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Expendable Bathythermograph Observations From the NMFS/MARAD Ship of Opportunity Program for 1975

Steven K. Cook, Barclay P. Collins, and
Christine S. Carty

January 1979

U.S. DEPARTMENT OF COMMERCE
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Richard A. Frank, Administrator
Terry L. Leitzell, Assistant Administrator for Fisheries
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Expendable Bathythermograph Observations From the NMFS/MARAD Ship of Opportunity Program for 1975

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ABSTRACT

This report is designed to show the results of the fifth year of operation of the NMFS/MARAD Ship of Opportunity Program (SOOP). The data are presented in the form of vertical distributions of temperature and horizontal distributions of sea surface temperture and salinity. Operational and data management procedures are discussed, and a descriptive analysis of the most dynamic transects showing the Yucatan, Loop, Florida, and Gulf Stream current systems is presented. The annual development and subsequent degradation of the cold cell off the Middle Atlantic Bight is also 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. The objective of the 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 various ships as relatively inexpensive platforms for the collection of data.

Annual reports encompassing the calendar year SOOP efforts have been published for 1971 through 1974 (Cook 1973, 1975, 1976; Cook and Hausknecht 1977). With the completion of this 1975 SOOP report the National Oceanographic Data Center (NODC) will publish all future SOOP data, beginning with January 1976, as a Data Availability Notice. The Data Availability Notice will show the monthly transect location of all SOOP runs along with an NODC access number that will allow interested users easier access to the SOOP data.

The program, conducted in support of the Marine Resources Monitoring Assessment and Prediction Program (MARMAP) of 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. Since 1970 the SOOP program has expanded to include U.S. Coast Guard cutters and university research vessels in addition to regular merchant ships.

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.

METHODS

The SOOP effort for 1975 consisted of a total of 65 cruises: 20 merchant vessels sailing from New York, 15 merchant vessels from New Orleans, 19 Coast Guard cruises from various ports, 7 ferryboat cruises across the Gulf of Maine, and 4 cruises utilizing university research vessels. Ninety-eight transects of subsurface temperature observations and associated surface data were obtained. A total of 1,619 XBTs were launched; of these, 1,426 (88%) were considered of sufficient quality to be archived. Approximately 241 XBT drops and associated surface data are not included in this report because the observations were too widely separated in time and space to be formed into useful transects. All data collected were archived by the NODC and are available at the NODC, Washington, DC 20235.

Subsurface temperature data were obtained by use of Sippican XBT systems. At the same time, surface water samples were collected with bucket thermometer units for later analysis to determine salinity. The surface water samples were analyzed on shore using an inductive salinometer calibrated with standard seawater at least once every 30 samples.

The XBT traces were submitted to 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 caused by anomalous XBT observations that could not be supported by other associated data such as sea surface

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temperature or nearby XBT observations. Consequently, a vertical section plot may have one or two missing observations, resulting from the deletion of inaccurate subsurface data.

During 1975 the data collection program was expanded by the addition of the MV *Bluenose*, an "auto/truck" ferry operated by the Canadian National Railway between Bar Harbor, Maine, and Yarmouth, Nova Scotia. Personnel from the NMFS Atlantic Environmental Group or Northeast Fisheries Center made the observations from the MV *Bluenose* on a monthly basis.

For purposes of consistency with this and past reports, all vertical temperature figures have been organized geographically and chronologically (Gulf of Mexico—January through December, Cape Hatteras—January through December, etc.) and included at the end of the report as appendix figures. Consequently, any particular feature being discussed first may not show up as the first figure within the appendix figures. However, at the beginning of each section that discusses a particular feature, we have listed all figures in the order in which they appear.

For this report all figures have been annotated to show: shelf water-slope water front—SSF; north wall of the Gulf Stream—G.S.; anticyclonic warm core eddy—clockwise circles; cold cell—cc; current flow direction: into the page—circled X, out of the page—circled dot.

RESULTS

Gulf of Mexico Transects

Loop Current.—The 20°C isotherm at 125 m depth has been used in the past as an indicator of the position of the left edge looking downstream of the Loop Current (Cook 1976) and was applied again in this report for consistency. Migrations of the Loop Current edge, along SOOP transects that passed through the Yucatan Straits, ranged from lat. 22°40′N to almost lat. 25°N.

In 1975 the Loop Current was crossed on 11 occasions (see Table 1 and App. Figs. 3, 4, 6, 11, 15, 17, and 21 through 25) by SOOP vessels.

In March the Loop Current was crossed twice by the *Delta Sud*. The two crossings of the Loop Current within 1 mo along the same transect provided the means of calculating the translational speed of the southward movement of the edge. The *Delta Sud* (App. Fig. 4) crossed the Loop Current at lat. 24°05′N and long. 86°22′W on 16 March at 0500 h. The *Delta Sud* (App. Fig. 6) again crossed the Loop Current at lat. 22°40′N and long. 86°15′W on 23 March at 2400 h. The excursion of the northern edge of the Loop Current was 80 n.mi. in 187 h, or 10.3 n.mi./day (19.1 km/day).

Table 1.—Crossings of the Loop Current made by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Position (lat., long.)
3	*Delta Sud*	75-02	25	2/9-10	23°06′N, 87°01′W
4	*Delta Sud*	75-03	13-12	3/15-16	24°05′N, 86°22′W
6	*Delta Sud*	75-35	13-14	3/23-24	22°40′N, 86°15′W
11	*Delta Norte*	75-05	27-28	5/17-18	22°34′N, 86°26′W
15	*Delta Sud*	75-09	13	9/6-7	24°07′N, 88°58′W
17	*Delta Sud*	75-09	40-39	9/11	24°13′N, 82°23′W
21	*Delta Sud*	75-10	10	10/18-19	24°56′N, 89°43′W
22	*Sea Land Venture*	75-09	29	10/20	26°06′N, 84°53′W
23	*Delta Norte*	75-09	14	10/24	24°18′N, 84°19′W
24	*Delta Sud*	75-10	22-23	11/23-24	24°00′N, 86°33′W
25	*Delta Sud*	75-12	11-12	12/2-3	24°07′N, 88°52′W

Low salinity surface water.—River runoff along the Gulf Coast forms a plume detectable by low surface salinities. Utilizing 34.5‰ as the cutoff between coastal and oceanic waters, it was possible to monitor the offshore extent of these low salinity plumes which sometimes extended to well beyond the shelf break. Six crossings of low salinity water were detected by SOOP vessels in the Gulf of Mexico in 1975 (see Table 2 and App. Figs. 3, 5, 12, 14, 20, and 23). Note that the surface salinities for the *Delta Norte* 75-09 (App. Fig. 18) should be considered suspect (they are all <34.5‰ while the transect is obviously in an oceanic region). They are included in this report because there is no other evidence to suggest that the values are false.

Table 2.—Low salinity (<34.5‰) coastal water encountered by SOOP vesels in the Gulf of Mexico in 1975.

App. Fig	Ship	Cruise number	Station number	Date	Estimated offshore extent n.mi (km)
3	*Delta Sud*	75-02	1-2	2/9-10	130 (240)
5	*Delta Sud*	75-35	1-2	3/22-23	80 (148)
12	*Delta Sud*	75-07	1-7	7/26-27	180 (334)
14	*Sea Land Venture*	75-08	1-3	8/31-9/1	60 (111)
20	*Sea Land Venture*	75-09	1-5	9/28-29	120 (222)
23	*Delta Norte*	75-09	17-16	10/24	150 (278)

Eddies.—Analysis of the vertical sections contained in this part shows 11 crossings of eddies or meanderlike structures in the Gulf of Mexico by SOOP vessels in 1975 (see Table 3 and App. Figs. 3, 4, 7, 10-12, 14, 15, 20, and

Table 3.—Eddies transected in the Gulf of Mexico by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Diameter n.mi. (km)
3	*Delta Sud*	75-02	14-22	2/9-10	A[1] 175 (324)
4	*Delta Sud*	75-03	18-13	3/15-16	A 215 (398)
7	*Delta Norte*	75-04	8-16	4/6	A 185 (343)
10	*Delta Norte*	75-04	33-27	5/11-12	A 94 (174)
11	*Delta Norte*	75-05	10-22	5/17-18	A 230 (426)
12	*Delta Sud*	75-07	11-17	7/26-27	C[2] 110 (204)
12	*Delta Sud*	75-07	17-21	7/26-27	A 95 (176)
14	*Sea Land Venture*	75-08	17-24	8/31-9/1	C 150 (278)
15	*Delta Sud*	75-09	6-12	9/6-7	A 120 (222)
20	*Sea Land Venture*	75-09	12-17	9/28-29	C 110 (204)
21	*Delta Sud*	75-10	5-8	10/18-19	C 105 (195)

[1]A = anticyclonic.
[2]C = cyclonic.

21). Unfortunately, the lack of areal detail provided from a single XBT transect prevents any conclusions regarding the formation of eddies from Loop Current meanders. However, for purposes of this report, all of these structures will be referred to as eddies. Eddy number 1 (App. Fig. 3) was an anticyclonic eddy crossed on 10 February and was centered along this transect at station 17 (lat. 25°14'N, long. 89°46'W). A sea surface temperature increase of more than 1°C above the surrounding water marked the center of the eddy, but no discernible sea surface salinity change was evident. The vertical expression of the eddy extended below 600 m in depth.

Eddy number 2 (App. Fig. 4) was a weak anticyclonic eddy crossed on 16 March and was apparently centered along this transect at station 14 (lat. 24°46'N, long. 86°54'W). The only change in the surface water was an anomalous decrease in the sea surface temperature. The weak characteristics of this eddy (depth of expression <500 m) suggest that it could have been a frictionally driven eddy on the edge of the Loop Current located just south of station 13.

Eddy number 3 (App. Fig. 7) was an anticyclonic eddy crossed on 6 April and was centered along this transect at station 12 (lat. 25°39'N, long. 90°09'W). The very slight increase in sea surface temperature indicates that the center of the eddy probably was located somewhat farther to the southwest than the subsurface temperature structure indicated. The subsurface vertical temperature structure extended to below 600 m.

Eddy number 4 (App. Fig. 10) was a relatively small anticyclonic eddy crossed on 11 May and was centered along this transect at station 30 (lat. 27°32'N, long. 88°38'W). A slight rise in sea surface temperature, as shown in the surface parameter plot, indicates the eddy influence reached the surface. The bending of the isotherms was detectable below 750 m.

Eddy number 5 (App. Fig. 11) was a large anticyclonic eddy crossed on 18 May and was centered along this transect at station 17 (lat. 24°57'N, long. 89°19'W). Only a gradual increase in sea surface temperature, peaking in the vicinity of the Loop Current at station 27, gave any surface indication of the eddy location. Monitoring or tracking of this eddy would have been difficult without the subsurface information provided by the XBT transect.

Eddies number 6 and 7 (App. Fig. 12) were crossed on 27 July and were centered along this transect at station 13 (lat. 26°33'N, long. 91°00'W) and 18 (lat. 25°37'N, long. 89°48'W), respectively. Eddy number 6, because of its less distinct structure and weaker appearance, may have been a frictionally driven eddy being forced by eddy number 7, but this was only speculation. Eddy number 7, an anticyclonic eddy, appeared much stronger (vertical temperature structure extending to > 700 m) than eddy 6.

Eddy number 8 (App. Fig. 14) was a cyclonic eddy crossed on 1 September and was centered along this transect at station 20 (lat. 26°00'N, long. 87°23'W). Very little surface expression in both temperature and salinity showed up on the surface parameter plot. It appeared that intense stratification masked the eddy structure. The subsurface eddy structure began to show in the temperature field at a depth of about 100 m and extended to more than 600 m.

Eddy number 9 (App. Fig. 15) was a weak anticyclonic structure crossed on 6 September and was centered along this transect at station 8 (lat. 25°22'N, long. 90°17'W). No discernible change in sea surface temperature was noticed possibly because of the stratification overlying the eddy structure. Even though the eddy structure was not very dynamic, it was still possible to see the bending of isotherms to below 600 m.

Eddy number 10 (App. Fig. 20) was a cyclonic eddy crossed on 28 September and was centered along this transect at station 15 (lat. 26°41'N, long. 89°12'W). A decrease in the sea surface temperature between stations 12 and 17 indicated that this cold core eddy influenced the surface waters as well as the subsurface water. The vertical extent of this eddy reached > 600 m.

Eddy number 11 (App. Fig. 21) was a cyclonic eddy crossed on 19 October and was centered along this transect at station 7 (lat. 25°51'N, long. 90°36'W). A slight decrease in surface salinity on the southeast edge (station 8) of the eddy was the only surface expression of the eddy's presence. The vertical temperature structure extended to > 700 m. There was no significant change in sea surface temperature in the presence of the eddy.

Cape Hatteras Transects

Gulf Stream.—Gulf Stream crossings were identified by the strong seaward dipping isotherms shown in the vertical temperature sections, and positions of the north wall were determined by using the 15°C isotherm at 200-m depth (Worthington 1964).

In 1975 the Gulf Stream was crossed on 13 occasions (see Table 4 and App. Figs. 27, 29, 31, 33-37, 39-42, and 45) by SOOP vessels in the Cape Hatteras area.

Table 4.—Gulf Stream crossings in the Cape Hatteras area by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Position (lat., long.)
27	*Santo Cruz*	75-01	4-3	1/4	35°08'N, 74°52'W
29	USCGC *Ingham*	75-03	15-14/ 3-2	3/26-27	31°36'N, 71°10'W/ 36°21'N, 72°49'W
31	*Santa Cruz*	75-04	5-6	4/9-10	31°39'N, 78°42'W
33	USCGC *Chase*	75-06	8-9	6/15	36°21'N, 73°40'W
34	USCGC *Chase*	75-65	14-13	6/16	36°21'N, 73°26'W
35	*Trident*	75-07	16	6/24-25	37°56'N, 69°53'W
36	*Mormac Argo*	75-09	10-9	9/8-9	37°07'N, 69°50'W
37	USCGC *Taney*	75-09	4-5/11	9/11-12	36°24'N, 73°17'W/ 36°41'N, 71°30'W
39	*Santo Cruz*	75-09	3-4	9/24-25	33°04'N, 77°27'W
40	USCGC *Ingham*	75-10	5/11	10/2-3	36°19'N, 72°58'W/ 36°58'N, 71°29'W
41	*Santa Cruz*	75-10	2-3	10/29-30	32°10'N, 79°14'W
42	*Mormac Argo*	75-10	9-10	10/31-11/1	36°22'N, 68°21'W
45	*Santa Cruz*	75-12	13-12	12/7	35°41'N, 74°26'W

Comparisons between the SOOP transects, *Gulfstream* monthly summaries (National Weather Service 1975), Experimental Gulf Stream Analysis (N-69) charts (National Environmental Satellite Service 1975), and NAVOCEANO Experimental Ocean Frontal Analysis Charts (U.S. Naval Oceanographic Office 1975) provided a good check on the many fluctuations in the Gulf Stream position.

The XBT transects and the satellite data complement each other in that the XBT data provided the needed ground truth to verify the satellite data, and the satellite data provided the necessary surface synopticity for such a large monitoring program. In addition, the XBT data provided another dimension to the monitoring network in the form of subsurface data. The subsurface data provided the means for monitoring subsurface features such as the "cold cell," the depth of anticyclonic eddies that impinged upon the continental slope and shelf, and the bottom temperatures on the continental shelf that affect many of the commercial finfish and shellfish species.

On 15 June the *Chase* (App. Fig. 33) crossed the Gulf Stream between stations 8 and 9 at about lat. 36°21'N, long. 73°40'W. As usual an increase in the sea surface temperature was noted. An unusual subsurface feature should be noted with this figure. A "bubble" or intrusion of colder water (<8°C) appeared along the edge or north wall of the Gulf Stream at about 100-m depth. This could have been an example of the "calving" process mentioned by Whitcomb (1970) where parcels of the cold cell on the continental shelf appear to break off and detach from the main body of the cold cell and flow seaward off the continental shelf.

In this area around Cape Hatteras three different water masses, shelf, slope, and Gulf Stream water, meet and mix (Fisher 1972). The shelf water mixes directly with Gulf Stream water and in the process pinches out the slope water. One possibility was that the Gulf Stream had moved closer to shore and impinged upon the shelf water mass where the cold cell had formed, and in turn, torn loose a piece of the cold cell and had dragged this cold parcel along the north wall of the Gulf Stream with some colder water reaching the surface. The cold filament mentioned by Fisher (1972) suggests that this could be the mechanism at work here.

Shoreward movement in this area of < 30 n.mi. (55.6 km) by the north wall of the Gulf Stream would be enough for the Stream influence to act upon the shelf water and cold cell. Comparing this XBT transect (App. Fig. 33) with the next (App. Fig. 34) obtained the very next day indicates that translational movements of the north wall of over 10 n.mi./day (18.5 km/day) can occur. What we might have detected was the north wall retreating seaward dragging this parcel of cool water behind it. Examination of the NAVOCEANO Experimental Ocean Frontal Analysis Charts for 9, 11, and 16 June support the contention of a shoreward, then seaward, movement in the north wall on the order of about 10 n.mi./day (18.5 km/day).

The sharp decrease in sea surface temperature (App. Fig. 33) at the shelf water-slope water front (station 7) indicates that the cool filament extended from >100-m depth all the way to the surface.

Another crossing of the Gulf Stream occurred along the same transect only 28 h later (App. Fig. 34). The difference in positions of the north wall crossings was 12 n.mi. (22.2 km), indicating translational movement of over 10 n.mi./day (18.5 km/day) which is the same order of magnitude for translational movements estimated in the past for both the Gulf Stream and Loop Current discussed earlier.

On 30 October the *Santa Cruz* (App. Fig. 41) made the second of two Gulf Stream crossings south of Cape Hatteras. The first was shown in Appendix Figure 31. As before, the north wall was so close to the shelf and the scale is so large on these vertical sections that it was difficult to pinpoint the exact position. The crossing of the north wall probably occurred between stations 2 and 3 at about lat. 32°10'N and long. 79°14'W. The transition between shelf water and Gulf Stream water was so abrupt that the surface parameters only indicated a gradual rise rather than a sharp step increase.

The *Mormac Argo* (App. Fig. 42) crossed through an eddy (discussed later) before transecting the Gulf Stream between stations 10 and 11 on 31 October at about lat. 36°22'N and long. 68°21'W. The anticipated increase in surface salinity showed up on the surface parameter plot and a decrease in sea surface temperature was noted at the point of crossing. The decrease in surface temperature could have been a cold filament similar to those discussed by Fisher (1972).

The last Gulf Stream crossing in the Cape Hatteras area in 1975 was obtained by *Santa Cruz* (App. Fig. 45) on 7 December. Again an eddy was transected prior to the crossing, which occurred between stations 12 and 13 at about lat. 35°41'N and long. 74°26'W. On this transect the surface parameter plots of sea surface temperature and surface salinity show an almost "textbook" example of the transitions between shelf water, slope water, eddy water, Gulf Stream water, and Sargasso Sea water.

Cold cell.—The formation, structure, and modification of the cold cell that exists on the Atlantic continental shelf between Cape Hatteras and Cape Cod have been discussed for more than 40 yr since Bigelow (1933) to Beardsley et al. (1976). Other descriptions of the cold cell hav been given by Ketchum and Corwin (1964) and Whitcomb (1970). Less detailed descriptions utilizing only SOOP data have been given by Cook (1976) and Cook and Hausknecht (1977).

So far the concensus appears to be that the cold cell is formed from winter water on the shelf and that the cold cell persists throughout the summer months decreasing in size and extent and increasing in in situ temperature. Some evidence suggests replenishment from the northeast (Beardsley et al. 1976) and that "calving" parcels of the cold cell into deeper slope water may contribute to the exchange of shelf and slope water (Wright 1976).

In 1975 SOOP vessels transected the cold cell in the Cape Hatteras area on seven occasions (see Table 5 and App. Figs. 28, 32 through 34, 36, 39, and 42).

Table 5.—Cold cell crossings in the Cape Hatteras area by SOOP vessels in 1975.

App Fig	Ship	Cruise number	Station number	Date
28	*Santa Cruz*	75-02	4-5	2/19-20
32	*Mormac Argo*	75-03	42-28	5/8-9
33	USCGC *Chase*	75-06	2-7	6/15
34	USCGC *Chase*	75-65	18-16	6/16
36	*Mormac Argo*	75-09	21-17	9/8-9
39	*Santa Cruz*	75-09	2-3	9/24-25
42	*Mormac Argo*	75-10	3-4	10/31-11/1

Some of these SOOP crossings show the winter water that eventually forms the cold cell, some show calving, and some show the cold cell extending off the continental shelf.

In February, the *Santa Cruz* (App. Fig. 28) crossed through winter water of <5°C near the mouth of Chesapeake Bay. This crossing was important because it shows the coldest water crossed by SOOP vessels in the Cape Hatteras area and implies that the cold cell which was formed from this water could not be any colder than that temperature section shows.

In May, the *Mormac Argo* (App. Fig. 32) crossed over a "double bubble" of the cold cell. The more inshore bubble had temperatures lower (<7°C) than that of the offshore bubble (<8°C). Because the transect was nearly parallel to shore, the "double bubble" could be an artifact of the contouring. Lobes have been detected in the shape of the cold cell, and if a transect crossed through two lobes, a "double bubble"-like feature would be indicated. Two transects in June (App. Figs. 33 and 34), both obtained by the USCGC *Chase,* showed the cold cell well developed with strong stratification above and offshore. The 15 June (App. Fig. 33) transect shows a parcel of cooler water that has "calved" off the main cold cell structure up on the shelf.

Just one day later, on 16 June (App. Fig. 34), almost the same transect as on 15 June was repeated and showed the parcel of cooler water that had "calved" off earlier almost totally mixed away.

The close proximity of the north wall of the Gulf Stream to the cold cell and the cold cell parcels warranted a closer look at the satellite imagery in that area for that time period. Examination of the Experimental Ocean Frontal Analysis Charts produced by the Naval Oceanographic Office from 28 May through 16 June of 1975 showed a maximum movement of the north wall 30 n.mi. in 12 days or about 2.5 n.mi./day (4.6 km/day), well within past observations of 10 n.mi./day in the same area. At the same time the Experimental Ocean Frontal Analysis Charts showed a shoreward movement between 28 May and 4 June then seaward movement between 9 and 16 June of the north wall of the Gulf Stream.

As discussed earlier in the Gulf Stream section, the translational velocities of the north wall of the Gulf Stream indicated the possibility that shoreward incursions of the Gulf Stream are large enough in the Cape Hatteras area to act upon the cold cell features on the shelf and possibly pull out parcels of the cold cell.

In summary, we feel that the section obtained on 15 June shows the aftereffects of the shoreward, then seaward, movement of the north wall, where the north wall has acted as the forcing agent in breaking a piece of the cold cell off from the main body and then dragging it seaward as the north wall again moves offshore.

The transects collected in September and October (App. Figs. 36, 39, and 42) show how the cold cell has eroded away throughout the summer. The lowest temperatures in the cold cell were only slightly <9°C in September and slightly <11°C in October.

Shelf water-slope water front.—XBT transects were made across the shelf water-slope water front (SSF) in the Cape Hatteras area on 12 occasions during 1975 (see Table 6 and App. Figs. 27, 28, 30, 34, 36, 37, 41, 42, and 45). Determinations of frontal crossings were made on the basis of subsurface temperature gradients shown on the vertical sections with additional supporting evidence being drawn from sea surface temperature and salinity data.

Table 6.—Self water-slope water front crossings in the Cape Hatteras area by SOOP vessels in 1975.

App Fig.	Ship	Cruise number	Station number	Date	Rate of temperature change across front computed at maximum thermal gradient
27	*Santa Cruz*	75-01	10-8	1/4	1°C/3.3n.mi. (6.1km)
28	*Santa Cruz*	75-02	10-11	2/19-20	1°C/1.8n.mi. (3.3km)
30	*Santa Cruz*	75-02	18-17	3/30-31	1°C/1.3n.mi. (2.4km)
31	*Santa Cruz*	75-04	2-4	4/9-10	1°C/4.2n.mi. (7.8km)
32	*Mormac Argo*	75-03	29-27	5/8-9	1°C/3.9n.mi. (7.2km)
33	USCGC *Chase*	75-06	7-8	6/15	1°C/2.8n.mi. (5.2km)
34	USCGC *Chase*	75-65	15-14	6/16	1°C/1n.mi. (1.9km)
36	*Mormac Argo*	75-09	17-16	9/8-9	1°C/13.8n.mi. (25.6km)
37	USCGC *Taney*	75-09	1-3	9/11-12	1°C/9.3n.mi. (17.2km)
41	*Santa Cruz*	75-10	1-2	10/29-30	1°C/10n.mi. (18.5km)
42	*Mormac Argo*	75-10	3-5	10/31-11/1	1°C/14.3n.mi. (26.5km)
45	*Santa Cruz*	75-12	21-19	12/7	1°C/8.8n.mi. (16.3km)

Because the SSF is so close to shore in the Cape Hatteras area, and many of the transects ran parallel or at highly oblique angles to the front, the position of the front is not as easily detectable as it is in the Middle Atlantic Bight (to be discussed later). However, a few good examples of the front showing how it develops through late winter and spring should be pointed out.

Santa Cruz (App. Figs. 27 and 28) crossed the SSF right at Cape Hatteras where the shelf water, slope water, and Gulf Stream meet. These crossings that occurred in January and February, respectively, show how the thermal structure develops as the coldest months of winter progress. At this time of the year, when the shelf waters were coldest, the interaction and mixing with Gulf Stream waters created a very distinct thermal front. The *Santa Cruz* (App. Fig. 30) again crossed the front just north of Cape Hatteras (between stations 17 and 18) showing a strong temperature gradient near the mixing region of the three water masses.

Two crossings were obtained in September, one by the *Mormac Argo* (App. Fig. 36) and the other by the USCGC *Taney* (App. Fig. 37). At this time of year the thermal gradient was not as strong as earlier and sea surface salinity was the more accurate frontal indicator.

Also in October the *Mormac Argo* (App. Fig. 42) crossed the SSF in the vicinity of an anticyclonic eddy. The thermal structure of the front was effectively masked by the presence of the eddy and the sea surface salinity values were essential for locating the front.

In December the *Santa Cruz* (App. Fig. 45) crossed the SSF again in the vicinity of an eddy. Although the thermal structure of the front was not as disrupted as in the previous month, it was still necessary to utilize the sea surface salinity as an indicator of the frontal position.

Low salinity surface water.—Utilizing water of <34.5‰ as the boundary between coastal or shelf water and the more oceanic water or slope water, it was possible to monitor positions of the SSF when thermal gradients were mixed or confused. When surface or subsurface temperature data were not available, the 34.5‰ isohaline was used to determine the SSF with confidence. Often when satellite imagery was poor or nonexistent and when temperature stratification was strong, the surface salinity data was the only reliable data available for determination of the shelf water-slope water boundary.

In 1975 SOOP vessels transected coastal water of <34.5‰ in the Cape Hatteras area on 12 occasions (see Table 7 and App. Figs. 27, 28, 30-32, 34, 36, 37, 41, 42, 45, and 46). The data were used independently and sometimes in conjunction with sea surface temperature data to determine the exact position of the SSF.

Eddies.—These XBT sections include only three crossings of Gulf Stream eddies in the Cape Hatteras area during 1975 (see Table 8 and App. Figs. 39, 42, and 45). Eddy number 1 (App. Fig. 39) was an anticyclonic eddy crossed by the *Santa Cruz* on 24 September and was centered along this transect at station 11 (lat. 30°50'N, long. 75°36'W). There was little, if any, surface expression reflected in the surface parameter plot (App. Fig. 39) and most of the temperature structure was found beginning about 100 m and becoming stronger at 300 m and below.

Table 7.—Low salinity (<34.5‰) coastal water encountered by SOOP vessels in the Cape Hatteras area in 1975.

App. Fig	Ship	Cruise number	Station number	Date	Estimated offshore extent n.mi. (km)
27	*Santa Cruz*	75-01	15-12	1/4	55 (102)
28	*Santa Cruz*	75-02	4-10	2/19-20	50 (93)
30	*Santa Cruz*	75-02	31-22	3/30-31	60 (111)
31	*Santa Cruz*	75-04	1-2	4/9-10	20 (37)
32	*Mormac Argo*	75-03	42-28	5/8-9	50 (93)
34	USCGC *Chase*	75-65	18-15	6/16	150 (278)
36	*Mormac Argo*	75-09	21-16	9/8-9	120 (222)
37	USCGC *Taney*	75-09	1-2	9/11-12	80 (148)
41	*Santa Cruz*	75-10	1-2	10/29-30	40 (74)
42	*Mormac Argo*	75-10	1-5	10/31-11/1	250 (463)
45	*Santa Cruz*	75-12	22-20	12/7	60 (111)
46	USCGC *Taney*	75-12	1-2	12/27	80 (148)

Comparison with the September 1975 issue of *Gulfstream* indicated agreement in location with an anticyclonic eddy shown on 10 September.

Eddy number 2 (App. Fig. 42) was an anticyclonic eddy crossed by the *Mormac Argo* on 31 October and was centered along this transect at station 5 (lat. 37°35'N, long. 69°55'W). There was a definite increase in sea surface temperature and salinity over the center of the eddy providing a good signal for satellite imagery. Comparison of this transect with the November 1975 issue of *Gulfstream* and with the Experimental Ocean Frontal Analysis Chart for 29 October-1 November 1975 did show good agreement in both the location and areal extent of the eddy.

Eddy number 3 (App. Fig. 45) was a cyclonic eddy crossed by the *Santa Cruz* on 7 December and was centered along this transect at station 16 (lat. 36°26'N, long. 74°18'W). There was definite surface expression in both temperature and salinity which peaked within the eddy. The decrease in sea surface temperature and salinity on the southern side of the eddy indicated the possible entrainment of shelf water along its northern and eastern edges. Comparisons made with the Experimental Ocean Frontal Analysis Chart (10-24 December 1975) produced by the Naval Oceanographic Office agreed well in position and with the possible

Table 8.—Eddies transected in the Cape Hatteras area by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Diameter n.mi (km)
39	*Santa Cruz*	75-09	9-13	9/24-25	C[1] 90 (167)
42	*Mormac Argo*	75-10	4-7	10/31-11/1	A[2] 115 (213)
45	*Santa Cruz*	75-12	18-13	12/7	A 50 (93)

[1]C = cyclonic.

[2]A = anticyclonic.

entrainment of shelf water by the eddy. Also, comparison of this XBT transect with the Experimental Gulf Stream Analysis N-69 for 4-6 December 1975 produced by the NESS from data obtained from the NOAA-4 satellite thermal infrared VHRR showed good agreement with regard to position and shelf water entrainment.

Middle Atlantic Bight Transects

The Gulf Stream crossings were determined in the same manner as discussed earlier in the Cape Hatteras section, that is, the north wall is located where the 15°C isotherm is encountered at 200 m. This location is usually reflected also by increases in surface temperature and salinity. Also the same comparisons between satellite data and XBT data were made as previously discussed.

Gulf Stream.—In 1975 the Gulf Stream was crossed on 13 occasions (see Table 9 and App. Figs. 47, 49, 51, 52, 58 through 64, 66, and 67) by SOOP vessels in the Middle Atlantic Bight.

Table 9.—Gulf Stream crossings in the Middle Atlantic Bight by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Position (lat., long.)
47	*Mormac Argo*	75-03	9-10	3/21-22	37°41'N, 70°19'W
49	*Export Defender*	75-04	10-11	4/27	37°45'N, 67°37'W
51	*Mormac Rigel*	75-05	11-10	5/21-22	38°00'N, 70°58'W
52	*Trident*	75-06	9-10	6/9-11	37°42'N, 69°09'W
58	*Mormac Rigel*	75-08	9	8/16-17	37°28'N, 70°29'W
59	*Mormac Argo*	75-99	14-15	9/20-21	37°20'N, 69°32'W
60	*Export Defender*	75-08	16-15	10/1-2	38°21'N, 67°03'W
61	*Mormac Rigel*	75-10	11-12	10/11-12	37°21'N, 70°25'W
62	*Export Defender*	75-10	15-16	10/17-18	37°42'N, 68°19'W
63	*Santa Cruz*	75-09	31-30	10/19-20	35°26'N, 74°43'W
64	*Mormac Argo*	75-99	30-29	10/22-23	37°50'N, 70°27'W
66	*Trident*	75-12	6-5	12/9-10	38°02'N, 68°30'W
67	*Export Defender*	75-10	32-31	12/11-12	37°02'N, 71°22'W

Cold Cell.—The importance of the formation, structure, and modification of the cold cell was discussed earlier in the Cape Hatteras section and will not be repeated here.

In 1975 there were 15 crossings of the cold cell in the Middle Atlantic Bight by SOOP vessels (see Table 10 and App. Figs. 47, 49, 51 through 56, and 58 through 64). Some of these transects were of crossings of winter water and not the cold cell feature, but were included in the cold cell section because of the importance of the winter water to the minimum temperature of the cold cell.

For purposes of discussion, nine of these observations that have occurred in the same geographic area have been grouped into one transect. This track has been designated the MORMAC transect because it is the track used by Moore McCormack Line ships and closely follows a line between New York and Bermuda (Fig. 1).

Figure 1 summarizes the changes in depth and temperature that occur in the cold cell throughout the year. The cold cell ranged in depth from a minimum of 40 m to a maximum of 90 m and randomly expanded and contracted its extent over the bottom.

Table 10.—Cold cell crossings in the Middle Atlantic Bight area by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date
47	*Mormac Argo*	75-03	1-6	3/21-22
49	*Export Defender*	75-04	1	4/27
51	*Mormac Rigel*	75-05	20-16	5/21-22
52	*Trident*	75-06	30-24	6/9-11
53	*Export Defender*	75-04	24-20	6/17
54	*Trident*	75-07	3-12	6/22-23
55	*Lash Atlantico*	75-07	2-13	7/7-8
56	*Trident*	75-07	36-33	7/11
58	*Mormac Rigel*	75-08	1-4	8/16-17
59	*Mormac Argo*	75-99	1-7	9/20-21
60	*Export Defender*	75-08	28-26	10/1-2
61	*Mormac Rigel*	75-10	1-4	10/11-12
62	*Export Defender*	75-10	2-4	10/17-18
63	*Santa Cruz*	75-09	43-38	10/19-20
64	*Mormac Argo*	75-99	40-38	10/22-23

The cold cell consistently warmed throughout the spring, summer, and into early fall when the fall overturn again began to cool the water column.

The random movement of the cold cell across the bottom could be the aftereffect of calving or the interaction with the SSF which, in turn, was responding to Gulf Stream eddies that may have been passing through the slope water adjacent to the MORMAC transect.

In March (App. Fig. 47) the winter water was <6°C between stations 1 and 6 while up on the continental shelf.

In April (App. Fig. 49) the water was well mixed with temperatures <7°C on the shoreward end of the transect. The cell structure was only beginning to form at this time of the year and was evident with the slight stratification of the isotherms in the near-surface water.

In May (App. Fig. 51) the cold cell was well developed. Temperatures at the bottom were still <6°C for the most part. The cell structure was on the continental shelf with a slight extension seaward over the shelf break.

There were three crossings of the cold cell in June (App. Figs. 52, 53, and 54). The first occurred 11 June and showed a well-developed cold cell with minimum temperatures slightly <7°C. The cold cell was well defined because of the strong stratification above and seaward of the cell. The second crossing occurred on 17 June at a more oblique angle to the cell structure, hence the exaggerated cell-like structure in Appendix Figure 53. At this time, the minimum temperature was still slightly <7°C, but there was an increase in temperature at the bottom between stations 22 and 23 which might be accounted for by an intrusion of warmer water from the shoreward side of the cell structure or just the angle at which the cell was transected, possibly along a lobe or meander of the cell. The third crossing occurred on 22 June and was a much more detailed transect. In this transect the entire cell structure has not been transected, but rather only the main core of the cold cell containing the minimum temperature. In this transect, as with the

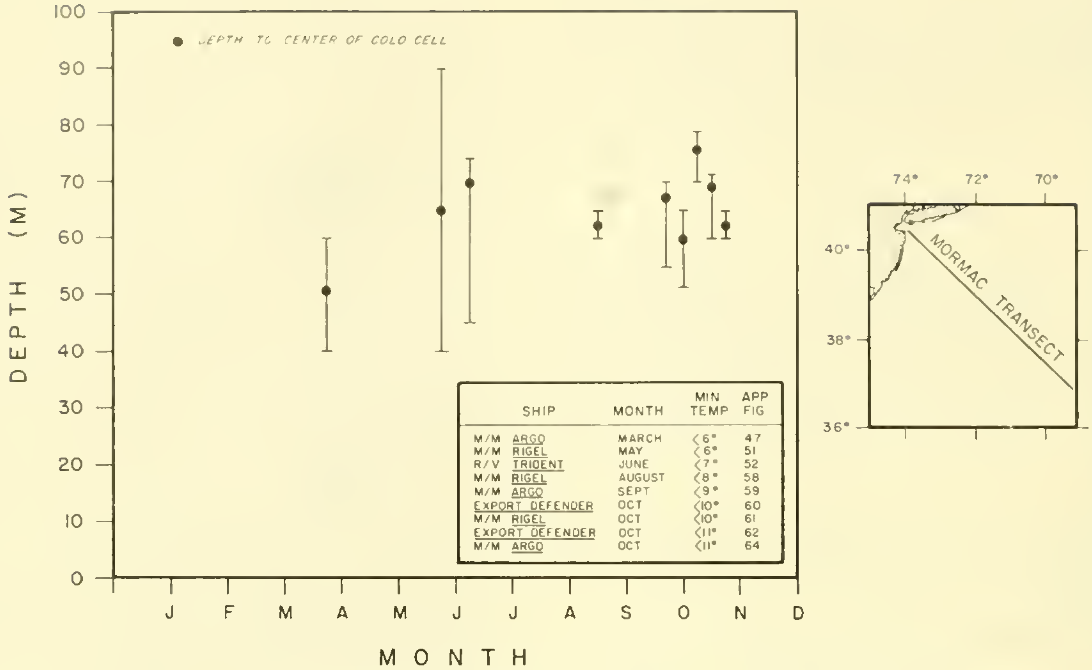

Figure 1.—Variations in cold cell temperature and depth along the MORMAC Transect.

other June transects, the minimum temperatures were slightly <7°C.

In July (App. Fig. 55) the cold cell was well developed and crossed at a nearly perpendicular angle. At this time the cell once again had a "double bubble" shape with the shoreward cell cooler (<8°C) than the seaward cell (<10°C). The cell structure was not as well developed as in May and June suggesting the cell has been eroded away, primarily from the seaward side by slope water as indicated by the warmer cell temperatures there. At this time the minimum temperatures within the cold cell were <8°C. Another crossing later in July by the *Trident* (App. Fig. 56) showed the minimum temperature to have increased to slightly <9°C.

In August (App. Fig. 58) the cell structure extended off the continental shelf break out into deeper water suggesting the possibility of the beginning of the "calving" process. The minimum temperatures within the cell were still slightly <9°C.

In September (App. Fig. 59) the cell structure again extended off the continental shelf into deeper water.

There were five crossings of the cold cell in October (App. Figs. 60 through 64). All transects showed how the cold cell had eroded away. The cell structure was weak at best and all transects showed the minimum cell temperature to be slightly <11°C. The most southern transect (*Santa Cruz* 75-09, App. Fig. 63) showed the minimum temperature in the cold cell to be slightly <9°C. This is consistent with past observations of the cold cell that showed minimum temperatures exist in the New York Bight Apex and just off the New Jersey Coast (Colton and Stoddard 1973).

Shelf water-slope water front.—SOOP transects crossed the SSF in the Middle Atlantic Bight on 20 occasions during 1975 (see Table 11 and App. Figs. 47 through 53, 55, and 59 through 68).

Determinations of frontal crossings were made, as previously discussed, on the basis of subsurface horizontal temperature gradients shown on the vertical sections with additional supporting evidence being drawn from sea surface temperature and salinity data. To provide a means of verification of the position of the front as determined from SOOP sections, comparisons were made when possible with the *Gulfstream* monthly summary (National Weather Service 1975), the NAVOCEANO Experimental Ocean Frontal Analysis Charts (U.S. Naval Oceanographic Office 1975), and the NESS Experimental Gulf Stream Analysis (N-69) charts (National Environmental Satellite Service 1975).

In general the frontal positions determined from the SOOP transects agreed within ±15 n.mi. (27.8 km) (usually much closer) with the various satellite data sources.

In March (App. Fig. 47) the front was crossed between stations 6 and 8. At this time the remnant winter water of <6°C was still in evidence.

There were three crossings of the SSF in April (App. Figs. 48, 49, and 50). The 3-5 April crossing (App. Fig. 48) showed the SSF extending well seaward of the 100-m depth contour usually associated with the front. Contrasting with this, the 28-29 April crossing (App. Fig. 50) showed the SSF back up on the continental shelf near the 100-m contour. Also with this transect was the eddy feature located between stations 25 and 28 (found in Bisagni 1976).

Table 11.—Shelf water-slope water front crossings in the Middle Atlantic Bight by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Rate of temperature change across front
47	*Mormac Argo*	75-03	6-8	3/21-22	1°C/12n.mi. (22.2km)
48	USCGC *Evergreen*	75-04	13-15	4/3-5	1°C/3.3n.mi. (6.1km)
49	*Export Defender*	75-04	1-2	4/27	1°C/18n.mi. (33.4km)
50	USCGC *Evergreen*	75-04	28-27	4/28-29	1°C/2.5n.mi. (4.6km)
51	*Mormac Rigel*	75-05	17-16/ 15-14	5/21-22	1°C/6.7n.mi. (12.4km)
52	*Trident*	75-06	24-23	6/9-11	1°C/4n.mi. (7.4km)
53	*Export Defender*	75-04	21-20/ 19-18	6/17	1°C/2.1n.mi. (3.9km)
55	*Lash Atlantico*	75-07	14-18	7/7-8	1°C/11.4n.mi. (21.1km)
59	*Mormac Argo*	75-99	7-10	9/20-21	1°C/12n.mi. (22.2km)
60	*Export Defender*	75-08	23-22	10/1-2	1°C/15n.mi. (27.8km)
61	*Mormac Rigel*	75-10	4-8	10/11-12	1°C/18n.mi. (33.4km)
62	*Export Defender*	75-10	5-6	10/17-18	1°C/9n.mi. (16.7km)
63	*Santa Cruz*	75-09	38-35	10/19-20	1°C/12.5n.mi. (23.2km)
64	*Mormac Argo*	75-99	37-36	10/22-23	1°C/10.7n.mi. (19.8km)
65	USCGC *Bibb*	75-12	1-3	12/5	1°C/4n.mi. (7.4km)
66	*Trident*	75-12	25-19	12/9-10	1°C/5.7n.mi. (10.6km)
67	*Export Defender*	75-10	38-37	12/11-12	1°C/9n.mi. (16.7km)
68	USCGC *Bibb*	75-12	20-19	12/27-28	1°C/3.5n.mi. (6.5km)

The April crossing (App. Fig. 49) was masked by the low sea surface temperatures and salinities. The vertical structure of the water column near the 100-m isobath was probably an artifact of contouring due to the large station separation between stations 1 and 2.

In May (App. Fig. 51) the SSF appeared separated. There was a strong surface gradient between stations 14 and 15 associated with low salinities and cooler water, but also between stations 16 and 17 there was a frontal structure near the 100-m isobath which is more usually associated with the SSF. The subsurface frontal structure was a good example of the early shape and extent of the cold cell.

In June (App. Fig. 52) the SSF crossing was reflected in a steep increase in both sea surface temperature and salinity. Once again a strong surface expression of the front was overlying a strong subsurface front and cold cell.

In June (App. Fig. 52) the SSF appeared at two different positions (between stations 18 and 19 and again between 20 and 21). This double crossing of the front probably reflected a small meander in the front.

In July (App. Fig. 55) the SSF surface temperature expression was weak, as is expected in the summer, and the front was better reflected in the subsurface temperature structure surrounding the cold cell.

In October (App. Fig. 62) the SSF was considerably stronger (1°C/9 n.mi. (16.7 km)) than the earlier crossing in October, probably because of increased surface cooling of the shelf waters.

The final October crossing of the SSF (App. Fig. 64) again showed the front was weak, but was detected by the steep increase in surface salinity and the large increase in sea surface temperature.

On 5 December (App. Fig. 65) the front had increased in strength (1°C/4 n.mi. (7.4 km)) and also was easily discernible from the large increase in both sea surface temperature and salinity.

On 10 December (App. Fig. 66) the SSF was still strong (1°C/5.7 n.mi. (10.6 km)) and easily evident from the sea surface temperature and salinity plots.

On 12 December (App. Fig. 67) the SSF temperature structure was not as strong as previous crossings and the front was more easily determined by the strong salinity gradient.

The final December crossing of the SSF was made on 28 December (App. Fig. 68). The front was particularly strong (1°C/3.5 n.mi. (6.5 km)) and was readily discernible by the large increase in sea surface temperature and salinity.

Low salinity surface water.—As previously discussed in the Cape Hatteras section, the utilization of the 34.5‰ surface isohaline as the salinity boundary of the shelf water-slope water has worked well in the past, corresponding closely with the temperature increase usually associated with the slope water.

In 1975 SOOP vessels transected coastal water of <34.5‰ in the Middle Atlantic Bight on 19 occasions (see Table 12 and App. Figs. 47 through 57, 59, and 62 through 68). The data were used in conjunction with sea surface temperature data and sometimes independently to determine the exact position of the SSF.

Eddies.—Analysis of the vertical sections contained in this section show five crossings of Gulf Stream eddies within the Middle Atlantic Bight during 1975 (see Table 13 and App. Figs. 52, 60 through 62, and 64). Unfortunately the five crossings were of only two different eddies. Eddy number 1 (App. Fig. 52) was an anticyclonic eddy crossed on 10 June and was centered along this transect between stations 16 and 17 (lat. 39°01'N, long.

