Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC Research Document 92/ 102

Comité scientifique consultatif des
pêches canadiennes dans l'Atlantique

CSCPCA Document de recherche 92/102

Overview of Environmental Conditions on Eastern Canadian Continental Shelves in 1991

by

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ABSTRACT

Environmental conditions in the continental waters off eastern Canada for 1991 are described using selected oceanographic and meteorological datasets. Very cold waters were observed on the Grand Banks, off northern Newfoundland and on the Labrador Shelf during 1991 with negative annual sea surface temperatures (SSTs) throughout the region. The largest negative values were observed during the late spring and summer with monthly anomalies (relative to 1972-90) reaching -3°C on the Grand Banks. Cold air and sea temperatures in winter, together with strong northerly winds, resulted in a heavy ice year off Newfoundland and in the Gulf of St. Lawrence. Warmer-than-normal SSTs persisted from the Scotian Shelf to the mid-Atlantic Bight with the amplitudes increasing southward. In the Laurentian Channel and in Emerald Basin on the Scotian Shelf the deep waters were the coldest recorded in 20 years. These cold conditions were not observed in the deep waters of the Gulf of Maine, however.

RÉSUMÉ

On décrit les conditions environnementales qui régnaient en 1991 dans les eaux continentales au large de l'est du Canada, en se fondant sur certains ensembles de données océanographiques et météorologiques. On constate que cette année-là les eaux des Grands Bancs de Terre-Neuve se trouvant au large du nord de Terre-Neuve et sur la plate-forme labradorienne étaient très froides et que les températures annuelles à la surface de l'eau étaient négatives dans l'ensemble de la région. C'est à la fin du printemps et en été que les plus basses températures négatives ont été relevées, les plus fortes anomalies mensuelles (par rapport à 1972-1990) atteignant -3 °C sur les Grands Bancs de Terre-Neuve. En raison des basses températures hivernales de l'air et de la mer, associées à de forts vents du nord, les glaces ont été abondantes au cours de l'année au large de Terre-Neuve et dans le golfe du Saint-Laurent. Les températures de la surface de l'eau se sont maintenues au-dessus de la normale dans la zone qui va de la plate-forme néo-écossaise au golfe médio-atlantique, les amplitudes augmentant vers le sud. Dans le Chenal Laurentien et le bassin Émeraude, sur la plate-forme néo-écossaise, la température des eaux profondes s'est révélée la plus basse en 20 ans. On n'a toutefois pas observé de telles conditions de froid dans les eaux profondes du golfe du Maine.

INTRODUCTION

This paper presents an overview of environmental conditions in the Northwest Atlantic during 1991 with emphasis on the region from the Gulf of St. Lawrence to the Gulf of Maine. Conditions north and east of Newfoundland (NAFO Subareas 2J3KL) have been reported by Narayanan et al. (1992). This review is based upon selected oceanographic and meteorological datasets including surface and subsurface temperature and salinity data, air temperatures, sea ice extent, and iceberg numbers. Anomalies for 1991 relative to their long term means are provided. Where possible the historical means have been calculated for the period 1951-80. A 30-yr base period is in accordance with meteorological convention as determined by the World Meteorological Organization.

OCEANOGRAPHIC OBSERVATIONS

Sea-Surface Temperatures

(1) Coastal Stations

Monthly averages of sea-surface temperature (SST) are available from Halifax Harbour in Nova Scotia, St. Andrews in New Brunswick, and Boothbay Harbor in Maine (see Fig. 1 for locations). The monthly mean temperature anomalies relative to the 1951-80 long-term averages (Trites and Drinkwater, 1984) at each of the sites for 1990 and 1991 are shown in Fig. 2.

The temperature patterns at the three sites show several differences. During the first five months of 1991 there appeared to be a gradient in SST across the region from above normal temperatures at Boothbay Harbor, to near normal at St. Andrews, and below normal at Halifax. In summer, Boothbay and Halifax temperatures were generally colder-than-normal but at St. Andrews they were warmer-than-normal. During the last four months of the year, temperatures at Halifax rose above normal, while at St. Andrews they fell below normal and at Boothbay they were near normal.

Annual SST mean temperatures for 1991 were 9.0°C (0.2°C above normal) at Boothbay Harbor, 7.15°C (0.15°C below normal) at St. Andrews, and 7.5°C (0.3°C below normal) at Halifax. The long-term trends, as represented by the 25-month running means, show that the temperatures at Boothbay Harbor have risen slightly in the past couple of years but are near their long-term mean (Fig. 3). The warm anomalies during the last half of 1990 and the first part of 1991 are unusual in their persistence compared to past anomalies (Fig. 3). At St. Andrews, SSTs continued to rise from a minimum recorded in the late 1980s and appear to be approaching the long term mean. At Halifax, the negative annual anomaly is consist with slightly colder-than-normal conditions that have persisted since the late 1980s. These temperatures are 2-2.5°C below the maximum anomaly recorded near the mid-1980s.

(2) Offshore

Sea-surface temperature anomalies determined from the "marine deck" observations were calculated for 24 areas in the Northwest Atlantic (35°-60°N, 40°-76°W) extending from Cape Hatteras to Greenland (Fig. 4). These data are derived primarily from ships-of-opportunity and obtained from measurements in the ship's intake. The areas into which the data were divided coincide with oceanographic regimes (e.g. the Labrador Current, Gulf Stream, etc.) or topographic features (e.g. Lahave Bank, Georges Bank, etc.). Monthly anomalies were determined by subtracting the long-term monthly averages for the 20-yr period 1971-1990.

The monthly anomalies for the 24 areas are listed in Table 1 and are contoured in Fig. 5. High negative anomalies (up to 3°C) were centered over the northern regions from the Labrador Coast to Western Grand Banks during the spring and summer months. This is consistent with the very cold conditions documented in NAFO subareas 2J3KL by Narayanan et al. (1992). Temperatures in these areas tended to reach above normal late in the year. In the Gulf of St. Lawrence and off southwestern Newfoundland (area SP) significant warm water anomalies were observed during the autumn. From the southern Scotian Shelf to the Mid-Atlantic Bight there was a predominance of positive anomalies throughout the year with maximum values in the southern most shelf area during the spring and early summer. In the Western Shelf Area negative anomalies were observed in all months except December.

The time series of annual mean anomalies of SST including 1991 for the 24 areas are shown in Fig. 6. As with the monthly values, the annual anomalies indicate very cold conditions in 1991 along the Labrador Shelf, throughout the Grand Banks, on Flemish Cap, and off southeastern Newfoundland. The 1991 values were of similar amplitude to the temperature anomaly minima recorded in 1985 and in the mid-1970s. The temperatures have declined in these regions by 1-2°C from highs in 1988. In the Gulf of St. Lawrence, off southwestern Newfoundland and on the eastern Scotian Shelf, the annual anomalies were near normal with a slight tendency towards positive values. The amplitude of the positive annual temperature anomalies increased southward with maximum values in the mid-Atlantic Bight. The opposing temperature trends on the Grand Banks and the mid-Atlantic Bight fit the 2nd mode of variability in an EOF analysis of SST in the region as determined by Thompson et al. (1988). The oscillating temperature trends between these two areas has been prominent through the 1980s and into the early 1990s. In the Slope Water during 1991 the eastern area was warmer-than-normal while the western region was colder-than-normal. Temperature variability in the Gulf Stream and Sargasso Sea was low throughout the period 1971-91.

Hydrographic Stations

(1) Prince 5 Temperatures and Salinities

Temperature and salinity measurements are taken once per month at Prince 5, a station off St. Andrews, New Brunswick, near the entrance to the Bay of Fundy (Fig. 1). Monthly anomalies relative to the 1951-80 means were calculated for 1991. Single measurements per month, especially in the surface layers in the spring or summer, under stratified conditions are not necessarily representative of the "average" conditions for the month and therefore the interpretation of the anomalies must be viewed with some caution. No significance should be placed on any individual anomaly but persistent anomaly features are likely to be real. There is generally strong similarity in the anomaly patterns of both temperature and salinity in all years throughout the water column. This relative homogeneity of the water column is due in large part to the strong tidal mixing in the Bay of Fundy.

In 1991 temperatures ranged from a minimum of approximately 2.5°C to a maximum of 11.5°C in August and near surface in September (Fig. 7). This resulted in positive anomalies of generally > 0.5°C in the upper 50 m and typically < 0.5°C below 50 m (Fig. 7). Slightly negative anomalies were observed in the near surface waters (< 25 m) during the last 4 months of the year but only during September and October did they extend throughout the water column. Waters at and below 50 m during November and December were above normal. The long-term temperature records at surface and 90 m for Prince 5 show high similarity (Fig. 8). The temperature anomalies were near normal but had increased from below normal values in the late 1980s. The dominant high and low were in the early 1950s and the mid 1960s, respectively.

Salinities in April fell to less than 29 which resulted in negative anomalies exceeding 2 psu (Fig. 7). This was probably due to an early freshwater discharge from the Saint John River but the values may not be representative of the mean for the month. The general trend was for fresher-than-normal conditions throughout the year with the exception of the late spring and early summer. Relatively high negative anomalies were observed in the late autumn.

(2) Emerald Basin Temperatures

Petrie et al. (1991) assembled a time series of monthly temperature data from 1946 to 1988 at multiple depths in Emerald Basin (Fig. 1). They showed that there was high temperature variance at low frequencies (periods of several years). This low-frequency signal was more visible at depth (below 75 m) where the variance was higher and there was less high-frequency (month to month) variability. High coherence was found at these low frequencies throughout the water column as well as horizontally from the mid-Atlantic Bight to the Laurentian Channel. In 1991, at the request of the AFAP Shelf Climate Working Group (see Drinkwater 1992), several CTD

profiles were obtained in Emerald Basin by research cruises in the area. The time series of temperatures from 250 m are plotted in Fig. 9 as anomalies from the monthly means averaged over the period 1951-80. Below normal temperatures of approximately 1°C were observed in 1991. These values represent a 3°C drop since the late 1980s. The trends at 250 m were representative of the waters below 75 m. Consistent with Petrie et al. (1991), salinities were positively correlated with temperatures, hence these cooler temperatures in Emerald Basin were accompanied by fresher then normal conditions.

