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Overview of Environmental Conditions in the Northwest Atlantic in 1987

by

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INTRODUCTION

This paper continues the series of annual environmental overviews of conditions in the Northwest Atlantic (Trites and Drinkwater 1984, 1985, 1986; Drinkwater and Trites 1987, 1988). As in previous reviews it includes 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 in 1987 are compared with those of the preceeding 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 (1961-1980) or 10-yr (1971-1980) base periods were used.

OCEANOGRAPHIC OBSERVATIONS

Coastal sea-surface temperatures

Monthly averages of sea-surface temperature (SST) were obtained for Halifax in Nova Scotia, St. Andrews in New Brunswick, and Boothbay Harbor in Maine (see Fig. 1 for locations). Figure 2 shows the monthly mean temperature anomalies relative to the 1951-80 long-term averages (Trites and Drinkwater, 1984) at each of the sites for 1987 and 1986.

The negative temperature anomalies observed towards the end of 1986 extended into 1987 persisting throughout the winter into spring at all three sites. During summer, temperatures at Halifax rose above normal reaching a peak anomaly of 1.7°C in July. This was in direct contrast to Boothbay Harbor where temperature anomalies remained below normal with the minimum observed in August (-1.6°C). At St. Andrews summer temperatures tended to be cooler than normal in general although no data were available during August due to an instrument malfunction. In the last few months of the year the temperatures at all three sites were again below normal.

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) and 8.2°C at Boothbay Harbor (0.6°C below normal). These continue the decreasing trend in the annual mean SST which began last year. Over the 11 months when data were available at St. Andrews, the mean temperature was 0.4°C below normal.

Offshore sea-surface temperatures

The pattern of monthly SST anomalies along the continental shelf from Chesapeake Bay to southern Labrador (Fig.4) for 1971-86 described by Drinkwater and Trites (1988) was examined for 1987 and compared to earlier years (Fig. 5). During the year, temperatures from the Scotian Shelf northward (areas 9-19) were generally above normal while the southern regions (areas 1-8) were generally below normal. The below normal temperatures recorded throughout the entire continental shelf area during the autumn of 1986 continued into January, 1987, for the area north of St.John's, Newfoundland, and through to the spring in most areas south of Nova Scotia. In the southern area, the below normal temperature pattern was interrupted for a period during summer when slight positive anomalies were evident. Between Halifax and St. John's above normal temperatures were generally reported throughout the year in contrast to the previous two years when below normal values were most prevalent.

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.) 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) for 1984-1986. The monthly mean temperature for each of the 24 areas was computed for 1987. The annual anomalies for 1983 to 1987 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 1972-87 period is shown in Fig.7.

The 1987 anomaly pattern from the Offshore Labrador Current (OLC) area northward and the offshore southern areas (ESW, WSW, and GS) was similar to that of the previous year. The anomaly pattern for the shelf areas from the east coast of Newfoundland (ILC) to Chesapeake Bay (MAB) has undergone a phase shift of 180°. In 1986 the areas from the southwestern Scotian Shelf northward (LHB to FC) displayed below normal temperatures while the areas from Yarmouth (Y) to the Mid-Atlantic Bight (MAB) were above normal. In 1987 the pattern was reversed. Loucks et al. (1986) and Thompson et al. (1988), using empirical orthogonal function anaylses with SST data for the 1946-80 period from the 24 areas, found that the second mode corresponded to temperature fluctuations of opposite sign on the Grand Banks and the Mid-Atlantic Bight with the nodal line across the Scotian Shelf. The 1986-87 anomalies fit this pattern closely. Thompson et al. (1988) believe that most of the SST variability in the Northwest Atlantic can be explained in terms of latent and sensible heat exchange with the atmosphere and is largely a result of changes in atmospheric circulation during the winter (i.e., the onshore-offshore winds).

Temperature and salinity stations

Station 27. Measurements of temperature and salinity have been routinely taken since 1946 at a site located approximately 10 km off St. John's, Newfoundland, designated as Station 27. This station is considered to be representative of the inshore Labrador Current. The station was visited 45 times in 1987, with a monthly maximum of 6 in May and June and a mimimum of one in January and March. The data were collected at, or linearily 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 in the upper 75 m were below normal through to May but were positive during the summer months, a pattern similar to 1986 (Drinkwater and Trites, 1988). In September, 1987, temperatures again fell below normal but rose above normal in the upper 30 m in October and throughout the upper 75 m by December. Negative anomalies in excess of 1°C occurred in January throughout the upper 75 m and again in September-October below 30 m. The limited data in January (1 observation) and September (2) may not, however, reflect the true strength or even sign of the monthly mean anomalies.

For the sixth consecutive year, lower-than-normal temperatures were observed below 75 m at Station 27. The water was colder than last year but comparable to 1984 and 1985 with temperature anomalies of approximately -0.4°C. Last year's decrease in the strength of the negative temperature anomalies relative to the earlier 1980s and the positive anomalies in December of 1986 obviously did not signify an end to the extreme cold conditions as we had speculated they might (Drinkwater and Trites, 1988).

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). The single measurements 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 persistant anomaly features are likely to be real.

During 1987, negative temperature anomalies were slightly more frequent and typically of larger magnitude than were the positive anomalies (Fig. 9). Negative anomalies in excess of 1°C were calculated for March, May, and December. Positive temperature anomalies were generally weak (<1°C). Salinity anomalies were weak (0.5) throughout the year except in the upper 10 m in April. It is likely that these low April salinities were a temporary condition rather than representing mean conditions for the month, however. The strong similarity in the anomaly patterns throughout the water column, most clearly evident in temperature, is due, in part, to the relative homogeneity of the water column caused by the strong tidal mixing in the Bay of Fundy region.

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 14 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 1988) reports that the annual mean frontal position in 1987 generally followed the 10-yr (1974-83) mean. The mean distance to the front, which was always seaward of the 200 m isobath generally decreased from Georges Bank to Cape Hattteras. The standard deviations were comparable to those in 1986 and less than the long-term mean values for all bearing lines. Although the frontal position along some of the section lines shows a tendency to be more offshore during spring and onshore during autumn, any seasonal cycle is overshadowed by shorter period fluctuations. Typically, the largest variability in position of the shelf-slope front is associated with the passage of a warm-core Gulf Stream ring. To date there is no evidence that the number of rings formed, the number present or the number passing through a given geographic zone, varies seasonally.

Warm-core rings

The life history of anticyclonic warm-core Gulf Stream rings in the region from 45°W to 75°W during 1987 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 25 warm-core rings were present in the area during some portion of 1987, four of which survived from 1986 into the new year. *Four of the 21 new rings which formed in 1987 persisted* into 1988. At least 12 of the rings formed in 1987 exceeded an age of 2 months. Their paths, along with those of the four rings from 1986, which also had lifespans of over 2 months, are shown in Fig. 10A. Rings, whose destruction occurred in 1987, ranged in age from less than two weeks to nearly 9 months and had a mean life of 3.5 months. This compares with an age range of one week to one year and a mean of just under 4 months for 1986. The statistics of ring formation and ring presence, compiled by zones, each covering 2.5° of longitude, are shown in Fig. 10B and 10C, respectively. As in 1986, one or more rings were generated in each of the zones east of 70°W. A maximum of 3 formed in each of three zones. The number of rings present in each of the longitutinal zones varied from 2 to 6 with highest number present in the 55°-70°W region. At least one or more rings formed in all months of the year except February and October. Four rings formed in both March and April, the most productive months.

A separate and more complete analysis of warm-core Gulf Stream rings present in 1987 in the slope water and west of 60°W was undertaken by Barton and Sano (MS 1988). The high resolution data from NOAA-9 satellite were atmospherically and geometrically corrected and enhanced to clearly identify thermal features. To help differentiate between clouds, fog and sea-surface thermal features, data from the geostationary satellites (GOES) were also used. *The Oceanographic Analysis maps prepared* by NOAA/NWS 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 1987. Lifespans of individual rings ranged from 10 to 247 d with a mean of just over 4 months. At least 2 rings were present in the slope water for each month of the year and 3 were present during 7 months. Numerous instances of dynamic interactions with shelf waters were noted as the rings move westward and southwestward. Three of the rings which formed in 1987 survived into 1988.

Shelf-slope tempertures in the Mid-Atlantic Bight

Monitoring thermal conditions along a transect extending seaward from New York Harbor across the shelf and slope continued in 1987 for the twelfth consecutive year. From the XBT profiles, depictions of the water column temperature structure and of bottom temperatures through the year have been derived (Benway, MS 1988). *He reports that in 1987 cold-pool water (i.e. <10°C) persisited on* the bottom until early November, which was more than a month later than normal. The geographic extent of bottom water <5°C, a subjective way of estimating winter intensity, was much greater than in previous years, extending offshore to about the 70 m depth contour. Its persistence until mid-April, however, was near normal. The passage of Gulf Stream warm-core rings southwestward across the transect in the offshore slope water may affect the thermal conditions on the shelf and upper slope. In 1987 two warm-core rings passed through the area. Only one, however, produced observable effects on bottom temperature on the shelf and upper slope, where values first increased by about 2°C in February and early March, and then decreased by about 3°C in April. In May, bottom temperatures on the shelf increased to about 13°C at depths of 80-100 m with the passage of the ring.

