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Overview of Environmental Conditions in the Northwest Atlantic during 1984

R. W. Trites and K. F. Drinkwater
Department of Fisheries and Oceans, Marine Ecology Laboratory
Bedford Institute of Oceanography, P. O. Box 1006
Dartmouth, Nova Scotia, Canada B2Y 4A2

Abstract

Using principally time series of oceanographic and meteorological data, such as those from fixed stations and the daily to weekly repetitive coverage of surface conditions by satellites and ships of opportunity, an overview is provided of 1984 conditions in the Northwest Atlantic. Although comparisons with conditions in 1983 and longer-term reference periods indicate that 1984 was a near-average year in many respects, some significant anomalies and trend changes are noted. These include lower surface salinities and deep-layer temperatures in the inshore component of the Labrador Current, a larger-than-normal quantity of surface water drawn off the Scotian Shelf by Gulf Stream rings, and indications that the "warm in the north" epoch in the sea-surface temperature pattern since about 1978 may be nearing an end.

Introduction

This paper is the third in a series of annual overviews of environmental conditions in the Northwest Atlantic, in response to a proposal of the Scientific Council of NAFO that the time series of environmental data be updated and reviewed annually (NAFO, 1983). In addition to helping the Environmental Subcommittee of the Scientific Council in its task of assessing environmental changes that occurred during 1984, a major objective of the reviews is to provide a climatic summary that may aid biologists and fisheries scientists in interpreting their data.

As in previous papers (Trites and Drinkwater, 1984, 1985), this overview includes selected sets of oceanographic and meteorological data as well as information from national research reports and other research documents which were presented at Scientific Council meetings. Conditions in 1984 are compared with those of 1983 and the long-term means. The latter have been standardized generally to a 30-year base period (1951-80), in compliance with the recommendation of the World Meteorological Organization, and those of the Scientific Council. Where 30 years of data were unavailable, 20-year (1961-80) or 10-year (1971-80) base periods were used.

Oceanographic Conditions

Coastal sea-surface temperatures

As part of long-term monitoring programs, sea-surface temperature (SST) measurements were taken twice daily during 1984 at Halifax in Nova Scotia, St. Andrews in New Brunswick, and Boothbay Harbor in Maine (Fig. 1). Monthly averages were calculated and compared to long-term means for the 1951-80 base period (Trites and Drinkwater, 1984). Monthly anomalies for 1983 and 1984 are shown in Fig. 2. The lack of

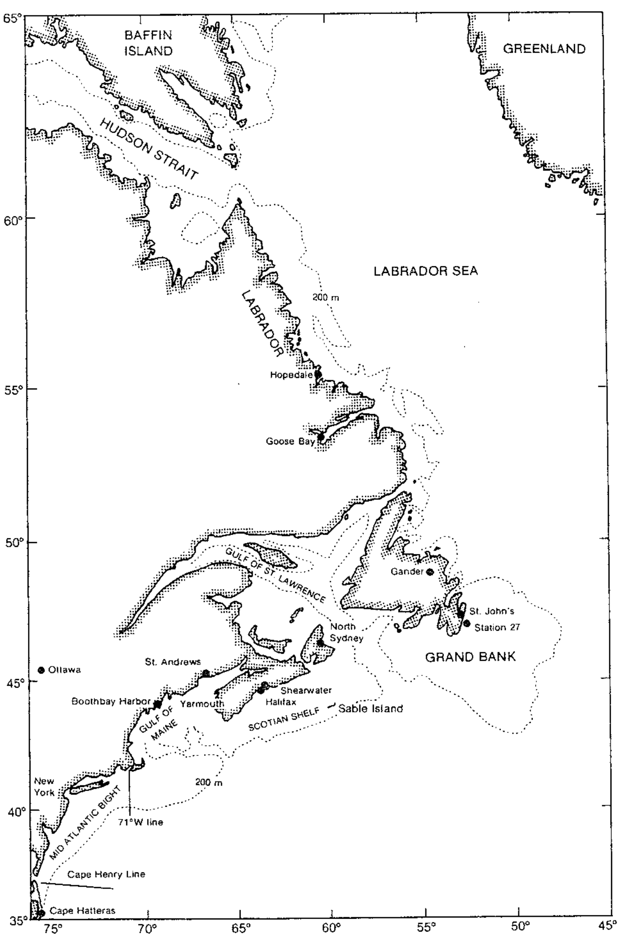

Fig. 1. Map of Northwest Atlantic showing oceanographic and meteorological stations and other place names mentioned in the text.

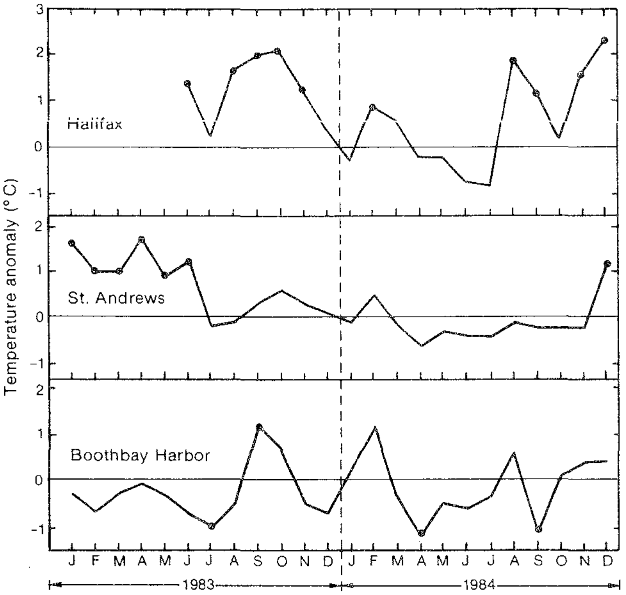

Fig. 2. Monthly sea-surface temperature anomalies at Halifax, St. Andrews and Boothbay Harbor 1983 and 1984 relative to monthly means for the 1951-80 base period. (Dots indicate months when the anomaly equalled or exceeded one standard deviation. Lack of January-May data for Halifax was due to instrument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

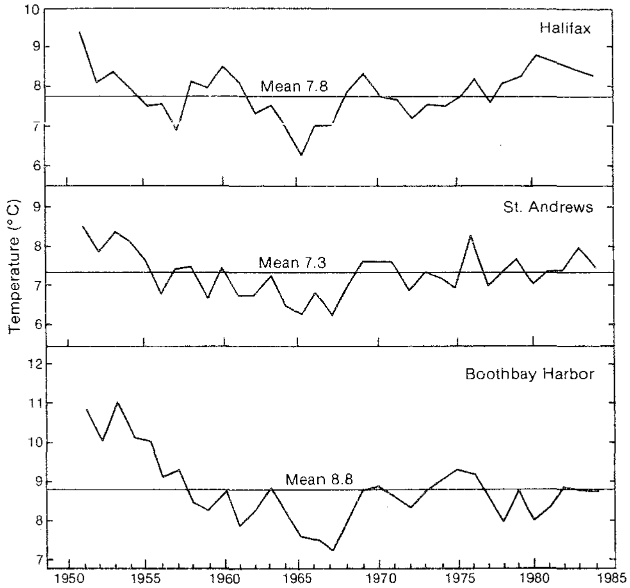

Fig. 3. Annual sea-surface temperatures at Halifax, St. Andrews and Boothbay Harbor during 1951-83, and the means for the 1951-80 base period.

data for Halifax during the first 5 months of 1983 were due to instrument problems.

During 1984, the amplitudes 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 stations, with positive peak anomalies in February, negative anomalies during spring and early summer, and above-normal temperatures at the end of the year. At Boothbay Harbor and Halifax, anomalies were also positive in August but they declined to minimum values in September and October respectively. These late summer anomalies were not observed at St. Andrews. At Halifax, the mean monthly anomalies exceeded their standard deviations (for 1951-80 period) in 5 of 12 months, including 4 of the last 6. This represents the second consecutive year when above-normal temperatures were recorded in the latter half of the year. The anomalies exceeded their standard deviations at St. Andrews only in December and at Boothbay Harbor only in April and September.

