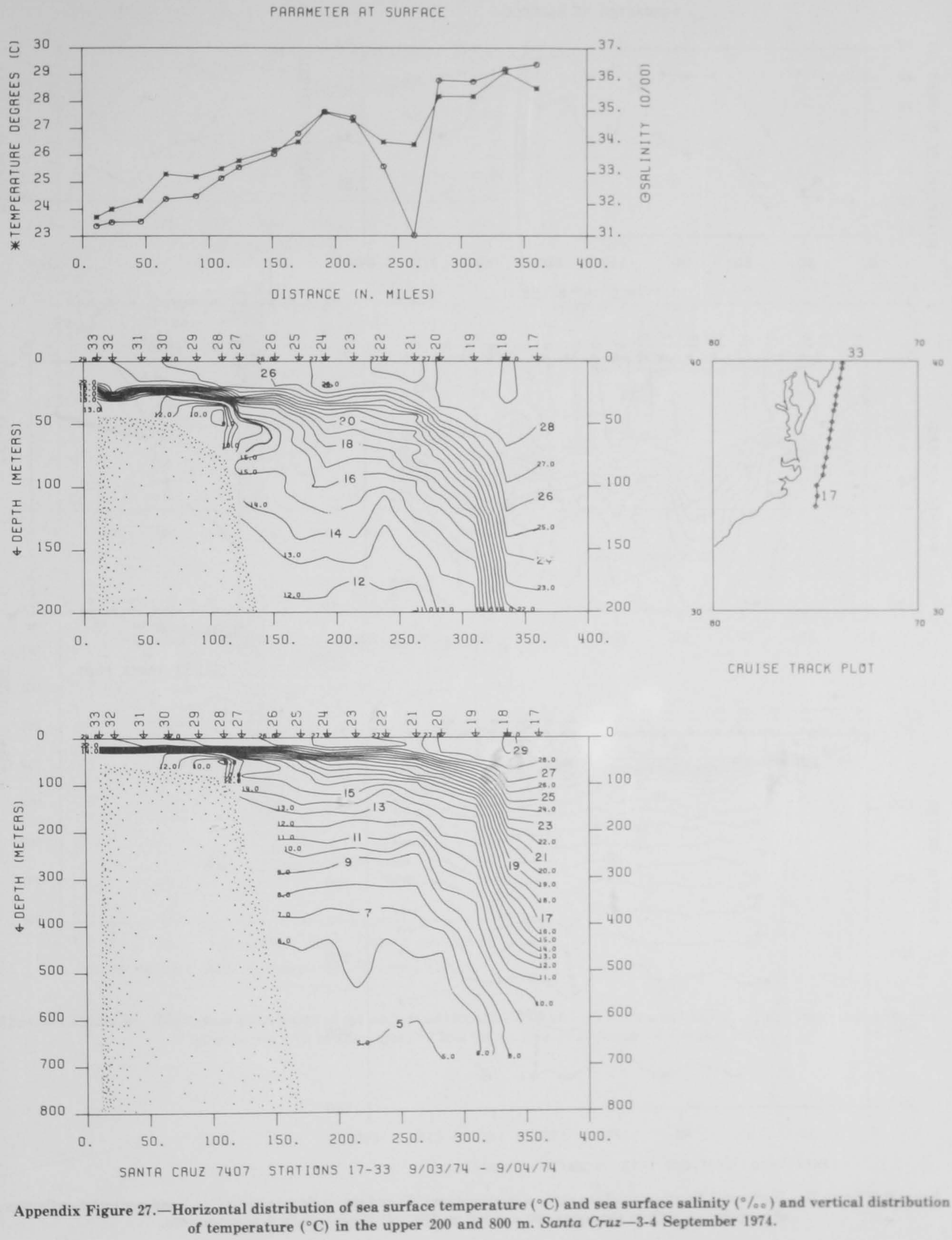
Appendix Figure 24.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/∘∘) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—28 July 1974.



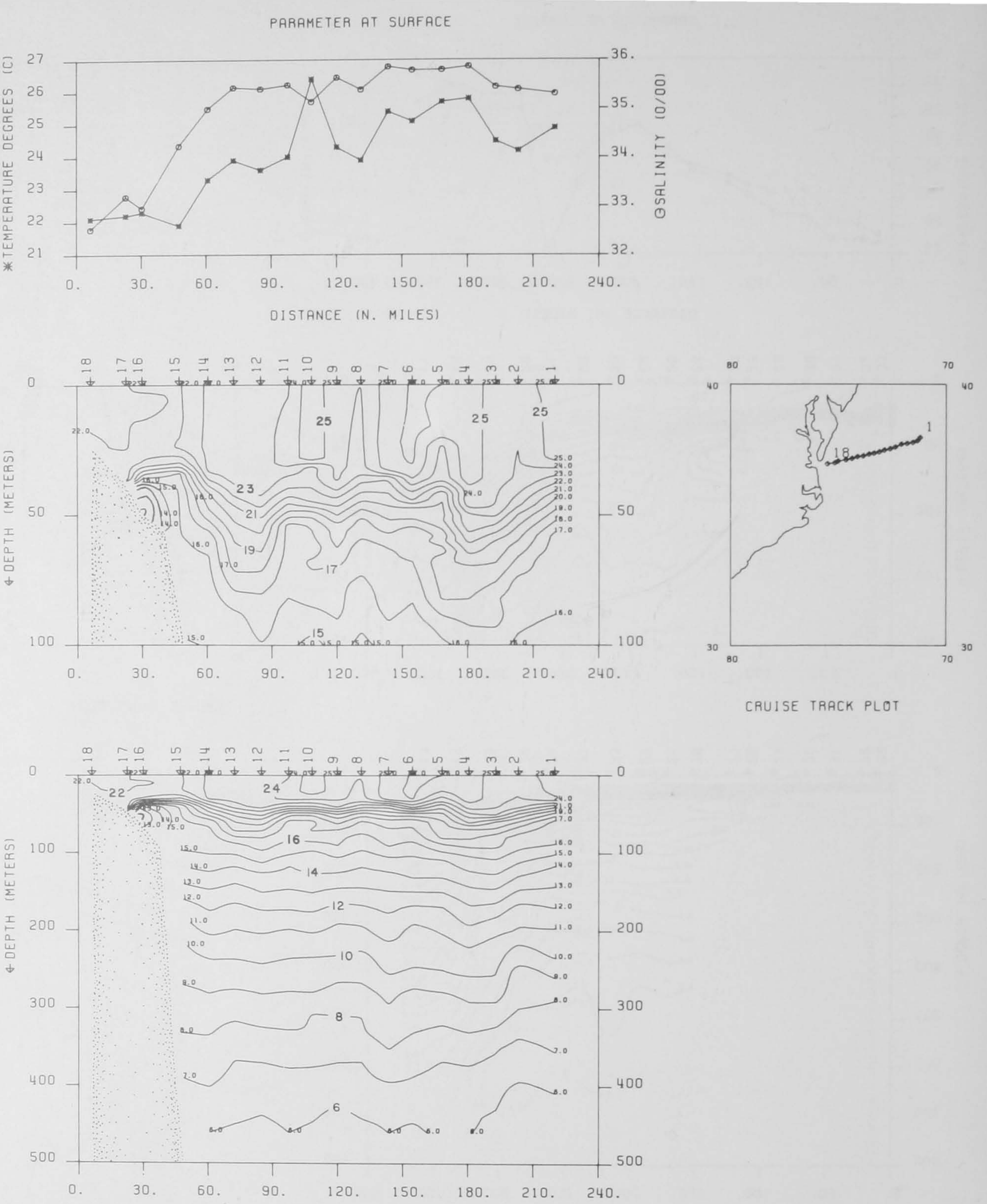
Appendix Figure 25.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Rigel*—14 August 1974.



