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Physical oceanographic conditions on the Newfoundland and Labrador Shelves during 2000

E. Colbourne

Department of Fisheries and Oceans
P. O. Box 5667
St. John's Newfoundland, Canada A1C 5X1

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Abstract

Oceanographic observations from Nain Bank on the Labrador Shelf to the Southern Grand Bank on the Newfoundland Shelf during 2000 are presented referenced to their long-term (1961-1990) means. The annual water column integrated temperature at Station 27 for 2000 cooled slightly compared to 1999 but remained above the long-term mean. Surface temperatures were above normal for 9 out of 12 months with anomalies reaching a maximum of near 1.5°C during August. The June, July and December values were about normal. Bottom temperatures at Station 27 were above normal (by >0.5°C) during the first 6 months of the year and about normal during the remainder. Salinities at Station 27 were below normal during the winter months and near normal during the rest of the year. The vertically integrated salinity for the summer months was about normal. Similar trends in temperatures and salinity were observed on the Flemish Cap and on Hamilton Bank during 2000. Temperatures at 10-m depth in Norte Dame Bay, Bonavista Bay and Placentia Bay along the east coast of Newfoundland during 2000 were above normal by up to 3°C during the summer months. The cross-sectional area of sub-zero °C (CIL) water on the Newfoundland and Labrador Shelves increased over 1999 values, ranging from below normal on the Grand Bank, near normal off the east coast of Newfoundland and slightly above normal on the southern Labrador Shelf. Bottom temperatures on the Grand Bank during the spring of 2000 ranged from 0.5°C above normal in NAFO Div. 3L and up to 2°C above normal in Div. 3O. During the fall on the Grand Bank they decreased to mostly below normal values in central areas, but remained above normal in northern 3L and along the edge of the bank. Fall bottom temperatures in Divs. 2J and 3K were above normal in most areas, however, the mean bottom temperature in all regions decreased from 1999 values. Correspondingly, the area of the bottom in all areas covered by water in the lower end of the temperature range (-1.7-1°C) increased slightly over 1999 values while the area of warm water (1-4°C) decreased. In summary during 2000, ocean temperatures were cooler than 1999 values but remained above normal over most areas continuing the warm trend established in 1996. Salinities on the Newfoundland and Labrador Shelves were similar to 1999 values, generally fresher than normal.

Résumé

Des observations océanographiques recueillies du banc Nain du plateau du Labrador au sud du Grand Banc du plateau de Terre-Neuve en 2000 sont présentées et comparées à la moyenne à long terme (1961-1990). La température annuelle intégrée de la colonne d'eau à la station 27 en 2000 était plus basse qu'en 1999, quoique au-dessus de la moyenne à long terme. La température en surface se situait au-dessus de la normale pendant 9 des 12 mois, les anomalies atteignant un maximum de près de 1,5 oC en août. Les valeurs pour juin, juillet et décembre se situaient près de la normale. La température au fond à la station 27 se situait au-dessus de la normale (par > 0,5 oC) pendant les six premiers mois de l'année et près de la normale pendant le reste de l'année. La salinité à la station 27 était inférieure à la normale pendant l'hiver et près de la normale le reste de l'année. La salinité verticalement intégrée pour les mois d'été était presque normale. Des tendances semblables de la température et de la salinité ont été observées sur le Bonnet flamand et le banc Hamilton en 2000. La température à 10 m de profondeur dans les baies Notre Dame, de Bonavista et de Plaisance, situées sur la côte Est de Terre-Neuve, en 2000 se situaient au-dessus de la normale parjusqu'à 3 oC pendant l'été. L'aire transversale des eaux de 0 oC ou moins (eaux intermédiaires froides) sur les plateaux de Terre-Neuve et du Labrador a augmenté par rapport à 1999, allant de sous la normale sur le Grand Banc à près de la normale au large de la côte Est de Terre-Neuve à légèrement au-dessus de la normale dans la partie sud du plateau du Labrador. La température au fond sur le Grand Banc au printemps 2000 allait de 0,5 oC au-dessus de la normale dans la division 3L jusqu'à 2 oC au-dessus de la normale dans la division 3O. Elle a baissé à l'automne, atteignant des valeurs en général sous la normale dans la partie centrale mais au-dessus de la normale dans la partie nord de 3L et le long de la limite du banc. La température au fond dans la plupart des parties des divisions 2J et 3K à l'automne se situait au-dessus de la normale, bien que la température moyenne au fond dans toutes les parties de ces divisions était plus basse qu'en 1999. De ce fait, la superficie du fond couverte d'eau d'une température du bas de la plage de températures (de -1,7 oC à 1 oC) a légèrement augmenté par rapport à 1999, tandis que la superficie d'eau plus chaude (de 1 oC à 4 oC) a diminué. En résumé, la température des eaux océaniques en 2000 était plus basse qu'en 1999, mais est demeurée au-dessus de la normale dans la plupart des régions, la tendance vers un réchauffement établie en 1996 se poursuivant. La salinité sur les plateaux de Terre-Neuve et du Labrador se rapprochait des valeurs de 1999, quoique les eaux étaient généralement plus douces que la normale.

Introduction

This report presents an overview of physical oceanographic conditions in the Newfoundland and Labrador Regions during 2000, with a comparison to long-term average conditions based on historical data. Where possible the long-term averages were standardised to a base period from 1961-1990 in accordance with the convention of the World Meteorological Organization and recommendation of the North Atlantic Fisheries Organization's (NAFO) Scientific Council. Most of the data time series 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. The information presented for 2000 is derived from the following sources; (1) observations made at Station 27 (Fig. 1) throughout the year from all research and assessment surveys, (2) measurements made along standard cross-shelf transects during annual spring, summer and fall oceanographic survey under the Atlantic Zonal Monitoring Program (AZMP), (3) temperature data from the Long-Term-Temperature-Monitoring-Program (LTTMP) sites in the inshore regions of Newfoundland and (4) oceanographic observations made during the spring and fall multi-species research vessel surveys. Data from other sources are also used to help define the long-term means and conditions during 2000.

Data Sources and Analysis

Oceanographic data are available from archives at the Marine Environmental Data Service (MEDS) in Ottawa and maintained in databases at the Bedford Institute of Oceanography in Dartmouth, Nova Scotia and at the Northwest Atlantic Fisheries Center (NAFC) in St. John's Newfoundland. Since 1977 (in Division 2J), and from 1981 (in Divisions 3KL) to 1989 the bulk of the fall data were collected during random stratified groundfish surveys. From 1971 to 1988 temperature data on these surveys were collected using bottles at standard depths and/or bathythermographs, mechanical or expendable (MBT/XBT), which were deployed usually at the end of each fishing set. Since 1989 net-mounted conductivity-temperature-depth (Seabird model SBE-19 CTD systems) recorders have replaced XBTs. This system records temperature and salinity data during trawl deployment and recovery and for the duration of the tow. Data from the net-mounted CTDs are not field calibrated, but are checked periodically and factory calibrated annually, maintaining an accuracy of 0.005^{o}C in temperature and 0.005 in salinity. The XBT measurements are accurate to within 0.1^{o}C.

Time series of temperature and salinity anomalies were constructed at standard depths from Hamilton Bank, Station 27 and the Flemish Cap. 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 depth was determined by fitting a least squares regression of the form $\mathbf{cos(\omega t\text{-}\phi)}$ to the data. Where ω is the annual frequency, **t** is the time in days and ϕ is the phase. The fitted values were the mean, the annual frequency ω and two of its harmonics. The seasonal cycle was then removed to determine anomalies. These anomalies (except Station 27) are based on data collected over relatively large geographical areas and therefore may exhibit variability due to spatial differences in the monthly estimates. Temperature anomalies were also constructed for the inshore region of Notre Dame Bay, Bonavista Bay and Placentia Bay from the Long-Term-Temperature-Monitoring thermograph sites by computing monthly means from the continuous hourly time series.

Bottom temperature grids for the Newfoundland Shelf were produced from all available data from 1961 to 1990 and for the spring and fall of 2000. All bottom-of-the-cast temperature values for each time period (except those for which the cast depths were not within 10% of the total water depth) were interpolated onto a regular grid and contoured using a geostatistical (2-diminsional Kriging) procedure. Bottom temperature anomalies were computed by taking the difference between the 2000 and the average grids. Some temporal and spatial biasing may be present in the analysis given the large area and wide time interval over which the surveys were conducted. For example, the annual fall ground fish survey normally starts early to mid-October and finishes around mid-December, a time period when rapid cooling of the water column is taking place.

Near-bottom temperature data from the multi-species assessment surveys were used to compute time series of the area of the bottom covered by water in selected temperature ranges. The mean near-bottom temperature for each grid element was calculated as described above and its area integrated to produce a yearly estimate of the percentage of the total area within each temperature range. The mean near-bottom temperature time series was also constructed for each region. The selected temperature ranges were ≤0°C, 0-1°C, 1-2°C, 2-3°C and ≥3°C. Potential sources of error in this analysis include temporal biasing, arising from the wide time interval during which a typical survey is conducted. This source of error is probably small, however, given the low magnitude of the annual cycle over most of the near-bottom depths encountered. An additional source of error that can potentially affect the results, particularly along the shelf edge, occurs when the spatial scales of temperature variations are shorter than the grid size. This effect however will probably be small, particularly over the Banks where the landscape is relatively flat.

Time Trends in Temperature and Salinity

Station 27 (Division 3L)

A total of 59 temperature and salinity profiles were collected in the Avalon Channel at Station 27 off Cape Spear (Fig. 1) during 2000. The data from this time series are presented in several ways to highlight seasonal and interannual variations over various parts of the water column. Depth versus time contour maps of the annual cycle in temperature and salinity and their associated anomalies for 2000 are displayed in Fig. 2. The monthly anomalies at the surface and bottom are displayed in Figs. 3-6 (top panels). The cold near isothermal water column during the winter months has temperatures ranging from 0°C to –1°C. These temperatures persisted throughout the year in the bottom layers. The surface layer temperatures were near constant at about 0°C from January to early April, after which the surface warming commenced. By late April upper layer temperatures had warmed to 1°C and to over 13°C by August at the surface, after which the fall cooling commenced. These values ranged from 0.25° to 0.5°C above normal for the winter months over most of the water column, but decreased to below normal values below 10-m depth during late June and July. This cold anomaly penetrated deeper into the water column during late summer and fall months reaching the bottom by the end of the year. Temperatures in the upper water column remained above normal from August to December with anomalies exceeding 1°C. Bottom temperatures ranged from 0.3° to 0.8°C above normal from January to June and near normal during the remainder of the year. Surface salinities reached a maximum of >32 by May and decreased to a minimum of <31 by late August. These values ranged from 0.1-0.4 below normal during the winter months to slightly above normal during the summer in the upper water column and slightly below normal during the remainder of the year. In the depth range from 50-100-m, salinities generally ranged from 32.2 to 32.7 and near bottom they varied throughout the year between 32.8 and 33.25, except during the fall when they decreased to less than 32.8. Except for the positive anomaly during the summer months salinities were generally below normal during most of 2000.

The annual time series of the surface and bottom temperature and salinity anomalies generally show three significant colder and fresher-than-normal periods at near decadal time scales since the early 1970s (Figs. 3 to 6 bottom panels). At the surface, the negative temperature anomaly that reached a minimum in the early 1990s began to moderate to near-normal conditions by the summer of 1994 and have continued above normal up to 2000. Near bottom at 175-m, temperatures were generally below normal from 1983 to 1994, the longest continuous period on record. During 1994 and 1995 bottom temperatures begin to warm and by 1996 were above the long-term average. Bottom temperatures from 1998 to 2000 have remained above the long-term average. Near-surface salinity anomalies (Fig. 5) 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. Salinities approached near normal values during 1996 but decreased to mostly below normal values from 1997 to 2000. In general, during the past several decades cold ocean temperatures and fresher-than-normal salinities, were associated with strong positive NAO index anomalies, colder-than-normal winter air temperatures, heavy ice conditions and larger than average summer cold-intermediate-layer (CIL) areas on the continental shelf (Drinkwater 1994, Colbourne et al. 1994, Drinkwater et al. 1996).

The vertically averaged (0-176 m) annual temperature anomaly (which is proportional to the water column heat content anomaly) time series (Fig. 7 top panel) 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. It reached a record low during 1991, a near record high during 1996, near normal in 1997 and 1998 and above normal during 1999 and 2000. The 0-50 m vertically averaged summer (July-September) salinity anomalies (Fig. 7 bottom panel) show similar behaviour as the heat content time series with fresher-than-normal periods generally corresponding to the colder-than-normal conditions. The magnitude of negative 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, these increased to near normal values in 1997 and 1998 but fell again to below normal values in 1999 and returned to normal conditions during 2000.

Flemish Cap (Division 3M)

Temperature anomalies on the Flemish Cap (Fig. 8) are also characterised by cold periods during the 1970s, mid-1980s and the late 1980s to the mid-1990s. The cold period, beginning around 1971, continued until 1977 in the upper layers, while temperature anomalies at 150-m depth were of a much lower magnitude. 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. By 1995 temperatures moderated and were above normal from 1997 to 2000.

The time series of salinity anomalies (Fig. 9) show large fresher-than-normal conditions from 1970 to 1975 with peak amplitudes reaching near 1 salinity unit below normal. Negative salinity anomalies also occurred during the mid-1980s and mid 1990s, however the amplitude was much smaller than the great salinity anomaly of the early 1970s. The trend in salinity values during the latter half of the 1990s ranged from slightly above normal at the surface to near normal at deeper depths. In general, temperature and salinity anomalies on the Flemish Cap are very similar to those at Station 27 and elsewhere on the continental shelf over similar depth ranges (Colbourne 1998).

Hamilton Bank (Division 2J)

Time series of temperature and salinity anomalies from 1950 to 2000 on Hamilton Bank are shown in Figs. 10 and 11 at the surface and at 150-m depth. The annual values show a high degree of variability that may indicate spatial variability over the bank at the same depth level. It should also be noted that these estimates are calculated from a variable number of observations. A low frequency trend was calculated by a 5-year running mean that suppresses the high frequency variations and gives a general indication of long-term trends.

The temperature time series is characterised by amplitudes ranging from near ±2^{o}C and with periods ranging from 2 to 10 years. The cold periods of the early 1970s, the mid-1980s and the early 1990s are apparent, but, the amplitude of the anomalies varied considerably with depth. The long-term trend indicates that temperatures on Hamilton Bank have moderated, particularly in the deeper layers, being above normal since the mid-1990s, similar to conditions further south at Station 27. During 2000 temperatures were above normal near the surface and near normal at 150-m depth. The salinity time series show similar trends as elsewhere on the shelf with fresher-than-normal conditions in the early 1970s, mid-1980s and early 1990s. Salinities from 1995-2000 varied about the long-term mean.

Coastal Near-Surface Temperatures (LTTMP)

Hourly temperature measurements at 10-m depth were made at inshore monitoring sites at Comfort Cove in Notre Dame Bay since 1981, Stock Cove in Bonavista Bay since 1967 and at Arnold’s Cove in Placentia Bay (Fig. 1) since 1981 as part of a long-tern temperature monitoring program (LTTMP). The complete time series except 2000 were used to calculate monthly means from which temperature anomaly time series were constructed (Fig. 12). Temperatures at Arnold’s Cove during 1999 ranged from near normal during the winter and fall months to 3-4^{o}C above normal during the remainder of the year. These warm temperatures continued into 2000 with temperatures reaching up to 3^{o}C above normal in July and decreasing to about normal conditions by November. Temperatures at Comfort Cove were above normal during the spring and summer months during both 1999 and 2000 and near normal during winter and fall. Data for the last 4 months of 2000 were not yet available for Comfort Cove. At Stock Cove temperatures were above normal for most of 1999, except during August, October and November. During 2000 they were above normal for all available months with maximum anomalies occurring during the summer. The negative anomaly during August 1999 at Stock Cove was due to the upwelling of colder sub-surface water caused by an extended period of strong offshore wind forcing. These events are frequently observed near shore along the East Coast of Newfoundland during the summer months.

Standard Monitoring Transects

In 1976 the International Commission for the Northwest Atlantic Fisheries (ICNAF) adopted a suite of standard oceanographic monitoring stations along transects in the Northwest Atlantic Ocean from Cape Cod (USA) to Egedesminde (West Greenland) (Anon. 1978). Four of these transects are occupied annually during mid-summer on an annual oceanographic survey conducted by DFO's Newfoundland Region, they are; (1) the Seal Island transect on the southern Labrador coast and Hamilton Bank, (2) the White Bay transect which crosses the relatively deeper portions of the northeast Newfoundland Shelf, (3) the Bonavista transect off the east coast of Newfoundland and (4) the Flemish Cap transect which crosses the Grand Bank at 47°N and continues eastward across the Flemish Cap. As part of an expanded Atlantic zonal monitoring program (AZMP) the Bonavista and Flemish Cap transects are now occupied during the spring and fall with the addition of the Southeast Grand Bank transect. Also, when time permits transects on Makkovik and Nain Banks on the mid-Labrador Shelf are occupied during the summer. In this section the physical oceanographic results from these transects for the spring, summer and fall of 2000 are presented.

Southeast Grand Bank

The Southeast Grand Bank transect was occupied twice during 2000, late April and early November (Figs. 13 and 14). Temperatures along this transect are generally above 0^oC except for in the relatively deep Avalon Channel and near the southeast edge of the Grand Bank in the offshore branch of the Labrador Current. During 2000 temperatures along the transect on the shallow Grand Bank ranged from $2\text{-}4^oC$ during spring and up to 13^oC during the fall near the surface. Except for the offshore portion of the transect these values were above normal by up 2^oC in some areas during both spring and fall. Near the edge of the Grand Bank in the Labrador Current, significant negative anomalies occurred with temperatures up to 2^oC below normal. Salinities along the transect generally range from <32.25 near the surface to >33 in the offshore region. Bottom salinities on the Grand Bank ranged from 32.5-33.0 and from 33-34.25 over the southeast slope of the Grand Bank. These values were fresher than normal by up to 0.5 during both spring and fall.

Flemish Cap

The Flemish Cap transect was occupied 3 times during 2000, April, July and November (Figs 15, 16 and 17). Near surface temperatures along this transect ranged from $1\text{->}5^oC$ during the spring to $8\text{-}10^oC$ during the summer, and $6\text{-}8^oC$ during the fall. Sub-zero (^oC) temperatures generally persisted throughout the year from below 50-m depth to the bottom over most of the Grand Bank. The coldest water is normally found in the Avalon Channel and at the edge of the Grand Bank corresponding to the inshore and offshore branches of the Labrador Current. Over the

Flemish Cap temperatures reach a maximum of about 12°C at the surface during July and remain at about 4-5°C at 80-m depth to the bottom throughout most of the year.

During the spring, temperatures were generally above normal along this transect but decreased to below normal values in the upper water column during the summer. During the fall, temperatures on the Grand Bank at intermediate depths were below normal while surface temperatures were above normal. Bottom temperatures over most of the Grand Bank were near 0.5°C above normal during the spring and near normal during both summer and fall. Deep-water temperatures over the Flemish Pass and Cap decreased from above normal values during the spring to near normal during the summer and below normal by about 0.5-1°C during the fall. Salinities along the transect on the Grand Bank were generally fresher than normal from spring to fall with the highest anomalies occurring during the spring.

Bonavista

The Bonavista transect was occupied 3 times during 2000, May, July and November (Figs. 18, 19 and 20). The dominant feature along this transect is the cold intermediate layer of <0°C water (CIL) which develops during early spring. Temperatures along the Bonavista transect in the upper 20-m of the water column ranged from <0°C during spring, reaching a maximum of 8-10°C during the summer and decreasing to 3-6°C during the fall. These values were generally below normal during the spring except in the offshore portion of the transect from 75 m depth to the bottom. These cold anomalies continued over most of the shelf at intermediate depths into the summer months but were above normal near the bottom. During the fall temperatures were above normal (up to 2°C) along most of the transect except near the coast where negative anomalies continued. Bonavista transect salinities generally range from <33 near the surface in the inshore region to >34 in the offshore region. Bottom salinities ranged from 32.5 in the inshore regions, to 34.75 at about 325-m depth near the shelf edge. Salinities were fresher-than-normal (up to 0.3) in the intermediate depths during the summer and generally saltier-than-normal in the surface waters and near bottom. During the fall salinities were generally saltier-than-normal along most of the transect.

White Bay

The White Bay transect which crosses the deeper portions of the northeast Newfoundland Shelf was occupied in July of 2000 (Fig. 21). The CIL is also quite evident along this transect with a large area of water with sub-zero °C temperatures extending from the coast and offshore to over 400 km. Temperatures along this transect were generally below normal during 2000 in the upper 50 m of the water column and over all depths at mid-shelf. Below 50-m depth temperatures were above normal near shore and in the offshore areas. Salinities generally ranged from <31.5 near the surface in White Bay to >34 in the offshore region. Bottom salinities ranged from 33 near shore to 34.75 at the edge of the shelf. These values were fresher than normal (up to 0.4) in areas corresponding to the CIL temperatures and generally above normal near the surface and in the deeper waters of the outer shelf regions.

Seal Island

The Seal Island transect which crosses Hamilton Bank on the southern Labrador Shelf was occupied in July of 2000 (Fig. 22). Upper layer temperatures across this region ranged from 0°C at 30-m depth to between 4-5°C at the surface. Temperatures below 50-m depth were generally sub-zero °C corresponding to the CIL over most of the shelf, except near bottom where they range from 1-2°C. Near the shelf break temperatures increase to over 3°C. Temperature anomalies in the surface layer ranged from 0.25-1°C above normal near-shore, but were up to 1°C below normal over Hamilton Bank. These colder than normal temperatures extended to the bottom over the bank but were near normal below 225 m depth in the offshore regions. Salinities in the near shore region and across most of the shelf were below normal with anomalies ranging from 0.75 near shore at the surface to around 0.4 on Hamilton Bank. Offshore of the shelf break salinities were near normal at depth and above normal in the upper water column.

Makkovik Bank and Beachy Island (Nain Bank)

The Makkovik Bank transect on the mid-Labrador Shelf was occupied in July of 2000 (Fig. 23). Upper layer temperatures over the shelf ranged from 0°C at 30-m depth to between 2-3°C at the surface. Temperatures below 30-m depth were generally sub-zero °C over the shelf but increased to above 0°C on the outer edge of the Bank and to >3°C on the shelf slope. Temperature anomalies in the upper layer were up to 1°C below normal but near normal over the rest of the water column on the bank and generally above normal in the offshore regions. Salinities were generally <32 near surface to >32.5 on the bank and >34 in the offshore regions. These values were below normal over the bank and above normal in the offshore regions.

The Beachy Island transect which crosses Nain Bank on the mid-Labrador Shelf was also occupied in late July of 2000 (Fig. 24). Temperatures along this transect were slightly warmer than that observed along the Makkovik Bank transect with surface values over 3°C and the area of water with temperatures below –1°C much less than that on Makkovik Bank. Offshore temperatures were very similar along both transects. Except for slightly fresher water near the surface, salinities along the both transects were also very similar. Insufficient data were available to calculate anomalies along the Beachy Island transect.

Cold Intermediate Layer (CIL) Time Series

As shown above in the cross-shelf contour plots, the vertical temperature structure on the Newfoundland Continental Shelf during late spring through to the fall is dominated by a layer of cold sub-zero °C water trapped between the seasonally heated upper layer and warmer slope water near the bottom. This water mass is commonly referred to as the cold intermediate layer or CIL (Petrie et al. 1988). The cold, relatively fresh, shelf water is separated from the warmer saltier water of the continental slope by a frontal region denoted by a strong horizontal temperature and salinity gradient near the edge of the continental shelf. Figure 25 shows a time series of the CIL cross-sectional area defined by of sub-zero °C water for the Flemish Cap, Bonavista, White Bay and Seal Island transects.

Along the Bonavista transect during the summer of 2000 the CIL extended offshore to about 220 km, with a maximum thickness of approximately 200 m corresponding to a cross-sectional area of around 27 km^2. This was about normal compared to the previous 4 years with below normal values, which corresponds to warm ocean conditions. From 1990 to 1994 the CIL area was above normal reaching a peak of more than 60% (compared to the 1961-1990 mean) during the cold year of 1991. The CIL area along the Seal Island transect was slightly above normal during 2000 compared to about 49% below normal during 1999. 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 below normal similar to the 1999 value and along the White Bay transect the CIL was about average. In general, the total cross-sectional area of sub-zero °C water on the Newfoundland Shelf during 2000 appeared below normal in the south on the Grand Bank and slightly above normal on Hamilton Bank (Fig. 25).

The total volume of sub-zero °C water on the Newfoundland and southern Labrador Shelves shoreward of the 1000-m isobath and within NAFO divisions 2J3KL is shown in Fig 26. The calculation of the volume of sub-zero °C water overlying the continental shelf has been described by Colbourne and Mertz (1995). The amount of sub-zero °C water is principally determined by the thickness of the layer of water <0°C on the shelf. 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 zero 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 sub-zero °C water over the 2J 3KL area shows maximum values during the cold periods of the mid-1980s and early 1990s (Fig. 26). The total volume of sub-zero °C water on the shelf increased from approximately 3.3 x 10^4 km^3 during the summer of 1989 to 5.6 x 10^4 km^3 in 1990, a 70% increase. Since 1991 the volume of sub-zero °C water on the Newfoundland Shelf has been slowly decreasing, and by 1995 it had decreased to values of the early and mid-to-late 1980s. The fall 2000 volume increased relative to the 1999 value but still continued the trend of below average values experienced during the last 5 years. The time series during the fall shows similar trends as in the summer however the total volume is only about 60% of the summer values. Due to data limitations, the volume estimates were not calculated prior to 1980 and during the summer of 2000.

