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Northwest Atlantic Fisheries Organization

Serial No. N674

NAFO SCR Doc. 83/VI/23

SCIENTIFIC COUNCIL MEETING - JUNE 1983

OVERVIEW OF ENVIRONMENTAL CONDITIONS IN 1982 WITHIN THE NAFO CONVENTION AREA

by

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CONTENTS

I INTRODUCTION

The Environmental Subcommittee of NAFO annually faces the task of assessing environmental conditions of the previous calendar year. In preparing a report the Committee relies almost exclusively on the data contained in available Research Documents and National Reports. While this in itself has been viewed as a worthwhile exercise, it clearly falls short of general expectations. There are a number of reasons for this. Often it is difficult to combine data from an array of documents, because environmental changes are generally expressed as anomalies from a "normal" or base period which differs from report to report. Moreover, much of the data collected during the previous year are often not processed to the point where they are available for analyses at the time of the NAFO annual meetings. Of even greater concern is how to deal with the aliassing problem since often there may only be one cruise in a particular area during a season or even a year. Under these circumstances it may be meaningless or even grossly erroneous to use such limited data to make inter-annual comparison, since often the week to week changes within a year may exceed the true between year variability.

There are a number of environmental data sets that are rarely utilized in preparing the environmental overview, but which, in our opinion, would greatly enhance the usefulness and reliability of the assessment. Included in these data sets are such things as: daily sea surface temperatures from coastal stations (e.g., Halifax, St. Andrews, Boothbay Harbor), and from offshore (e.g., radioteletype, ships messages and from satellite IR imagery); subsurface temperature and salinity data from fixed stations (e.g., Station 27 off St. John's, Prince 5 in Bay of Fundy); mean sea level from tide guages; wave and swell from ships of opportunity; and a range of meteorological parameters, including air temperatures, measured wind speed and direction, and geostrophic winds.

Although some of these comprehensive data sets are not available until many months have elapsed, a number of them can be accessed quickly. This document represents an initial attempt to utilize a few of these data sets. Additionally, we have incorporated data from the Research Documents available at the time of writing. If this "pilot" project is judged to provide significant improvement in evaluating 1982 environmental conditions, it should be feasible to make it more comprehensive in future years.

II REFERENCE PERIODS AND DATA UTILIZED

Our aim is to assess environmental conditions by comparing values in 1982 with those of 1981 and with some long term reference period. Where sufficiently long data sets exist we have chosen the 30-year period 1951-80 as the long-term reference period, which is the current 30-year period for climate normals as recommended by the World Meteorological Organization. A number of data sets are shorter than this and consequently shorter base periods (within the 1951-80 period) have been used in these instances. The basic data sets used in this report are listed together with their sampling frequency and sampling period in Tables la and lb. Other information, derived principally from NAFO Research Documents, has been utilized as well. We have included in this report tables of the data for several of the parameters, so as to be readily available to other interested investigators.

III OCEANOGRAPHIC OBSERVATIONS

A. Temperature and Salinity

1. Coastal Sea Surface Temperatures

Long term records of coastal sea surface temperature (SST) were available from Entry Island, Quebec, Port Borden, P.E.I., Halifax, N.S., St. Andrews, N.B., and Boothbay Harbor, Maine (See Fig. 1 for locations). Unfortunately the Entry Island and Port Borden stations ceased operation at the end of 1981. Winter data (Jan-Apr) for these two stations often were unavailable due to ice cover in the Gulf of St. Lawrence. Monthly averages from the available mean monthly data in the period 1951-80 were calculated for all stations and are presented together with their standard deviations in Table 2. Monthly anomalies from these means were then determined for the 1981-82 data except for Halifax where instrument errors resulted in data of questionable quality in 1982 and perhaps 1981.

The monthly anomalies of the SST data at St. Andrews (Fig. 2) show temperatures were 1.5°C below the 30-y normal in January 1981, near normal from February 1981 to October 1982 and >1°C above normal for the last two months of 1982. A similar trend of low temperatures near the beginning of 1981 and high temperatures near the end of 1982 was also observed at Boothbay Harbor but with larger fluctuations from the 30-y norm than at St. Andrews during the remainder of the period. This is consistent with larger monthly standard deviations at Boothbay Harbor compared to St. Andrews (see Table 2) and is likely due in part to the decrease in tidal mixing outwards from the Bay of Fundy. In the Gulf of St. Lawrence, the SST anomalies for 1981 show a decrease from April through October at Port Borden followed by a rise until the data ended in December (Fig. 2). No trend is evident at Entry Island however temperatures tended to increase during December as observed at Port Borden.

The yearly means for Halifax, St. Andrews and Boothbay Harbor for 1951 onwards (Fig. 3) show a decrease from above the 30-y normal temperatures in the early 1950's to peak below normal values in the mid-1960's as indicated by earlier studies (e.g., Lauzier 1965, Sutcliffe et al. 1976). The annual means for 1981 and 1982 at St. Andrews and Boothbay were near their 1951-80 averges continuing the pattern of the 1970's. Lack of winter data prohibited calculations of annual means for Entry Island and Port Borden however means for the period May-October showed near normal values during 1981 and 1982.

Investigations of the SST data at coastal stations (Akenhead et al. 1981) indicate they represent trends fairly well but for periods of a year or less they may only be representative of a very local area.

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° x 1° square for which enough data have been reported each month.

Sea surface temperatures for 1982 within the area 35-46°N, 60-77°W, have been reported by Ingham and McLain (1983) as follows: "Sea surface temperatures in the first quarter of 1982 were anomalously cold in the middle Atlantic Bight (west of 72°W), continuing a trend which began in this area in the fall of 1981. By April this area of negative anomalies had decreased considerably in extent and intensity. In the Gulf of Maine an area of warmer than usual water appeared in April and May. During this period, the coastal weather station at Portland, Maine, (43.7°N) observed above-normal air temperatures, with anomalies ranging up to +13°F during the last half of April and up to +6°F during the first half of May. At the same time, winds frequently were from the SE-SW quadrant, bringing warm air into the region. The pattern of positive SST anomalies reappeared in this area in October-December. Although the December data are rather sparse and it is difficult to define the extent of the positive anomaly pattern, it probably was present then because January 1983 data show it to be well-developed at that time."

"Sea surface temperature data collected in the 40-41°N, 68-69°W one-degree square are more abundant than in other areas because of six-hourly SST reports taken from the hull thermistor of a NOAA meteorological buoy moored in about 50 m of water on southwestern Georges Bank since 1978. As a consequence, the total number of observations recorded for that 1° square in a month may exceed 600 and thus represents a more significant recent time series than the data from other squares. During 1982, the data from this square showed the surface water to be cooler than the long-term average in every month, with SST anomalies ranging from -5.1°C in July to -0.1°C in December. The negative anomalies recorded in this square during 1982 were more intense in the summer and early fall months than in 1980 and 1981, but less intense in November and December."

Analyses of SST data on a monthly and one degree square basis typically display relatively high spatial and temporal variability. Undoubtedly, some of this variability is real, while some is the result of undersampling. On the assumption that major variations in offshore temperatures should be coherent over areas much larger than a 1° square, 14 subareas within the areas 35-50°N, 45-76°W, were identified for data grouping (Fig. 4). The subareas were chosen (to within 1°) to coincide or be imbedded within major water masses or where T-S characteristics were thought to be relatively uniform (e.g., Labrador Current, Gulf Stream, Gulf of Maine). Monthly SST's were computed at PEG (McLain, pers. comm.) for the period March 1971 - December 1982. The monthly data were further grouped into semi-annual and annual mean anomalies compared to the 1972-1980 period. Only preliminary (and provisional) results are as yet available and are subject to further checking to ensure errors have been minimized.

The results indicate that temperature changes are coherent over much larger areas than the subareas chosen (Fig. 5 and Table 3) and that anomalies often tend to persist for a number of years. The region from about the Gulf of Maine northward appears to display appreciable coherence. Likewise, temperature changes in the area from about the Gulf of Maine southward to Cape Hatteras, including the warmer offshore waters, has a fair degree of coherence, and with opposite phase to that of the northern areas. In 1982 water in the northern areas were generally warmer than the 9 year mean, while waters in the southern areas were cooler than normal.

In the 1972-75 period, positive anomalies were present in the southern area and negative ones in the north. In 1976 the situation appears to have been in the process of reversing, and over the 1977-82 period above normal annual mean temperatures occurred in the north while southern and offshore temperatures generally have been below normal.

A listing of the 6-month anomalies for the 2-year period, Oct 1980 - Sept 1982 (Table 4) indicates that the positive anomalies in the northern areas, which reached their maximum southern extent (to about the mid-Atlantic Bight) in the April - Sept. 1981 period, receded northward to the Labrador Current area a year later.

3. Temperature, Salinity Stations

Monitoring of the vertical profiles of the temperature and salinity on approximately a once per month basis or better has been carried out by the Dept. of Fisheries and Oceans at Station 27, 1 km offshore from the harbour mouth at St. John's, Newfoundland, since 1947 and at Station Prince 5 in the Bay of Fundy offshore from St. Andrews, N.B. since 1959 (see Fig. 1.). The last few years of Prince 5 data were unavailable to us at the time of writing and hence no disucssion of this data set is presented. Station 27 data have been analyzed and means for the 1950-59 period (Huyer and Verney 1975) and the 1946-77 period (Keeley 1981) have been published. The 1981-82 Station 27 data were obtained and monthly averages of temperature and salinity at the standard depths of 0, 10, 20, 30, 50, 75, 100, 125 and 150 m were calculated. Keeley (1981) produced long term means of the temperature and salinity for the beginning and middle of each month (his Appendix C, p. 25-28). The latter were used to produce monthly anomalies for the 1981-82 data which are shown in Fig. 6. The isolated peaks or troughs are probably not significant due to the low frequency of sampling, for example the high temperatures and low salinities observed throughout the water column in November 1982 are based on one set of measurements only. More significant are the relatively high or low anomalies which persist with time. Thus the water was warmer than normal near surface in May to July 1981 and throughout the water column from November 1981 to January 1982. Colder than normal temperatures were observed in the near surface waters from February to April 1982 and below 50 m from February to September 1982. The most persistent salinity features are the negative anomalies from September to December 1981 and the positive anomalies from January to July 1982.

4. Position of Shelf/Slope Front

The Shelf/Slope Front, situated over or near the Continental Slope from Florida to the Grand Banks, delineates the boundary between the cooler, less saline Shelf Water and the warmer, more saline Slope Water that lies offshore. The surface position of the Shelf/Slope Front can usually be determined from thermal infrared satellite imagery. This information has been extracted annually by the Atlantic Environmental Group, National Marine Fisheries Service, for the past decade. For 1982, the annual mean position of the front was displaced seaward of the 1973-77 mean by about 35 km (Armstrong, 1983). Geographically the displacement tended to increase from south to north, ranging from near zero off Cape Romain to about 100 km along the Casco Bay 120° line (Fig. 7).

On a seasonal basis, the front in the Cape Cod to Cape Hatteras area is typically positioned in a more offshore location during the first half of the year and more shoreward during the latter half of the year. From Cape Hatteras south the seasonal progression is generally the inverse. In 1982, the seasonal frontal pattern approximated the normal, except off Georges Bank where the seasonal pattern is overshadowed by large excursions which correspond with the passage of warm core eddies (Armstrong 1983).

5. Warm-Core Eddies

Monitoring the life-history of warm-core Gulf Stream Eddies or Rings has been undertaken since 1974, for the area between 60°W and Cape Hatteras (Celone and Price 1983). Summary statistics on eddy generation by location, month, and year as well as monthly standing crop is given in Table 5. For the 8 zones (Fig. 8) defined by Fitzgerald and Chamberlin (1980), and for the period 1976-81 inclusive, it is seen that the principal generating area is within zones 1-3. Out of the 49 eddies generated over the 6-year period, the average lifetime was approx. 4 months. Looking at eddy generation by month shows the April-June period to have the highest quarterly generation. The winter months, however, may be biassed towards low values because of the relatively infrequent sea surface infrared imagery available owing to extensive cloud cover in the northeasterly areas.

Looking at the "standing crop" of eddies on a monthly basis reveals no marked seasonal pattern although it appears that the late spring-early summer period has appreciably higher counts than does the December-March period. Over the 7-year period the number of eddies generated annually has varied from a low of 7 in 1976 and 1981 to a high of 11 in 1982. Two eddies formed in 1981 were present as well in 1982 and likewise two eddies formed in October 1982 persisted into 1983. Average lifetime of eddies whose death occurred in 1982 was 113 days, - a lifespan close to the 6 year mean.

No published summaries are available on warm-core eddies formed in the area east of 60°W. The Oceanographic Analysis maps, prepared by the National Earth Satellite Service of the National Weather Service, were used to extract information on warm core eddies formed in the 50-60°W zone during 1982. It was found that about 20 eddies (with a lifespan of greater than 7 days) were generated. Maximum lifespan was about 70 days, with a mean of about one month. It thus appears that eddies form more frequently in the 50-60°W zone than in the 60-70°W zone, but their lifespan is much shorter.

6. Shelf temperatures in the mid Atlantic Bight Area

Monitoring the shelf water temperatures in the area near 71°W has been undertaken since 1974 (Crist and Armstrong, 1983). Further south, a transect extending from the entrance of New York Harbor across the Shelf and upper continental slope has been monitored since 1976 (Cook, 1983). In 1982, a total of 19 XBT transects were run along the 71°W line and 26 XBT transects along the New York line.

During winter, vertically homogeneous shelf water progressively cools from nearshore to offshore along the bottom to beyond the 100 m isobath, accompanied by deepening of the shelf/slope front and intensification of the frontal gradient. In 1982 the wintertime decline was interrupted by intrusions along and near bottom and were related to the pressure of Gulf Stream warm-core eddies fruther offshore (Crist and Armstrong, 1983, Cook, 1983).

In 1982, the cold pool water (less than 10°C), was dissipated by the end of September, compared to 1981 when it lasted until mid-October, dispite the fact that less than 5°C water in 1982 lasted longer than usual early in season. The average position of the cold pool off the New York Bight shifted slightly shoreward in 1982, extending into depths of less than 30 m, about 5 m shallower than in previous years. The cause of the shoreward movement is unknown.

Along the 70°W transect, the seasonal progression of shelf bottom temperatures was considered typical, based on the 1974-81 data. At the shelf break, in the 100-200 m depth zone, bottom temperatures were above 10°C for all of 1982, except during April when cooler conditions prevailed. Highest temperatures in the warm band developed from mid-January through February, during passage of warm-core eddy 81-F (Crist and Armstrong 1983). Bottom temperatures at 400 m reached 8.5°C in June, 1982, about 2°C warmer than normal. Only in 1976 have bottom temperatures greater than 8°C been recorded at 400 m depth.

