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Overview of Environmental Conditions in the Northwest Atlantic in 1982

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

Abstract

Using principally time series of data such as those taken at fixed sites and the daily to weekly repetitive coverage of sea-surface conditions by satellites and ships of opportunity, an overview is presented of 1982 environmental conditions in the Northwest Atlantic. Comparisions are made to 1981 conditions and to longer-term reference periods. Where sufficiently long data sets exist, a 30-year period (1951-80) was chosen as the reference or base period. In general, conditions in 1982 were not significantly different from those observed in 1981 or from the long-term means where data were available. Analysis of sea-surface temperature patterns indicated that large-scale events and processes generally operate on time and space scales of years and several thousand kilometers respectively.

Introduction

At NAFO Scientific Council meetings, the Environmental Subcommittee annually faces the task of assessing environmental conditions during the previous calendar year. In preparing its report, the Subcommittee has relied almost exclusively on data contained in research documents and national research reports. Although this in itself has been viewed as a worthwhile exercise, it clearly falls short of general expectations for a number of reasons. Often it is difficult to combine data from an array of reports, 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 analysis at the time of the June meeting. Of even greater concern is how to deal with the aliasing problem, because often there may be only one hydrographic survey 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 interannual comparisons, because week to week changes within a year may often exceed between-year variability.

There are several environmental data sets which are rarely utilized in preparing the environmental overview but which would greatly enhance the usefulness and reliability of the assessment. Such data sets include (a) daily sea-surface temperatures from coastal stations (e.g. Halifax, St. Andrews, Boothbay Harbor) and from offshore waters (ships' weather reports, satellite infrared imagery), (b) subsurface temperature and salinity data from fixed stations (e.g. Station 27 off St. John's, Prince 5 in Bay of Fundy), (c) mean sea level from tide guages, (d) wave and swell data from ships of opportunity and (e) a variety of meteorological data, including air temperature, measured wind speed and direction, and geostrophic winds.

Although some of these comprehensive data sets are not available until many months have elapsed, others can be accessed quickly. This overview represents an initial attempt to utilize a few of these data sets. Additionally, data have been incorporated from research documents which were available at the time of preparing this report. If this "pilot" project is judged to provide significant improvement in evaluating environmental conditions in 1982, it should be feasible to make it more comprehensive in future years.

Reference Periods and Data Utilized

The aim of this paper is to assess environmental conditions by comparing values in 1982 with those in 1981 and with some long-term reference period. Where sufficiently long data sets exist, a 30-year period (1951-80) was chosen as the long-term reference period, which is the current period recommended for climate "normals" by the World Meteorological Organization. A number of data sets are shorter than this, and, consequently, shorter base periods (within the 1951-80 period) were used in these instances. The basic data sets used in this report are listed in Table 1. Summarized data for several of the parameters are included in tabular form so as to be readily available to other interested investigators. The region covered by this overview of environmental conditions together with locations of oceanographic and meteorological stations are shown in Fig. 1.

TABLE 1. Oceanographic and meteorological data sets utilized in preparing the environmental overview.

Data set	Sampling frequency	Period of observations	Normal period
Oceanographic Data Sets			
Sea-surface temperature (coastal)			
— Entry Island, Quebec	2/day	1930-81	1951-80
— Port Borden, Prince Edward I.	"	1951-81	1951-80
— Halifax, Nova Scotia	"	1926-82	1951-80
— St. Andrews, New Brunswick	"	1921-82	1951-80
— Boothbay Harbor, Maine	"	1906-82	1951-80
Sea-surface temperature (offshore) 35°-50°N, 47°-76°W[a]	1/day	1971-82	1972-80
Subsurface temperature			
— Station 27 (off St. John's)	1-5/month	1947-82	1947-77
Sea-level elevation			
— St. John's, Newfoundland	1/hr	1957-82	1957-80
— Halifax, Nova Scotia	"	1920-82	1951-80
Waves	2/day	1970-82	1970-80
Shelf-slope front and warm-core eddies[b]	1-3/week	1973-82	1973-77
Meteorological Data Sets			
Air temperature			
— Hopedale, Labrador	1/hr	1942-82	1951-80
— St. John's, Newfoundland	"	1942-82	1951-80
— Grindstone, Quebec	"	1934-82	1951-80
— Sable Island, Nova Scotia	"	1915-82	1951-80
— Shearwater, Nova Scotia	"	1945-82	1951-80
— Eastport, Maine	"	1874-1982	1951-80
— New Haven, Connecticut	"	1780-1982	1951-80
— Ottawa, Ontario	"	1890-1982	1951-80
Wind velocity and direction			
— Grindstone, Quebec	1/hr	1955-82	1955-80
— Sable Island, Nova Scotia	"	1955-82	1955-80
Atmospheric pressure			
— Goose Bay, Labrador	4/day	1953-82	1953-80
— Gander, Newfoundland	"	1953-82	1953-80
— North Sydney, Nova Scotia	"	1953-82	1953-80
— Sable Island, Nova Scotia	"	1955-82	1955-80
— Shearwater, Nova Scotia	"	1953-82	1953-80
— Yarmouth, Nova Scotia	"	1953-82	1953-80

[a] Source: Teletype, FNOC, Monterey, California.
[b] Source: Satellite imagery, U. S. National Weather Service.

Oceanographic Observations

Coastal sea-surface temperatures

From the long-term records of sea-surface temperatures at Entry Island, Port Borden, Halifax, St. Andrews and Boothbay Harbor (Fig. 1), monthly averages and their standard deviations were calculated for the 1951-80 base period (Table 2). Winter data (January-April) were often not available for Entry Island and Port Borden in the Gulf of St. Lawrence due to ice cover, and, unfortunately, these stations ceased operations in 1981. Monthly anomalies from these means were determined for the 1981 and 1982 data, except for Halifax where instrument errors resulted in data of questionable quality.

The monthly anomalies of data for St. Andrews show that sea-surface temperatures were 1.5°C below the 30-year norm in January 1981, near normal from February 1981 to October 1982, and above normal (>1°C) for the last 2 months of 1982 (Fig. 2). A similar trend of low temperatures in early 1981 and high temperatures near the end of 1982 was observed at Boothbay Harbor, but fluctuations from the 30-year norm were greater than those for St. Andrews during the remainder of the period. This is consistent with

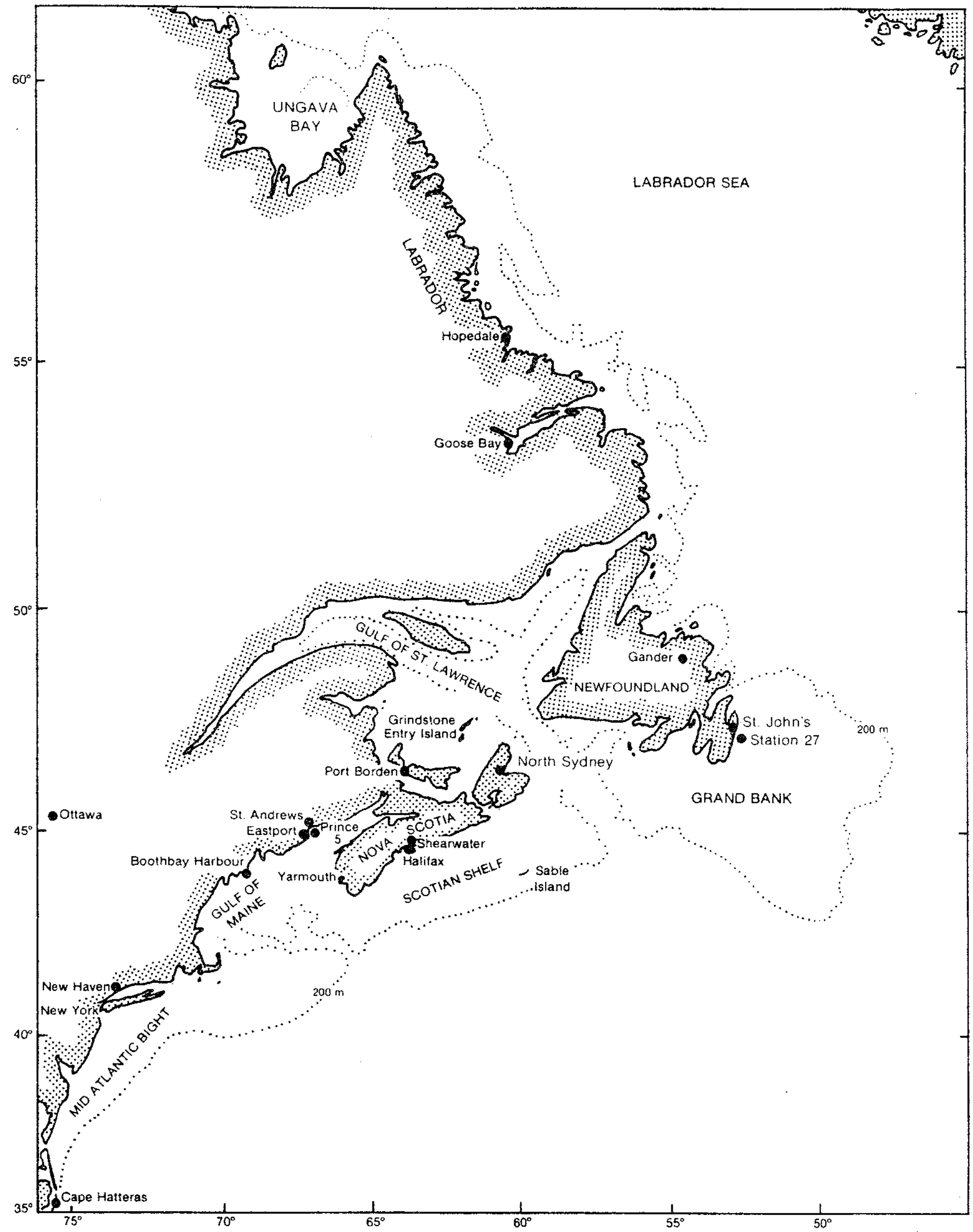

Fig. 1. The Northwest Atlantic showing oceanographic and meteorological stations.

larger monthly standard deviations at Boothbay Harbor than at St. Andrews (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 1981 anomalies show a decrease in sea-surface temperature from April to October at Port Borden, followed by an increasing trend in November and December. Data were incomplete for Entry Island, but no trend is evident except for the increase in December 1981, as was observed at Port Borden.