(3) Laurentian Channel Temperatures

Long-term temperature variability in the deep waters (200-300 m average) of the Laurentian Channel in the Gulf of St. Lawrence has been studied by Bugden (1991) from data collected between the late 1940s to 1988. The variability was dominated by low-frequency (decadal) fluctuations with no discernible seasonal cycle. A phase lag was observed along the major axis of the channel such that events propagated from the mouth towards the St. Lawrence Estuary on time scales of several years. The time series for Cabot Strait has recently been updated (Bugden, BIO, personal communication). The data show that in recent years temperatures have steadily declined such that by November, 1991, the average temperatures in 200-300 m depth range had fallen to near 4.5°C (Fig. 10). This is the lowest mean deep water temperature in Cabot Strait since the late 1960s.

Ice

(1) Sea Ice in the Gulf of St. Lawrence

During early December, a record cold Arctic air mass accompanied by moderate northly to northwesterly winds covered the Gulf of St. Lawrence. By mid-December cumulative freezing degree days were up over the long term mean by 300% over the northern Gulf and an order of magnitude in the southern Gulf. This resulted in pack ice in Northumberland Strait and along the New Brunswick coast, the formation of new ice in the St. Lawrence Estuary and fast ice along sections of the North Shore of Quebec (Fig. 11). These ice conditions were about 3 weeks ahead of normal. By the end of December ice covered the Strait of Belle Isle, the Bay of Chaleur, and along the northern coast of New Brunswick which was near normal for that time of the year. At mid-January new ice formed over the central and northeastern regions of the Gulf, slightly earlier than normal, while over the western Gulf the ice thickened (Fig. 11). Cold air temperatures persisted through January which continued to increase the thickness and areal extent of the sea ice. The extent and thickness of the ice cover by mid-February remained greater than normal due to the persistent cold temperatures (Fig. 11). Ice began to drift through Cabot Strait with some reaching 45°N and 58°W. By the end of the month the ice had moved westward on the Scotian Shelf to Chedabucto Bay. Ice thickness still exceeded normal by mid-March but open areas developed along western Newfoundland, along the south shore of Prince Edward Island, around the Gaspe Peninsula, and along parts of the north

shore of Quebec (Fig. 11). Continued cold air temperatures during April meant that ice conditions were typically 2 weeks later than normal during that month. Warmer-than-normal temperatures in May lead to rapid melting so that by mid-May the only ice in the Gulf was that in the northeastern Gulf. Through June and into mid-July ice continued to drift into the Gulf through Belle Isle Strait due to the persistence of ice on the Labrador and Newfoundland shelves. Mid-July for the last presence of ice in the Belle Isle region set a new record. Normally ice leaves the region by late April.

(2) Icebergs

The number of icebergs drifting south of 48°N latitude in each year is monitored by the International Ice Patrol Division of the United States Coast Guard. Data are collected using SLAR (Side-Looking Airborne Radar). During the 1990/91 iceberg season (October to September), a total of 1754 icebergs were spotted south of 48°N. The monthly totals for February to August were, respectively, 20, 115, 144, 269, 1030, 325, and 71. No icebergs were spotted before February and after August. The number of icebergs detected in 1991 were twice that in 1990 and 6-9 times that recorded in the other years since the introduction of SLAR in 1986 (Fig. 12). The heavy concentrations of sea ice and their late persistence off Labrador and northern Newfoundland (Narayanan et al. 1992) contributed to the preservation of the icebergs through reduced wave action and maintaining low sea surface temperatures. The increased easterly winds also would have kept the icebergs inshore in the colder waters longer.

AIR TEMPERATURE

The Atmospheric Environment Service of Canada publishes the monthly mean air temperature anomalies for Canada in the Monthly Supplement to Climatic Perspectives. The 1991 monthly anomalies are plotted in Fig. 13. Of particular significance is the large negative anomalies in the winter and spring reaching upwards of -8°C below normal on the southern Labrador Coast in January. On the Labrador Coast and in Newfoundland air temperatures were below normal during 9 months of the year. In contrast, air temperatures over the southern Gulf of St. Lawrence and in Nova Scotia were above normal during 9 months of the year. In December of 1991 air temperature anomalies through the region were negative with the largest values over southern Labrador.

The annual air temperature anomaly pattern again highlights the very cold conditions along the Labrador and off northern Newfoundland with negative values of over 2°C. These exceeded the standard deviations of the long-term means by approximately 1°C. Slightly negative anomalies prevailed over most of the Gulf of St. Lawrence while in the southeastern Gulf and off Nova Scotia the annual air temperature anomalies were positive.

SUMMARY

In 1991 very cold conditions were observed in the waters off north and eastern Newfoundland. The SST data presented herein indicate that the spatial extent of the anomalies covered all of the Grand Banks, Flemish Cap and the Labrador Shelf. Temporally the largest anomalies occurred during the late spring and summer months. These anomalies resulted in below normal annual mean SSTs for these regions. Warmer-than-normal conditions persisted from the Scotian Shelf to the mid-Atlantic Bight with the amplitude of the anomalies increasing southward. Increasing positive anomalies in SST southward was also seen in the annual coastal station data. These gradients in ocean temperatures coincided with a similar north south gradient in air temperatures. The deep waters in the Laurentian Channel at Cabot Strait (200-300 m) and in Emerald Basin (250 m) recorded much colder water than normal. Temperatures were the lowest in a decade in Emerald Basin and in two decades in Cabot Strait. These cold conditions were not observed in the bottom waters at the mouth of the Bay of Fundy (Prince 5), however. Sea ice arrived early in the Gulf of St. Lawrence, spread more rapidly than normal, and in the region of the Strait of Belle Isle sea ice persisted longer than every before remaining until mid-July. This was due to advection of ice from off Labrador and northern Newfoundland.

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Table 1. Monthly SST anomalies in degrees Celsius for 1991 from the long-term base period 1971-90. The area names are shown on Fig. 4.

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
CF	-0.81	-0.25	0.78	0.68	0.54	0.53	1.26	0.08	-0.21	0.40	-0.64	-1.23
LS	-0.12	-0.32	0.07	-0.32	0.78	-	-0.31	-0.86	-0.21	-0.02	-0.14	0.29
LCS	-0.68	-	0.85	0.19	-	-2.18	-0.27	-1.38	-0.64	-0.01	0.52	-0.49
OLC	-0.46	-0.46	-0.28	0.53	-0.59	-2.23	-2.21	-2.53	-1.39	-0.10	0.34	-0.28
ILC	0.35	0.21	0.10	0.07	-1.25	-1.74	-1.65	-1.39	-1.50	0.25	1.11	0.47
FC	-0.49	-0.16	-0.42	-0.64	-1.27	-1.65	-1.51	-2.83	-0.54	-0.76	-	0.06
CGB	-0.09	-0.06	-0.35	-0.43	-0.85	-1.99	-3.10	-1.80	-0.81	-0.22	0.46	0.47
WGB	-0.38	0.09	-0.11	-0.35	-0.47	-1.49	-2.54	-1.76	-1.22	0.02	0.96	-0.25
SP	0.59	-0.27	-0.04	0.11	0.24	0.53	-0.02	-0.86	-1.22	2.22	1.14	0.42
GSL	-0.74	-0.89	-0.45	0.33	0.43	0.05	-0.01	0.17	-0.48	1.10	1.27	0.65
ESS	0.65	0.22	0.48	0.36	-0.07	0.39	0.33	-0.53	-0.78	0.47	1.07	0.11
SI	0.02	0.16	0.20	0.01	-0.15	-0.55	-0.96	-0.70	-0.47	-0.09	-0.11	-0.28
SH	0.04	0.32	-0.11	0.74	-	-0.18	-0.39	0.11	-2.15	0.46	0.37	0.98
LHB	0.23	-0.01	1.66	0.82	0.69	1.14	0.34	0.91	0.13	0.89	0.67	-0.22
BR	-0.07	0.24	0.89	0.06	1.47	0.76	0.13	0.29	-0.54	0.46	0.14	1.32
Y	0.37	0.15	0.58	0.30	-0.62	0.52	0.40	-0.57	-1.09	0.31	1.17	1.18
GOM	0.26	0.30	0.13	0.41	-	0.76	-0.44	-0.26	-0.28	0.29	-0.32	0.13
GB	0.16	1.03	0.72	0.39	1.36	0.99	0.34	-0.46	-0.62	0.84	-0.53	-0.12
SNE	0.33	0.62	0.65	1.53	2.62	-0.41	1.08	-0.01	-0.01	2.30	0.34	-0.19
MAB	-0.15	1.51	1.70	1.72	2.56	1.10	1.34	0.35	0.24	0.35	0.03	0.36
ESW	1.44	-1.33	-0.70	0.12	-0.15	-1.79	-1.80	-0.43	-0.39	0.23	0.68	1.24
WSW	-0.10	-1.31	-0.72	-0.94	-0.35	-0.09	-0.20	-0.73	-0.87	-1.75	-0.92	0.47
GS	0.19	-0.44	-0.20	0.81	1.26	0.28	0.42	-0.14	0.26	-0.53	-1.32	-0.43
SS	0.66	0.45	0.57	0.35	-0.11	-0.24	-0.67	0.12	-0.50	-0.18	0.03	-0.06

