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OCEANOGRAPHIC CONDITIONS IN THE NEWFOUNDLAND REGION IN 1997

by

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Abstract

Oceanographic observations from St. Pierre Bank, Grand Bank, Northeast Newfoundland Shelf and the Southern Labrador Shelf during 1997 are presented and referenced to the long-term (1961-1990) mean. The time series of temperatures at Station 27 show values ranging from 0.0 to 0.5 °C above normal for the winter months over most of the water column. By mid April a strong negative surface temperature anomaly developed with anomalies reaching near 1.0 °C below normal by mid May and continued throughout the summer, while bottom temperatures remained near normal throughout the year. The summer upper layer salinities were normal, the first time since 1990, as well the annual depth average temperature at Station 27 was about normal. Time series from the inshore regions show below normal temperatures during mid 1997 but recovered to near normal values late in the year. Temperature anomalies on St. Pierre Bank show the cold period which started around 1984, continued to the spring of 1995, showed moderation during 1996, particularly in the upper layer, but decreased again to below normal values in 1997. During the summer of 1997 the CIL area off Bonavista and Hamilton Bank was well below normal continuing a trend established in 1994. Across the Grand Bank the CIL was above normal compared to near normal conditions in 1996. The total volume of sub-zero °C water on the Newfoundland Shelf during both summer and fall is continuing a below normal trend established in 1995. During the fall of 1997 bottom temperatures were above normal over many areas, particularly on the offshore portion of the Northeast Newfoundland Shelf, continuing a trend established in 1996. During the spring of 1997 deep water bottom temperatures in the 3Ps area appeared to be above normal while most of St. Pierre Bank was below normal by more than 1.0 °C on the southeast portion of the bank. While 1996 temperatures were somewhat higher in the 3Ps area, conditions in this region are highly variable and it appears that the cold trend on St. Pierre Bank is continuing into 1997. In general, during 1997 oceanographic conditions were above normal over many areas, particularly over the deeper portions of the Northeast Newfoundland Shelf. The exception being the near shore in the upper water column and over the shallow portions of the Grand Bank where temperatures were colder than normal during late spring and early summer.

Résumé

Les résultats d'observations océanographiques réalisées sur le banc Saint-Pierre, le Grand Banc, le nord-est du plateau de Terre-Neuve et le sud du plateau du Labrador au cours de 1997 sont présentés et appariés aux moyennes à long terme (1961-1990). La série chronologique des températures dans presque toute la colonne d'eau à la station 27 est formée de valeurs de 0,0 à 0,5 °C supérieures à la normale pendant l'hiver. À la mi-avril, une forte anomalie négative de la température de surface est apparue et des anomalies atteignant près de 1.0 °C en deçà de la normale à la mi-mai se sont maintenues tout au long de l'été tandis que les températures du fond sont demeurées presque normales tout au long de l'année. La salinité de la couche supérieure en été était normale, pour la première fois depuis 1990, et la température moyenne annuelle en profondeur à la station 27 était presque normale. La série chronologique des régions côtières indique des températures inférieures à la normale au milieu de 1997, mais un rétablissement à des valeurs approchant la normale plus tard au cours de l'année. Les anomalies de températures du banc Saint-Pierre montrent que la période froide qui a débuté vers 1984 s'est maintenue jusqu'au printemps de 1995, s'est modérée en 1996, notamment dans la couche supérieure, pour revenir à des valeurs inférieures à la normale en 1997. Pendant l'été de 1997, la température de la CFI au large de Bonavista et sur le banc Hamilton était bien inférieure à la normale, et conforme à la tendance apparue en 1994. Au-dessus du Grand Banc, la température de la CFI était supérieure à la normale, les conditions ayant été presque normales en 1996. Le volume total d'eau à température inférieure à zéro °C du plateau de Terre-Neuve pendant l'été et l'automne s'inscrivait dans la tendance de température inférieure à la normale apparue en 1995. Pendant l'automne de 1997, les températures au fond étaient supérieures à la normale dans bon nombre de zones, notamment dans la partie du large du plateau nord-est de Terre-Neuve, conformément à la tendance apparue en 1996. Au cours du printemps de 1997, les températures des eaux des fonds profonds de la division 3Ps semblaient supérieures à la normale tandis que les températures des eaux du banc Saint-Pierre étaient inférieures à la normale de plus de 1,0 °C dans la partie sud-est du banc. Les températures ont été légèrement supérieures en 3Ps en 1996, mais les conditions de cette zone sont très variables et il semble que la tendance aux températures froides du banc Saint-Pierre se soit maintenue en 1997. De façon générale, les conditions océanographiques de 1997 ont été supérieures à la normale dans bon nombre de zones, notamment dans les parties les plus profondes du nord-est du plateau de Terre-Neuve. Les eaux de la partie supérieure à proximité de la côte et celles des zones peu profondes du Grand Banc font cependant exception, leur température ayant été inférieure à la normale à la fin du printemps et au début de l'été.

INTRODUCTION

This report presents an overview of oceanographic conditions in the Newfoundland region during 1997, with a comparison to the long-term average conditions based on historical data. Where possible the long-term means were standardized to a base period from 1961-1990 in accordance with the convention of the World Meteorological Organization and recommendation of the NAFO Scientific Council. Most of the long-term averages computed for this report had good temporal coverage over the years 1961-1990 except during the fall period for which most data are from the late 1970s to present. Much of the information presented here is based on oceanographic observations made at Station 27 and along standard cross-shelf transects (Fig. 1) during an annual oceanographic survey in July and August since 1946. Data from the inshore regions around Newfoundland including temperature time series from three Long-Term-Temperature-Monitoring-Program (LTTMP) sites are also used. In addition, all oceanographic observations made during the spring and fall pelagic and groundfish research vessel surveys from the late 1970s to 1997 in NAFO Divisions 2J to 3NO and 3Ps are included. Data from all other available sources are also used to help define the long-term means.

DATA SOURCES AND ANALYSIS

Oceanographic data for NAFO Divisions 2J3KL, 3NO and 3Ps are available from archives at the Marine Environmental Data Service (MEDS) in Ottawa and the Northwest Atlantic Fisheries Center (NAFC) in St. John's Newfoundland. During the fall period since 1977 (in Division 2J), and since 1981 (in Divisions 2J3KL) to 1989 the bulk of these data were collected during the stratified random groundfish surveys using XBTs. Since 1989 conductivity-temperature-depth (CTD) recorders have replaced XBTs. Data in subdivisions 3Pn and 3Ps are from the Canadian assessment surveys conducted in February, March and April mainly since 1973, however some historical data dating back to 1950 were also available. Measurements of temperature and salinity were made using several models of CTD recorders including Seabird-911s, SBE-25s and SBE-19s. Data from the net-mounted SBE-19 CTDs are not field calibrated, but are checked periodically and are factory calibrated annually. The SBE-25 and 911s are field calibrated on each survey maintaining accuracies of 0.005 °C in temperature and 0.005 PSU in salinity.

Time series of temperature and salinity were constructed at standard depths from Hamilton Bank, Station 27, Flemish Cap, St. Pierre Bank and the inshore region around Random Island, Trinity Bay and Placentia Bay (Colbourne 1997). The 1961-1990 data sets from these areas were sorted by day of the year to determine the annual cycle. Following the general methods of Petrie et al. 1992 and Myers et al. 1990, the seasonal cycle at the selected depths was removed by fitting a least squares regression of the form $\mathbf{cos(\omega t-\phi)}$ to the data. Unlike the time series of anomalies from fixed points like Station 27 these anomalies are based on data over large geographical areas such as St. Pierre Bank and therefore exhibit significant spatial variability. Temperature anomalies were constructed for the years 1990 to 1997 from the Long-Term-Temperature-Monitoring thermograph sites by computing monthly means from the continuous time series. Average bottom temperature maps were produced from all available data from 1961 to 1990 and for the spring of 1997 in division 3Ps and for the fall of 1997

on the Eastern Newfoundland Shelf. These maps were produced by contouring all bottom of the cast temperature values and rejecting values for which the cast depths were not within 10 % of the total water depth. Some temporal and spatial biasing may be present in the analysis given the large area and wide time interval over which the maps were produced. For example, the annual fall groundfish survey is conducted from mid-October to mid-December a time period when rapid cooling of the water column is taking place.

TEMPORAL ANOMALIES IN TEMPERATURE AND SALINITY

Station 27 (Division 3L)

A total of 53 temperature and salinity profiles were collected at Station 27 off Cape Spear during 1997. The data from this time series are presented in several ways to highlight various parts of the water column and the time series. Depth versus time contour maps of temperature and salinity values and their associated anomalies are displayed in Figs. 2 and 3. The annual time series of monthly temperature and salinity anomalies at standard depths are shown in Figs. 4 and 5.

The cold isothermal water column during the winter months has temperatures ranging from 0.0 °C to -1.0 °C and throughout the year near the bottom. The time series shows upper layer (generally the 0 to 50 m depth range) temperatures near constant at about 0.0 °C from January to early April, after which the surface warming commenced. By early May the upper layer temperature had warmed to 2.0 °C and to above 12.0 °C by August at the surface, after which the fall cooling commenced. These temperatures ranged from 0.0 to 0.5 °C above normal for the winter months over most of the water column. By mid April a strong negative surface temperature anomaly developed with anomalies reaching near 1.0 °C below normal by mid May. These colder than normal temperatures penetrated deeper into the water column reaching 100 m depth by October. Fall temperatures in the upper layer were about normal. Bottom temperatures throughout the year were near normal.

Upper layer salinities reach a maximum of 32.2 PSU in mid February and decrease to a minimum of 31.0 PSU by September. These values were slightly below the long term mean. In deeper water salinities generally ranged from 32.4 to 33.0 PSU. Except for a positive anomaly (up to 0.5 PSU) centered at about 50 m depth during fall, these values were generally near to slightly below normal throughout the year.

The interannual time series of temperature and salinity anomalies at standard depths show three major colder and fresher than normal periods at near decadal time scales since the early 1970s (Fig. 6). At the surface the negative temperature anomalies that began in late 1990, reaching a peak in mid 1991, had moderated to above normal conditions by the summer of 1994, returned to colder than normal by the summer of 1995, above normal throughout 1996 and near normal during 1997. At the greater depths of 100 and 175 m negative temperature anomalies have persisted since 1983 with only a few periods of positive anomalies during the mid to late 1980s. During 1994 and 1995 bottom temperatures have been slowly returning to more normal values and by 1996 were above the long-term normal, returning to about normal during 1997.

Upper layer salinity anomalies show the large fresher than normal anomaly that began in early 1991 had moderated to near normal conditions by early 1993 but returned to fresher conditions by the summer of 1995 which continued into 1996. Salinities appear to approach near normal conditions during 1997. Other periods with colder and fresher than normal salinities particularly in the early 1970s and mid 1980s are associated with strong positive NAO index anomalies, colder than normal winter air temperatures (Findlay and Deptuch-Stapf, 1991), heavy ice conditions and larger than average summer cold-intermediate-layer (CIL) areas on the continental shelf (Drinkwater 1994, Colbourne et al. 1994).

The vertically averaged annual temperature anomaly (which is proportional to the water column heat content anomaly) time series (Fig. 7) shows large amplitude fluctuations, at near decadal time scales, with cold periods during the early 1970s, mid 1980s and early 1990s. During the time period from 1950 to the late 1960s the heat content of the water column was generally above the long-term mean. The heat content of the water column reached a record low in 1991, has since recovered to a near record high value during 1996 and near the long-term mean in 1997. The 0 to 50 m vertically averaged summer (July-September) salinity anomalies (Fig. 7) shows similar behaviour as the heat content time series with fresher than normal periods corresponding to the colder than normal conditions. The low salinity anomaly on the inner Newfoundland Shelf during the early 1990s is comparable to that experienced during the 'Great Salinity Anomaly' of the early 1970s (Dickson et al. 1988). During 1993 summer salinities started returning to more normal values but decreased again by the summer of 1995 to near record lows but increased again in 1996 and returned to near normal values in 1997.

Hamilton Bank (Division 2J)

The time series of temperature and salinity anomalies from 1950 to 1997 on Hamilton Bank are shown in Fig. 8a and 8b at standard depths of 0, 50, 75 and 150 m. The monthly values show high frequency variations, which may indicate spatial variability over the bank at the same depth level. A low frequency trend was calculated by smoothing the time series using a five-point running mean. This suppresses the high frequency variations at seasonal scales, which gives an indication of the long-term variations. It should be noted that the monthly averages consist of a variable number of observations.

The time series is characterized by large variations with amplitudes ranging from ± 1.0 °C and with periods ranging from 2 to 10 years. The cold periods of the early 1970s, the mid 1980s and to a lesser extent the early 1990s are present, however, the amplitude of these anomalies vary considerably with depth. The long-term trend indicates that temperatures on Hamilton Bank appear to be moderating, particularly in the deeper layers, where the trend has been below normal since the early 1980s, similar to conditions further south at Station 27. During 1997 temperatures appear to be near normal at the surface and above normal near bottom at 150 m depth. The smoothed salinity time series show very similar conditions as elsewhere on the shelf with fresher than normal conditions in the early 1970s, mid 1980s and early 1990s. With the exception of the surface layer the below average trend established in the early 1990s is continuing into 1996, however, measurements made during 1997 indicate moderating conditions.

Flemish Cap (Division 3M)

The time series of monthly temperature and salinity anomalies on the Flemish Cap at various standard depths to at least 100 m (Fig. 9a) are characterized by 3 major cold periods: most of the 1970s, mid 1980s and the late 1980s to early 1990s. The cold period beginning around 1971 continued until 1977 in the upper layers, while temperature anomalies in the 1970s near the bottom at 200 m were insignificant. From 1978 to 1984 the temperature anomalies showed a high degree of variability in the upper water column with a tendency towards positive anomalies. By 1985 in the top 100 m of the water column, negative temperature anomalies had returned. This cold period moderated briefly in 1987 but returned again by 1988 and continued into the early 1990s. Since 1995 upper layer temperatures have moderated somewhat, particularly in the upper layers, however below normal conditions still exist below 100 m depth.

The time series of salinity anomalies (Fig. 9b) shows large fresher than normal conditions from 1971 to 1976 and from 1983 to 1986 in the upper 100 m of the water column with peak amplitudes reaching 0.6 PSU below normal. The trend in salinitiy values during the early 1990s range from slightly above normal at the surface to below normal at 50 and 100 m depth and about normal at 200 m depth. In general, the temperature and salinity anomalies are very similar to those at Station 27 and elsewhere on the continental shelf over similar depth ranges (Colbourne 1993).

St. Pierre Bank (Division 3Ps)

As described above, monthly temperature anomalies from 1950 to 1997 on St. Pierre Bank bounded by the 100 m isobath were computed at standard depths of 0, 20, 50 and 75 m (Fig. 10). This temperature time series is characterized by large variations in the monthly averages with amplitudes ranging from ± 3.0 °C. The long-term trend shows amplitudes generally less than ±1.0 °C with periods between 5 to 10 years. The cold periods of the mid 1970s and the mid 1980s in the upper water column are coincident with severe meteorological and ice conditions in the Northwest Atlantic and colder and fresher oceanographic anomalies over most of the Canadian Continental Shelf. During the cold period beginning around 1984 temperatures decreased by up to 2.0 °C in the upper water column and by 1.0 °C in the lower water column. This below normal trend continued until 1994 in the upper water column. Since 1994 the temperature trend have moderated over the top 50 m of the water column but have remained below average at 75 m depth. During 1996 and 1997 temperature anomalies fluctuated above and below normal, respectively.

