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Overview of Environmental Conditions in the Northwest Atlantic in 1984

by

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INTRODUCTION

This report is our third annual overview of environmental conditions in the Northwest Atlantic. In addition to helping the Environmental Subcommittee of the NAFO Scientific Council in their task of assessing environmental changes that occurred during the previous year in the NAFO area, the main objective of the review is to provide a climatic summary that may aid biologists and fisheries scientists in interpreting their data. As in our previous papers (Trites and Drinkwater 1984, 1985), this overview includes selected sets of oceanographic and meteorological data as well as information from NAFO research documents and national reports. Conditions in 1984 are compared to the previous year and the long-term mean. The latter has been standardized to the period 1951 to 1980 in compliance with the World Meteorological Organization Convention and the NAFO Scientific Council recommendations. Where thirty years of data are unavailable, 20-year (1961-1980) or 10-year (1971-1980) base periods are used, if possible.

OCEANOGRAPHIC OBSERVATIONS

Coastal Sea-Surface Temperatures

As part of long-term monitoring programs sea-surface temperature (SST) measurements were taken twice daily during 1984 at Halifax, N.S., St. Andrews, N.B., and Boothbay Harbor, Maine (for locations see Fig. 1). Monthly averages were calculated and compared to long-term means for the 1951-80 base period presented in Trites and Drinkwater (1984). The monthly anomalies are shown in Fig. 2 together with those from 1983. The lack of data for Halifax during the first 5 months of 1983 were due to instrument problems.

During 1984 the amplitude of the monthly mean temperature anomalies were highest at Halifax and lowest at St. Andrews. There was some similarity in the trends at all three locations with a peak positive anomaly in February, negative anomalies during the spring and early summer and above normal temperatures at the end of the year. At Boothbay Harbor and Halifax there was also a positive anomaly in August followed by a decrease to a minimum in September and October, respectively. These were not observed at St. Andrews. At Halifax the monthly mean anomalies exceeded their standard deviations (for the period 1951-80) in 5 out of 12 months including 4 of the last 6. It represents the second straight year that above normal temperatures have been measured in the later half of the year. At St. Andrews the anomalies exceeded the standard deviations only during December and at Boothbay Harbor only during April and September.

The mean annual sea surface temperature was 8.3°C at Halifax, 7.4°C at St. Andrews and 8.7°C at Boothbay Harbor (Fig. 3). They represent anomalies of 0.5°, 0.1° and -0.1°C, respectively, from their 1951-1980 averages. The near normal means in 1984 at St. Andrews and Boothbay Harbor continue the pattern established over the last 15 years of relatively low variability and lack of any distinct trend. At Halifax, the absence of data between 1981 and 1983 due to suspected instrumental errors precludes the establishment of any recent trend.

Offshore Sea-Surface Temperatures

The extensive data base of offshore sea-surface temperatures is derived principally from radio weather messages and logbook records that are transmitted by merchant vessels to the U.S. National Climatic Center. Analyses of these data by the Pacific Environmental Group of the U.S. National Marine Fisheries Service include computations of average monthly temperatures and anomalies (from 1948-67 means) for each 1° x 1° quadrangle for which enough data have been reported in each month.

Observations on sea-surface temperatures during 1984 within the region bounded by 35° - 46°N and 60° - 77°W were reported by Ingham and McLain (MS 1985) as follows:

"During 1984 the area off southeastern Nova Scotia (43-46°N, 60-66°W) showed strong positive SST anomalies (up to +2.6°C) in June, a broken, scattered pattern in July and the return of an extensive, strong pattern (up to +2.5°C) in August. There were no consistent or extensive patterns, either positive or negative, in this area for the remainder of the year.

There were no significant, extensive patterns of positive or negative SST anomalies in the Gulf of Maine or over Georges Bank (40-44°N, 66-70°W) during the year.

In the Middle Atlantic Bight (2° longitude coastal band between 36° and

41°N) an extensive pattern of negative SST anomalies, (down to -2.4°C) showed in January, weakened in February and disappeared in March. Strong positive anomalies (up to +3.5°C) appeared in the southern end in May, and a pattern of positive anomalies was seen throughout the Bight in June. However, in July a pattern of negative anomalies was seen in the bight instead. The cool anomalies reappeared in September and October, but were replaced by a warm pattern in November."

The monthly pattern of sea-surface temperatures along the continental shelf from Cape Hatteras to southern Labrador (Fig. 4) for 1971-83, described by Trites et al. (1985), was examined for 1984, and compared with earlier years (Fig. 5). The pattern of generally above normal temperatures northward from the Gulf of Maine area, and below normal southward from this area which persisted for the previous 5 years, continued into 1984, but towards the end of the year, evidence was mounting that the pattern was commencing to shift. In the area from Cape Race northward, temperatures were generally in the range of 0-2°C below normal in the October-December period. The area from Georges Bank southward showed periods of both below and above-normal (by more than one standard deviation), but on balance there was an increasing tendency for above normal temperatures to occur more frequently. Sea-surface temperatures from a larger 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) were grouped into 24 smaller areas to coincide with major water masses (Labrador Current, Gulf Stream, etc.) or fishing banks (Georges Bank, Flemish Cap, etc.). Annual sea surface temperature anomalies for each year in the 1972-83 period were reported by Trites and Drinkwater (1985). This analysis was extended to include 1984 and the results are shown in Table 1 and Fig. 7. Although temperatures above the 1972-80 annual average existed over most of the areas from the Labrador Shelf to Southern New England, temperatures were generally lower (by nearly 1°C in some areas) from Georges Bank to the Labrador Sea, suggesting that the "warm in the north" epoc may be nearing an end.

Station 27 Temperature and Salinity

Since 1946 a time series of temperature and salinity profiles have been collected on a continuing basis at Station 27 located approximately 10 km off St. John's, Newfoundland. The station is representative of the inshore Labrador Current. During 1984 it was occupied a total of 33 times with a monthly maximum of 5 in August and November but none during March. Monthly averages were calculated at standard depths (0,10,20,30,50,75,100,125 and 150 m) using linear interpolation in the vertical where necessary. Anomalies from the mid-monthly means (Keeley, 1981) were then computed and are shown in Fig. 8.

In the lower layers (at depths greater than 50 m) temperatures were typically -1.1° to -1.6°C and below normal by, on average, 0.5°C. It is the third consecutive year that the deep waters at Station 27 have been colder than normal. Salinities in the lower layer were below normal until May, above normal through until October and then dropped below normal in the last two months of the year. However, salinity anomalies were low (approximately 0.1) and are not considered significant. In the upper layers (above 50m) both temperature and salinity were below normal from January to June. Anomalies were maximum in May and June with temperatures of 2° to 4°C below normal and salinities of 0.3 to 0.9 psu (practical salinity units) below normal. During the summer the salinity anomaly strengthened as surface salinities were less than 30.5, 1 psu below normal. At the same time rapid surface heating produced positive temperature anomalies of up to 1.8°C above normal. The increased stratification resulting from the low surface salinities may have trapped the surface heat into a shallow layer thus accounting for the warmer than normal surface temperatures. Upper layer temperatures returned to below normal during October and November. In December they were near normal although slightly positive. The high positive temperature anomaly and negative salinity anomaly at 50 m in October results from a deeper than normal surface layer.

Position of Shelf-Slope Front

Information on the position of the shelf-slope water front from Georges Bank to Cape Romain, South Carolina, has been extracted from thermal infrared satellite imagery and reported annually since 1973 by the Atlantic Environmental Group (now Marine Climatology Investigation) of the U.S. National Marine Fisheries Service. Based on a ten year data set (1974-83), the mean position of the shelf water front north and east of Cape Henry is typically further offshore during spring and moves shoreward during late summer and early autumn. From Cape Romain to Cape Henry, the front is generally located more offshore during summer and is more shoreward during winter. Armstrong (MS 1985) reported that during 1984 the frontal position generally followed the long term annual cycle from Georges Bank to just north of Cape Hatteras. South of Cape Hatteras, no seasonal pattern was evident in the frontal position, although its mean annual position was about 15 km shoreward of the 1974-83 average. Off Georges Bank, the location of the front seemed to be dominated by the presence of warm-core Gulf Stream rings at various times during the year.

Warm-Core Rings

Monitoring the life-history of anticyclonic warm-core Gulf Stream rings has been carried out since 1974 for the area between 60°W and Cape Hatteras and reported annually by the U.S. National Marine Fisheries Service (Price, MS 1985). The analysis is based primarily on satellite infrared imagery and augmented with _in situ_ data where available. A total of 10 warm-core rings were present in this area in 1984. Two rings were formed late in 1983 and survived into 1984. Eight rings formed during 1984 with two persisting into 1985. During the 1974-1983 period ring formation averaged 9 per year, ranging from 5 in 1974 to a maximum of 11 in 1979 and 1982 (Price, MS 1985). The average lifetime of rings whose destruction occurred in 1984 was 97 days, much shorter than the 1983 average of 143 days and less than the 1976-81 mean of 120 days. In terms of total ring-months there were 25 in 1984, compared with 51 in 1983 and a 1976-81 average of 38. This was the second lowest total in the 1974-83 period. The generation zone pattern for 1984 was generally similar to the mean but only two rings reached 70°W before their destruction. It was the first time in the past 11 years that no rings were observed in the slope water area between Cape Hatteras and 72°W.

Monitoring of the warm-core rings in the slope water area in the 50°-60°W zone is more difficult than in areas further southwestward owing to the increased presence of cloud cover and fog, resulting in less frequent and less reliable satellite thermal imagery and thus producing considerable uncertainty in the warm-core ring statistics. From an examination of the Oceanographic Analysis Charts of the U.S. National Weather Service, it is estimated that 14 rings were present in 1984. Four rings, formed in the September-December period of 1983 survived into 1984 and 10 new ones formed in 1984, compared with 12 in 1983. Lifetimes for the 10 rings whose destruction occurred in 1984, varied from less than one month to more than 6 months, with a mean of about 3 months. Only 3 of the rings moved westward beyond the 60°W meridian.

Shelf-Slope Temperatures in the Mid-Atlantic Bight

Temperatures across the shelf and slope on or near the 71°W longitude line (see Fig. 1) have been monitored by the U.S. National Marine Fisheries Service since 1974. During 1984 16 XBT (expendable bathythermograph) transects were obtained. Analysis of bottom temperatures, reported by Armstrong (MS 1985) includes a comparison of 1984 conditions with the 1974-83 mean (Fig. 9). During

1984 nearshore bottom temperatures south of New England were generally above normal for most of the year. At mid-shelf depths (20-70m) bottom waters were cooler than normal for about half the year (principally during spring and summer), and warmer than normal for the other half of the year. Beyond the 70 m isobath, bottom temperatures were above the ten-year means for about 90% of the year. Bottom waters in 1984 were particularly warmer than normal at bottom depths of about 70 m to 90 m in February and in late October-early November. During 1984, only one warm core ring passed through the slope water along the transect. For the ten years, 1974-1983, 3 to 4 rings per year were typical, with minimum of 3 during 4 of the years and a maximum of 7 in 1977.

In addition to the 71°W transect, thermal events have been monitored along a transect extending seaward from New York Harbor across the Shelf and Slope since 1976. In 1984, 24 XBT sections were taken (Benway, MS 1985). Benway reports as follows:

"During late February and early March of 1984, the normal cooling of shelf waters along the bottom was interrupted by an intrusion of warm water from offshore. In June and July, at mid-shelf, the coldest water in the cold pool (<6°C) was located off the bottom at a depth of about 40 m..... Cold pool temperatures were warmer than usual in 1984 and <10°C water remained on the bottom only until mid-September, about two weeks briefer than usual.... Fall overturn occurred about two weeks earlier than in 1983, and bottom temperatures across the shelf were about 2°C warmer.... On the upper slope, at depths of 100m to 200m depth, bottom temperatures in 1984 were greater than 12°C for all years, except in later March and early April. Never, since 1977, has >12°C water persisted on the bottom of the upper slope for this much of the year."

