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Northwest Atlantic Fisheries Organization

Serial No. N2299 NAFO SCR Doc. 93/106

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1993

Environmental Conditions in Atlantic Canada, Mid-Summer 1993 With Comparisons to the Long-Term Mean

by

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1. INTRODUCTION

This report describes the state-of-the-ocean in Atlantic Canada during mid-summer of 1993, with a comparison to the average conditions based on all available historical data. The report presents a subset of the data collected on the third oceanographic cruise of the 1993 field season funded by the Northern Cod Science Program (NCSP) aboard the chartered vessel PETREL V. The report also presents meterological and ice cover data for Atlantic Canada during the winter, spring and summer of 1993. This study is intended to provide information on oceanographic conditions during the inshore migration of northern cod to the bays along the east coast of Newfoundland at approximately one month intervals prior to, during, and after the peak cod migration.

Oceanographic measurements were made along 14 transects running from the inshore areas of the southern Avalon Peninsula to Nain Bank on the Labrador coast and offshore to the shelf edge, data from other fisheries research cruises as well as all historical data in the area are included in the analysis. Measurements along the transects included vertical profiles of currents, temperature, salinity, chlorophyll and dissolved oxygen. In addition, water and zooplankton samples were collected at each station for salinity, chlorophyll, oxygen and biological analysis.

2. METEOROLOGICAL AND ICE CONDITIONS

The monthly air temperature anomalies over Canada from January to April of 1993 are shown in Fig 1a, the shaded areas indicate a positive anomaly. This data is published by the Atmospheric Environment Service of Canada in the Monthly Supplement to Climate Perspectives (Saulesleja, 1993). The anomalies are referenced to the 1951 to 1980 mean. In January air temperature anomalies were generally around -4.0 °C along the coast of Newfoundland and Labrador but had intensified to between -4.0 to -6.0 °C by February and warmed somewhat to -2.0 to -4.0 °C by March of 1993. The coldest monthly anomalies during the past three years occurred in January 1991 when the mean air temperature for the month dropped to -8.0 °C below normal. By April of 1993 the air temperatures had moderated to between 0.0 °C over Newfoundland to between -2.0 to -4.0 °C over Labrador. Figure 1b shows the monthly air temperature anomalies over Canada for May and June as well as the weekly air temperature anomalies for July 5 to 18, 1993. In May the air temperatures ranged from about normal in southern areas to slightly below normal in northern areas. By June however, strong negative anomalies had returned to the island of Newfoundland with temperatures up to -2.0 °C below normal. The first half of July again saw temperatures ranging from 0.0 to 4.0 °C below normal over most regions.

The negative air temperature anomalies experienced this past winter are a continuation of a cold trend that began during the late 1980s. In contrast to the colder than normal conditions in Atlantic Canada in the past several years western and most of central Canada have experienced above normal air temperatures, indicated by the shaded areas in Fig. 1.

The maximum extent of the ice edge (defined by one-tenth total coverage) during mid-February to mid-May of 1993 together with the median and maximum positions of the ice edge for the period 1962 to 1987 along the coast of Newfoundland are shown in Fig. 2a. The mid-monthly positions of the ice edge for 1993 were digitized from the daily ice charts published by Ice Central of Environment Canada in Ottawa, the median and maximum positions of the ice edge were published by Cote (1989). Figure 2b shows the position of the ice edge for early June, mid June, late June and early July 1993.

The large upper layer negative water temperature (-1.0 to -2.0 °C) anomalies along the east coast of Newfoundland reported for the fall of 1992 (Colbourne, 1993) together with the large negative air temperature anomalies experienced during the winter of 1993 had favoured extensive local ice growth along the Newfoundland and Labrador coast during the winter months. This together with the prevailing winter northwesterly winds had resulted in near record ice coverage by mid-February, reaching south of 46° N latitude. By mid-April the ice edge had receded to about 47° N latitude and to about 48° N by mid-May as a result of favourable winds during the latter half of April. In early June 1993 the ice edge had receded to about 51° N, close to the median positions in contrast to 1992 when the ice edge was close to the maximum position, south of 50° N. By late June and early July the ice edge had receded to about 55° N about normal for this time period. In general ice conditions along the east coast during the winter and early spring of this year were more severe (in terms of total ice coverage) than in 1992, but not as severe as in 1991, particularly in the inshore areas. The rapid retreat of the ice edge during late May and early June also indicates that the ice was not as heavy as in the previous two years.

3. STATION 27 TIME SERIES

Depth versus time contour maps of the temperature field and temperature anomalies based on all XBT and CTD profile data collected at station 27 during the winter months and up to July 28, 1993, a total of 34 profiles are plotted in Fig. 3. The anomalies were calculated from the mean of all data collected on the station since 1946.

These maps shows the cold isothermal water column with temperatures ranging from -1.0 °C to -1.7 °C throughout the time series at depths below 80 meters. The time series (upper panel) shows upper layer (generally 0 to 50 m depth) temperatures decreasing from 0.0 °C in early January to -1.7 °C by early February, which persisted until mid-March. By the end of April and early May the upper layer temperature had again warmed to about 0.0 °C and to 8.0 °C by late July. By early July the depth of the 0.0° C isotherm was deeper than normal.

The sea surface temperature had warmed to 1.0 °C by mid-May 1993 compared to the first week of May 1992 and to the first week of June 1991 (Colbourne, 1992). The thickness of the warm upper layer (above 1.0 °C) by early June 1993 was about 20 m thick compared to about 35 m in 1992 and to about 20 m in 1991. By early July the thickness of the upper layer had increased to 60 m, (up to 20 m thicker than normal) but had rebounded to about normal by the end of July. This deepening of the thermocline was restricted to early July and may be the result of a meteorological wind forcing event. In water depths from 80 m to the bottom temperatures remained at about 0.5 °C below normal.

Figure 3 (bottom panel) shows negative temperature anomalies ranging from -1.0 °C in January and between -0.50 to -0.75 °C by April in the upper layer. By early June and into July these anomalies had intensified to -1.5 °C in the surface layer. In the depth range from 40 to 60 m temperature anomalies were up to 2.0°C above normal in early July as a result of the deeper than normal thermocline discussed above.

The monthly temperature and salinity anomalies at Station 27 from 1970 to July 28 of 1993 at standard depths of 0, 30, 100 and 175 m, again referenced to a 1946 to 1993 mean are shown in Fig. 4. The high frequency variations in the anomalies have been filtered out. At the surface the negative temperature anomalies that began in late 1990 and reached a peak in mid 1991 have continued into the summer of 1993. At 30.0 m depth the negative temperature anomalies have continued into June, indicating a delayed warming of the upper layer, but are up to 2.0 °C above normal in July as discussed above. At the deeper depths of 100 and 175 m strong negative temperature anomalies have persisted since 1983 with a few periods of positive anomalies during the mid to late 1980s.

The time series of salinity anomalies (bottom panel) at the surface and at 30 m depth shows that the large fresher than normal anomaly that begin in early 1991 had returned to near normal conditions for a brief period in 1992 but had returned to fresher than normal in 1993. Salinities in the deeper water (100-175 m) have returned to near normal conditions in the spring and summer of 1993. Note also the large negative (fresher than normal) salinity anomaly beginning in 1983 and lasting to the end of 1984 particularly in the upper water column. These events are correlated with colder than normal air temperatures, heavy ice conditions and large than average summer cold-intermediate-layer (CIL) areas on the continental shelf (Drinkwater, 1993).

4. VERTICAL TEMPERATURE AND SALINITY DISTRIBUTION

The vertical distribution (depth versus horizontal distance from the shore) of the temperature and temperature anomaly field along the standard Cape Bonavista transect for July, 1993 are presented in Fig. 5. These anomalies are calculated from the mean temperature field for July of all available data for the transect since the early 1930s. No attempts were made to adjust the mean for possible temporal biasing arising from variations in the number of observations within this time interval.

The temperature in the upper 20 m of the water column ranged from 1.0 to 5.0 °C. In deeper water (50 m to the bottom) the temperatures ranged from -1.0 to -1.5 °C near the coast, to 0.0 to 3.0 °C further offshore near the edge of the continental shelf and beyond. The corresponding temperature anomalies (bottom panel) ranged from 0.0 to -2.0 °C in the surface layer and to -0.5 °C to 150 m depth near the shelf edge. In deeper water the temperature were about normal except near the bottom on the inshore portion of the shelf.

The cold intermediate layer extends offshore to about 240 km, with a maximum thickness of about 250 m corresponding to a cross-sectional area of approximately 33 km^2 compared to 48 km^2 in June. The core of the CIL (temperatures less than -1.5 °C) extends to about 125 km offshore and has a maximum thickness of about 125 m corresponding to a cross-sectional area of approximately 11 km^2 compared to 21 km^2 in June. In July 1992 the CIL of water less than 0.0 °C extended to about 220 km offshore with a maximum thickness of about 200 m, corresponding to a cross-sectional area of 28 km^2 and about 5 km^2 for water less than -1.5 °C. The bottom temperature across the shelf were similar both in years. Figure 6 shows a time series of the CIL area anomaly (top panel) and CIL minimum temperatures (bottom panel) from 1948 to 1993. In 1993 the CIL area is about 28 % above normal compared to 8 % in 1992. The minimum temperatures observed in the core of the CIL were -1.74 °C in 1993 compared to -1.68 °C in 1992, slightly below normal.