Coastal Temperature Time Series

To investigate oceanographic conditions in the inshore regions around Newfoundland a time series of temperature was constructed in the Smith Sound Random Island area and in Placentia Bay for 1950-1997 at 100 m depth (Fig. 11) as described above. In addition, temperature time series from thermograph monitoring sites in Notre Dame Bay, Bonavista Bay and Placentia Bay (Fig. 1) at 10 m depth are presented.

As shown in Fig. 11 temperatures in the Trinity Bay area prior to the 1980s were near or above the mean, below normal during the early 1990s, above normal during 1996 and returned to below normal in late 1997. In Placentia Bay data are very limited but indicate warmer conditions in the early 1950s and late 1960s and generally below average conditions in the early 1990s. Monthly mean temperatures were calculated from the thermograph time series and used to generate annual anomalies at 10 m depth for 1990 to 1997 (Fig. 12). These results indicate that temperatures were up to 4.0 to 6.0 °C below average during 1991 and 1993 in the summer months in Notre Dame and Bonavista Bays and up to 2.0 °C below average in Placentia Bay. During 1994 temperatures were from 1.0 to 3.0 °C above normal during the summer months and from 1.0 to 3.0 °C above normal throughout most of 1996 at all 3 sites. By mid 1997 temperatures were below normal at all three sites but recovered to near normal values late in the year.

NF SHELF VERTICAL TEMPERATURE AND SALINITY FIELDS

As is well known, the vertical temperature structure on the Newfoundland continental shelf during the summer is dominated by a layer of cold water (temperatures less than 0.0 °C), commonly referred to as the CIL (Petrie et al. 1988), trapped between the seasonally heated upper layer and warmer slope water near the bottom. Along the Bonavista transect during the summer of 1997 the CIL extended offshore to about 180 km, with a maximum thickness of about 220 m corresponding to a cross-sectional area of about 19 km^2 (Fig. 13a), compared to the 1961-90 average of 26.8 km^2. Temperatures along the transect in the upper 20 m of the water column ranged from 6.0 °C to 8.0 °C over most of the continental shelf, about 0.25 to 2.0 °C below normal. Close to shore these cold anomalies penetrated down to near 100 m depth. In the depth range from 50 m to the bottom, temperatures ranged from -1.5 °C near the coast and to 0.0 °C to 3.5 °C further offshore near the edge of the continental shelf and beyond. Except for a very thin layer of surface water with below normal temperatures the corresponding temperature anomalies ranged from 0.0 to 2.5 °C above normal over the continental shelf and to 0.0 to 1.0 °C above normal at intermediate depths. Bonavista transect salinities (Fig. 13b) ranged from 32.0 PSU near the surface to 33.5 PSU near the bottom over the inshore portion of the transect to 34.75 PSU at about 325 m depth near the shelf edge. Except for fresher than normal conditions near the shore, salinity in general were above normal (from 0.1 to 0.4 PSU) over most of the water column across the shelf.

CIL Time Series

Figure 14 shows a time series of the CIL cross-sectional area for the Seal Island, Bonavista and Flemish Cap transects, the positions of which are shown in Fig 1. During the summer of 1997 the CIL area off Bonavista was about 28 % below normal compared to 10 % below normal in 1996 and 30 % below normal in 1995. From 1990 to 1994 the CIL was above normal reaching a peak of more than 60 % above normal in 1991. The CIL area along the Seal Island transect was also below normal by about 38 % during 1997, 12 % in 1996 and 32 % during 1995. During 1994 the CIL along the Seal Island transect was 36 % above normal and up to 61 % above normal in 1991. Along the Flemish Cap transect the CIL was about 20 % above normal compared to slightly below normal conditions during the summer of 1996 (24 km^2 versus an average of 25 km^2). In 1995 it was about 18 % above normal (29.8 km^2) compared to 12 % in

1994 and to 48 % during 1991. In general, the total cross-sectional area of sub-zero °C water on the Newfoundland Shelf, except on the Grand Bank, is continuing a below normal trend established in 1995.

The intensity or minimum core temperatures of the CIL for all three transects from 1948 to 1997 are shown in Fig. 15. The minimum temperature observed in the core of the CIL along the Seal Island transect during the summer of 1997 was about -1.62 °C compared to a normal of –1.57 °C. Core temperatures along the Bonavista transect were -1.66 °C compared to a normal of -1.63 °C and about normal along the Flemish Cap transect at about -1.51 °C. These minimum temperatures were somewhat colder than values during the same time period in 1996.

The total volume of water on the Newfoundland and southern Labrador shelves shoreward of the 1000 m isobath and within NAFO divisions 2J3KL is approximately 2.0×10^5 km^3. The calculation of the volume of sub-zero °C water overlying the continental shelf is described by Colbourne and Mertz (1995). The spatial variation in the amount of subzero °C water on the shelf in different years is determined by calculating the thickness of the layer of water less than 0.0 °C on the Northeast Newfoundland Shelf in NAFO Divisions 2J and 3KL during the summer and fall periods. The isolines of CIL thickness show large variations from summer to fall of the same year and from cold years to warm years (Colbourne, 1995). The average thickness of the CIL is maximum (> 150 m) along the east coast of Newfoundland within 100 km of the shore and decreases to 0.0 m near the edge of the shelf, on the southern Grand Bank and on Hamilton Bank during warm years in the fall.

The time series of total volume of subzero °C water over the 2J, 3KL area (Fig. 16) shows maximum values during the cold periods of the mid 1980s and early 1990s. The total volume of subzero °C water on the shelf increased from approximately 3.3×10^4 km^3 during the summer of 1989 to 5.6×10^4 km^3 in 1990, a 70 % increase. Since 1991 the volume of subzero °C water on the Newfoundland Shelf during summer and fall has been slowly decreasing, and by 1995 it had decreased to values of the early 1980s and from 1986 to 1989. The 1997 volume decreased slightly over 1996 values in both summer and fall, both years were significantly below average. The 1980 to 1997 average volume of subzero °C water on the shelf during the summer is approximately $4.0 \pm 0.9 \times 10^4$ km^3 roughly one-quarter of the total volume of water on the shelf. The time series during the fall shows similar trends but the total volume is reduced to $2.4 \pm 0.8 \times 10^{14}$ km^3 about one-half the summer value. Due to limited data sets the volume estimates were not calculated prior to 1980. Time series of the volume of subzero °C water over the 2J3KL area and the average CIL cross sectional areas along widely spaced transects (Seal Island, Bonavista and Flemish Cap) exhibits some differences but are highly correlated with correlation coefficients of 0.85 and 0.76 for the summer and fall periods respectively (Colbourne and Mertz 1995).

BOTTOM TEMPERATURES

The average (1961-90) and the 1997 fall bottom temperature for the 2J3KLNO area are shown in Fig. 17 (isotherms are -1, -0.5, 0, 1, 2, 3 and 3.5 °C, bathymetry lines are 300 and 1000 m). The average bottom temperature over most of the Northeast Newfoundland shelf (2J3K) ranges from less than 0.0 °C inshore, to above 3.0 °C offshore at the shelf break. The average temperature over most of the Grand Bank varies from -0.5 °C to 0.0 °C over the central and northern areas, 0.0 to 3.0 °C over southeastern regions and to above 3.0 °C at the shelf break.

In general, bottom isotherms follow the bathymetry exhibiting east-west gradients over most of the Northeast shelf. The percentage area of water less than -0.5 °C over the Grand Bank and Northeast shelf from 1990 to 1994 was much larger than the 1961-1990 average. In 1992 and 1993 the bottom temperature anomalies ranged from -0.25 °C to -0.75 °C over the Northeast shelf and from -0.25 °C to -1.0 °C over the Grand Bank (Colbourne 1994). During the fall of 1996 bottom temperatures warmed over most areas on the Newfoundland Shelf with anomalies up to 0.5 °C above normal in many places. During 1996 the percentage area of water less than -0.5 °C on the Grand Bank was below average with a complete absence of sub-zero °C water on the Northeast Newfoundland Shelf from the Northern Grand Bank to Nain Bank. Bottom temperatures during the fall of 1997 were still above normal over many areas, particularly on the offshore portion of the Northeast Newfoundland Shelf.

The 1961-90 average and the 1997 April bottom temperature maps for the 3Ps and 3Pn areas are shown in Fig. 18. In general, the bottom isotherms follow the bathymetry around the Laurentian Channel and the Southwestern Grand Bank increasing from 2.0 °C at 200 m depth to 5.0 °C in the deeper water. The average bottom temperatures during April ranges from 5.0 °C in the Laurentian, Burgeo and Hermitage Channels to about 3.0 °C to 4.0 °C on Rose Blanche Bank and on Burgeo Bank and from 0.0 °C on the eastern side of St. Pierre Bank to 2.0 to 3.0 °C on the western side. During April 1996 temperatures were about average over Burgeo Bank and Hermitage Channel and along the western side of St. Pierre Bank. However on St. Pierre Bank temperatures were still slightly below average, but an increase over 1995 values was observed, particularly on the eastern side of the bank (Colbourne 1996). During the spring of 1997 deep water temperatures appear to be above normal while most of St. Pierre Bank was below normal by more than 1.0 °C in the southeast. In general, temperature conditions in this region are highly variable (Fig. 12) and it appears that the cold trend on St. Pierre Bank is continuing into 1997.

SUMMARY

Time series of temperatures at Station 27 shows values ranging from 0.0 to 0.5 °C above normal for the winter months over most of the water column. By mid April a strong negative surface temperature anomaly developed with anomalies reaching near 1.0 °C below normal by mid May. These colder than normal temperatures appear to have propagate deeper into the water column reaching 100 m depth by October. Fall temperatures in the upper layer were about normal, while bottom temperatures throughout the year were near normal. Salinities over most of the water column were slightly below normal throughout the year except in the fall at mid depth when they were up to 0.5 PSU above normal.

Temperature anomalies on St. Pierre Bank show the cold period which started around 1984, continued to the spring of 1995 but showed some evidence of moderation during 1996, particularly in the upper layer. During 1997 however, temperatures decreased again to below normal values. In the inshore regions temperatures were significantly below normal during the early 1990s but had warmed considerably by the summer of 1994 and throughout 1996. By mid 1997 however, temperatures were below normal over most inshore regions but recovered to near normal values late in 1997.

During the summer of 1997 the CIL area off Bonavista and Hamilton Bank was well below normal continuing a trend established in 1995. Along the Flemish Cap transect across the Grand Bank the CIL was above normal compared to near normal conditions in 1996. In general, however, the total volume of sub-zero °C water on the Newfoundland Shelf during both summer and fall is continuing a below normal trend established in 1995. Minimum CIL core temperatures were near normal over all areas during the summer of 1997.

Bottom temperatures on Hamilton Bank and the Grand Bank during the fall period of 1996 increased significantly over previous years and were up to 0.5 °C above normal over many areas. During the fall of 1997 bottom temperatures were still above normal over many areas, particularly on the offshore portion of the Northeast Newfoundland Shelf. During the spring of 1997 in division 3Ps deep water bottom temperatures appear to be above normal while most of St. Pierre Bank was below normal by more than 1.0 °C on the southeast portion of the bank. In general, while 1996 temperatures were somewhat higher, conditions in this region are highly variable (Fig. 12) and it appears that the cold trend on St. Pierre Bank is continuing into 1997.

In general the analysis presented here shows the below normal oceanographic trends in temperature and salinity, established in the late 1980s reached a peak in 1991. This cold trend continued into 1993 but started to moderate during 1994 and 1995. During 1996 temperature conditions were above normal over most regions, however, summer salinity values continue to be slightly below the long-term normal. During 1997 oceanographic temperatures were still above normal over many areas, particularly over the deeper portions of the Northeast Newfoundland Shelf. The exception being the near shore coastal regions in the upper water column and over the shallow portions of the Grand Bank where temperatures were colder than normal during late spring and early summer.

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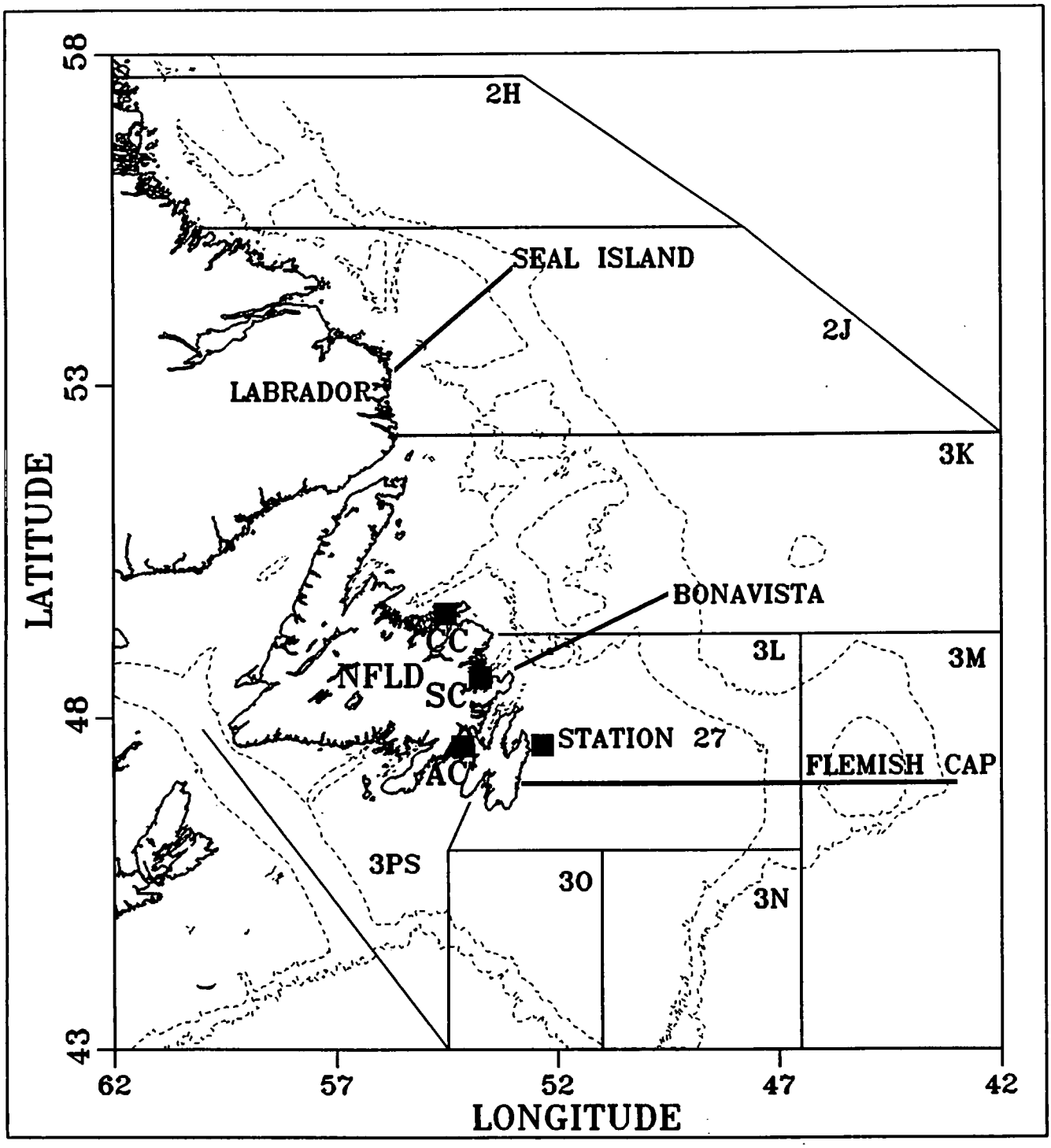

Fig. 1. Location map showing the position of the Seal Island, Bonavista and the Flemish Cap (47 °N) transects. The locations of the Long-Term-Temperature-Monitoring (LTTM) sites Arnold's Cove (AC), Stock Cove (SC), Comfort Cove (CC) and Station 27 are also shown. Bathymetry lines are 300 and 1000 m.

