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Overview of Environmental Conditions in the Northwest Atlantic in 1983

by

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I INTRODUCTION

Last year as a "pilot" project we produced an overview of environmental conditions in the NAFO region during 1982 (Trites and Drinkwater, 1983). It contained information from available Research Documents and National Reports plus additional oceanographic and meteorological data sets. Both the Standing Committee on Fishery Science (STACFIS) and the Scientific Council of NAFO (Scientific Council Reports 1983) noted the usefulness of such an analysis and suggested the updating of the various time series on a yearly basis. Based on the positive feedback we received we have undertaken a similar approach in reviewing the 1983 environmental conditions. Comparisons are made to conditions during 1982 and to the long-term normal. The latter, as recommended by Trites and Drinkwater (1983) and adopted by the Scientific Council of NAFO (Scientific Council Reports 1983, p. 23), is defined as the mean over the 30-year period 1951-80 assuming sufficient data. Where the data are of shorter duration, a 20-year (1961-80) or 10-year (1971-80) base period is used.

We have made a conscious effort to broaden the geographical coverage over that contained in last year's report, most noticeably by extending (1) the sea surface temperature data eastward and northward to include Flemish Cap, Labrador Shelf, Labrador Sea and the Cape Farewell area, (2) the air temperature data to cover all of eastern Canada and the New England States and (3) sea surface air pressure maps to include the entire North Atlantic. This reflects our understanding of the linkages between the large horizontal-scale and the long time-scale processes.

II OCEANOGRAPHIC OBSERVATIONS

A. Temperature and Salinity

1. Coastal Sea Surface Temperatures

Twice daily measurements of sea surface temperature (SST) were taken at Halifax, N.S., St. Andrews, N.B., and Boothbay Harbor, Maine (see Fig. 1 for locations) during 1983. Monthly averages were determined and compared to their long-term means (1951-1980) listed in Trites and Drinkwater (1983). The monthly anomalies are shown in Fig. 2 together with those from 1982. The absence of data for Halifax during 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 through until June 1983. Their magnitudes were between 1^{o} and $2^{o}C$, and higher than the monthly standard deviations (s.d.) which were all approximately $0.8^{o}C$. During the last half of 1983 temperatures were nearer to, but still above, normal. At Boothbay Harbor temperatures during 1983 were $<1^{o}C$ below normal until September when they rose to $\sim 1^{o}C$ above normal and remained there until December. Except in September, the monthly temperature anomalies were within 1 s.d. ($\sim 1^{\circ}C$) from their means. From May to December, when data at Halifax was judged to be of good quality, temperatures were above normal by up to $2.5^{o}C$. With standard deviations of $\sim 1^{o}C$, the monthly anomalies exceeded 1 s.d. in five of the seven months.

The annual average temperature at St. Andrews in 1983 was $8.0^{o}C$ which was the highest since 1976 and the second highest since the early fifties (Fig. 3). It compares to the 1982 average of $7.4^{o}C$ and the 1951-80 mean of $7.3^{o}C$. At Boothbay Harbor the annual average equalled the long-term mean of $8.8^{o}C$ and was near the 1982 mean of $8.9^{o}C$ (Fig. 3).

2. Offshore Sea Surface Temperatures

The largest sea surface temperature (SST) data base, derived principally from cooling water intake temperatures of merchant vessels, is reported in radio weather messages and log books transmitted to the U.S. Fleet Numerical Oceanography Center (FNOC) and the National Climatic Center. The "real-time" data reports provided by the radio messages are analyzed by FNOC and the Pacific Environmental Group (PEG) of the National Marine Fisheries Service. Computation by PEG include average monthly temperatures and anomalies (from 1948-67 means) for each $1^{o} \times 1^{o}$ square for which enough data have been reported each month.

Sea surface temperatures for 1983 within the area 35-46°N, 60-77°W, have been reported by McLain and Ingham (1984) as follows: "The most significant SST anomaly shown in the mapped area during 1983 appeared off southeastern 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 8 or more 1° squares showing temperatures greater than 1°C above the long term mean, except during August when only 4 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 6 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 vicinity 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 - December 1982 continued during January and February 1983, weakened in March and April, and disappeared in April. Pooled average SST 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."

An indication of the extent along the continental shelf of the anomalously warm water reported by McLain and Ingham (1984) is given by Trites et al. (1984). Compared to the average for the 1971-80 period, temperatures were generally above normal, particularly in the area from the Scotian Shelf northward, with maximum positive anomalies generally occurring in the May-July period. For the area from the Gulf of Maine southward the anomalies (both positive and negative) tended to be confined to a single subarea or to a single month, and with values generally less than the standard deviation for the 10-year period. When 1983 is viewed against the previous three years, there is an indication that the "warmer in the north" trend has been progressing southward encompassing almost the entire area 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 much larger than a 1° square, Trites and Drinkwater (1983) identified 14 subareas within the region (35-50°N, 45-76°W) for data grouping. The subareas were chosen (to within 1°) to coincide with the areas of major water masses (e.g. Labrador Current, Gulf Stream, Sargasso Sea) or with fishing banks or areas (e.g. Georges Bank, Western

Scotian Shelf). Monthly temperatures were computed for the period from March, 1971, onwards and were further grouped to provide semi-annual and annual mean anomalies relative to the 1972-80 period. The temporal and spatial coherence displayed in this analyses encouraged us to both extend and refine the data groupings to include a total of 24 subareas within the region 35-60°N, 40-76°W (Fig. 4). Selected results from this analysis are given in Table 1 and Figure 5. It can be seen, that nearly all of the subareas displayed a mean annual temperature in 1983 that was above normal. Only in the Cape Farewell-Labrador Sea region, and in Western Slope Water area were below normal temperatures found. Not only has the areal extent of the above normal temperatures increased from 1982 but the magnitude, particularly in the Grand Banks-Scotian Shelf region, has also increased. A study of SST's using empirical orthogonal functions (Loucks and Trites, 1984) to identify major features in SST patterns and offering preliminary suggestions of the possible relationship of SST's to large scale meteorological variations, freshwater discharge from the rivers and offshore forcing by the Gulf Stream system, appears to provide useful new insights on some of the important driving mechanisms.

3. Temperature, Salinity Station

Vertical profiles of temperature and salinity were taken by scientists from the Northwest Atlantic Fisheries Center during 1983 at Station 27, approximately 1 km offshore from St. John's, Newfoundland. These data are considered to be representative of the inshore Labrador Current. The sampling frequency was approximately 1.5 per month and continues a time series begun in 1946. Monthly averages of the temperature and salinity for 1983 at standard depths of 0, 10, 20, 30, 50, 75, 100, 125 and 150 m were calculated using linear interpolation in the vertical where necessary. Monthly anomalies were then determined from the mid-month means published by Keeley (1981) using an averaging period 1946-1977. The anomalies are shown in Fig. 6.

Several features are noteworthy. From April to December the surface waters are warmer (up to 2.0°C) and less saline (lower by as much as 0.8) than normal. In the deeper waters (generally >50 m) the temperatures are colder than normal by ~ 0.4 to 0.5°C throughout most of the year and although of higher salinity it is only by ∿0.1 and not considered significant. The maximum negative anomalies are 2 to 3°C at 30 m during June and July and coupled with higher than normal temperatures at 20 m reflect a much stronger thermocline than usual. The fall deepening of the near surface high temperature and low salinity anomalies coincide with the actual deepening of the surface layer. If the surface layer deepening were 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 anomalies appear to have increased (e.g. November) leading one to conclude that advective effects must be important. This is consistent with the strong southward flow in the region (Petrie and Anderson 1983).

4. Position of Shelf-Slope Front

Information on the position of the Shelf-Slope front has been extracted from thermal infrared satellite imagery and reported annually since the early 1970's by the Atlantic Environmental Group of the U.S. National Marine Fisheries Service. Positions for 1983 are reported by Armstrong (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 mean 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 (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 positions seemed to be related to meanders in the Gulf Stream or the absence of slope water along the bearing line".

5. 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 (Price and Celone, 1984). A total of 12 warm-core rings occurred in the Slope Water region between Cape Hatteras and 60°W during 1983. Two rings, formed in 1982, survived throughout much of 1983. Ring 83A actually formed in December 1982 but was first labelled after crossing west of 60°W in early January 1983. The 9 rings which formed in the area west of 60°W in 1983 was above the 1976-81 average (8) but less than the number formed in 1982 (11). Average lifetime of rings whose destruction occurred in 1983 was 143 days considerably above the 1982 figure of 113 days and higher than the 6 year mean of 4 months. Expressed in terms of total ring-months there were 51 in 1983, the same as for 1982 but well above 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 appeared to be appreciably different with no rings at all being generated in the May-June period, compared to the 6-year total of 6 and 8 for May and June respectively.

Oceanographic Analysis maps prepared by the National Earth Satellite Service of the U.S. National Weather Service were perused by Trites and Drinkwater (1983) to get an estimate of the frequency of formation and duration of Warm Core rings in the 50-60°W zone in 1982. A quick scan of the 1983 maps indicates that about 12 were formed, compared to about 20 in 1982. Average lifetime of rings whose death occurred in 1983 was about 70 days which is about twice the age of those reported for the previous year.

6. Shelf-Slope Temperatures in the Middle Atlantic Bight

Monitoring of Shelf and Slope Water temperatures in the area near 71°W has been undertaken since 1974 (Armstrong, 1984b). Further south a transect extending from the entrance to New York Harbor across the continental shelf and slope has been monitored since 1976 (Cook, 1984). A total of 23 XBT (expendable bathythermographs) transects of the 71°W line and 21 XBT transects of the New York line were carried out in 1983.