The yearly means for Halifax, St. Andrews and Boothbay Harbor (Fig. 3) decreased from above normal values in the early 1950's to below-normal values in the mid-1960's, as noted in earlier studies (Lauzier, 1965; Sutcliffe *et al.*, 1976). The annual means for 1981 and 1982 at St. Andrews and Boothbay Harbor were near their 1951–80 averages, continuing the pattern of the 1970's. Lack of winter data prohibited calculation of annual means for Entry Island and Cape Borden, but means for the May–October period were near normal in 1981. From a study of sea-surface temperature data for coastal stations, Akenhead *et al.* (1981) noted that such data may represent trends fairly well but, for periods of a year or less, they may only be representative of the local areas.

TABLE 2. Monthly mean sea-surface temperature (°C), standard deviations, and numbers of years of available data for coastal stations, 1951–80.

	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
	0.9	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

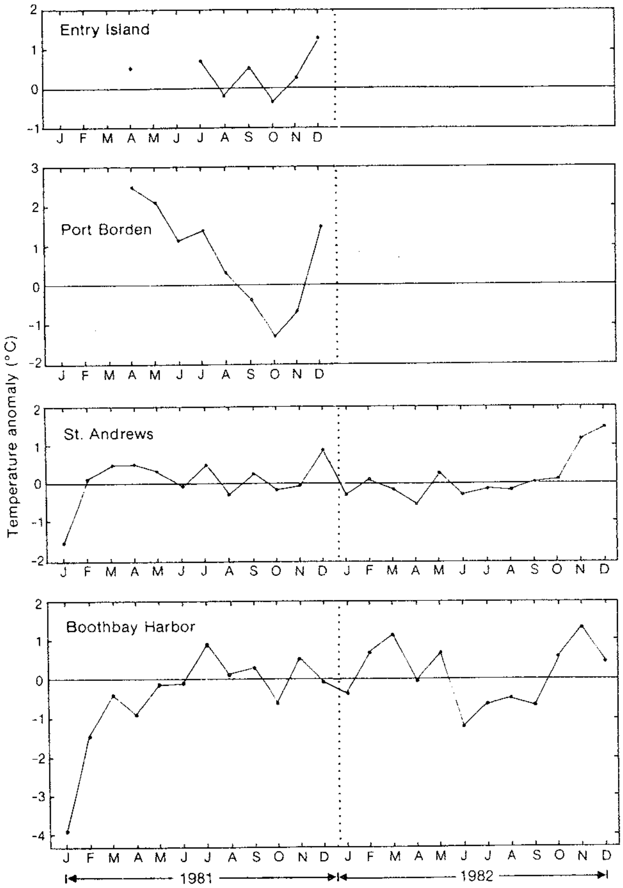

Fig. 2. Monthly sea-surface temperature anomalies at the coastal stations during 1981-82 relative to the means for the 1951–80 base period.

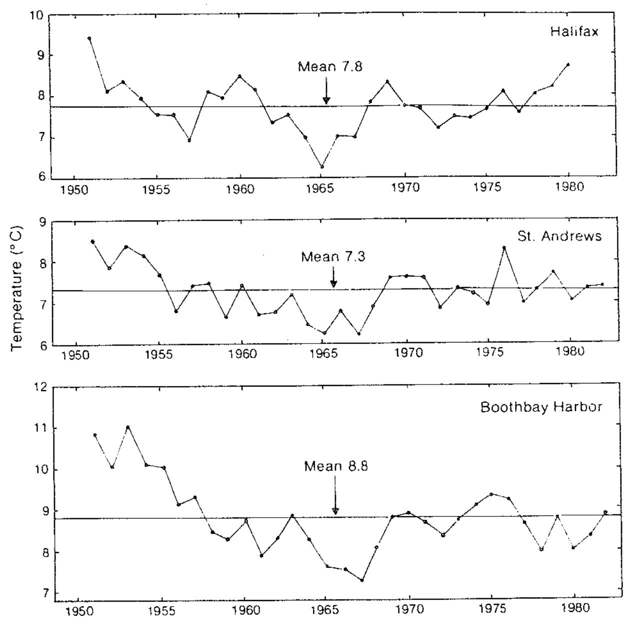

Fig. 3. Annual mean sea-surface temperatures at coastal stations in 1951–82 including the mean for the 1951–80 base period.

Offshore sea-surface temperatures

The largest data base of sea-surface temperatures, derived principally from cooling water intake temperatures of merchant vessels, is accumulated from radio weather messages and logbook records transmitted to the U.S. Fleet Numerical Oceanography Center (FNOC) and the National Climate Center. The "real-time" data reports, provided by radio messages, are analyzed by FNOC and the Pacific Environmental Group of the National Marine Fisheries Service. Computations include average monthly temperatures and anomalies (from 1948–67 means) for each 1° x 1° quadrangle for which enough data have been reported in each month.

Sea-surface temperatures (SST) for 1982 within the region bounded by 35°–46° N latitude lines and 60°–77° W longitude lines were reported by Ingham and McLain (MS 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 sea-surface temperature anomalies reappeared in this area in OctoberDecember. 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 the 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 6-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 represent 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."

Analysis of sea-surface temperature data on a monthly and one-degree quadrangle basis typically displays relatively high spatial and temporal variability. Undoubtedly, some of this variability is real but some is the result of undersampling. On the assumption that major variation in offshore temperatures should be coherent over areas much larger than 1° quadrangles, 14 subareas within the region (35°-50° N, 45°-76° W) were identified for data-grouping (Fig. 4). The subareas were chosen (to within 1°) to coincide with the areas of major water masses or where T-S characteristics were thought to be relatively uniform (e.g. Labrador Current, Gulf Stream, Gulf of Maine). Monthly temperatures were computed for the period from March 1971 to December 1982 and were further

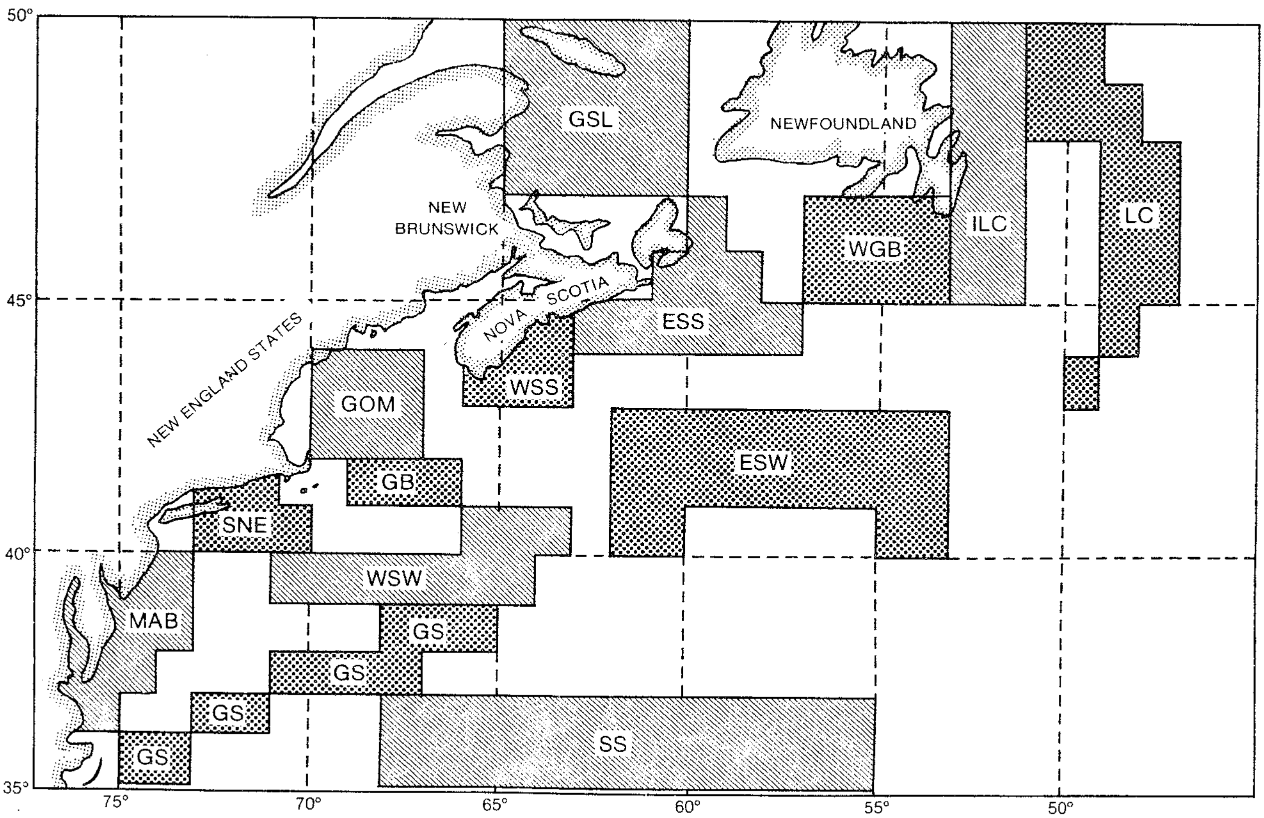

Fig. 4. Geographic boundaries of 14 subregions for which sea-surface temperatures received by teletype at FNOC (Monterey, California) have been analyzed on a monthly basis for the 1971-82 period. **LC** = Labrador Current; **ILC** = Inshore Labrador Current; **WGB** = West Grand Bank; **GSL** = Gulf of St. Lawrence; **ESS** = East Scotian Shelf; **WSS** = West Scotian Shelf; **ESW** = East Slope Water; **WSW** = West Slope Water; **GB** = Georges Bank; **GOM** = Gulf of Maine; **SNE** = Southern New England; **MAB** = Middle Atlantic Bight; **GS** = Gulf Stream; **SS** = Sargaso Sea.

