Northwest Atlantic Fisheries Organization

Serial No. N391

NAFO SCR Doc. 81/IX/93

THIRD ANNUAL MEETING - SEPTEMBER 1981

Water Column Thermal Structure Across the Shelf and Slope Southeast of Sandy Hook, New Jersey, in 1980[1]

by

Melissa M. Hughes and Steven K. Cook

Atlantic Environmental Group
National Marine Fisheries Service
RR 7, South Ferry Road
Narragansett, RI 02882, USA

Monitoring of shelf water and upper continental slope water T°C events in the New York Bight continued in 1980. Temperature-depth profiles were constructed from 24 expendable bathythermograph (XBT) transects collected from the entrance of New York Harbor to the 106 Dumpsite. The transects collected, and the oceanic features monitored in the New York Bight, are presented in Table 1.

A bottom temperature diagram (Fig. 1) and five contoured sections (Figs. 2-6) represent the major oceanographic/climatological events occurring in the New York Bight during 1980. The bottom temperature diagram was constructed according to Crist and Chamberlin (Annls. biol., Copenh. 34:21-27). To summarize, bottom temperatures were derived from each contoured section, plotted against depth and date and contoured at 1°C intervals. The southwesterly passage of warm core Gulf Stream rings in adjacent slope water is indicated by lines along the bottom of figure 1. The duration and timing of the rings were derived from analysis by Fitzgerald and Chamberlin (MS 1981). The five representative sections include cooling of vertically mixed winter water (Fig. 2), cold cell formation (Fig. 3), summer stratification and thermocline intensification (Fig. 4), thermocline deepening (Fig. 5), and formation of winter water following fall overturn (Fig. 6).

Two distinct water masses, shelf water and slope water, reside in the New York Bight. A transition zone, the shelf/slope front (SSF), separates the two water masses, and is visible at the surface on satellite imagery

[1] Submitted for publication in ICES Annales Biologiques

most of the year. An arrow at the surface of each figured transect marks the surface frontal position. The 10°C isotherm, characterizing the SSF on the bottom, historically occurs between 80-120 m depth (Wright, 1976).

Shelf and Slope Water Events

Winter Water

Above average air temperatures prevailed in the New York area for most of December 1979 and January 1980 (Taubensee, 1980; Wagner, 1980). In January 1980 vertically mixed shelf water temperatures of 6°-11°C were comparable to those measured in January 1978-1979, but 1°-4° cooler than 1976 shelf water sea surface temperatures (SSTs). The shelf water in February reflected the above average air temperatures of the previous two months (Fig. 2). Vertically mixed shelf water was from 2°-6°C warmer in 1980 than in mid-February 1976-1978 (Cook, 1979a, 1979b; Cook and Hughes, 1980).

The coldest 1980 air temperatures in the New York Bight occurred during February. Below average air temperatures were recorded in March (Livezey, 1980). The coldest shelf water temperatures were recorded in early March 1980, ranging from 4°-7°C. The nearshore minimum was 1°-2°C warmer than that observed in 1977-1979. Data collected in March 1976 showed shelf water of 7°-9°C (Cook, 1979a, 1979b, 1980; Hughes and Cook, in press).

Minimum shelf water bottom temperatures of <3°C occurred from early February through mid-March 1980 (Fig. 1), while from 1977-1979 minimum bottom temperatures of <1°C occurred in January and February. Bottom water warmed to >3°C in March from 1977 through 1980. Cold 4°C water persisted on the bottom until early June in 1977 and 1978, but only remained until late March 1979 and mid-April 1980 (Cook, 1979b, 1980; Hughes, in press).

Cold Cell Formation

In late April vernal warming of surface waters began seasonal stratification, resulting in the isolation of colder bottom winter water and formation of the cold cell.