In 1983 the wintertime decline in Shelf Water temperatures along the 71°W line and the deepening of the Shelf-Slope front was interrupted in late March by intrusions along the bottom of warmer waters of apparent offshore origin. The intrusion coincided with the passage of warm core ring 82-I (Price and Celone, 1984). Along the New York line an unusual warming event in the early-October to mid-November period between the 140 to 240 m depth range 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, and is positioned between the Shelf-Slope front and the nearshore bottom water. Along the 71°W line the cold pool water ($< 10°C$) was present until late October, compared to 1982 when it lasted only until the end of September. By contrast the presence of 5°C water was less than normal. In 1983, it persisted only until mid-March and occupied only about two-thirds of its usual area (Cook, 1984). The Shelf-Slope front off New York advanced shoreward from a depth of about 110 m in April to near the 80 m isobath in September, resulting in bottom temperature at 100 m increasing from about 7°C to

11.5°C. The diminishing size of the cold pool in this area was typical for average conditions found in the 1976-82 period.

Bottom temperatures in deeper slope water (>200 m) along the 71°W transect were within the typical range during 1983 as compared to those of the 1974-82 period, with the exception of the February-early March period when temperatures were about 2°C warmer than normal. The elevated temperatures coincided with the passage of ring 82-I (Armstrong, 1984a).

B. Waves

Waves 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) in Halifax, Nova Scotia (for methods of analyses see Neu, 1982). Trites and Drinkwater (1984) provided summary statistics for three grid points referred to as Scotian Shelf (42.5°N, 62.5°W) Grand Banks (47.5°N, 47.5°W), and Labrador Sea (57.5°N, 52.5°W), for each year in the period 1970-82. Table 2 gives the monthly significant wave height for 1983. For convenience the 1982, and the 1970-80 mean heights are included in the table. Plots of the monthly significant wave height anomalies (compared to 1970-80 mean) for the three areas are shown in Figure 7. The most notable changes in 1983 conditions compared with those in 1982 occurred in the Labrador Sea area in the January-May period when wave heights were well below normal. The remainder of the year also experienced wave conditions less severe than in 1982 and only marginally above normal. For the Grand Banks area, the winter months wave conditions were also less severe than in 1982, with the year as a whole experiencing above normal wave heights. Conditions on the Scotian Shelf in 1983 were generally similar to those in 1982.

Another measure of wave conditions, indicative of events for the year as a whole, is the frequency of storms. The number of occurrences of waves equal to or greater than 6, 7 and 8m in the three areas are shown in Figure 8. All three areas showed a marked reduction in the frequency of occurence of large waves. The decline in severe storms was most marked in the Labrador Sea area, with conditions comparable to the early 1970's. It is not known whether the moderating wave conditions in 1983 is simply within the limits of normal year to year variability or whether the general trend towards more severe wave conditions that has occurred over the past decade is levelling off or starting to decline.

C. 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, N.S. (see Fig. 1 for locations). Atmospheric pressure effects were removed assuming an inverted barometer response, using monthly mean sea level pressures for Gander and Shearwater for the St. John's and Halifax data respectively. Anomalies of these monthly mean adjusted sea levels (ASL) were calculated relative to the long-term averages for the period 1961-80.

These monthly ASL anomalies (Fig. 9) show higher than average values throughout the year at both sites. Part of the Halifax anomaly is due to a trend of increasing sea level. However, such is not the case at St. John's (Trites and Drinkwater, 1983). There is a seasonal pattern in the anomalies at both stations with a minimum in summer and a maximum in the latter months. The maximums may reflect a steric effect as 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 from the Gulf of St. Lawrence, in the case of Halifax (Sutcliffe et al., 1976).

D. Sea Ice

The Canadian Atmospheric Environment Service has a program of sea-ice reconnaissance and forecasting for Canadian Atlantic and Arctic waters. The Ice Climatology Division has analyzed 24 sites in the Gulf of St. Lawrence and east of Newfoundland for the timing of the first occurrence and the last presence of sea ice at each site, and compared them to the median date and the extremes (Fig. 10, Table 3). 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 southern most 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 westward 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."

E. Icebergs

Icebergs are monitored by the International Ice Patrol (IIP) and usually reported as the number of icebergs crossing the 48°N latitude. Over 90% of these cross during the months of March to July. In these months for the period 1951-80 the average number of icebergs was 408 with a maximum of 1518 in 1972 and a minimum of 0 in 1966. Iceberg statistics extend back to 1880.

In 1983 the number of icebergs reported by the IIP from March to July was 1174. This was the fourth highest in over one hundred years with more being recorded only in 1972, 1974 (1324) and 1929 (1320). In 1982 the number of icebergs was 188. The total number of icebergs from October 1982 to September 1983 was 1352 with the monthly values of 2, 9, 165, 124, 339, 465, 168, 76 and 4 from December 1982 to August 1983. The icebergs arrived much earlier than normal in 1982 (December) and were greater in numbers during the period prior to March. The seasonal total is the third highest on record with more being recorded only in 1972 and 1974.

III. METEOROLOGICAL OBSERVATIONS

A. Air Temperatures

Plots of the monthly mean air temperature anomalies for 1983 over eastern Canadian and the New England States are shown in Fig. 11. The Canadian data for January through April were obtained from the monthly publications of the Canadian Weather Review. This was replaced in May by the Monthly Supplement to the weekly Climatic Perspectives both published by the Atmospheric Environment Service of Canada. The U.S. data were taken from the Climatological Data, New England, Volume 95 published by the National Oceanic and Atmospheric Administration.

During the first three months temperatures in the southern areas were above normal by up to 2°C while Northern Quebec, Labrador and Baffin Island were well below normal (> 10°C in Eastern Baffin Island in January) continuing trends begun in the late months of 1982 (see Trites and Drinkwater, 1983). In April the higher than normal temperatures extended northward with anomalies > 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 (Jan-Mar, Dec) vary from $\sim$4°C on Baffin Island and northern Labrador to ~ 2°C in Newfoundland and

Nova Scotia. In summer they reduce to ∿1°C in all regions.

The warmer than normal temperatures in the south and colder than normal in the north are also evident in the annual anomalies (Fig. 12). For the Baffin Island coast the anomalies are > 2 s.d. and for the Atlantic coast > 1 s.d. from normal and thus are highly significant.

B. Sea Surface Pressure

The large scale winds are known to play an important role in the circulation on continental shelves and in the open ocean. Direct measurements over the water are few, however, information can be obtained from air pressure measurements. Through the geostrophic relationship the wind moves parallel to the isobars with higher pressures on the right looking downwind 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 (∿0.7) and rotated anticlockwise by ~ 10-20° compared to the geostrophic winds .

Recently Thompson and Hazen (1983) published climatological wind stress and Ekman upwelling maps over the North Atlantic for the period 1950-1980 using seasonal sea surface pressure data. Thompson (personal communiction) calculated seasonal sea surface pressure anomalies for 1983 over the North Atlantic relative to their 1951-1980 means. The seasons, similar to those in Thompson and Hazen (1983), are winter (DJF), spring (MAM), summer (JJA) and autumn (SON). The mean conditions for the period 1951-1980 are similar to those during 1950-1975 published by Thompson and Hazen (1983) and consist in all seasons of a low pressure area (cyclonic winds) centered between Greenland and Iceland and a high pressure area (anticyclonic winds) centered near the Azores. The low is most intense in winter and the high is maximum in summer. The gradient between the centres of the two pressure systems, and hence the strength in the westerly winds, are maximum in winter.

The winter anomalies (Fig. 13) show a large high pressure area covering most of the North Atlantic. This suggests an anomalously warm easterly flow over eastern North America as far north as Newfoundland. In the Labrador Sea and on the Labrador coast the anomalous winds would be directed from the northwest. In spring the center of the high has shifted westward and slightly to the north. The resultant anomalous winds are from the southeast between Newfoundland and southern Nova Scotia and appear to be from the south or southwest off Labrador.

In summer the high has moved to the east with conditions near normal over the NAFO region. In the fall a low develops near the Azores and a high between Iceland and Greenland. The anomalous winds over eastern North America are therefore from the east.

IV DISCUSSION

On the large scale, 1983 average annual sea surface temperatures extending from the Grand Banks to the Mid-Atlantic Bight area were well above the 1972-80 mean, with some of the subareas having record high temperatures. On a localized and month to month basis more variable conditions were displayed with above normal temperatures occurring at one site during part of the year while at the same time below normal values were occurring at a neighbouring site (e.g., St. Andrews and Boothbay Harbor). Additionally it must not be assumed that SST's represent anything more than the surface mixed layer. Data from Station 27 readily demonstrate this point. The surface layer displayed above normal temperatures throughout most of the year, while water below the thermocline was below normal. In this particular instance it appears that local surface layer conditions were more influenced by air-sea exchange and horizontal advection than by vertical mixing between the surface and deeper layer. Lower than normal salinity in the surface layer may have contributed indirectly to producing these conditions, through increased stability and hence less vertical mixing.