TABLE 3. Annual sea-surface temperature anomalies for 1972-82 relative to the 1972-80 base period. (Geographic locations of water masses are shown in Fig. 4.)

Water mass	Surface water temperatures (°C)											1972-80 average
	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	
LC	-0.28	-0.07	-0.38	-0.12	-0.16	0.12	0.19	0.68	0.01	0.82	0.24	5.17
ILC	-0.06	-0.25	-0.57	-0.30	0.22	-0.11	0.27	0.61	0.20	0.96	0.40	4.83
WGB	0.05	-0.11	-0.33	-0.63	0.34	0.16	0.31	0.30	-0.08	1.19	0.19	6.13
GSL	-0.56	-0.00	-0.38	-0.22	0.11	0.10	0.25	0.48	0.22	0.49	0.41	5.40
ESS	-0.07	-0.28	-0.39	-0.43	0.27	0.03	0.35	0.49	0.03	0.66	0.26	7.30
WSS	0.14	-0.35	-0.43	-0.34	0.22	-0.15	0.27	0.29	0.35	0.41	-0.36	8.03
GOM	-0.17	-0.20	-0.05	-0.25	0.35	0.10	-0.11	0.39	-0.05	0.11	0.07	9.59
GB	-0.27	-0.36	0.23	0.00	0.72	-0.01	-0.50	0.00	0.19	-0.39	-0.46	10.17
SNE	-0.26	-0.11	0.56	0.17	-0.01	-0.31	-0.31	0.28	-0.01	-0.50	-0.03	12.23
MAB	-0.22	0.15	0.62	0.57	-0.52	-0.08	-0.36	-0.20	0.04	-0.43	-0.06	14.87
ESW	0.12	-0.41	0.31	0.23	0.16	0.34	0.25	-0.65	-0.33	-0.01	-0.28	15.85
WSW	-0.15	0.27	0.37	-0.17	0.15	0.02	-1.02	0.53	-0.01	-0.92	-0.48	18.50
GS	0.15	0.10	0.26	0.20	-0.15	0.03	-0.15	-0.04	-0.40	-0.26	-0.16	22.94
SS	-0.05	-0.10	0.15	0.10	-0.01	0.01	-0.09	0.11	-0.12	-0.38	-0.07	22.26

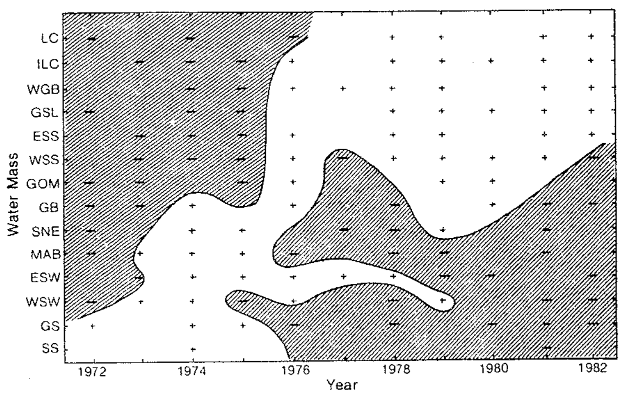

Fig. 5. Distribution of positive (+) and negative (-) annual sea-surface temperature anomalies in 1972-82 by water mass (see Fig. 4) relative to the means for the 1972-80 base period. (Only anomalies <-0.15°C and >0.15°C have been used.)

TABLE 4. Six-month sea-surface temperature anomalies (°C) for the period from October 1980 to September 1982, relative to the 1972-80 base period. (Geographic locations of water masses are shown in Fig. 4.)

Water mass	Oct 1980-Mar 1981	Apr 1981-Sep 1981	Oct 1981-Mar 1982	Apr 1982-Sep 1982
LC	-0.12	1.07	0.85	0.12
ILC	0.26	1.02	0.75	0.30
WGB	0.44	1.21	0.99	-0.01
GSL	-0.04	0.31	1.26	-0.34
ESS	0.09	0.69	0.66	-0.16
WSS	0.12	0.45	0.00	-0.87
GOM	-0.73	0.49	-0.24	-0.07
GB	-0.76	-0.03	-0.58	-0.43
SNE	-0.60	0.64	-1.18	0.17
MAB	-0.76	0.07	-0.89	-0.18
ESW	-0.21	-0.03	-0.44	-0.22
WSW	-0.10	-0.85	-1.05	-0.63
GS	-0.34	0.07	-0.59	0.22
SS	-0.29	-0.39	-0.35	0.11

grouped to provide semiannual and annual mean anomalies relative to the 1972-80 period.

The results of the analyses, which must be considered provisional because further checking is required to minimize errors, indicate that temperature changes are coherent over much larger areas than the subareas chosen (Fig. 5, Table 3) and that anomalies often tend to persist for a number of years, with appreciable coherence being displayed for the region northward from the Gulf of Maine. Likewise, temperature changes in the subareas from the Gulf of Maine southward to Cape Hatteras, including the warmer offshore water, showed a fair degree of coherence, with opposite phase to that of the northern subareas. In 1982, water in the northern subareas was generally warmer than the 9-year mean, whereas water in the southern subareas was cooler than normal.

During 1972-75, positive anomalies were present in the southern region and negative anomalies in the northern region (Table 3). In 1976, the situation appears to have been in the process of reversing. During 1977-82, above-normal annual mean temperatures occurred in the northern region and below-normal values generally occurred in the southern region. During the period from October 1980 to September 1982 (Table 4), positive (6-month) anomalies, which reached their maximum southern extent (to about the Middle Atlantic Bight) in April-September 1981, receded northward to the area of the Labrador Current a year later.

Temperature and salinity stations

Vertical profiles of temperature and salinity have been monitored approximately once per month or more frequently at Station 27 off St. John's, Newfoundland, since 1947, and at Prince 5 off St. Andrews in the Bay of Fundy since 1959. Recent data for Prince 5 were not available at the time of preparing this report, and hence only the data for Station 27 are considered here. These data have been analyzed and mean temperatures and salinities for the 1950-59 period (Huyer and

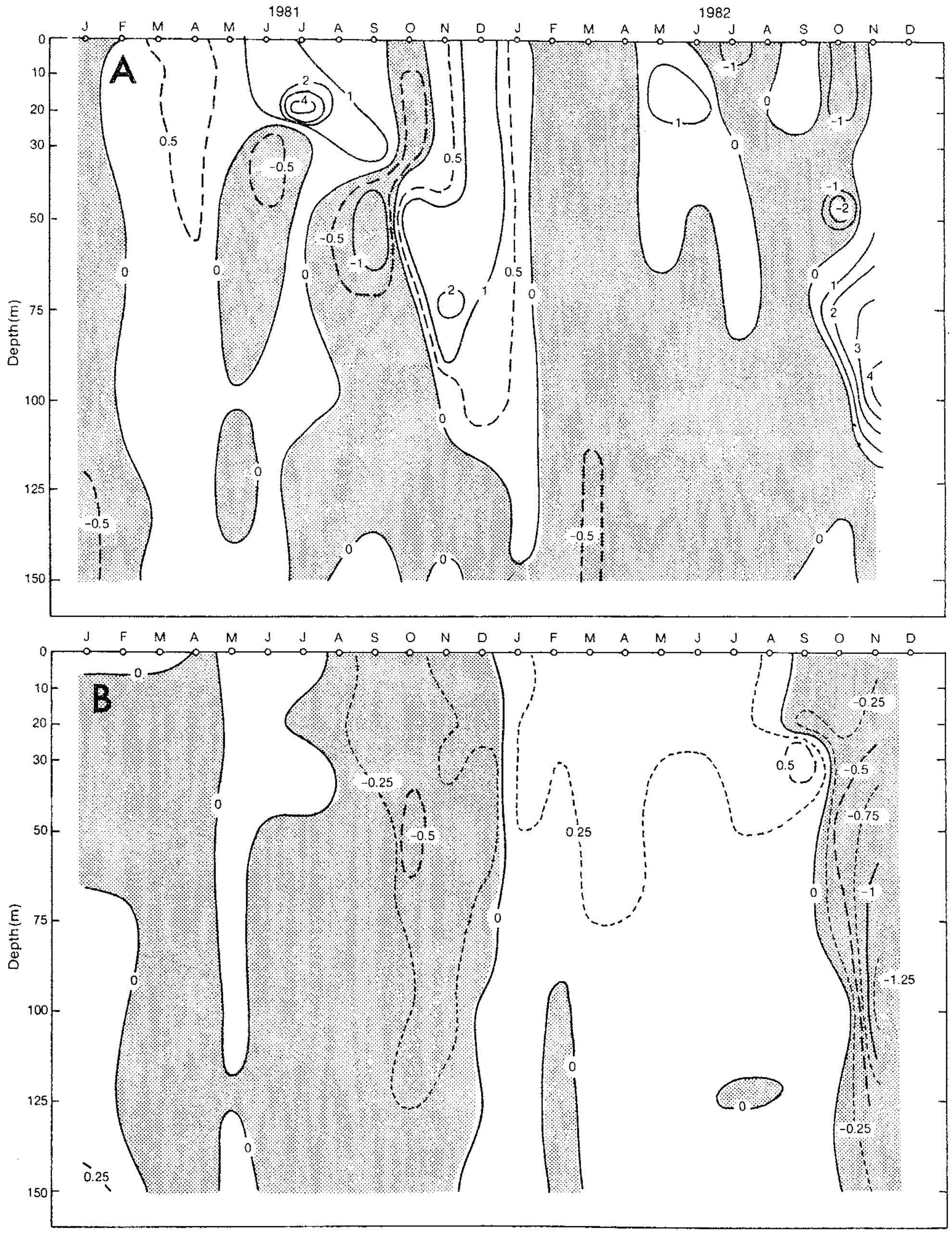

Fig. 6. Monthly temperature (**A**) and salinity (**B**) anomalies at Station 27 off St. John's, Newfoundland, during 1981–82 relative to the means for the 1946–77 base period. (Shaded areas represent negative anomalies.)

