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Oceanographic conditions in NAFO Subdivisions 3Pn and 3Ps during 1997 and 1998 with comparisons to the long-term (1961-1990) average

by

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Abstract

Oceanographic data from NAFO subdivisions 3Pn and 3Ps during 1997 and 1998 are examined and compared to the long-term (1961-1990) average. The data are presented in several ways, as vertical transects across the major banks and channels, horizontal bottom temperature maps, time series of areal extent of bottom water in selected temperature ranges and as time-series of temperature anomalies at standard depths. Time series of temperature anomalies in the 3Ps St. Pierre Bank area show anomalous cold periods in the mid-1970s and since the mid-1980s, similar to conditions on the continental shelf along the east coast of Newfoundland. The most recent cold period, which started around 1984, continued to the early 1990s with temperatures up to 1°C below average over all depths and up to 2°C below the warmer temperatures of the late 1970s and early 1980s in the surface layers. Temperatures in deeper water off the banks show no significant trends. Since 1991, temperatures have moderated in some areas from the lows experienced from the mid to late 1980s and early 1990s but negative temperature anomalies continued over large areas of the banks into the spring of 1995. During 1996 temperatures started to moderate, decreased again during the spring of 1997 and returned to more normal values during 1998. An analysis of the areal extent of subzero °C bottom water covering the banks shows a dramatic increase since the mid-1980s, very low values in 1996 and 1998, while in 1997 it represented approximately 60% of the total area. The areal extent of bottom water with temperatures above 1°C was about 50% of the total area of the banks in the 3Ps region during 1998 the first significant amount since 1984.

Résumé

Les données océanographiques des subdivisions 3Pn et 3Ps de l'OPANO pour les années 1997 et 1998 sont examinées puis comparées aux moyennes à long terme (1961-1990). Elles se présentent sous plusieurs formes, suivant des coupes verticales au-dessus des principaux bancs et chenaux, des cartes horizontales des températures au fond, des séries chronologiques des superficies d'eaux de fond correspondant à des plages de températures déterminées et des séries chronologiques d'anomalies de température à des profondeurs de référence. Les séries chronologiques d'anomalies de température dans le secteur 3Ps du banc Saint-Pierre révèlent qu'il y a eu, au milieu des années 1970 et depuis le milieu des années 1980, des périodes où les eaux ont été anormalement froides, rappelant les conditions retrouvées sur la plate-forme continentale de la côte est de Terre-Neuve. La plus récente période froide a débuté vers 1984 et s'est poursuivie jusqu'au début des années 1990, avec des températures pouvant descendre jusqu'à 1 °C sous la moyenne pour toutes les profondeurs et 2 °C sous les températures les plus chaudes enregistrées dans les couches de surface entre la fin des années 1970 et le début des années 1980. Au large des bancs, on n'a noté aucune tendance particulière des températures en eaux profondes. Depuis 1991, les températures dans certains secteurs se sont adoucies par rapport aux minimums enregistrés entre le milieu des années 1980 et le début des années 1990. Cependant, sur de larges portions des bancs, ces anomalies négatives se sont prolongées jusqu'au printemps 1995. En 1996, les températures ont commencé à se réchauffer pour fléchir de nouveau au printemps 1997 et revenir plus près des normales au cours de 1998. Une analyse des étendues d'eaux de fond aux températures inférieures à 0 °C sur les bancs révèle qu'elles ont connu une expansion spectaculaire depuis le début des années 1980. En 1996 puis en 1998, elles ont été très faibles, alors qu'en 1997, elles correspondaient à environ 60 % de la superficie totale. En 1998, l'étendue des eaux de fond dont la température s'élevait au-dessus de 1 °C représentait près de 50 % de la superficie totale des bancs dans 3Ps, soit la première étendue significative depuis 1984.

INTRODUCTION

The general circulation in the 3Ps region consists of modified Labrador Current water, the inshore branch of which flows through the Avalon Channel, and around Cape Race. This branch then divides into two parts, one flowing to the west around the north of St. Pierre Bank, and the other flows to the south between Green Bank and Whale Bank. Additionally, part of the offshore branch of the Labrador Current flows around the tail of the Grand Bank, westward along the continental slope (where it may interact with the Gulf Stream and slope waters), to the Laurentian Channel and into the Gulf of St. Lawrence.

Since the early 1970s the oceanographic, meteorological, and ice conditions of the Northwest Atlantic have been dominated by three anomalous periods: early 1970s, mid-1980s and the early 1990s. During these time periods, colder-than-normal winter air temperatures prevailed over the Northwest Atlantic which were correlated with strong positive winter North Atlantic Oscillation (NAO) index anomalies. This resulted in increased winter and spring ice cover and colder and fresher than normal water mass characteristics over most of the continental shelf in Atlantic Canada (Colbourne et al. 1994; Drinkwater et al. 1992; Narayanan et al. 1994). The extent to which these oceanographic anomalies may have influenced the 3Ps region are documented by several studies (Hutchings and Myers 1994; Moguedet and Mahe 1991; Battaglia and Poulard 1987; Forest and Poulard 1981; Colbourne 1994,1996).

This report summarizes oceanographic conditions in NAFO subdivisions 3Pn and 3Ps (Fig. 1) during 1997 and 1998 with a comparison to the long-term mean. The mean base period has been defined as the 30-year period from 1961-1990 in accordance with the convention of the World Meteorological Organization and recommendations from the North Atlantic Fisheries Organization's (NAFO) Scientific Council. Similar reports were published for data from 1990-1994 (Colbourne 1994) and for 1995 and 1996 (Colbourne 1996).

DATA AND METHODS

Oceanographic data for NAFO Subdivisions 3Ps and 3Pn 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. The bulk of these data are mainly temperatures collected during the Canadian groundfish assessment surveys of February, March and April since 1973. The station positions for the 1997 and 1998 surveys are shown in Fig. 2. Since the winter of 1990, water temperatures on these surveys have been measured, for the most part, using a trawl-mounted Seabird 19 CTD. Prior to that, XBTs were the primary instrument. Data from the net-mounted SBE-19 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 psu in salinity. The XBTs

are accurate to within 0.1°C. In addition to these data, all available historical data were used to establish the long-term means.

A cross-section of the temperature field across the region was constructed by projecting the positions of all observations in corridor A (Fig. 1) along a straight line with their offshore distances calculated from the shoreline. The transect was constructed for April of the years 1961-1990, 1997 and 1998. It starts near Rose Blanche on the south coast of Newfoundland, then follows a southeasterly direction crossing Burgeo Bank, Hermitage Channel, St. Pierre Bank and terminates near the edge of the continental shelf on the southwestern Grand Bank.

Bottom temperature maps were produced from all available data from 1961 to 1990 and for the spring surveys of 1997 and 1998. These maps were produced by contouring all bottom-of-the-cast temperature values and rejecting ones 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 (up to one month) over which the maps were produced.