Salinities generally ranged from 32.0 psu near the surface to 33.5 psu near the bottom over the inshore portion of the transect (Fig. 7, top panel), to 34.75 psu at about 325 m depth near the shelf edge. The salinity anomalies (Fig. 7, bottom panel) shows saltier than normal conditions in the upper 20 m of the water column by up to 0.5 psu and slightly fresher than normal near the shelf edge in water depths of 50 to 150 m. This is in contrast to Station 27 where the upper 30 m of the water column shows fresher than normal salinities. Salinities near the bottom were about normal along the complete transect.

5. VERTICAL OXYGEN DISTRIBUTION

The Cape Bonavista oxygen transect data collected in conjunction with the temperature, salinity and chlorophyll data are shown in Fig. 8. These measurements were made with a Beckman type polarographic element dissolved oxygen sensor with factory calibrated end-points at zero and air-saturated water oxygen levels. The sensor was interfaced to a Seabird-9 CTD system. A total of 300 water samples were collected at standard oceanographic depths for field oxygen calibrations. The oxygen levels of these samples were determined by semi-automated analytical chemistry using a modified Winkler titration technique. A least-squares fit of the titration measurements to the electronic sensor measurements was then computed. The corrected sensor readings were found to be related by a linear equation with a slope of 0.9648 and an intercept of 0.3576 (ie. corrected probe value = 0.9648 x titration value + 0.3576). These results indicate that the sensor was reading about 0.15 ml/l lower than the titrated values. The offset was near linear as indicated by the slope of the fitted line across the range of oxygen concentrations encountered.

This survey shows corrected dissolved oxygen levels of 6.5 ml/l near the bottom to 8.5 ml/l near the surface. The corresponding oxygen saturations ranged from 100 % from the surface to about 40 m depth and about 85 to 90 % from 40 m to the bottom. The dissolved oxygen values reported here are about 0.5 ml/l lower than the values found on the Grand Banks during a cruise in late April. This decrease may be attributed to lower phytoplankton levels in July compared to April when the plankton bloom is near maximum. During a cruise in July 1992 along the same transect the oxygen values ranged from 7.0 ml/l (90 to 100% saturation) in the upper layer to about 5.5 ml/l (65 to 70 % saturation) near the bottom, about 1.0 ml/l lower than in 1993.

6. HORIZONTAL TEMPERATURE AND SALINITY FIELD

Figure 9 shows horizontal maps of the average surface temperatures field in Atlantic Canada for July 1993 from all available data (left panel) and from the data collected between July 3 to July 28, 1993 (right panel). These contours were derived from unweighted averages (ie. data for the entire time period are assumed synoptic) of all data in a square grid of 0.25 degrees. The average sea surface temperature for this time period ranged from 10.0 °C over the southern Grand Banks to 4.0 °C off southern Labrador. The surface temperatures during July 1993 ranged from 6.0 over the Grand Banks to about 3.0 °C off southern Labrador. In general the surface temperature over most of the surveyed area was about 1.0 to 2.0 °C below the July average. Similarly Figure 10 shows the horizontal temperature field at 75 m depth (close to the bottom over most of the Grand Banks) about at the center of the CIL during the same time periods. The average temperature at this depth ranged from 1.0 °C over the southern Grand Banks to -1.0 °C over parts of the northeast Newfoundland and Labrador shelves. The temperatures over the surveyed area in July at 75 m depth ranged from -1.6 °C near the coast to 1.0 °C at the shelf edge, about 0.5 to 1.0 °C below the long term average.

Figures 11 and 12 shows horizontal maps of the salinity field at 0.0 and 75.0 m depth. Salinities at both depths are near normal except along the inshore area of the northeast Newfoundland shelf where salinities are up to 0.5 psu above normal.

7. THE LABRADOR CURRENT

The Labrador current along the transects occupied in July was mapped with a hull-mounted 300 kHz RDI Acoustic Doppler Current Profiler (ADCP) at a spatial resolution of approximately 1.5 km horizontally by 4.0 m vertically. Figure 13 shows the along-shelf vertical distribution of currents across the northeast Newfoundland shelf for July 1992 (top panel) and July 1993 (bottom panel), the negative values correspond to southward flowing water. Preliminary analysis of this data shows a well defined offshore branch up to 150 meters deep with current velocities reaching 30 cm/s in a general southerly alongshelf direction. Across the shelf currents speeds generally ranged from 5 to 15 cm/s with slightly larger transport in 1992. It should be noted that these surveys are a one day snapshots of the Labrador current and may not represent the mean flow. Apparent counter currents (northward flowing water) are seen in the 1993 transect with speeds up to 5 cm/s over the outer portion of the shelf. These currents are not unusual, and have been observed on several ADCP surveys during 1991 and 1992, they also appear in drifter track data and satellite images. They are larger than predicted barotrophic tidal currents and are thought to the result of eddies at scales of about 10 to 15 km.

ACKNOWLEDGEMENTS

I would like to thank the technical staff of the oceanography section at NAFC for the professional job done in data collection and processing and for the computer software support. I also thank D. Foote for data processing and technical assistance in the preparation of this document. I would also like to thank the captain and crew of the Petrel V. This project is funded by the Northern Cod Science Program (NCSP).

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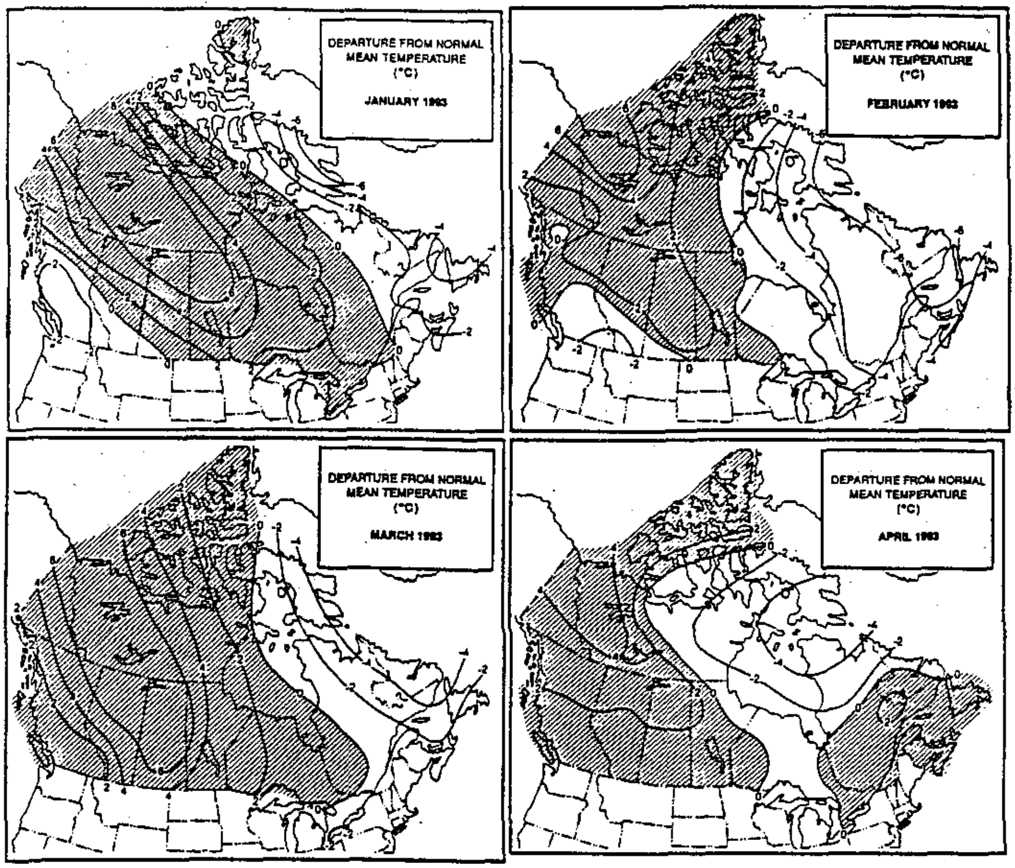

Fig. 1a Monthly air temperature anomalies over Canada for the winter and early spring of 1993. (From Climatic Perspectives, Vol. 15, 1993)