Verney, 1975) and for the 1947–77 period (Keeley, 1981) have been published. In Appendix C of his paper, Keeley (1981) produced long-term means of temperature and salinity at standard depths (0, 10, 20, 30, 50, 75, 100, 125 and 150 m) for the beginning and the middle of each month in 1947–77. Monthly averages of temperature and salinity at Station 27 in 1981 and 1982 were used in conjunction with the mid-month values for the 1947–77 period to obtain monthly anomalies for 1981 and 1982, which are shown in Fig. 6. The isolated peaks and troughs are probably not significant due to the low frequency of sampling (e.g. the high temperatures and low salinities in November 1982 are based on one measurement only). More significant are the relatively high or low anomalies which persist with time. The water was warmer than normal near the surface in May–July 1981 and throughout the water column from November 1981 to January 1982. Lower-than-normal temperatures were observed in the near-surface water 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.

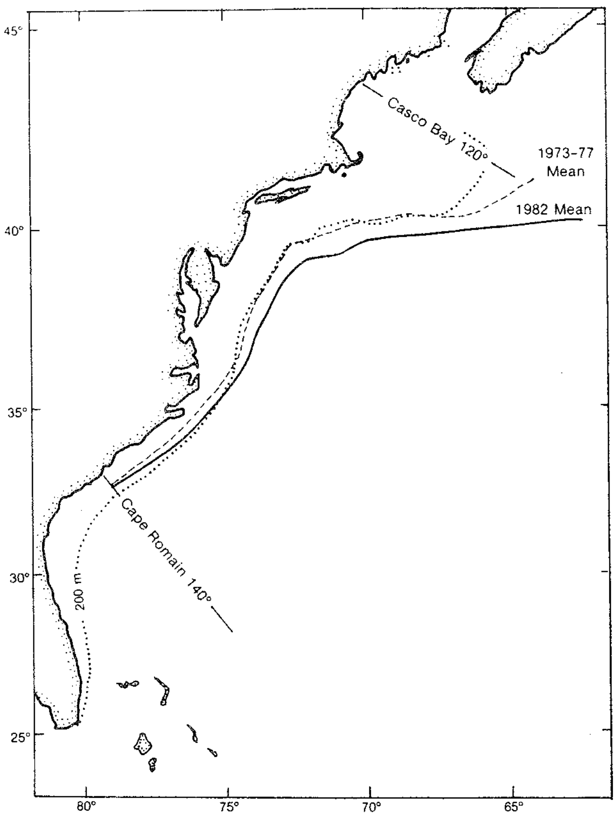

Fig. 7. Mean locations of the shelf-slope water front at the surface in 1973-77 and 1982. (Data from Armstrong, MS 1983.)

Position of shelf-slope front

This frontal zone, which is situated over or near the continental slope from Florida to the Grand Bank off Newfoundland, delineates the boundary between the cooler, less saline Shelf Water and the warm, more saline Slope Water that lies farther offsho:e. The surface position of this frontal zone can usually be determined from thermal infrared satellite imagery. This information has been extracted and reported annually since the early 1970's by the Atlantic Environmental Group of the U.S. National Maine Fisheries Service. For 1982, the annual mean position of the front was displaced seaward of the 1973-77 mean by about 35 km (Armstrong, MS 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 farther offshore in the first half of the year than in the latter half of the year. From Cape Hatteras southward, the seasonal progression is generally the reverse. In 1982, the seasonal frontal pattern approximated the normal situation, except off Georges Bank where the pattern was overshadowed by large excursions associated with the passage of warm-core eddies (Armstrong, MS 1983).

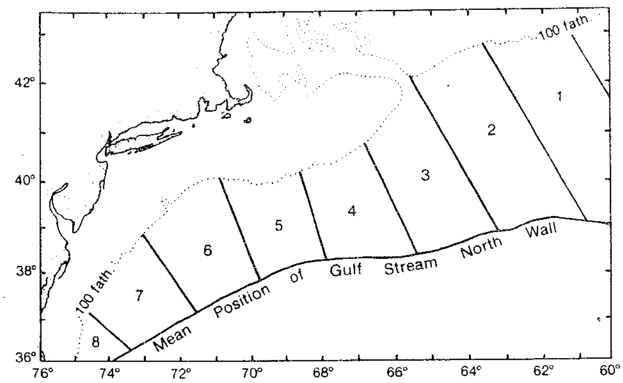

Fig. 8. Locations of the eight zones used to compile statistics on warm-core Gulf Stream eddies. (From Fitzgerald and Chamberlin, MS 1980.)

Warm-core eddies

Monitoring the life-history of warm-core Gulf Stream eddies or rings has been carried out since 1974, for the area between 60°W and Cape Hatteras (Celone and Price, MS 1983). Summary statistics on eddy generation by location, month and year are given in Table 5. During the 1976-81 period for the eight zones defined by Fitzgerald and Chamberlin (MS 1980), the principal generating area is within zones 1-3 (Fig. 8). The average lifetime of the 49 eddies generated during 1976-81 was approximately 4 months. The highest generation of eddies by quarter seems to have occurred in April-June, but the winter months may be biased toward low values because of relatively infrequent infrared imagery coverage of the northeastern areas due to extensive cloud cover.

The statistics on "standing crop" of eddies by month (Table 5) reveal no marked seasonal pattern, although the counts in late spring and summer (May-August) were higher than in winter (December-March). During the 1976-82 period, the number of eddies generated annually varied from 7 in 1976 and 1981 to 11 in 1982. Two eddies which formed in 1981 were present in 1982, and likewise two eddies which formed in October 1982 persisted into 1983. Average lifetime of eddies whose destruction occurred in 1982 was 113 days, a lifespan close to the 6-year mean of 4 months.

No published summaries are available on warm-core eddies formed in the area east of 60°W. The Oceanographic Analysis maps, prepared by the U.S. National Earth Satellite 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 lifespans greater than 7 days) were generated. Maximum lifespan was about 70 days, with a mean of about 1 month. It appears, therefore, that eddies form more frequently in the 50°-60°W zone than in the 60°-70°W zone but their lifespan is much shorter.

TABLE 5. Statistics on warm-core Gulf Stream eddies west of 60° W for 1976-81 (**A** and **B**), and number generated yearly in 1976-82 (**C**).

A. Zones (see Fig. 8)	1	2	3	4	5	6	7	8	Total			
No. generated (1976-81)	10	14	10	9	4	2	0	0	49			
B. Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No. generated (1976-81)	2	1	4	7	6	8	2	5	1	6	3	4
Total standing crop	17	15	14	18	24	24	23	22	18	20	15	16
Mean standing crop	2.8	2.5	2.3	3.0	4.0	4.0	3.8	3.7	3.0	3.3	2.5	2.7
C. Years	1976	1977	1978	1979	1980	1981	1982					
No. generated	7	8	9	10	8	7	11					

Shelf temperatures in the Middle Atlantic Bight

Monitoring of Shelf Water temperatures in the area near 71° W has been undertaken since 1974 (Crist and Armstrong, MS 1983). Further south, a transect extending from the entrance to New York Harbor across the continental shelf and slope has been monitored since 1976 (Cook, MS 1983). A total of 19 XBT (expendable bathythermograph) transects of the 71° W line and 26 XBT transects of the New York line were carried out in 1982.

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 near bottom along the shelf due to the presence of Gulf Stream warm-core eddies further offshore (Crist and Armstrong, MS 1983; Cook, MS 1983). The cold-pool water (<10° C) was less dissipated by the end of September 1982 than in 1981 when it lasted until mid-October, despite the fact that cold (<5° C) water in 1982 persisted longer than usual early in the season. The average position of the cool-pool water off New York Bight shifted slightly shoreward in 1982, extending into depths 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 bottom temperatures on the shelf was considered typical, relative to the 1971-81 observations. At the shelf break (100-200 m), bottom temperatures were above 10° C throughout 1982, except in April when cooler conditions prevailed. Highest temperatures in the warm band occurred from mid-January to the end of February 1982 during the passage of warm-core eddy 81-F (Crist and Armstrong, MS 1983). The bottom temperature at 400 m reached 8.5° C in June 1982, about 2° C higher than normal. Only in 1976 have bottom temperatures higher than 8° C been recorded at a depth of 400 m.

Waves

Wave and weather observations from 40 to 100 locations in the North Atlantic (weather ships, Canadian and United States government and naval ships, merchant ships, and oil-drilling platforms) are transmitted every 6 hr to the Canadian Meteorological and Oceanographic Center (METOC) in Halifax, Nova Scotia. These data are analyzed and synoptic wave charts are produced at 12-hr intervals. The Bedford Institute of Oceanography (BIO) has collected these charts since January 1970, and wave statistics for a gird of points at 5° intervals of latitude and longitude have been reported by Neu (1982). The data provided on the charts include wave heights, periods and directions based mainly on visual estimates. The estimated height is therefore not the height of an individual wave but rather is a general measure of the severity of the sea state. In practice, the estimated wave height has been found to closely approximate the mean height of the highest one-third of the waves and is referred to as significant wave height (H_{sig}). The maximum wave height is generally about 1.8-2.0 times larger than H_{sig}, but only data for the latter are used in this paper with reference to three grid points (Table 6), which for convenience are referred to as Scotian Shelf (42.5° N, 62.5° W), Grand Bank (47.5° N, 47.5° W) and Labrador Sea (57.5° N, 52.5° W).

Monthly differences in significant wave height for 1981 and 1982 from the base-period (1970-80) means were computed for the three areas (Fig. 9). It is noteworthy that, during most months of this 2-year period, wave conditions were more severe than those of the base period. Departure from the base-period means was most marked for Grand Bank and least for the Labrador Sea. The most severe conditions occurred on Grand Bank in January-May 1982.