Waves

Wave observations from many locations in the North Atlantic (*weather ships, government, naval and merchant* vessels, and oil drilling platforms) are transmitted every 6 hr to the Canadian Meteorological and Oceanographic Centre (METOC) at Halifax, Nova Scotia (Neu, 1982). Trites and Drinkwater (1984, 1985, 1986) and Drinkwater and Trites (1987, 1988) provided summary statistics of monthly significant wave heights at three grid points in the northwest Atlantic for each year of the 1970-86 period. The monthly statistics were computed from the 12-hr symoptic wave charts prepared by METOC. The mean monthly significant wave heights in 1986 and 1987, together with the averages for the 1970-80 period, are given in Table 2. The monthly significant wave heights anomalies (relative to the 1970-80 means) for the three areas during 1986 and 1987 are illustrated in Fig. 11. The Labrador Sea wave conditions for 1987 were generally slightly more severe than the 11-yr mean. Positive wave height anomalies occurred in 8 out of the 12 months reaching a maximum in June of 0.68 m. On the Grand Banks, all but the months of March (-0.25 m) and April (-0.5 m) experienced positive anomalies, reaching a maximum of 0.72 m in December. The mean anomaly for the year was only 0.15 m. On the Scotian Shelf, the mean anomaly for the year was 0.11 m, with positve values occuring in 8 of the months. The maximum anomaly (0.57 m) occurred in January and the minimum (-0.34 m) in July.

Using the number of occurrences of significant wave-heights equal to or exceeding 6, 7, and 8 m (Fig. 12) as an index of frequency of storms, indicates that 1987 was less stormy than 1986 in all three regions. The most marked decline occurred on the Grand Banks where the number of occurrences of waves ≥ 6 m was among the lowest in the 1970-87 period (only 1973 and 1984 had lower numbers). The number of storm events in the Labrador Sea was somewhat lower than the 18-yr median, while events for the Scotian Shelf was near the long-term median.

Sea ice

The Ice Climatology and Applications Division of the Canadian Atmospheric Environment Service undertakes an annual analysis of ice conditions in the Gulf of St. Lawrence and off the east coast of Newfoundland and southern Labrador by determining the time of onset, duration and latest presence of ice at 24 grid sites (Fig. 13). Results for 1982/83 to 1985/86 were previously summarized by Trites and Drinkwater (1985, 1986) and Drinkwater and Trites (1987, 1988). The present analysis has been updated to include data for the 1986/87 season. For each site, the extracted data were ice duration in weeks for the 1986/1987 season, mean duration for all years of record, as well as minimum, maximum and mean duration for years when ice was present (Table 3). Within the Gulf of St. Lawrence, ice duration was longer than normal and reached maximum values at two sites (G7, G22). Ice duration off the east coast of Newfoundland and southern Labrador was generally comparable to the long-term mean with the exception of the site off St. John's (N228) where a 10-week duration was well above normal. The timing of first and last ice, the mean dates and the dates for 1985/86 and 1986/87 ice seasons are shown in Fig. 14. Ice formed early within the Gulf of St. Lawrence with earliest dates on record for several sites (G7, G22, G86). Time of last ice was generally later than normal with one area (G31) clearing at a record late date. Off the east coast of Newfoundland and southern Labrador the time of onset was generally earlier than normal for the inshore areas (N19, N21, N62, N108, N110, N228) and later than normal for the offshore areas (N23, N25, N66, N68, N112, N114).

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 1986/87 iceberg season (October to September), a total of 318 icebergs were spotted south of 48°N. No icebergs were observed in October and November, 1986, and September, 1987. The monthly totals for December to August are, respectively, 5, 2, 14, 48, 76, 29, 127, 15, and 2. In the primary iceberg season, March to August, 297 icebergs were observed which represents 93% of the annual total. The numbers of bergs detected in 1986/87 is an increase of over 100 from the 1985/86 season. For both years there were fewer icebergs reported than in each of the three previous years. While the latter were the first years that the SLAR was used for iceberg detection and the reported numbers are believed to be overestimates, the years 1982/83, 1983/84, and 1984/85 were heavy ice years (N. Thayer, U.S. Coast Guard, personal communication).

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 1987 monthly anomalies are plotted in Fig. 15. The main feature over southern Baffin Island was the negative temperature anomalies during the winter and spring months that reached a peak of 4°C below normal near Cape Dyer. Positive air temperature anomalies occurred along the entire Labrador coast in 6 out of the 12 months while negative anomalies were observed during 2 months. For the remainder the anomalies on the northern and southern Labrador coasts were of opposite sign. Typically the northern regions were colder-than-normal and the southern warmer-than-normal. Off Newfoundland, in the Gulf of St. Lawrence, and off Nova Scotia air temperature anomalies showed more variability but tended toward negative values during the winter (January-March) and at the end of the year (November-December). Temperature anomalies in these coastal regions were generally of low magnitude (<2°C).

The annual air temperature anomalies were predominantly above normal over most of eastern Canada during 1987 with the strength of the anomalies generally increasing westward (Fig. 16). Over Hudson Strait and southern Baffin Island negative temperature anomalies occurred with the latter reaching magnitudes of over 1°C. Annual mean temperatures in the extreme southwestern corner of the Gulf of St. Lawrence and off Nova Scotia were also slightly below normal. The anomaly pattern contrasts with that observed in 1986 which showed mainly negative anomalies and the magnitude generally increasing to the northeast.

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 1987 relative to the 1951-80 means (provided by K.R. Thompson, Dalhousie University, Halifax) are shown in Fig. 17. Winter covers December 1986 to February 1987, spring is March to May, summer is June to August and autumn is September to November.

In winter, a slight westward shift in the position of the Icelandic Low and a southward shift in the Bermuda-Azores High resulted in predominantly below normal pressures over the Northwest Atlantic (exceeding -6 mb). This pattern suggests anomalous northeasterly winds over Newfoundland and southern Labrador and north to northwesterly over the Gulf of St. Lawrence and Nova Scotia. The wintertime pattern was replaced during the spring with an equally strong positive anomaly. The pressure anomalies in the northwest Atlantic weakened during the summer and autumn to a minimum of slightly less than -3 mb and a maximum slightly over 3 mb in autumn.

SUMMARY

Sea-surface temperatures showed a general trend of warmer-than-normal in the north and colder-than-normal in the south with the mid-Scotian Shelf as the approximate nodal area. This is similar to the SST pattern of the late 1970s and early 1980s but opposite that of the last two years. The deep waters (>75 m) at Station 27, off St. John's, Newfoundland, were colder-than-normal for the 6th consecutive year. They were also colder than last year having dropped to values close to those observed earlier this decade.

The position of the shelf-slope front between Cape Hatteras and Georges Bank was near normal in 1987 although the cold pool water on the shelf persisted one month later than normal. The number of warm-core Gulf Stream rings that formed was similar to 1986.

The Grand Banks appeared less stormy than usually with the number of occurances of waves ≥6 m being the third lowest over the 18 year record. The Labrador Sea had slightly fewer large waves than normal while the Scotian Shelf was near normal. While sea ice duration off northern Newfoundland was average, off St. John's it lasted 6 weeks longer than normal. Ice also lasted longer in the Gulf of St. Lawrence having formed early and left late. There were a third more icebergs reaching 48°N in 1987 than last year.

Mean annual air temperatures were slightly above normal on the Labrador Shelf, around Newfoundland, and in most of the Gulf of St. Lawrence in 1987. Colder-than-normal air temperatures were recorded around Nova Scotia, in Hudson Strait, and on Baffin Island.

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TABLE 1. Mean sea-surface temperatures for selected areas of the Northwest Atlantic in 1972-80 and anomalies for 1983 to 1987 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) 1983	1984	1985	1986	1987
CF	3.62	-0.12	-0.01	1.03	0.99	1.12
LS	5.54	-0.11	-0.59			0.34
LCS	2.19					-0.21
OLC	5.17	0.32	0.06	-0.90	-0.19	-0.30
ILC	4.83	0.99	0.52	-0.38	0.24	0.31
FC	7.88	0.46	-0.14	-0.80	-0.24	0.08
CGB	6.48	1.37	0.84	-0.54	-0.16	0.19
WGB	6.13	1.11	0.62	-0.69	-0.23	0.39
SP	5.91	0.87	0.79	-0.36	-0.28	0.91
GSL	5.82	0.91	-0.02	-0.01	0.08	0.42
ESS	7.10	1.28	0.56	-0.29	-0.24	0.42
SI	8.27	0.96	0.97	-0.49	-0.57	0.02
SH	7.85	1.43	0.66	-0.18	-0.34	0.70
LHB	8.87	0.86	0.42	-0.33	-0.53	0.02
BR	8.84	1.07	0.51	0.17	-0.05	-0.43
Y	7.64	0.05	0.10	-0.45	0.29	-0.37
GOM	9.59	0.45	0.45	0.10	0.25	-0.74
GB	10.17	0.48	0.37	0.21	0.14	-0.66
SNE	12.23	0.38	1.08	0.14	0.09	-0.51
MAB	14.87	0.61	0.08	0.80	0.15	-0.43
ESW	15.54	0.51	1.25	0.02	-0.34	0.10
WSW	18.50	-0.27	-0.17	0.52	-0.16	-0.65
GS	22.94	0.08	0.08	0.11	0.46	0.30
SS	22.26	0.04	-0.05	-0.14	0.04	-0.08

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

TABLE 2. Monthly mean significant wave heights (m) at three locations in the Northwest Atlantic (derived from 12-hr wave charts) for 1986 and 1987 relative to the 1970-80 mean.

	Labrador Sea (57.5°N 52.5°W)			Grand Bank (47.5°N 47.5°W)			Scotian Shelf (42.5°N 62.5°W)		
Mon	1970-80	1986	1987	1970-80	1986	1987	1970-80	1986	1987
JAN	3.50	3.66	3.03	3.76	4.00	4.06	2.91	3.68	3.48
FEB	3.36	3.50	3.73	3.48	3.63	3.70	2.77	2.93	3.07
MAR	3.20	3.56	2.79	2.88	3.32	2.63	2.80	2.95	2.68
APR	2.56	2.48	2.67	2.78	2.42	2.28	2.35	2.65	2.40
MAY	2.02	2.35	2.47	2.22	2.21	2.39	1.82	2.37	1.79
JUN	1.84	2.30	2.52	2.07	2.37	2.48	1.70	2.02	1.80
JUL	1.75	1.85	2.03	1.94	2.24	2.18	1.57	1.60	1.23
AUG	2.01	1.92	2.02	2.22	2.21	2.31	1.62	2.00	1.52
SEP	2.61	2.45	2.58	2.75	2.50	2.77	1.76	1.90	1.97
OCT	3.14	4.03	3.13	3.19	3.19	3.31	2.16	2.48	2.29
NOV	3.33	3.47	3.58	3.41	4.20	3.68	2.69	2.63	2.83
DEC	3.64	2.87	3.98	3.96	3.74	4.68	3.00	3.03	3.37

TABLE 3. Historical data on presence and duration of sea ice at 24 sites off eastern Canada and ice duration at these sites in the 1986/87 (October-September) ice year with 1985/86 data in parentheses.