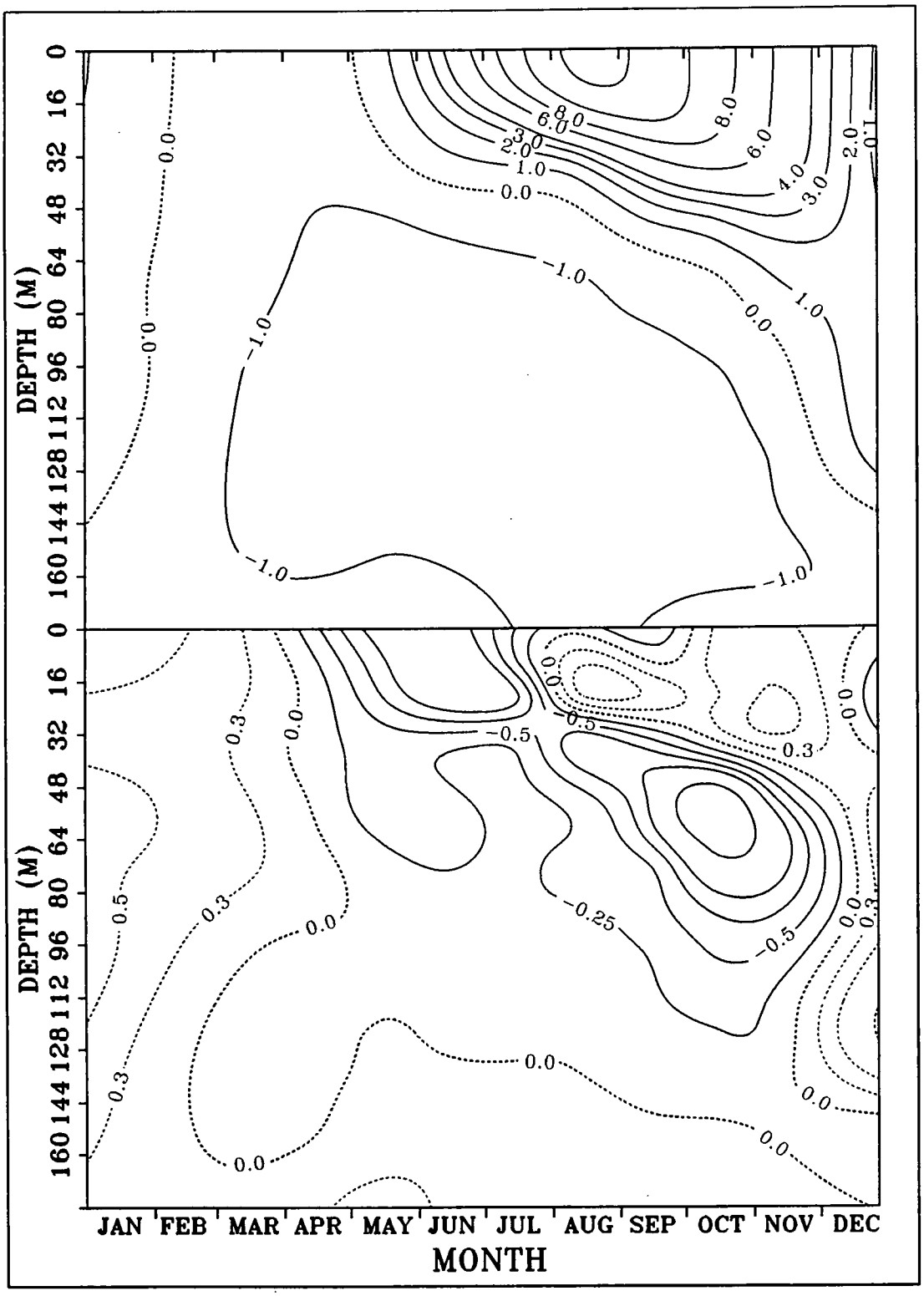

Fig. 2. Monthly temperatures (top panel) and anomalies (bottom panel) at Station 27 as a function of depth for 1997.

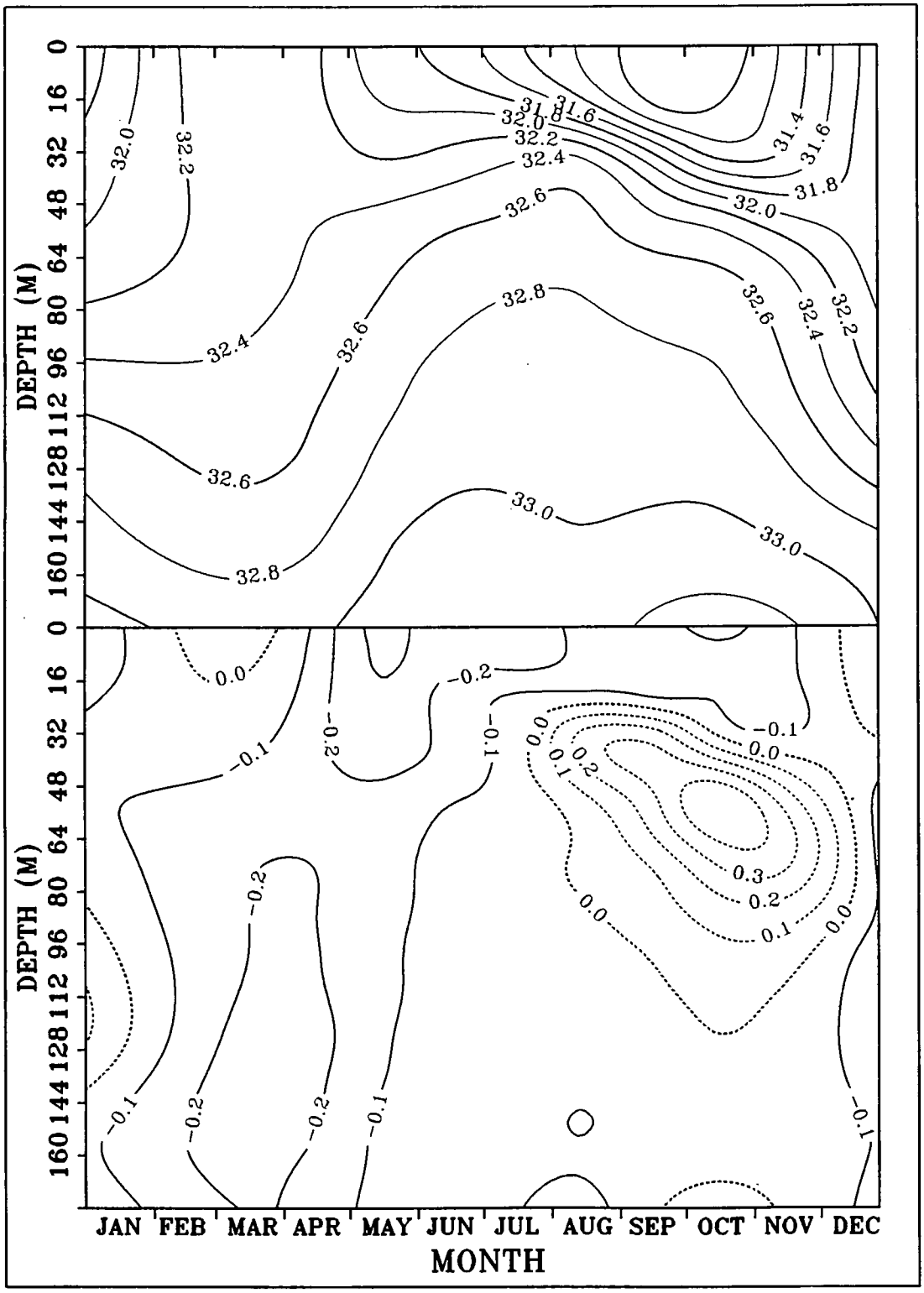

Fig. 3. Monthly salinity (top panel) and anomalies (bottom panel) at Station 27 as a function of depth for 1997.

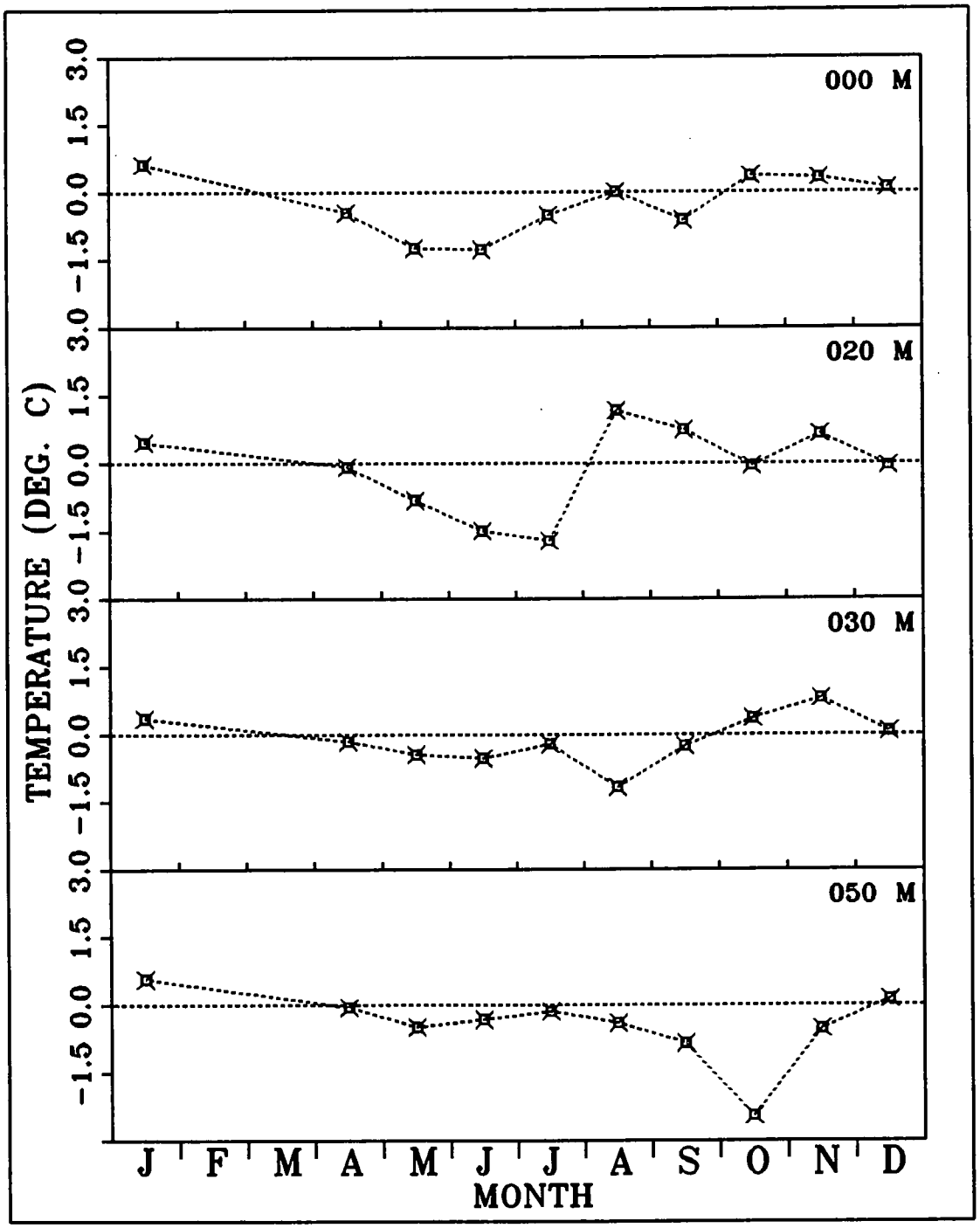

Fig. 4a. Time series of monthly temperature anomalies at Station 27 at standard depths during 1997.

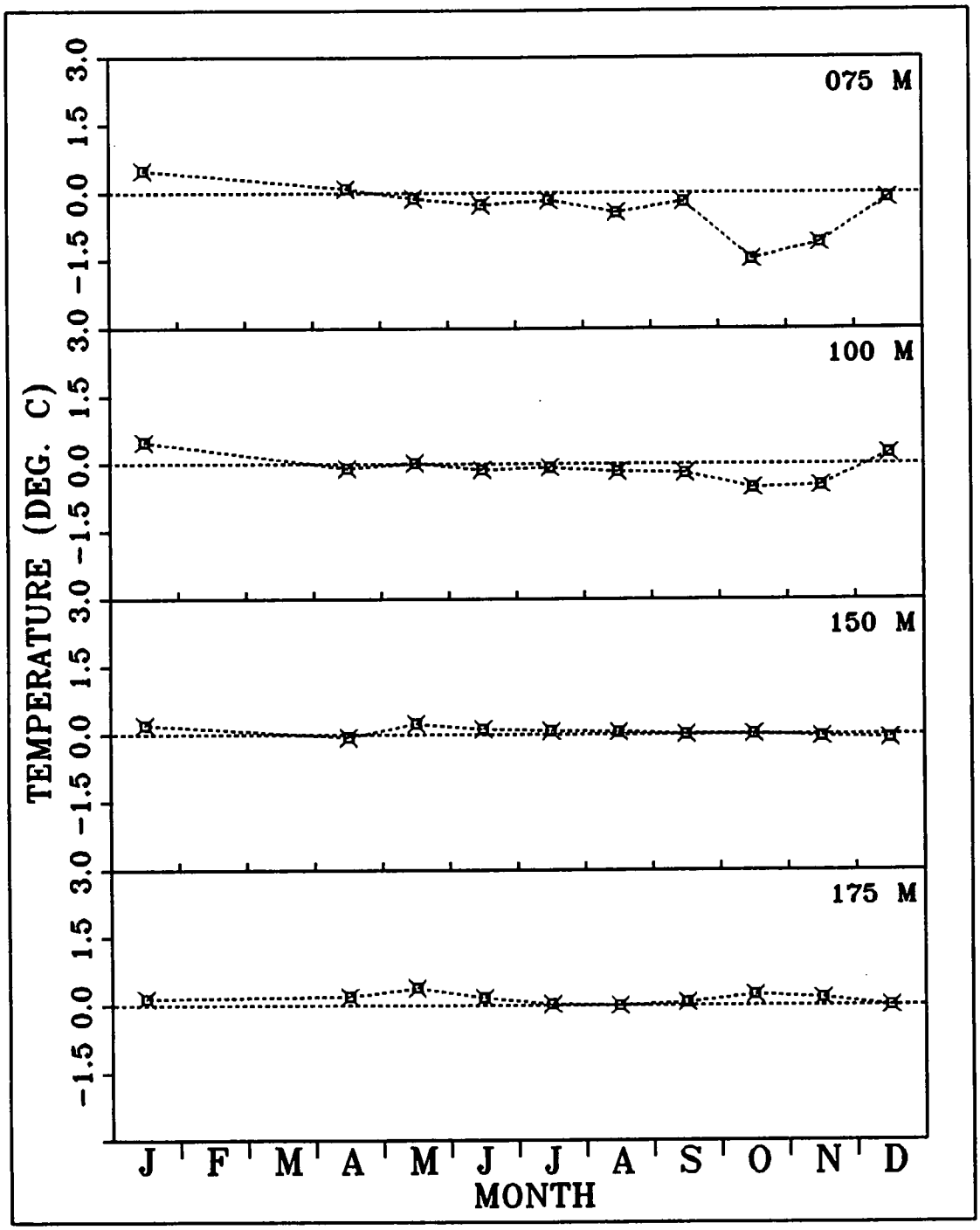

Fig. 4b. Time series of monthly temperature anomalies at Station 27 at standard depths during 1997.