Another measure of wave conditions, indicative of events for the year as a whole, is the frequency of storms. The numbers of occurrences of waves equal to or greater than 6, 7 and 8 m in the three areas are shown in Fig. 10. Of particular interest is the evidence that the

TABLE 6. Mean monthly significant wave heights (m) at three locations in the Northwest Atlantic derived from 12-hr wave charts for 1970-82 and mean heights for 1970-80.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Labrador Sea (57.5° N, 52.5° W)												
1970	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
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
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
Grand Bank (47.5° N, 47.5° W)												
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
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
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
Scotian Shelf (42.5° N, 62.5° W)												
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
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
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

trend in frequency of occurrence of large waves has been markedly upward over the 13-year period in all three areas. However, the whole region did not experience the shift in storm conditions of comparable magnitude or direction in any given year. For example, conditions on the Grand Bank were markedly more severe in 1982 (severest of the 13-year period) than in 1981, whereas conditions on the Scotian Shelf were substantially less severe in 1982 than in 1981 (Fig. 10).

Coastal sea-level elevations

Mean monthly sea-level elevations were obtained from observations at St. John's, Newfoundland, for the 1957-82 period, and Halifax, Nova Scotia, for the 1953-82 period. The atmospheric pressure effect on sea level was removed by assuming an inverted barometer response. The pressure data were taken from observations at Gander, Newfoundland, for adjusting the St. John's sea-level data and at Shearwater, Nova Scotia, for adjusting the Halifax sea-level data. Monthly mean adjusted sea levels were then averaged by month over the base periods of 1957-80 for St. John's and 1953-80 for Halifax (Table 7). Anomalies relative to these periods for 1981 and 1982 (Fig. 11) show increasing sea level during the first half of 1981 followed by a general decrease until April 1982. Also,

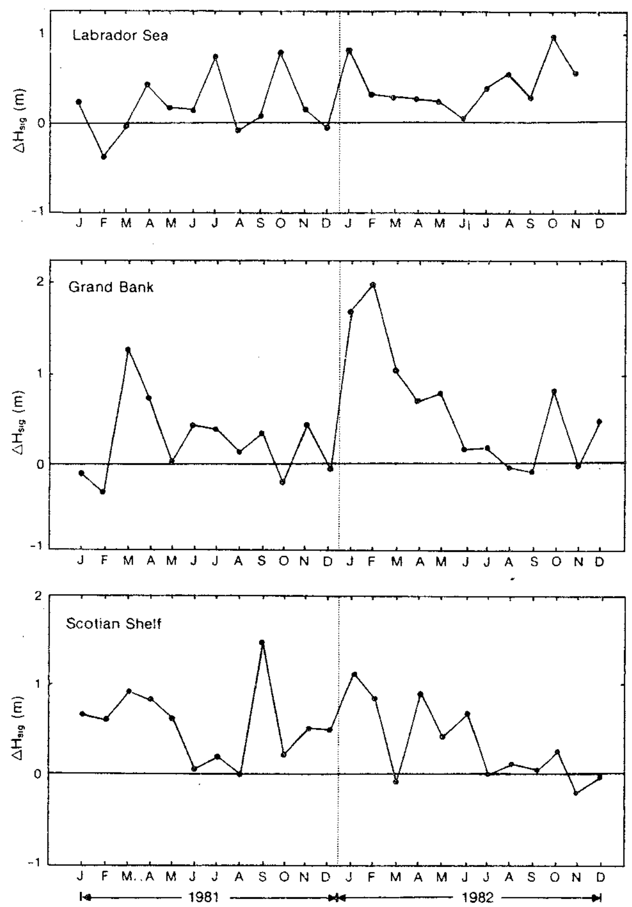

Fig. 9. Monthly significant wave-height anomalies (ΔH_{sig}) in three areas of the Northwest Atlantic during 1981–82 relative to the means for the 1970–80 base period.

there is an indication of a peak positive anomaly in the autumn of 1982.

Annual mean adjusted sea levels at St. John's fluctuated about the average for the 1957–80 period with no obvious trend (Fig. 12), but sea levels at Halifax increased from below-normal values in 1953–66 to above-normal values during most of the remaining period to 1981. Annual means were not calculated for 1982 because data were missing for 3–4 months at both localities.

Sea ice

The Canadian Atmospheric Environment Service has a program of sea-ice reconnaissance and forecasting for Canadian Atlantic and Arctic waters. The program began as an "ice patrol" in the Gulf of St. Lawrence in 1940 and operated there during late winter and spring months until the late 1950's, when it was expanded to support shipping in all Canadian waters during the period of ice encumbrance. Ice data are acquired from several sources, including aircraft reconnaissance, ship reports, shore reports from lighthouses and other coastal installations, and satellite imagery. These data, together with information on prevailing wind and temperature conditions, are used to produce daily and composite weekly charts showing ice distribution. Ice charts, depicting the median, maximum and minimum edges for all types of sea ice in each week of the year, have been published recently (Sowden and Geddes, 1980). Data for the 1964–73 period were used to determine the median edges and data for 1964–79 were used for the two extremes. Additional ice information for the Gulf of St. Lawrence, Newfoundland and southern Labrador has been published by Markham (1980). Sea-ice conditions in the Northwest Atlantic during 1982 are summarized by NAFO divisions in the following paragraphs.

In the northernmost divisions, the spring breakup of ice began slightly earlier than normal in 1982, but this trend changed and sea ice was last to leave Div. 1A, 1C and 1D in early September. This was approximately 4 weeks later than normal, and the departure of ice in Div. 1C approached a near record late date. The last sea ice to leave Div. 1B and 1F was 2 weeks later than normal and ice disappeared from Div. 1E 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 in Div. 1A, 1B, 1C, 1D and 1F and about 1 week ahead of normal in Div. 1E.

In Div. 2G, 2H and 2J, the eastern extent of sea ice off Labrador during January-March 1982 was generally near or slightly less than normal. However, slower-than-normal spring melting and prevailing seaward winds resulted in a greater-than-normal eastern extent of the ice floes during April–June. Sea ice disappeared from Div. 2H and 2J in mid-July, which was about normal for Div. 2H and 2 weeks later than normal for Div. 2J. In Div. 2G, ice disappeared during the second week of August which was almost 2 weeks later than normal. Sea ice reappeared in Div. 2G in early November which was almost 2 weeks earlier than normal. However, the initial growth of sea ice in Div. 2H and 2J occurred 1-2 weeks later than normal.

In Div. 3K, sea ice first appeared during early January 1982, which was near normal, but the seaward extent of pack ice was generally less than normal throughout January-March and in May. In April and June, however, the eastern edge of the pack ice drifted well beyond its historical median limit. Again, due to adverse spring conditions, the last floes of sea ice to leave Div. 3K occurred almost 2 weeks later than normal. In Div. 3L, development of sea ice began normally in early February, but rapid growth and extension of the floes resulted in a greater-than-normal southward extent during late February and March. During April, the ice pack receded northward about 2 weeks earlier than normal, but it drifted back into the northernmost part of Div. 3L for a brief period in May. There was no

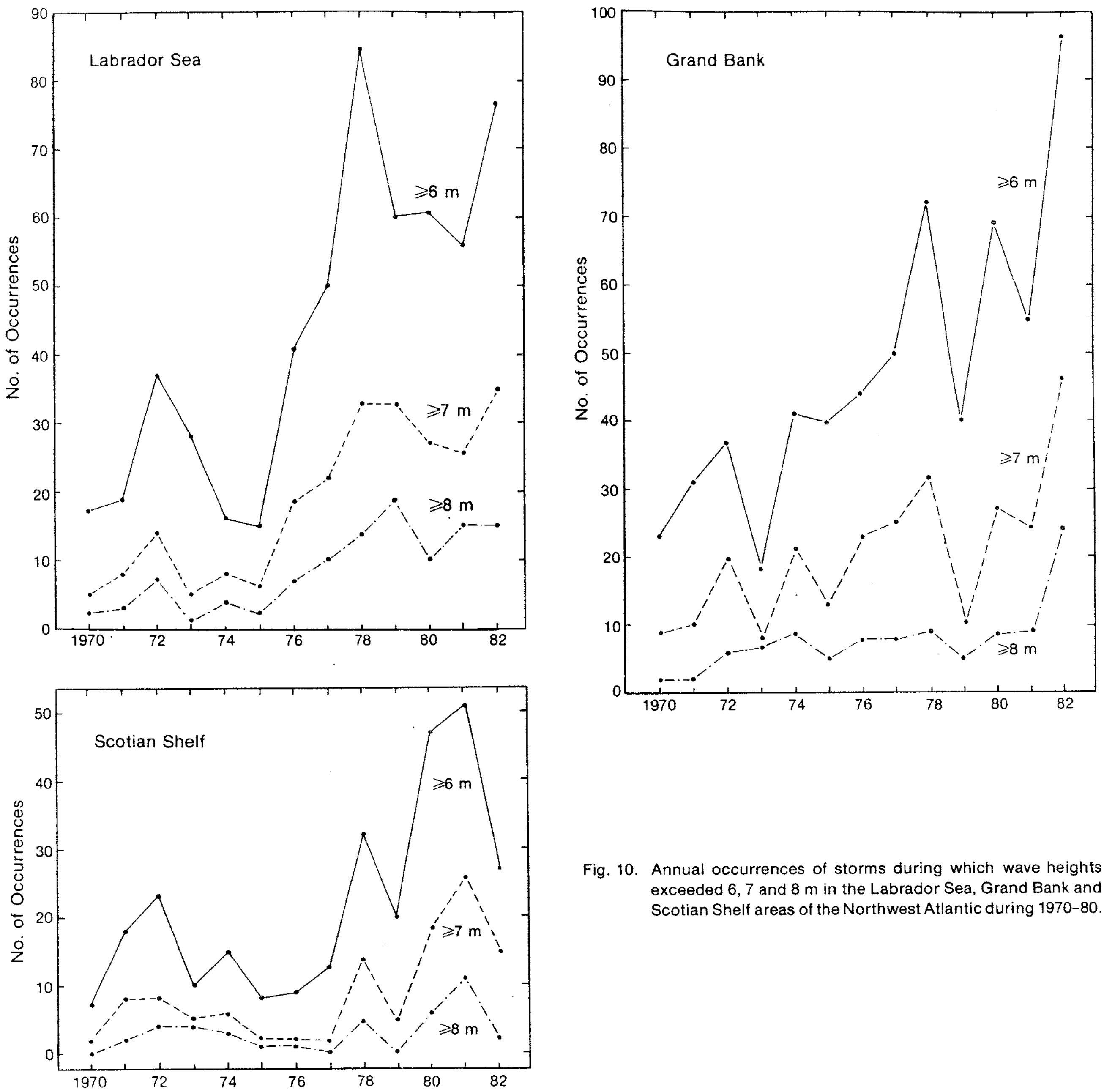

Fig. 10. Annual occurrences of storms during which wave heights exceeded 6, 7 and 8 m in the Labrador Sea, Grand Bank and Scotian Shelf areas of the Northwest Atlantic during 1970–80.

sea ice reported in Div. 3M, 3N and 3O, which is normally the case.

