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Overview of Environmental Conditions in the Northwest Atlantic During 1983

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Abstract

Data series, such as those for fixed hydrographic stations or sections, and daily to weekly repetitive coverage of sea-surface conditions by satellites and ships of opportunity are used to provide an overview of environmental conditions in the Northwest Atlantic during 1983. Comparisons are made to 1982 conditions and to longer-term reference periods. Environmental conditions in 1983 stand out in three respects: large positive sea-surface temperature anomalies from the Grand Bank to the Mid-Atlantic Bight, large air temperature anomalies which were positive south of Labrador and negative off Labrador and Baffin Island, and large number of icebergs which drifted south of 48° N to the Grand Bank. It is pointed out that at least some of the environnmental variability in the Northwest Atlantic may be induced by global-scale meteorological changes which gave rise, for example, to "El Nino" in the southern hemisphere.

Introduction

At the request of the Scientific Council of NAFO, an overview of environmental conditions in the Northwest Atlantic during 1982 was prepared as a "pilot" project (Trites and Drinkwater, 1984). It contained analyses of selected sets of oceanographic and meteorological data and information from research documents and national research reports. The Scientific Council noted the usefulness of such analyses and endorsed the proposal of its Standing Committee on Fishery Science that the relevant time series should be updated on a yearly basis (NAFO, 1983). Consequently, a similar approach was undertaken in reviewing environmental conditions during 1983. Comparisons are made with conditions in 1982 and with the long-term means. The latter are based on 30-year (1951-80), 20-year (1961-80) or 10-year (1971-80) base periods, depending on the extent of the available time series.

An effort was made to broaden the geographic coverage over that reported by Trites and Drinkwater (1984). Most noticeably, this has been achieved by extending information on (i) sea-surface temperatures eastward and northward to include Flemish Cap, Labrador Shelf, Labrador Sea and South Greenland, (ii) air temperatures to cover all of eastern Canada and northeastern United States, and (iii) sea-surface pressure maps to include the entire North Atlantic. This reflects our understanding of the linkages between large horizontal-scale and long time-scale processes.

Oceanographic Observations

Coastal sea-surface temperatures

Measurements of sea-surface temperature were taken daily during 1983 at Halifax, St. Andrews and Boothbay Harbor (Fig. 1). Monthly averages were determined and compared with the long-term means for the 1951-80 base period (Trites and Drinkwater, 1984). The monthly anomalies for 1982 and 1983 are shown in Fig. 2. The absence of data for Halifax from

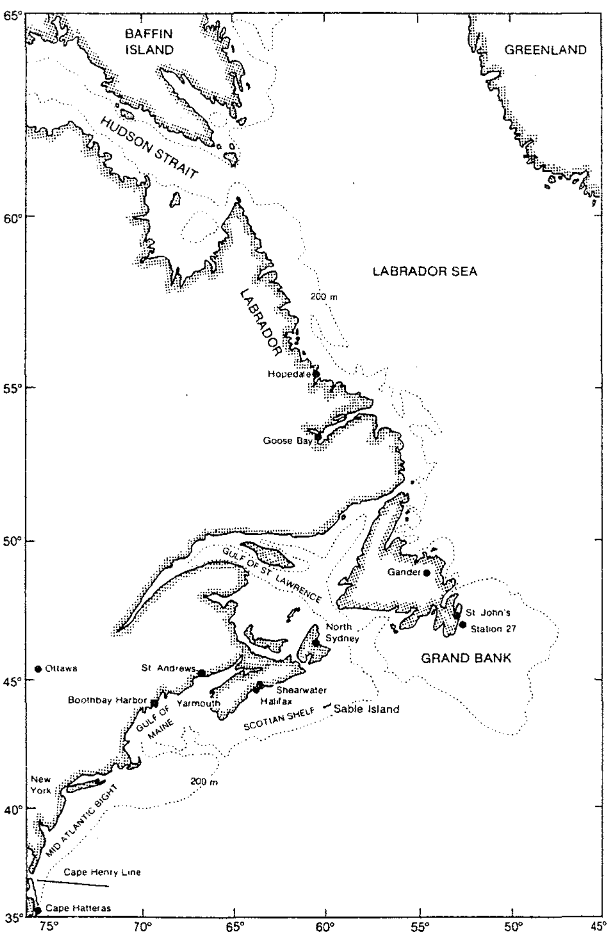

Fig. 1. Map of Northwest Atlantic showing oceanographic and meteorological stations and other place names mentioned in the text.

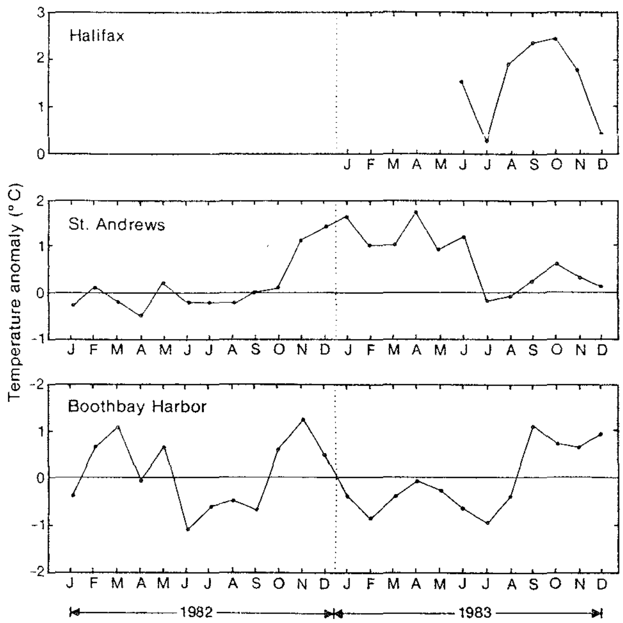

Fig. 2. Monthly sea-surface temperature anomalies at Halifax, St. Andrews and Boothbay Harbor for 1982 and 1983 relative to means for the 1951-80 base period. (Errors are suspected in Halifax data for 1982 and early 1983.)

January 1982 to April 1983 is due to suspected instrument errors.

The most significant event at St. Andrews was the period of positive anomalies that began in late 1982 and extended to June 1983 (Fig. 2). Their magnitudes (1° to 2° C) were higher than the monthly standard deviations which were all approximately 0.8° C. During the last 4 months of 1983, temperatures were closer to but still above normal. At Boothbay Harbor during 1983, the temperatures were below normal until August and about normal for the remaining 4 months of the year. Except in September, the monthly anomalies in 1983 were within a standard deviation (about 1° C) of their means. For the 7-month period (June-December) when data at Halifax were judged to be of good quality, surface temperatures were above normal by as much as 2.5° C, and the anomalies exceeded their standard deviations (about 1° C) in 5 of the 7 months.

The average surface temperature at St. Andrews in 1983 was 8.0° C, which was the highest since 1976 and the second highest since the early 1950's (Fig. 3). It compares with the 1982 average of 7.4° C and the long-term (1951-80) mean of 7.3° C. At Boothbay Harbor, the average surface temperature in 1983 equalled the long-term mean of 8.8° C and was slightly below the 1982 mean of 8.9° C.

Offshore sea-surface temperatures

The extensive data base of offshore sea-surface temperatures (SST) is derived principally from radio

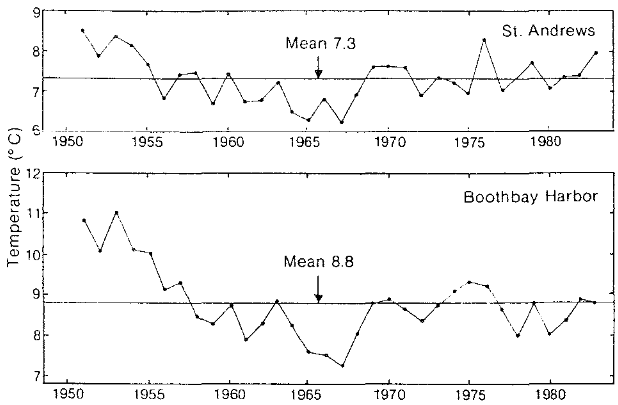

Fig. 3. Annual mean sea-surface temperatures at St. Andrews and Boothbay Harbor for 1951-83, and the mean for the 1951-80 base period.

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

Observations on sea-surface temperatures during 1983 within the region bounded by 35°-46° N and 60°-77° W were reported by McLain and Ingham (MS 1984) as follows:

"The most significant SST anomaly shown in the mapped area during 1983 appeared off southwestern Nova Scotia in May and persisted through October. The region of anomalously warm water extended to the eastern boundary of the mapped area and generally involved eight or more 1° squares showing temperatures greater than 1° C above the long-term mean, except during August when only four squares were involved. The largest anomaly in the period was +4.4° C in the 1° square off Halifax during July, but that was based on only six observations. Squares which involved more than 100 observations showed anomalies ranging from +1.0 to +3.0° C.