CF - Cape Farewell
LS - Labrador Shelf
LCS - Labrador Coast
OLC - Outer Labrador Current
ILC - Inner Labrador Current
FC - Flemish Cap
CGB - Central Grand Bank
WGB - Western Grand Bank
SP - St. Pierre
GSL - Gulf of St. Lawrence
ESS - Eastern Scotian Shelf
SI - Sable Island Bank
SH - South Shore
LHB - LaHave Bank
BR - Browns Bank
Y - Yarmouth
GOM - Gulf of Maine
GB - Georges Bank
SNE - Southern New England
MAB - Mid-Atlantic Bight
ESW - Eastern Slope Water
WSW - Western Slope Water
GS - Gulf Stream
SS - Sargasso Sea

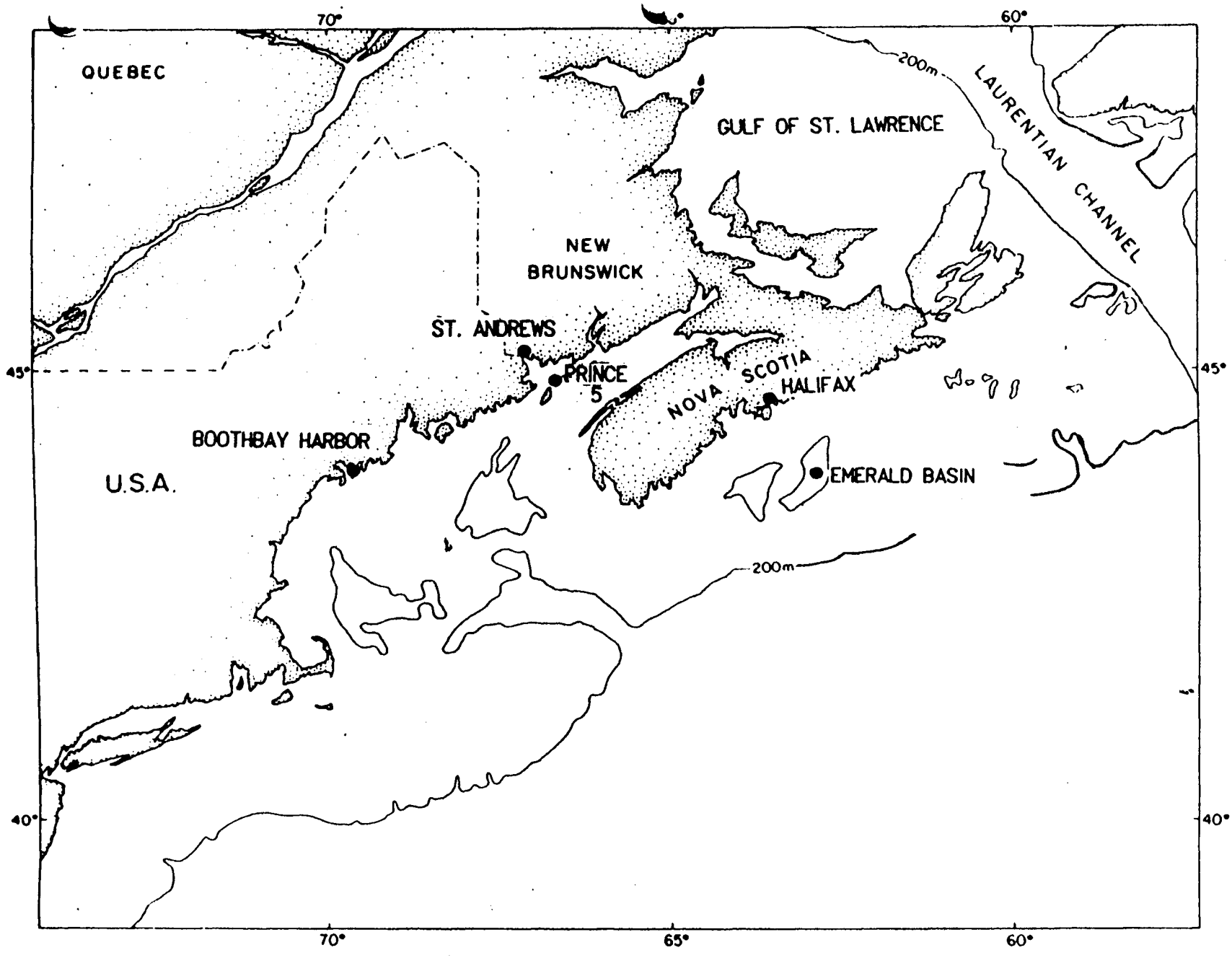

Fig. 1. Map showing coastal and offshore hydrographic stations.

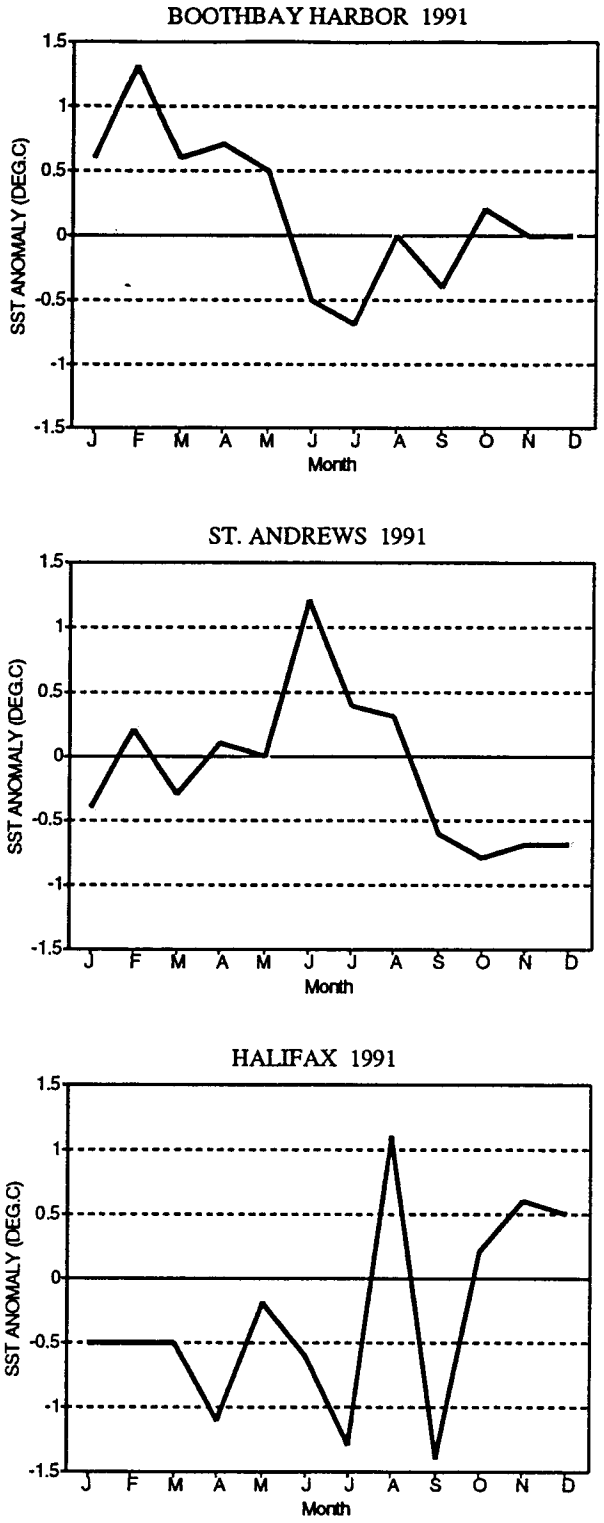

Fig. 2. Monthly SST anomalies at coastal sites in 1991 from 1951-80 mean.

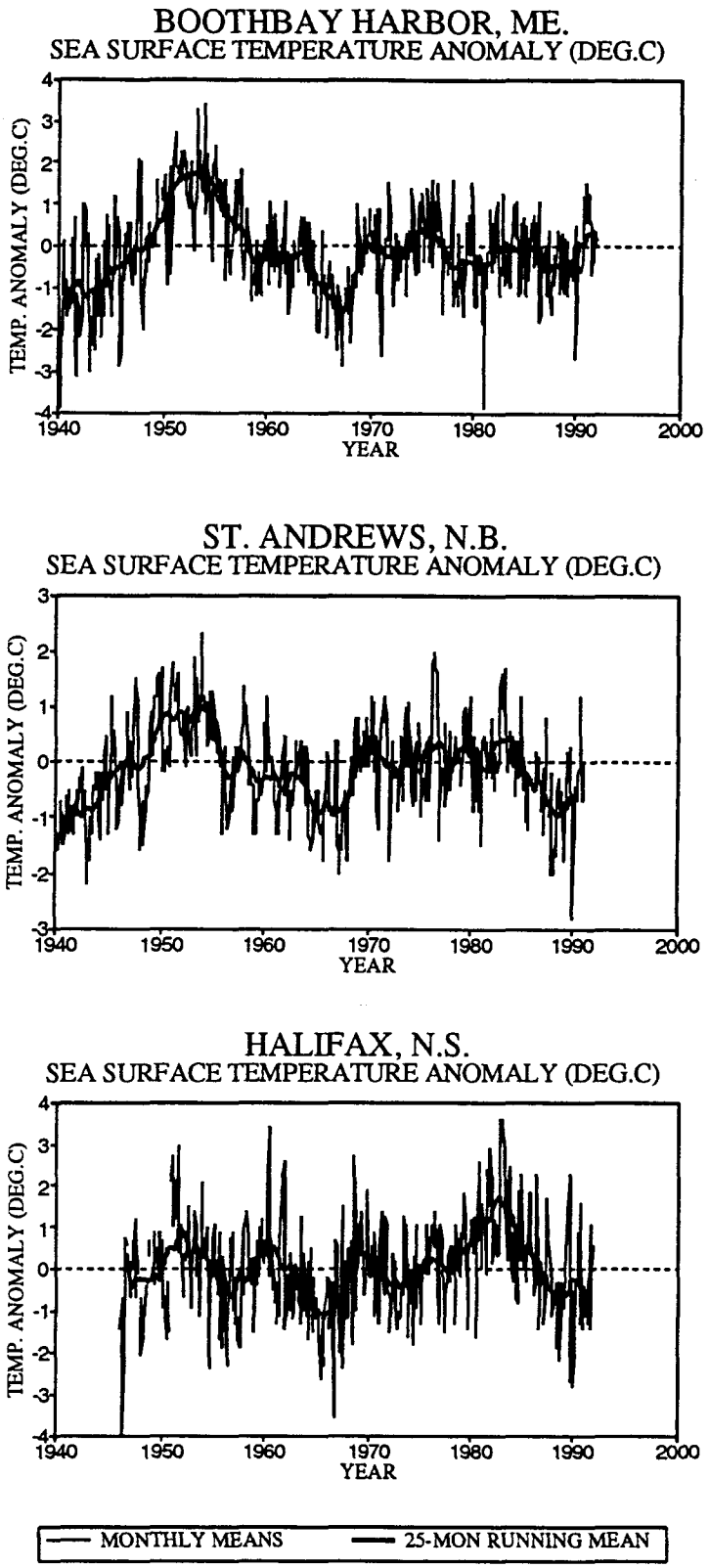

Fig. 3. Monthly and 25-month running mean of SST anomalies (from 1951-80 means) at coastal sites.

