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Overview of Environmental Conditions in the Northwest Atlantic in 1989

by

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ABSTRACT

Environmental conditions in the Northwest Atlantic during 1989 are summarized from time series of oceanographic and meteorological data such as those from fixed stations and the repetitive coverage of surface conditions by satellites and ships of opportunity. Of particular note is above normal summertime temperatures covering most of the shelf from the mid-Atlantic Bight to southern Labrador. Extreme cold conditions (sea surface temperature anomalies exceeding -2°C) were observed over much of the NAFO region during December, 1989.

INTRODUCTION

This paper provides a brief review of environmental conditions in the Northwest Atlantic during 1989.. As in previous reviews (Trites and Drinkwater 1984, 1985, 1986, MS 1989; Drinkwater and Trites 1987, 1988, 1989), it is based on selected sets of oceanographic and meteorological data as well as information from national research reports and other research documents prepared for the NAFO Scientific Council. Conditions are compared with those of the preceding year and the long-term means. The latter have been standardized to a 30-yr base period (1951-1980) in accordance with the convention of the World Meteorological Organization and recommendation of the NAFO Scientific Council. Where 30 years of data were unavailable, 20-yr or 10-yr base periods were used, where possible.

OCEANOGRAPHIC OBSERVATIONS

Coastal sea-surface temperatures

Monthly averages of sea-surface temperature (SST) are available from Halifax 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 1988 and 1989 are shown in Figure 2.

During 1989 negative anomalies were predominant at St. Andrews, continuing a trend that began near the end of 1987. Maximum negative temperature anomalies occurred early and late in the year (-1.8°C in April, -2°C in December) with summertime temperatures approaching near normal. At Halifax, the temperature anomaly pattern was similar to that at St. Andrews with cold temperatures in winter of 1988/89, warming up in summer and ending 1989 with extremely cold temperatures. In contrast to St.

Andrews, however, the Halifax summer temperatures were well above normal. The greatest positive and negative temperature anomalies at Halifax in 1989 were in July (2.3°C) and December (-2.8°C), respectively. At Boothbay Harbor, the monthly temperature anomalies were also predominantly negative, with only September and November showing above normal temperatures. The maximum negative anomaly occurred in December matching the extreme cold conditions observed at Halifax and St. Andrews.

The annual SST anomalies at all sites were below their long-term means (Fig.3). The annual mean was 7.6°C at Halifax (0.2°C below normal), 6.5°C at St. Andrews (0.8°C below normal) and 8.2°C at Boothbay Harbor (0.6°C below normal). At Halifax, the annual mean exceeded last years value by 0.8°C and reversed the downward trend observed over the past several years, at least temporarily. At Boothbay Harbor the mean temperature decreased slightly relative to that of 1988 while at St. Andrews the annual mean rose from the extreme low temperature recorded in 1988. The missing data in Fig. 3 were due to instrument malfunctions at Halifax and extensive wharf reconstruction at St. Andrews.

Offshore sea-surface temperatures

The pattern of monthly SST anomalies along the continental shelf from Chesapeake Bay to southern Labrador (Fig.4) for 1971-87 described by Trites and Drinkwater (1989) was examined for 1989 and compared to earlier years (Fig. 5). Near normal temperatures were present throughout the entire area for the first four months of the year, followed by above-normal values during spring and early summer with temperatures elevated between 2 and 3°C. For the year as a whole, the Georges Bank area displayed minimum variations from normal.

Sea-surface temperature anomalies for a large region of the Northwest Atlantic (35°-60°N, 40°-76°W), which extends from the southern boundary of the NAFO area northward to southern Greenland (Fig. 6) and is divided into 24 smaller areas to coincide with major water masses (Labrador Current, Gulf Stream, etc.) or fishing banks (Lahave, Georges, etc.) were reported by Trites and Drinkwater (1985) for 1972 to 1983 (compared with the 1972-80 base period) and were extended by Drinkwater and Trites (1987, 1988, 1989) for 1984-1987 and by Trites and Drinkwater (MS 1989) for 1988. The monthly mean temperature for each of the 24 areas was computed for 1989. The annual anomalies for 1985 to 1988 relative to the 1972-80 base period and the mean annual temperature for the base period are shown in Table 1. A space-time plot of the annual anomalies for the 24 areas during the 1972-89 period is shown in Fig.7.

The 1989 pattern indicates that the positive anomalies present in the Labrador Current-Grand Banks areas in 1988 have persisted and expanded southward to include all but one of the remaining regions. The positive mean annual temperatures were primarily a result of high summertime values. The only region that experienced below normal temperatures was the Western Slope Water area, whose anomaly of -1.36°C was the largest over the past 18 years.

Temperature and salinity stations

Station 27. Measurements of temperature and salinity have been routinely taken since 1946 at a site (station 27) located approximately 10 km off St. John's, Newfoundland. This station is considered to be representative of the inshore Labrador Current. The station was visited 41 times in 1989, with a monthly maximum of 9 in May and a minimum of zero in March. The data were collected at, or linearly interpolated to, standard depths (0, 10, 20, 30, 50, 75, 100, 125, and 150 m) and monthly means were calculated for each depth. Temperature and salinity anomalies for 1986 relative to the mid-month means for 1947-77 (Keeley, 1981) are shown in Fig. 8.

Temperature anomalies during the first part of the year were generally negative with the largest values occurring in January.

During the spring and summer the water temperatures at depths down to 100 m increased, resulting in positive anomalies that at times exceeded 1°C. In the autumn the temperatures throughout most of the water column oscillated between warmer and colder-than-normal. The near bottom temperatures (125 and 150 m) were below normal throughout the year continuing the trend of the last seven years. Similar to last year, these anomalies were generally weak (<-0.5°C).

Salinity anomalies were mostly positive but weak (<0.5). The largest anomaly occurred during the spring over the top 50 m of the water column.

Prince 5. 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). Anomalies were calculated relative to the 1951-80 means as determined by Drinkwater (1987). No measurements were taken in December due to a problem with the ship that is used to collect the data. The single measurement per month may not necessarily be representative of the "average" conditions for the month and therefore the interpretation of the anomalies must be viewed with caution. No significance should be placed on any individual anomaly but persistent anomaly features are likely to be real. The strong similarity in the anomaly patterns throughout the water column, evident in both temperature and salinity, is due, in part, to the relative homogeneity of the water column caused by the strong tidal mixing in the Bay of Fundy region.

In 1989, temperature anomalies throughout the water column were largely negative for the first five months of the year (Fig. 9), and were fairly consistent with sea-surface temperatures measured at nearby St. Andrews, N.B. The maximum negative anomaly at Prince 5 was observed in January with values slightly more than -1°C. The summer months were typically warmer-than-normal with a suggested peak in September. Although the timing of this peak does not match that recorded at St. Andrews, the warming trend from the spring to summer period was similar at both stations. In the autumn temperatures at Prince 5 varied from below to above normal.

The positive salinity anomalies observed at Prince 5 in 1988 (Trites and Drinkwater MS 1989) continued through most of 1989 (Fig. 9). These were generally weak, i.e. an anomaly of less than 0.5. A significant freshening of the upper portion of the water column was found, however, during the spring. It lasted three months and produced a near-surface salinity anomaly that exceeded -1. The timing corresponds to the expected period of the peak discharge from the Saint John River.

