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Overview of Environmental Conditions in the Northwest Atlantic in 1986

by

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Introduction

The following paper examines environmental conditions in the Northwest Atlantic during 1986. As in our past reviews (Trites and Drinkwater, 1984, 1985, 1986; Drinkwater and Trites, 1987), it is based on selected sets of oceanographic and meteorological data augmented by information obtained from national research reports and other research documents presented at the NAFO Scientific Council meetings. Comparisons are made with the previous year's conditions and with the long-term mean conditions. Where possible, the long-term means have been based on the 1951-80 period, in compliance with the convention of the World Meteorological Organization and recommendations of the NAFO Scientic Council.

Oceanographic Oberservations

Coastal sea-surface temperatures

Monthly averages of sea-surface temperature (SST) were obtained for Halifax, Nova Scotia, St. Andrews, New Brunswick, and Boothbay Harbor, Maine (see Fig. 1 for locations). Anomalies for 1985 and 1986 relative to the 1951-80 long-term means (Trites and Drinkwater, 1984) are presented in Fig. 2. The absence of data at St. Andrews during late 1985 and early 1986 was due to wharf reconstruction at the measurement site.

The monthly temperature anomalies at all three sites show negative values during the latter four months of the year. The average anomalies for this period were 0.4-0.6°C with the largest at St. Andrews and smallest at Halifax. At Halifax temperatures from February to April were below normal but the magnitudes of the anomalies were small (less than 0.6°C). The large positive anomaly (2.3°C) at Halifax in June indicates a much more rapid warming than normal. At Boothbay Harbor temperatures fluctuated above and below normal during the first five months of the year. Although peak summer temperatures were normal (August), early summer (June-July) temperatures were well below normal (-1.6°C). Summer temperatures at St. Andrews were near normal.

The mean annual SST at Halifax was 7.8°C equalling the 1951-80 mean (Fig. 3). This was a decrease from the positive anomalies experienced over the past several years. At Boothbay Harbor the annual SST was 8.5°C, slightly below normal (-0.3°C), and not significantly different from the trend of near normal temperatures since 1982. The absence of data during the first 4 months at St. Andrews prevented determination of an annual average, however, over the last eight months of the year the mean temperature was slightly below normal (-0.4°C), consistent with the observations at Boothbay Harbor.

Offshore sea-surface temperatures

The pattern of monthly SST anomalies along the continental shelf from Cape Hatteras to southern Labrador (Fig. 4) for 1971-85, described by Drinkwater and Trites (1987), was examined for 1986 and compared to earlier years (Fig. 5). The onset of colder temperatures in the areas north of the Gulf of Maine which commenced in the latter part of 1984 and continued in 1985, appears to have been confined to the Scotian Shelf-Grand Banks regions in 1986 (areas 8 to 13). Anomalies in the southern Labrador-northeast Newfoundland regions were generally positive during the first nine months of the year. November and December displayed small negative anomalies. For the region from the Gulf of Maine to Chesapeake Bay temperatures were running about 1-2°C above normal during the spring months, while values were generally near or slightly below the 1971-80 monthly means during the later half of the year.

SST 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 (Georges Bank, Flemish Cap, etc.) were reported by Trites and Drinkwater (1985) for the years from 1972 to 1983 (compared with the 1972-80 base period), and extended by Drinkwater and Trites (1987) for 1984 and 1985. The monthly mean temperature for each of the 24 areas was computed for 1986. The annual anomalies for 1982 to 1986 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 1972-86 period is shown in Fig. 7. The pattern in 1986 was generally similar to that of 1985 with the area from Browns Bank to Flemish Cap displaying below normal temperatures for the year as a whole. Scarcity of data further north makes it difficult to draw any firm conclusion, although the Cape Farewell area continued to display above-normal temperatures in 1986. From the Yarmouth area southward, above-normal temperatures again persisted in 1986 with the exception of the two slope water areas. Overall, SST conditions in 1986 closely matched those of about a decade earlier (1975).

Temperature and salinity stations

Fyllas Bank. Hydrographic conditions on a standard section across Fyllas Bank off West Greenland are monitored by the Greenland Fisheries and Environmental Research Institute, Copenhagen, Denmark, and the Sea Fisheries Institue, Hamburg, Federal Republic of Germany. This area is influenced by the relatively cold low-salinity waters of the East Greenland Current and the warm high-salinity waters of the Irminger Current. In 1986 autumn temperatures in the upper 200 m were approximately 0.7°C above the 1963-85 mean of 2.6 °C (Stein, MS 1987). This represents the second year of above-normal temperatures on Fyllas Bank following the extremely cold temperatures between 1981 and 1984. Upper layer salinities were near normal but slightly positive. Warmer temperatures and higher saline waters usually indicate an increased influence of the Irminger component (Stein, MS 1987).

Station 27. Measurements of temperature and salinity have been routinely taken by the Northwest Atlantic Fisheries Centre, St. John's, Newfoundland, since 1946 at a site located approximately 10 km off St. John's designated Station 27. This station is considered representative of the inshore Labrador Current. The station was visited 38 times in 1986 with a monthly maximum of 5 in May and June and a minimum of once in October and December. The data were linearly interpolated to standard depths (0, 10, 20, 30, 50, 75, 100, 125, and 150 m), where necessary, and monthly means were calculated at each of these depths. Temperature and salinity anomalies for 1986 relative to the mid-month means for 1947-77 calculated by Keeley (1981) are shown in Fig. 8.

Temperature anomalies in the upper 50 m were below normal during January to April, above normal in May to August-September, and below normal for the remainder of the year. Peak positive anomalies (above 1°C) occurred between 10 and 30 m during May to August while peak negative anomalies (below -1°C) occurred between 30 to 50 m in September and October. The latter was based on only a few measurements (2 in September and 1 in October) so may not be significant. Below 75 m temperatures were generally below normal. There was a tendency for the magnitude to decrease through the year and indeed by November and December temperatures were above normal. This represents the fifth consecutive year of lower-than-normal temperatures in the lower layers at Station 27 but the rise in temperature in the latter months of the year suggest that the extreme cold conditions observed in recent years may be ending.

Monthly salinity anomalies in 1986 were typically weak being less than 0.25 psu (practical salinity units) but with a tendency for positive anomalies in the upper layers and negative in the lower layers.

Prince 5. Temperature and salinity measurements are taken once per month by personnal from the St. Andrews Biological Staion at Prince 5, a station off St. Andrews near the entrance to the Bay of Fundy (Fig. 1). Anomalies relative to the 1951-80 mean conditions (Drinkwater, 1987) were calculated and are displayed in Fig. 9. The measured data were compared to means adjusted for the day of observation using linear interpolation and assuming the long-term means as representing mid-month conditions. The limited measurements may not necessarily be representative of 'average' conditions and thus the interpretation of the anomalies must be viewed with caution. No significance should be given to any one particular anomaly as it may represent short-term conditions, however, persistent anomaly features are likely to be real.

During 1986 temperature anomalies were typically small (less than 1°C) with positive values throughout the water column during the major portion of the year. At the beginning of the year, however, temperature anomalies below 10 m were negative with values of greater than -1°C in February. Below-normal temperatures were also observed in December in the upper 50 m but the magnitude of the anomalies was small. Salinity anomalies were also generally positive, the exceptions occurring in September-October. No anomalies exceeded 0.5 psu except the November surface values when the salinity was extremely low (29.4 which is 2.9 psu below the 1951-80 mean). As discussed above, this single measurement may not be representative of the 'average' conditions for the month.

Position of shelf-slope front

The postion of the shelf-slope front from Georges Bank to Cape Hatteras continues to be monitored by the Physical Oceanography Branch of the U.S. National Marine Fisheries Service. The position of the front, which is determined from satellite imagery, is normally extracted at weekly intervals along 9 section lines and plotted with respect to the 200 m isobath. Armstrong and Strout (MS, 1987) report that the mean positions for 1986 were shoreward of the long term means (1974-83) for all bearing lines. To the extent that seasonal variations can be discerned, frontal postions generally followed the long-term mean seasonal pattern, although any seasonal cycle is largely overshadowed by shorter period fluctuations associated with the passage of warm-core eddies. Variability of the frontal postions in 1986 was also less than the long-term means on all bearing lines with standard deviations estimated to be about 25% less than the ten-year values.

Warm-core rings

The life history of anticyclonic warm-core Gulf Stream rings in the region from 45°W to 75°W during 1986 was derived from the NOAA/NWS Oceanographic Analysis Maps and from the "State of the Oceans: Gulf of Maine to the Grand Banks" reports which are issued monthly by the Bedford Institute of Oceanography. Owing to the frequency of cloudy or foggy conditions, particularly in the area east of about 65°W, often several weeks elapse between clear thermal images of the sea surface. Therefore, there is frequently uncertainty about the creation or continued existence of a particular ring and accordingly, the statistics derived solely from this data source must be viewed cautiously.

A total of 23 warm-core rings were present in the area during some portion of 1986, four of which survived from 1985 into the new year while four of the 19 new rings formed in 1986 persisted into 1987. Nine of the rings formed in 1986 exceeded an age of 2 months. Their paths, along with those of the four rings from 1985, which also had lifespans of over 2 months, are shown in Fig. 10A. Rings, whose destruction occurred in 1986, ranged in age from 7 to 365 days and had a mean life of 117 days. This compares with an age range of 9 to 362 days and mean of 123 days for 1985. 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. Although one or more rings were generated in all zones east of 70°W, the maximum number (5) were generated in the 62.5°-65.0°W zone. Interestingly, it was this same zone which had the greatest number (8) present at some time during the year. At least one or more rings formed in all months of the year except February and April. July and August were the most productive months when 3 and 4, respectively, were formed. In most respects the ring statistics for 1986 are similar to those for 1985 (Drinkwater and Trites, 1987).