A further analysis of the bottom temperature data from the surveys was made by calculating the total area of the grids used in the bottom temperature maps within selected temperature ranges. The mean bottom temperature of all grid values was also computed. A time-series of the percent of the total area covered by bottom water in selected temperature ranges as well as the average bottom temperatures were constructed from 1970 to 1998.

Finally time-series of monthly temperature anomalies were constructed at standard depths from St. Pierre Bank corresponding to area B of Fig. 1. The 1961-1990 data set from this area 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 determined by fitting a least squares regression of the form $\mathbf{cos(\omega t-\phi)}$ 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. Unlike the time series of anomalies from fixed points, like Station 27, these anomalies are based on data collected over larger geographical areas and therefore may exhibit variability due to spatial differences in the monthly estimates.

VERTICAL TEMPERATURE FIELD

The vertical cross-section (depth versus horizontal distance from the shore along the transect) of the average temperature field for April based on the historical data is shown in Fig. 3. No attempts were made to adjust this average for possible temporal or spatial biasing arising from variations either in the number of observations within the time

interval or within the area. An examination of the data indicates that the observations are well distributed geographically across the complete transect; however, temporally most of the data have been collected since the early 1970s.

The average upper layer temperature for April from near shore at Rose Blanche on the south coast of Newfoundland over Burgeo Bank and Hermitage Channel is about 1°C. Over St. Pierre Bank the temperature ranges from 1°C near the bottom to 2°C near the surface and beyond the shelf edge in the upper 100-m of the water column. In the deeper water of Burgeo and Hermitage Channels and on the continental slope region the temperature ranges from 2°C at approximately 125-m depth to 5° to 6°C near the bottom. At the edge of the continental shelf on the southwestern Grand Bank the temperature field is marked by a strong front separating the warmer slope water from the Labrador Current water over St. Pierre Bank. In this region temperatures increase from 1°C at about 100-m depth to between 5° to 6°C at about 175-m depth, an average vertical temperature gradient of 1°C per 15-m depth change (Fig. 3).

During April of 1997 (Fig. 4, upper panel) upper layer (0-75 m) temperatures ranged from 0° to 0.25°C near the coast and over St. Pierre Bank and from 0° to –0.25°C over the edge of the shelf. These values were generally about 0.5° to 1°C below average on the Banks and near-shore and up to 1.5°C below normal in the upper water column at the shelf edge. In the deeper waters of Burgeo and Hermitage Channels temperature were near normal at about 1°C at approximately 125-m depth to 5° to 7°C near the bottom. On the continental slope near bottom temperatures ranged from 3° to 4°C, which were about 3°C below average.

During April of 1998 (Fig. 4, bottom panel) upper layer (0-75 m) temperatures increased over the previous year to 0.75° to 2°C near the coast and over St. Pierre Bank and up to 2° to 7°C over the edge of the shelf. These values were near normal on the Banks and near shore and up to 5°C above normal in the upper water column at the shelf edge. In the deeper waters of Burgeo and Hermitage Channels, 1998 temperatures ranged from 1° to 4°C in the depth range of approximately 125 to 200 m, these were about 1°C below normal. Near-bottom temperatures in the channels were about normal, between 4° to 7°C. On the continental slope near-bottom temperatures were also about normal, except at around 90-m depth where a small area of subzero °C water was found.

BOTTOM TEMPERATURES MAPS

The average bottom temperatures for April ranges from 5°C in the Laurentian, Burgeo and Hermitage Channels to about 3° to 4°C on Rose Blanche and Burgeo Banks (Fig. 5). St. Pierre temperature ranges from 0°C on the eastern side to 2° to 3°C on the western side. In general, the bottom isotherms follow the bathymetry around the Laurentian Channel and the southwestern Grand Bank decreasing from 2°C at 200-m depth to 5°C in the deeper water.

During the spring of 1997 deep-water temperatures in the channels were above normal while most of St. Pierre Bank was below normal, by up to 1°C particularly over the eastern and south-eastern areas, and was similar to 1995. During April 1998 temperatures were about average over Burgeo Bank and Hermitage Channel and appear to have moderated to near normal values over most of St. Pierre Bank where temperatures ranged from 0.5° to 3°C (Fig. 6). This represents an increase from 1997 values. It thus appears that temperature conditions in the 3Ps region during the last year have moderated significantly from the cold period of the mid to late 1980s and the early 1990s.

BOTTOM TEMPERATURE AREAL INDEX

Oceanographic data from groundfish assessment surveys have been collected in the 3Ps region since the early 1970s between January and June. These data together with other oceanographic data were gridded for the winter-spring time period of each year at a spatial resolution of 97 km^2 or approximately 0.1° latitude by 0.1° longitude. A total of 580 grid points or 56,260 km^2 were used within the boundaries of the 3Ps and 3Pn regions. Except for 1980 (which is not included), the percentage of the total area gridded ranged from about 85% to 100%. The mean bottom temperature for each grid was then calculated and combined with the grid area to produce a time series of bottom area covered by water in selected temperature ranges. The areas are expressed as a percentage of the total surveyed area.

Shown in Fig 7 are time series of the areal extent of the bottom covered with water in the temperature ranges of -1.8°C to 0°C, 0°C to 1°C and greater than 1°C. Note the large increase in the percentage area of the bottom covered by subzero °C water in 1985 that persisted well into the mid-1990s. The percentage area of subzero °C during the spring of 1998 decreased to pre-1985 levels. The bottom area covered with water between 0°C to 1°C, except for 1979 and 1988, have remained below 20%. The bottom area with temperatures above 1°C before 1985 was approximately 70% to 80% and since 1984 is has been nearly constant between 50% to 70%.

Shown in Fig. 8 are the areal indices for the same temperature ranges but restricted to water depths less than or equal to 100-m, which includes Burgeo, St. Pierre and Green Banks. During 1985 the areal extent of subzero °C bottom water increased from an average of approximately 20% to 100%. Except for 1988 it remained near 80% until 1994, at which time it began to decrease and was less than 10% in 1998. The area in the temperature range of 0°C to 1°C exhibit large fluctuations with relatively high values during the 1970s, 1988 and during 1996. The area of these banks covered with bottom water with temperatures greater than 1°C was significant prior to 1985, virtually non-existent until 1996 and had increased to about 50% in 1998.

The average bottom temperature of the surveyed area in Subdivision 3Ps ranged

between 3° to 4°C from 1970 to 1984 and decreased to between 2° to 2.5°C from 1985 to 1998 (Fig. 9, upper panel). On the banks, in water depths generally less than 100-m, the average temperature from 1970 to 1985 ranged between approximately 0.5° to 1°C, decreased significantly during 1985 and has slowly recovered to about 1°C by 1998 (Fig. 9, bottom panel).