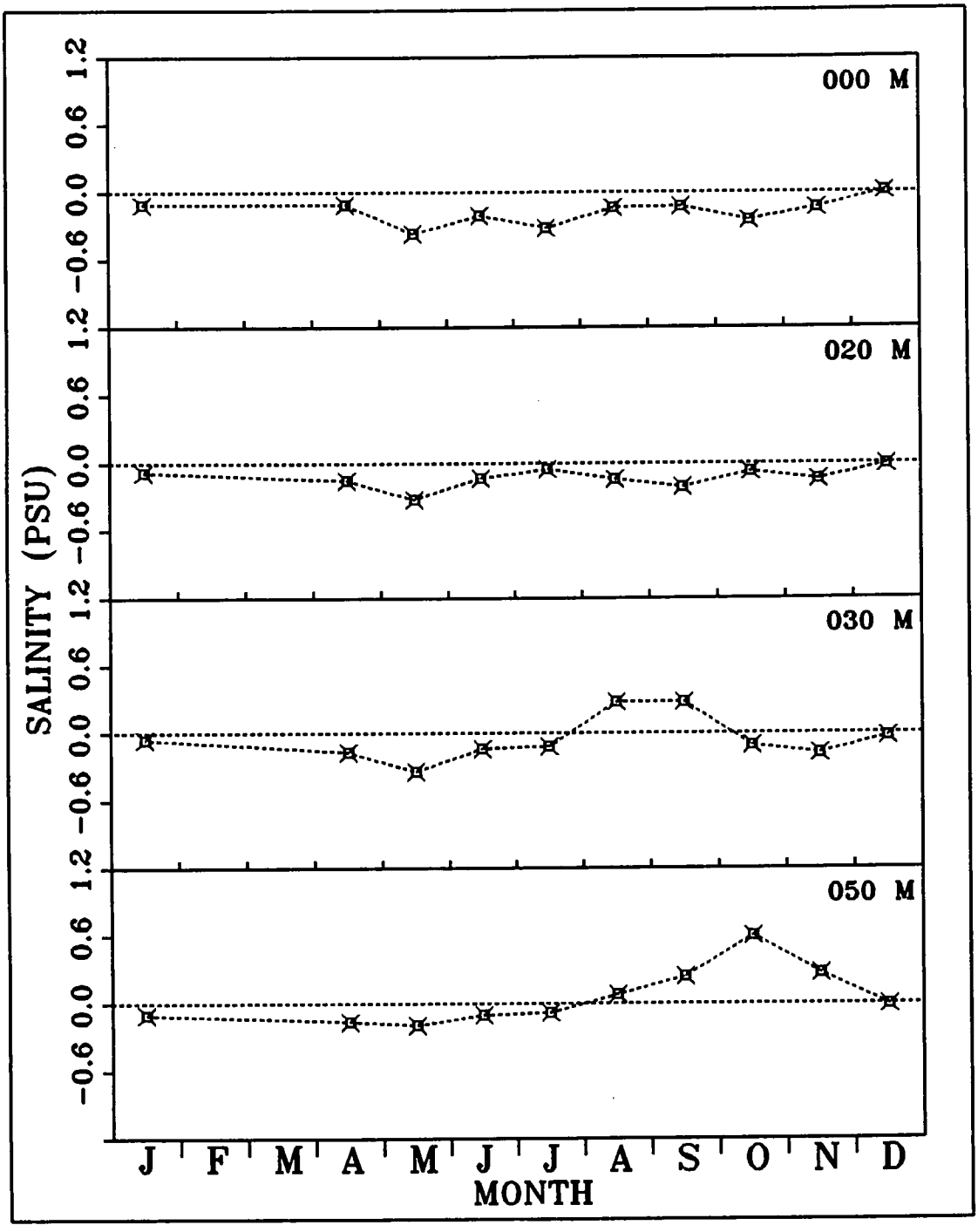

Fig. 5a. Time series of monthly salinity anomalies at Station 27 at standard depths during 1997.

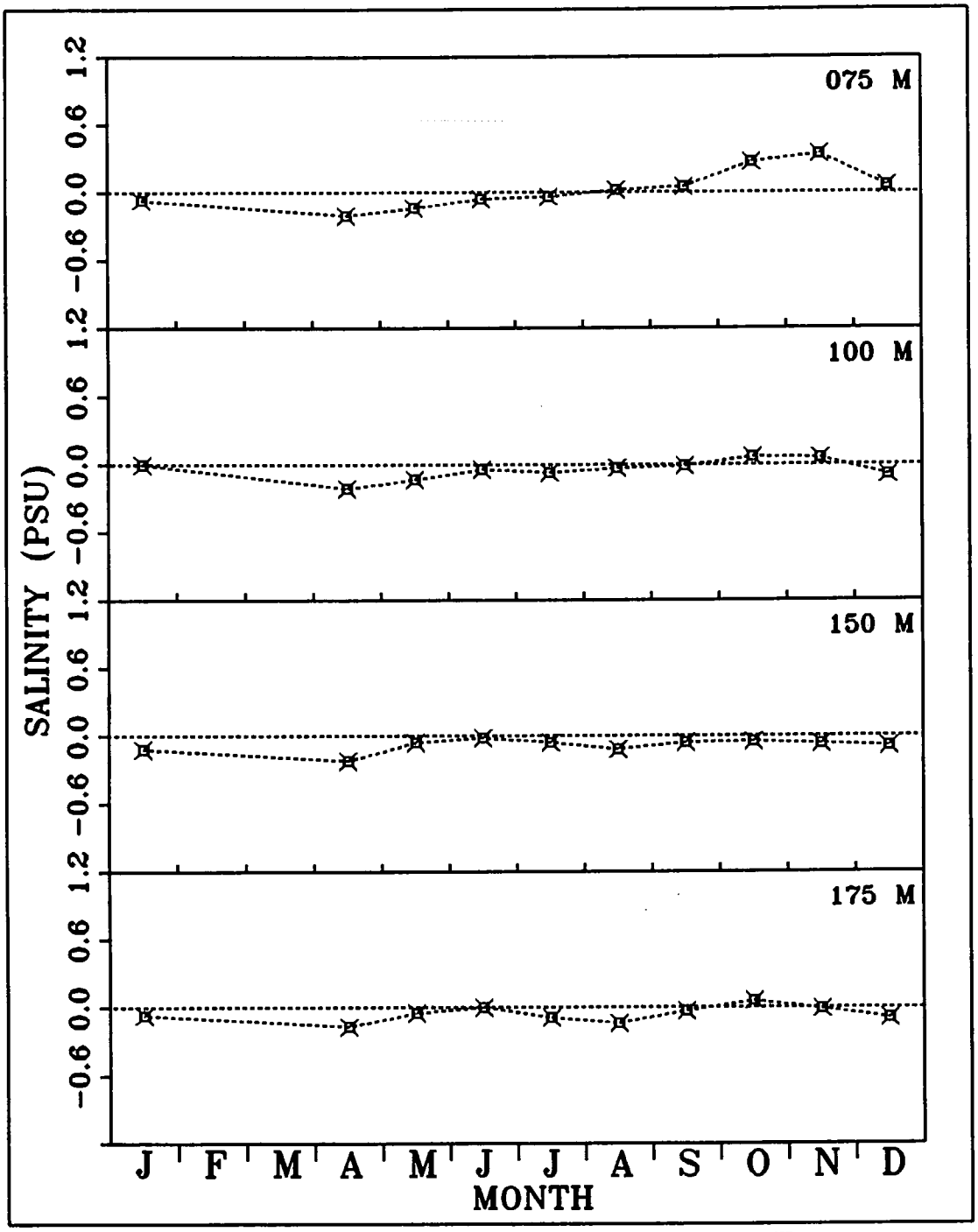

Fig. 5b. Time series of monthly salinity anomalies at Station 27 at standard depths during 1997.

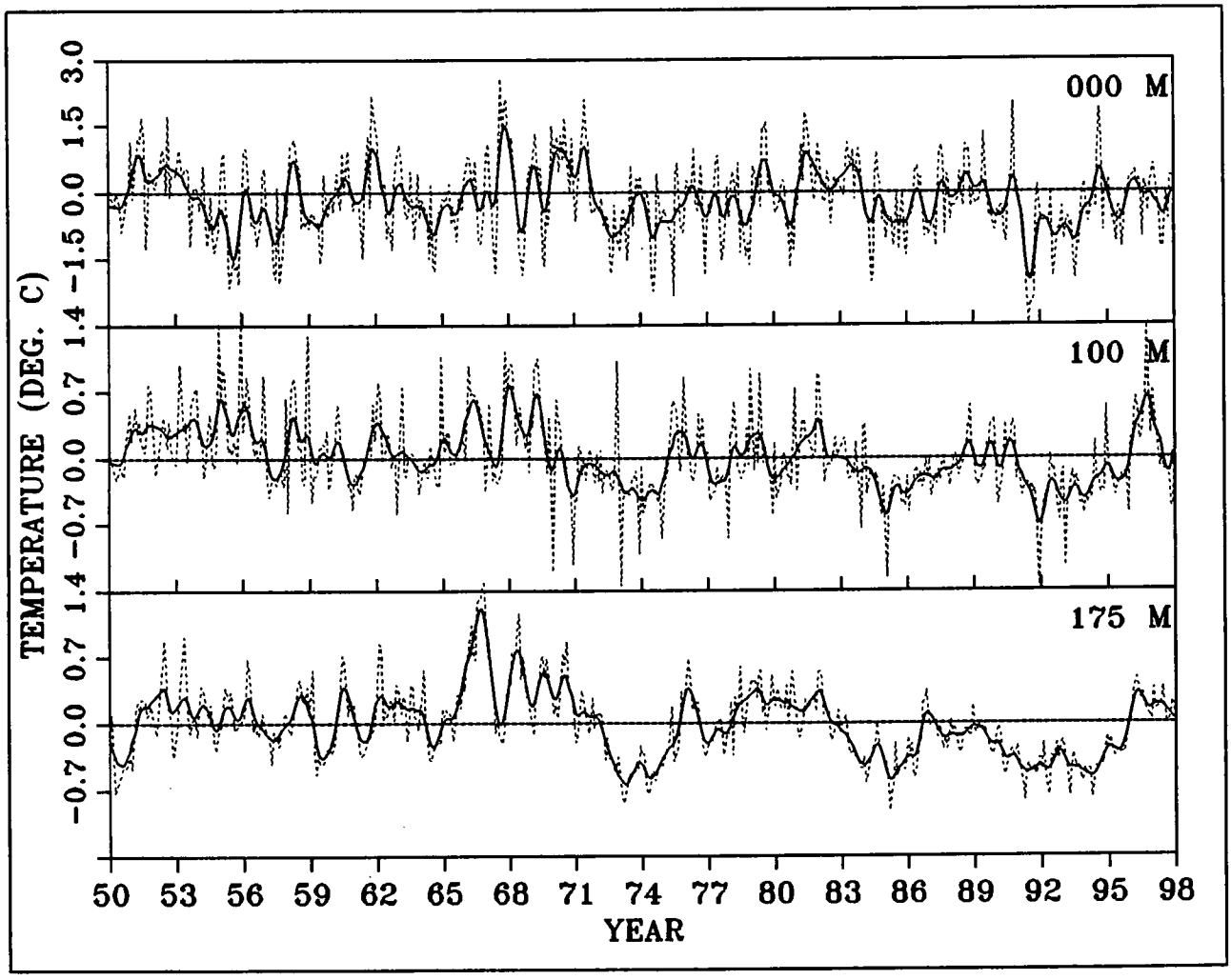

Fig. 6a. Time series of monthly temperature anomalies at Station 27 at standard depths from 1950 to 1997. The heavy lines represent the low-passed filtered values.

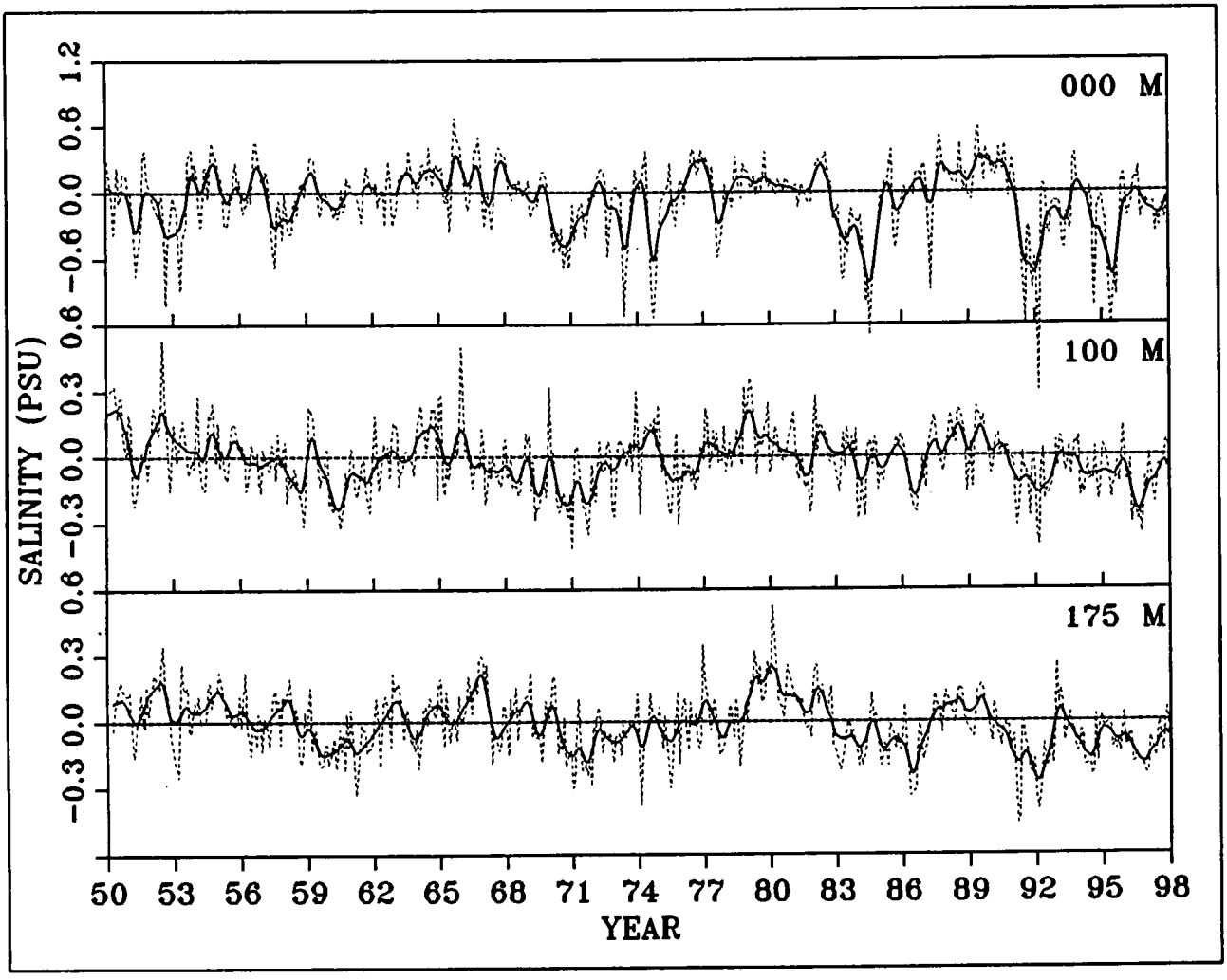

Fig. 6b. Time series of monthly salinity anomalies at Station 27 at standard depths from 1950 to 1997. The heavy lines represent the low-passed filtered values.