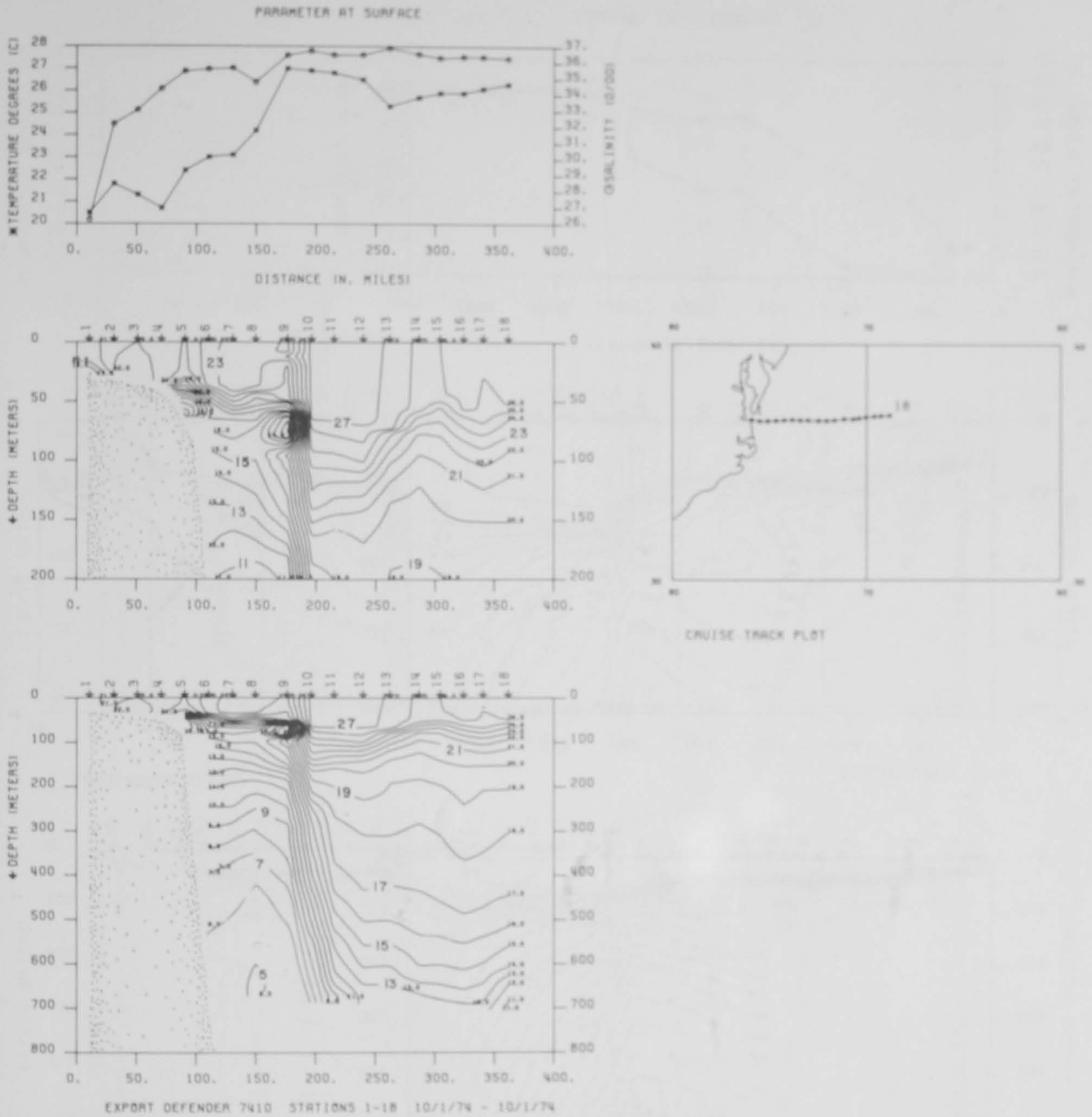
Appendix Figure 26.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. USCGC *Taney*—20-21 August 1974.