Many of the sea ice anomalies can be related, not surprisingly, to the meteorology. Thus with colder than normal fall and winter air temperatures in 1982-83 off Baffin Island and the Labrador coast, ice formed earlier. In the Gulf of St. Lawrence where air temperatures were warmer than normal, ice conditions were much lighter and left earlier than average. The heavy pack ice along the Labrador coast and the colder air temperatures would have acted to protect any icebergs that were on the Labrador Shelf in winter. The stronger than normal north westerly winds in winter would have intensified the southeastward movement of the water, pack ice and icebergs along the Labrador Shelf thereby accounting for the early arrival and the large number of icebergs that passed south of 48°N latitude plus greater southward penetration of sea-ice. Curiously, one might have expected that the more extensive ice distribution in the area from the Grand Banks northward, would have resulted in below normal SST's. Although below normal SST's were reported in the Oct-Dec period of 1982 in the Grand Banks-Southern Labrador region (Trites et al., 1984), the winter spring 1983 period was generally well above normal. The relatively few temperature observations taken in the northern areas (and generally where there is no ice) may be partly responsible for producing this apparent discrepancy.

The large air temperature anomalies (warm in south, cold in the north) can be related qualitatively to anomalies in the large-scale wind patterns. During the winter and spring the anomalous easterly to southeasterly winds over the southern NAFO region are consistent with warmer air than normal being carried into the region. Similarly the anomalous northwesterly winds in the northern region would be expected to bring in colder than normal air.

The environmental conditions in the NAFO area during 1983 stands out in several respects, e.g., the large SST anomalies, the high air temperature anomalies, the high number of icebergs. These in turn are consistent with the response to the anomalous wind patterns as discussed above. It is noteworthy during 1983 that the strongest El Nino event in over one hundred years of records was recorded. El Nino refers to anomalous warm water in the eastern tropical Pacific but has been shown recently (e.g., see Rasmusson and Wallace 1983) to be part of a larger oceanic-atmospheric interaction. The effects are felt almost world wide and it appears likely that the anomalous sea level pressure pattern over the North Atlantic is at least partially related to the atmospheric response associated with the El Nino but the nature of any relationship needs further research.

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Table 1. Annual SST anomalies for the 1972-83 period, using the normal period 1972-80. Geographic locations of water masses are shown in Fig. 4.

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

TABLE 2. Mean monthly significant wave height (m) at three locations in the Northwest Atlantic derived from 12-hr wave charts for 1982-83 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)												
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
1970-80	3.50	3.36	3.20	2.56	2.02	1.84	1.75	2.01	2.61	3.14	3.33	3.64
Grand Banks (47.5°N, 47.5°W)												
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
1970-80	3.76	3.48	2.88	2.78	2.22	2.07	1.94	2.22	2.75	3.19	3.41	3.96
Scotian Shelf (42.5°N, 62.5°W)												
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	1.65	2.21	3.17	3.26
1970-80	2.91	2.77	2.80	2.35	1.82	1.70	1.57	1.62	1.76	2.16	2.69	3.00

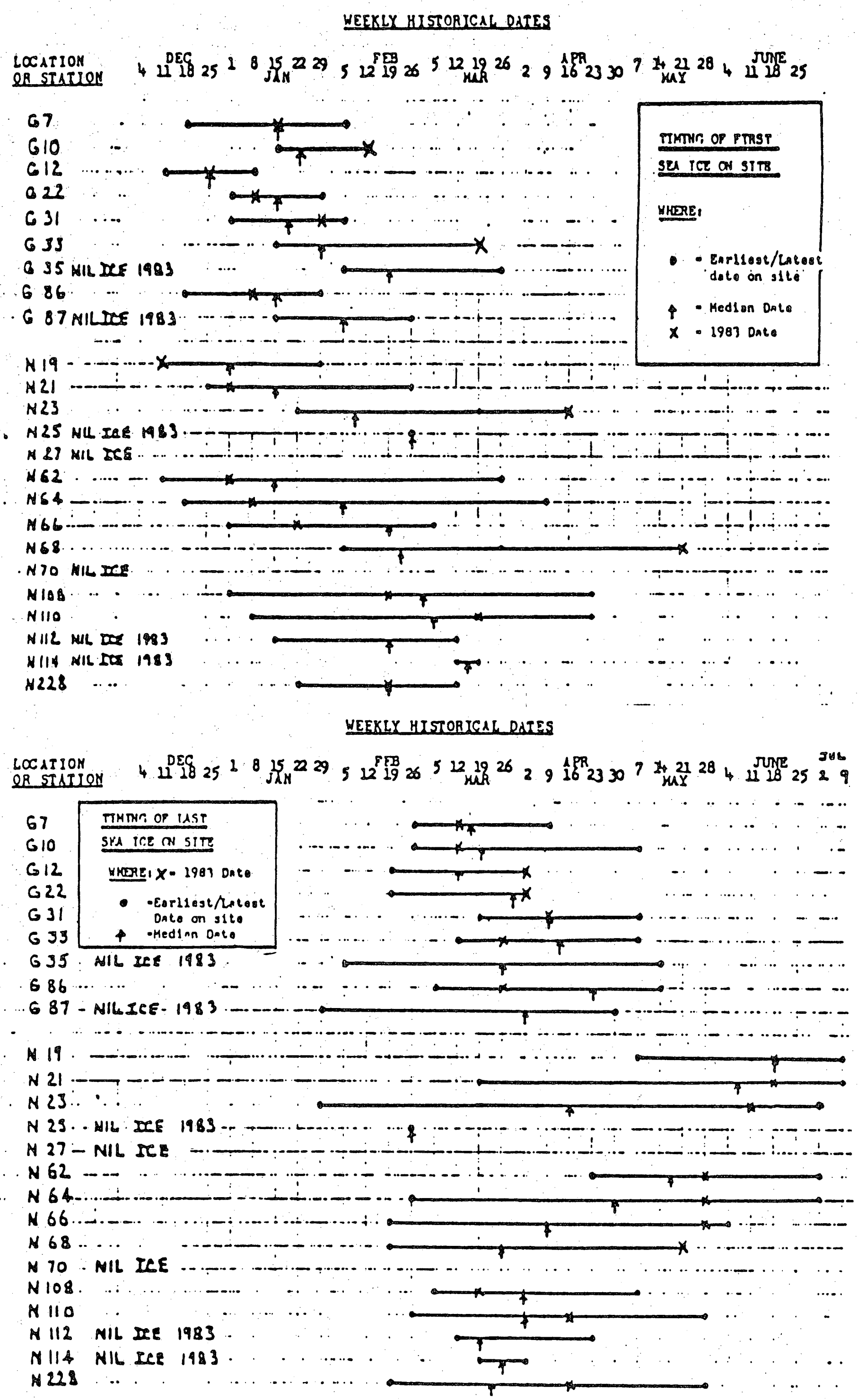

Table 3. Historical data for sea ice showing the dates of first presence (upper half of table) and dates of last presence (lower half of table) for each of 24 locations (Fig. 10). Earliest, latest, median, and 1983 dates are shown for each site.

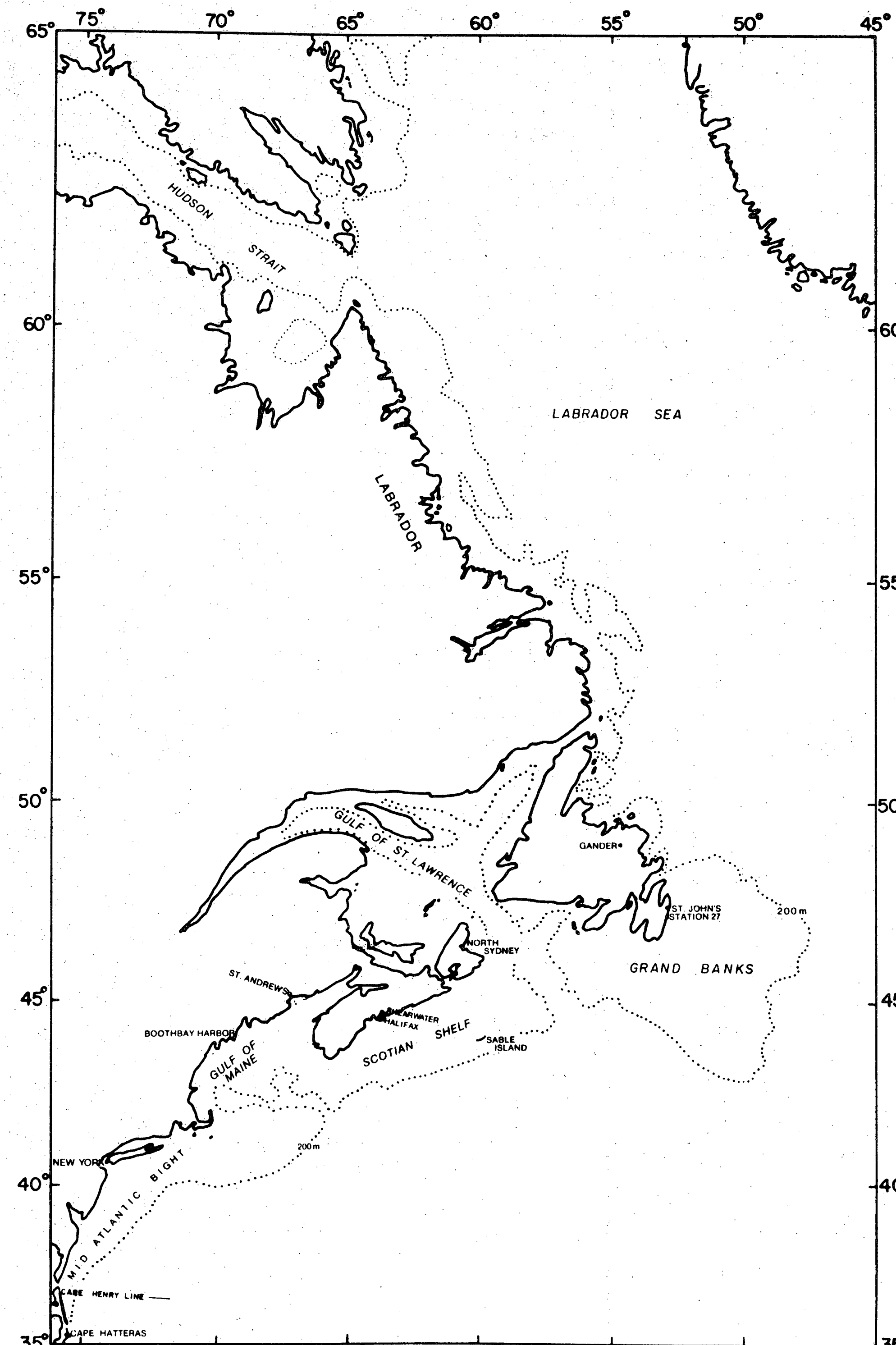

Figure 1. Map of NAFO area showing location of oceanographic and meteorological stations.