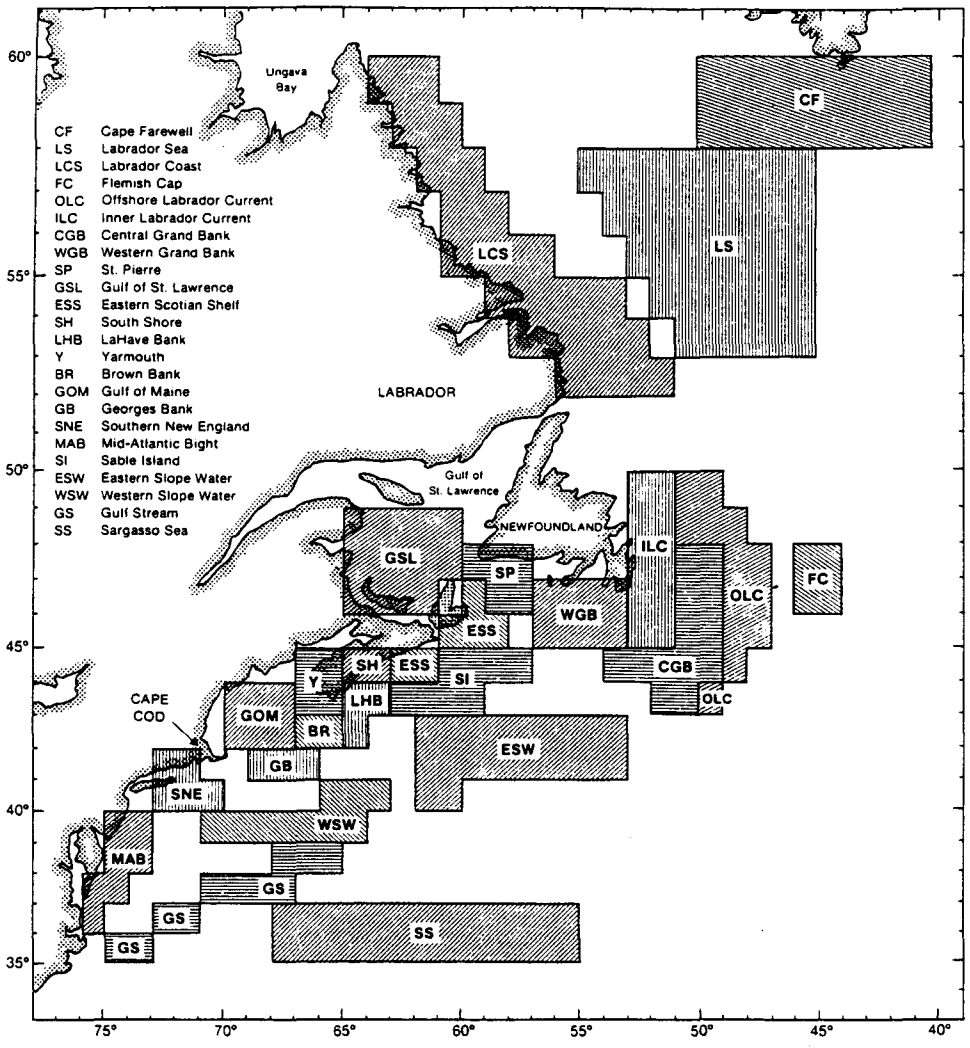

Fig. 4. Map showing areas for which SST data were averaged.

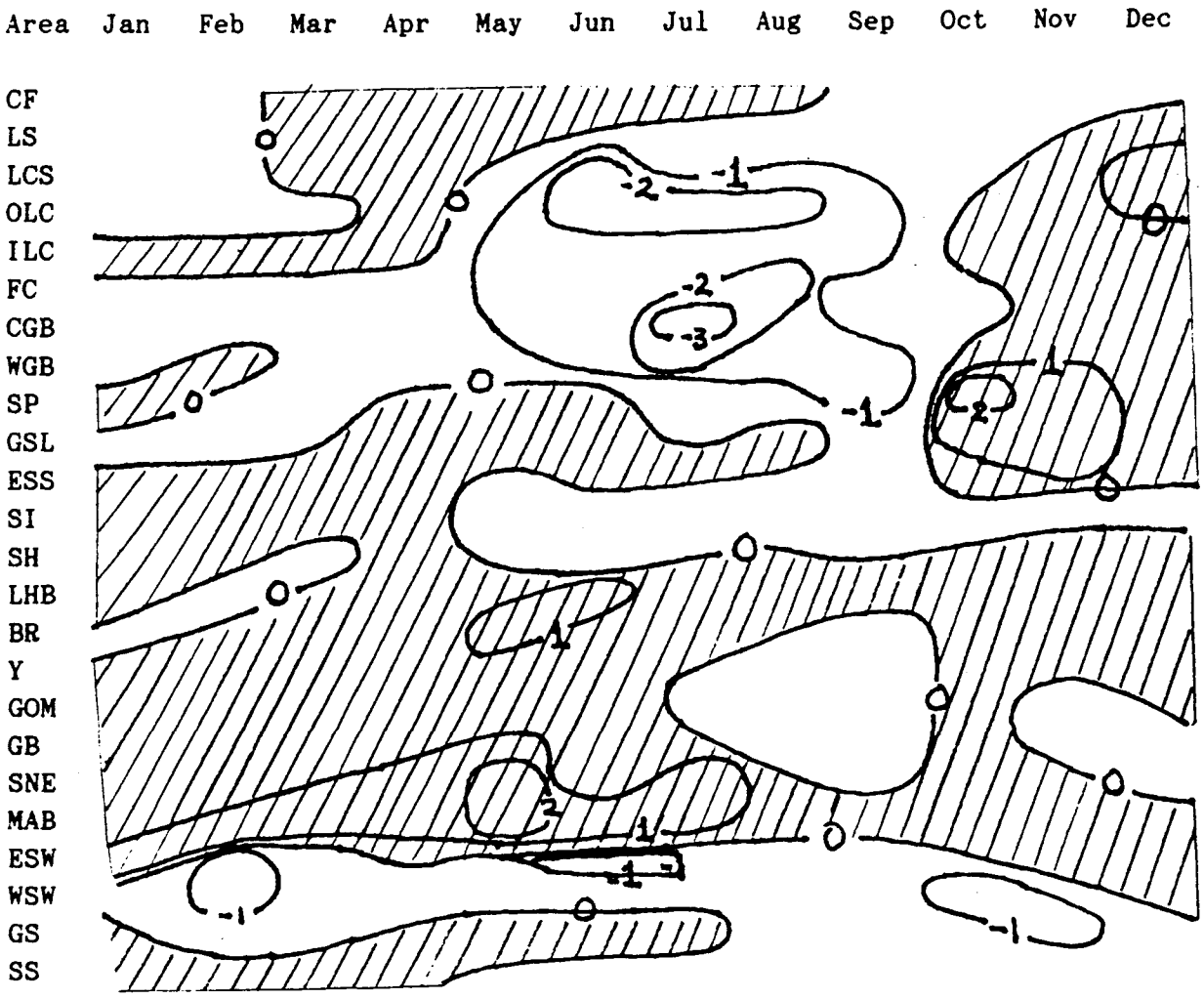

Fig. 5. The monthly anomalies of SST in offshore areas in 1991 from 1971-90 mean. Positive anomalies are shaded.