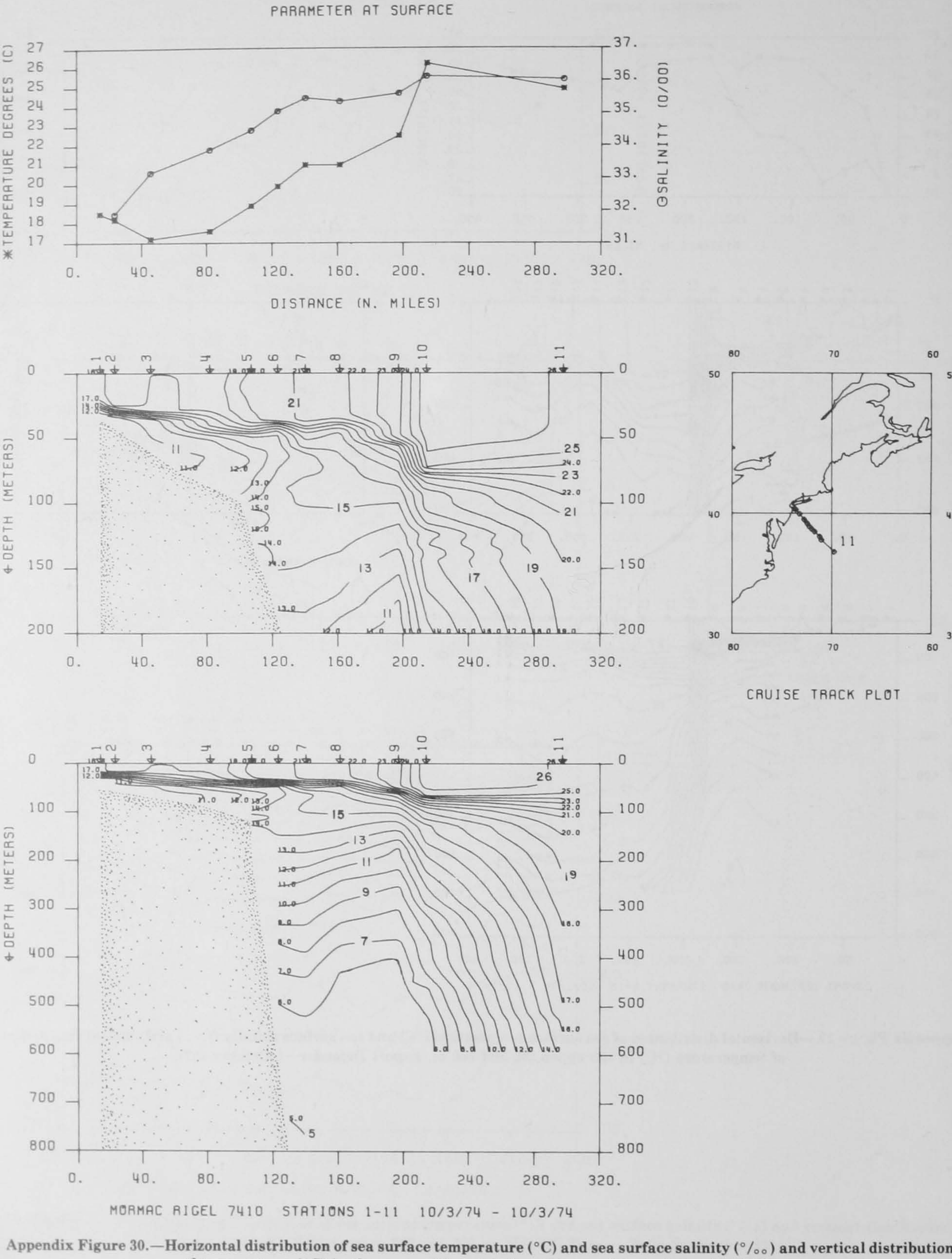
Appendix Figure 27.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—3-4 September 1974.



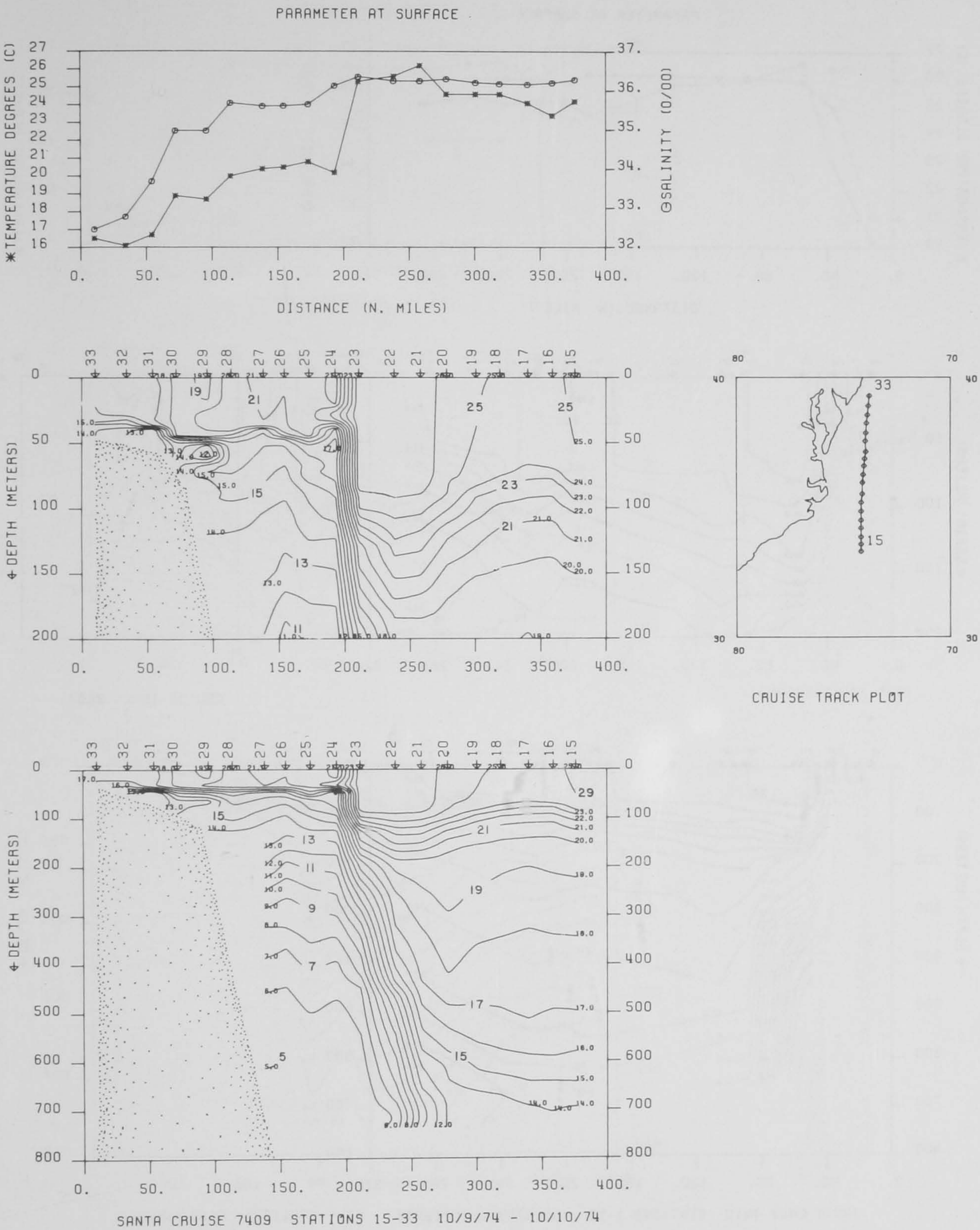
Appendix Figure 28.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. USCGC *Taney*—29-30 September 1974.