Minimum temperatures measured in the core of the CIL for all four transects during the summer from 1950 to 2000 are shown in Fig. 27. The minimum temperature observed along the Flemish Cap, White Bay, Seal Island and the Bonavista transects during 2000 were -1.47°, -1.6°, –1.59°, and -1.61°C, respectively. These near normal values represent a decrease over the 1999 values at all four sites.

Geostrophic Circulation and Transport

The temperature and salinity data from the summer 2000 survey were used to calculate geostrophic currents relative to 300 m along the Flemish Cap, Bonavista, White Bay, Seal Island, Makkovik Bank and the Beachy Island (Nain Bank) transects (Fig. 28). The geostrophic component of the speed of the southward flowing Labrador Current along these transects generally show distinct inshore and offshore branches. The inshore branch is much weaker than the shelf-slope offshore branch and is usually restricted to the inshore troughs within approximately 50-100 km of the coast. Typical geostrophic current speeds in these regions range from 0.05-0.10 m/s. The much stronger offshore branch is normally located at the shelf break in water depths generally greater than 500 m. The offshore distance and the width of the current vary according to the underlying topography. Along the Seal Island and Bonavista transects, for example, the core of the offshore branch is about 100 km wide, centred at about 225 km offshore over the 500-m isobath, while off Makkovik and Nain Banks the width of the current is approximately 50 km centred at about 125 km offshore. In the offshore branch, current speeds range from 0.05 m/s at 175-m depth to greater than 0.2 m/s in the upper water column. At mid-shelf the currents sometimes reverse direction, with clockwise circulation on Hamilton Bank, for example. These currents are generally weak however with speeds generally less that 0.05 m/s. The geostrophic flow perpendicular to the Flemish Cap transect show the well-known features of the circulation. The strong baroclinic component of the offshore branch of the Labrador Current near the edge of the Grand Bank, the general anticyclonic circulation around the Cap and the northward flowing water of the North Atlantic Current east of the Cap are evident (Fig 28). In general, geostrophic currents along the Labrador Shelf (Seal Island, Makkovik Bank and Nain Bank) appear stronger than on the eastern Newfoundland Shelf with speeds over 0.30 m/s offshore from Nain Bank for example.

The historical (1950-2000) summer (July-August) temperature and salinity data along the Seal Island, Bonavista and Flemish Cap transects were used to compute a time series of geostrophic transports. The volume transport was calculated by integrating the speed both vertically through the water column and horizontally through the offshore branch of the current. A common reference level of 135-m was chosen for these calculations since this was the deepest level common to all three transects that did not intersect the bottom, thus eliminating potential problems associated with a bottom reference level. Also, the main interest was to examine variations in volume transport during recent ocean climate changes on the continental shelf. Short-term climate changes generally result in variations in upper layer shelf stratification due mainly to salinity changes resulting from increased ice formation and melt. This determines in part, the magnitude of the shelf-slope density front and hence the strength of the geostrophic component of the Labrador Current. The time series of volume transport of the offshore branch of the Labrador Current for the three transects (Fig. 29) show large interannual variations with an average transport of between 0.4-0.5 Sv (1 Sv = 10^6 m^3/s) to the south, relative to 135 m. In general, the time series indicate higher than average transport during the late 1950s and into the 1960s, lower than average values during the cold period of the early 1970s and to a lesser extent during the cold period of the mid-1980s. During the late 1980s the transport increased to above average values, which for the most part continued into the mid-to-late 1990s. Except for the Bonavista transect, the transport in the offshore branch of the Labrador Current during 2000 increased slightly over the 1999 values.

Multi-Species Survey Results

Canada has been conducting stratified random groundfish trawl surveys in NAFO Sub-areas 2 and 3 since 1971. Each NAFO Div. has been stratified based on the depth contours of available standard navigation charts. Areas within each division with a selected depth range were divided into strata and the number of fishing stations in an individual stratum are based on an area weighted proportional allocation (Doubleday 1981). Temperature profiles of the water column are available for each fishing set in each stratum. Surveys have been conducted for the following NAFO Divisions, time periods and depth ranges: 3P in winter and/or spring from 1972 to 2000, in water depths down to 366 m until 1979 and to 548 m since then; 3L in spring from 1971-2000, except 1983 and 1984; 3NO in spring from 1971-2000, except 1983 in 3N and 1972, 1974 and 1983 in 3O, in water depths down to 366 m in most years and more recently to 548 m; 2J fall from 1977-2000; 3K in fall from 1978-2000; 3L in fall from 1981-2000, 3NO in fall from 1990-2000.

In this section the 2000 near-surface and near-bottom temperature fields and their anomalies for NAFO Divs. 2J and 3KLNO on the Newfoundland Shelf are presented for the spring and fall periods. Interannual variations are then examined by computing the areal extent of the bottom covered with water in various temperature ranges as described earlier. The objective of this analysis is to provide some indication of potential changes in any temperature dependent near-bottom habitat for various fish species.

3LNO Spring

The spring 2000 surface and bottom temperatures and their anomalies for NAFO Divs. 3LNO are shown in Fig. 30. Surface temperatures range from 1-2°C in northern 3L to 7-8°C on the southern Grand Bank. Except for areas of below normal values in the inshore regions of 3L and in the southern areas of 3NO these temperatures were generally above normal by 1-3°C in most areas. In the northern areas spring bottom temperatures ranged from sub-zero °C in the inshore regions of the Avalon Channel to over 3°C at the shelf edge. Over the central and southern areas bottom temperatures ranged from 1°C to >3.5°C on the Southeast Shoal and above 3°C along the edge of the Grand Bank. During the spring of 2000, sub-zero °C water was restricted to the Avalon Channel and Div. 3L and above normal conditions persisted over the entire northern Grand Bank with temperatures up to 0.5°C above average. Over southern areas bottom temperatures ranged from 1-3°C above the long-term average.

Shown in Fig. 31 are time series of the areal extent of the bottom covered by water in various temperatures ranges during spring for the 3LNO region and for the Grand Bank in fishing strata with water depths within 100-m. In the 3LNO region from 1975 to 1983 most of the bottom area was covered by water above 0°C with only approximately 20% covered by sub-zero °C water. Since 1984 there was a large increase in the area of sub-zero °C water with percentages averaging about 50% and reaching a maximum of more than 70% during 1991. Since 1994 there has been a general decrease in the percentage area of the bottom covered by sub-zero °C water and a corresponding increase in the area covered by water ≥1°C. During the spring of 1998 and 1999 water with temperatures above 1°C covered 50-60% of the bottom area on the Grand Bank in water depths <100 m, compared to about 10% in 1990. The 1998 and 1999 values represents the largest area of relatively warm water on the Grand Bank since the late 1970s. During 1999 the area of sub-zero °C water on the Grand Bank decreased to less than 10% but increased to about 25% during 2000.

The time series of average bottom temperature for the 3LNO region (also shown in Fig. 31) shows large interannual variations of about 1°C amplitude and a downward trend that started in 1984. This trend continued until the early 1990s. The highest temperature in the 25-year record occurred in 1983 when the average temperature was 3.2°C and the lowest temperature of -0.3°C occurred in 1991. Recently, temperatures have increased over the lows of the early 1990s with the average bottom temperature during the spring of 2000 reaching 2°C. On the Grand Bank in strata with water depths (<100 m) bottom temperatures reached 1.8°C during 1999 but decreased to 1°C during the spring of 2000.

3LNO Fall

The fall 2000 surface and bottom temperatures and their anomalies for NAFO Divs. 3LNO are shown in Fig. 32. Fall surface temperatures generally ranged from <1°C in northern 3L to over 14°C in southern 3O. These values were generally below normal in 3L by up to 4°C and above normal in 3O. Fall bottom temperatures generally ranged from sub-zero °C on the northern Grand Bank and in the Avalon Channel to 3°C at the shelf edge. Over the central and southern areas bottom temperatures ranged from 1°C to >4°C on the Southeast Shoal and to >3°C along the edge of the Grand Bank. During the fall of 2000 bottom temperatures over the surveyed area were above normal on the northern Grand Bank and along the edge of the Grand Bank by up to 0.5°C. Bottom temperatures over southern 3L and regions of 3NO were below normal by over 1°C in some areas.

Shown in Fig. 33 are time series of the areal extent of the bottom covered by water in various temperatures ranges during fall for the 3LNO region and for the Grand Bank in fishing strata with water depths within 100-m. In general, in the 3LNO region the percentage area of the bottom covered by sub-zero °C water decreased significantly during 1995 to roughly one-half the value during the first half of the 1990s. A corresponding increase in the areal extent of water ≥1°C occurred during 1995. From 1995 to 1998 this remained relatively constant at about 50% but increased to over 80% during 1999. During the fall of 2000 the area of sub-zero °C water remained below the values of the early 1990s but increased over 1999 values to near 40%. On the Grand Bank, in strata with water depths ≤100-m, the trends were very similar but slightly more pronounced.

The average bottom temperature for all strata in Divs. 3LNO during the fall decreased from approximately 1.5°C during 1990 to 1°C during 1993, then increased to approximately 1.8°C during 1995. These remained relatively constant up to 1998 but then increased to over 2.5°C during 1999, the highest in the 10 year record (Fig. 33 bottom panel). On the Grand Bank in water depths ≤100-m the average temperature decreased from 1.2°C in 1990 to 0.3°C in 1994. They then increased to about 1.5°C in 1995 and remained relatively constant through to 1998 but increased further to near 2.8°C during the fall of 1999. During the fall of 2000 the mean bottom temperature decreased significantly over 1999 values, but was still above the cold condition of the early 1990s.

3K Fall

The fall 2000 surface and bottom temperatures and their anomalies for NAFO Div. 3K are shown in Figs 34 and 35. Surface temperatures ranged between 2-3°C in most areas of 3K during the survey. Except for near-shore regions and near the edge of the shelf these values were generally above average. Most of 3K has water depths >200-m, as a result relatively warm slope water floods through the deep troughs between the northern Grand Bank and southern Funk Island Bank and between northern Funk Island Bank and southern Belle Isle Bank. Bottom temperatures on these banks during the fall of 2000 ranged between 2-3°C, which were about 0.5-1°C above their long-term means. Near the edge of the continental shelf in water depths below 500-m temperatures are generally around 3.5^{o}C, which was about normal.

Shown in Fig. 36 are time series of the areal extent of the bottom covered by water in various temperature ranges and the mean bottom temperature during the fall for Div. 3K for all strata and for strata with water depth ≤300 m. The latter include most of the inner northeast Newfoundland Shelf, Funk Island Bank and southern Belle Isle Bank. The percent area of the bottom covered by sub-zero ^{o}C water for including depths >300 m is generally less than 30%, again with significant amounts appearing only during the cold periods of the early to mid-1980s and the early 1990s. In water depths ≤300-m the percent area is higher but generally less than 50%. Since 1995, the area covered by sub-zero ^{o}C water has been insignificant. For temperature >3^{o}C, the bottom area in 3K covered has been relatively constant ranging from 20-35% from 1979 to 1995 after which it increased to near 50% from 1997 to 2000.

The time series of the average bottom temperature in Div. 3K (Fig. 36, bottom panel) during the fall ranged from 1^{o}C in 1982 to 2.3^{o}C in 1986 with an overall average of about 2^{o}C. From 1995 to 1999 they increased to above average values reaching about 2.7^{o}C during 1999. In water depths ≤300-m average temperatures were near 0^{o}C during the cold periods of the mid-1980s and early 1990s and from 1995 to 1999 they increased, reaching about 2^{o}C during 1999. During the fall of 2000 bottom temperatures remained relatively warm but decreased over 1999 values by about 0.5^{o}C.

2J Fall

The fall 2000 surface and bottom temperatures and their anomalies for NAFO Div. 2J are shown in Figs 37 and 38. Surface temperatures ranged between 1.5-2^{o}C in most areas of 2J during the fall survey. Except for the edge of the shelf, these values were generally above average. Bottom temperatures during the fall of 2000 ranged from <1^{o}C inshore, to >3.5^{o}C offshore at the shelf break. Bottom temperatures over Hamilton Bank ranged from <1^{o}C on the inshore portion of the bank, to >2^{o}C on the southern portion. Bottom temperature anomalies were about 0.5^{o}C above normal on Hamilton Bank and about normal along the edge of the shelf.

Shown in Fig. 39 are time series of the areal extent of the bottom covered by water in various temperature ranges and the mean bottom temperature during the fall for Div. 2J, for all surveyed strata and for strata with water depth ≤200 m. The percent area of the bottom covered by sub-zero ^{o}C water in Div. 2J is very low during the fall with significant amounts appearing only during the cold periods of the early to mid-1980s and early 1990s, when it ranged between 20% to 40%. On Hamilton Bank and in the near shore region in strata with depths <200-m however, the percent area of sub-zero ^{o}C water reached a maximum of near 80% in 1984 and over 90% in 1993. For temperatures >3^{o}C in 2J the bottom area covered ranged from a low of 15% in 1989 to a maximum of near 50% during 1999. Since 1996 the area of the bottom covered with sub-zero ^{o}C water decreased to near 0%. In general, for all areas, the trends are more extreme on the banks.

Bottom temperatures during the fall in Div. 2J averaged about 2^{o}C, overall, and less than 1^{o}C on the banks (depths ≤200-m) with sub-zero ^{o}C values during the cold periods of the early to mid-1980s and early 1990s. During the latter half of the 1990s average bottom temperatures increased to above normal values from the record lows of the early 1990s. During 2000 mean bottom temperatures decreased over 1999 values by about 0.5°C on the Hamilton Bank.

Summary

The annual water column averaged temperature at Station 27 for 2000 cooled slightly compared to 1999 but remained above the long-term mean. Surface temperatures were above normal for 9 out of 12 months with anomalies reaching a maximum of near 1.5°C during August. The June, July and December values were about normal. Bottom temperatures at Station 27 were above normal (by >0.5°C) during the first 6 months of the year and about normal during the remainder. Salinities at Station 27 were below normal during the winter months and near normal during the rest of the year. The vertically averaged salinity for the summer months was about normal. Similar trends in temperatures and salinity were observed on the Flemish Cap and on Hamilton Bank during 2000. Temperatures at 10-m depth in the inshore regions along the east coast of Newfoundland during 2000 were above normal by up to 3°C during the summer months.

The cross-sectional area of sub-zero °C (CIL) water on the Newfoundland and Labrador Shelves during the summer of 2000 increased over 1999 values. The CIL areas ranged from below normal on the Grand Bank (Flemish Cap transect), near normal on the east coast (Bonavista transect) and slightly above normal off southern Labrador (Seal Island Transect). The total volume of sub-zero °C water on the shelf during the fall increased compared to 1999 but amounts were still below that observed during cold years. Minimum CIL core temperatures during the summer of 2000 were about normal but slightly cooled than the 1999 values.

Bottom temperatures on the Grand Banks during the spring of 2000 ranged from 0.5°C above normal in 3L and up to 2°C above normal in 3O. During the fall they decreased to mostly below normal values except in regions of northern 3L. Fall bottom temperatures in Divs. 2J and 3K were above normal in most areas, however, the mean bottom temperature in all regions decreased from 1999 values. Correspondingly, the area of the bottom in all areas covered by water in the lower end of the temperature range (<1°C) increased slightly over 1999 values while the area of warmer water decreased. The largest increase in the area of sub-zero °C water occurred over the Grand Banks during both summer and fall with still no sub-zero °C water in 2J during the fall of 2000.

In general, the below normal 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 to 1999 ocean temperatures continued to warm over most areas, with 1999 one of the warmest years in the past couple of decades. In summary, during 2000 ocean temperatures were cooler than 1999 values, but remained above normal over most areas continuing the trend established in 1996. Salinities during 2000 were similar to 1999 values, generally fresher than normal throughout most regions, which is a continuation of the trend observed during most of the 1990s.

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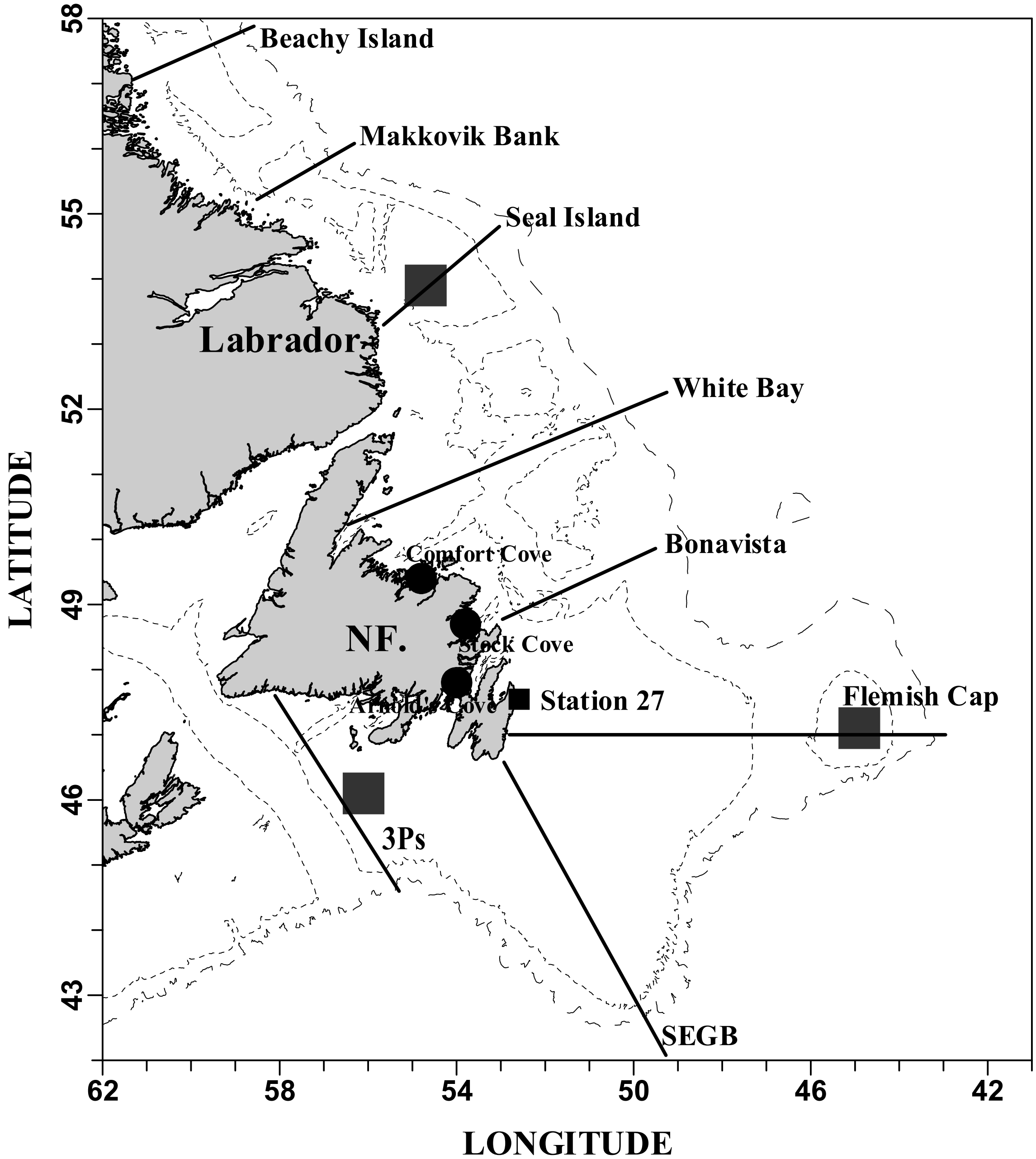


Fig. 1. Location map showing the position of the Seal Island, Bonavista and Flemish Cap (47° N) transects. The locations of the Long-Term-Temperature-Monitoring (LTTM) sites, Arnold's Cove (AC), Stock Cove (SC), Comfort Cove (CC) and Station 27 are also shown. Bathymetry contours are 300 and 1000 m.

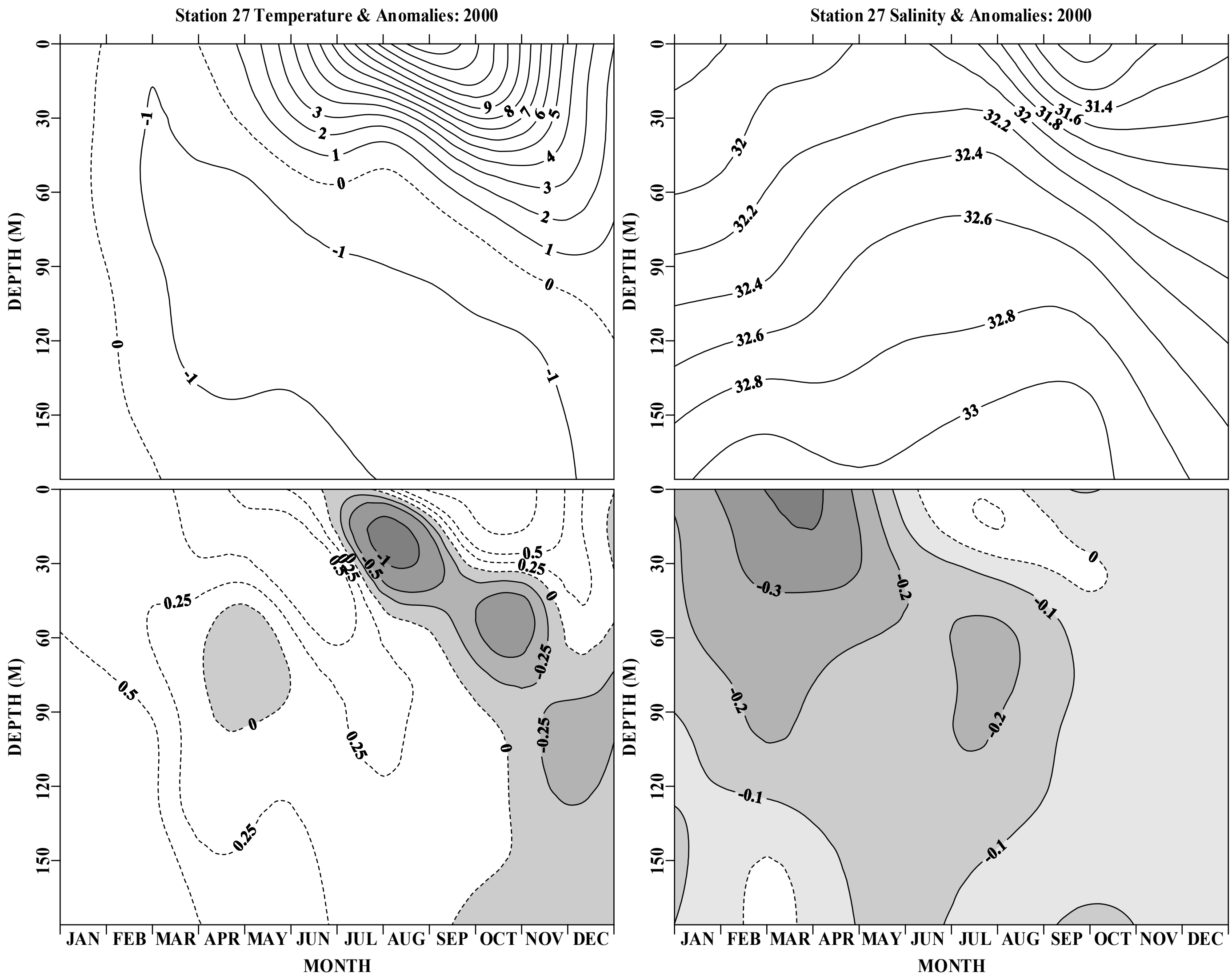
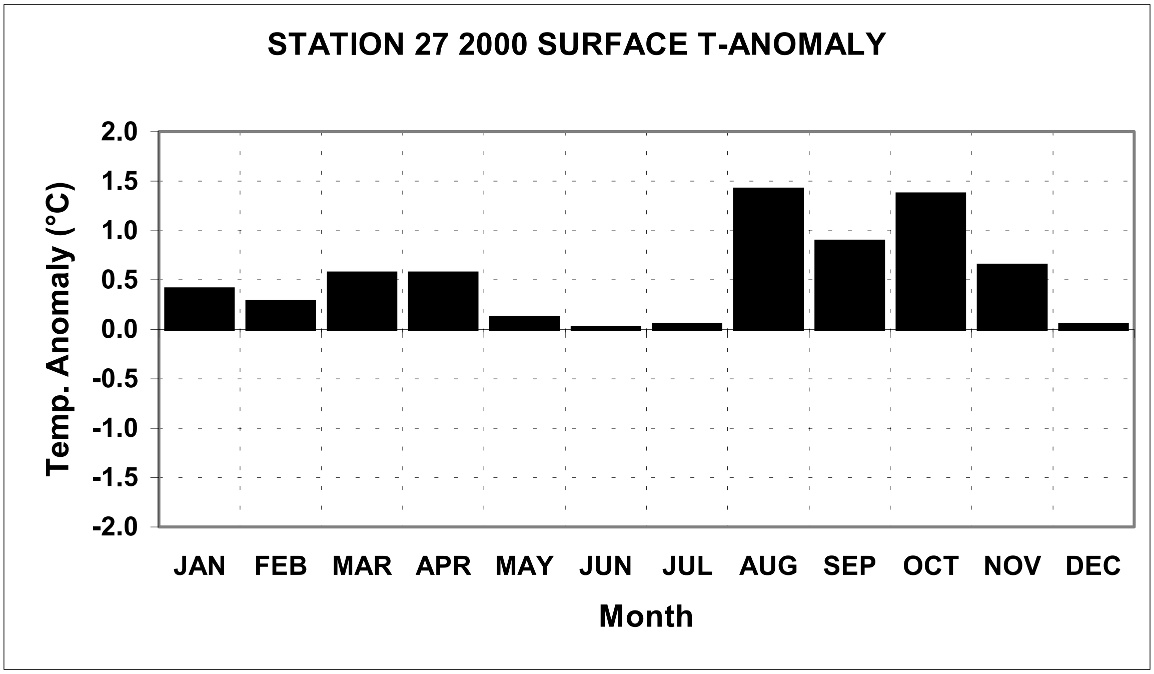


Fig. 2. Monthly temperatures (left panels) and salinity (right panels) and their anomalies (in °C) at Station 27 as a function of depth for 2000.