Three warm core rings, E, I, and K passed through the New York Bight between January and May (Fig. 1). The rings affected both shelf and slope water temperature conditions. Mixed slope and Gulf Stream water (12°-13°) appeared to 200 m depth during ring 79-I (Fig. 2, Sts. 13-24), while water

>13°C went to depths >400 m in ring 79-K (Fig. 3, Sts. 2-6). The shelf/ slope front was displaced 32 nm shoreward of the 200 isobath as ring 79-I passed. The SSF was maintained slightly seaward of the shelf break during the passage of ring 79-K. The 10°C isotherm at the bottom followed a similar trend: a shoreward migration to 66-68 m depth during passage of ring 79-I, followed by a deepening on the bottom to 200 m depth during passage of ring 79-K. As the rings passed, water 12°-13°C contacted bottom from 74-240 m depth (Fig. 1).

Shelf SSTs warmed from 11°C in May to 16°C in mid-June (Fig. 3). A mixed surface layer to 20 m depth overlaid the thermocline which ranged from 7°-10°C. In mid-June the thermocline temperature range intensified to 5°-16°C with a 1°C/meter gradient.

Intensified stratification in mid-May further sealed off the cold cell and the average cold cell temperature rose to 6.6°C (Fig. 3) (Table 1). A seaward excursion of the 10°C isotherm to 140 m depth in mid-May probably indicated that shelf water was entrained seaward along the trailing edge of ring 79-K as it migrated southwest of the transect (Hughes, in press).

Summer Stratification

Shelf water SSTs increased to 24°C by July (Fig. 4), attained a maximum of 25°-26°C in early August, then decreased to 21°C in mid-September. The surface mixed layer became shallowest, 6-8 m, during July and August due to normal lulls in storm activity, but deepened to 14 m in September with an increase in storm activity. During July and August thermocline temperatures ranged from 9°-24°C, but decreased to 9°-20°C in mid-September. The thermocline temperature gradient intensified from 1°C/meter in mid-June to 2°C/meter in July to about 3°C/meter in August.

Cold bottom water <6°C appeared at 42-70 m depth, decreasing the cold cell average temperature from 7.6°C to 6.9°C in early July (Fig. 1) (Table 1). The average cold cell temperature warmed to 8.5°C in mid-September, an average increase of 0.8°C/month.

From June to mid-August the SSF remained nearly stationary, probably due to the continued presence of ring 79-H (Figs. 1 and 4) (Table 1). In mid-August slope water >12°C no longer touched bottom, slope water salinities had decreased, and the SSF had migrated 27 nm seaward of the 100 m isobath, as ring 80-A moved south of the transect.

Entrainment of shelf water along the seaward edge of a ring was observed in May 1979 (Hughes, in press) and again in July 1980 (Fig. 4). Colder temperatures and reduced surface salinities differentiate this water mass from surrounding slope water. The upwelling at Sts. 20-22 (Fig. 4) surrounds parcels of 10°-11°C water which has been "calved" off or entrained from the cold cell water present between stations 10 and 11.

Rings 79-K and 79-H exerted a sustained influence on the mid-Atlantic Bight from mid-April to early August. Water <12°C only appeared on the slope bottom (180-250 m) between rings (Fig. 1). The duration and persistence of slope water >12°C on the slope bottom in 1980 did not occur in 1977-1979 as the passage of rings appeared to be of shorter duration (Cook, 1979b, 1980; Hughes, in press).

Thermocline Deepening and Isothermal Winter Water

The shelf water SST range decreased to 17°-20°C in early October, while vertically mixed water 10°-12°C appeared in early December, completing the yearly cycle of temperature conditions in the New York Bight (Figs. 5 and 6). Observed (October through December) 1980 SSTs were comparable to those recorded in 1977-1979, while water 1°-2°C warmer occurred in early October 1976. (Cook, 1979a, 1979b, 1980; Hughes. in press).

In October the thermocline deepened to between 25-40 meters and the temperature range narrowed to 11°-17°C. The cold cell dissipated in early December, but lack of data from mid-October to early December precluded the exact timing of cold core erosion, or fall overturn. In previous years this event had occurred between mid-October and early November.