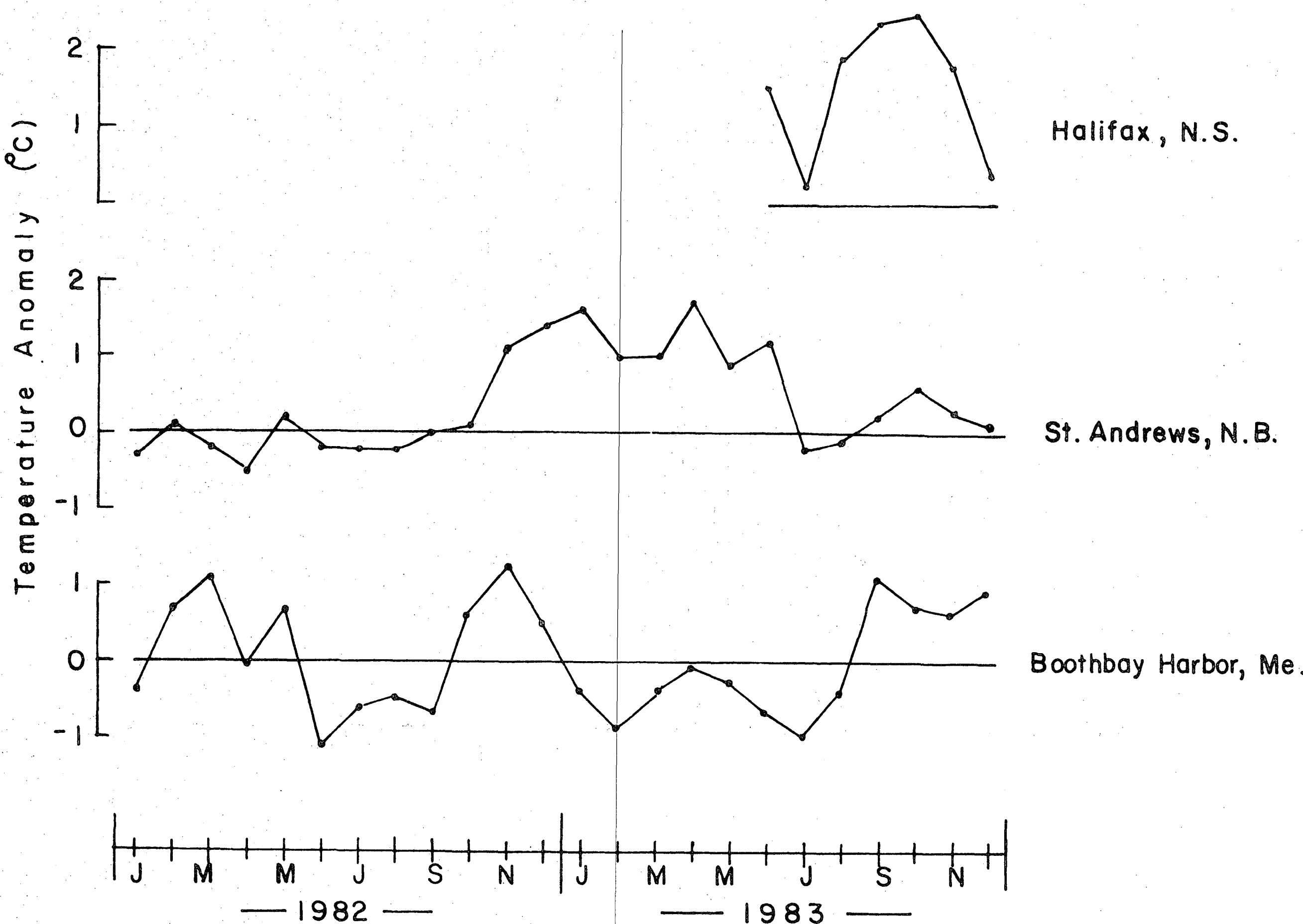

Figure 2. Monthly SST anomalies at Halifax, St. Andrews and Boothbay Harbor for 1982 and 1983.

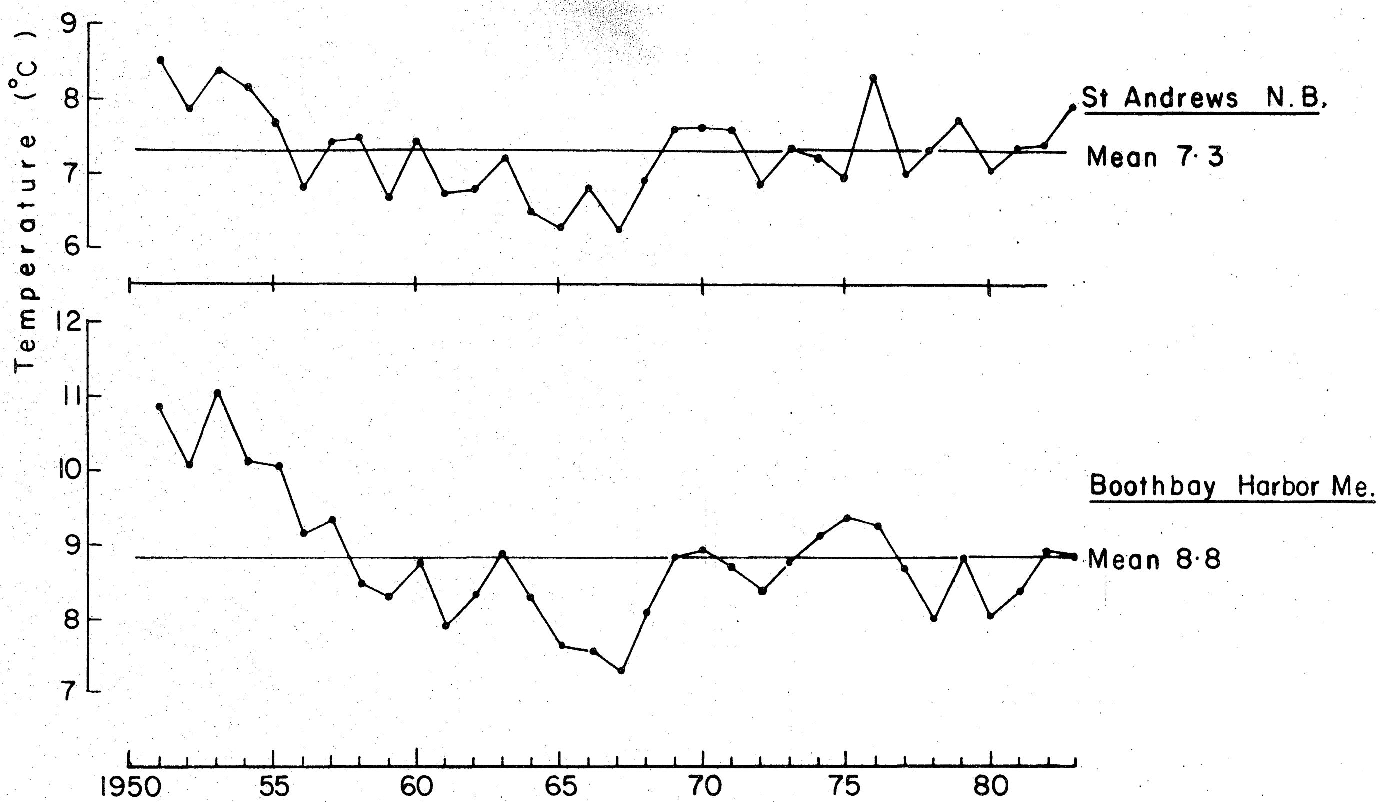

Figure 3. Annual means of SST for coastal stations. The overall mean is that for the period 1951-80.