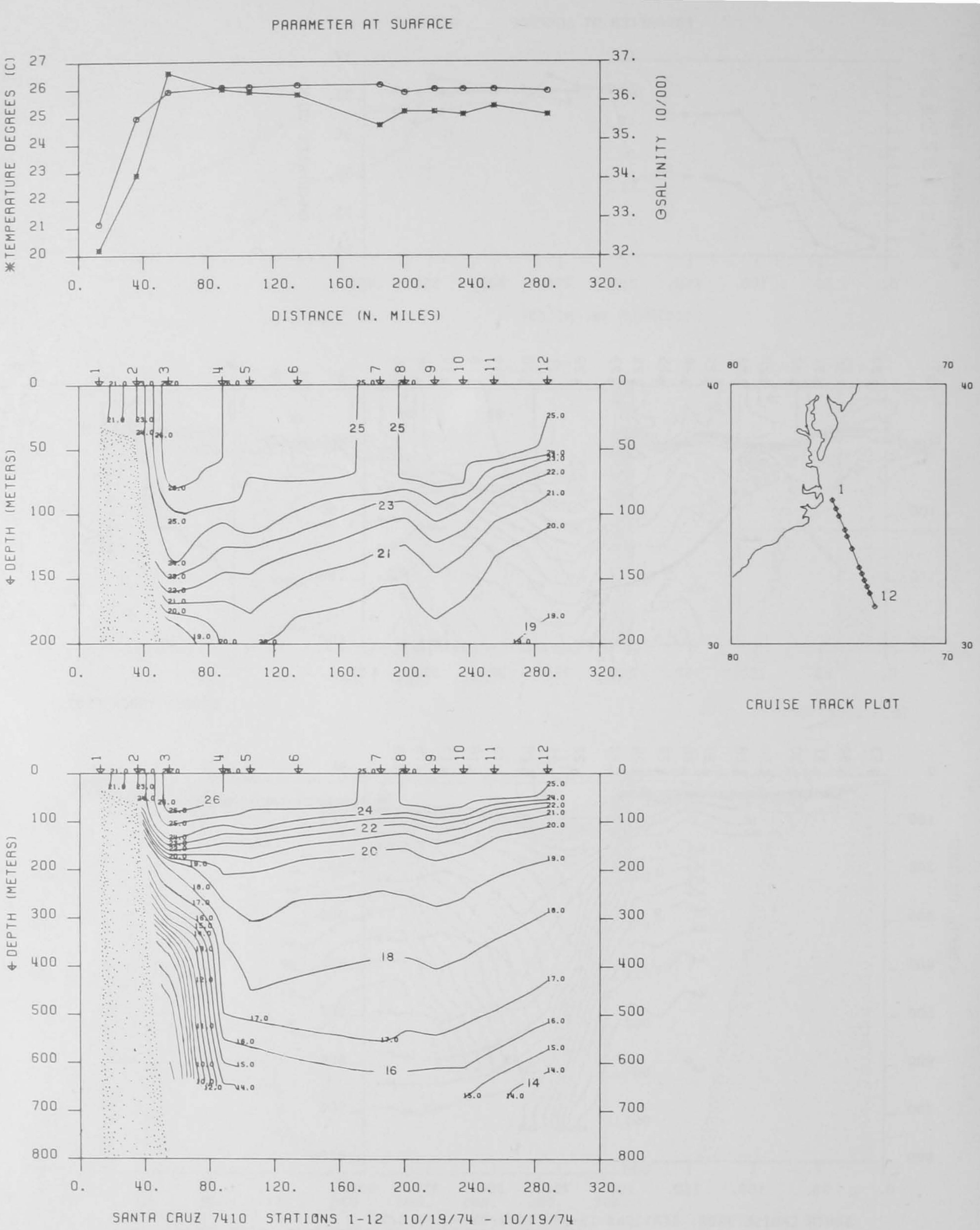
Appendix Figure 29.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Export Defender*—1 October 1974.



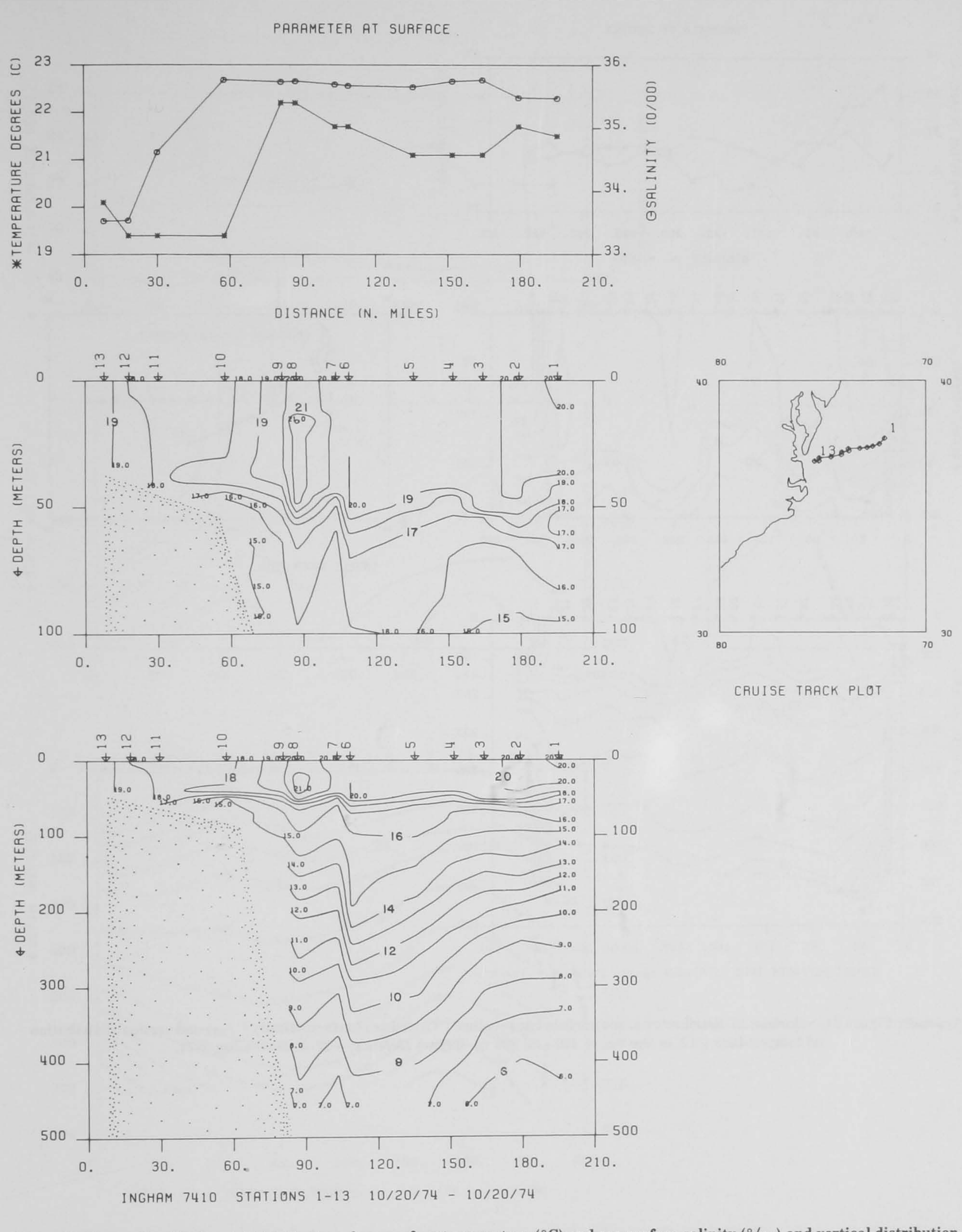
Appendix Figure 30.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Rigel*—3 October 1974.