Maximum bottom temperatures occur during fall overturn (Fig. 1). Slope water >12°C appeared again in October after a hiatus of two months and continued to warm to 13.3°C in early December (Fig. 6). Slope water >13°C intruded to 66 m depth in 1980 (Fig. 1). Sections from 1976-1979 also illustrate slope water intrusions moving shoreward to 50-100 m depth (Cook, 1979a, 1979b, 1980; Hughes, in press).

From mid-September to mid-October ring 80-A was present in the New York Bight, but its influence on the shelf and slope appears minimal (Fig. 5).

Summary

Warmer than average winter air temperatures kept January and February 1980 water temperatures 2°-6°C warmer than 1976-1979; and cold water <4°C did not persist on the shelf bottom as in 1977 and 1978. The passage and duration of 5 warm core rings caused persistence of 12°-13°C water on the slope bottom for much of the time, a phenomenon that had not been observed in previous years.

REFERENCES

Cook, S. K. 1979a. Water column thermal structure across the shelf and slope southeast of Sandy Hook, New Jersey, USA, in 1976. U.S. Dept. Commerce, NOAA Tech. Rep. NMFS CIRC. 427, June 1979, pp. 231-257.

Cook, S. K. 1979b. Water column thermal structure across the shelf and slope southeast of Sandy Hook, New Jersey, USA, in 1977. Annls. biol., Copenh. 34:14-21.

Cook, S. K. and Hughes, M. M. 1980. Water column thermal structure across the shelf and slope southeast of Sandy Hook, New Jersey, USA, in 1978. Annls. biol., Copenh., 35:14-25.

Crist, R. W. and Chamberlin, J. L. (in press). Bottom temperatures on the continental shelf and slope south of New England during 1979. Annls. biol., Copenh., 36.

Fitzgerald, J. L., and J. L. Chamberlin. MS 1981. Anticyclonic warm core Gulf Stream rings off the northeastern United States during 1980. NAFO SCR Doc. 81/IX/90, Serial No. N388.

Hughes, M. M. and Cook, S. K. (in press). Water column thermal structure across the shelf and slope southeast of Sandy Hook, New Jersey, in 1979. Annls. biol., Copenh., 36.

Livezey, R. E. 1980. Weather and circulation of March 1980. Monthly Weather Review 108:6, pp. 833-839.

Taubensee, R. E. 1980. Weather and circulation of December 1979. Monthly Weather Review 108:3, pp. 377-383.

Wagner, A. J. 1980. Weather and circulation of January 1980. Monthly Weather Review 108:4, pp. 531-538.

Wright, W. R. 1976. The limits of shelf water south of Cape Cod, 1941 to 1972. J. Mar. Res. 34:1-14.