TEMPERATURE TRENDS

As described above, monthly temperature anomalies from 1950 to 1998 on St. Pierre Bank bounded by the 100-m isobath (region B in Fig. 1) 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°C. The long-term trend shows amplitudes generally less than ±1°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°C in the upper water column and by 1°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 colder than average below 50 m depth. During 1997 and 1998 temperature anomalies fluctuated, but were mostly above normal, indicative of a warming trend. Examination of deeper (200–400 m) bottom temperatures revealed considerable variability, but no significant trend was detected during the time period from 1950 to 1996 (Colbourne 1996).

SUMMARY

Time series of temperature anomalies in the 3Ps (St. Pierre Bank) area show anomalous cold periods in the mid 1970s and since the mid-1980s, similar to conditions on the continental shelf along the east coast of Newfoundland. The most recent cold period, which started around 1984, continued to the early 1990s with temperatures up to 1°C below average over all depths and up to 2°C below the warmer temperatures of the late 1970s and early 1980s in the surface layers. Temperatures in deeper water off the banks show no significant trends. Since 1991, temperatures have moderated in some areas from the lows experienced from the mid to late-1980s and early 1990s but negative temperature anomalies continued over large areas of the banks into the spring of 1995. During 1996 temperatures started to moderate, decreased again during the spring of 1997 and returned to more normal values during 1998. An analysis of the areal extent of subzero °C bottom water covering the banks shows a dramatic increase since the mid-1980s, very low values in 1996 and 1998, while in 1997 it represented approximately 60% of the total area. The areal extent of bottom water with temperatures above 1°C was

about 50% of the total area of the banks in the 3Ps region during 1998 the first significant amount since 1984.

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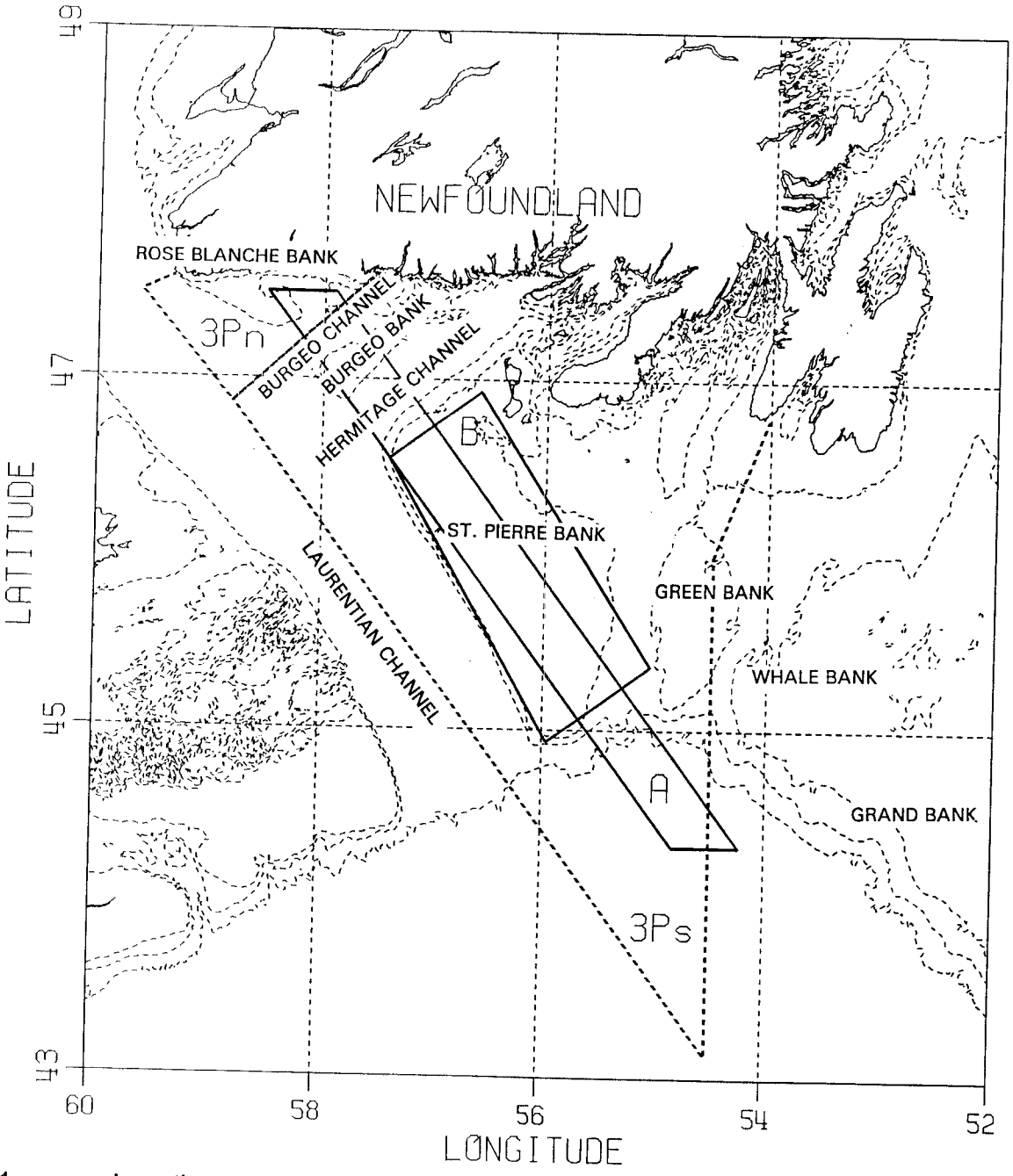

Fig. 1. Location map showing NAFO Subdivisions 3Pn and 3Ps and the areas A and B from which data were examined. The bathymetry lines are 100, 200 and 1000 m.