The mean annual sea-surface temperatures were 8.3°C at Halifax, 7.4°C at St. Andrews, and 8.7°C at Boothbay Harbor (Fig. 3), and their respective anomalies from the 1951-80 averages were 0.5°, 0.1° and -0.1°. The near-normal means at St. Andrews and Boothbay Harbor in 1984 continued the pattern of the last 15 years with low variability and lack of a distinct trend. At Halifax, the questionable quality of data in 1981 to 1983 due to suspected instrumental errors precludes any comment on a recent trend.

Offshore and sea-surface temperatures

The extensive data base of offshore sea-surface temperatures is derived principally from cooling water intakes of merchant vessels and reported in radio weather messages and logbook records that are transmitted to the U.S. Fleet Numerical Oceanographic Center and the U.S. National Climatic Center for processing and archiving. Analyses of these data by the Pacific Environmental Group of the U.S. National Marine Fisheries Service include computation 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 McLain and Ingham (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 the 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."

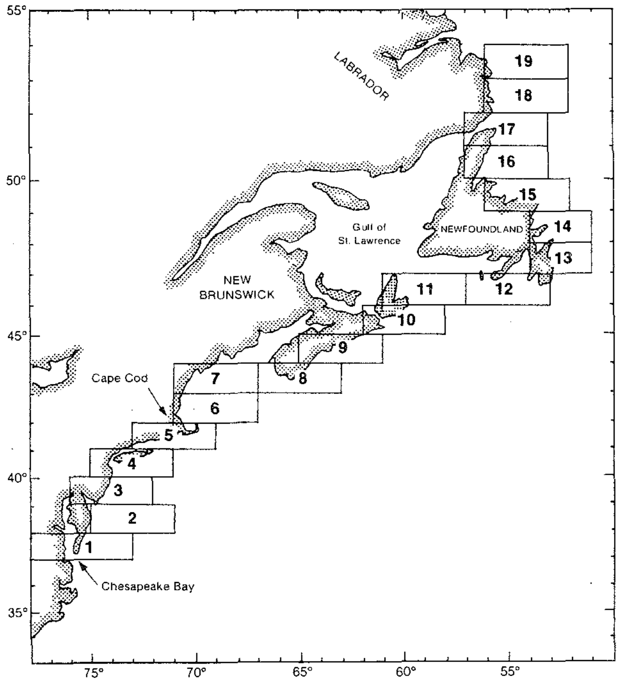

Fig. 4. Locations of 19 areas in the Northwest Atlantic (Chesapeake Bay to southern Labrador) for which sea-surface temperatures were grouped for analysis.

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 temperatures southward from this area, which persisted for the previous 5 years, continued into 1984, but toward 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° to 2°C below normal in the October-December period. The area from Georges Bank southward showed periods of both below-normal and above-normal temperatures (by more than one standard deviation), but, in general, there was an increasing tendency for above-normal temperatures to occur more frequently.

Sea-surface temperatures for 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 temperatures anomalies for each year in the 1972-83 period were reported by Trites and Drinkwater (1985). That 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, indi-

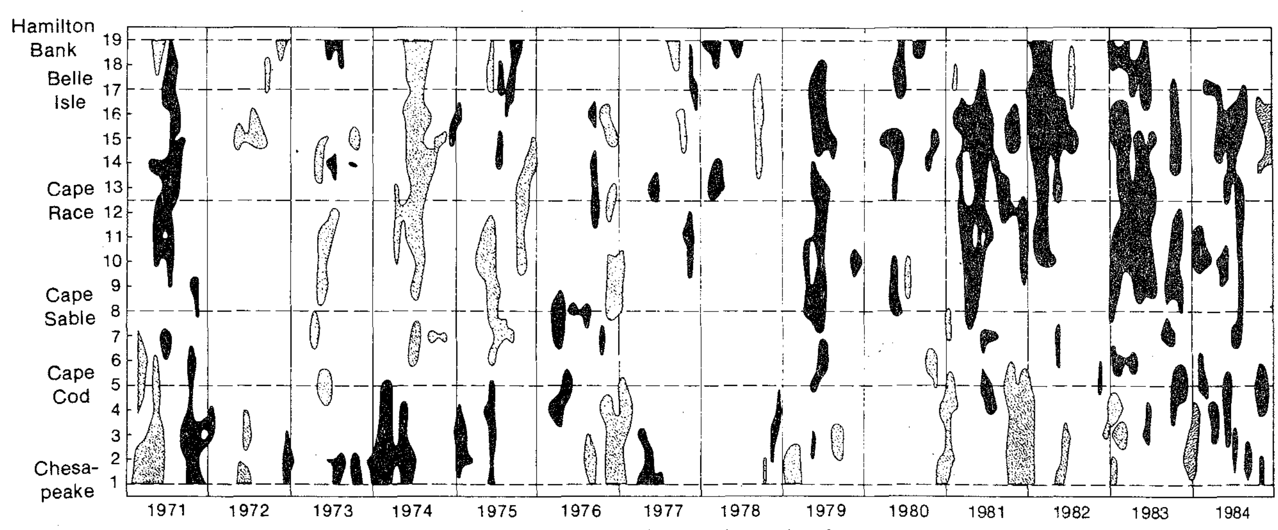

Fig. 5. Contoured plot of monthly sea-surface temperature anomalies (relative to the 1971-80 base period) by area for the 1971-84 period. (Only anomalies exceeding 1°C (black) and less than -1°C (dotted) which extended in space through at least two neighboring areas and in time for at least two consecutive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