Table 1. Water Column Thermal Structure in 1980

Vessel	Cruise no.	Date	Cold cell weighted avg. temp. (°C)	Depth range of cold cell minimum/maximum depth (m)	Bottom depth (m) of 10°C isotherm	Position km of shelf/slope front shoreward (-) or seaward (+) of 200 m isobath	Rings present along transect
"Argo"	80-01	22 Jan	Isothermal (<6-11°C)	-	83	-12	79-E
"Gallatin"	80-01	24-25 Jan	Isothermal (<7-11°C)	-	66	-25	79-I
"Rigel"	80-01	3 Feb	Isothermal (<5-11°C)	-	68	-32	79-I
"Gallatin"	80-03	9-10 Mar	Isothermal (<4-7°C)	-	>200	>+7	79-K
"Rigel"	80-03	6 Apr	Isothermal (<5-8°C)	-	116	0	79-K
"Gallatin"	80-09	8 Apr	Isothermal (<5-8°C)	-	82	+2	79-K
"Evrika"	80-01	23 Apr	5.7	60-68	-	-	79-K
"Kelez"	80-02	16 May	6.6	35-74	130	+5	79-K
"Rigel"	80-04	17-18 May	6.4	42-74	100	+5	79-H
"Argo"	80-06	2 Jun	-	-	-	>-18	79-H
"Delaware II"	80-03	4 Jun	6.0	20-90	106	-	79-H
"Argo"	80-07	12 Jun	5.4	32-80	100	+4	79-H
"Argo"	80-08	1 Jul	7.6	40-86	105	+14	79-H
"Tamaroa"	80-01	5 Jul	6.9	29-72	90	+7	79-H
"Evrika"	80-06	23 Jul	7.3	28-88	108	-	79-H
"Kelez"	80-03	9-11 Aug	7.8	40-64	88	-	79-H
"Rigel"	80-05	16 Aug	8.0	40-70	74	-	-
"Argo"	80-09	8-9 Sep	8.3	42-92	100	+17	-
"Tamaroa"	80-02	16-17 Sep	8.5	40-96	106	+27	-
"Argo"	80-09	20 Sep	-	-	-	-	-
"Tamaroa"	80-03	11 Oct	10.1	42-102	78	+8	80-A
"Rigel"	80-06	11 Oct	9.9	44-94	84	-9	80-A
"Tamaroa"	80-04	2 Dec	Isothermal (10-12°C)	-	-	-	-
"Albatross IV"	80-12	5 Dec	Isothermal (<8-13°C)	-	-	-	-

