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An Overview of Meteorological, Sea Ice and Sea-Surface Temperature Conditions off Eastern Canada during 2003

by

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Abstract

A review of meteorological, sea ice and sea-surface temperature conditions in the Northwest Atlantic in 2003 is presented. During 2003, the NAO index was below normal for the third consecutive year and close to the 2002 value. Air temperatures over the northwest Atlantic region were above normal, with annual values ~2°C above normal in the northern Labrador Sea decreasing to the south to ~0.2°C above normal at Sable Island. There was about 20% less ice coverage than normal during the ice season (December 2002–May 2003) for the southern Labrador-Newfoundland shelf region. In the Gulf of St. Lawrence the seasonal coverage was about 10% above the long-term mean, the first year above normal since 1995. The Scotian Shelf had twice the long-term January-May coverage and was dominated by March, when coverage approached the long-term maximum. This also was the first year since 1995 with the ice season coverage above the long-term mean. The 927 icebergs that reached the Grand Bank were about equal to the 877 counted in 2002. The analysis of satellite data indicates a north-south gradient of sea-surface temperatures with above normal annual anomalies as large as 1.2°C from the northern Labrador Sea to the northeast Newfoundland Shelf and Flemish Pass and generally below normal values on the Grand Banks, in the Gulf of St. Lawrence and over the Scotian Shelf.

Introduction

This paper examines the meteorological, sea ice and sea-surface temperature conditions during 2003 in the Northwest Atlantic (Fig. 1). Specifically, it discusses air temperature trends, atmospheric sea level pressures, winds, sea-ice coverage, iceberg drift and sea surface temperatures (SST). It complements the oceanographic reviews of the waters in and around the Gulf of St. Lawrence, Newfoundland and Labrador, and the Scotian Shelf and Gulf of Maine, which together constitute the annual physical environmental overviews to the Fisheries Oceanography Committee (FOC). Environmental conditions are compared with those of the preceding year as well as to the long-term means. The latter comparisons are usually expressed as anomalies, i.e. deviations from their long-term mean or normal, and where the data permit, the latter have been standardized to a 30-year base period (1971-2000). This is in accordance with the convention of North American meteorologists and the recommendations of both the Northwest Atlantic Fisheries Organization (NAFO) and the FOC. Having a standardized base period allows direct comparison of anomalies both between sites and between variables.

Meteorological Observations

Air Temperatures

The German Weather Service publishes monthly air temperature anomalies relative to the 1961-1990 means for the North Atlantic Ocean in the publication *Die Grosswetterlagen Europas* (Deutscher Wetterdienstes, 2002). Slightly warmer-than-normal temperatures of about 1°C dominated over most of eastern Canadian waters during 2003 (Fig. 2A). Negative annual anomalies were less than 1°C below normal and were limited to the St. Lawrence Estuary. Seasonally, warm air over the eastern Arctic, Labrador and the Labrador Sea in January gave way to a large scale cold anomaly from February to April (Fig. 2B). Negative anomalies as low as -6°C were found in February to the west of Hudson Bay and in March over northern Labrador. These cold months were followed by two months of above normal temperatures in the same region. To the south, the Gulf of St. Lawrence, Newfoundland and Maritimes region lay in the transition area between below and above normal temperatures. January through April these regions were colder-than-normal; in May and June they had slightly above normal air temperatures. In the July to December period, the east coast from Labrador to the Gulf of Maine was dominated by warmer-than-normal air temperatures.

Monthly air temperature anomalies for 2002 and 2003 relative to their 1971-2000 mean at eight sites, from Nuuk in Greenland to Cape Hatteras on the eastern coast of the United States, are shown in Fig. 3 (see Fig. 1 for locations). Data from the Canadian sites were available from the Environment Canada website and for non-Canadian locations from *Monthly Climatic Data for the World* (NOAA, 2003). There is a systematic latitudinal variation from generally above normal temperatures in the north, characterized by the Nuuk and Iqaluit observations, to a mixture of below normal temperatures early in 2003 changing to above normal temperatures late in the year at Cartwright and St. John's. The duration of below normal temperatures early in the year continues to grow from Cartwright to Boston, where about half the temperatures are below normal and half above. The magnitude of the above normal anomalies decreases from Iqaluit (up to 6°C) to Boston (~1°C). Cape Hatteras featured near normal temperature conditions throughout 2003.