Due to abnormally high air temperatures in the Gulf of St. Lawrence (Div. 4R, 4S and 4T), growth of sea ice was 2–3 weeks slower than normal in 1982. Although below-normal air tempeatures occurred in January, causing the ice cover to approach normal extent during February and March, 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 parts of Div. 4R and 4S, however, sea ice remained for 3–4 weeks later than normal due to slightly lower spring temperatures in the region and to the influx of ice through the Strait of Belle Isle. In Cabot Strait, ice first arrived in Div. 4Vn near the end of January, which was near normal, and disappeared in mid-May which was about 1 week earlier than normal. Rapid ice growth and accelerated eastward ice drift in February, however, carried ice from the Gulf of St. Lawrence to Div. 3Pn and 3Ps approximately 2 weeks earlier than normal and to the northern part of Div. 4Vs about 4 weeks earlier than normal. Some of this drift ice moved southward along the Nova Scotia coast to Div. 4W about 1 week earlier than normal. Although this

TABLE 7. Monthly means, standard deviations and numbers of observations of adjusted sea levels (m) at St. John's, Newfoundland, during 1957-80 and at Halifax, Nova Scotia during 1953-80.

Location		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
St. John's	Mean	0.82	0.80	0.76	0.73	0.72	0.72	0.71	0.74	0.81	0.84	0.83	0.83
	S.D.	0.05	0.06	0.04	0.06	0.09	0.08	0.03	0.04	0.04	0.04	0.04	0.06
	No.	23	24	24	24	24	24	22	23	23	23	23	24
Halifax	Mean	1.29	1.26	1.25	1.23	1.23	1.23	1.22	1.22	1.26	1.29	1.31	1.29
	S.D.	0.04	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.06
	No.	28	28	28	28	28	28	28	27	28	27	28	27

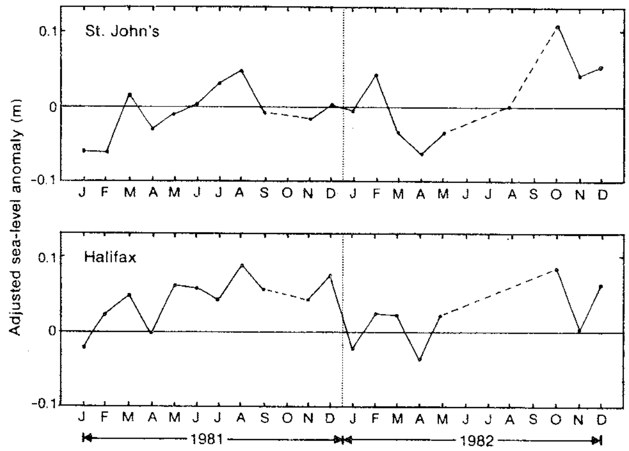

Fig. 11. Monthly anomalies of adjusted sea levels during 1981-82 relative to means at St. John's for the 1957-80 base period and at Halifax for the 1953-80 base period.

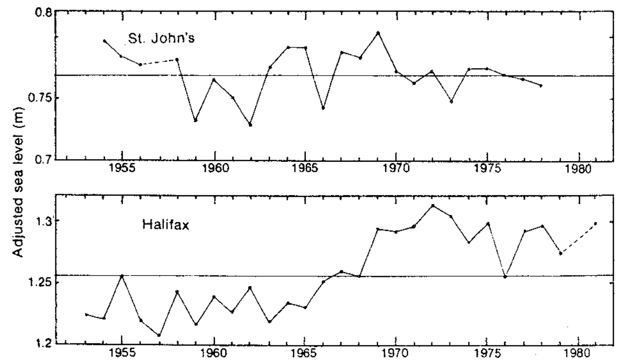

Fig. 12. Annual mean adjusted sea levels during 1957-81 at St. John's and 1953-81 at Halifax relative to the means for their respective base periods of 1957-80 and 1953-80.

tongue of ice approached the entrance to Halifax, it deteriorated rapidly and disappeared from Div. 4W almost 2 weeks earlier than normal. The greater-than-average transport of ice through Cabot Strait in an eastward rather than a southeastward direction resulted in ice extending well beyond the normal limit in Div. 3Pn and 3Ps and remaining there for 2-3 weeks longer than normal. In Div. 4Vs, the seaward extent of drift ice was beyond the median limit, but final departure occurred only 1 week later than normal. As is usually the case, no sea ice was reported in the southern half of Div. 3Ps, in the southern three-quarters of Div. 4Vs and 4W, or in Div. 4X and 5Y.

Icebergs

The glaciers of West Greenland are the source of nearly all icebergs found in eastern Canadian waters, 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 in 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 Bank area. The International Ice Patrol has determined that the average number of icebergs south of lat. 48° N during 1945-72 was 259, with 93% of them entering the area during 1 March-30 June. A maximum number of 1,587 icebergs was observed in the area in 1972 and the minimum was zero in 1966.

With respect to iceberg distribution by NAFO divisions, there is insufficient long-term monthly data to evaluate recent conditions except for Div. 3L, 3M, 3N, 3O and 3Ps. Information from the International Ice Patrol indicate that fewer than normal icebergs drifted south of 48° N in 1982. On a monthly basis, no icebergs were reported south of 48° N in January, February and August-October. In March, April, May, June and July, the numbers of bergs observed south of this latitude were 17, 61, 13, 94 and 3 respectively, resulting in a seasonal total of 188, which is less than the annual average of 276 during 1946-82. In the autumn of 1982, icebergs arrived much earlier than normal with some drifting southward to near 50° N in November and south of 48° N on 26 December. As a prelude to the 1983 season, more than 1,250 icebergs drifted south of 48° N between 26 December and the end of May 1983, indicating that a record year may be in progress.

Meteorolgoical Observations

Air temperatures

Monthly mean air temperatures at coastal stations were obtained at Hopedale, St. John's, Grindstone, Sable Island, Shearwater (Halifax), Eastport and New

TABLE 8. Monthly means and standard deviations of air temperature (°C) at selected meteorological stations, 1951-80.

Station	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	15.0	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	15.5	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

Haven (Table 1, Fig. 1). Monthly averages and standard deviations for the 1951-80 base period are given in Table 8.

An overall trend of decreasing air temperature anomalies was observed during 1981 and 1982 at Hopedale and St. John's (Fig. 13). Several prominent anomaly features were observed throughout the whole region, including warmer than normal conditions in February 1981, a large positive anomaly in December 1981 followed by a large negative anomaly in January or February 1982, and increasing temperatures near the end of 1982, except at Hopedale where the anomaly increased negatively from -1° to -4°C.

The annual mean air temperatures in 1951-82 (Fig. 14) generally show a pattern similar to the coastal sea temperatures (Fig. 3), i.e. high values in the early 1950's decreasing to minimum values in the first half of the 1960's. The means were more than 1°C above normal in 1981 and declined to about 0.5°C below normal in 1982, except at Hopedale where the amplitude of the anomalies were much larger. These fluctuations about the norm are consistent with the pattern of sea-surface temperatures during the 1970's. Only at New Haven was a trend evident, with temperatures increasing.

Winds

Direct measurements. Monthly summaries of average wind speed and percent frequency of direction were derived from observations at Grindstone and Sable Island (Table 1, Fig. 1) from the beginning of 1981 to September 1982 (data from October onwards were not available at the time of preparing this paper). These stations were chosen for their relative isolation from large land masses and their possible representation of large-scale winds over the southern Gulf of St. Lawrence and on the Scotian Shelf respectively. Studies by Petrie and Smith (1977) and Sandstrom (1980) have shown that winds at Sable Island are indeed representative of large-scale wind conditions off the Atlantic coast of Nova Scotia. From the wind-speed and percent-frequency data, monthly mean vector speeds and directions were determined. Speed and direction anomalies were then calculated for 1981 and 1982 relative to monthly averages for the 1955-80 period (Table 9) as published by the Canada Climate Program (1982).

Winds at Grindstone were much stronger than normal during April 1981 and from December 1981 to April 1982 (Fig. 15), a pattern which was also observed at Sable Island. During both of these periods at both stations, the winds were rotating or progressing anticlockwise from the normal directions of Grindstone (290°-310°) and Sable Island (280°-310°). Lower-than-normal wind speeds were observed in February 1981 at Sable Island and through the summer and early autumn of 1981 (July-October) at both stations. For the latter period, winds were westerly (260°), which corresponds to normal at Grindstone, but rotated clockwise about 20° from normal at Sable Island.