A separate and more complete analysis of warm-core Gulf Stream rings in the area west of 60°W during 1986 was undertaken by Price and Barton (MS, 1987). They used, in addition to the NOAA/NWS oceanographic analysis maps, geometrically corrected and enhanced processing of satellite imagery to more clearly identify sea-surface thermal features. Opportunistic shipboard data received from scientists and firsherman were also incorporated when available. Their analysis indicated that 10 warm-core rings formed west of 60°W in 1986, the same number as reported for 1985. Longevity of the rings ranged from 30 to 302 days and compares to a 1985 lifespan range of 18 to 362 days. Owing to interpretation difficulties, arising principally from large gaps in clear satellite imagery, as well as the procedure of Price and Barton (MS, 1987) of labelling and assigning a formation date only when a ring has moved west of 60°W, some slight discrepancies arise between the BIO monthly reports and the analysis of Price and Barton.

Shelf-slope temperatures in the Mid-Atlantic Bight

Thermal conditions along a transect extending seaward from New York Harbor across the shelf and slope continued to be monitored in 1986 for the 11th year. Benway (MS, 1987) reported that for 1986 cold pool temperatures (below 10°C) on the bottom at mid-shelf during summer were warmer than observed in 1985 and were about 2°C warmer than normal. At mid- to outer shelf depths, bottom temperatures along the upper slope (100-200 m) remained above 12°C for the entire year. Benway (MS, 1987) further reported that there is evidence of a pattern of steady warming of upper slope bottom water through the period since 1977. Although three warm-core rings moved through the slope water along the transect line in 1986, none seemed to have had any persisting influence on bottom temperatures over the shelf and upper slope.

Waves

Wave and weather observations from many locations in the North Atlantic (weather ships, government, naval and merchant vessels, and oil-drilling rigs) are transmitted every 6 hr to the Canadian Meterological and Oceanographic Center (METOC) at Halifax, N.S. (see Neu, 1982). Trites and Drinkwater (1984, 1985, and 1986) and Drinkwater and Trites (1987) combined provide summary statistics of monthly significant wave heights at three grid points in the northwest Atlantic for each year of the 1970-85 period. The monthly statistics were computed from the 12 hr synoptic wave charts prepared by METOC. The mean monthly significant wave heights in 1985 and 1986, together with the averages for the 1970-80 period, are given in Table 2. The monthly significant wave height anomalies (relative to the 1970-80 means) for the three areas during 1985 and 1986 are illustrated in Fig. 11. For the Labrador Sea, wave conditions in 1986 were generally more severe than the 11-yr mean, although wave height anomalies diminished from a maximum of 0.89 m in October to a minimum of -0.77 m in December. For the Grand Banks wave conditions were more severe for 6 of the 12 months compared to the long-term mean and at or below normal for the other 6 months. On the Scotian Shelf, conditions in 1986 were generally more severe than in 1985 and all months except November experienced significant wave heights above the base period mean.

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, 1986 was less stormy than 1985 on the Grand Banks and in the Labrador Sea. The Scotian Shelf on the other hand displayed slightly more frequent stormy conditions in 1986 compared to 1985, but frequencies of waves exceeding 6, 7 and 8 m were comparable to the 11-yr base period.

Sea ice

The Ice Climatology Division of the Canadian Atmospheric Serivce undertakes annually an 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 the 1982/83-1984/85 period were previously summarized by Trites and Drinkwater (1985, 1986) and Drinkwater and Trites (1987). The present analysis has been updated to include data for the 1985/86 season. For each site, the extracted data were ice duration in weeks for the 1985/86 season, average duration for all years of record, as well as maximum, minimum and average duration for years when ice was present (Table 3). The timing of first and last ice, the median dates and the dates for 1984/85 and 1985/86 seasons are shown in Fig. 14. The time of ice formation in the Gulf of St. Lawrence was generally earlier than normal, but comparable to that of the previous year. Ice drifting out of the Gulf, through Cabot Strait, moved eastward reaching site G35 by 22 January, a record early date. For the area off southern Labrador and off the east coast of Newfoundland, ice generally was first present earlier than the median date and earlier than in 1984/85 by about two weeks (Fig. 14). In terms of duration, ice was present in most areas (except for the offshore area east of Newfoundland) for much longer than normal. Compared to the previous year, duration times for the Gulf of St. Lawrence were not markedly different, but for the area east of Newfoundland, ice was present generally for a few weeks less than in 1984/85. Veale (1986) reports on ice conditions off the east coast as follows: "...by February ice cover was a little narrower than usual along the Labrador coast, but it extended further southwards than normal. At the end of the month, it extended as far as 400 km east-southeast of St. John's. The normal northerly to northwesterly winds, which push the ice southward along the Labrador coast into east Newfoundland waters did not materialize in April and May. As a result, by the end of May, the pack ice cleared south of Goose Bay, much earlier than normal. According to statistics, this should occur this early only once in about every ten years."

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 during the last 4 years have been collected with the use of SLAR (Side-Looking Airborne Radar) which is believed to detect more icebergs than previous visual aircraft reconnaissance methods (Thayer, 1986). During the the 1985/86 iceberg season (October to September), a total of 204 icebergs were spotted south of 48°N. No icebergs were observed from October 1985 to January 1986 and during August and September of 1986. From February to July the monthly iceberg numbers were 3, 40, 60, 59, 24, and 18. Only 1.5% of the icebergs passed 48°N outside of the primary season of March to July. The number of icebergs in 1986 is the lowest total since the SLAR method was deployed and is lower by a factor of 5 compared to last season's total. The weaker than normal northerly and northwesterly winds in the spring and the smaller than normal ice cover likely contributed to the low number of bergs in the 1985/86 season. The presence of sea-ice suppresses waves thereby slowing the deterioration of the icebergs by wave action.

Meteorological Observations

Air temperatures

The 1986 monthly mean air temperature anomalies for Canada, published by the Atmospheric Environment Service of Canada in the Monthly Supplement to Climatic Perspectives, are presented in Fig. 15. During January to May temperatures over Baffin Island and Labrador were generally above normal with peak anomalies of +6°C on Baffin Island in February. This is a continuation of a general trend of high temperatures begun in late 1985 (Drinkwater and Trites, 1987). A noteable exception to the warmer-than-normal temperatures occurred in March when values over most of Labrador were more than 4°C colder than normal. Over Newfoundland, the Gulf of St. Lawrence, and the Gulf of Maine regions, temperatures in the first six months of the year oscillated above and below normal. In the latter half of the year the temperatures throughout the region from southern Baffin Island to Nova Scotia were generally below normal with anomalies of larger than -2°C during October through December in Labrador and Baffin Island.

The annual air temperature anomalies throughout the region were negative (Fig. 16) due primarily to the cold temperatures observed during the latter months of 1986. The magnitude of the anomalies generally increased northeastward with values of over 1°C below normal in northern Quebec, Labrador and Baffin Island. These anomalies are on the same order as the standard deviations of the annual temperatures (Trites and Drinkwater, 1986). The pattern of uniform below-normal temperatures throughout eastern Canada contrasts with past years (since 1983) when annual temperature anomalies in Labrador and Baffin Island were usually of the opposite sign to those in the more southern regions of eastern Canada (Trites and Drinkwater, 1985, 1986; Drinkwater and Trites, 1987).

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 a winter maxima to summer minima. Seasonal averages for 1986 and anomalies from the 1951-80 means (K.R. Thompson, Dalhousie University, Halifax, pers. comm.) were calculated for winter (December 85-February), spring (March-May), summer (June-August) and autumn (September-November) and are shown in Fig. 17.

In winter a westward shift in the Icelandic Low resulted in below-normal pressures (up to nearly 8 mb) over northern Quebec and Hudson Bay with an equal magnitude positive anomaly centered near Iceland. These would have resulted in anomalous southerly winds over western Greenland and easterly winds over much of eastern Canada. In the southern North Atlantic, the Bermuda-Azores High strengthened (up to a maximum of 5 mb) leading to stronger westerlies over the western North Atlantic. In the spring the Icelandic Low remained strong resulting in below-normal pressures in the northern regions. The High in the southern regions remained strong and shifted slightly more northwestward. Weak anomalies of sea-surface pressures generally prevailed in the the summer months but in autumn a strong (up to 7 mb) negative anomaly was observed east of Labrador and north of 45°N. At the same time centers of high pressure anomalies were located in the Atlantic due south of Nova Scotia on 40°N and over western Europe. This brought anomalous northerly winds to eastern Canada, thereby contributing to the colder-than-normal temperatures over the region in the last few months of the year.

Summary

Although no large anomalous climatic features were observed in the northwest Atlantic region in 1986, there were several interesting trends. From the mid-1970's to 1984 SST anomalies in the region north of the Gulf of Maine tended to be positive while south of the Gulf of they were negative (Trites and Drinkwater, 1986). Last year suggested a reversal in this trend (Drinkwater and Trites, 1987) which is further supported by the 1986 data. An exception is off western Greenland where 1986 SST anomalies were positive. Also for the second consecutive year above-normal temperatures were observed in the upper 200 m of the water column at Fyllas Bank off West Greenland. This follows several years of colder-than normal temperatures. At Station 27 off St. John's, Newfoundland, temperatures below 75 m remained cold for the fifth consecutive year but the anomalies were smaller in magnitude than in past years and during the last months of 1986 the temperature anomalies rose above normal suggesting the possibility that the extremely cold conditions in the subsurface water off Newfoundland may be coming to an end. The position of the shelf-slope front between Georges Bank and Cape Hatteras was shoreward of the long-term mean for the third straight year and the higher temperature Slope water closer inshore may have contributed to the observed warmer-than-normal temperatures over the continental shelf.

For the second consecutive year ice in the Gulf of St. Lawrence and off Newfoundland occurred earlier than usual and had a longer duration than normal. It was not, however, as severe an ice year as 1984/85 had been. The number of icebergs crossing south of 48°N were low during 1986 ending a period of three years of high numbers of icebergs.

Finally, annual air temperature anomalies for 1986 were observed to be negative throughout eastern Canada primarily due to cold conditions during the last four months of the year.