The mean annual air temperature anomalies for 2003 were also calculated at all eight sites (Fig. 4). A strong latitudinal variation of the anomalies was evident with the largest above normal anomalies in the north: Nuuk (2.33°C), Iqaluit (2.04°C), Cartwright (1.16°C), St. John's (0.68°C), Magdalen Islands (0.66°C), Sable Island (0.17°C), Boston (-0.83°C), Cape Hatteras (-0.12°C). In 2002, all sites had above normal anomalies ranging from 0.05°C to 0.78°C, with the largest values of ~0.7°C Nuuk, Boston and Cape Hatteras. The average distance between all possible pairs of these eight stations is about 1700 km and the mean distance for the square of the correlation to fall to 0.5 (i.e. accounting for half of the variability) is 600 (750) km for the annual (5 year running mean) temperature anomalies. This indicates that although the air temperature anomalies look coherent in 2003, the eight stations shown undersample the variability. However, we archive more air temperature data than are shown here and can fill in the gaps at a finer resolution if needed.

Sea Surface Air Pressures

Climatic conditions in the Labrador Sea area are closely linked to large-scale pressure patterns and atmospheric circulation. Monthly mean atmospheric sea-surface pressures over the North Atlantic are published in *Die Grosswetterlagen Europas*. The long-term seasonal mean pressure patterns are dominated by the Icelandic Low, centred between Greenland and Iceland, and the Bermuda-Azores High, centred between Florida and northern Africa (Thompson and Hazen, 1983). The strengths of the Low and High vary seasonally from a winter maximum to a summer minimum. Seasonal anomalies of the sea-surface pressure for 2003, relative to the 1971-2000 means, are shown in Fig. 5. Winter includes December 2002 to February 2003, spring is March to May, summer is June to August and autumn is September to November.

In winter, an extensive anomalous low covered eastern Canada with its center (6 mb below normal) located east of Newfoundland. The system extended northwards to Baffin Bay and eastwards to western Europe and northwestern Africa. A high pressure anomaly (to 6 mb above normal) was situated to the east of Greenland. The winter pressure anomalies in 2003 indicate a weakening of both the Iceland Low and the Azores High, i.e. a reduction in the strength of the large-scale atmospheric circulation, similar to 2002.

The spring of 2003 featured a negative pressure anomaly trough (minimum about -3 mb) stretching from the Canadian Archipelago to northwestern Africa. This anomaly was flanked by a weak, small scale high pressure anomaly off Nova Scotia and a stronger positive anomaly running from Iceland to Western Europe. This pressure pattern indicates near normal Iceland Low and Azores High.

The pressure anomaly field during the summer of 2003 was atypical, featuring a strong below normal anomaly (minimum –5 mb) in the central North Atlantic. There was a positive anomaly (~3 mb maximum) over the Nordic seas.

In the autumn, the pattern was dominated by many small scale anomalies with peak magnitudes of ~3 mb.

NAO Index

The North Atlantic Oscillation (NAO) Index is the difference in winter (December, January and February) sea level atmospheric pressures between the Azores and Iceland and is a measure of the strength of the winter westerly winds over the northern North Atlantic (Rogers, 1984). A high NAO index corresponds to a deepening of the Icelandic Low and a strengthening of the Azores High. Strong northwest winds, cold air and sea temperatures and heavy ice in the Labrador Sea area are usually associated with a high positive NAO index (Colbourne *et al*., 1994; Drinkwater, 1996). The opposite response occurs during low NAO years. The annual NAO index is derived from the measured mean sea level pressures at Ponta Delgada (up to 1997) or Santa Maria (since 1997) in the Azores minus those at Akureyri in Iceland. The small number of missing data early in the time series was filled using pressures from nearby stations. The NAO anomalies were calculated by subtracting the 1971-2000 mean.

In 2003, the NAO index was below normal (-3.3 mb anomaly) and nearly unchanged from 2002 (-3.2 mb anomaly). As indicated, low NAO is usually accompanied by warm air temperatures over the Labrador Sea in winter. This is consistent with air temperature anomalies which were ~2°C above normal from Nuuk and Iqaluit to near 0 at Sable Island.