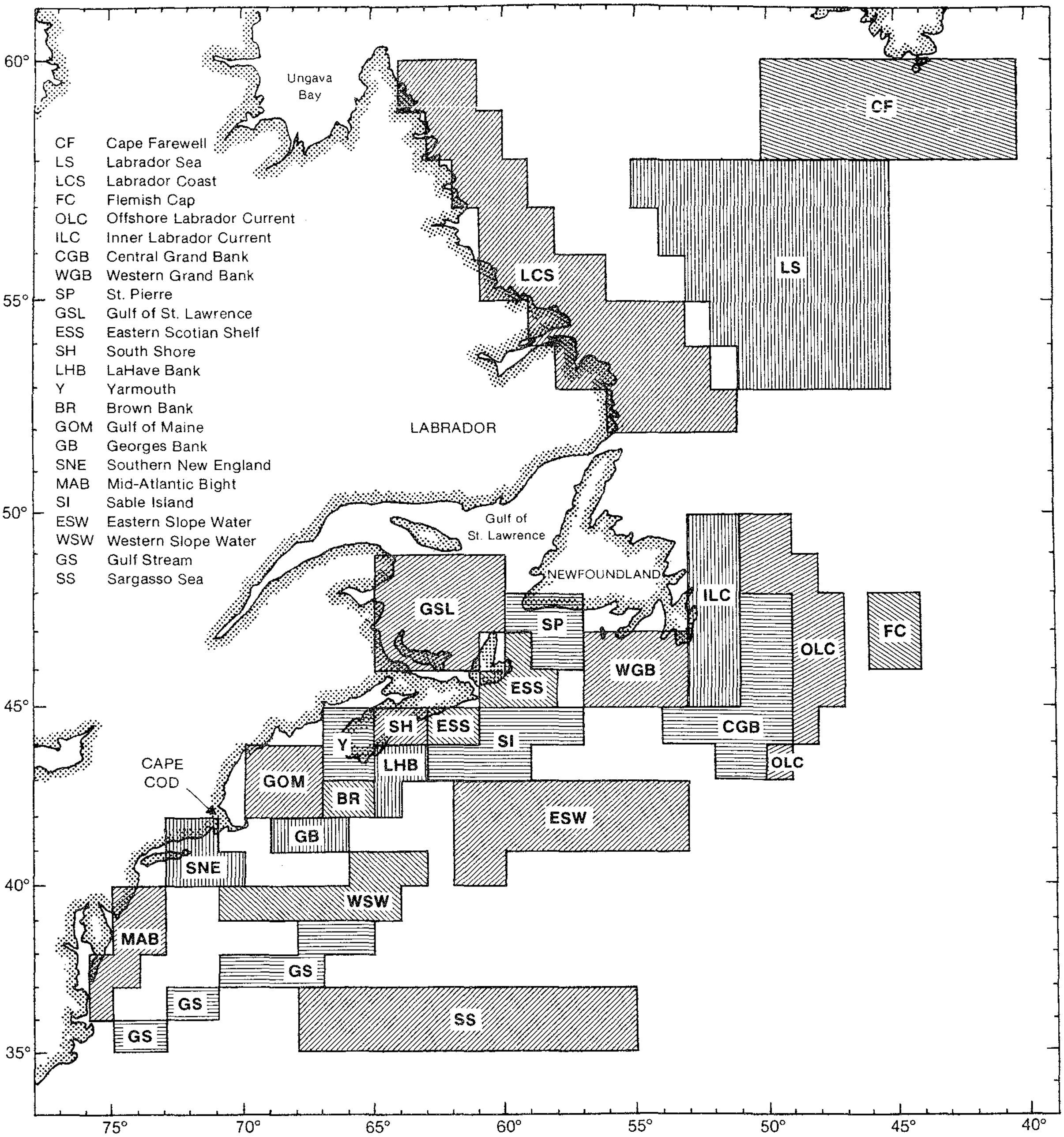

Fig. 6. Geographic boundaries of 24 subregions for which sea-surface temperatures were analyzed on a monthly basis for the 1972–84 period.

cating that the "warm in the north" epoch may be nearing an end.

Station 27 temperature and salinity

Temperature and salinity profiles have been collected at Station 27, approximately 10 km off St. John's, Newfoundland, on a continuing basis since 1946. These data are considered to be representative of the inshore Labrador Current. The station was occupied on 33 occasions in 1984, with a maximum of five times in August and November but none in March. Monthly averages of temperature and salinity at standard depths (0, 10, 20, 30, 50, 75, 100, 125, 150 m) were calculated for 1984, using linear interpolation in the vertical, where necessary. Anomalies from the mid-monthly means for 1946-77 (Keeley, 1981) were then computed and are illustrated in Fig. 8.

In depths greater than 50 m temperatures in 1984 were typically -1.1° to -1.6°C and below normal by about 0.5°C, on the average. This is the third consecutive year that the deep water at Station 27 has been

TABLE 1. Mean sea-surface temperatures for selected areas of the Northwest Atlantic in 1972-80, and anomalies for 1981 to 1984 relative to the base period. (Geographic locations of water masses are shown in Fig. 6; blank spaces indicate that annual averages not computed when data missing for one or more months.)

Water mass	Mean temp. 1972-80[a]	Annual anomalies (° C) 1981	1982	1983	1984
CF	3.62		0.10	-0.12	-0.01
LS	5.54		-0.43	-0.11	-0.59
LCS	2.19	-0.10			
OLC	5.17	0.82	0.24	0.32	0.06
ILC	4.83	0.96	0.40	0.99	0.52
FC	7.88	0.83	-0.39	0.46	-0.14
CGB	6.48	1.11	0.34	1.37	0.84
WGB	6.13	1.19	0.19	1.11	0.62
SP	5.91	1.14	0.35	0.87	0.79
GSL	5.82	0.56	0.46	0.91	-0.02
ESS	7.10	0.46	0.45	1.28	0.56
SI	8.27	0.85	-0.20	0.96	0.97
SH	7.85			1.43	0.66
LHB	8.87	0.30	-0.07	0.86	0.42
BR	8.84	0.25	-0.28	1.07	0.51
Y	7.64	0.18	-0.20	0.05	0.10
GOM	9.59	0.11	0.07	0.45	0.45
GB	10.17	-0.39	-0.46	0.48	0.37
SNE	12.23	-0.50	-0.03	0.38	1.08
MAB	14.87	-0.43	-0.06	0.61	0.08
ESW	15.54	-0.03	-0.37	0.51	1.25
WSW	18.50	-0.92	-0.48	-0.27	-0.17
GS	22.94	-0.26	-0.16	0.08	0.08
SS	22.26	-0.37	-0.07	0.04	-0.05

[a] See Trites and Drinkwater (1985) for annual anomalies pertinent to this base period.

colder than normal. Salinities in the deep water were below normal until May, above normal in June-October, and below normal in the last 2 months of the year. However, the anomalies were quite small (approximately 0.1) and were not considered to be significant. In the near-surface layer (<50 m), both temperature and salinity were below normal from January to June, with maximum anomalies in May and June of 2° and 4°C for temperature and 0.3 and 0.9 practical salinity units (psu) for salinity. During the summer months, surface salinities were less than 30.5, about 1 psu below normal. At the same time, rapid surface heating produced positive temperature anomalies 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 higher-than-normal surface temperatures. Upper-layer temperatures returned to below-normal values in October and November but were near normal or slightly positive in December. The high positive temperature anomaly and negative salinity anomaly at 50 m in October resulted from a deeper-than-normal surface layer.

Position of shelf-slope front

Information on the position of the shelf-slope front from Georges Bank to Cape Romain, South Carolina; has been extracted from thermal infrared satellite

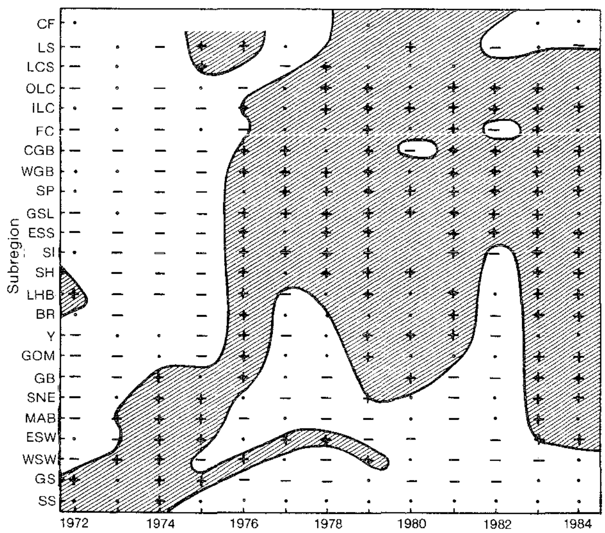

Fig. 7. Distribution of positive (+) and negative (-) annual sea-surface temperature anomalies in 1972-84 by subregions (Fig. 6) relative to the means for the 1972-80 base period. (Only anomalies less than -0.15°C and greater than 0.15°C were used in drawing the contours.)

imagery and reported annually since 1973 by the Atlantic Environmental Group (now Marine Climatology Investigation) of the U.S. National Marine Fisheries Service. From a 10-year data series (1974-83), the mean position of the front north and east of Cape Henry (Fig. 1) is typically farther 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 more shoreward during winter. Armstrong (MS 1985) reported that the frontal position in 1984 generally followed the long-term annual cycle in the region 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 position in 1984 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 (eddies) 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 (75° W) 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. Ten warm-core rings were present in the area in 1984. Two rings were formed in late 1983 and survived into 1984 and 8 rings were formed in 1984, two of which persisted into 1985. Ring formation averaged 9 per year during 1974-83, ranging from 5 in 1974 to a maximum of 11 in 1979 and 1982. The average lifetime of rings whose destruction occurred in 1984 was 97 days, which is much shorter than the 1983 average of 143 days and less than