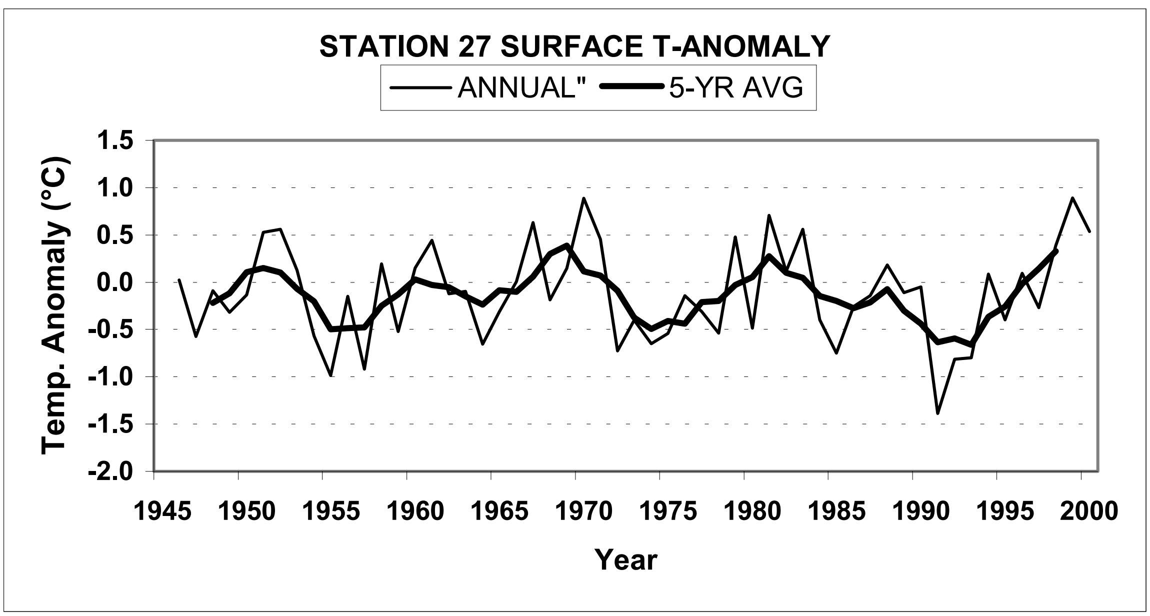
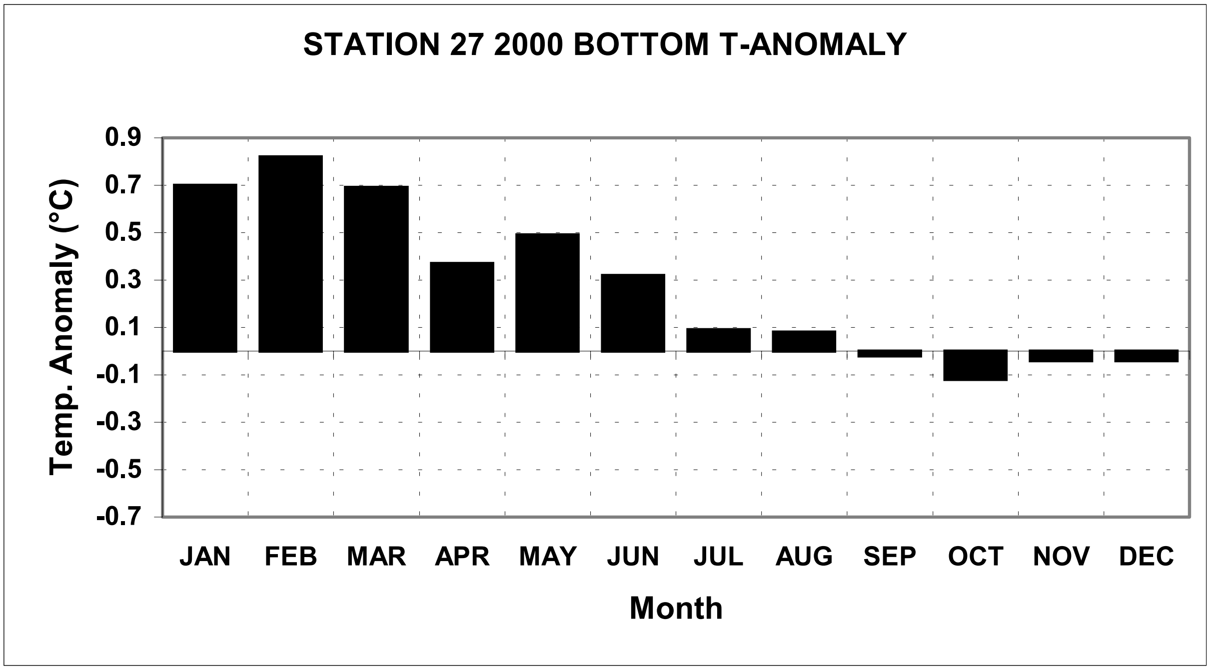


Fig. 3. Monthly surface temperature anomalies at Station 27 during 2000 (top) and the annual surface temperature anomalies and their 5-year running means (bottom).



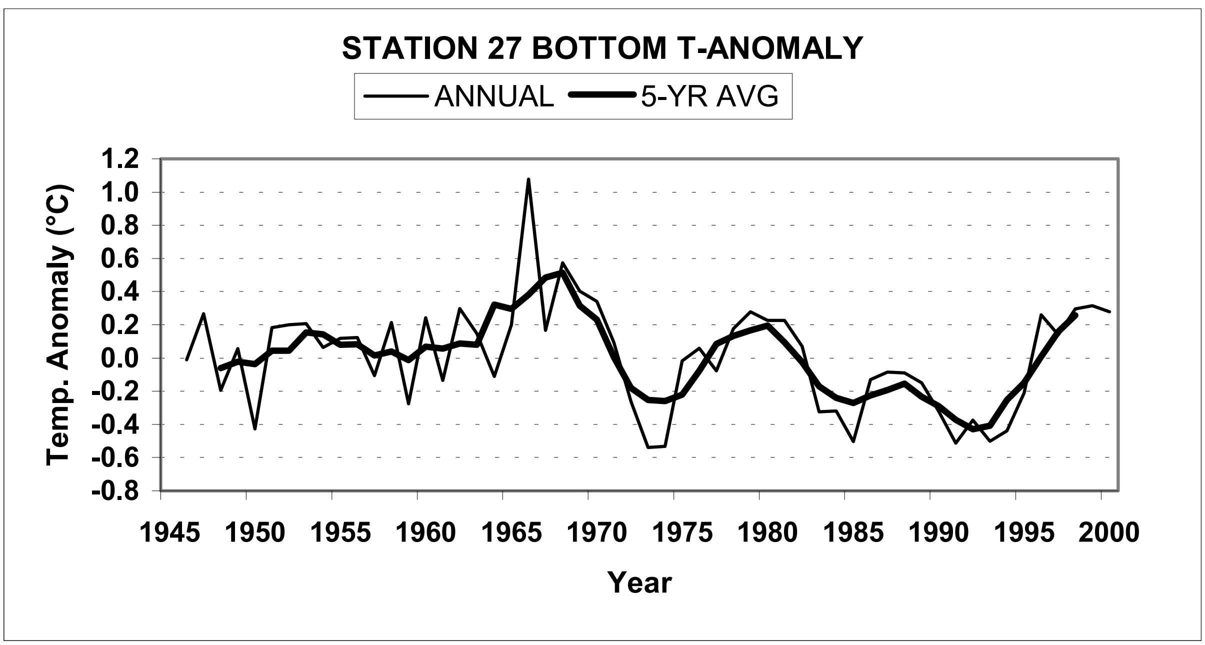
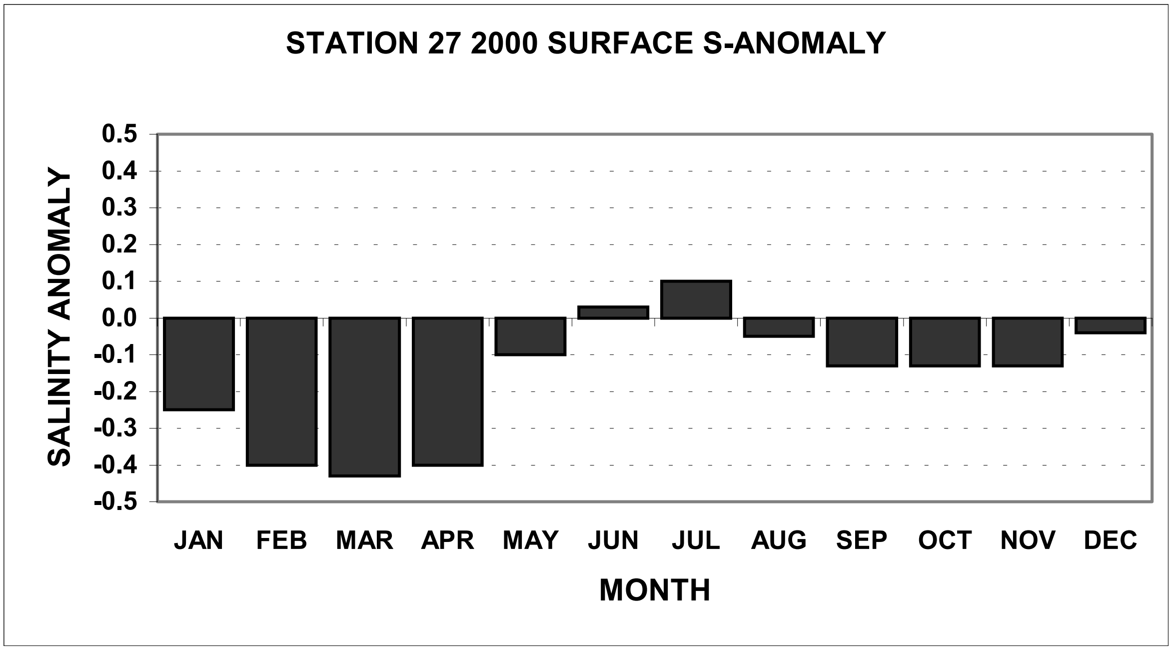


Fig. 4. Monthly bottom temperature anomalies at Station 27 during 2000 (top) and the annual bottom temperature anomalies and their 5-year running means (bottom).



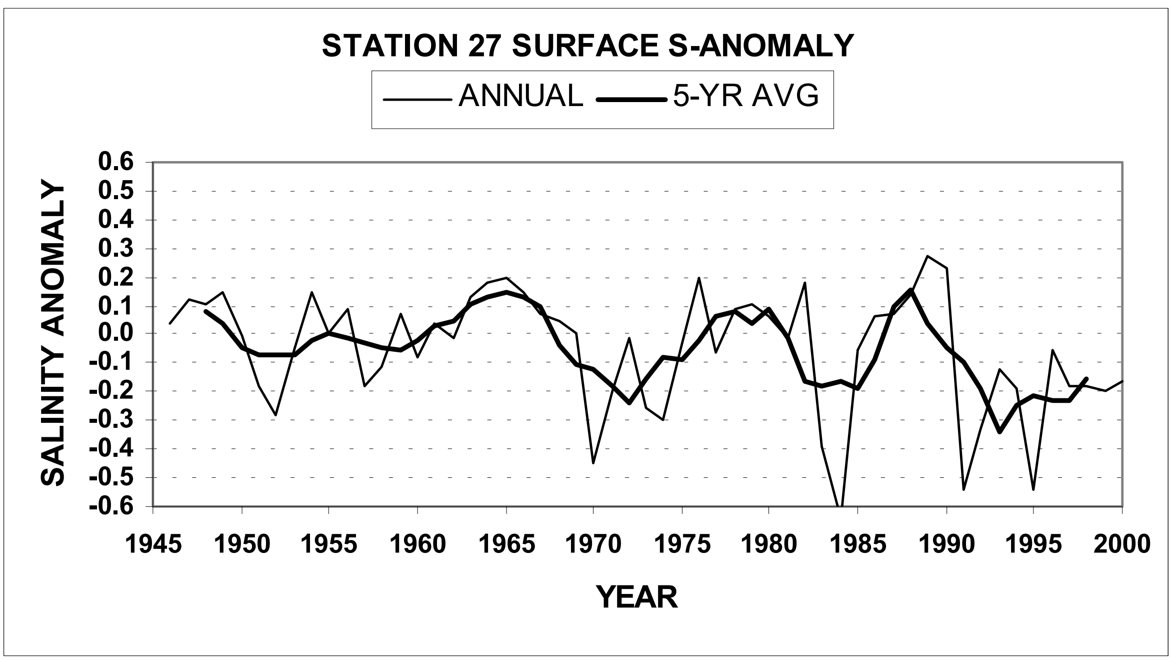
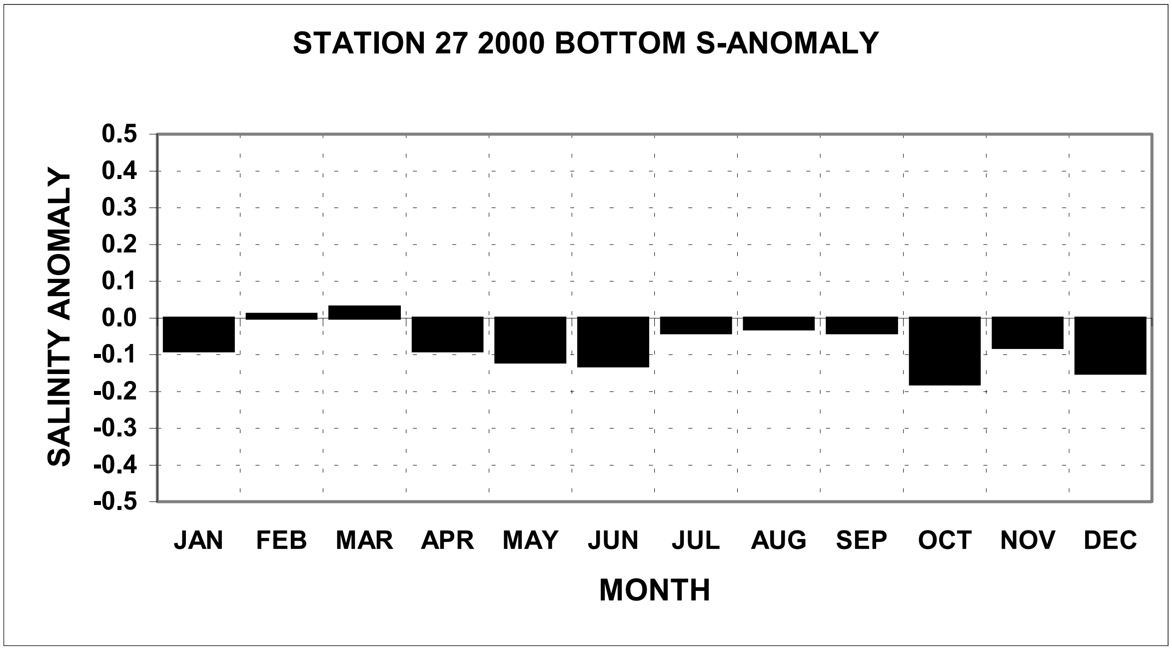


Fig. 5. Monthly surface salinity anomalies at Station 27 during 2000 (top) and the annual surface salinity anomalies and their 5-year running means (bottom).



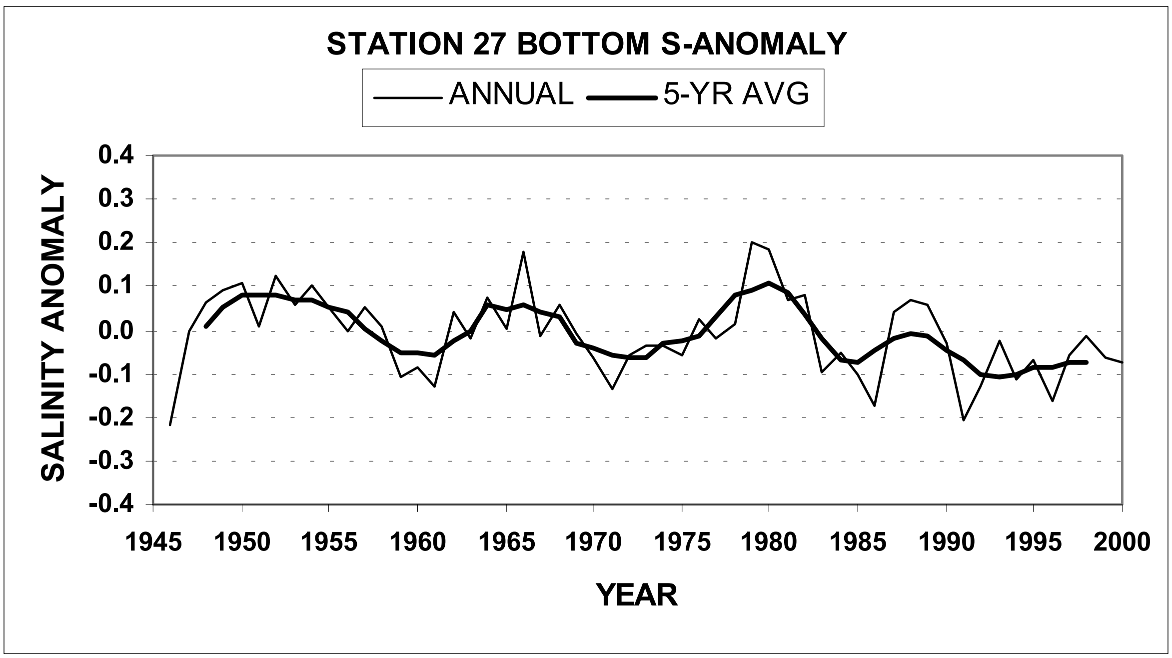
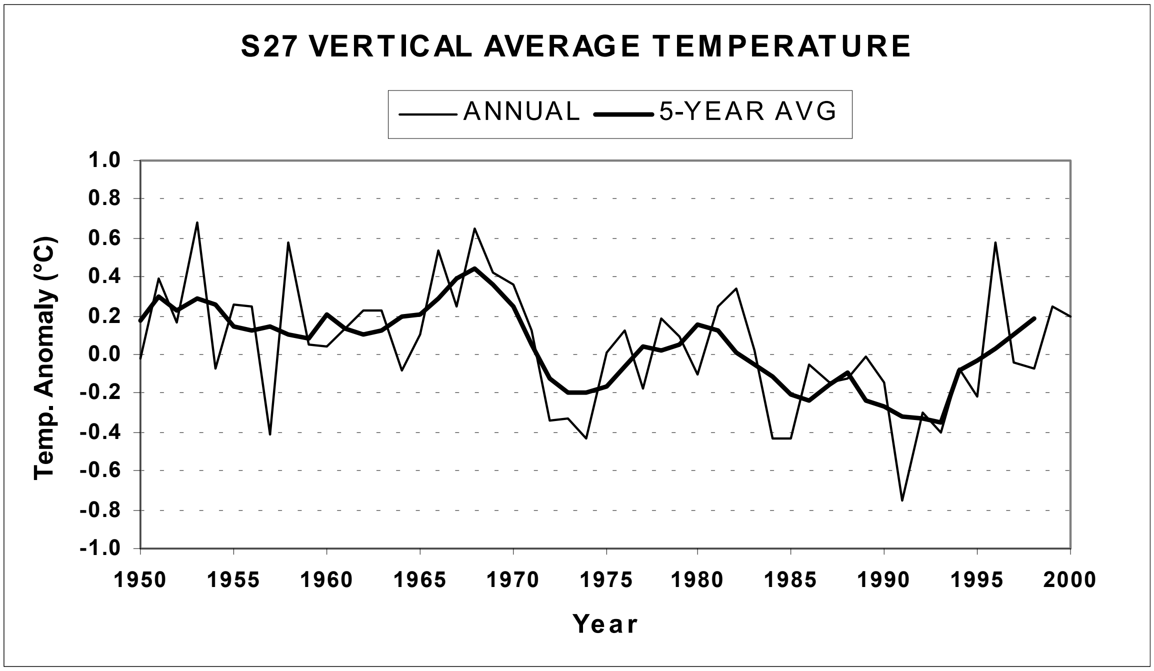


Fig. 6. Monthly bottom salinity anomalies at Station 27 during 2000 (top) and the annual bottom salinity anomalies and their 5-year running means (bottom).



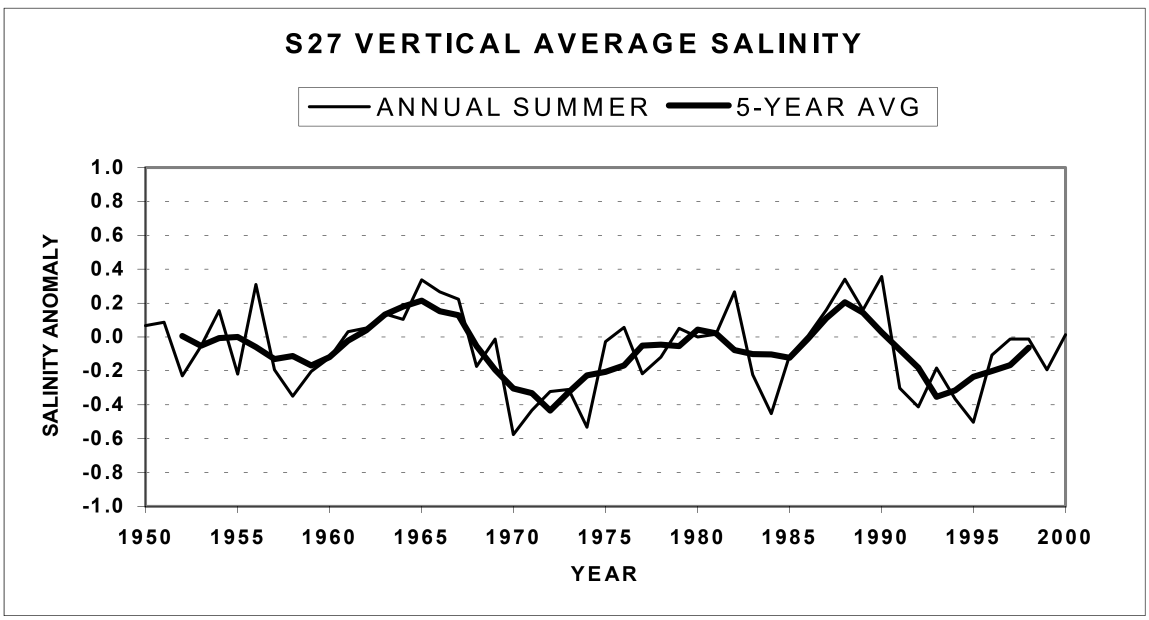
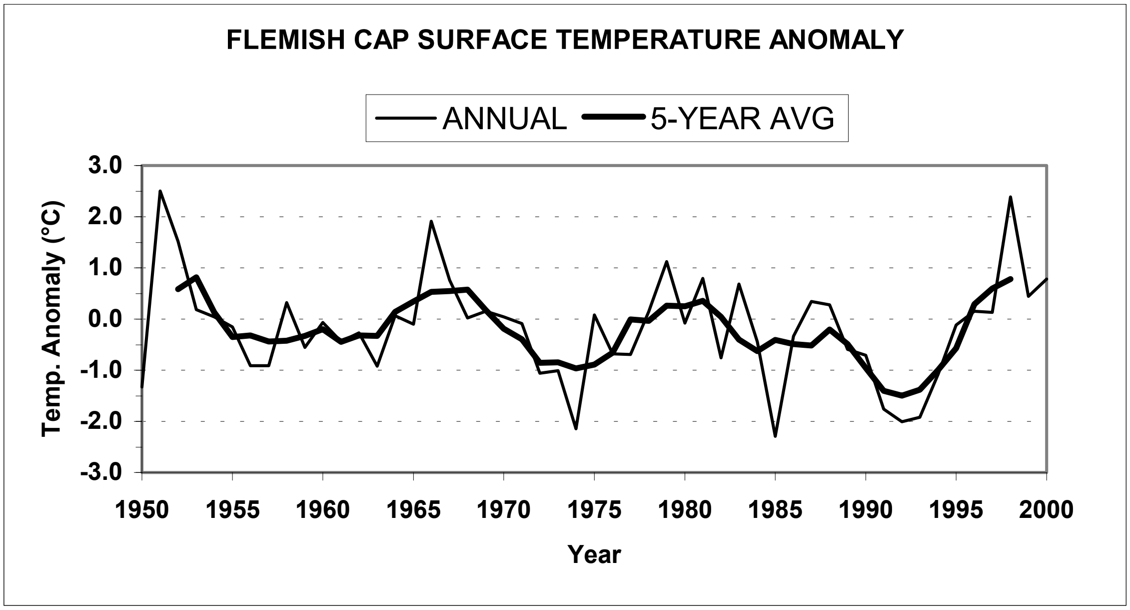


Fig. 7. The annual vertically averaged (0-176 m) Station 27 temperature anomalies and the vertically averaged (0-50 m) summer (July-Sept.) Station 27 salinity anomalies. The heavy lines are the 5-year running means.