Waves

Wave and weather observations from 40 to 100 locations in the North Atlantic (weather ships, Canadian and United States government and naval ships, merchant ships, and oil-drilling platforms) are transmitted every 6 hr to the Canadian Meteorological and Oceanographic Center (METOC) at Halifax, Nova Scotia (see Neu, 1982). Trites and Drinkwater (1984,1985) provided summary statistics of significant wave heights at three grid points in the Northwest Atlantic for each year of the 1970-1983 period. The mean monthly significant wave heights in 1983 and 1984, together with the averages for the 1970-80 period, are given in Table 2. The monthly significant wave height anomalies (relative to 1970-80 means) for the three areas are illustrated in Fig. 10. For the Labrador Sea area the seasonal pattern in 1984 was very similar to that of 1983. During the first half of the year significant wave heights were well below the 1970-80 mean, while the last half of the year the inverse conditions ensued. For the Grand Banks and the Scotian Shelf there was no apparent seasonality in the anomaly patterns. A general downward trend in anomalies to near normal or slightly below normal was evident for the Scotian Shelf and Grand Banks, but not for the Labrador Sea area.

Another measure of wave conditions, which may be indicative of events for the year as a whole, is the frequency of storms. The numbers of occurrences of waves equal to or greater than 6, 7 and 8 m in the three areas are shown in Fig. 11. The Scotian Shelf and Grand Bank areas both showed a continuing decline in frequency of large waves from the 14-year maximum which occurred in 1981 on the Scotian Shelf and in 1983 on the Grand Bank area. For the Labrador Sea area, frequency of large wave occurrences were up from those of 1983 but still well down from the highs in the 1971-82 period. Although there is high year-to-year variability on wave severity and occurrence of large waves it appears that there is a continuing downward trend to values comparable to the early 1970's.

Sea Ice

The Ice Climatology Division of the Canadian Atmospheric Environment Service (AES), undertook in 1984 an analysis of 24 experimental grid sites in the Gulf of St. Lawrence and off the east coast of Newfoundland and Labrador (Fig. 12). The results of this analysis were summarized by Trites and Drinkwater (1985). The analysis has been updated to include 1984 data. For each site, the data extracted were ice duration in weeks for 1984, average duration for all years of record, and maximum, minimum and average duration for years when ice was present (Table 3). The timing of first and last sea ice, the median dates and the 1984 dates are shown in Fig. 13). In terms of duration, ice was present at most Gulf of St. Lawrence sites for longer than normal. Only Cabot Strait and east of Cape Breton (sites G33, G35, G87) were durations shorter than normal. Ice durations off northeast Newfoundland and southern Labrador were much longer than normal, whereas at sites east of the Avalon Peninsula, the duration was nearer to normal. Radomski (1985) in a narrative description of ice conditions during the winter of 1984-85, writes that: "Ice conditions in the Gulf were more extensive than usual, the heaviest in the last five years. Heaviest ice conditions developed in the southeast and along the west coast of Newfoundland into the Strait of Belle Isle...". In late winter and early spring below normal temperatures in the Gulf resulted in ice persisting longer than normal and "persistent westerly winds have continually pushed loose ice through the Cabot Strait, and at one time the ice threatened the Venture drill sites near Sable Island". For the Grand Banks-northeast Newfoundland area Radomski (1985) reports that "the Arctic ice pack, 300 to 500 km wide, was much further south than normal, and encompassed the Hibernia drilling fields forcing all drilling rigs off site".

Icebergs

The International Ice Patrol monitors the number of icebergs drifting south past 48°N latitude. During the period October, 1983, to September, 1984, they reported a total of 2202 icebergs. No icebergs were reported during the first five months. For March to September the monthly totals were 101, 953, 484, 227, 335, 93 and 9, respectively. The seasonal distribution in 1983/84 was similar to previous years with over 90% of the icebergs appearing from March to July. The number of icebergs were much higher than observed in 1982/83 (1352) although they did not begin to reach 48°N until much later in the season (March compared to December). Data during both years had been collected using SLAR (Side-Looking Airborne Radar). Prior to 1982/83 iceberg counts had been determined visually, initially from ship sightings and after 1945 from routine aerial reconnaisance. Ongoing studies by the Ice Patrol indicate SLAR detects over twice as many icebergs than visual methods. Until these studies are complete, meaningful comparisons between years with different observational techniques cannot be made. Therefore, although the 1983/84 iceberg total between March and July (2100) is the highest in over one hundred years of record keeping, it is unclear whether this number represents an average or above-average iceberg year. It may suggest instead that the absolute numbers obtained by visual methods were gross underestimates.

In last year's environmental overview (Trites and Drinkwater, 1984) we compared the 1982/83 data to earlier iceberg statistics and suggested it was a heavy iceberg year. It was unknown to us at the time that the Ice patrol had switched to SLAR. As a result of the change in observational methods, we no longer believe that the comparisons made in that paper truly represent a measurement of relative iceberg conditions.

METEOROLOGICAL OBSERVATIONS

Air Temperatures

Monthly mean air temperature anomalies for Canada are available in the Monthly Supplement to <u>Climatic Perspectives</u> published by the Atmospheric

Environment Service of Canada. For the northeastern United States anomalies are published by the National Oceanic and Atmospheric Administration (NOAA) in Climatological Data, New England. The data base includes well over 100 stations.

Contours of monthly anomalies of air temperature for 1984 from the 1951-80 mean for eastern Canada and the New England States are presented in Fig. 14. On Baffin Island and the Labrador Coast negative anomalies were observed from January to April with temperatures of 6°C below normal in January and up to 12°C below normal on Baffin Island in February. Throughout the remainder of the year anomalies were weak and variable except in December when temperatures fell to 4°C below normal. This year represents the second consecutive cold winter in the north. From the Gulf of Maine to southern Newfoundland including the Gulf of St. Lawrence monthly mean air temperatures were near normal or slightly above normal for most of the year. Exceptions included negative anomalies of about 2°C throughout the region in January and 2° to 4°C below average in the Gulfs of Maine and St. Lawrence in March and positive anomalies of 2° to near 6°C in February. Except for the winter months (January to March) air temperature anomalies generally did not exceed one standard deviation (Fig. 15). The 1984 anomalies exceeded the 1951-80 standard deviations in January by 1° to 3°C, in February by up to 8°C in Baffin Island and 2° to 4°C in the south and in March by up to 3°C in the south.

The annual air temperature anomalies show a colder than normal year to the north in northern Newfoundland, Labrador, Hudson Strait and Baffin Island (Fig. 16). Amplitudes reach 1°C below normal but are within one standard deviation (Fig. 17). To the south anomalies were positive, low in magnitude (less than 1°C), and within one standard deviation. The pattern of annual anomalies is similar to 1983 (Trites and Drinkwater, 1985) but slightly lower in magnitude.

Sea-Surface Pressure

Monthly sea-surface pressure data over the North Atlantic were obtained from the publication 'Die Grosswetterlagen Europas', Deutscher Wetterdienst, Offenbach. The data were averaged by season (winter, December-February; spring, March-May; summer, June-August; autumn, September-November) and anomalies from the seasonal means over the period 1951-80 were calculated. The means were provided by K.R. Thompson (pers. comm., Dalhousie University). The large-scale wind patterns can be estimated from the pressure data assuming geostrophy. The wind blows approximately parallel to the isobars with increasing pressures to the right looking downwind, i.e., high pressure systems represent clockwise (anti-cyclonic) and low pressure systems represent anti-clockwise (cyclonic) motion. The wind speed is proportional to the cross-wind pressure gradient. Near-surface winds are slightly lower in magnitude and rotated anti-clockwise by 10°-20° relative to pure geostrophic winds due to frictional effects. The mean pressure patterns are dominated throughout the year by the Icelandic Low and the Bermuda-Azores High although their strengths vary from winter maxima to summer minima (Thompson and Hazen, 1983).

In 1984, the winter to summer seasons were dominated by high pressure anomalies located over the central North Atlantic Ocean (Fig. 18). The center of the anomalous highs shifted eastward during this time and decreased about 2 mb in intensity from the wintertime maximum of 6.8 mb. In the autumn the high was replaced by an anomalous low centered over northern Scotland. The pressure patterns over the North Atlantic in 1984 were similar to the previous year (Trites and Drinkwater, 1985), that is with a dominate high from winter through summer and a low in autumn. Over the NAFO region the seasonal geostrophic wind anomalies were from the south or southeast during the winter, spring and summer and then from the north in autumn. The gradients were weak, however, especially during the last half of the year when the pressure systems were centered in the eastern North Atlantic.

DISCUSSION

In many respects 1984 was an average year climatologically. The year was characterized by variability both spatially and from month-to-month but in general there were few persistent anomalous features. This was especially true of sea-surface and air temperatures. In spite of this several important trends are noteworthy. Since the mid-1970s there has been a tendency for positive annual SST anomalies north of the Gulf of Maine and negative anomalies south of the Gulf (Trites and Drinkwater, 1985). Data from 1984 showed a sharpe decline in the amplitude of the positive anomalies and may signify a shift to a new SST anomaly pattern in the region. Wave data collected in 1984 continue to suggest a general decline in wave height and the frequency of large waves from maxima in the early 1980s and are now near mid 1970 conditions.

One exception to the near-normal conditions was at Station 27 off St. John's, Newfoundland, where lower layer (below 50 m) temperatures were colder than the mean for the third consecutive year. Surface salinities at Station 27 were also below normal throughout the year continuing a trend beginning in September of 1982. Summer salinities of 30,5 are one of the lowest since the timne series began in 1946.

Although the number of Gulf Stream Rings west of 60° W longitude was normal and the total amount of ring months was the second lowest in over 10 years of records, infrared imagery suggested sinificant effects on the southern Scotian Shelf surface waters (63°-66° W). No long-term statistics of Shelf Water entrainment by rings are available, however, based on visual analysis of satellite imagery over several years it appears to us that in 1984 there was a larger than normal amount of surface water drawn off the Scotian Shelf by such rings. During September two eddies have been roughly estimated to entrain Shelf water whose surface area equalled 25% of the area of the entire Scotian Shelf. Further details of entrainment features off the Scotian Shelf are contained in the monthly State-of-the-Ocean Reports which appear as an appendix to the Weekly Briefing Sheet from the Bedford Institute of Oceanography, Dartmouth, N.S. and a brief summary is presented in Perry and Losier (MS 1985). The effects that the presence of such rings have on the subsurface waters are not well known.

Finally, the number of icebergs drifting southward of 48° N latitude was the highest recorded in over 100 years, however, the large number is believed in part to result from a change in technology with radar replacing visual observations. Detailed intercomparisons between the two methods are required if present iceberg counts are to be compared with the long data set collected by visual methods.

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Table 1. Annual SST anomalies for the 1972-84 period, using the normal period 1972-80. Geographic locations of water masses are shown in Fig. 6.