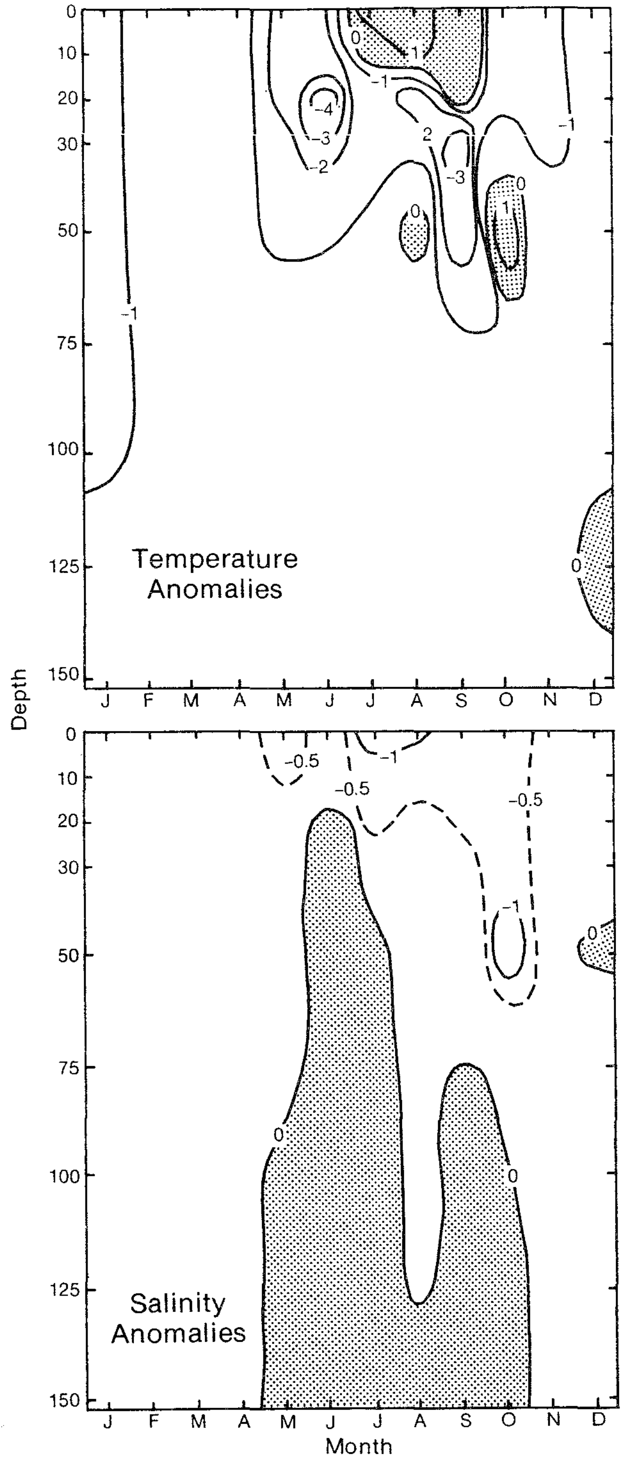

Fig. 8. Monthly temperature and salinity anomalies at Station 27 off St. John's, Newfoundland, for 1984 relative to the 1946–77 period used by Keeley, 1981. (Shaded areas represent positive anomalies.)

the 1976–81 mean of 120 days. In terms of total ring-months, there were 25 in 1984, compared with 51 in 1983 and the 1976–81 mean of 38. This was the second lowest total in the 1974–83 period. The generation-zone pattern for 1984 was generally similar to the

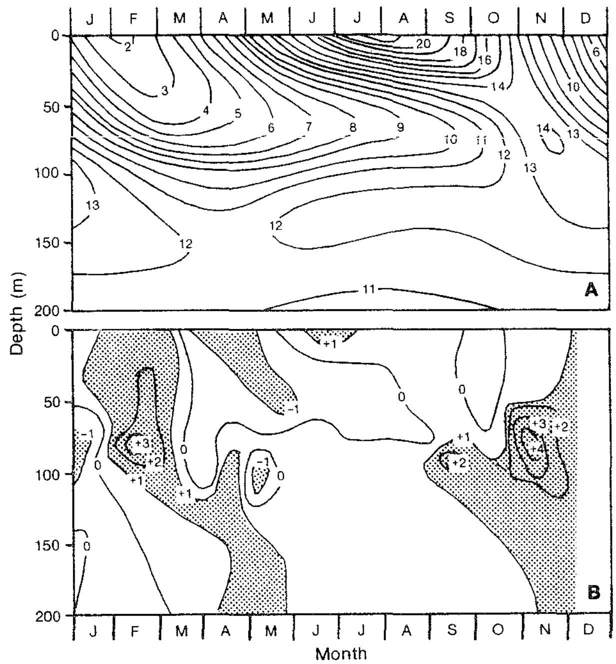

Fig. 9. Bottom temperature (°C) on the continental shelf and upper slope at approximately 71°W. **A**, 10 yr means, 1974–83; **B**, anomalies in 1984 relative to the 10-year means, with positive values exceeding 1°C shaded. (From Armstrong, MS 1985a).

mean, but only two rings reached 70° W before their destruction. This 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 warm-core rings in slope water between 50° and 60° W is more difficult than in areas farther southwestward due to the increased presence of cloud cover and fog, resulting in less frequent and less reliable satellite thermal imagery and greater uncertainty in the statistics on warm-core rings. Examination of the Oceanographic Analysis Charts of the U.S. National Weather Service indicated that 14 rings were present in 1984. Four rings which were formed during September–December 1983 survived into 1984 and 10 new ones formed in 1984, compared with 12 in 1983. Lifetimes of the 10 rings, whose destruction occurred in 1984, varied from less than 1 month to more than 6 months, the average being 3 months. Only 3 of the rings moved westward of 60° W.

Shelf-slope temperatures in the Mid-Atlantic Bight

Temperatures on the shelf and slope along a transect at approximately 71° W (see Fig. 1) have been monitored by the U.S. National Marine Fisheries Service since 1974. During 1984, 16 expendable bathythermograph (XBT) transects were carried out. Analysis of bottom temperatures by Armstrong (MS 1985a) included a comparison of 1984 conditions with the mean for 1974–83 (Fig. 9). Nearshore bottom temperatures along the transect in 1984 were generally above normal for most of the year. At mid-shelf depths (20–70 m), bottom water was cooler than normal for about half of the year (principally spring and summer) and warmer than normal at other times. Bottom temperatures in depths exceeding 70 m were above the 10-year means in most months of the year and particularly so at 70–90 m in February and late October–early November. Only one warm-core ring passed through slope water along the transect in 1984. During the 10-year period (1974–83), 3 or 4 rings per year were typical, with a minimum of 3 in 4 of the years and a maximum of 7 in 1977.

In addition to the 71° W transect, thermal events have been monitored since 1976 along a transect which extends seaward across the shelf and slope from New York Harbor. In 1984, XBT casts were made on 24 occasions, and the events were reported by Benway (MS 1985) 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 100 to 200 m, bottom temperatures in 1984 were greater than 12° C for all years, except in late 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 1970–83 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, and the anomalies (relative to 1970–80 means) are illustrated in Fig. 10. For the Labrador Sea, the seasonal pattern in 1984 was very similar to that of

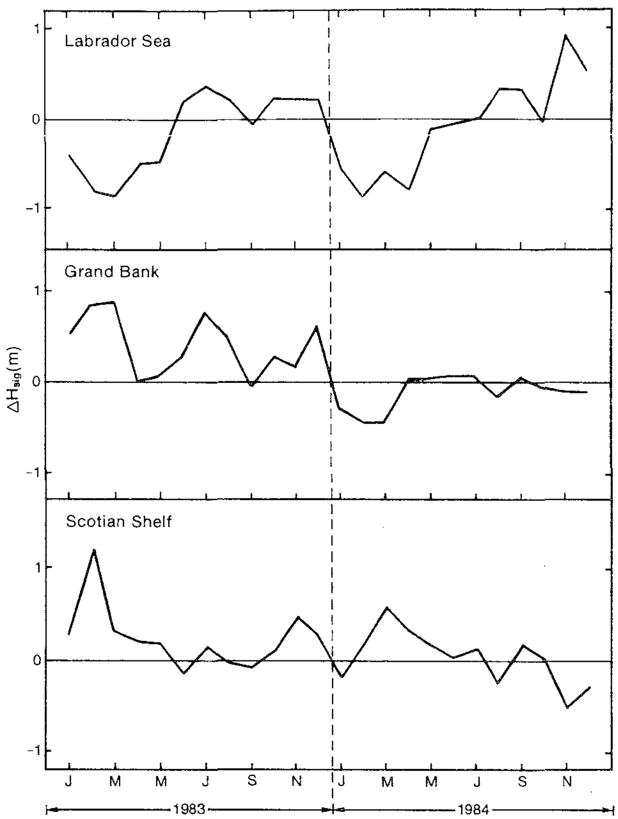

Fig. 10. Monthly significant wave-height anomalies (ΔH_{sig}) in three regions of the Northwest Atlantic for 1983–84 relative to the means for the 1970–80 base period.