Position of shelf-slope front

The position of the shelf-slope front from Georges Bank to Cape Hatteras has been monitored by the Physical Oceanography Branch of the U.S., National Marine Fisheries Service over the past 16 years. The frontal position, which is derived from satellite infrared imagery, is normally extracted at weekly intervals along 9 section lines and plotted with respect to the 200 m isobath. Strout (MS 1990) discussed the frontal data for 1989. He noted that the frontal positions were similar to the pattern of the long-term means from the Nantucket (180°) to Cape Hatteras (Albelmarle Sound line) with no clear pattern along a transect in the central Gulf of Maine (Casco Bay line - 120°). The front did not appear to be as far offshore during the winter and spring months as the long-term seasonal averages. The largest variability in the positions was associated with the absence of slope water off Cape Hatteras and with the passage of warm core rings. Annual mean positions for the front were approximately near normal although the positions east of Long Island (Sandy Hook line) exhibited greater variability than the ten-year averages.

Warm-core rings

The life history of anticyclonic-warm-core Gulf Stream rings in the region from 45°W to 75°W during 1989 was derived from the NOAA/NWS Oceanographic Analysis maps and from the

"*State-of-the-Ocean: Gulf of Maine to the Grand Banks*" reports issued monthly at the Bedford Institute of Oceanography. Owing to the relatively common occurrence of cloudy or foggy conditions, particularly in the eastern half of the region, several weeks may elapse between clear thermal images of the sea surface. Consequently there is frequently uncertainty about the creation or continued existence of a particular ring and, therefore, the statistics derived solely from this data source should be viewed cautiously.

A total of 32 warm-core rings were present in the area during some portion of 1989, seven of which survived from 1988 into the new year. Nine of the 25 new rings which formed in 1989 persisted into 1990. At least 13 of the rings present in 1989 had a lifespan exceeding 2 months. Rings, whose destruction occurred in 1989, ranged in age from less than two weeks to more than seven months and had a mean life of a little less than 3 months. This compares with an age range of two weeks to more than a year and a mean of just over three months for 1988.

A separate and more complete analysis of warm-core Gulf Stream rings present in 1988 in the slope water and west of 60°W was undertaken by Sano and Wood (MS 1990). The high resolution data from NOAA-9 and NOAA-11 satellites were atmospherically and geometrically corrected and enhanced to clearly identify thermal features. The Oceanographic Analysis maps prepared by NOAA/National Ocean Service as well as opportunistic *in situ* data received from scientists and fishermen were used in the compilation. Their analyses indicated that 14 rings were present in the slope water of which 10 were new rings formed in 1989. During the 1974-88 period, the number of rings formed annually ranged from a minimum of 4 in 1974 to a maximum of 15 in 1988, and averaged 9 for the 15 year period. Lifespans of individual rings that disappeared in 1988 ranged from 18 to greater than 158 d with a mean of 70 days. Only one of the rings which formed in 1989 survived into 1990.

Shelf-slope temperatures in the Mid-Atlantic Bight

Monitoring thermal conditions along a transect extending seaward from New York Harbor across the shelf and slope continued in 1989 for the fourteenth consecutive year (Jossi and Benway, MS 1990). During the first half of the year surface temperatures over much of the shelf were above average, as were those at the seaward end of the transect, where anomalies in excess of +4°C were associated with warm core rings present during the period.

The time-space extent of bottom water cooler than 5°C is used as a way of estimating winter intensity. During 1989 the <5°C water occupied only the inner 30 km of the transect during March as compared to the 1978-1987 average of 100 km and persisting from late January until early April, suggesting there was a mild winter in 1989. Inshore bottom temperatures in the July-September period were as much as 9°C above the 10-year average and are thought to have been the result of downwelling of surface waters along the coast during this period. In 1989, autumn overturning of the water column was completed at the end of November, about two weeks later than average. This late overturning could account for the bottom temperatures at mid-shelf in October being 4°C below average. In December, bottom waters were cooler than average, paralleling surface patterns.

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 is presently being collected using SLAR (Side-Looking Airborne Radar). During the 1988/89 iceberg season (October to September), a total of 301 icebergs were spotted south of 48°N. The monthly totals for October 1988 to July 1989 were, respectively, 3, 0, 0, 0, 19, 127, 68, 39, 35, and 10. No icebergs were spotted south of 48° during August and September of 1989. In the primary iceberg season, March to August, 279 icebergs were observed which represents 93% of the annual total. The numbers of bergs detected in 1988/89 is an increase of over 100 from the 1987/88 season and is the largest number recorded in the past three years.

METEOROLOGICAL OBSERVATIONS

Air temperatures

The Atmospheric Environment Service of Canada publishes the monthly mean air temperature anomalies for Canada in the *Monthly Supplement to Climatic Perspectives*. The 1989 monthly anomalies are plotted in Fig. 10. Negative anomalies were found over most of the eastern Canada during winter and again in autumn. Maximum amplitudes in winter appeared in northern Labrador and Baffin Island with a -6°C anomaly on Baffin Island in January. The highest negative anomalies occurred in December in southeastern Canada. At that time temperature anomalies increased to the northeast, producing an air temperature anomaly gradient opposite that normally observed. From May to September air temperature anomalies from the Gulf of Maine to southern Labrador were mainly positive.

The annual air temperature anomalies were negative over all of eastern Canada except off northern Labrador and a relatively small area in southern Quebec (Fig. 11). The largest negative temperature anomaly was located over eastern Hudson Bay where the magnitude exceeded 2°C. Adjacent to the marine areas off eastern Canada annual air temperature anomalies were typically between 0 and -1°C. Off Baffin Island, along the Labrador Shelf, northern Baffin Island, over Newfoundland, and off Nova Scotia. The anomaly pattern for 1989 is more uniform and generally of larger magnitude than that observed in recent years.

Sea-surface air pressure

Monthly mean sea-surface pressures over the North Atlantic are published in *Die Grosswetterlagen Europas* by Deutscher Wetterdierst, Offenbach, Federal Republic of Germany. The long-term mean pressure patterns are dominated by the Icelandic Low, a low pressure system centered between Greenland and Iceland, and the Bermuda-Azores High, a high pressure system centered between Florida and northern Africa (Thompson and Hazen, 1983). The strengths of the Low and High vary seasonally from winter maximum to summer minimum. Seasonal anomalies of the sea-surface pressure for 1989 relative to the 1951-80 means are shown in Fig. 12. Winter includes December 1988 to February 1989, spring is March to May, summer is June to August and autumn is September to November.

Throughout 1989, sea level pressures were below normal in the northern regions of the North Atlantic indicating an intensification of the Icelandic Low. There was also a shift in the position of the Icelandic Low from east to west between the spring and autumn. The maximum negative pressure anomaly occurred in winter with a magnitude of 12.3 mb located over eastern Greenland. The Bermuda-Azores High was also stronger (positive pressure anomalies) during 1989 and underwent a major eastward shift in position between winter and spring. In winter, the large positive pressure anomaly over Europe and negative anomaly over Iceland would have resulted in strong westerly winds over eastern North America. Over the western North Atlantic, the westerlies would have increased only slightly above normal given the pressure patterns and assuming geostrophy. In spring, the anomalous high off the east coast of Canada would have brought warm air masses into the southern NAFO areas whereas the stronger Icelandic Low would have resulted in winds from the north over most of the Labrador Sea. Pressure anomalies in summer were generally weak although an anomalous low was situated over southern Greenland. This would have tended to produce weak anomalous northerly winds in the NAFO region. In the autumn three broad bands of pressure anomalies were observed; negative over the eastern and northern regions of the North Atlantic, positive over the central North Atlantic, and negative further to the southeast.