Water Mass	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	Mean
CF	-.14							.14			.10	-.12	-.01	3.62
LS	-.75	.11	-.24	.44	.16	-.13			.40		-.43	-.11	-.59	5.54
LBT	-.41	02		30		-.23	.16	.11	.04	-.10				2.19
LC	-.28	-.07	-.38	-.12	-.16	.12	.19	.68	.01	.82	.24	.32	.06	5.17
ILC	-.06	-.25	-.57	-.30	.22	-.11	.27	.61	.20	.96	.40	.99	.52	4.83
FC	-.19	.02	-.27	.03	-.18	-.05	.07	.70	-.12	.83	-.39	.46	-.14	7.88
CGB	-.28	-.37	-.20	-.46	.51	.46	.09	.50	-.26	1.11	.34	1.37	.84	6.48
WGB	.05	-.11	-.33	-.63	.34	.16	.31	.30	-.08	1.19	.19	1.11	.62	6.13
SP	.03	-.24	-.52	-.35	-.04	.44	.30	.22	.18	1.14	.35	.87	.79	5.91
GSL	-.64	-.14	-.53	-.15	.11	.17	.30	.73	.15	.56	.46	.91	-.02	5.82
ESS	-.20	-.28	-.29	-.44	.20	-.05	.39	.53	.14	.46	.45	1.28	.56	7.10
SI	.11	-.38	-.40	-.62	.52	.33	.17	.39	-.11	.85	-.20	.96	.97	8.27
SH		-.24	-.61	-.34	.16	-.04	.35	.33	.39			1.43	.66	7.85
LHB	.31	-.47	-.25	-.35	.26	-.28	.13	.51	.14	.30	-.07	.86	.42	8.87
BR	.05	-.28		-.39	.86	-.12	.03	-.05	-.10	.25	-.28	1.07	.51	8.84
Y	-.19	-.13	-.03	-.15	.42	-.43	-.13	.42	.22	.18	-.20	.05	.10	7.64
GOM	-.17	-.20	-.05	-.25	.35	.10	-.11	.39	-.05	.11	.07	.45	.45	9.59
GB	-.27	-.36	.23	.00	.72	-.01	-.50	.00	.19	-.39	-.46	.48	.37	10.17
SNE	-.26	-.11	.56	.17	-.01	-.31	-.31	.28	-.01	-.50	-.03	.38	1.08	12.23
MAB	-.22	.15	.62	.57	-.52	-.08	-.36	-.20	.04	-.43	-.06	.61	.08	14.87
ESW	.12	-.39	.30	.28	.12	.39	.22	-.65	-.39	-.03	-.37	.51	1.25	15.54
WSL	-.15	.27	.37	-.17	.15	.02	-1.02	.53	-.01	-.92	-.48	-.27	-.17	18.50
GS	.15	.10	.26	.20	-.15	.03	-.15	-.04	-.40	-.26	-.16	.08	.08	22.94
SS	-.08	-.09	.15	.10	-.01	.02	-.08	.11	-.12	-.37	-.07	.04	-.05	22.26

TABLE 2. Monthly mean significant wave heights at three locations in the Northwest Atlantic derived from 12-hr wave charts for 1983 and 1984, and the mean heights for 1970-1980.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Labrador Sea (57.5°N, 52.5°W)												
1983	3.10	2.55	2.33	2.03	1.55	2.02	2.10	2.19	2.53	3.35	3.52	3.82
1984	2.95	2.48	2.61	1.77	1.90	1.78	1.74	2.34	2.93	3.08	4.27	4.16
1970-80	3.50	3.36	3.20	2.56	2.02	1.84	1.75	2.01	2.61	3.14	3.33	3.64
Grand Banks (47.5°N, 47.5°W)												
1983	4.29	4.34	3.76	2.72	2.27	2.35	2.68	2.68	2.67	3.44	3.55	4.56
1984	3.44	3.02	2.40	2.78	2.23	2.12	2.00	2.05	2.78	3.11	3.30	3.81
1970-80	3.76	3.48	2.88	2.78	2.22	2.07	1.94	2.22	2.75	3.19	3.41	3.96
Scotian Shelf (42.5°N, 62.5°W)												
1983	3.15	3.93	3.06	2.53	1.97	1.52	1.71	1.56	1.65	2.21	3.17	3.26
1984	2.68	2.90	3.47	2.65	1.98	1.73	1.68	1.35	1.92	2.15	2.12	2.68
1970-80	2.91	2.77	2.80	2.35	1.82	1.70	1.57	1.62	1.76	2.16	2.69	3.00

Table 3 Historical data on presence and duration of sea ice at 24 sites off eastern Canada, and ice duration at these sites in 1984.

Site	period studied	No. of years	Years with ice	Ice duration weeks: when ice present min	max	mean	overall mean	1984
G-7	1966-84	17	17	6	14	9.8	9.8	13
G-10	1977-84	08	08	3	13	8.7	8.7	11
G-12	1968-84	17	17	2	15	11.0	11.0	13
G-22	1977-84	08	08	7	14	11.0	11.0	14
G-31	1969-84	16	15	8	17	12.0	11.2	11
G-33	1971-84	14	13	2	14	9.6	8.9	04
G-35	1962-84	23	11	1	11	3.7	1.8	00
G-86	1976-84	09	08	6	16	12.9	11.4	15
G-87	1971-84	14	13	1	12	6.6	6.2	02
N-19	1967-84	18	18	17	28	24.5	24.5	27
N-21	1968-84	17	17	5	27	17.8	17.8	25
N-23	1960-84	25	19	1	17	5.3	4.0	17
N-25	1960-84	25	02	1	1	1.0	0.0	01
N-27	1960-84	25	00	0	0	---	---	00
N-62	1968-84	17	17	8	24	17.5	17.5	23
N-64	1960-84	25	24	3	24	11.1	10.7	16
N-66	1960-84	25	19	1	15	7.0	5.3	12
N-68	1960-84	25	09	1	10	3.7	1.4	10
N-70	1961-84	24	00	0	0	---	---	00
N-108	1960-84	25	19	1	17	5.4	4.1	01
N-110	1960-84	25	18	1	11	4.2	3.0	04
N-112	1960-84	25	06	1	10	4.8	1.0	04
N-114	1960-84	25	02	1	02	1.5	0.1	00
N-228	1960-84	25	15	1	14	5.0	3.0	03

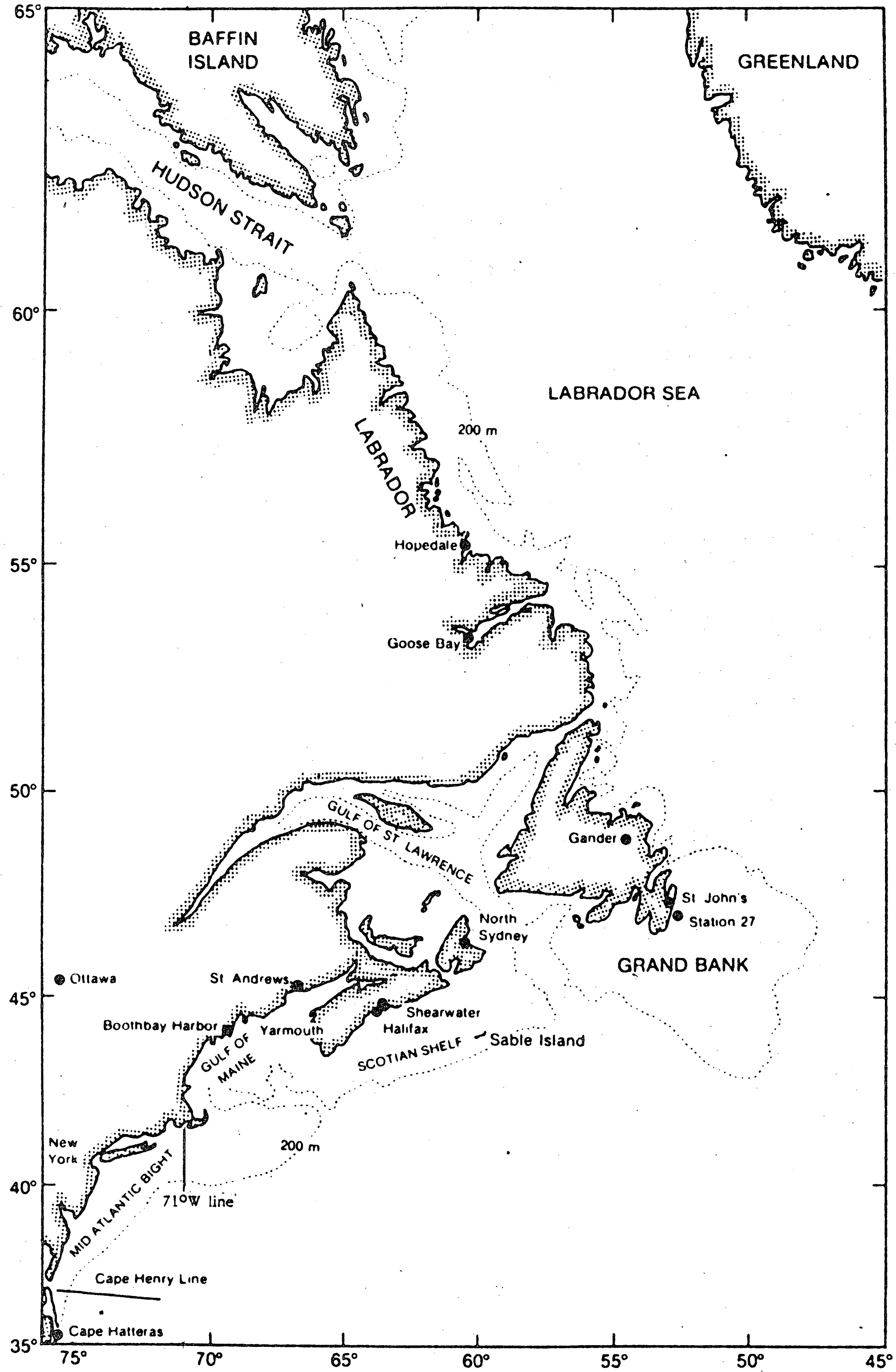

Fig. 1 Map of Northwest Atlantic showing oceanographic and meteorological stations and other place names mentioned in text.