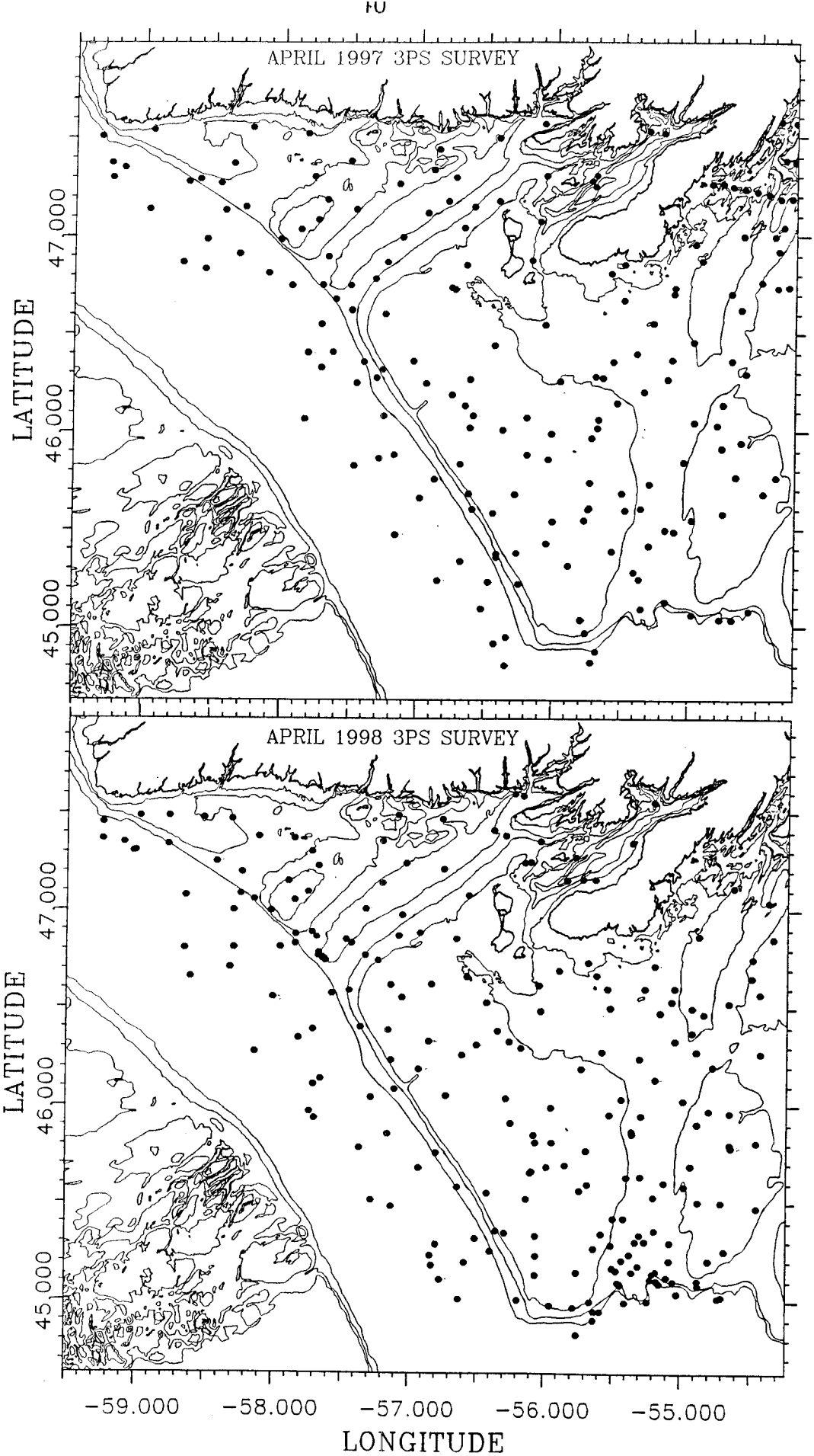

Fig. 2. Location map showing the positions of oceanographic measurements in NAFO Subdivisions 3Pn and 3Ps during the 1997 and 1998 spring groundfish surveys. The bathymetry lines are 100, 200 and 300 m.

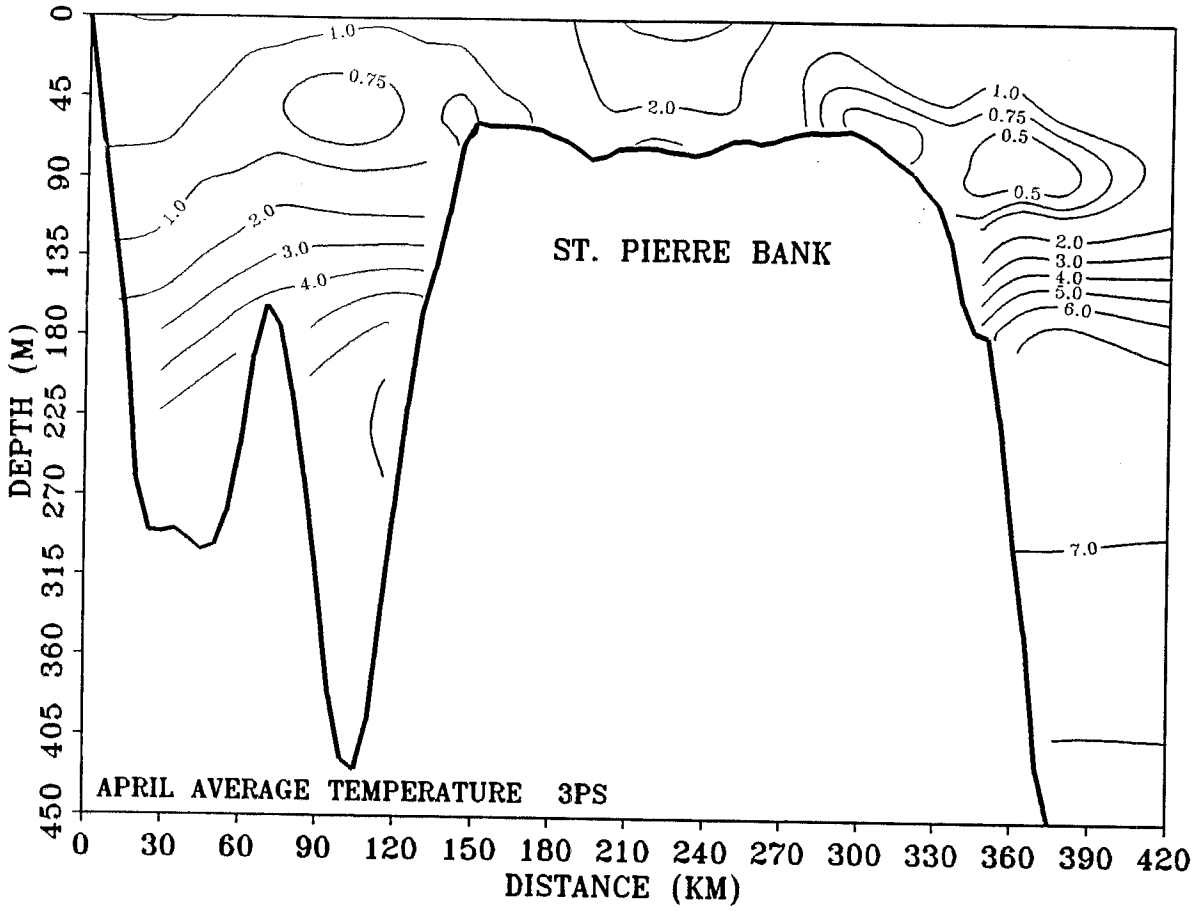

Fig. 3. The April average temperature (in °C) along the transect constructed from the data in Box A of Fig. 1 for NAFO Subdivisions 3Pn and 3Ps based on the historical data from 1961 to 1990.