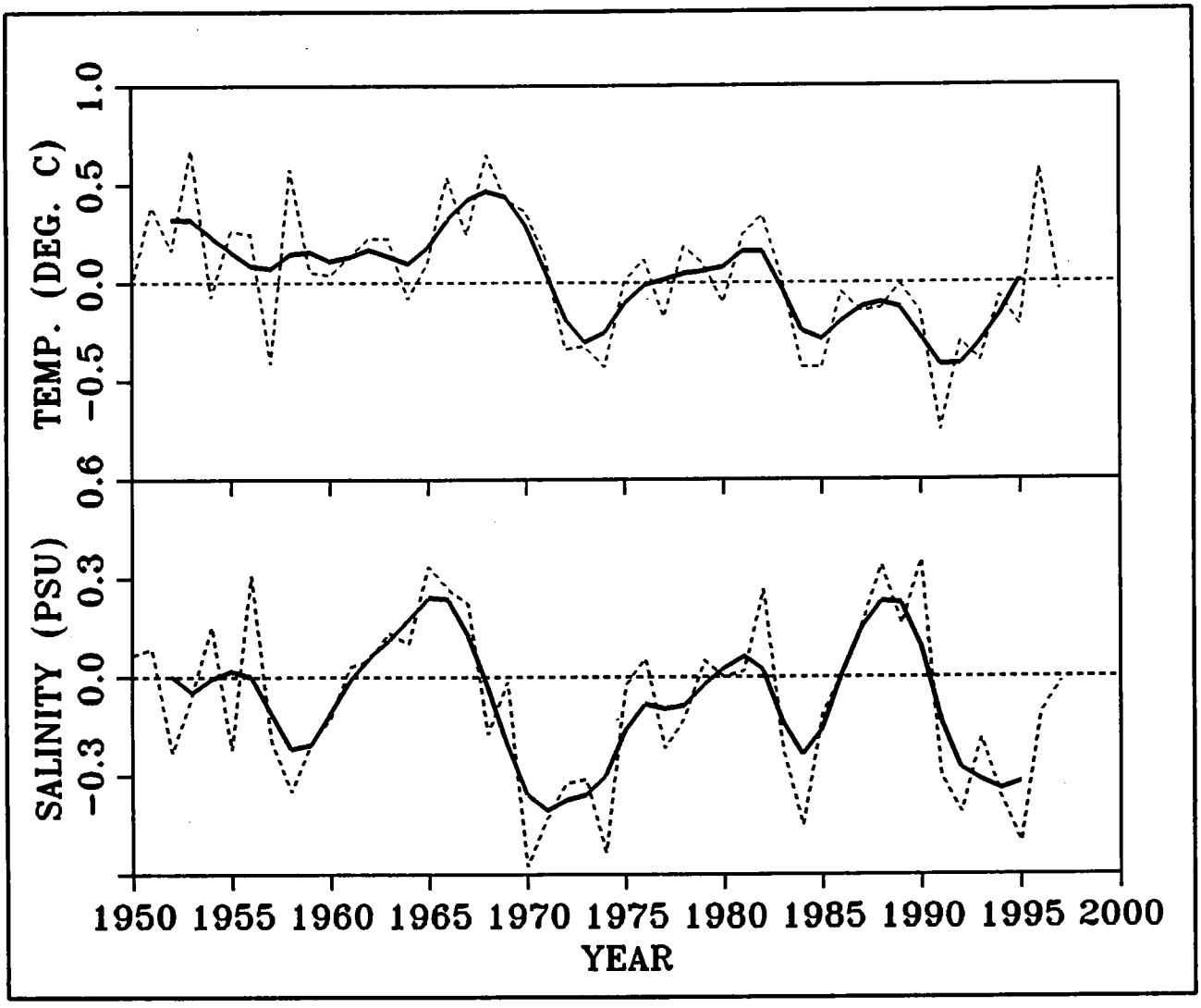

Fig. 7. Time series of the annual vertically averaged (0-176 m) Station 27 temperature anomalies and the vertically averaged (0-50 m) summer (July-Sept.) Station 27 salinity anomalies. The heavy lines are the three year running means.

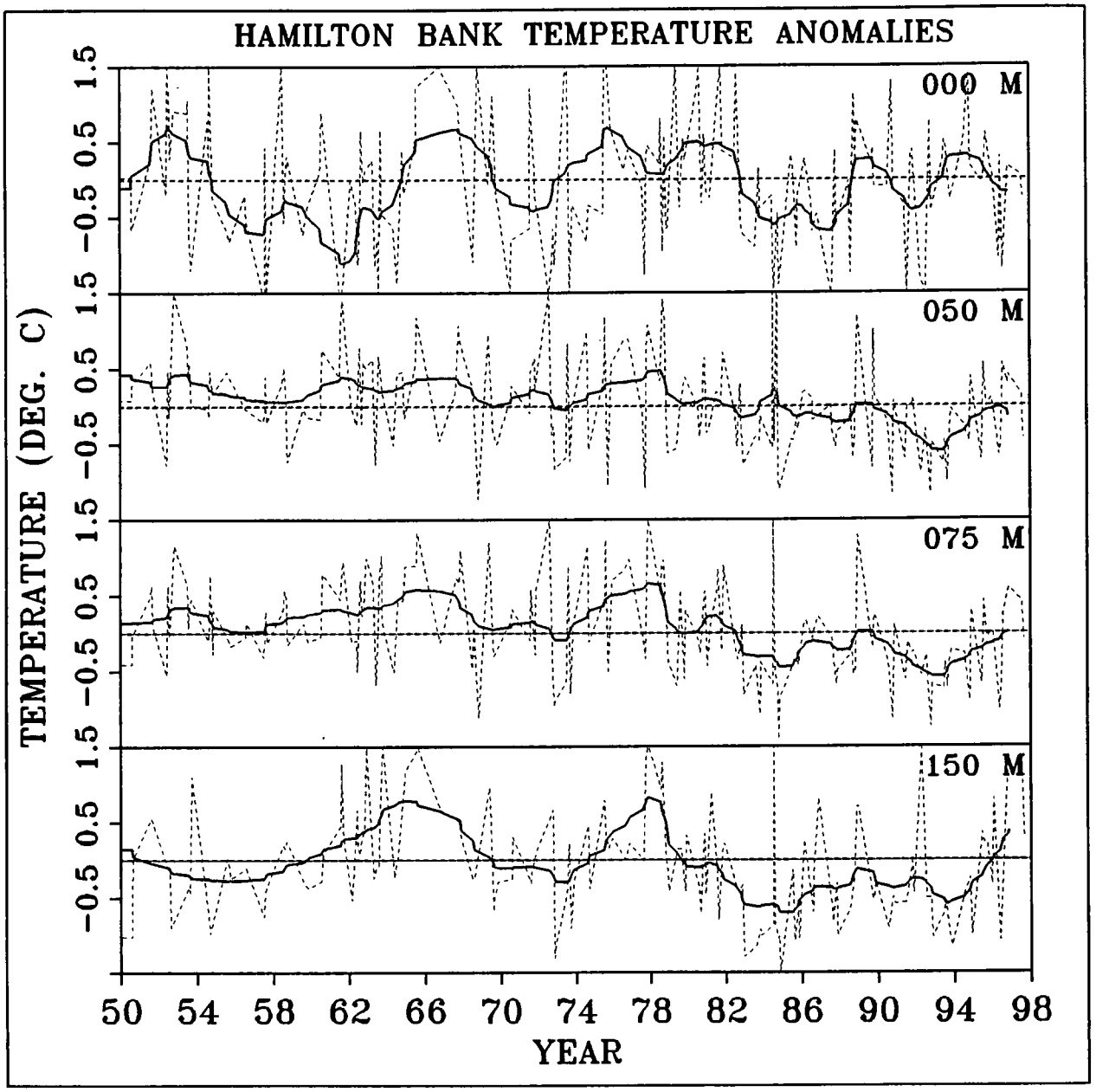

Fig. 8a. Time series of monthly temperature anomalies at standard depths of 0, 50, 75 and 150 m on Hamilton Bank in NAFO Division 2J. The solid line represents the smoothed temperature anomalies.

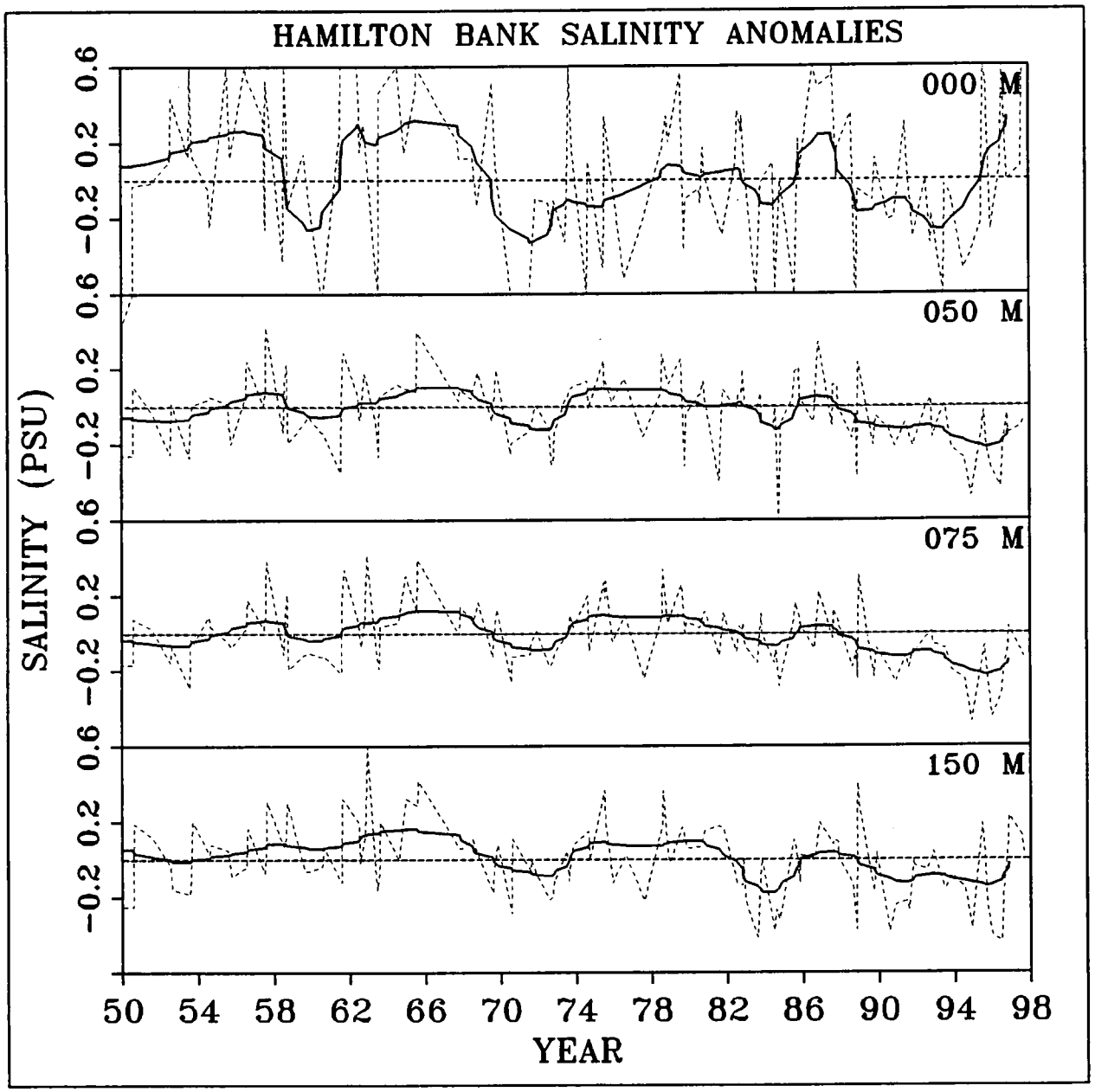

Fig. 8b. Time series of monthly salinity anomalies at standard depths of 0, 50, 75 and 150 m on Hamilton Bank in NAFO Division 2J. The solid line represents the smoothed salinity anomalies.