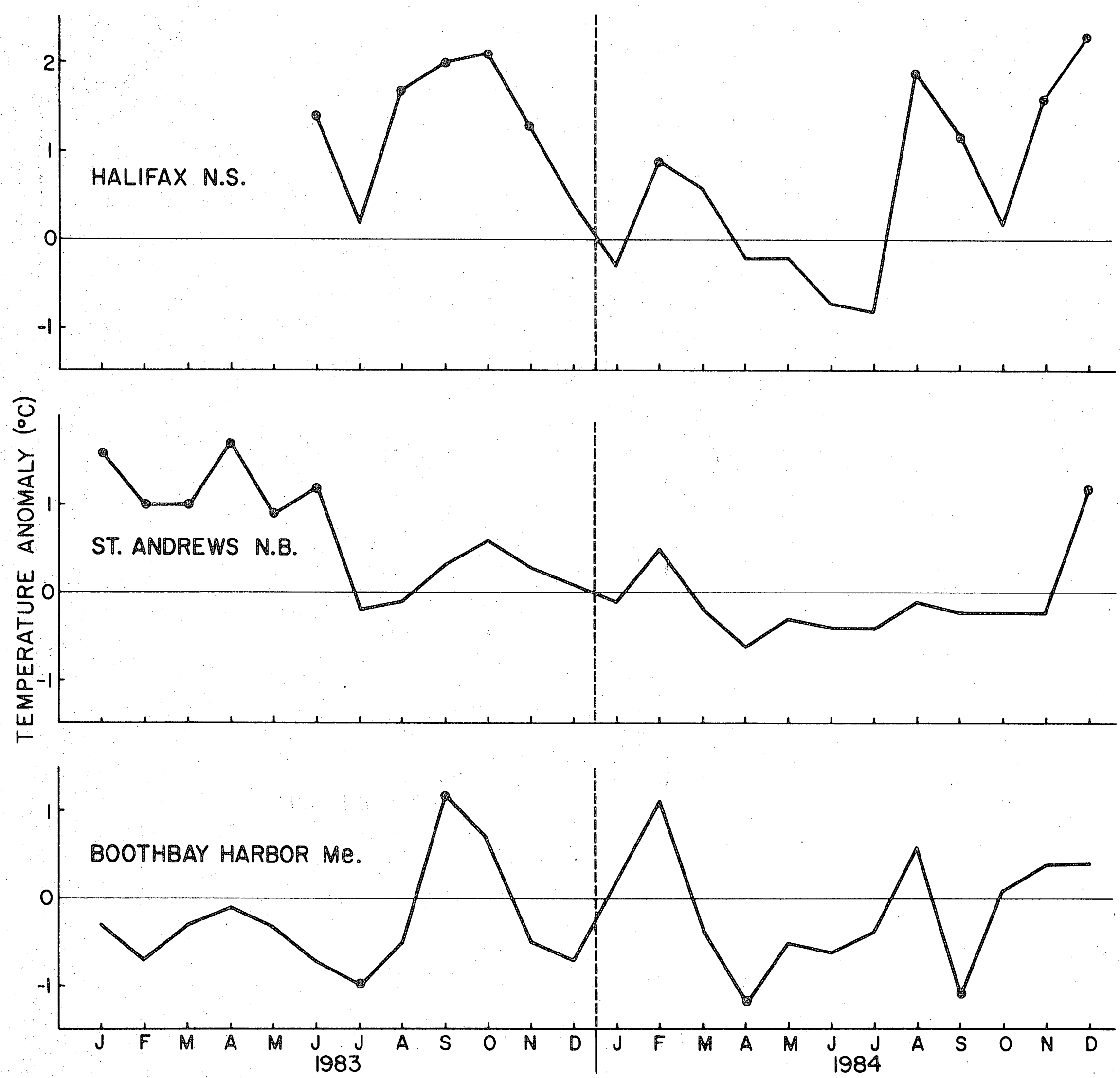

Fig. 2 Monthly sea-surface temperature anomalies at Halifax, St. Andrews and Boothbay Harbor during 1983 and 1984 relative to monthly means for the 1951-80 base period. Dots indicate months when the anomaly equalled or exceeded one standard deviation. (Lack of data for January to May, 1983, at Halifax was due to instrument problems).

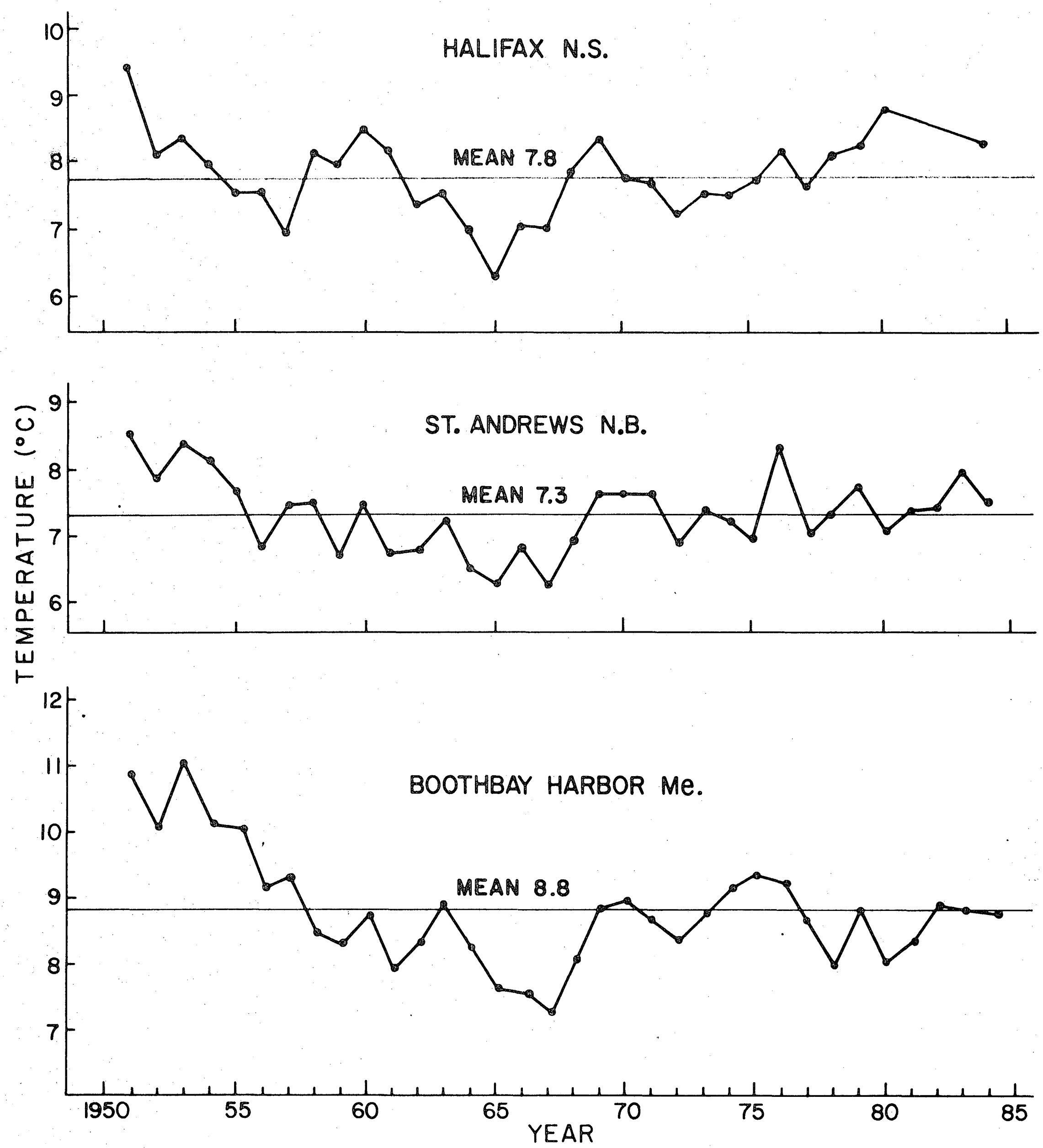

Fig. 3 Annual sea-surface temperature anomalies at Halifax, St. Andrews and Boothbay Harbor during 1951-1983. The mean was calculated over the base period, 1951-80.

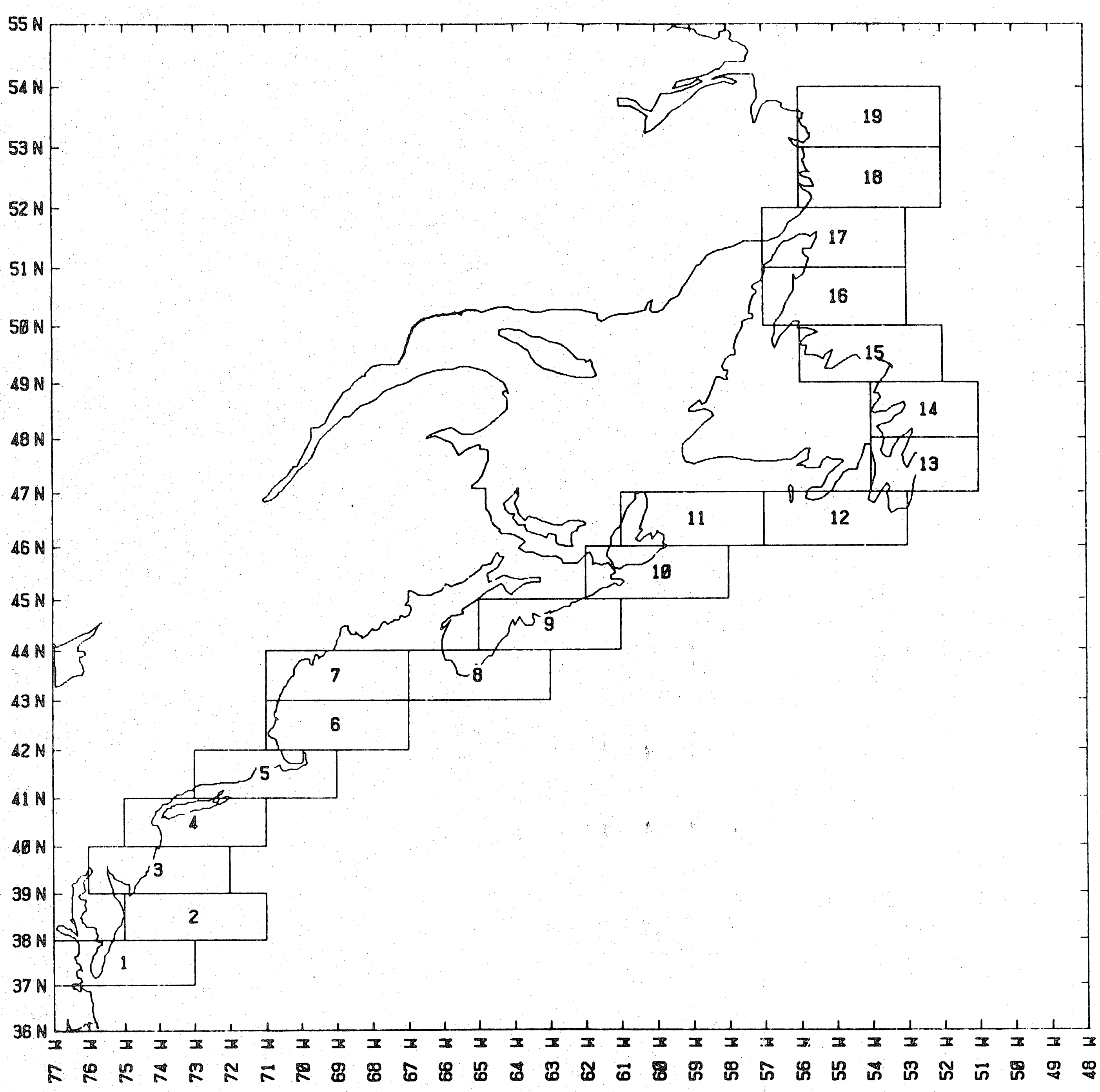

Fig. 4 Locations of 19 areas in the Northwest Atlantic (Chesapeake Bay to southern Labrador) for which sea-surface temperature data were grouped for analysis.