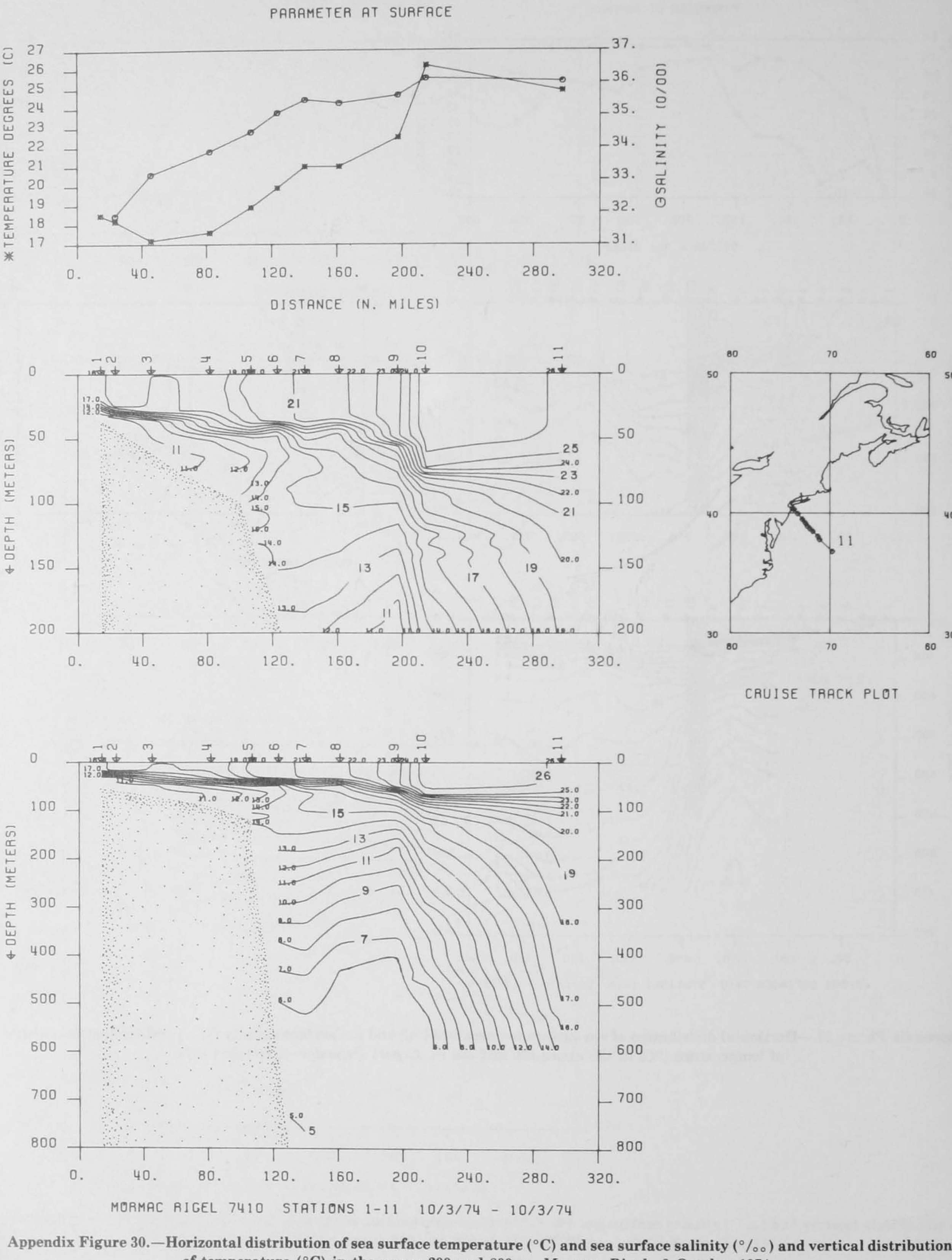
Appendix Figure 31.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—9-10 October 1974.