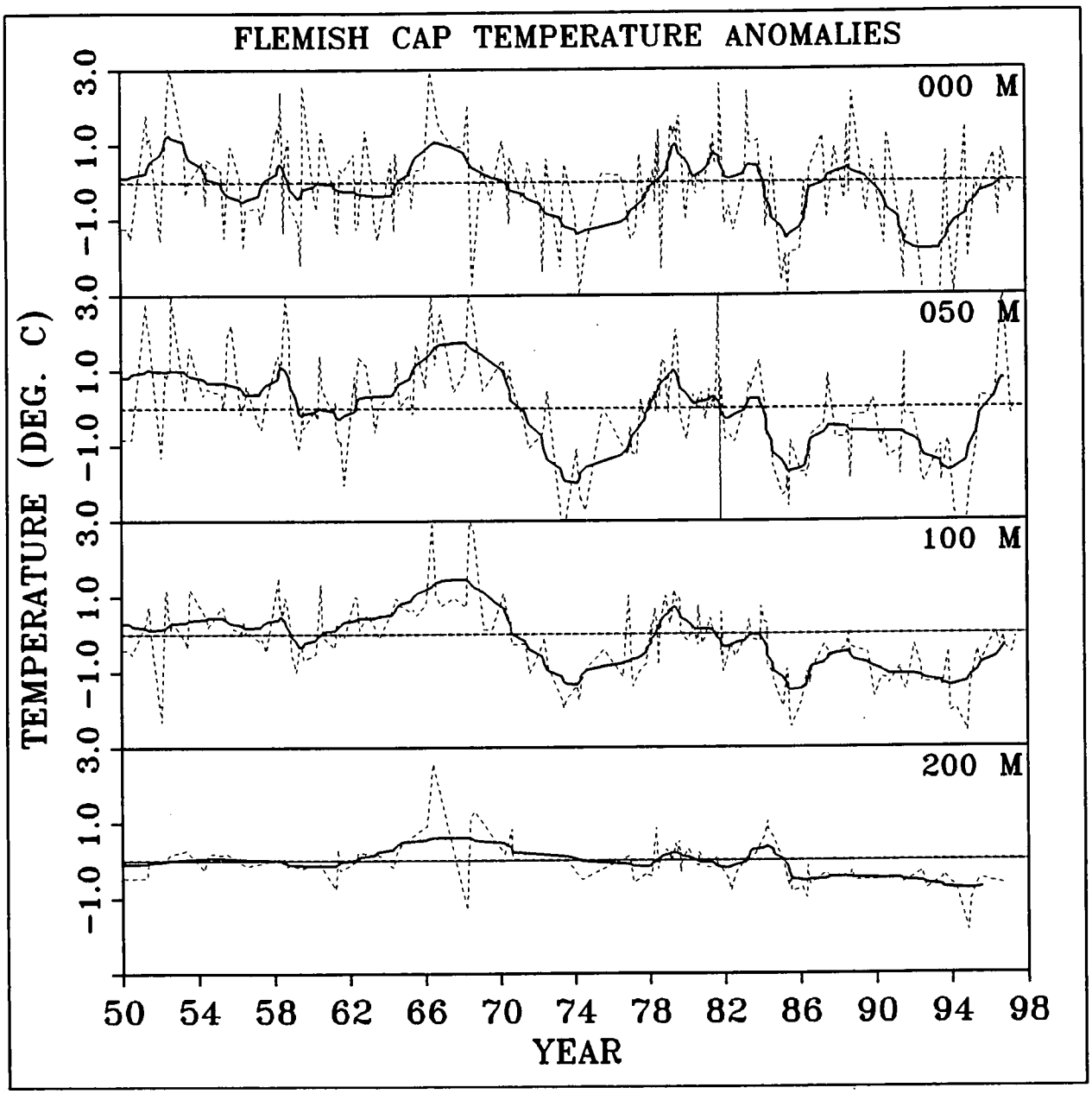

Fig. 9a. Time series of monthly temperature anomalies at standard depths of 0, 50, 100 and 200 m on the Flemish Cap in NAFO Division 3M. The solid line represents the smoothed temperature anomalies.

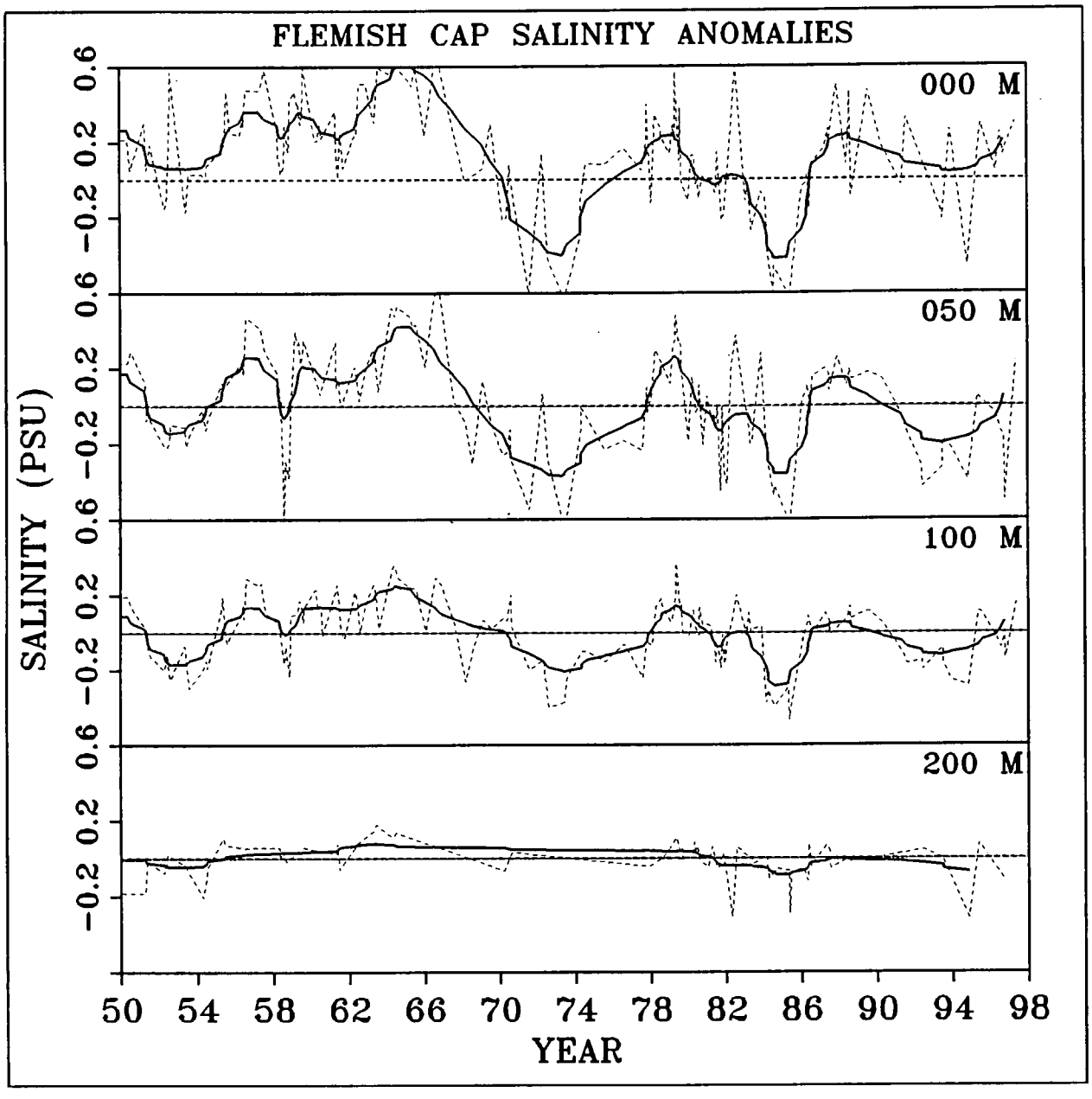

Fig. 9b. Time series of monthly salinity anomalies at standard depths of 0, 50, 100 and 200 m on the Flemish Cap in NAFO Division 3M. The solid line represents the smoothed salinity anomalies.

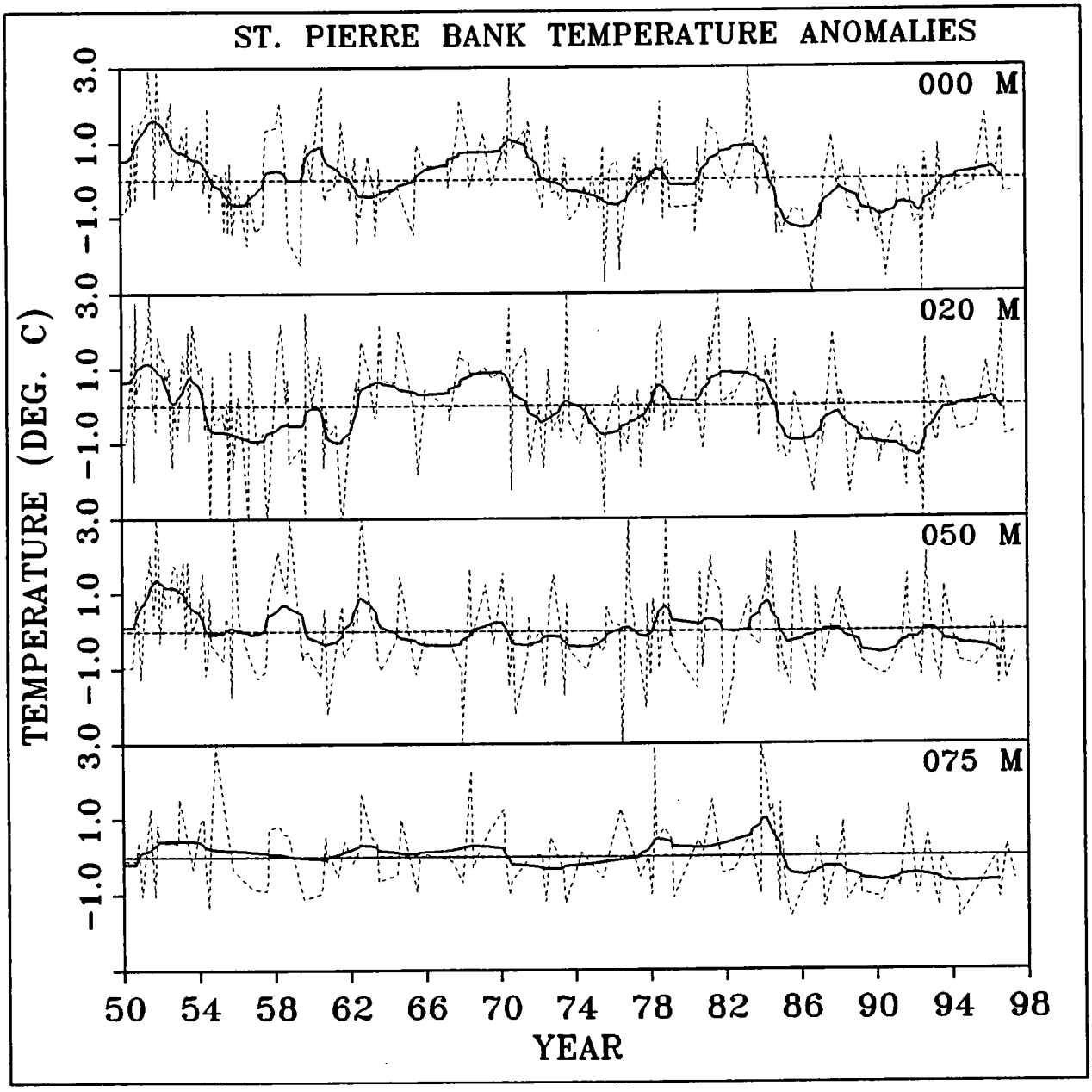

Fig. 10. Time series of monthly temperature anomalies at standard depths of 0, 20, 50 and 75 m on St. Pierre Bank in Subdivision 3Ps. The solid line represents the smoothed temperature anomalies.

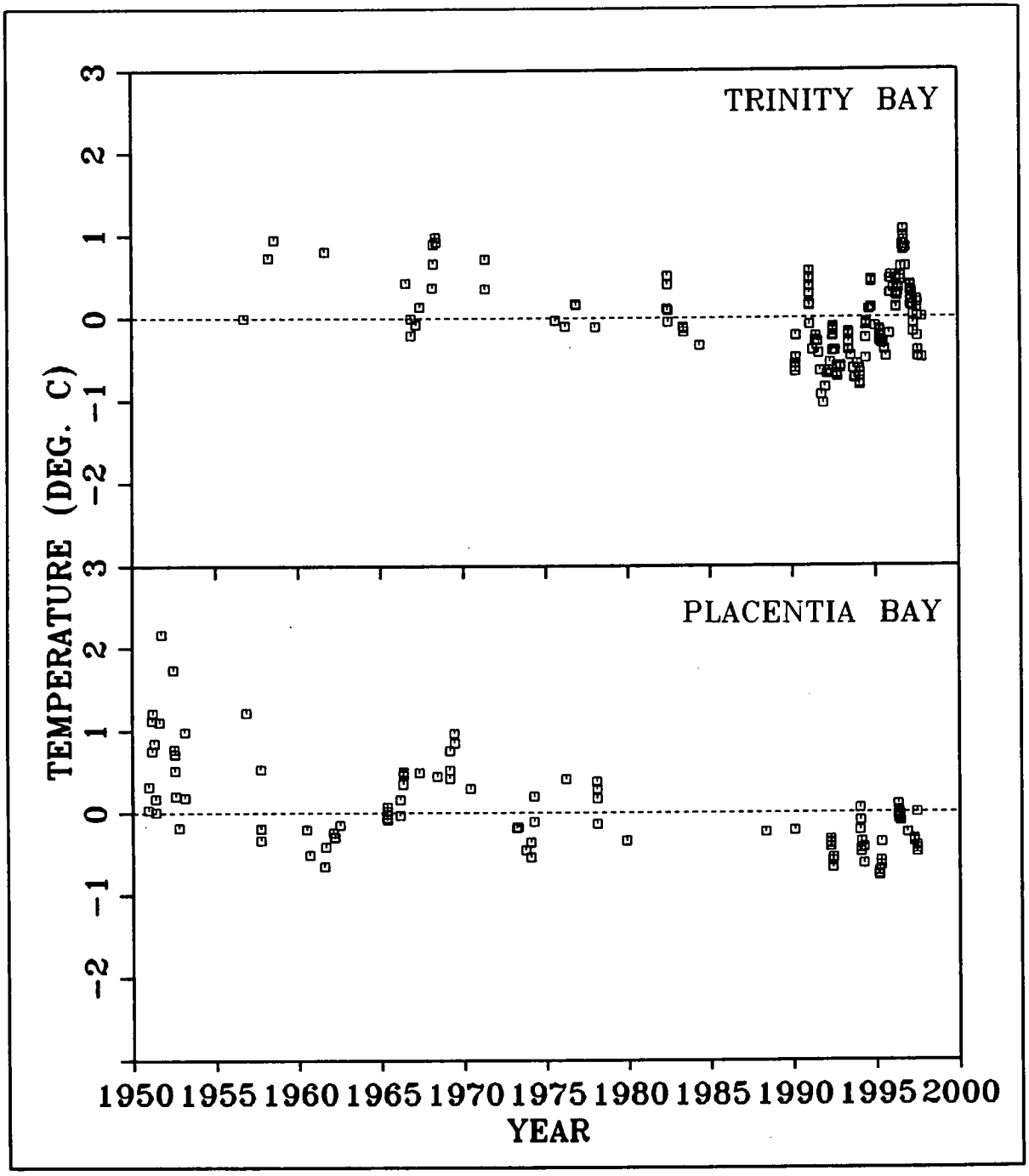

Fig. 11. Time series of temperature anomalies at 100 m depth for the Random Island area in Trinity Bay and for Placentia Bay.