				Ice Duration (weeks)				
Site	Seasons studied	# of Yr	Yrs with ice	When ice present Min	Max	Mean	Over-all Mean	1986-87 (1985-86)
G-7	67/68-86/87	20	20	6	16	10.5	10.5	16 (15)
G-10	76/77-86/87	11	11	3	17	10.5	10.5	12 (17)
G-12	67/68-86/87	20	20	2	15	11.3	11.3	14 (12)
G-22	76/77-86/87	11	11	7	14	11.6	11.6	14 (13)
G-31	68/69-86/87	19	18	8	17	12.2	11.6	15 (13)
G-33	71/72-86/87	16	16	2	14	9.7	9.7	8 (11)
G-35	59/60-86/87	28	13	1	11	3.7	1.7	0 (6)
G-86	76/77-86/87	11	11	6	22	14.7	14.7	15 (22)
G-87	70/71-86/87	17	16	1	12	7.0	6.6	7 (8)
N-19	66/67-86/87	21	21	17	30	23.5	23.5	24 (21)
N-21	67/68-86/87	20	20	5	28	17.9	17.9	14 (13)
N-23	59/60-86/87	28	22	1	17	5.1	4.0	3 (1)
N-25	59/60-86/87	28	2	1	1	1.0	0.1	0 (0)
N-27	59/60-86/87	28	0	0	0	0.0	0.0	0 (0)
N-62	67/68-86/87	20	20	8	27	18.1	18.1	20 (18)
N-64	59/60-86/87	28	27	3	25	12.0	11.6	13 (15)
N-66	59/60-86/87	28	22	1	16	7.2	5.7	1 (10)
N-68	59/60-86/87	28	11	1	10	3.4	1.3	0 (1)
N-70	60/61-86/87	27	0	0	0	0.0	0.0	0 (0)
N-108	59/60-86/87	28	22	1	17	5.5	4.4	4 (7)
N-110	59/60-86/87	28	21	1	12	4.6	3.4	2 (6)
N-112	59/60-86/87	28	9	1	10	4.3	1.4	1 (2)
N-114	59/60-86/87	28	3	1	2	1.3	0.1	0 (0)
N-228	59/60-86/87	28	18	1	14	5.3	3.4	10 (4)

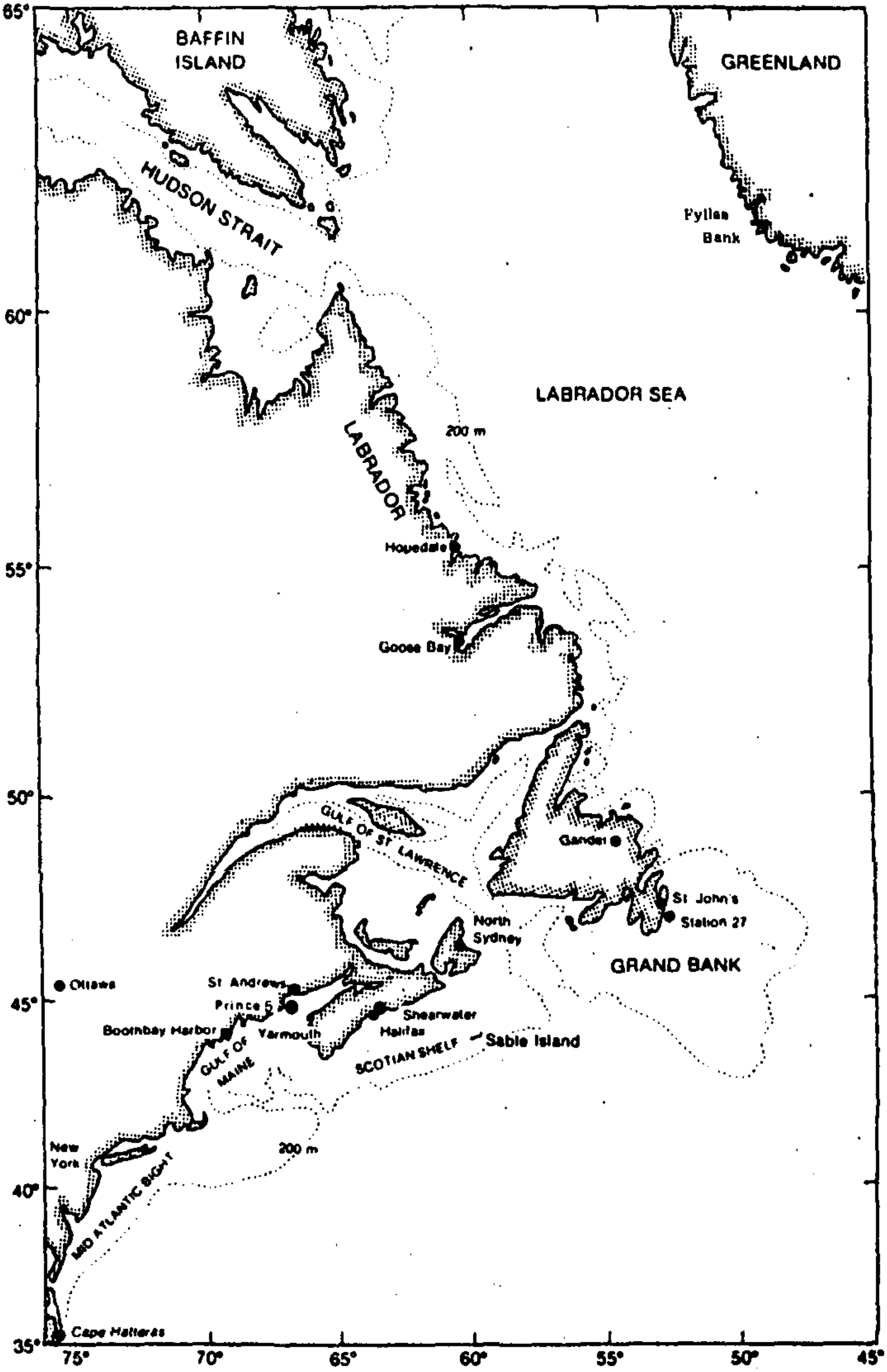

Fig. 1. Map of Northwest Atlantic showing oceanographic stations and other sites mentioned in the text.

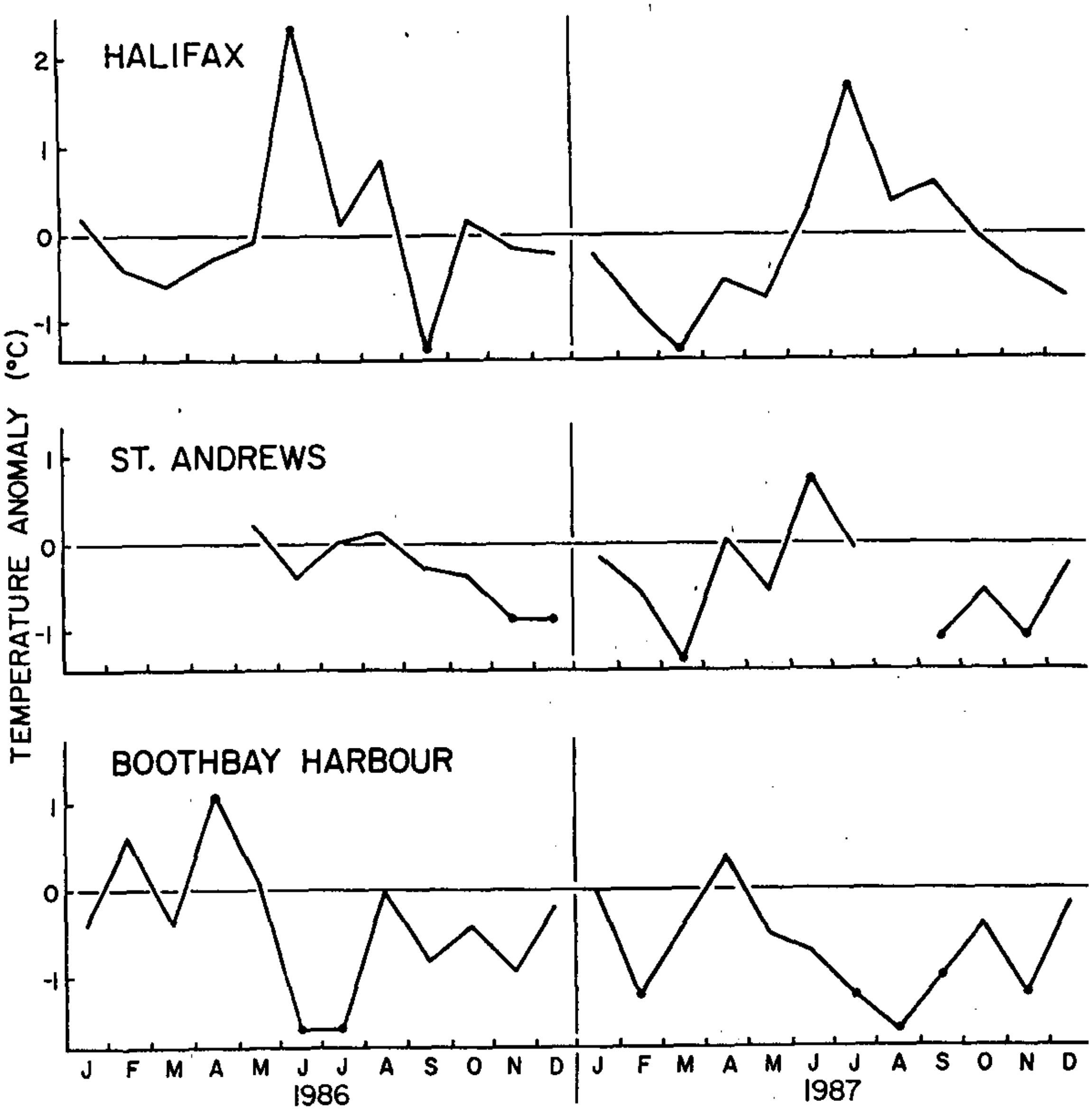

Fig. 2. Monthly sea-surface temperature anomalies at Halifax, St. Andrews and Boothbay Harbor in 1986 and 1987 relative to the 1951-80 means. (Dots indicate months when the anomalies equalled or exceeded one standard deviation. The missing data for St. Andrews during the early months of 1986 were due to wharf reconstruction and during August, 1988, due to an instrument malfunction.