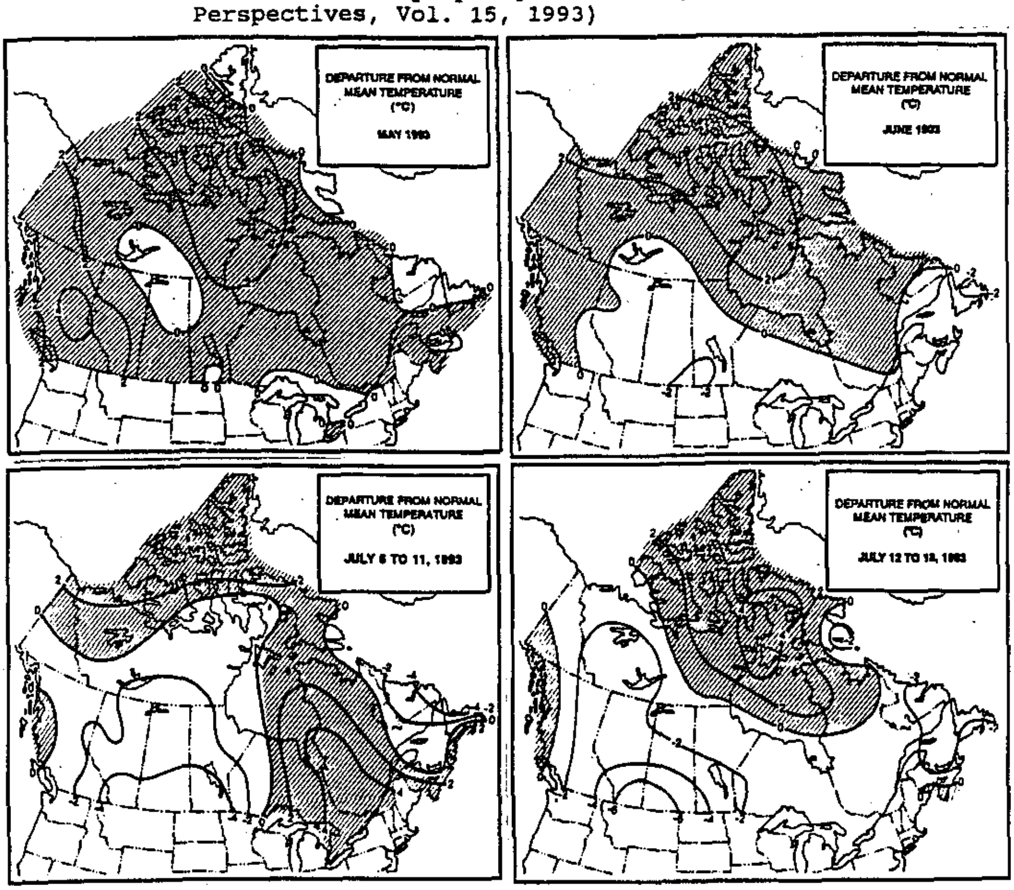

Fig. 1b Monthly air temperature anomalies over Canada for May and June and from July 5 to 18 of 1993. (From Climatic Perspectives, Vol. 15, 1993)

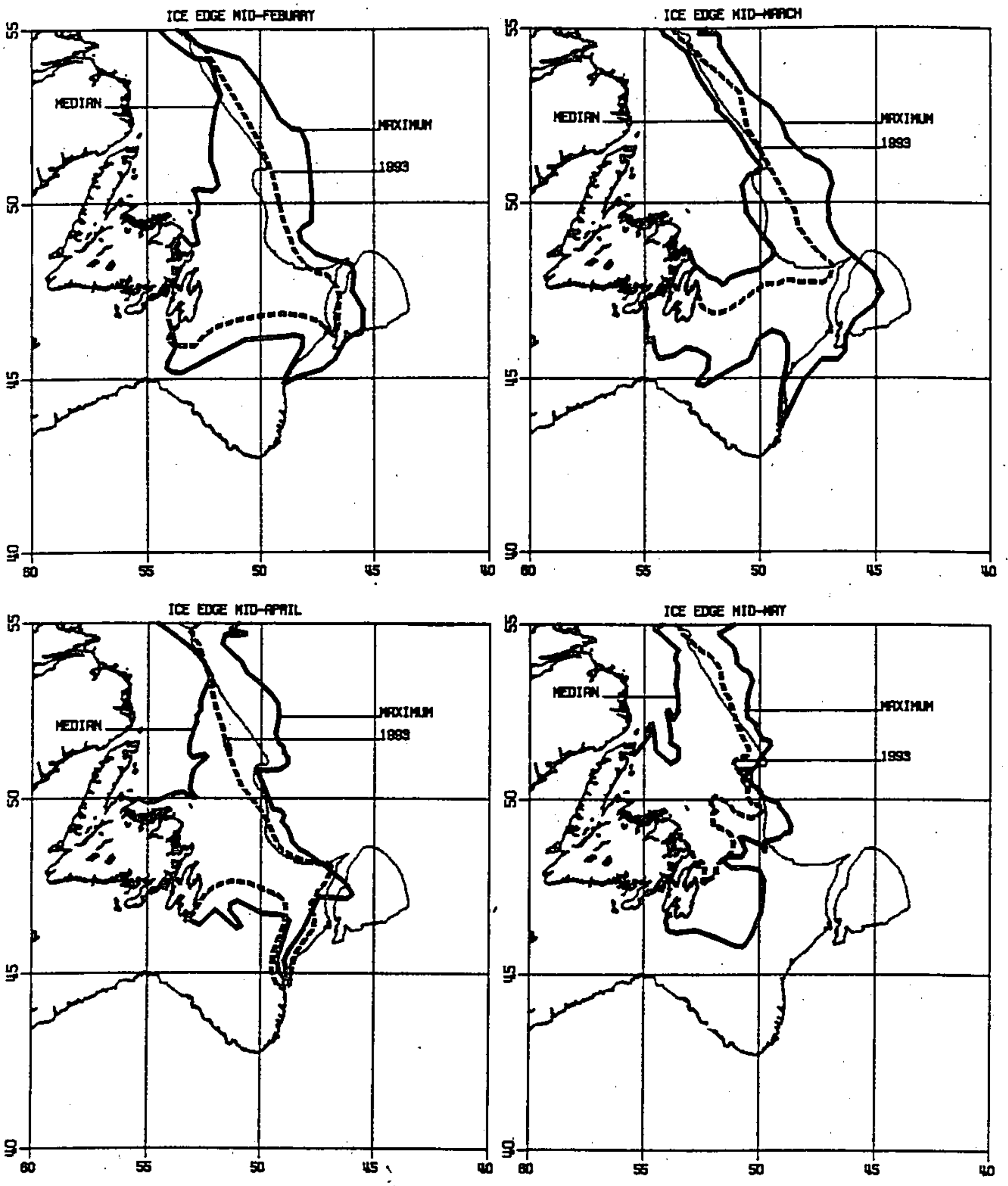

Fig. 2a Ice edge locations for mid-February to Mid-May. The dashed lines are locations for 1993, the two heavy solid lines are the median and maximum positions for the same time period based on historical data from 1962 to 1987. (from Cote, 1989)