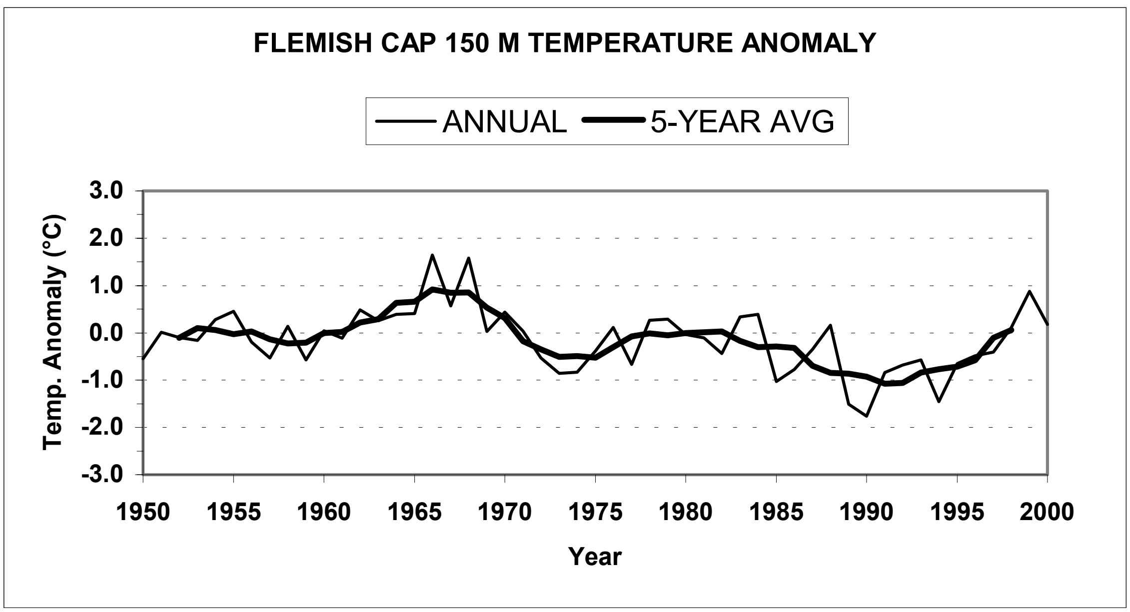
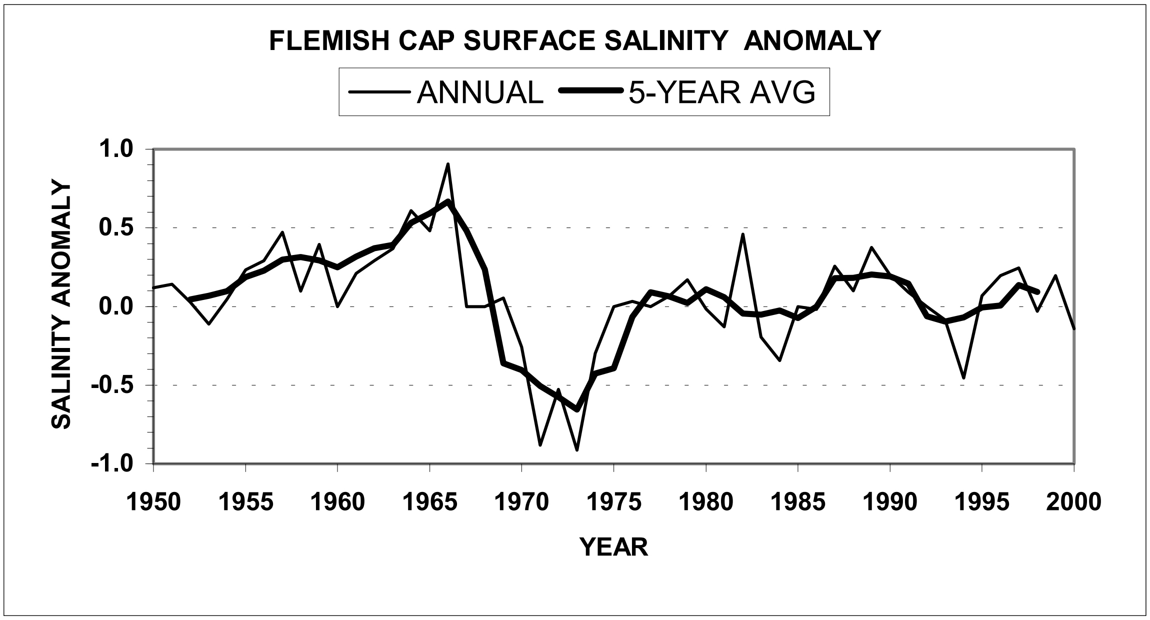


Fig. 8. The annual near surface and 150 m temperature anomalies on the Flemish Cap in NAFO Division 3M. The heavy lines are the 5-year running means.



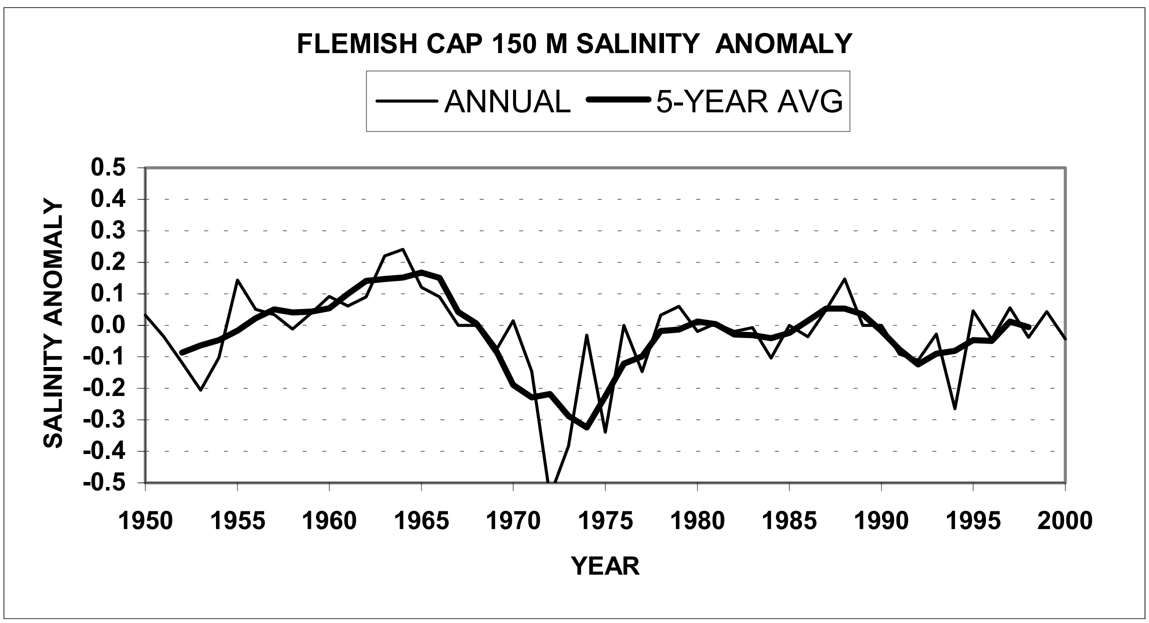
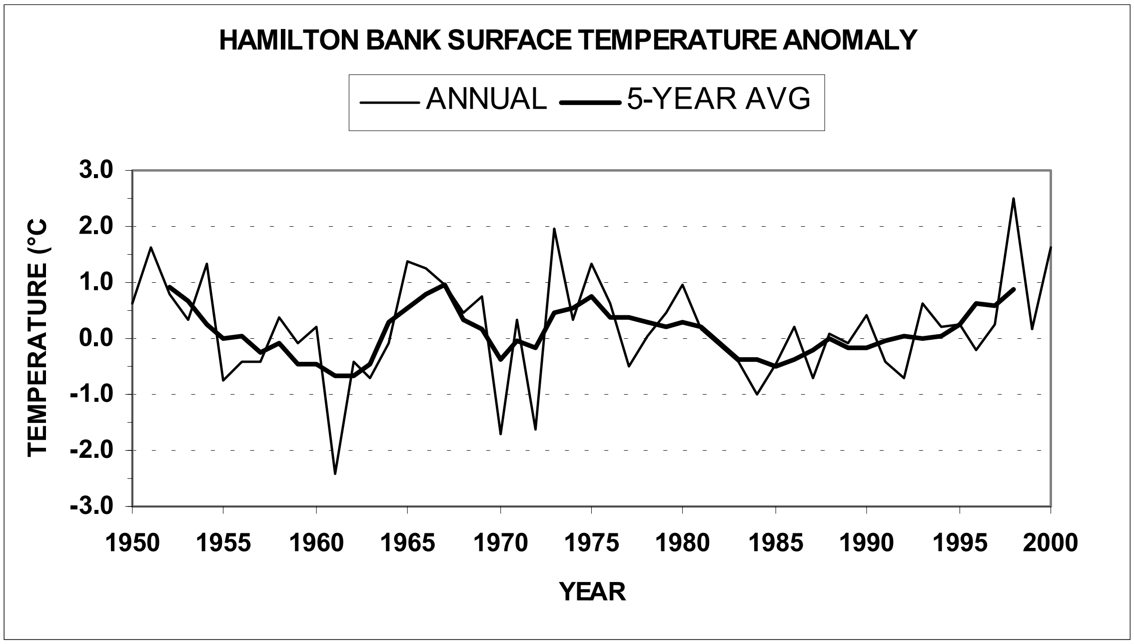


Fig. 9. The annual near surface and 150 m salinity anomalies on the Flemish Cap in NAFO Division 3M. The heavy lines are the 5-year running means.



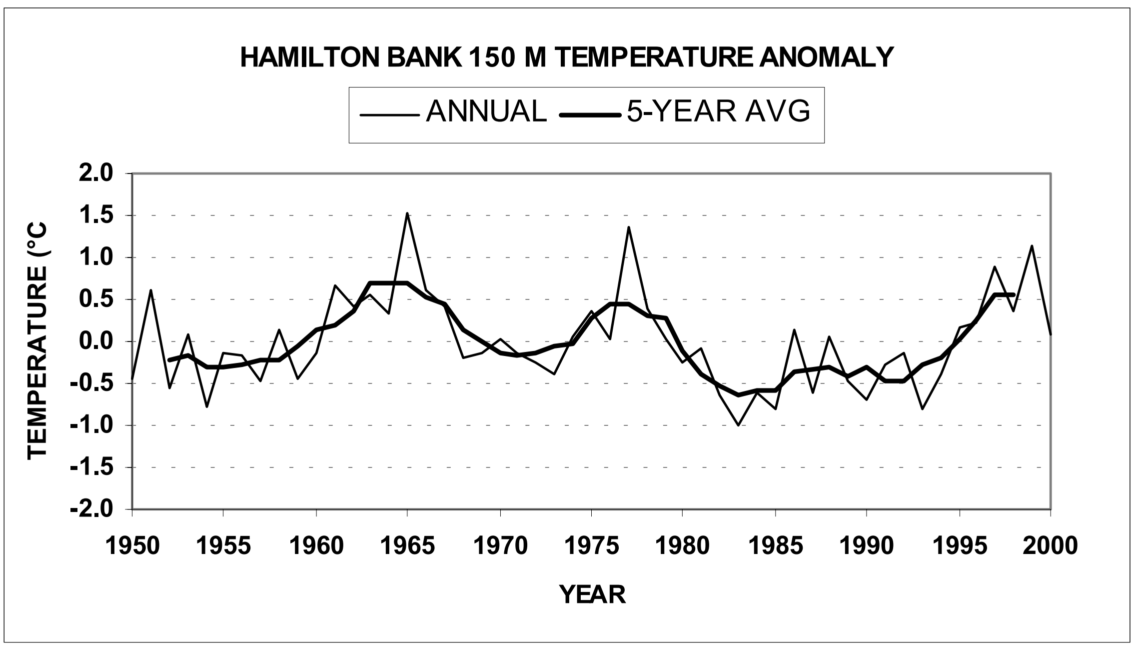
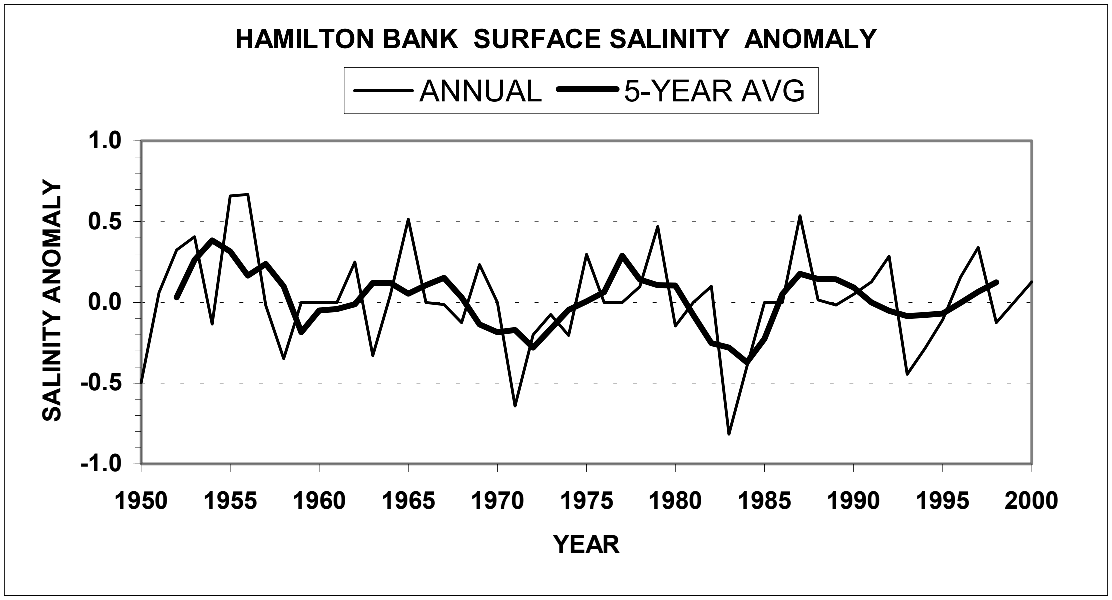


Fig. 10. The annual near surface and 150 m temperature anomalies on Hamilton Bank in NAFO Division 2J. The heavy lines are the 5-year running means.



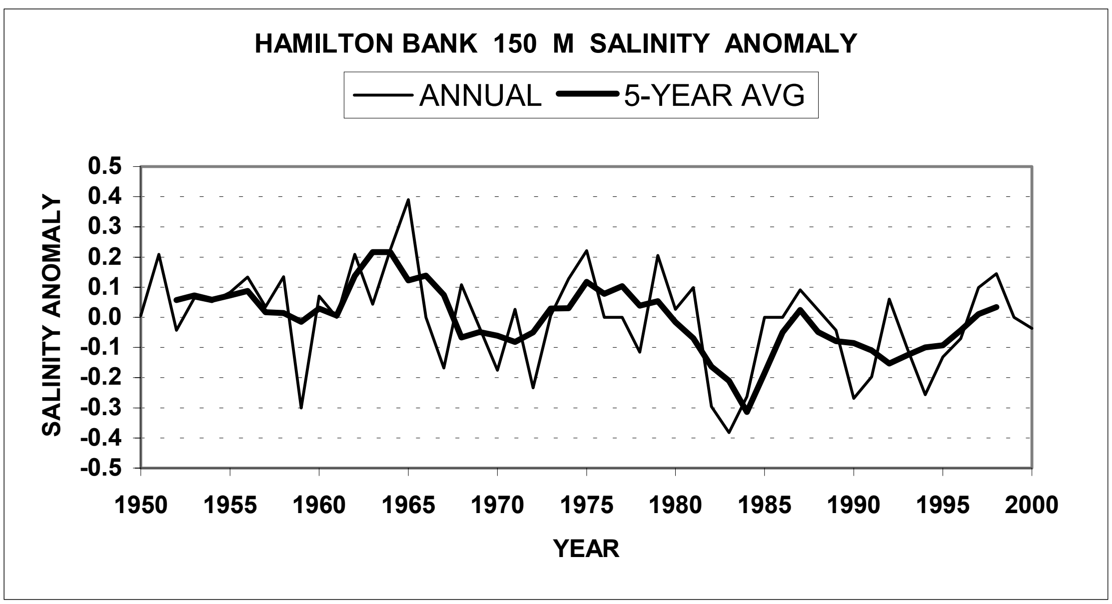


Fig. 11. The annual near surface and 150 m salinity anomalies on Hamilton Bank in NAFO Division 2J. The heavy lines are the 5-year running means.

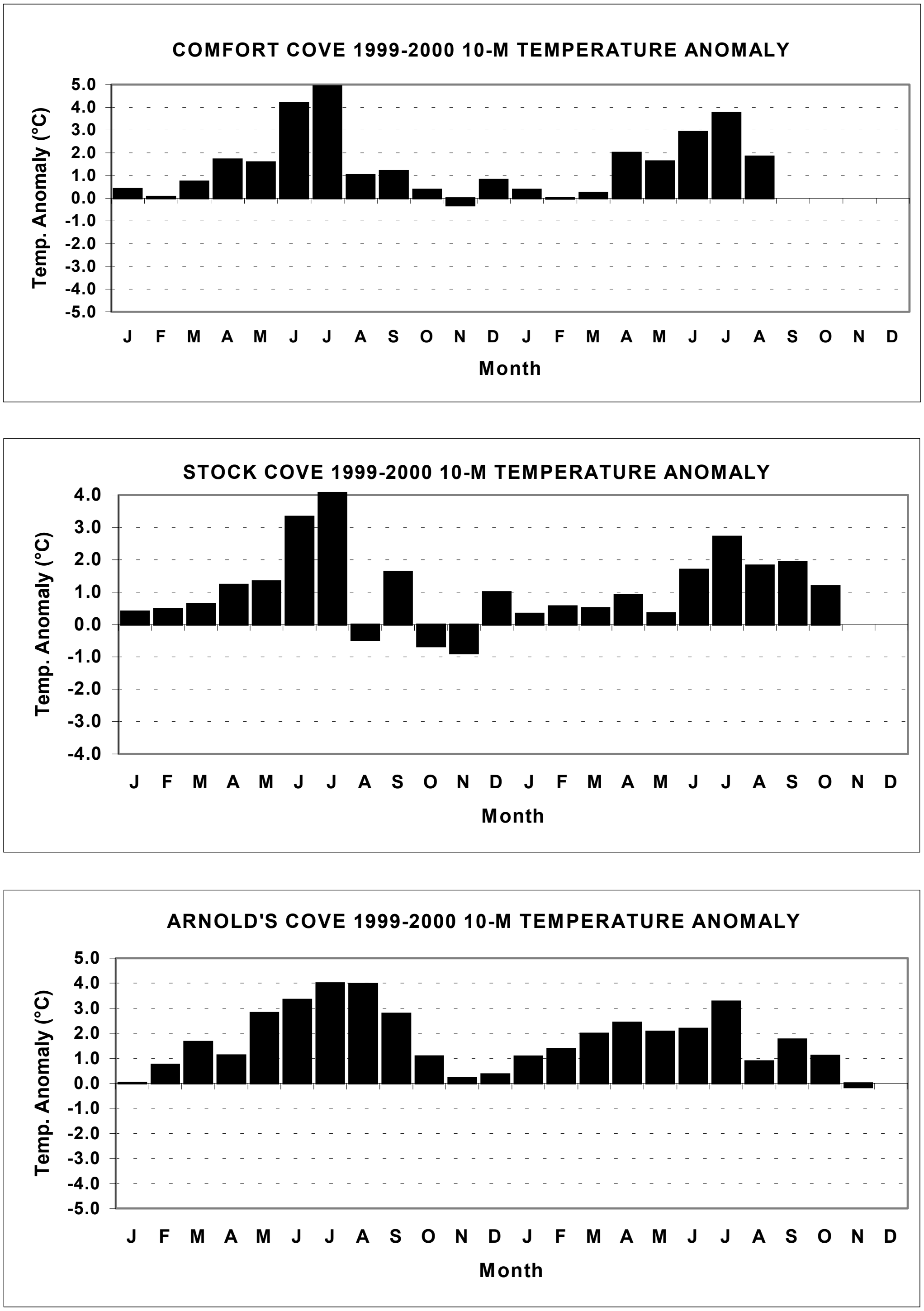


Fig. 12. Monthly near-surface (10-m) temperature anomalies during 1999 and 2000 for Comfort Cove Notre Dame Bay, Stock Cove Bonavista Bay and for Arnold's Cove Placentia Bay (Fig. 1).

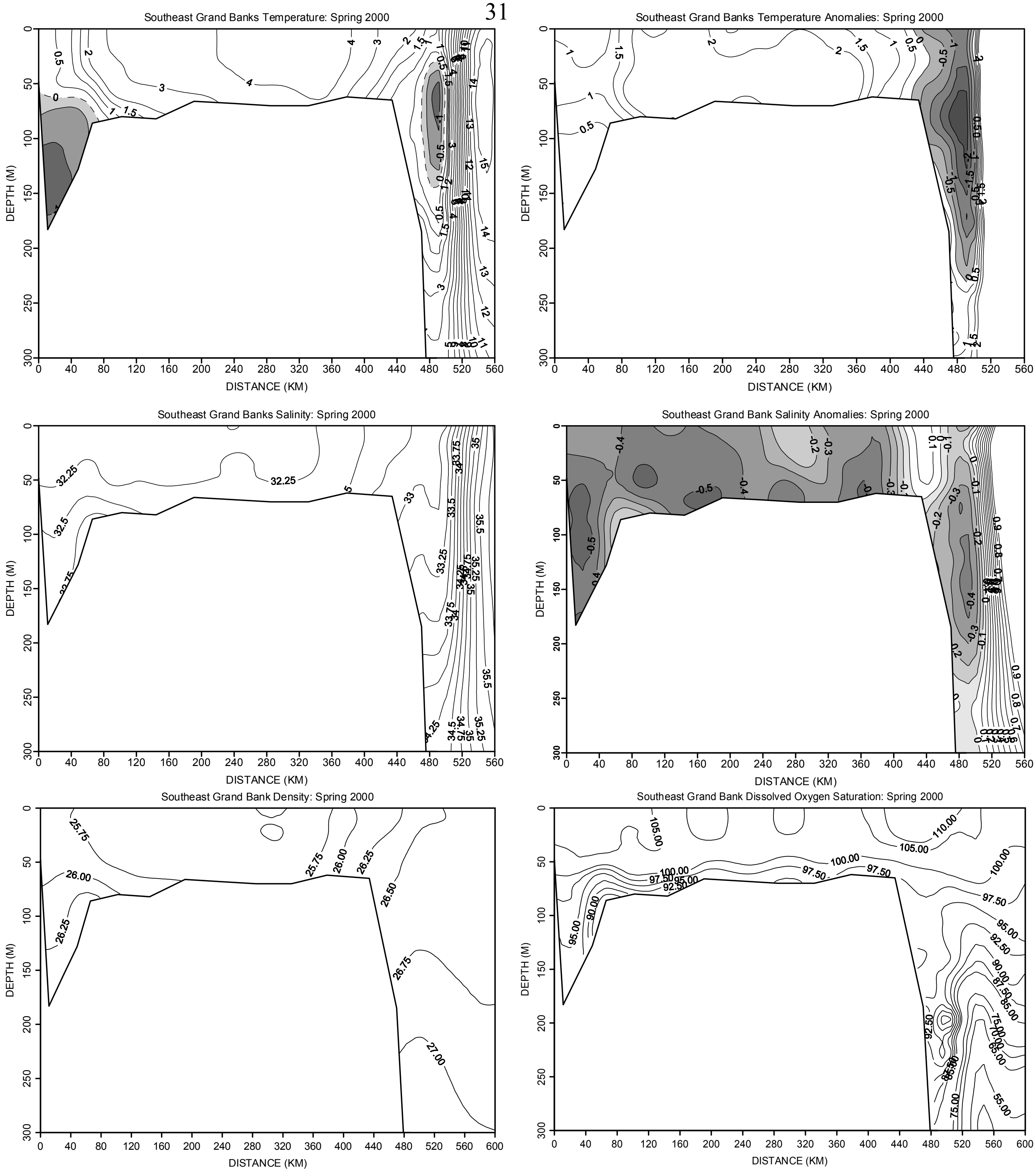


Fig. 13. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the South East Grand Bank transect during the spring of 2000.