TABLE 2. Monthly mean significant wave heights (m) at three locations in the Northwest Atlantic, derived from 12-hr wave charts, for 1983 and 1984 relative to means for the 1970–80 period.

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

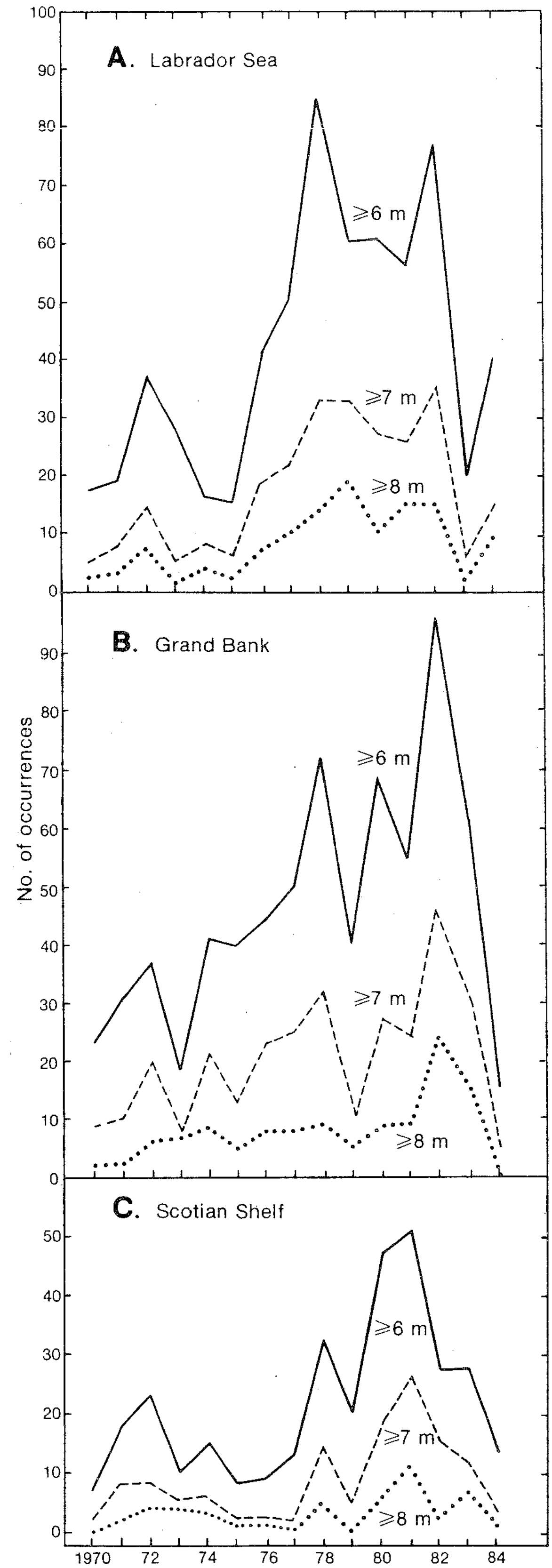

Fig. 11. Annual occurrences of storms during which wave heights exceeded 6, 7 and 8 m in three regions of the Northwest Atlantic during 1970-84.

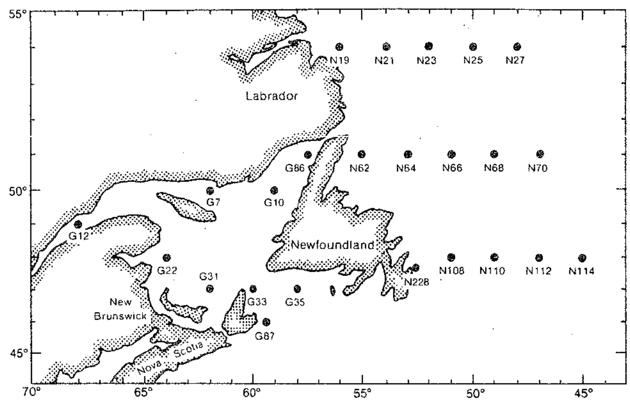

Fig. 12. Locations of 24 grid points where ice statistics have been extracted from ice charts by the Climatology Division of the Canadian Atmospheric Environment Service.

1983. During the first half of the year significant wave heights were well below the 1970-80 means, whereas the reverse condition existed during the last half of the year. For the Grand Bank and 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 latter two areas but not for the Labrador Sea.

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. For the Scotian Shelf and Grand Bank areas, there was 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. In the Labrador Sea, the frequency of large waves was higher than in 1983 but still well below the high values of the 1971-82 period. Although the year-to-year variability of wave severity and occurrence of large waves is high, there appears to be a declining trend to values similar to those of the early 1970's.

Sea ice

The Ice Climatology Division of the Canadian Atmospheric Environment Service (AES) has selected 24 experimental grid points in the Gulf of St. Lawrence and off eastern Newfoundland and Labrador for analysis of ice conditions throughout the region (Fig. 12), and the results of the analysis for 1960-83 were summarized by Trites and Drinkwater (1985). The update for 1984 includes minimum, maximum and average duration (weeks) when ice was present, and the average duration for all years of record (Table 3). The timing of first and last sea ice, the median dates and the 1984 dates are shown in Fig. 13.

Ice was present at most Gulf of St. Lawrence sites for longer-than-normal periods in 1984. Only in Cabot

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 (Fig. 1)	Period studied	No. of years	Years with ice	Ice duration (weeks) When ice present Min.	Max.	Mean	Overall mean	1984
G-7	1968–84	17	17	6	14	9.8	9.8	13
G-10	1977–84	8	8	3	13	8.7	8.7	11
G-12	1968–84	17	17	2	15	11.0	11.0	13
G-22	1977–84	8	8	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	4
G-35	1962–84	23	11	1	11	3.7	1.8	0
G-86	1976–84	9	8	6	16	12.9	11.4	15
G-87	1971–84	14	13	1	12	6.6	6.2	2
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	2	1	1	1.0	0.0	1
N-27	1960–84	25	0	0	0	—	—	0
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	9	1	10	3.7	1.4	10
N-70	1961–84	24	0	0	0	—	—	0
N-108	1960–84	25	19	1	17	5.4	4.1	1
N-110	1960–84	25	18	1	11	4.2	3.0	4
N-112	1960–84	25	6	1	10	4.8	1.0	4
N-114	1960–84	25	2	1	2	1.5	0.1	0
N-228	1960–84	25	15	1	14	5.0	3.0	3