SUMMARY

In 1989, the sea surface temperatures from coastal stations, ships of opportunity, and standard offshore stations (including Prince 5 in the Bay of Fundy, and Station 27 off St. John's) indicate extensive warm water conditions during the summer from the Mid-Atlantic Bight to southern Labrador. At the same time above average air temperatures were observed in the region. The anomalous sea surface pressure field in the spring (March-May) suggested southerly winds which would have promoted large air-sea heat exchanges. The ships of opportunity data and the coastal stations also revealed intense cooling during December with anomalous temperatures exceeding -2°C at Halifax, St. Andrews, and Boothbay Harbor. Whereas the high summer temperatures caused positive mean annual anomalies in most of the offshore areas, at the coastal stations cool conditions in the winter and autumn resulted in colder-than-normal annual mean temperatures.

ACKNOWLEDGEMENTS

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TABLE 1. Mean sea-surface temperatures for selected areas of the Northwest Atlantic in 1972-80 and anomalies for 1984 to 1988 relative to the base period. (Geographic locations of water masses are shown in Fig. 6. Blank space indicates that annual average not computed when data missing for one or more months.)

Water mass	Mean temp. 1972-80[a]	Annual anomalies (°C) 1985	1986	1987	1988	1989
CF	3.62	1.03	0.99	1.12	1.17	0.50
LS	5.54			0.34	0.20	0.00
LCS	2.19			-0.21	-0.42	
OLC	5.17	-0.90	-0.19	-0.30	0.08	0.02
ILC	4.83	-0.38	0.24	-0.31	0.85	0.74
FC	7.88	-0.80	-0.24	0.08	0.52	0.04
CGB	6.48	-0.54	-0.16	0.19	1.03	0.76
WGB	6.13	-0.69	-0.23	0.39	0.61	0.34
SP	5.91	-0.36	-0.28	0.91	0.42	0.01
GSL	5.82	-0.01	0.08	0.42	0.33	0.29
ESS	7.10	-0.29	-0.24	0.42	0.04	0.45
SI	8.27	-0.49	-0.57	0.02	-0.18	0.53
SH	7.85	-0.18	-0.34	0.70	-0.12	0.68
LHB	8.87	-0.33	-0.53	0.02	-0.62	0.19
BR	8.84	0.17	-0.05	-0.43	0.14	0.66
Y	7.64	-0.45	0.29	-0.37	0.05	0.38
GOM	9.59	0.10	0.25	-0.74	-0.40	0.19
GB	10.17	0.21	0.14	-0.66	-0.31	0.09
SNE	12.23	0.14	0.09	-0.51	-0.18	0.69
MAB	14.87	0.80	0.15	-0.43	-1.15	0.13
ESW	15.54	0.02	-0.34	0.10	0.06	0.61
WSW	18.50	0.52	-0.16	-0.65	-0.82	-1.36
GS	22.94	0.11	0.46	0.30	-0.11	0.19
SS	22.26	-0.14	0.04	-0.08	0.24	0.18

[a] See Trites and Drinkwater (1985) for annual anomalies pertinent to the 1972-80 base period.

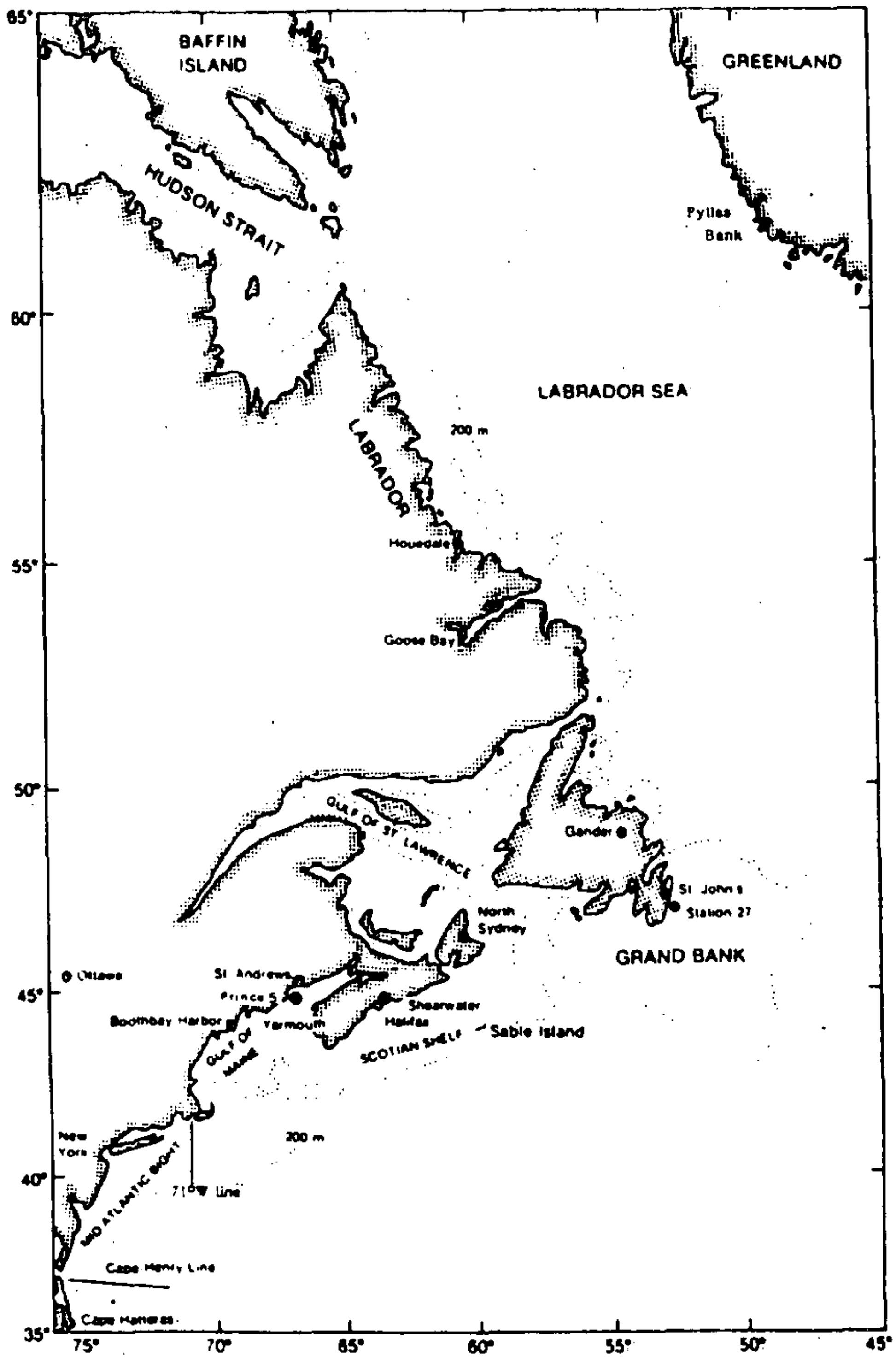

Fig. 1. Map of Northwest Atlantic showing oceanographic stations and other sites mentioned in the text.