Table 12.—Low salinity (<31.5‰) coastal water encountered by SOOP vessels in the Middle Atlantic Bight in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Estimated offshore extent n.mi. (km)
47	*Mormac Argo*	75-03	1-6	3/21-22	100 (185)
48	USCGC *Evergreen*	75-04	1-14	4/3-5	160 (296)
49	*Export Defender*	75-04	1-2	4/27	120 (222)
50	USCGC *Evergreen*	75-04	43-28	4/28-29	175 (324)
51	*Mormac Rigel*	75-05	20-15	5/21-22	120 (222)
52	*Trident*	75-06	30-23	6/9-11	60 (111)
53	*Export Defender*	75-04	24-19	6/17	160 (296)
54	*Trident*	75-07	1-12	6/22-23	
55	*Lash Atlantico*	75-07	1-16	7/7-8	330 (611)
56	*Trident*	75-07	37-33	7/11	
57	*Lash Atlantico*	75-07	40-33	8/8-9	200 (370)
59	*Mormac Argo*	75-99	1-10	9/20-21	170 (315)
62	*Export Defender*	75-10	1-5	10/17-18	105 (195)
63	*Santa Cruz*	75-09	46-35	10/19-20	90 (167)
64	*Mormac Argo*	75-99	42-37	10/22-23	110 (204)
65	USCGC *Bibb*	75-12	1-2	12/5	90 (167)
66	*Trident*	75-12	29-22	12/9-10	90 (167)
67	*Export Defender*	75-10	44-38	12/11-12	105 (195)
68	USCGC *Bibb*	75-12	21-20	12/27-28	90 (167)

Table 13.—Eddies transected in the Middle Atlantic Bight by SOOP vessels in 1975.

App. Fig.	Ship	Cruise number	Station number	Date	Diameter n.mi. (km)
52	*Trident*	75-06	19-14	6/9-11	A[1] 65 (120)
60	*Export Defender*	75-08	22-20	10/1-2	A 80 (148)
61	*Mormac Rigel*	75-10	5-9	10/11-12	A 85 (158)
62	*Export Defender*	75-10	6-9	10/17-18	A 45 (83)
64	*Mormac Argo*	75-99	35-32	10/22-23	A 65 (120)

[1]A = anticyclonic.

70°22'W). The surface expression of this eddy showed as a peak in the sea surface salinity and a steep increase in the sea surface temperature.

This eddy was discussed in detail in the June issue of *Gulfstream* and comparisons made between this XBT transect, the *Gulfstream*, and with the Experimental Ocean Frontal Analysis Chart (18 June 1975) showed quite good agreement in both position and areal extent.

Eddy crossings two through five (App. Figs. 60 through 62 and 64) were all the same anticyclonic eddy. Two of the crossings (App. Figs. 60 and 61) were on the edge of the eddy and two of the crossings (App. Figs. 62 and 64) were closer to the center. From the two crossings that were near the center of the eddy, an estimate of the translational speed of the eddy was possible. The *Export Defender* (App. Fig. 62) crossed the eddy on 18 October and was centered along this transect between stations 7 and 8 (lat. 38°57'N, long. 71°03'W). The *Mormac Argo* (App. Fig. 64) crossed the eddy on 22 October and was centered between stations 33 and 34 (lat. 38°36'N, long. 71°21'W). The distance between the two estimated center points was 25 n.mi. and the time difference was 109 h (Fig. 2). The calculated translational speed was 5.5 n.mi./day (10.2 km/day) which is somewhat higher than

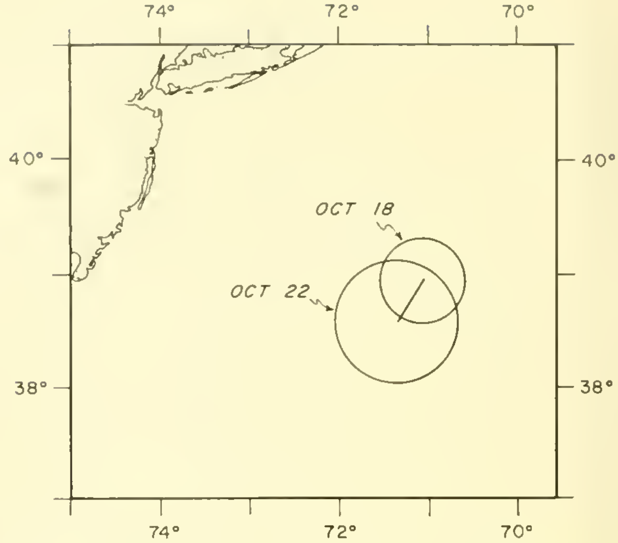

Figure 2.—Distance between the estimated center points of an anticyclonic eddy crossed in October 1975.

other translational speed measurements of the same eddy (Bisagni 1976).

Gulf of Maine Transects

Beginning in June, we began making monthly XBT transects across the Gulf of Maine utilizing the Canadian National Railway Ferry MV *Bluenose*. These transects, in conjunction with other opportunistic Coast Guard transects, are employed in the monitoring of the seasonal variations of temperature in the Gulf of Maine. This program is expected to continue into 1976 and 1977 to determine if the Gulf of Maine continues its warming trend (Chamberlin et al. 1978).

Brief analyses of these monthly transects were distributed to fishermen and scientists in both the United States and Canada, and copies are available from the Northeast Fisheries Center at Woods Hole, Mass. A more detailed analysis of these transects exists in Chamberlin et al. (1978).

Features and conditions looked for in the Gulf of Maine were slope water and Scotian shelf water influence and general circulation. Slope water is usually identified by the 9°C isotherm at 200-m depth (Worthington 1964). The warmer water that exists in the deeper basins of the Gulf of Maine, especially in the winter months, could be attributed to intrusions of slope water through the northeast channel.

Although some transects showed 9°C or warmer water at depth (App. Figs. 76, 79 through 82), without supporting subsurface salinity data, verification that this is due to intrusion of slope water into the Gulf of Maine is impossible.

One transect (App. Fig. 76) in particular was rather striking. In July the USCGC *Evergreen* transected 11°C water at depth, north of Georges Bank. This 11°C water was closely associated with the northeast channel and even without supporting subsurface salinity data was assumed to be a slope water intrusion into the Gulf of Maine.

Directly above the warm water intrusion was a strong thermal front extending to >50-m depth and indicating a flow out of the Gulf. Another thermal gradient existed between stations 1 and 4 indicating a flow into the Gulf from off the Scotian shelf, which is consistent with past observations (McLellan 1954), and is considered to be a mixture of St. Lawrence, Scotian shelf water, and surface slope water. The minimum temperature observed along this transect (App. Fig. 76) was <4°C and occurred as an intrusion at depth and can be attributed to Scotian shelf water influence. Earlier in the year the Scotian shelf water influence was much more evident (App. Fig. 74). A tongue of 2°C water at about 50-m depth extended the whole length of the transect as far south as lat. 42°27'N and long. 65°49'W. At the most northern end of the transect (lat. 43°24'N, long. 64°06'W), 1°C water was also becoming evident.

ACKNOWLEDGMENTS

Appreciation is extended to the Maritime Academy Training representatives T. Hannigan and A. Findley in New York, N.Y., and L. Heroy 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 is extended to H. O. Travis and the National Maritime Research Center for their continuing support of the SOOP effort. In addition, thanks are extended to the Moore McCormack Lines, American Export 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 Service Branch, Commander Atlantic Area, U.S. Coast Guard, for making possible the utilization of the many Coast Guard ships in support of the SOOP program.

Because this is the last of these SOOP reports to be published by NMFS, it is appropriate to acknowledge all the people involved with preparation of this and past SOOP reports. Appreciation for the many typings of the many manuscripts is given to Gertrude Kavanagh, Jennie Dunnington, Judy Cichy, Lynn Howell, and Susan Burkhardt. Deep and imbuing gratitude to Lianne Armstrong for her many hours of layout and drafting services patiently provided over the years. Approbation is also given to Reed Armstrong for his assistance and detailed examination of many of the Gulf of Mexico transects.

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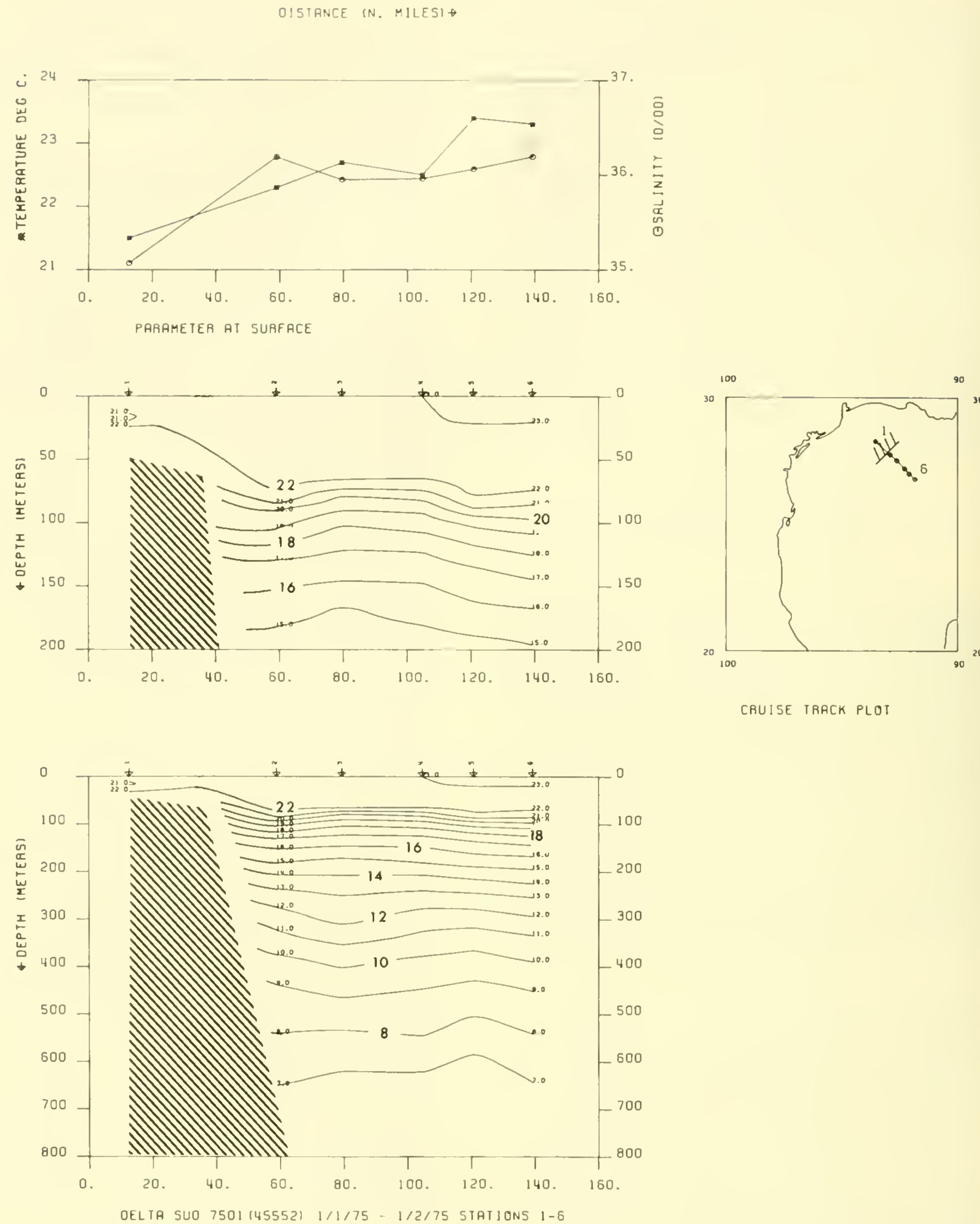
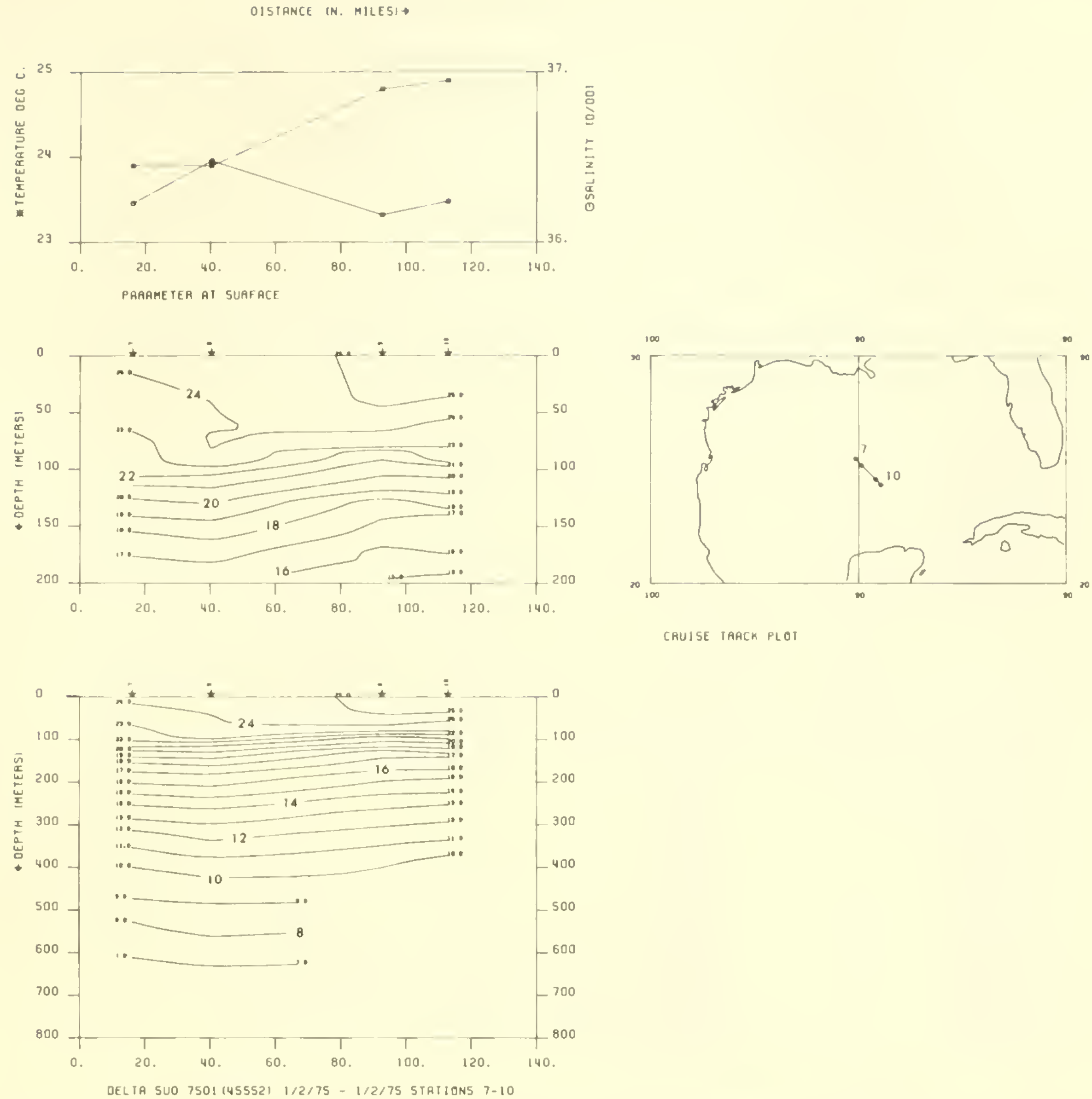
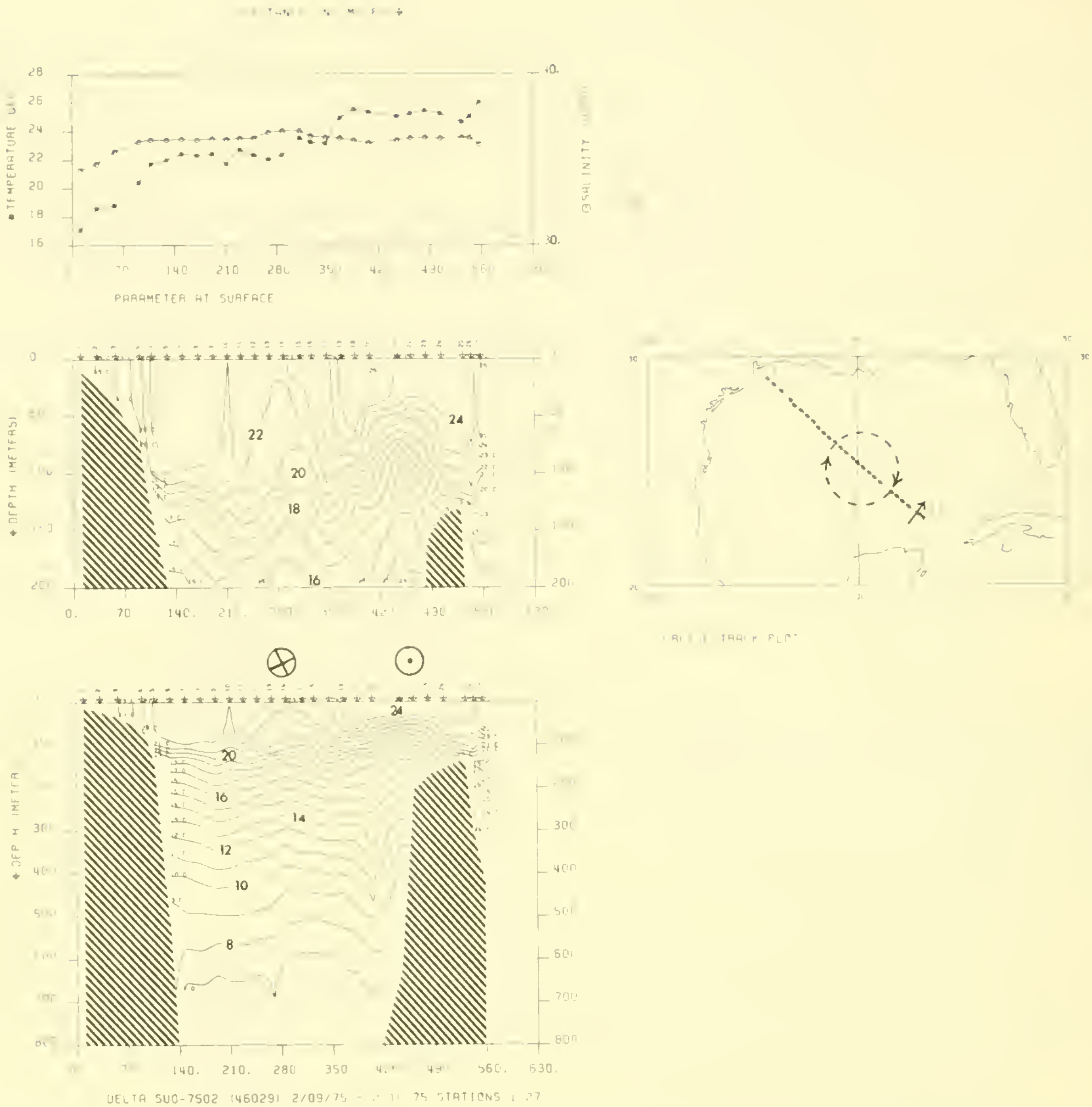


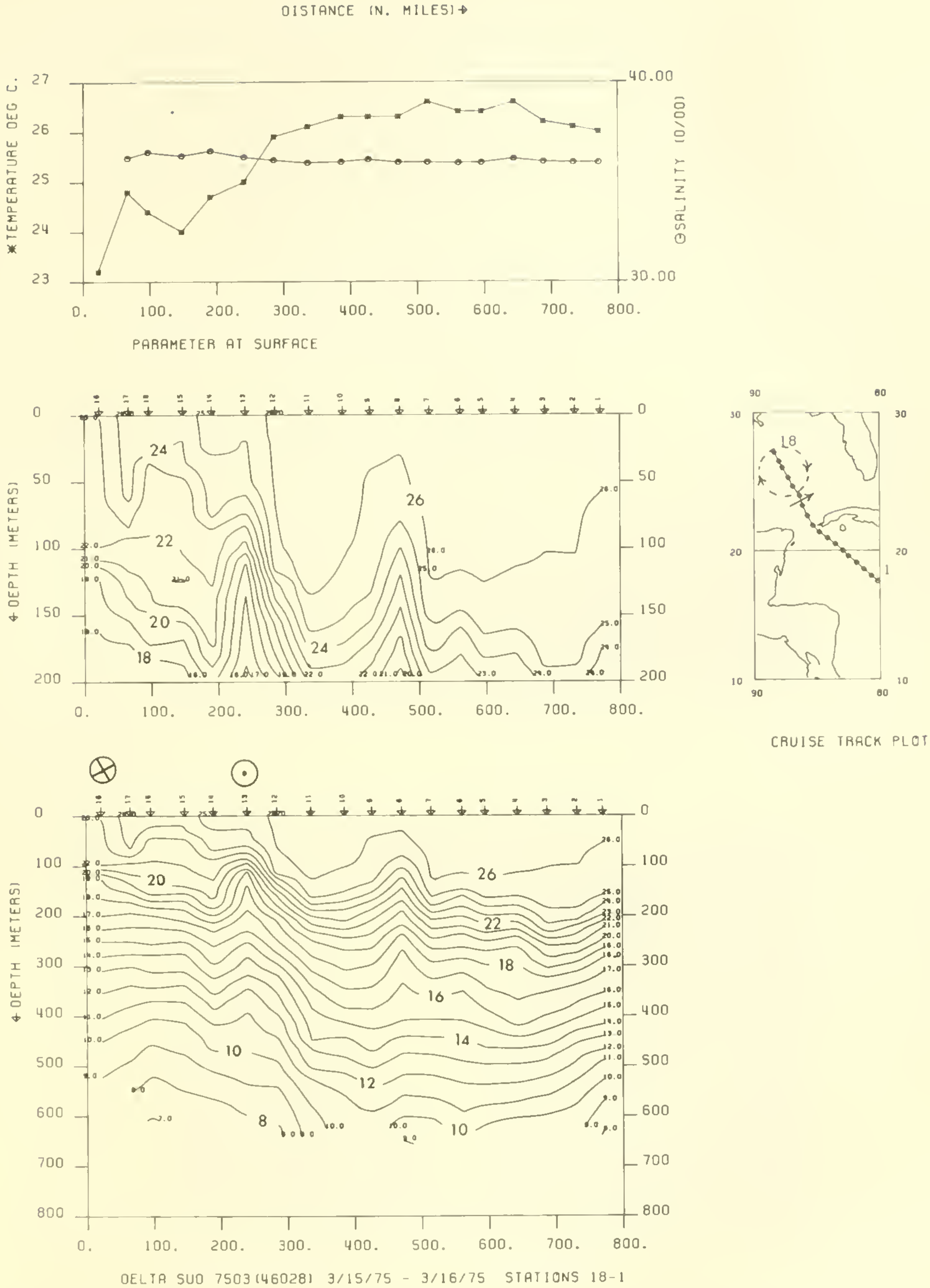
Appendix Figure 1.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—1-2 January 1975.



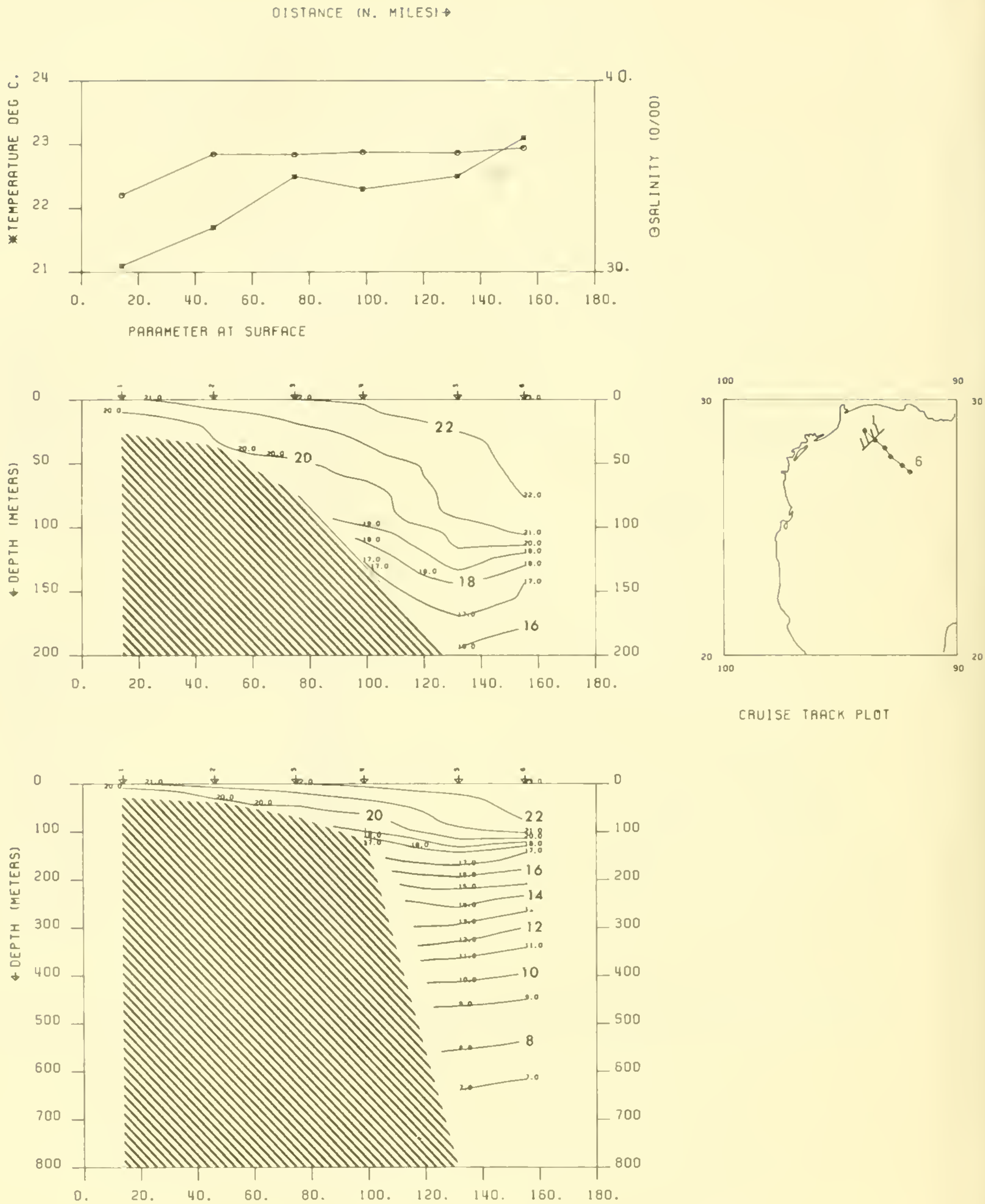
Appendix Figure 2.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—2 January 1975.



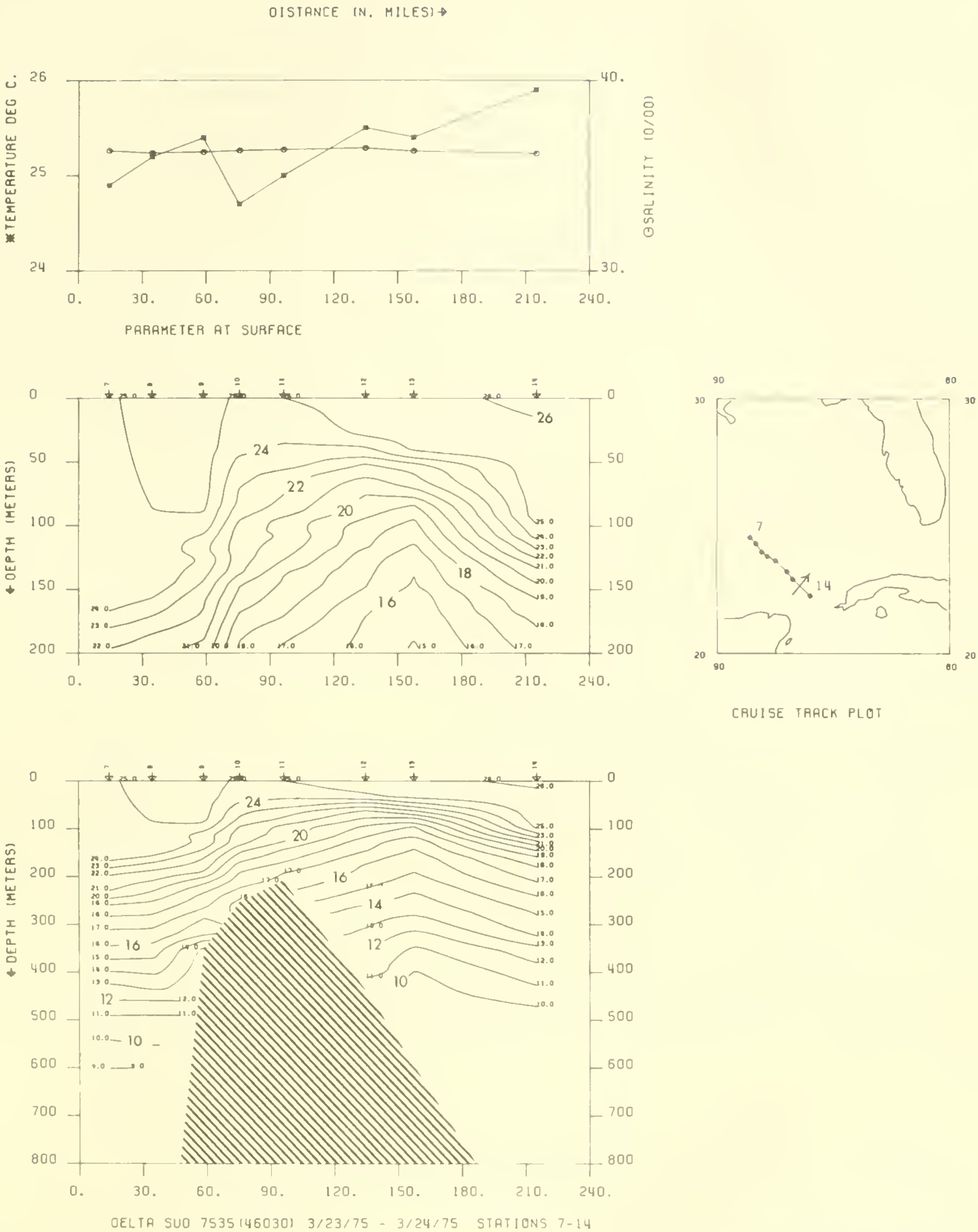
Appendix Figure 3.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—9-10 February 1975.



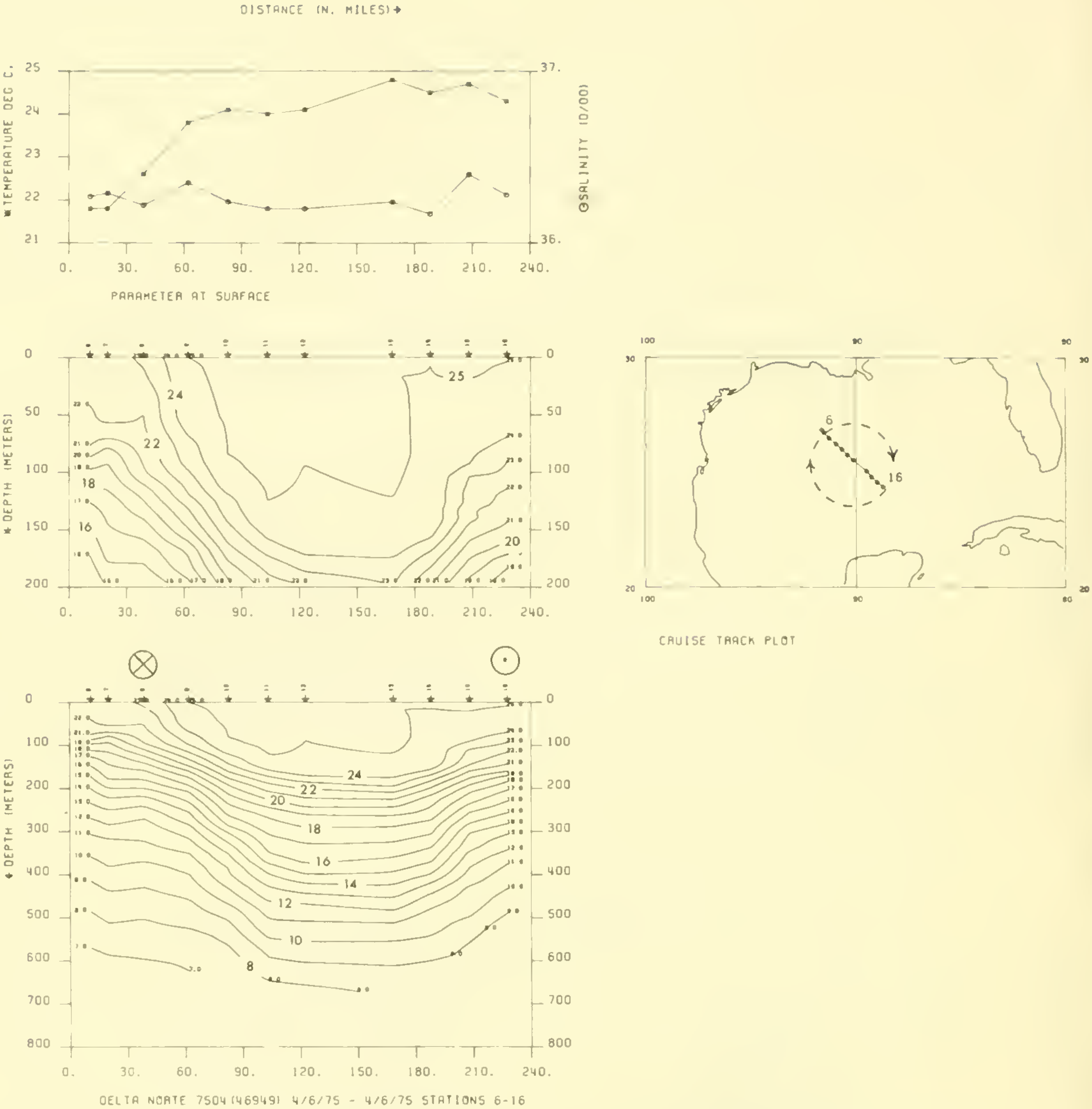
Appendix Figure 4.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—15-16 March 1975.



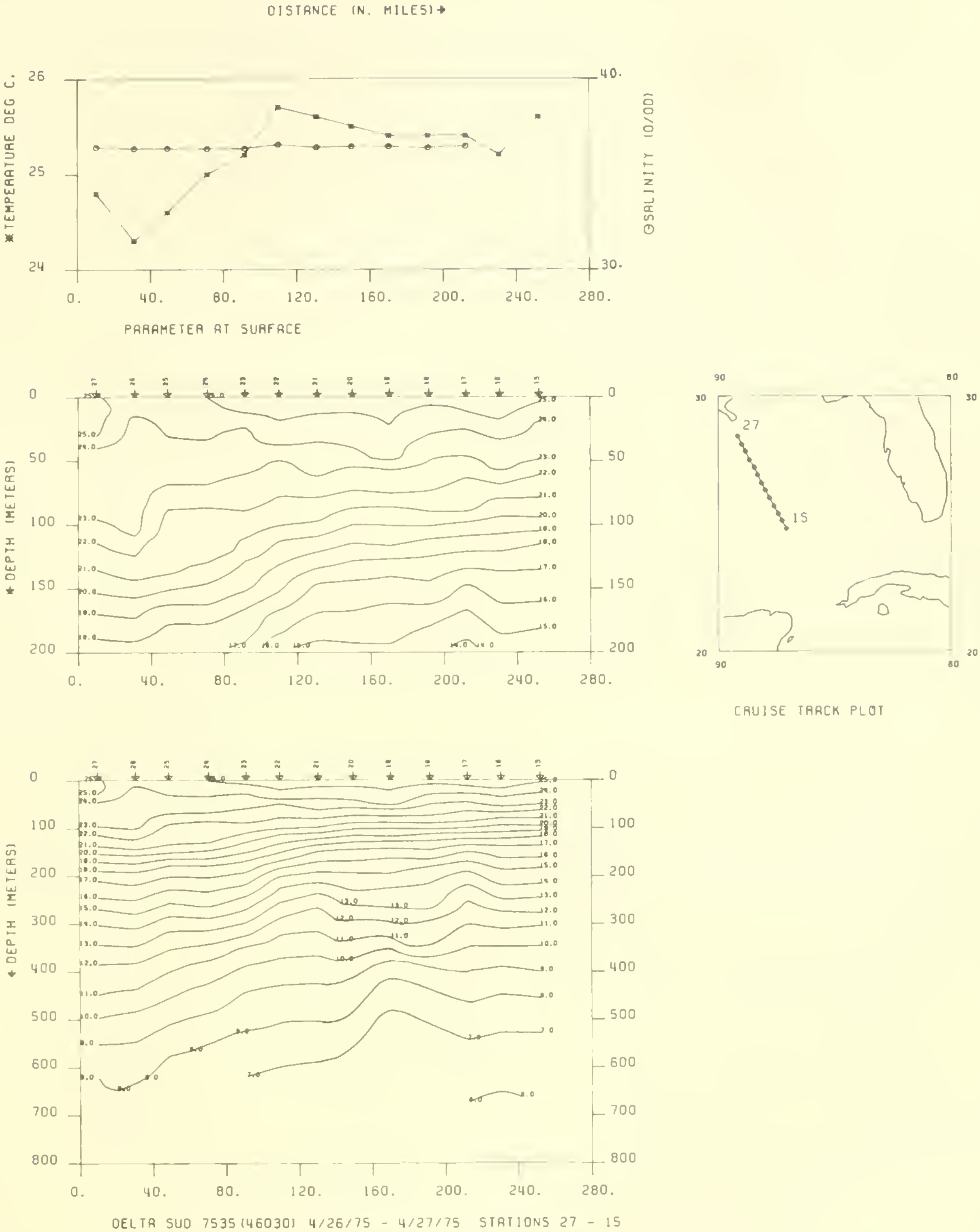
Appendix Figure 5.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—22-23 March 1975.



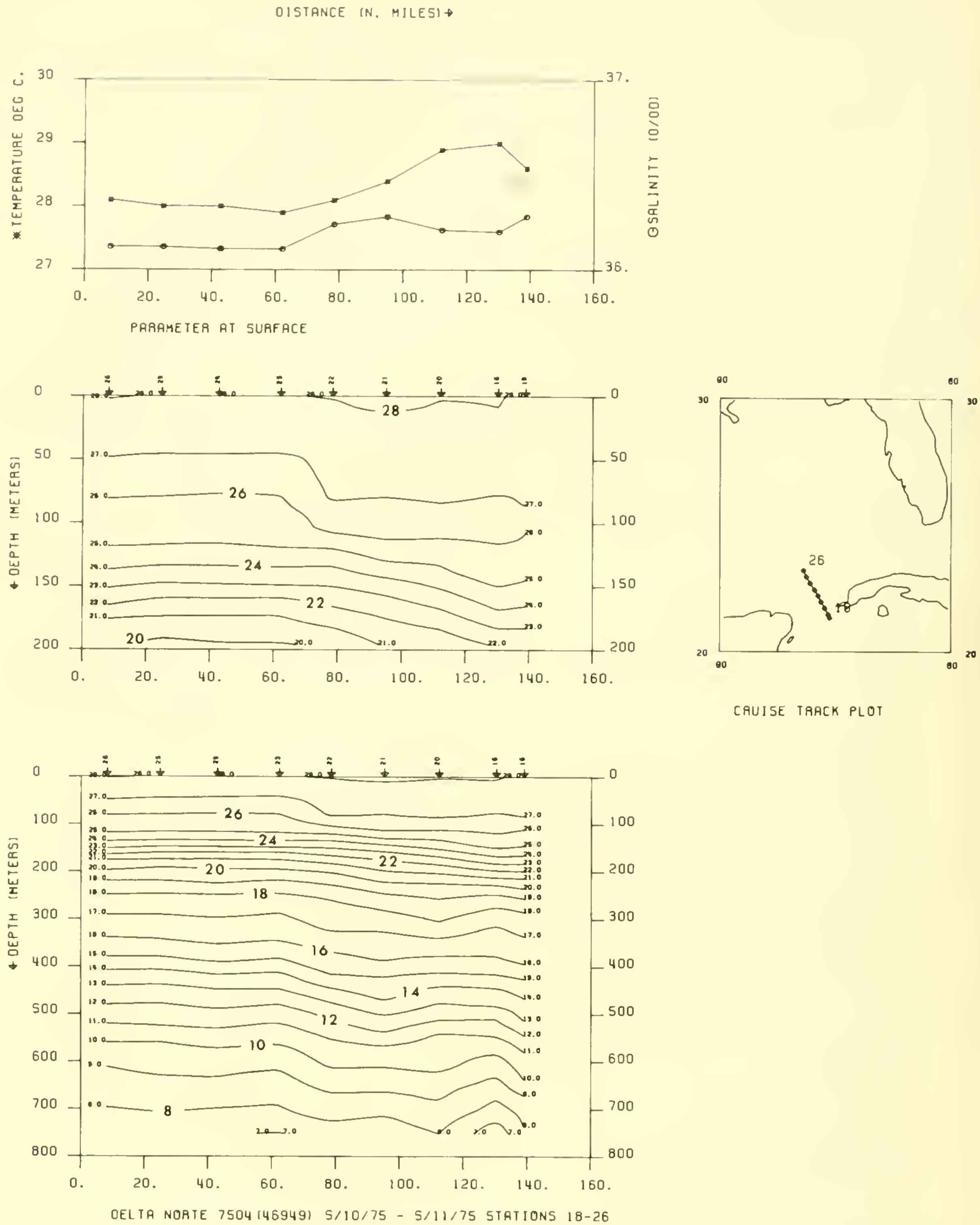
Appendix Figure 6.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—23-24 March 1975.



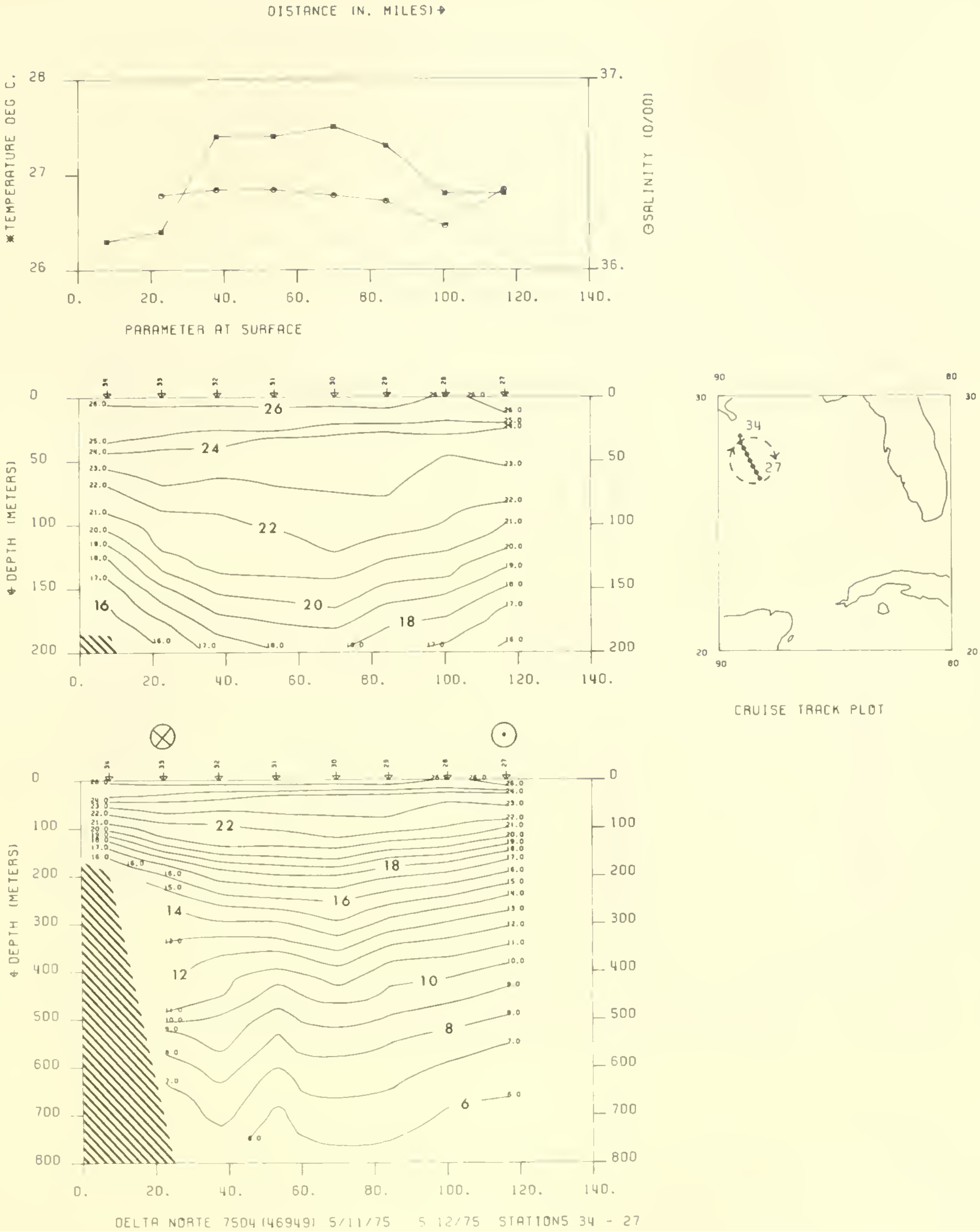
Appendix Figure 7.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—6 April 1975.