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Table 1.

Mean sea-surface temperatures for selected areas of the Northwest Atlantic in 1972-80, and anomalies for 1982 to 1986 relative to the base period. (Geographic locations of water masses are shown in Fig. 6. Blank space indicates that annual averages not computed when data missing for one or more months.)

Water mass	Mean Temp 1972-80*	Annual Anomalies (°C) 1982	1983	1984	1985	1986
CF	3.62	0.10	-0.12	-0.01	1.03	0.99
LS	5.54	-0.43	-0.11	-0.59		
LCS	2.19					
OLC	5.17	0.24	0.32	0.06	-0.90	-0.19
ILC	4.83	0.40	0.99	0.52	-0.38	0.24
FC	7.88	-0.39	0.46	-0.14	-0.80	-0.24
CGB	6.48	0.34	1.37	0.84	-0.54	-0.16
WGB	6.13	0.19	1.11	0.62	-0.69	-0.23
SP	5.91	0.35	0.87	0.79	-0.36	-0.28
GSL	5.82	0.46	0.91	-0.02	-0.01	0.08
ESS	7.10	0.45	1.28	0.56	-0.29	-0.24
SI	8.27	-0.20	0.96	0.97	-0.49	-0.57
SH	7.85		1.43	0.66	-0.18	-0.34
LHB	8.87	-0.07	0.86	0.42	-0.33	-0.53
BR	8.84	-0.28	1.07	0.51	0.17	-0.05
Y	7.64	-0.20	0.05	0.10	-0.45	0.29
GOM	9.59	0.07	0.45	0.45	0.10	0.25
GB	10.17	-0.46	0.48	0.37	0.21	0.14
SNE	12.23	-0.03	0.38	1.08	0.14	0.09
MAB	14.87	-0.06	0.61	0.08	0.80	0.15
ESW	15.54	-0.37	0.51	1.25	0.02	-0.34
WSW	18.50	-0.48	-0.27	-0.17	0.52	-0.16
GS	22.94	-0.16	0.08	0.08	0.11	0.46
SS	22.26	-0.07	0.04	-0.05	-0.14	0.04

* 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 1985 and 1986 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)		
Month	1970-80	1985	1986	1970-80	1985	1986	1970-80	1985	1986
Jan	3.50	4.64	3.66	3.76	4.10	4.00	2.91	3.77	3.68
Feb	3.36	3.57	3.50	3.48	2.98	3.63	2.77	2.52	2.93
Mar	3.20	3.79	3.56	2.88	3.00	3.32	2.80	2.79	2.95
Apr	2.56	2.68	2.48	2.78	3.02	2.42	2.35	2.20	2.65
May	2.02	2.84	2.35	2.22	2.63	2.21	1.82	2.06	2.37
Jun	1.84	1.75	2.30	2.07	2.12	2.37	1.70	2.10	2.02
Jul	1.75	1.95	1.85	1.94	2.02	2.24	1.57	1.77	1.60
Aug	2.01	1.82	1.92	2.22	2.19	2.21	1.62	1.35	2.00
Sep	2.61	2.80	2.45	2.75	2.75	2.50	1.76	1.65	1.90
Oct	3.14	3.69	4.03	3.19	3.52	3.19	2.16	1.94	2.48
Nov	3.33	3.65	3.47	3.41	4.03	4.20	2.69	2.43	2.63
Dec	3.64	4.39	2.87	3.96	4.95	3.74	3.00	2.98	3.03

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 1985/86 (October-September) ice year, with 1984/85 data in parentheses.

Site (Fig.1)	Period studied	# of years	Years with ice	Ice duration (weeks) When ice present Min	Max	Mean	Overall Mean	1985/86 (1984/85)
G-7	1966-86	19	19	6	15	10.1	10.1	15(13)
G-10	1977-86	10	10	3	17	10.3	10.3	17(16)
G-12	1968-86	19	19	2	15	11.1	11.1	12(12)
G-22	1977-86	10	10	7	14	11.4	11.4	13(13)
G-31	1969-86	18	17	8	17	11.9	11.3	13(11)
G-33	1971-86	16	15	2	14	9.9	9.3	11(13)
G-35	1962-86	25	13	1	11	3.7	1.9	6(1)
G-86	1976-86	11	10	6	22	14.7	13.4	22(22)
G-87	1971-86	16	15	1	12	6.9	6.5	8(11)
N-19	1967-86	20	20	17	30	24.6	24.6	21(30)
N-21	1968-86	19	19	5	28	18.0	18.0	13(28)
N-23	1960-86	27	21	1	17	5.3	4.1	1(10)
N-25	1960-86	27	2	1	1	1.0	0.0	0(0)
N-27	1960-86	27	0	0	0	0.0	0.0	0(0)
N-62	1968-86	19	19	8	27	18.0	18.0	18(27)
N-64	1960-86	27	26	3	25	11.8	11.4	15(25)
N-66	1960-86	27	21	1	16	7.6	5.9	10(16)
N-68	1960-86	27	11	1	10	3.4	1.4	1(3)
N-70	1961-86	26	0	0	0	0.0	0.0	0(0)
N-108	1960-86	27	21	1	17	5.7	4.5	7(11)
N-110	1960-86	27	20	1	12	4.7	3.5	6(12)
N-112	1960-86	27	8	1	10	4.7	1.4	2(7)
N-114	1960-86	27	3	1	2	1.3	0.1	0(1)
N-228	1960-86	27	17	1	14	5.0	3.2	4(7)

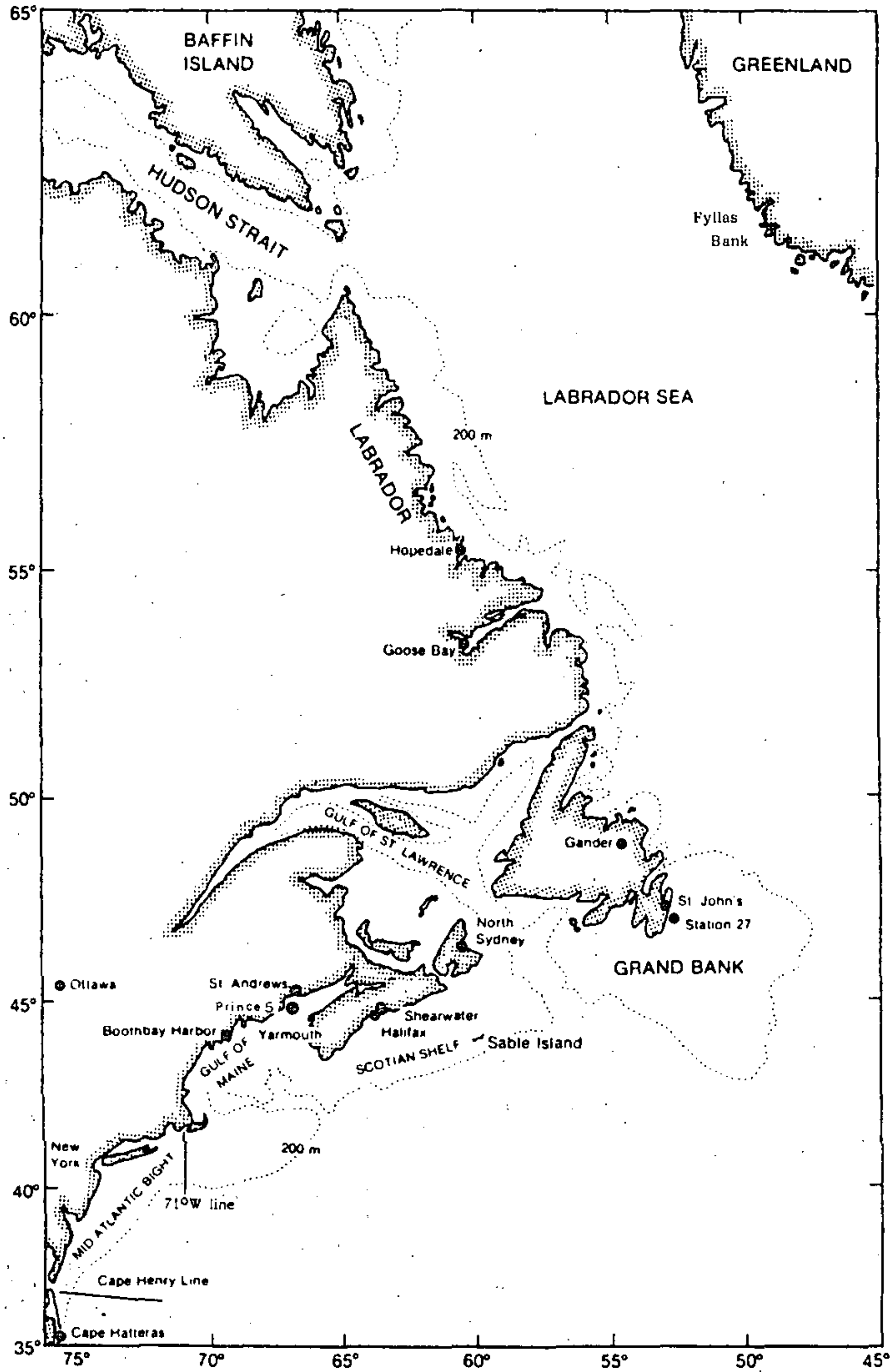

Fig. 1. Map of Northwest Atlantic showing oceanographic stations and other sites mentioned in the text.