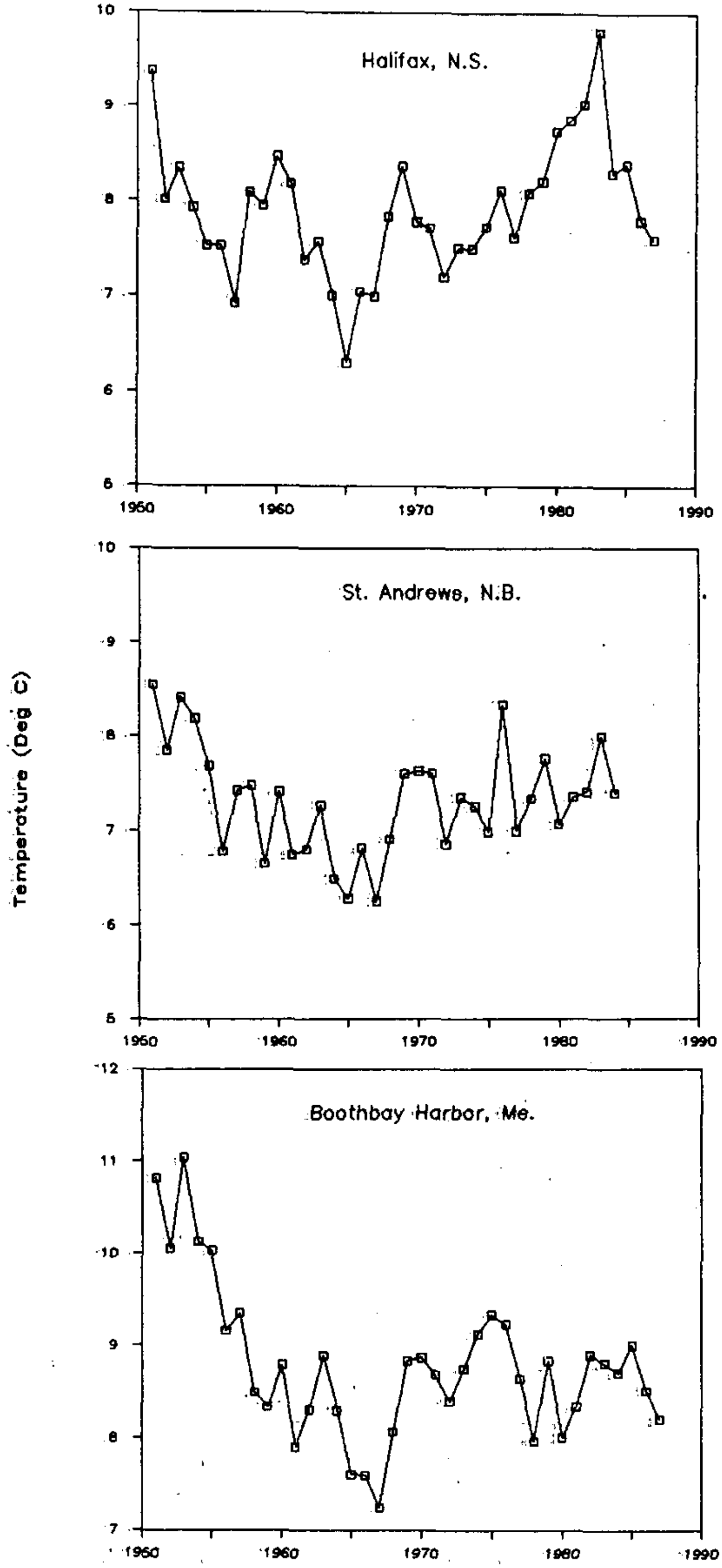

Fig. 3. Annual sea-surface temperatures at Halifax, St. Andrews and Boothbay Harbor during 1951-87.

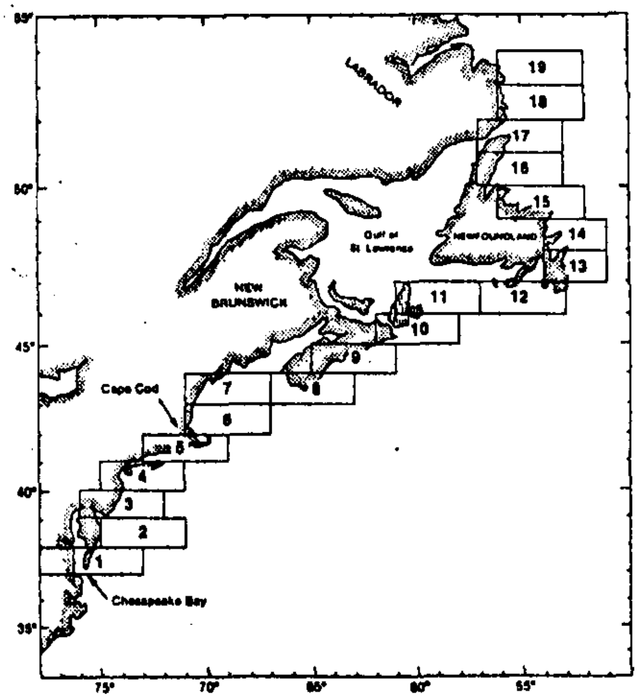

Fig. 4. Locations of 19 areas in the Northwest Atlantic (Chesapeake Bay to southern Labrador) for which sea-surface temperature data were grouped for analysis.

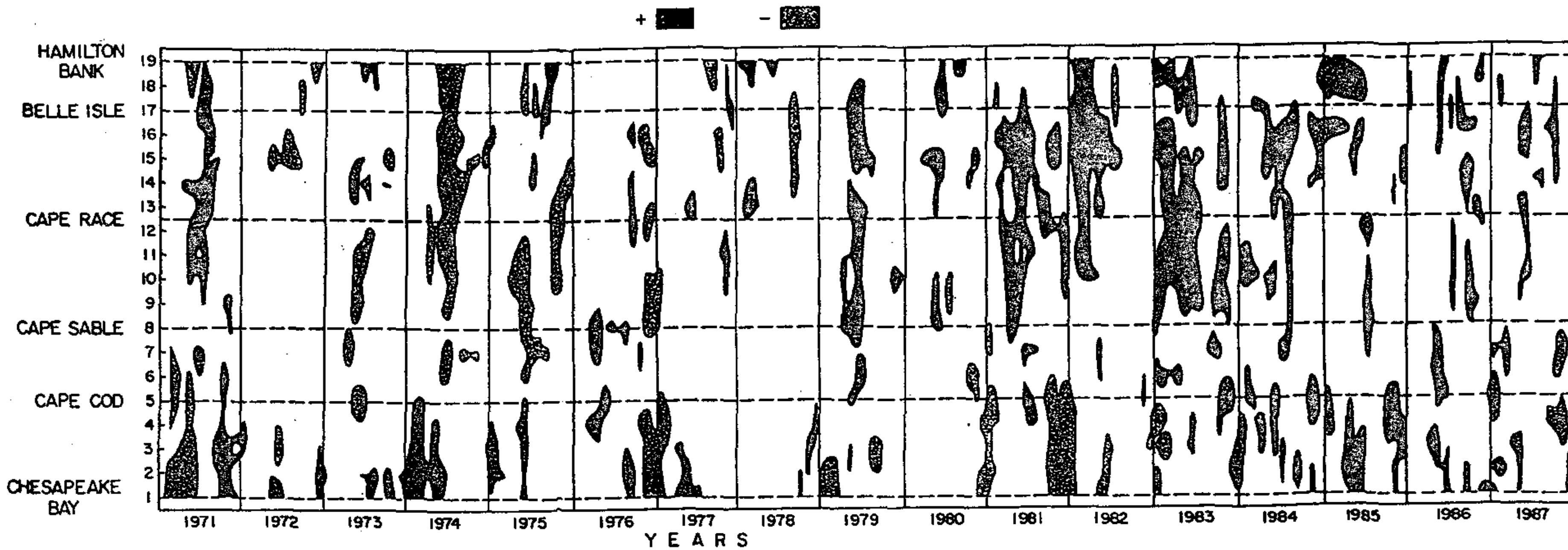

Fig. 5. Contoured monthly sea-surface temperature anomalies (relative to the 1971-80 means) for the 1971-87 period by area (Fig. 4). (Only anaomalies exceeding 1°C (black) and less than -1°C (dotted) which extended in space through at least two neighbouring areas or in time for at least two consecutive months have been contoured.)