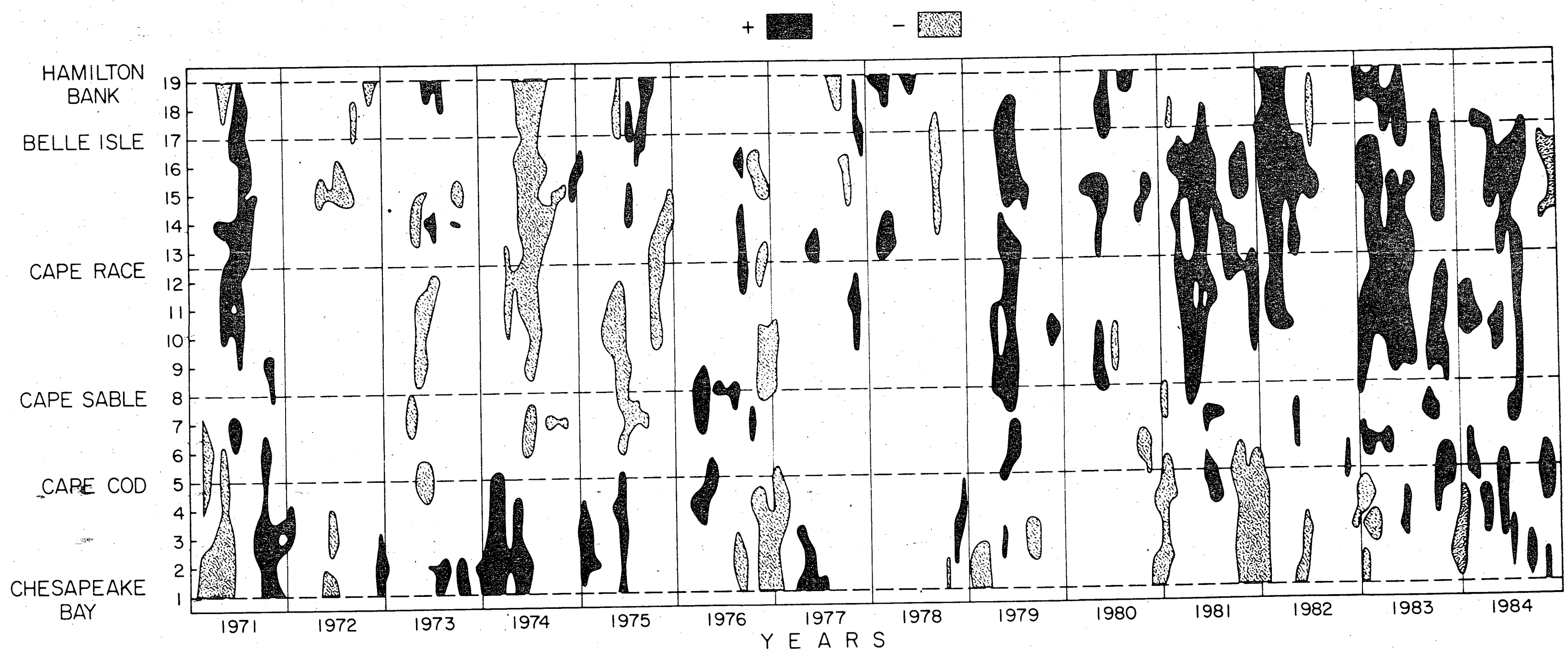

Fig. 5 Contoured plot of monthly sea-surface temperature anomalies (relative to the 1971-80 base period) by area for the 1971-84 period. (Only anomalies exceeding 1°C (dark) and less than -1°C (light) which extended in space through at least two neighbouring areas or in time for at least two consecutive months have been contoured).

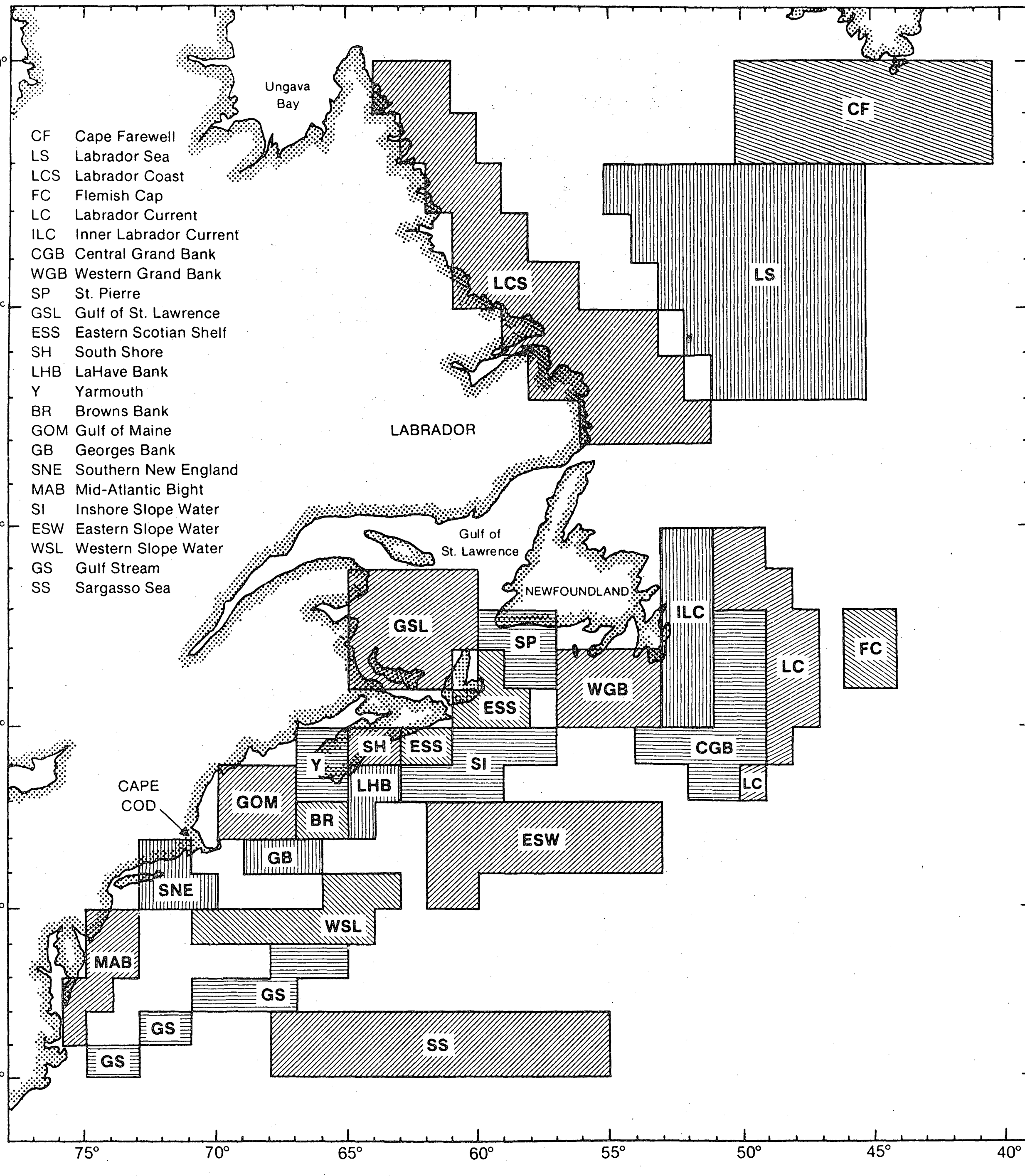

Fig. 6 Geographic boundaries of 24 subregions for which sea-surface temperatures were analyzed on a monthly basis for the period 1972-84 period.

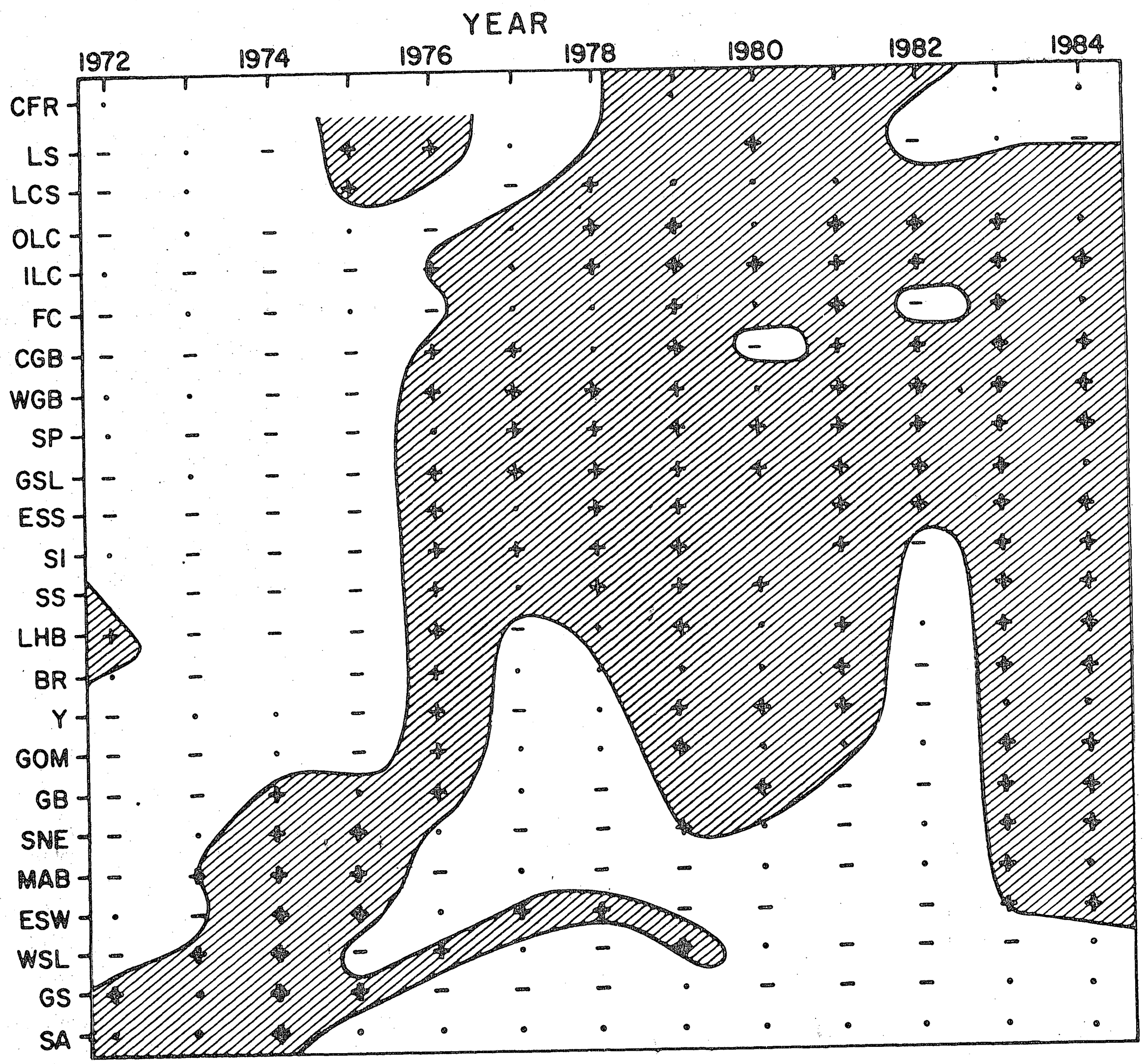

Fig. 7 Distribution of positive (+) and negative (-) annual sea-surface temperature anomalies in 1972-84 by subregions (Fig. 4) relative to the means for the 1972-80 base period. (Only anomalies <-0.15°C and >0.15°C were used in drawing the contours).

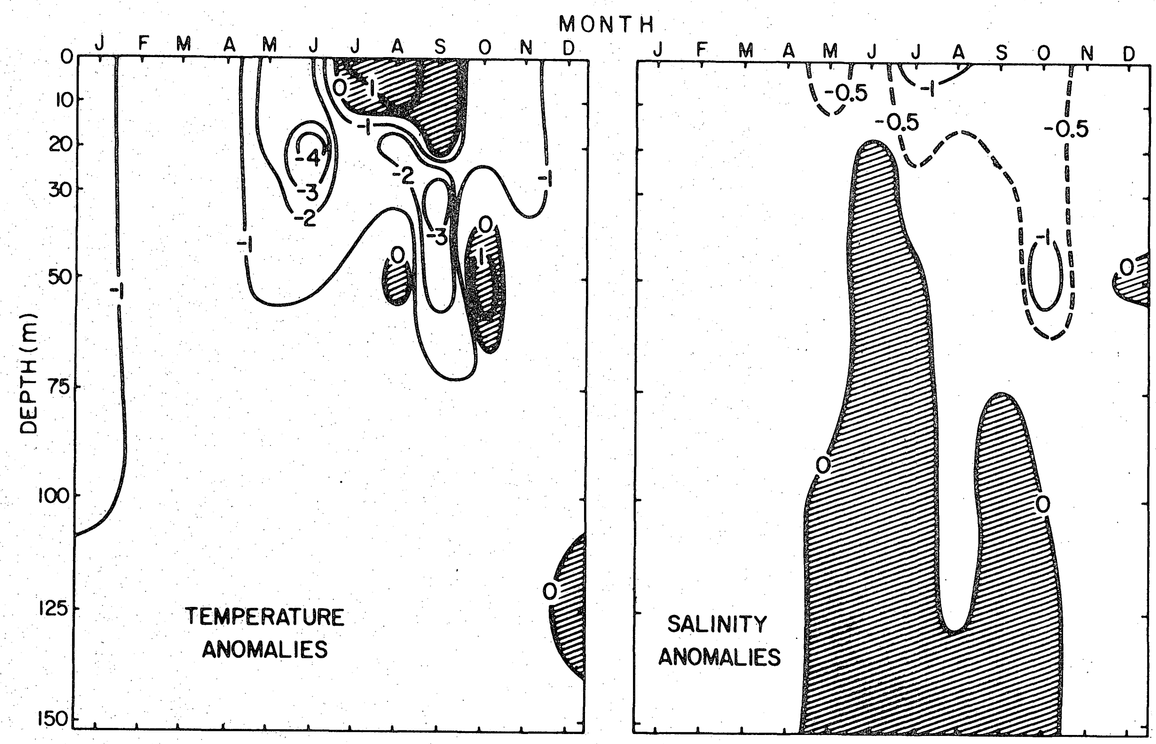

Fig. 8 Monthly temperature and salinity anomalies at Station 27 off St. John's, Newfoundland, for 1984 relative to 1946-77 (Keeley, 1981). No data were collected in March. Shaded areas represent positive anomalies.