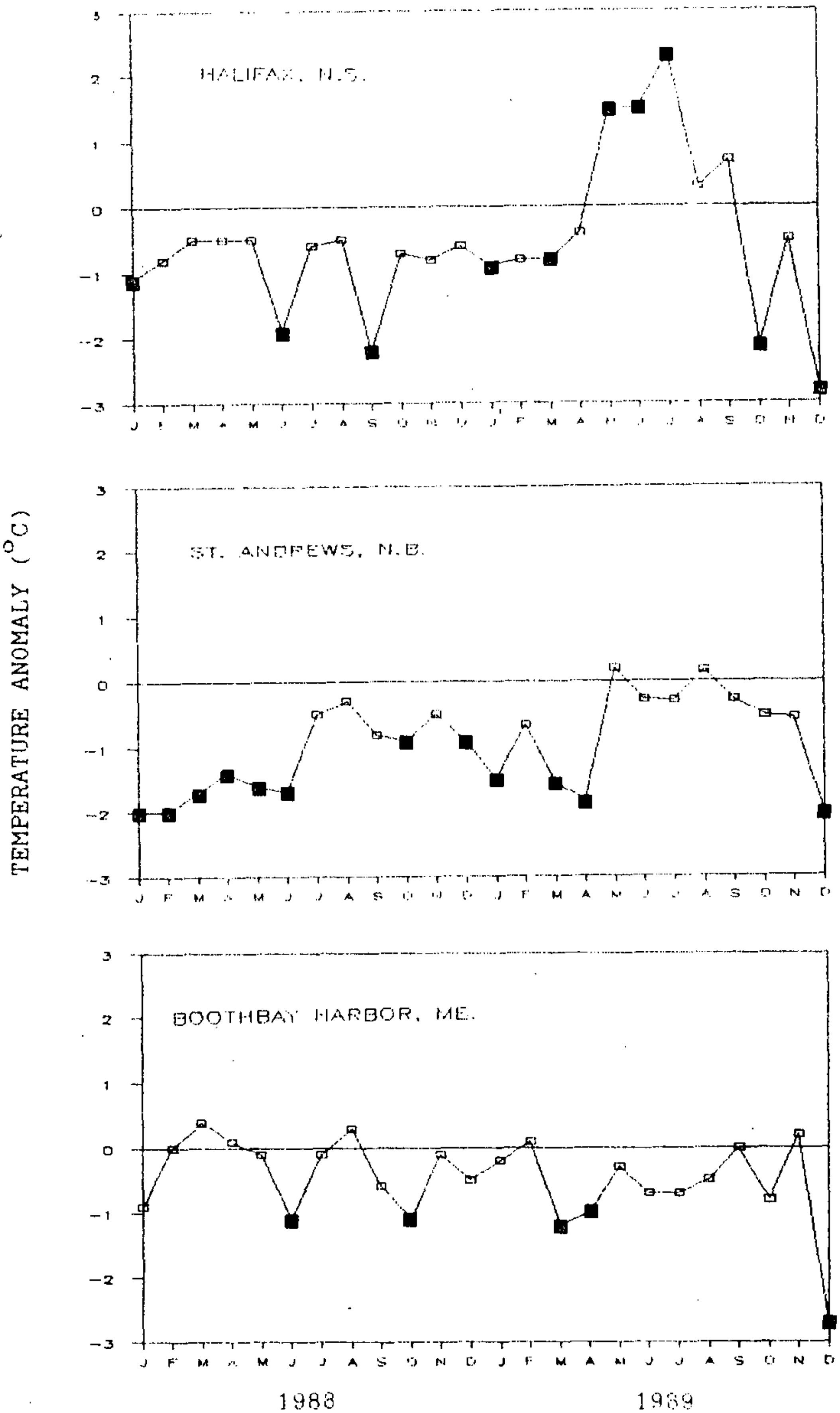

Fig. 2. Monthly sea-surface temperature anomalies at Halifax, St. Andrews and Boothbay Harbor in 1988 and 1989 relative to the 1951-80 means. (Solid squares indicate months when the anomalies equaled or exceeded one standard deviation.)

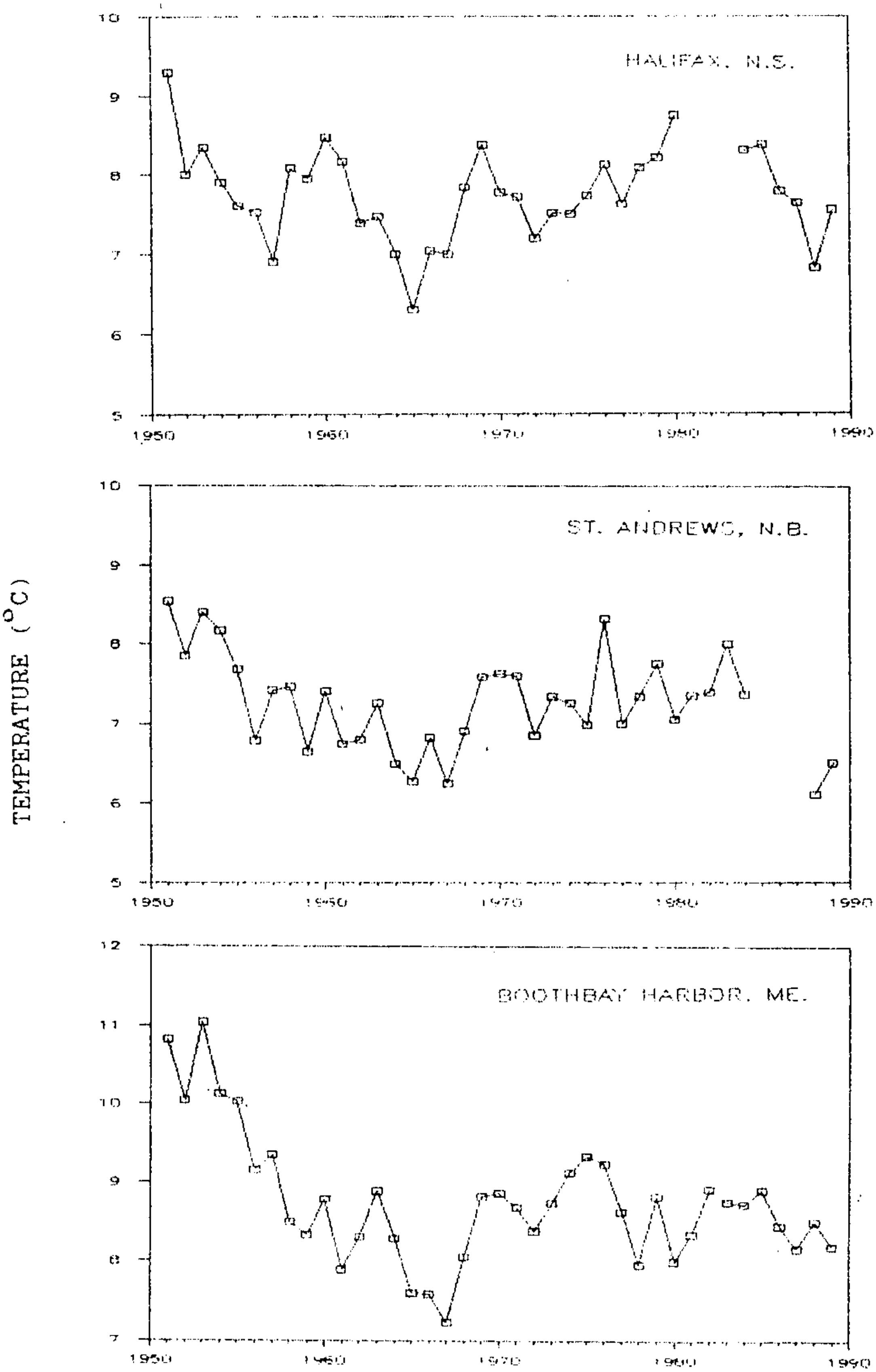

Fig. 3. Annual sea-surface temperatures at Halifax, St. Andrews and Boothbay Harbor during 1951-88.