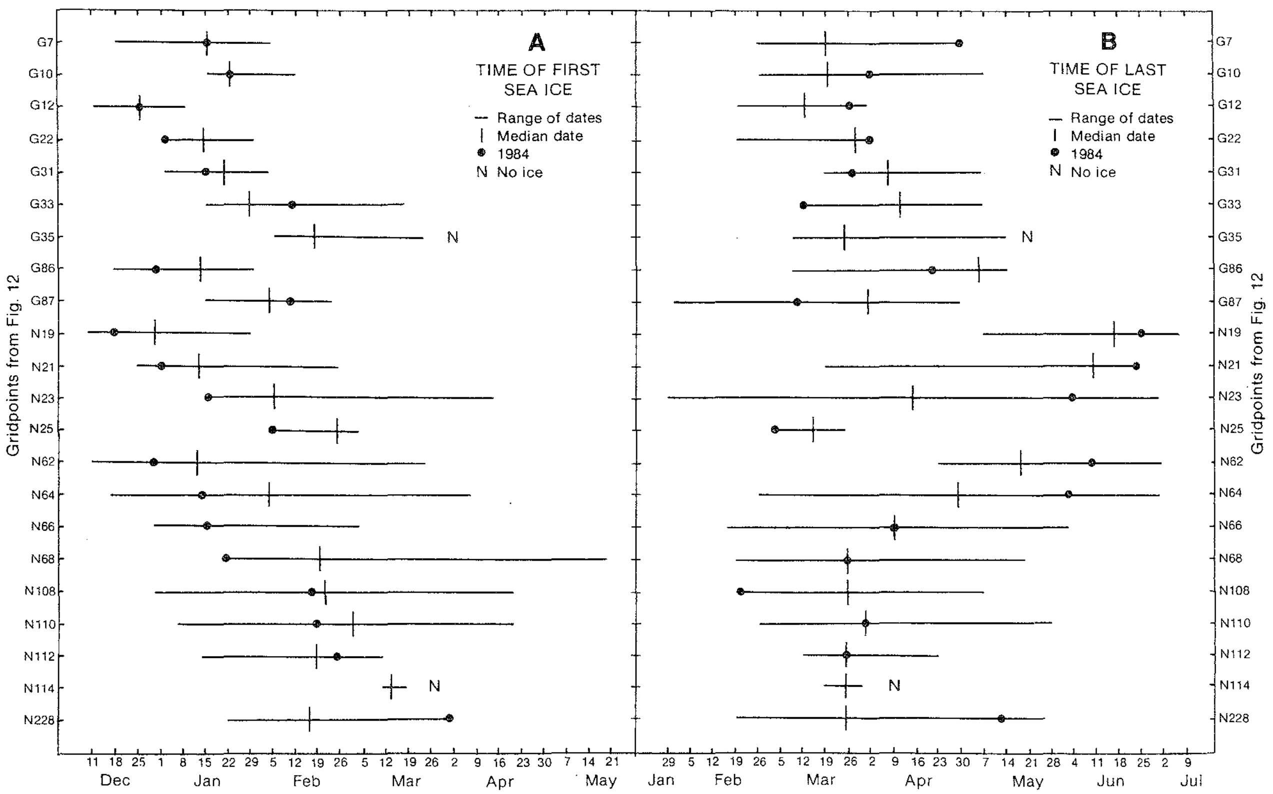

Fig. 13. Ranges of dates for the presence of first sea-ice (**A**) and last sea-ice (**B**) at 24 locations in the Northwest Atlantic, with median dates and 1984 dates.

Strait and east of Cape Breton (G33, G35, G87) were the durations shorter than normal. Ice durations were near normal at sites off southeastern Newfoundland but were much longer than normal off southern Labrador and northeastern Newfoundland. Radomski (1985), in a narrative description of ice conditions during the winter of 1984-85, writes: "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. Persistent westerly winds continually pushed loose ice through Cabot Strait, and at one time the ice threatened the Venture drilling sites near Sable Island. For the Grand Bank-Northeast Newfoundland region, Radomski (1985) reported 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 the site".

Icebergs

The International Ice Patrol monitors the number of icebergs which drift south of 48° N latitude off eastern Newfoundland. During the period from October 1983 to September 1984, a total of 2,202 icebergs were reported. No icebergs were reported during the first 5 months of the period, but the monthly totals during March-September were 101, 953, 484, 227, 335, 93 and 9 respectively. The seasonal distribution in 1983/84 was similar to those of previous years, with more than 90% of the icebergs appearing from March to July. The number of icebergs was much higher in 1983/84 (2,202) than in 1982/83 (1,352), but they did not begin to reach 48°N until much later in the season (March compared to December). Data for both years were obtained by using Side-Looking Airborne Radar (SLAR). Prior to 1982/83, iceberg counts were determined visually by ship sightings until 1945 and by aerial reconniasance afterwards. Ongoing studies by the Ice Patrol indicate that SLAR detects more than twice as many icebergs as visual methods. Until these studies are completed, meaningful comparisons between years with different observational techniques cannot be made. Although the iceberg count during March-July 1984 (2,100) was the highest in over 100 years of record-keeping, it is unclear whether this number is representative of an average or above-average iceberg year. It may indicate that the absolute numbers that were obtained by visual methods were gross underestimates.

In the overview of environmental conditions for 1983, Trites and Drinkwater (1985) noted that the 1982/83 iceberg count (1,352) was the third highest on record, but it was not known at that time that a different observational method (SLAR) was used. Consequently, the comparison of 1982/83 data with earlier observations in that paper is not now believed to represent a true measurement of relative iceberg conditions.

Meteorological Observations

Air temperatures

Monthly mean air temperature anomalies for Canada are published in the Monthly Supplement to *Climatic Perspectives* by the Atmospheric Environment Service of Canada. Similar data for the northeastern United States are published in *New England Climatological Data* by the National Oceanic Atmospheric Administration. The data base includes data for more than 100 stations.

Monthly air temperature anomalies in 1984 were negative in Baffin Island and along most of the Labrador coast during January to April, with temperatures more than 6° C below normal in January and as much as 12° C below normal in Baffin Island in February (Fig. 14). Anomalies were low and variable during the remainder of the year 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 the Gulf of St. Lawrence and southern Newfoundland, mean air temperatures were near normal or slightly above normal during most of 1984, the exceptions being negative anomalies of about 2° C throughout the region in January and 2° to 4° C in the Gulf of Maine and Gulf of St. Lawrence in March, with positive anomalies of 2° to 6° C in February. Except for the winter months (January-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 (Fig. 16) show that the year was colder than normal to the north (northeast Newfoundland to Baffin Island). Temperatures were as much as 1° C below normal but were within one standard deviation (Fig. 17). In the southern part of the area, anomalies were positive, low in magnitude (less than 1° C), and within one standard deviation of the long-term mean. The pattern of annual anomalies in 1984 was similar to that in 1983 (Trites and Drinkwater, 1985), but the anomalies were 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 seasons — winter (December-February), spring (March-May),