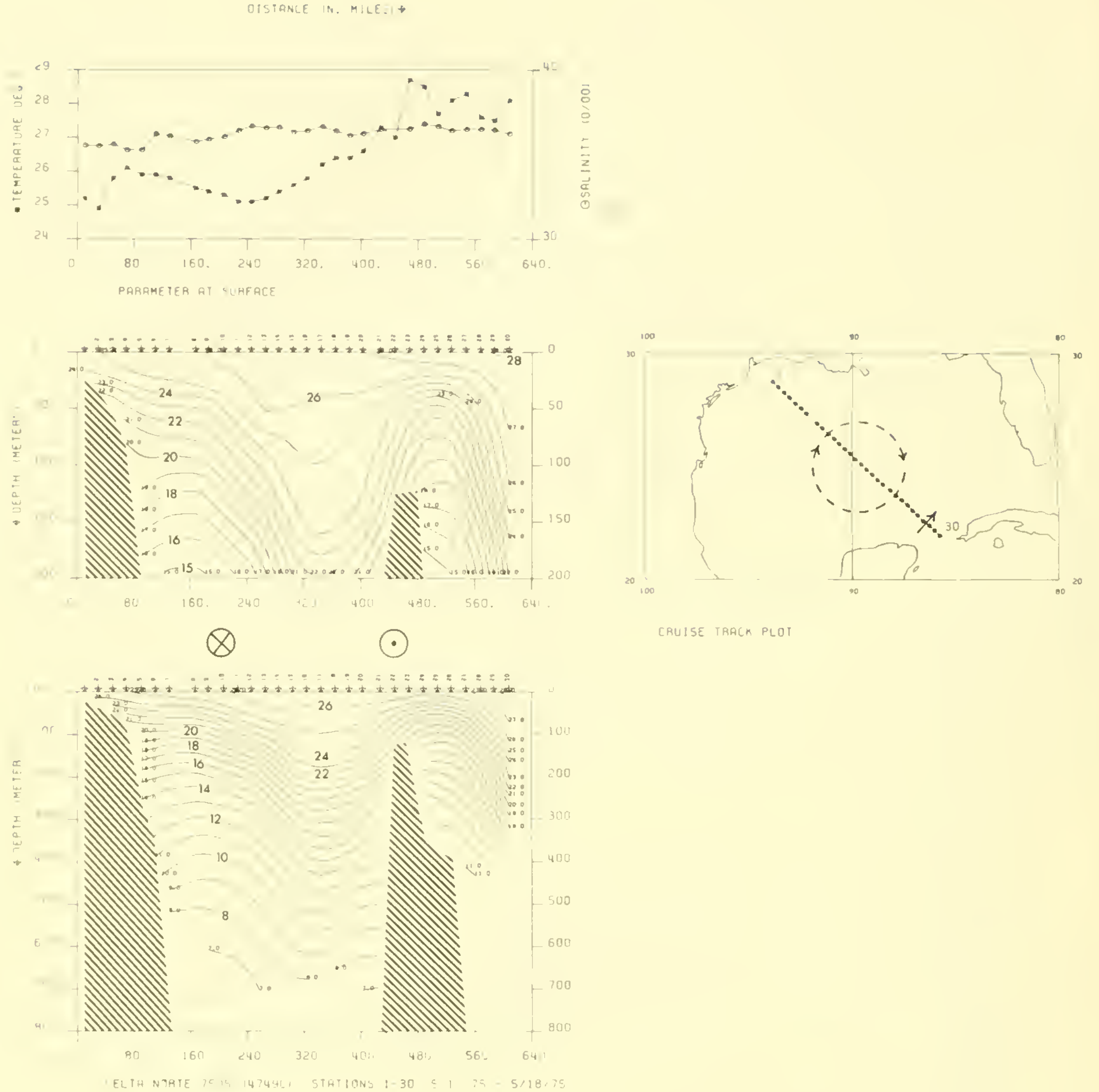
Appendix Figure 8.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity ( ) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—26-27 April 1975.



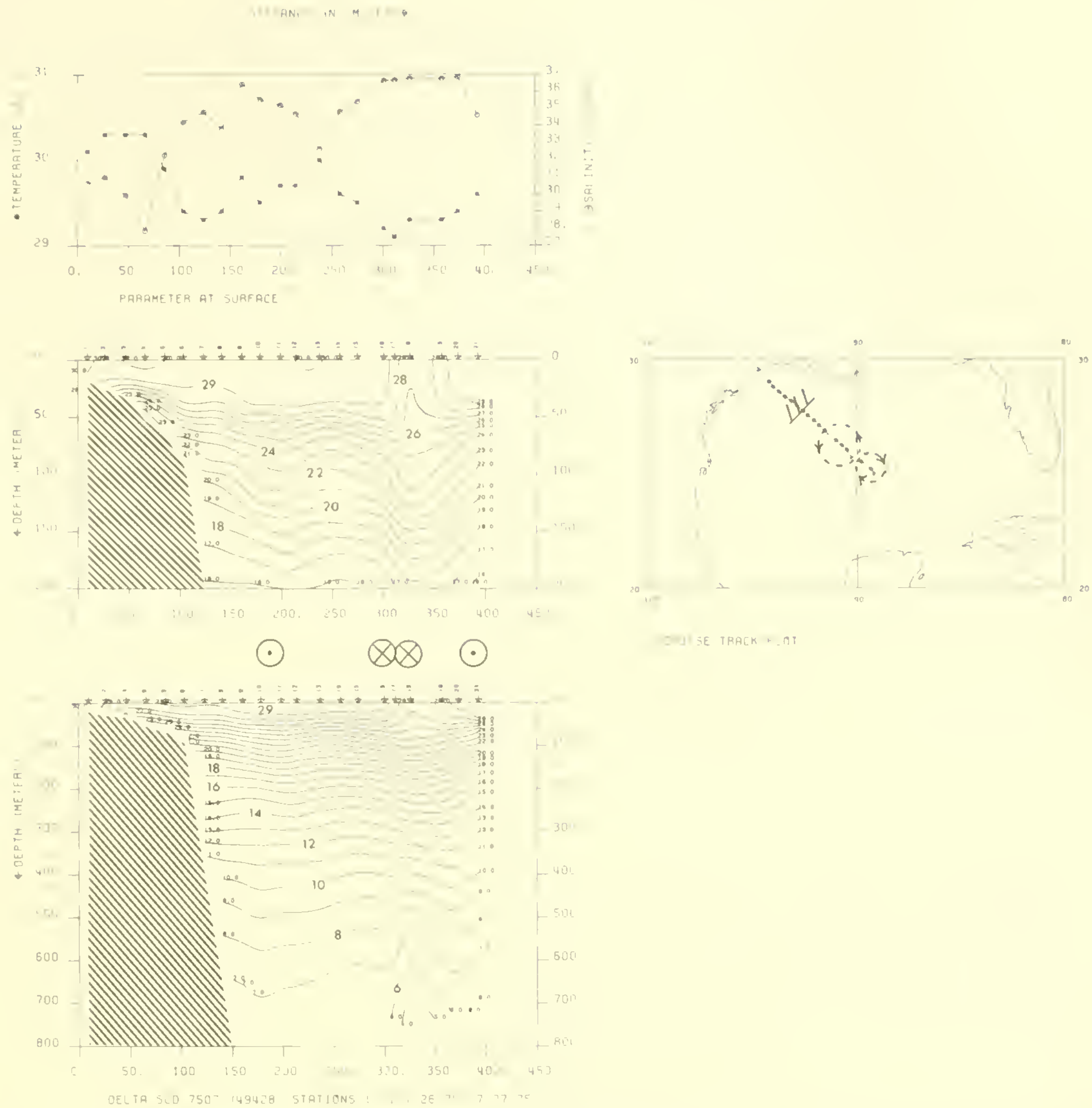
Appendix Figure 9.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—10-11 May 1975.



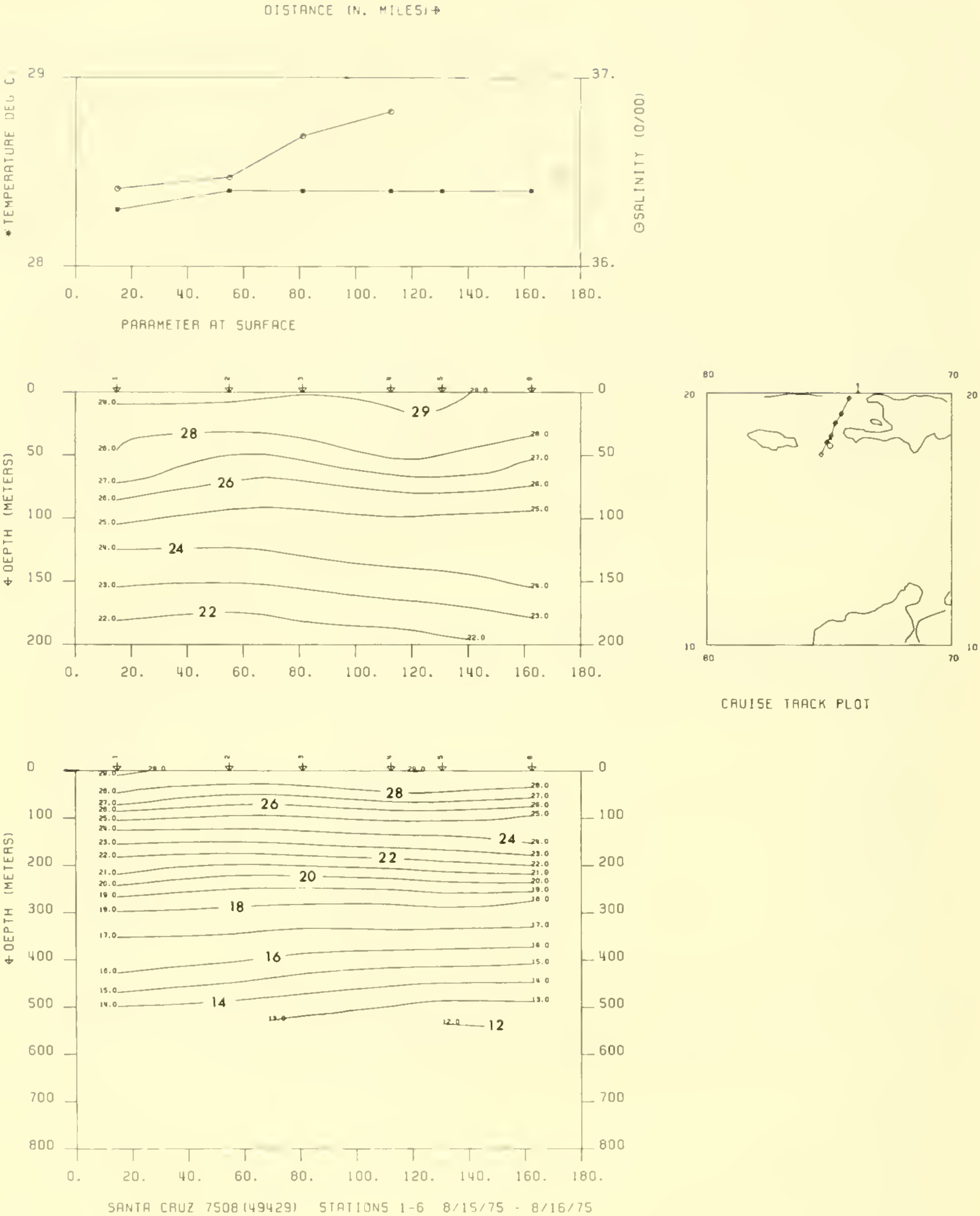
Appendix Figure 10.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—11-12 May 1975.



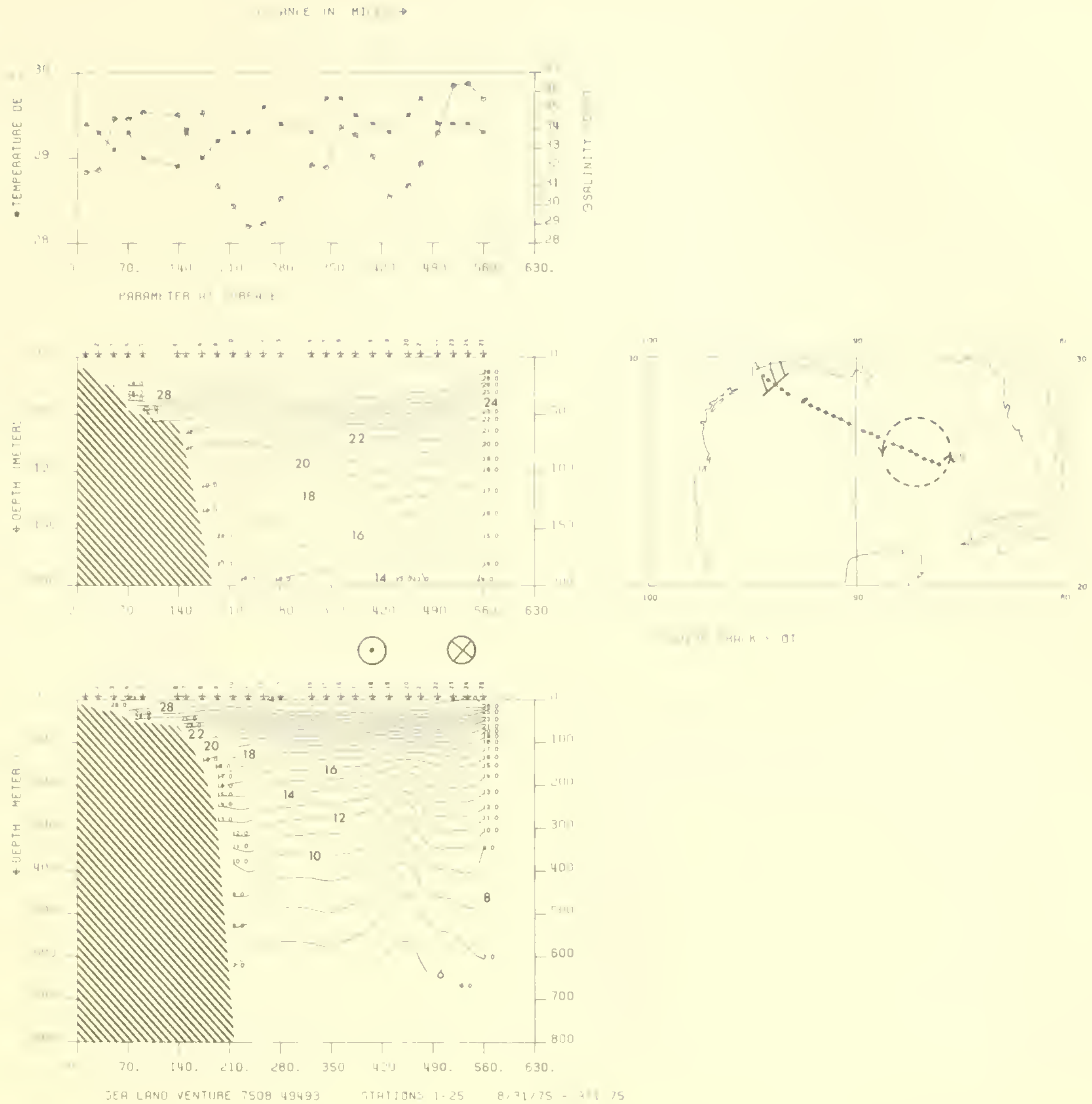
Appendix Figure 11.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—17-18 May 1975.



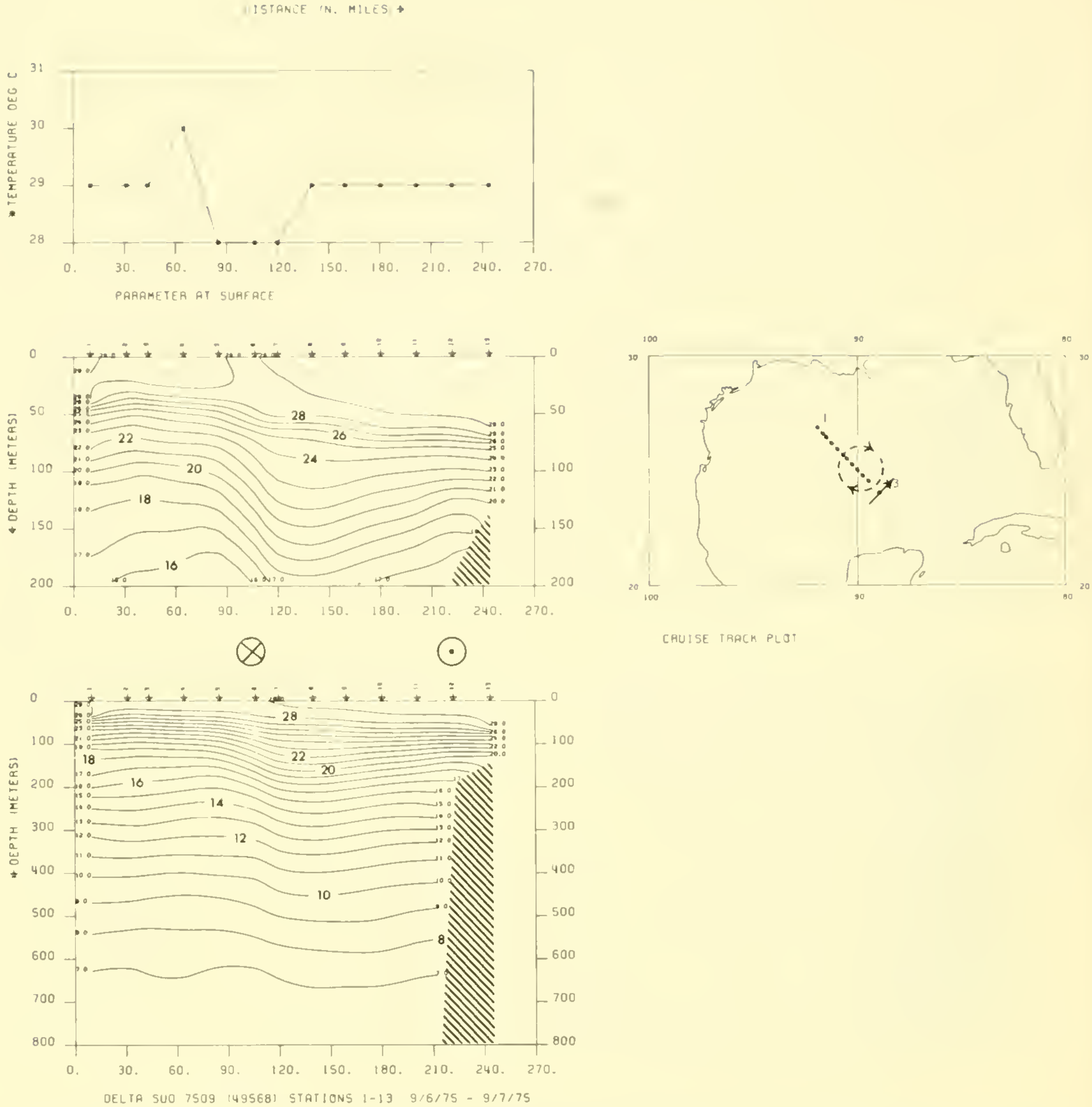
Appendix Figure 12.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delto Sud*—26-27 July 1975.



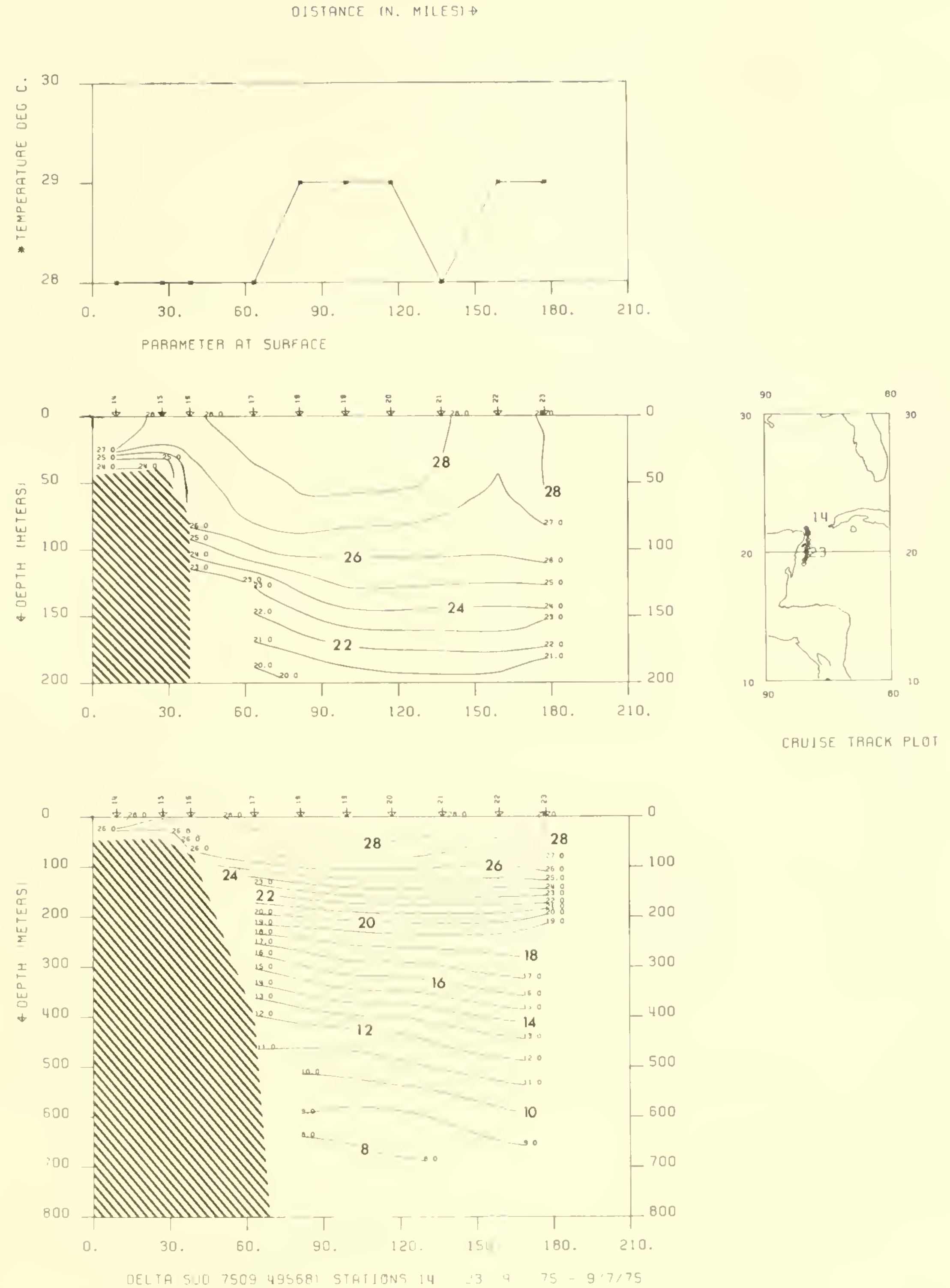
Appendix Figure 13.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—15-16 August 1975.



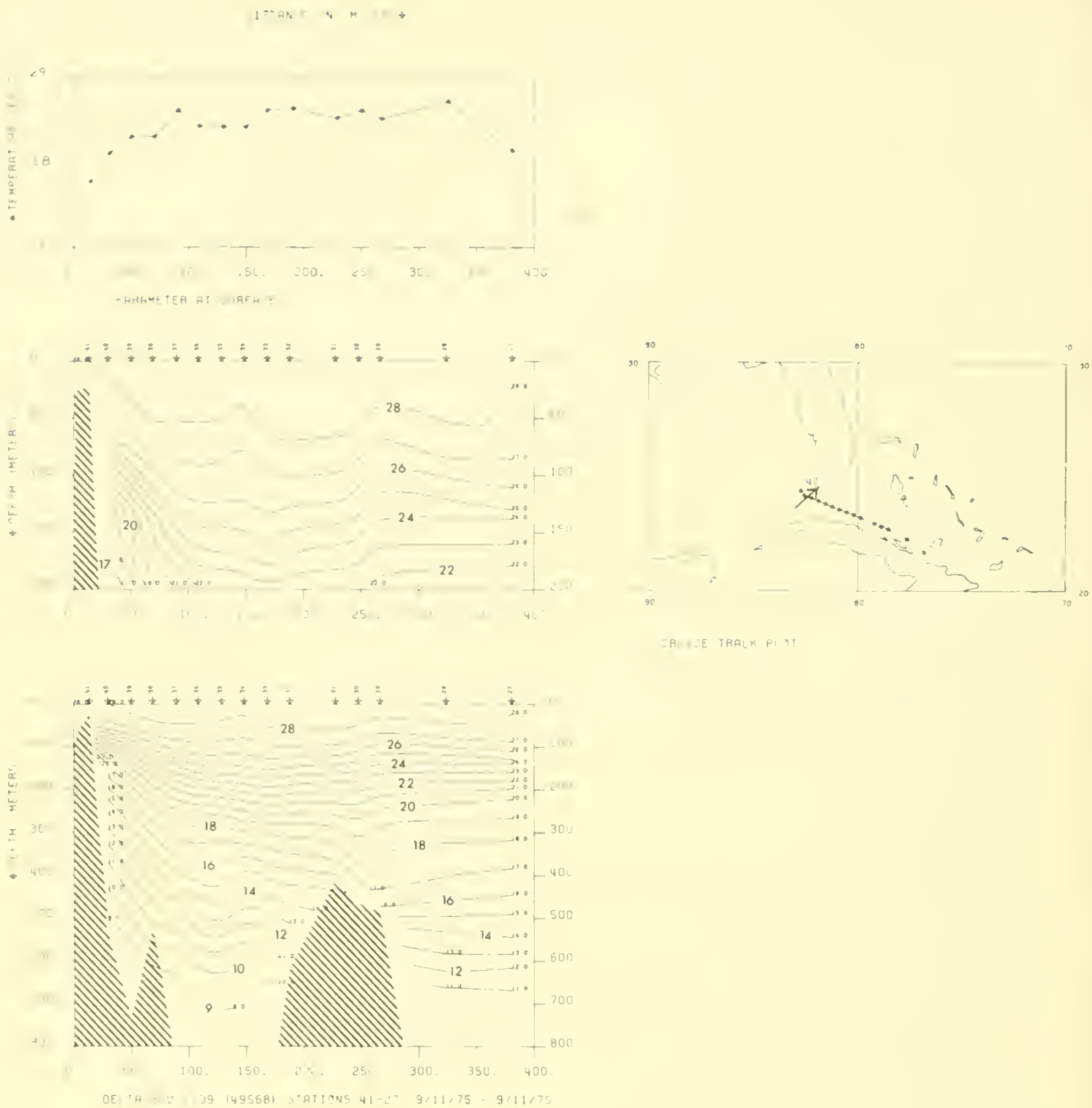
Appendix Figure 14.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Sea Land Venture*—31 August-1 September 1975.



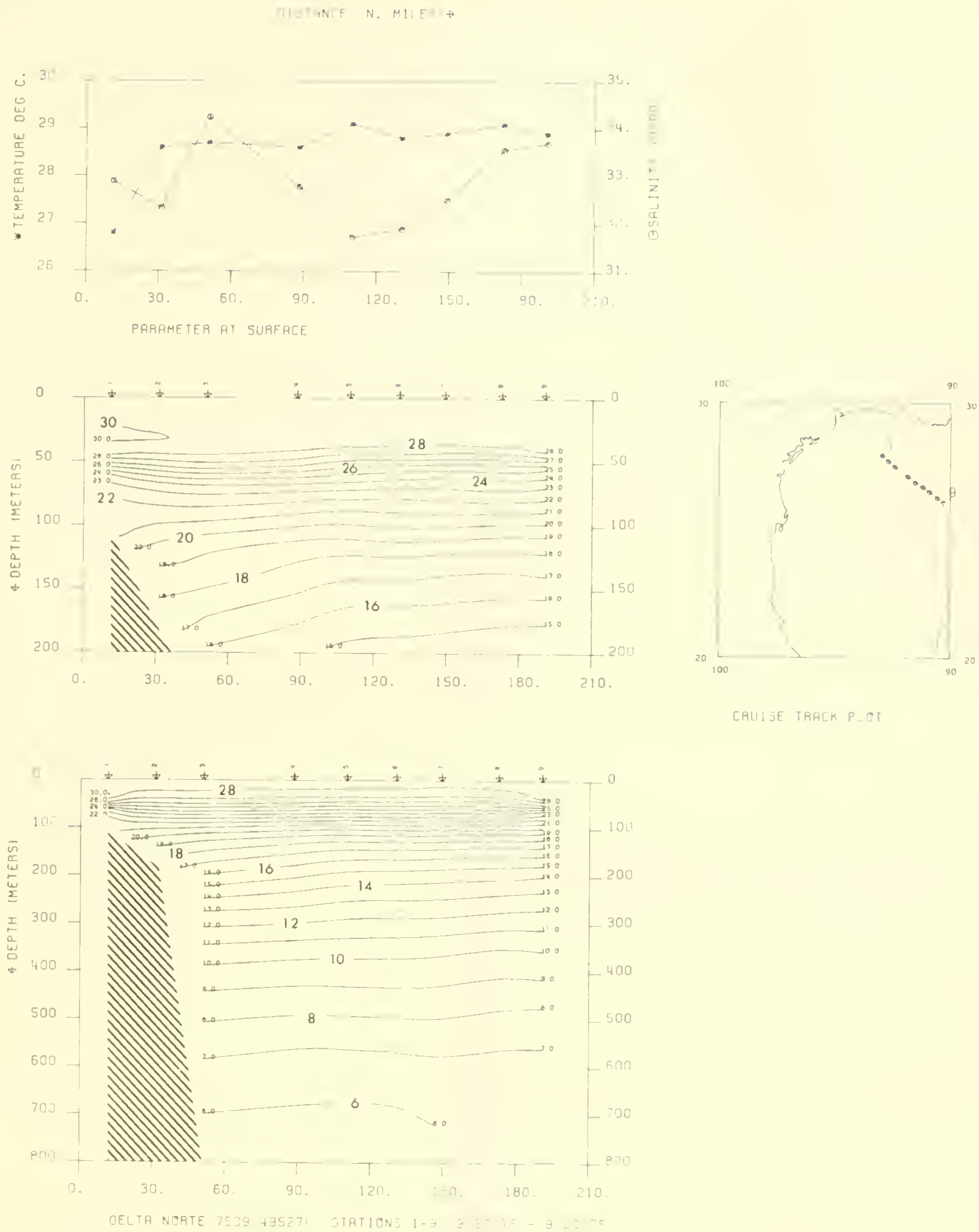
Appendix Figure 15.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—6-7 September 1975.



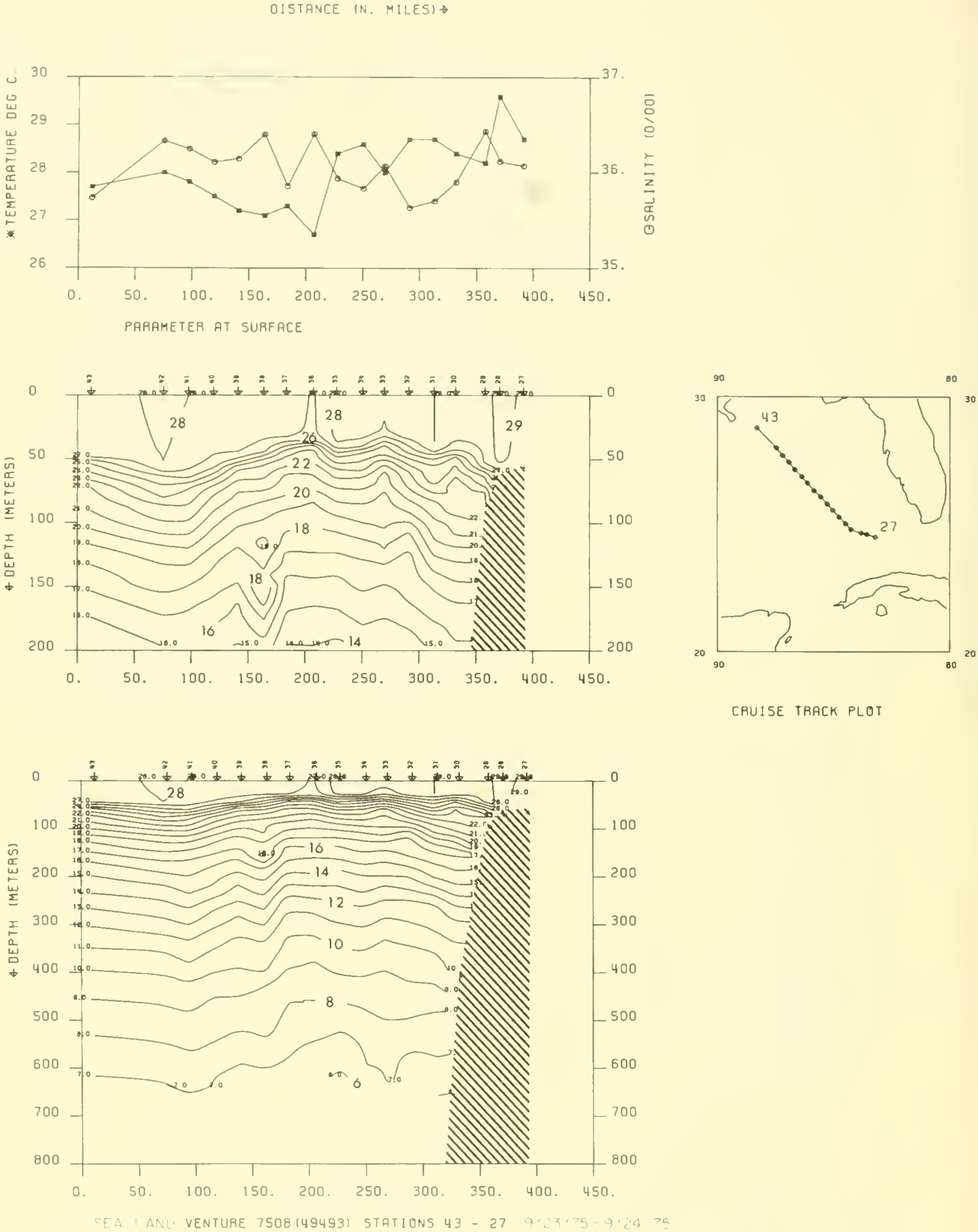
Appendix Figure 16.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—7 September 1975.



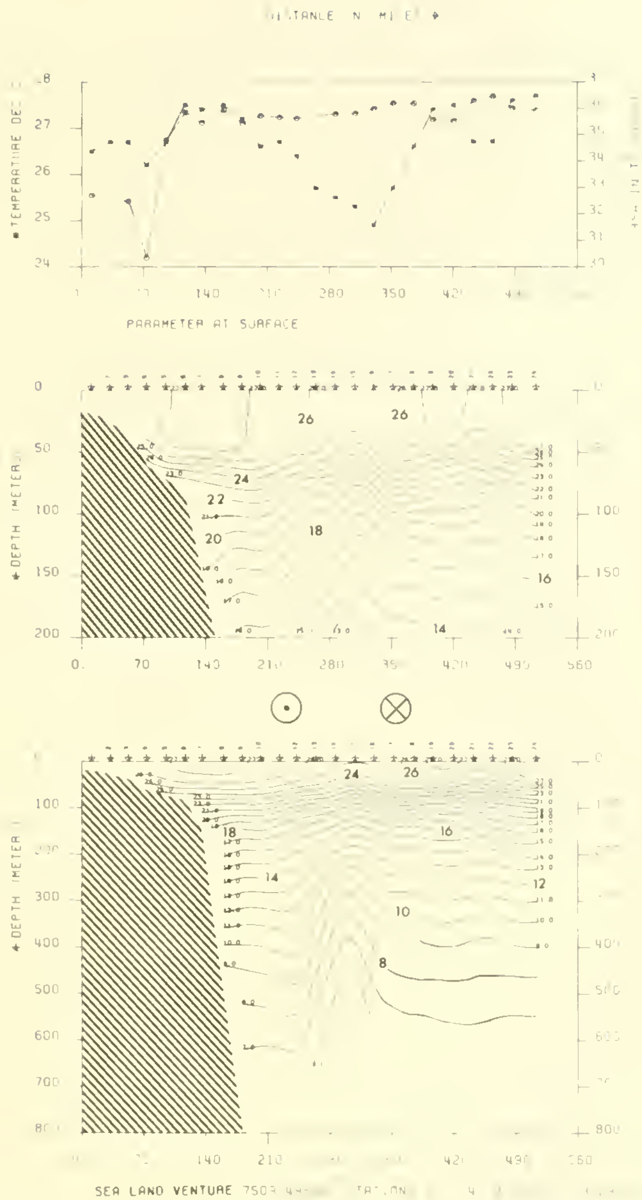
Appendix Figure 17.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—11 September 1975.

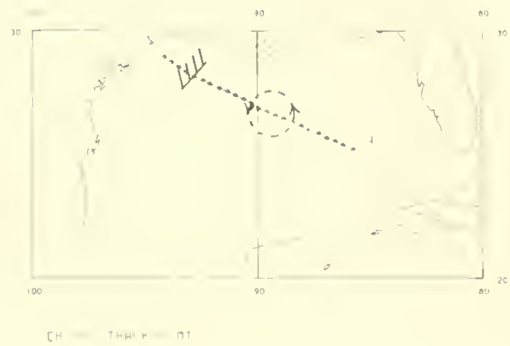


Appendix Figure 18.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—20 September 1975.

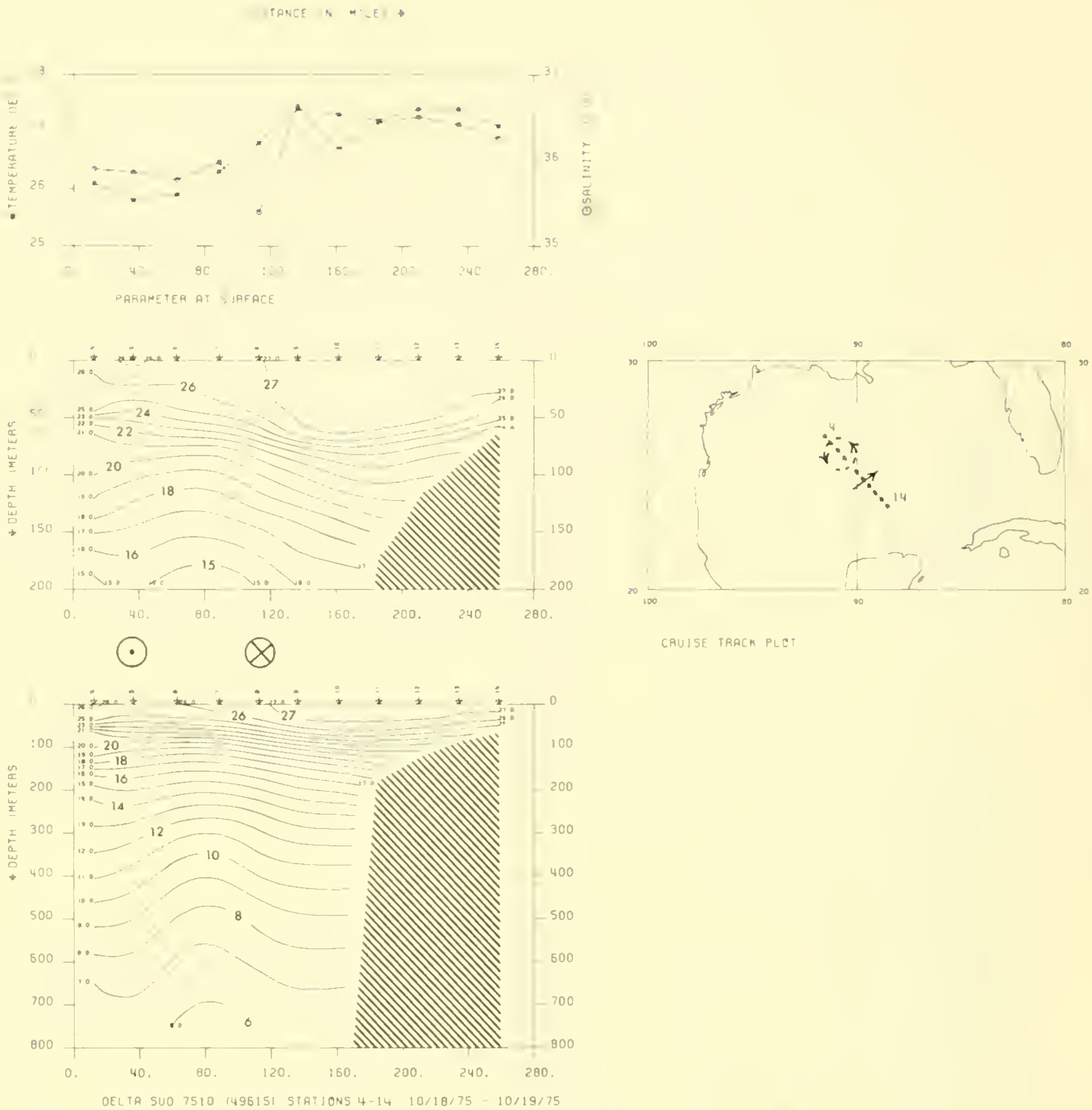


Appendix Figure 19.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Sea Land Venture*—23-24 September 1975.

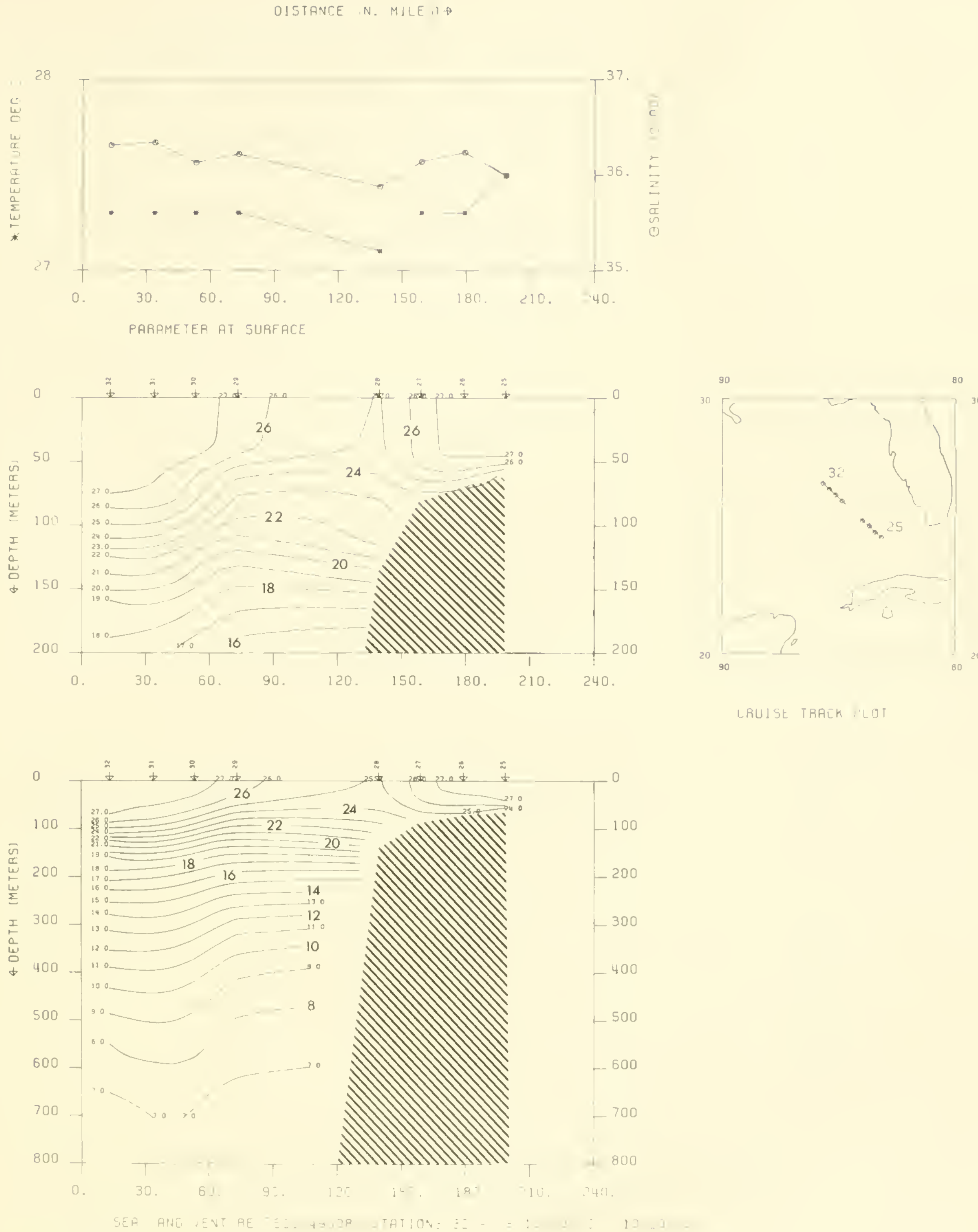




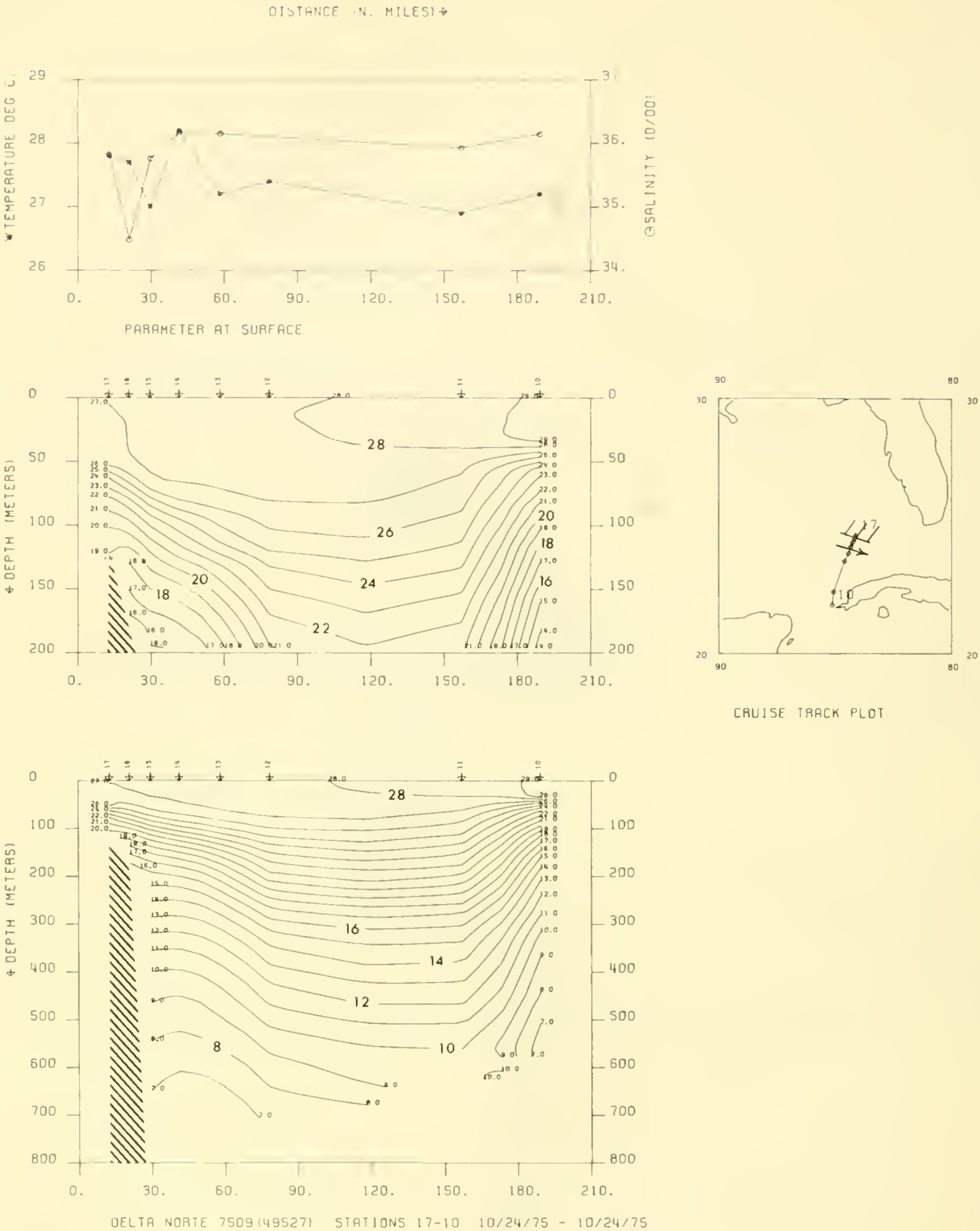
Appendix Figure 20.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Sea Land Venture*—28-29 September 1975.