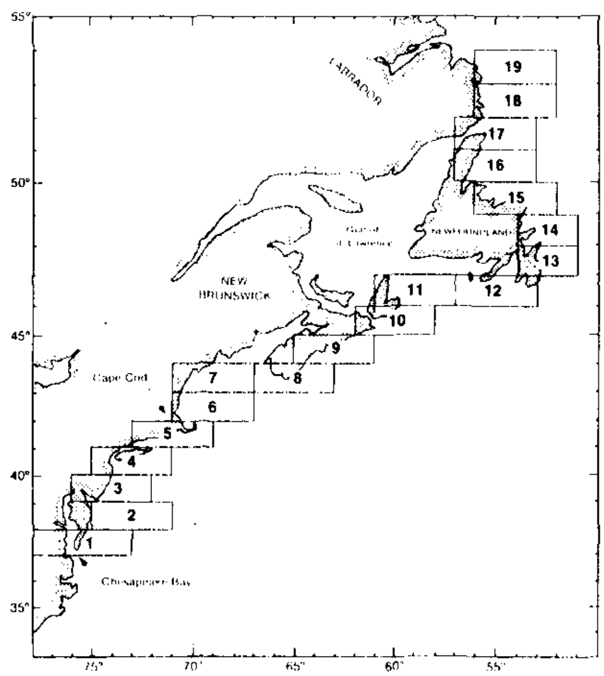

Fig. 4. Locations of 19 areas in the Northwest Atlantic (Chesapeake Bay to southern Labrador) for which sea-surface temperature data were grouped for analysis.

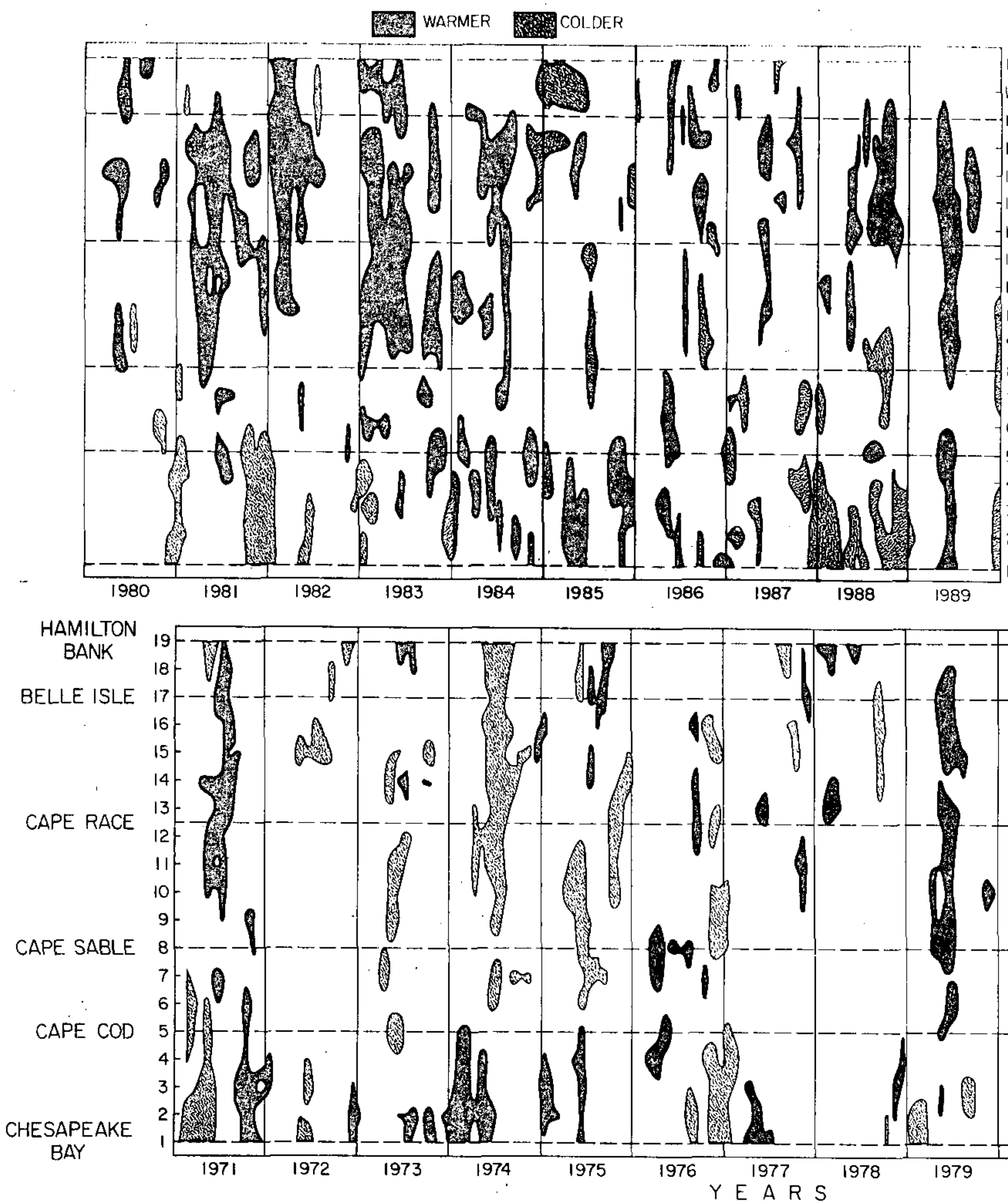

Fig. 5. Contoured monthly sea-surface temperature anomalies (relative to the 1971-80 means) for the 1971-89 period by area (Fig. 4). (Only anomalies exceeding 1°C (black) and less than -1°C (dotted) which extended in space through at least two neighbouring areas and in time for at least two consecutive months have been contoured.)