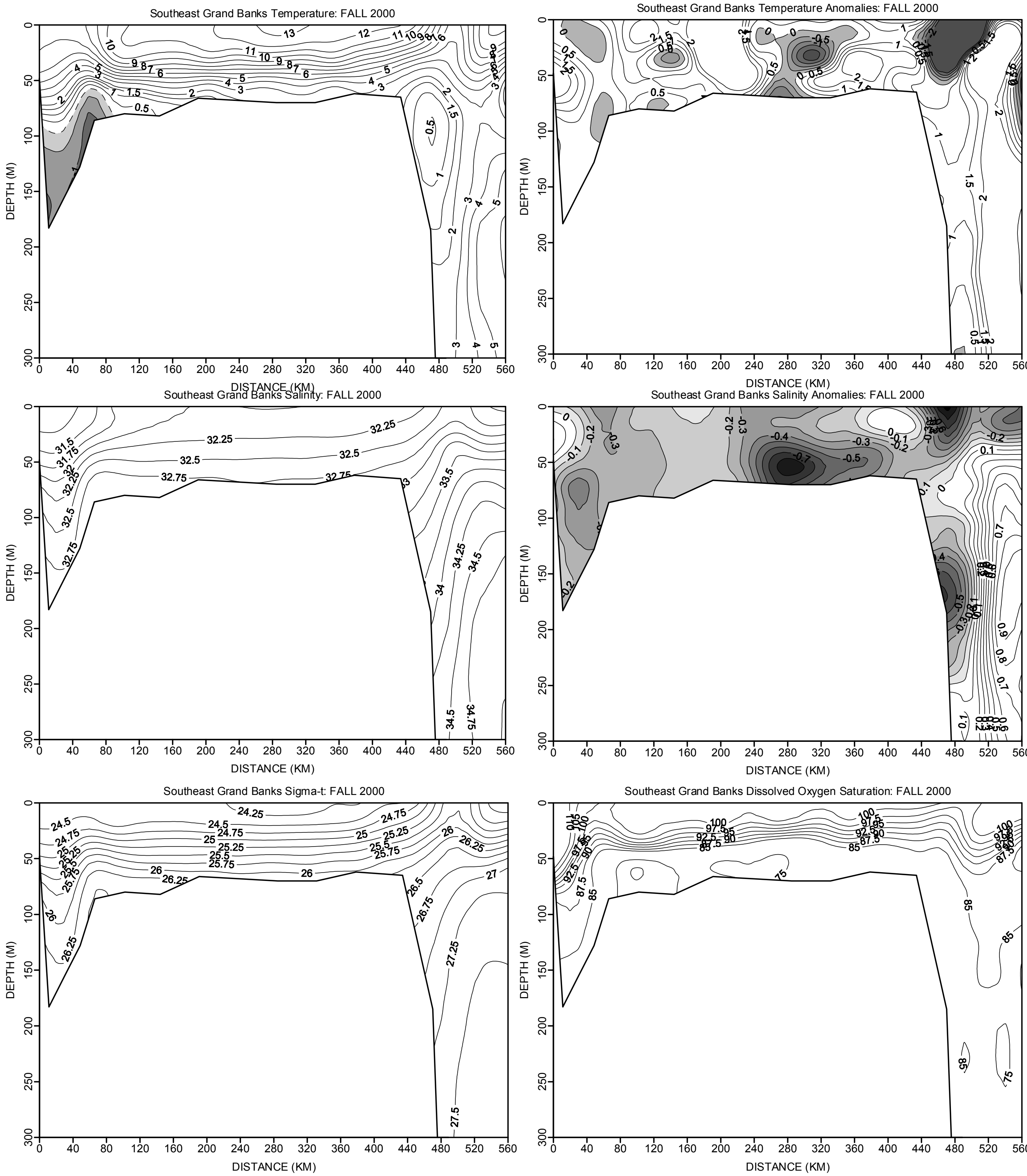


Fig. 14. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the South East Grand Bank transect during the fall of 2000.

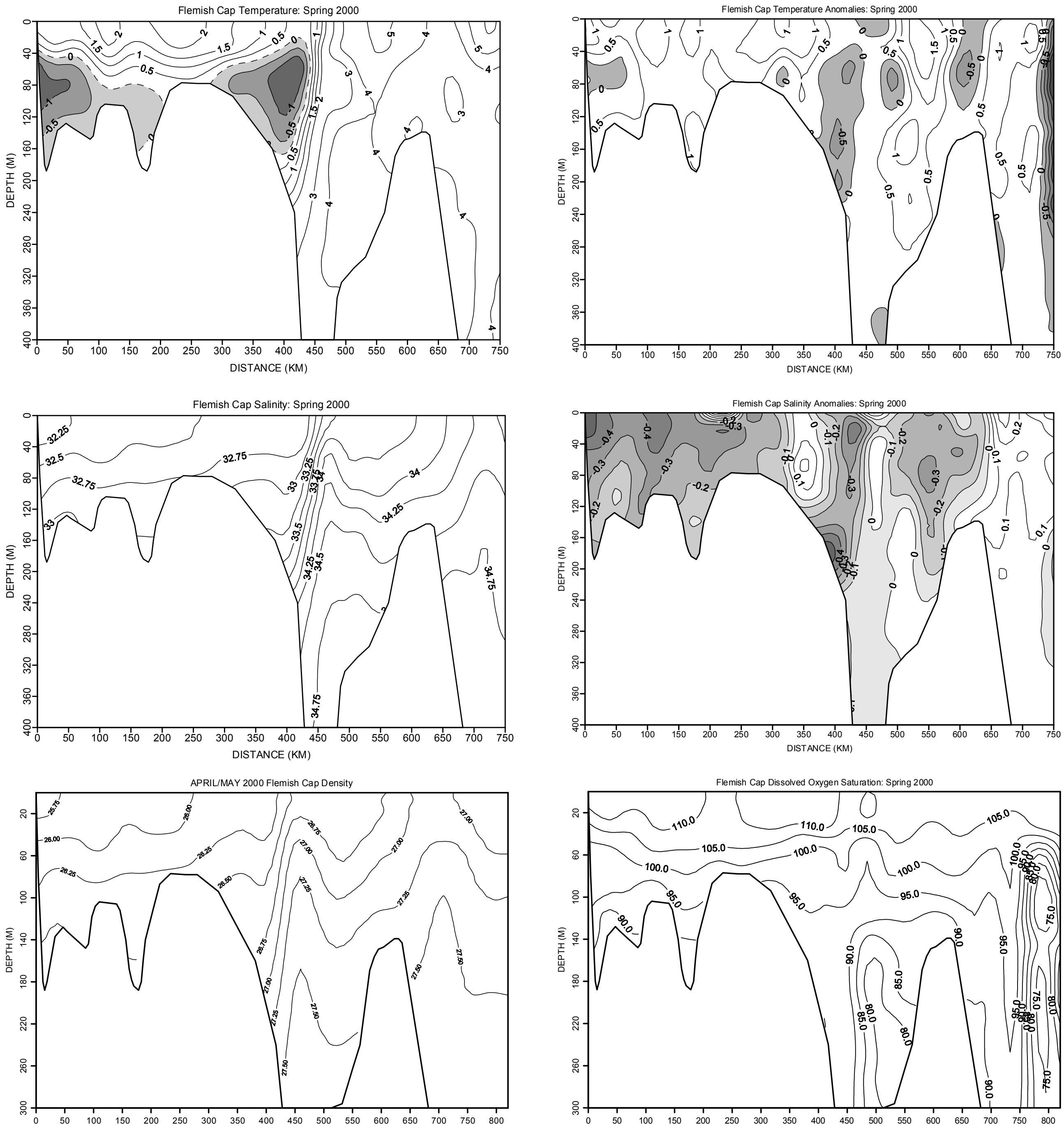


Fig. 15. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Flemish Cap transect during the spring of 2000.

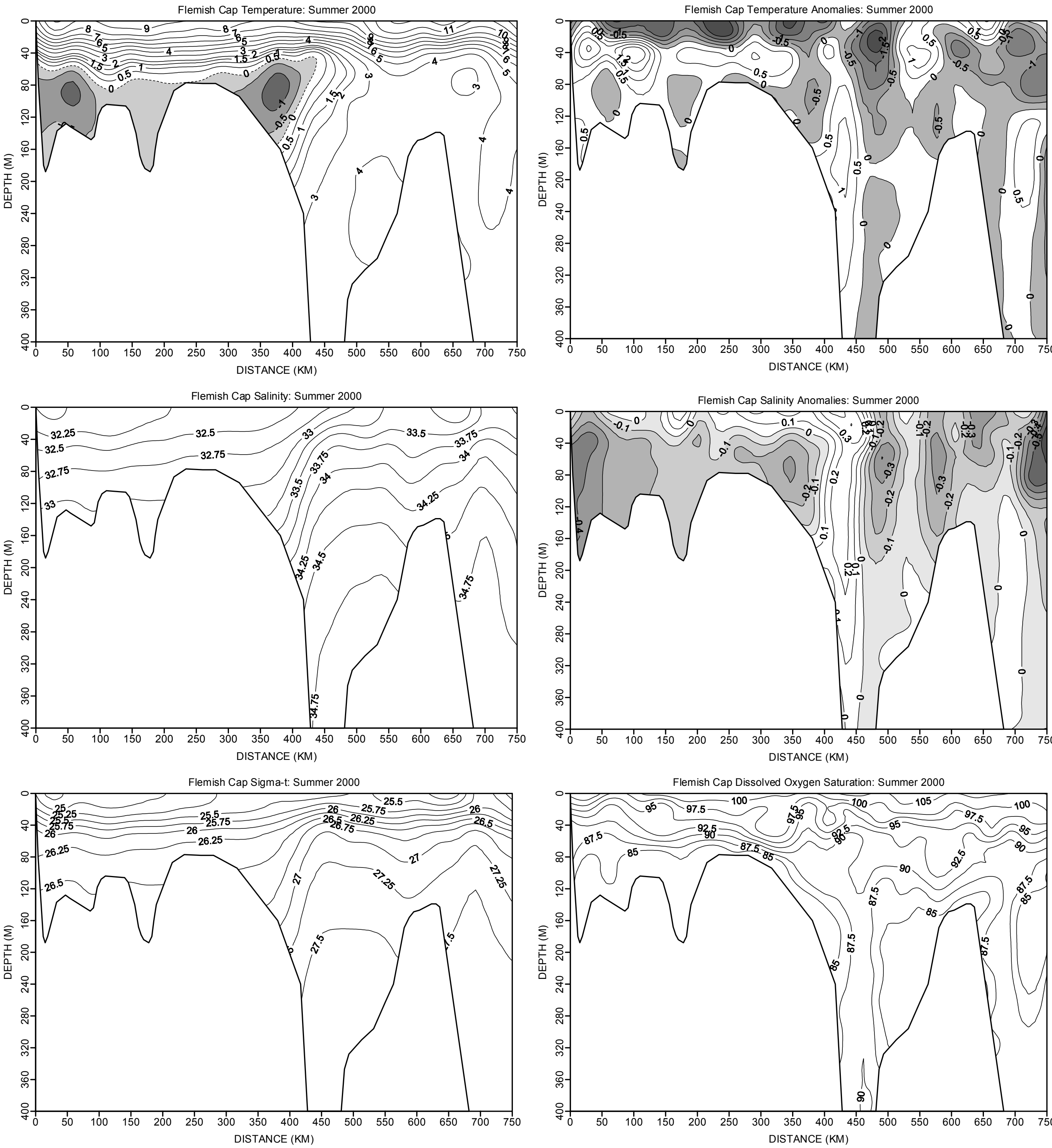


Fig. 16. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Flemish Cap transect during the summer of 2000.

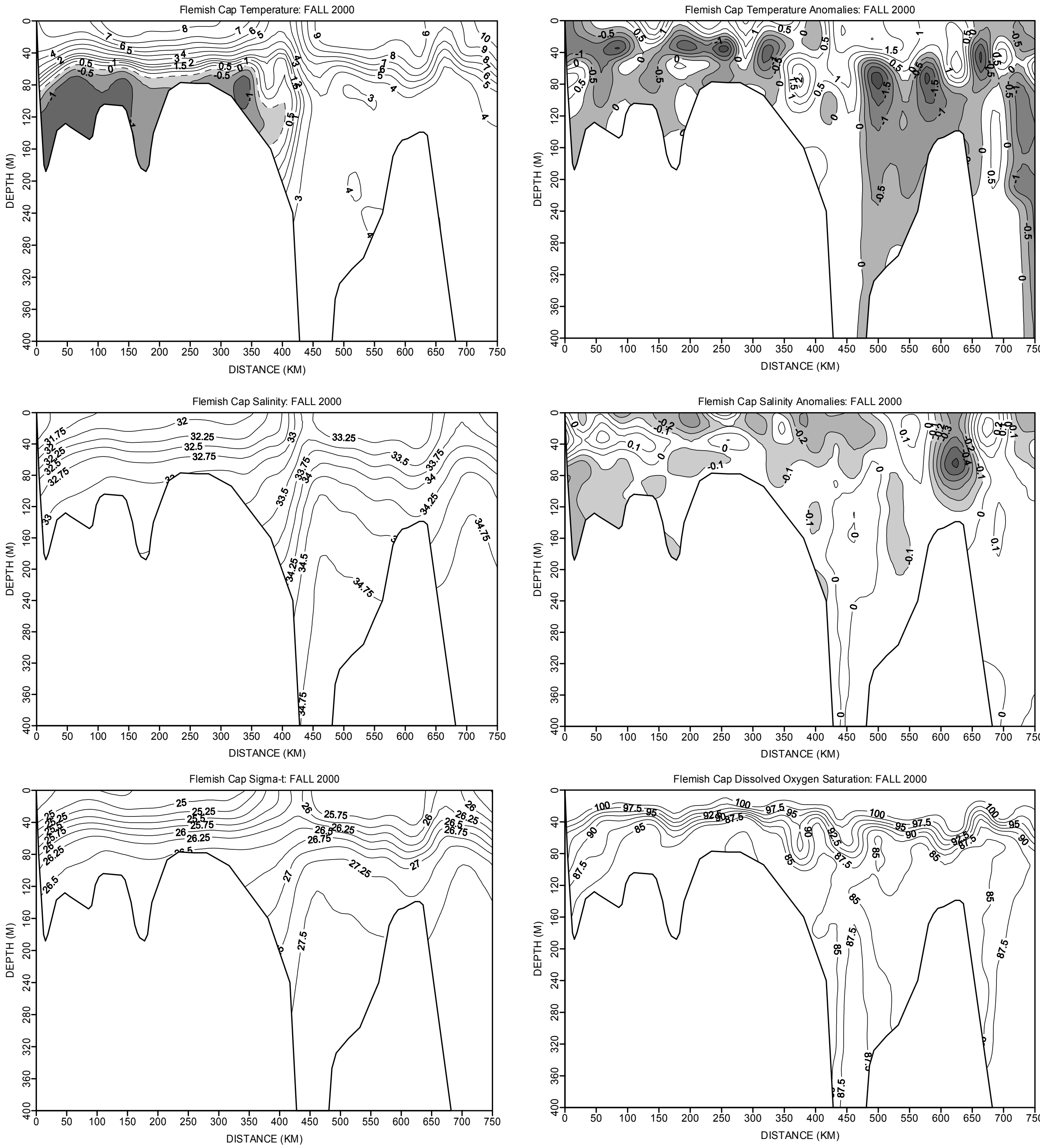


Fig. 17. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Flemish Cap transect during the fall of 2000.

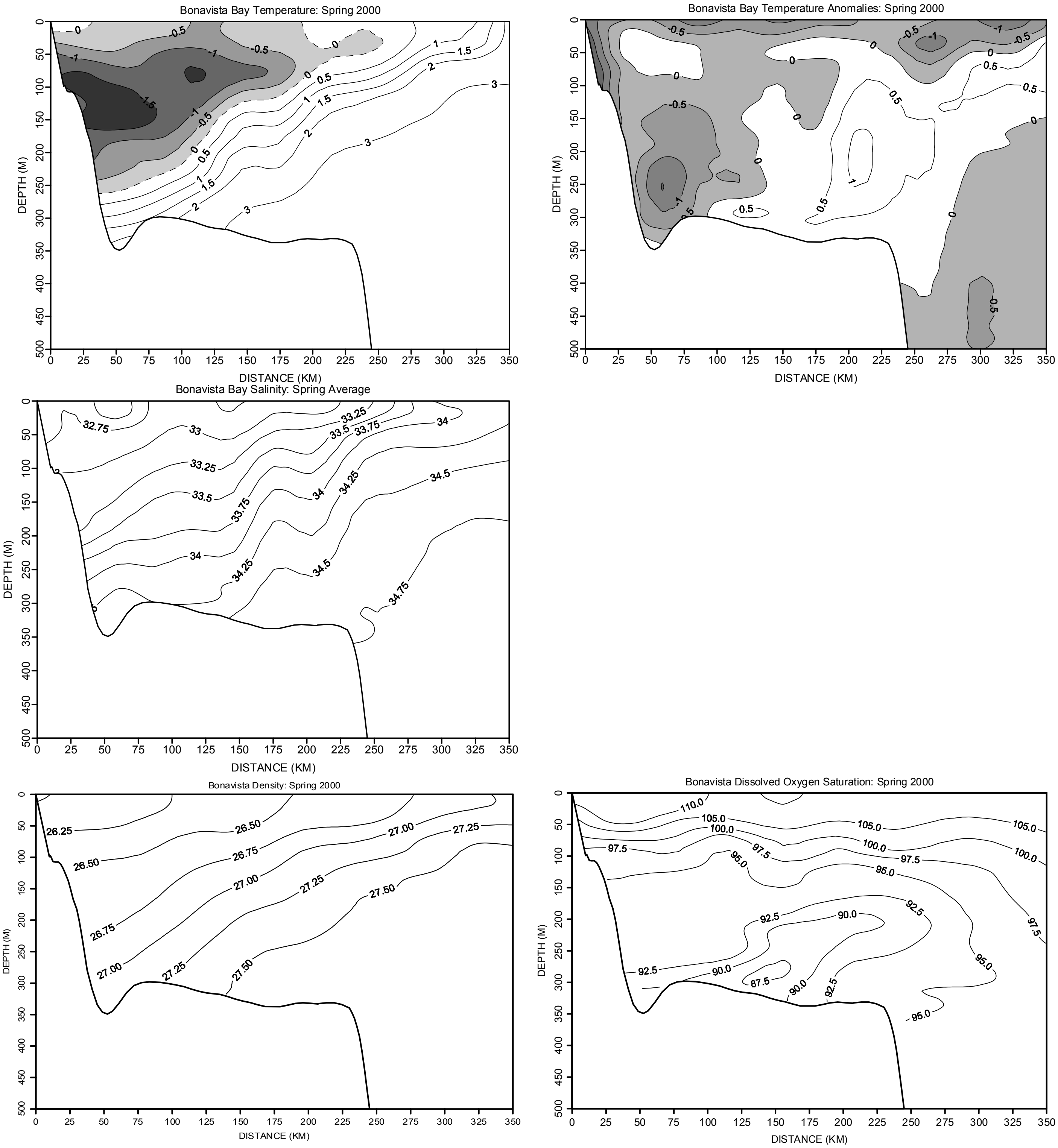


Fig. 18. Contours of temperature and temperature anomalies, salinity, sigma-t and dissolved oxygen saturation along the standard Bonavista transect during the spring of 2000. There were insufficient salinity data during this time period to produce a reliable average.

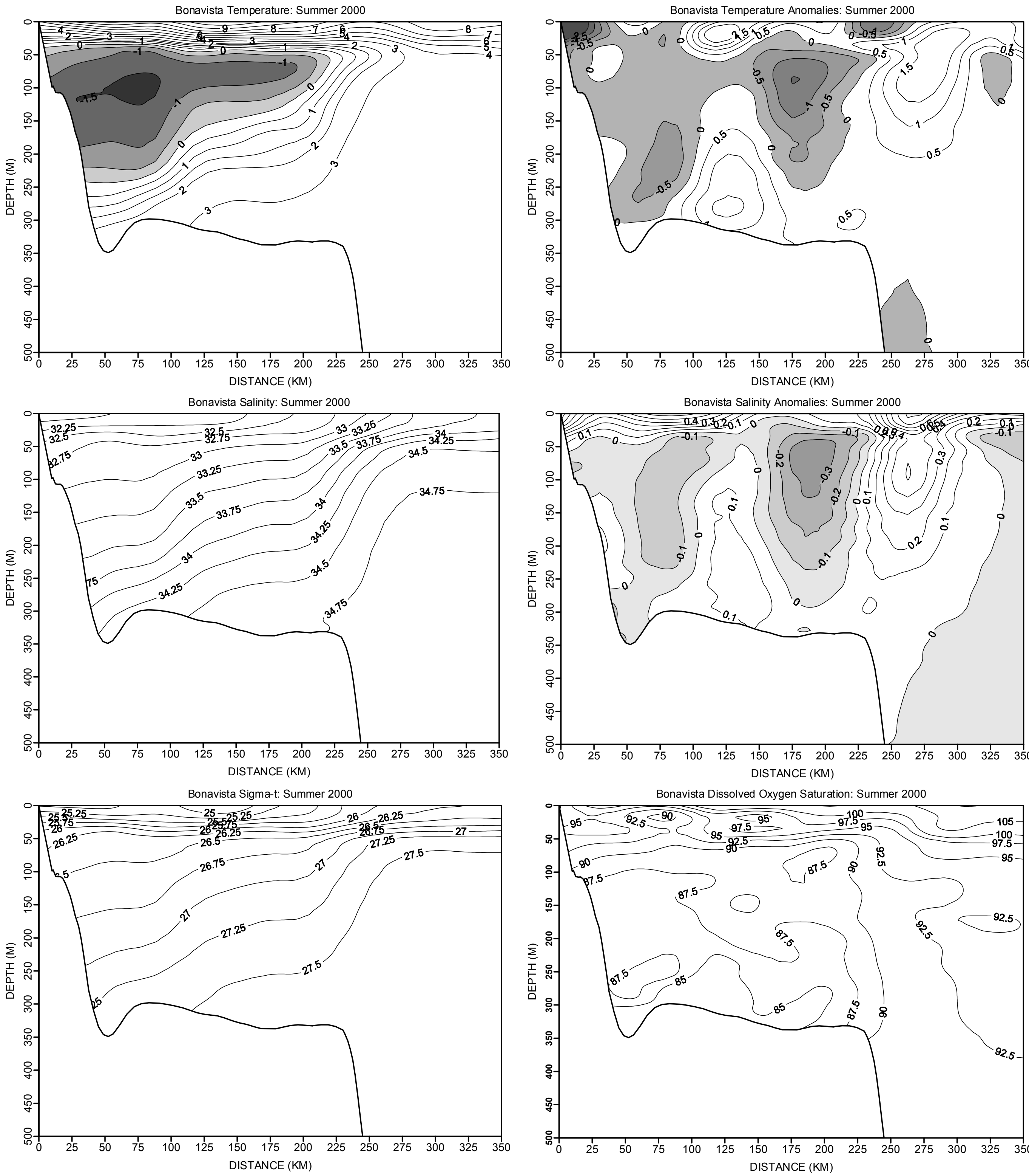


Fig. 19. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Bonavista transect during the summer of 2000.

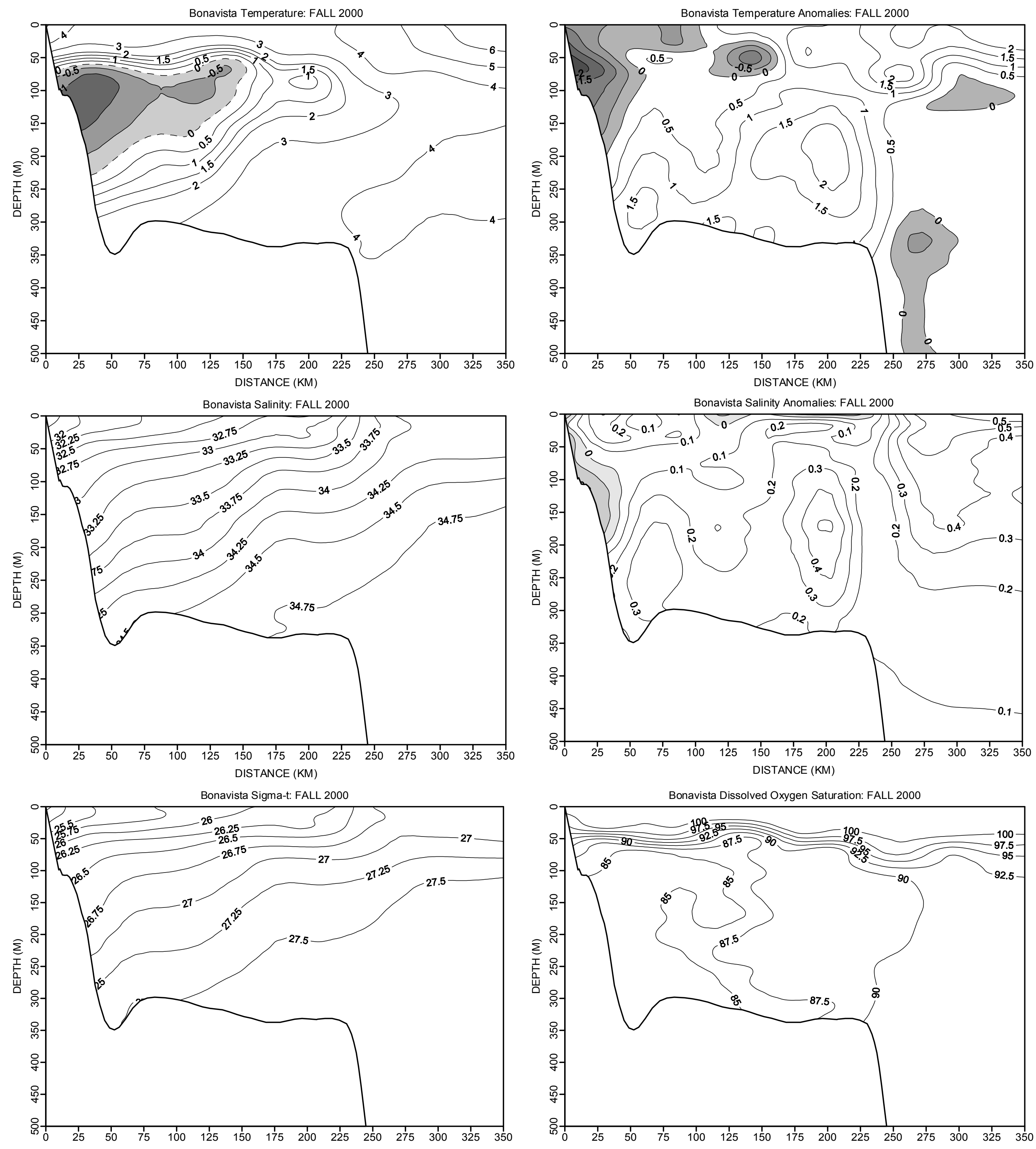


Fig. 20. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Bonavista transect during the fall of 2000.