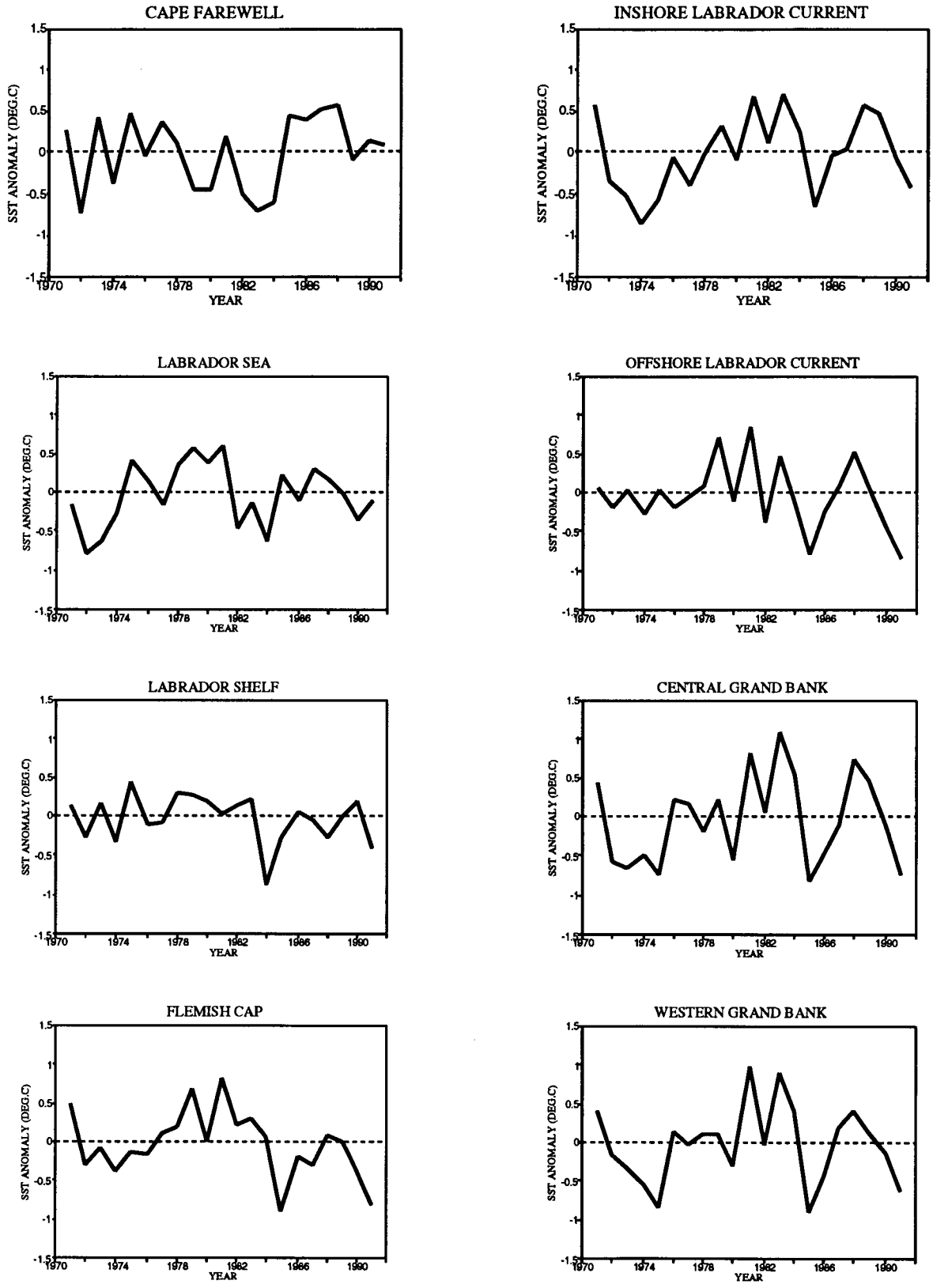

Fig. 6A. The annual anomalies of SST (relative to 1971-90) for the offshore areas - Cape Farewell to Western Grand Bank.

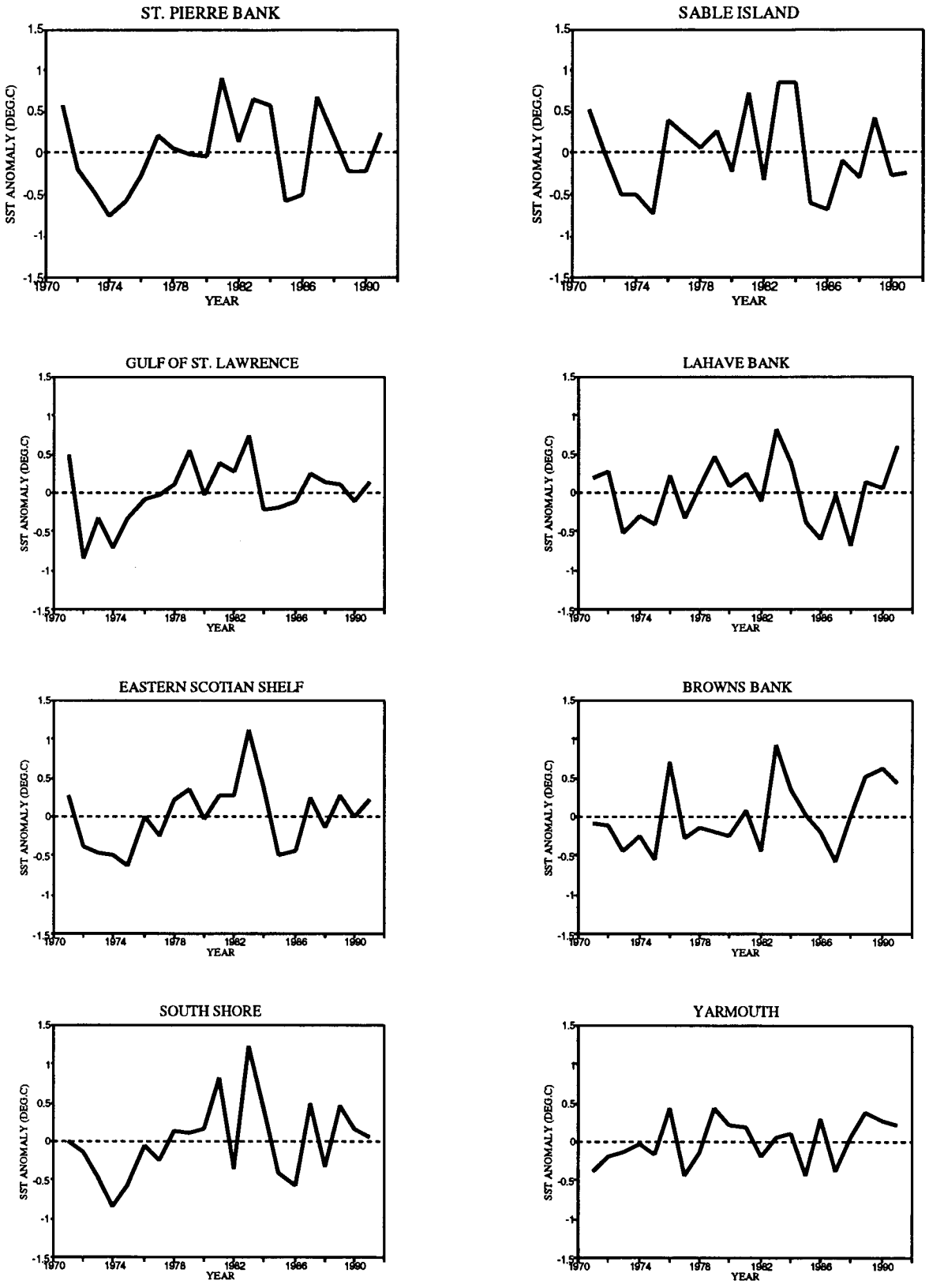

Fig. 6B. The annual anomalies of SST (relative to 1971-90) for the offshore areas - St. Pierre Bank to Yarmouth.

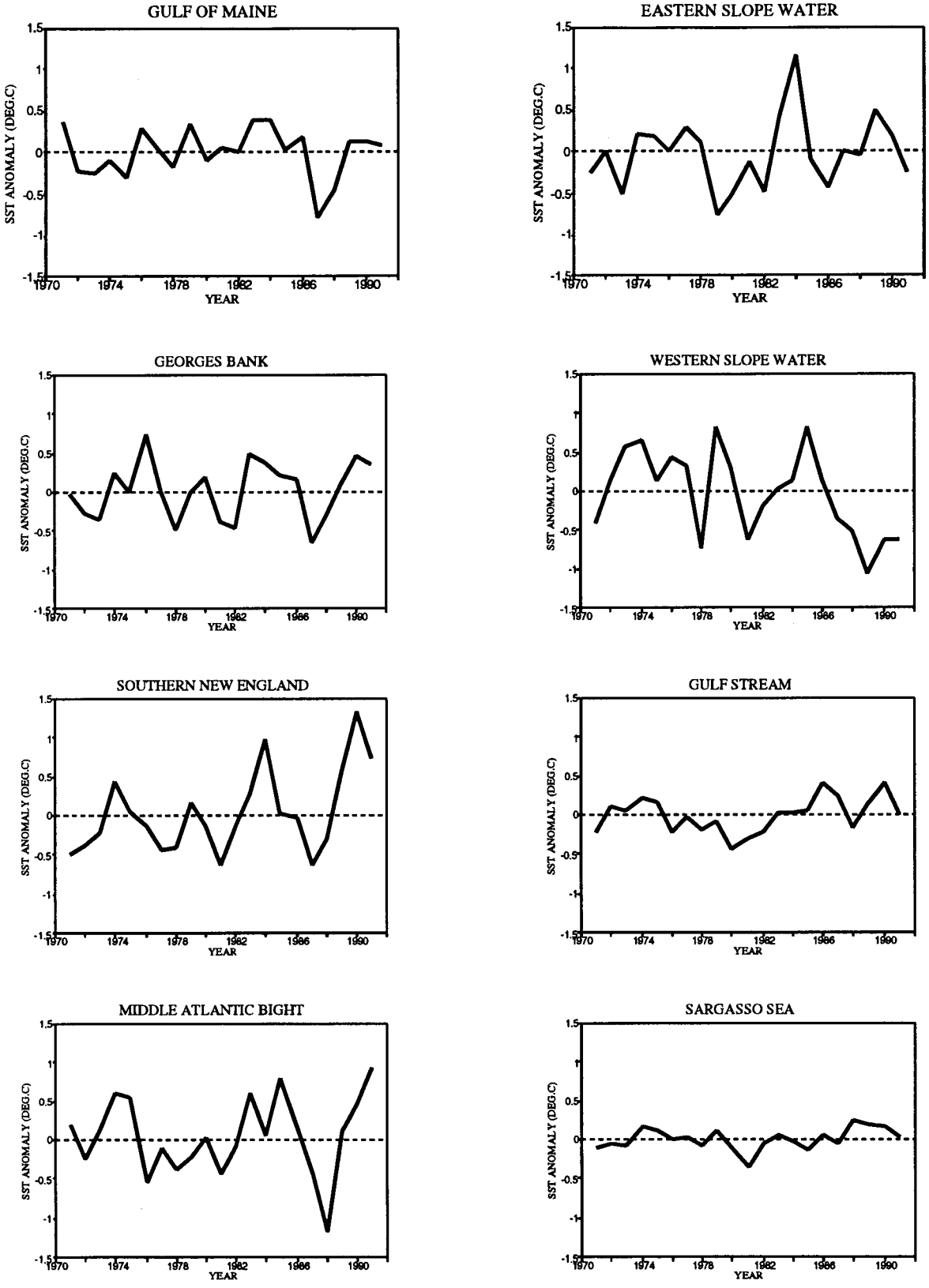

Fig. 6C. The annual anomalies of SST (relative to 1971-90) for the offshore areas - Gulf of Maine to the Sargasso Sea.