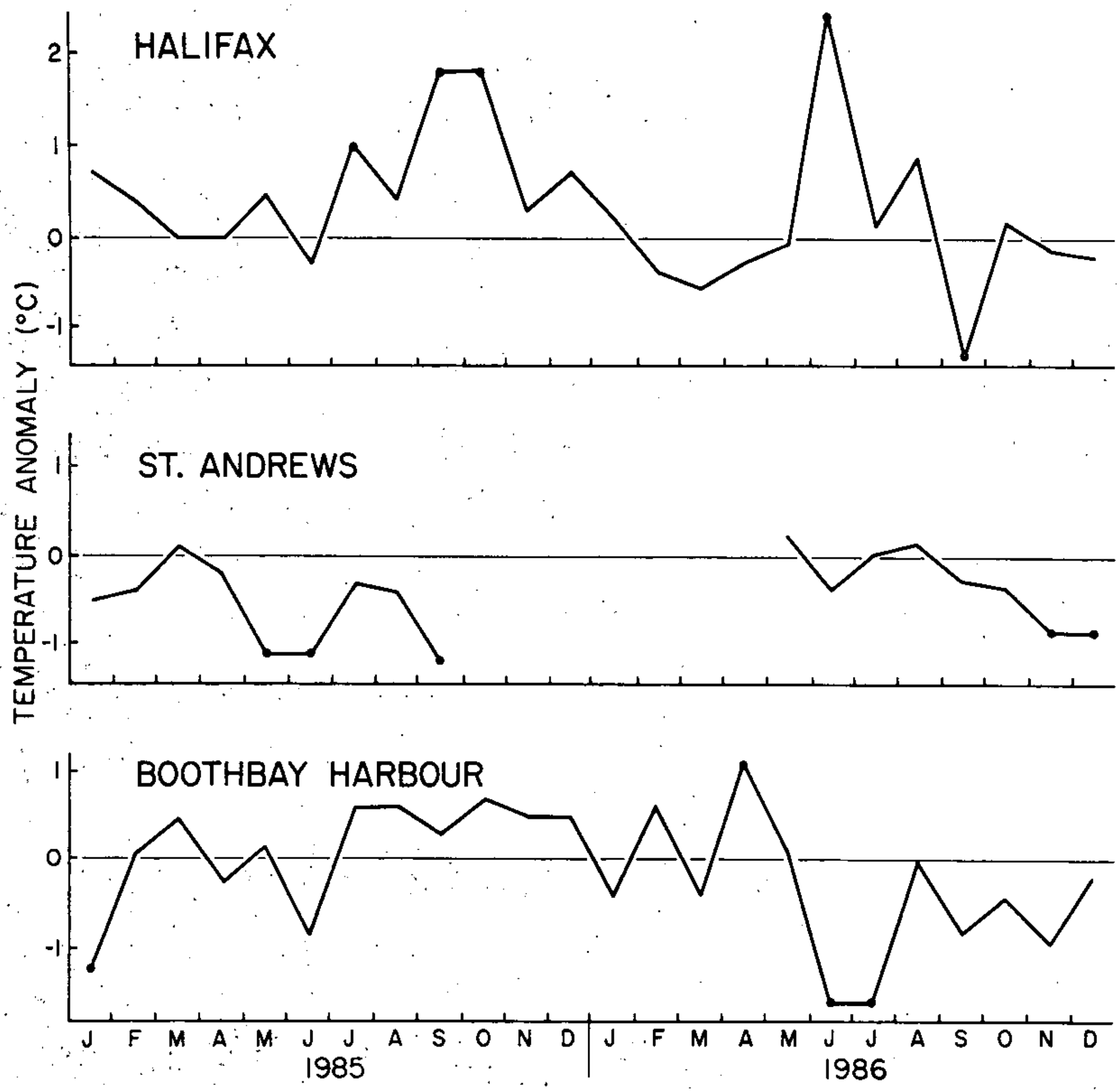

Fig. 2. Monthly sea-surface temperature anomalies at Halifax, St. Andrews and Boothbay Harbor in 1985 and 1986 relative to the 1951-80 means. (Dots indicate months when the anomalies equalled or exceeded one standard deviation. Lack of data for October 1985 to April 1986 at St. Andrews was due to wharf reconstruction at the measurement site.)

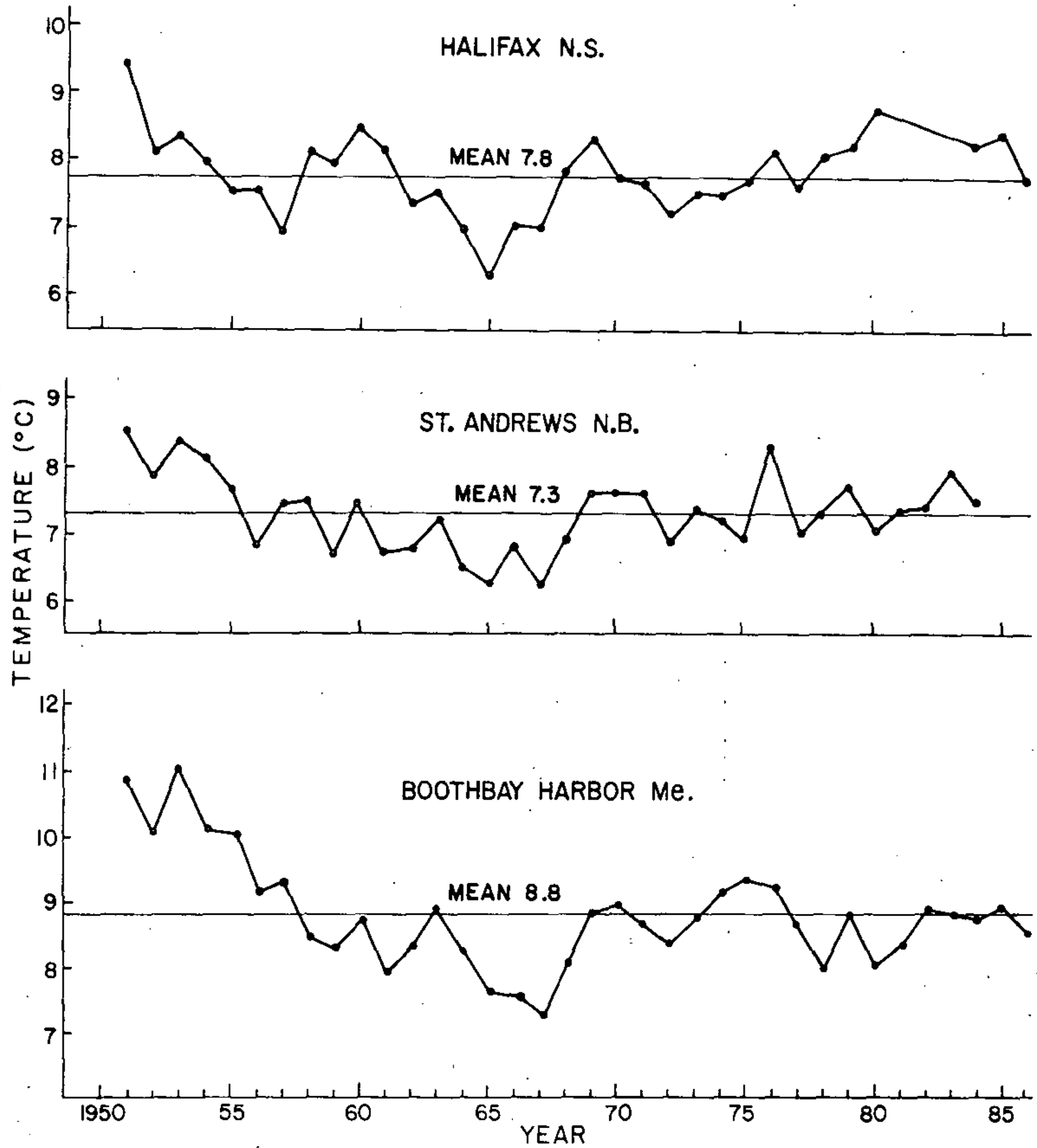

Fig. 3. Annual sea-surface temperatures at Halifax, St. Andrews and Boothbay Harbor during 1951-86. The mean is based on the period 1951-80.

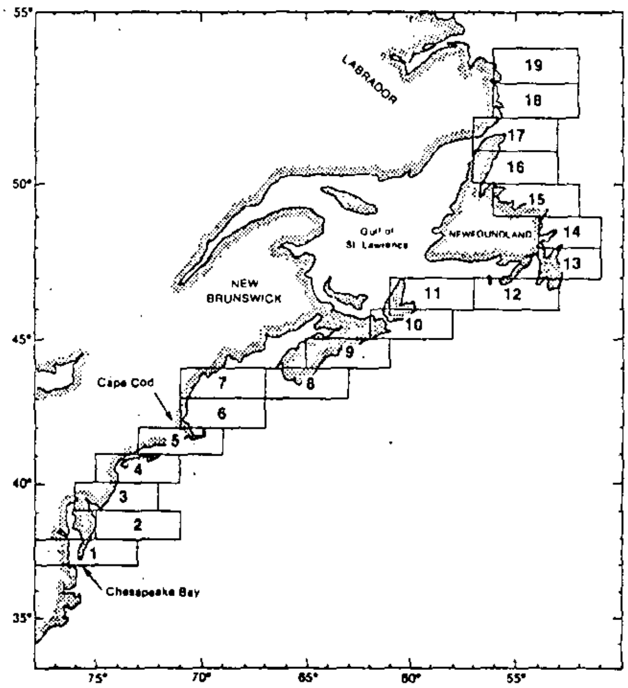

Fig. 4. Locations of 19 areas in the Northwest Atlantic (Chesapeake Bay to southern Labrador) for which sea-surface data were grouped for analysis.