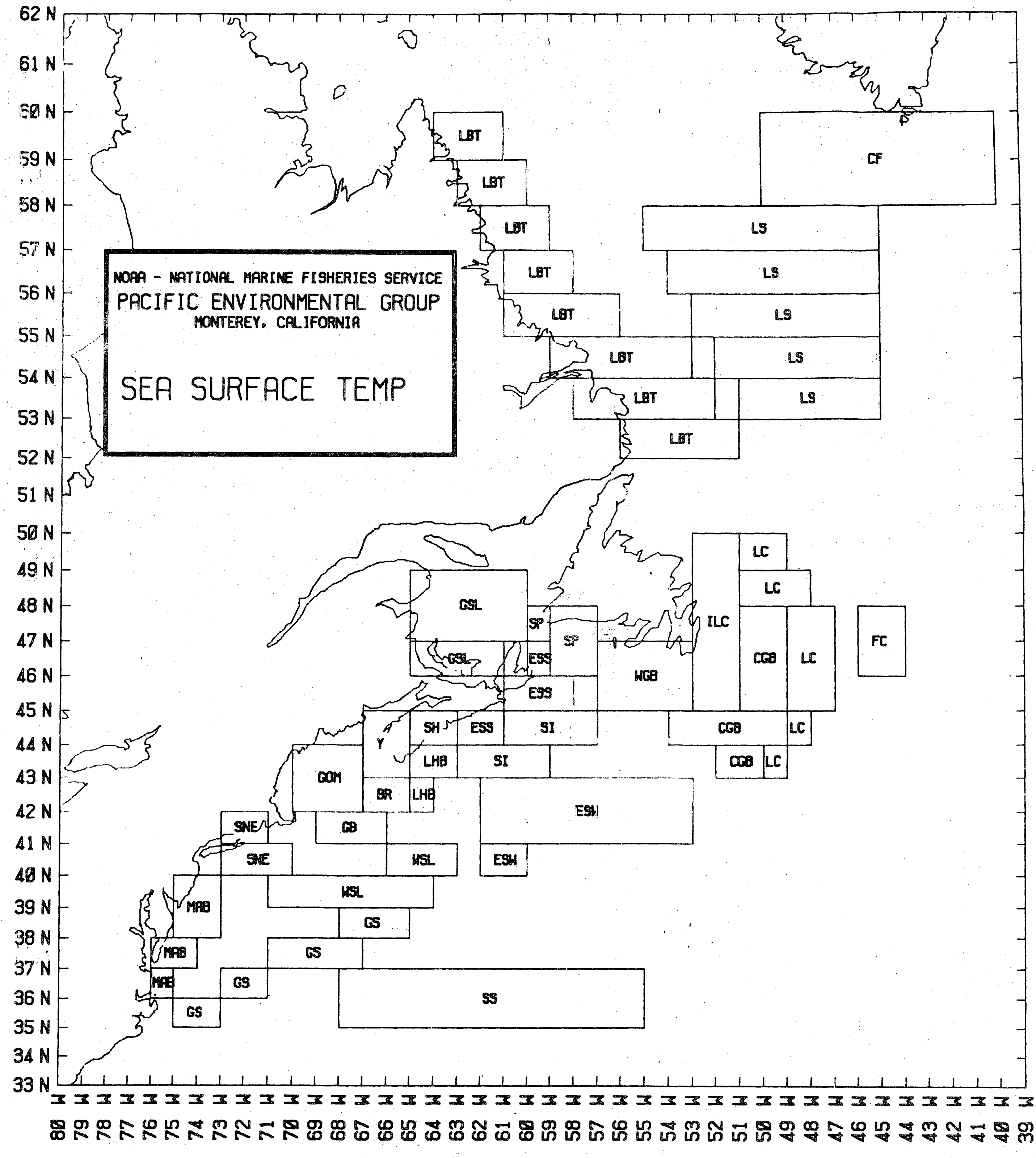

Figure 4. Geographic boundaries of 24 subregions for which sea-surface temperatures received by teletype at FNOC (Monterey, California) have been analyzed on a monthly basis for the 1971-83 period.

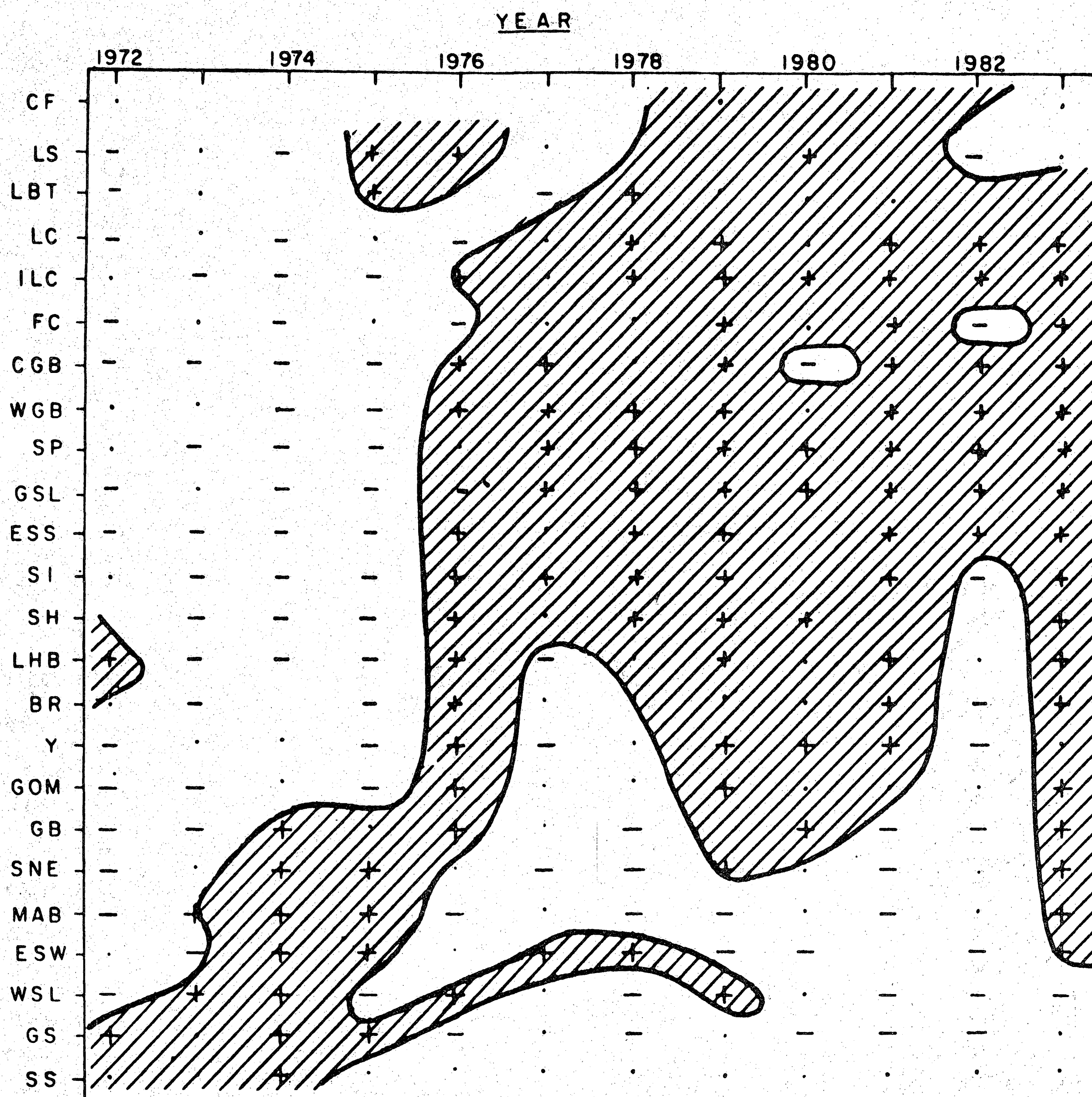

Figure 5. Distribution of annual sea surface temperature anomalies in 1972-83 by subareas (see Fig. 4) relative to the means for the 1972-80 base period. (A "+" or a "-" symbol represents anomalies which exceed 0.15°C, and a "." represents anomalies with a magnitude less than 0.15°C). Only anomalies exceeding 0.15°C have been used in constructing the contours.