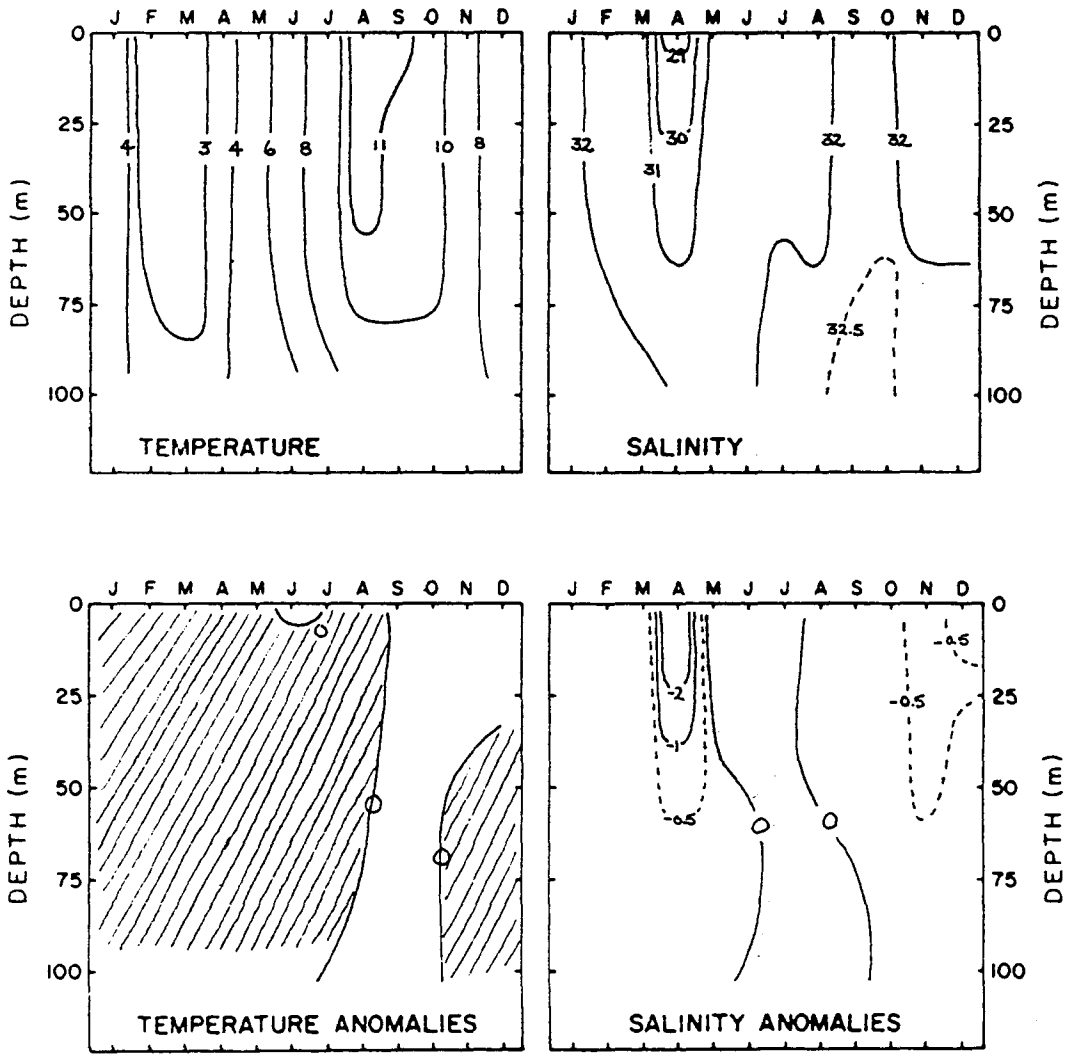

Fig. 7. Monthly temperature and salinity values and anomalies at Prince 5 in 1991. Anomalies are relative to 1951-80 mean. Positive anomalies are shaded.

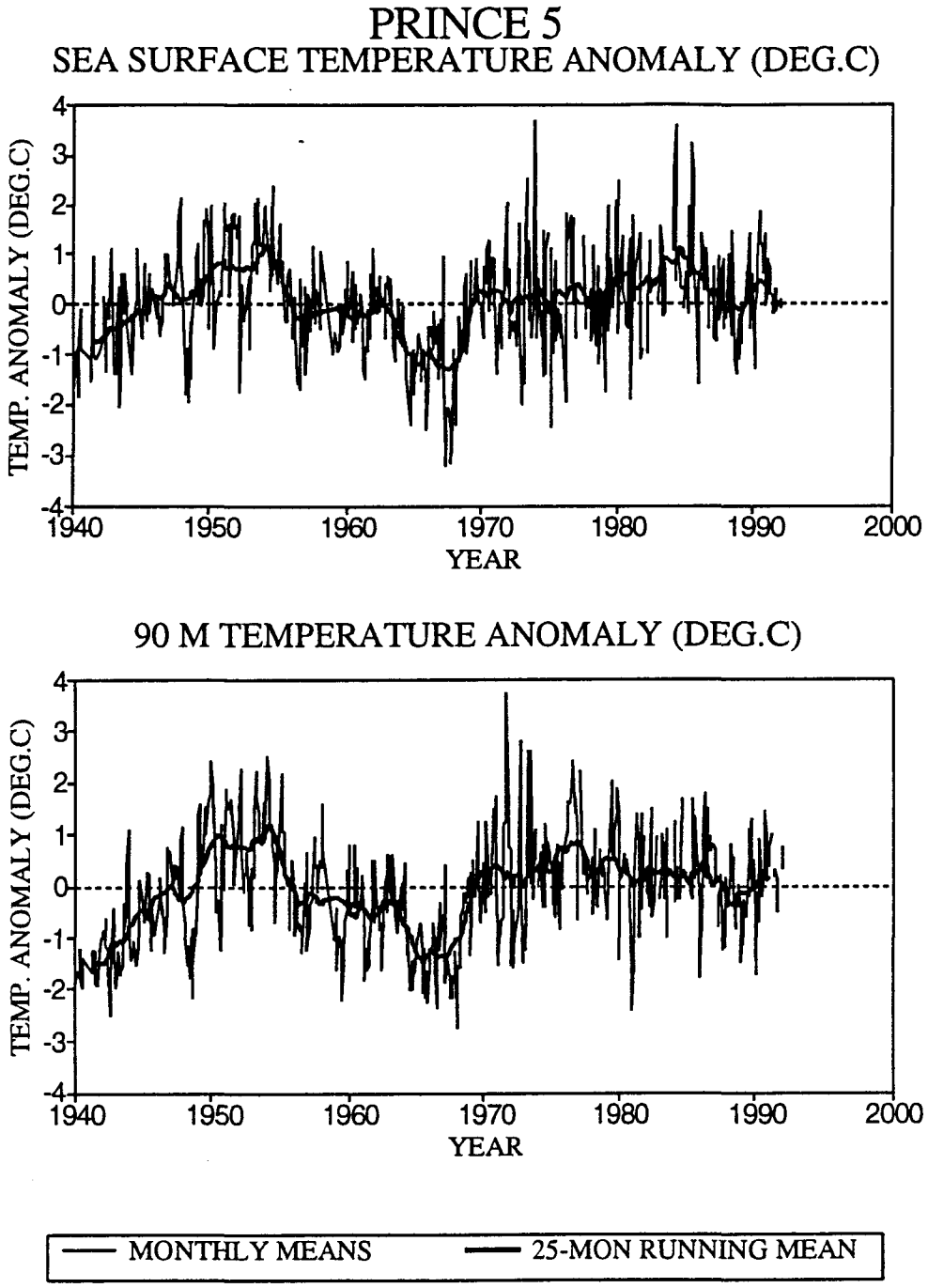

Fig. 8. Monthly and 25-month running means of temperature anomalies (relative to 1951-80 means) at Prince 5 for 0 and 90 m depth.