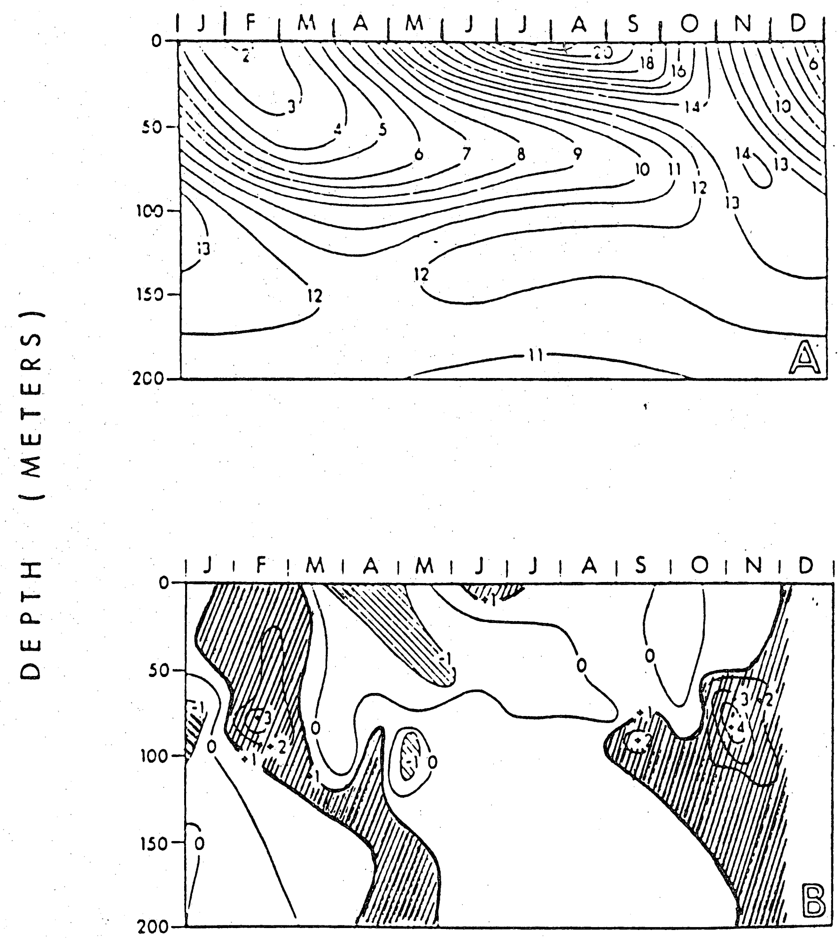

Fig. 9 Bottom temperature (°C) on the continental shelf and upper slope south of New England. (A) Ten-year (1974-1983) mean. (B) Anomaly of 1984 bottom temperature, referenced to ten-year mean, in °C. Hatching denotes anomalies in excess of 1°C. (From Armstrong, 1985a).

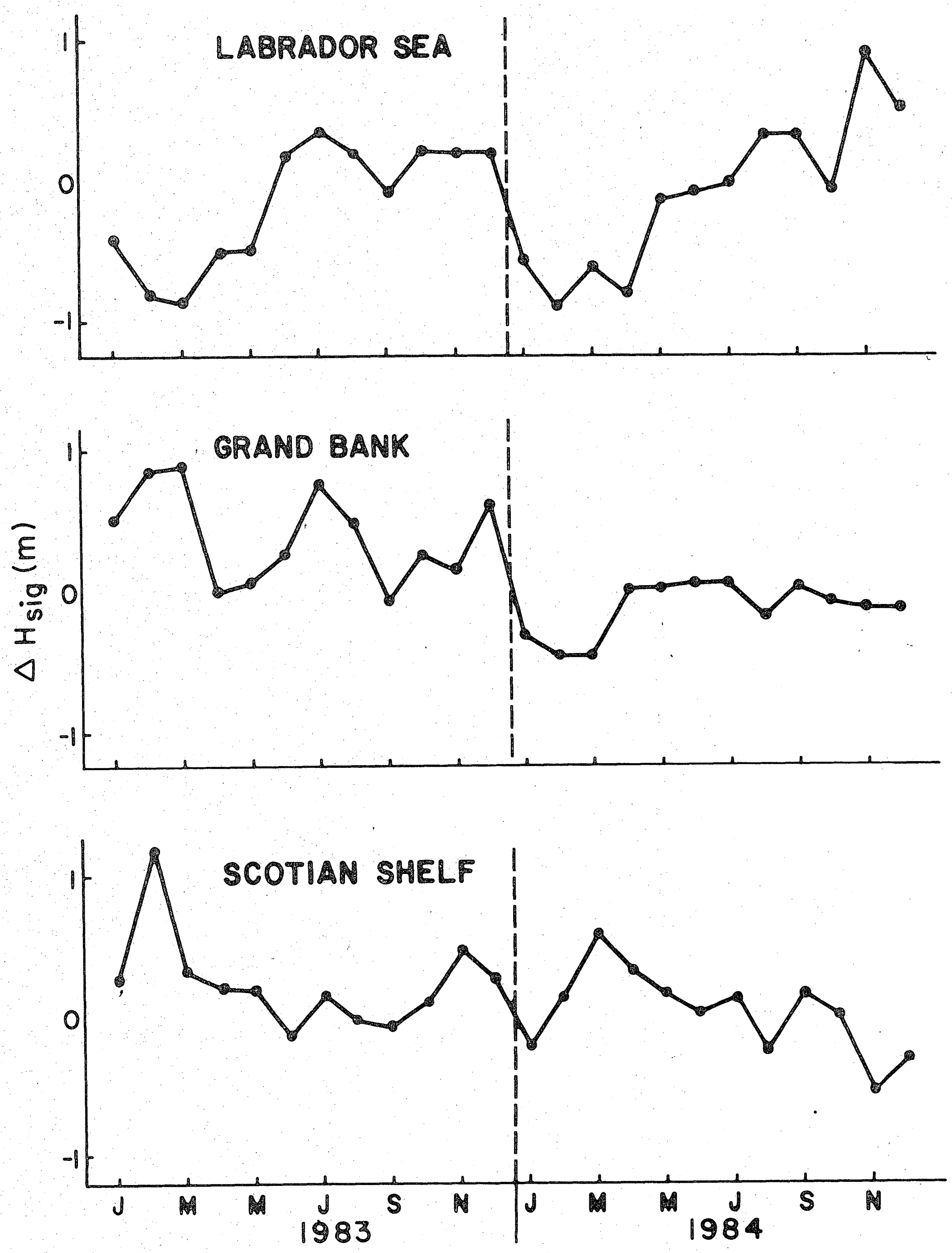

Fig. 10 Monthly significant wave-height anomalies (ΔH_{sig}) in three regions of the Northwest Atlantic for 1983-84 relative to the means for the 1970-80 base period.

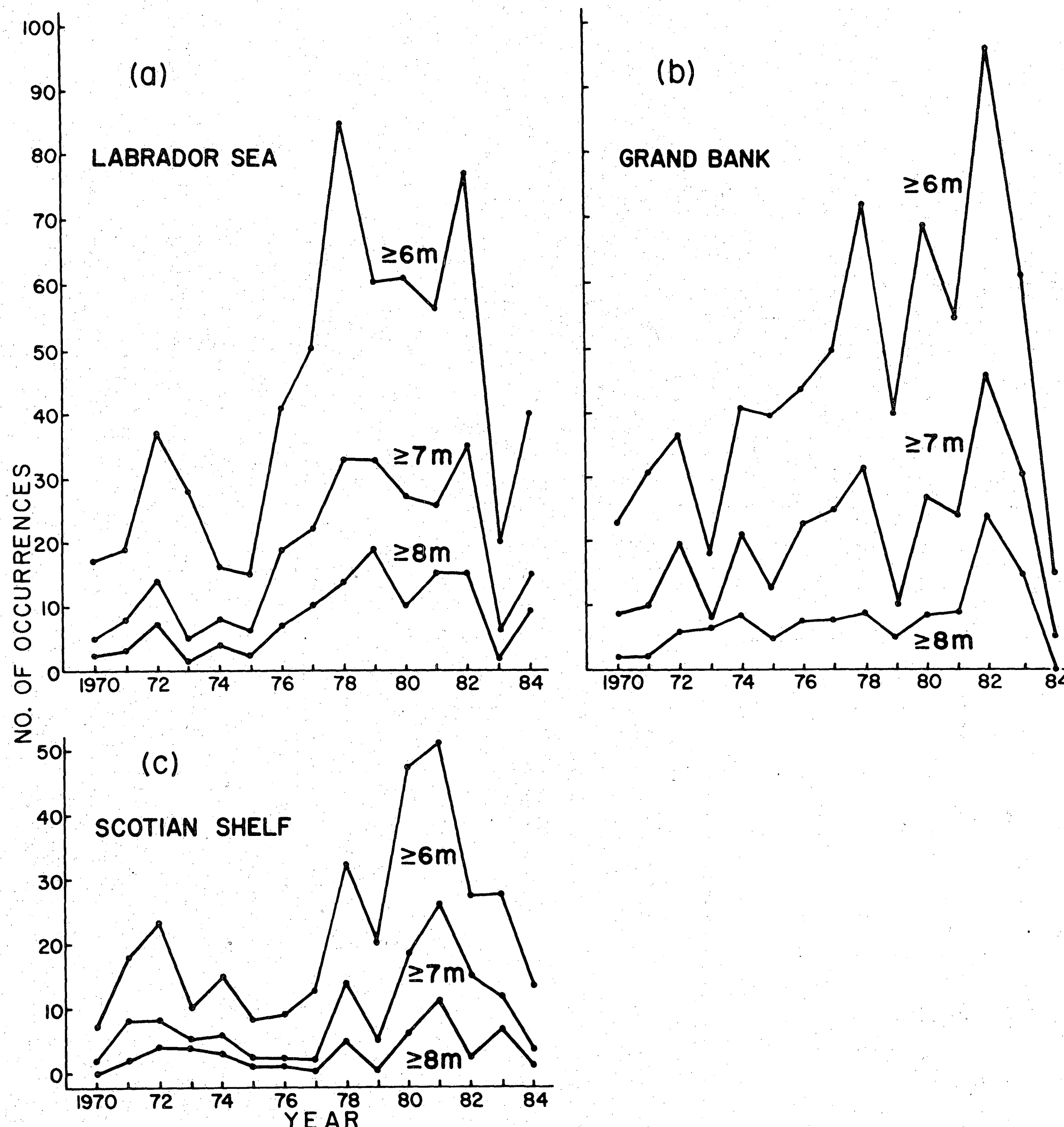

Fig. 11 Annual occurrences of storms during which wave heights exceeded 6, 7 and 8 m in three regions of the Northwest Atlantic during 1970-84.