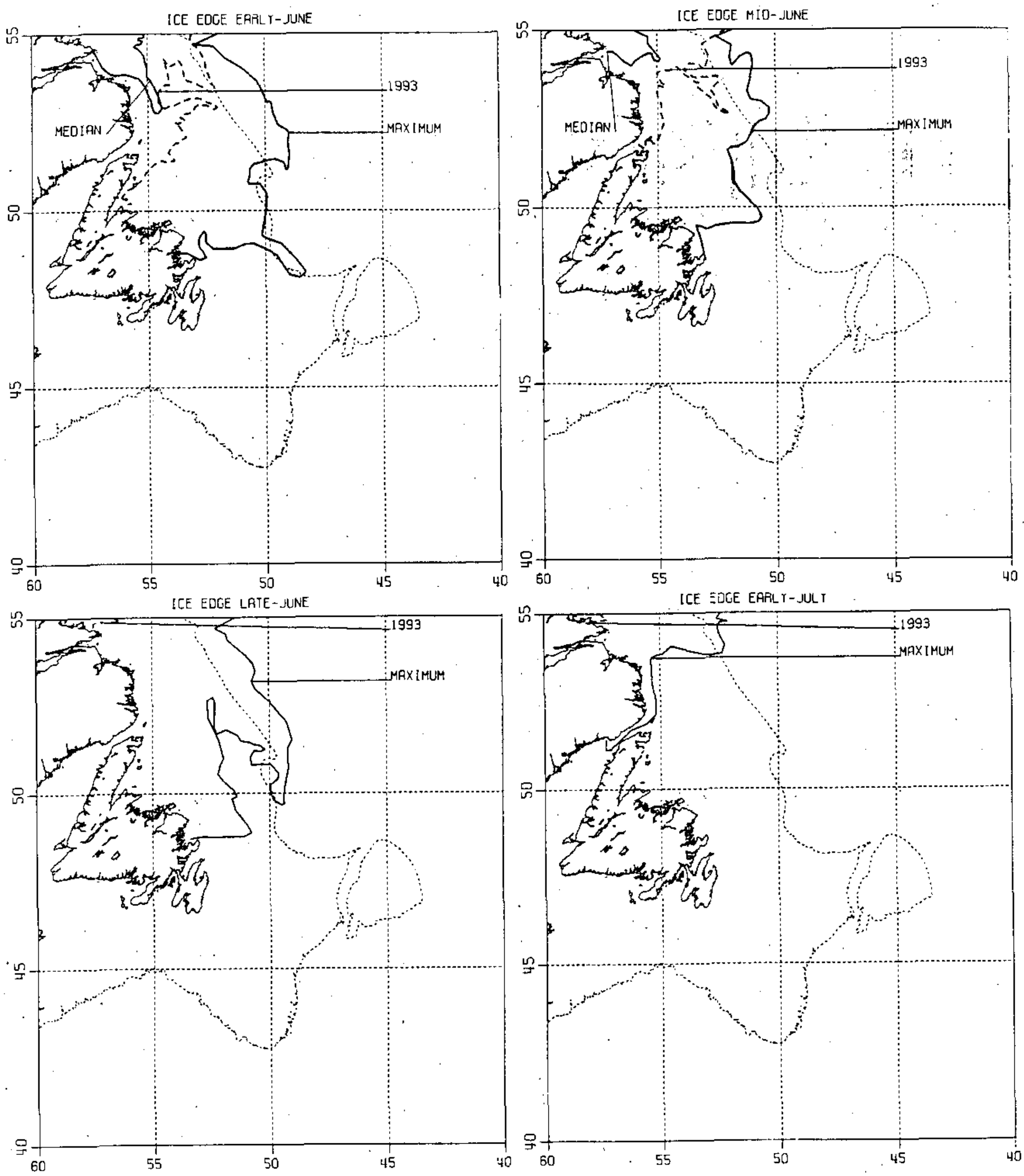

Fig. 2b Ice edge locations for early June to early July 1993. The dashed lines are locations for 1993, the two heavy solid lines are the median and maximum positions for the same time period based on historical data from 1962 to 1987 (from Cote, 1989).

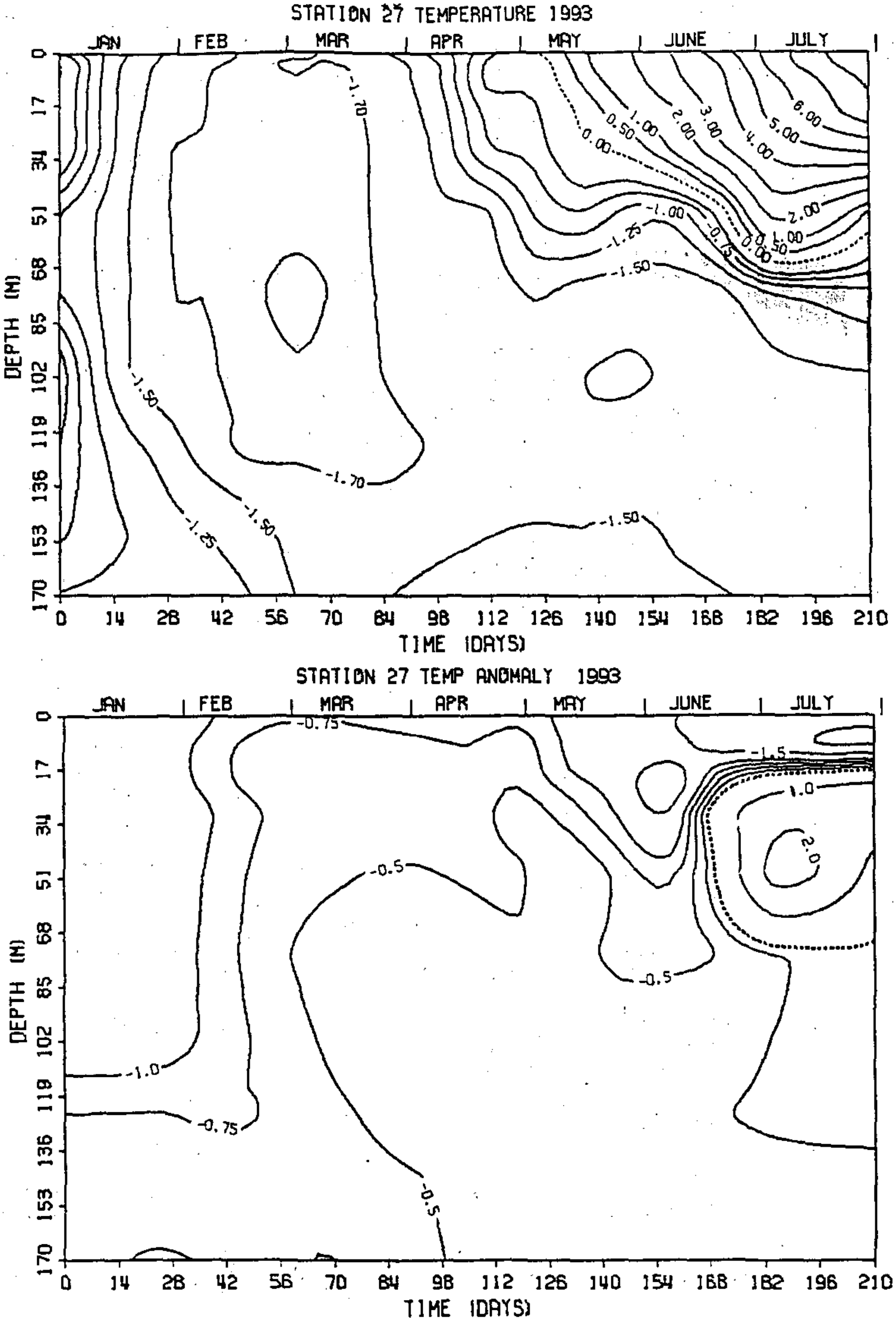

Fig. 3. Time series of temperatures and anomalies at Station 27 from January to July 28, 1993.

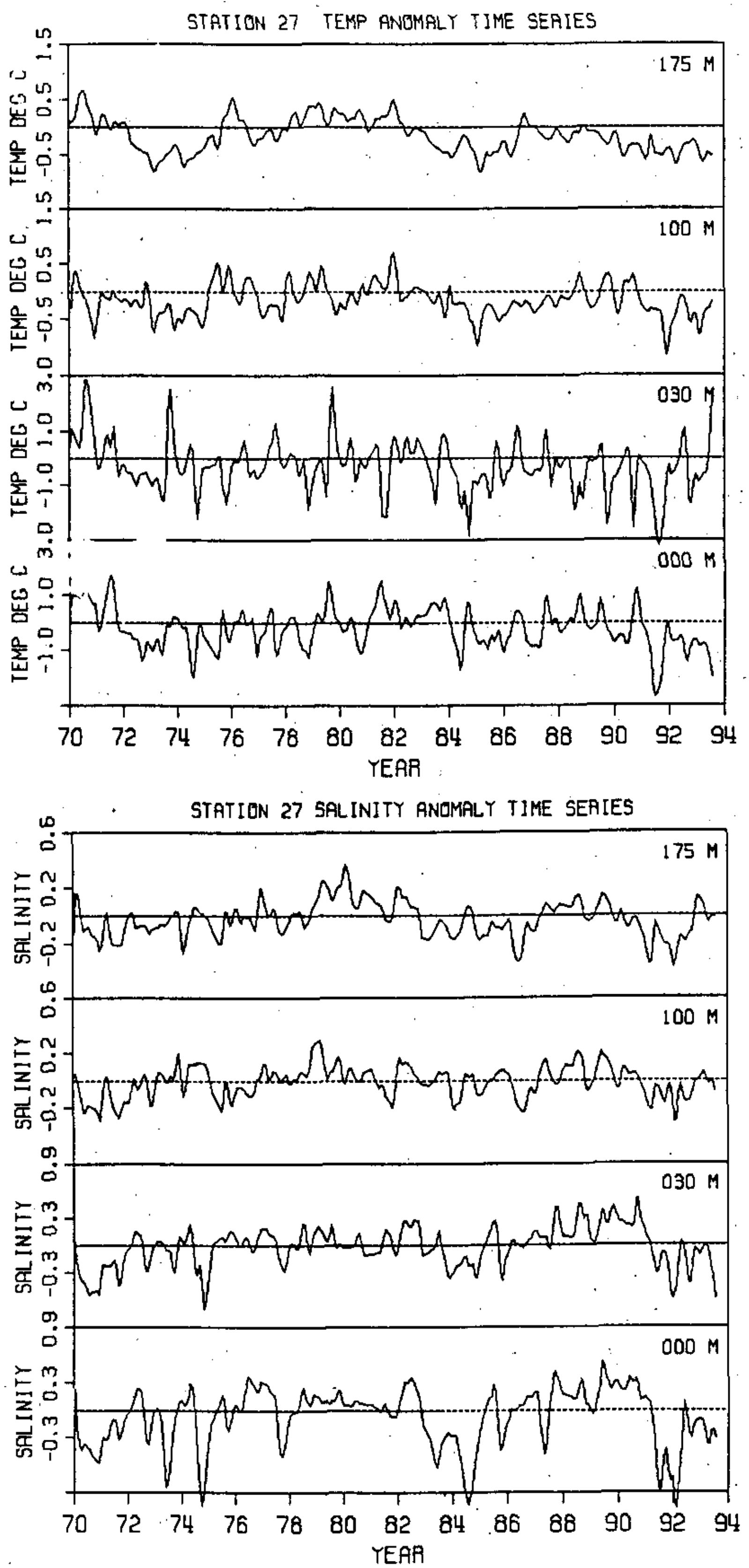

Fig. 4. Time series of monthly temperature and salinity anomalies at Station 27 at standard depths from 1970 to July of 1993.