Geostrophic winds. Information on large-scale wind fields can be obtained from air pressure measurements through the geostrophic relationship (i.e. the magnitude of the wind is proportional to the air pressure gradient between two stations and the direction is nearly perpendicular to the straight line joining these stations, with the higher pressure to the right of the wind). Long-term monthly air-pressure records were available from Goose Bay, Gander, North Sydney, Sable Island, Shearwater and Yarmouth (Fig. 1). Measurements began at all stations in 1953 except for

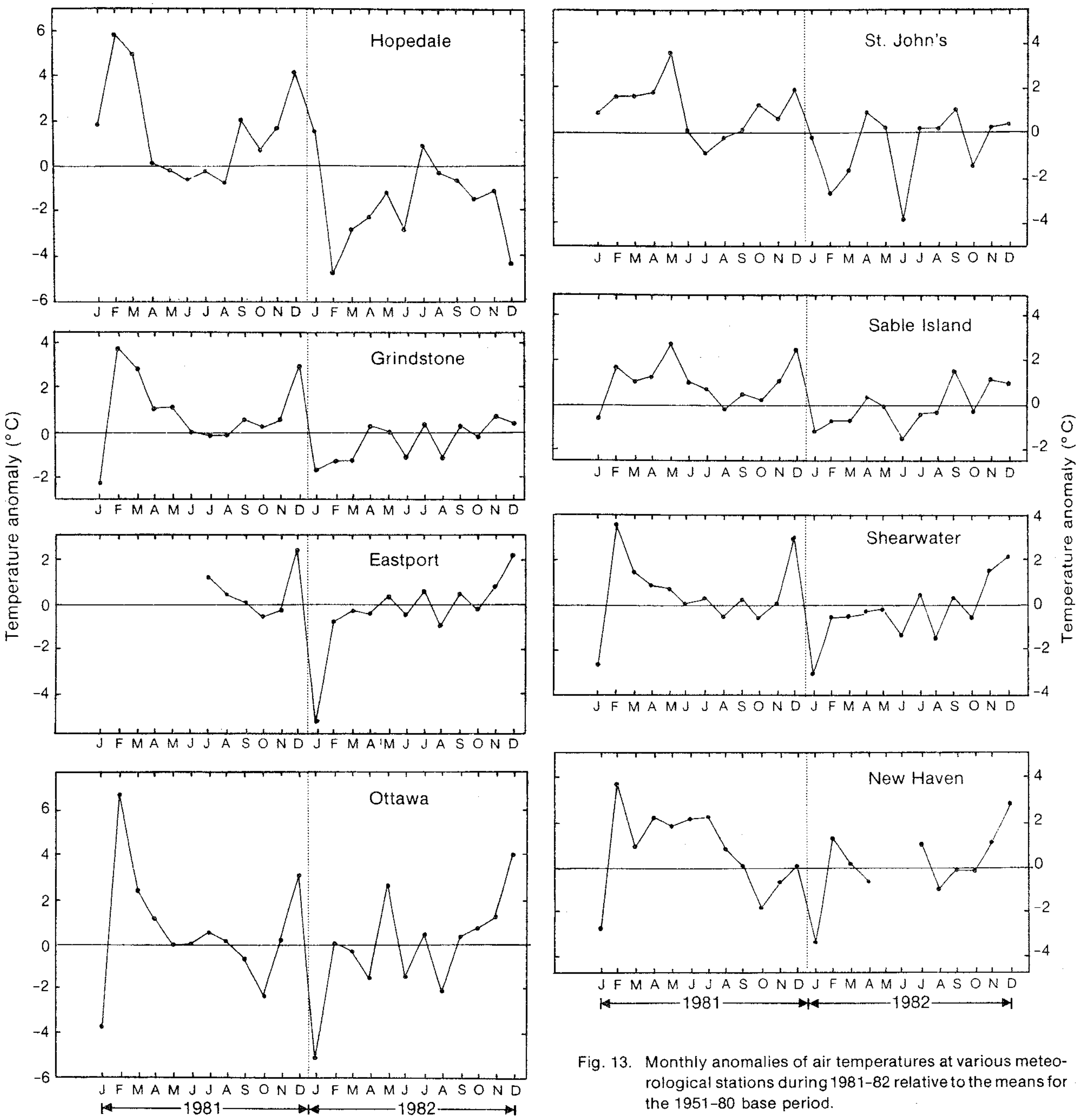

Fig. 13. Monthly anomalies of air temperatures at various meteorological stations during 1981-82 relative to the means for the 1951-80 base period.

Sable Island where they began in 1957. The monthly sea-surface pressure gradients were calculated between Gander and Goose Bay (G-GB), Sable Island and the mid-point (St. Mary's) between Shearwater and North Sydney (SI-SM), North Sydney and Gander (NS-G), and between Yarmouth and North Sydney (Y-NS). The G-GB and SI-SM gradients indicate geostrophic winds directed basically toward the northeast (+) or southwest (–), whereas the NS-G and Y-NS gradients indicate winds directed toward the southeast (+) or northwest (–). The G-GB geostrophic winds represent cross-shelf winds (+ offshore) on the Labrador Shelf and Northeast Newfoundland Shelf as well as winds directed into (+) or out of (–) the northeastern part 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 frequencies of about 0.1 cycles per day (periods 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 along-shore on the Scotian Shelf, whereas 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

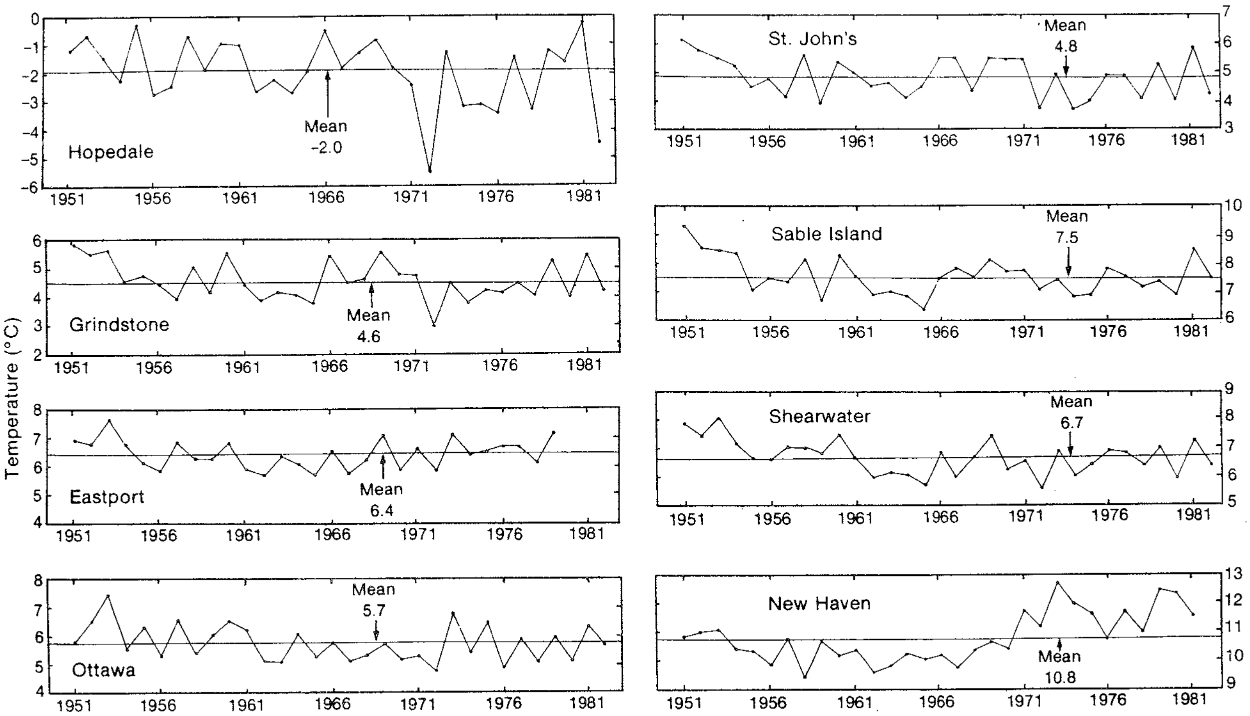

Fig. 14. Annual mean air temperatures at various meteorological stations during 1951-82 including the means for the 1951-80 base period.

TABLE 9. Monthly mean wind vector speeds (m/sec) and directions (nearest 10°) at stations representative of the Gulf of St. Lawrence and the Scotian Shelf, 1955-80.

Station	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

St. Lawrence through Cabot Strait. All of the calculated pressure gradients were normalized to a distance of 770 km, therefore making a pressure gradient of 0.1 kpa/km, approximately equivalent to a geostrophic wind of 1 m/sec. The monthly mean geostrophic winds were then determined and average monthly values were calculated for the period 1953-80 (Table 10). These values were used to calculate monthly anomalies of geostrophic winds for 1981 and 1982.

The monthly anomalies of geostrophic winds for 1981 and 1982 (Fig. 16) reveal several features. Firstly, the geostrophic winds with like orientation have similar characteristics, the correlation coefficient being 0.66 for the G-GB and SI-SM anomalies and 0.67 for the NS-G and Y-NS anomalies. Secondly, the winds directed northeast-southwest (G-GB and SI-SM) had anomalies with greater fluctuations than those directed southeast-northwest (NS-G and Y-NS). Thirdly, the negative anomaly in February 1981 and the positive anomalies in April 1981 and April 1982 at Y-NS and/or SI-SM correspond to similar anomalies in the measured winds at Sable Island. Fourthly, no overall trend in any of the geostrophic wind data is evident.

The annual mean geostrophic winds for the 1953-82 period (Fig. 17) indicate below-normal values for 1981 and a return to near-normal or above-normal values for 1982.