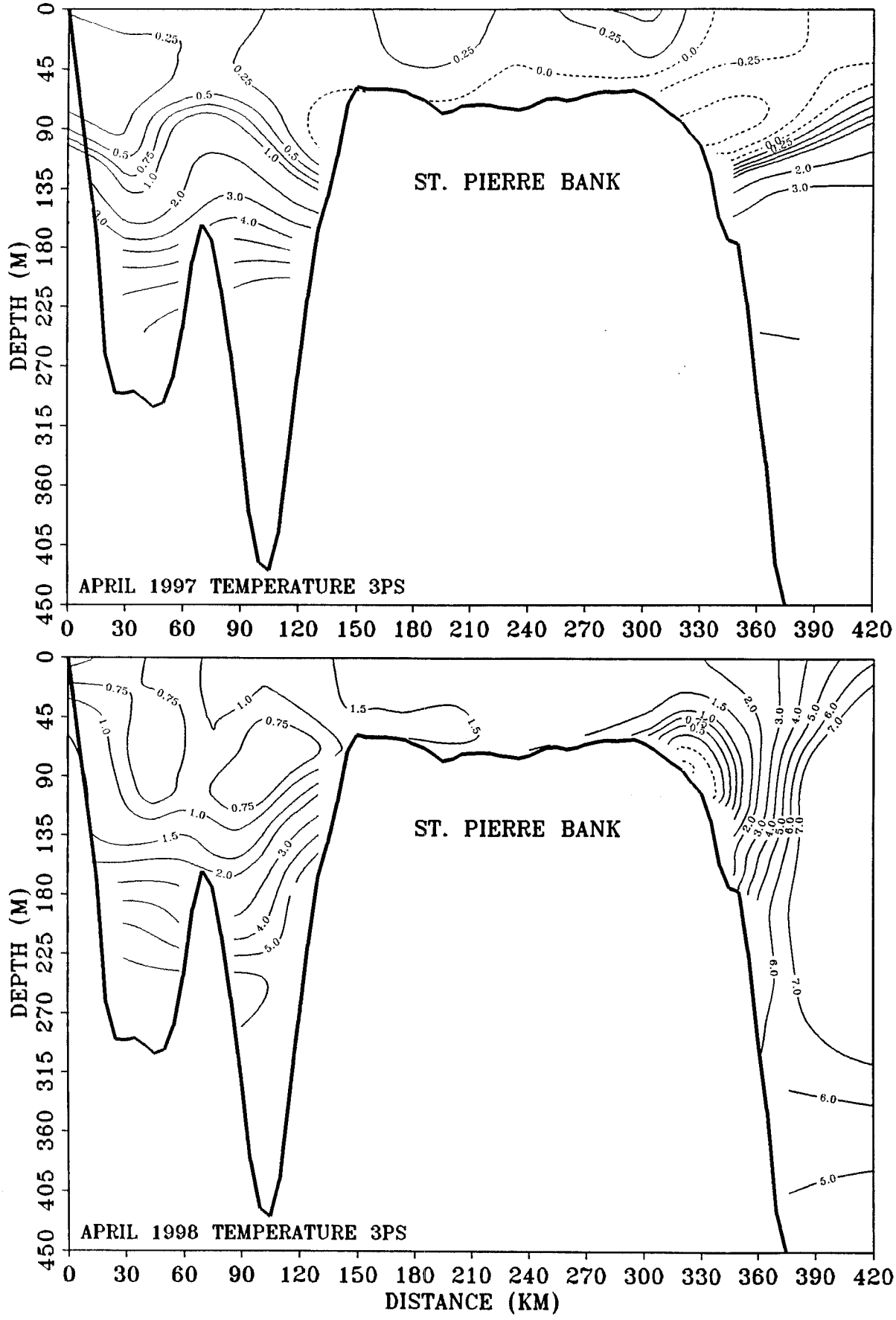

Fig. 4. The 1997 and 1998 April temperature (in °C) along the transect constructed from the data in Box A of Fig.1 for NAFO Subdivisions 3Pn and 3Ps.

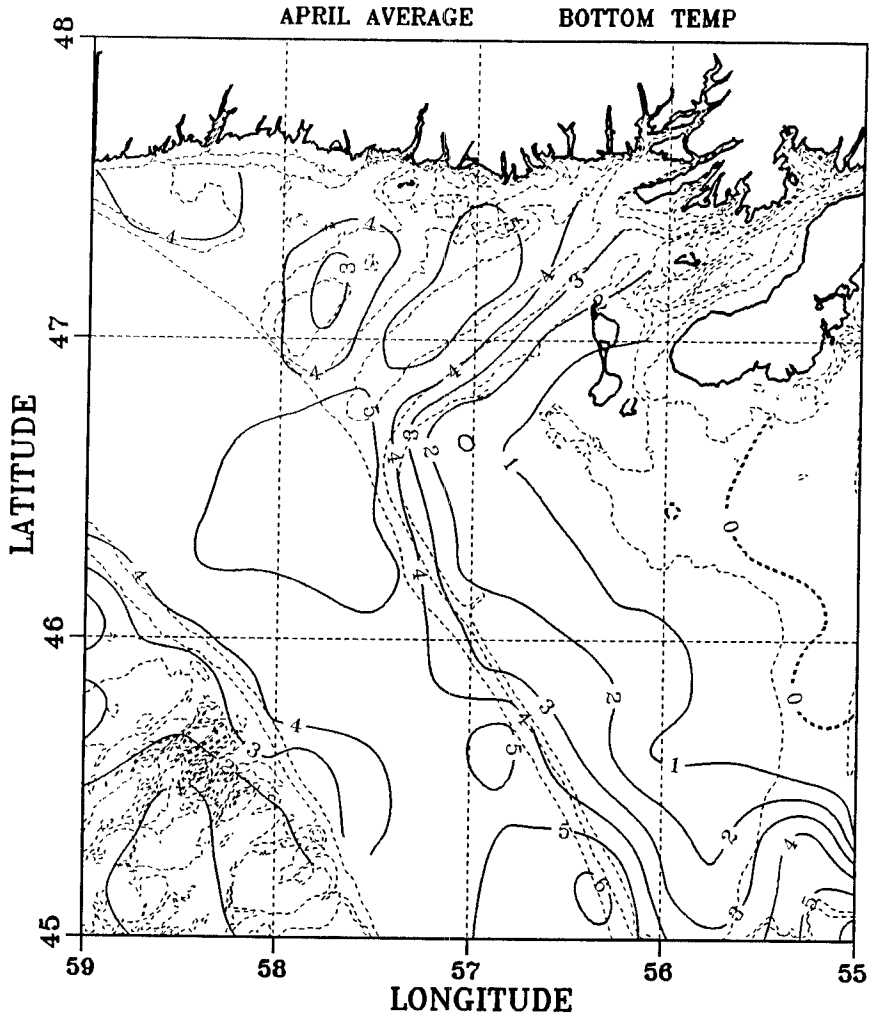

Fig. 5. The April average bottom temperature (in °C) in NAFO Subdivisions 3Pn and 3Ps based on the 1961-1990 historical data set.