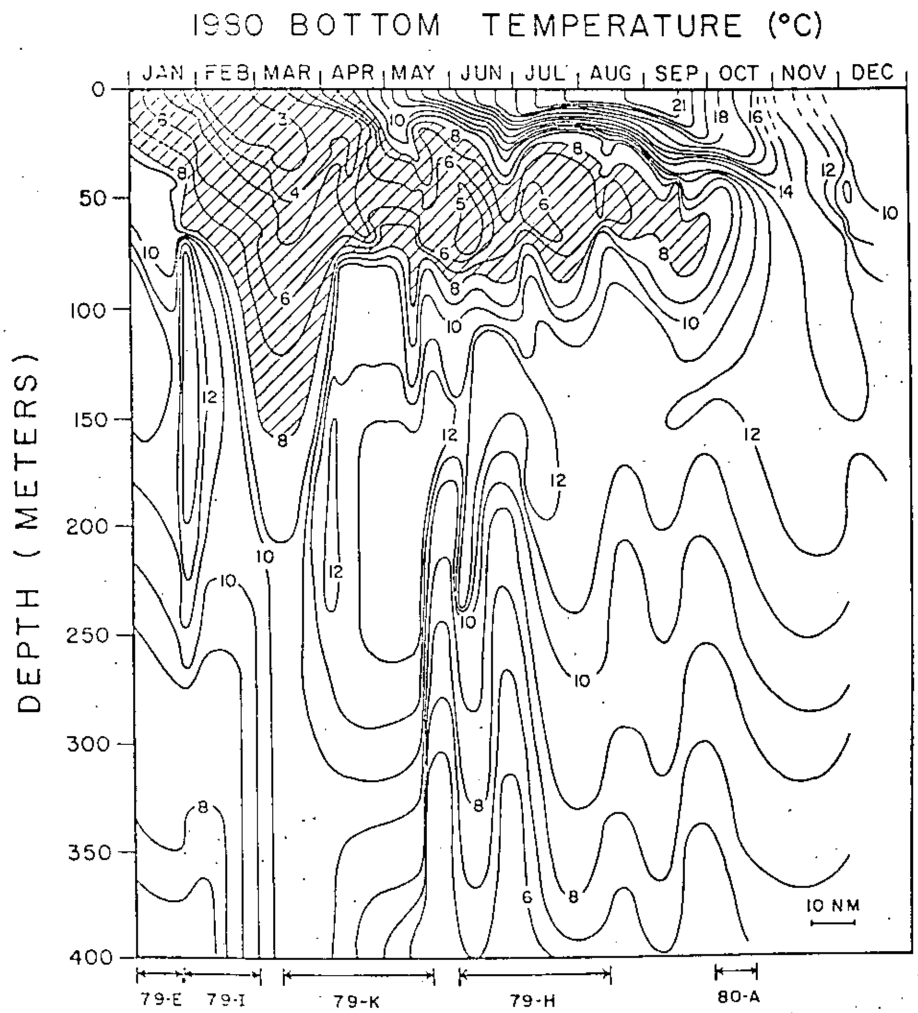

Figure 1. Bottom temperature diagram of the continental shelf and slope waters from New York Harbor to the 106 Dumpsite. Lines at the bottom of the diagram indicate the duration of warm core Gulf Stream rings in the New York Bight area.