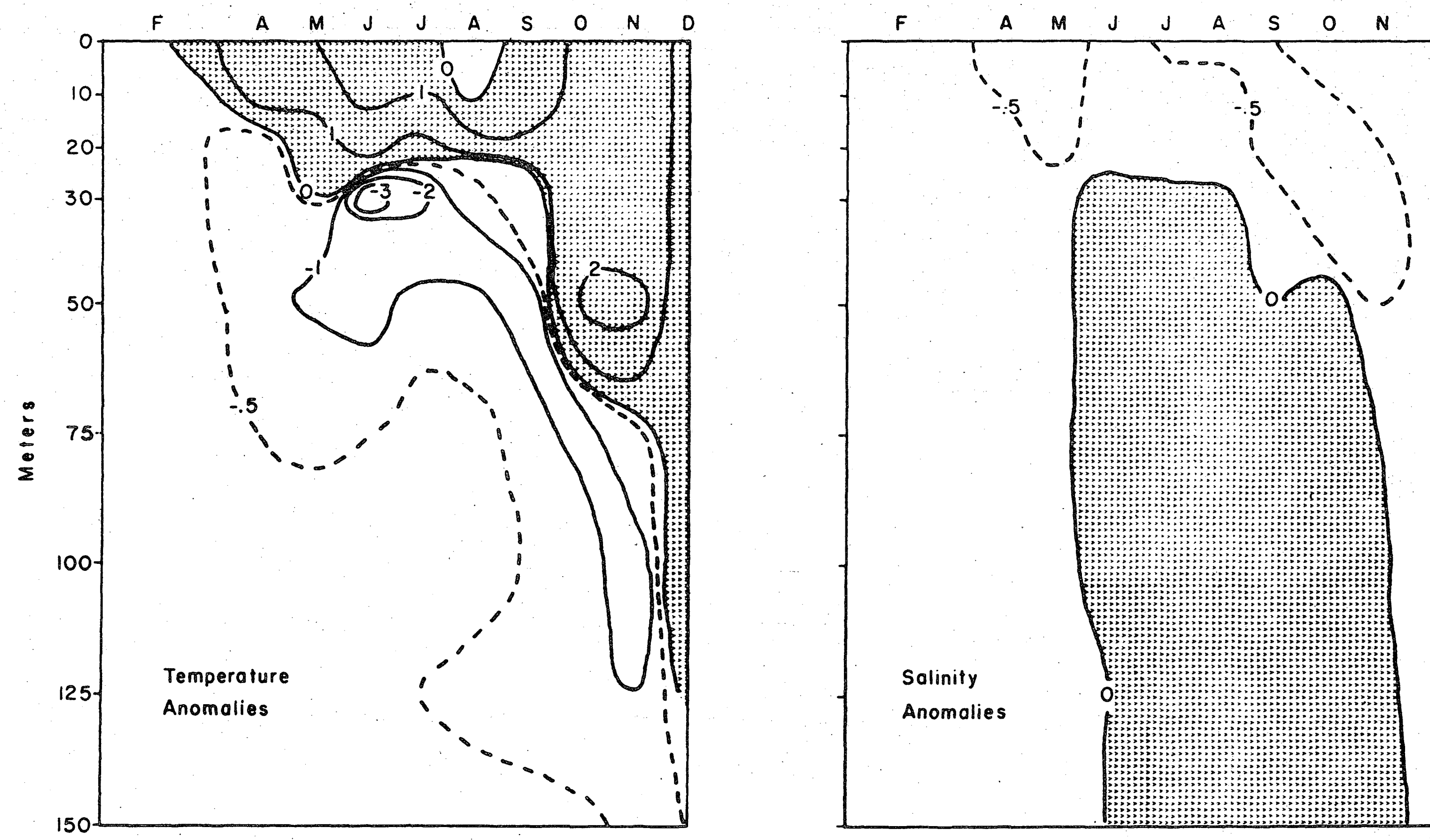

Figure 6. The monthly temperature and salinity anomalies for station 27 for 1983 relative to the period 1946-1977 (from Keeley 1981).

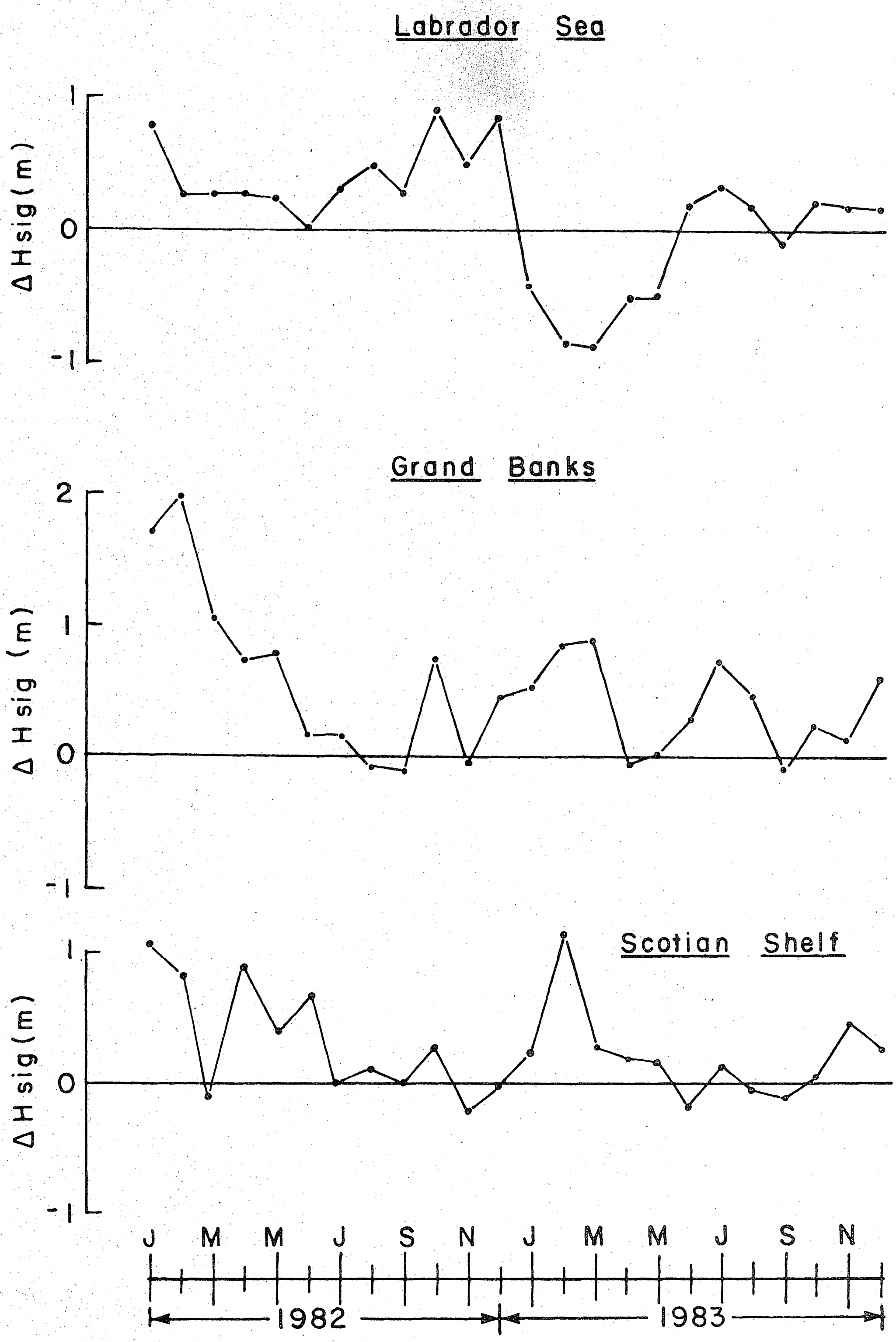

Figure 7. Monthly significant wave-height anomalies in metres in three areas of the Northwest Atlantic during 1982-83 relative to the means for the 1970-80 base period.

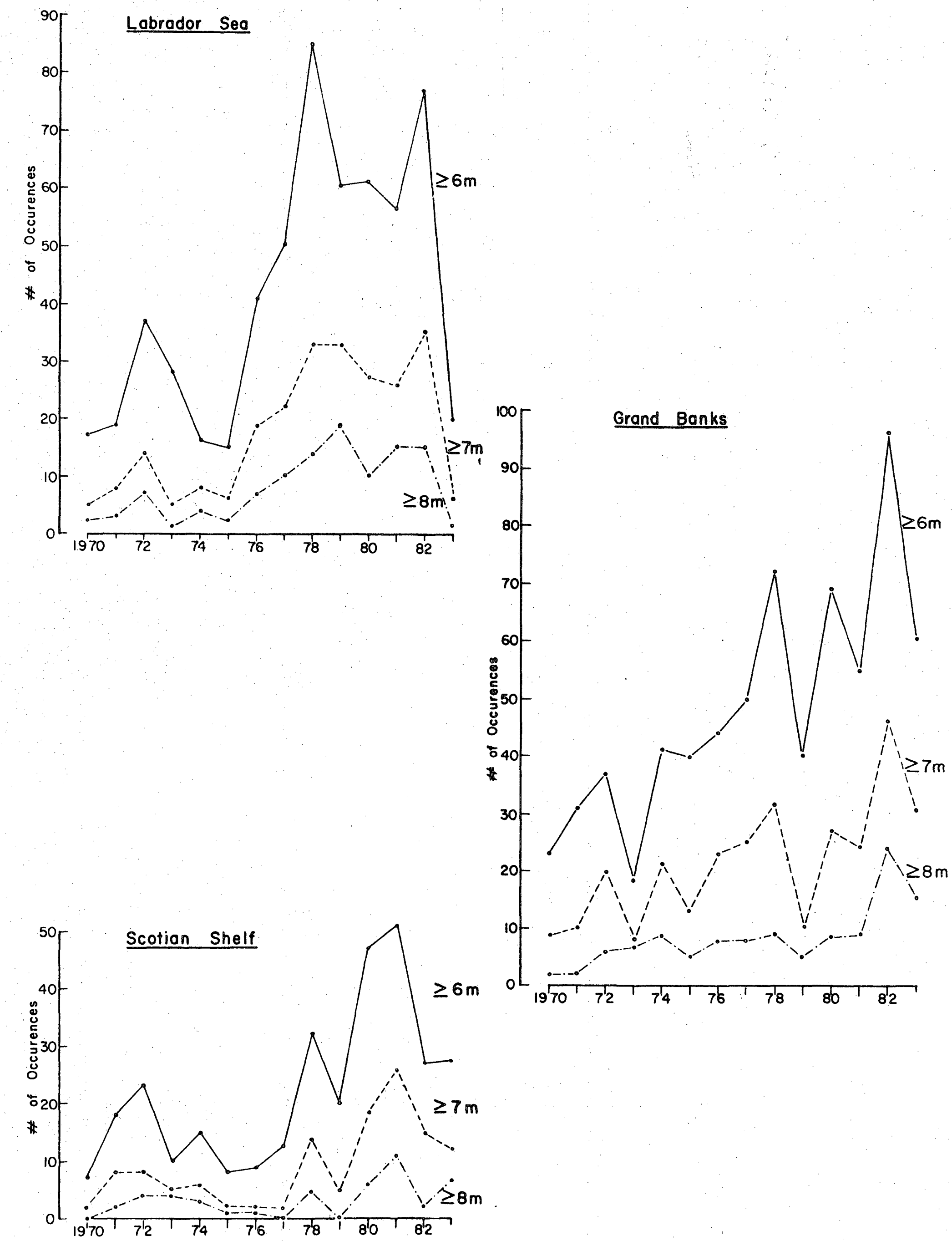

Figure 8. Annual occurrences of storms during which wave heights exceeded 6, 7 and 8 m in three areas (Labrador Sea, Grand Banks, and Scotian Shelf) of the Northwest Atlantic during 1970-83.