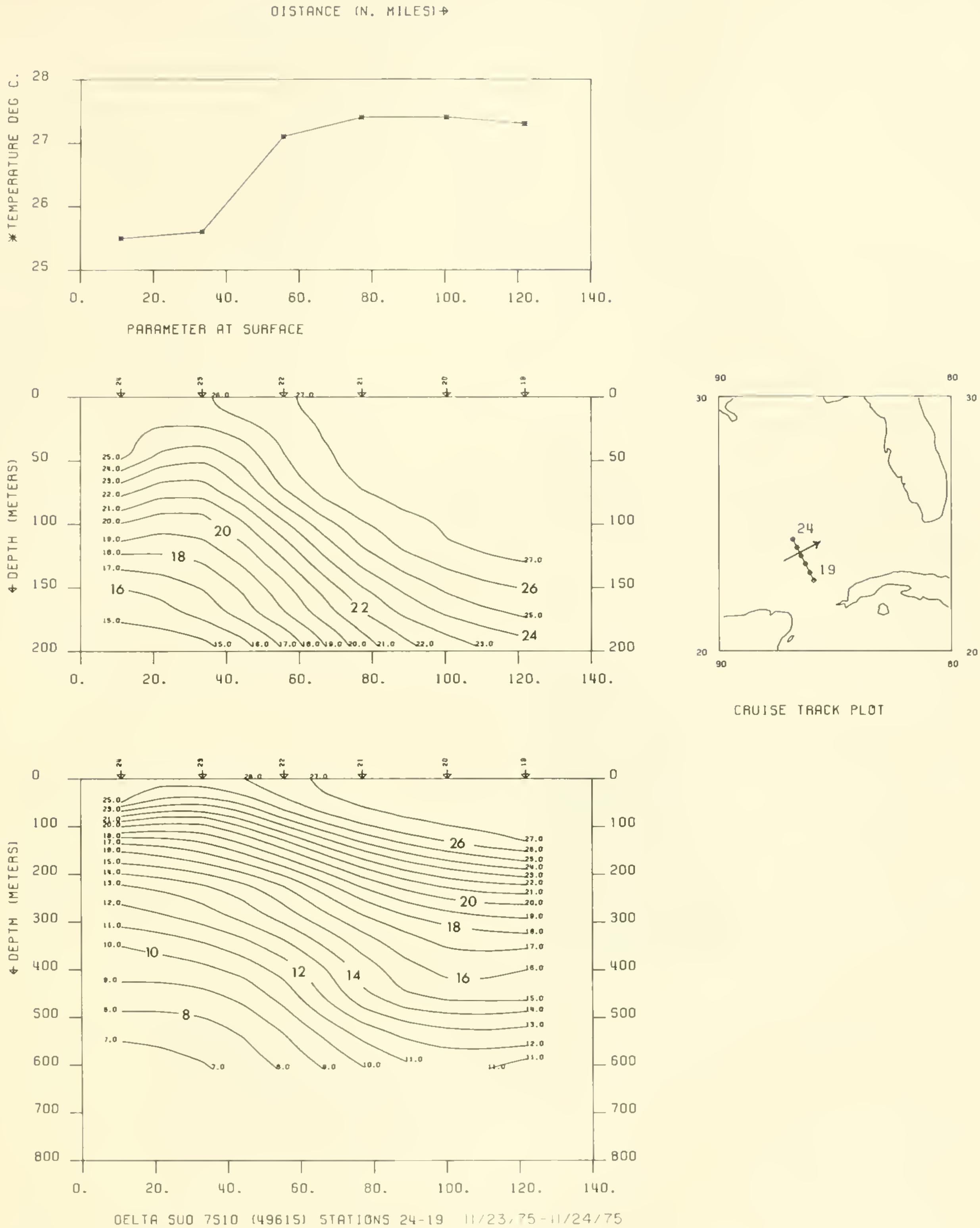
Appendix Figure 21.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—18-19 October 1975.



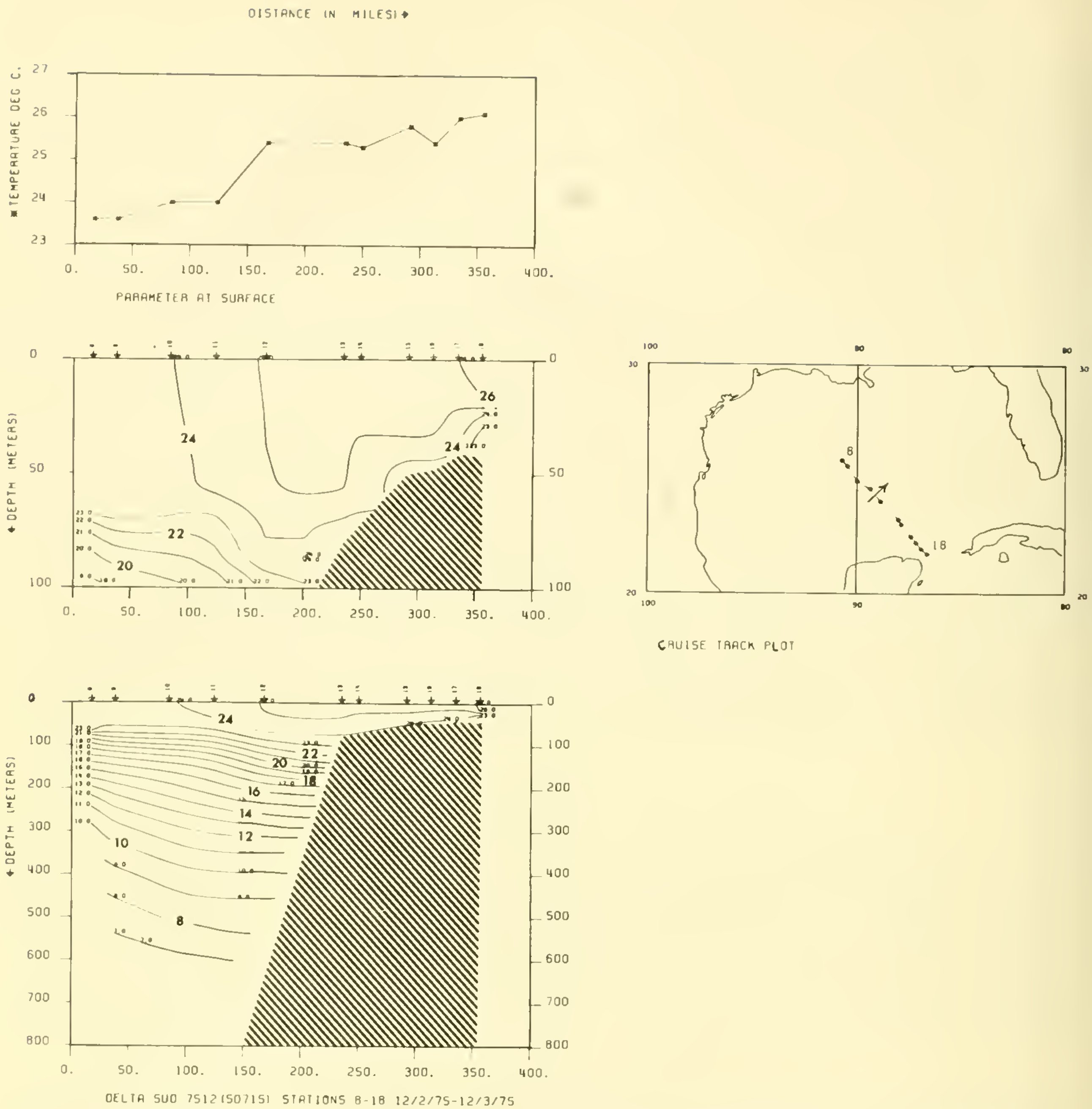
Appendix Figure 22.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Sea Land Venture*—20 October 1975.



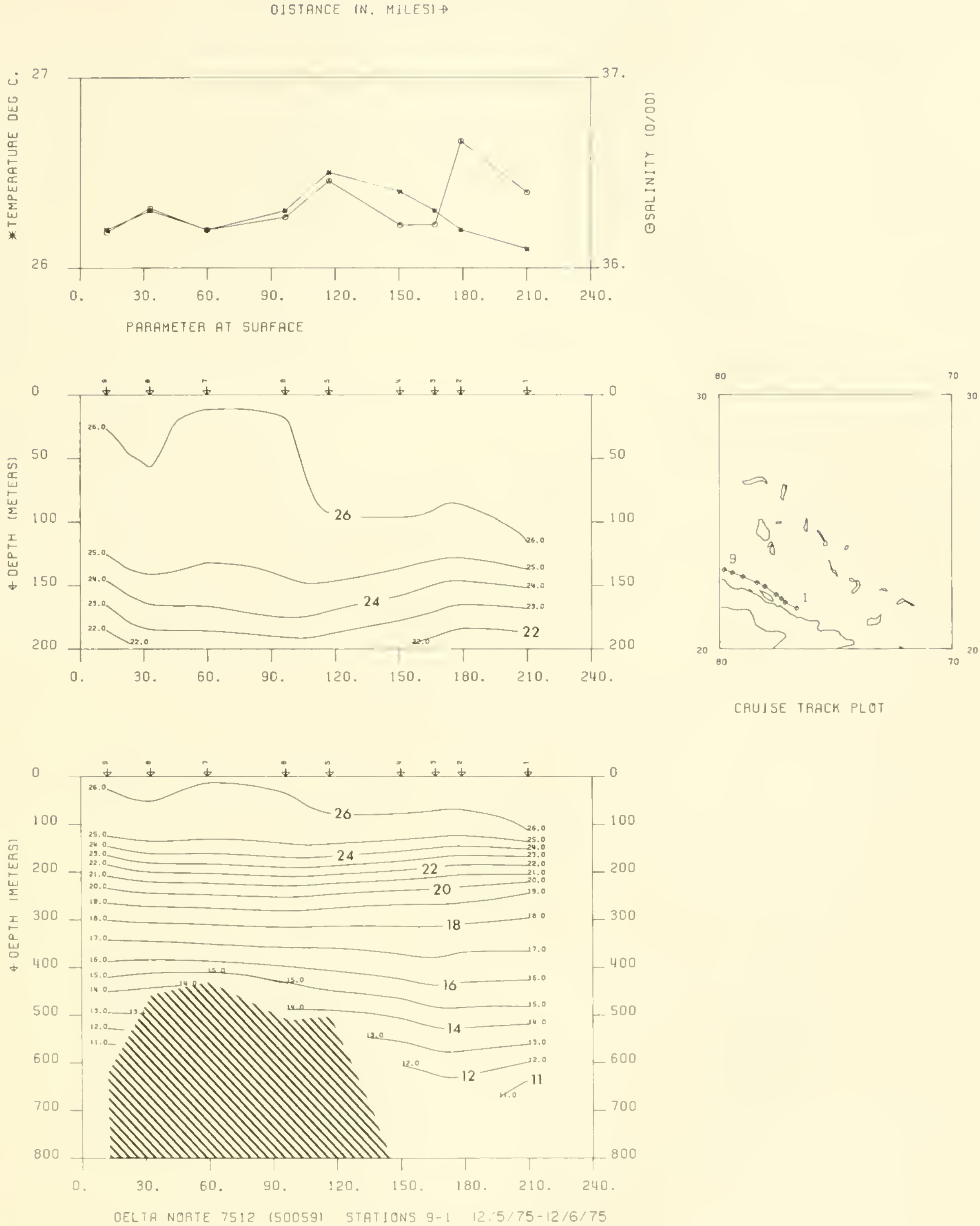
Appendix Figure 23.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—24 October 1975.



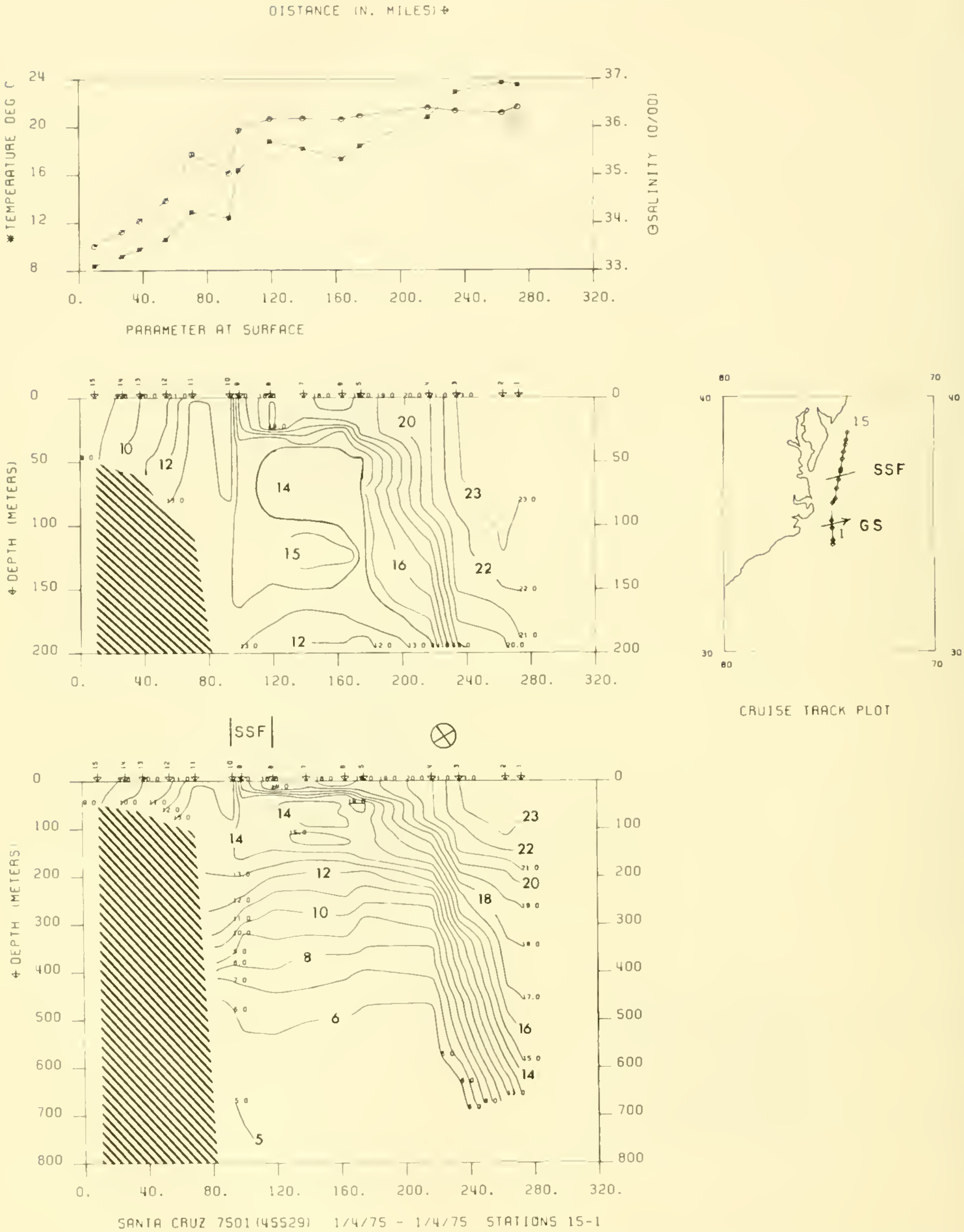
Appendix Figure 24.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—23-24 November 1975.



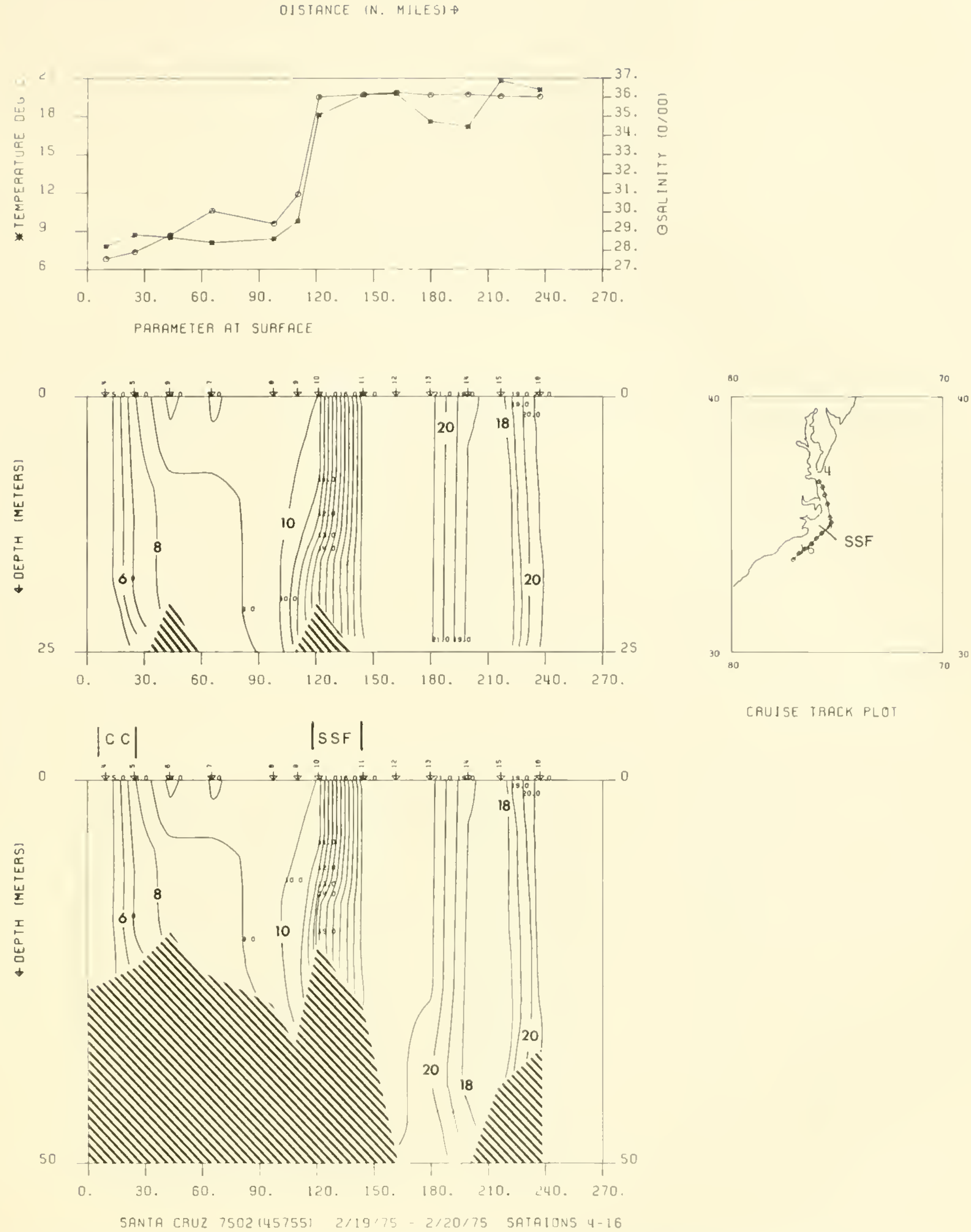
Appendix Figure 25.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—2-3 December 1975.



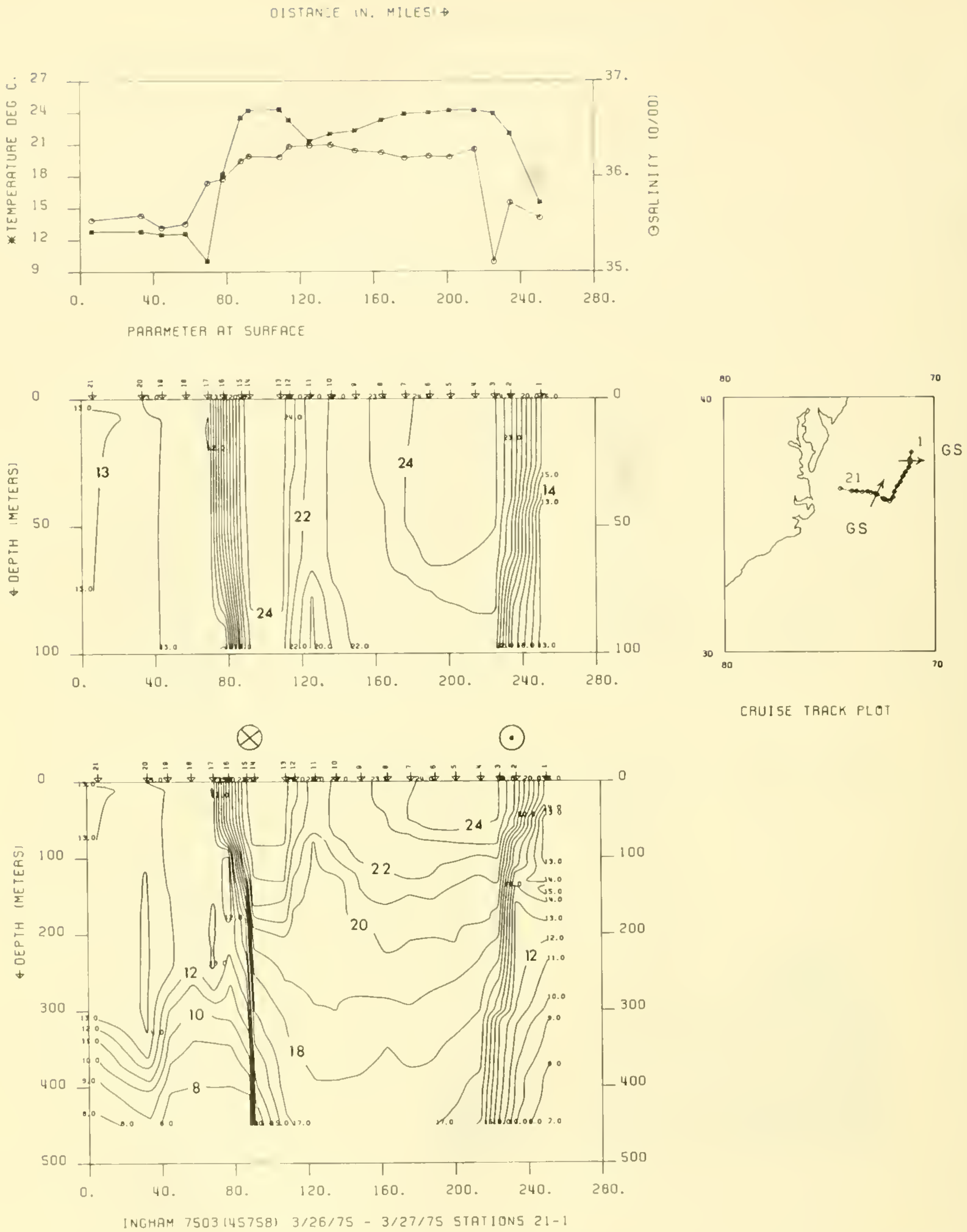
Appendix Figure 26.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Norte*—5-6 December 1975.



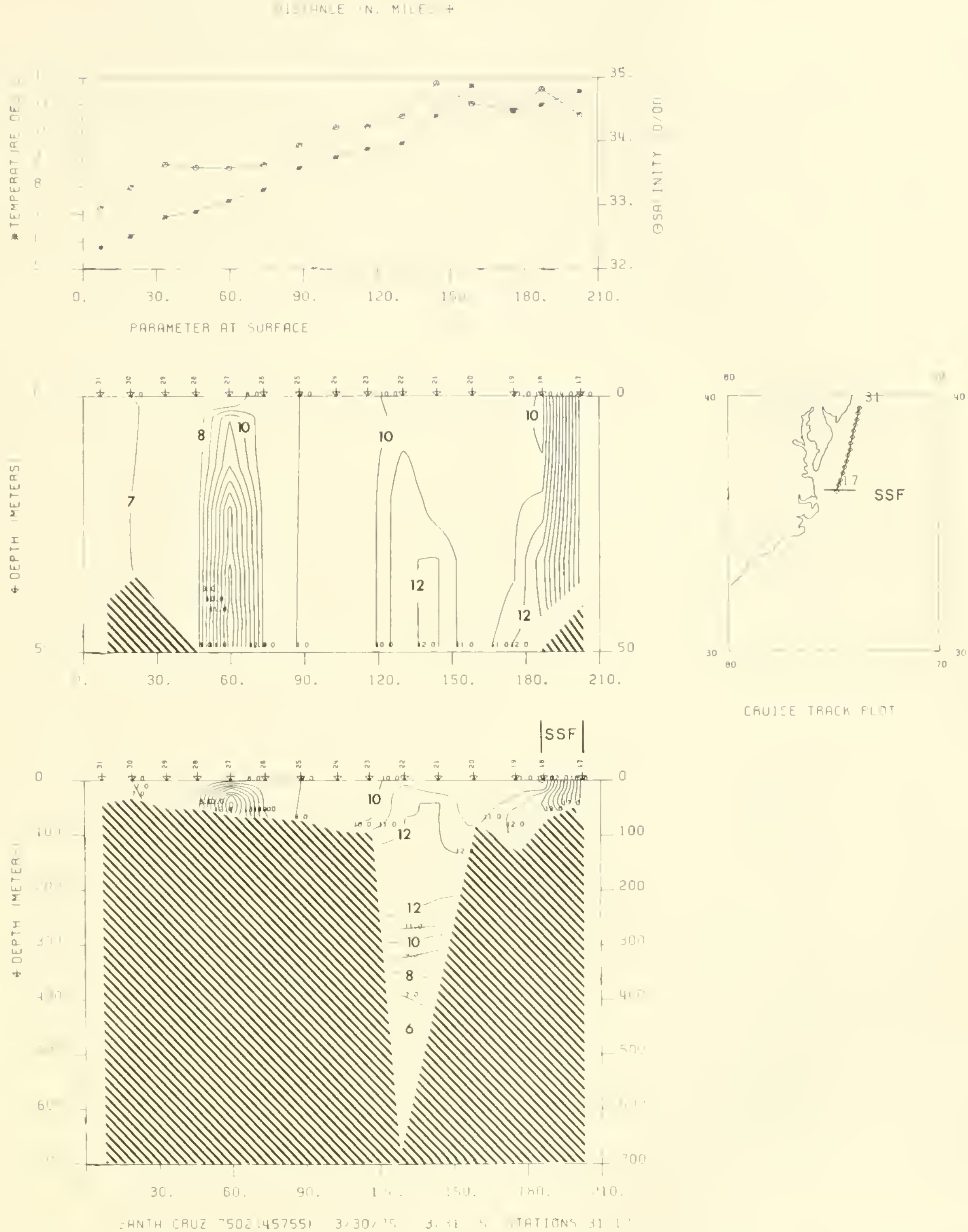
Appendix Figure 27.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—4 January 1975.



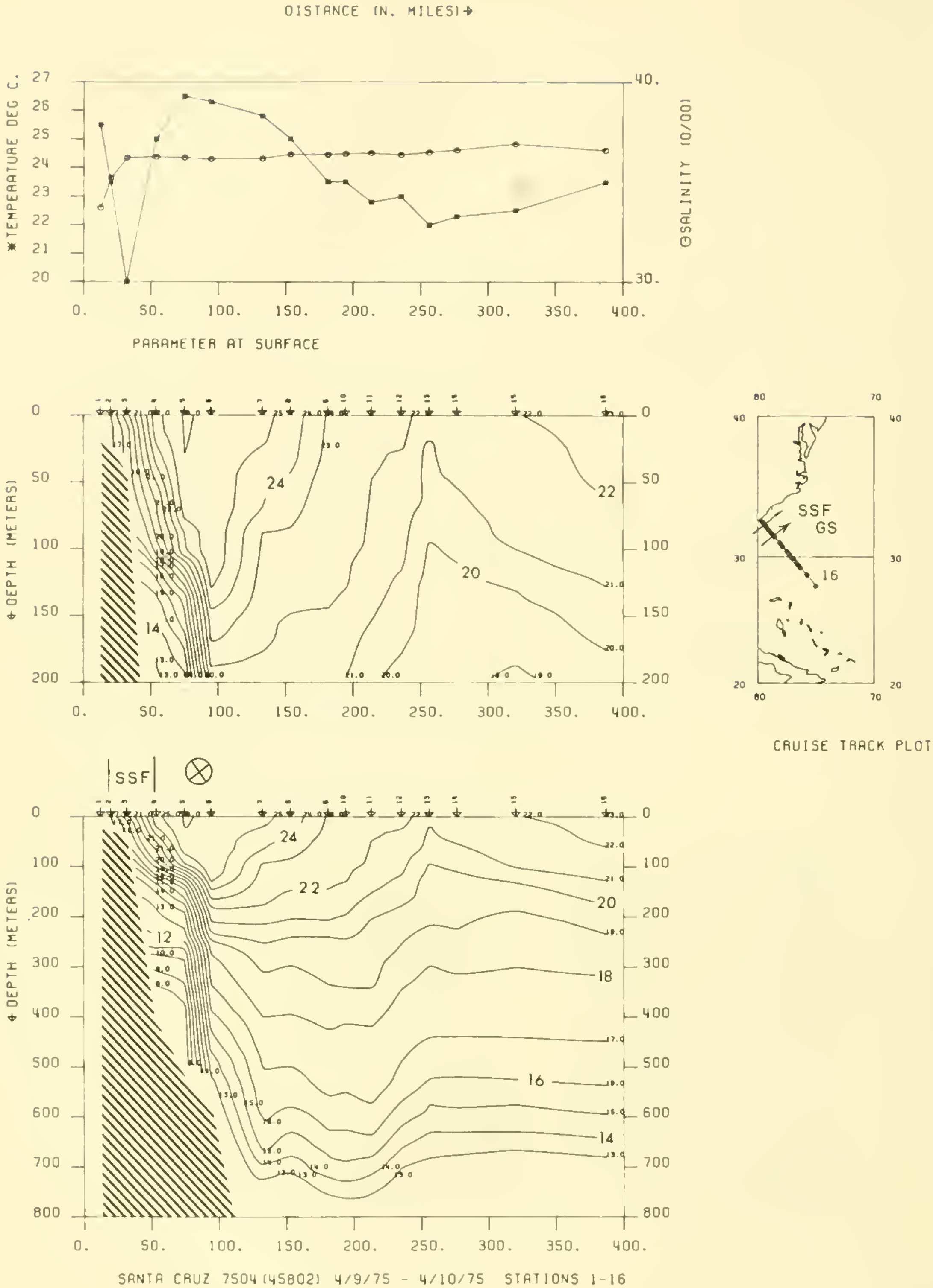
Appendix Figure 28.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 25 and 50 m. *Santa Cruz*—19-20 February 1975.



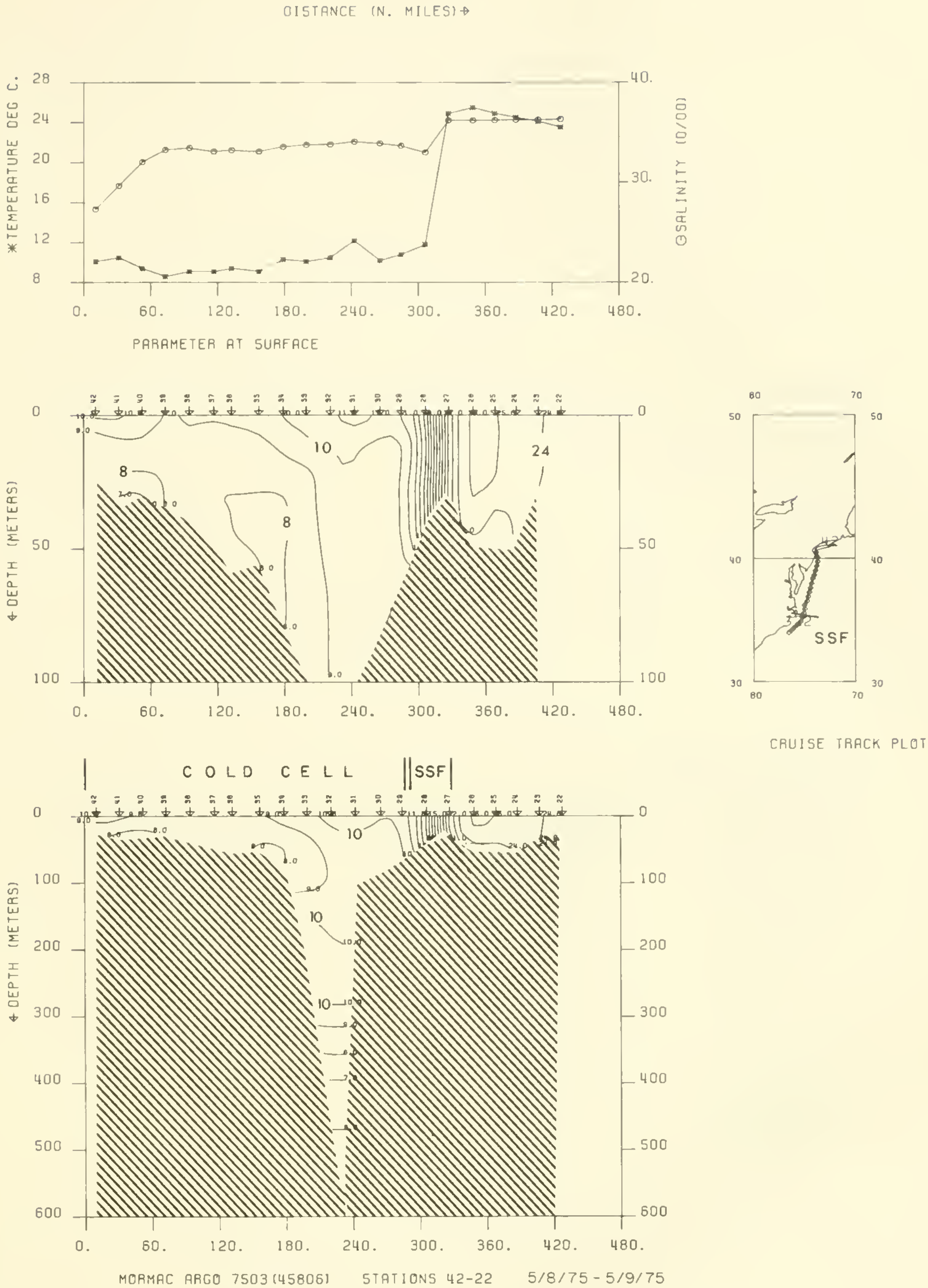
Appendix Figure 29.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Ingham*—26-27 March 1975.



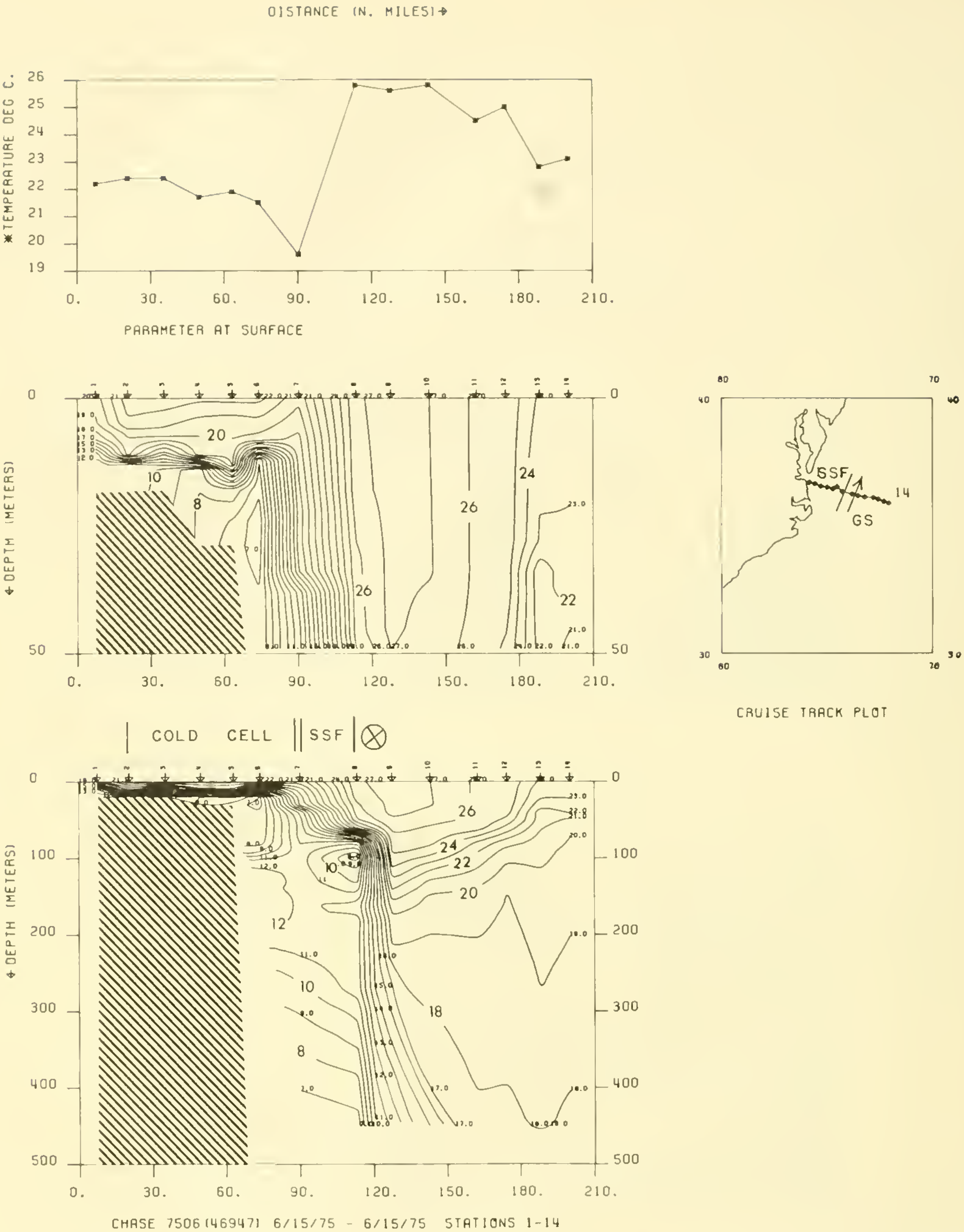
Appendix Figure 30.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 700 m. *Santa Cruz*—30-31 March 1975.



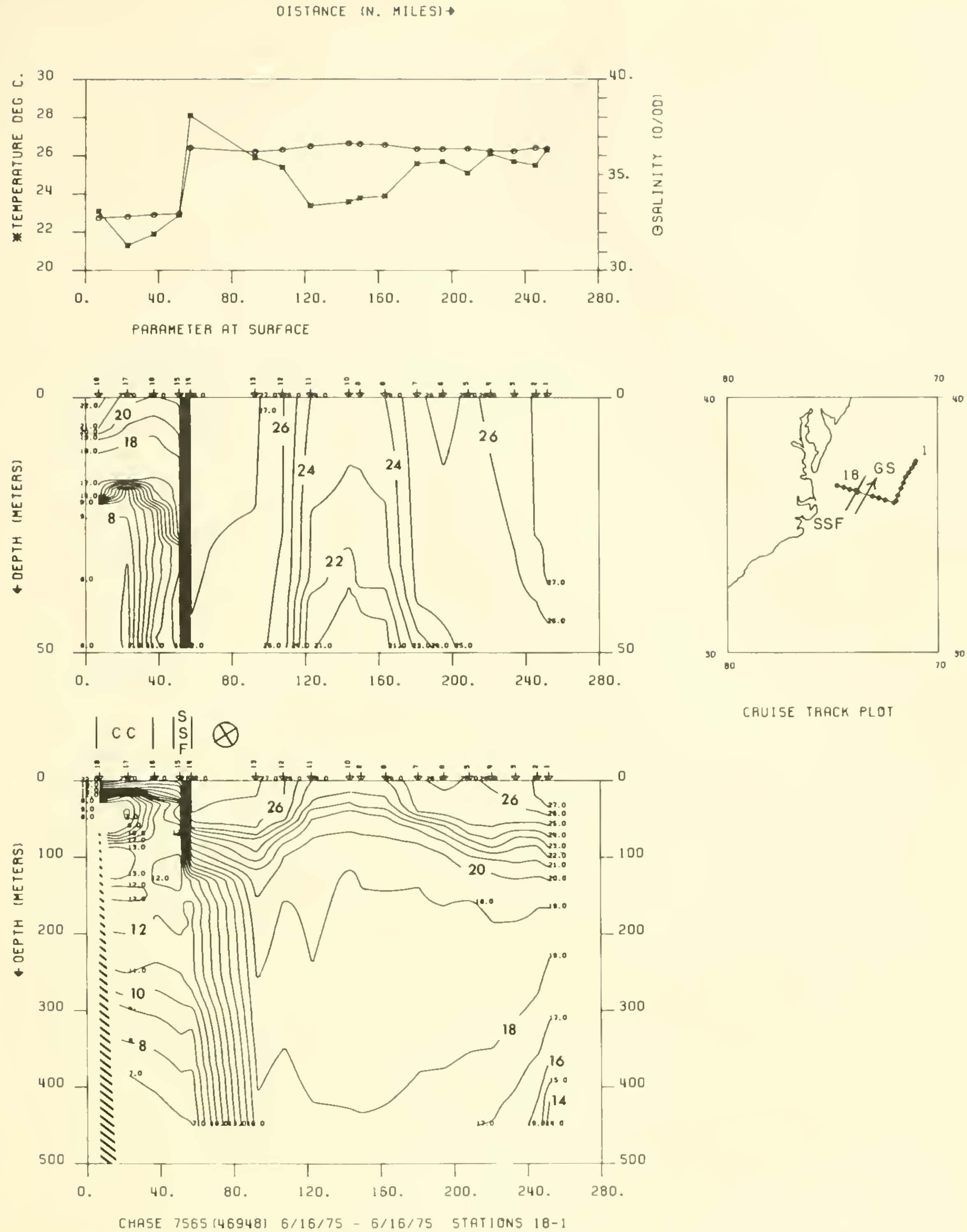
Appendix Figure 31.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—9-10 April 1975.