"A variable band of negative anomalies appeared in May and continued through September in the vicintiy of southern Georges Bank (40°-41° N, 65°-70° W) .... A pattern of positive anomalies seen in the Gulf of Maine (42°-44° N, 66°-70° W) during October-November 1982 continued during January and February 1983, weakened in March and disappeared in April. Pooled average SST temperature anomalies for the entire area north of 35° N and west of 60° W were weakly positive for all months except July, August and December, when they were weakly negative. All of the anomalies were much smaller than the monthly standard deviations."

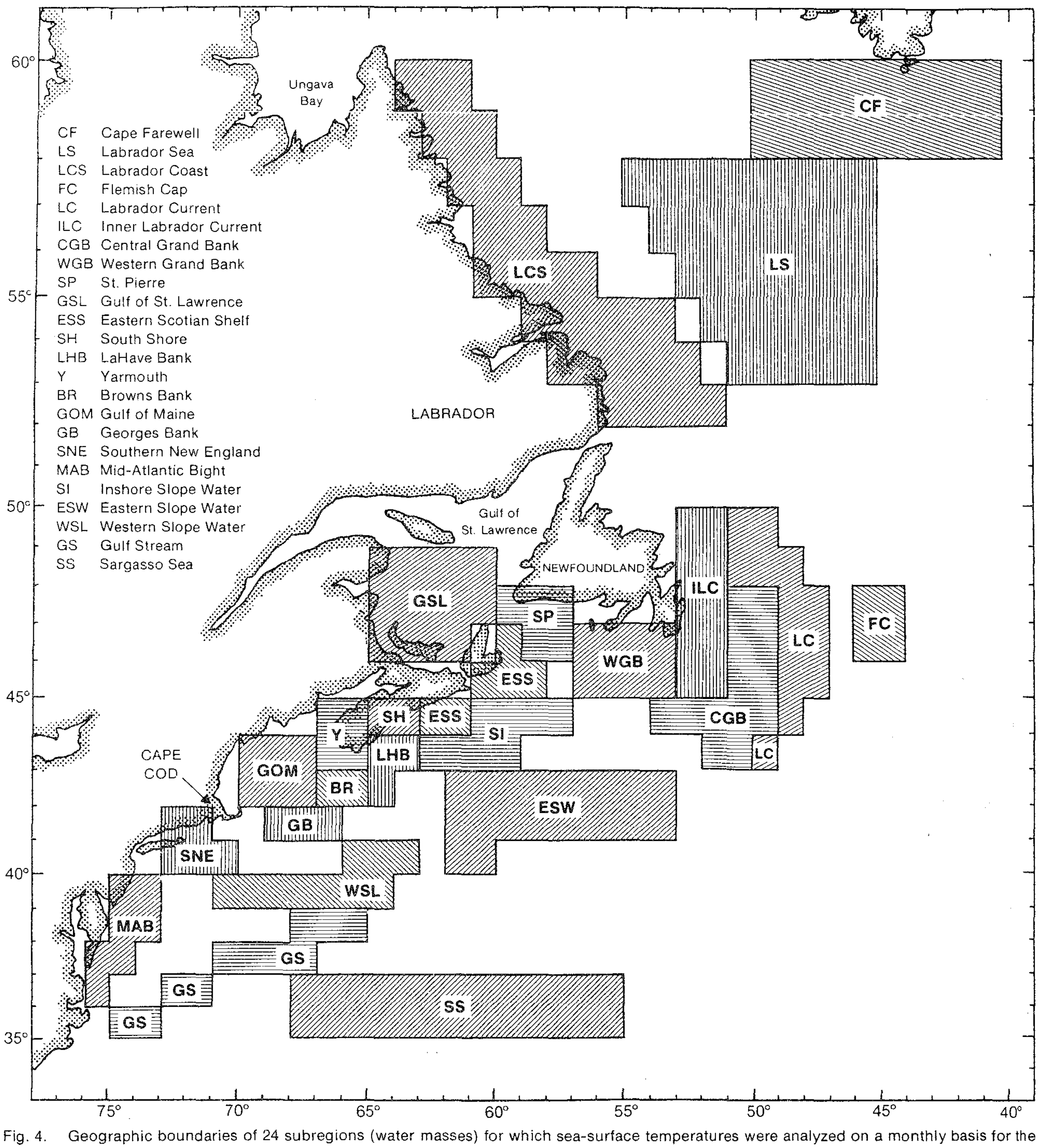

Fig. 4. Geographic boundaries of 24 subregions (water masses) for which sea-surface temperatures were analyzed on a monthly basis for the 1972–83 period.

An indication of the extent along the continental shelf of the anomalously warm water, that was reported by McLain and Ingham (MS 1984), was given by Trites *et al*. (1985). Compared with the average for 1971–80 period, temperatures were generally above normal, particularly in the region from the Scotian Shelf northward, with maximum positive anomalies generally in the May–July period. In the region from the Gulf of Maine southward, the anomalies (both positive and negative) tended to be confined to a single subarea or a single month, and their values were generally less than the standard deviation for the 1971–80 period. When 1983 is viewed against the previous 3 years, there is an indication that the "warmer in the north" trend has been progressing southward and encompassing almost the entire region from southern Labrador to the Mid-Atlantic Bight.

On the assumption that major variations in offshore temperatures should be coherent for periods longer than a month and over areas larger than 1° quadrangles, Trites and Drinkwater (1984) identified 14 areas within the region (35°-50° N, 45°-76° W) for the data-grouping. The areas were chosen (to within 1°) to coincide with the locations of major water masses (e.g. Labrador Current, Gulf Stream, Sargasso Sea) and with fishing banks (e.g. Georges Bank, western Scotian Shelf). Monthly temperatures were computed for each area from 1972 onwards and were further grouped to provide semiannual and annual mean anomalies relative to the 1972-82 base period. The temporal and spatial coherence displayed by that analysis (Trites and Drinkwater, 1984) encouraged the extension and refinement of the data groups to include a total of 24 areas within a larger region (35°-60° N, 40°-76° W) which extends from the southern boundary of the NAFO Area northward to southern Greenland (Fig. 4). Selected results from this analysis are given in Table 1 and displayed in Fig. 5. Mean annual temperature in 1983 were above normal in nearly all of the areas. Only in the Cape Farewell-Labrador Sea region and in the Western Slope Water were below-normal temperatures found. Not only had the areal extent of the above-normal temperatures increased from 1982 to 1983, but their magnitudes, particularly in the Grand Bank and Scotian Shelf areas, also increased.

From a study of sea-surface temperatures and their possible relationship to large-scale meteorological variations, freshwater discharge from rivers, and offshore forcing by the Gulf Stream system (Loucks and Trites, MS 1984), some useful new insights were provided about some of the important driving mechanisms.

Temperature and salinity stations

Vertical profiles of temperature and salinity at Station 27, approximately 10 km off St. John's, Newfoundland, were taken at a frequency of about 1.5 per month in 1983, continuing the time series which began in 1946. These data are considered to be representative of the inshore part of the Labrador Current. Mid-monthly averages of temperature and salinity at standard depths (0, 10, 20, 30, 50, 75, 100, 125 and 150 m) were determined for 1983, and monthly anomalies were then computed from the mid-monthly mean temperature and salinity values that were reported for the 1946-77 period by Keeley (1981). The monthly anomalies for 1981 and 1982 were illustrated by Trites and Drinkwater (1984).

Several features are noteworthy from the temperature and salinity anomalies at Station 27 in 1983 (Fig. 6). From April to December, the temperature of the surface water was higher (up to 2.0° C) and the salinity lower (by as much as 0.8) than normal. In the deeper water (generally >50 m), the temperature was about 0.4° C lower than normal throughout most of the year, but the salinity was only about 0.1 lower and not considered significant. The negative anomalies of 2° to 3° C at 30 m in June and July and the higher-than-normal temperatures at 20 m reflect a much more prominent thermocline than usual. With the deepening

TABLE 1. Annual sea-surface temperature anomalies for selected areas of the Northwest Atlantic in 1972-83 relative to the 1972-80 base period. (Geographic locations of water masses are shown in Fig. 4. Blank spaces indicate that annual averages not computed when data missing for one or more months.)