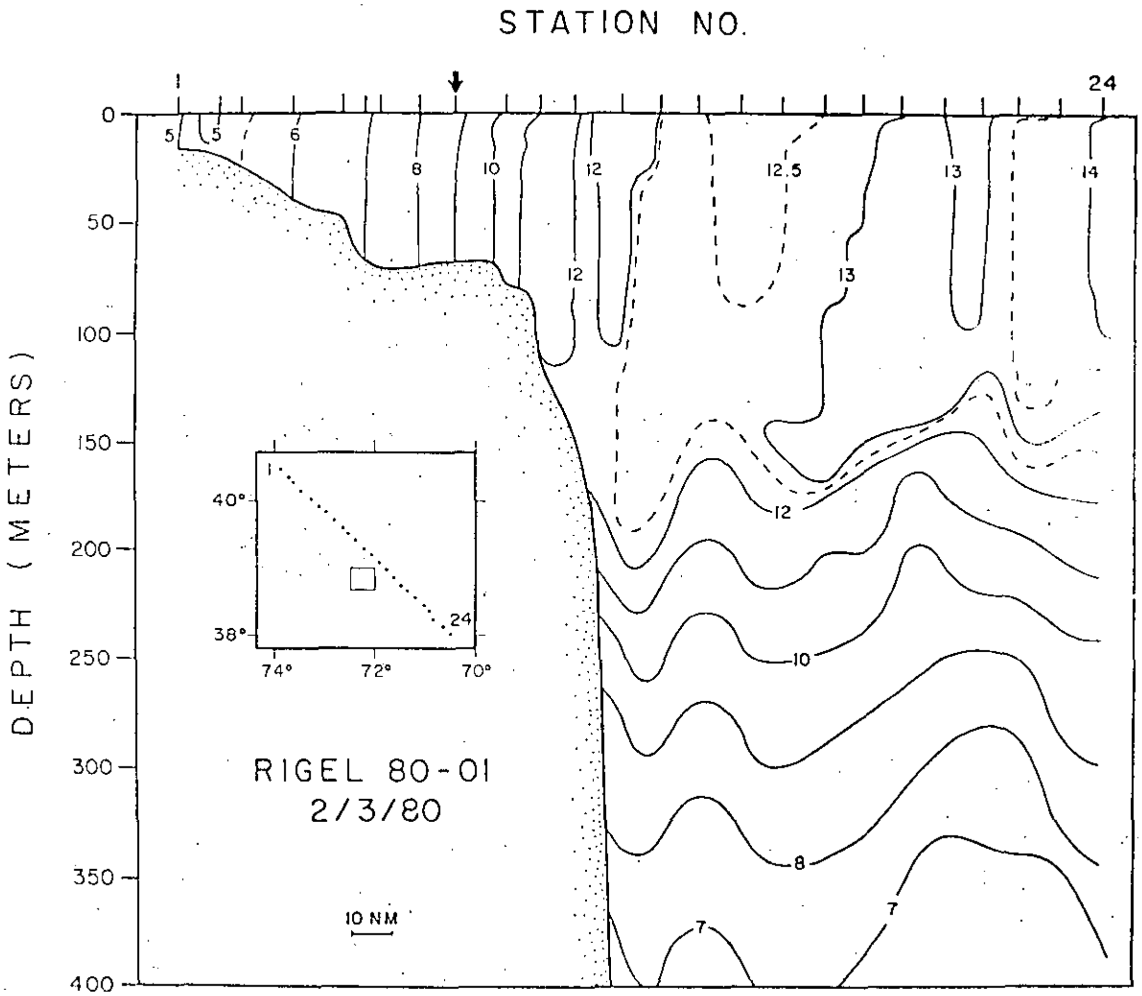

Figure 2. Temperature (°C) transect collected on 3 February 1980 showing vertically mixed winter water.

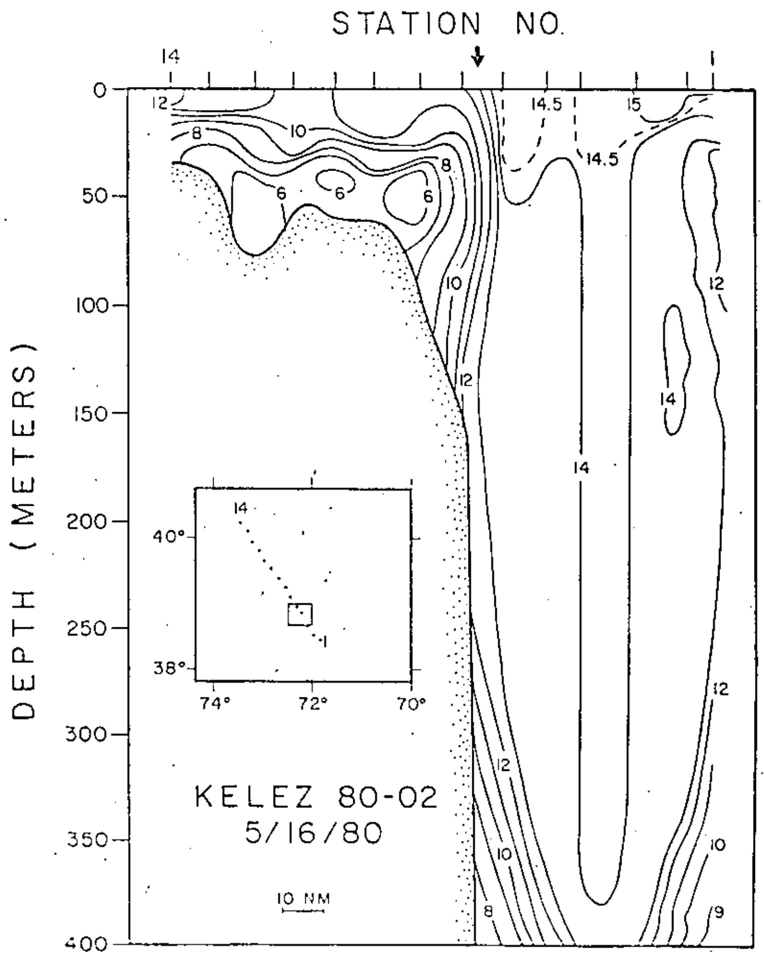

Figure 3. Temperature (°C) transect collected on 16 May 1980 showing cold cell formation.