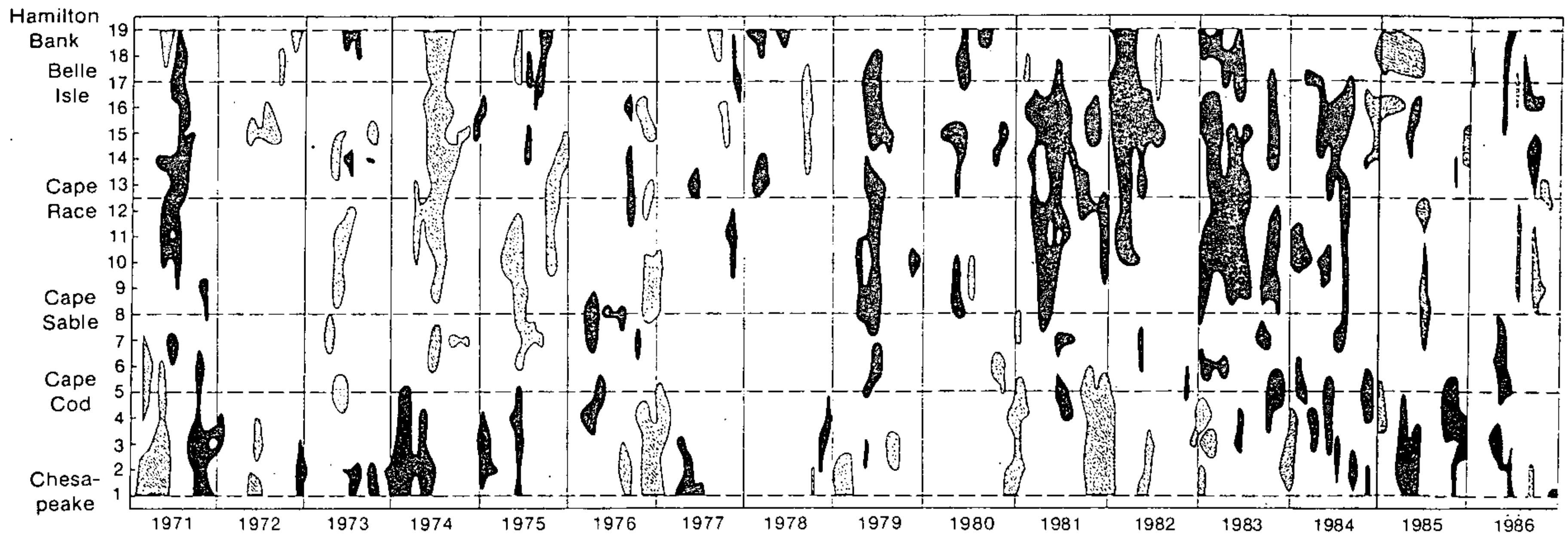

Fig. 5. Contoured monthly sea-surface temperature anomalies (relative to the 1971-80 mean) for the 1971-86 period by area (Fig. 4). (Only anomalies exceeding 1°C (black) and less than -1°C (dotted) which extended in space through at least two neighbouring areas and in time for at least two consecutive months have been contoured.)

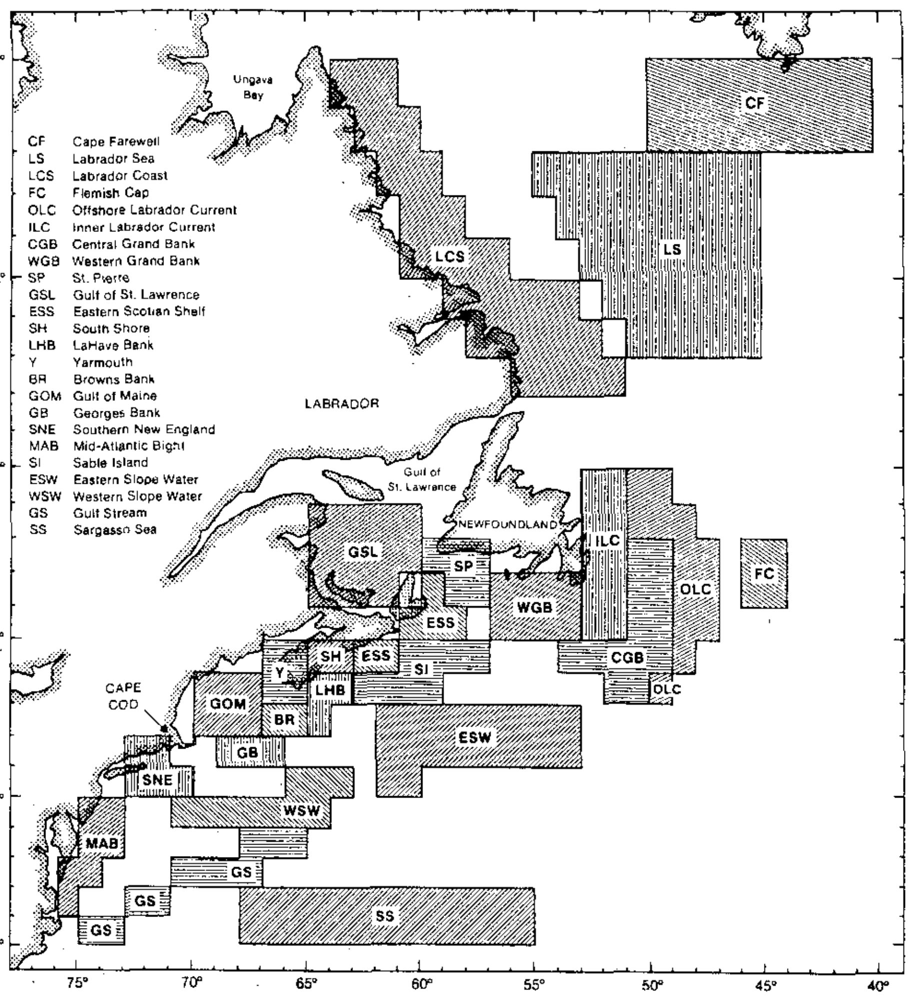

Fig. 6. Geographic boundaries of 24 subregions (Cape Hatteras to Cape Farewell) for which sea-surface temperatures were analyzed on a monthly basis.

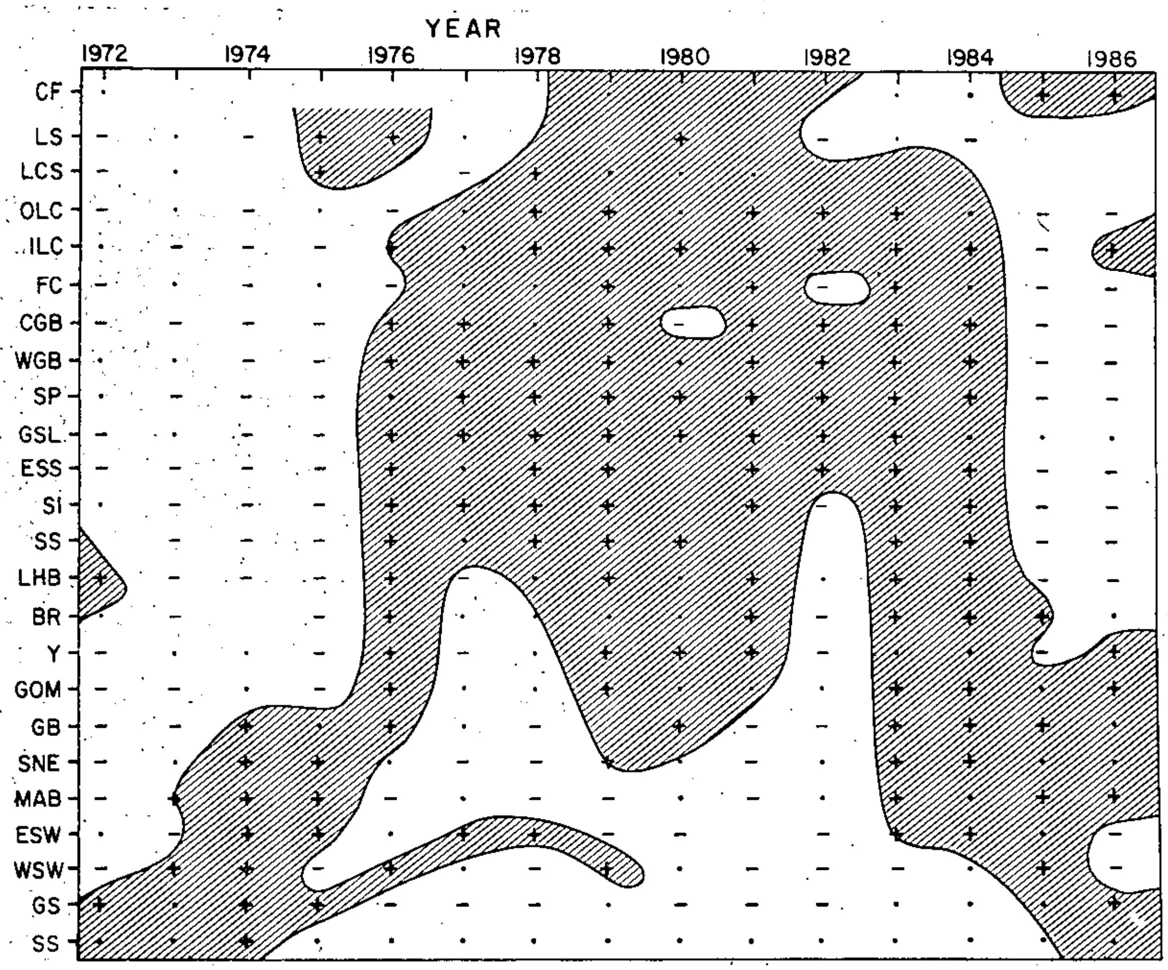

Fig. 7. Distribution of positive (+) and negative (-) annual sea-surface temperature anomalies in 1972-86 by subregion (Fig. 6) relative to the 1972-80 means. (Only anomalies less than -0.15°C and greater than +0.15°C were used in drawing the contours.)