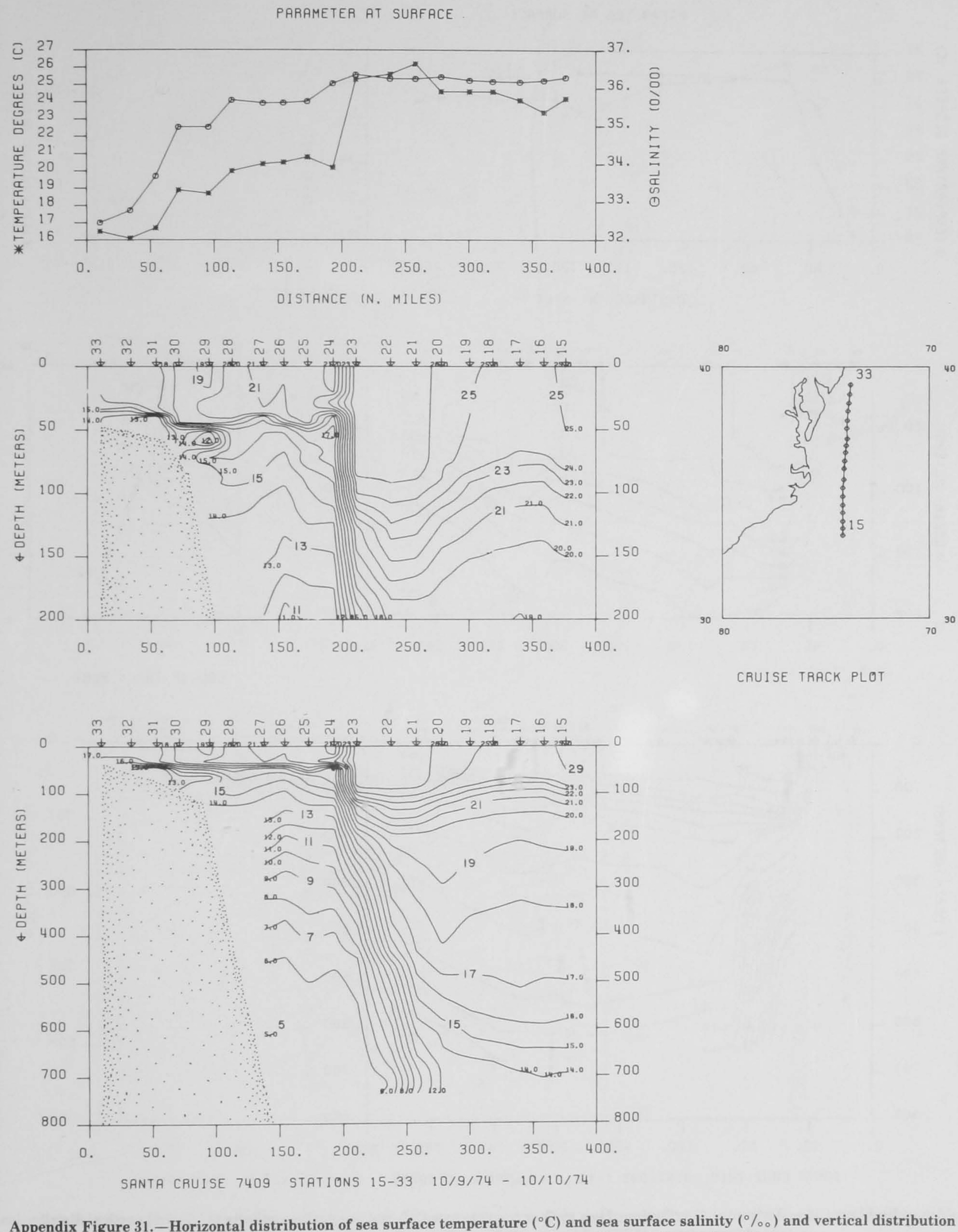
Appendix Figure 32.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—19 October 1974.



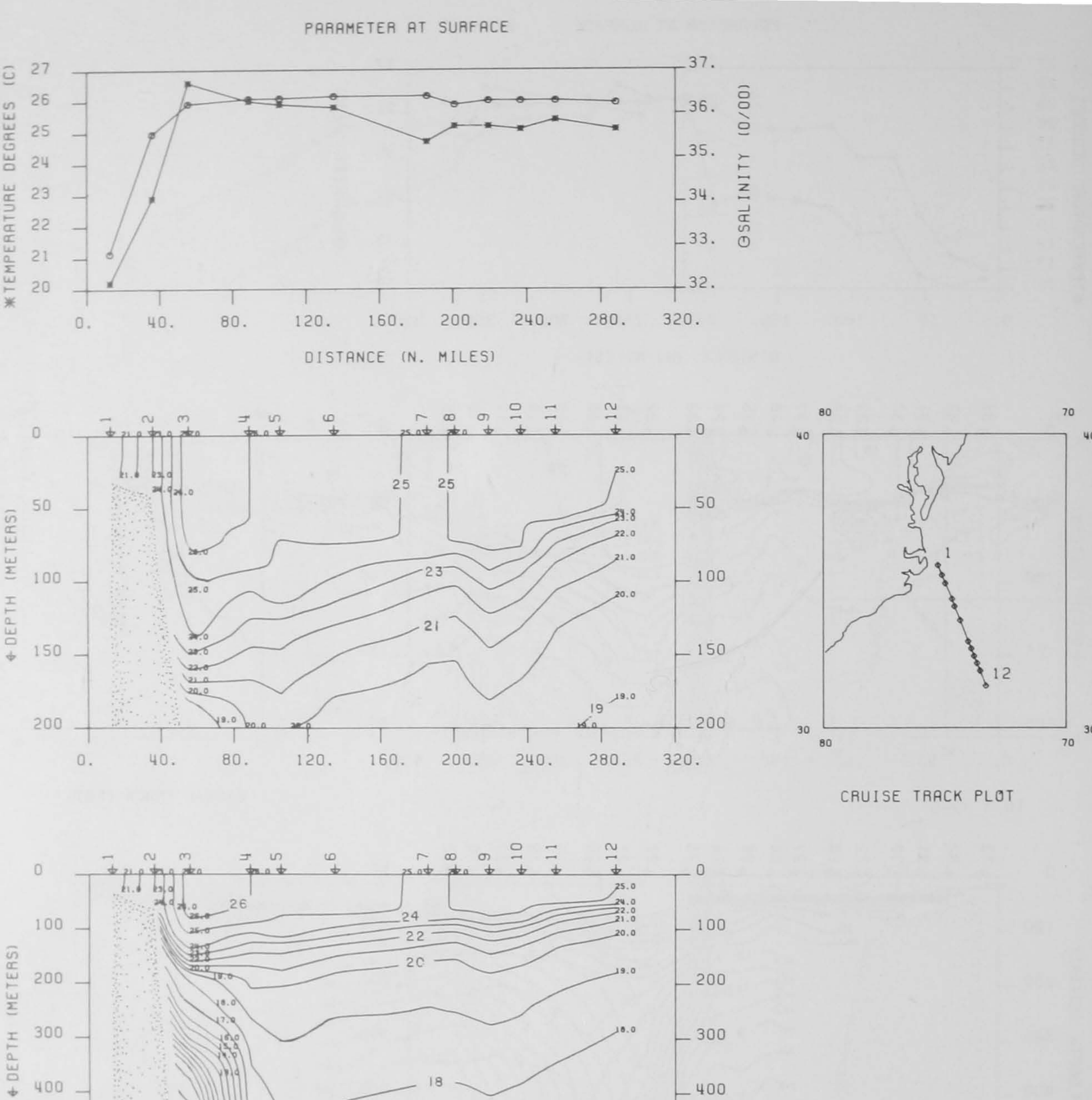
Appendix Figure 33.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/∘∘) and vertical distribution of temperature (°C) in the upper 200 and 800 m. USCGC *Ingham*—20 October 1974.