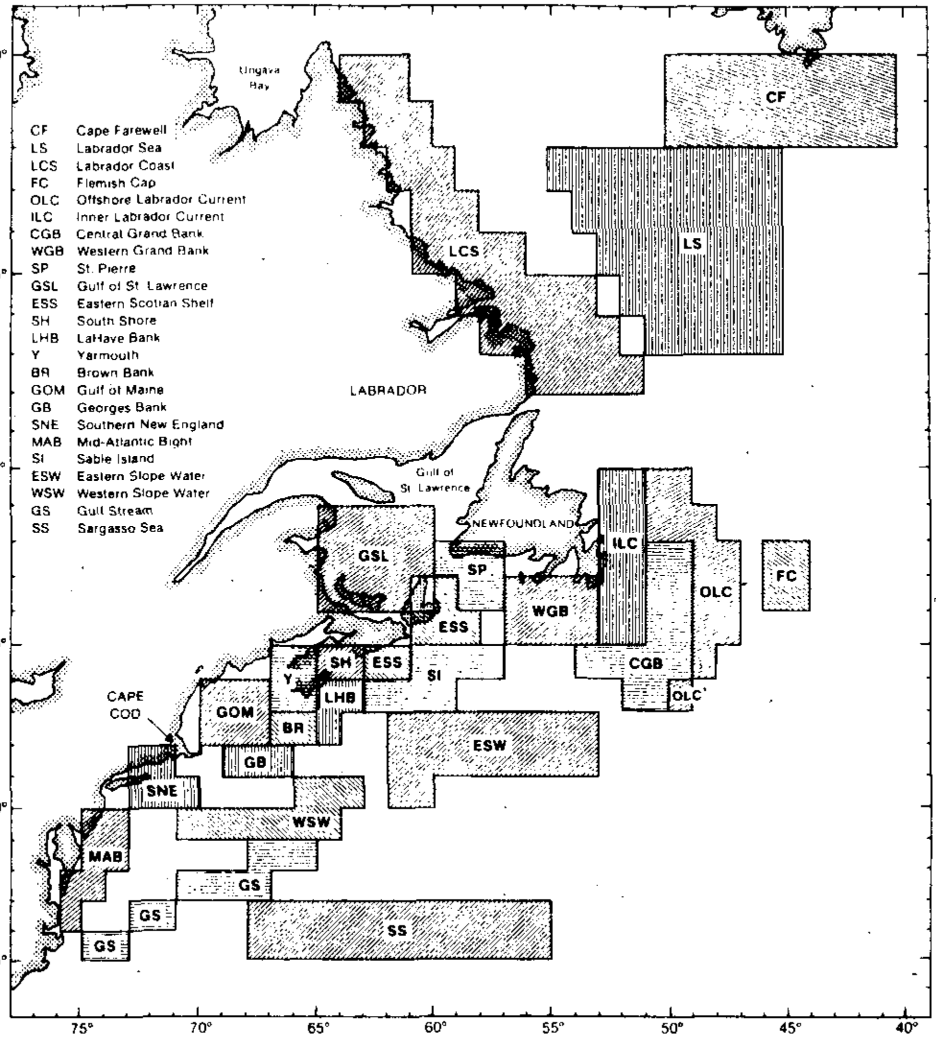

Fig. 6: Geographic boundaries of 24 subregions (Cape Hatteras to Cape Farewell) for which sea-surface temperatures were analyzed on a monthly basis.

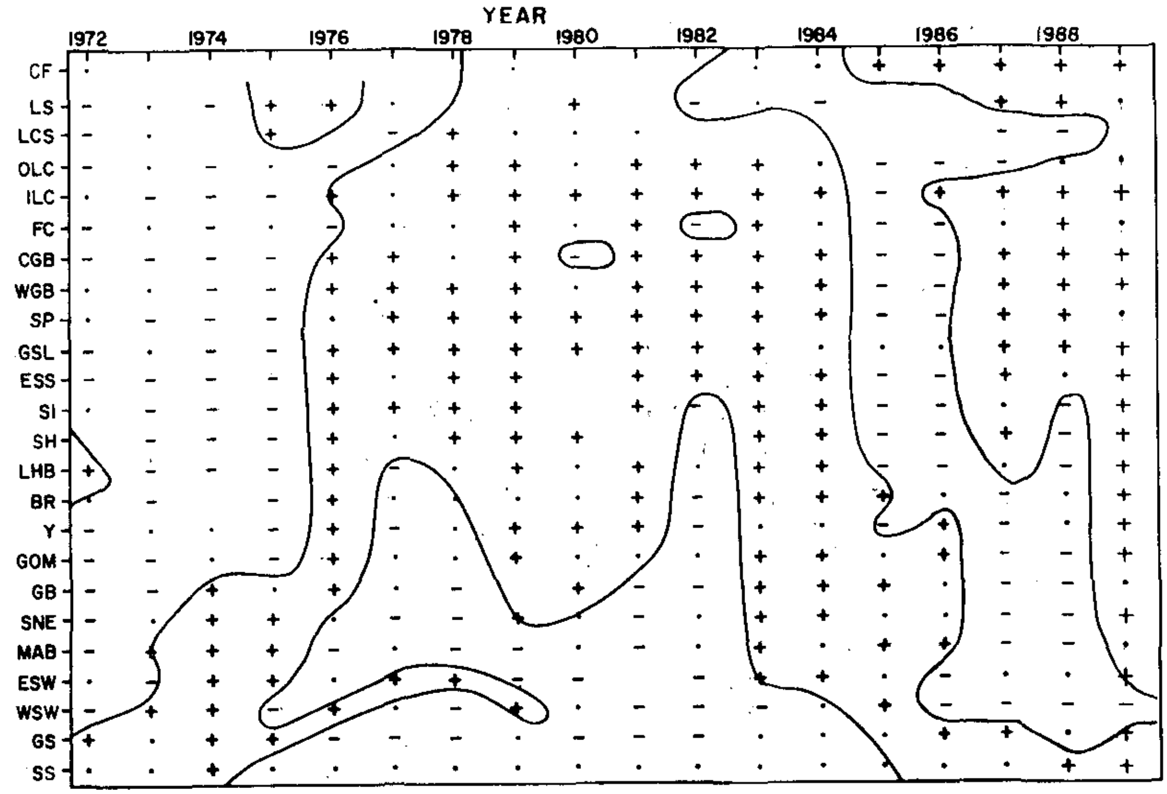

Fig. 7. Distribution of positive (+) and negative (-) annual sea-surface temperature anomalies in 1972-89 by subregion (Fig. 6) relative to the 1972-80 means. (Only anomalies less than -0.15°C and greater than +0.15°C were used in drawing the contours.)