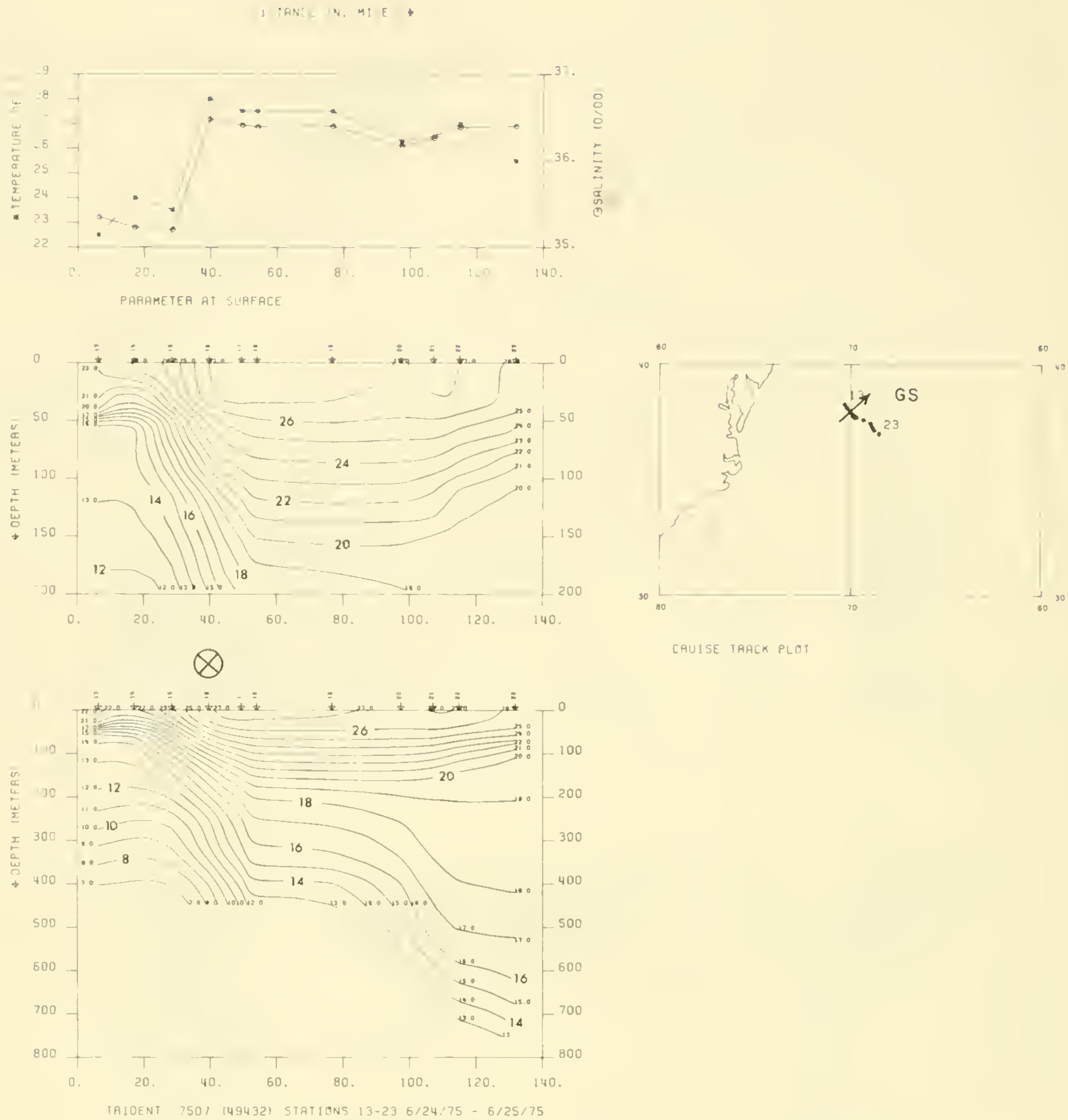
Appendix Figure 32.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Delta Sud*—2 January 1975.



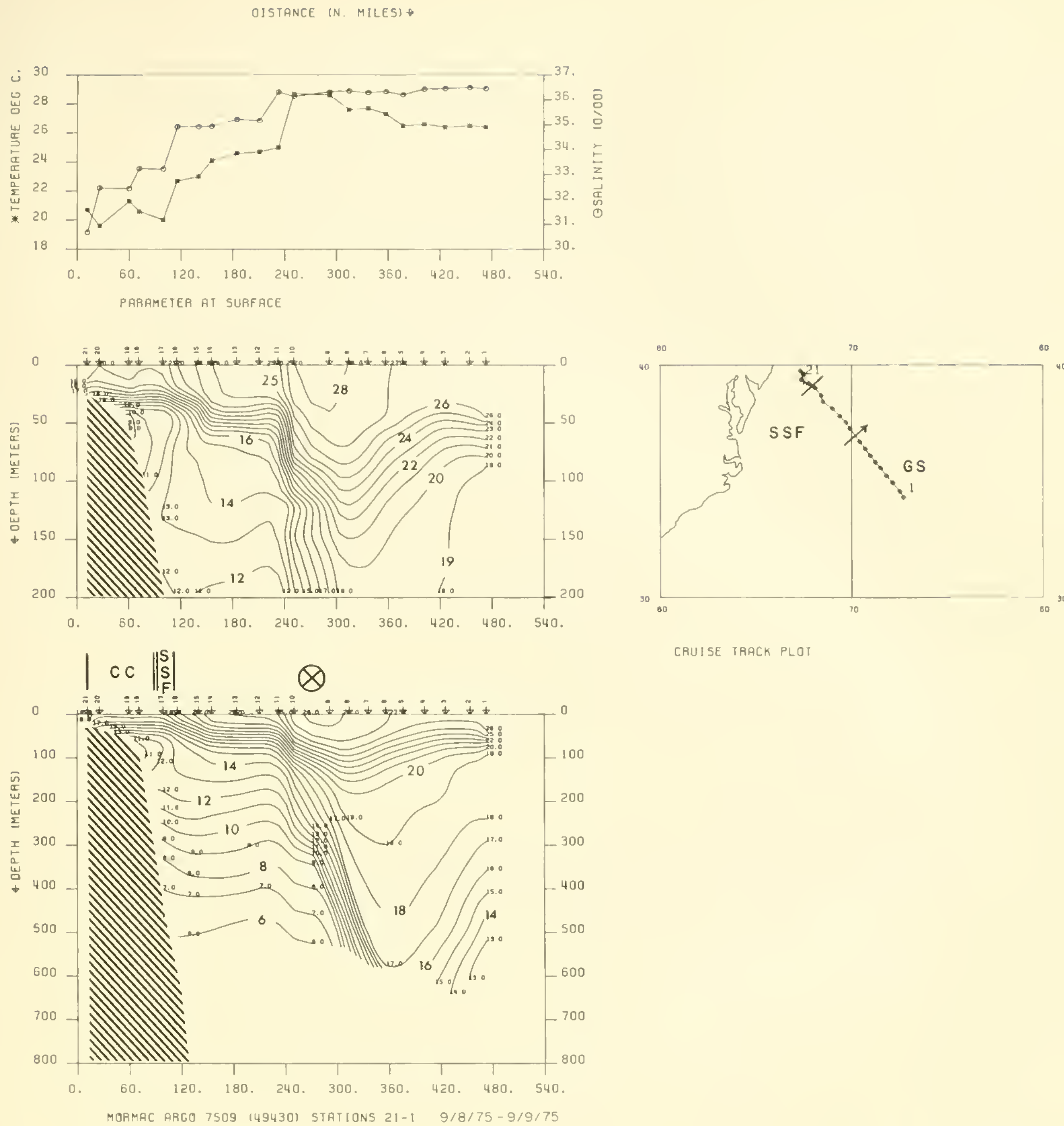
Appendix Figure 33.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 500 m. *Chase*—15 June 1975.



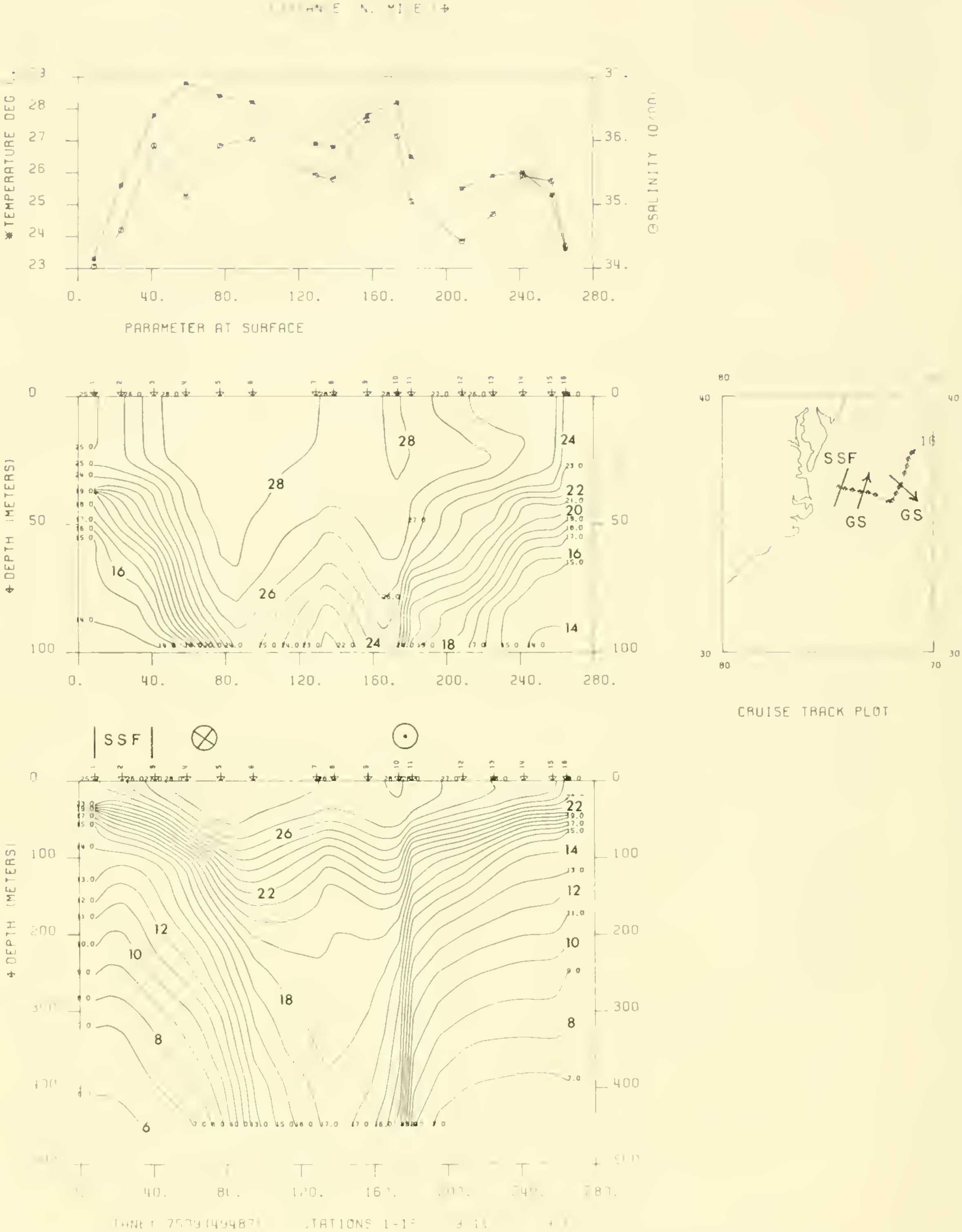
Appendix Figure 34.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 500 m. *Chase*—16 June 1975.



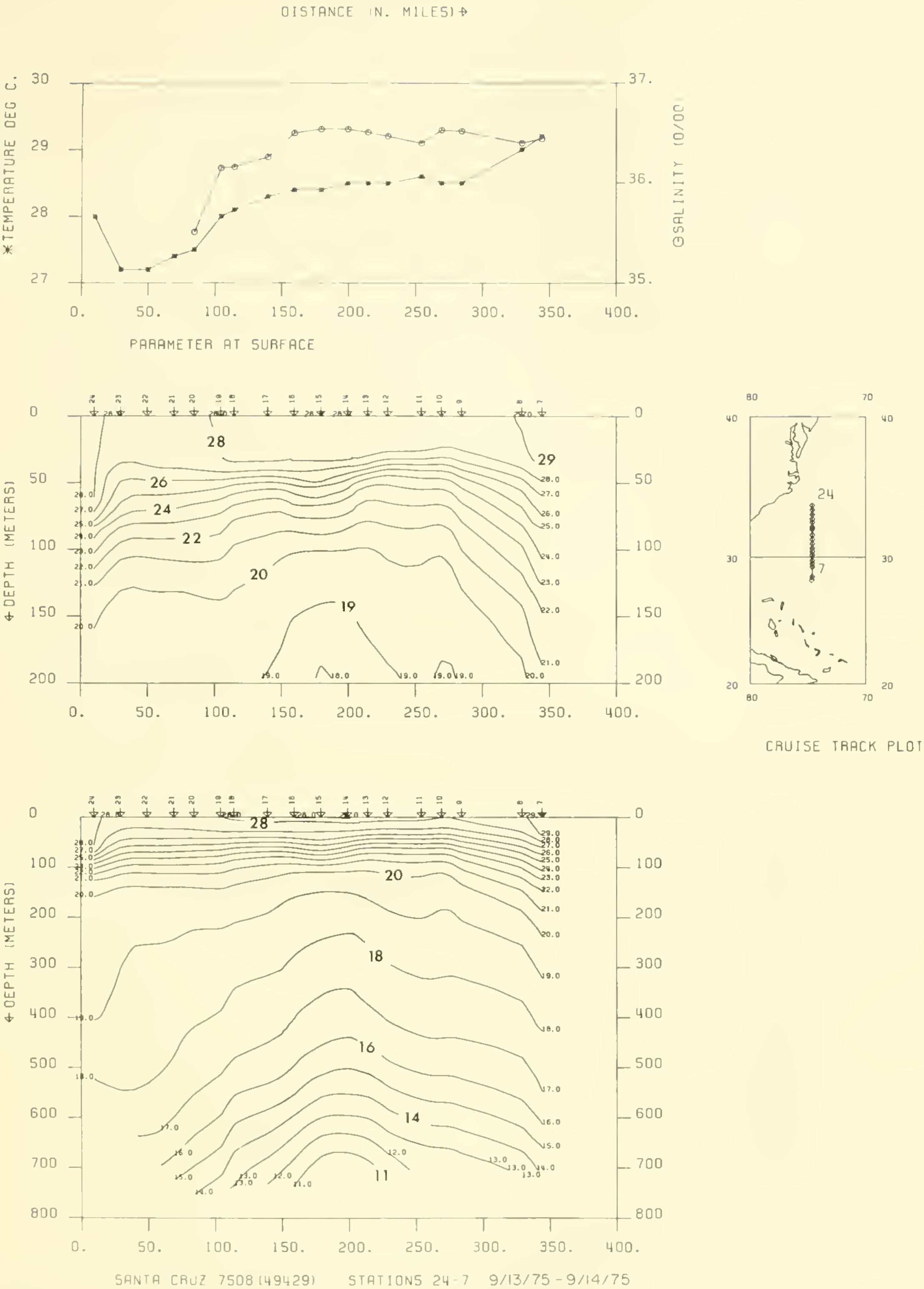
Appendix Figure 35.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Trident*—24-25 June 1975.



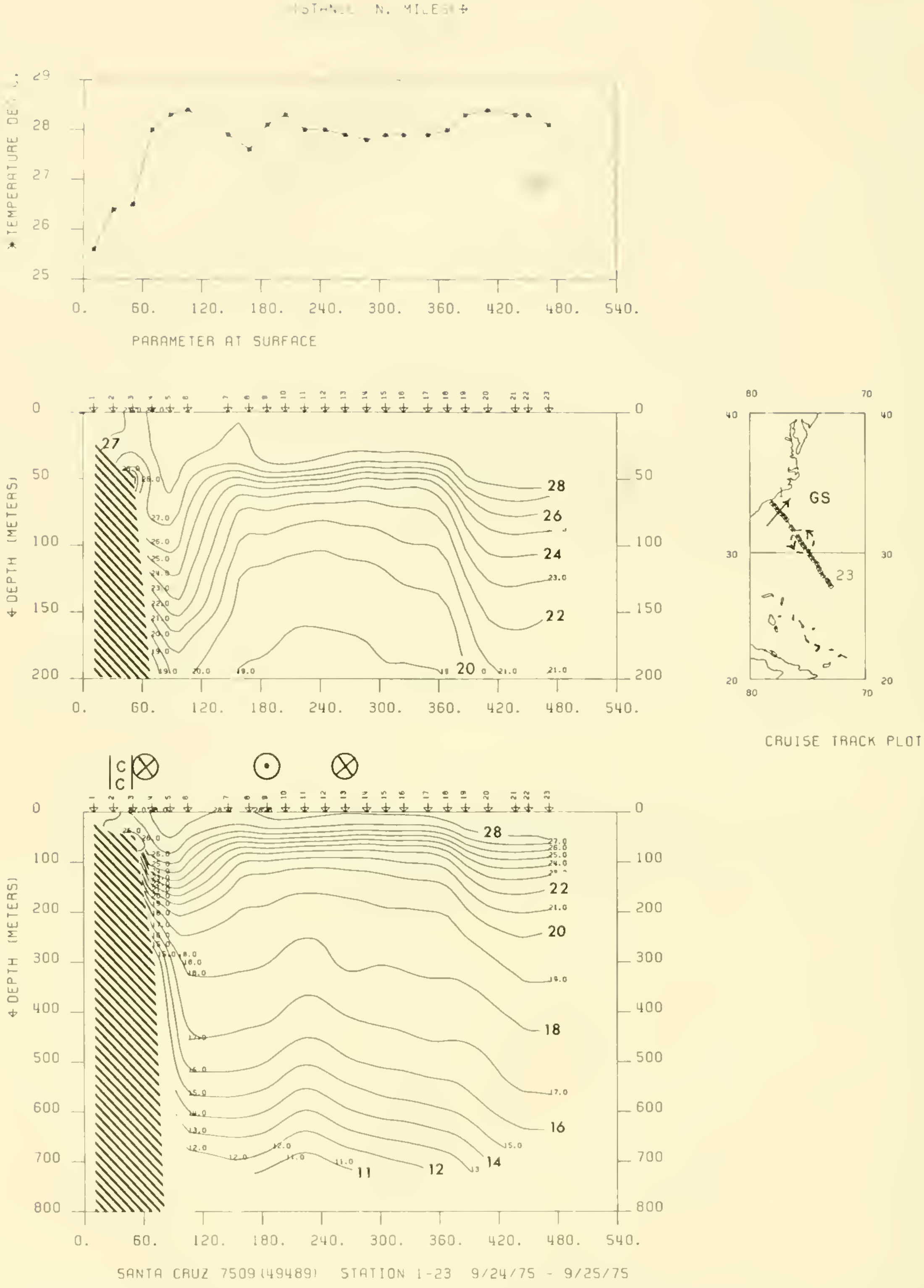
Appendix Figure 36.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Argo*—8-9 September 1975.



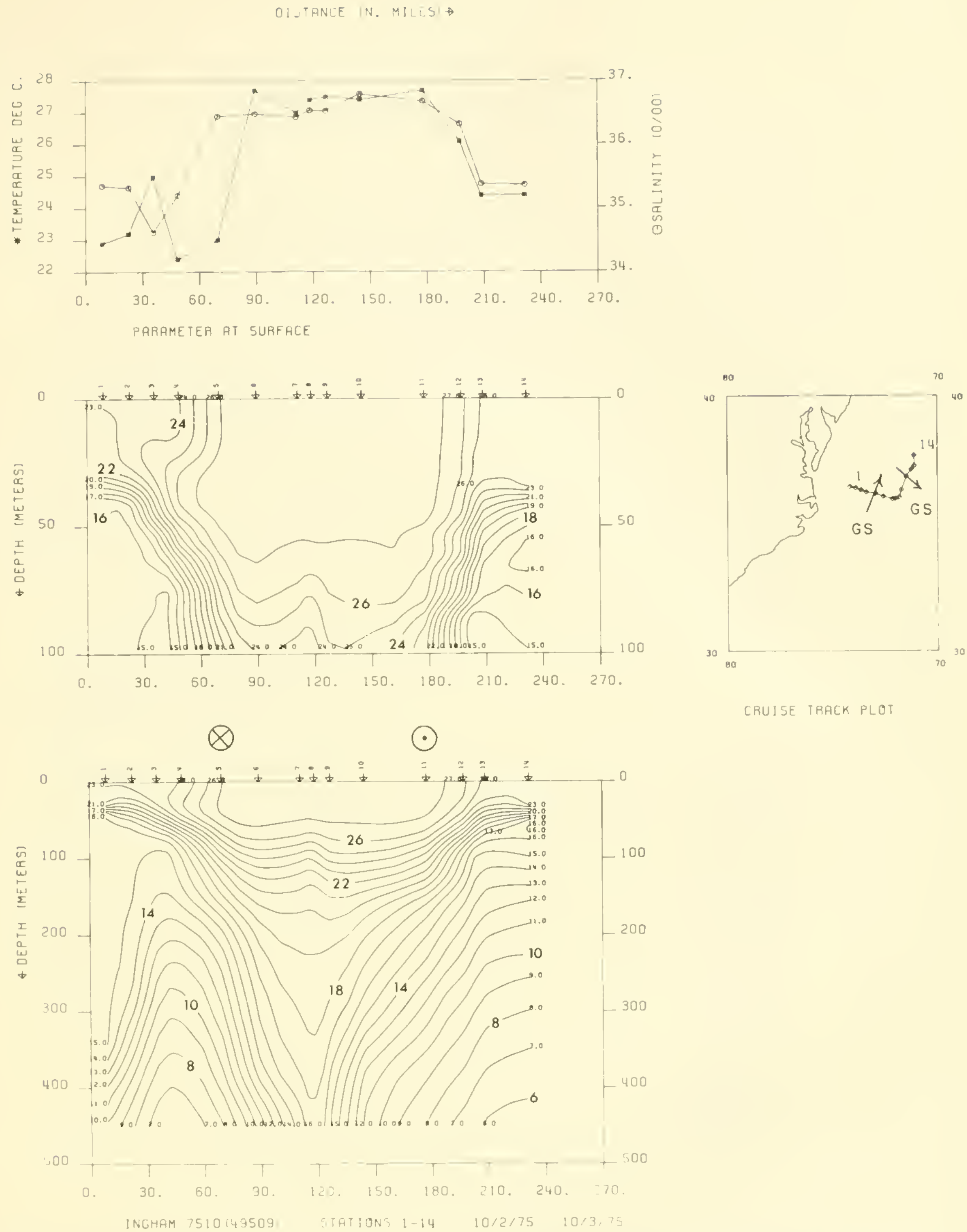
Appendix Figure 37.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Taney*—11-12 September 1975.



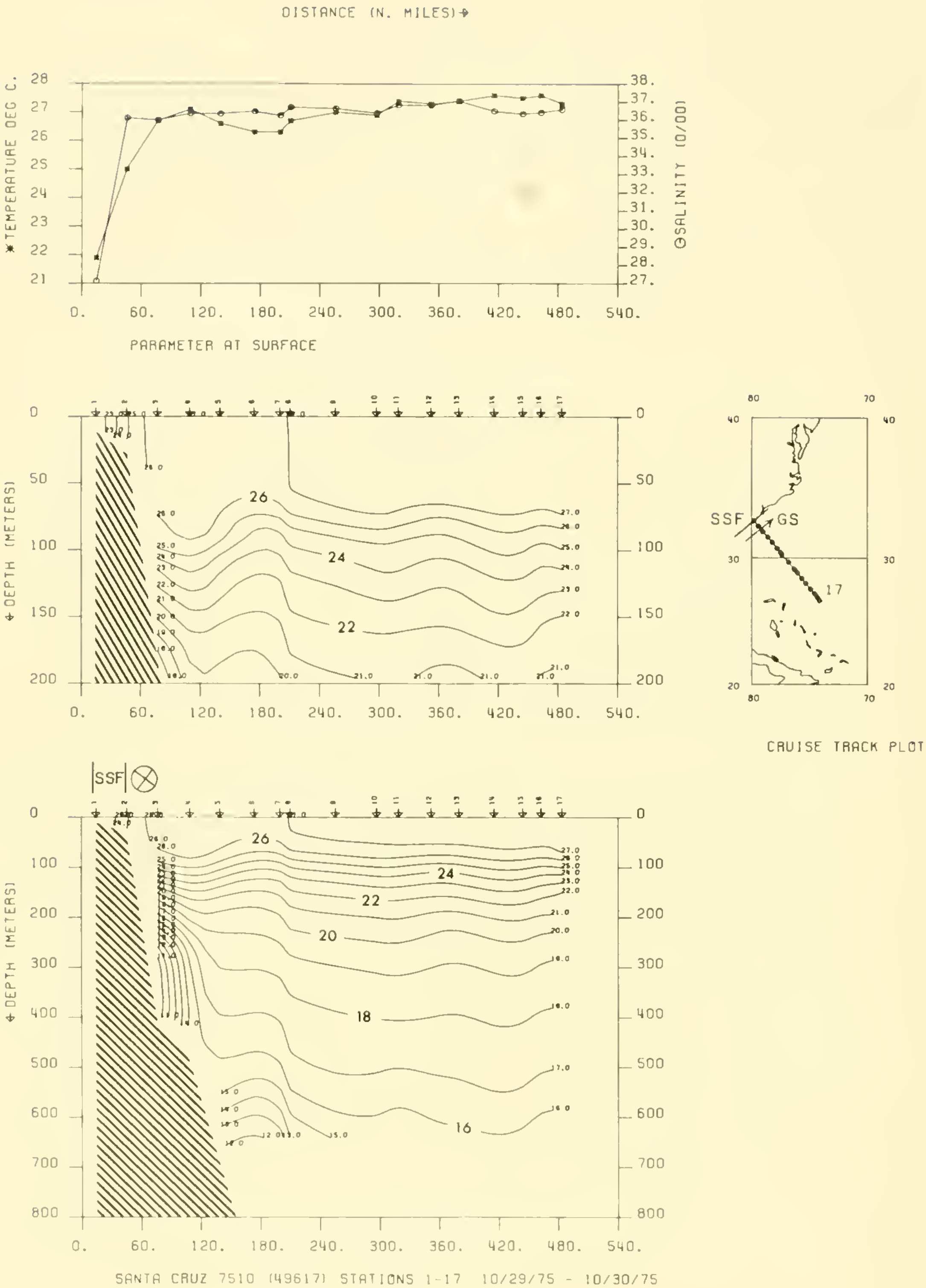
Appendix Figure 38.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—13-14 September 1975.



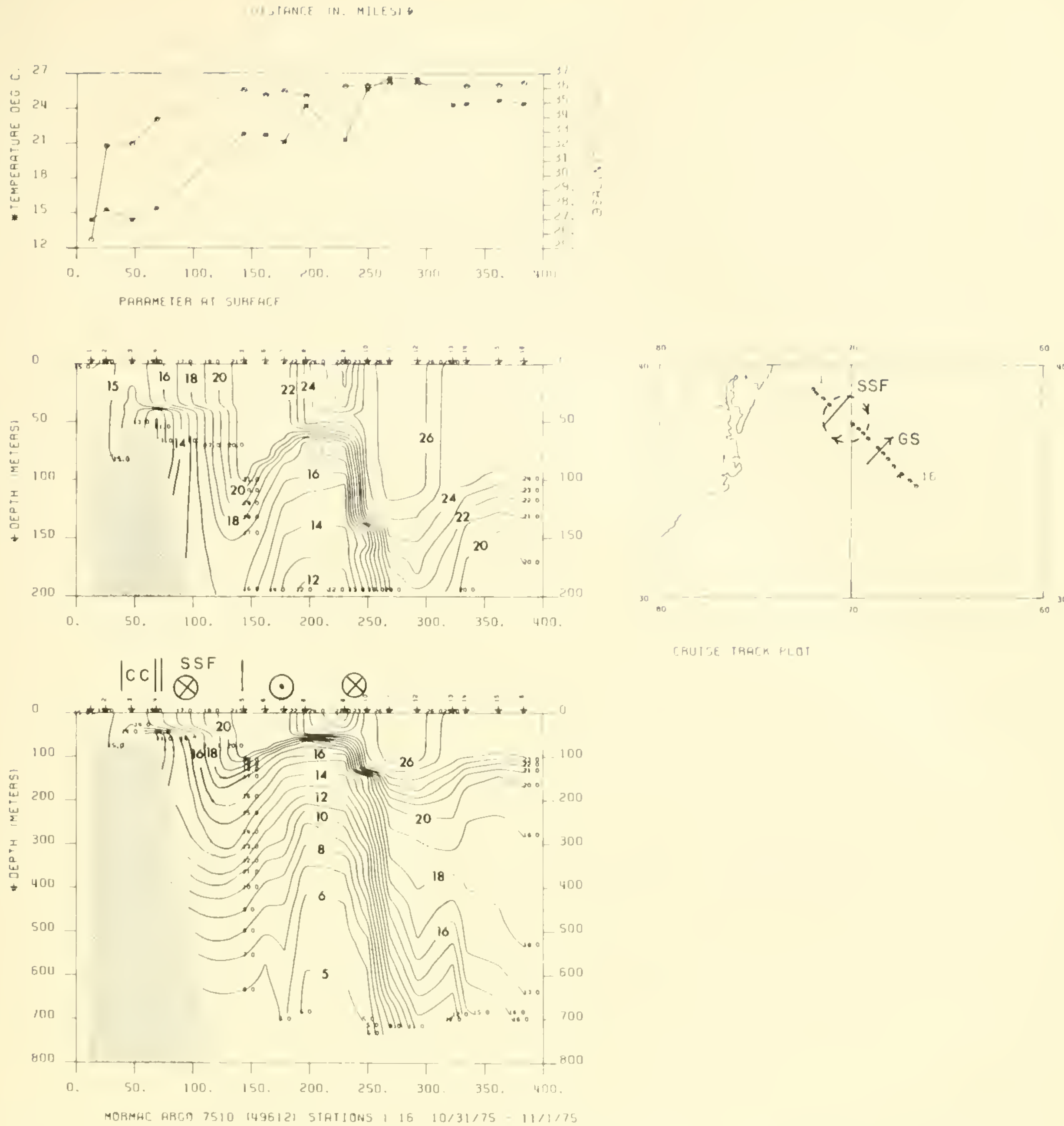
Appendix Figure 39.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—24-25 September 1975.



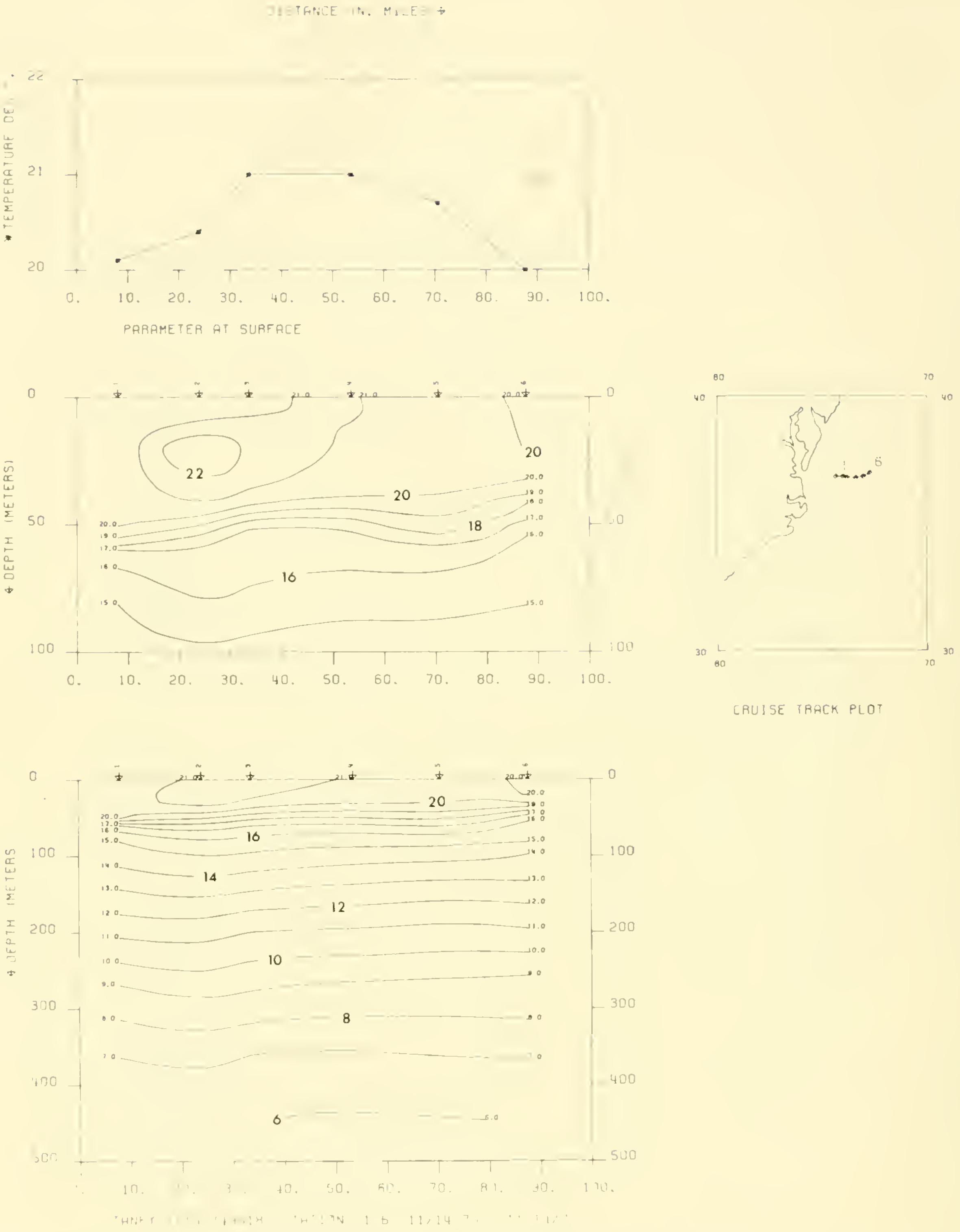
Appendix Figure 40.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Ingham*—2-3 October 1975.



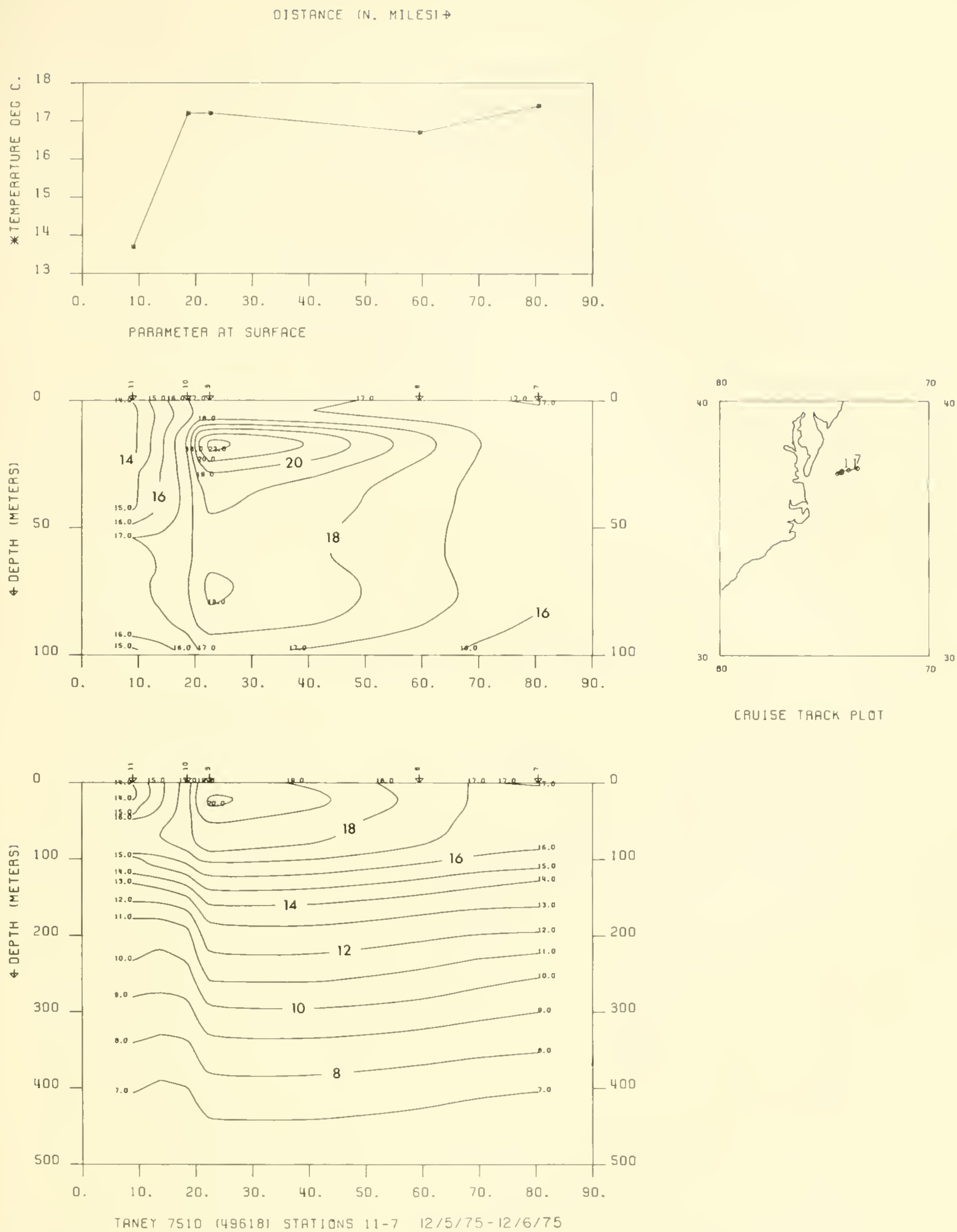
Appendix Figure 41.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—29-30 October 1975.



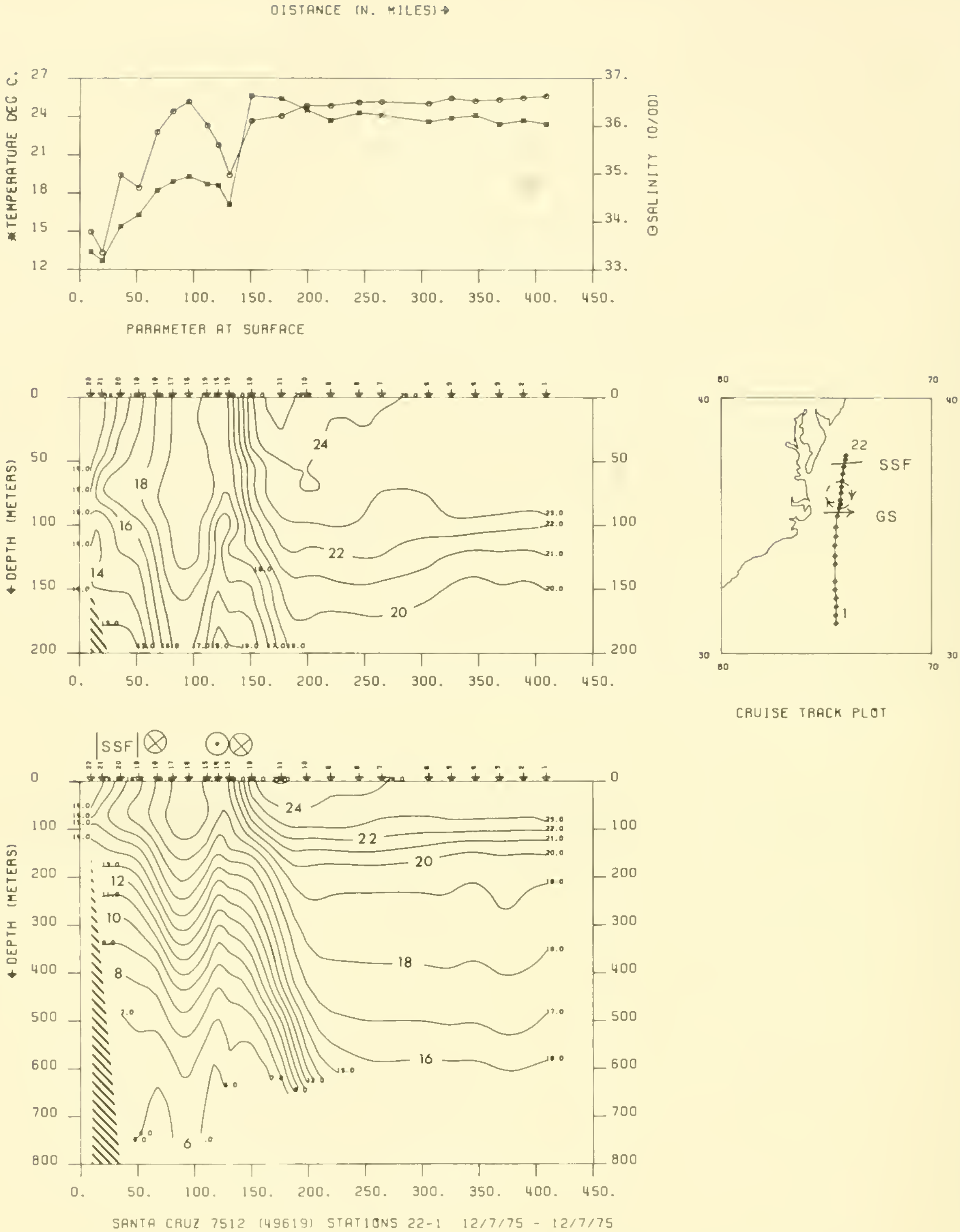
Appendix Figure 42.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Argo*—31 October-1 November 1975.



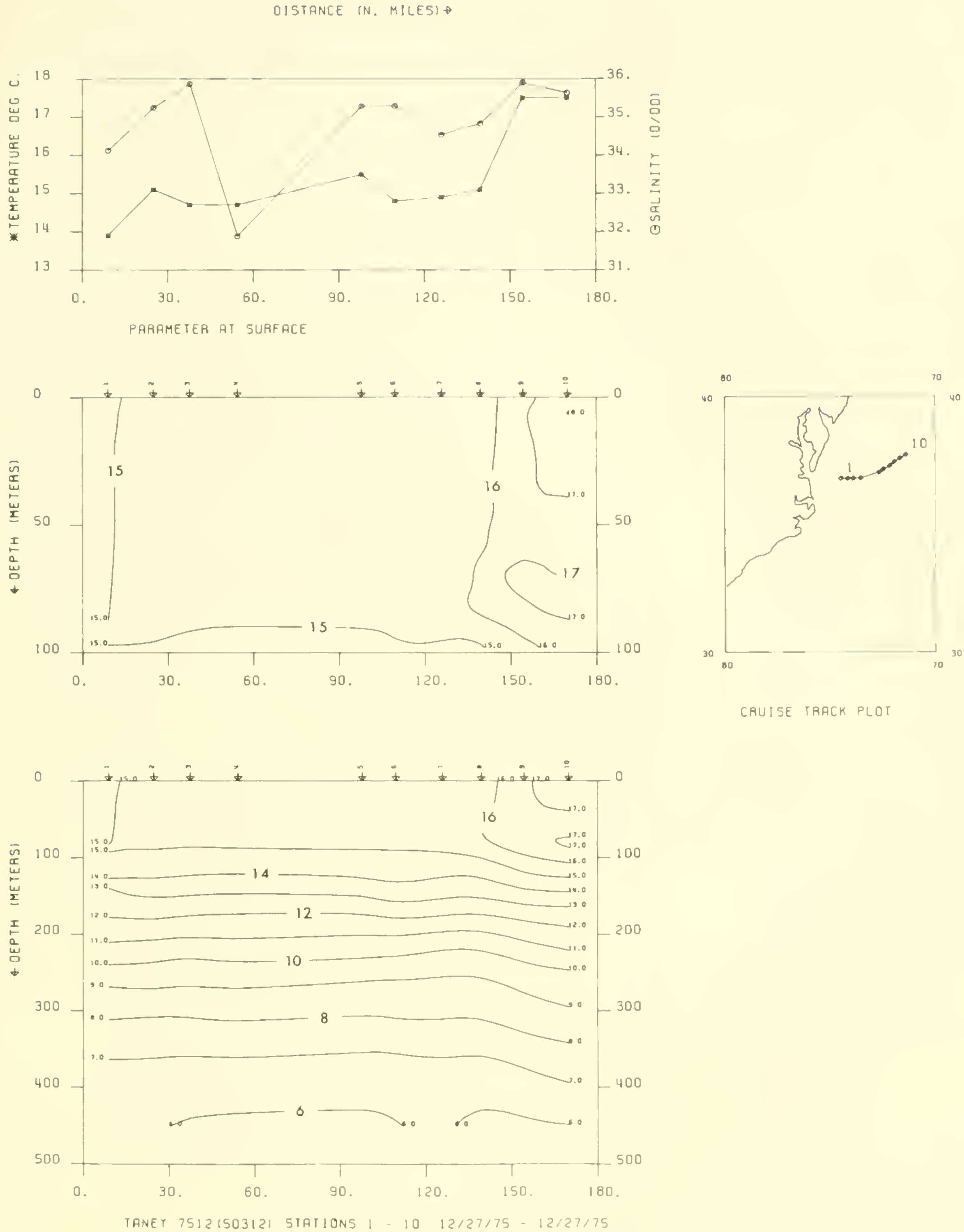
Appendix Figure 43.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Taney*—14 November 1975.