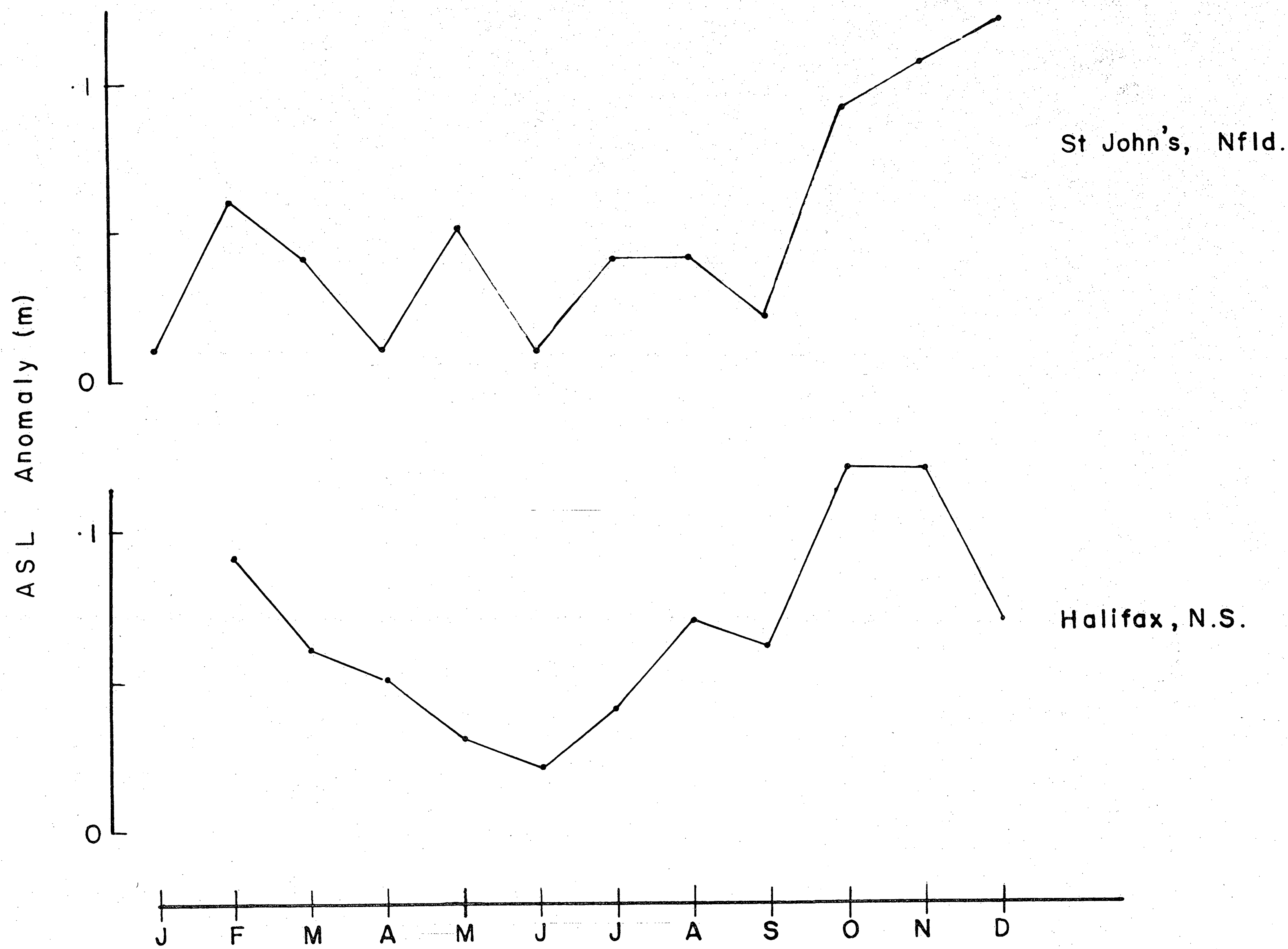

Figure 9. Monthly anomalies of the adjusted sea levels (ASL) in metres for 1983.

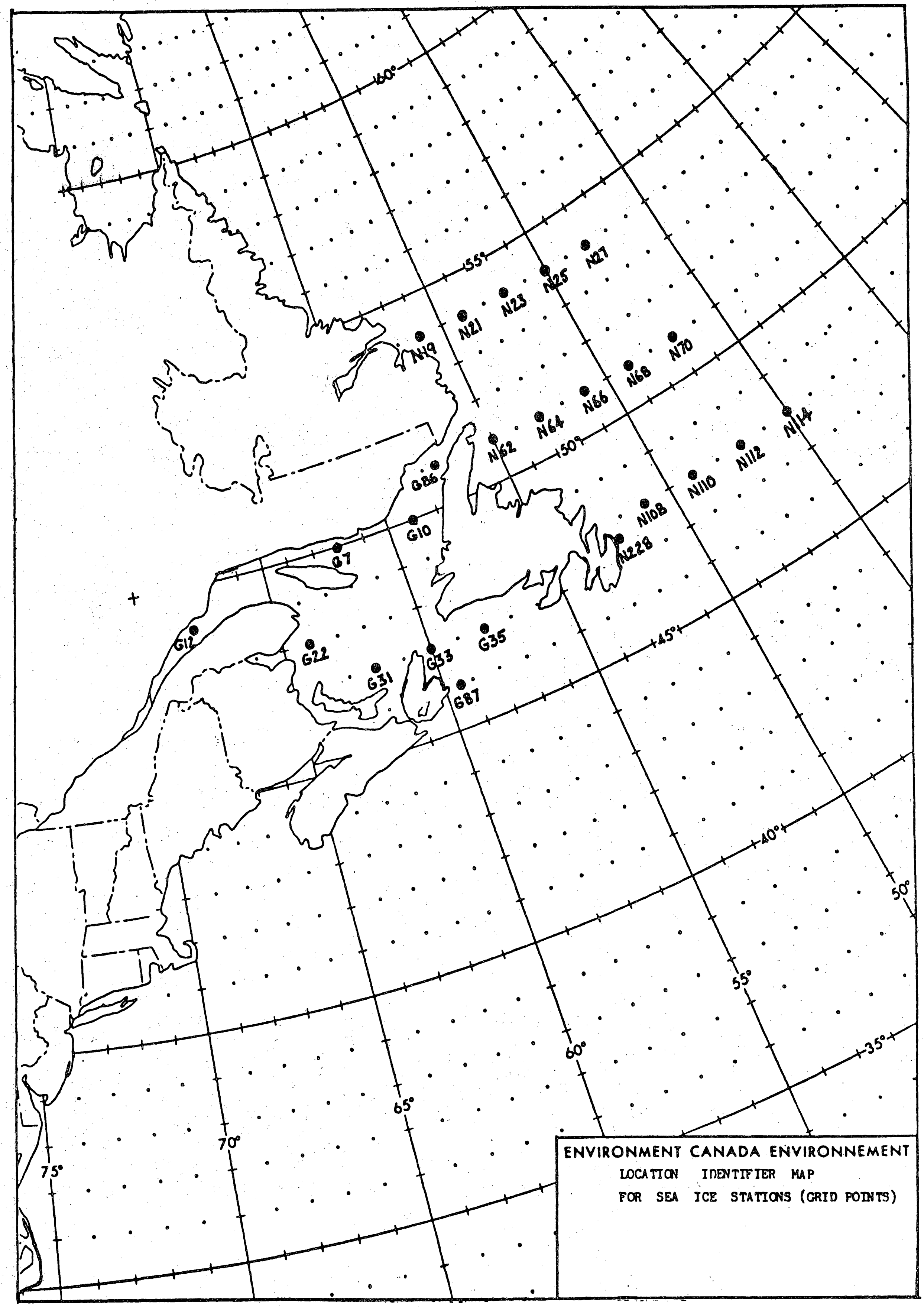

Figure 10. Map showing location of 24 sites (grid-points) where timing of first and last sea ice was observed.