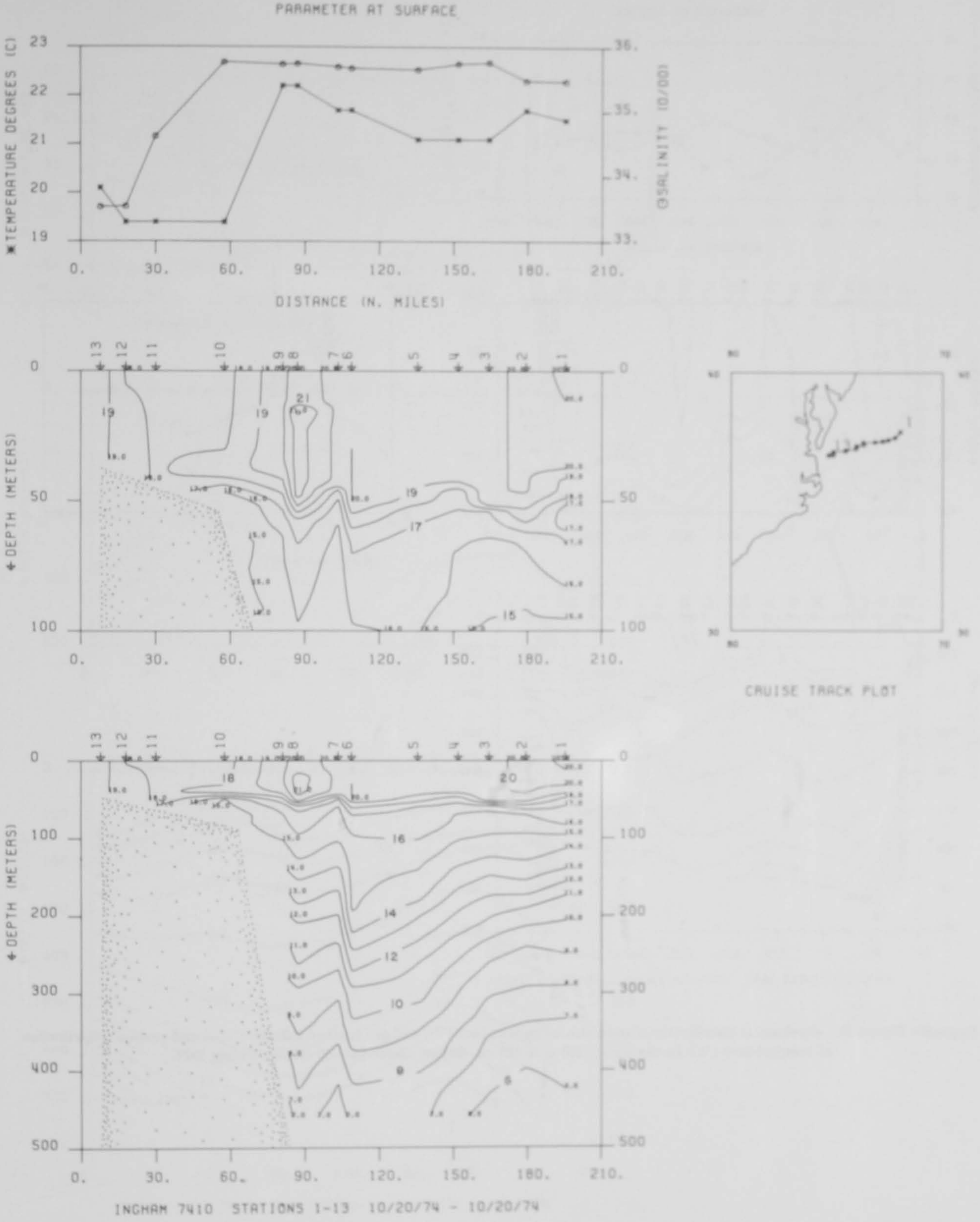
Appendix Figure 30.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Rigel*—3 October 1974.