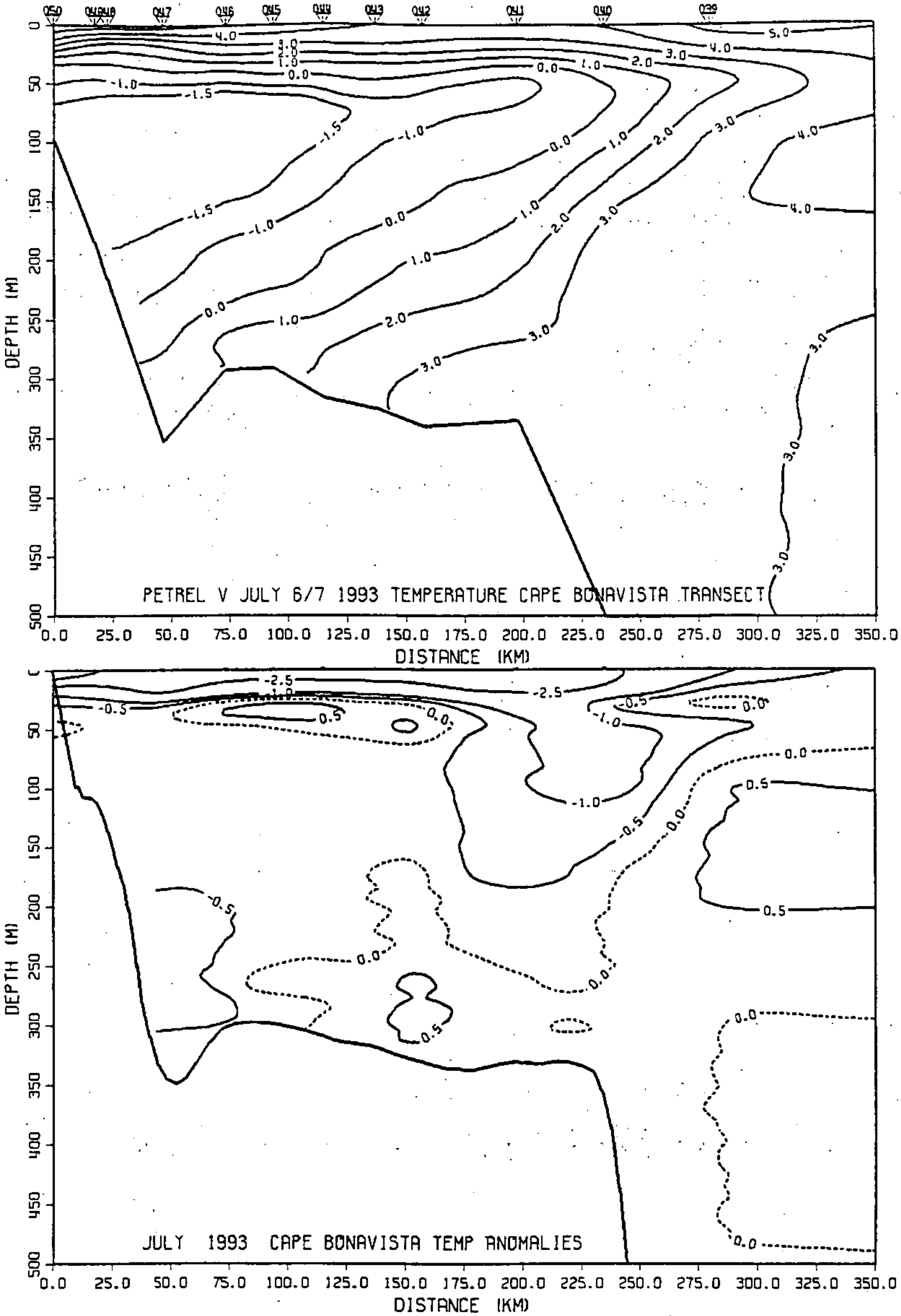

Fig. 5. The vertical distribution of temperature and anomalies along the standard Cape Bonavista transect for early July, 1993.

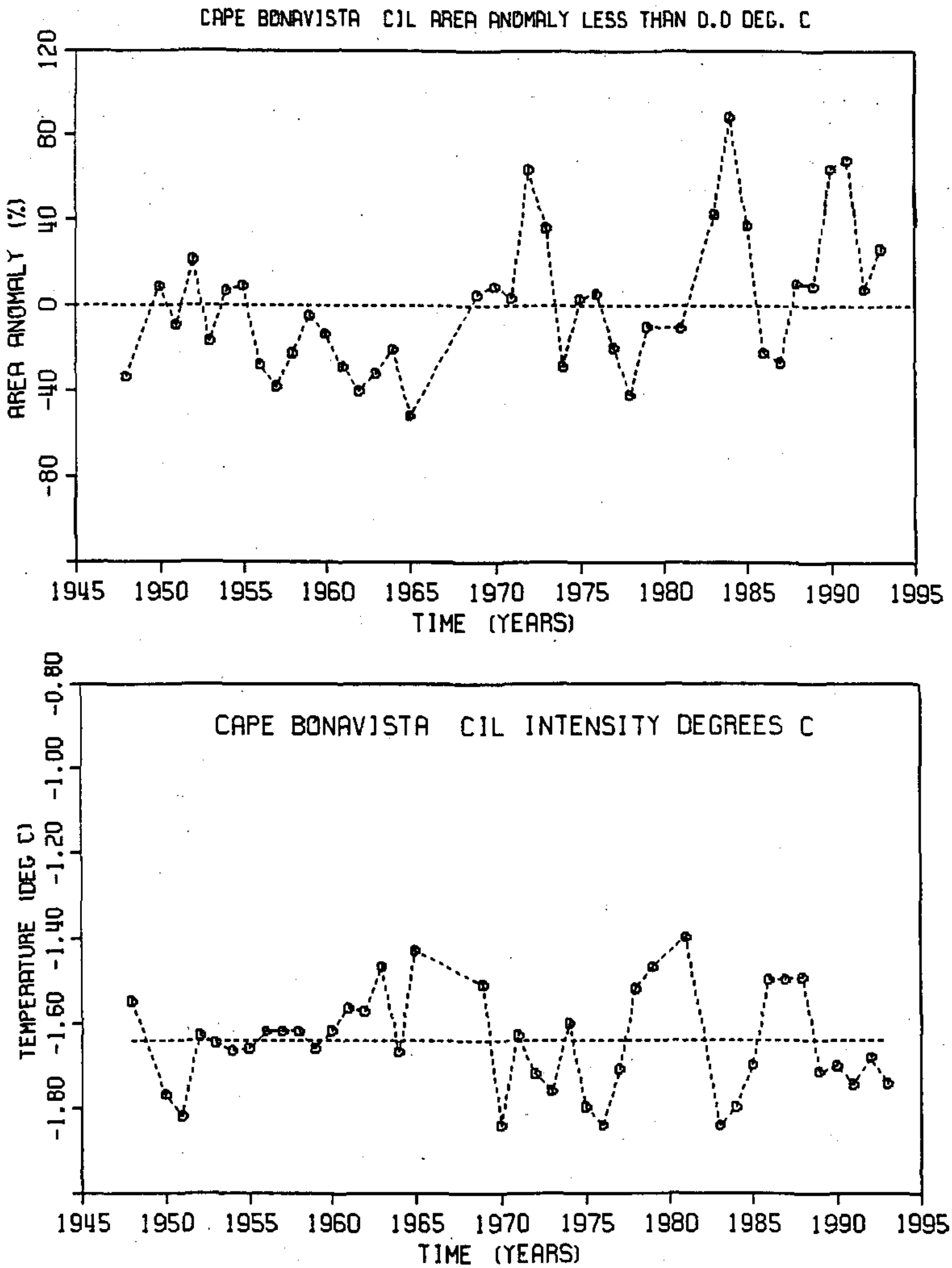

Fig. 6. A time series of CIL area anomaly along the Cape Bonavista transect (top panel) and the CIL intensity or minimum temperature (bottom panel). The dashed line represents the average.