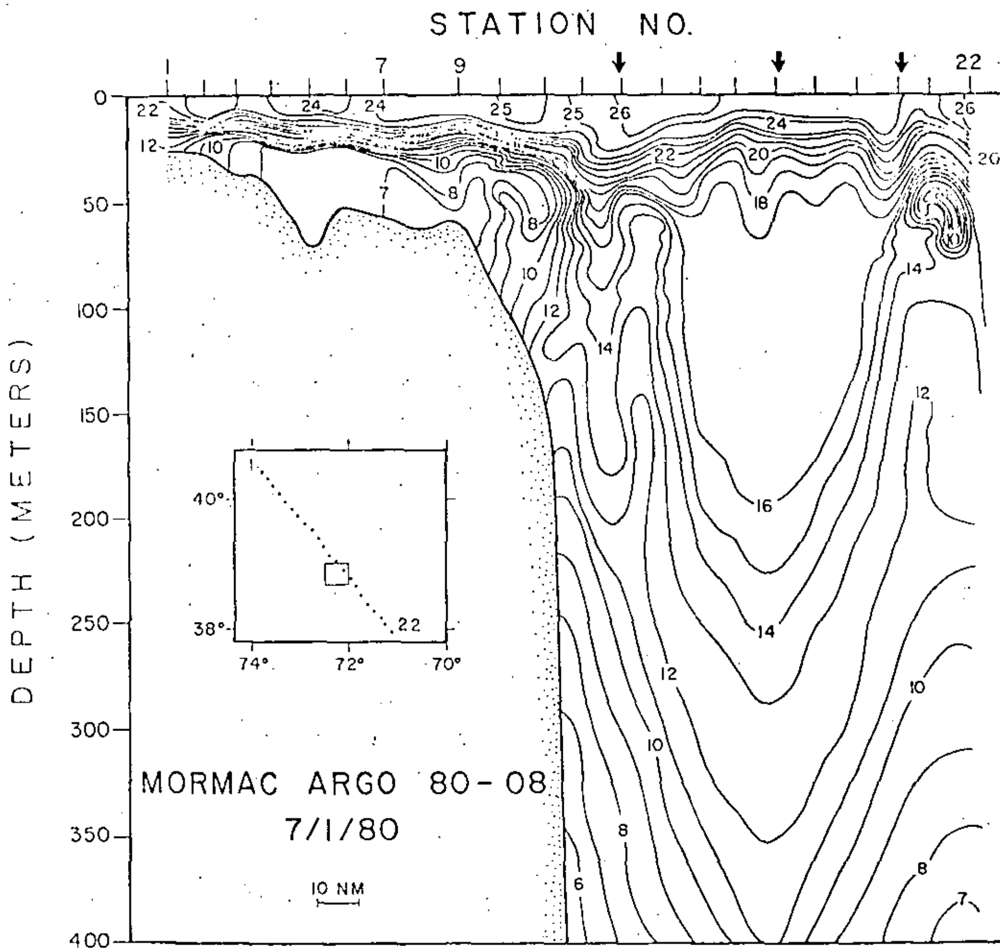

Figure 4. Temperature (°C) transect collected on 1 July 1980 showing summer stratification and offshore shelf water entrainment.