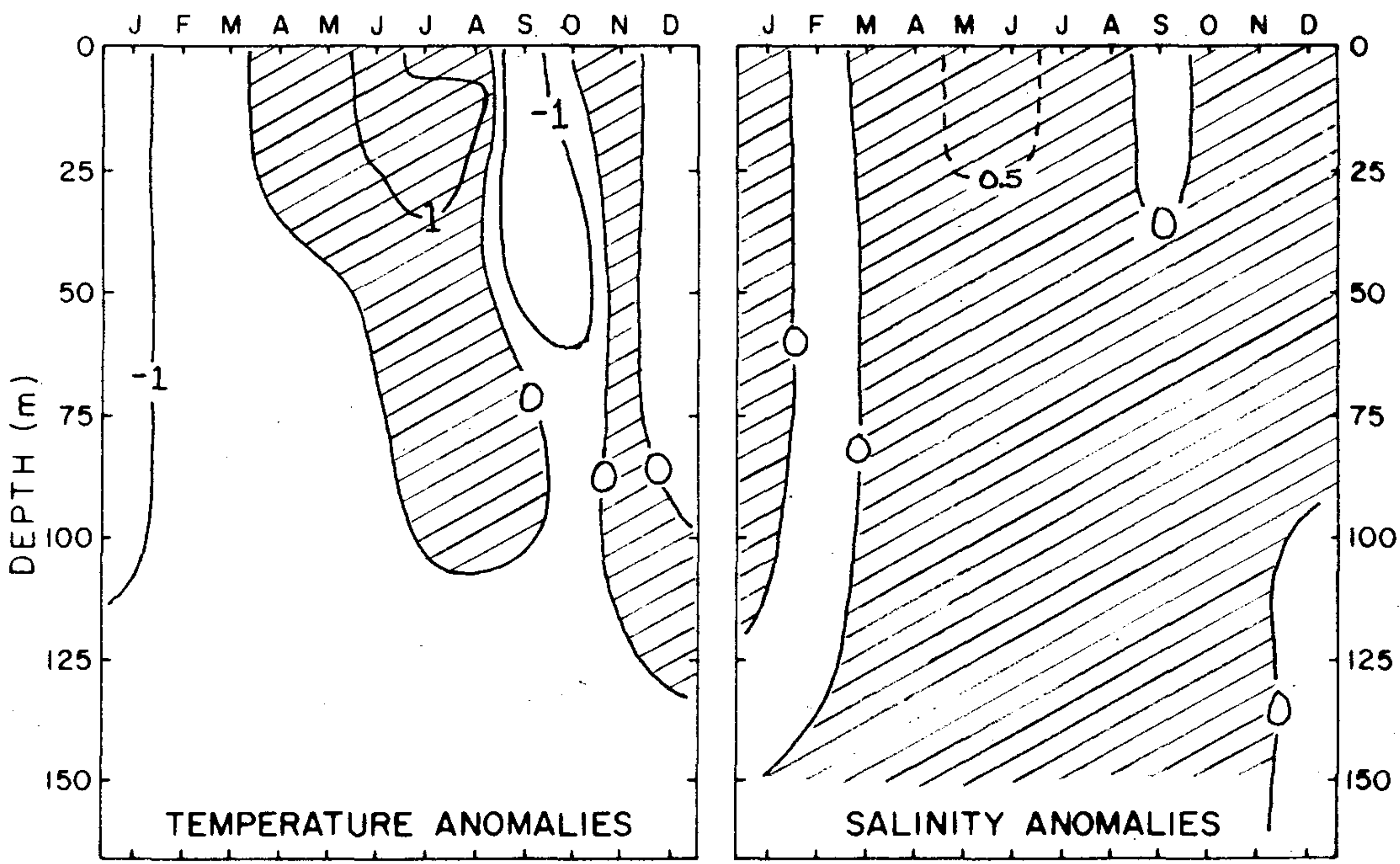

Fig. 8. Monthly temperature and salinity anomalies at Station 27 off St. John's during 1989 relative to the 1946-77 means (Keeley, 1981). (Shaded areas represent positive anomalies)

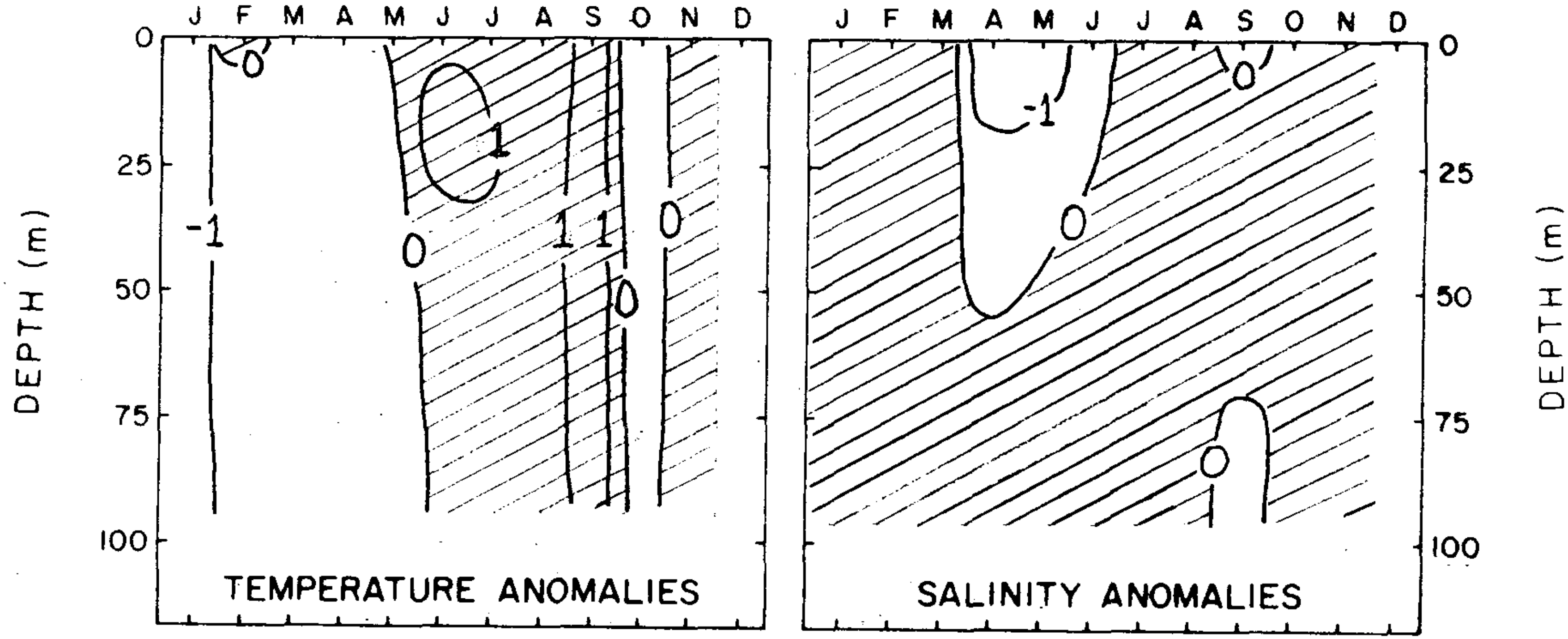

Fig. 9. Monthly temperature and salinity anomalies at Prince 5 near the entrance to the Bay of Fundy during 1989 relative to the 1951-80 means (shaded areas represent positive anomalies).