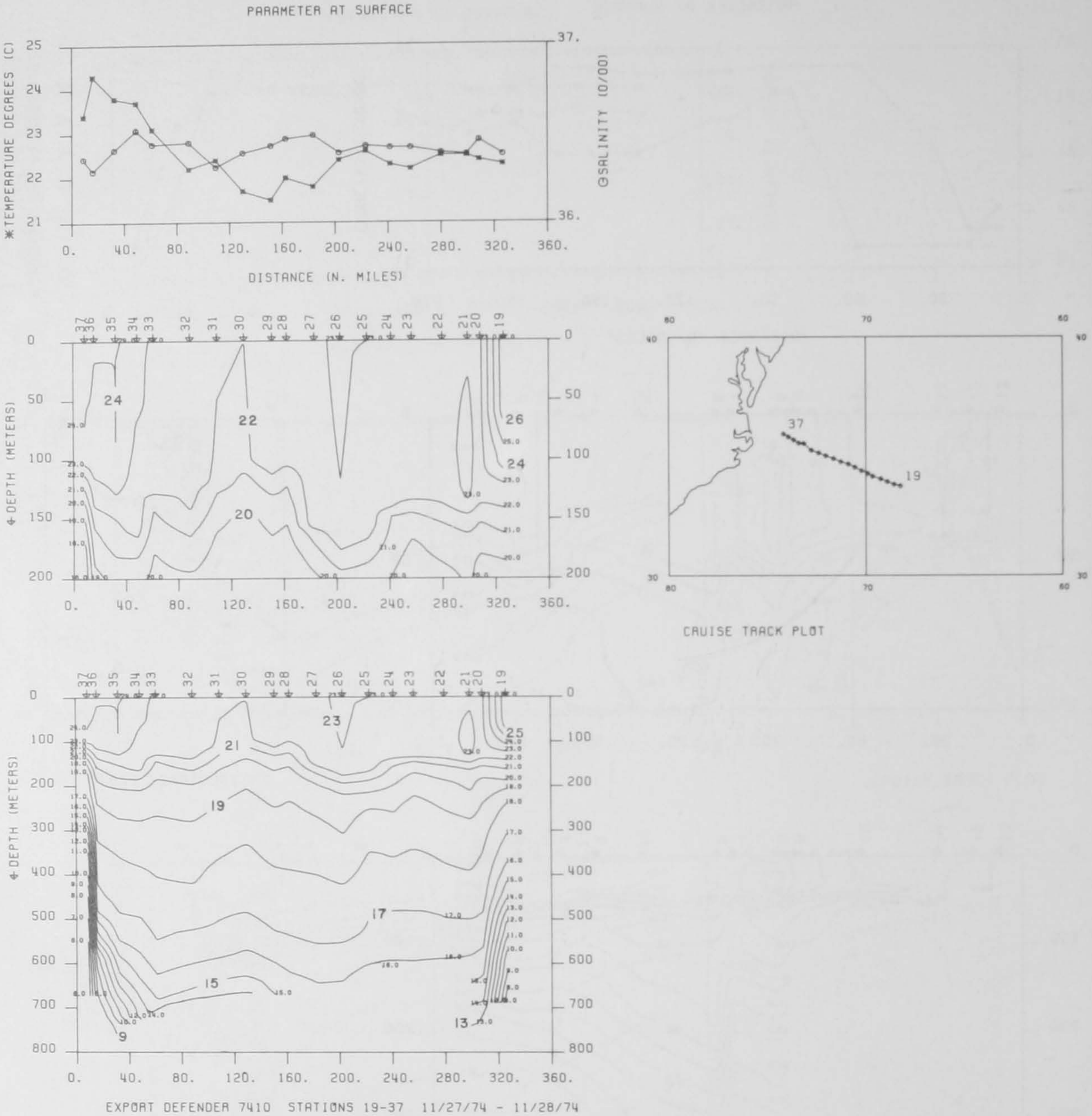
Appendix Figure 31.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/∘∘) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—9-10 October 1974.



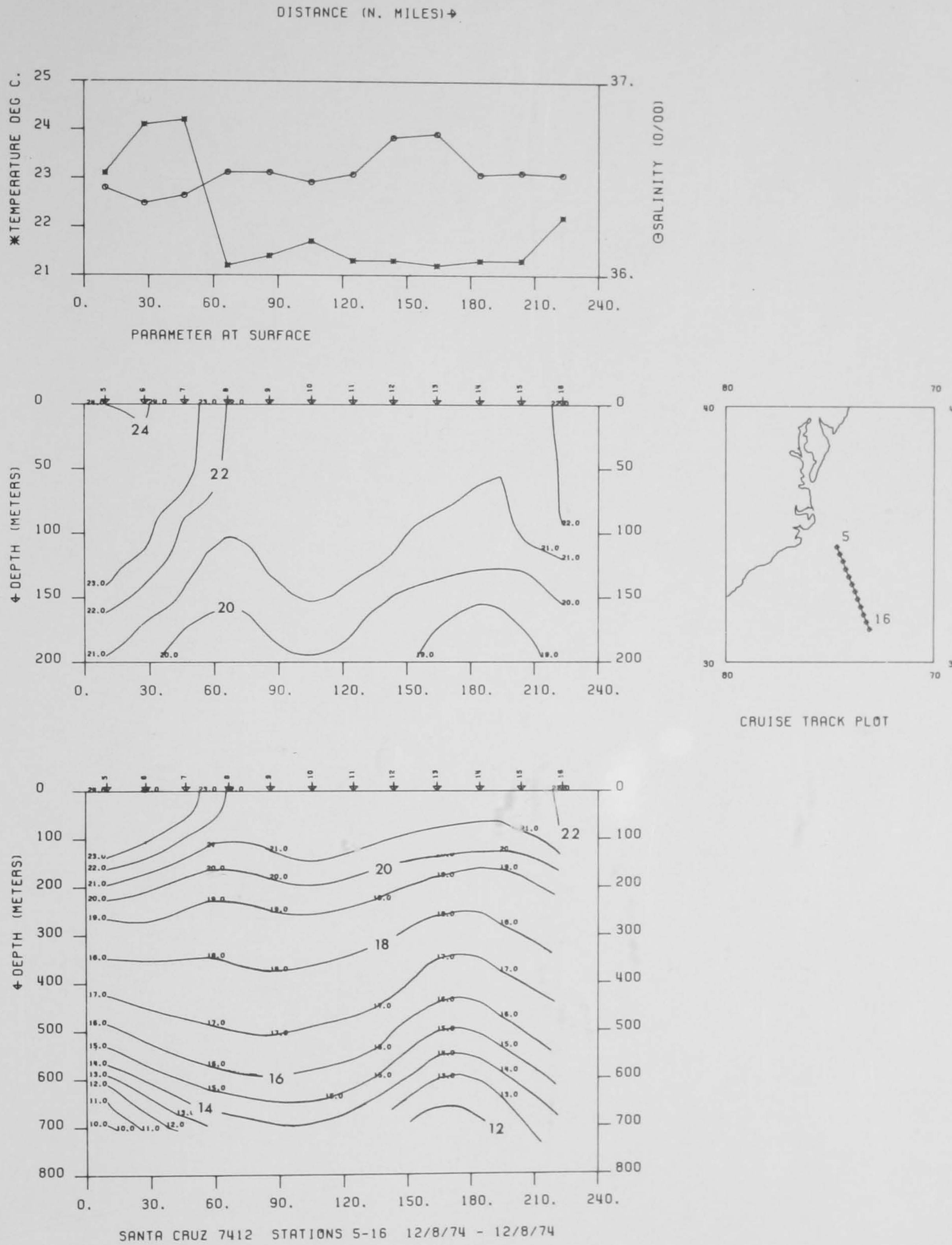
Appendix Figure 32.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—19 October 1974.



Appendix Figure 33.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. USCGC *Ingham*—20 October 1974.



Appendix Figure 34.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Export Defender*—27-28 November 1974.



Appendix Figure 35.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (°/₀₀) and vertical distribution of temperature (°C) in the upper 200 and 800 m. ***Santa Cruz*—7-8 December 1974.**