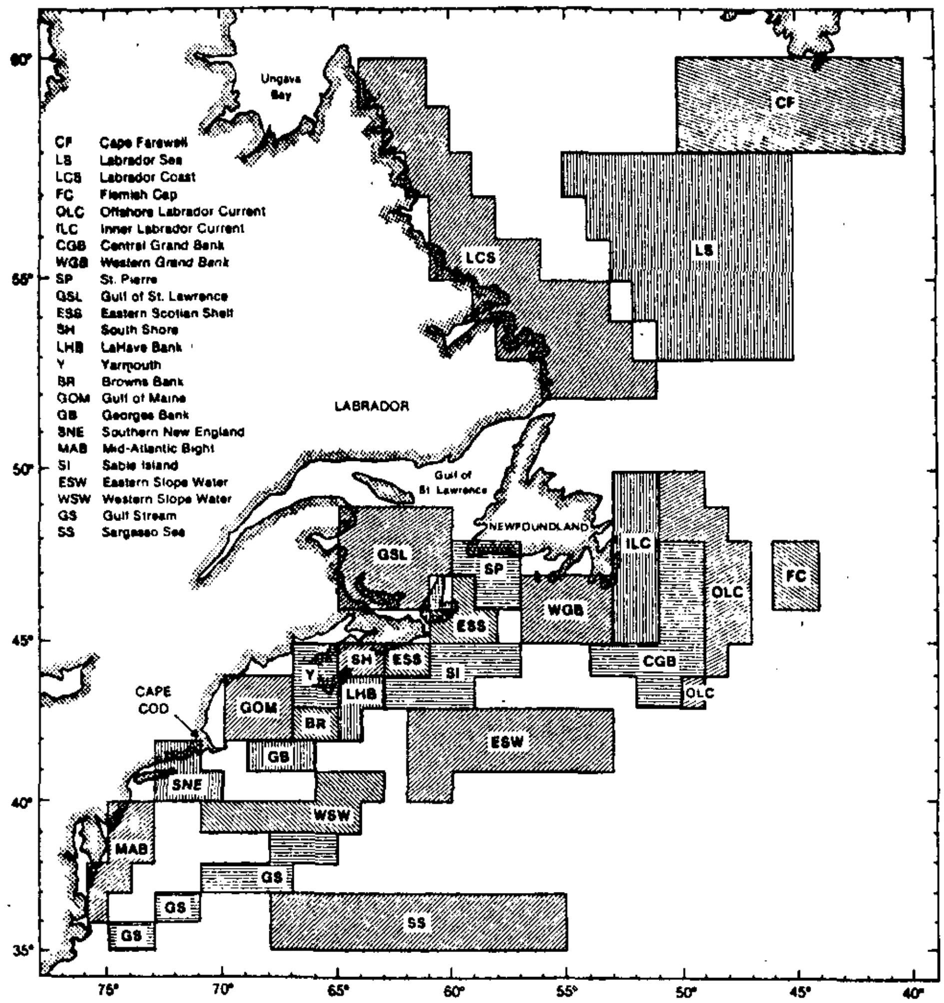

Fig. 6. Geographic boundaries of 24 subregions (Cape Hatteras to Cape Farewell) for which sea-surface tmeperatures were analyzed on a monthly basis.

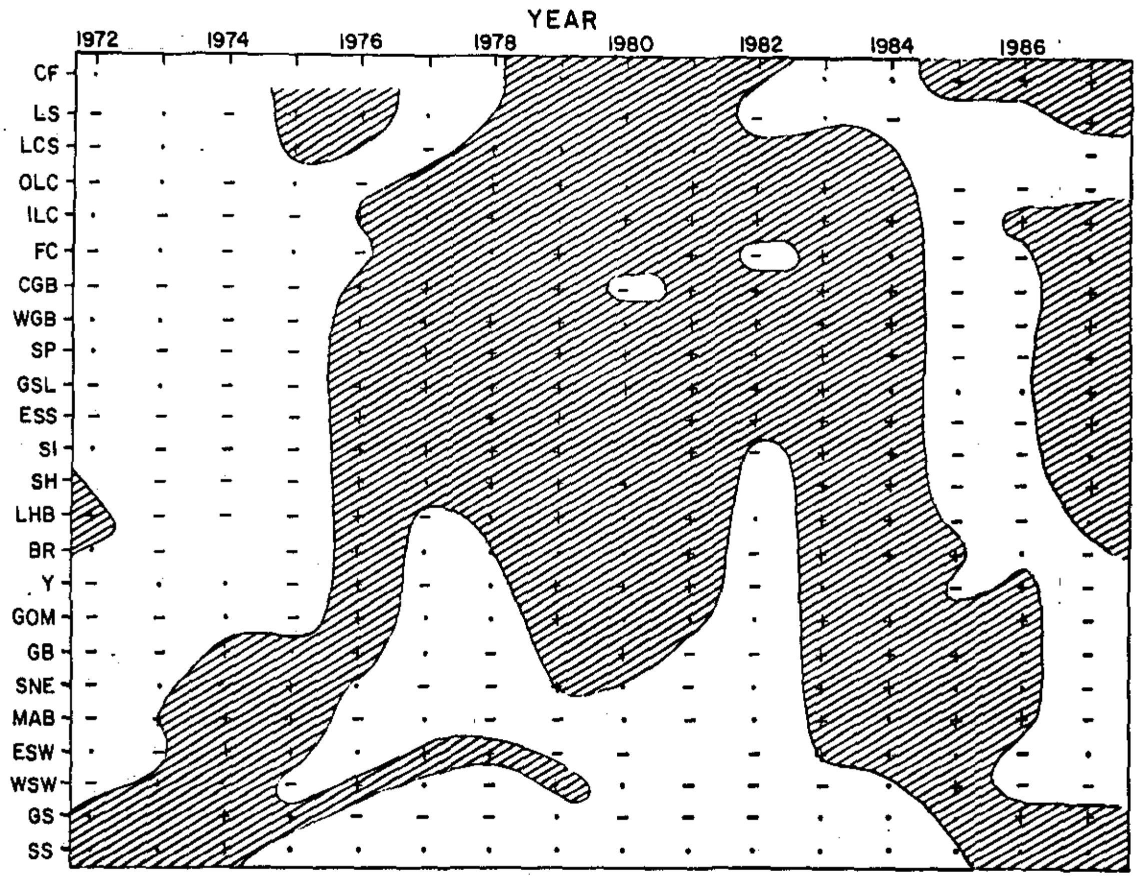

Fig. 7. Distribution of positive (+) and negative (−) annual sea-surface temperature anomalies in 1972–87 by subregion (Fig. 6) relative to the 1972–80 means. (Only anomalies less than −0.15°C and greater than +0.15°C were used in drawing the contours.)

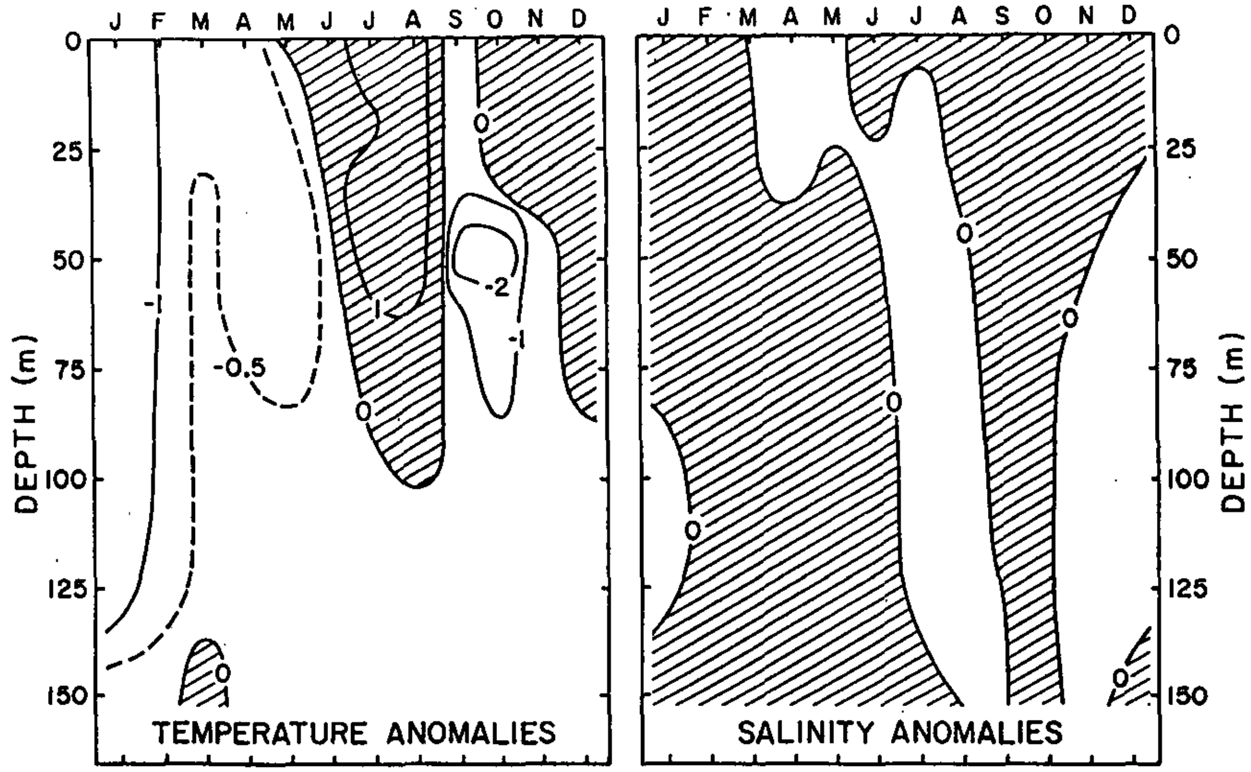

Fig. 8. Monthly temperature and salinity anomalies at Station 27 off St. John's during 1987 relative to the 1946-77 means (Keeley, 1981). (Shaded areas represent positive anomalies)