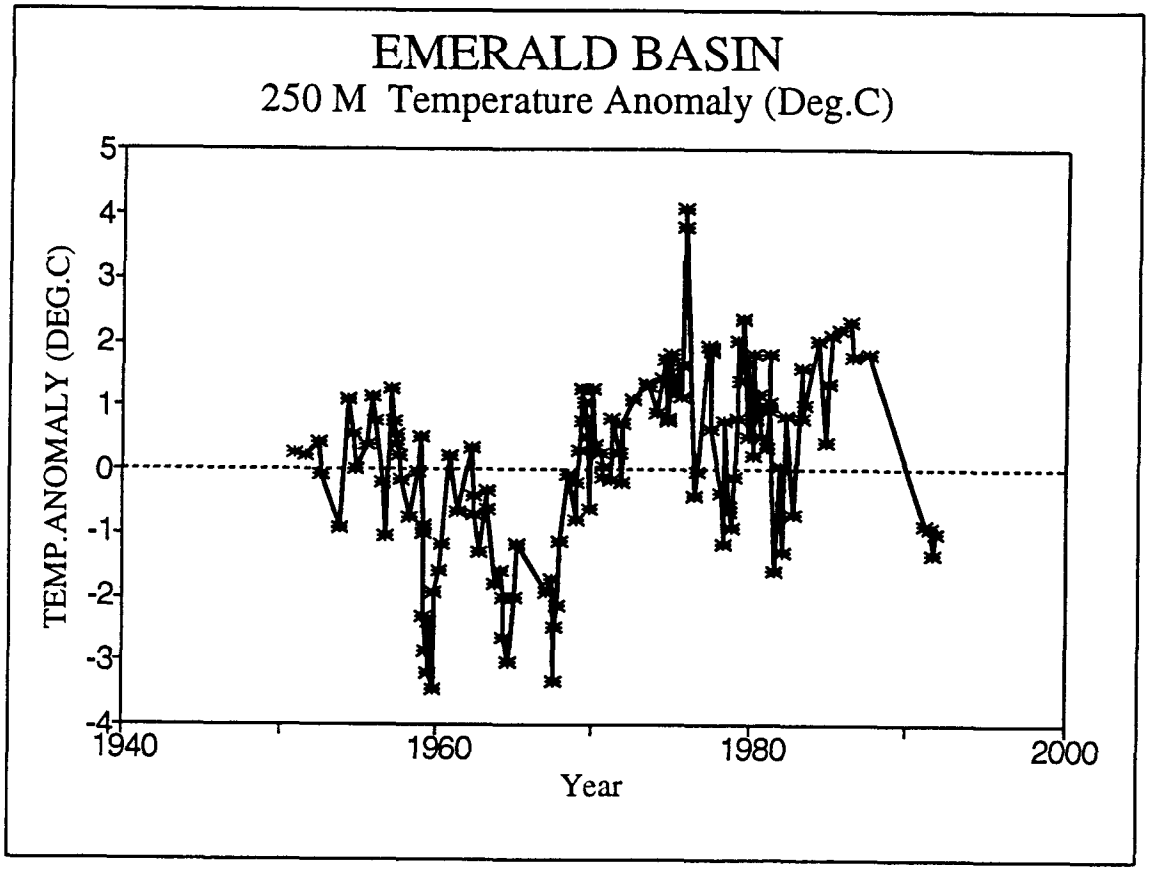

Fig. 9 Temperature anomalies (relative to 1951-80) at Emerald Basin at 250 m.

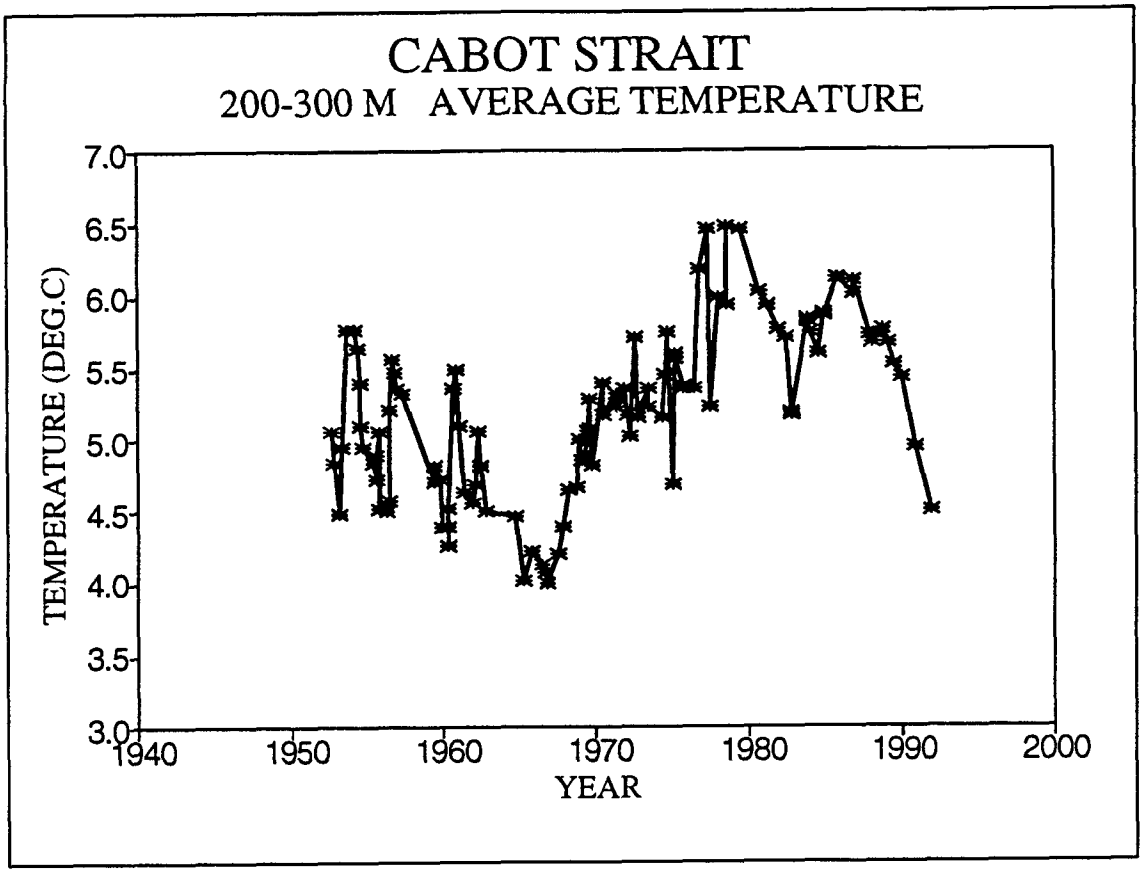

Fig. 10 Mean temperatures for 200-300 m in Cabot Strait.

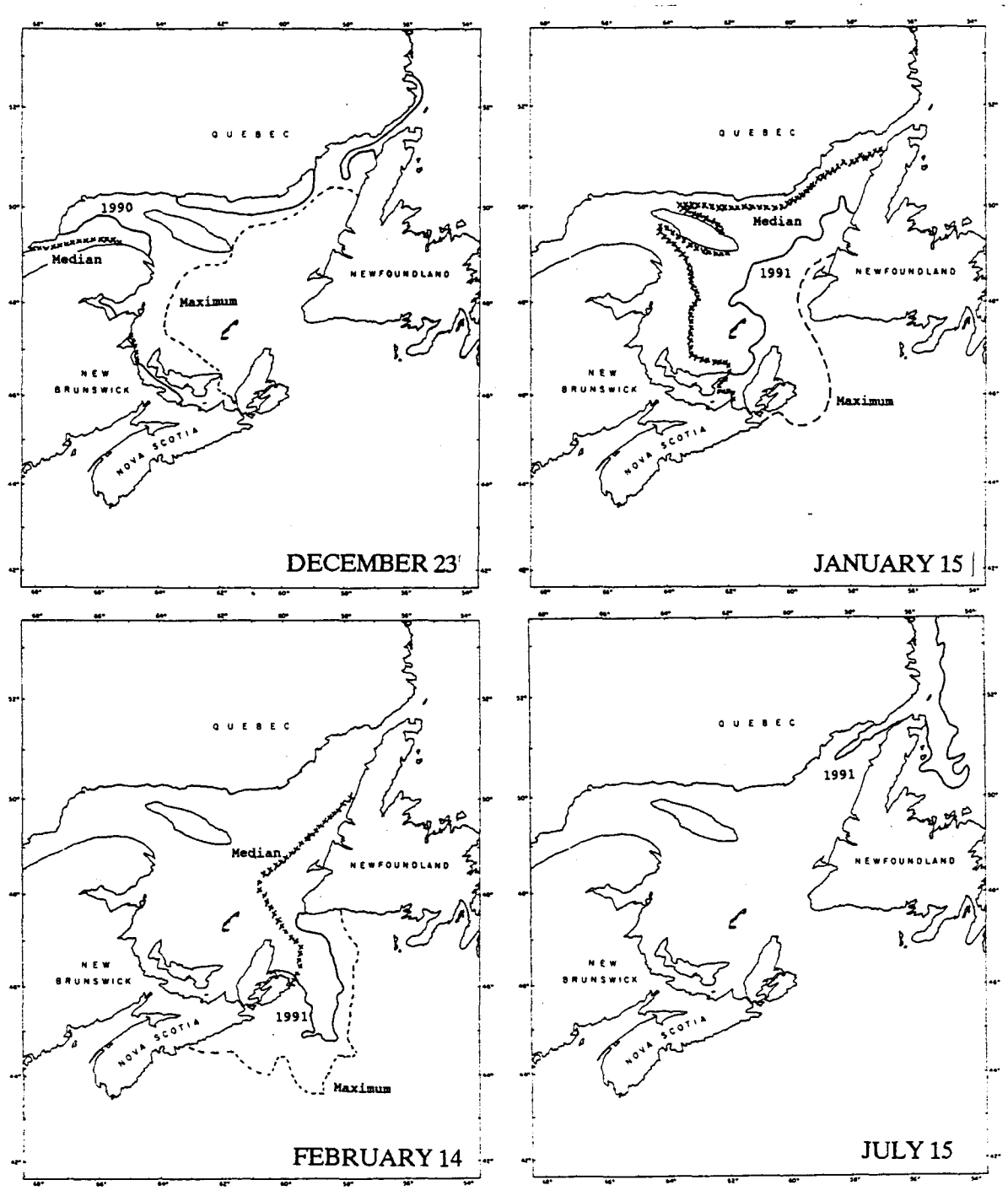

Fig. 11 Sea ice distributions over time for the Gulf of St. Lawrence showing the 1991, median, and maximum ice edges. The median and maximum are taken from Coté (1989).