Discussion

In preparing this overview, several important features became evident. Foremost among these was the indication, from offshore sea-surface temperature data (Fig. 5), of large-scale events with opposite phase to the north and south of an area approximaely coincident with the Gulf of Maine. The time scale of these events appers to be in the order of several years. A cursory visual examination of the coastal sea-surface temperature data and surface data from Station 27

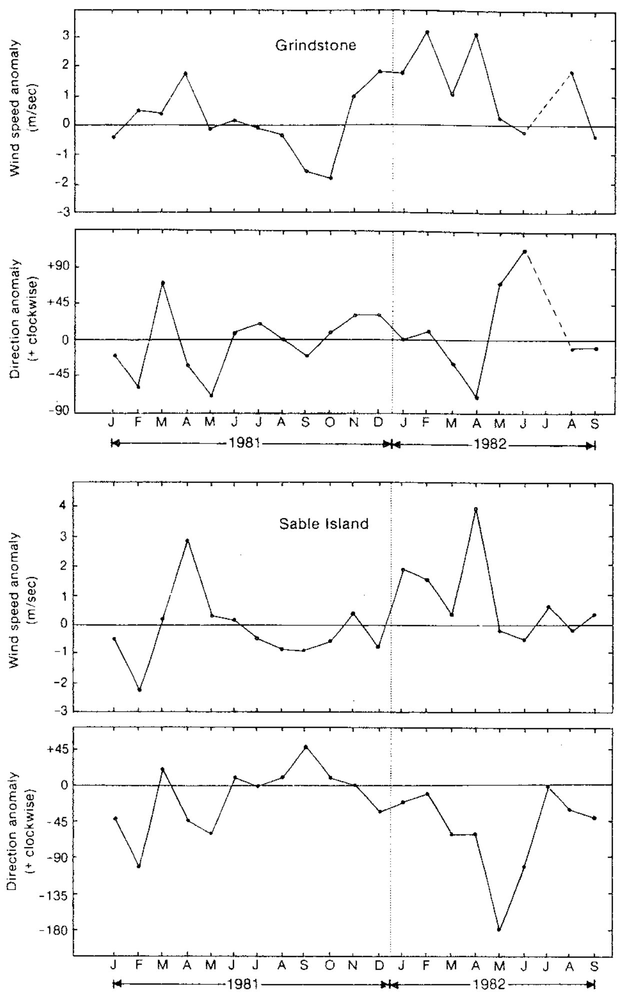

Fig. 15. Monthly anomalies of vector wind speeds and directions at two stations during 1981-82 relative to the means for the 1955-80 base period.

indicates some consistency with the patterns indicated in Fig. 5. Therefore, recent data (1981 and 1982) must be put into the context of these larger events. The continued increase in significant wave height and the greater occurrence of intense storms in the Northwest Atlantic from the Labrador Sea to the Scotian Shelf from 1970 to the present time is noteworthy. Neither the measured winds nor the geostrophic winds indicated any correlation with the wave data during the period. However, average wind speeds, which were not discussed in this paper, may have a greater connection with wave height than mean vectors or mean geostrophic winds.

As stated in the Introduction, this overview of environmental conditions is a "pilot" project, which could be expanded in several directions if it were deemed important and necessary. From the oceanographic viewpoint, sea-surface temperature and sea-level data from additional coastal stations could be utilized, and the profiles of temperature and/or salinity along standard sections or at standard stations could be incorporated. Several meteorological parameters

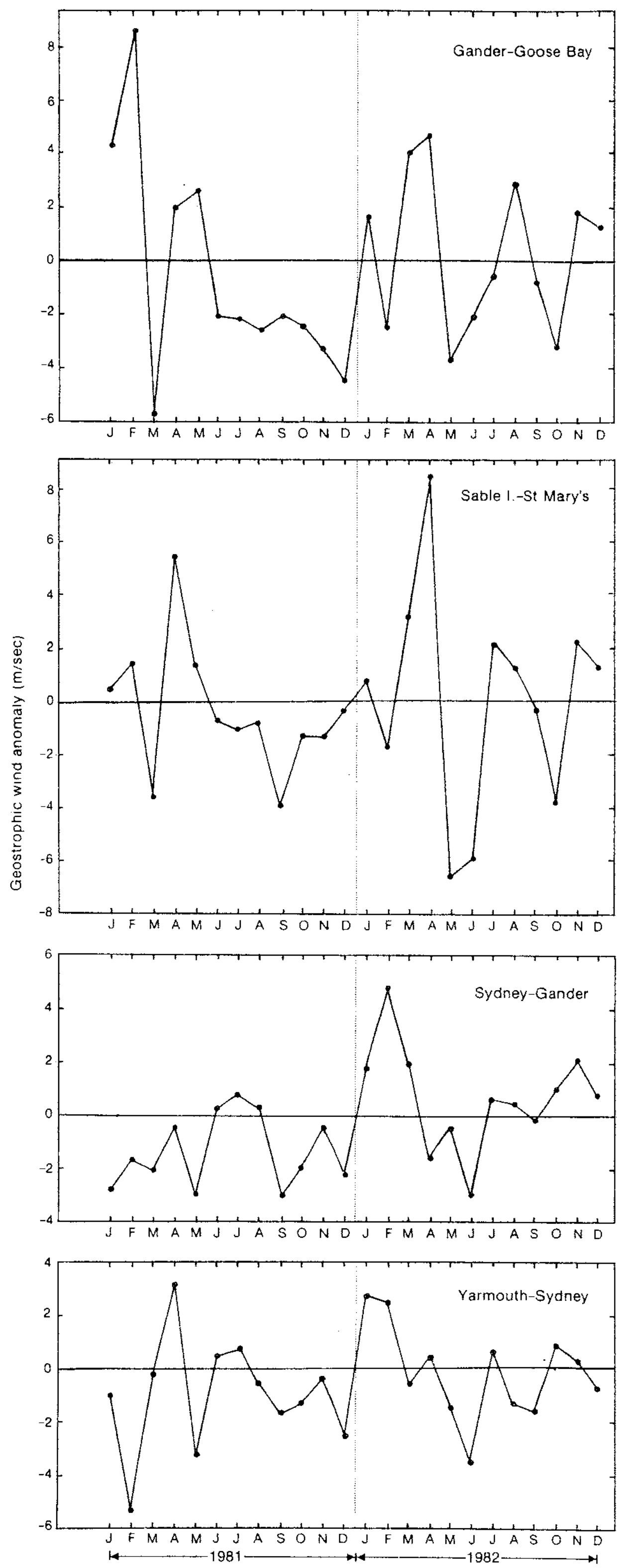

Fig. 16. Monthly anomalies of estimated geostrophic winds for four areas during 1981-82 relative to the means for the 1953-80 base period.

could be added, including solar radiation and precipitation and the expansion of air temperature and wind data bases. Also, freshwater discharge from certain of

TABLE 10. Monthly means, standard deviations and numbers of observations of geostrophic winds (m/sec) for selected areas, 1953-80.

	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
(G-GB)	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 I.-St. Marys	1.4	1.1	0.4	1.9	3.4	5.4	6.0	4.4	2.8	2.6	1.9	1.8
(SI-SM)	2.4	2.8	3.6	3.0	2.6	2.2	1.8	2.3	1.6	1.8	1.3	2.4
	25	25	25	25	25	25	25	25	25	26	26	26
N. 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
(NS-G)	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-N. 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
(Y-NS)	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

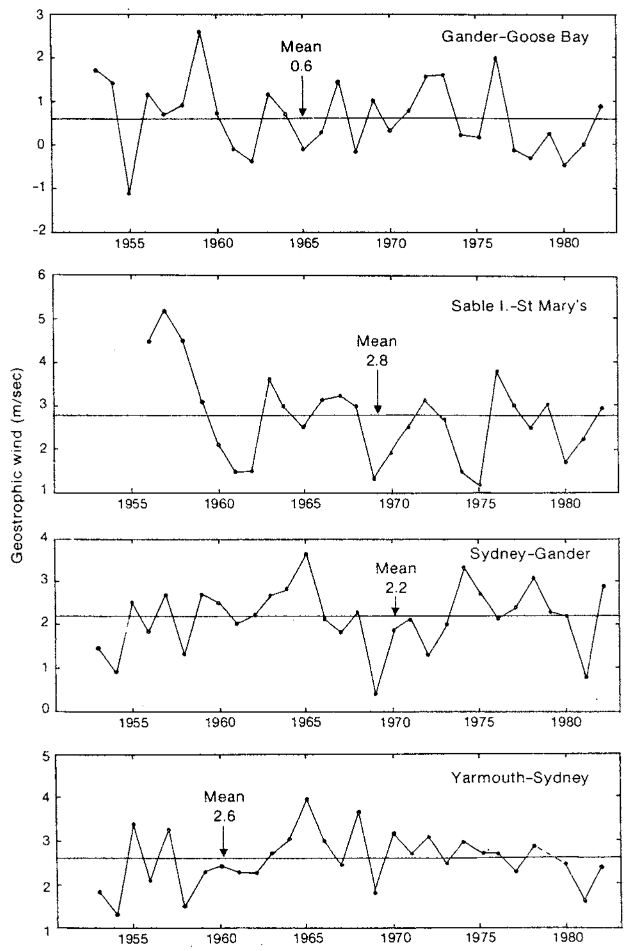

Fig. 17. Annual mean estimated geostrophic winds during 1953-82 including the means for the 1953-80 base period.

the major river systems could be included. With regard to expanding the data bases, it has been stated that individual stations probably represent long-term trends fairly well, but the higher frequency fluctuations of a year or less may only represent local conditions (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 scarcity of data north of Newfoundland in the data bases used for the preparation of this paper, and some effort should be made both to obtain what is presently available and to monitoring conditions there.

In addition to expanding the data bases, a standard normal period should be utilized. The World Meteorological Organization (WMO) Convention of a 30-year mean using the previous three decades (presently 1951-80) should be adopted. For data sets with less than 30 years of data, 20-year (1961-80) or 10-year (1971-80) averaging periods are recommended. If less than 10 years of data are available, the averages should pertain to data within the 1971-80 period. These base periods should 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 (correlation or coherence analysis) and modelling. In this way, key environmental parameters may be identified and an effort made to ensure their adequate monitoring both spatially and temporally.

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