Winds

The re-analyzed NCEP (National Centre for Environmental Prediction) – NCAR (National Center for Atmospheric Research) winds (Kistler *et al*., 2001) are available from the International Research Institute of the Lamont-Doherty Earth Observatory at Columbia University. Based upon correlations with observed winds, the vector components of the NCEP winds capture most of the observed variability in the wind field. They represent winds measured at a height of 10 m and are gridded at intervals of 1.88° longitude and 1.90° latitude. We have averaged the winds seasonally and obtained anomalies for the gridded wind data covering an area approximately from 40°-68°N and 40°-75°W (Fig. 7). The magnitude of the wind anomalies tend to be larger in the north, hence for presentation purposes, we show the Labrador Sea separately from regions farther south.

The anomalies of the mean winter winds during 2003 over the Labrador Sea were variable, being primarily easterly in the south and weaker, with more directional variability, in the north (Fig. 8). Along the northern Labrador coast the wind anomalies were from the north and stronger than in 2002. Over Atlantic Canada, winter wind anomalies were primarily from the north over the Gulf of Maine and the Scotian Shelf, switching to southwesterlies over the Grand Bank (Fig. 9). In the Gulf of St. Lawrence, the wind anomalies were from the west. The anomalous winds in the spring are from the west in the Labrador Sea, from the east over the Gulf of Maine, nearly 0 over the Scotian Shelf, and generally from the west to west-northwest over the Gulf of St. Lawrence and the Grand Banks. The pattern changed again in summer, with anomalies from the northeast over the southern Labrador Sea rotating clockwise to anomalies from the southeast over the northern Labrador Sea. There were strong anomalies from the southwest over Georges Bank and from the northwest over the northern shoulder of Grand Bank and Flemish Cap, but elsewhere the anomalies were negligible. The autumn wind anomalies over the Labrador Sea and Atlantic Canada were predominantly from the south.

Sea Ice Observations

The locations and concentrations of sea ice are available from the daily ice charts published by Ice Central of Environment Canada in Ottawa. The long-term median, maximum and minimum positions of the ice edge (concentrations above 10%) are based on the 1971-2000 data (Canadian Ice Service, 2002). The ice edge can vary rapidly over short periods of time (~days) due primarily to changes in the winds. We also include an analysis of the time of onset, duration and last presence of sea ice based upon the sea-ice database maintained at the Bedford Institute of Oceanography for the Newfoundland region (Peterson and Prinsenberg, 1990) and for the Gulf of St. Lawrence and the Scotian Shelf (Drinkwater et al., 1999). The weekly concentration and types of ice within 0.5° latitude by 1° longitude areas were recorded through the ice season. The dates of the first and last appearance of ice within these areas, as well as the duration of ice, were determined. The data begin in the early 1960s and continue through to the present. Long-term means (30-years, 1971-2000) of each variable were determined (using only data from years ice was present) and were subtracted from the 2003 values to obtain anomalies.

Newfoundland and Labrador

Sea-Ice. At the beginning of 2003, the only sea ice present lay off the southern Labrador coast in the vicinity of Hamilton Inlet (Fig. 10A). This coverage was less than the long-term median for the beginning of the year. By mid-January, ice had spread south to the Strait of Belle Isle, slightly less than the long-term median coverage. The distribution was relatively unchanged by February 1 and was closer to the minimum coverage than the median for this time of the year. By March 1 there was a considerable expansion of ice coverage such that the distribution approached the median. Nearshore open areas are evident on the first of April and May but overall the coverage exceeded the median (Fig. 10B). A small amount of ice was present on June 1 in the northwest corner of the area; by July all ice had vanished from the analysis region.