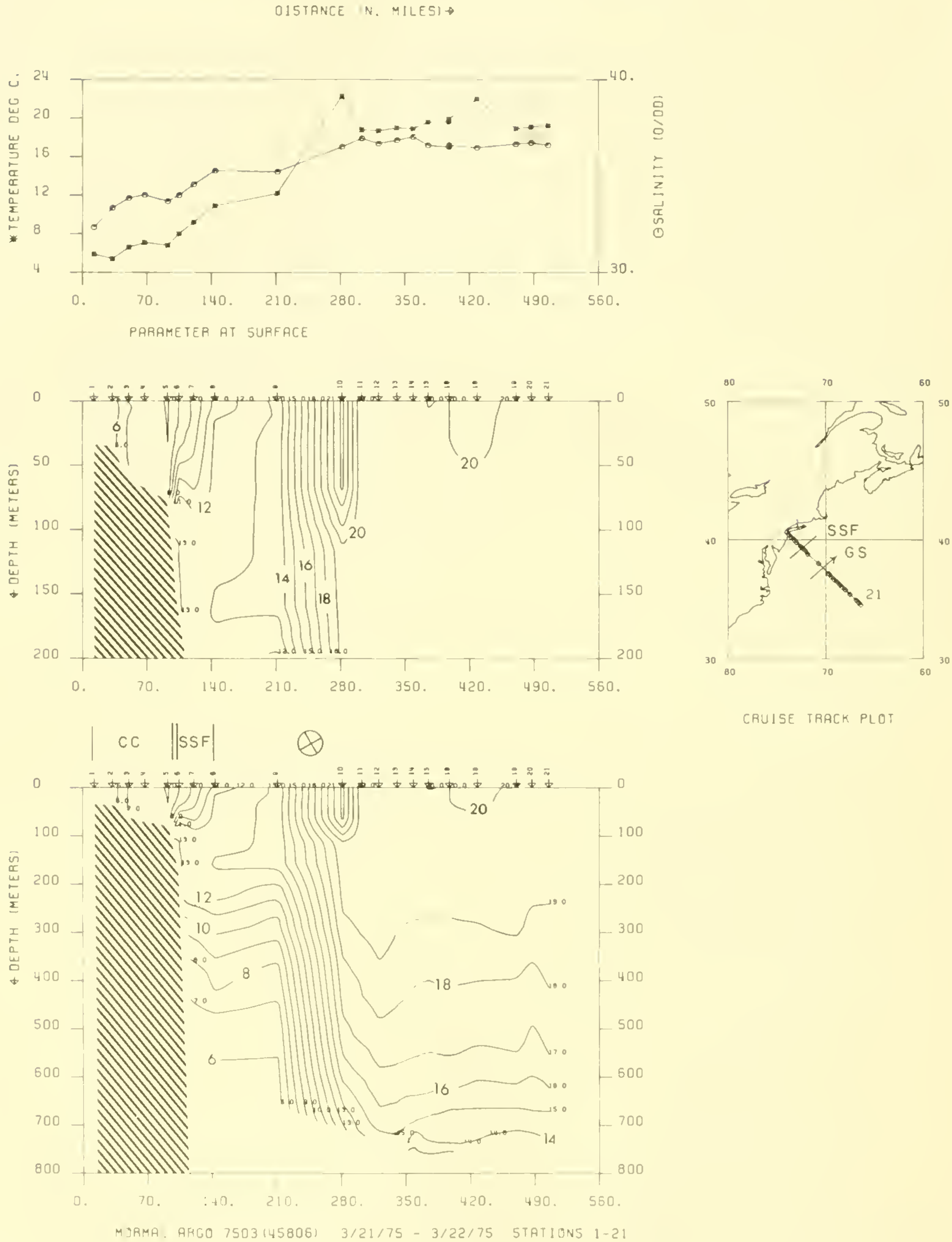
Appendix Figure 44.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Taney*—5-6 December 1975.



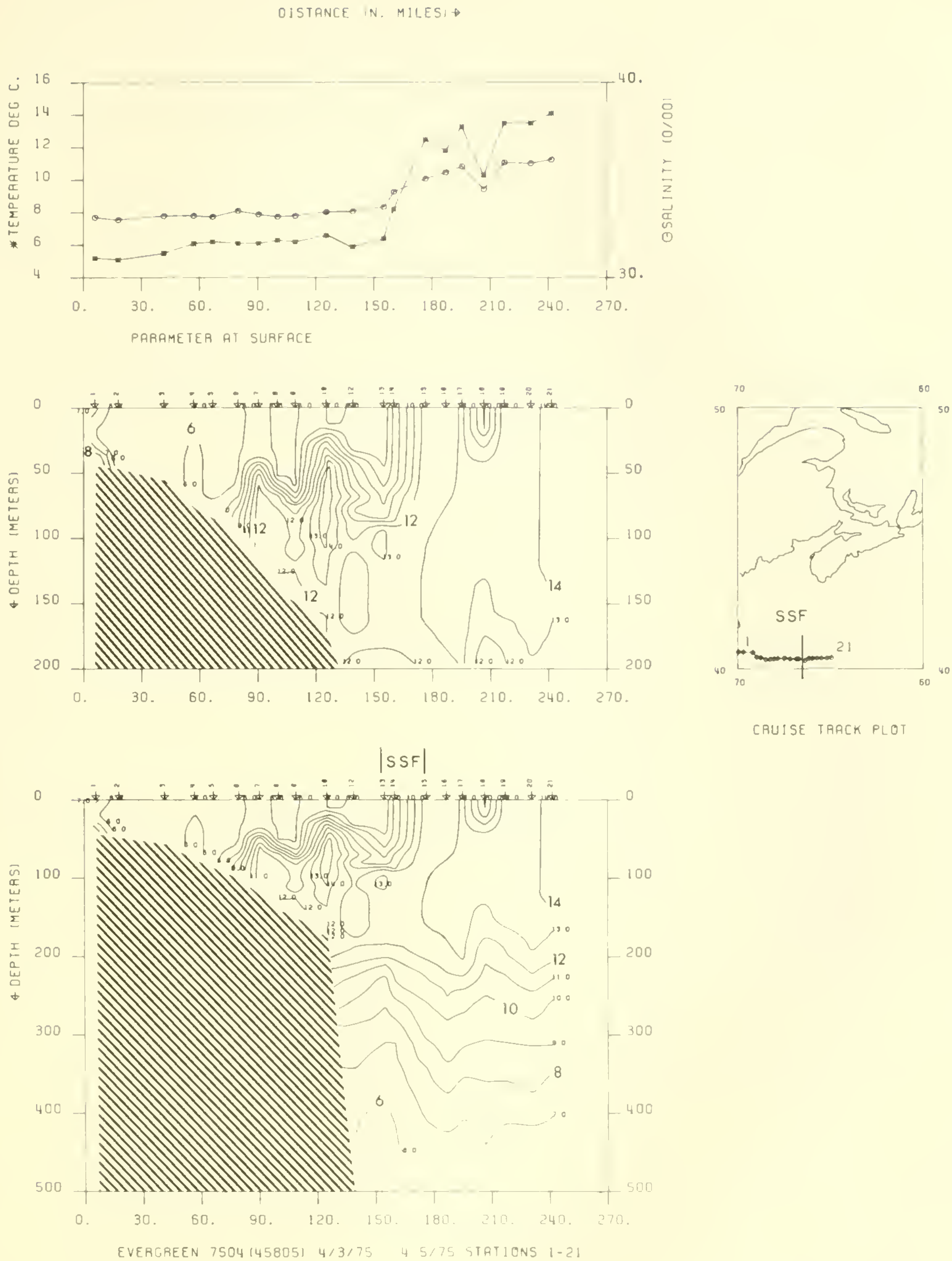
Appendix Figure 45. Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—7 December 1975.



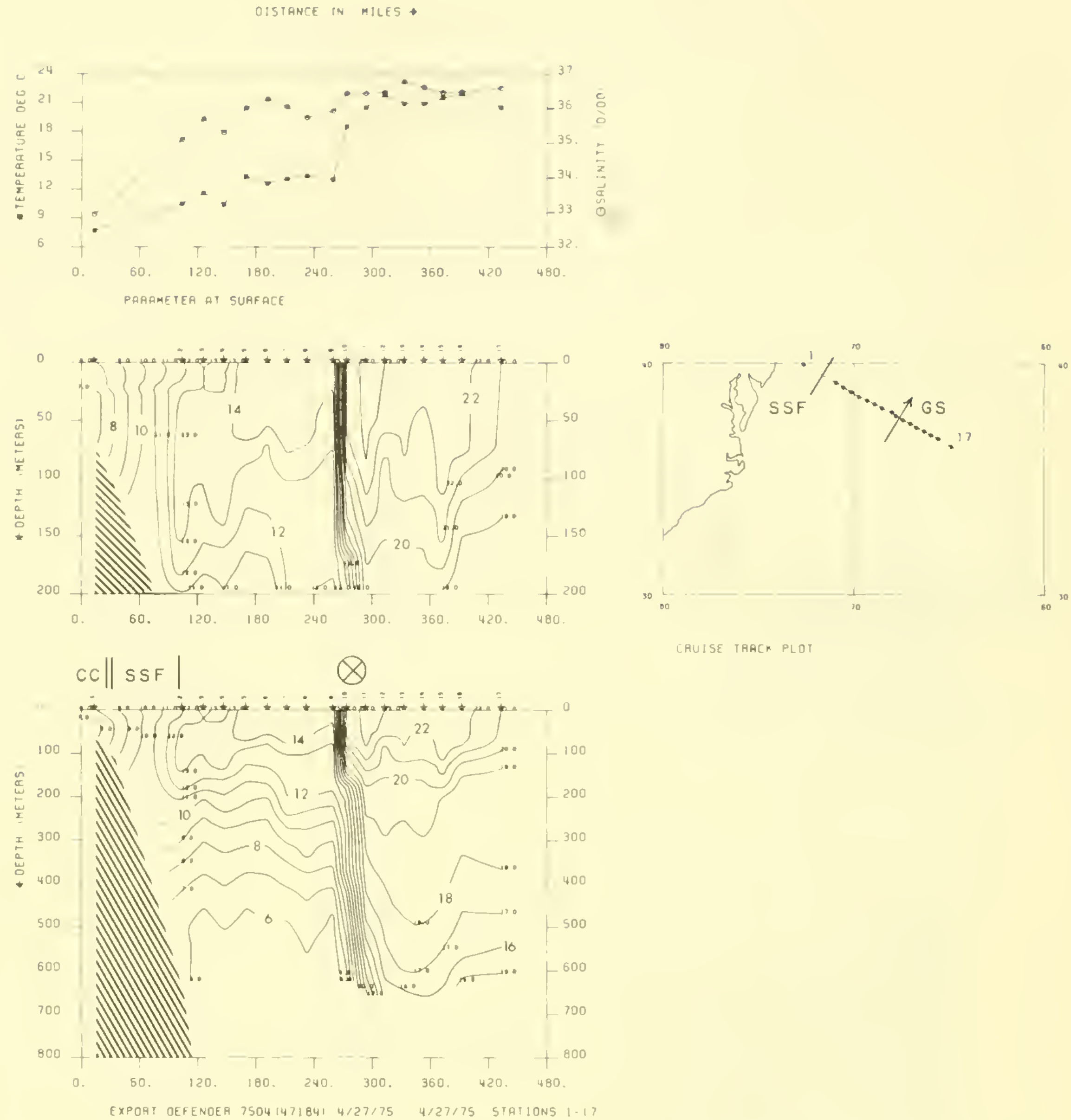
Appendix Figure 46.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Taney*—27 December 1975.



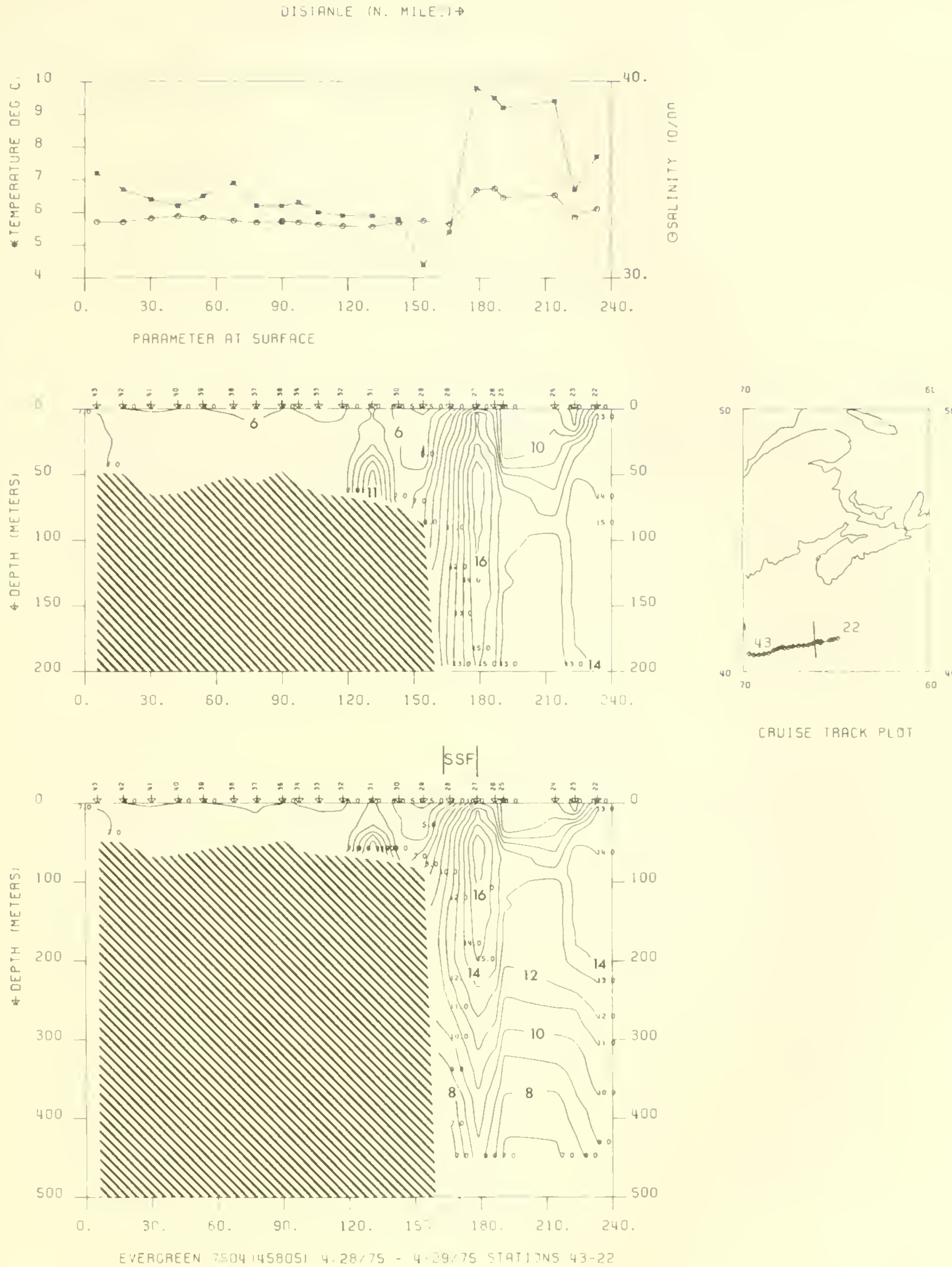
Appendix Figure 47.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Argo*—21-22 March 1975.



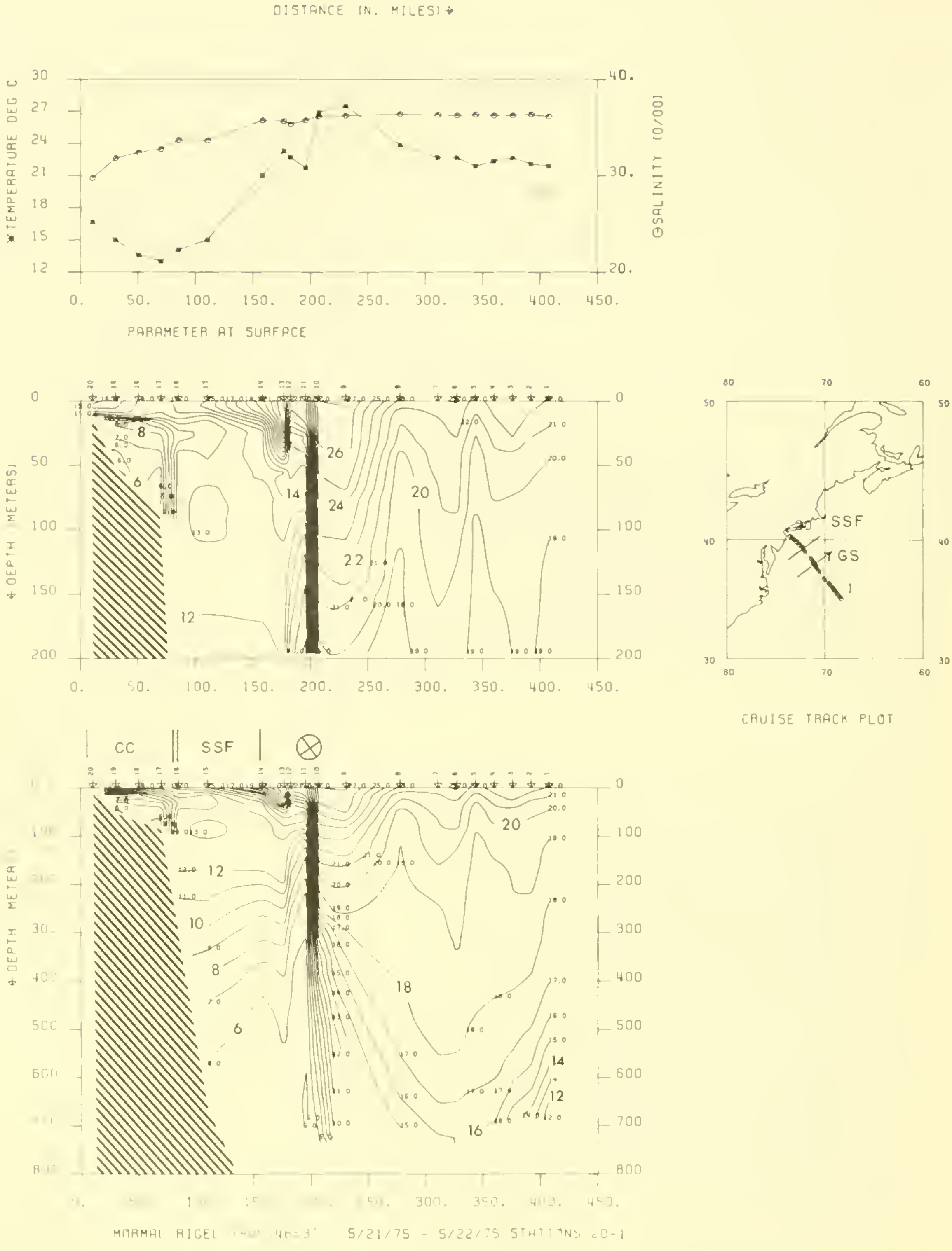
Appendix Figure 48.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity ( ) and vertical distribution of temperature (°C) in the upper 200 and 500 m. *Evergreen*—3-5 April 1975.



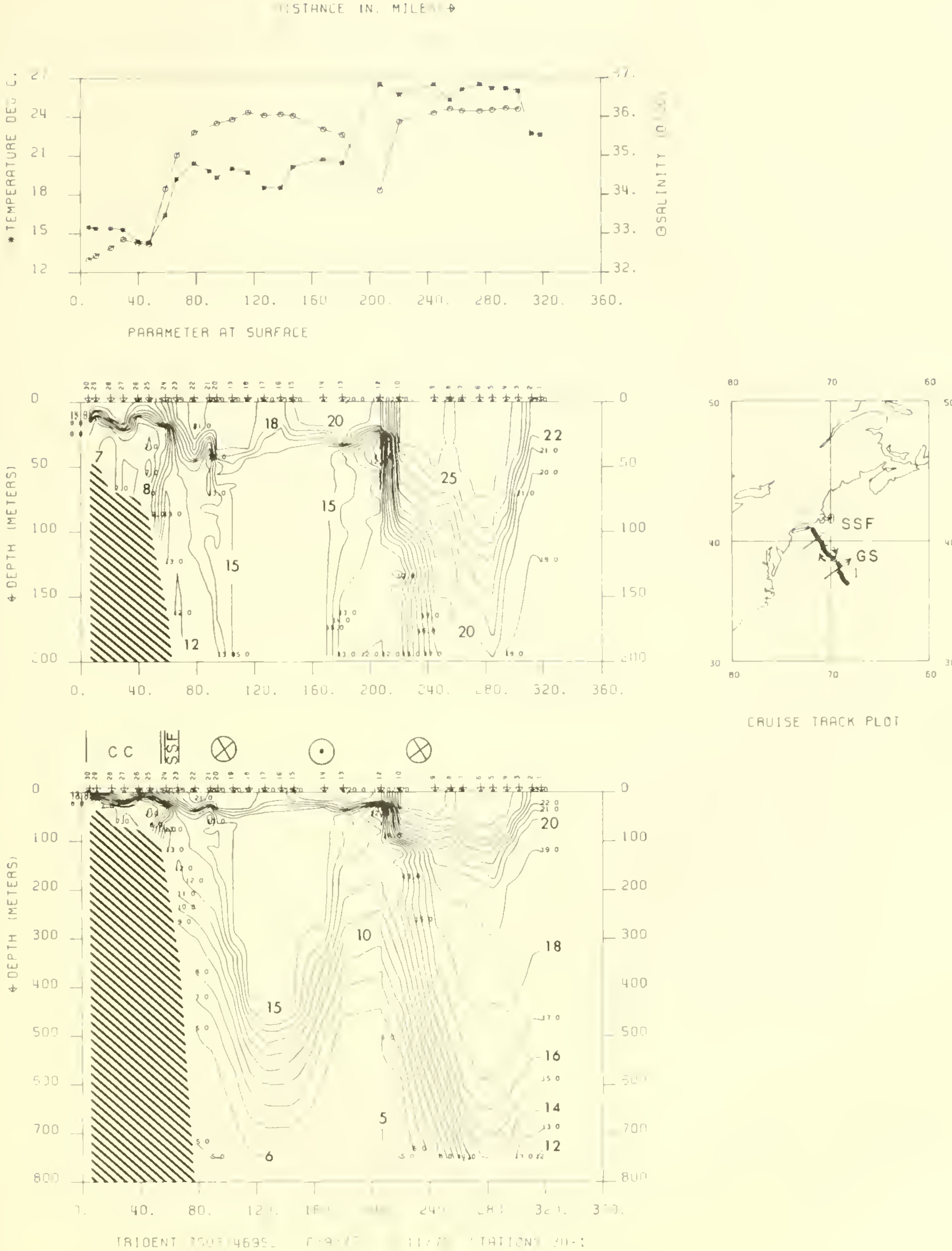
Appendix Figure 49.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Export Defender*—27 April 1975.



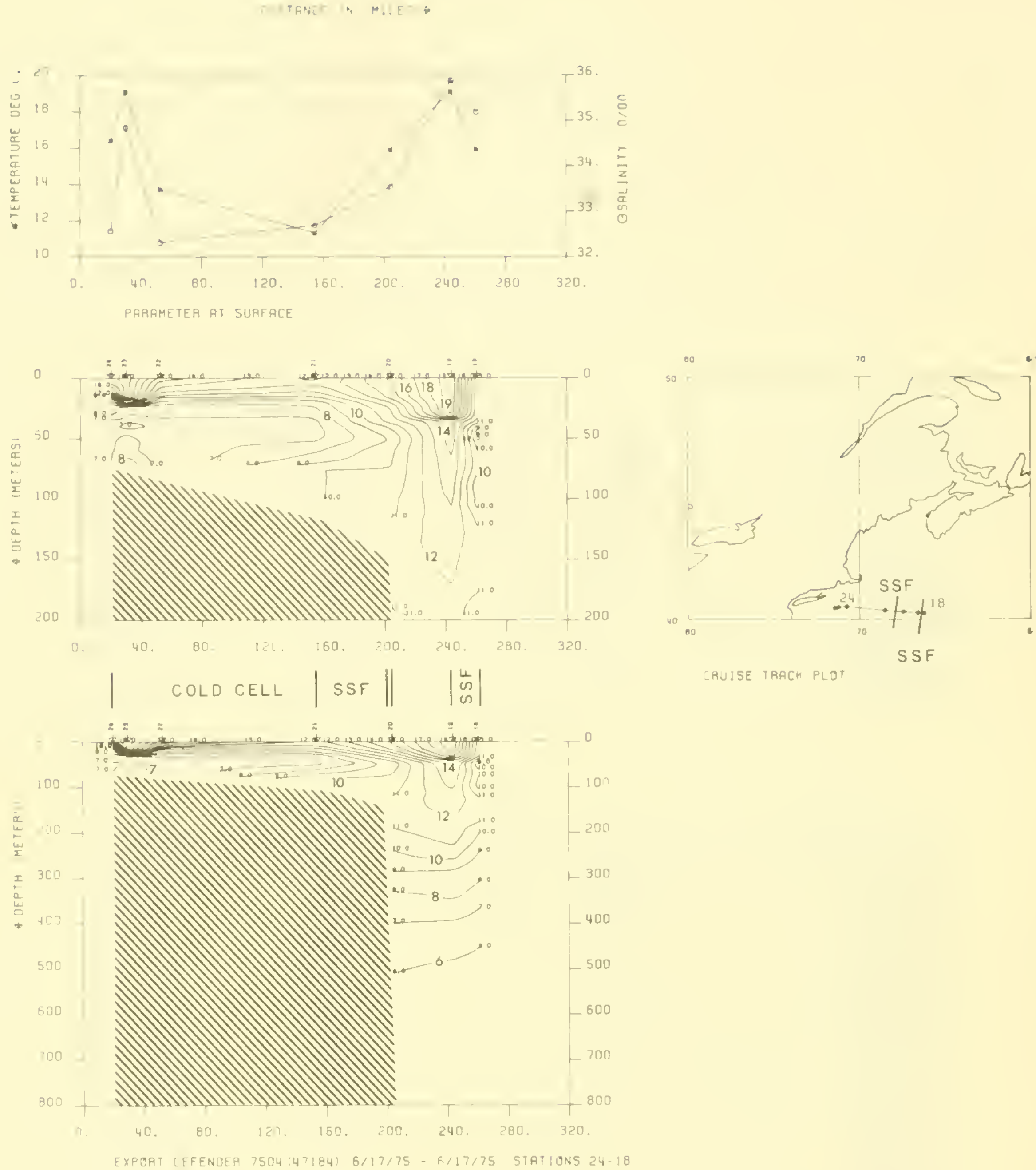
Appendix Figure 50.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 500 m. *Evergreen*—28-29 April 1975.



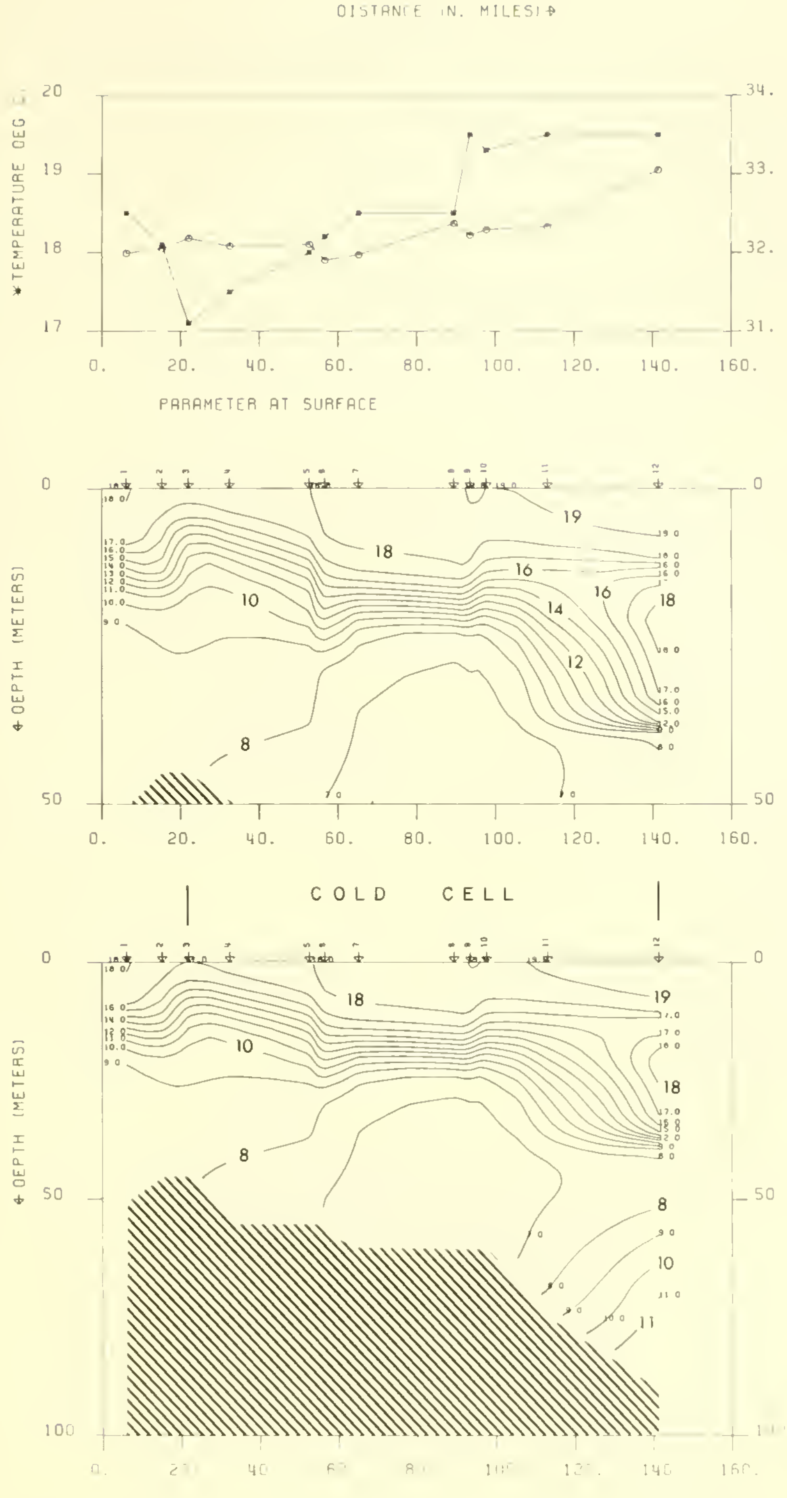
Appendix Figure 51.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Rigel*—21-22 May 1975.

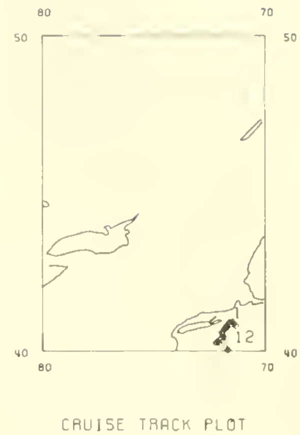


Appendix Figure 52.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Trident*—9-11 June 1975.

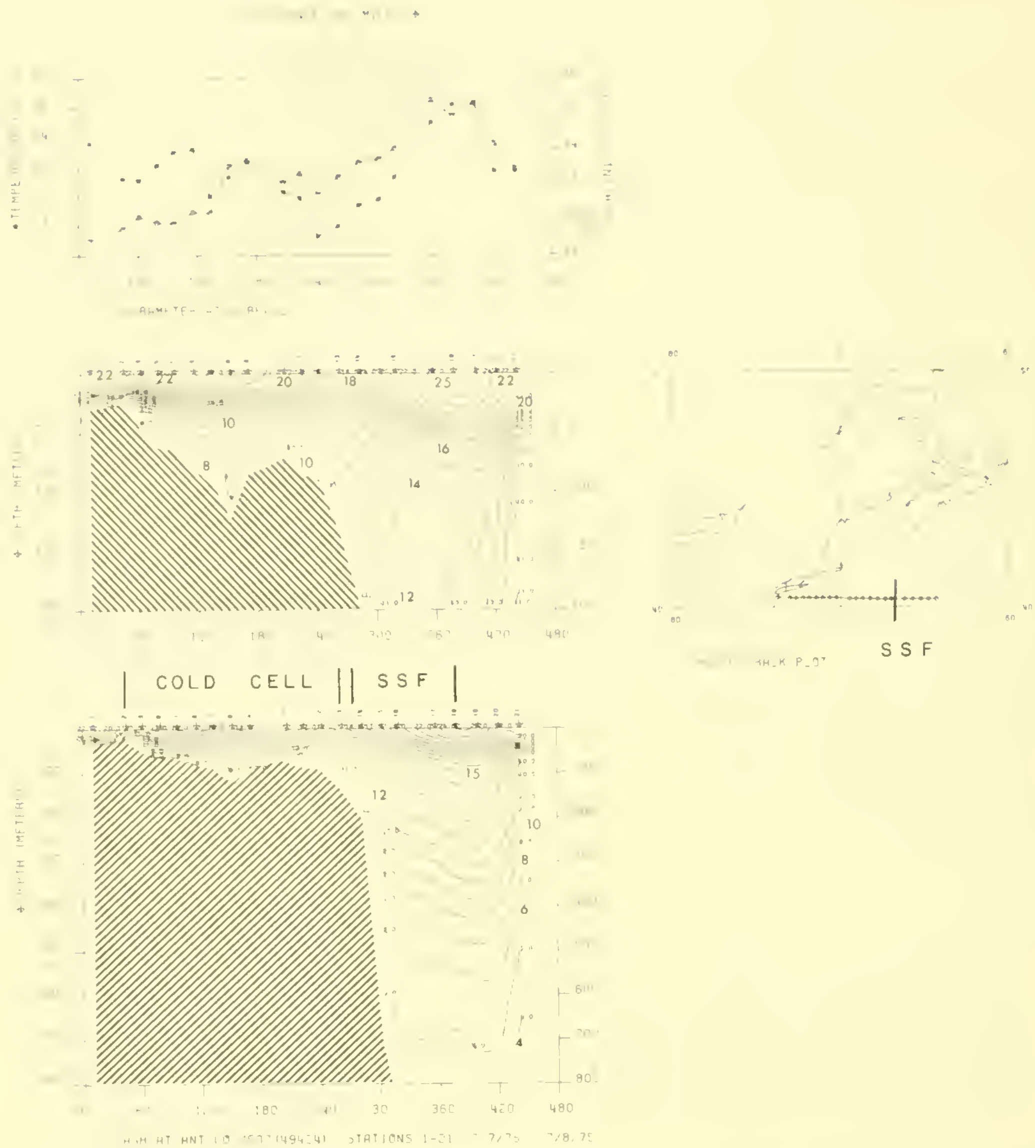


Appendix Figure 53.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Export Defender*—17 June 1975.

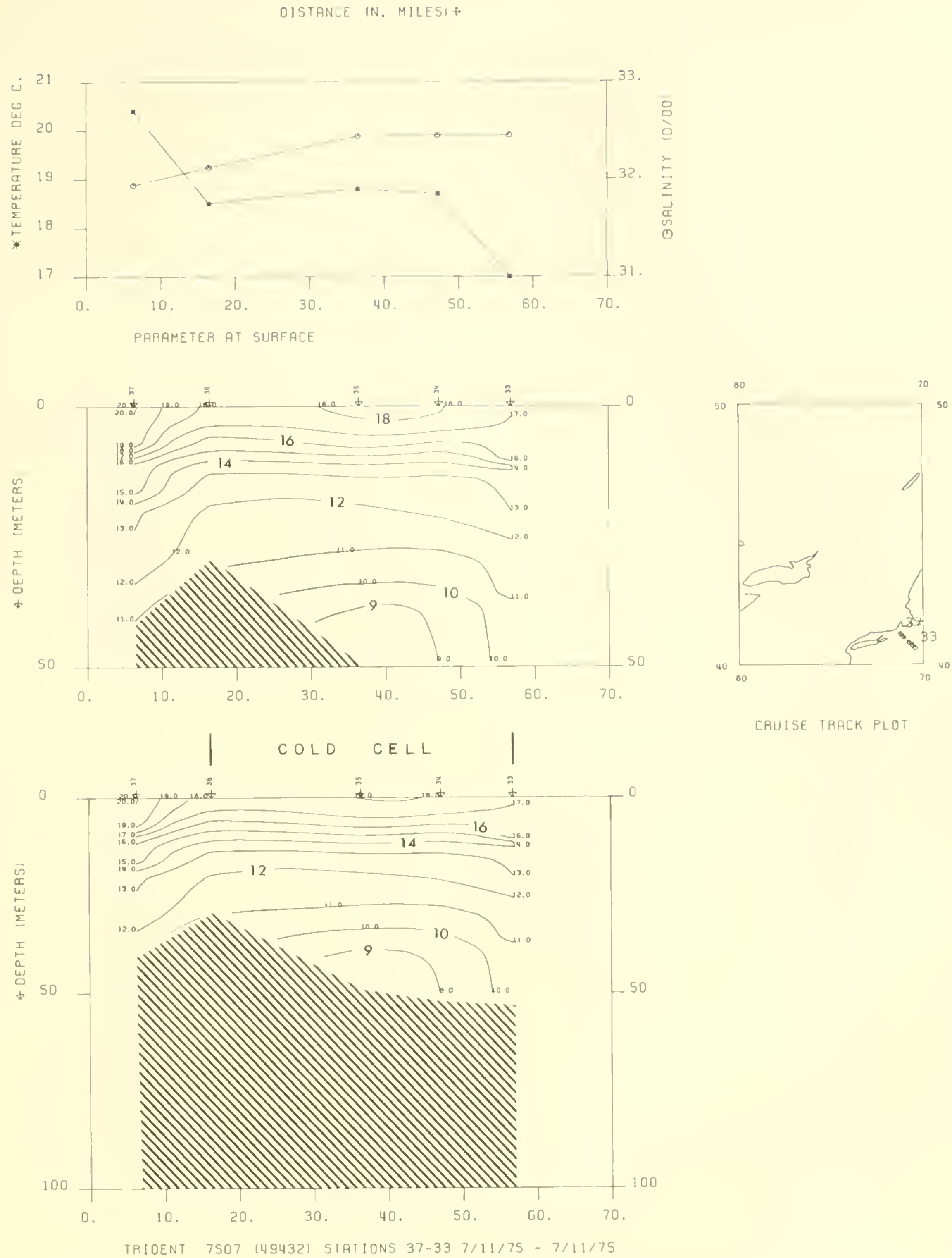




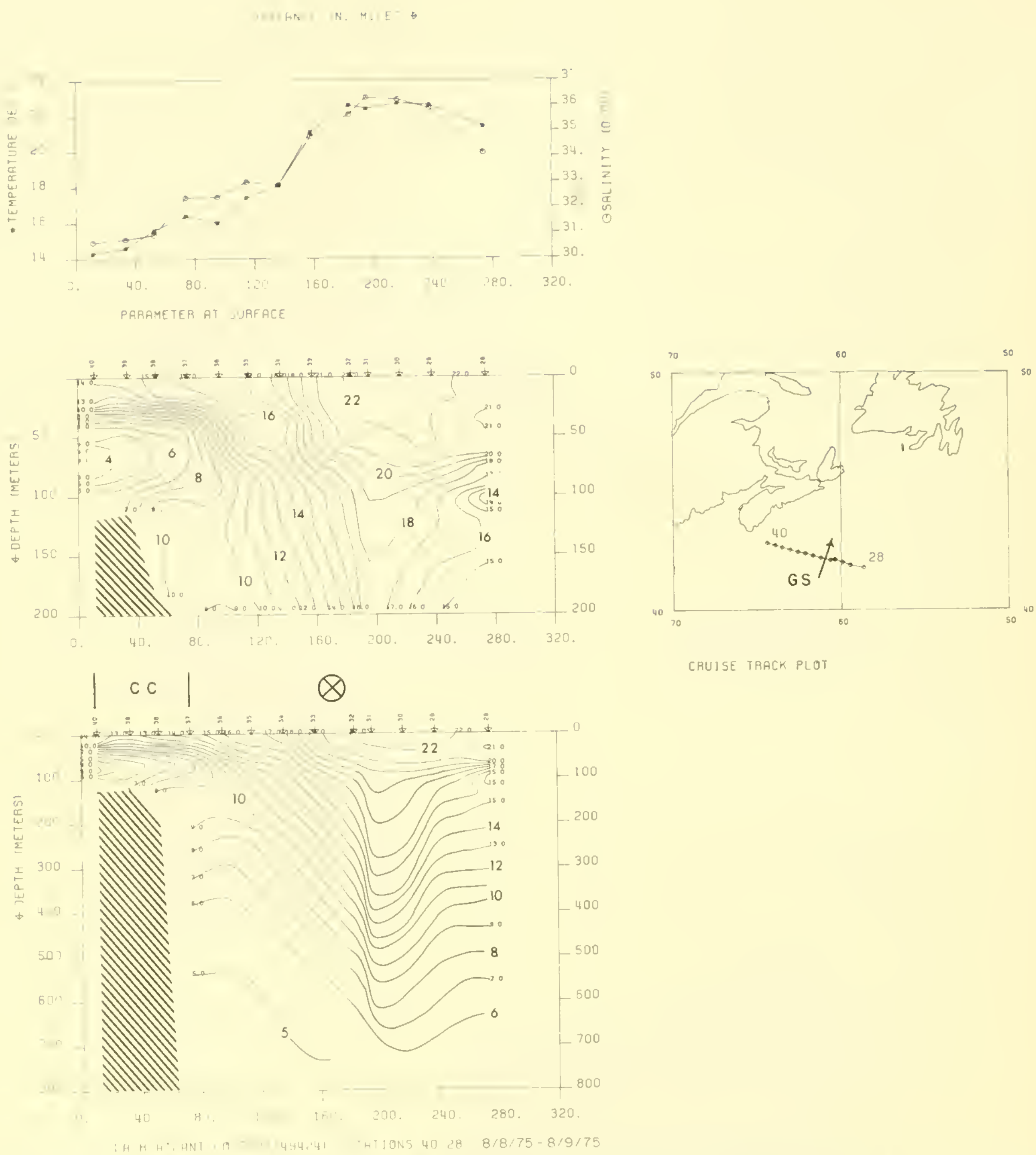
Appendix Figure 54.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 100 m. *Trident*—22-23 June 1975.



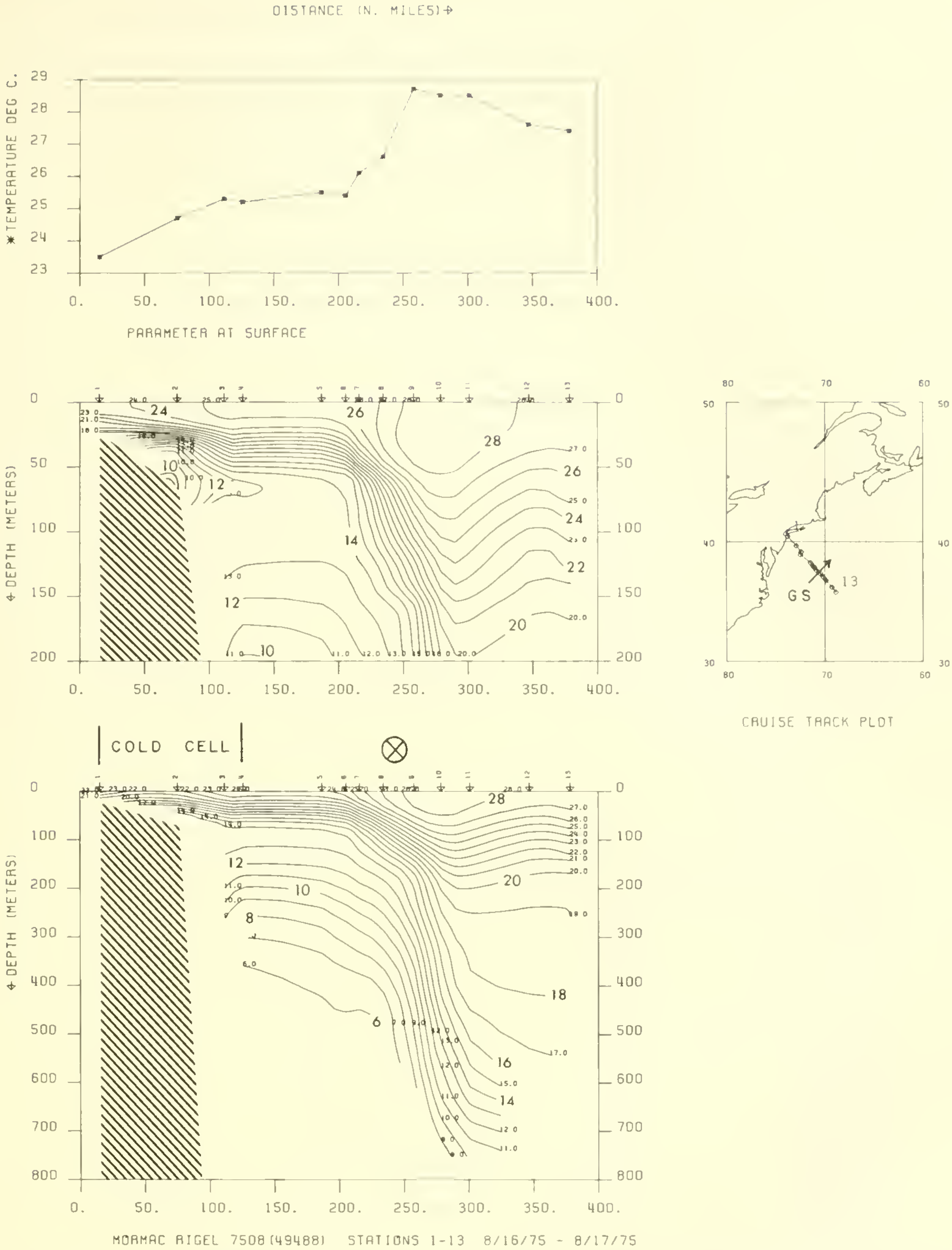
Appendix Figure 55.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Lash Atlantico*—7-8 July 1975.