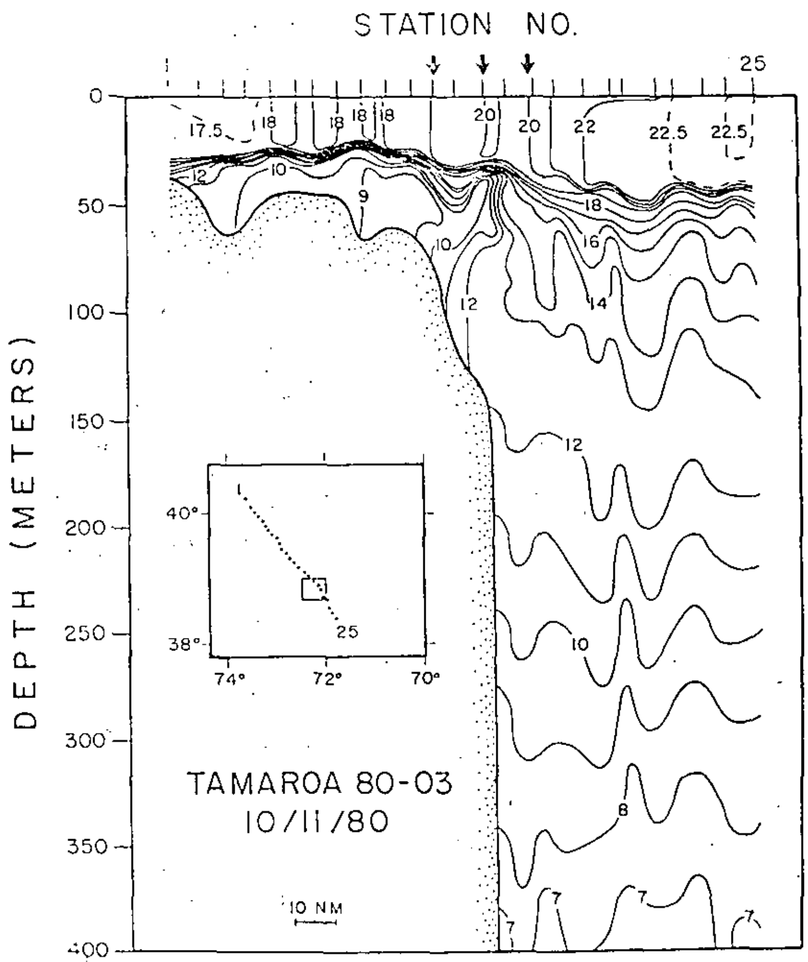

Figure 5. Temperature (°C) transect collected on 11 October 1980 showing thermocline deepening.

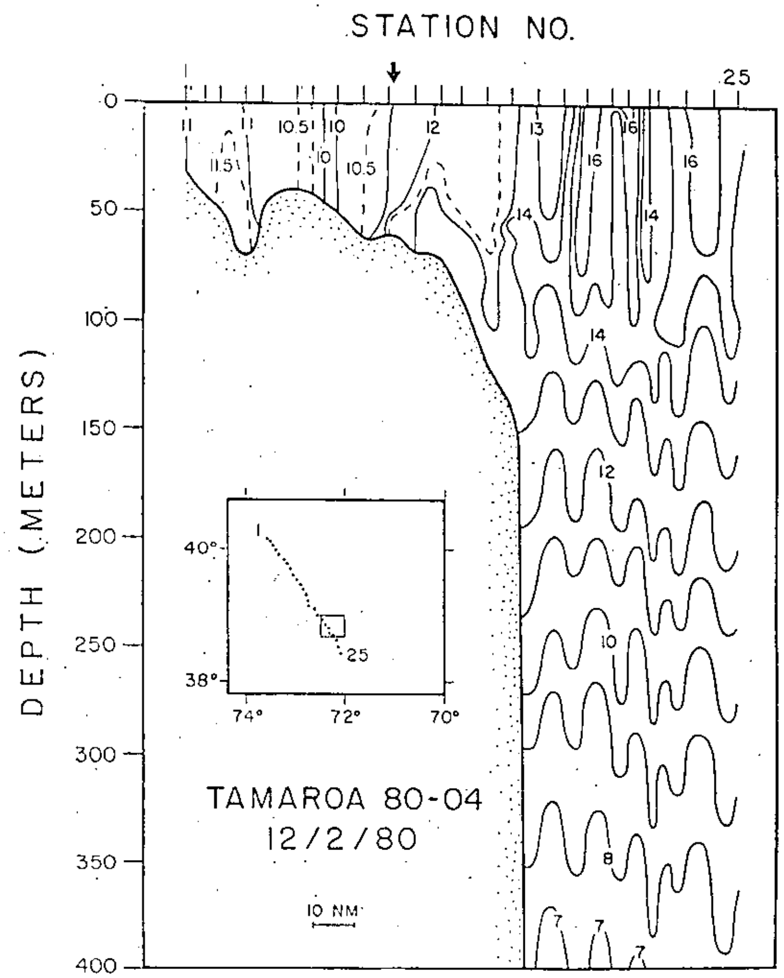

Figure 6. Temperature (°C) transect collected on 2 December 1980 showing winter water after fall overturn.