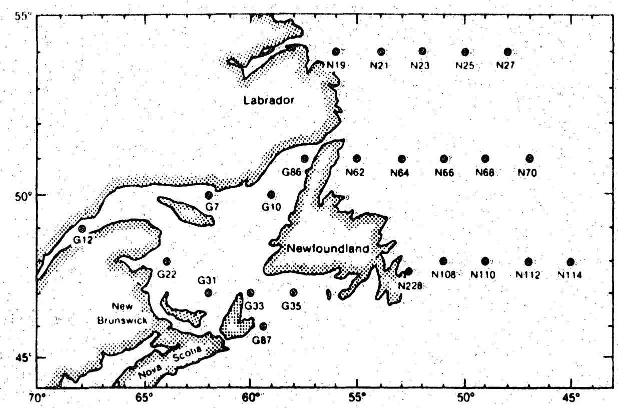

Fig. 12 Locations of 24 sites (grid points) where ice statistics have been extracted from ice charts by the Climatology Division of the Canadian Atmospheric Environment Service.

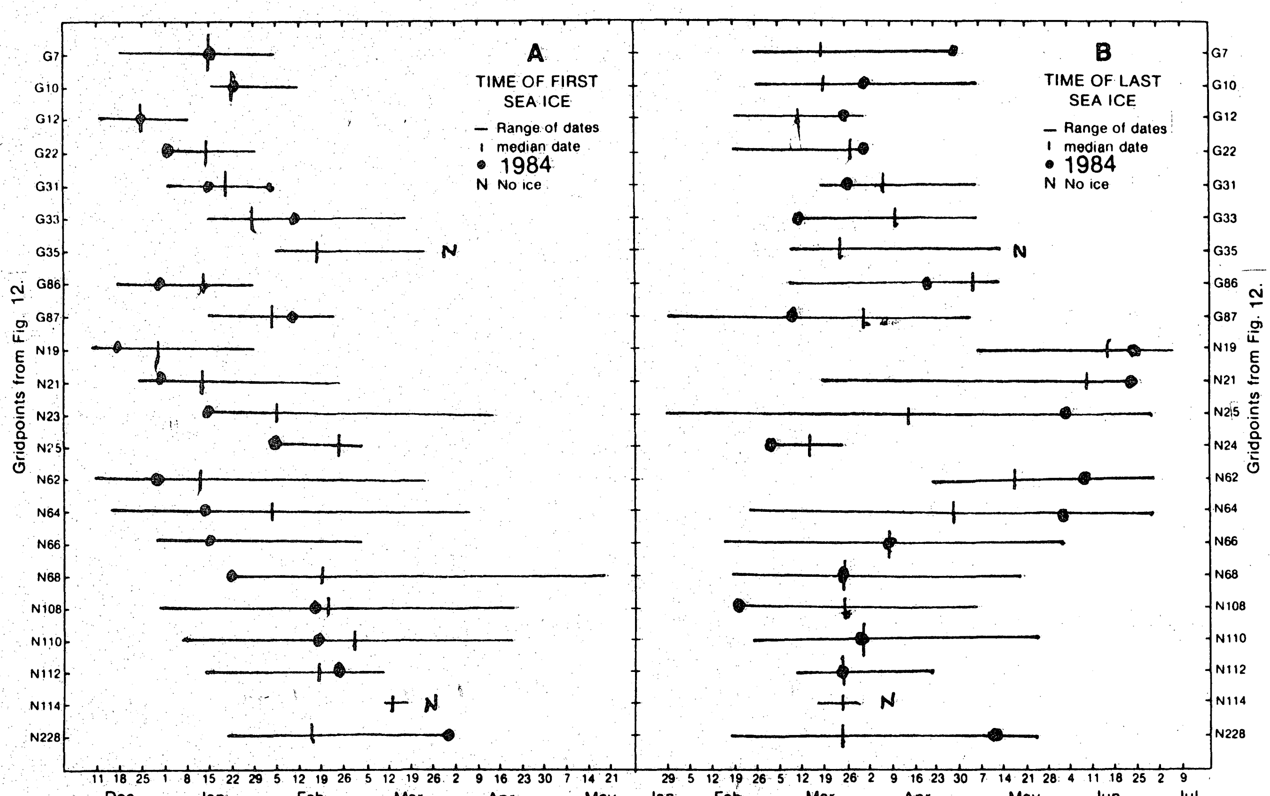

Fig. 13 Ranges of dates for the presence of first sea-ice (A) and last sea-ice (B) at 24 locations in the northwest Atlantic, with median dates and 1984 dates.

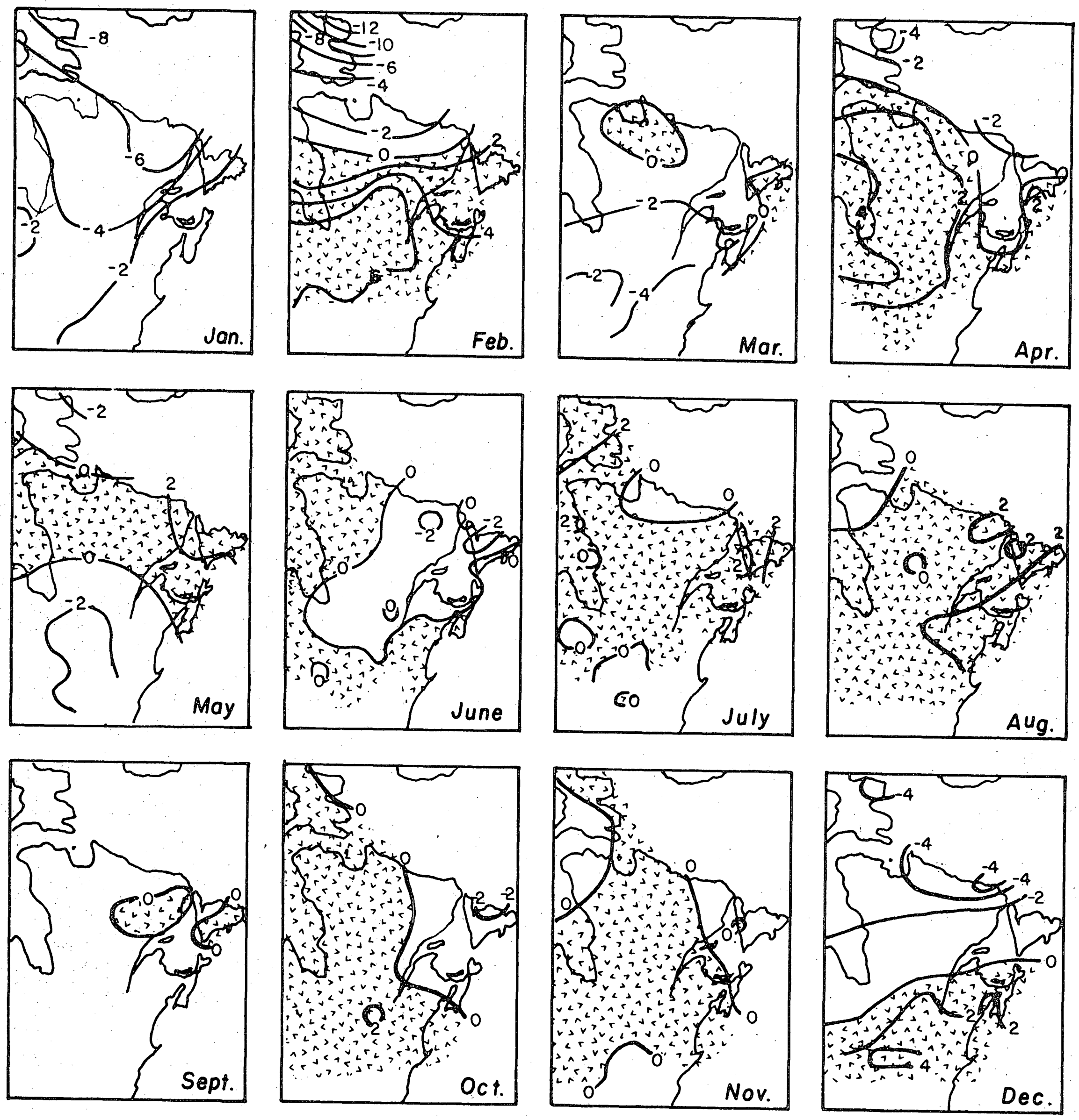

Fig. 14 The 1984 monthly air temperature anomalies (in ^{o}C) relative to 1951-80 mean.

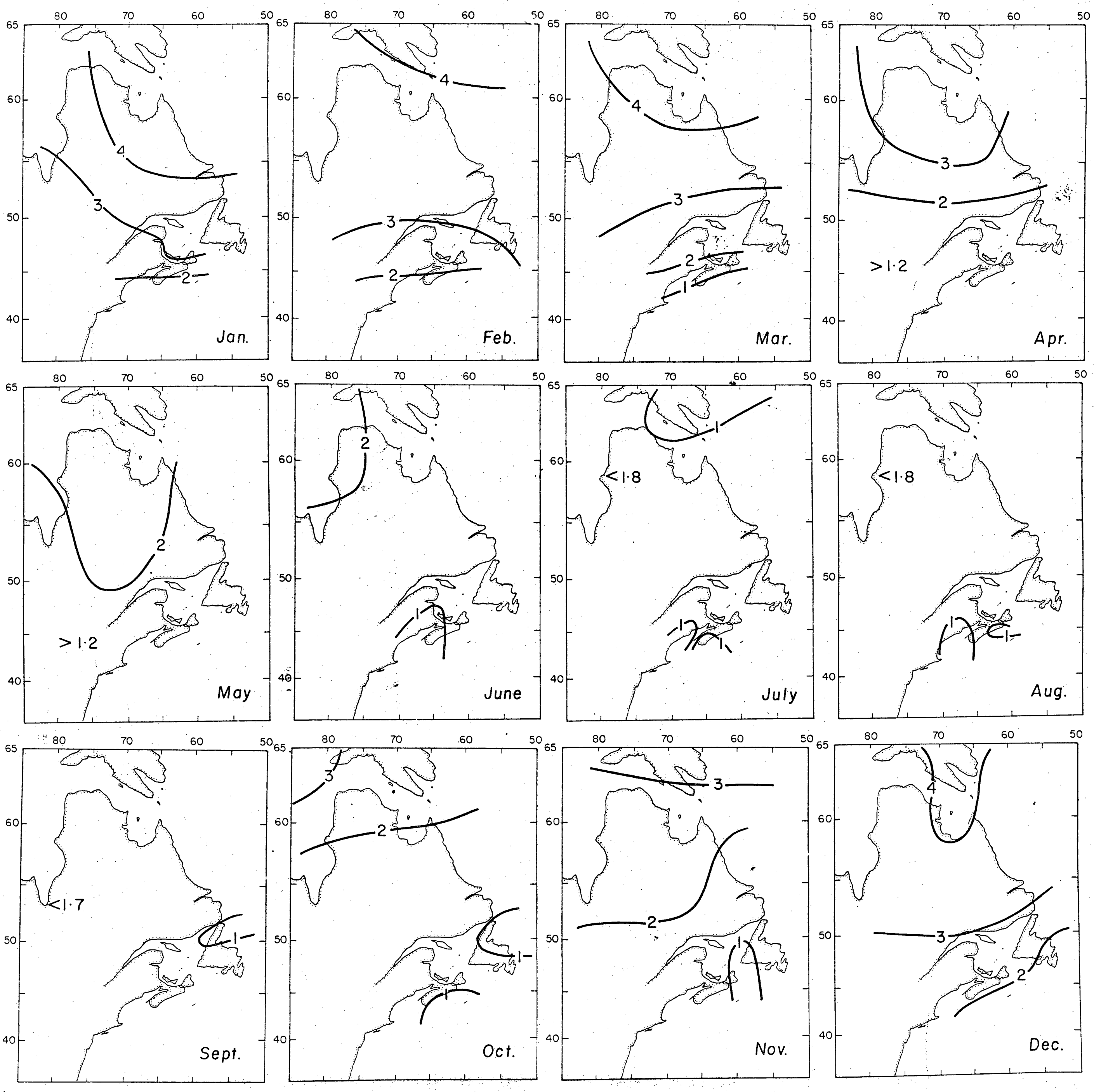

Fig. 15 Standard deviations of the monthly air temperature anomalies (in °C) for 1951-80.