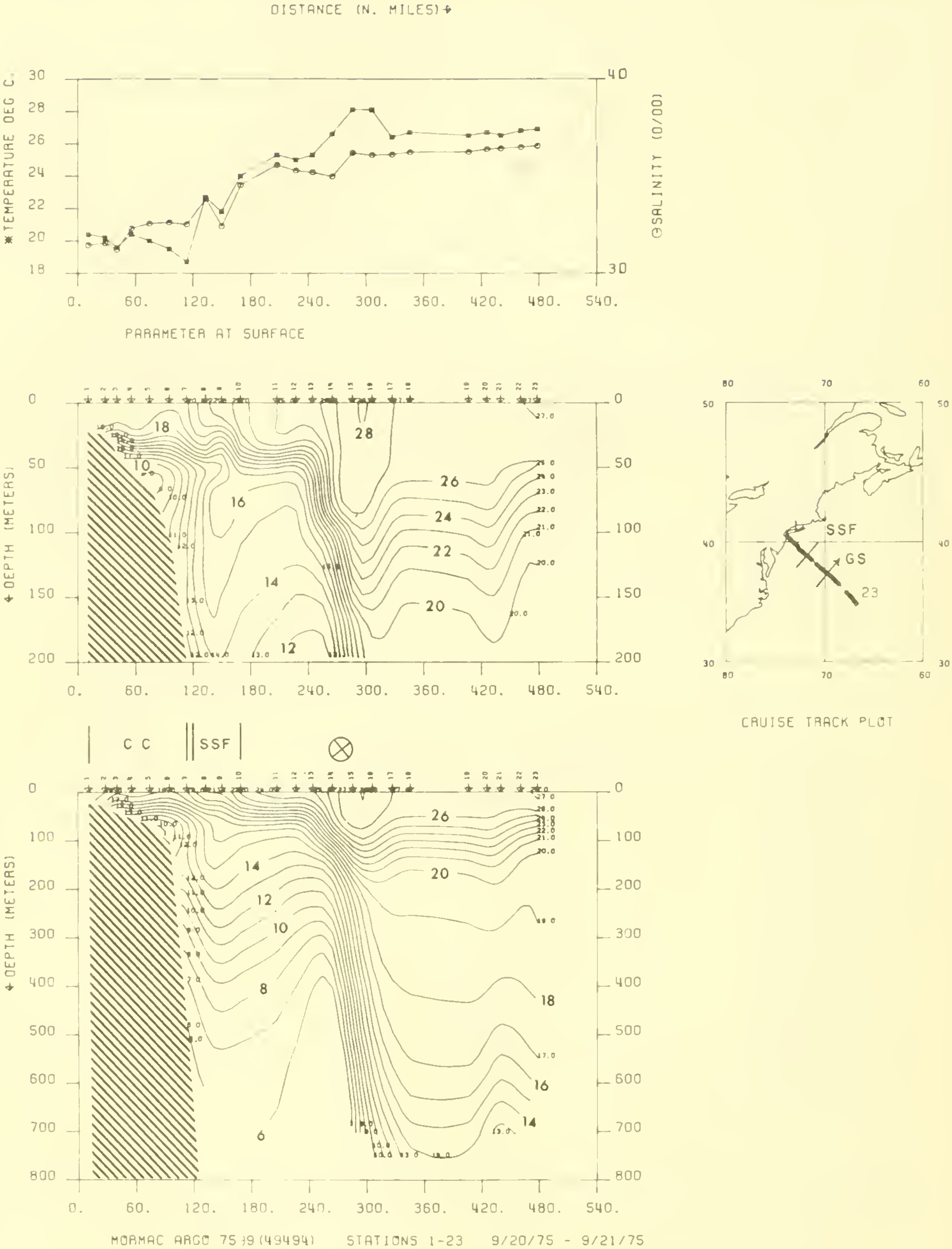
Appendix Figure 56.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 100 m. *Trident*—11 July 1975.



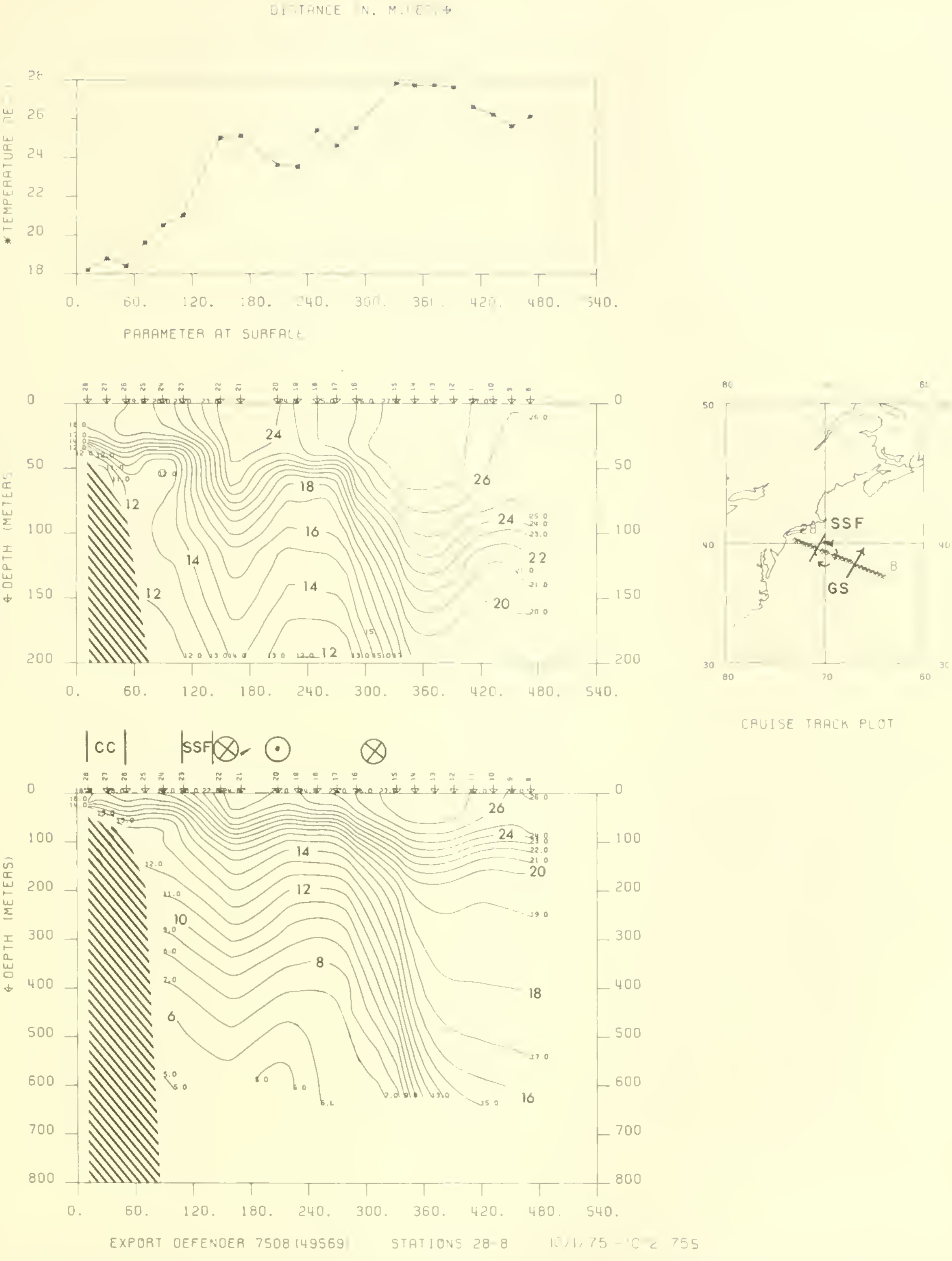
Appendix Figure 57. Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Lash Atlantico*—8-9 August 1975.



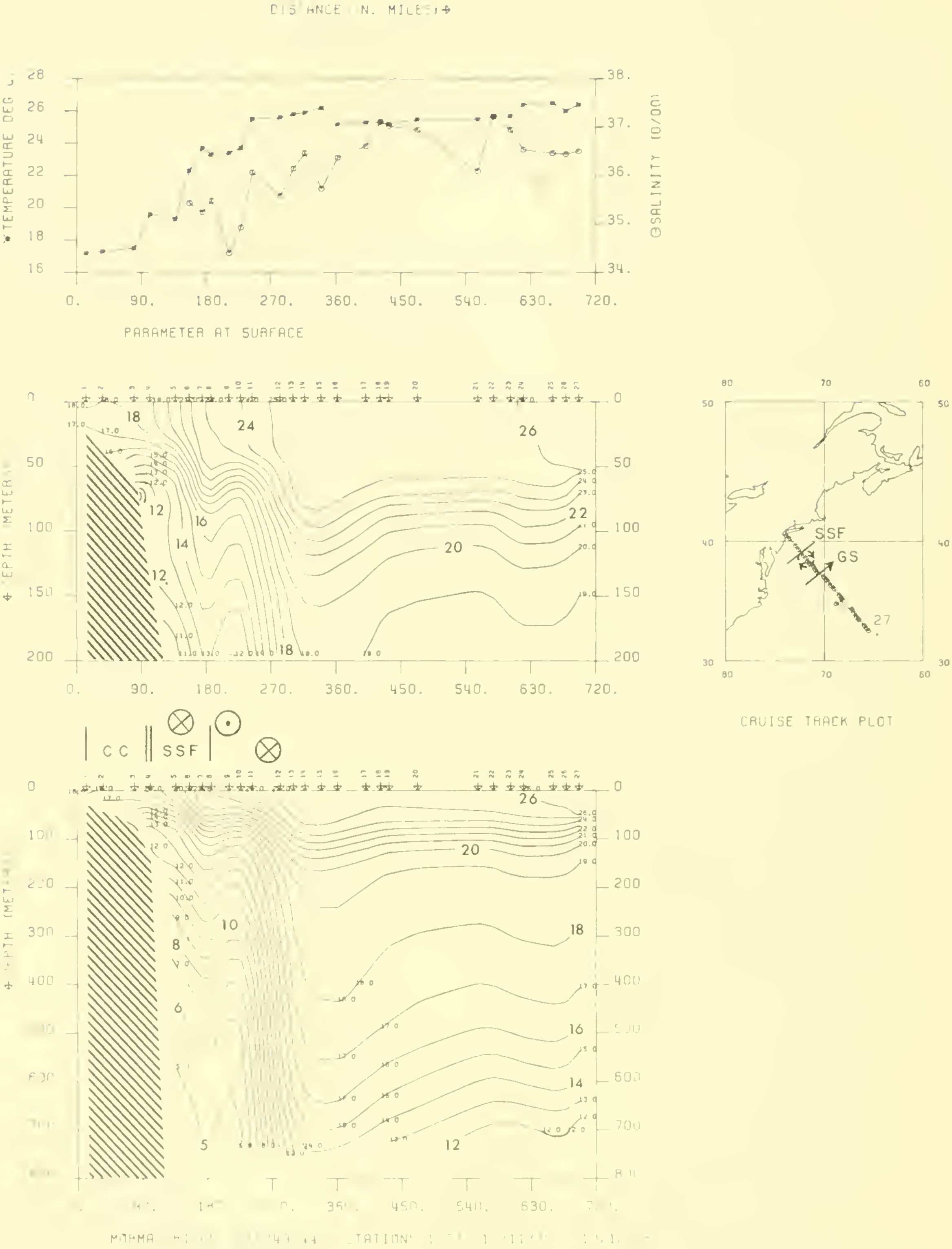
Appendix Figure 58.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. ***Mormac Rigel*****—16-17 August 1975.**



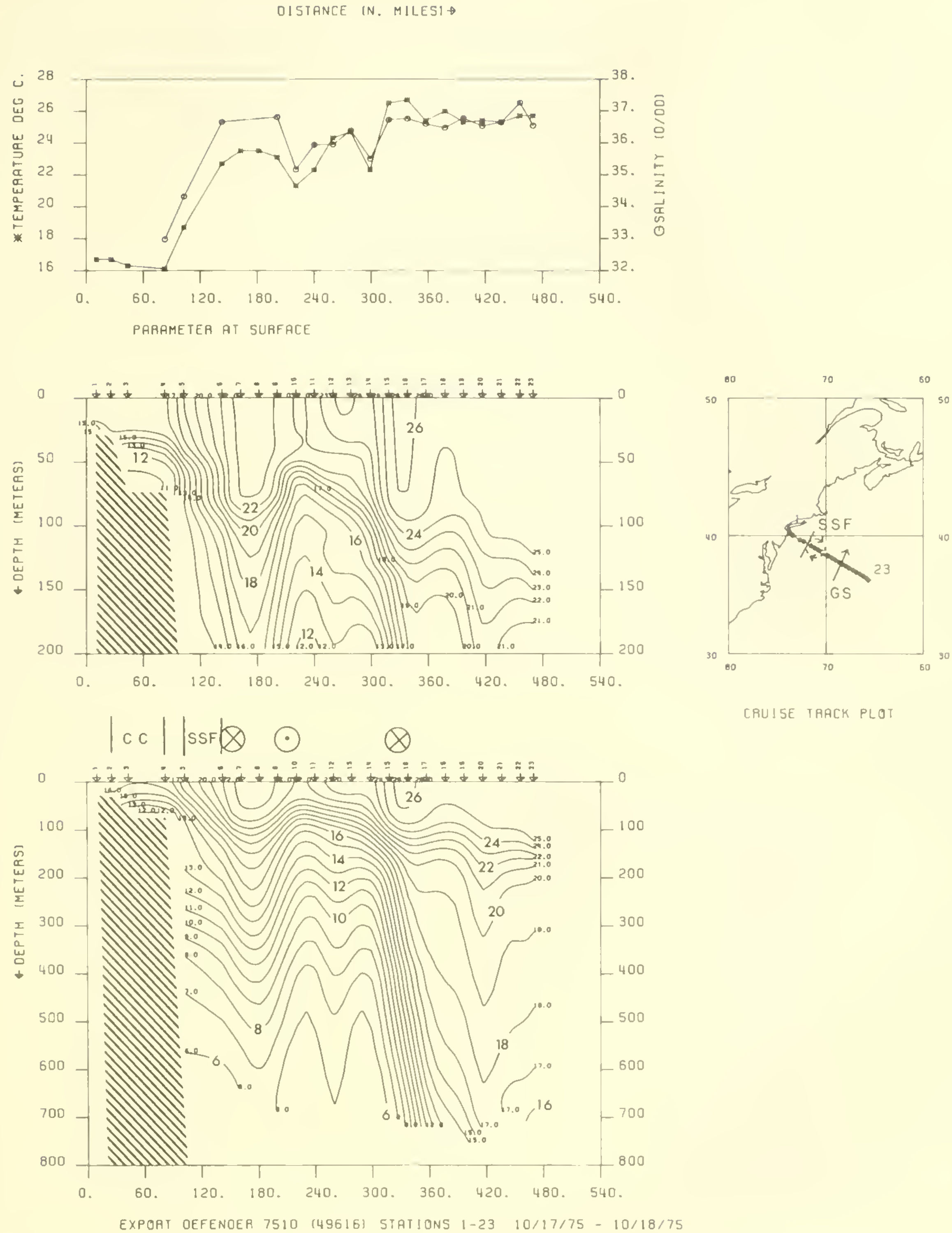
Appendix Figure 59.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Argo* 20-21 September 1975.



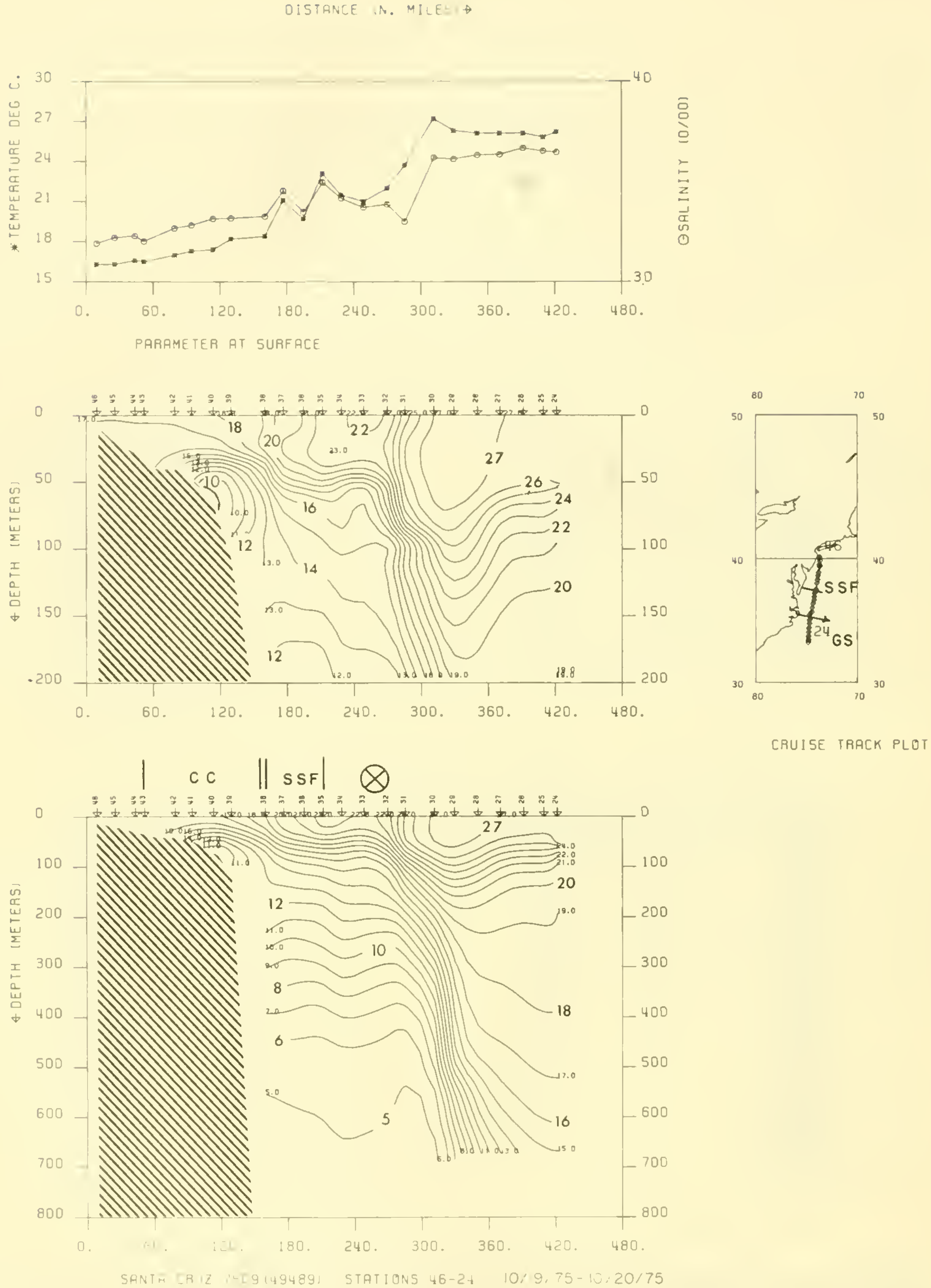
Appendix Figure 60.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Export Defender*—1-2 October 1975.



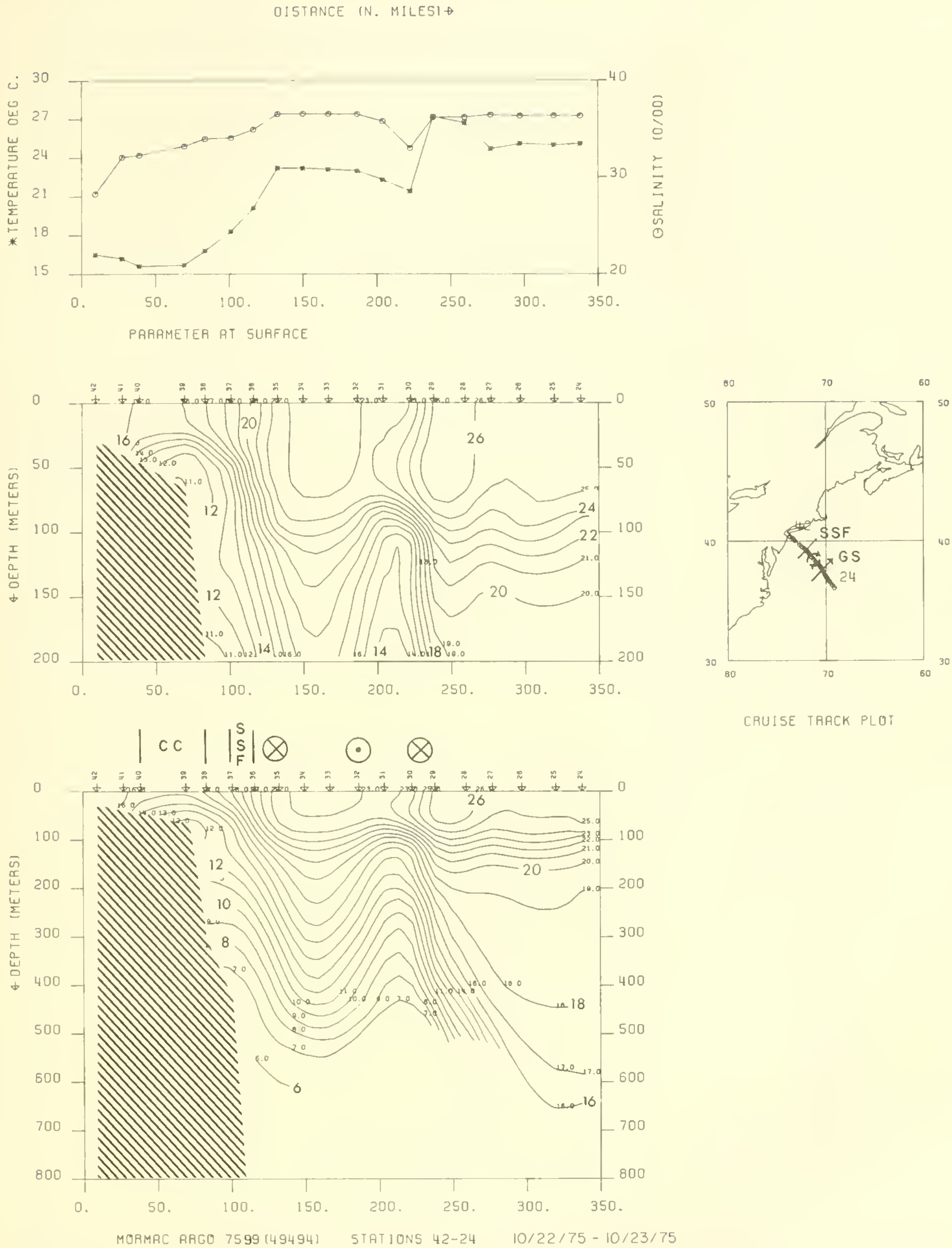
Appendix Figure 61.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Rigel*—11-12 October 1975.



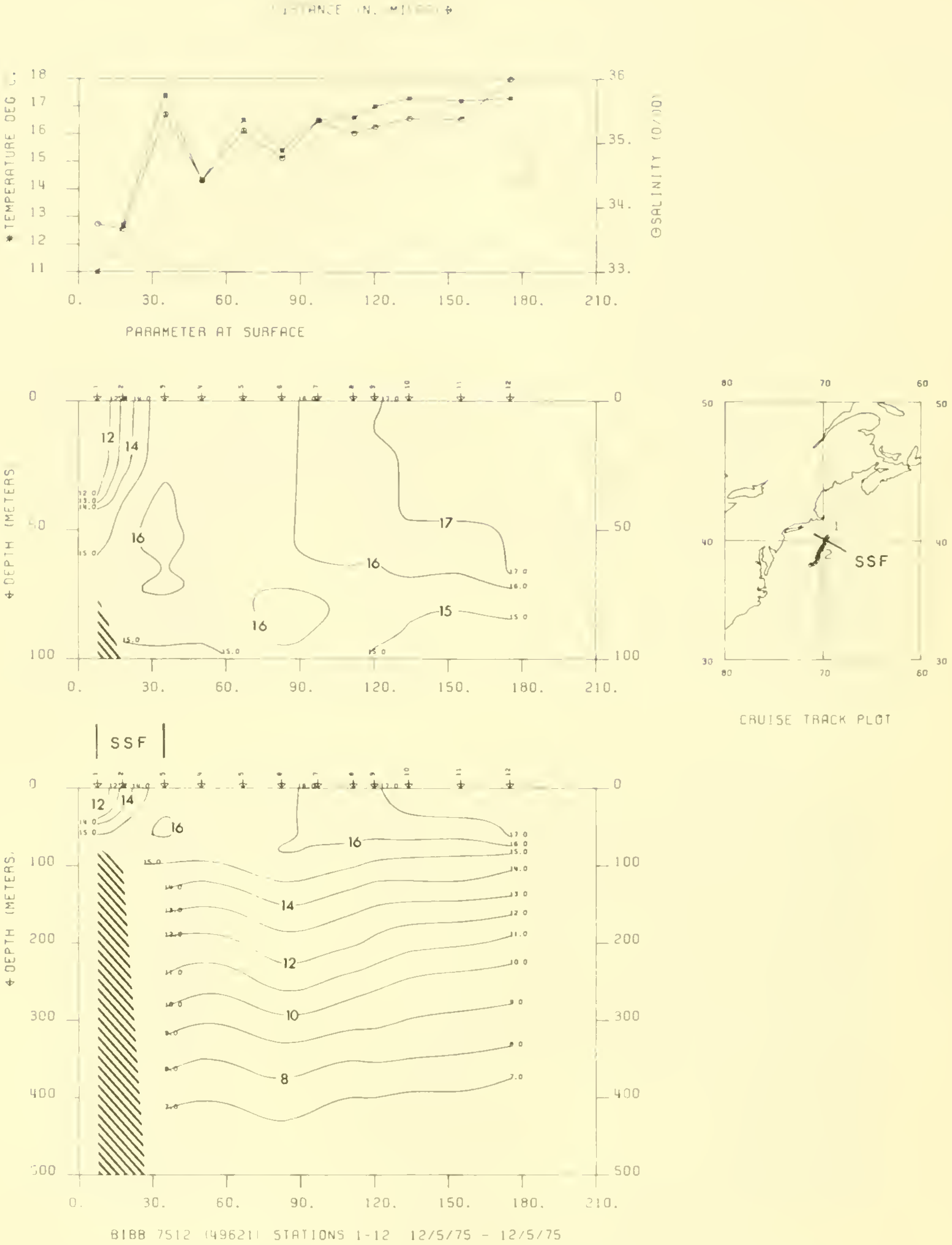
Appendix Figure 62.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Export Defender*—17-18 October 1975.



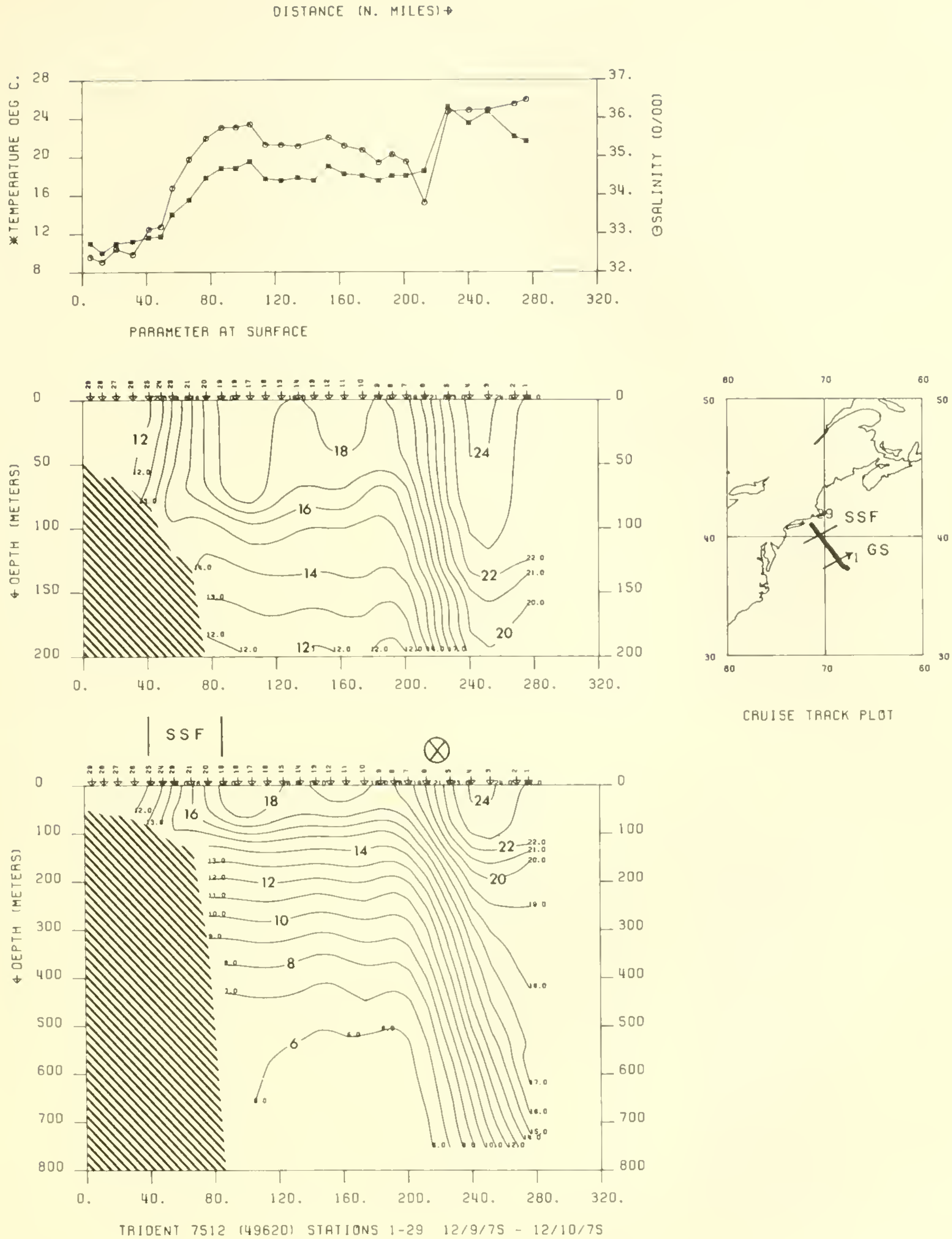
Appendix Figure 63.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Santa Cruz*—19-20 October 1975.



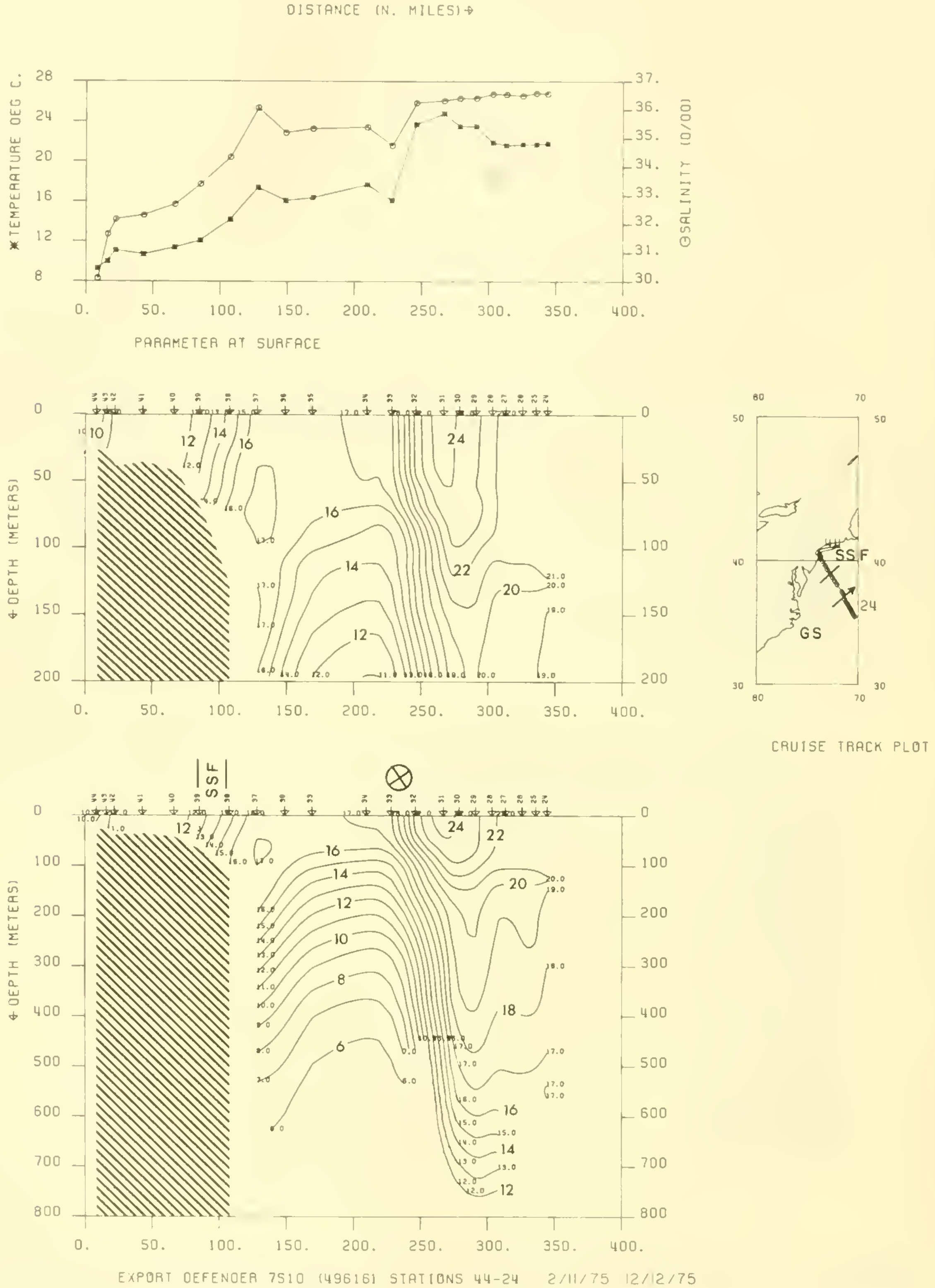
Appendix Figure 64.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Mormac Argo*—22-23 October 1975.



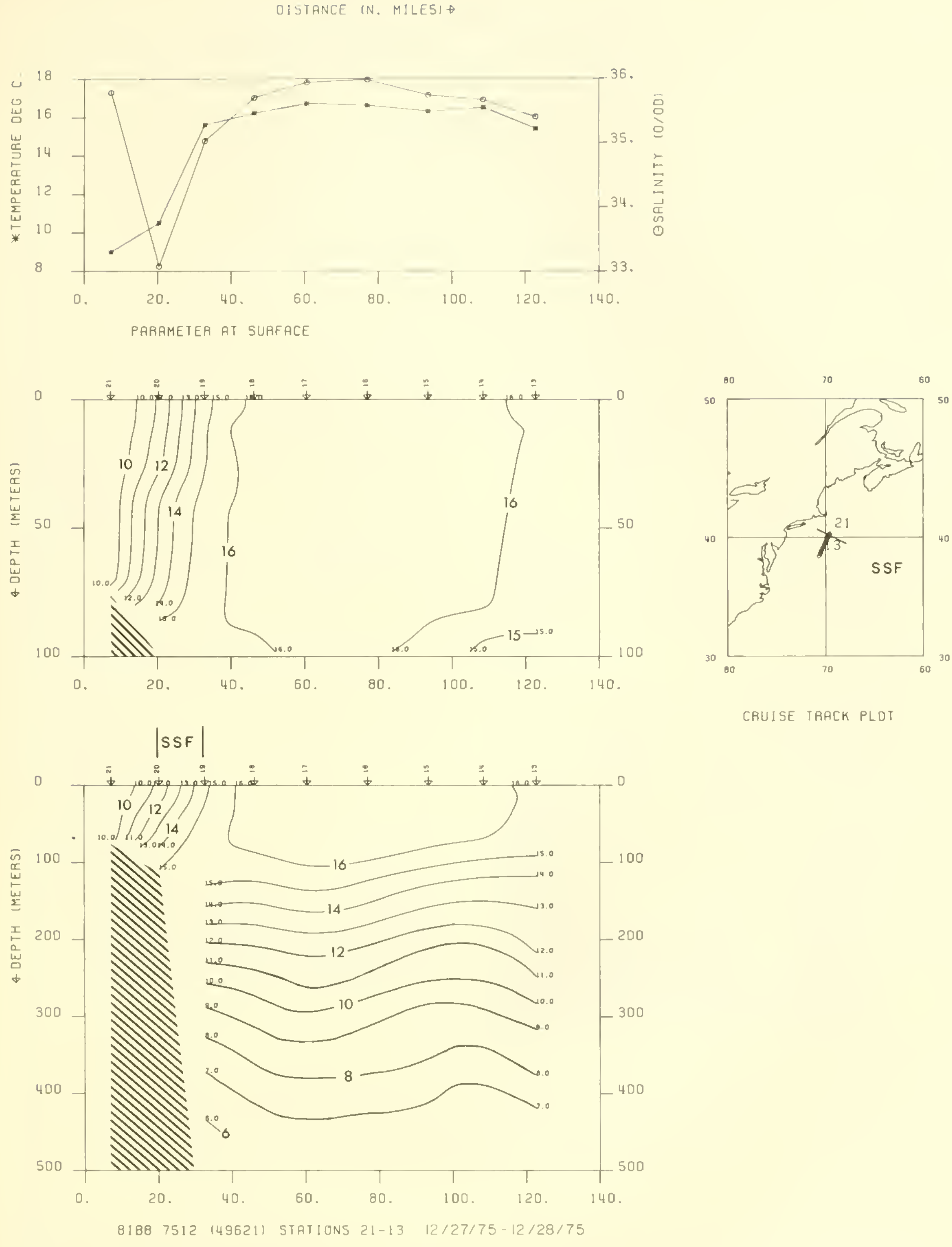
Appendix Figure 65.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Bibb*—5 December 1975.



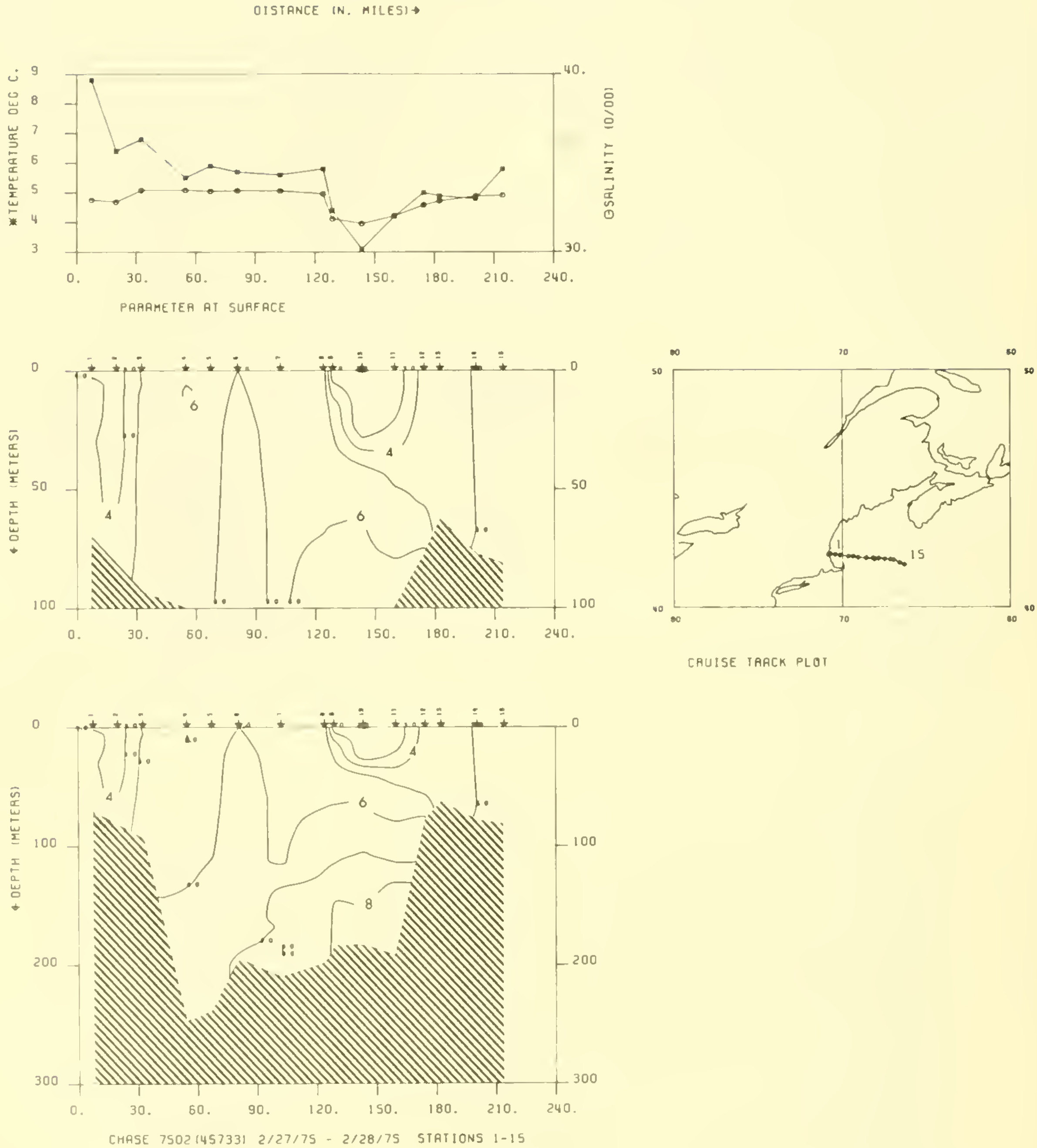
Appendix Figure 66.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Trident*—9-10 December 1975.



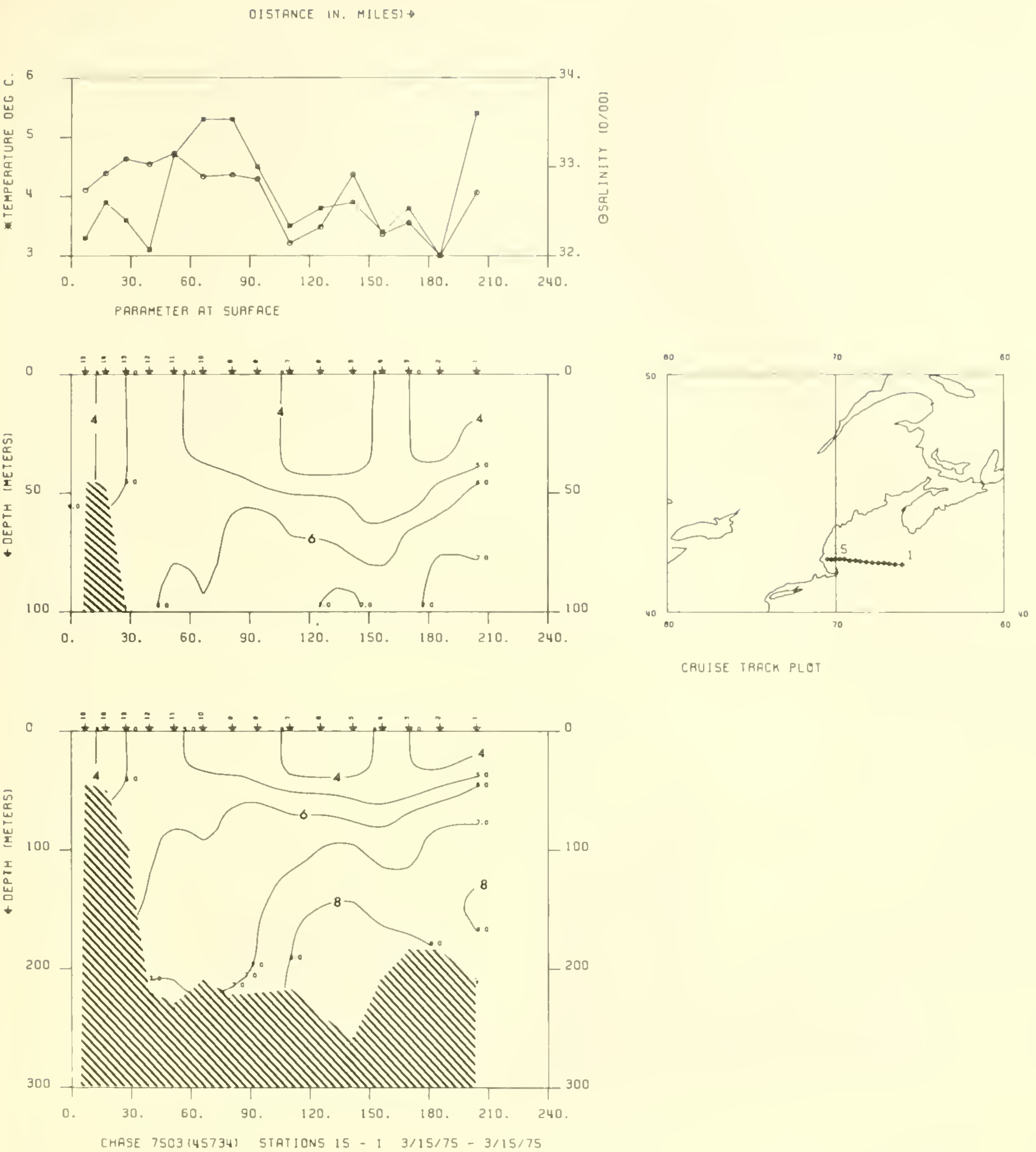
Appendix Figure 67.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 200 and 800 m. *Export Defender*—11-12 December 1975.