B. Waves

One of the few important sources of consistent wave data covering the entire Northwest Atlantic are those analyzed from ship reports by the Meteorological and Oceanographic Center (METOC) in Halifax. Wave and weather observation from 40 to 100 stations across the North Atlantic, consisting of weather ships, Canadian and U.S. government and navy ships, merchant ships, and oil-drilling platforms, are transmitted every 6 hours to METOC. From these observations, and guided by surface atmospheric pressure charts, synoptic wave charts are produced at 12 hour intervals. The Bedford Institute of Oceanography (BIO) has collected these charts for the period January 1970 to date.

Data provided on the charts are wave heights, periods, and directions, based mainly on visual estimates. The height given is therefore not the height of an individual wave but rather is a general measure of the severity of the sea state. In practice it has been found that the estimated wave height closely approximates the mean height of the highest one-third of the waves and is referred to as the significant wave height (H_{sig}). The maximum wave height is generally about 1.8 to 2.0 times larger than H_{sig}. Wave statistics have been derived from these wave charts at 12 hour intervals for a grid of points at 5° intervals of latitude and longitude (Neu 1982). In this report data will be used from only 3 grid points which for convenience will be 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). In addition only significant wave height data will be used (see Table 6).

Using the 11-year period, 1970-1980 as a base period, monthly differences in significant wave height for 1981 and 1982 from the base period were computed (Fig. 9). It is noteworthy that during most months in this 2-year period, the wave conditions were more severe than those of the base period. The departure from the mean was most marked for the Grand Banks and least for the Labrador Sea. The most severe conditions occurred on the Grand Banks in the January-May 1982 period.

Another measure of wave conditions, indicative of conditions for the year as a whole, is the frequency of storms or events. The number of occurrences of waves equal to or greater than 6M, 7M, and 8M, for each of the three areas is shown in Fig. 10. Of particular interest is the fact that the frequency of occurrence of waves of a given height has been trending markedly upwards over the 13 year period in all three areas.

While the same general trend towards increasing occurrences of storms at all "intensities" is evident in all areas, the whole area doesn't necessarily experience a shift in conditions of comparable magnitude or direction in any given year. For example, while 1982 conditions on the Grand Banks was the severest of the 13-year period, and a marked increase from those of 1981 (Fig. 10) conditions on the Scotian Shelf moderated substantially from those of 1981 (Fig. 10).

C. Coastal sea level elevations

Mean monthly sea level elevations were obtained for St. John's, Newfoundland and Halifax, N.S. (see Fig. 1). The atmospheric pressure effect on sea level was removed assuming an inverted barometer response. The pressure data were taken from Gander for adjusting the St. John's sea levels and from Shearwater for Halifax levels (see Fig. 1 for locations). The monthly mean adjusted sea levels (ASL) were then averaged by month for the period 1953-80 for Halifax and 1957-80 for St. John's and are presented in Table 7. The anomalies relative to these periods were then determined for the 1981-82 period.

The ASL anomalies (Fig. 11) show increasing sea level through the first half of 1981 followed by a general decrease through until April of 1982. Also there is a suggestion of a peak positive anomaly in the fall of 1982.

Annual means of the ASL data were also calculated and are plotted in Fig. 12. At St. John's there is no overall trend and the 1981 ASL is near normal. However, at Halifax there was an increase in mean sea level of over 0.5 m during the late 1960's. The 1981 ASL at Halifax was near the 1970 levels. No annual means were calculated for either St. John's or Halifax in 1982 as 3 and 4 months of data were missing from the respective data sets.

D. Sea Ice

The Atmospheric Environment Service of Environment Canada, undertakes a program of sea ice reconnaissance and forecasting off the Canadian Atlantic seaboard and in the Arctic as well. The initial program began as an "Ice Patrol" in the Gulf of St. Lawrence in 1940 and operated in the late winter and spring months until the late 1950's, when it was expanded to support shipping in all ice-encumbered Canadian waters during the operational season. Ice data are acquired in several ways including: aircraft reconnaissance, ship reports, shore reports from lighthouses and other coastal installations, and satellite imagery. These data, combined with prevailing wind and temperature conditions are used to produce daily, and weekly composite, charts showing ice distribution.

Ice charts depicting the median, maximum and minimum ice edges for all types of sea ice for each week of the year has recently been published (Sowden and Geddes, 1980). The data base for these edges is the 1964-73 period for the median edge and 1964-79 for the two extremes. Additional ice information for the Gulf of St. Lawrence, Newfoundland and southern Labrador areas has been published by Markham (1980). Sea ice conditions for 1982, within the various NAFO subareas, is summarized in the following paragraphs.

In the northernmost areas spring break-up began slightly ahead of normal but this trend changed and sea ice was last to leave NAFO Divisions 1A, 1C and 1D in early September. This was approximately four weeks later than normal and in Divisions 1C it approached a near record late date. In Divisions 1B and 1F the last sea ice to leave was two weeks later than normal and in Division 1E, sea ice disappeared in mid June which was only a few days later than normal. The first ice to reappear in November occurred very close to normal dates for 1A, 1B, 1C, 1D and 1F. In 1E, first ice appeared in the third week of November about one week ahead of normal.

In NAFO Divisions 2G, 2H and 2J, the eastern extent of sea ice off the Labrador coast through January, February and March was generally near normal or slightly less than normal. Slower than normal spring melt and prevailing seaward winds, however, resulted in a greater than normal eastern extent of the ice pack through April, May and June. The last ice disappeared from 2H and 2J in mid July which was near normal for 2H but almost two weeks later than normal for 2J. Sea ice left 2G during the second week of August which was just short of two weeks later than normal. Next season's sea ice appeared in 2G during the second week of November which was almost two weeks earlier than normal. The initial growth of sea ice in the more southern areas (2H and 2J) was one to two weeks later than normal, however.

In NAFO Division 3K first ice appeared during the first week of January which was near normal but the seaward extent of pack ice in this area was generally less than normal throughout the months of January, February, March and May. In April and June, however, the eastern edge of the pack ice drifted well beyond its historical median limit. Again, due to a sluggish spring, the last floes of sea ice to leave 3K were almost two weeks later than normal. In 3L offshore sea ice development began normally during the first week of February but rapid growth and extension of the pack resulted in a greater than normal southward extent through the second half of the month and into March. Although during April the ice pack receded northward two weeks ahead of normal, it drifted back into the northernmost portions of 3L for a brief period in May. There was no sea ice reported in 3M, 3N or 3O during 1982 which is normally the case.

Due to above normal air temperatures in the Gulf of St. Lawrence, sea ice growth in Divisions 4R,4S and 4T was two to three weeks slower than normal. Although a below normal air temperature trend developed in January causing the drift ice cover to approach normal extent through February and March, spring ice thicknesses in the Gulf were generally less than normal. Thus, with near normal spring weather, pack ice in most of the Gulf disappeared a week or so earlier than normal. In the extreme northern portions of 4R and 4S, however, sea ice lingered three to four weeks longer than normal due to cooler spring temperatures in the region and the influx of ice through the Strait of Belle Isle. In Cabot Strait first ice arrived in 4Vn toward the end of January which was near normal. Drift ice cleared this area in mid May which was about one week earlier than normal. Rapid ice growth and accelerated eastward ice drift in February, however, brought Gulf ice to 3Pn and 3Ps approximately two weeks earlier than normal and into the northwest corner of 4Vs about one month earlier than normal. Some of this drift ice moved southward along the Atlantic coast of Nova Scotia to enter 4W a week ahead of normal. Although this tongue of ice approached the entrance to Halifax Harbour it deteriorated rapidly resulting in the last ice to leave 4W almost two weeks earlier than normal. There appeared to be a greater than average volume transport of ice through Cabot Strait due to a more eastward than southeastward drift pattern resulted in sea ice extending well beyond the normal spring limit and remaining in 3Pn and 3Ps two to three weeks longer than normal. In 4Vs the seaward extent of drift ice was east of the spring median but final clearing was only a week later than normal. In 1982 no sea ice was reported in 4X and 5Y nor was it reported in the southern half of 3Ps or in the southern three quarters of areas Vs and 4W. This is usually the case.

E. Icebergs

The glaciers of west Greenland are the source of nearly all the icebergs found on the eastern Canadian seaboard but a few originate from the Canadian Archipelago, and on rare occasions a berg from east Greenland may reach Canadian waters. Total annual production of icebergs from Baffin Bay is thought to range from 20,000 to 40,000 (Markham, 1980). The general movement of icebergs southward from Baffin Bay bears a close relationship to the current patterns. Icebergs break up and melt as they move southward resulting in less than 1% of the estimated annual production eventually reaching the Grand Banks area. The International Ice Patrol has determined that the average annual number of icebergs crossing latitude 48°N, for the 1945-72 period is 259, with 93% of them entering the area in the March 1 - June 30 period. A maximum number of 1587 occurred in 1972 and a minimum of 0 in 1966.

With respect to NAFO subareas, there is insufficient long-term monthly distribution data available to evaluate recent conditions except for Divisions 3L, 3M, 3N, 3O, and 3Ps. According to statistics received from the International Ice Patrol, there were fewer than normal icebergs drifting south of 48N latitude in 1982. On a monthly basis, no icebergs were reported south of 48N latitude in January, February, August, September or October. In March, April, May, June and July the number of bergs reported to have drifted south of this latitude were 17, 61, 13, 94 and 3 respectively resulting in a seasonal total of 188 which falls short of the 1946-82 average of 276. Next season's icebergs, however, arrived much earlier than normal with icebergs drifting southward to near latitude 50°N in November and south of latitude 48°N on the 26th of December. As a prelude to the 1983 season, over 1,250 icebergs have drifted south of latitude 48°N between December 26, 1982 and the end of May 1983 indicating a record year may be in progress.

IV. METEOROLOGICAL OBSERVATIONS

A. Air temperatures

Monthly mean air temperatures at coastal stations were obtained from: Hopedale, Labrador; St. John's, Newfoundland; Grindstone, Quebec; Sable Island, N.S.; Halifax (Shearwater), N.S.; Eastport, Maine; and New Haven, Connecticut. One inland station, Ottawa, Ontario, has also been included for comparison. The station locations are shown in Fig. 1. Monthly averages for the period 1951-80 (see Table 8) and the monthly anomalies relative to this period for the 1981-82 data were calculated at all stations.

An overall trend of decreasing air temperature anomalies was observed (Fig. 13) through 1981-82 at the two most northern stations, Hopedale and St. John's. Several prominant anomaly features were observed throughout the whole region including a warmer than normal February in 1981, a large positive anomaly in December 1981 followed by a large negative anomaly in January or in February 1982 and increasing temperatures at the end of 1982 except at Hopedale where the temperature anomaly dropped by >3°C.

The annual means of the air temperatures for 1951-82 generally show (Fig. 14) a pattern similar to the coastal sea temperatures, that is high values in the early 1950's decreasing to minimum values in the early to mid-1960's. The means were generally >1°C above normal in 1981 and decreased to 0.5°C below normal in 1982 except at Hopedale where the amplitude of the anomalies were much larger. These fluctuating levels about the norm are consistent with the pattern through the 1970's. Only at New Haven is a trend evident, with temperatures rising.

B. Winds

(1) Direct measurements

The monthly summaries of the average wind speed and percent frequency by direction were obtained for Grindstone, Quebec and Sable Island, N.S. for 1981 through to September 1982. The data from October onwards were unavailable at the time of writing. These stations were chosen for their relative isolation from large land masses and should be indicative of the large scale winds over the southern Gulf of St. Lawrence and the Scotian Shelf respectively. Studies by Petrie and Smith (1977) and Sandstrom (1980) have indicated Sable Island winds are indeed representative of the large scale winds off the Atlantic coast of Nova Scotia. From the wind speed and percent frequency data, the monthly mean vector speeds and directions were calculated for the 1981-82 data. Speed and direction anomalies for 1981-82 were then calculated using monthly averages for the period 1955-80 (see Table 9) as presented in the Canada Climate normals published by Canadian Climate Program (1982). The wind-driven oceanic circulation is related to the vector winds hence their representation rather than the mean wind speeds and prevailing directions.

The winds at Grindstone were much stronger than normal during April 1981 and in the winter (Dec-Apr) of 1981-82, a pattern which was also observed at Sable Island (Fig. 15). During both these periods and at both locations, the winds were rotated or progressing anti-clockwise from the normal directions of (290^{o}-310^{o}) at Grindstone and (280^{o}-310^{o}) at Sable Island. Lower than normal wind speeds were found in February 1981 at Sable Island and through the summer and early autumn of 1981 (July-Oct) at both stations. For the latter period the winds were westerlies (260^{o}) which were normal at Grindstone but rotated clockwise 20^{o} from normal at Sable Island.

(ii) Geostrophic winds

Information on the large scale wind fields can also be obtained from air pressure measurements through the geostrophic relationship.[1] Long-term

[1] The magnitude of the wind is proportional to the air pressure gradient between two stations and the direction is perpendicular to the straight line joining those stations, with the higher pressure to the right looking upwind.

monthly air pressure records were obtained for Goose Bay, Labrador, Gander, Newfoundland, plus North Syndey, Sable Island, Shearwater and Yarmouth in Nova Scotia (see Fig. 1). All stations began measurements in 1953 with the exception of Sable Island where they were started in 1957. The monthly sea surface pressure gradients were calculated between Gander and Goose Bay (G-GB), Sable Island and the midway point between Shearwater and North Sydney which lies near St. Mary's (SI-SM), North Sydney and Gander (NS-G) and Yarmouth and North Sydney (Y-NS). The G-GB and SI-SM gradients indicate geostrophic winds directed basically towards the northeast (+) or southwest (-) while the NS-G and Y-NS indicate winds directed towards the southeast (+) or northwest (-). The G-GB geostrophic winds represent cross-shelf winds (+ offshore) on the Labrador Shelf and northern Newfoundland Shelf as well as winds directed into (+) or out of (-) the northeast corner of the Gulf of St. Lawrence. These winds have been shown (Garrett and Toulany 1982) to drive the flow through the Strait of Belle Isle at periods on the order of 10 days through opposing set-up and set-down on the Labrador Shelf and in the Gulf of St. Lawrence respectively. The SI-SM winds are those alongshore on the Scotian Shelf while the Y-NS are the cross-shelf winds (+ offshore) for the same area. The NS-G winds would tend to force surface water out of (+) or into (-) the southern Gulf of St. Lawrence through Cabot Strait.

The monthly mean geostrophic winds were then determined and average monthly values were calculated for the available period 1953-80 (Table 10). Monthly anomalies from these means were also calculated using the 1981-82 data.