Water mass	Base period temperature anomalies (° C)									Mean temp. 1972-80	Anomalies (° C)		
	1972	1973	1974	1975	1976	1977	1978	1979	1980		1981	1982	1983
CF	-0.14							0.14		3.62		0.10	-0.12
LS	-0.75	0.11	-0.24	0.44	0.16	-0.13			0.40	5.54		-0.43	-0.11
LBT	-0.41	0.02		0.30		-0.23	0.16	0.11	0.04	2.19	-0.10		
LC	-0.28	-0.07	-0.38	-0.12	-0.16	0.12	0.19	0.68	0.01	5.17	0.82	0.24	0.32
ILC	-0.06	-0.25	-0.57	-0.30	0.22	-0.11	0.27	0.61	0.20	4.83	0.96	0.40	0.99
FC	-0.19	0.02	-0.27	0.03	-0.18	-0.05	0.07	0.70	-0.12	7.88	0.83	-0.39	0.46
CGB	-0.28	-0.37	-0.20	-0.46	0.51	0.46	0.09	0.50	-0.26	6.48	1.10	0.34	1.37
WGB	0.05	-0.11	-0.33	-0.63	0.34	0.16	0.31	0.30	-0.08	6.13	1.19	0.19	1.11
SP	0.03	-0.24	-0.52	-0.35	-0.04	0.44	0.30	0.22	0.18	5.91	1.14	0.35	0.87
GSL	-0.64	-0.14	-0.53	-0.15	0.11	0.17	0.30	0.73	0.15	5.82	0.56	0.46	0.91
ESS	-0.20	-0.28	-0.29	-0.44	0.20	-0.05	0.39	0.53	0.14	7.10	0.46	0.45	1.28
SI	0.11	-0.38	-0.40	-0.62	0.52	0.33	0.17	0.39	-0.11	8.27	0.85	-0.20	0.96
SH		-0.24	-0.61	-0.34	0.16	-0.04	0.35	0.33	0.39	7.85			1.43
LHB	0.31	0.47	-0.25	-0.35	0.26	-0.28	0.13	0.51	0.14	8.87	0.30	-0.07	0.86
BR	0.05	-0.28		-0.39	0.86	-0.12	0.03	-0.05	-0.10	8.84	0.25	-0.28	1.07
Y	-0.19	-0.13	-0.03	-0.15	0.42	-0.43	-0.13	0.42	0.22	7.64	0.18	-0.20	0.05
GOM	-0.17	-0.20	-0.05	-0.25	0.35	0.10	-0.11	0.39	-0.05	9.59	0.11	0.07	0.45
GB	-0.27	-0.36	0.23	0.00	0.72	-0.01	-0.50	0.00	0.19	10.17	-0.39	-0.46	0.48
SNE	-0.26	-0.11	0.56	0.17	-0.01	-0.31	-0.31	0.28	-0.01	12.23	-0.50	-0.03	0.38
MAB	-0.22	0.15	0.62	0.57	-0.52	-0.08	-0.36	-0.20	0.04	14.87	-0.43	-0.06	0.61
ESW	0.12	-0.39	0.30	0.28	0.12	0.39	-0.22	-0.65	-0.39	15.54	-0.03	-0.37	0.51
WSL	-0.15	0.27	0.37	-0.17	0.15	0.02	-1.02	0.53	-0.01	18.50	-0.92	-0.48	-0.27
GS	0.15	0.10	0.26	0.20	-0.15	0.03	-0.15	-0.04	-0.40	22.94	-0.26	-0.16	0.08
SS	-0.08	-0.19	0.15	0.10	-0.01	0.02	-0.08	0.11	-0.12	22.26	-0.37	-0.07	0.04

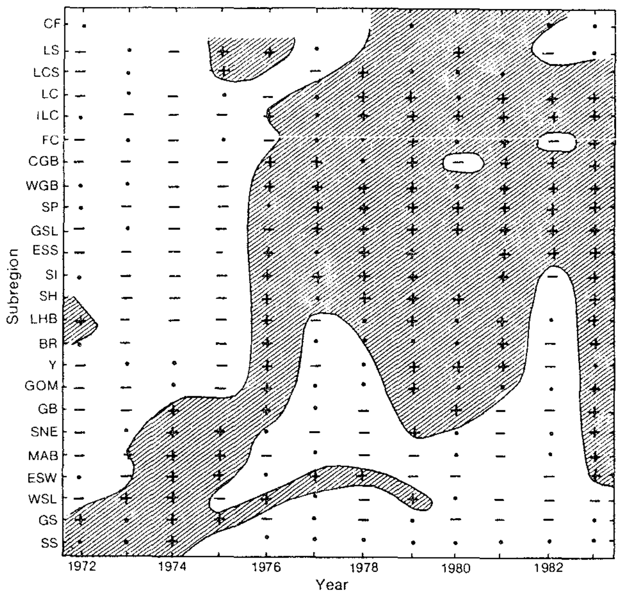

Fig. 5. Distribution of positive (+) and negative (-) annual sea-surface temperature anomalies in 1972-83 by subregions (Fig. 4) relative to the means for the 1972-80 base period. (Only anomalies <-0.15°C and >0.15°C were used in drawing the contours.)

of the mixed layer in autumn, the high temperature and low salinity anomalies penetrated to depths below 50 m. If the thickening of the near-surface layer was due solely to local mixing processes, such mixing of the surface and bottom waters would be expected to reduce the magnitude of the temperature and salinity anomalies in both layers. Instead, the increased anomalies (e.g. in November) lead to the conclusion that advective effects must be important. This is consistent with the strong southward flow in the region (Petrie and Anderson, 1983).

Position of shelf-slope front

Information on the position of the shelf-slope front off the Atlantic coast of the United States has been extracted from thermal infrared satellite imagery and reported annually since 1973 by the Atlantic Environmental Group of the U.S. National Marine Fisheries Service. Positions of the front in 1983 were reported by Armstrong (MS 1984a) as follows: "The mean positions of the shelf water front followed the general geographic trend of the 1973-77 means but were displaced seaward of the long-term positions ..... Variability in the shelf water front positions in 1983 was comparable to the long-term values on all bearing lines, as indicated by the standard deviation ..... For the waters north of the Cape Henry (see Fig. 1) bearing line, most of the departures of the front from the 1973-77 monthly mean positions corresponded to the passage of five long-lived warm core rings ..... South of the Cape Henry area, departures of the front from the long-term mean

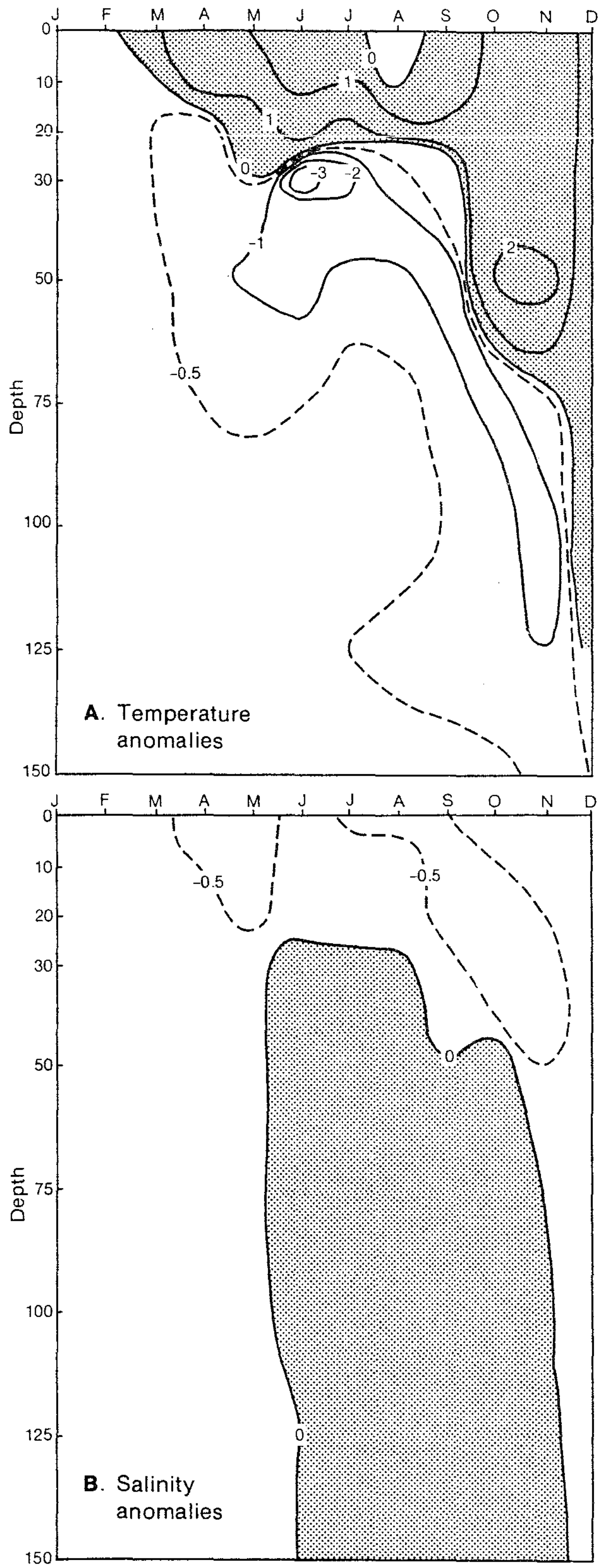

Fig. 6. Monthly temperature (**A**) and salinity (**B**) anomalies at Station 27 off St. John's, Newfoundland for 1983 relative to the 1946-77 base period used by Keeley (1981). (Shaded areas represent positive anomalies.)

positions seemed to be related to meanders in the Gulf Stream or the absence of slope water along the bearing line."