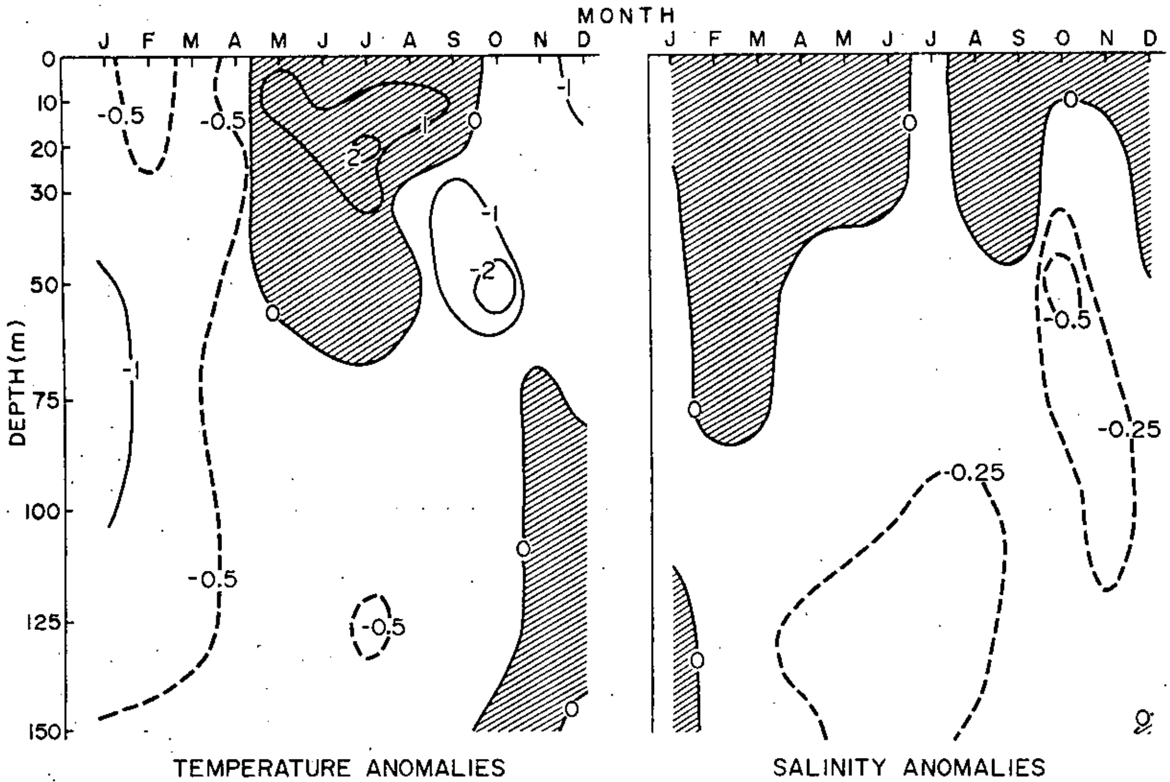

Fig. 8. Monthly temperature and salinity anomalies at Station 27 off St. John's, Newfoundland, during 1986 relative to the 1946-77 means (Keeley, 1981). (Shaded areas represent positive anomalies.)

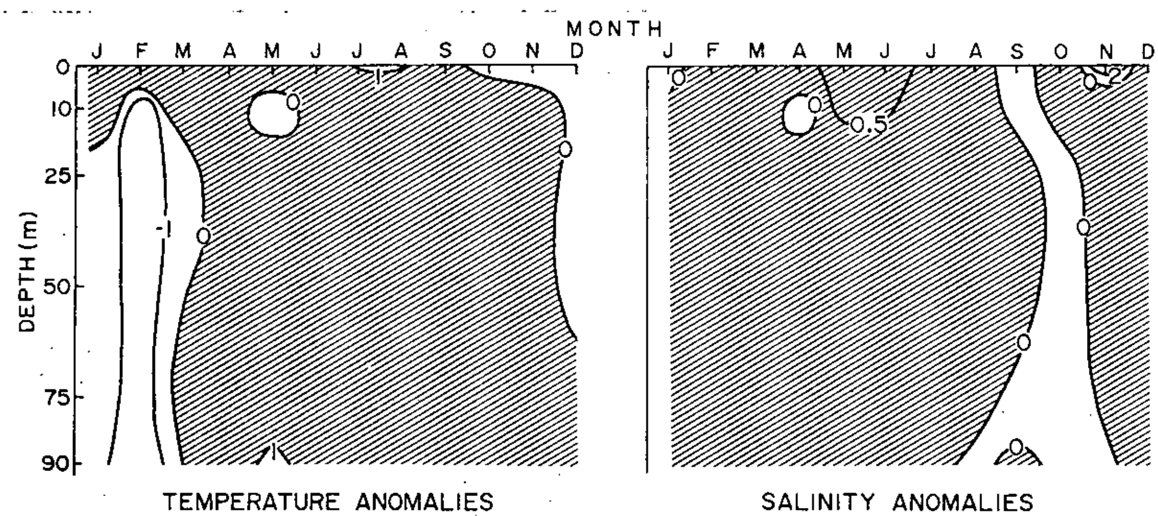

Fig. 9. Monthly temperature and salinity anomalies at Prince 5 near the entrance to the Bay of Fundy during 1986 relative to the 1951-80 means (Shaded areas represent positive anomalies).

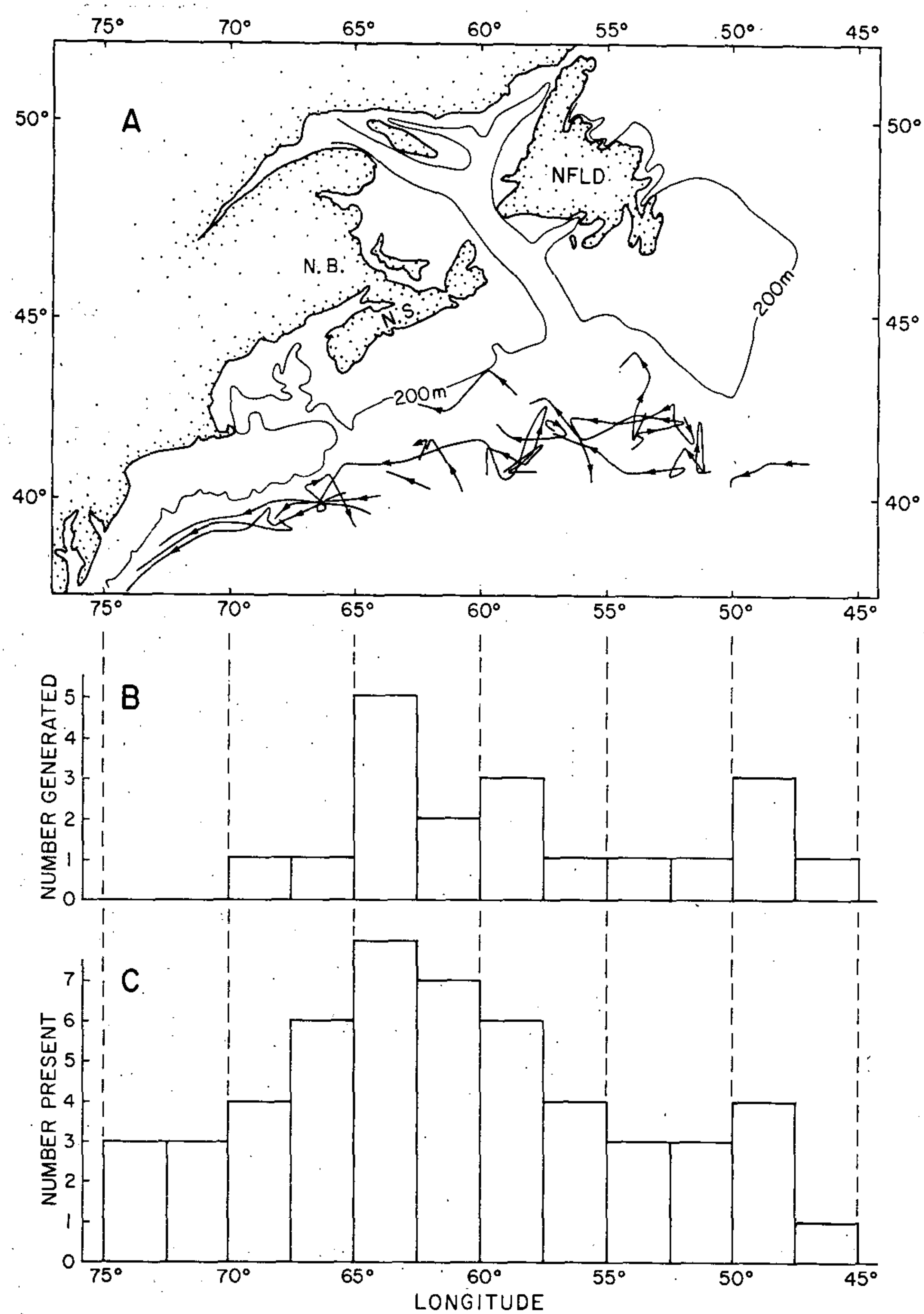

Fig. 10. Warm-core Gulf Stream rings in the region between 45°W and 75°W during 1986: (A) tracks of rings with a lifespan longer than 2 months; (B) number of rings generated in each 2.5° zone of longitude; and (C) number of rings present in each 2.5° zone during some part of the year.