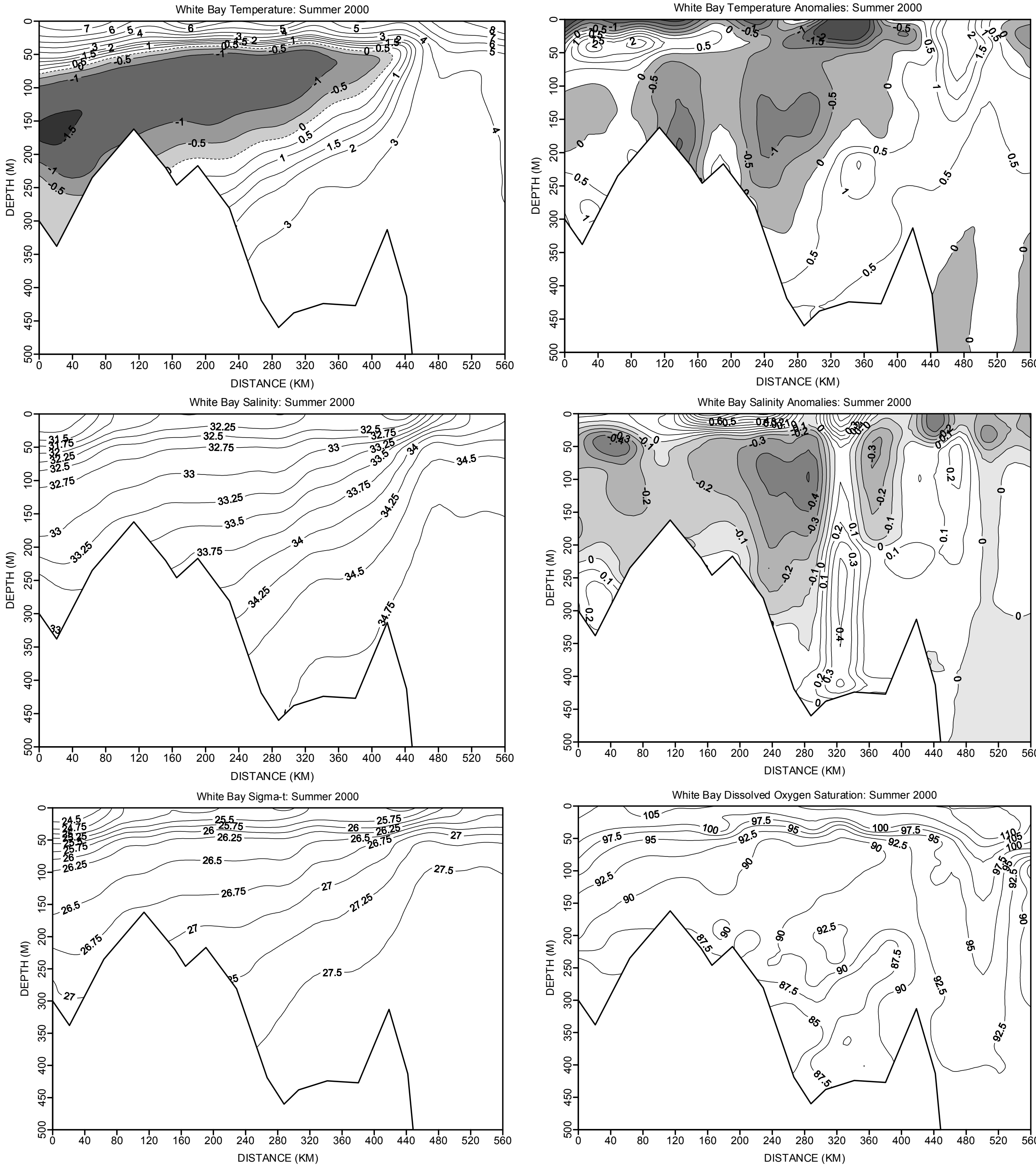


Fig. 21. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard White Bay transect during the summer of 2000.

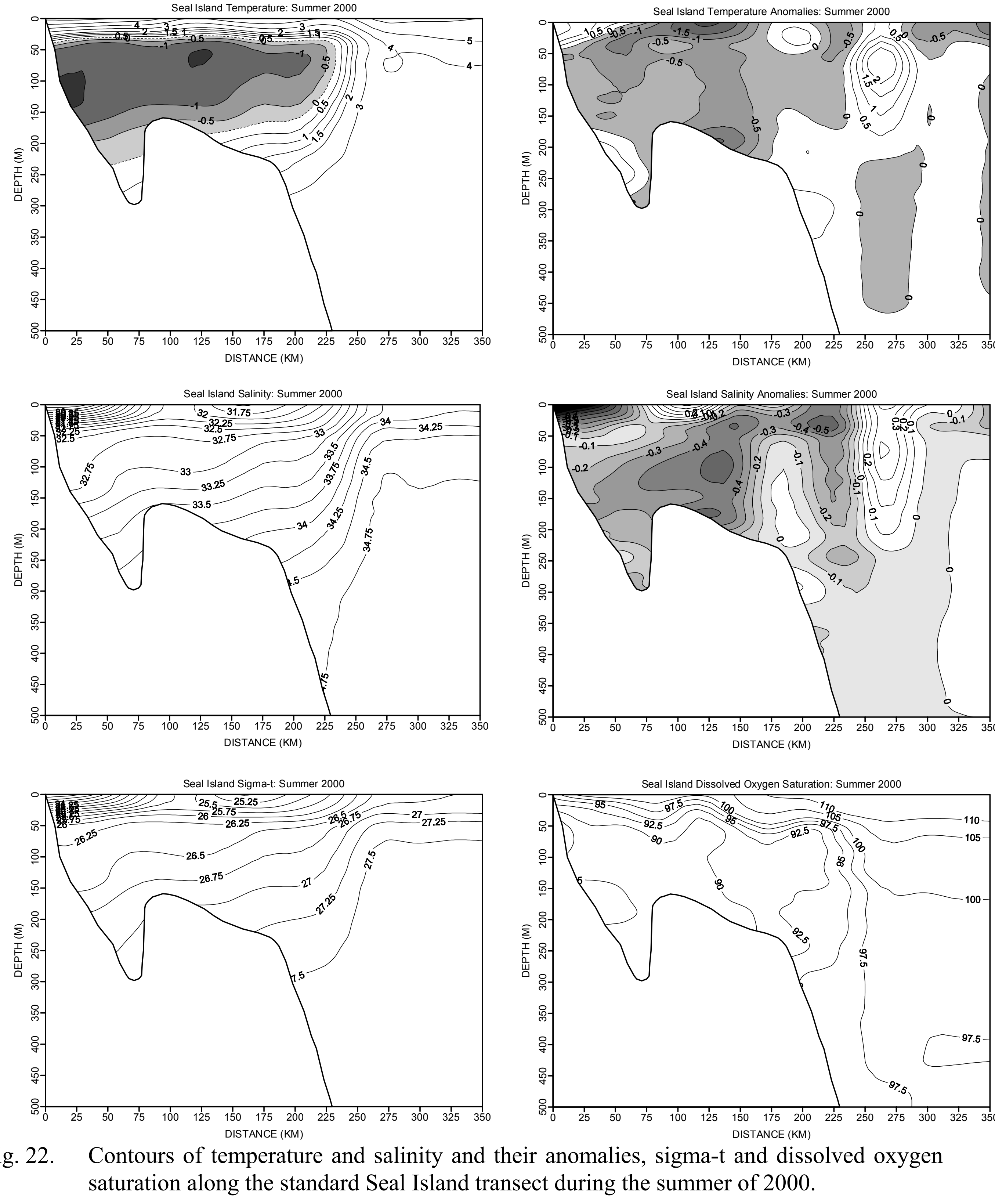


Fig. 22. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the standard Seal Island transect during the summer of 2000.

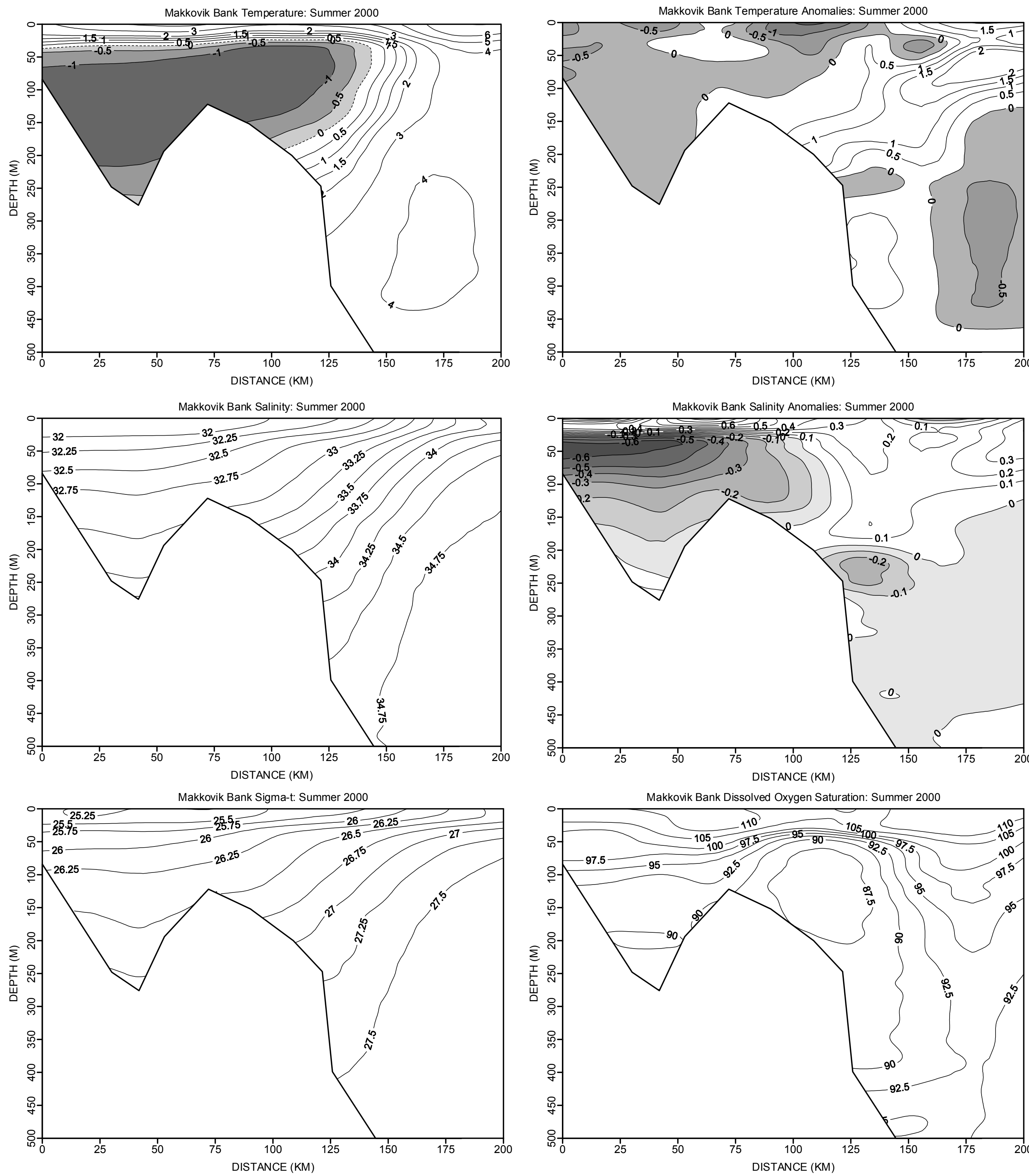


Fig. 23. Contours of temperature and salinity and their anomalies, sigma-t and dissolved oxygen saturation along the Makkovik Bank transect during the summer of 2000.

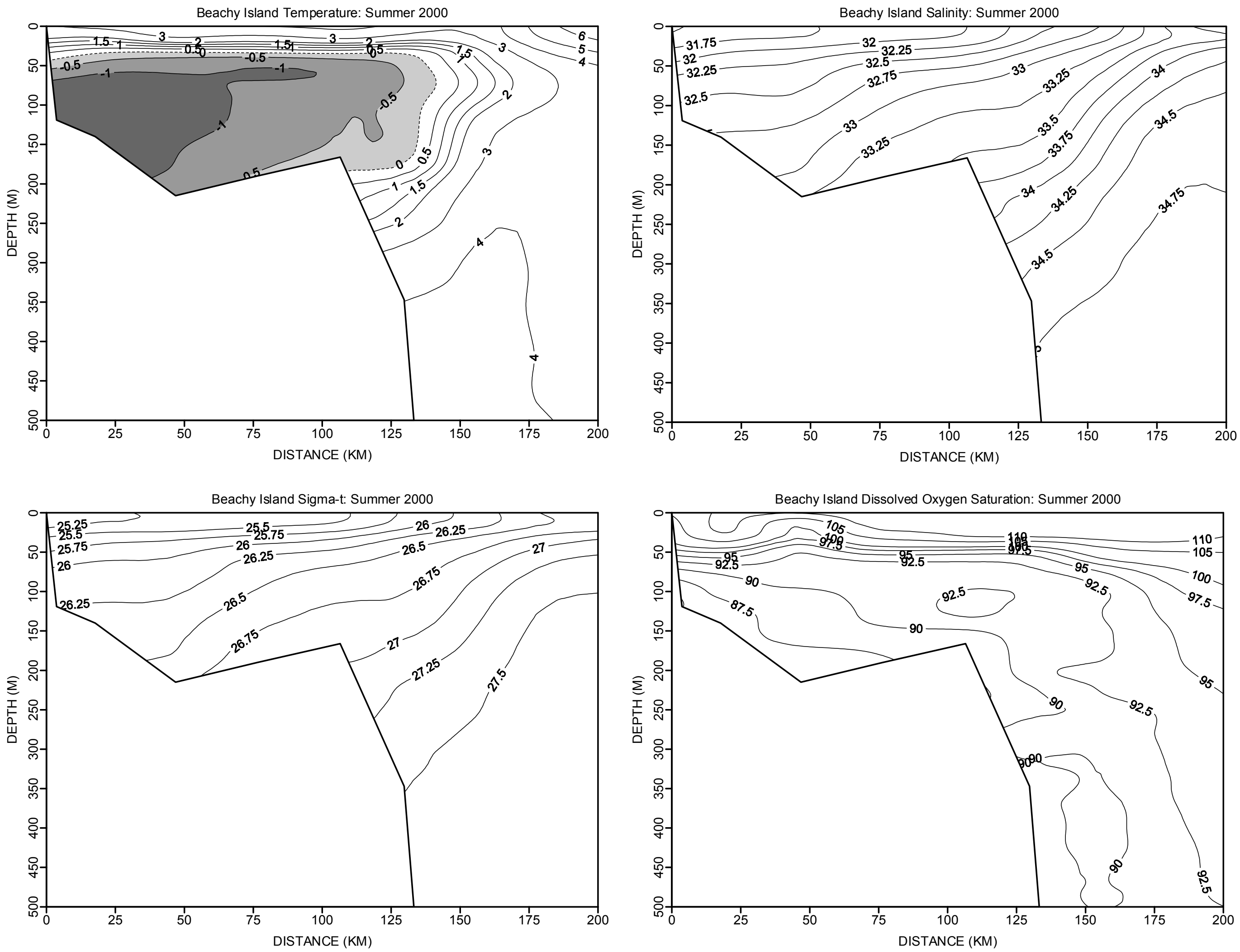


Fig. 24. Contours of temperature, salinity, sigma-t and dissolved oxygen saturation along the Standard Beachy Island transect during the summer of 2000.

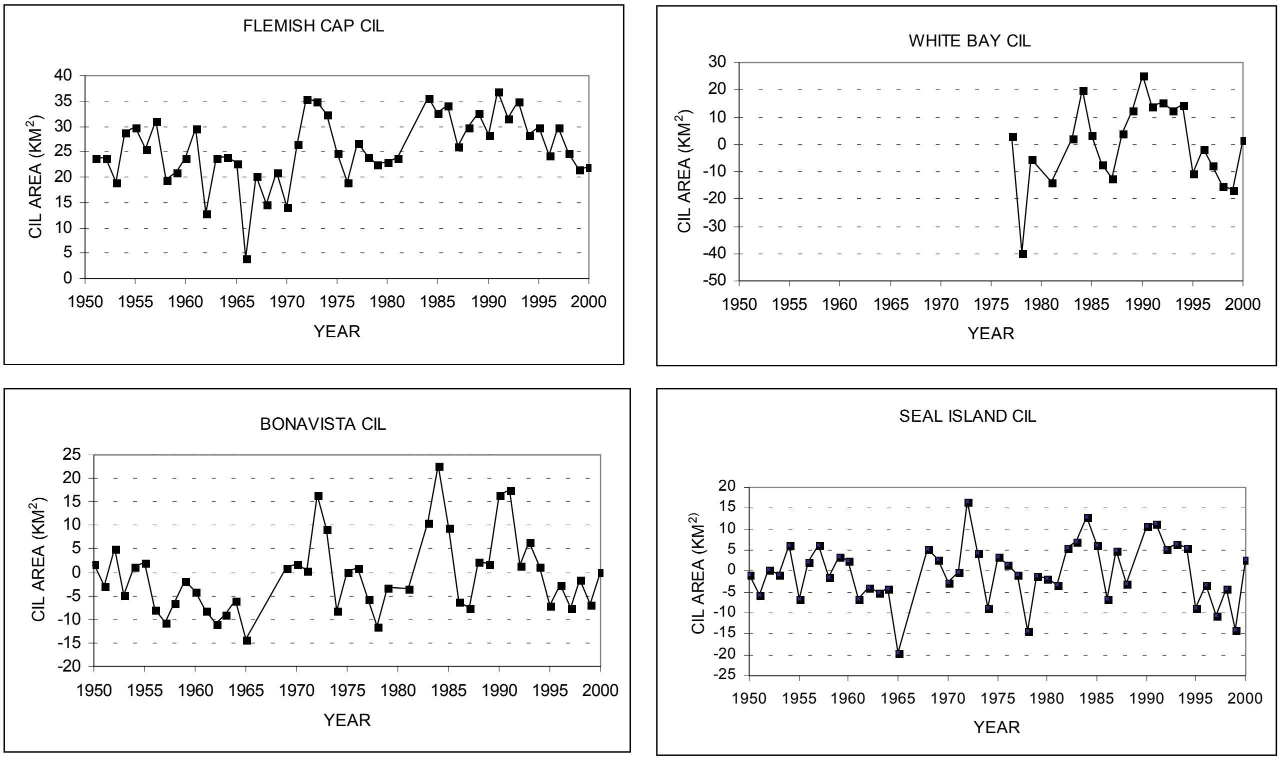


Fig. 25. Time series of CIL cross-sectional area anomalies along the Flemish Cap, Bonavista, White Bay and Seal Island transects during the summer of 2000. The anomalies are references to the 1961-1990 mean.

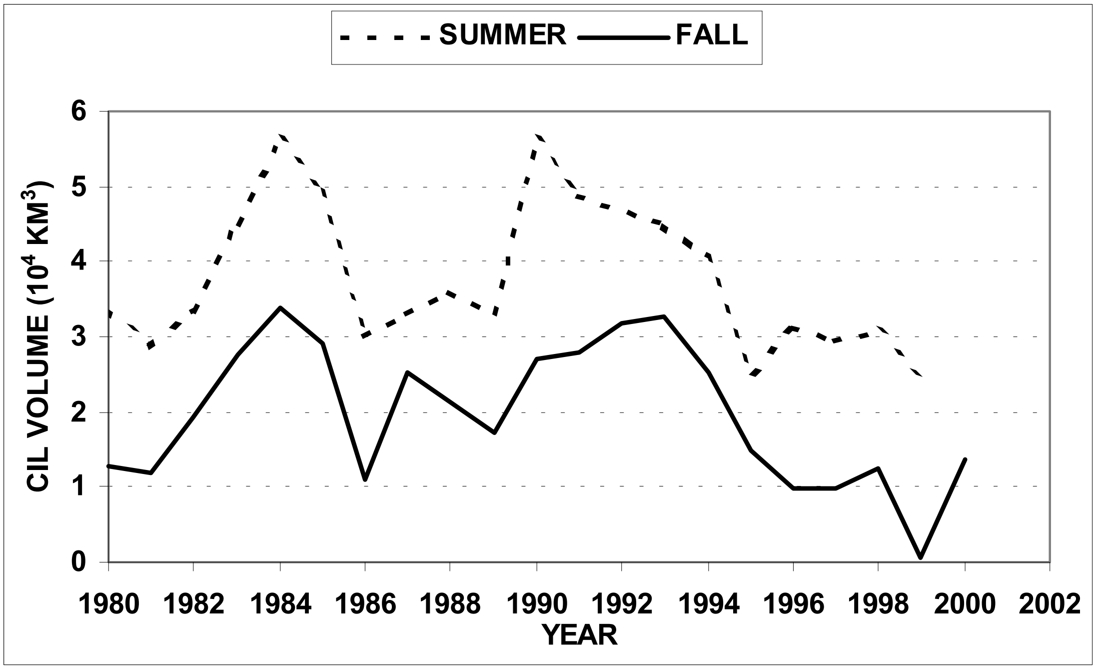


Fig. 26. Time series of summer and fall cold-intermediate-layer (CIL) volumes with temperatures <0°C over the 2J3KL areas. There were insufficient data to calculate the summer 2000 value.

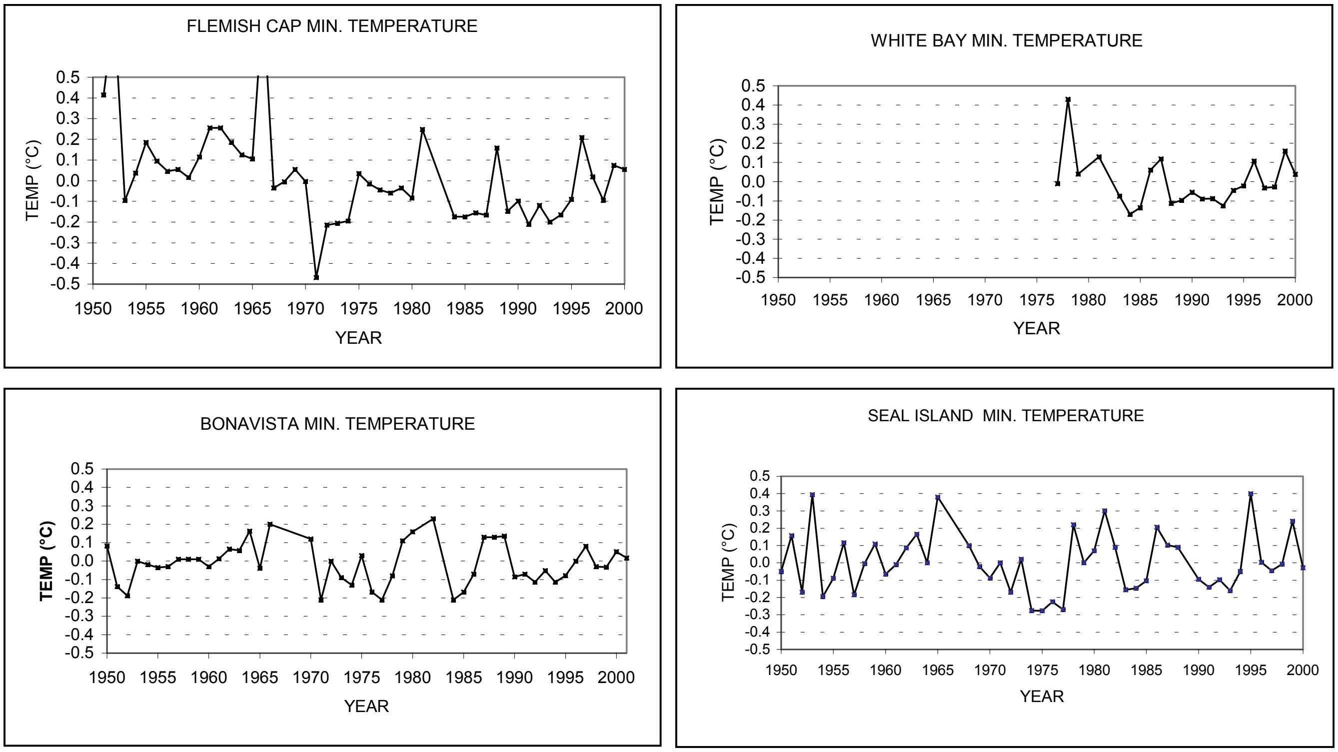


Fig. 27. Time series of minimum CIL temperature anomalies along the Flemish Cap, Bonavista, White Bay and Seal Island transects during the summer of 2000. The anomalies are references to the 1961-1990 mean.