We analysed for the first and last presence of ice. Ice appeared along the southern Labrador coast in mid-December 2002 (indicated by –15, Fig. 11), and gradually spread southward to northeastern Newfoundland waters by late-January, mid-February 2003 (day 30-45). Ice reached the northern Grand Bank in early to mid-March. Relative to the long-term mean, ice generally appeared near its normal time over most of the Labrador Shelf, and later-than-normal over the northeastern Newfoundland Shelf by about 2 weeks (Fig. 11). Ice began to disappear from the shoulder of Grand Bank in late March (day 90; Fig. 12). It did not begin to retreat from inshore northern Newfoundland waters and southern Labrador until early to mid-May (day 120-135). Ice lasted in the Hamilton Bank region from the end of May to mid-June (day 150-165). Over much of the Labrador Shelf, ice disappeared earlier-than-normal (negative anomaly) by about 2 weeks. Ice remained about 2 weeks longer than average over the Labrador Slope and much of the northeast Newfoundland Shelf and upper slope. The duration of sea ice is the number of days that ice, at a minimum concentration of 10%, is present. It is not simply the date of the first presence minus the last presence because the ice may disappear for a time and then reappear. Duration ranged from <30 days on the northern Grand Bank to over 170 days along the Labrador coast (Fig. 13). The ice duration was greater-than-normal over most of the Newfoundland and Labrador Shelves by as much as 40 days.

The time series of the monthly ice coverage on the Newfoundland and southern Labrador shelves (45-55^{o}N; I. Peterson, pers. comm., Bedford Institute) show that the peak extent during 2003 was largest since 1997 (Fig. 14). Relative to 2002, the average ice area rose slightly during advancement (January to March) and retreat (April to June). In 2003 (Dec 2002-May 2003) the integrated ice area ranked 19th for the 1965-2003 (39 year) period, was 80% of the 1971-2000 long-term mean, and was 57% of a standard deviation below the long-term mean (=100*(Integrated Area 2003-long-term mean)/standard deviation). The monthly means of ice area show that the 2003 seasonal coverage was greater than that of 2002 during December, January and March-May, equal in February, and less in June and July. In all months except March and April, the ice area was below the long-term average (1971-2000); the coverage was about 10% above the long-term mean during March and April (Fig. 15). In summary, 2003 overall was a lighter-than-average ice year on the Labrador and Newfoundland shelves. Although no estimates of ice volume were made for 2003, studies in the Gulf of St. Lawrence (Drinkwater *et al*., 1999) suggest that the temporal variability of the ice volume would be similar to that of the ice area.

Icebergs. The International Ice Patrol Division of the United States Coast Guard monitors the number of icebergs that pass south of 48ºN latitude each year. Since 1983, data have been collected with SLAR (Side-Looking Airborne Radar). During the 2002/2003 iceberg season (October 2002 to September 2003), a total of 927 icebergs were detected south of 48^{o}N. The first icebergs were seen south of 48^{o}N in March 2003. The monthly totals for March to July were 84, 263, 494, 76 and 10 (Fig. 16). The 1985-2000 period is considered to have reliable SLAR measurements. A higher percentage of icebergs than usual arrived in April and May in 2003. The total number of icebergs was up slightly from the 877 recorded in 2002; the 15th highest number of icebergs were recorded for the March-July, 2003 period in 124 years (Fig. 16).

Gulf of St. Lawrence

The locations of the ice edge within the Gulf of St. Lawrence during the 2002-2003 winter season are shown in Fig. 17. Ice first appeared in early December as small patches in several coastal regions. Coverage grew but was less than the median until the beginning of February. By early March most of the Gulf was covered and ice had spilled onto the Scotian Shelf where it reached the long-term maximum, to Halifax in the southwest and Sable Island offshore. By April 1, the Estuary, Gaspé and most of the northwestern Gulf was clear of ice but coverage in the central Gulf remained above the long-term median. Small amounts of ice were found in the northeastern Gulf in early May and along the north shore in early June.

The times of first appearance of ice in the Gulf of St. Lawrence were generally 0-15 d earlier-than-normal (Fig. 11). By the end of January, ice had covered most of Gulf for at least some period of time. The last presence of ice varied from mid-April to early June; this was 0-15 d later-than-normal for the southern Gulf, most of the Laurentian Channel, the Estuary and the northwestern Gulf (Fig. 12). There was a strong gradient of last presence of ice in the northeastern Gulf to a maximum of ~60 d later-than-average north of Anticosti. Ice duration varied from 90-150 d; ice duration was less than the long-term mean in a broad band from the northwestern Gulf to Cape Breton (Fig. 13). Away from this band, the duration increased to as much as 40 d longer-than-normal.