Warm-core rings

Monitoring the life-history of anticyclonic warm-core Gulf Stream rings or eddies has been carried out since 1974 for the area between 60° W and Cape Hatteras (Price and Celone, MS 1984). A total of 12 warm-core rings occurred in the slope-water region between Cape Hatteras and 60° W during 1983. Two rings which formed in 1982 survived throughout much of 1983. Ring 83A actually formed in December 1982, but it was first labelled after crossing west of 60° W in early January 1983. The actual number of rings (9) which formed in the area west of 60° W in 1983 was above the average (8) for 1976–81 but less than the number (11) formed in 1982. The average lifetime of rings whose destruction occurred in 1983 was 143 days, which is considerably higher than the 1982 average of 113 days and the 1976–81 mean of 120 days. In terms of total ring-months, there were 51 in 1982 and also in 1983, in contrast to the 1976–81 average of 38. The generation-zone pattern for 1983 was generally similar to the 6-year average, but the monthly generation pattern was appreciably different, with no rings being formed in May and June of 1983 in contrast to totals of 6 and 8 respectively for these months of the 1976–81 period.

Trites and Drinkwater (1984) examined Oceanographic Analysis Charts of the U.S. National Weather Service to obtain an estimate of the frequency of formation and the duration of warm-core rings in the 50°–60° W slope-water zone during 1982. A quick scan of the 1983 maps indicates that about 12 rings were formed in 1983 in contrast to about 20 in 1982. The average lifetime of rings whose destruction occurred in 1983 was about 70 days which is about twice the age of those observed in the previous year.

Shelf-slope temperatures in the Middle Atlantic Bight

Monitoring of shelf and slope water temperatures on a transect approximately 71° W has been undertaken since 1974 (Armstrong, MS 1984b). Further south, a transect from the entrance to New York Harbor across the continental shelf and slope has been monitored since 1976 (Cook, MS 1984). A total of 23 XBT (extendable bathythermograph) transects of the 71° W line and 21 XBT transects of the New York line were carried out in 1983.

The usual wintertime decline in shelf-water temperatures along the 71° W line and the deepening of the shelf-slope front was interrupted in late March 1983 by the intrusion along the bottom of warm water which apparently originated offshore. The intrusion coincided with the passage of warm-core ring 82-I (Price and Celone, MS 1984). Along the New York line, the unusual warming of the water at 140–240 m from early October to mid-November 1982 was coincident with the passage of ring 82-D.

From spring to autumn, the coolest water on the bottom across the shelf is found in the cold pool (<10° C), which is positioned between the shelf-slope front and the nearshore bottom water. Along the 71° W line, the cold-pool water was present until late October 1983, whereas it lasted only until the end of September in 1982. By contrast, the presence of 5° C water was less than normal in 1983, when it lasted only until mid-March and occupied only about two-thirds of its usual area (Cook, MS 1984). The shelf-slope front off New York advanced shoreward from a depth of about 110 m in April 1983 to near the 80 m isobath in September, and bottom temperatures at 100 m increased from about 7° to 11.5° C. The diminishing size of the cold-pool in this area was typical of average conditions during the 1976–82 period.

Bottom temperatures in deep slope water on the 71° W transect during 1983 were generally within the range of those observed during the 1974–82 period, except during February–early March when temperatures were about 2° C higher than normal. These elevated temperatures coincided with the passage of ring 82-I (Armstrong, MS 1984a).

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) provided summary statistics of significant wave heights at three grid points in the Northwest Atlantic for each year of the 1970–82 period. The mean monthly significant wave heights in 1982 and 1983, together with the averages for the 1970–80 period, are given in Table 2. The monthly significant wave height anomalies (relative to 1970–80 means) for the three areas are illustrated in Fig. 7. The most notable change in 1983, compared with 1982, occurred in the Labrador Sea during January–May when wave heights were well below normal. Wave conditions during the remainder of 1983 were less severe than in 1982 and were only marginally above normal. For the Grand Bank area, winter wave conditions were also less severe in 1983 than in 1982, but above-average wave heights generally prevailed throughout the year. Wave conditions on the Scotian Shelf in 1983 were generally similar to those in 1982.

TABLE 2. Monthly mean significant wave heights (m) at three locations in the Northwest Atlantic derived from 12-hr wave charts for 1982 and 1983, and mean heights for 1970-80.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Labrador Sea (57.5° N, 52.5° W)												
1970-80	3.50	3.36	3.20	2.56	2.02	1.84	1.75	2.01	2.61	3.14	3.33	3.64
1982	4.29	3.66	3.45	2.80	2.23	1.85	2.13	2.53	2.88	4.08	3.87	4.53
1983	3.10	2.55	2.33	2.03	1.55	2.02	2.10	2.19	2.53	3.35	3.52	3.82
Grand Bank (47.5° N, 47.5° W)												
1970-80	3.76	3.48	2.88	2.78	2.22	2.07	1.94	2.22	2.75	3.19	3.41	3.96
1982	5.44	5.45	3.89	3.47	3.00	2.20	2.10	2.16	2.63	3.97	3.34	4.42
1983	4.29	4.34	3.76	2.72	2.27	2.35	2.68	2.68	2.67	3.44	3.55	4.56
Scotian Shelf (42.5° N, 62.5° W)												
1970-80	2.91	2.77	2.80	2.35	1.82	1.70	1.57	1.62	1.76	2.16	2.69	3.00
1982	4.02	3.63	2.73	3.28	2.26	2.38	1.61	1.74	1.82	2.45	2.47	2.98
1983	3.15	3.93	3.06	2.53	1.97	1.52	1.71	1.56	1.64	2.21	3.17	3.26

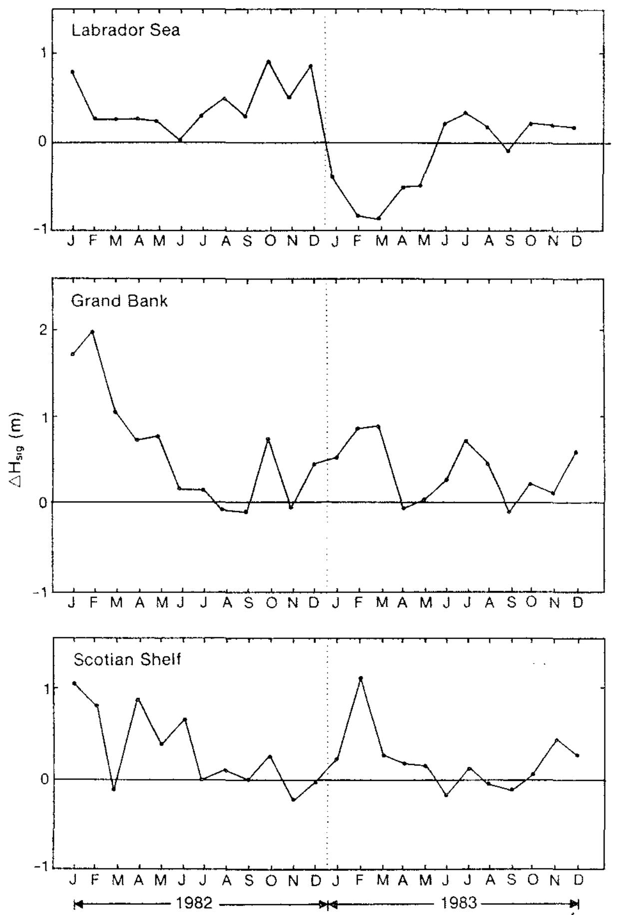

Fig. 7. Monthly significant wave-height anomalies (ΔH_{sig}) in three regions of the Northwest Atlantic for 1982-83 relative to the means for the 1970-80 base period.