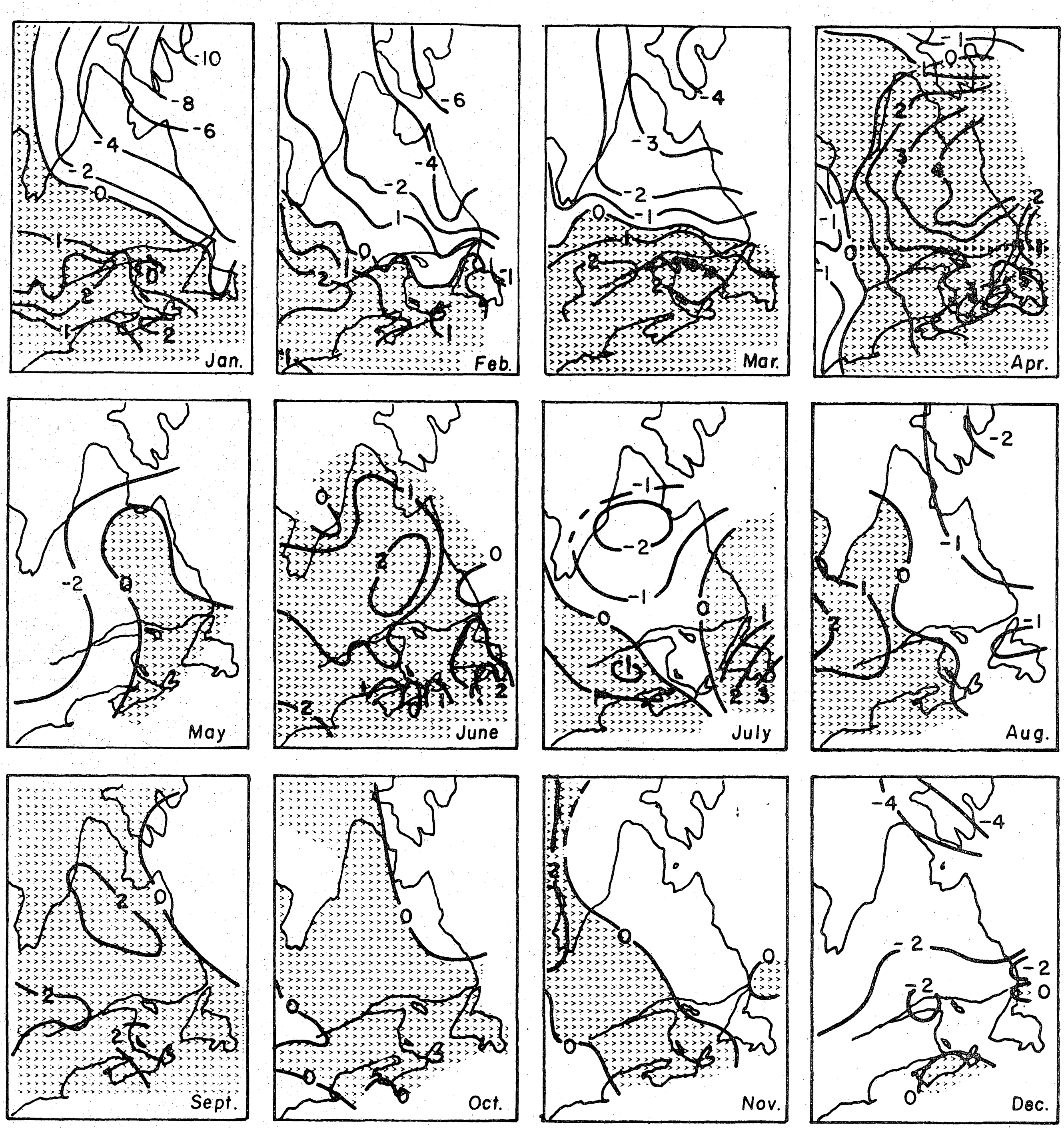

Figure 11. Mean monthly air temperature anomalies in °C for 1983.

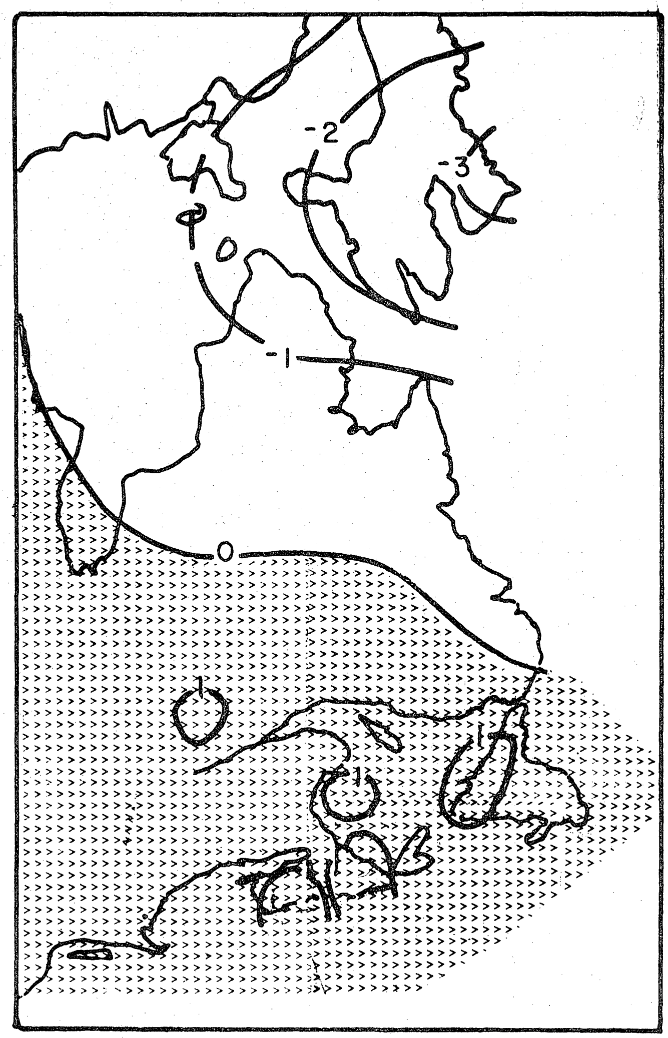

Figure 12. Mean annual air temperature anomalies in °C for 1983.

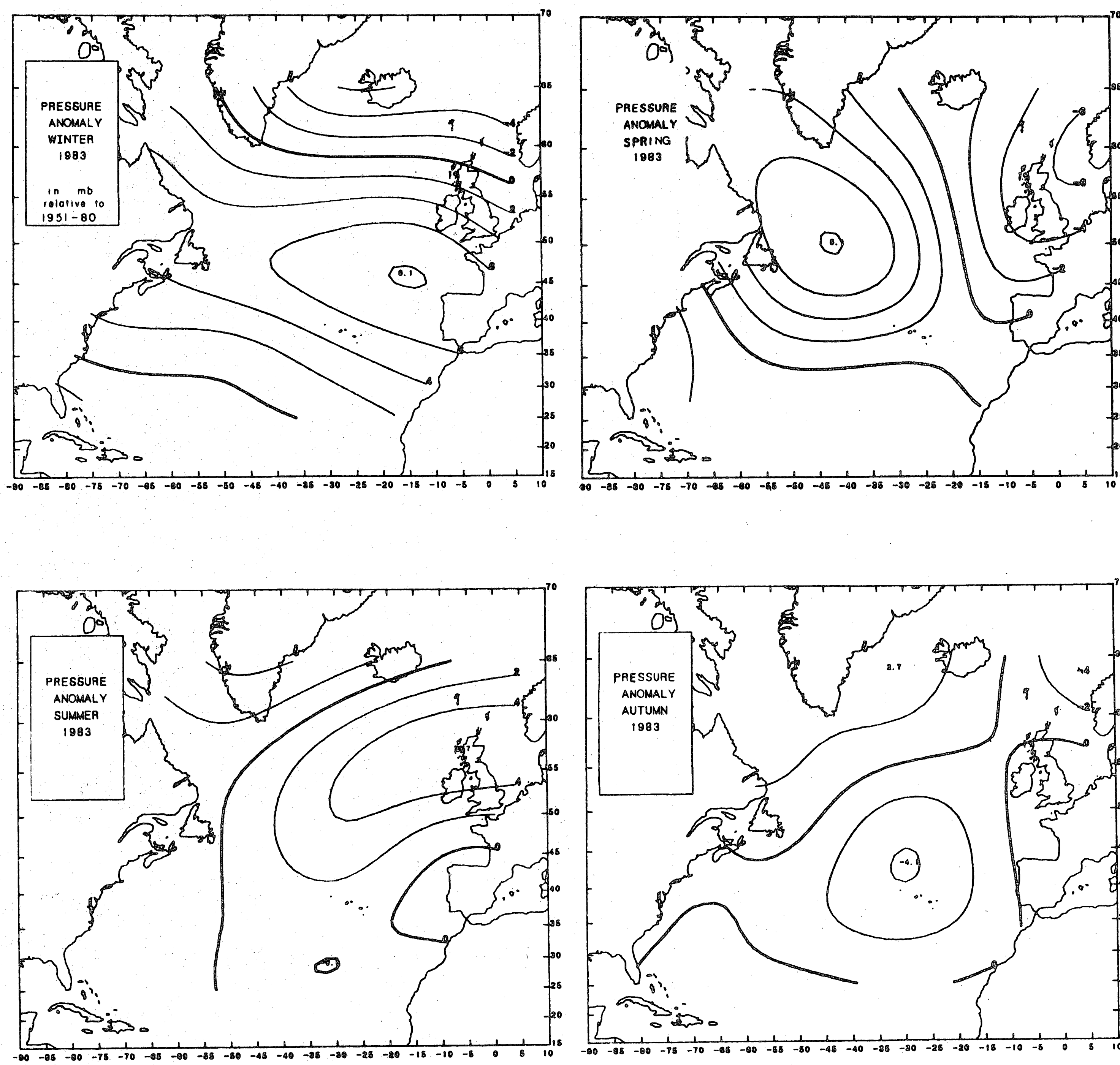

Figure 13. Seasonal anomalies of the sea surface pressure [illegible]
Atlantic during 1983.