The plot of the monthly anomalies of the geostrophic winds for 1981-82 (Fig. 16) reveal several features. First there are similarities between the geostrophic winds with like orientation. The correlation coefficient between the G-GB and SI-SM geostrophic wind anomalies for 1981-82 was 0.66 while between the NS-G and Y-NS wind anomalies the coefficient was 0.67. Second the winds directed northeast-southwest (G-GB and SI-SM) had anomalies which underwent larger fluctuations than those directed southeast-northwest (NS-G and Y-NS). Third the negative anomaly in February 1981 and the positive anomalies in April 1981 and 1982 at Yarmouth-Sydney and/or Sable Island-St. Mary's correspond to similar anomalies in the measured winds at Sable Island. Fourth no overall trend in any of the geostrophic wind data is evident.

The annual mean geostrophic winds are shown in Fig. 17. The 1981 values were all below their long term means but in 1982 returned to near normal or above normal.

V. DISCUSSION

In preparing this overview several important features became evident. Foremost amongst these was that the offshore SST data (Fig. 5) indicate there are large scale events with opposite phase to the north and south of a region approximately coincident with the Gulf of Maine. The time scale of these events appears to be of the order of several years. A cursory visual comparison of the coastal SST data and surface data from Station 27 indicates they are consistent with the patterns indicated in Fig. 5. Therefore the recent data such as for 1982 must be put into context of these larger events. The continual increase in significant wave height and the greater occurrence of intense storms in the NAFO regions from the Labrador Sea to the Scotian Shelf from 1970 to the present day is intriguing . Neither the measured or geostrophic winds indicated any correlation with the wave data during this time. However, average wind speeds which have not been discussed are expected to have a greater connection with wave height than a mean vector or mean geostrophic wind.

As stated in the introduction this review is a 'pilot' project and could be expanded in several directions if it was deemed important and necessary. First expansion of the data bases could be carried out. From the oceanographic side further coastal SST and sea level stations than appeared herein are available. Also profiles of temperature and/or salinity at standard stations or sections could be incorporated. Several meteorological parameters could be added including solar radiation and precipitation while the air temperature and wind data bases could be expanded. Also freshwater discharge from certain of the larger river systems could be included. In regard to expanding the data bases it should be restated that individual stations probably represent long time scale trends fairly well but the higher frequency fluctuations of a year or less may only represent local conditions (see Akenhead et al. 1981). Larger data bases in both time and space for a particular parameter offer the advantage of better determining spatial and temporal scales of coherence. There is a distinct lack of data north of Newfoundland discussed within the present report and some effort should be undertaken both to obtain what is presently available and to monitoring conditions there.

As well as expanding the data bases we believe a standard normal period or periods should be adopted. We propose the WMO convention of a 30-year mean using the previous 3 decades which is presently 1951-80. For those data sets where 30 years are unavailable we recommend 20-year (1961-80) or 10-year (1971-80) averaging periods. If less than 10 years of data are available in the period 1971-80 then an average of the total number within that period should be used. We further recommend that such standards remain fixed until the end of the present decade, i.e., 1991.

Finally, research should be undertaken to determine the physical relationships between environmental variables such as meteorological and oceanographic conditions through both statistical methods using correlation or coherence analysis and by modelling. In this way key environmental parameters may be identified and an effort made to ensure their adequate monitoring both spatially and temporally.

VI. ACKNOWLEDGMENTS

The authors acknowledge the assistance of many individuals during the preparation of this document. In particular, thanks are expressed to Dr. D. R. McLain for providing monthly mean sea surface temperature data from the FNOC teletype file, for grouped subareas within the NAFO area for the 1971-82 period; to H.J.A. Neu and R.W. Walker for wave data; to D. Mudry of the Ice Climatology and Application Division of the Dept. of Environment, Ottawa, for providing the information on sea ice and iceberg conditions in 1982; to F. Amirault at the Atmospheric Environment Service, Bedford, N.S., for meterological data; to the Dept. of Fisheries & Oceans, especially J. Anderson at St. John's, Newfoundland, and J. Hull at St. Andrew's, N.B., for temperature and salinity data from coastal stations; to Dr. W. Welch at the Bigelow Laboratory, Boothbay Harbor, ME., for sea surface temperature data and to G. B. Taylor and D. L. Allen for drafting and typing assistance.

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Table 1a. Oceanographic data sets utilized in preparing environmental overview

	Sampling Frequency	Total Period of Obs.	Normal Period Used
Sea Surface Temperature (SST)			
A. Coastal Stations			
Entry Island, Que.	2/day	1930-81	1951-80
Port Borden, PEI	2/day	1951-81	1951-80
Halifax, N.S.	2/day	1926-82	1951-80
St. Andrews, N.B.	2/day	1921-82	1951-80
Boothbay Harbor, Maine	2/day	1906-82	1951-80
B. Offshore[1]			
35°-50°N, 47°-76°W	1/day	Mar 71-Dec 82	1972-80
Hydrographic Data (T,S)			
Station 27 (off St. John's, Nfld)	1-5/mon	1950-82	1946-77
Sea level elevation			
St. John's, Nfld.	1/hour	1957-82	1957-80
Halifax, N.S.	1/hour	1920-82	1951-80
Waves	2/day	1970-82	1970-80
Shelf/Slope Front and Warm Core Eddies[2]	1-3/week	1973-82	1973-77

[1] Data Source Teletype, FNOC, Monterey, California

[2] Data Source Satellite Imagery, U.S. National Weather Service

Table 1b. Meteorological data sets utilized in preparing environmental overview.

Data Set	Sampling Frequency	Total Period of Obs.	Normal Period Used
Air Temperature			
Hopedale, Labrador	1/hr	1942-82	1951-80
St. John's, Nfld. (Torbay Airport)	1/hr	1942-82	1951-80
Grindstone, Que.	1/hr	1934-82	1951-80
Sable Island, N.S.	1/hr	1915-82	1951-80
Shearwater, N.S.	1/hr	1945-82	1951-80
Eastport, Maine	1/hr	1874-1982	1951-80
New Haven, Conn.	1/hr	1780-1982	1951-80
Ottawa, Ont.	1/hr	1890-1982	1951-80
Wind			
Grindstone, Que	1/hr	1955-82	1955-80
Sable Island, N.S.	1/hr	1955-82	1955-80
Atmospheric Pressure			
Goose Bay, Labrador	4/day	1953-82	1953-80
Gander, Nfld.	4/day	1953-82	1953-80
North Sydney, N.S.	4/day	1953-82	1953-80
Sable Island, N.S.	4/day	1955-82	1955-80
Shearwater, N.S.	4/day	1953-82	1953-80
Yarmouth, N.S.	4/day	1953-82	1953-80

Table 2 Monthly means of SST (°C) for coastal stations during the period 1951-80, their standard deviations and number of years data is available.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Entry Island	-0.9	-1.3	-0.5	1.5	5.3	10.1	15.0	17.3	14.4	9.8	5.2	1.1
	0.6	0.4	0.8	1.1	1.4	1.0	1.2	1.0	0.8	0.8	1.0	1.1
	12	6	6	22	30	30	29	29	28	29	25	19
Port Borden	-0.9	-1.2	-0.7	1.4	7.3	13.6	17.5	18.8	16.5	11.4	5.8	0.5
	0.6	0.4	0.5	0.9	1.9	1.3	0.8	0.8	0.7	1.0	1.3	1.2
	13	13	14	29	29	30	30	30	30	29	29	29
Halifax	2.4	1.2	1.6	3.4	6.4	10.3	13.4	14.9	14.4	11.6	8.4	5.1
	6.9	0.9	0.8	1.0	1.1	1.1	1.1	1.2	1.2	1.2	1.1	1.1
	30	29	29	30	30	29	30	29	29	30	30	30
St. Andrews	2.1	1.0	1.7	3.9	7.0	9.8	12.2	13.3	12.8	10.9	8.2	4.7
	0.9	0.8	0.8	0.9	0.9	0.8	0.9	0.9	0.7	0.7	0.6	0.8
	30	30	30	30	30	30	30	30	30	30	30	30
Boothbay Harbor	3.4	2.2	2.8	5.2	8.9	12.6	15.2	15.8	14.3	11.3	8.4	5.7
	1.3	1.3	1.2	1.1	1.1	1.0	1.0	0.8	1.0	1.1	2.0	1.3
	30	30	30	30	30	30	30	30	30	30	30	30

Table 3 Annual SST anomalies for the 1972-82 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	1972-80 Mean
LC	-.28	-.07	-.38	-.12	-.16	.12	.19	.68	.01	.82	.24	5.17
ILC	-.06	-.25	-.57	-.30	.22	-.11	.27	.61	.20	.96	.40	4.83
WGB	.05	-.11	-.33	-.63	.34	.16	.31	.30	-.08	1.19	.19	6.13
GSL	-.56	-.00	-.38	-.22	.11	.10	.25	.48	.22	.49	.41	5.40
ESS	-.07	-.28	-.39	-.43	.27	.03	.35	.49	.03	.66	.26	7.30
WSS	.14	-.35	-.43	-.34	.22	-.15	.27	.29	.35	.41	-.36	8.03
GOM	-.17	-.20	-.05	-.25	.35	.10	-.11	.39	-.05	.11	.07	9.59
GB	-.27	-.36	.23	.00	.72	-.01	-.50	.00	.19	-.39	-.46	10.17
SNE	-.26	-.11	.56	.17	-.01	-.31	-.31	.28	-.01	-.50	-.03	12.23
MAB	-.22	.15	.62	.57	-.52	-.08	-.36	-.20	.04	-.43	-.06	14.87
ESW	.12	-.41	.31	.23	.16	.34	.25	-.65	-.33	-.01	-.28	15.85
WSW	-.15	.27	.37	-.17	.15	.02	-1.02	.53	-.01	-.92	-.48	18.50
GS	.15	.10	.26	.20	-.15	.03	-.15	-.04	-.40	-.26	-.16	22.94
SS	-.05	-.10	.15	.10	-.01	.01	-.09	.11	-.12	-.38	-.07	22.26

Table 4 Six-month SST anomalies for the period Oct. 1981-Sept. 1982, using the normal period 1972-80. Geographic locations of water masses are shown in Fig. 4.

Water Mass	Oct 80-Mar 81	Apr 81-Sep 81	Oct 81-Mar 82	Apr 82-Sep 82
LC	-.12	1.07	.85	.12
ILC	.26	1.02	.75	.30
WGB	.44	1.21	.99	-.01
GSL	-.04	.31	1.26	-.34
ESS	.09	.69	.66	-.16
WSS	.12	.45	.00	-.87
GOM	-.73	.49	-.24	-.07
GB	-.76	-.03	-.58	-.43
SNE	-.60	.64	-1.18	.17
MAB	-.76	.07	-.89	-.18
ESW	-.21	-.03	-.44	-.22
WSW	-.10	-.85	-1.05	-.63
GS	-.34	.07	-.59	.22
SS	-.29	-.39	-.35	.11

Table 5. Statistics on warm-core Gulf Stream Eddies west of 60°W longitude.

	Zone								
	1	2	3	4	5	6	7	8	Total
Number Generated 1976-81	10	14	10	9	4	2	0	0	49

	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Number Generated 1976-81	2	1	4	7	6	8	2	5	1	6	3	4
Standing Crop (6-yr total)	17	15	14	18	24	24	23	22	18	20	15	16
6-yr Mean	2.8	2.5	2.3	3.0	4.0	4.0	3.8	3.7	3.0	3.3	2.5	2.7

	Year						
	1976	1977	1978	1979	1980	1981	1982
Number Generated	7	8	9	10	8	7	11

Table 6 Mean monthly significant wave height (H_{sig}) in meters from 1970 to 1982 including mean for 11-year period, 1970-80. Upper table is for Labrador Sea (575°N, 52.5°W), middle table, Grand Banks (47.5°N, 47.5°W), and lower table, Scotian Shelf (42.5°N, 62.5°W). Data derived from 12-hour wave charts produced by METOC and extracted at 5° intervals by Atlantic Oceanographic Laboratory, B.I.O.

LABRADOR SEA

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	3.29	2.98	2.58	2.42	1.84	1.62	1.39	1.97	2.52	2.77	2.37	3.44
1971	2.32	2.59	3.27	2.15	1.58	2.22	1.63	2.00	2.35	2.97	2.83	3.15
1972	3.71	3.69	2.03	2.33	1.85	1.42	1.73	2.02	2.62	2.71	2.88	3.45
1973	3.37	2.84	2.97	2.45	1.34	1.80	1.65	1.48	2.50	2.81	3.12	3.08
1974	3.61	2.64	3.82	2.42	1.85	1.68	1.34	2.00	1.90	3.18	2.83	2.48
1975	2.52	2.77	2.63	2.55	2.05	1.65	1.55	1.81	2.37	3.06	3.12	3.61
1976	2.95	2.83	3.89	2.30	1.90	1.95	1.97	2.15	2.42	3.35	3.80	4.35
1977	4.56	3.39	3.19	2.55	2.19	2.02	2.18	1.97	3.00	2.79	3.77	4.35
1978	3.95	4.36	4.79	3.70	2.66	2.00	1.85	2.68	2.82	3.52	4.55	4.50
1979	3.35	4.43	3.03	2.78	2.40	2.00	2.08	2.26	3.52	3.79	3.68	3.94
1980	4.87	4.36	3.00	2.47	2.53	1.93	1.87	1.79	2.15	3.55	3.45	3.73
1981	3.73	3.00	3.16	2.98	2.16	1.97	2.45	1.90	2.68	3.90	3.43	3.56
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
70-80 Mean	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

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	3.50	2.79	2.50	2.68	1.77	1.92	1.68	2.13	2.43	2.65	2.34	3.55
1971	3.77	2.64	2.69	2.55	2.02	2.18	2.05	2.24	2.34	3.11	2.78	3.84
1972	3.63	3.26	2.21	3.05	2.08	1.96	1.55	2.05	2.65	2.69	3.95	4.16
1973	2.58	2.71	1.92	2.32	1.61	2.20	1.90	2.47	2.50	3.60	3.59	2.97
1974	4.52	3.30	2.85	2.25	2.08	1.75	2.05	1.81	2.42	2.77	2.80	4.23
1975	3.55	3.04	2.08	2.67	2.92	1.93	1.69	2.19	2.61	4.03	3.68	3.71
1976	3.98	3.62	3.03	3.13	2.13	2.39	1.85	2.11	2.40	3.32	3.77	4.21
1977	4.08	3.64	3.13	2.40	2.23	1.96	2.11	2.13	3.25	3.21	3.46	4.58
1978	3.87	4.66	4.50	3.20	2.44	2.23	2.02	2.35	3.30	3.27	3.34	4.56
1979	3.82	3.80	3.11	3.10	2.24	1.65	2.26	1.98	3.05	3.10	3.35	3.94
1980	4.03	4.84	3.65	3.18	2.94	2.58	2.19	2.90	3.27	3.29	4.43	3.87
1981	3.65	3.16	4.15	3.52	2.24	2.52	2.31	2.35	3.04	2.98	3.85	3.87
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
70-80 Mean	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