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. 8. All three areas showed a marked reduction in the frequency of occurrence of large waves. The decline in severe storms was most significant in the Labrador Sea, with conditions comparable to those of the early 1970's. It is not known whether the moderating wave conditions in 1983 were simply within the limits of normal year-to-year variability or represent a return to more moderate conditions than had existed in the late 1970's and early 1980's.

Coastal sea-level elevations

Monthly mean sea-level elevations during 1983 were obtained from the Canadian Hydrographic Service for St. John's, Newfoundland, and Halifax, Nova Scotia. Atmospheric pressure effects were removed by assuming an inverted barometer response, using monthly mean sea-level pressures at Gander, Newfoundland, and Shearwater, Nova Scotia, for adjustment of the St. John's and Halifax sea-level elevations respectively. Anomalies of these mean adjusted sea levels were calculated relative to the long-term averages for the 1961-80 base period (Table 3). These averages have been altered from those given by Trites and Drinkwater (1984) in order to conform to the recommended base period.

The mean adjusted sea levels were higher than normal at both sites throughout 1983 (Fig. 9). Part of the Halifax anomaly is due to a trend of increasing sea level, but such is not the case for St. John's (Trites and Drinkwater, 1984). There is a seasonal pattern in the anomalies at both stations, with a minimum in summer and a maximum in autumn. The maxima may reflect a steric effect because they occur at the expected times of arrival of low density water from Hudson Bay, in the case of St. John's (Petrie and Anderson, 1983), and

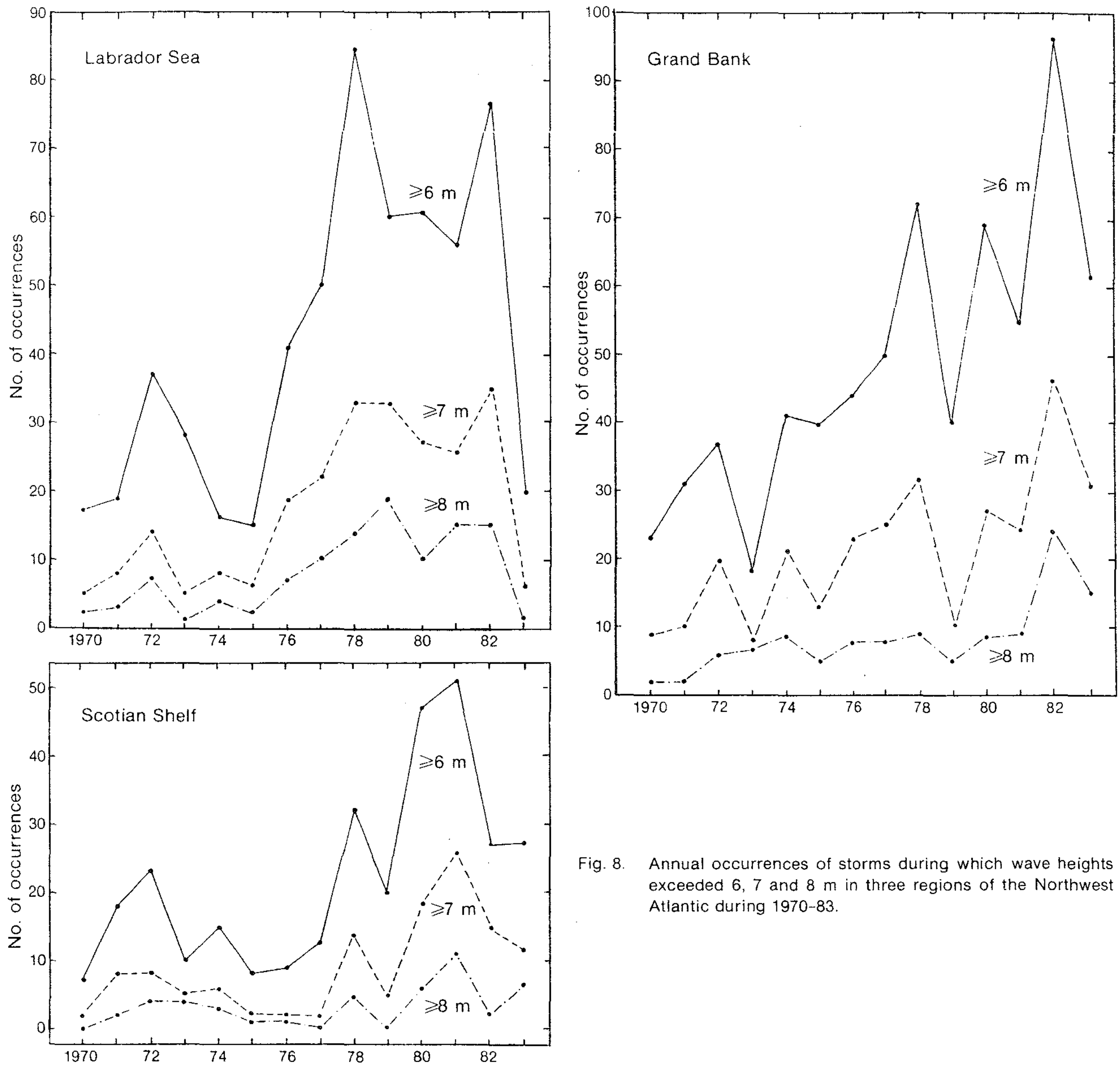

Fig. 8. Annual occurrences of storms during which wave heights exceeded 6, 7 and 8 m in three regions of the Northwest Atlantic during 1970–83.

TABLE 3. Monthly means, standard deviations and numbers of observations of adjusted sea levels (m) at St. John's, Newfoundland and Halifax, Nova Scotia, during 1961–80.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. John's	Mean	0.82	0.79	0.75	0.71	0.69	0.70	0.71	0.74	0.81	0.84	0.83	0.83
	S.D.	0.06	0.06	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.04	0.07
	No.	20	20	20	20	20	20	19	19	20	20	20	20
Halifax	Mean	1.30	1.27	1.25	1.24	1.24	1.24	1.23	1.23	1.28	1.30	1.33	1.32
	S.D.	0.04	0.05	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.05	0.04	0.05
	No.	20	20	20	20	20	20	20	19	20	19	20	19

from the Gulf of St. Lawrence, in the case of Halifax (Sutcliffe *et al.*, 1976).

Sea ice

The Canadian Atmospheric Environment Service (AES) provides a sea-ice reconnaissance and forecasting service for Canadian Atlantic and Arctic waters. The program, which was initiated in 1940 on a limited basis, was expanded subsequently to support shipping in all Canadian waters during the period of ice encumbrance (Markham, 1980; Sowden and Geddes, 1980). In an attempt to further characterize and quantify ice coverage, the Ice Climatology Division of AES has selected 24 experimental grid sites for the Gulf of St. Lawrence and the area east of Newfoundland and off

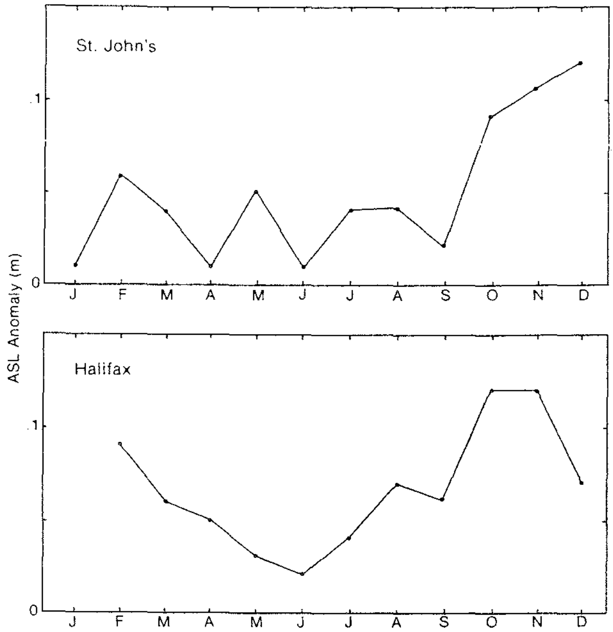

Fig. 9. Monthly anomalies of adjusted sea levels at two locations in the Northwest Atlantic during 1983 relative to the means for the 1961-80 base period.

southern Labrador (Fig. 10). For each site, the data extracted were ice duration in weeks for 1983, average duration for all years of record, and maximum, minimum and average duration for years when ice was present (Table 4). The timing of first and last sea ice,

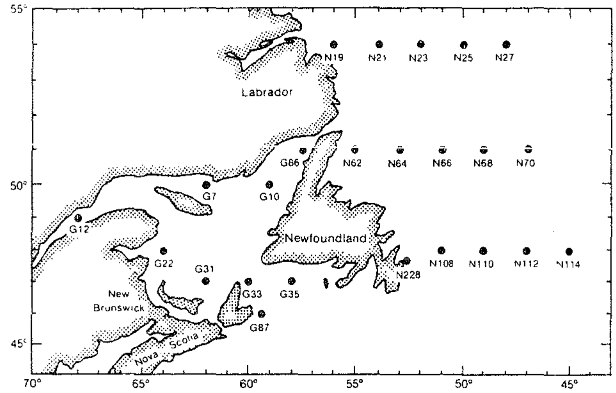

Fig. 10. Locations of 24 sites (grid points) where ice statistics have been extracted from ice charts by the Climatology Division of the Canadian Atmospheric Environment Service.

the median dates and the 1983 dates are shown in Fig. 11.