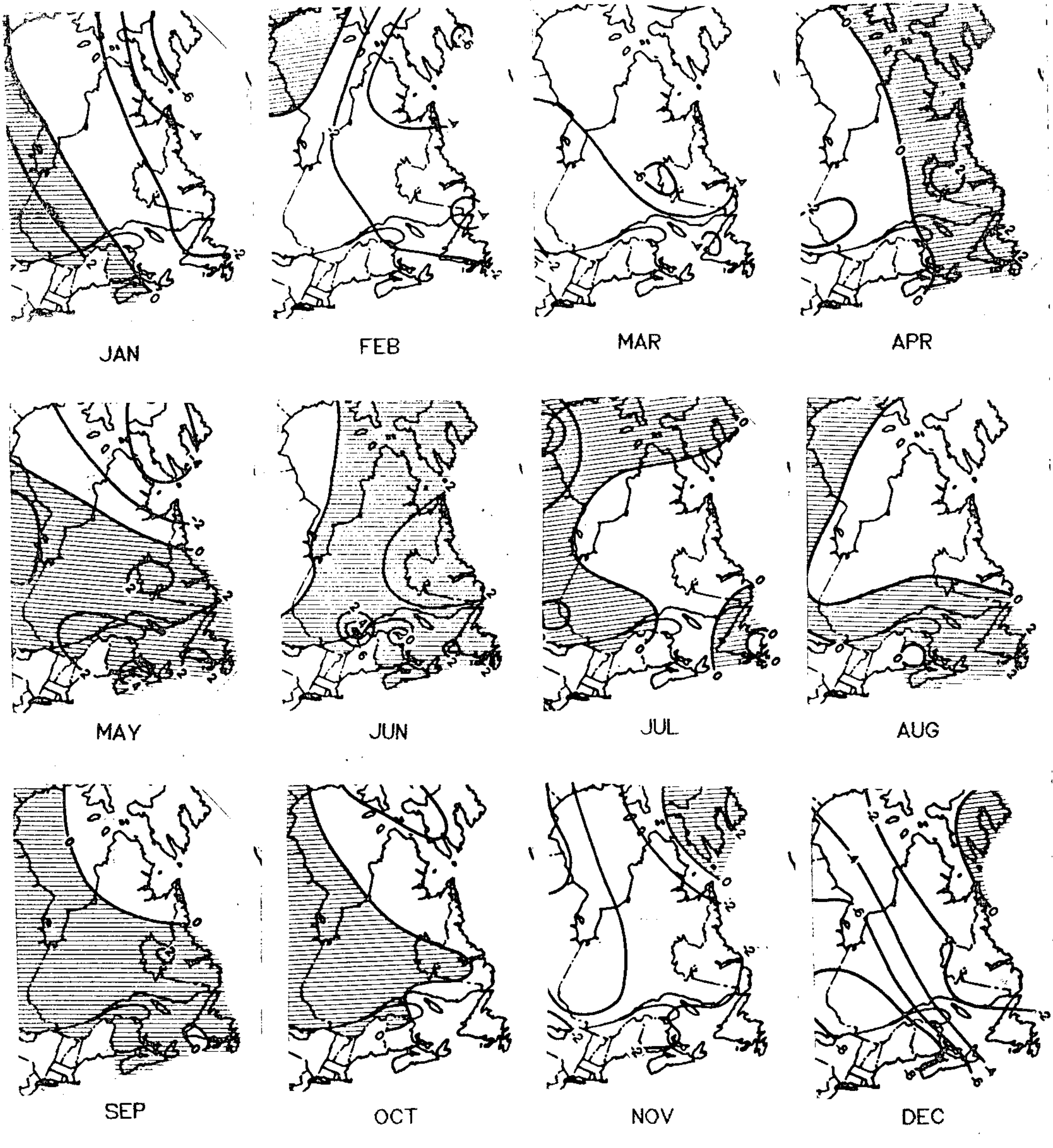

Fig. 10. Monthly air temperature anomalies (°C) over eastern Canada in 1989 relative to the 1951-80 means. (Positive anomalies are shaded.)

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Fig. 11. Annual air temperature anomalies (°C) over eastern Canada in 1989 relative to the 1951-80 means. (Positive anomalies are shaded.)

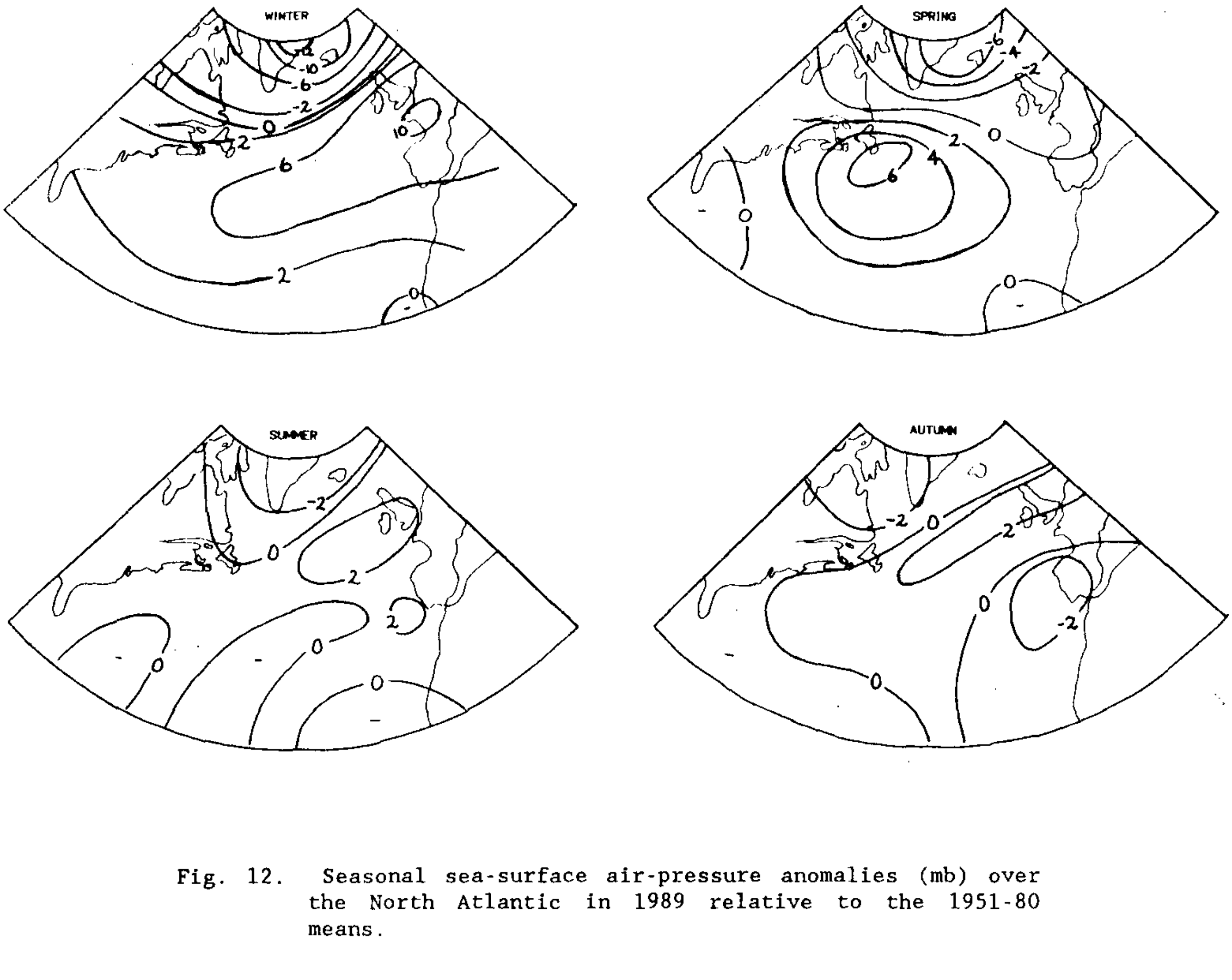

Fig. 12. Seasonal sea-surface air-pressure anomalies (mb) over the North Atlantic in 1989 relative to the 1951-80 means.