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1970	2.35	2.75	2.31	2.08	1.53	1.43	1.32	1.68	1.48	1.65	2.20	2.58
1971	2.53	2.41	3.06	2.28	1.79	1.45	1.39	1.68	1.30	1.63	2.83	2.48
1972	2.48	2.98	2.63	2.20	1.73	1.62	1.27	1.32	1.53	2.11	3.18	2.92
1973	2.71	2.89	2.45	2.48	1.76	1.67	1.60	1.58	1.80	2.11	2.63	2.48
1974	1.94	3.07	2.92	2.18	1.73	1.58	1.47	1.55	1.88	2.06	2.53	3.03
1975	2.65	2.16	2.56	2.38	1.50	1.58	1.84	1.27	1.65	2.15	2.15	2.58
1976	2.60	2.74	2.45	2.12	1.94	1.53	1.42	1.73	1.65	2.52	2.95	3.39
1977	3.27	2.61	2.55	2.23	2.00	1.82	1.53	1.50	2.03	2.32	2.40	3.32
1978	3.81	2.73	3.18	2.78	2.08	2.08	1.66	1.71	1.97	2.24	2.47	3.50
1979	3.50	2.98	2.97	2.48	2.08	1.73	1.74	1.85	2.07	2.50	2.45	3.50
1980	4.15	3.12	3.74	2.65	1.89	2.20	1.98	1.97	2.03	2.48	3.82	3.18
1981	3.58	3.38	3.71	3.17	2.42	1.77	1.73	1.61	3.23	2.40	3.22	3.52
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
70-80 Mean	2.91	2.77	2.80	2.35	1.82	1.70	1.57	1.62	1.76	2.16	2.69	3.00

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Table 7. Monthly means, standard deviations and number of observations of the adjusted sea levels (in m) for St. John's during the period 1957-80 and for Halifax during the period 1953-80.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. John's	0.82	0.80	0.76	0.73	0.72	0.72	0.71	0.74	0.81	0.84	0.83	0.83
	0.05	0.06	0.04	0.06	0.09	0.08	0.03	0.04	0.04	0.04	0.04	0.06
	23	24	24	24	24	24	22	23	23	23	23	24
Halifax	1.29	1.26	1.25	1.23	1.23	1.23	1.22	1.22	1.26	1.29	1.31	1.29
	0.04	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.06
	28	28	28	28	28	28	28	27	28	27	28	27

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Table 8. Monthly means and the standard deviations of air temperature (in °C) for the period 1951-80.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hopedale	-15.9	-15.4	-11.0	-4.9	1.4	6.4	10.5	10.8	7.3	2.0	-3.4	-11.3
	4.1	3.6	3.6	2.6	1.4	1.6	1.5	1.2	1.1	1.2	1.7	3.5
St. John's	-3.9	-4.4	-2.3	1.2	5.4	10.9	15.	15.3	11.6	6.9	3.4	-1.5
	2.0	2.5	1.6	1.4	1.4	1.6	1.5	1.5	1.0	0.8	1.5	1.9
Grindstone	-5.8	-7.3	-3.9	0.5	5.8	11.6	16.5	16.9	12.9	7.6	2.8	-2.6
	2.2	2.6	1.7	1.4	1.1	0.9	1.2	1.1	1.0	1.0	1.3	1.8
Sable Island	0.1	-1.0	0.7	3.3	6.7	10.9	15.5	17.5	15.7	11.5	7.1	2.5
	1.5	1.7	0.8	1.1	1.1	0.9	1.0	1.0	0.9	0.9	1.3	1.6
Shearwater	-4.1	-4.5	-0.8	4.0	8.9	13.8	17.4	17.8	14.5	9.6	4.6	-1.5
	2.1	2.0	1.3	1.2	1.0	0.8	1.0	0.9	1.0	1.1	1.4	2.2
Eastport	-5.1	-4.8	-0.3	4.8	9.8	14.0	17.0	17.0	13.8	9.1	4.1	-2.5
	2.3	1.8	1.4	0.9	1.1	0.9	1.0	0.8	0.8	1.0	1.3	2.3
New Haven	-1.5	-0.7	3.6	9.1	14.5	19.7	23.0	22.4	18.5	12.7	7.0	0.9
	2.3	1.9	1.8	1.4	1.5	1.2	1.2	1.4	1.5	1.4	1.6	2.2
Ottawa	-10.8	-9.4	-2.9	5.5	12.8	18.0	20.6	19.2	14.3	8.1	1.2	-7.6
	2.5	2.5	2.1	1.5	2.0	1.1	1.2	1.3	1.4	1.6	1.7	2.9

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Table 9. The monthly mean vector speeds (m s^{-1}) and directions (to the nearest tenth) for the period 1955-80.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Grindstone	4.4	3.5	2.6	1.4	1.2	2.3	3.4	2.8	2.9	3.2	3.2	3.7
	290	290	300	310	270	220	230	250	270	280	290	290
Sable Island	3.3	3.0	2.0	1.2	1.4	2.3	2.9	2.2	3.5	1.9	1.8	2.9
	290	290	310	280	230	210	210	230	260	270	280	290

Table 10. Monthly means, standard deviations and number of observations of the geostrophic winds (in ms^{-1}) for the period 1953-1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Gander-Goose Bay	-3.1	-2.1	-3.6	-2.6	0.3	3.3	5.2	4.1	3.7	2.4	1.5	-1.3
	4.2	3.5	3.8	2.9	3.1	1.8	1.7	1.8	1.7	1.9	2.9	3.3
	28	28	28	28	28	28	28	28	28	28	28	28
Sable Island-St. Mary's	1.4	1.1	0.4	1.9	3.4	5.4	6.0	4.4	2.8	2.6	1.9	1.8
	2.4	2.8	3.6	3.0	2.6	2.2	1.8	2.3	1.6	1.8	3.1	2.4
	25	25	25	25	25	25	25	25	25	26	26	26
North Sydney-Gander	4.0	3.6	2.8	1.7	1.1	0.8	0.7	1.3	2.3	2.6	2.0	3.2
	3.3	3.5	2.9	2.6	1.9	1.8	1.5	1.1	1.5	1.3	2.6	2.5
	28	28	28	28	28	28	28	28	28	28	28	28
Yarmouth-North Sydney	4.2	3.7	3.2	2.1	1.4	1.3	1.5	2.2	2.4	2.8	2.5	3.9
	3.1	2.6	2.2	2.2	1.8	1.7	1.0	1.1	1.2	1.3	2.3	2.4
	28	28	28	28	28	28	28	28	28	27	27	28

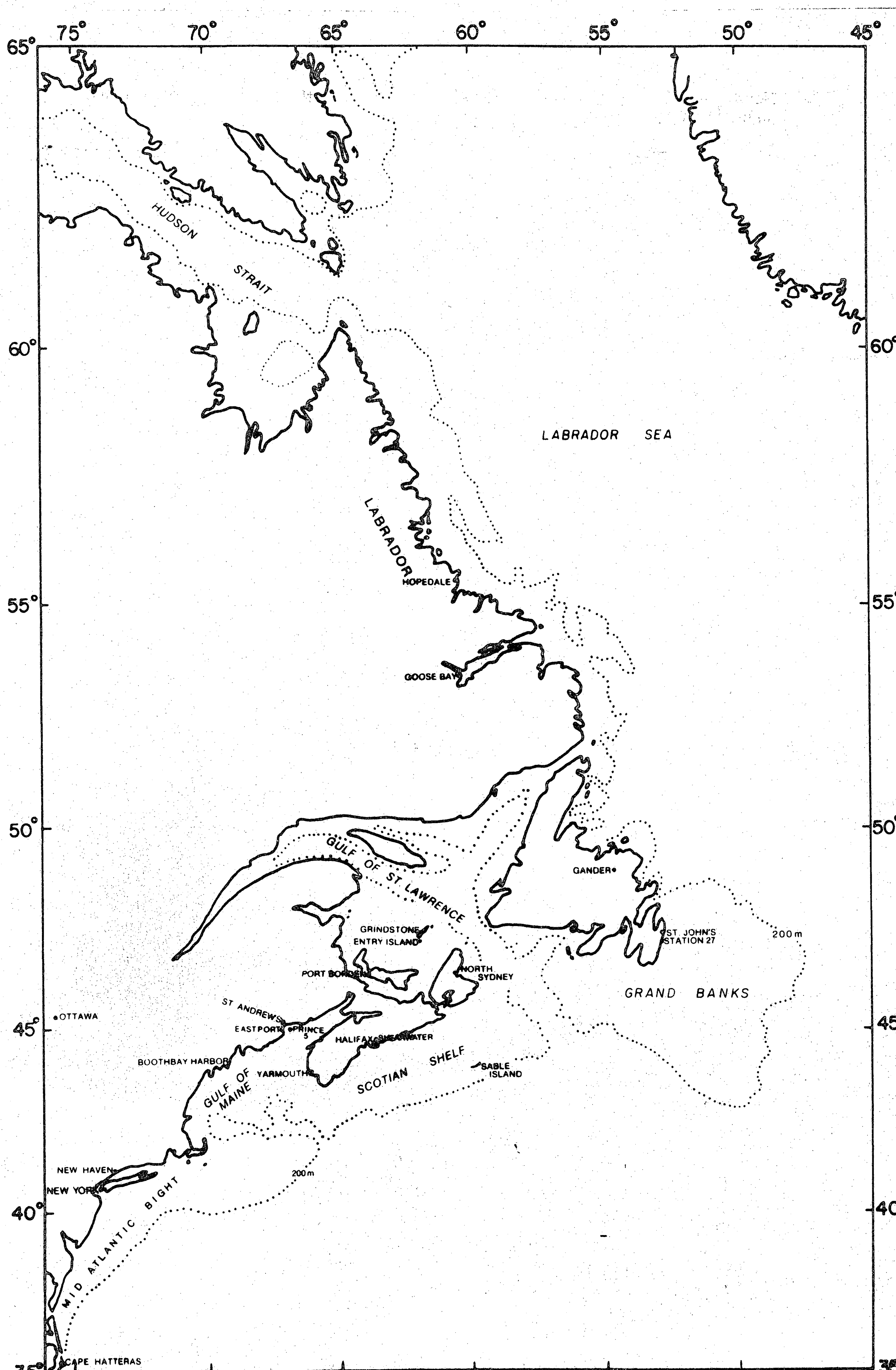

Figure 1 Map of NAFO area showing location of oceanographic and meteorological stations.

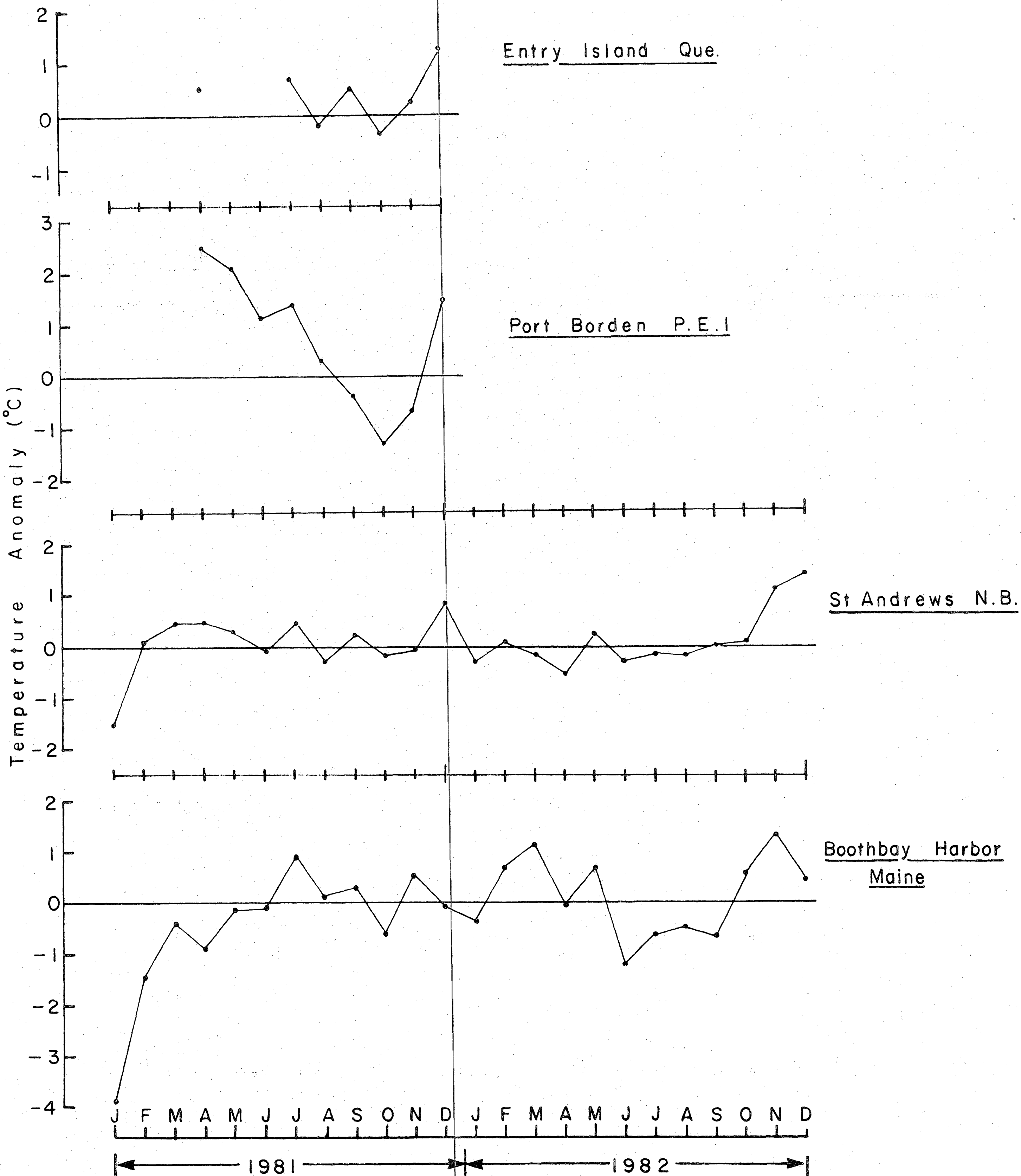

Figure 2 Monthly SST anomalies at coastal stations for 1981-82 from the base period 1951-80.