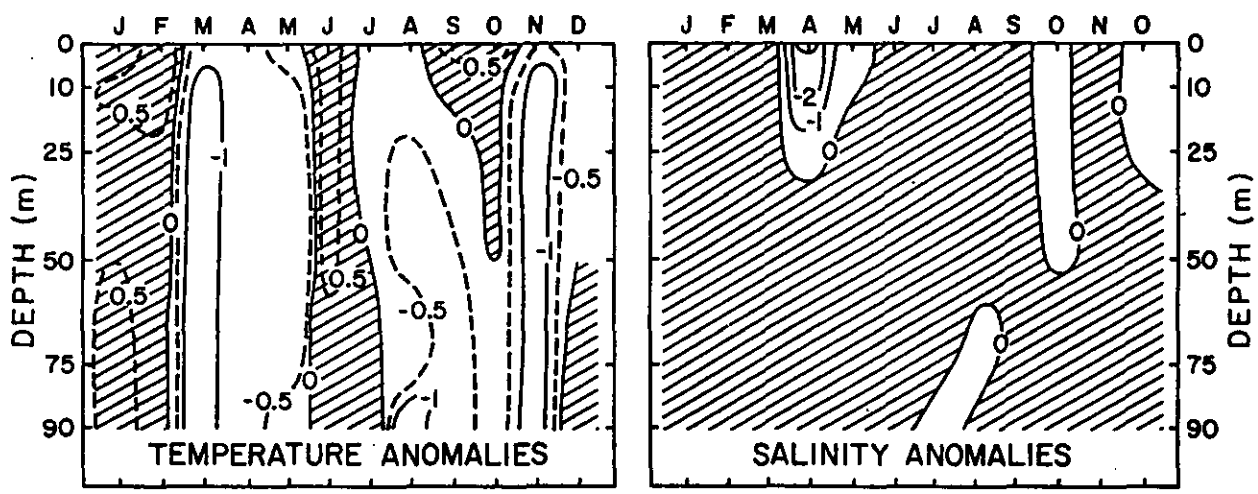

Fig. 9. Monthly temperature and salinity anomalies at Prince 5 near the entrance to the Bay of Fundy during 1987 relative to the 1951-80 means (shaded areas represent positive anomalies).

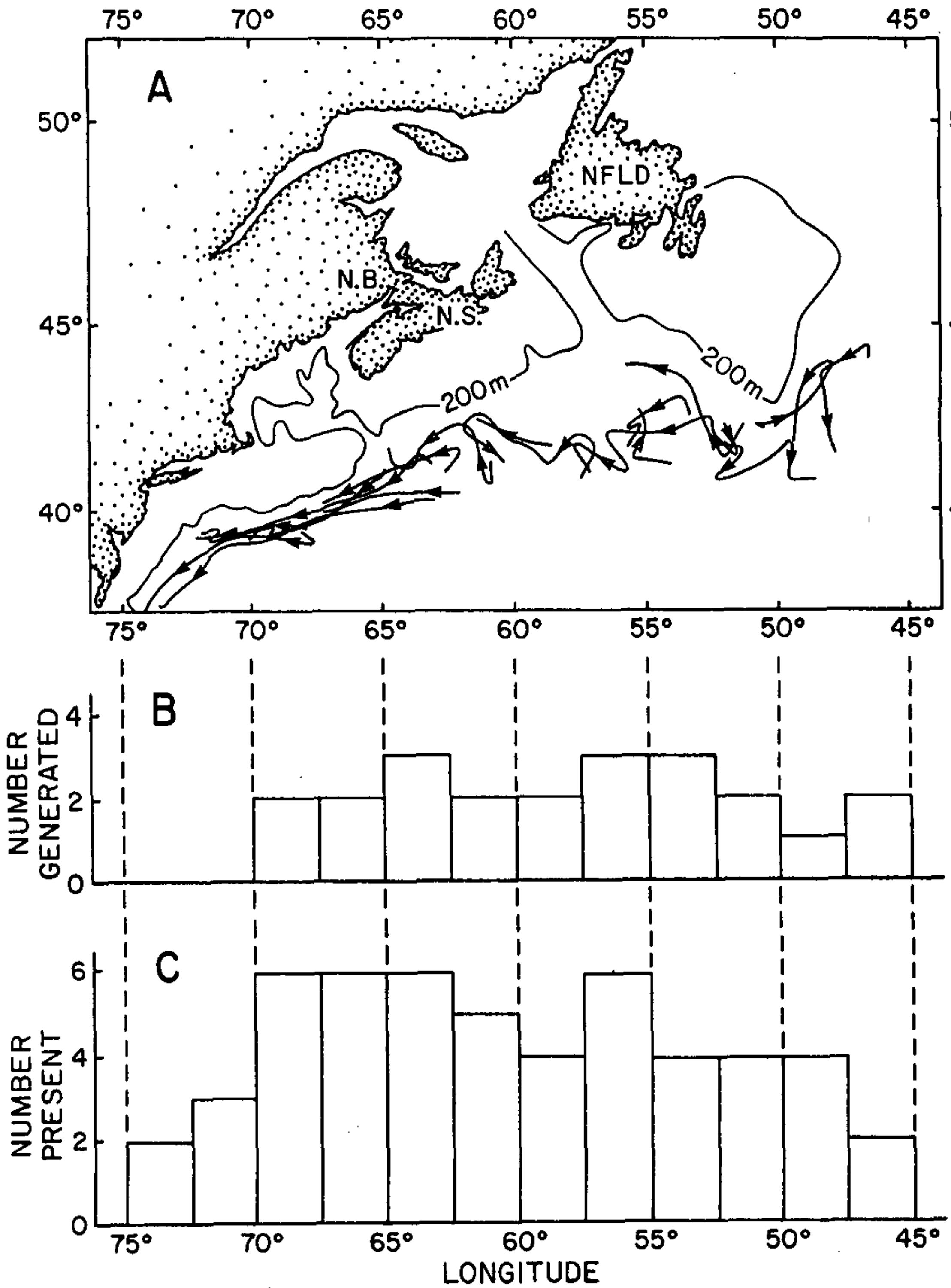

Fig. 10. Warm-core Gulf Stream rings in the region between 45°W and 75°W during 1987: (A) tracks of rings with a lifespan longer than 2 months; (B) number of rings generated in each 2.5° zone of longitude; and (C) number of rings present in each 2.5° zone during some part of the year.

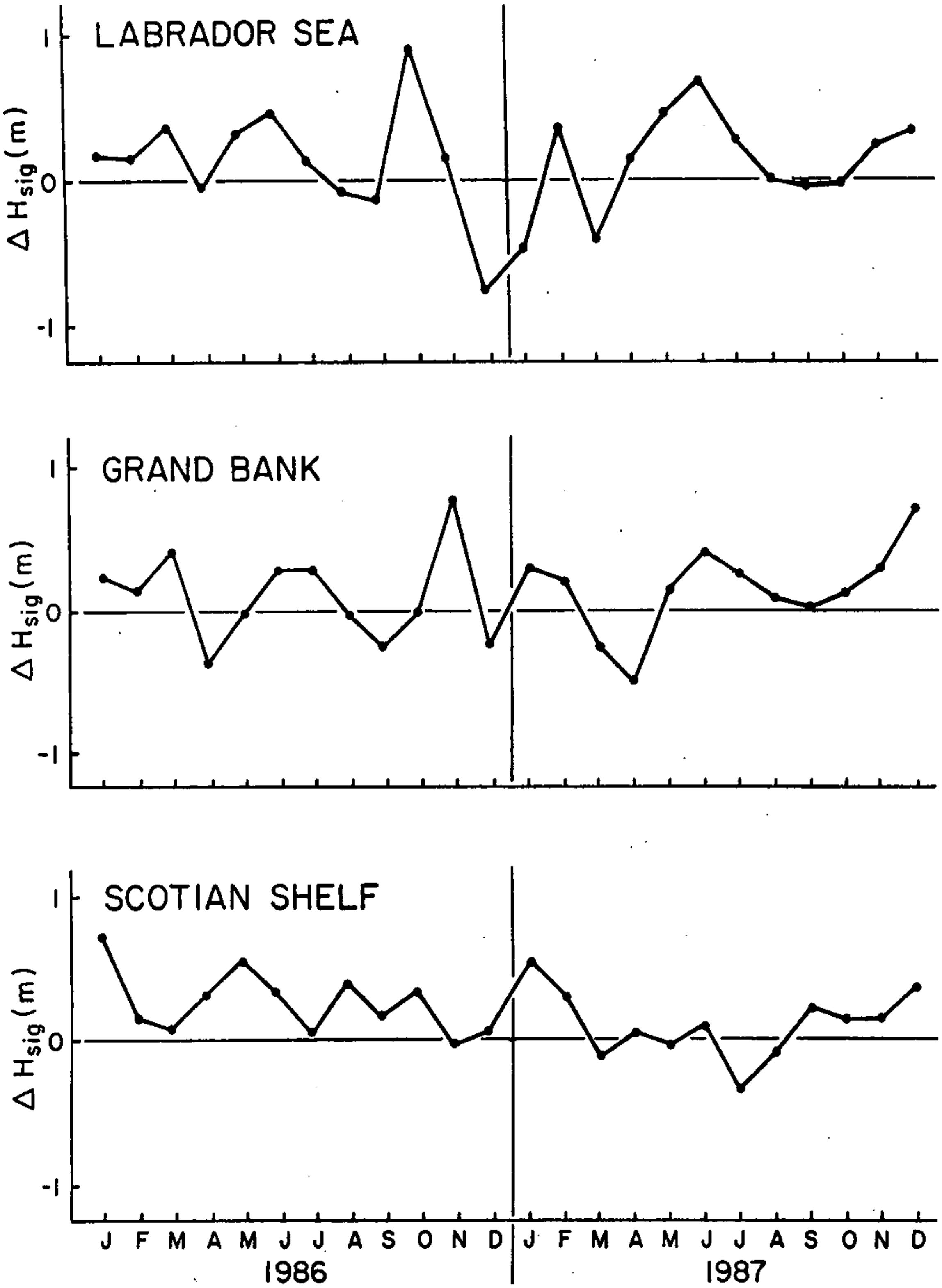

Fig. 11. Monthly significant wave heights (ΔH_{sig}) in three regions of the Northwest Atlantic during 1986 and 1987 relative to the 1970–80 means.