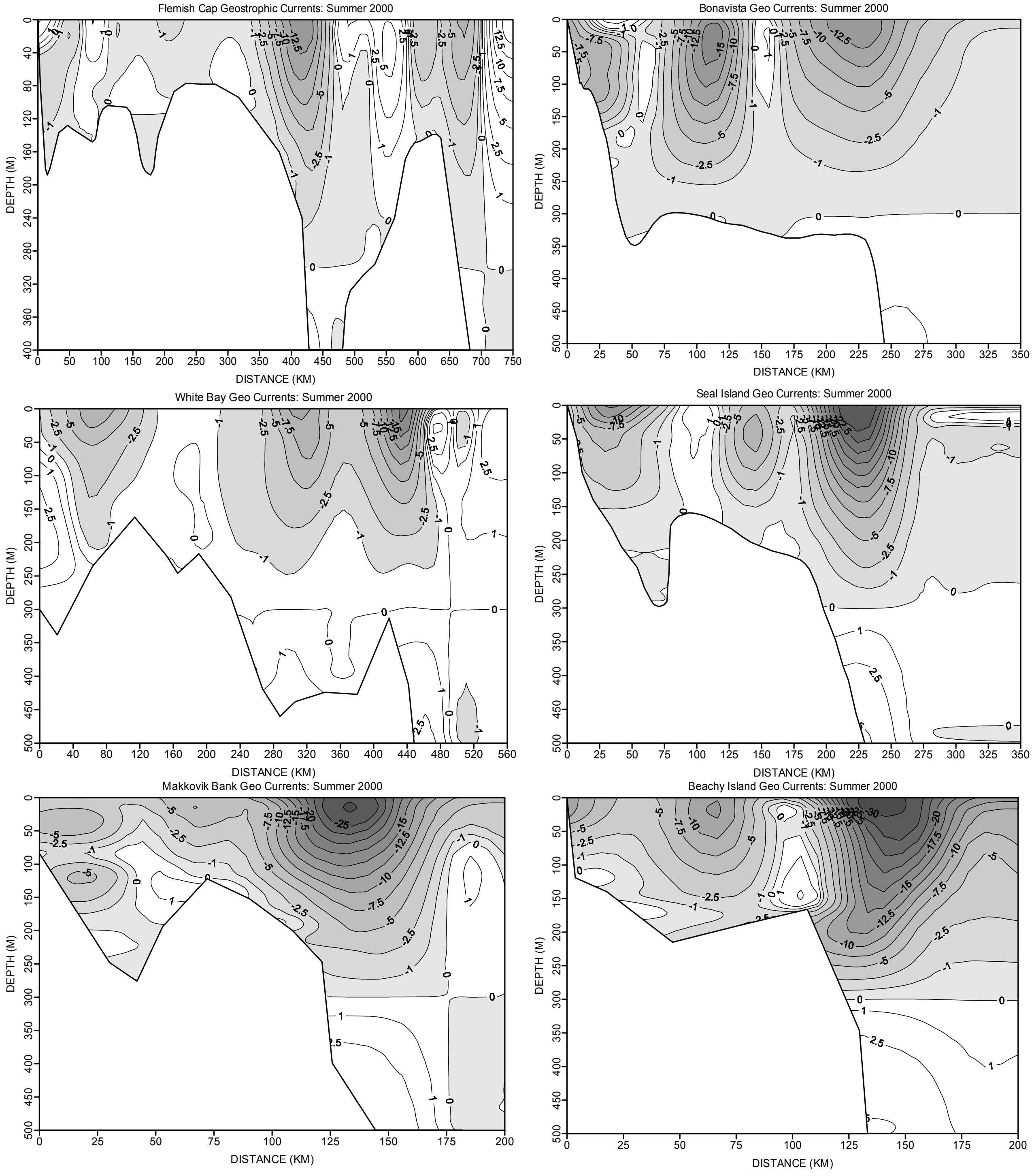


Fig. 28. Contours of geostrophic currents (in cm/s) along the Flemish Cap, Bonavista, White Bay, Seal Island, Makkovik Bank and Beachy Island transects during the summer of 2000. Negative shaded values are southward.

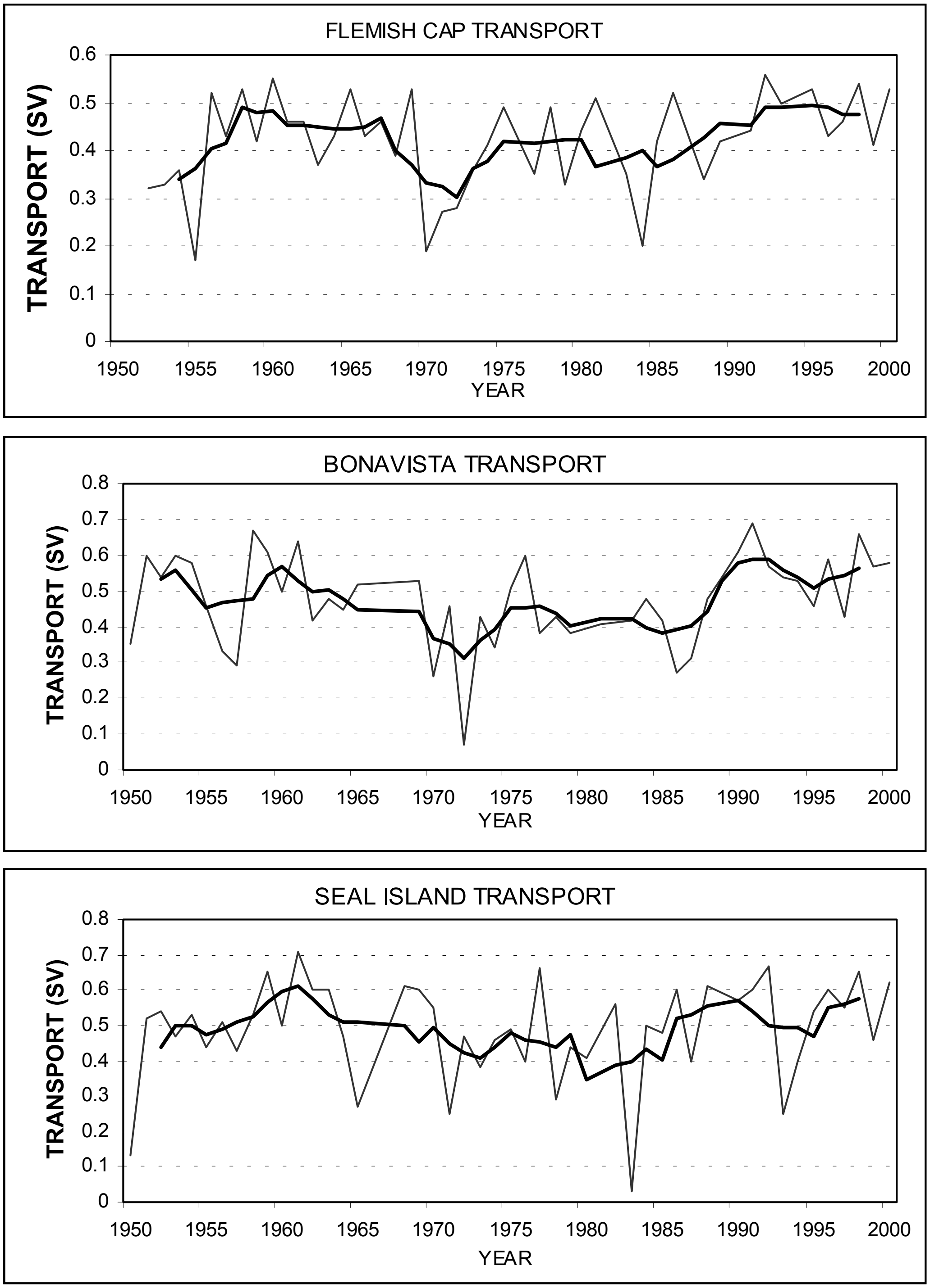


Fig. 29. Time series of geostrophic transport (10^6 m^3/s) relative to 130-m depth of the offshore branch of the Labrador Current through the Seal Island, Bonavista and Flemish Cap transects.

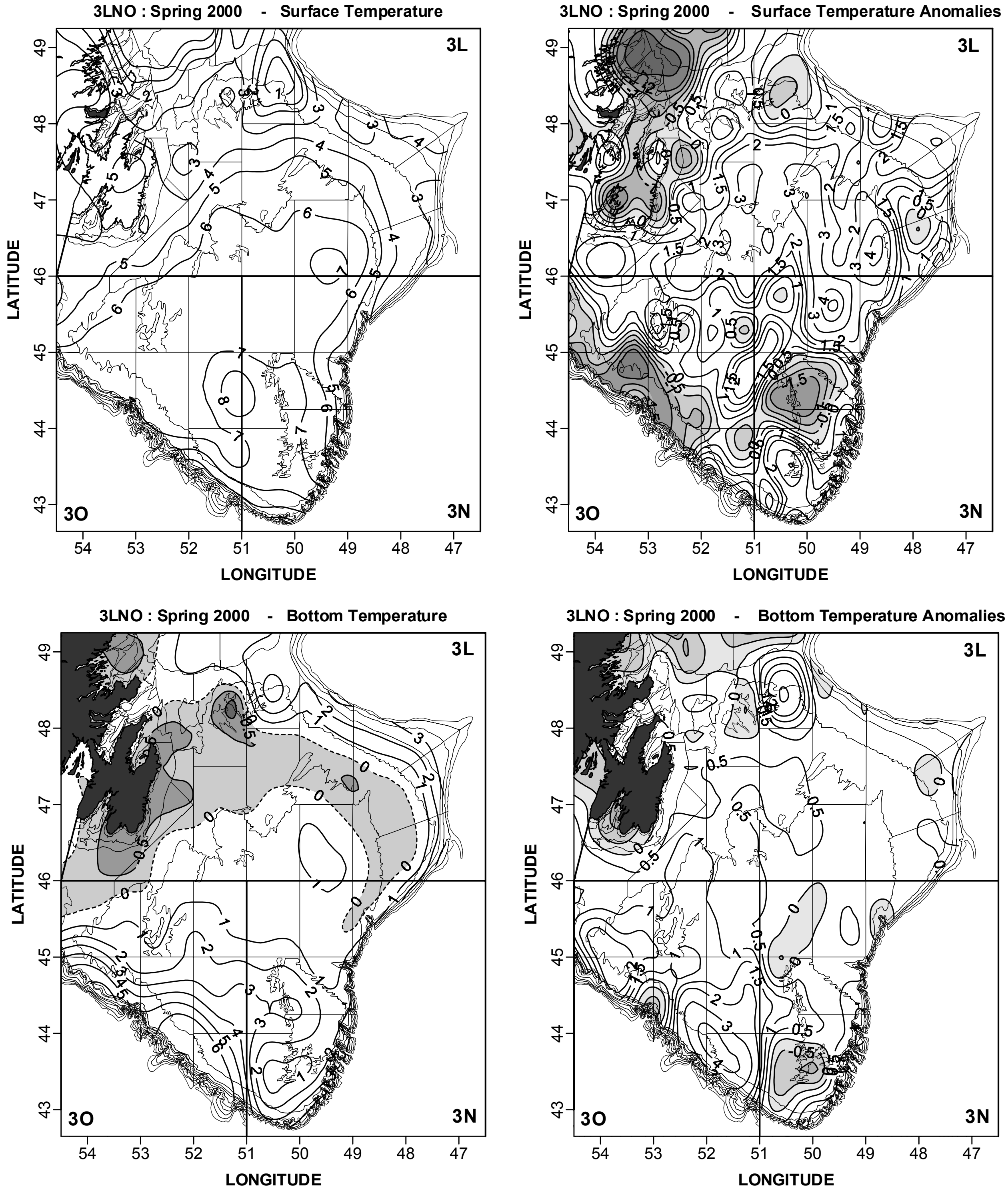
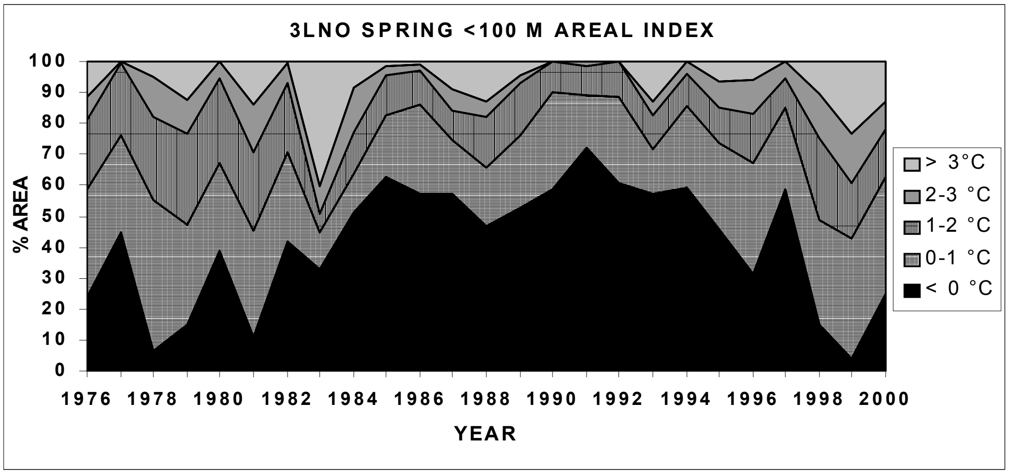
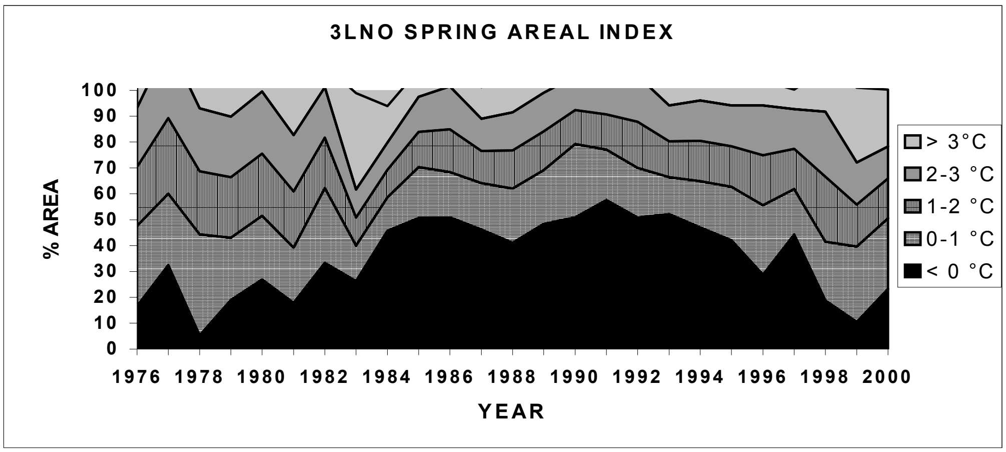


Fig. 30. Contours of surface and bottom temperature and their anomalies (in °C) for the spring of 2000 from the multi-species survey of NAFO Divs. 3LNO.





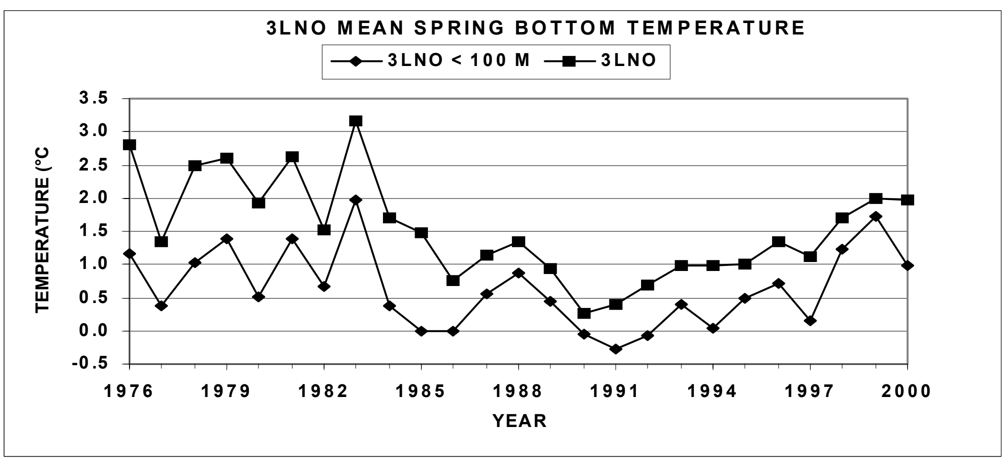


Fig. 31. Time series of the percentage area of the bottom in NAFO Divs. 3LNO covered by water with temperatures ≤ 0°C, 0-1°C, 1-2°C, 2-3°C and ≥3°C during spring for strata ≤100-m (top) for all surveyed strata (bottom) and the mean bottom temperature in °C.

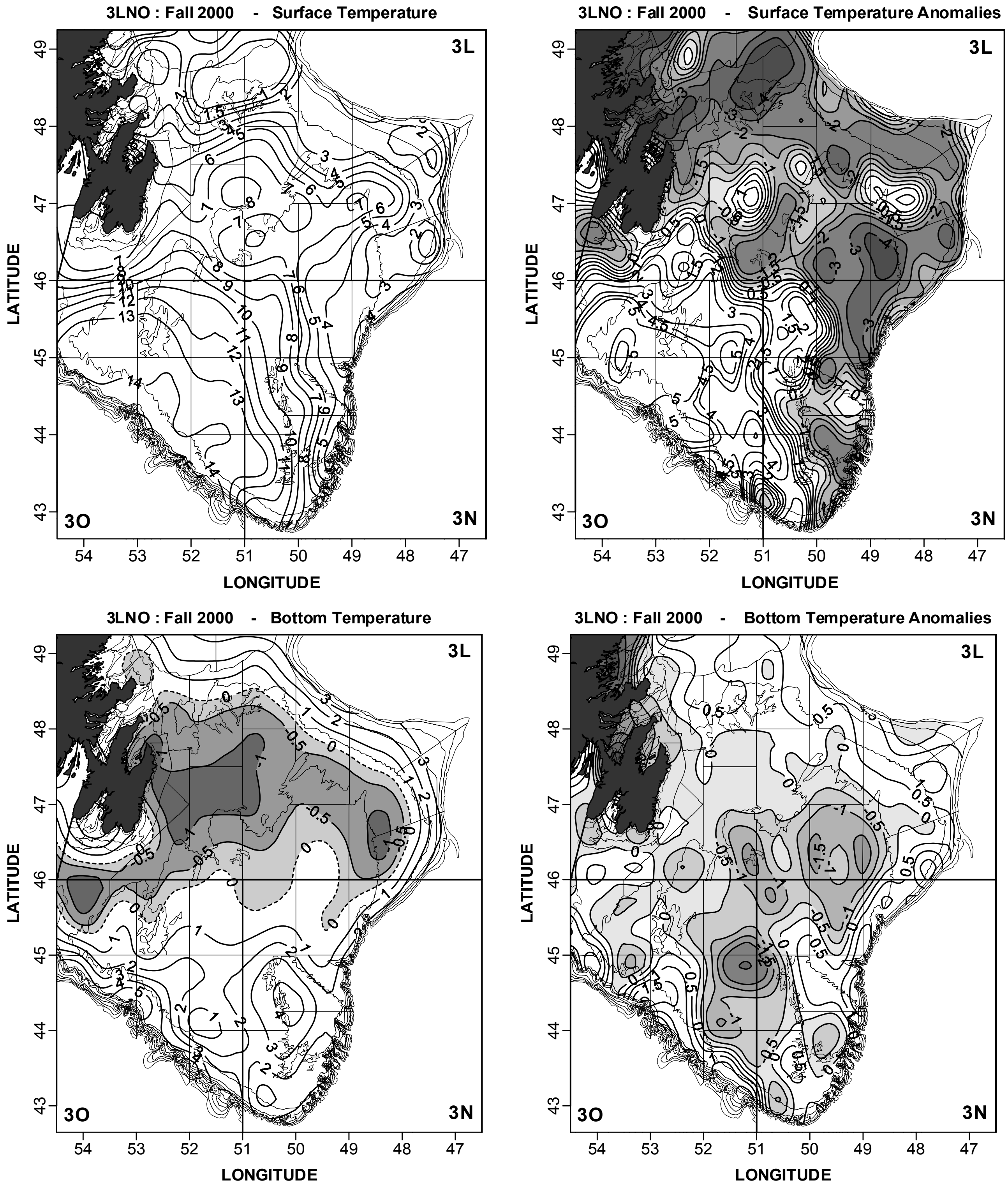
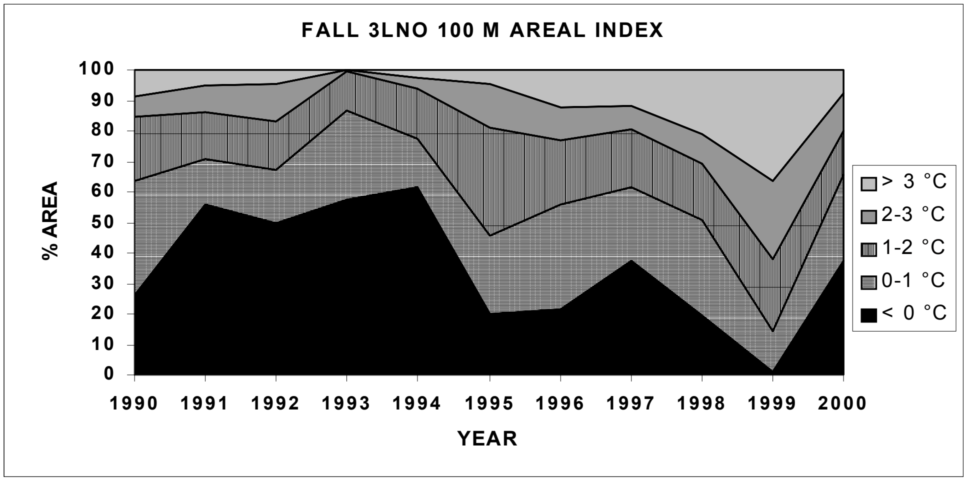
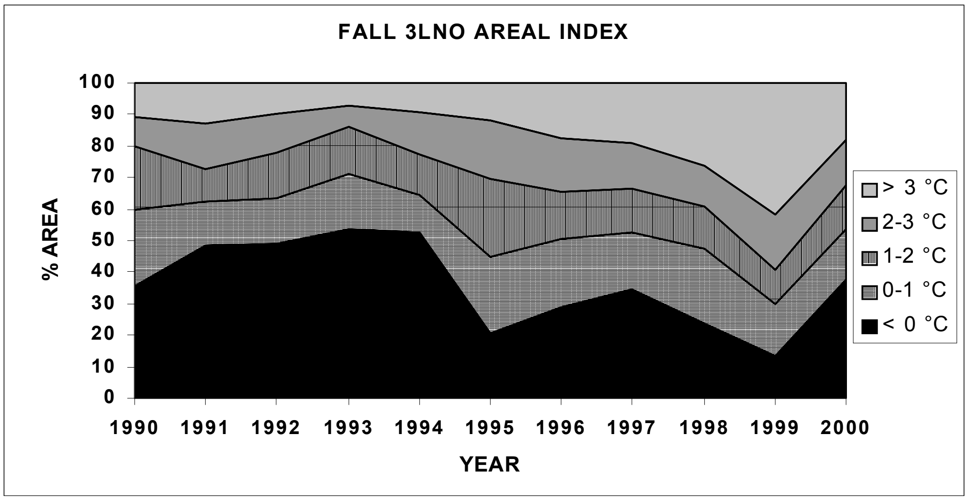


Fig. 32. Contours of surface and bottom temperature and their anomalies (in °C) for the fall of 2000 from the multi species survey of NAFO Divs. 3LNO.





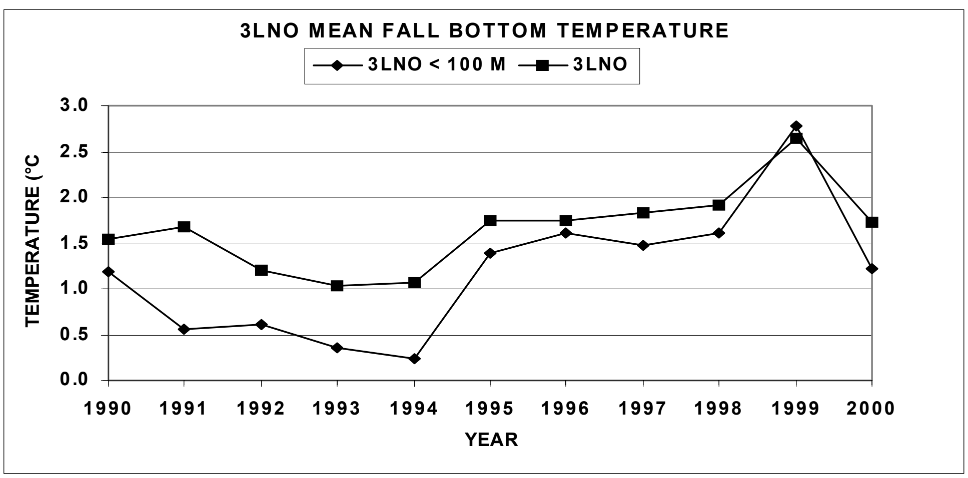
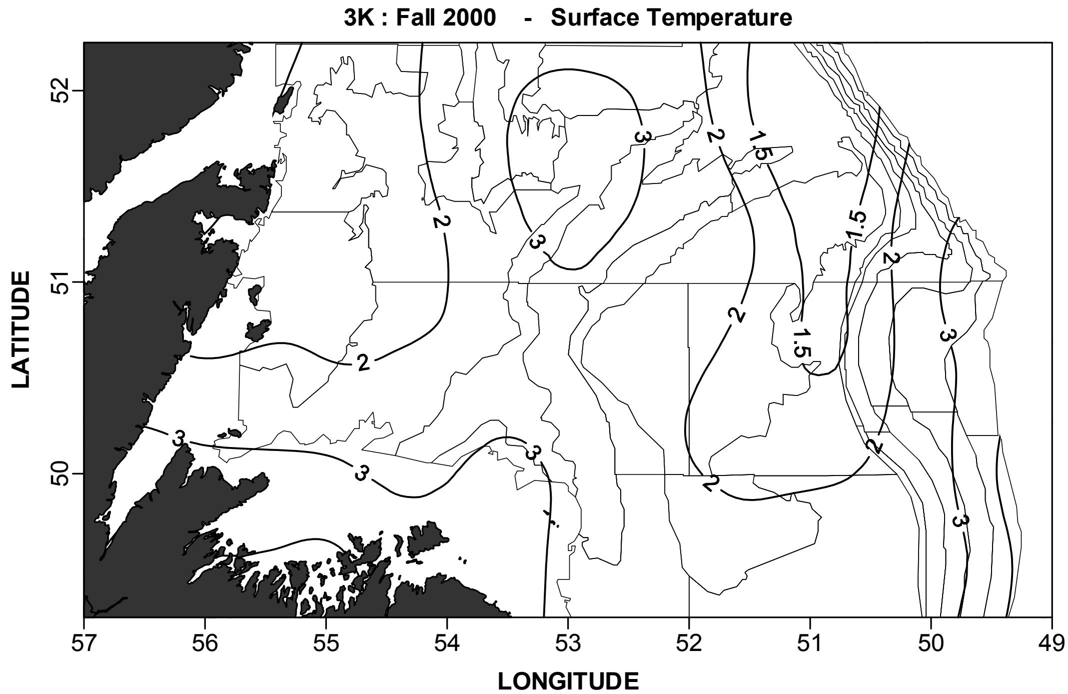


Fig. 33. Time series of the percentage area of the bottom in NAFO Divs. 3LNO covered by water with temperatures ≤ 0°C, 0-1°C, 1-2°C, 2-3°C and ≥3°C during the fall for strata ≤100-m (top) and for all surveyed strata (bottom) and the mean bottom temperature in °C.