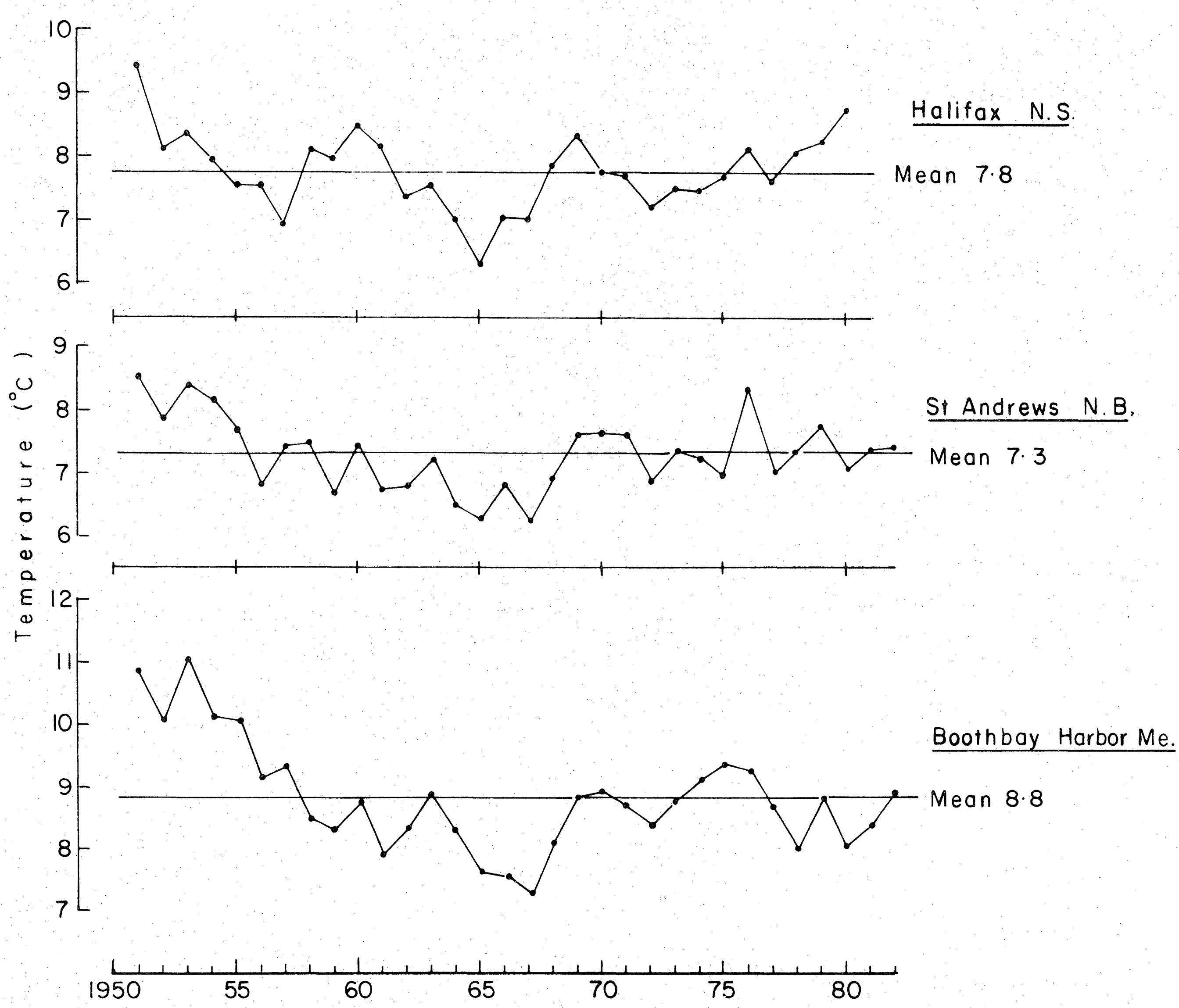

Figure 3 Annual means of SST for coastal stations. The overall means are based on the period 1951-80.

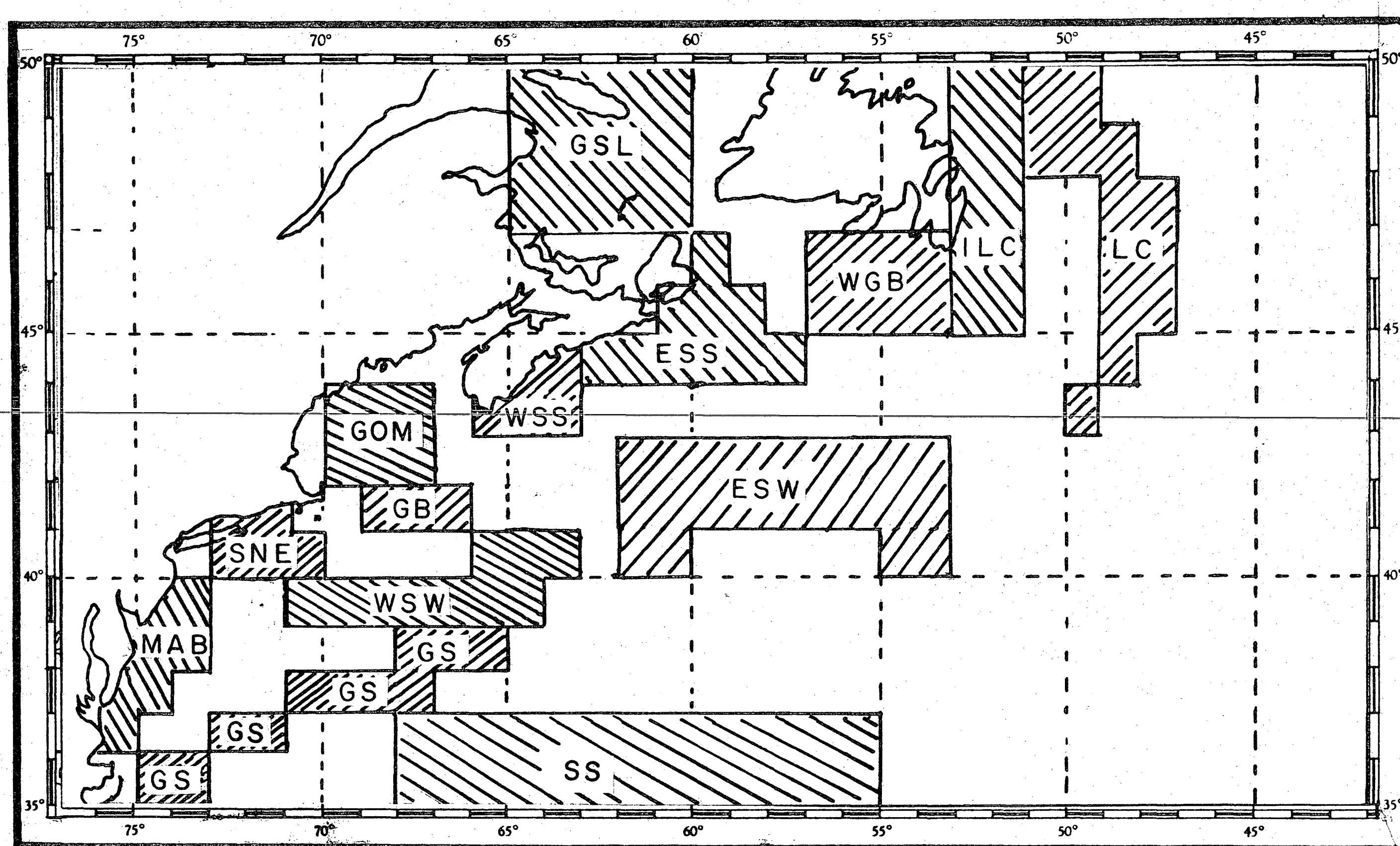

Figure 4 Map delineating geographic boundary of 14 subareas where sea surface temperatures received by teletype at FNOC (Monterey, Cal.) have been analyzed on a monthly basis for period 1971-82.

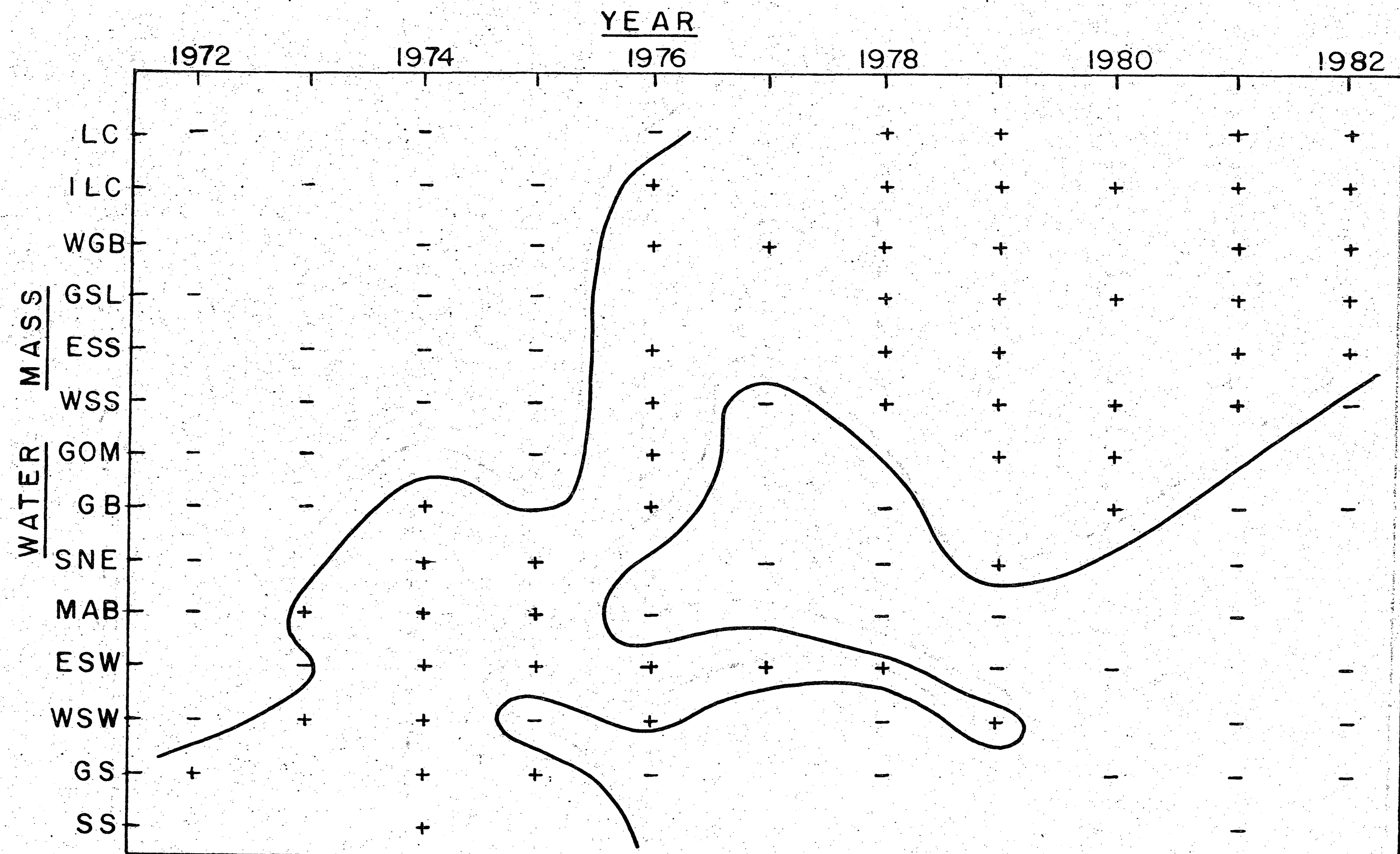

Figure 5 Map of sea surface temperature mean annual anomaly (from the 1972-80 base period) for the 14 subareas shown in Figure 4, for the 1972-82 period. In contouring the positive and negative areas, only anomalies $\geq 0.15^{\circ}C$ have been utilized.

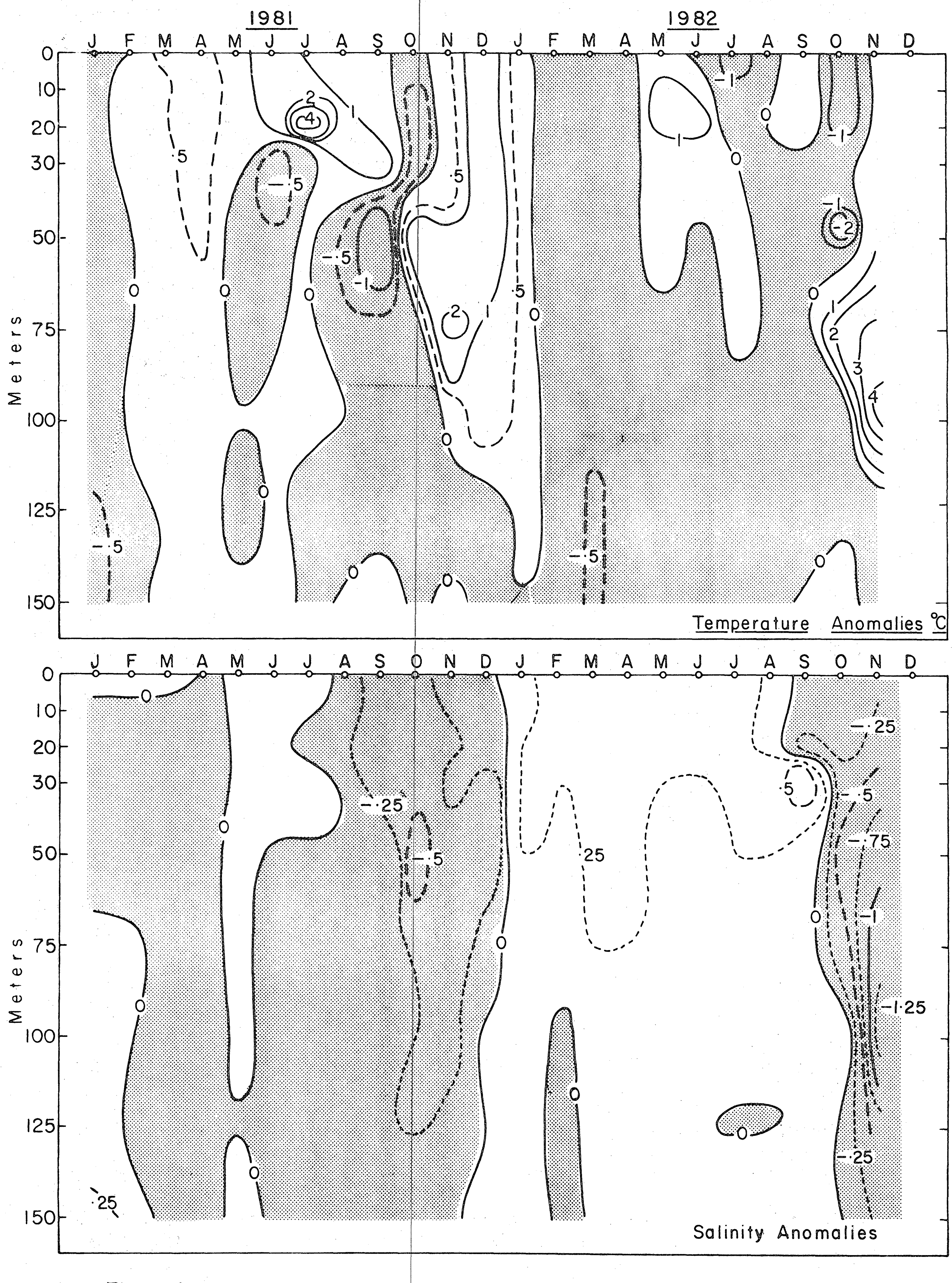

Figure 6 The monthly temperature and salinity anomalies for station 27 during 1981-82 from the base period 1946-77.