Ice duration in 1983 was well above average in the western Gulf of St. Lawrence off Newfoundland (e.g. sites G12, G22, G31, N21, N62, N64, N66, N228) (Table 4). Also, the time of first and last sea ice at a given site was highly variable (Fig. 11). For example, at site N64, time of onset varied by up to 3.5 months, whereas at N23 the dates of last presence of ice varied by as much as 5 months. For 1983, ice appeared earlier and was present later than the median for the western Gulf of St. Lawrence and the inshore areas off southeastern New-

TABLE 4. Historical data on presence and duration of sea ice at 24 sites off eastern Canada, and ice duration at these sites in 1983.

Site (Fig. 1)	Period studied	No. of years	Years with ice	Ice duration (weeks): When ice present Min.	Max.	Mean	Overall mean	1983
G-7	1968-83	16	16	6	14	9.6	9.6	9
G-10	1977-83	7	7	3	13	8.4	8.4	3
G-12	1968-83	16	16	2	15	10.9	10.9	15
G-22	1977-83	7	7	7	14	10.6	10.6	13
G-31	1969-83	15	14	8	17	12.1	11.3	11
G-33	1971-83	13	12	2	14	10.1	9.3	2
G-35	1962-83	22	11	1	11	3.7	1.9	0
G-86	1976-83	8	7	6	16	12.6	11.0	10
G-87	1971-83	13	12	1	12	7.0	6.5	0
N-19	1967-83	17	17	17	28	24.4	24.4	22
N-21	1968-83	16	16	5	27	17.3	17.3	25
N-23	1960-83	24	18	1	11	4.6	3.5	7
N-25	1960-83	24	1	1	1	1.0	0.0	0
N-27	1960-83	24	0	0	0	—	—	0
N-62	1968-83	16	16	8	24	17.1	17.1	21
N-64	1960-83	24	23	3	24	10.9	10.5	18
N-66	1960-83	24	18	1	15	6.7	5.0	8
N-68	1960-83	24	8	1	7	2.9	1.0	1
N-70	1961-83	23	0	0	0	—	—	0
N-108	1960-83	24	18	1	17	5.6	4.2	4
N-110	1960-83	24	17	1	11	4.2	3.0	4
N-112	1960-83	24	5	1	10	5.0	1.0	0
N-114	1960-83	24	2	1	2	1.5	0.1	0
N-228	1960-83	24	14	1	14	5.1	3.0	9

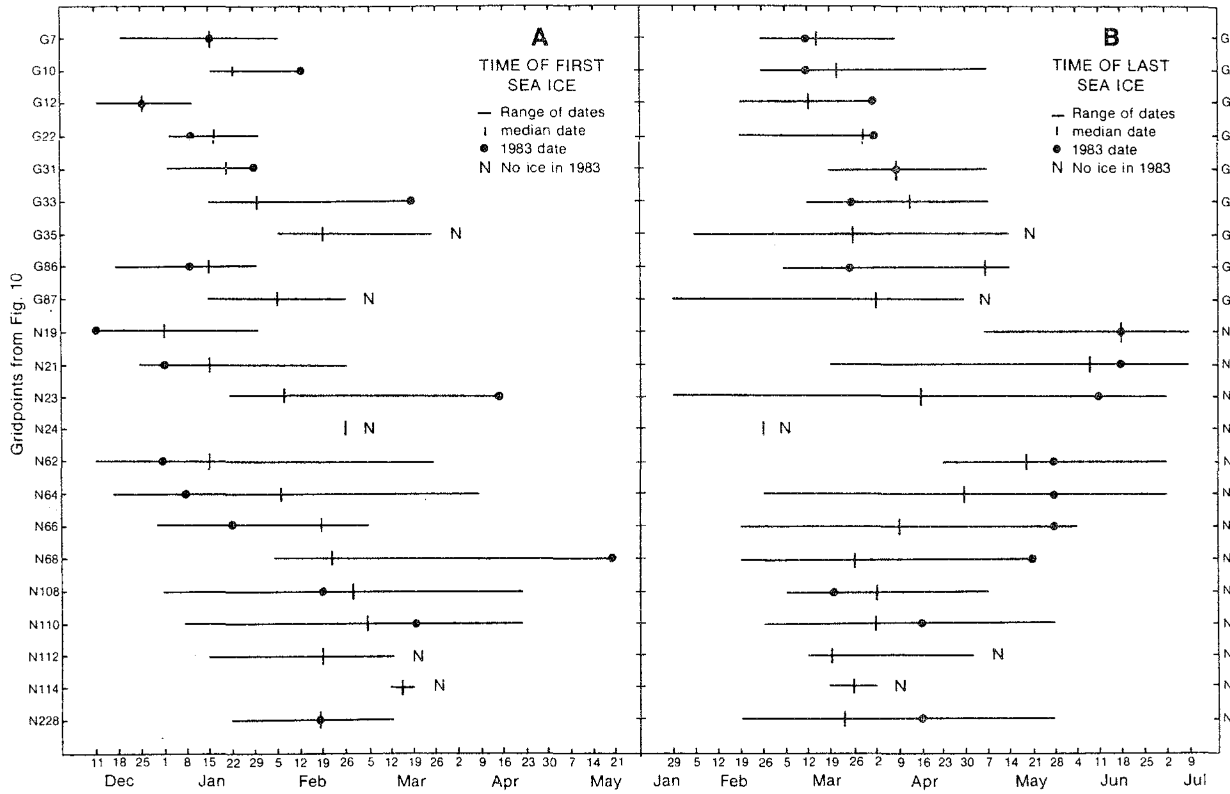

Fig. 11. Ranges of dates for the presence of first sea-ice (**A**) and last sea-ice (**B**) at 24 locations in the Northwest Atlantic (see Fig. 10), with median dates and 1983 dates. (Ice has not been observed at sites N27 and N70.)

foundland and southern Labrador. By contrast, the inverse occurred in the eastern half of the Gulf of St. Lawrence, with ice appearing later and disappearing earlier than usual. Gillingham (1983) has given a narrative description of ice conditions as follows:

"Temperatures in eastern Labrador during the late fall and the winter of 1982–83 averaged much below normal. As a result, ice formed along the Labrador coast earlier than usual and spread rapidly southward. Normally, the Labrador pack ice reaches the Strait of Belle Isle by the end of December and attains its southernmost limit, which is about 70 km north of St. John's, by the end of February. During the past winter, however, the pack pushed as far south as 250 km south of St. John's and some ice from the southern part of the pack moved eastward into Placentia Bay on Newfoundland's south coast.

"In the Gulf of St. Lawrence, ice conditions were much lighter than average. Ice coverage in the Gulf reached its maximum during the second week of March but even then the eastern two-thirds of the Cabot Strait and the eastern one-fifth of the Gulf remained open water."

Icebergs

The International Ice Patrol has monitored the presence of icebergs off eastern Canada for many decades, and their significance in the region has usually been reported as the number drifting south across 48°N latitude. More than 90% of the icebergs cross during the months of March to July. In those months during 1951–80, the average number was 408, with a maximum of 1,518 in 1972 and a minimum of zero in 1966. Iceberg statistics extend back to 1880.

In 1983, the number of icebergs that were reported south of 48°N during March–July was 1,174. This was the fourth highest number in more than 100 years, the previous records being in 1972 (1,518), 1974 (1,324) and 1929 (1,320). The number of icebergs in 1982 was only 188. During the 12-month period from October 1982 to September 1983, the total number of icebergs was 1,352, with monthly values of 2, 9, 165, 124, 339, 465, 168, 76 and 4 for December 1982 to August 1983. The icebergs arrived much earlier than normal in late 1982 and their number was higher than usual in the period prior to March 1983. The seasonal total for 1982/83 was the third highest on record, with more icebergs being recorded only in 1972 and 1974.