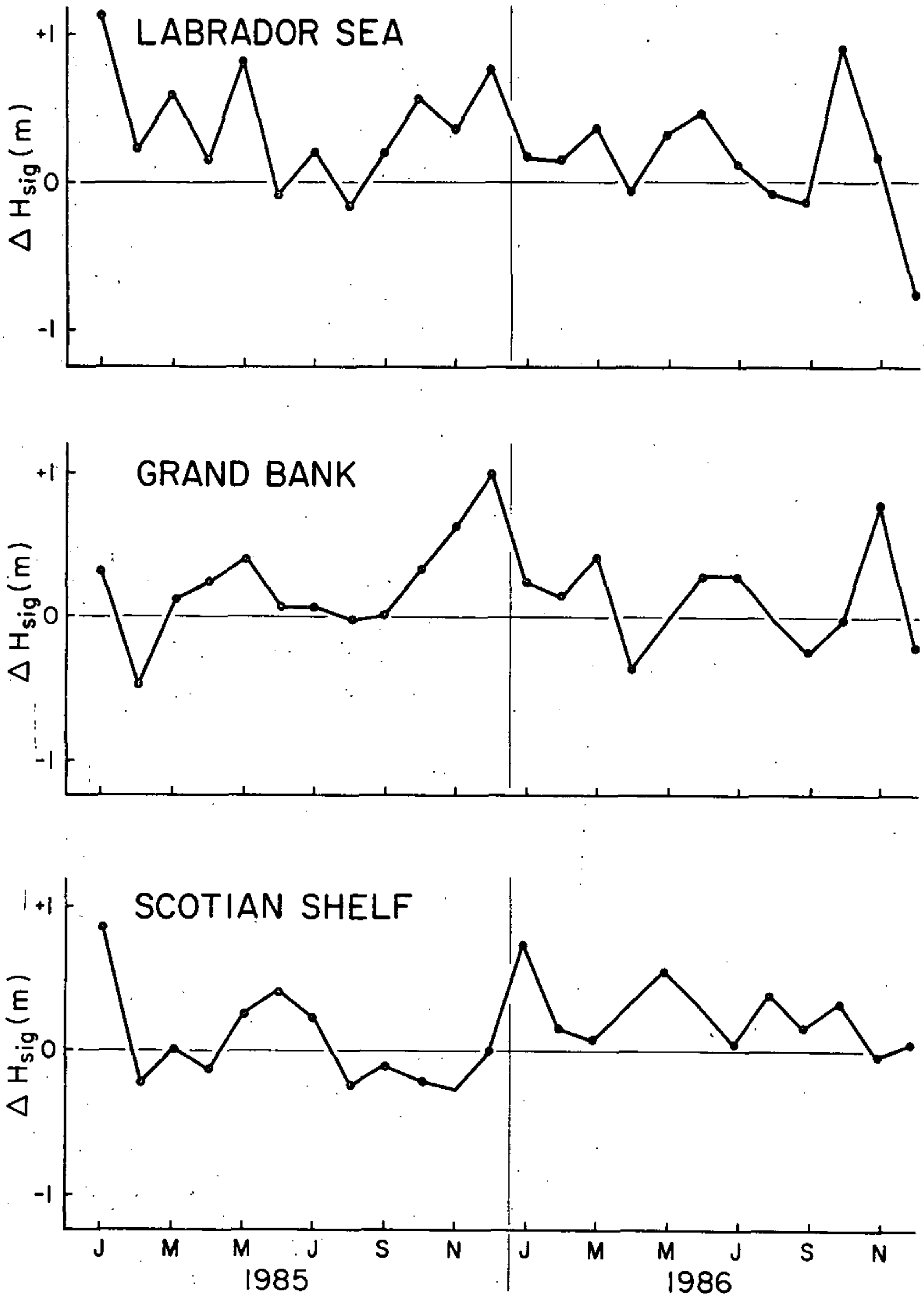

Fig. 11. Monthly significant wave-height (ΔH_{sig}) in three regions of the NorthwestAtlantic during 1985 and 1986 relative to the 1970-80 means.

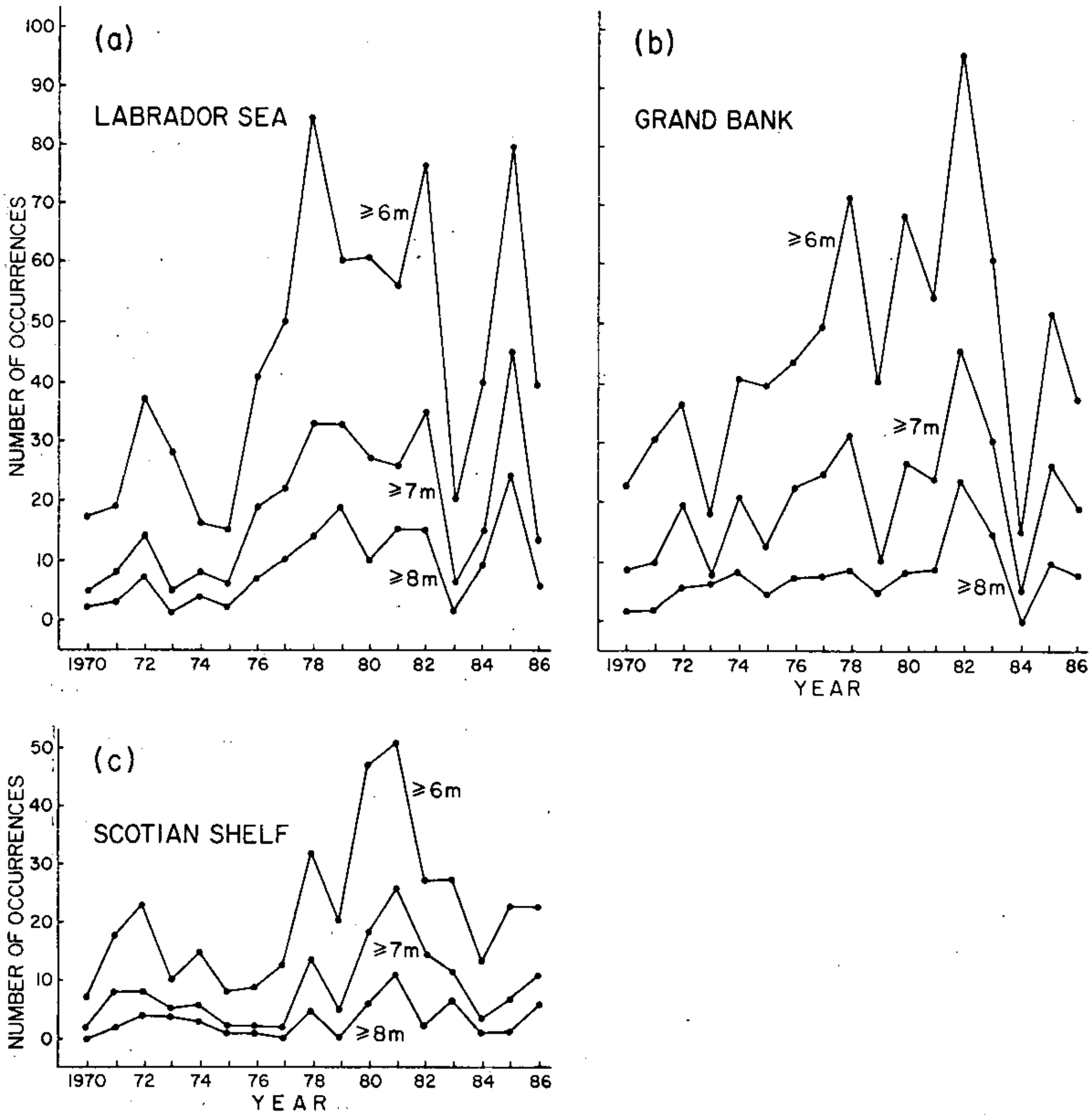

Fig. 12. Annual occurrences of storms during which wave heights exceeded 6, 7 and 8 m in three regions of the Northwest Atlantic during 1970-86.

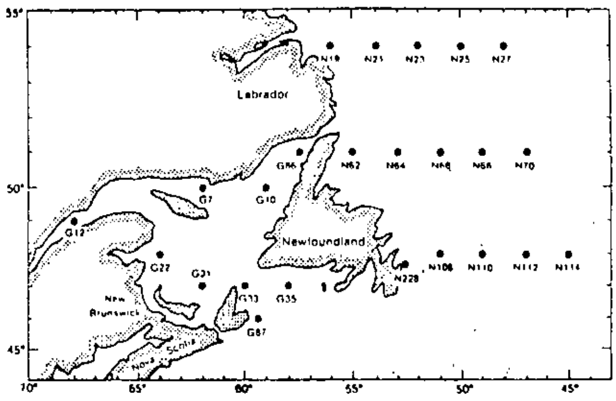

Fig. 13. Locations of 24 grid points where ice statistics have been extracted from ice charts by the Climatology Division of the Canadian Atmospheric Environment Service.

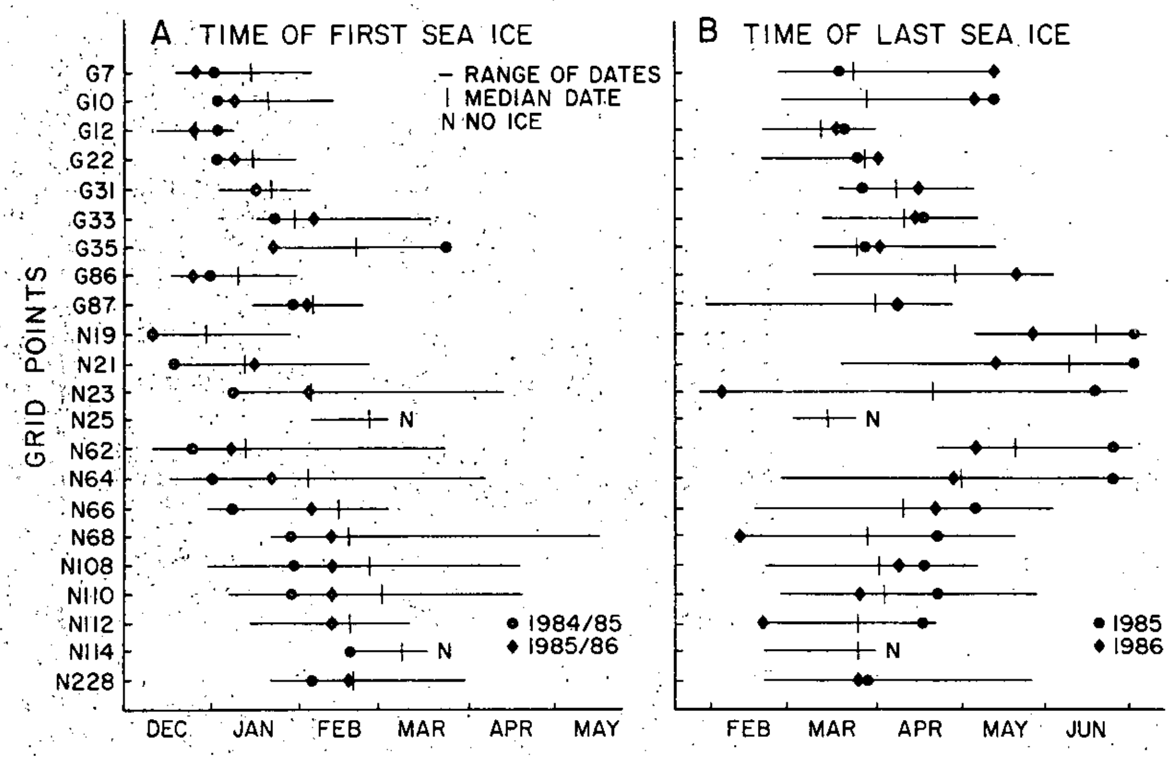

Fig. 14. Ranges of dates for the presence of first sea ice (A) and last sea ice (B) at 22 sites (Fig. 13) in the Northwest Atlantic, with median dates and the 185 and 1986 dates. (Ice has never been observed at N27 and N70).