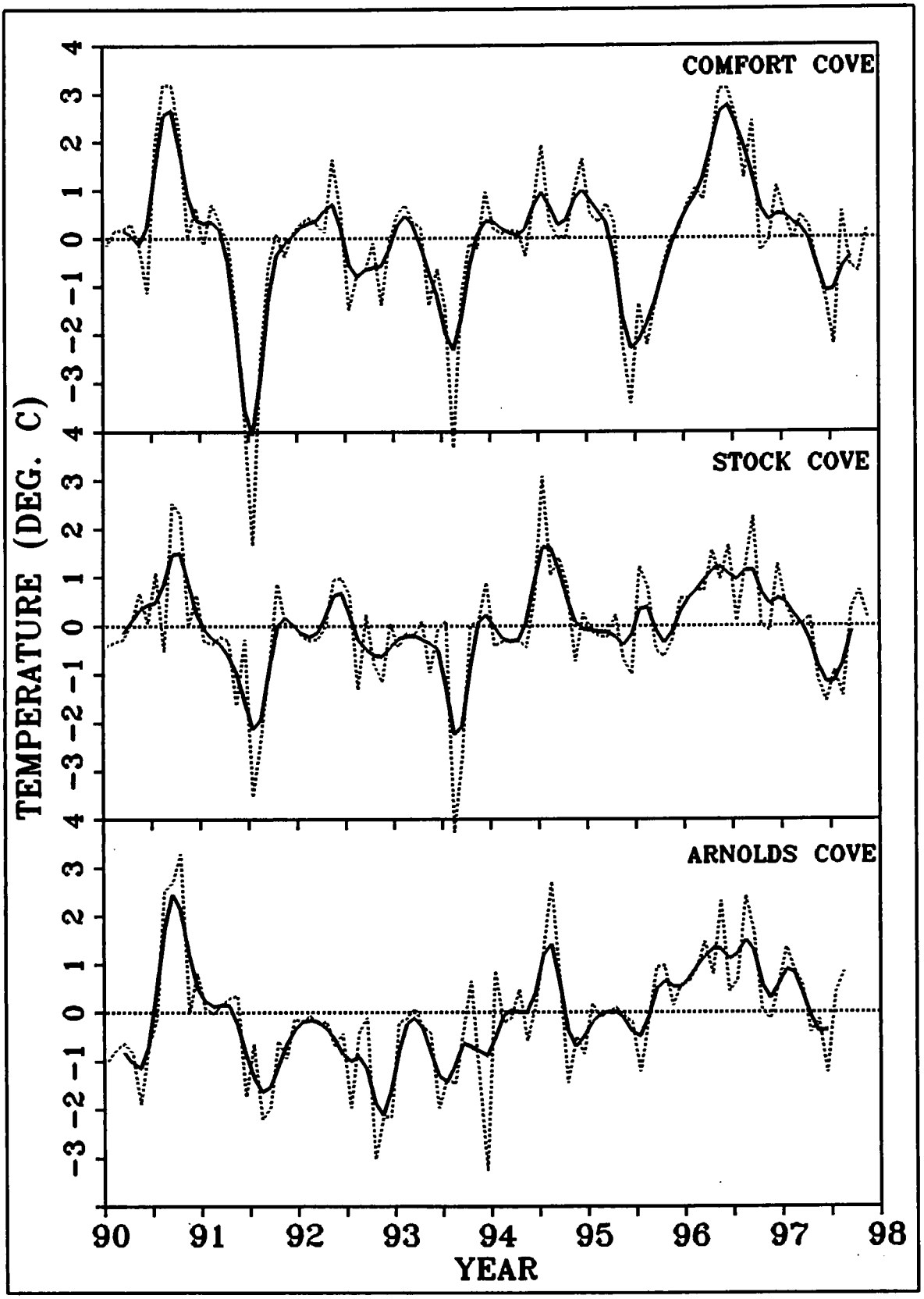

Fig. 12. Monthly temperature anomalies at 10 m depth for Comfort Cove, Notre Dame Bay, Stock Cove, Bonavista Bay and for Arnold's Cove, Placentia Bay (Fig. 1).

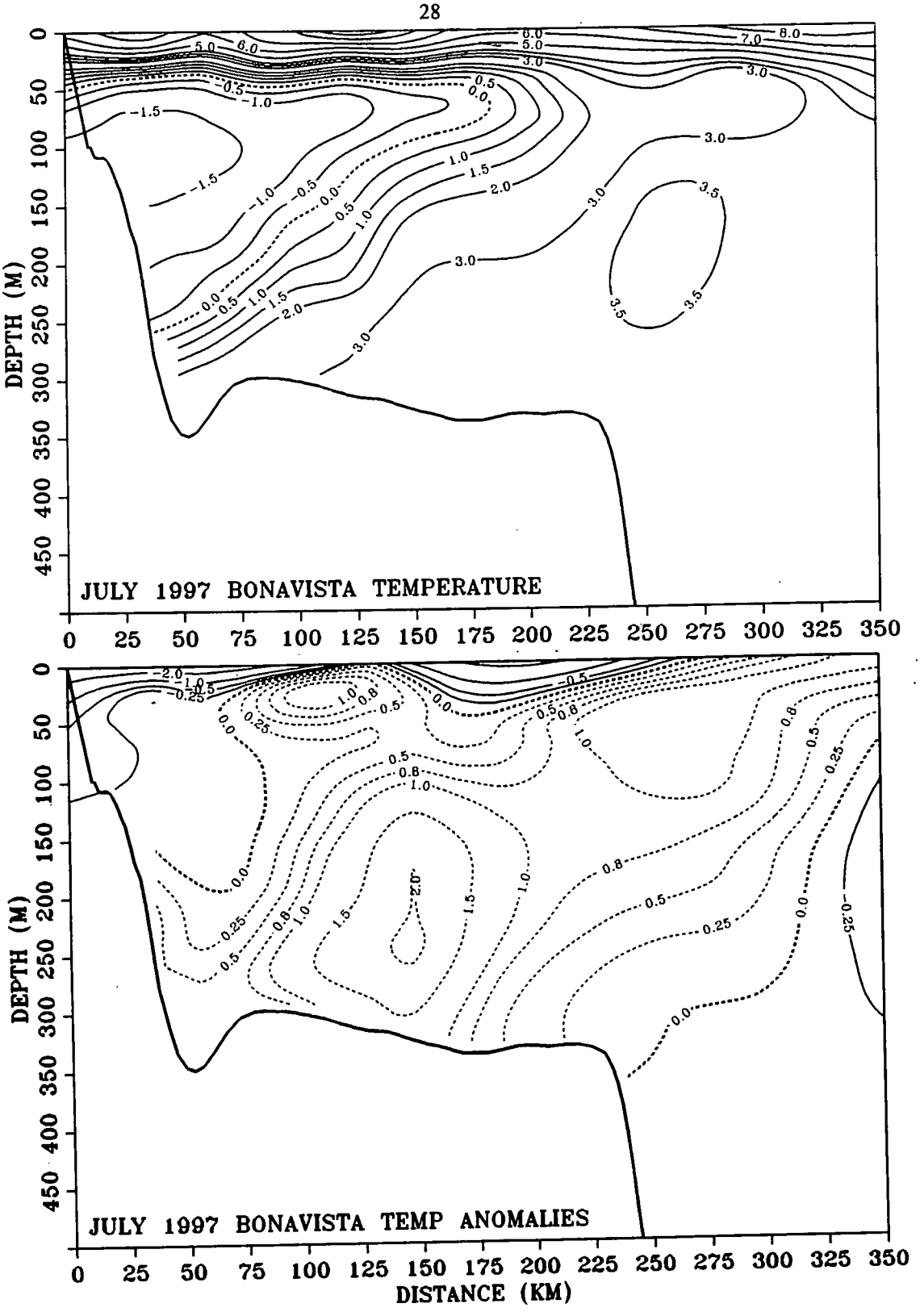

Fig. 13a. A vertical cross section of temperature and temperature anomalies along the standard Bonavista transect for the summer of 1997.

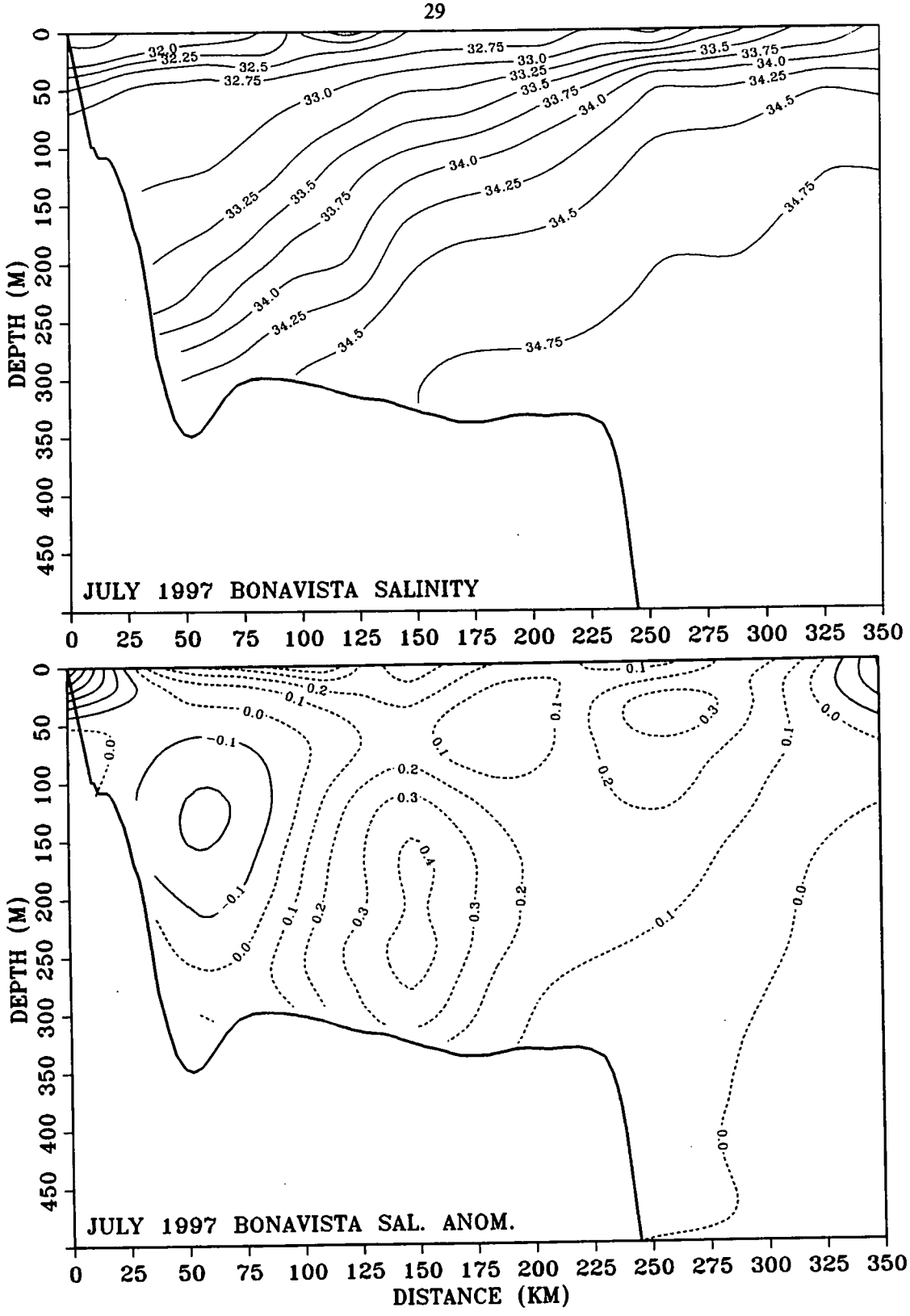

Fig. 13b. A vertical cross section of salinity and salinity anomalies along the standard Bonavista transect for the summer of 1997.

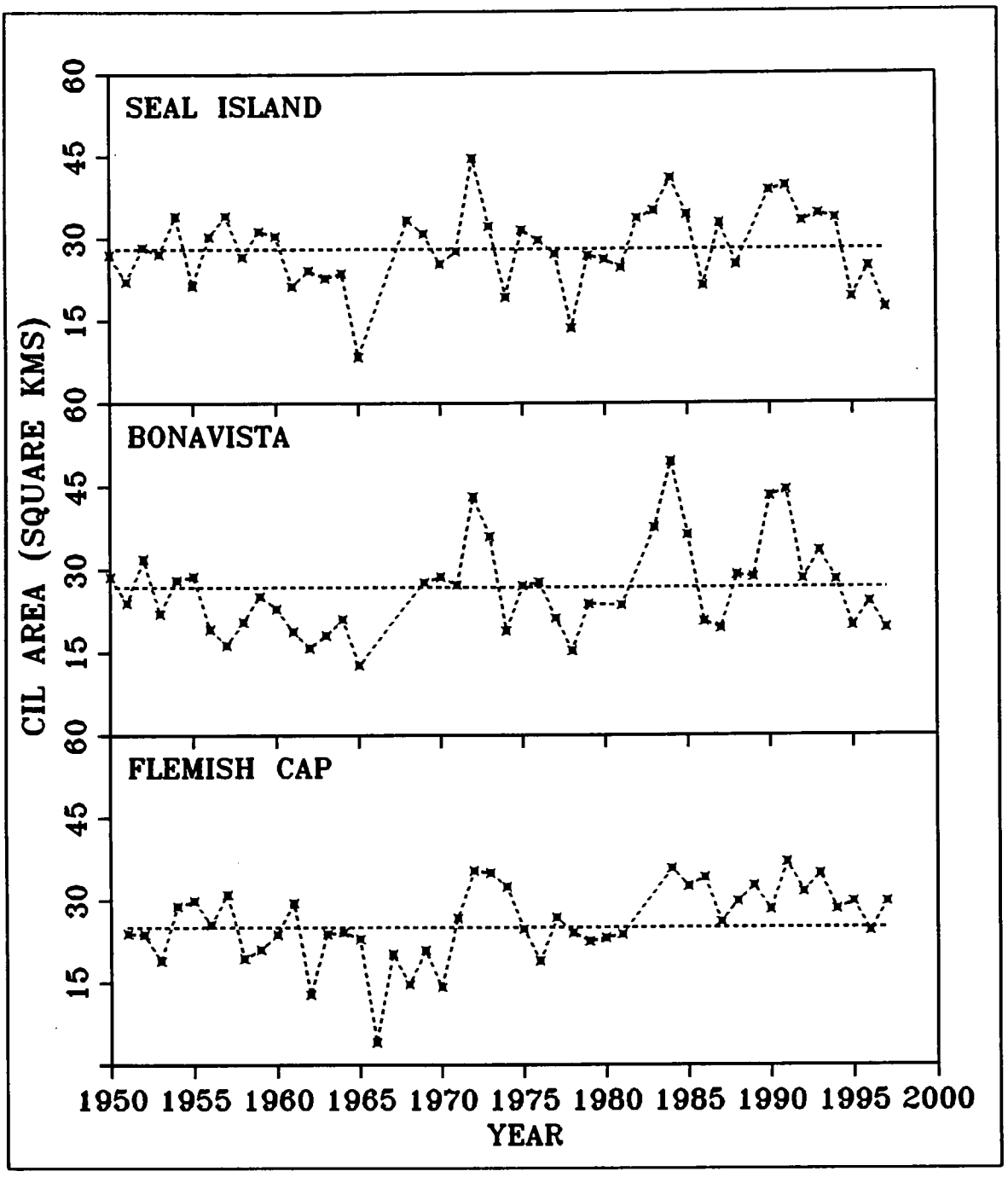

Fig. 14. Time series of CIL area along the Seal Island, Bonavista and Flemish Cap transects. The horizontal dashed line represents the 1961-90 average.