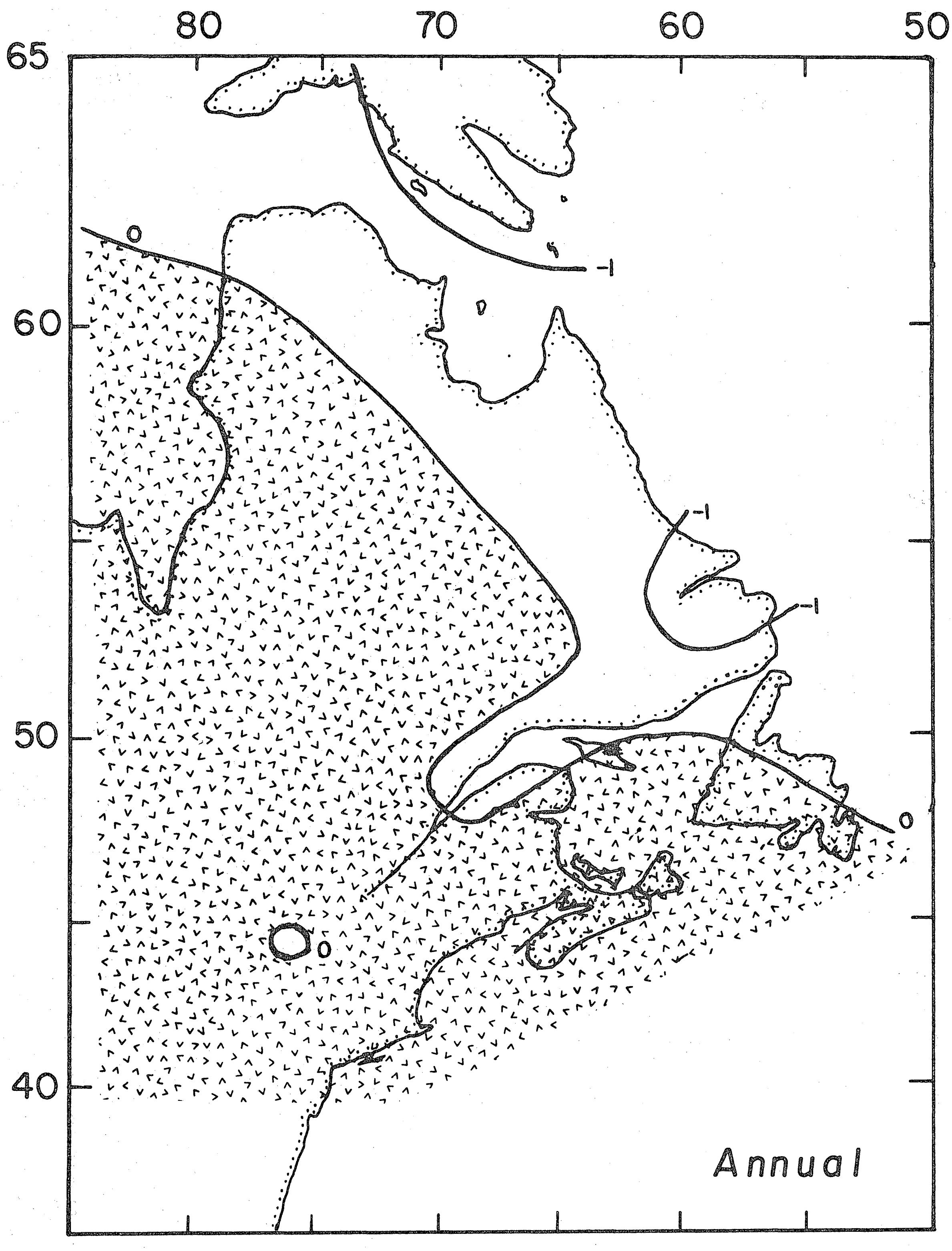

Fig. 16 The 1984 annual air temperature anomalies (in ^{o}C) relative to the 1951-80 mean.

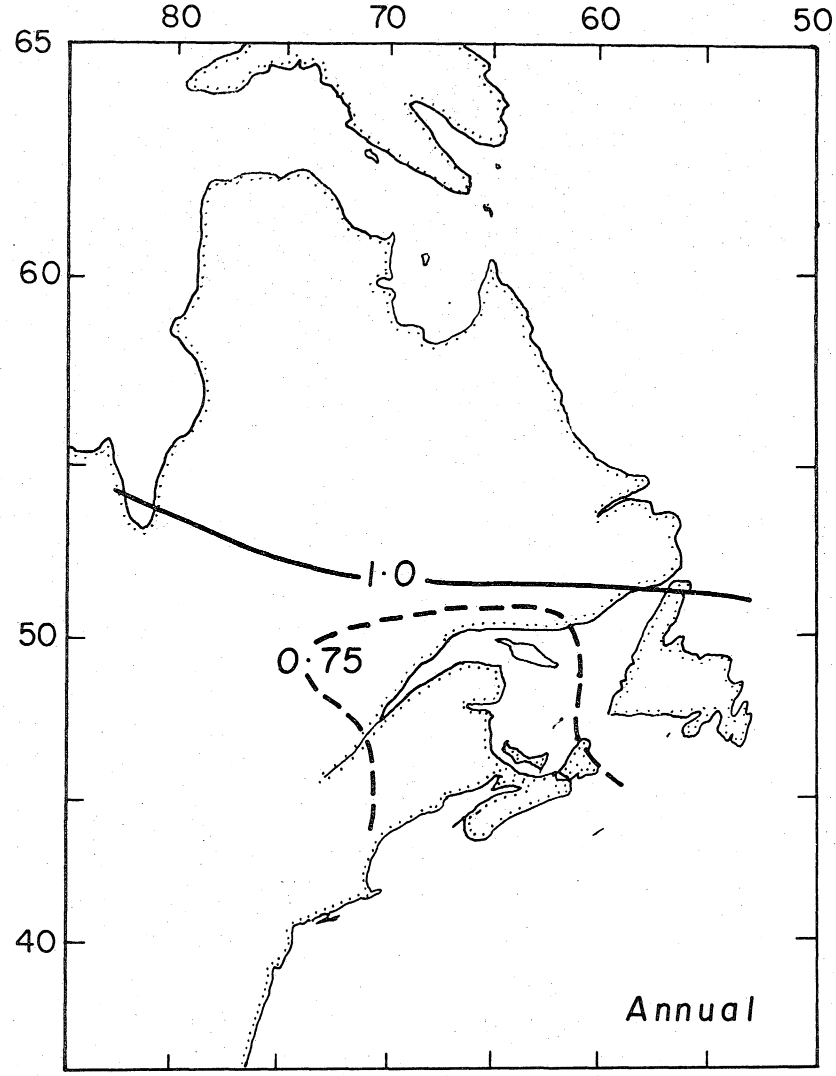

Fig. 17 Standard deviations of the annual air temperature anomalies (in °C) for 1951-80.

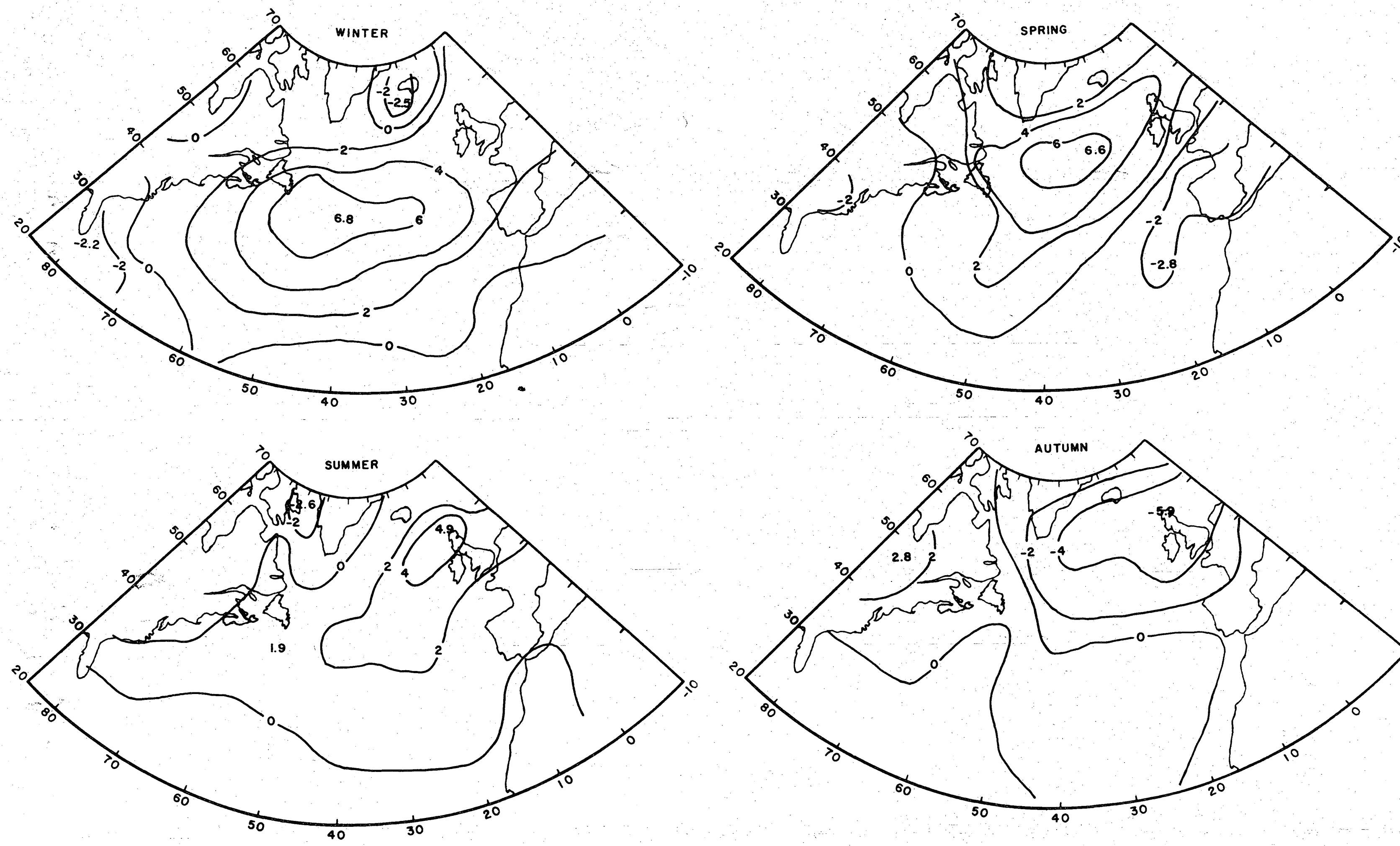

Fig. 18 Seasonal sea-pressure anomalies (in mb) relative to the 1951-80 base period.