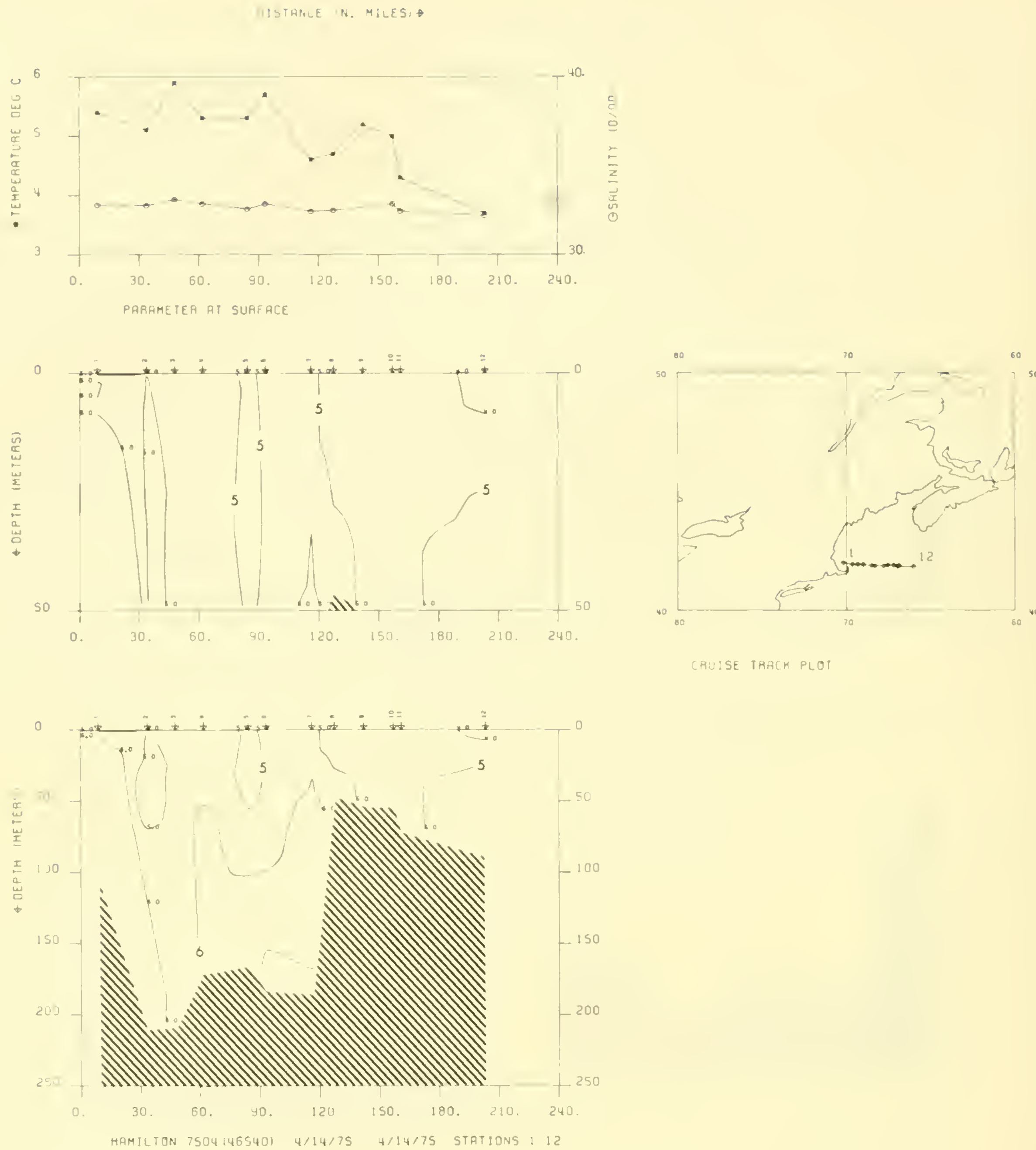
Appendix Figure 68.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 500 m. *Bibb*—27-28 December 1975.



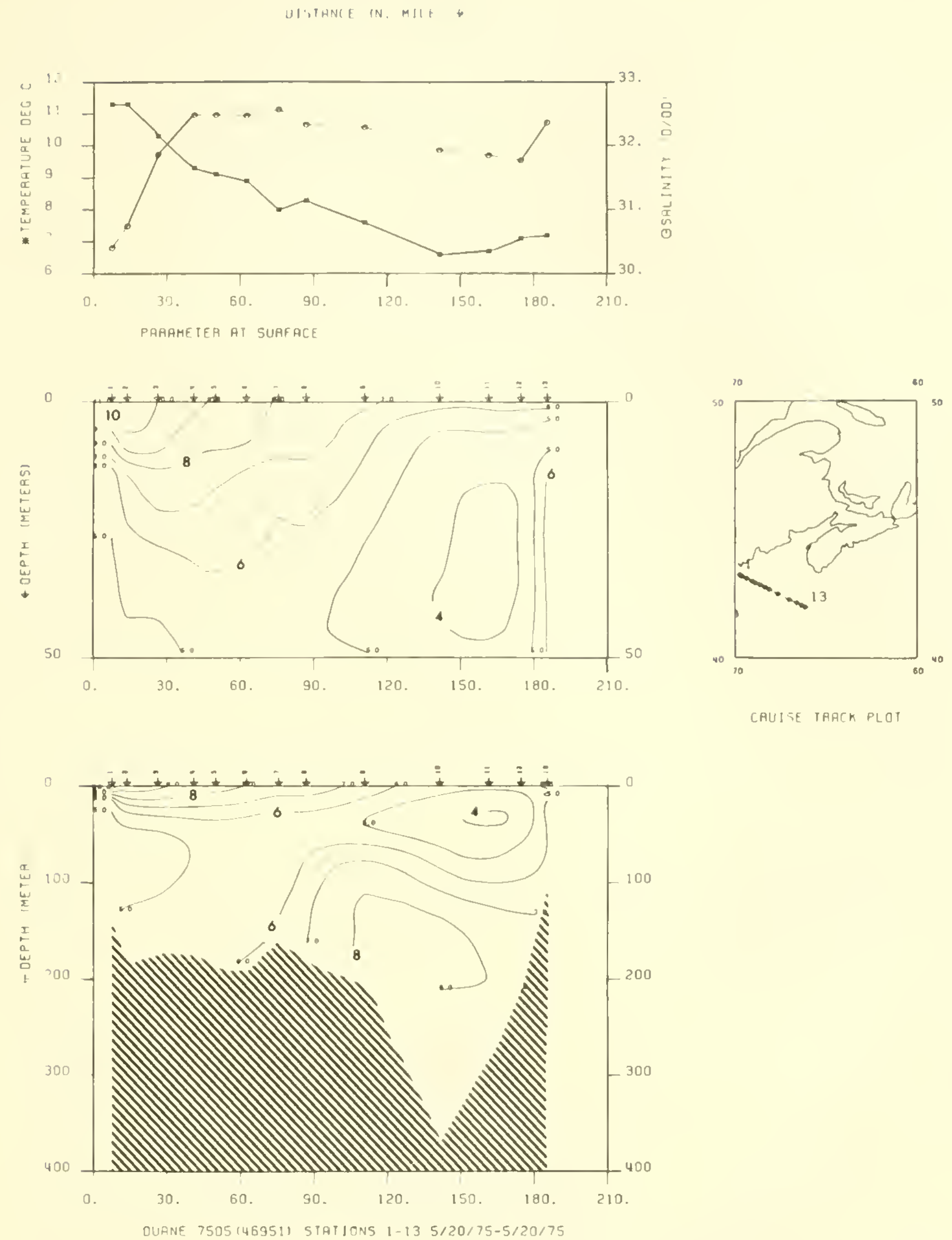
Appendix Figure 69. Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 300 m. *Chase*—27-28 February 1975.



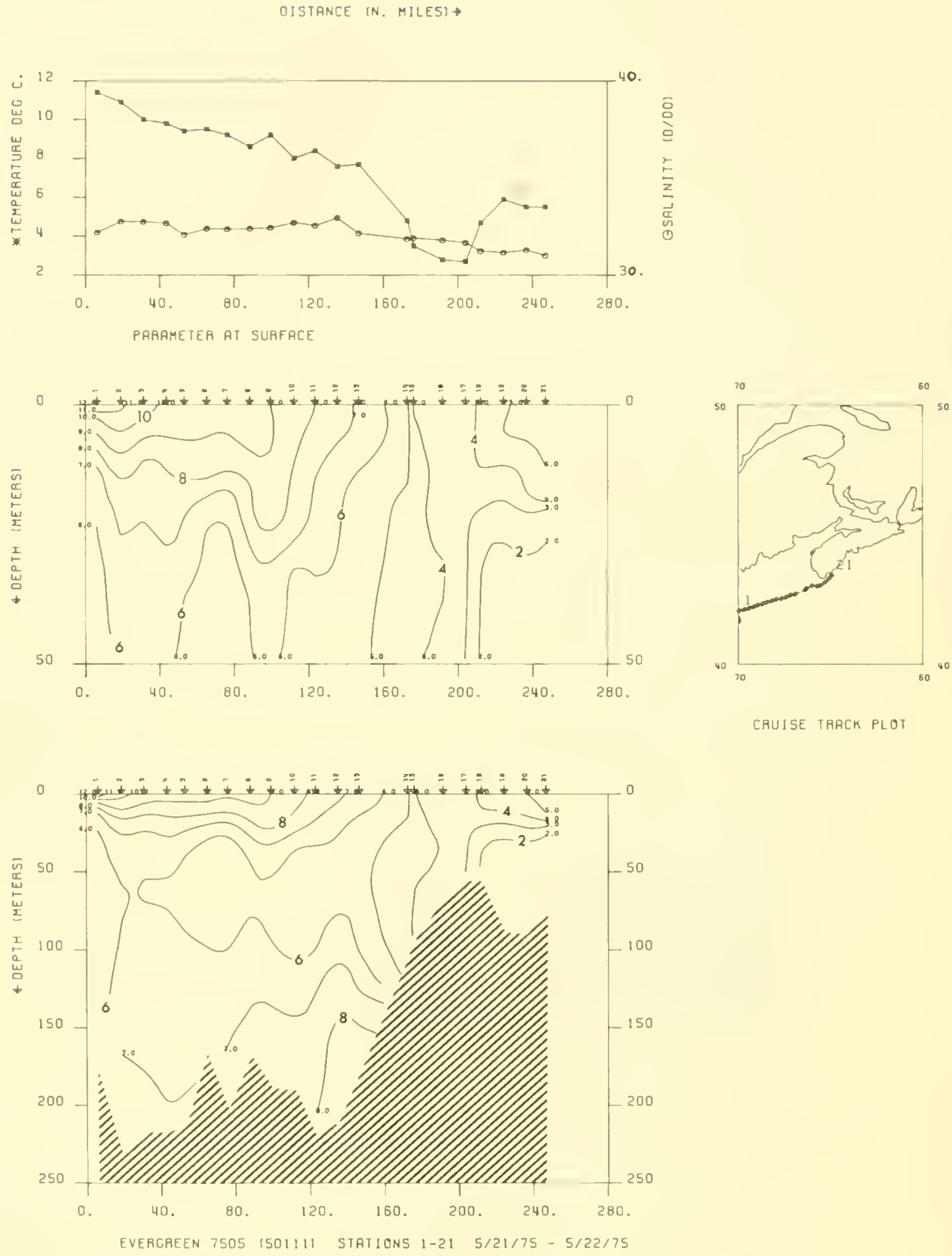
Appendix Figure 70.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 100 and 300 m. *Chase*—15 March 1975.



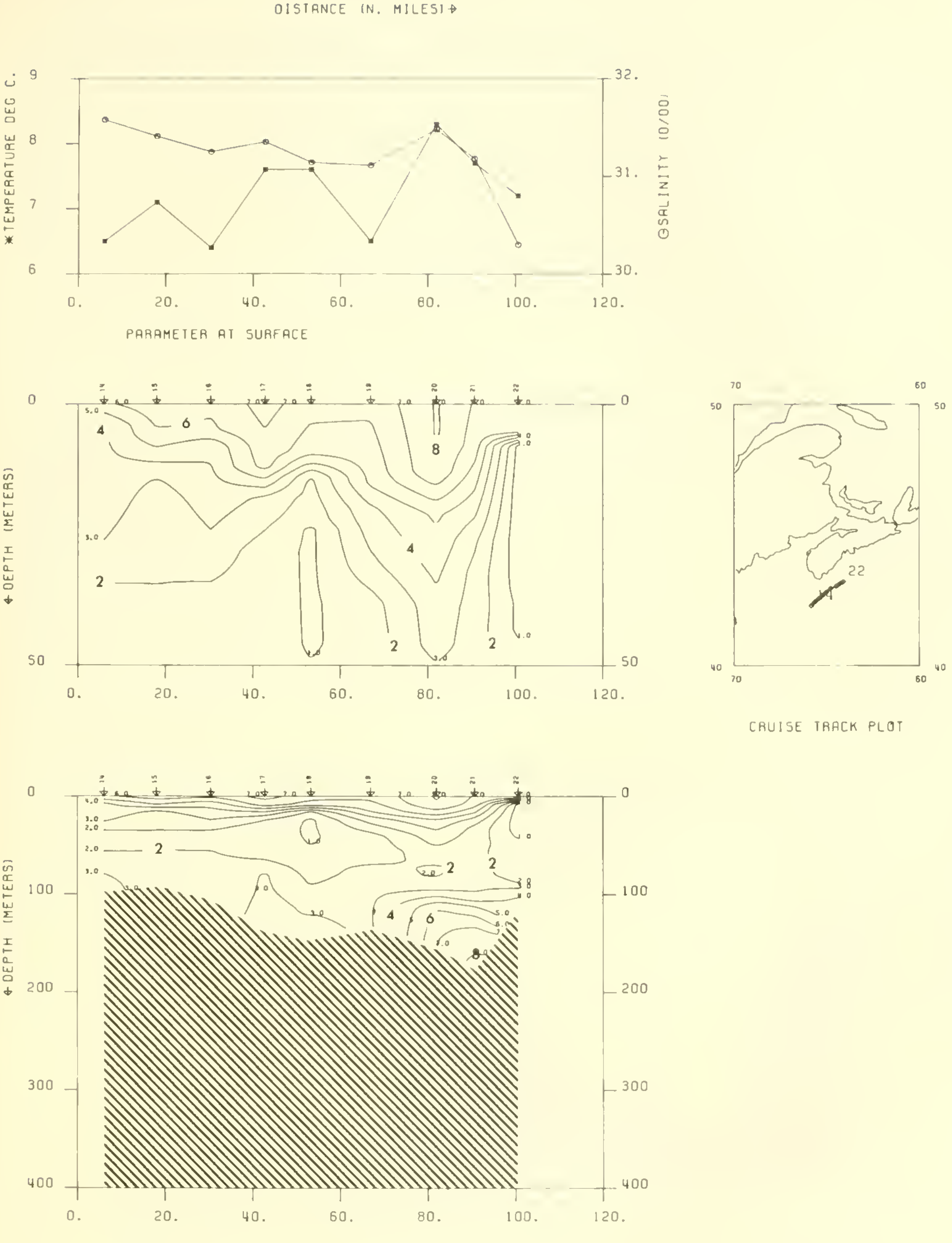
Appendix Figure 71.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 250 m. *Hamilton*—14 April 1975.



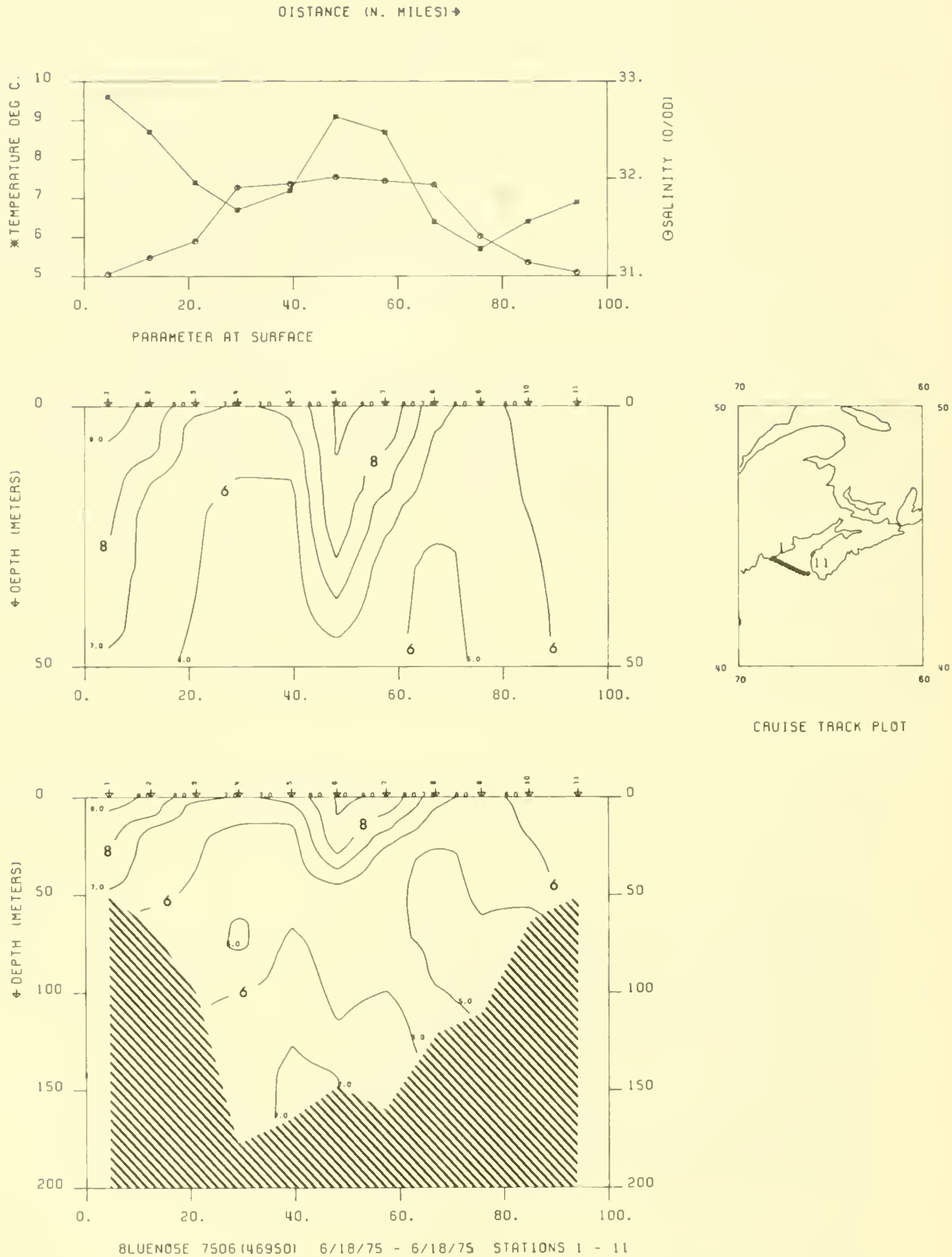
Appendix Figure 72.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 400 m. *Duone*—20 May 1975.



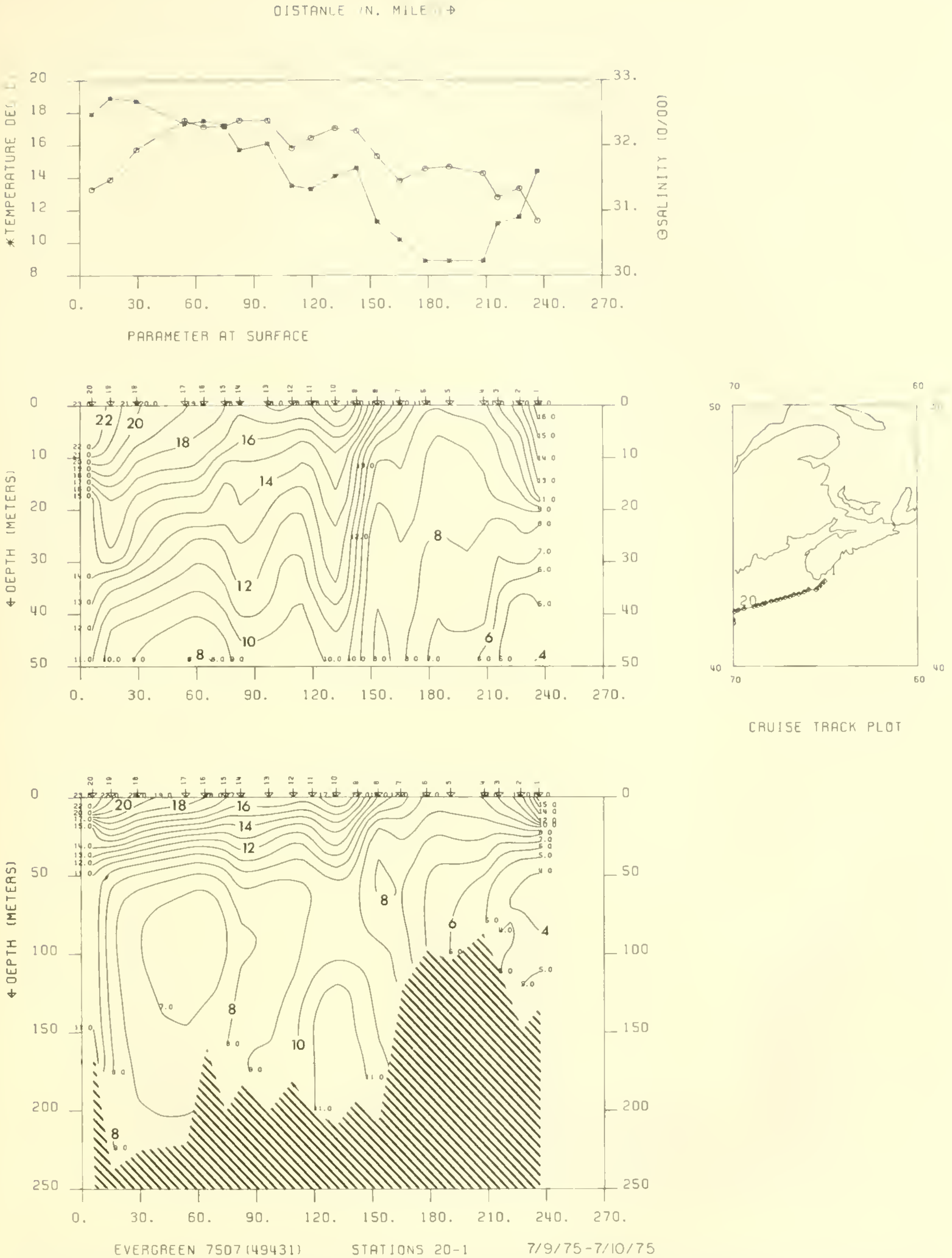
Appendix Figure 73.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 250 m. *Evergreen*—21-22 May 1975.



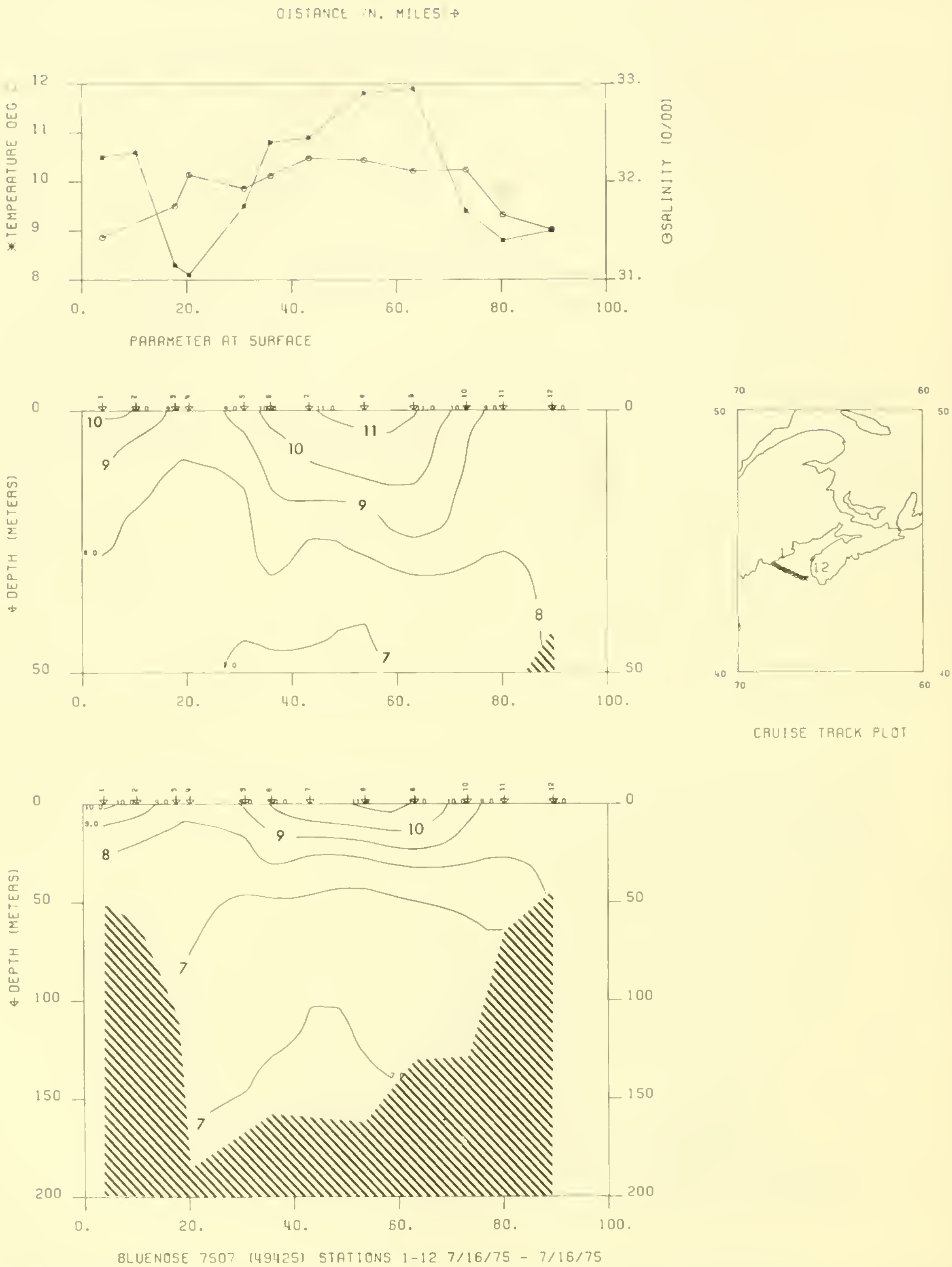
Appendix Figure 74.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 400 m. *Duane*—31 May 1975.



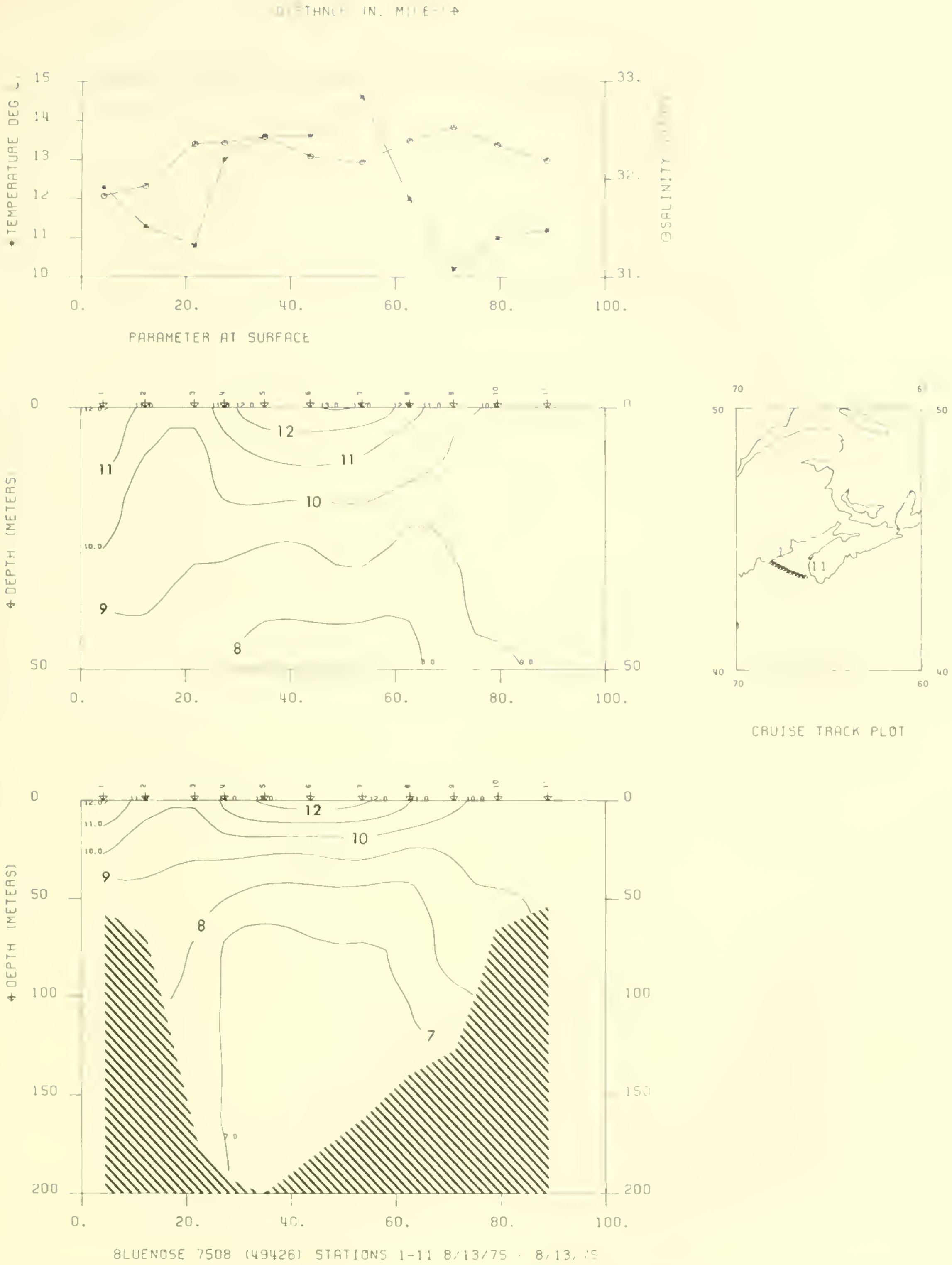
Appendix Figure 75.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 200 m. *Bluenose*—18 June 1975.



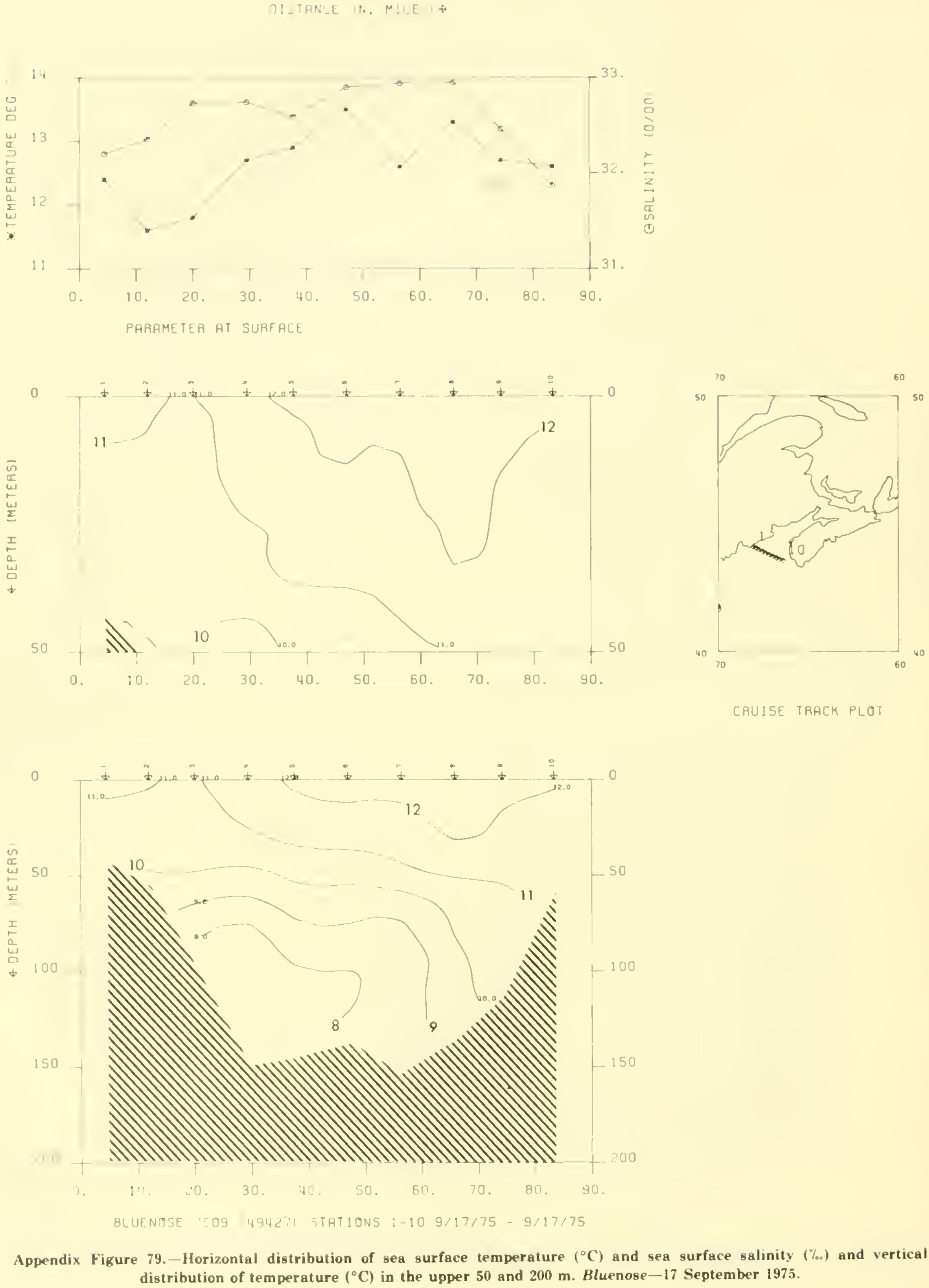
Appendix Figure 76.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 250 m. *Evergreen*—9-10 July 1975.



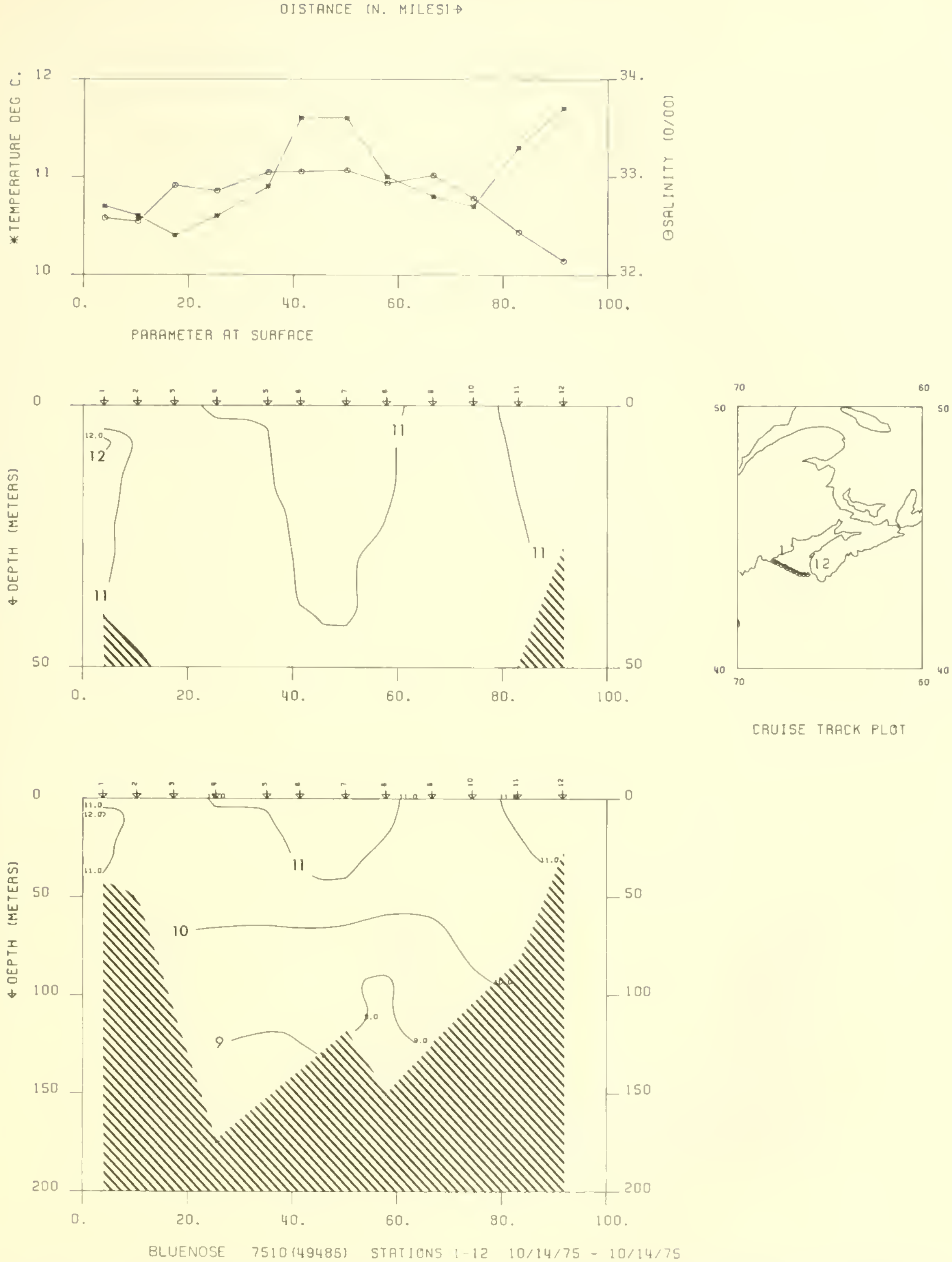
Appendix Figure 77.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 200 m. *Bluenose*—16 July 1975.



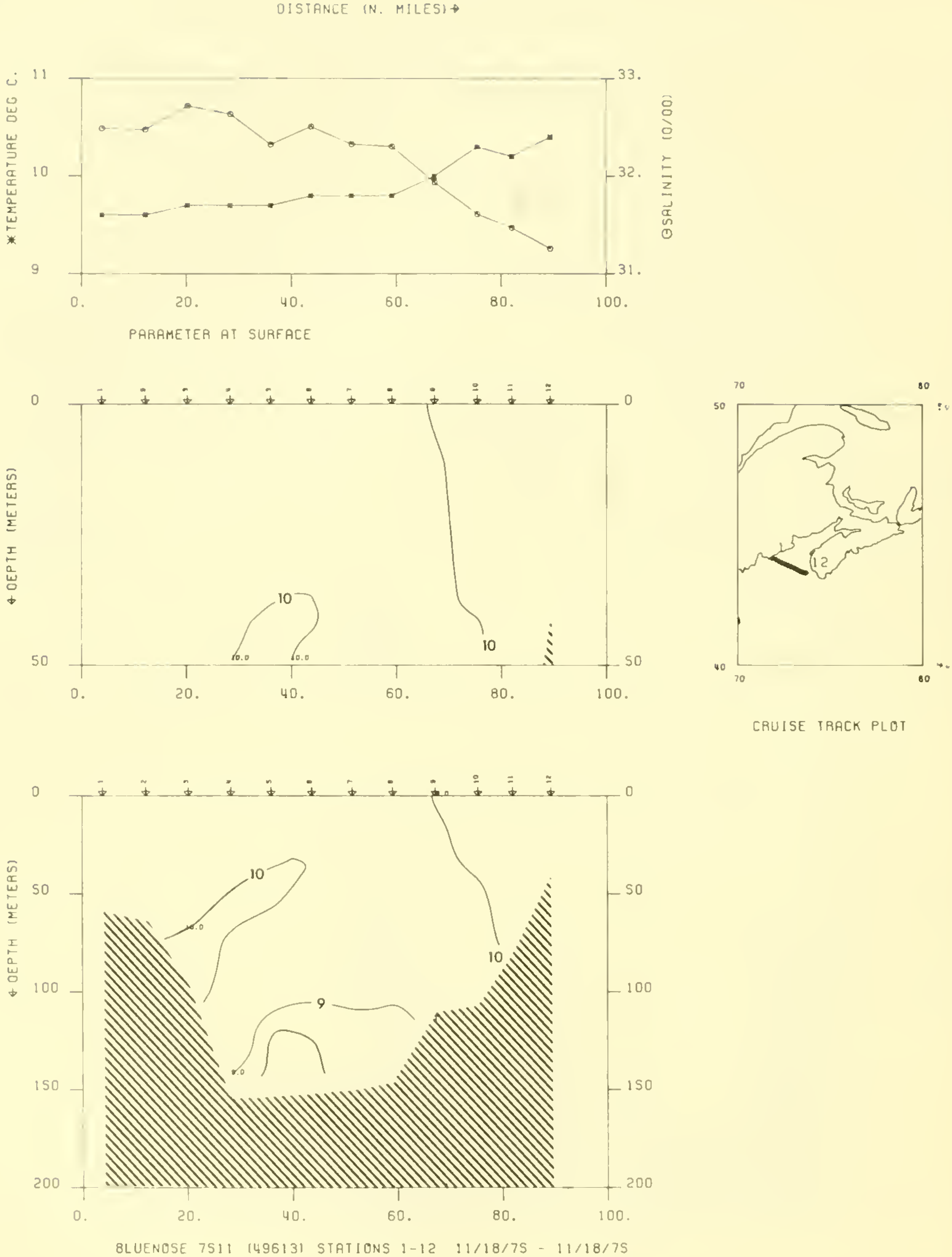
Appendix Figure 78.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 200 m. *Bluenose*—13 August 1975.



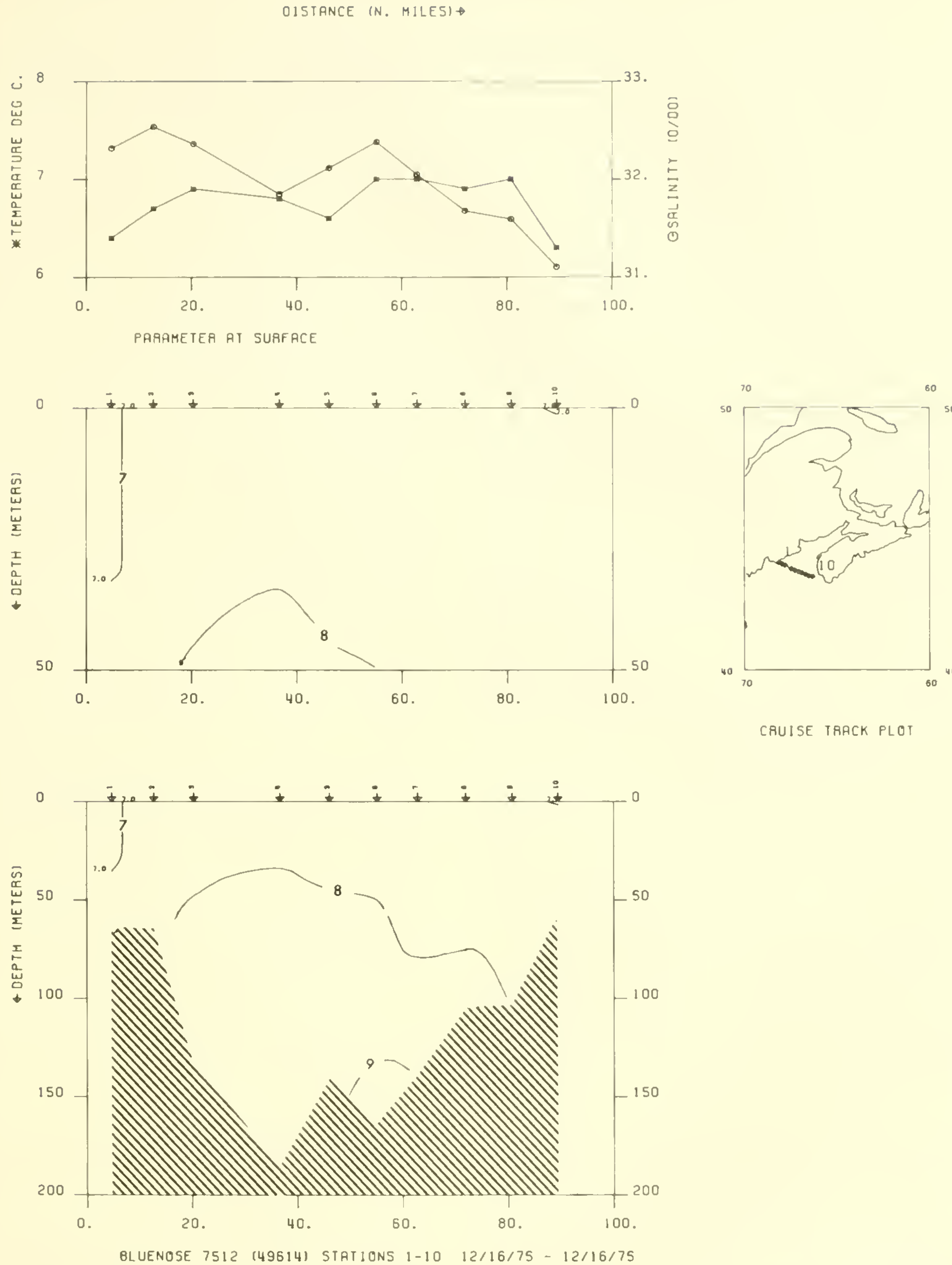
Appendix Figure 79.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 200 m. *Bluenose*—17 September 1975.



Appendix Figure 80.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 200 m. *Bluenose*—14 October 1975.



Appendix Figure 81.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 200 m. *Bluenose*—18 November 1975.



Appendix Figure 82.—Horizontal distribution of sea surface temperature (°C) and sea surface salinity (‰) and vertical distribution of temperature (°C) in the upper 50 and 200 m. *Bluenose*—16 December 1975.

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672. Seasonal occurrence of young Gulf menhaden and other fishes in a northwestern Florida estuary. By Marlin E. Tagatz and E. Peter H. Wilkins. August 1973, iii + 14 p., 1 fig., 4 tables. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

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