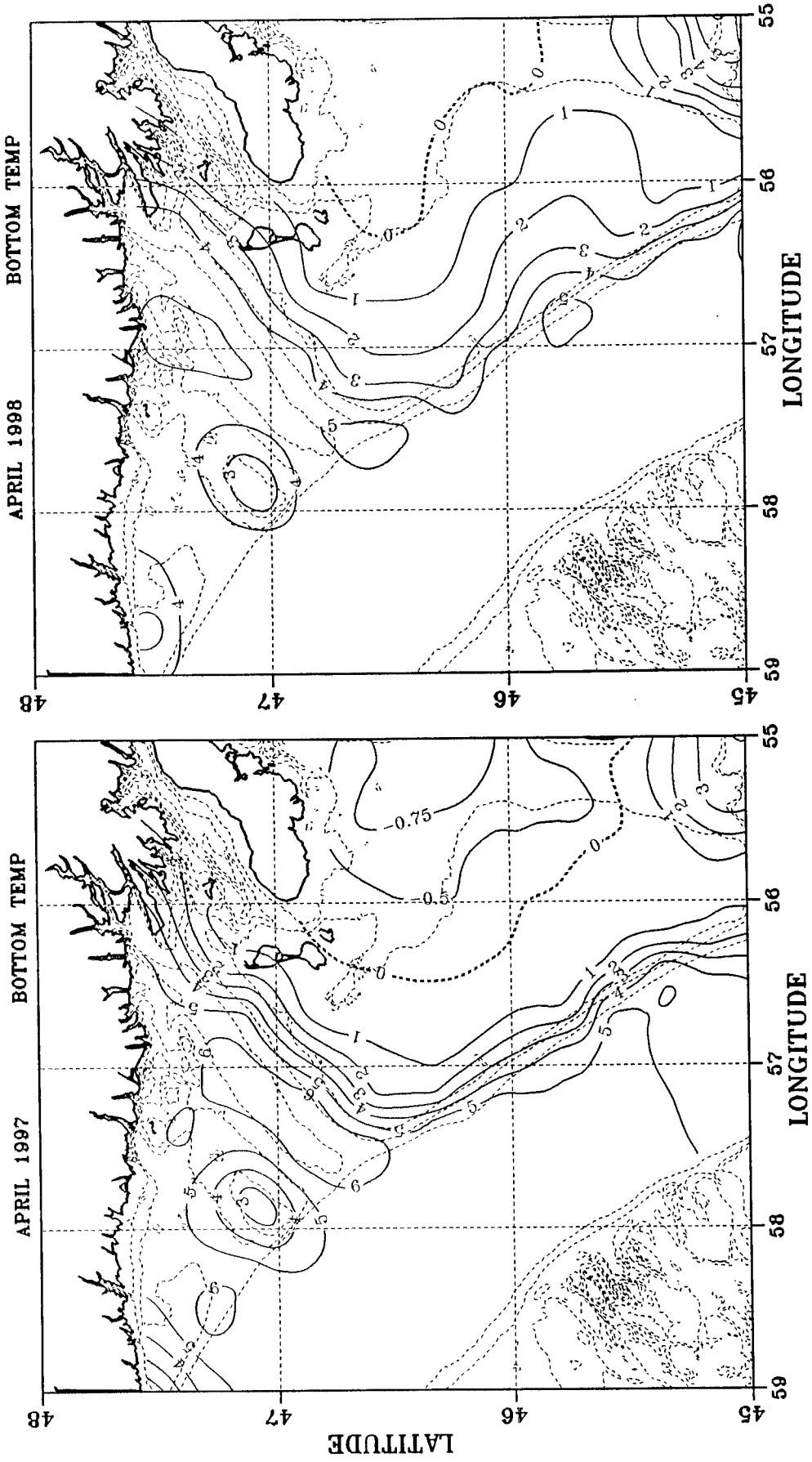

Fig. 6. The 1997 and 1998 April bottom temperature (in °C) in NAFO Subdivisions 3Pn and 3Ps.