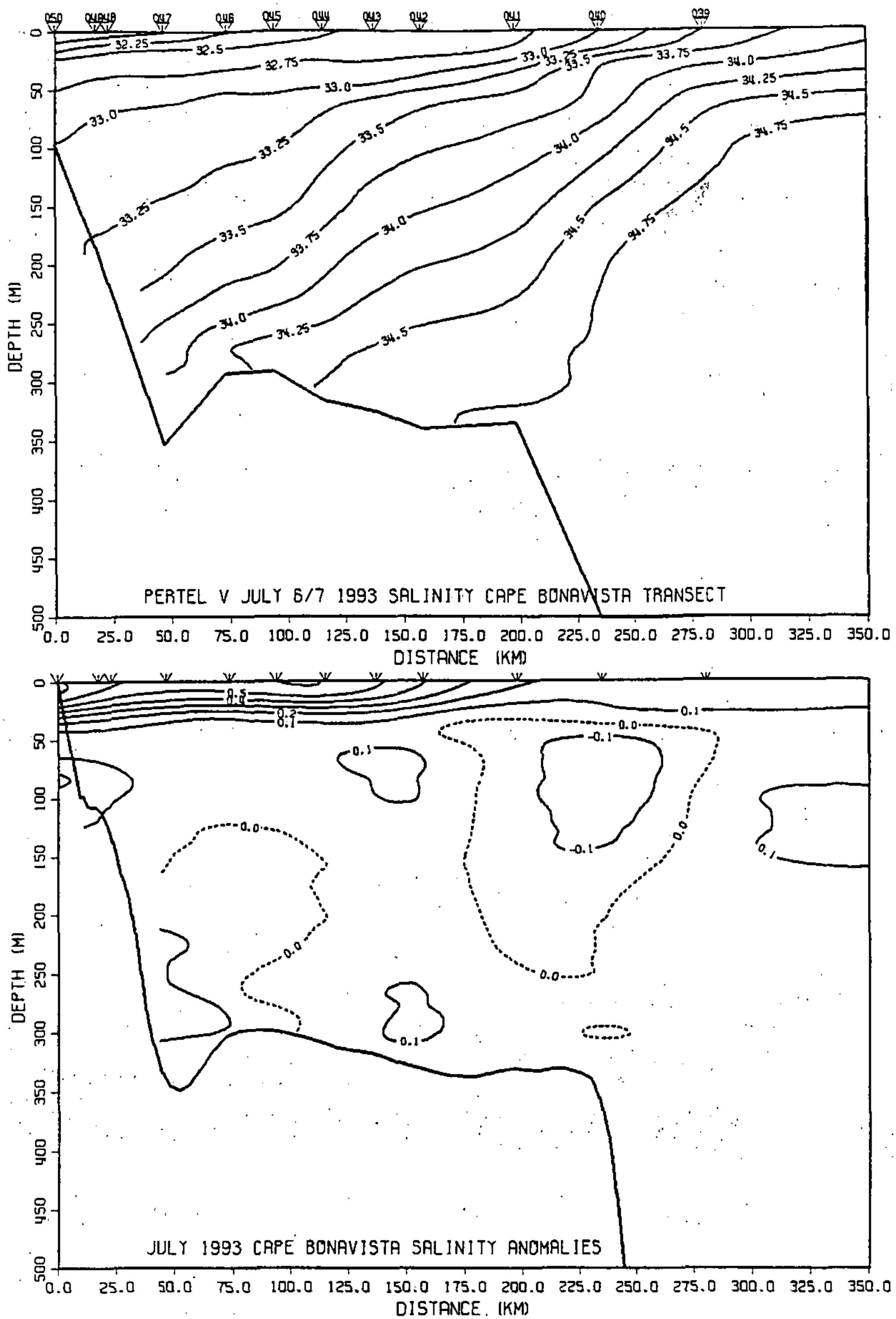

Fig. 7. The vertical distribution of salinity and anomalies along the standard Cape Bonavista transect for early July, 1993.

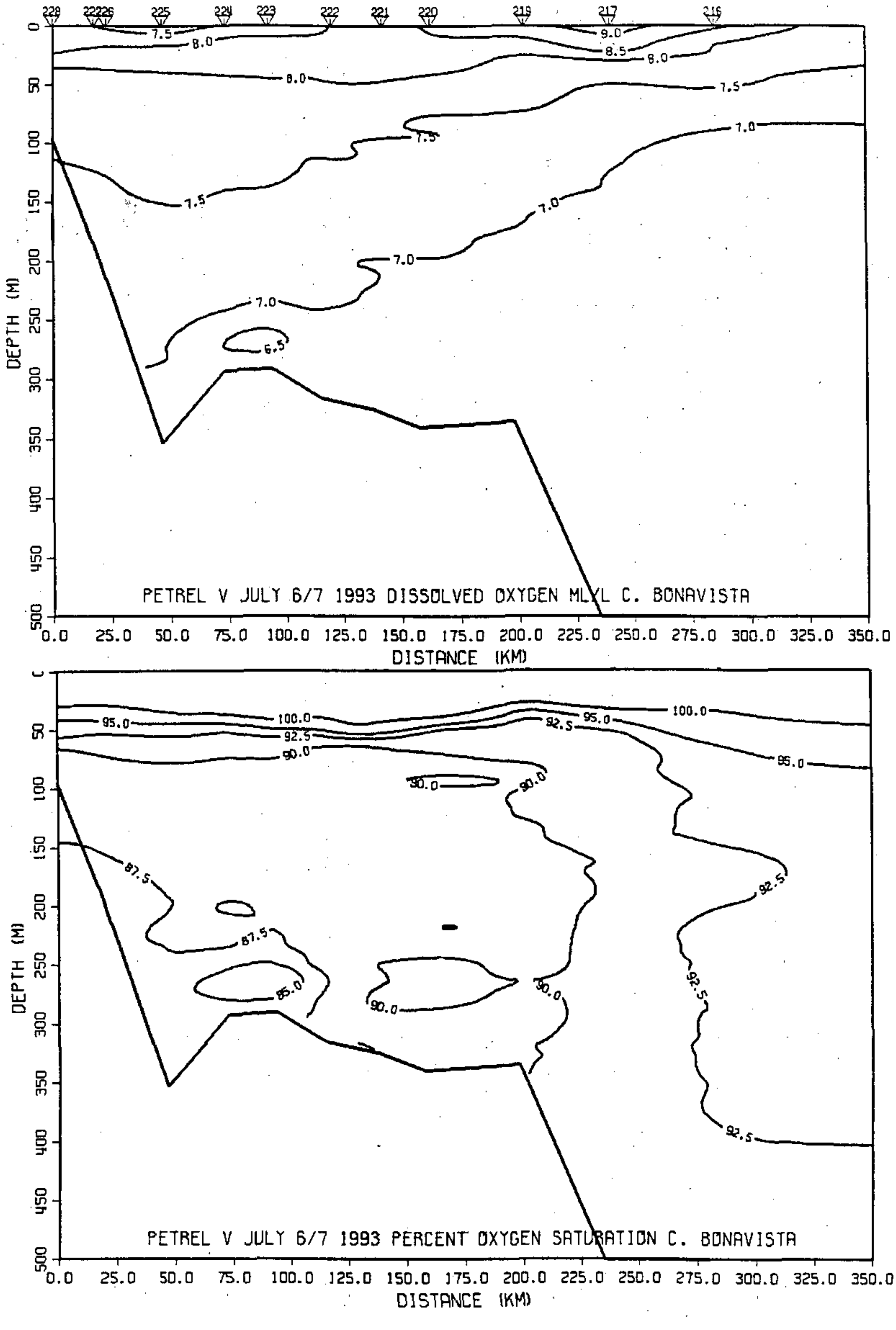

Fig. 8. The vertical distribution of dissolved oxygen concentration and saturation along the standard Cape Bonavista transect for early July, 1993.