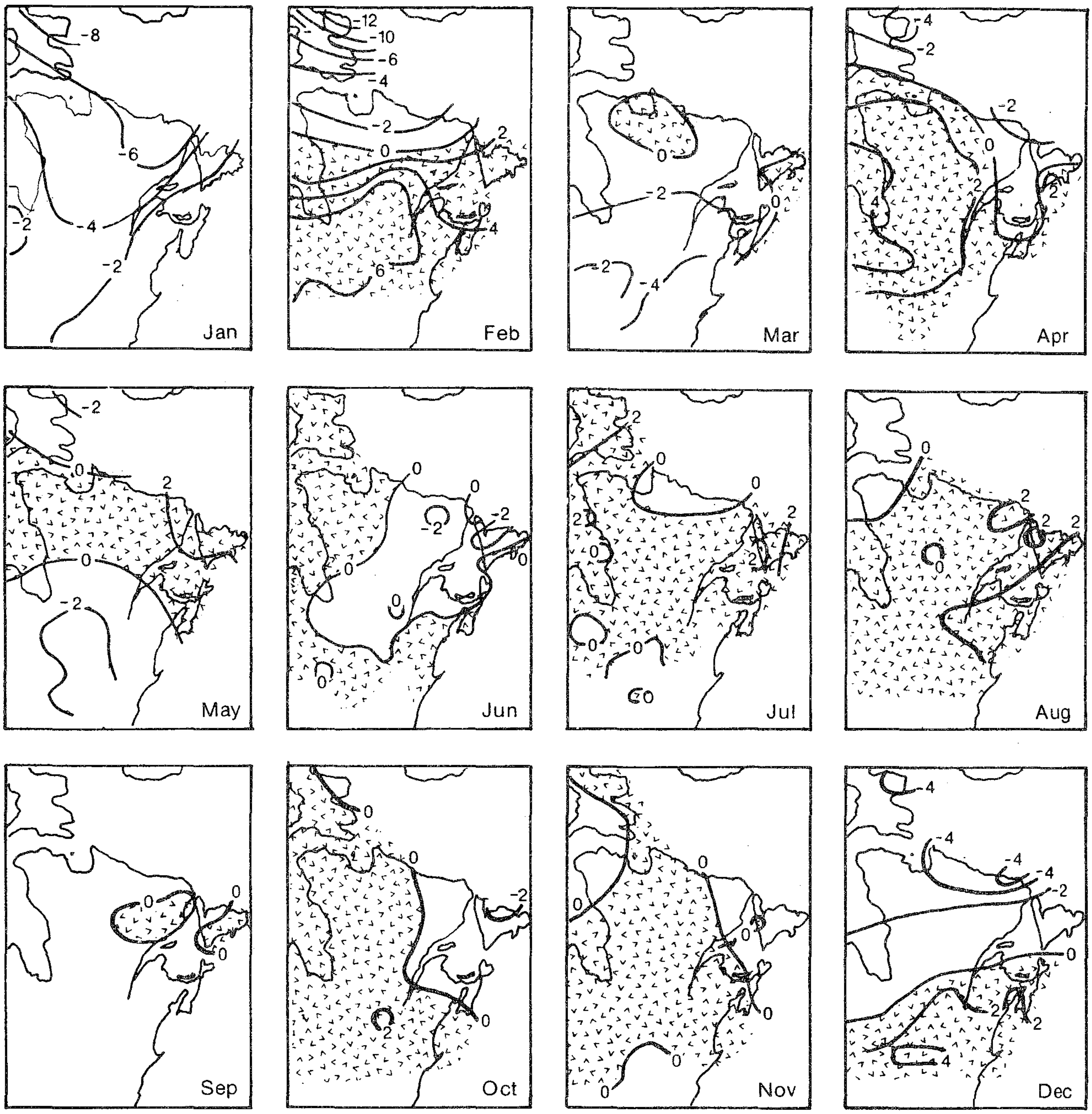

Fig. 14 Monthly air temperature anomalies (°C) over eastern Canada in 1984 relative to means for the 1951–80 base period.

summer (June–August), and autumn (September–November) — and anomalies from the seasonal means for the 1951–80 period were calculated. The means were provided by K. R. Thompson (Dalhousie University, Halifax, Nova Scotia, pers. comm.). Large-scale wind patterns can be estimated from the pressure data by assuming geostrophy. Wind direction is approximately parallel to the isobars, with low pressure to the left and high pressure to the right. High pressure systems represent clockwise (anticyclonic) and low pressure systems represent anticlockwise (cyclonic) motion. The wind speed is proportional to the cross-wind pressure gradient. Near-surface winds are slightly lower in magnitude and are rotated anticlockwise by 10-20° relative to pure geostrophic winds due to frictional effects. In the North Atlantic, the mean pressure patterns are dominated throughout the year by the Icelandic Low and the Bermuda-Azores High, with variation in the strengths of these systems from winter maxima to summer minima (Thompson and Hazen, 1983).

In 1984, the winter to summer seasons were dominated by high pressure anomalies over the central North Atlantic (Fig. 18). The center of the anomalous

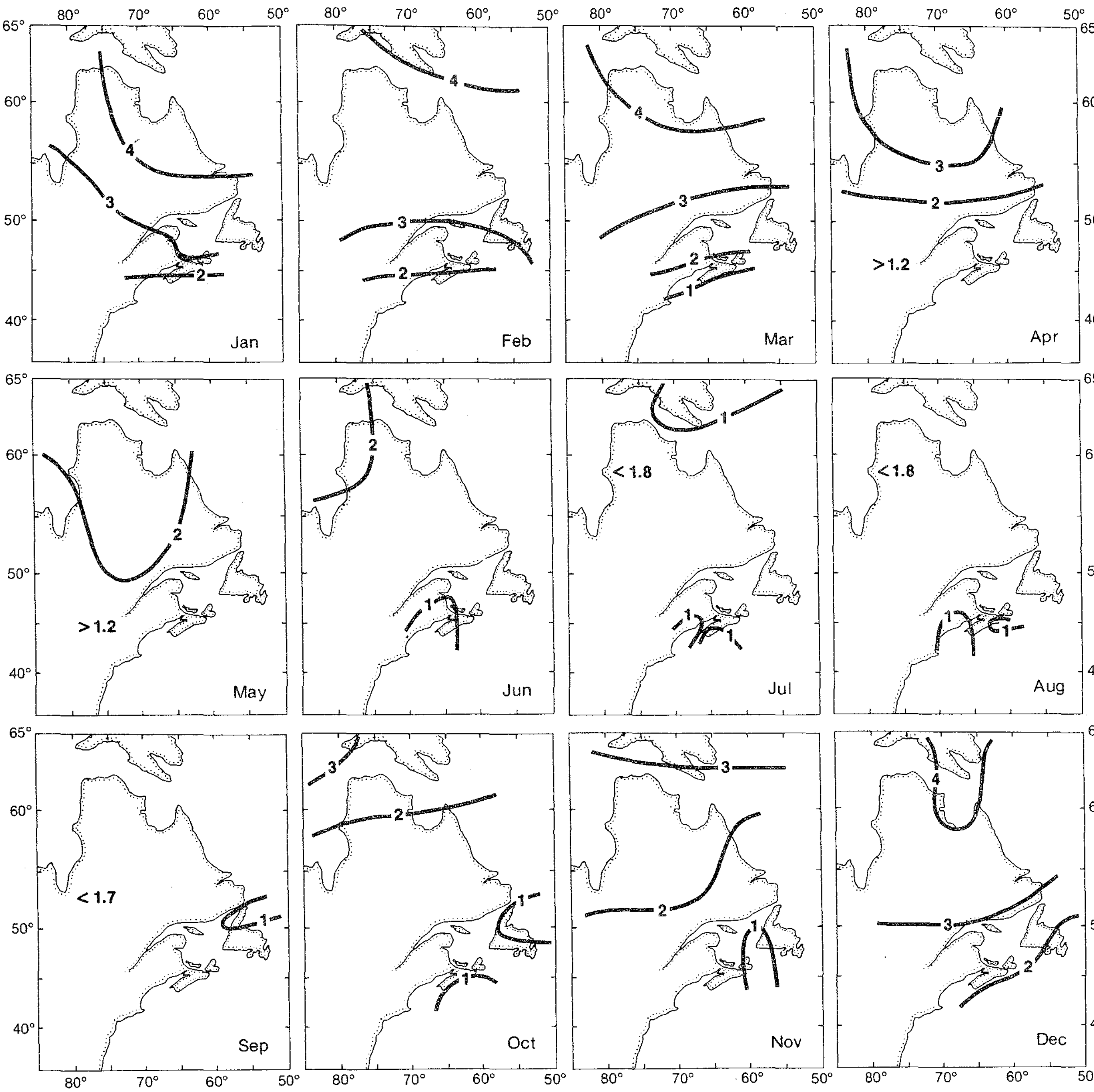

Fig. 15. Standard deviations of the monthly air temperature anomalies (°C) over eastern Canada for the 1951-80 period.

highs shifted eastward during this period and decreased about 2 mb in intensity from the winter maximum of 6.8 mb. In the autumn, the high was replaced by an anomalous low which was centered over Scotland. The pressure patterns over the North Atlantic in 1984 were similar to those in 1983 (Trites and Drinkwater, 1985), with a dominant high from winter to summer and a low in the autumn. Over the Northwest Atlantic, the seasonal geostrophic wind anomalies were from the south or southeast during the winter, spring and summer and from the north in the autumn. However, the gradients were weak, especially during the last half of the year when the pressure systems were centered over the eastern North Atlantic.