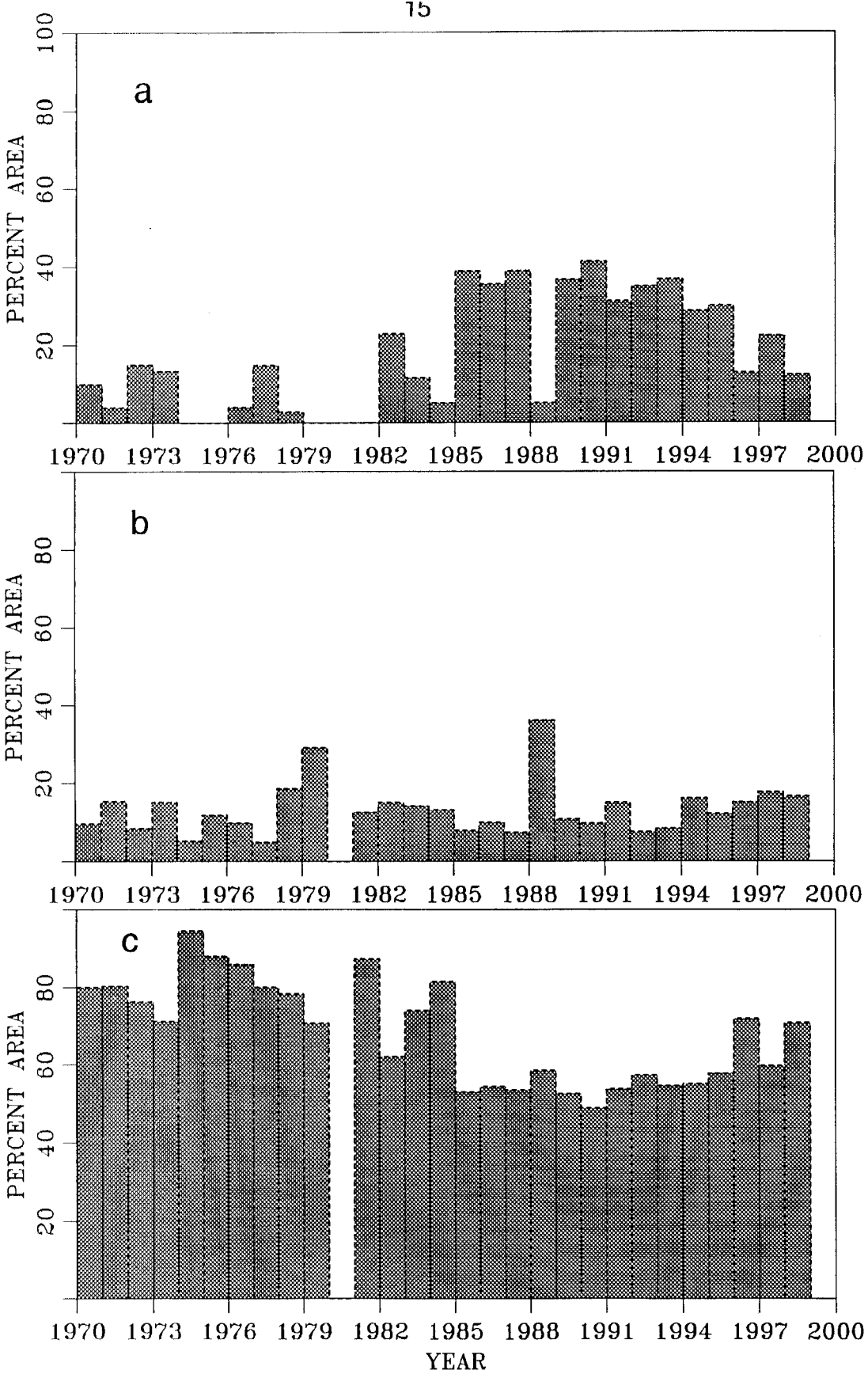

Fig. 7. Time series of the percentage area of the 3Pn and 3Ps NAFO Subdivisions covered by water with bottom temperatures in the range of (a) –1.8 to 0 °C, (b) 0 to 1 °C and (c) greater than 1 °C.

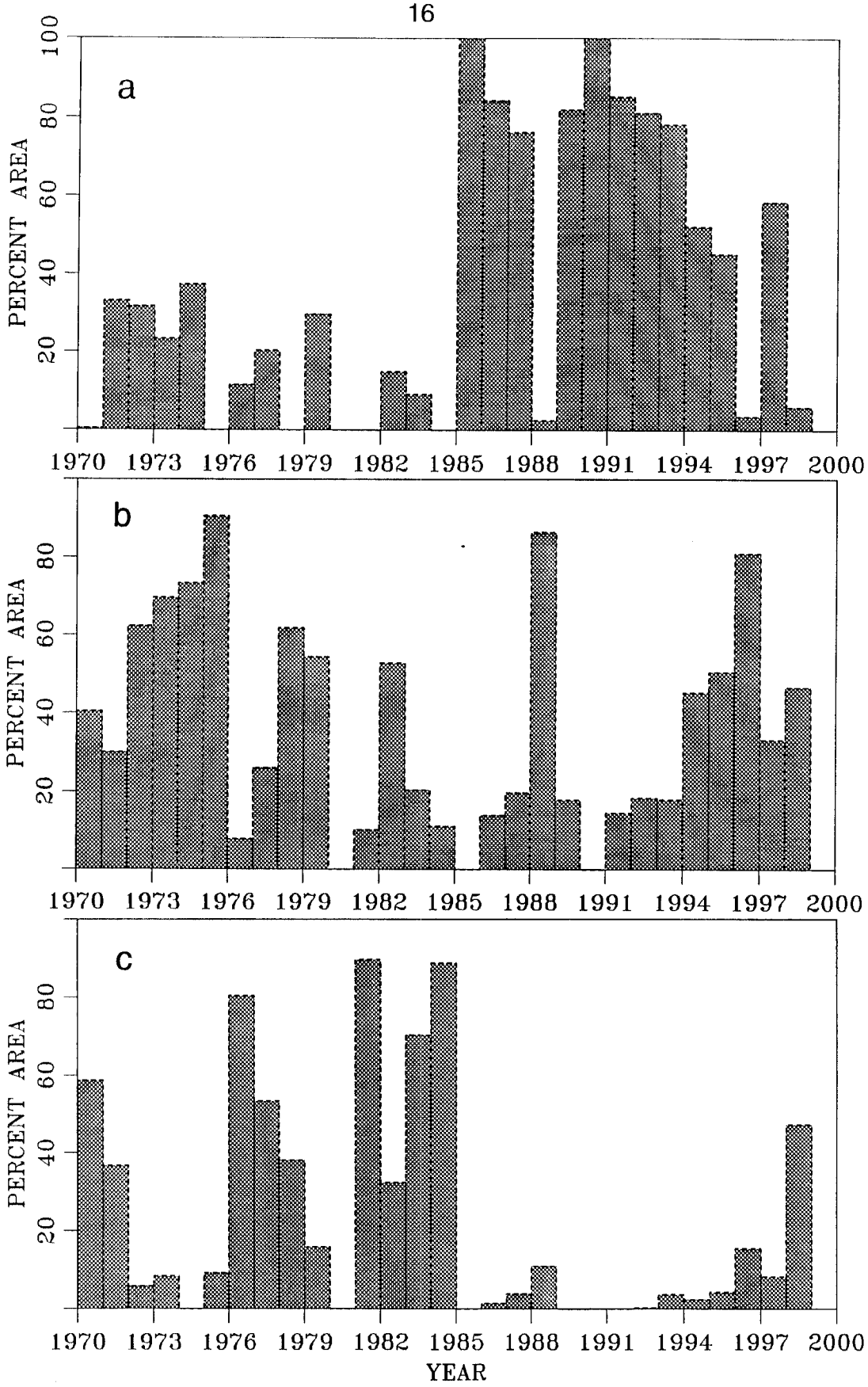

Fig. 8. Time series of the percentage area of Burgeo, St. Pierre and Green Banks, located in NAFO Subdivisions 3Pn and 3Ps, covered by water with bottom temperatures in the range of (a) –1.8 to 0 °C, (b) 0 to 1 °C and (c) greater than 1 °C.