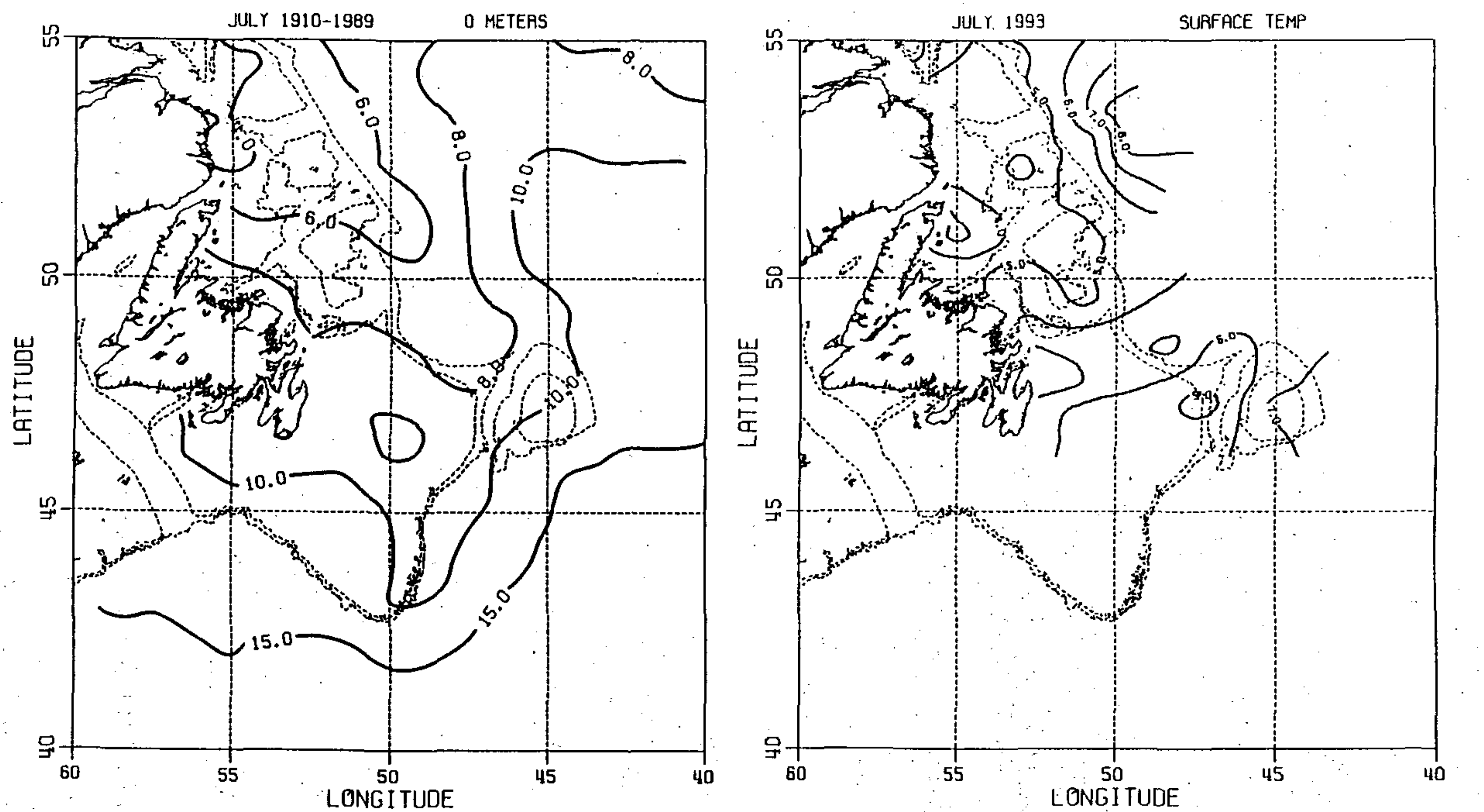

Fig. 9. The July mean and July 1993 horizontal surface temperature maps for the Newfoundland region.

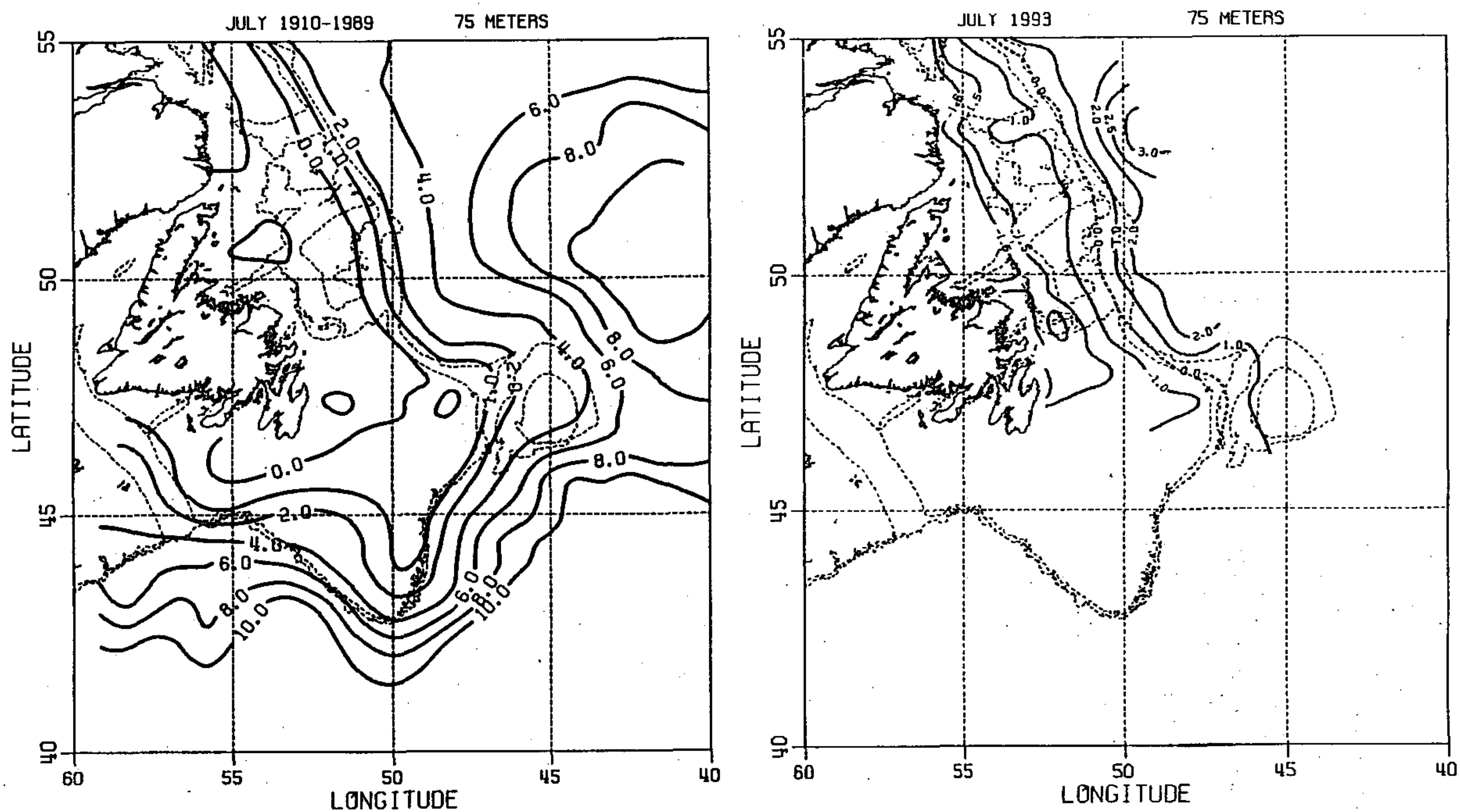

Fig. 10. The July mean and July 1993 horizontal temperature maps at 75 m depth for the Newfoundland region.

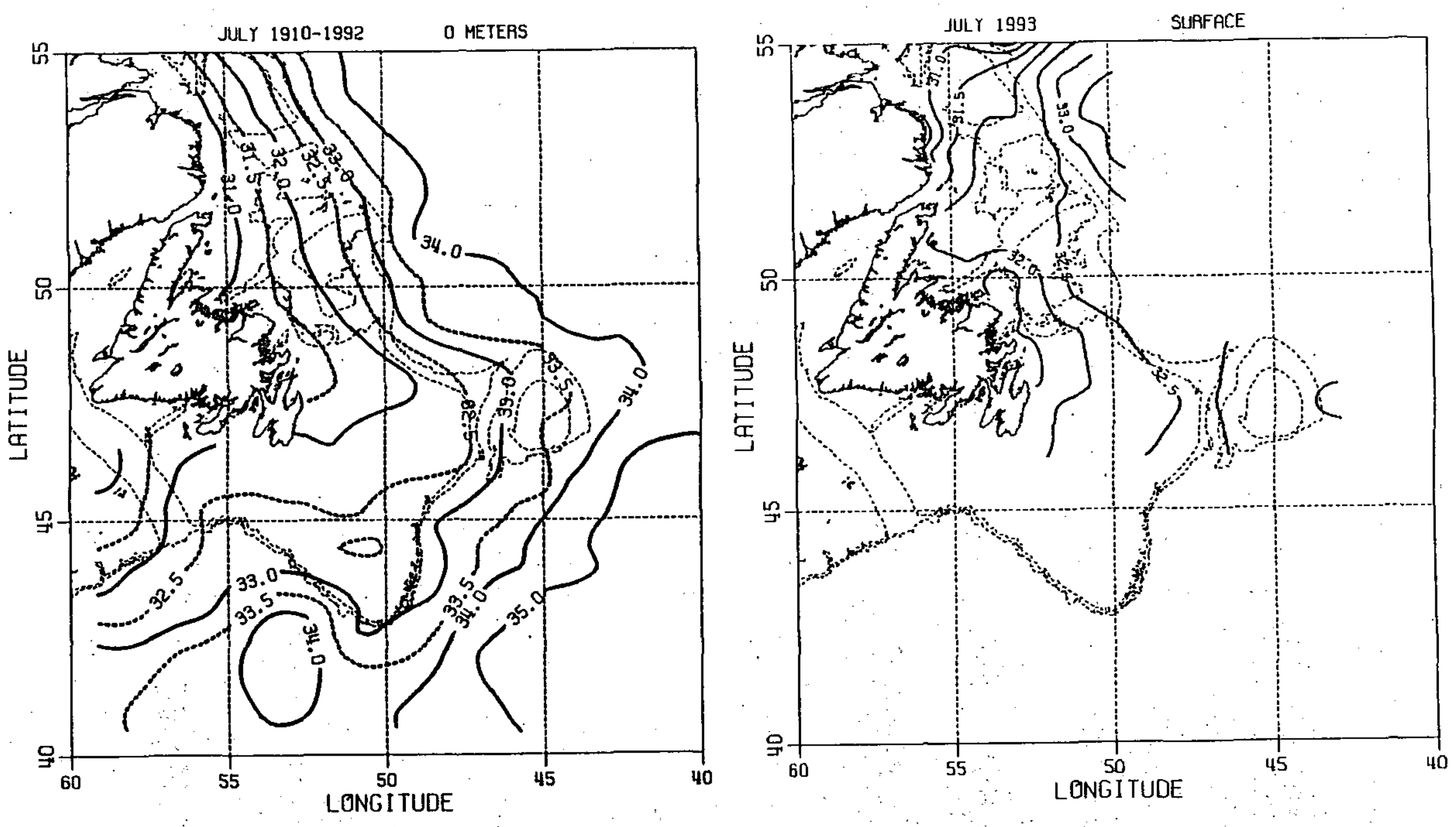

Fig. 11. The July mean and July 1993 horizontal surface salinity maps for the Newfoundland region.