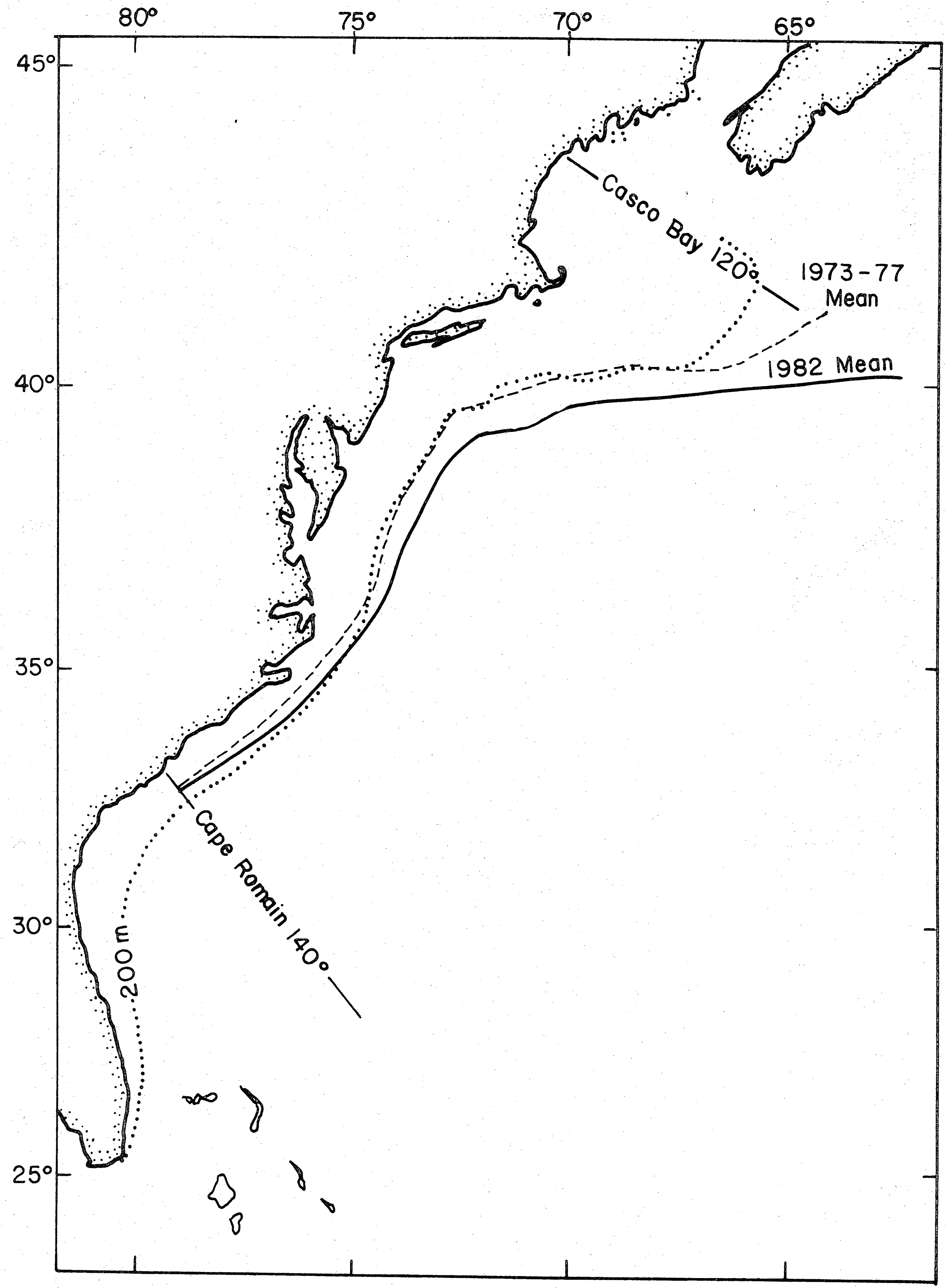

Figure 7 Map showing the mean location at the sea surface of the Shelf/Slope Front for the year 1982 and for the 1973-77 period. (Data taken from Armstrong, 1983.)

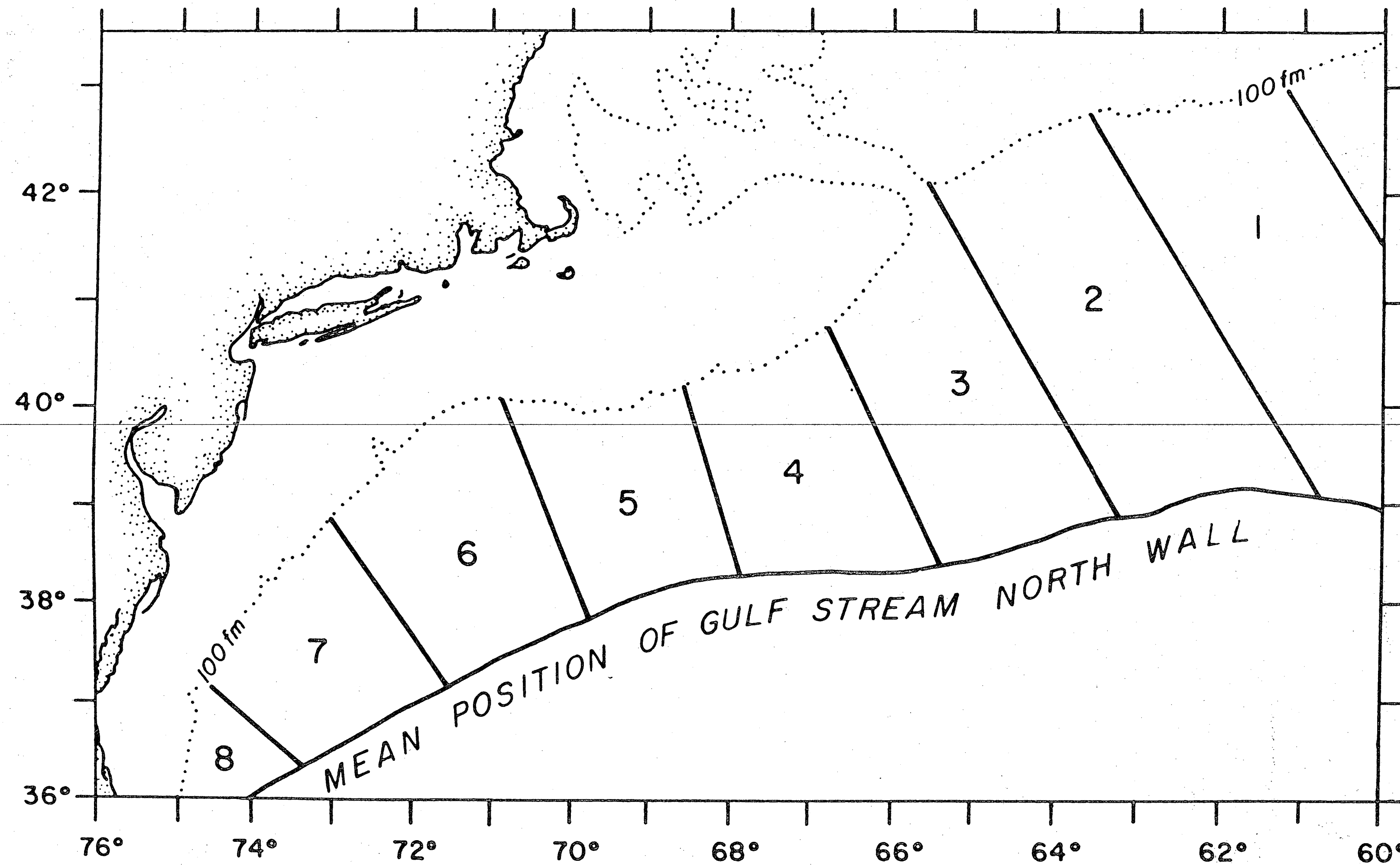

Figure 8 Location of the 8 zones used to compile statistics on warm-core Gulf Stream Eddies (from Fitzgerald and Chamberlin, 1980).

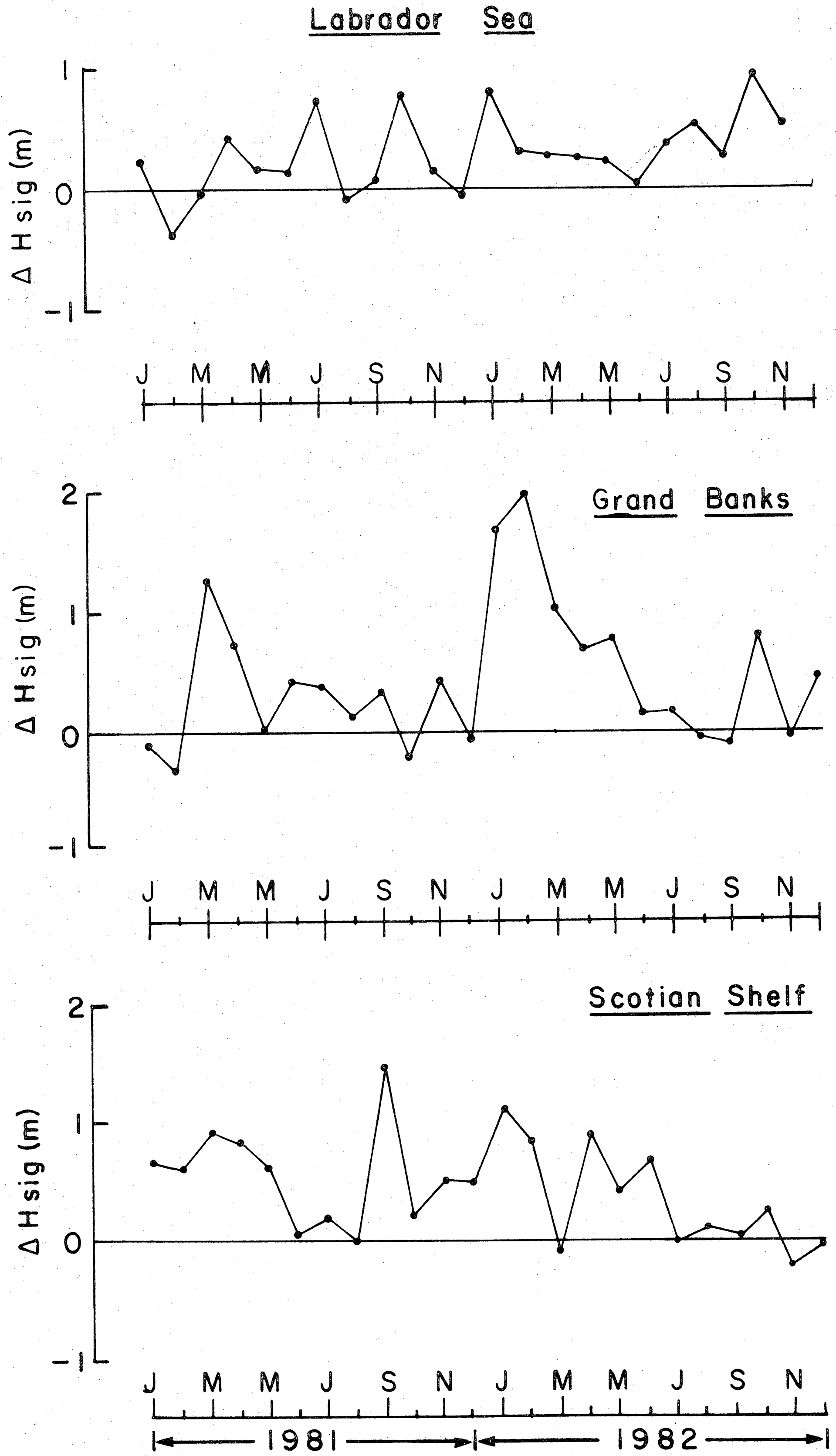

Figure 9 Monthly anomaly in significant wave height (ΔH_{sig}) for 1981-82 compared to the 1970-80 period for Labrador Sea (upper diagram), Grand Banks (middle diagram), and Scotian Shelf (lower diagram).