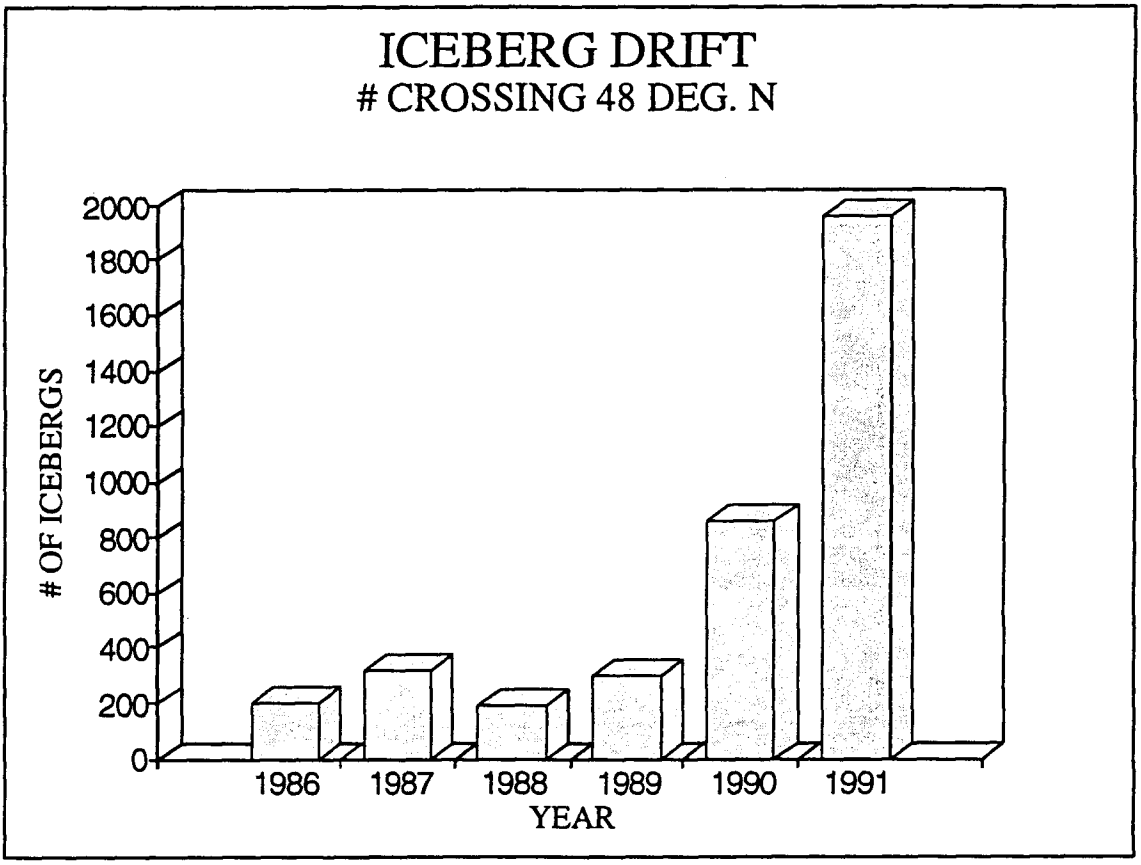

Fig. 12 Number of icebergs crossing 48°N latitude between October of the previous year and September.

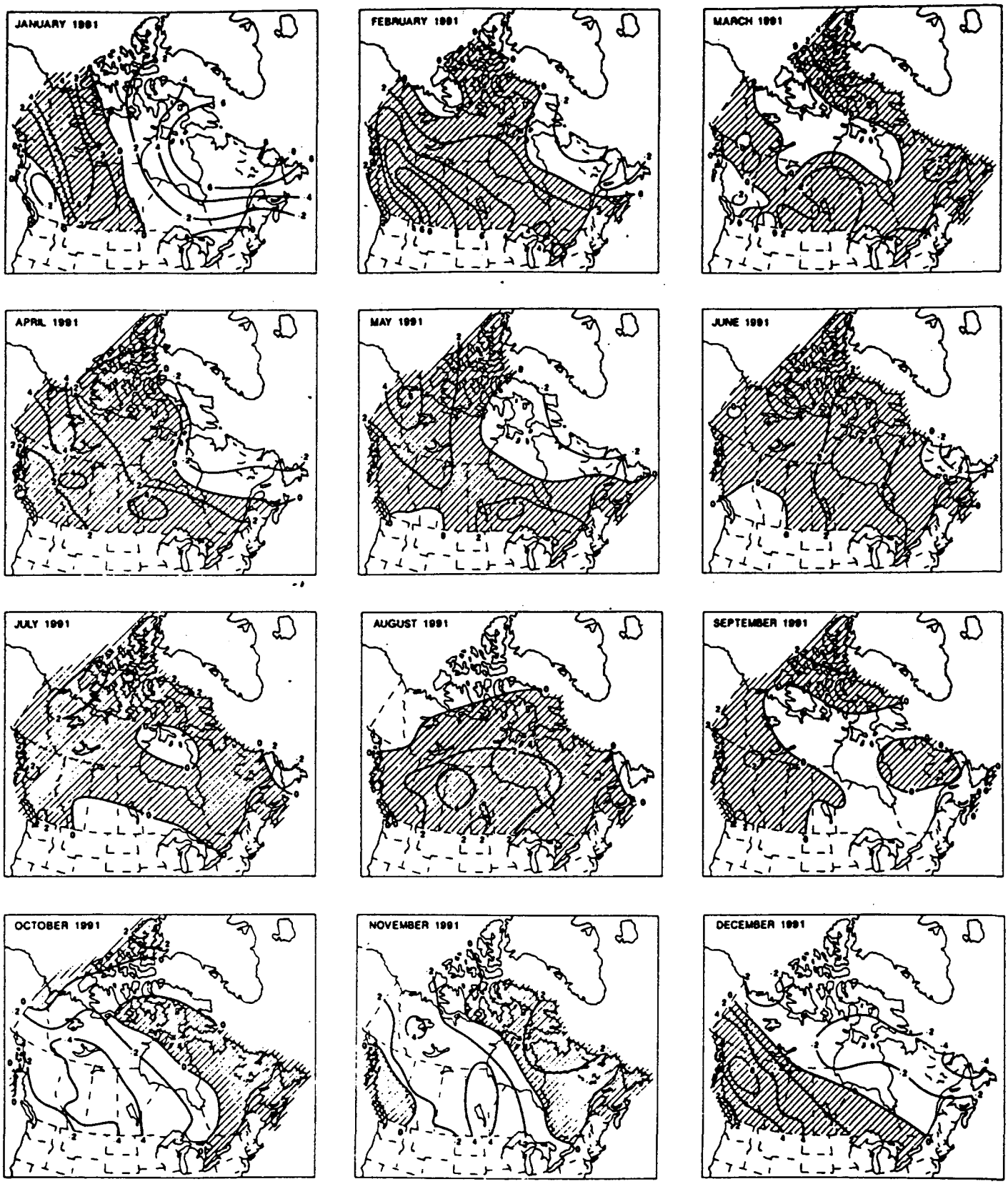

Fig. 13 Monthly air temperature anomalies (°C). Positive anomalies are shaded.

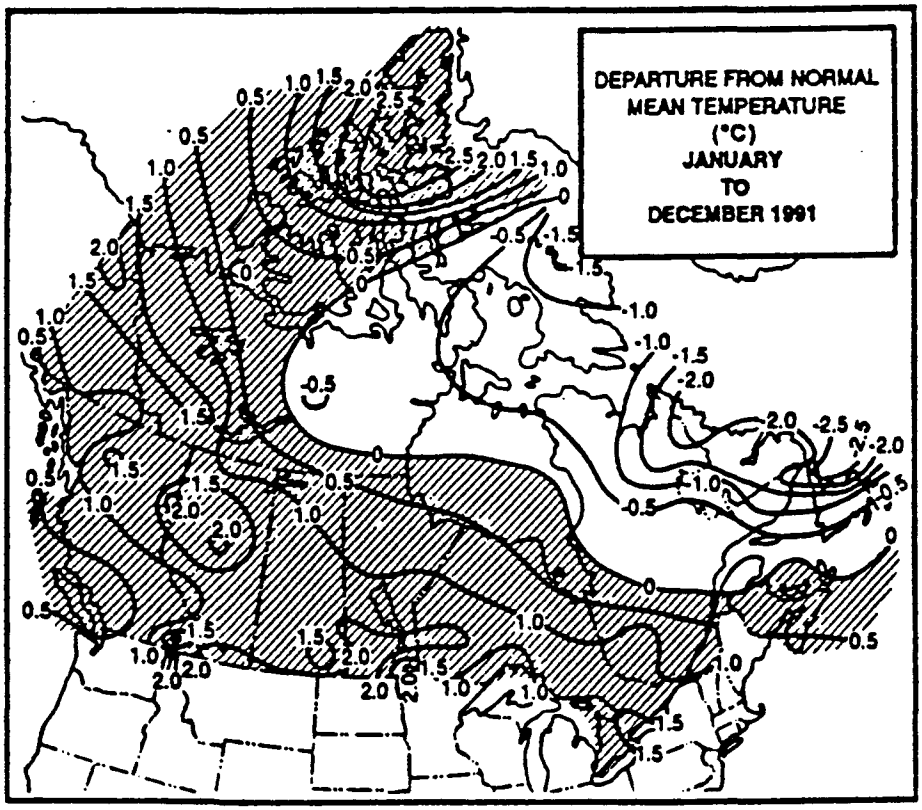

Fig. 14 Annual air temperature anomalies (°C). Positive anomalies are shaded.