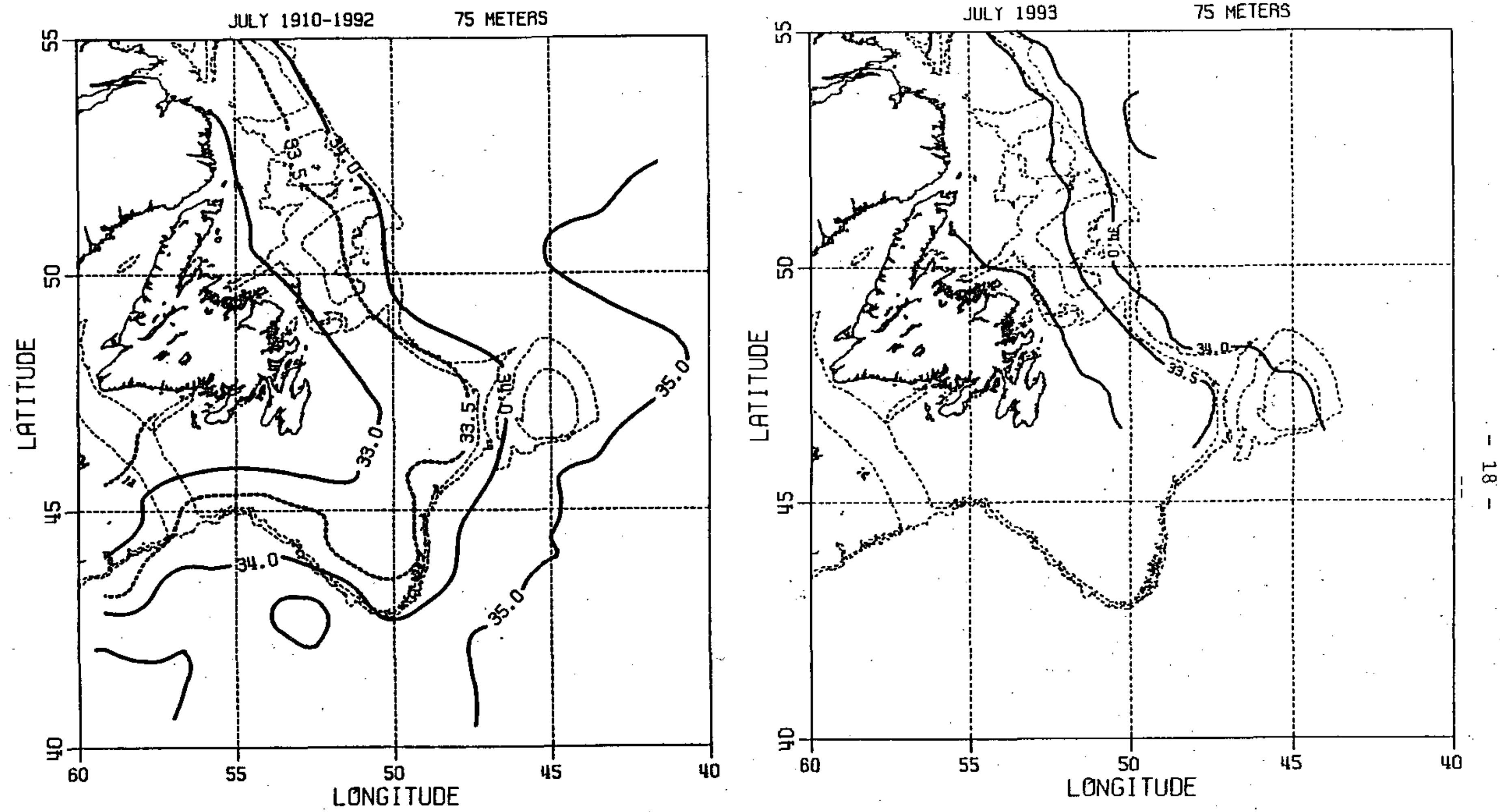

Fig. 12. The July mean and July 1993 horizontal salinity maps at 75 m depth for the Newfoundland region.

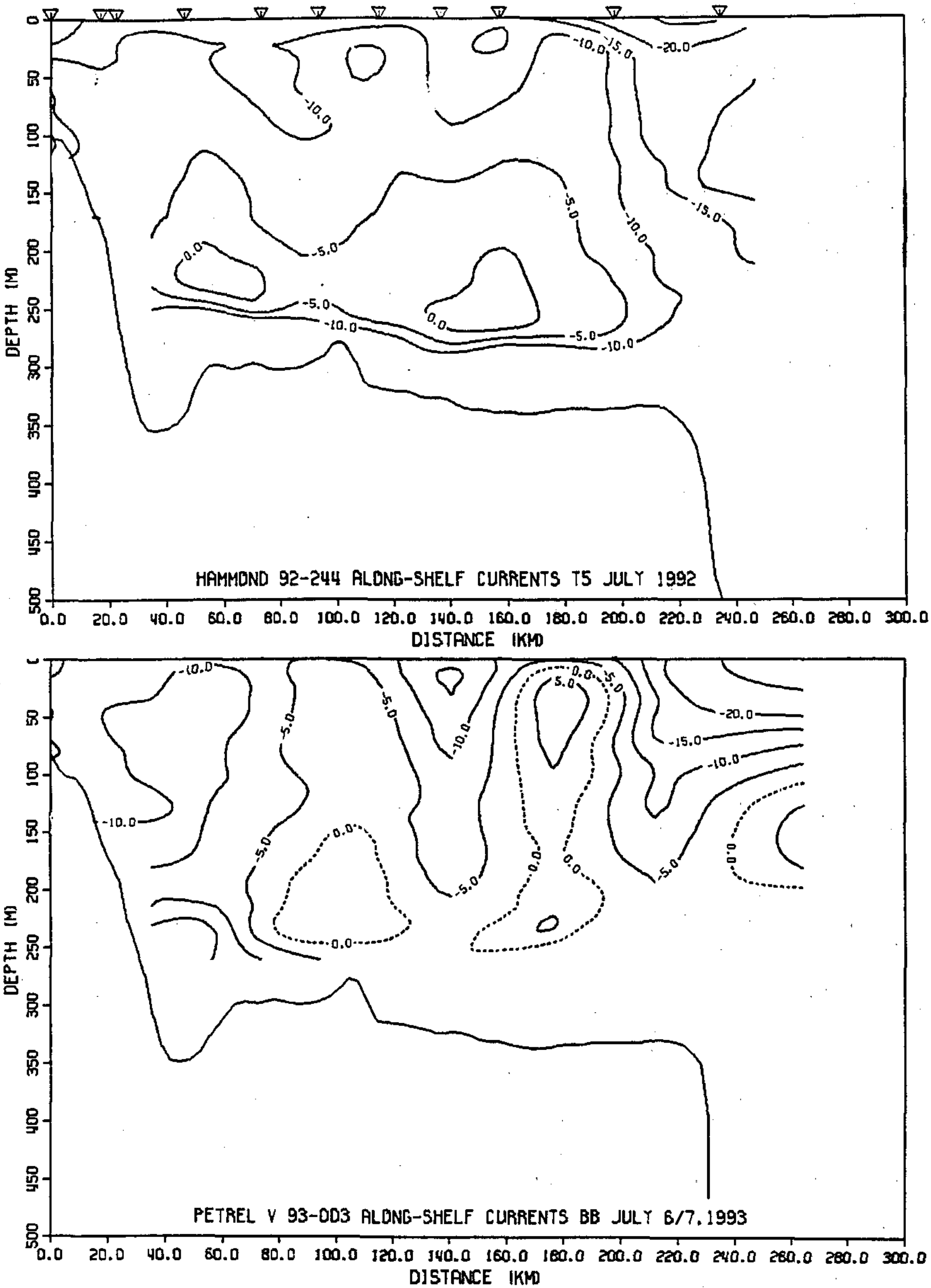

Fig. 13. The vertical distribution of the current field along the Cape Bonavista transect. Negative currents are southward, from an ADCP survey.