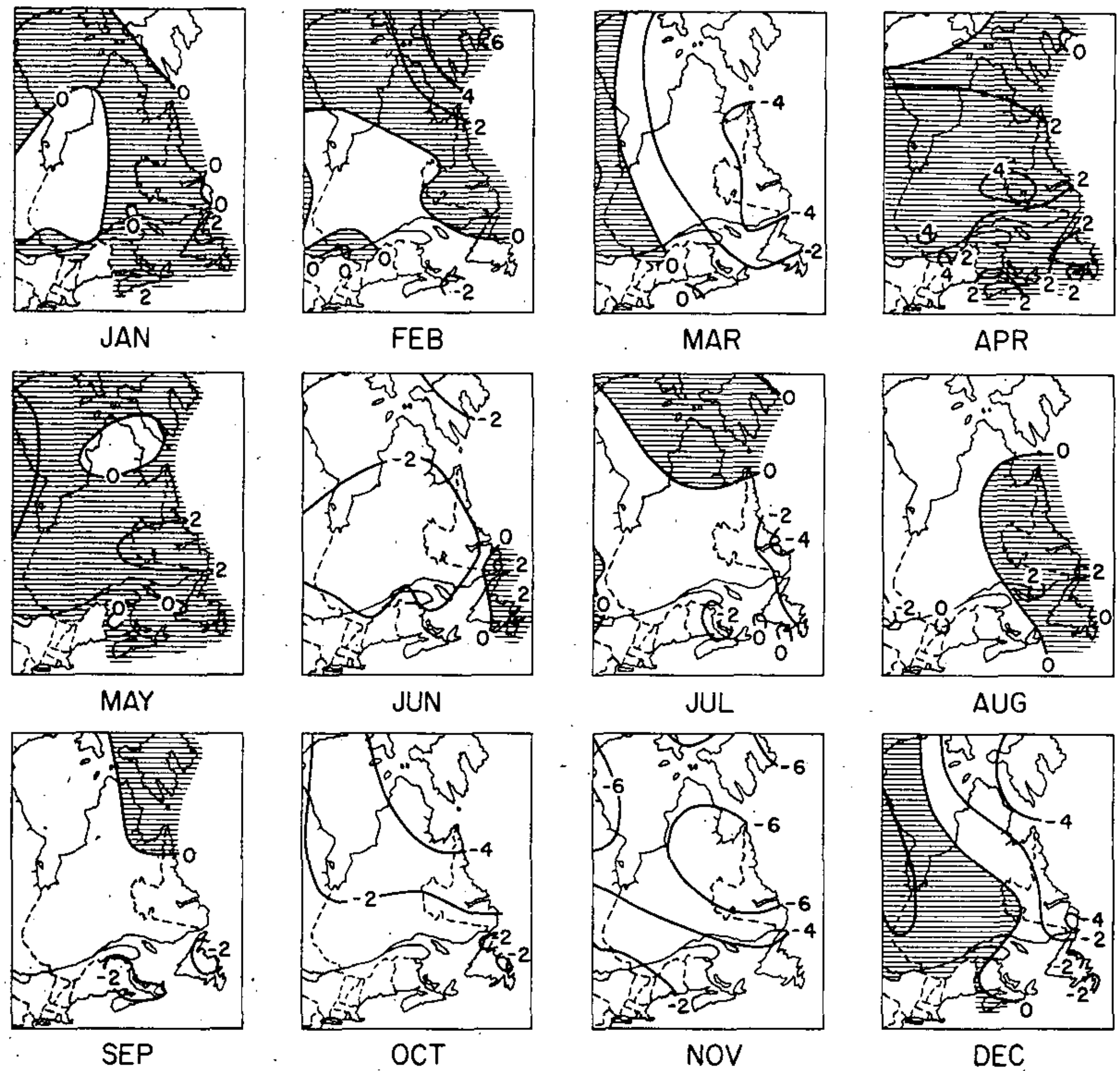

Fig. 15. Monthly air temperature anomalies (°C) over eastern Canada in 1986 relative to the 1951-80 means. (Shaded regions are positive anomalies.)

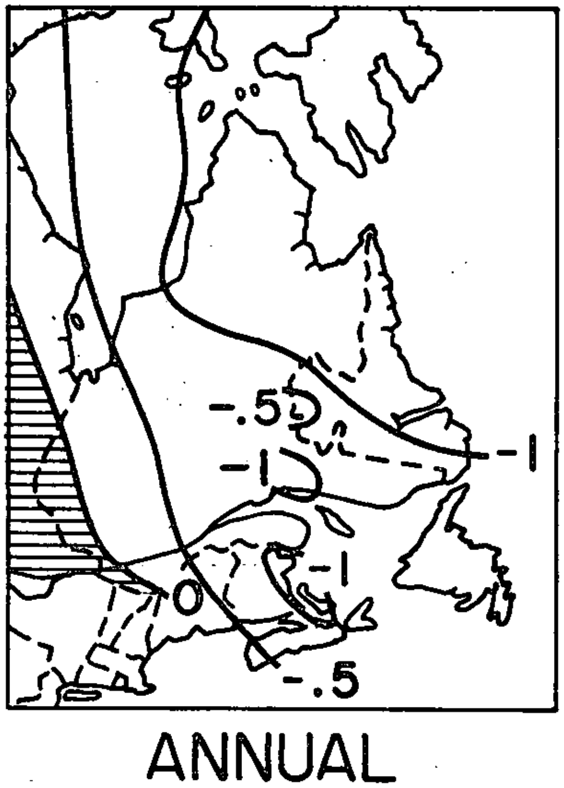

Fig. 16. Annual air temperature anomalies (°C) over eastern Canada in 1986 relative to the 1951-80 means. (Shaded regions are positive anomalies.)

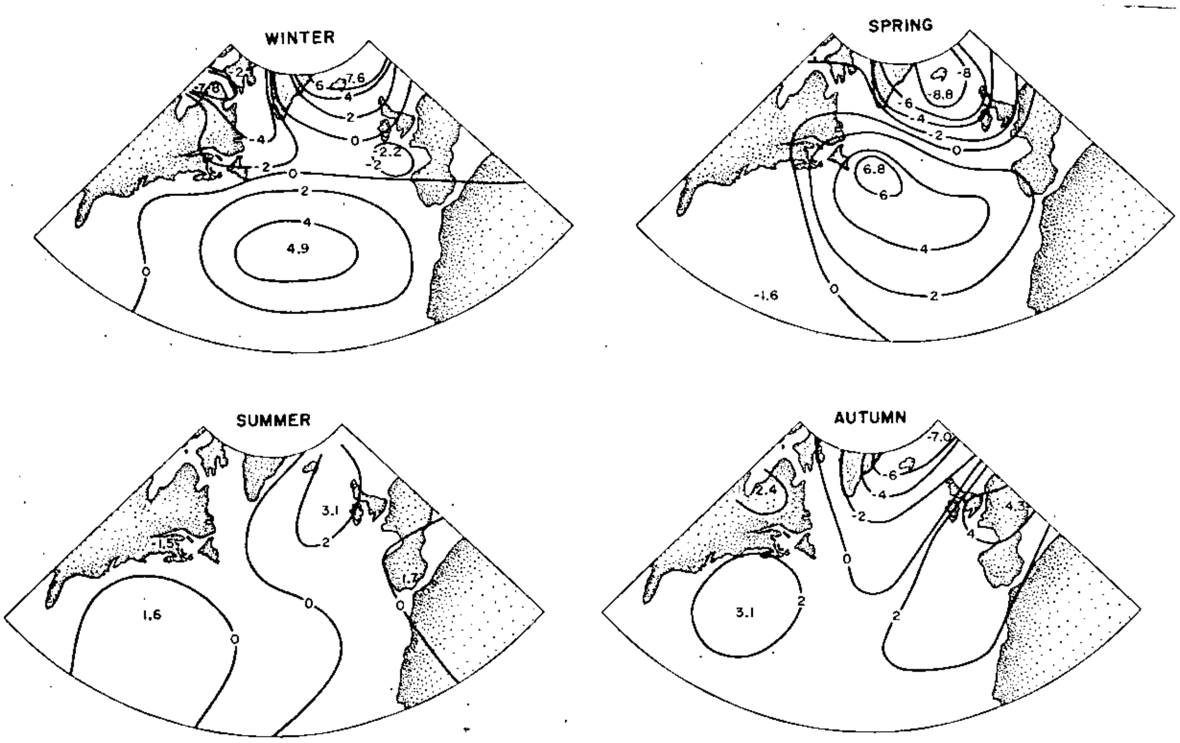

Fig. 17. Seasonal sea-surface air-pressure anomalies (mb) over the North Atlantic in 1986 relative to the 1951-80 means.