Discussion

In many respects, 1984 was an average year climatologically. The year was characterized by variability in conditions both spatially and from month to month, but generally there were few persistent anomalous features. This was especially true of sea-surface and air temperatures. However, several important trends are noteworthy. Since the mid-1970's, there has been the tendency for the SST anomalies to be positive in the region north of the Gulf of Maine and negative in the southern area (Trites and Drinkwater, 1985). The 1984 SST data indicate a sharp decline in the amplitude of the positive anomalies and may signify the commence-

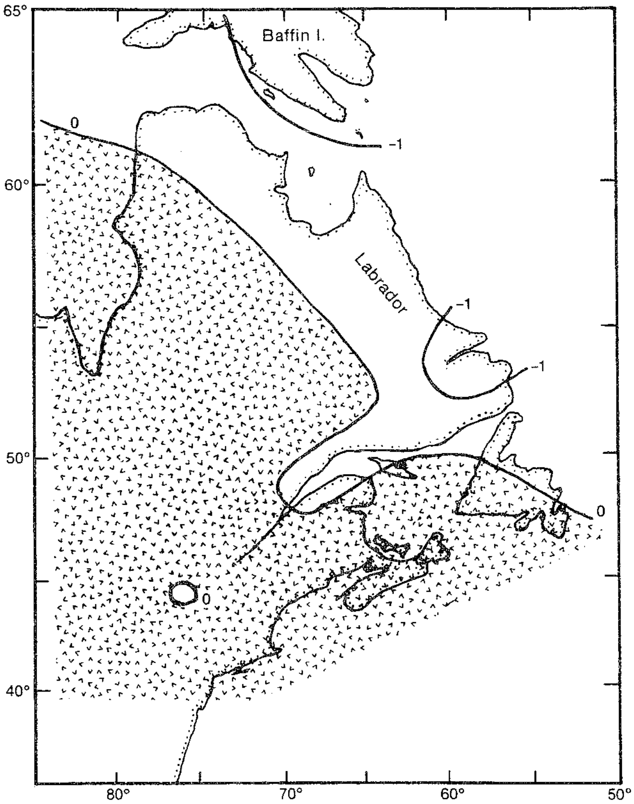

Fig. 16. Annual air temperature anomalies (° C) over eastern Canada in 1984 relative to the 1951-80 base period.

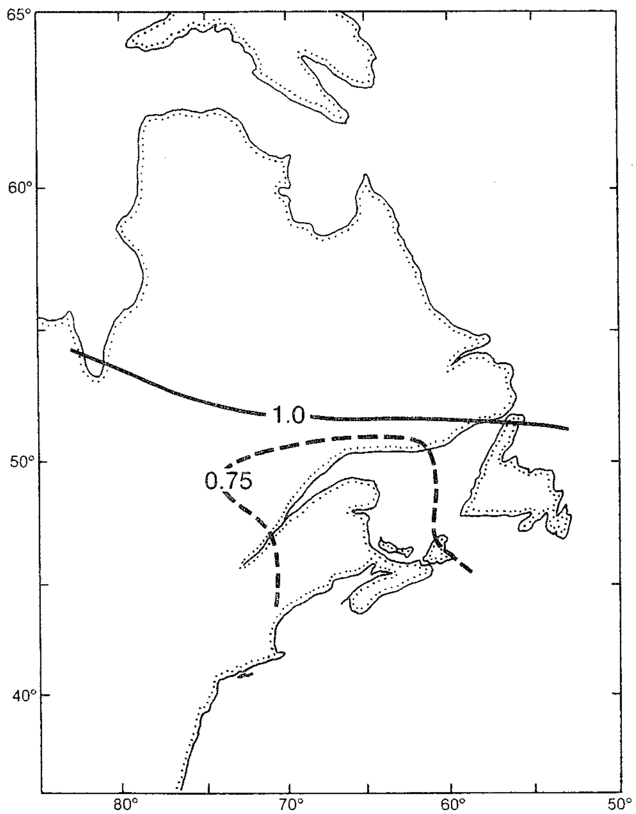

Fig. 17. Standard deviations of the annual air temperature anomalies (° C) for the 1951-80 base period.

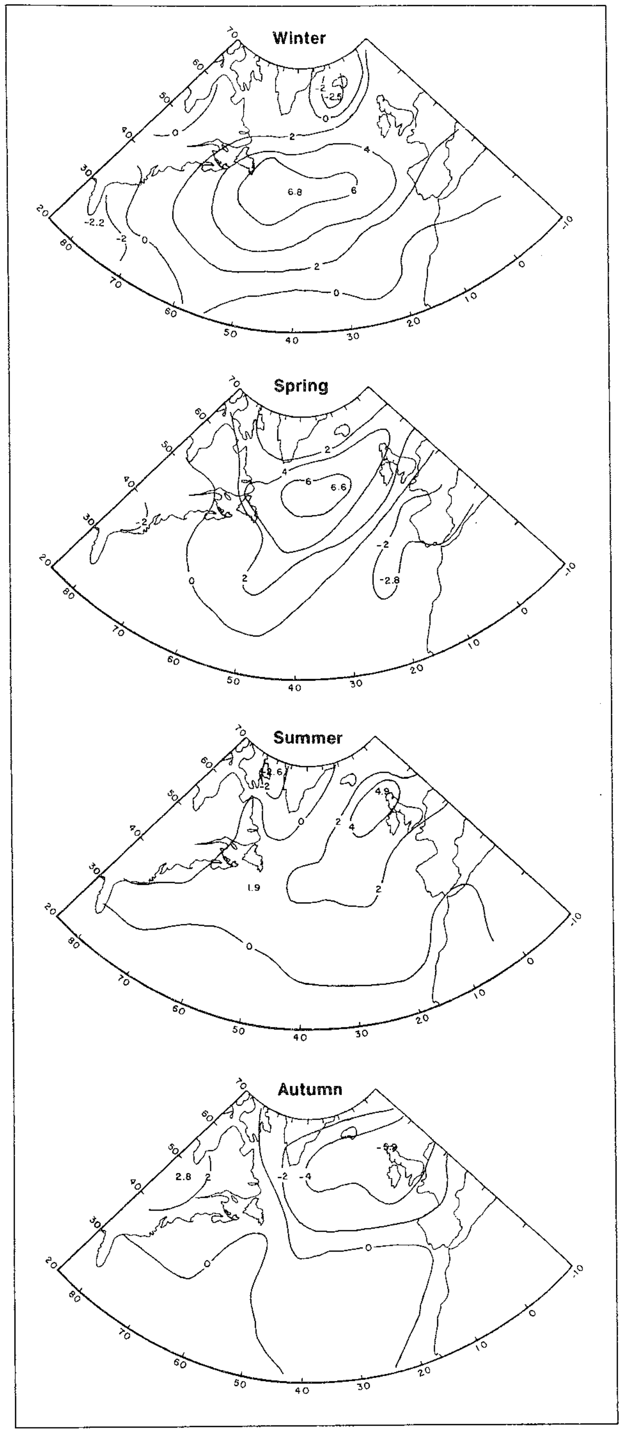

Fig. 18. Seasonal sea-pressure anomalies (mb) over the North Atlantic in 1984 relative to the 1951-80 base period.

ment of a shift to a new SST anomaly pattern in the region. The 1984 wave data indicate a continuation in the decline of wave height and frequency of large waves from maxima in the early 1980's to the more normal conditions of the early to mid-1970's.

One exception to the near-normal conditions in 1984 was evident at Station 27 off St. John's, Newfoundland, where temperatures at depths exceeding 50 m were lower than the mean for the third consecutive year. Surface salinities were also below normal throughout the year, continuing a trend which began in September 1982. The summer salinity of 30.5 is one of the lowest since the time series began in 1946.

Although the number of Gulf Stream rings west of 60° W and the total number of ring months in 1984 were the second lowest in 11 years of record, infrared imagery indicated that the rings may have had significant effects on water masses of the southern Scotian Shelf (63–66° W). No long-term statistics of shelf-water entrainment by rings are available, but visual analysis of satellite imagery over several years indicates that a larger-than-normal amount of surface water may have been drawn off the Scotian Shelf by such rings in 1984. During September, two eddies were roughly estimated to have entrained shelf water with a surface area which equalled 25% of the area of the Scotian Shelf. Further details of entrainment features off the Scotian Shelf are contained in the monthly State-of-the-Ocean-Report which appears as an appendix to the Weekly Briefing Sheet from the Bedford Institute of Oceanography, Dartmouth, Nova Scotia. The effects that the presence of such rings have on subsurface waters are not well known.

Finally, the number of icebergs which drifted south of 48° N off Newfoundland in 1984 was the highest on record (more than 100 years of observations). However, the large number is believed to be due, in part, to a change in technology, with radar replacing visual observations. The relative efficiencies of the two methods must be determined before the present iceberg counts can be compared with the long time-series of data based on visual methods.

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