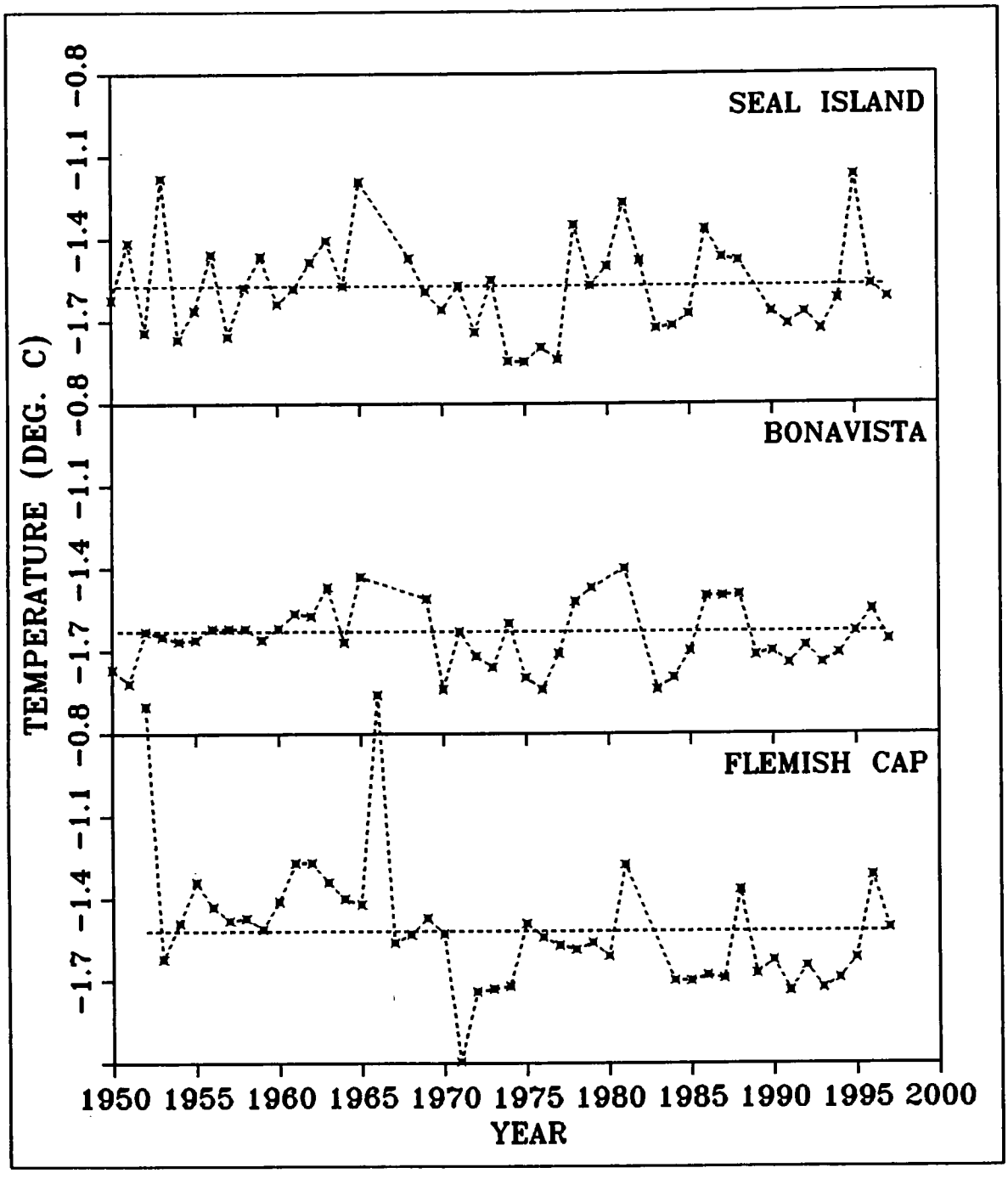

Fig. 15. Time series of CIL minimum temperature along the Seal Island, Bonavista and Flemish Cap transects. The horizontal dashed line represents the 1961-90 average.

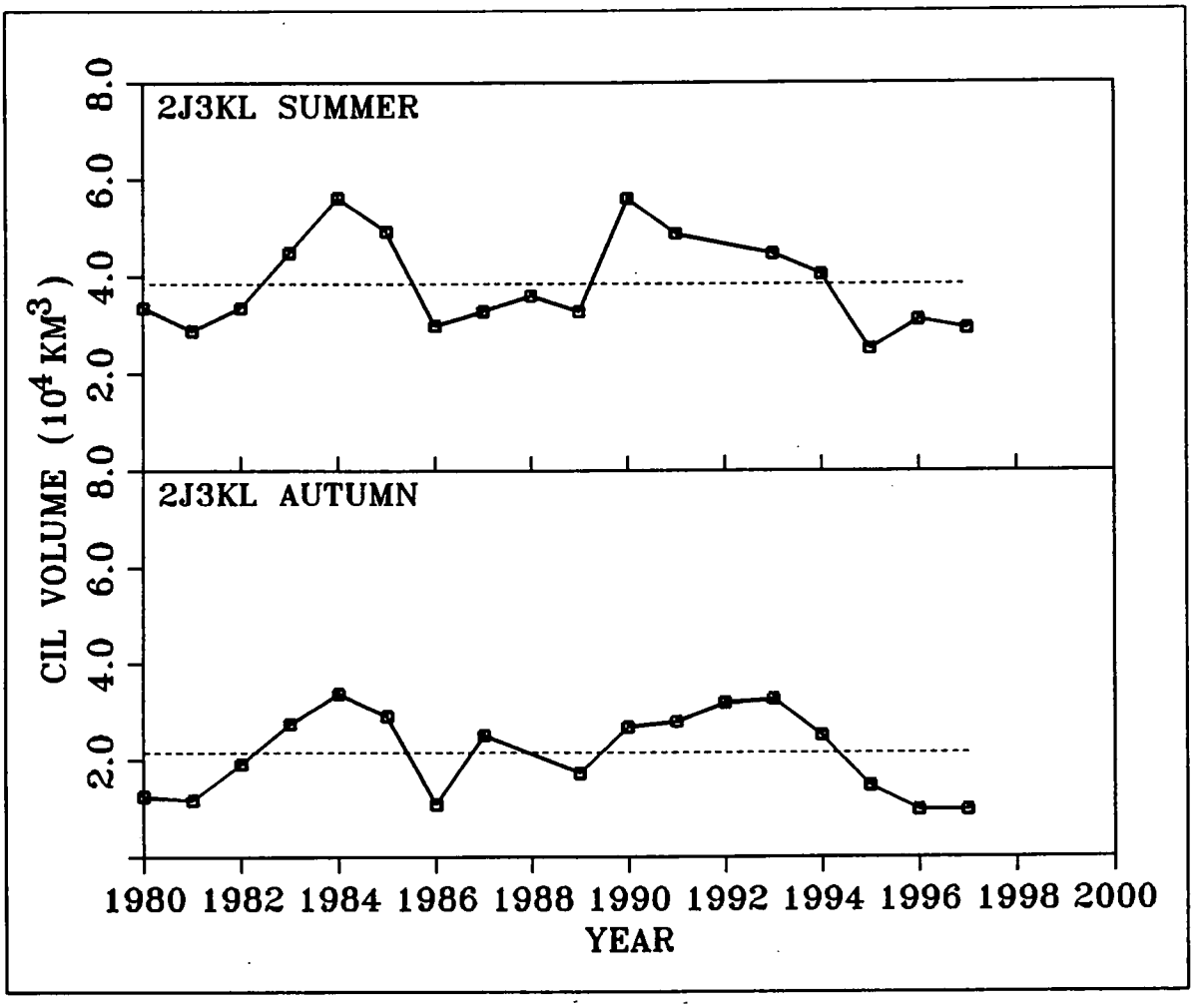

Fig. 16. Time series of summer and fall CIL volumes (km^3) over the 2J to 3KL areas from 1980 to 1997. The horizontal dashed line is the 1980-1997 average.

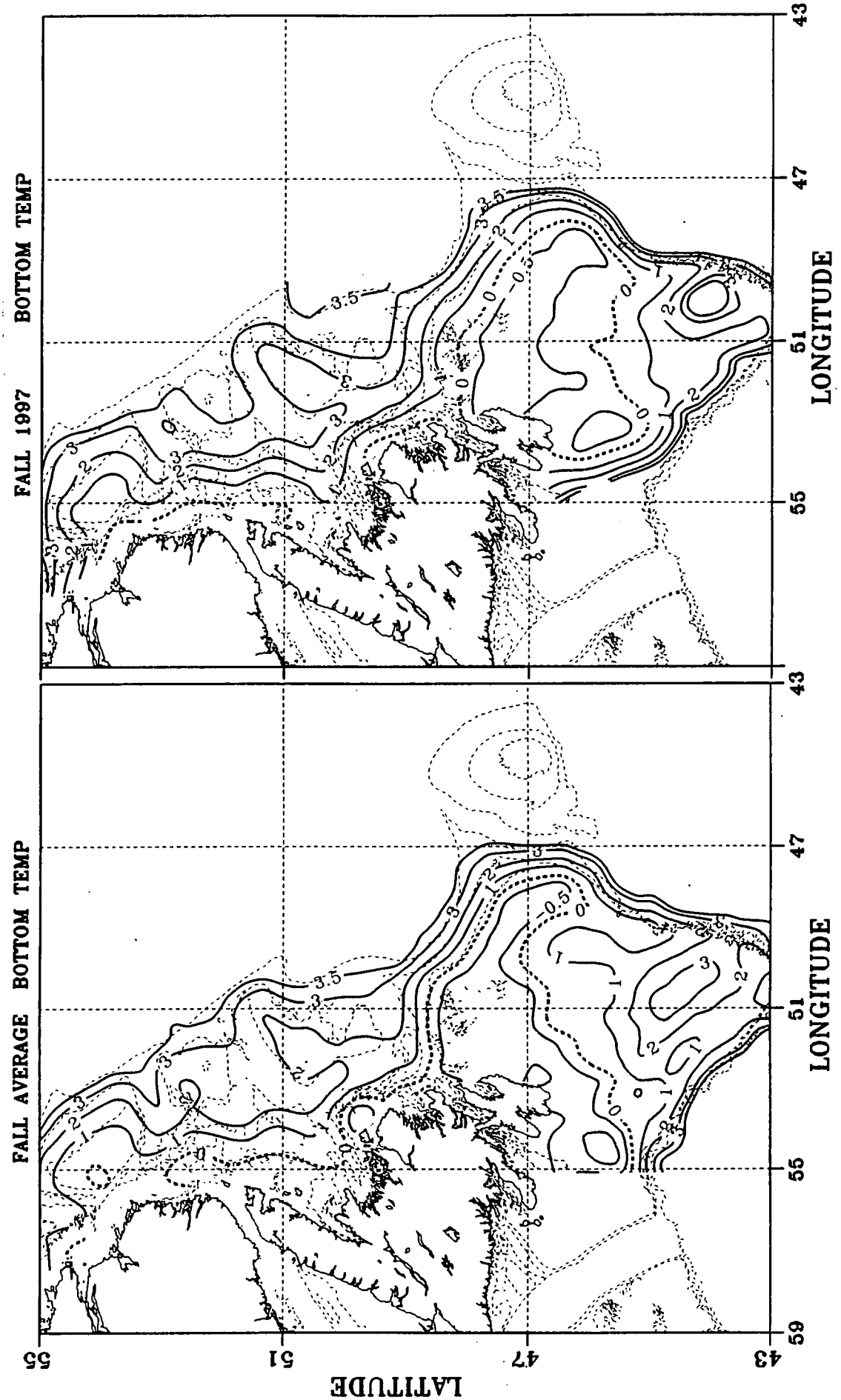

Fig. 17. Horizontal bottom temperature maps for the fall average (1961-1990) and for the fall of 1997 for the Newfoundland Shelf region.

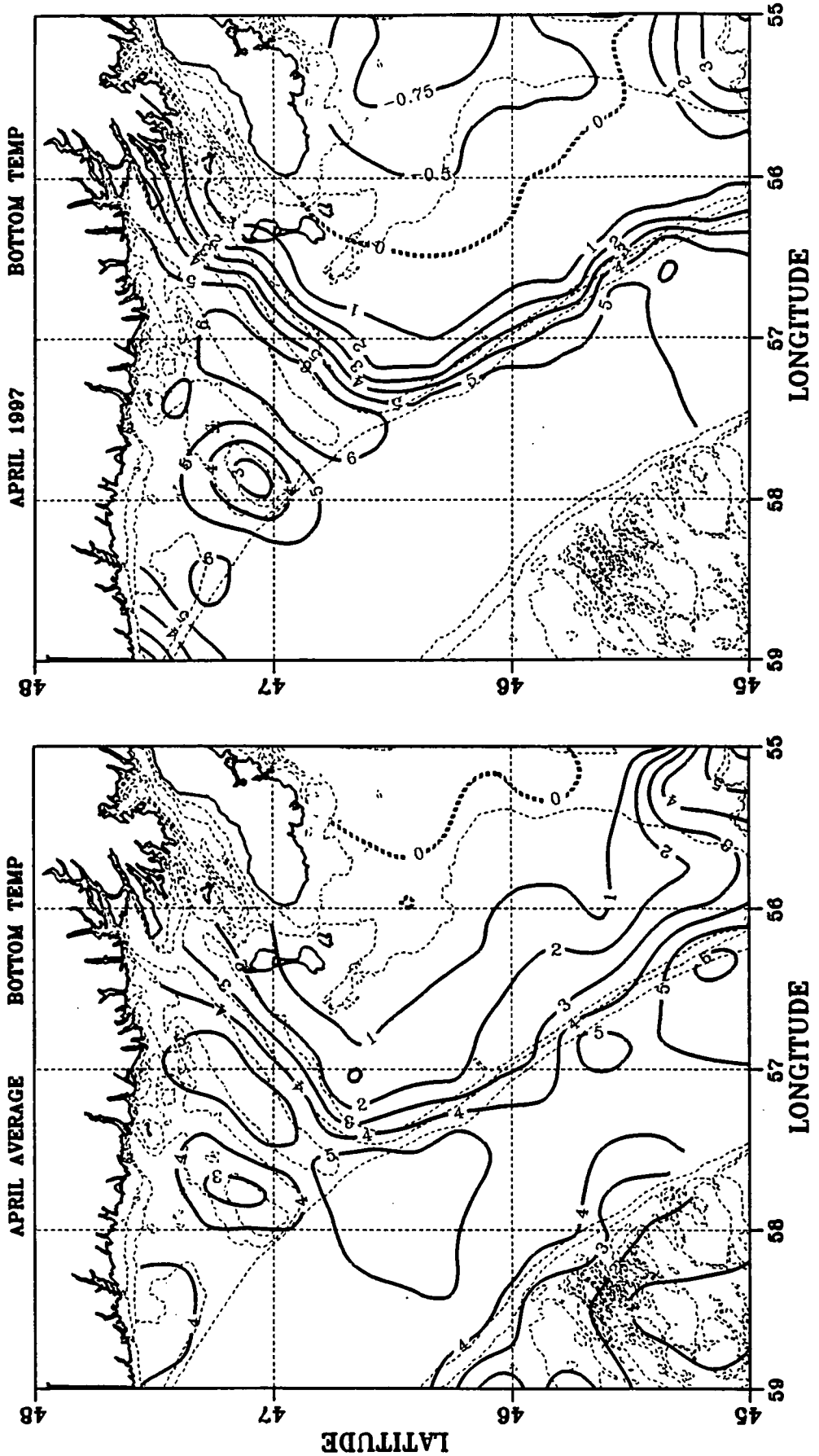

Fig. 18. Horizontal bottom temperature maps for the April average and April of 1997 in NAFO Subdivisions 3Pn and 3Ps.