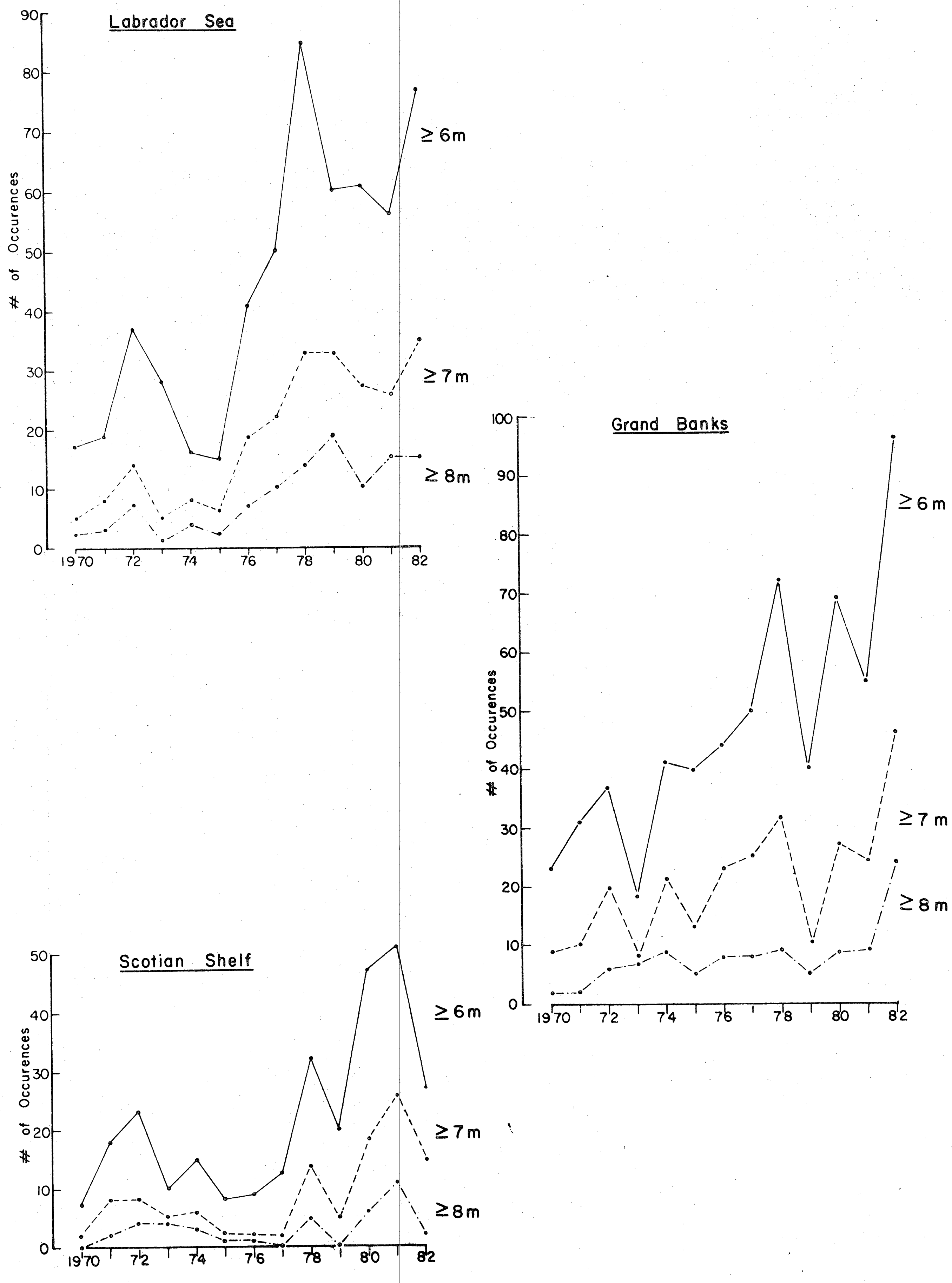

Figure 10 Number of occurrences (annually) of storms where waves equalled or exceeded 6M, 7M and 8M, for the Labrador Sea (upper diagram), Grand Banks (middle diagram), and Scotian Shelf (lower diagram) in the 1970-82 period.

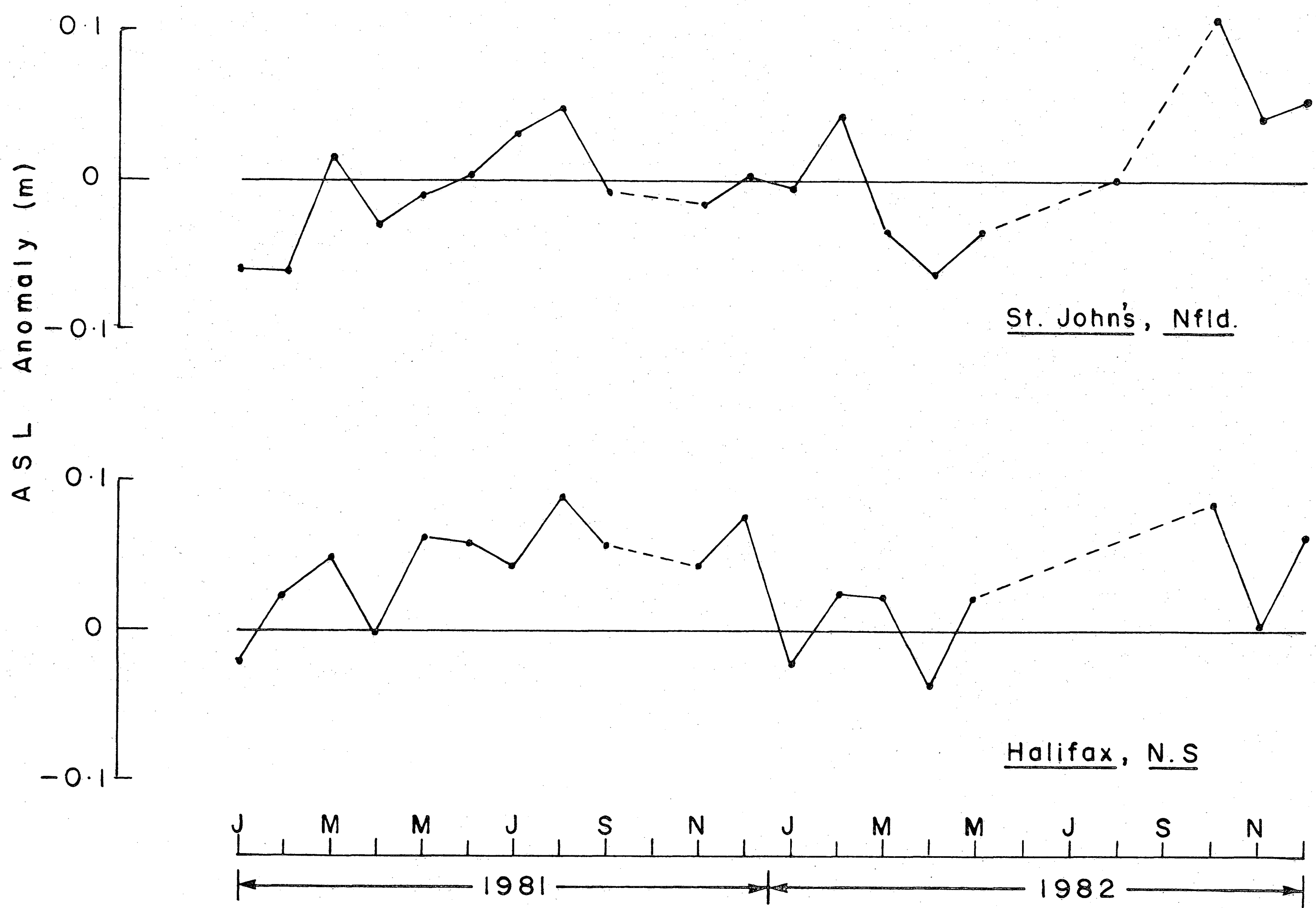

Figure 11 Monthly anomalies of the adjusted sea levels (ASL) for 1981-82 from the base period 1957-80 for St. John's and 1953-80 for Halifax.

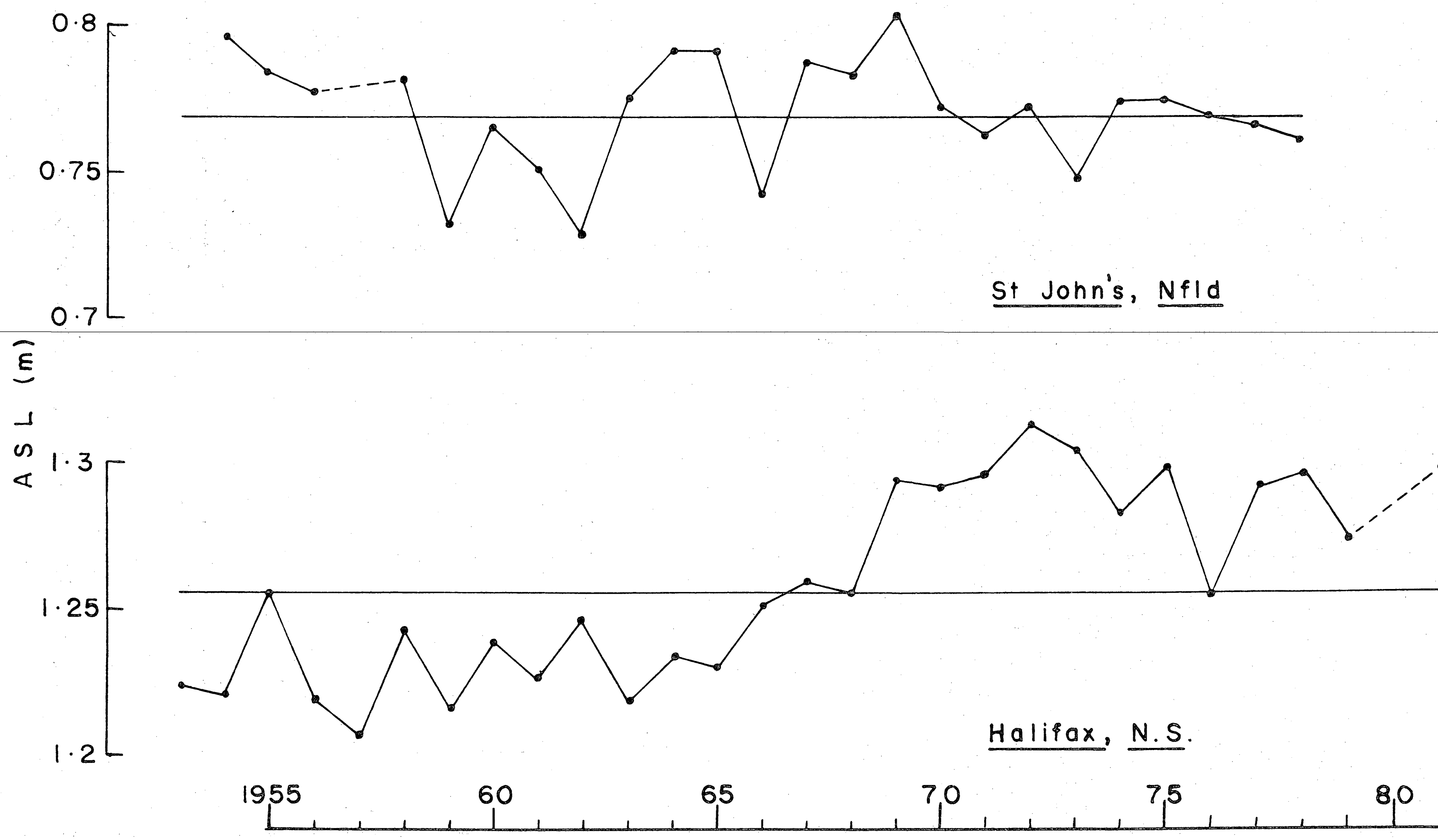

Figure 12 Annual means of ASL for St. John's and Halifax. The overall means are based on the period 1957-80 and 1953-80 respectively.

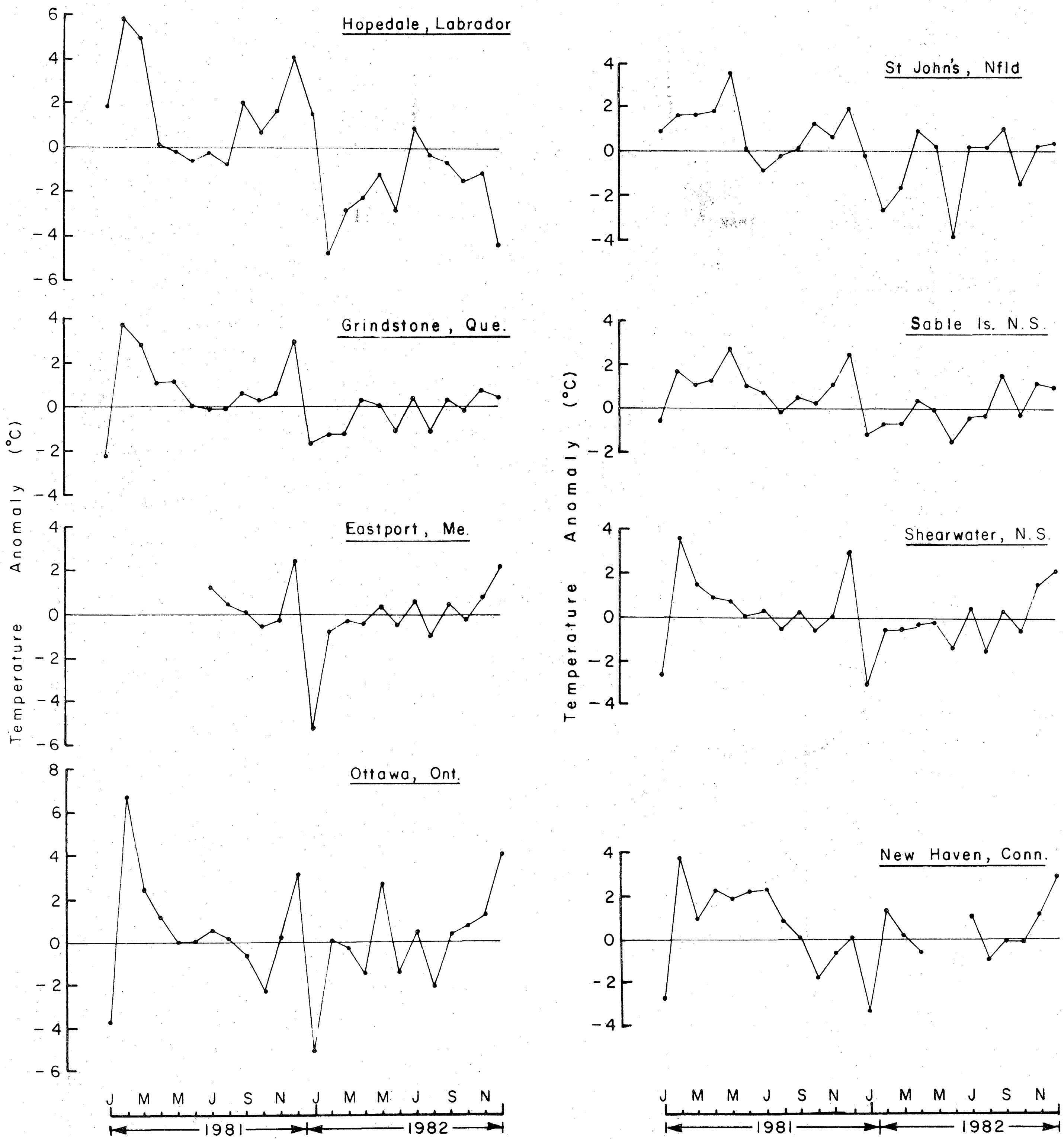

Figure 13 Monthly anomalies of air temperatures for 1981-82 from the base period 1951-80.