Meteorological Observations

Air temperatures

In the environmental overview for 1982 (Trites and Drinkwater, 1984), air temperatures in the Northwest

Atlantic region were examined by considering monthly and yearly anomalies (relative to 1951-80) at eight selected stations. Although these showed certain trends in the coastal areas, it was decided for the present overview to draw on the larger data base and provide better spatial resolution. Therefore, data for more than 100 stations were used to determine monthly mean air temperature anomalies for 1983 over eastern Canada and the New England states of USA, relative to the 1951-80 base period (Fig. 12). The Canadian data for January-April 1983 were obtained from the monthly publication *Canadian Weather Review* which was replaced in May by the *Monthly Supplement* to the weekly *Climatic Perspectives*, both published by Atmospheric Environment Service of Canada. The United States data were taken from *Climatological Data, New England*, Vol. 95, published by the National Oceanic and Atmospheric Administration.

During the first 3 months of 1983, air temperatures in the southern areas were above normal by up to 2° C (Fig. 12), whereas northern Quebec, Labrador and Baf-

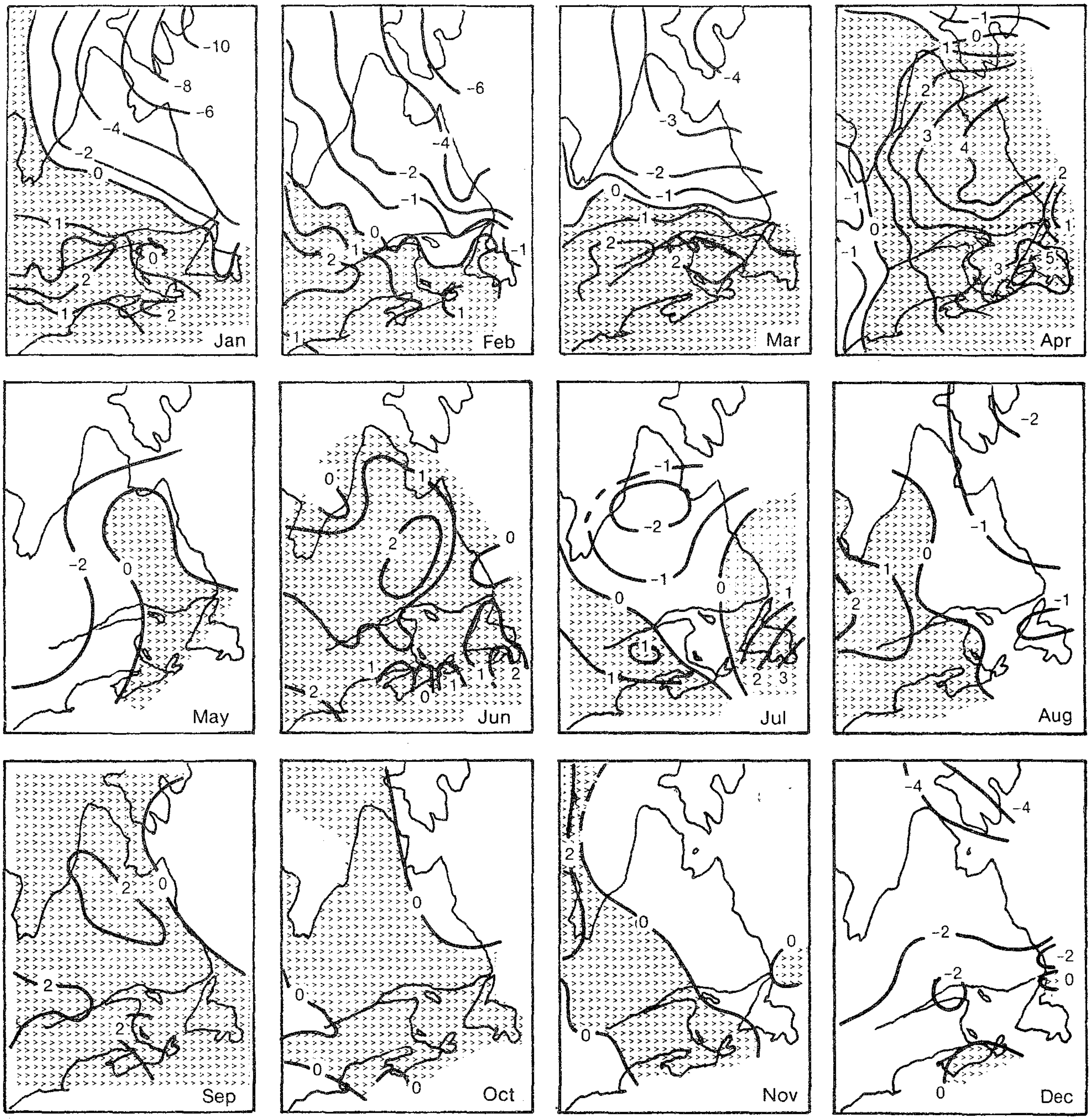

Fig. 12. Monthly air temperature anomalies (° C) over eastern Canada in 1983 relative to the 1951-80 base period.

fin Island were well below normal (<10° C in eastern Baffin Island in January), continuing trends which began in the late months of 1982 (Trites and Drinkwater, 1984). In April, the higher-than-normal temperatures extended northward with anomalies greater than 4° C along the Labrador coast. For the remainder of the year, temperatures typically remained above normal in the southern regions and below normal along the Labrador and Baffin Island coasts. To place the anomalies in perspective, the standard deviations of the monthly means in the winter months (January–March, December) vary from about 4° C on Baffin Island and northern Labrador to about 2° C in Newfoundland and Nova Scotia. In summer they were about 1° C in all regions. The higher-than-normal temperatures in the south and lower-than-normal temperatures in the north are also evident in the annual anomalies (Fig. 13). For the Baffin Island coast, the anomalies differ from the means by more than 2 standard deviations and, for the Atlantic coast, they differ by more than 1 standard deviation from normal, and thus are highly significant.

Sea-surface pressure

Large-scale winds are known to play an important role in circulation on the continental shelves and in the open ocean. Direct measurements of wind over the ocean are few, but information can be derived from air pressure measurements. In the case of geostrophic circulation, the wind moves parallel to the isobars, with higher pressures on the right in the down-wind direction, and the magnitude is proportional to the air pressure gradient in the cross-wind direction. Friction results in the near-surface winds being of slightly reduced amplitude (about 0.7) and being rotated anticlockwise by about 10–20° relative to the geostrophic winds.

Recently, Thompson and Hazen (1983) published climatological wind stress and Ekman upwelling maps of the North Atlantic for the 1950–75 period, using sea-surface pressure data. K. R. Thompson (pers. comm., 1984) calculated seasonal sea-surface pressure anomalies by season for 1983 relative to mean values for the standard 1951–80 base period. The seasons were designated as winter (December–February), spring (March–May), summer (June–August) and autumn (September–November). The mean conditions in all seasons for 1951–80 were very similar to those reported by Thompson and Hazen (1983) for the 1950–75 period, with a low pressure area (cyclonic winds) centered between Greenland and Iceland and a high pressure area (anticyclonic winds) centered near the Azores. The "low" was most intense in winter and the "high" was at its maximum in summer. The gradient between the centers of the two pressure systems, and hence the strength of the westerly winds, was maximum in winter.

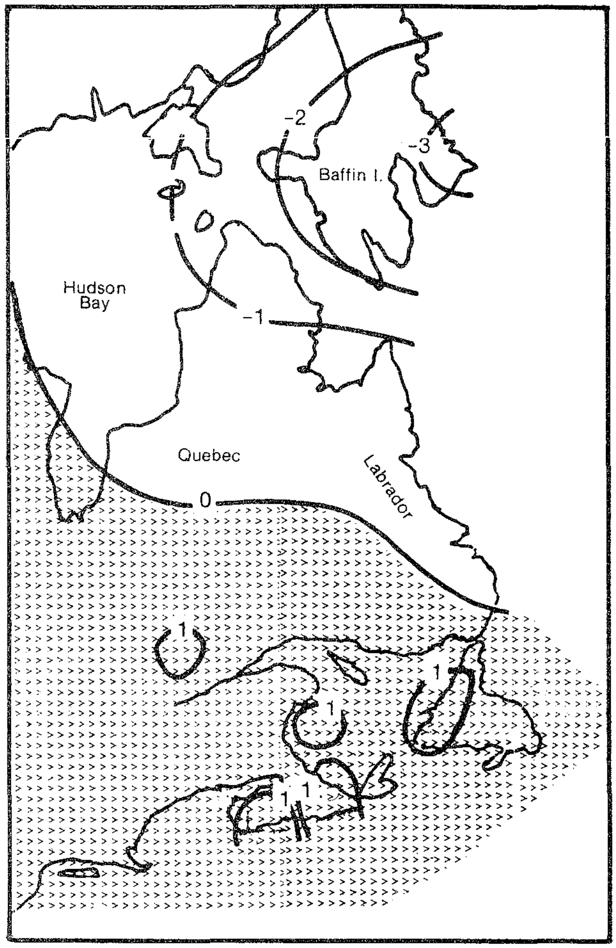

Fig. 13. Mean annual air temperature anomalies (° C) over eastern Canada in 1983 relative to the 1951–80 base period.