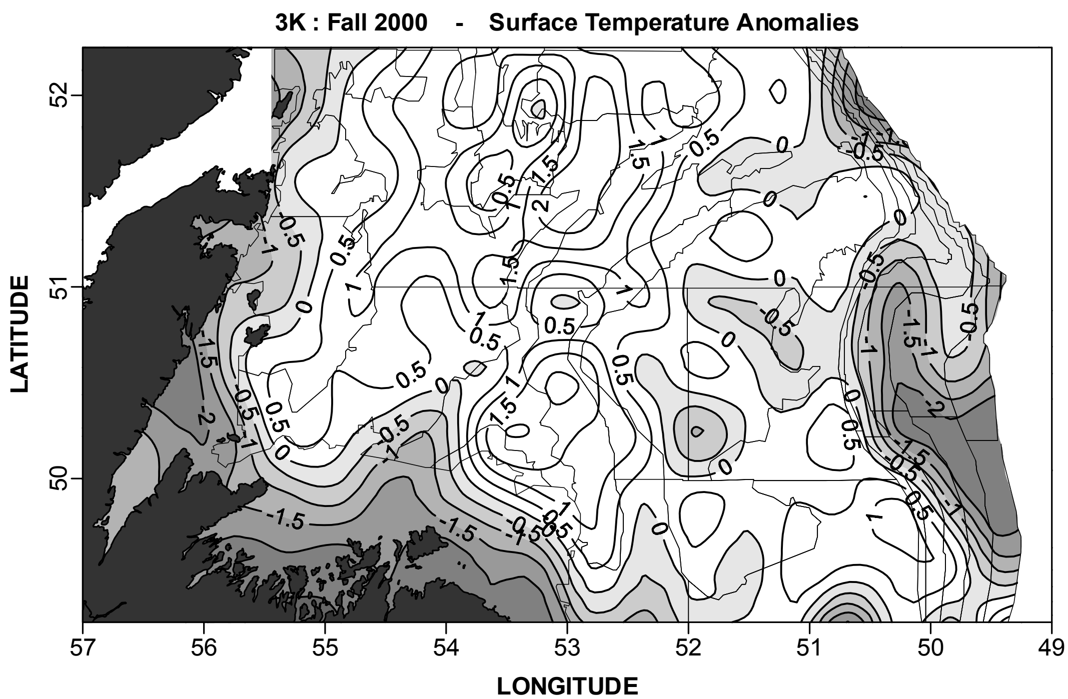
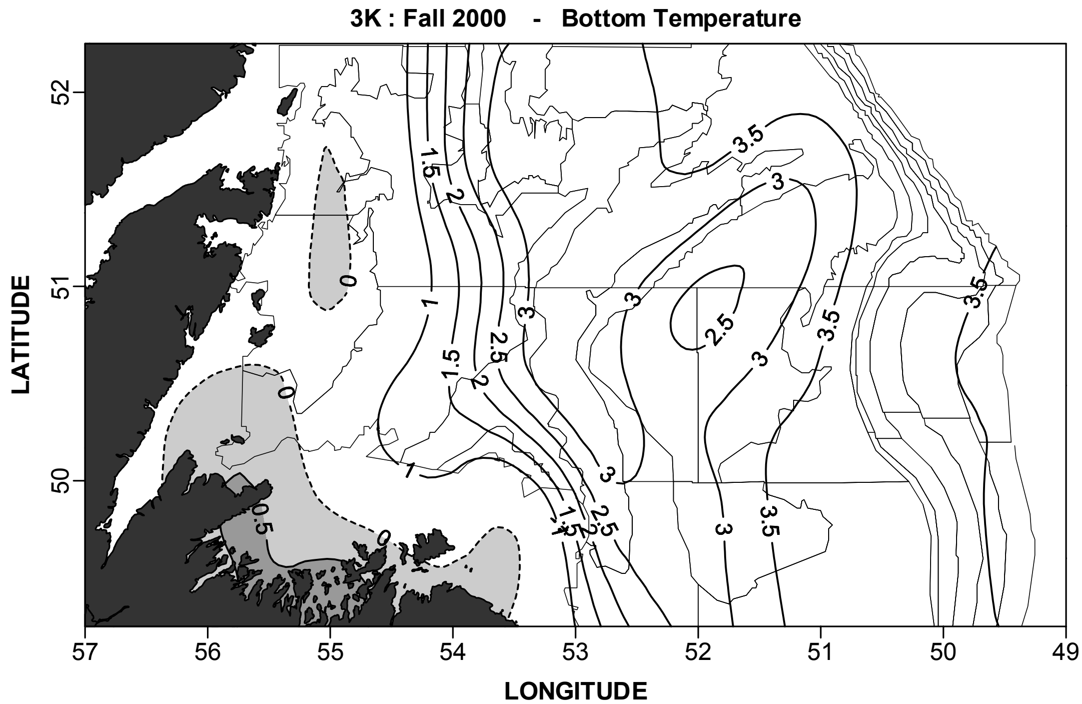


Fig. 34. Contours of surface temperature and anomalies (in °C) for the fall of 2000, from the multi-species survey of NAFO Div. 3K.



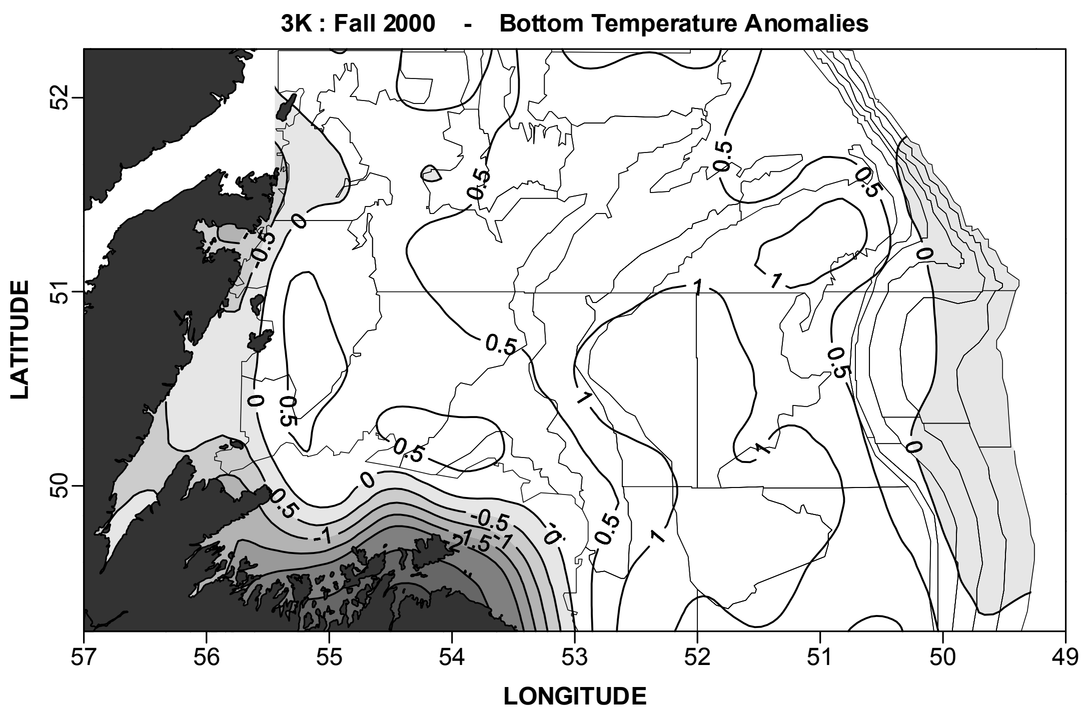


Fig. 35. Contours of bottom temperature and anomalies (in °C) for the fall of 2000, from the multi-species survey of NAFO Div. 3K.

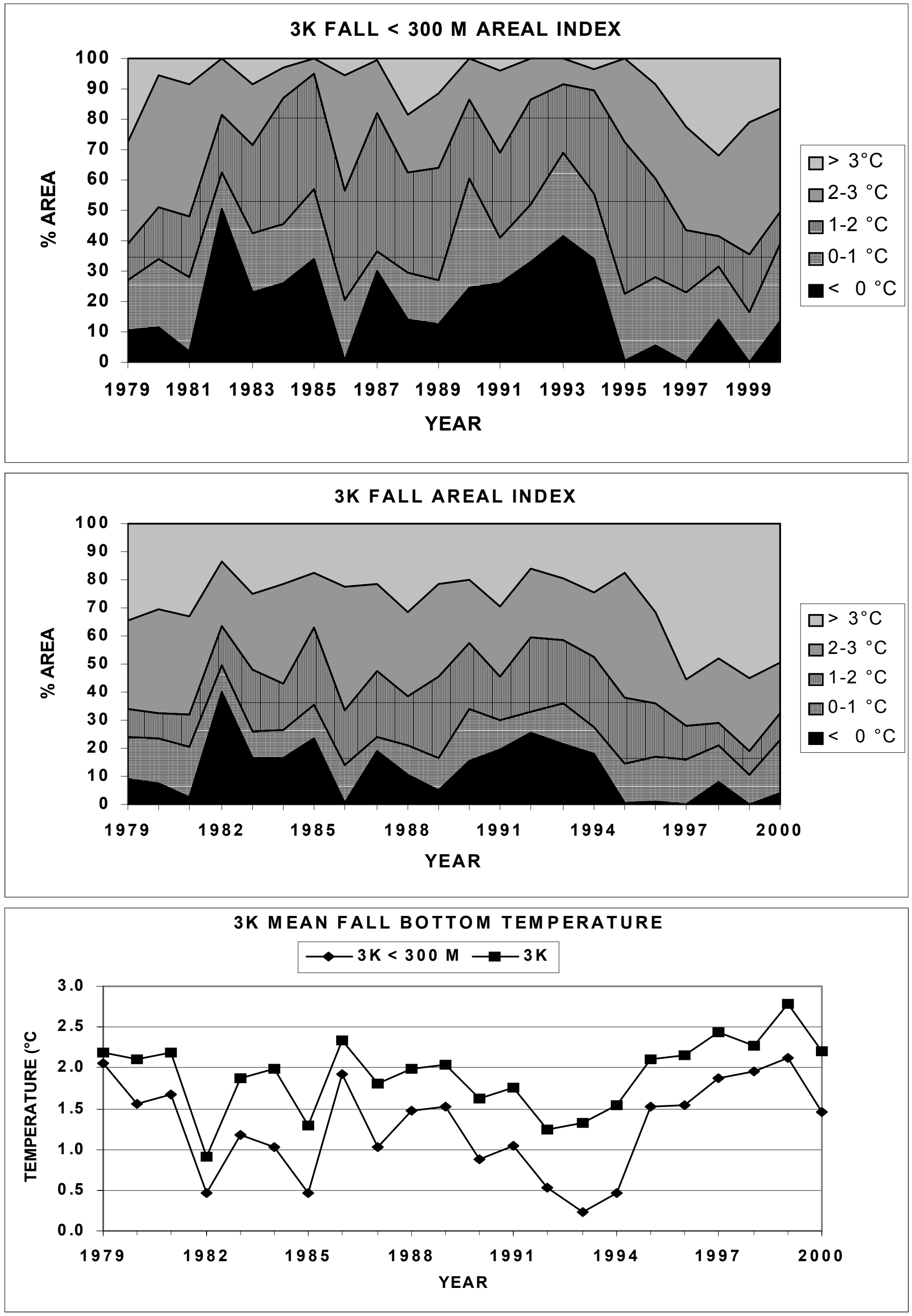
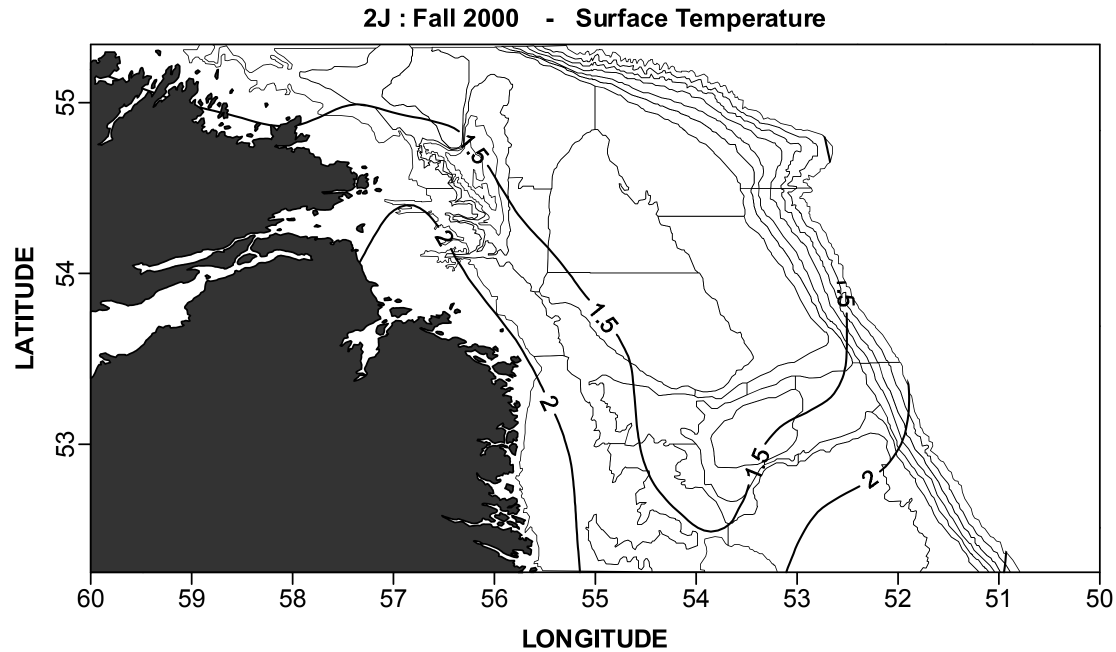


Fig. 36. Time series of the percentage area of the bottom in NAFO Div 3K covered by water with temperatures ≤ 0°C, 0-1°C, 1-2°C, 2-3°C and ≥3°C during the fall for strata ≤300-m (top) and for all surveyed strata (bottom) and the mean bottom temperature in °C.



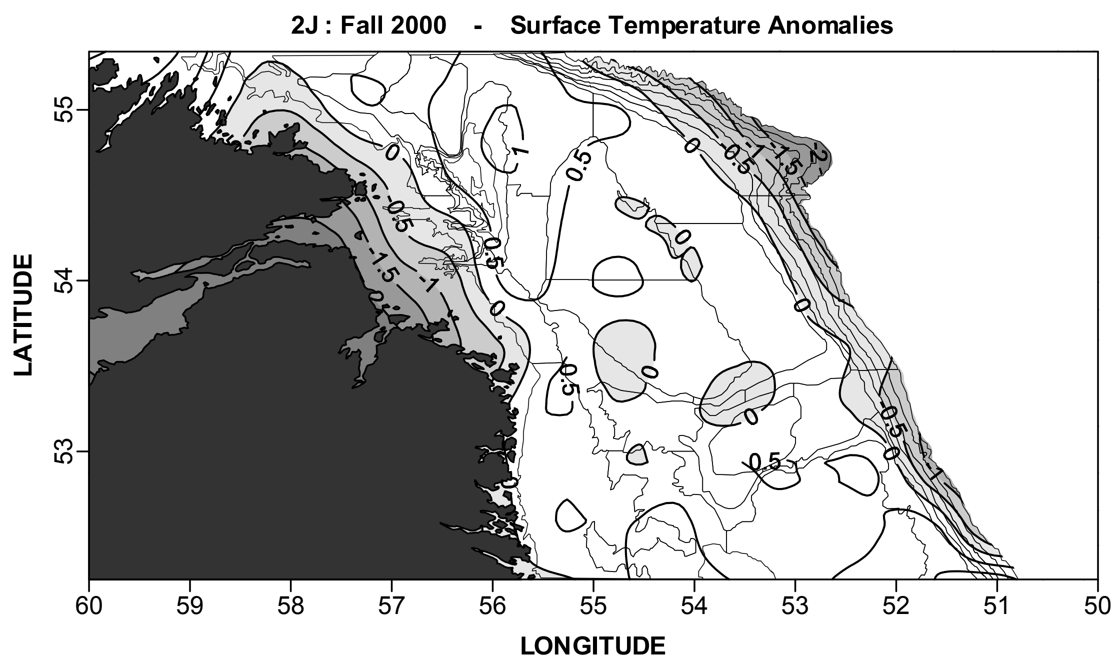
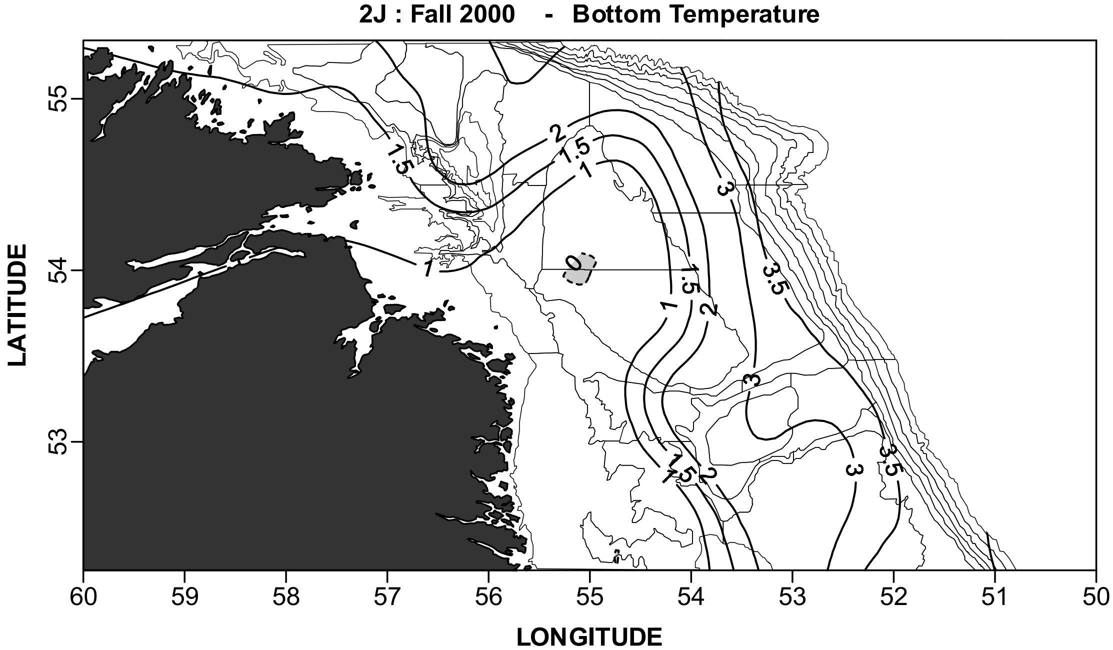


Fig. 37. Contours of surface temperature and anomalies (in °C) for the fall of 2000, from the multi-species survey of NAFO Div. 2J.



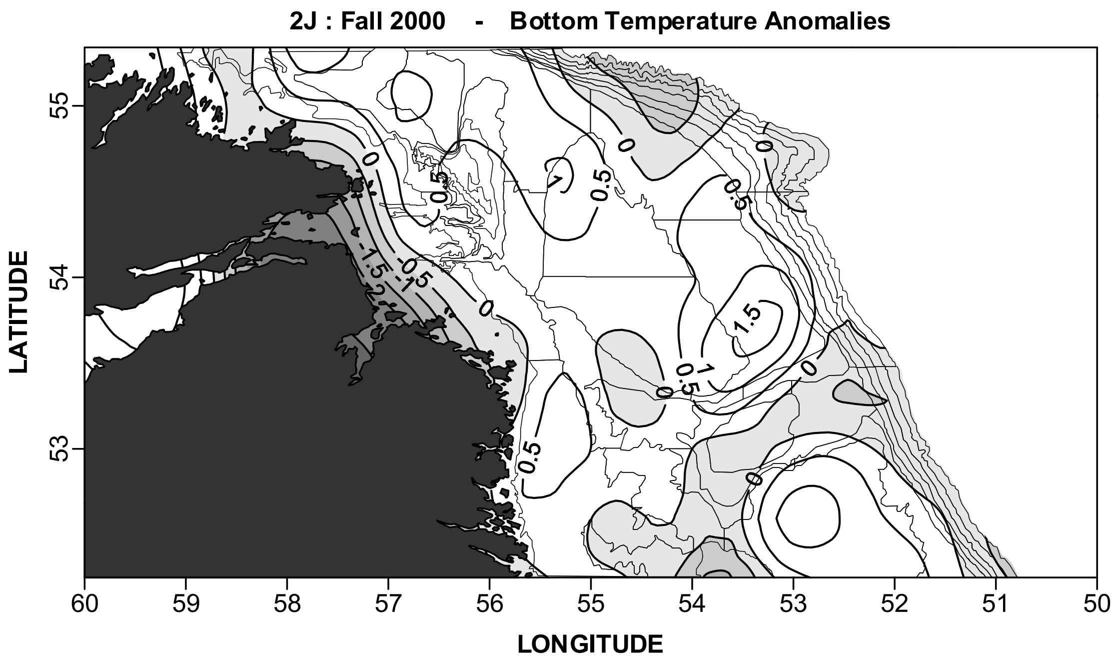


Fig. 38. Contours of bottom temperature and anomalies (in °C) for the fall of 2000, from the multi-species survey of NAFO Div. 2J.

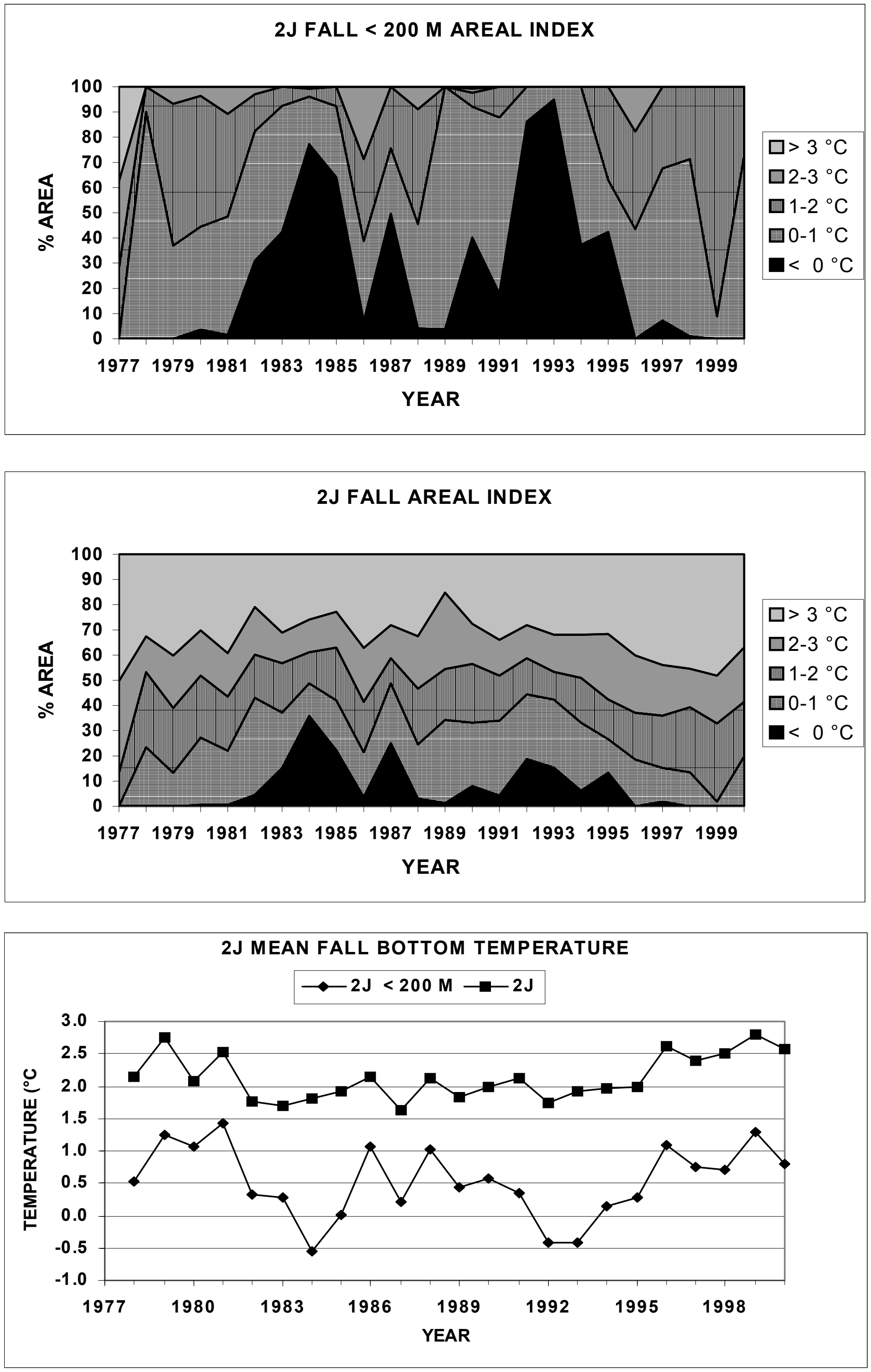


Fig. 39. Time series of the percentage area of the bottom in NAFO Div 2J covered by water with temperatures ≤ 0°C, 0-1°C, 1-2°C, 2-3°C and ≥3°C during the fall for strata ≤200-m (top) and for all surveyed strata (bottom) and the mean bottom temperature in °C.