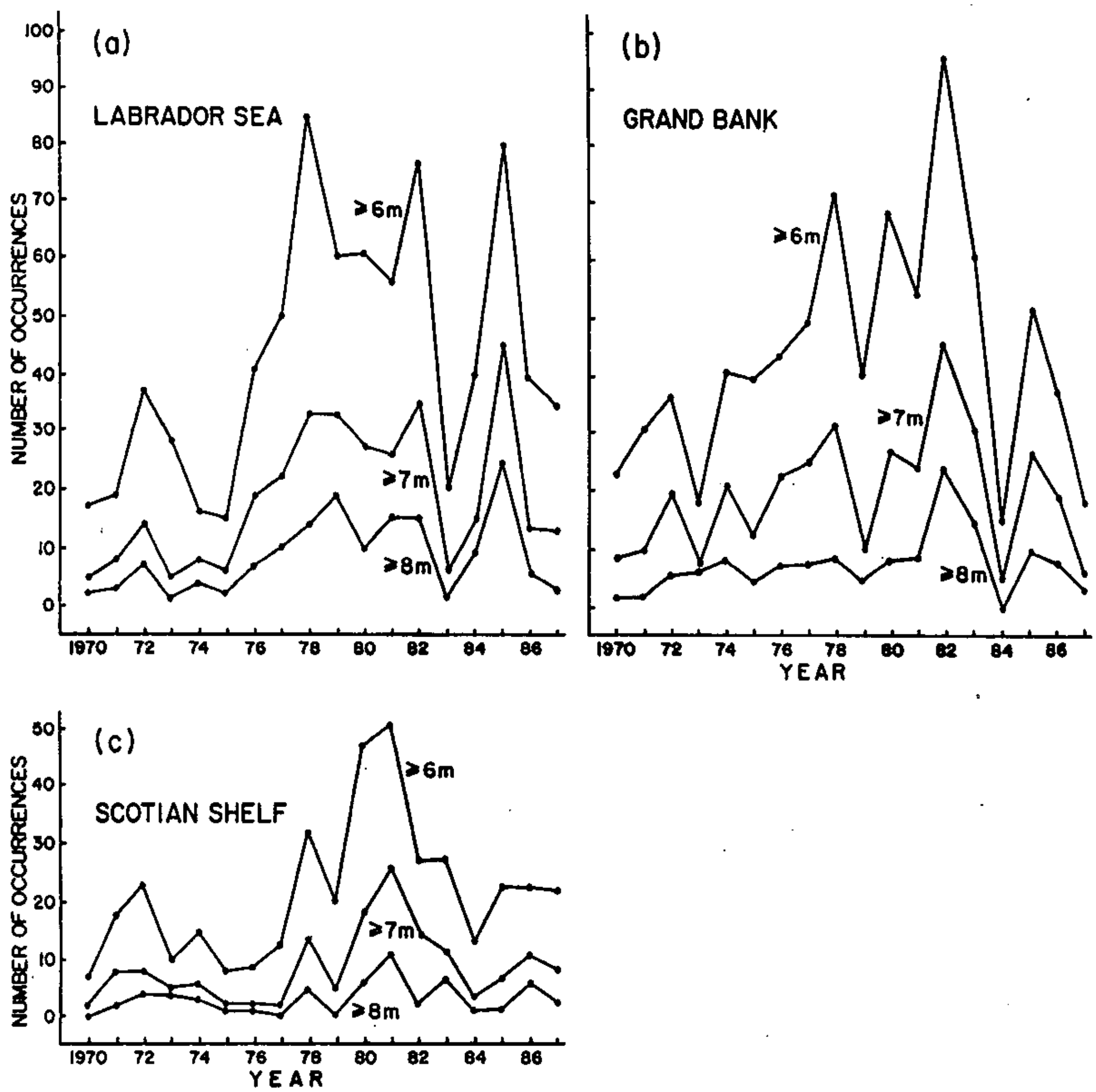

Fig. 12. Annual occurrences of storms during which wave heights exceeded 6, 7, and 8 m in three regions of the Northwest Atlantic during 1970-87.

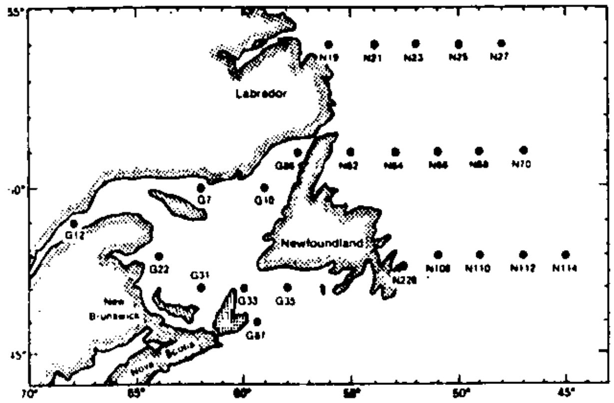

Fig. 13. Locations of 24 grids points in the Northwest Atlantic where ice statistics have been extracted from ice charts.

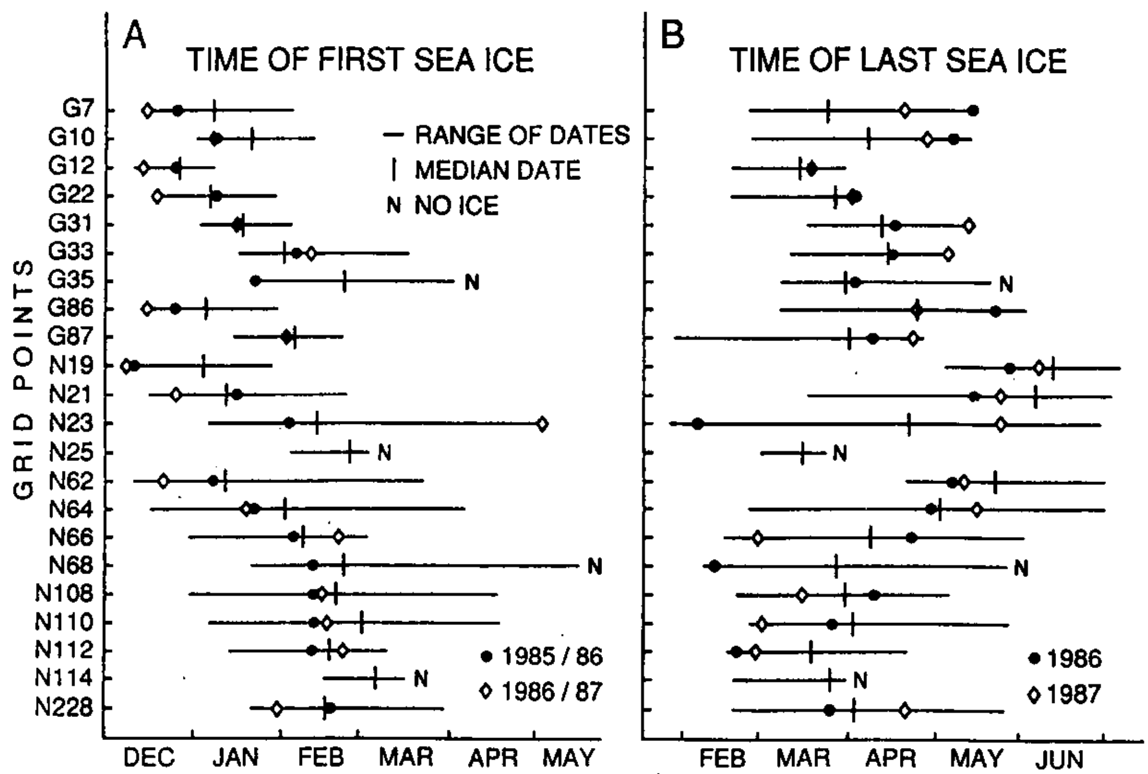

Fig. 14. Ranges of dates for the presence or first sea-ice (A) and last sea-ice (B) at 22 sites in the Northwest Atlantic (Fig. 13) with mean dates and the 1986 and 1987 dates. (Ice has never been observed at N27 and N70.)