In 1983, the winter anomalies show a large high pressure system over most of the North Atlantic (Fig. 14). This indicated an easterly flow of anomalously warm winds over eastern North America as far north as Newfoundland, with winds from the northwest in the Labrador Sea and along the Labrador coast. In spring, the center of the "high" had shifted westward and slightly to the north, resulting in anomalous winds from the southeast between Newfoundland and Nova Scotia and from the south or southwest off Labrador. In summer, the high pressure system had moved eastward over Scotland and conditions were near normal in the Northwest Atlantic. In autumn, the high pressure system was located between Greenland and Iceland and the "low" near the Azores, and the anomalous winds over eastern North America were from the east.

Discussion

On a large scale, the annual average sea-surface temperatures in 1983 for areas from the Grand Bank to

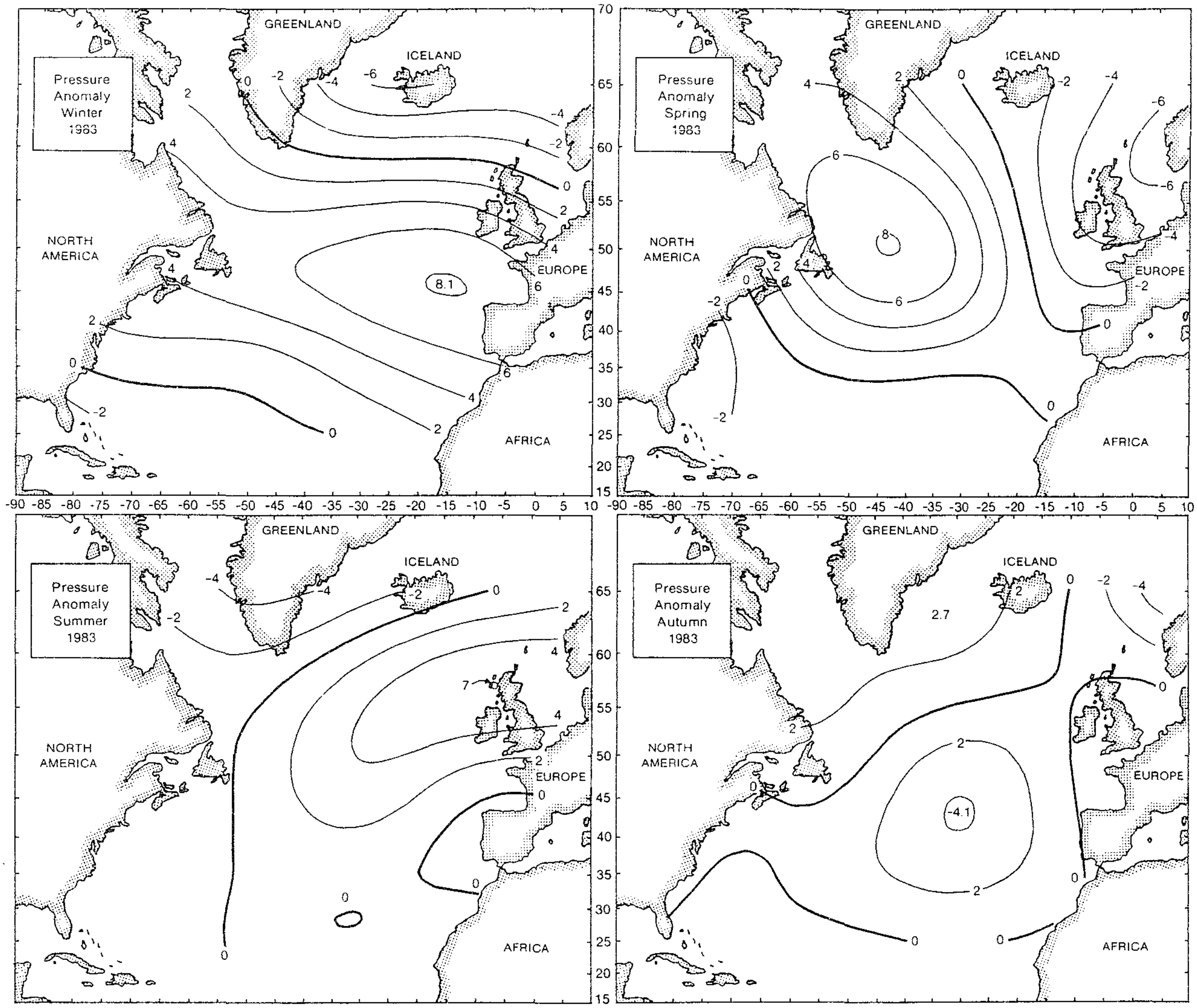

Fig. 14. Seasonal sea-surface pressure anomalies (in mb relative to the 1951–80 base period) over the North Atlantic in 1983 (from K. R. Thompson, Dalhousie University, Halifax, pers. comm.).

the Mid-Atlantic Bight were well above the base period (1972–80) means, with record high temperatures in some areas. On a localized and month-to-month basis, conditions were quite variable, with above-normal temperatures at one site during part of the year and below-normal values at a neighboring site at the same time (e.g. St. Andrews and Boothbay Harbor). Additionally, it must not be assumed that the sea-surface temperatures represent anything more than the mixed surface layer. Data from Station 27 off St. John's illustrate this point. The surface layer displayed above-normal temperatures throughout most of the year, whereas temperatures below the thermocline were below normal. In this particular instance, it appears that local surface water was influenced more by air-sea exchange and horizontal advection than by vertical mixing within the water column. Lower-than-normal salinity of the surface layer may have contributed indirectly to producing these conditons through increased stability and hence less vertical mixing.

Many of the sea-ice anomalies can be related, not surprisingly, to meteorological conditions. With lower-than-normal air temperature in the autumn of 1982 and winter of 1983 off Baffin Island and Labrador, ice formed earlier than usual. In the Gulf of St. Lawrence, where air temperatures were higher than normal, ice conditons for much of the area were lighter and the ice disappeared earlier than usual. The heavy pack ice along the Labrador coast and the lower air temperatures evidently acted to prevent the destruction of icebergs that were on the Labrador Shelf in winter. The stronger-than-normal northwesterly winds intensified the southeastward movement of the water, pack ice and icebergs along the Labrador coast, thereby accounting for the greater southward penetration of sea-ice off Newfoundland and also the early arrival and the large number of icebergs that drifted south of 48° N in the early months of 1983. The extensive distribution of ice off eastern Newfoundland should have resulted in below-normal surface temperatures. However, although below-normal temperatures occurred in October-December 1982 in the region from southern Labrador to the Grand Bank (Trites *et al.*, 1985), surface temperatures during winter and spring were well above normal. This apparent discrepancy may have been partly due to the relatively few temperature observations in the northern areas where there was generally no ice.

The large air temperature anomalies (positive in the south and negative in the north) can be related quantitatively to the large-scale wind patterns during 1983. During winter and spring, the anomalous easterly and southeastly winds over the southern part of the NAFO region carried warmer-than-normal air into the region, whereas the similarly anomalous northwesterly winds carried colder-than-normal area into the northern part of the region.

The environmental conditions in the Northwest Atlantic during 1983 stand out in three respects: large sea-surface temperature anomalies, large air temperature anomalies, and large number of icebergs. These are consistent with responses to the anomalous wind patterns that were discussed above. It is noteworthy that the strongest "El Nino" event in more than 100 years was recorded in 1983. The term "El Nino" refers to anomalous warm water in the eastern tropical Pacific, but it has recently been shown to be part of a larger oceanic-atmospheric interaction (Rasmussen and Wallace, 1983), which may have world-wide effects. It is likely that the anomalous sea-level pressure pattern over the North Atlantic is partially related to the atmospheric response of the "El Nino", but the nature of any relationship needs further research.

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