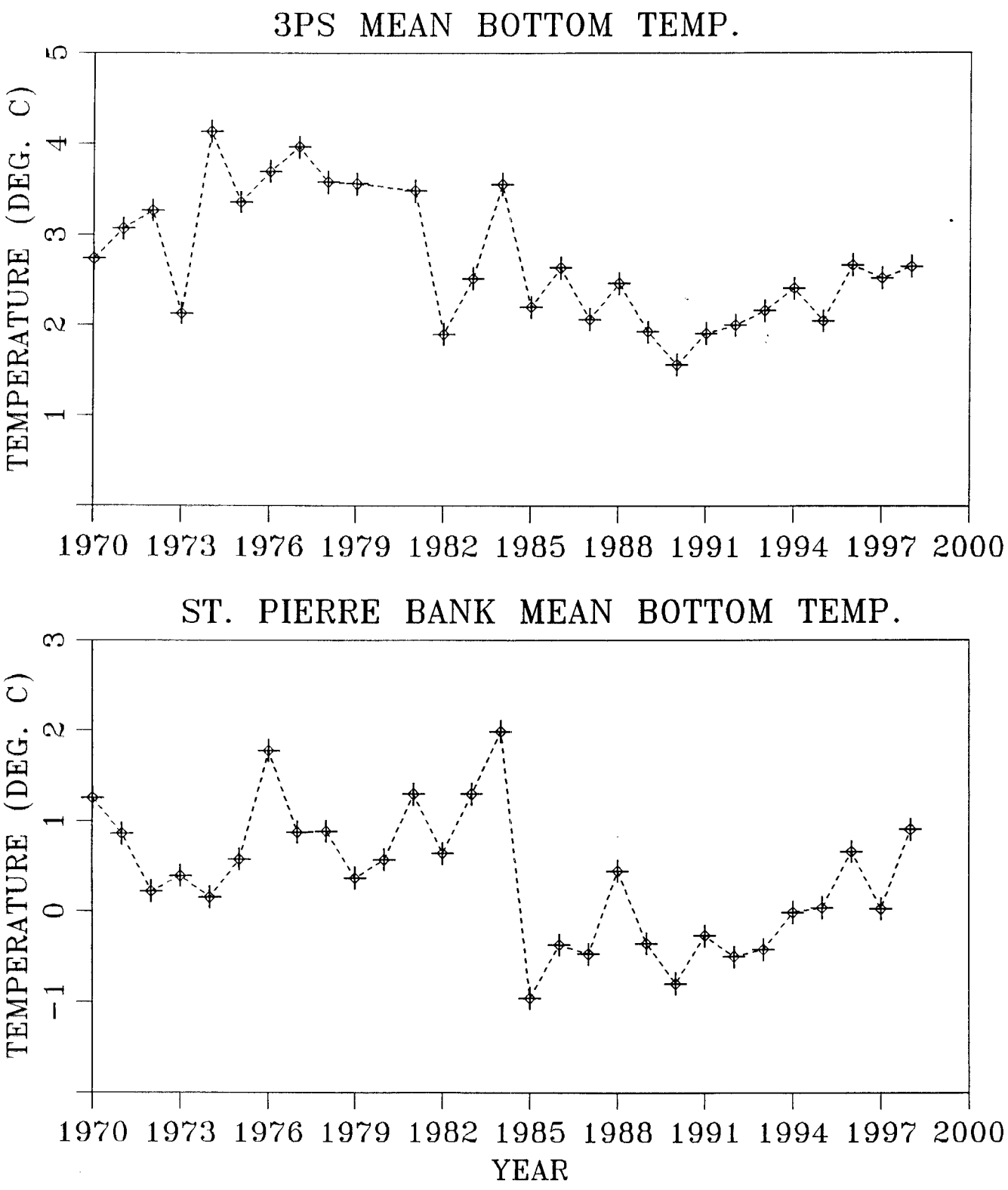

Fig. 9. Time series of the mean bottom temperature (in °C) in NAFO Subdivisions 3Pn and 3Ps (top panel) and the mean bottom temperature of Burgeo, St. Pierre and Green Banks (bottom panel).

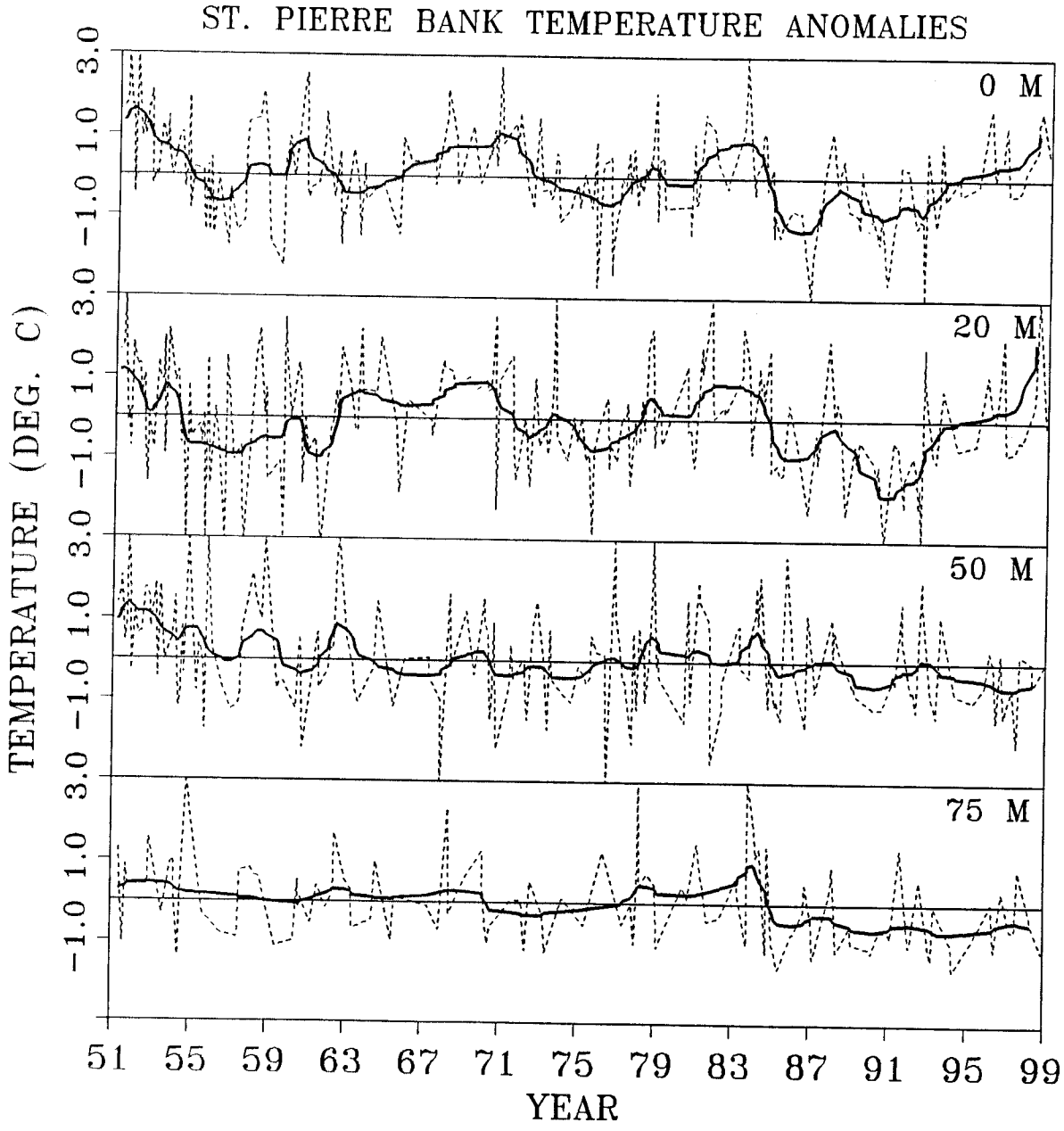

Fig. 10. Monthly temperature anomaly time series (in °C) at standard depths of 0, 20, 50 and 75 m for Box B in Fig. 1. The heavy solid line represents the low passed filtered temperature anomalies.