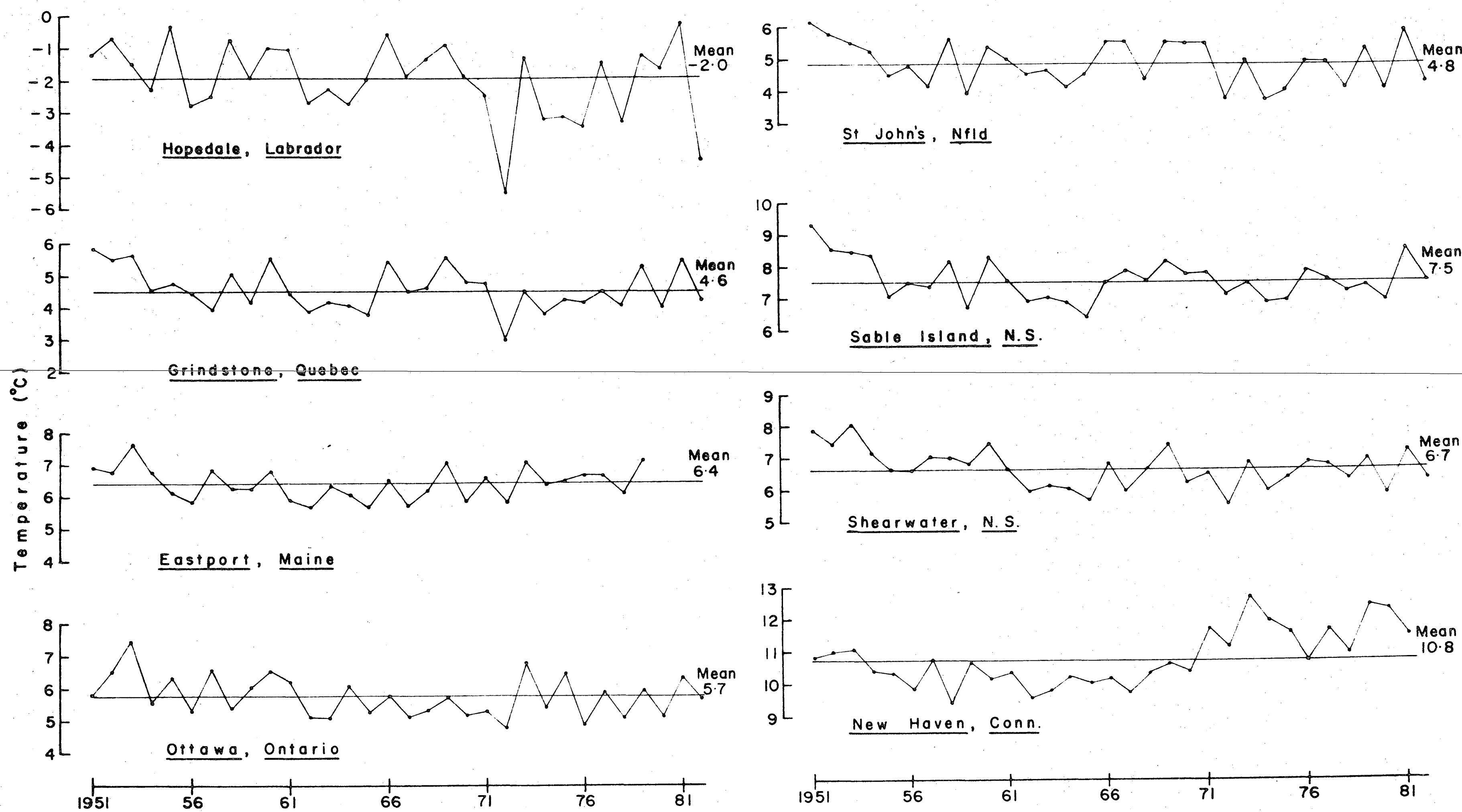

Figure 14 Annual means of air temperatures. The overall means are based on the period 1951-80.

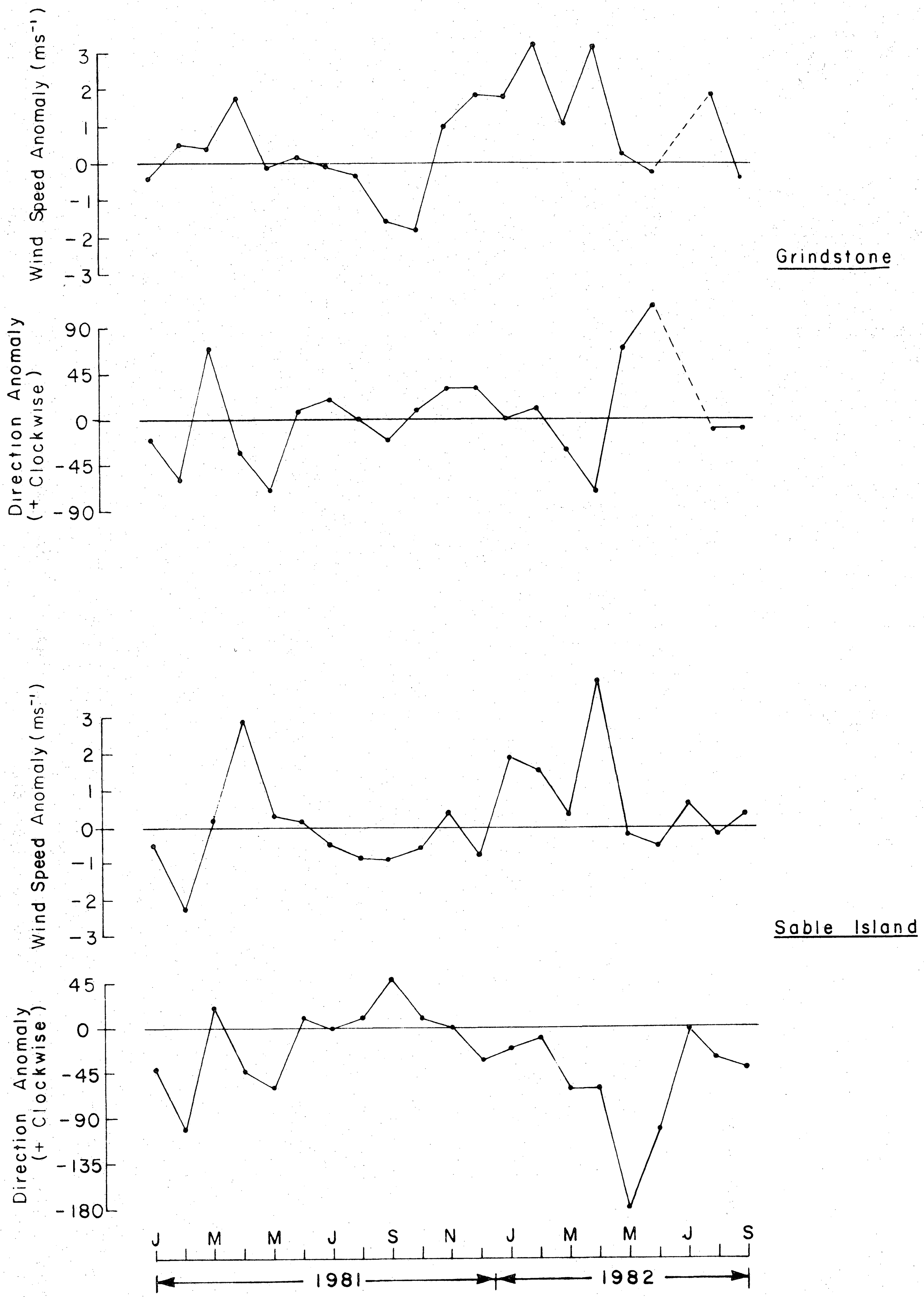

Figure 15 Monthly anomalies of the vector wind speeds and directions for 1981-82 from the base period 1955-80 at Grindstone and Sable Island.

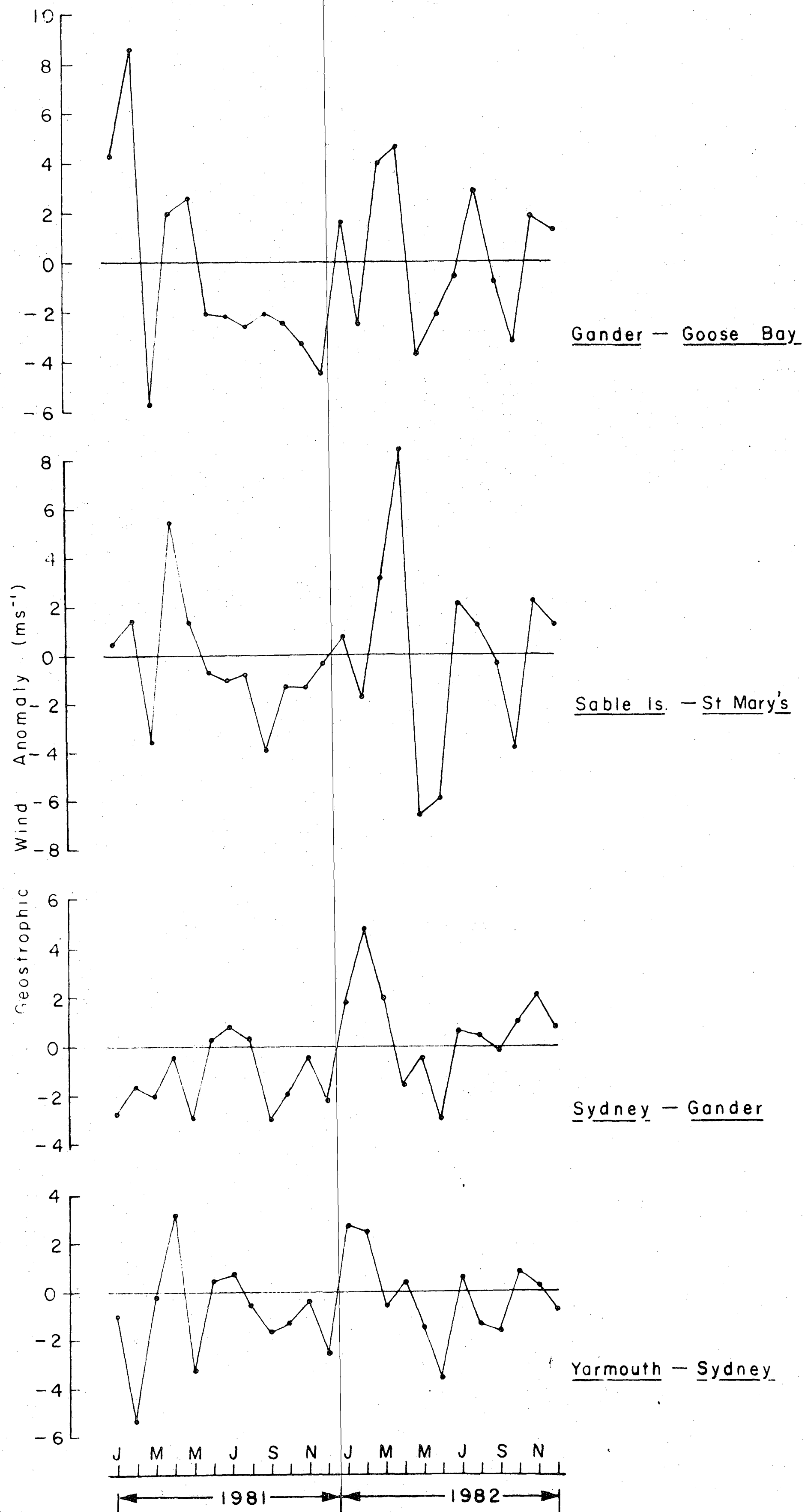

Figure 16 Monthly anomalies of the estimated geostrophic winds for 1981-82 from the base period 1953-80.

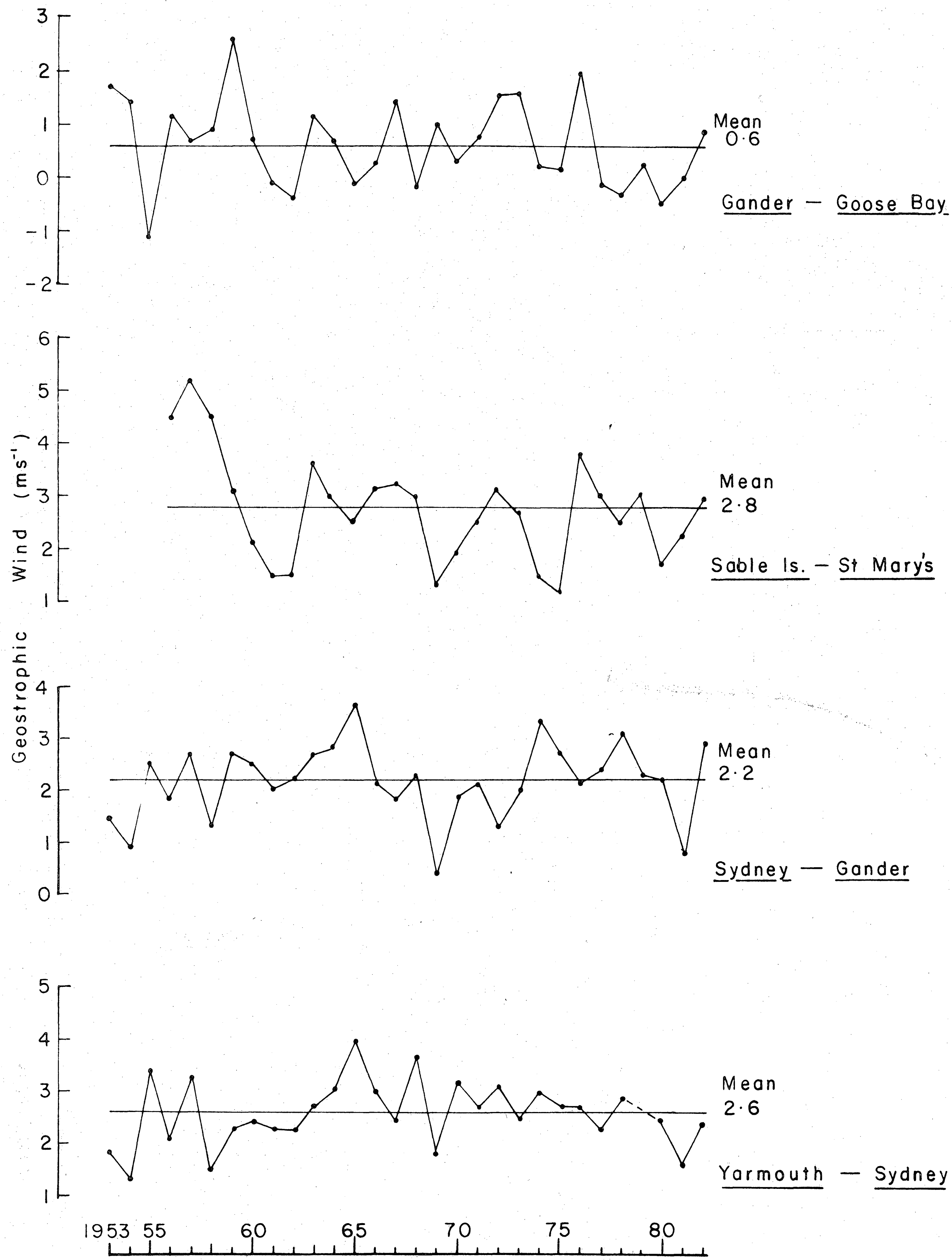

Figure 17 Annual means of the estimated geostrophic winds. The overall means are based on the period 1953-80.