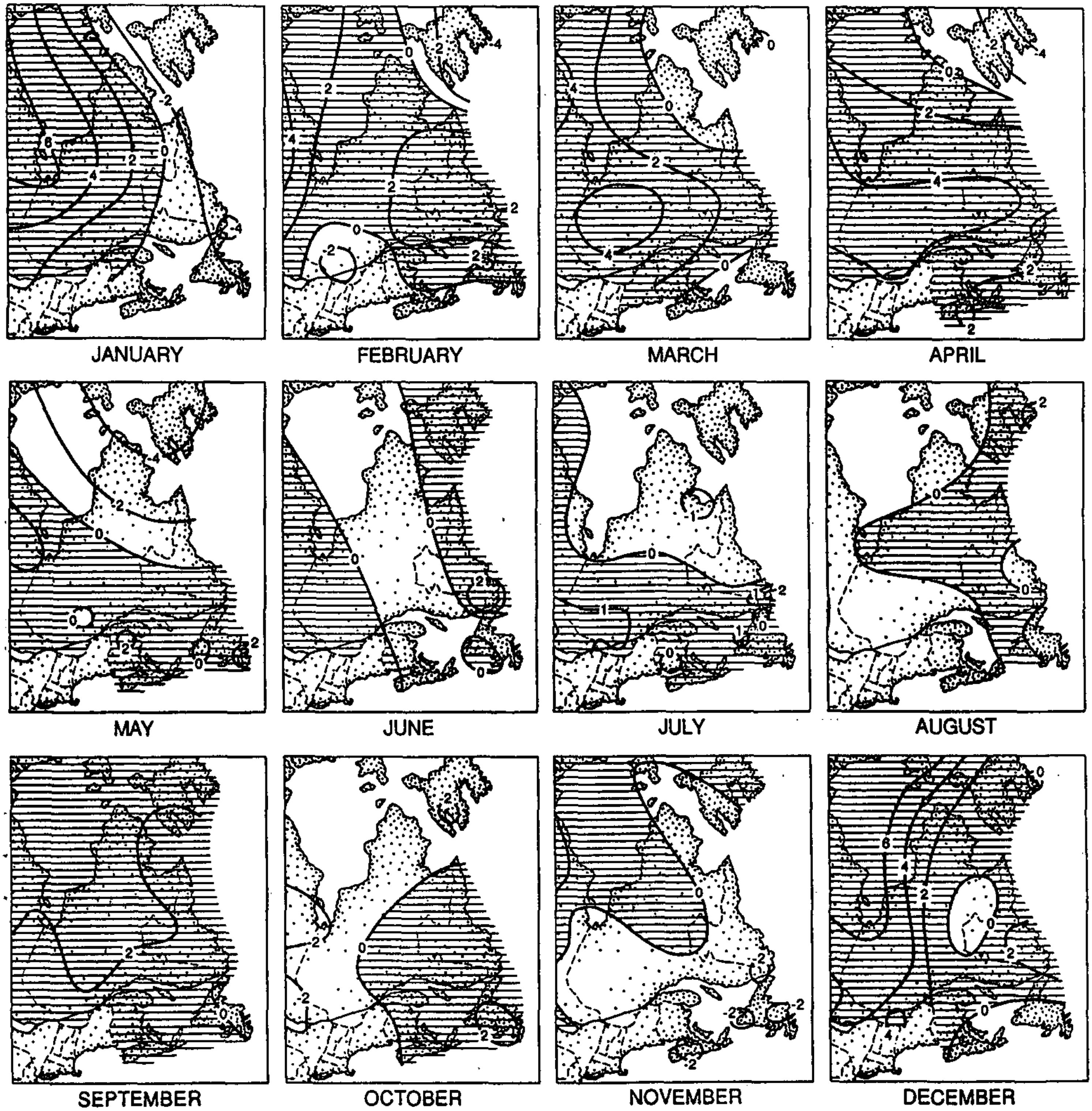

Fig. 15. Monthly air temperature anomalies (°C) over eastern Canada in 1987 relative to the 1951-80 means. (Positive anomalies are shaded.)

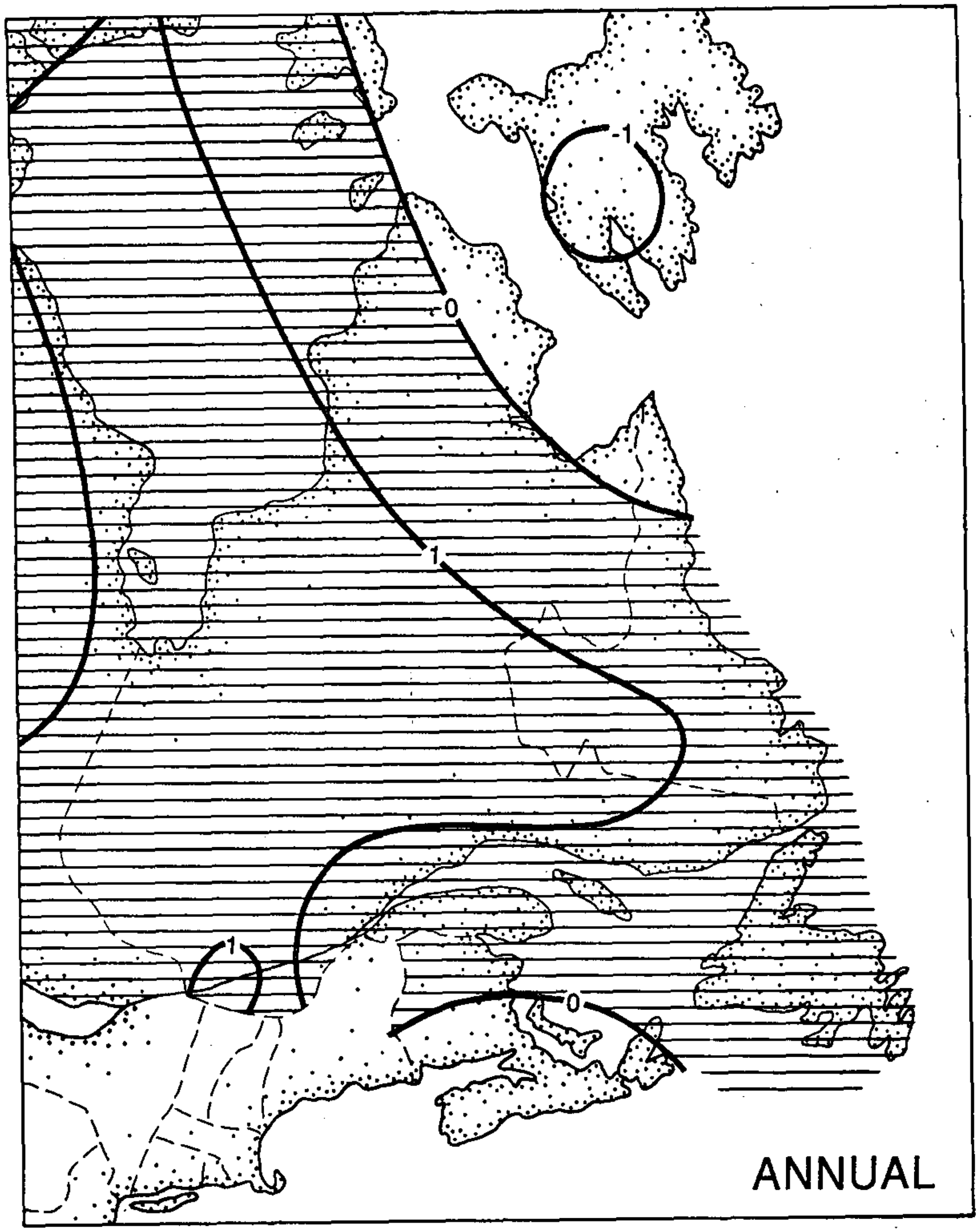

Fig. 16. Annual air temperature anomalies (°C) over eastern Canada in 1987 relative to the 1951-80 means. (Positive anomalies are shaded.)

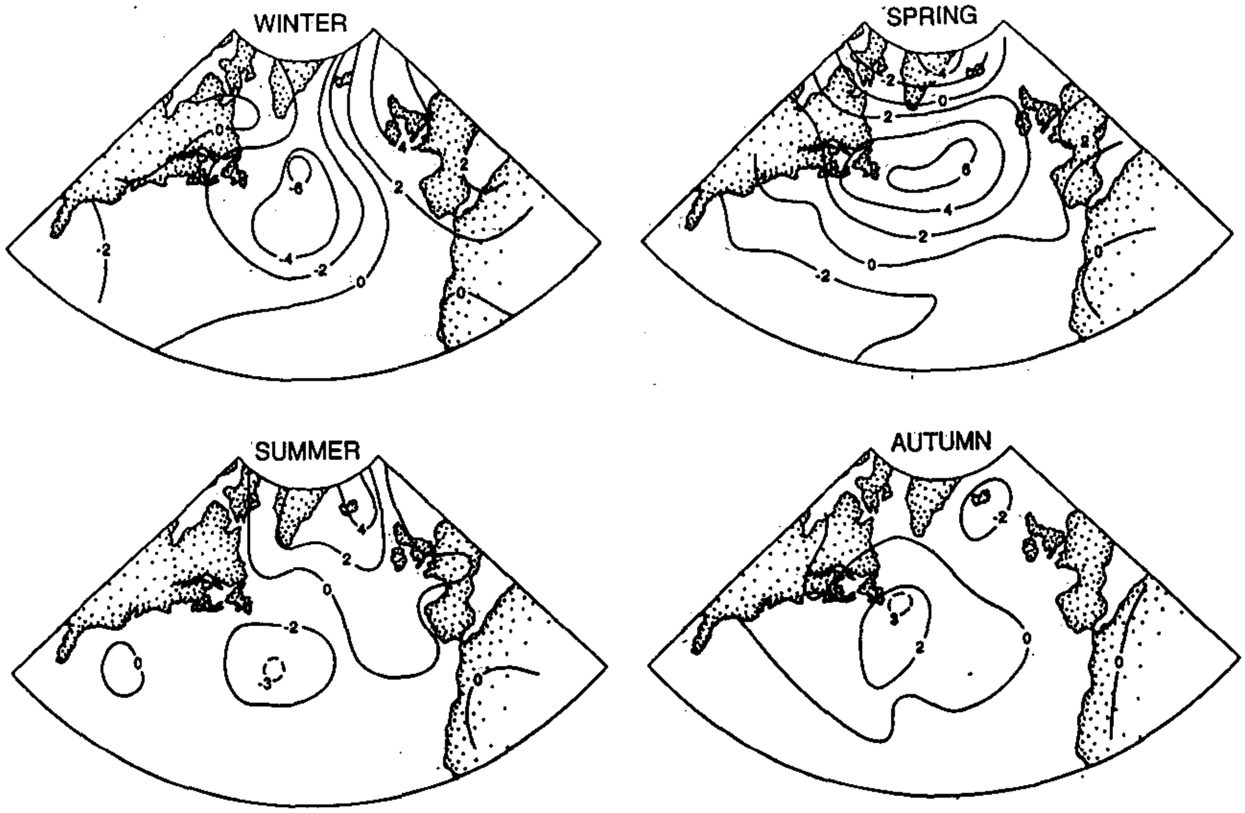

Fig. 17. Seasonal sea-surface air-pressure anomalies (mb) over the North Atlantic in 1987 relative to the 1951-80 means.