We have estimated the monthly mean area of the Gulf covered by ice. The time series shows that in 2003 the peak areal coverage rose compared to 2002 and the previous several years (Fig. 18). Ice coverage from December to May for the 2003 ice season was about 10% greater than the 1971-2000 average; this is +0.47 of a standard deviation above normal. The 2003 ice season ranked as the 15 highest in 41 years and the first year since 1995 with above normal coverage. Estimates of the duration of ice showed that on average, the 2003 season was the 5th longest in the 41 years, it was 21 d longer than the 1971-2000 average duration, 1.2 standard deviations above normal. To summarize, 2003 featured slightly above normal ice coverage for a significantly longer than normal duration in the Gulf of St. Lawrence.

Scotian Shelf

Sea ice is generally transported out of the Gulf of St. Lawrence through Cabot Strait, pushed by northwesterly winds and ocean currents. In 2003, ice first appeared seaward of the Strait during mid to late January, which is slightly earlier-than-usual (Fig. 11). It maintained a relatively constant presence in the Cabot Strait area until mid-April; the duration in Sydney Bight was 10-20 d longer than normal (Fig. 12, 13, 17). Overall the duration of ice was the 15th longest of the 42 year record, 10 d or 0.5 standard deviations longer than normal. The ice coverage on the Scotian Shelf was exceptional in 2003 and was dominated by March when it was 2.6 times the 1971-2000 mean (Fig. 17, 19, 20). Overall the January-May coverage was the 3rd highest in the 42 year record, more than twice the long-term mean and 1.7 standard deviations above normal.

The 2003 ice season breaks the pattern of eight years with below normal coverage. Based upon data collected since the 1960s, the farthest south that the ice penetrates is along the Atlantic coast of Nova Scotia to just past Halifax. Records prior to 1960 suggest that during heavy ice years, ice occasionally was found much farther south, for example in the 1880s sea ice was observed in the southwestern Scotian Shelf (Hill *et al.*, 2002).

Remotely-Sensed Sea Surface Temperature

We maintain the 9 km resolution Pathfinder sea surface temperature data in a public database at BIO. In the following analysis we substituted the 18 km resolution MCSST data for the Pathfinder observations in 1999 because we noticed serious degradation of the latter, particularly towards the end of the year. This deterioration of the Pathfinder data was not evident in other years nor was it found for the MCSST data.

Annual anomalies for 23 Subareas, stretching form the Labrador Sea to the Gulf of Maine (Fig. 21), were determined from the averages of monthly anomalies. The results are shown as annual temperature anomalies in Fig. 22 where data are plotted from north to south. In 2003, the largest annual SST anomaly of 1.2^{o}C was observed in the Labrador Sea at Bravo; anomalies generally decreased from Bravo southward along the Labrador Shelf to near 0 on the northern Grand Bank. Flemish Pass had a positive anomaly of ~0.9^{o}C. The remaining stations had anomalies of about 0-0.6^{o}C below normal.

The coherence among the time series is striking, with episodes of both below and above normal temperatures. In particular, there was a region-wide warm period from 1998 to 2002 with some indication of an earlier onset at northern sites and ongoing above normal SST from the northern Labrador Sea to Flemish Pass. This variability is similar to that seen in the air temperature anomaly series which are replotted in Fig. 23. Many of the features seen in the SST anomaly plot are evident in air temperature: the 1998-2003 warm period, warm periods at the southern sites in 1990-92, centered around 1994, the subsequent southern cold period, etc. The visual similarity encouraged us to try to link the air temperature anomalies, assumed to be the forcing, to the SST anomalies, considered the response. We reduced the air temperature field to the 3 leading empirical orthogonal modes which accounted for 92% of the SST variability. We added the NAO anomaly time series as the fourth forcing term and regressed each SST anomaly time series on these 4 series. The SST field was then reconstructed from the regressions (Fig. 24). The results are very satisfying with 77% of the SST variance accounted for by the statistical model.

Summary

During 2003, the NAO index was below normal for the third consecutive year and close to the 2002 value. Air temperatures over the northwest Atlantic region were above normal, with annual values ~2^{o}C above normal in the northern Labrador Sea decreasing to the south to ~0.2^{o}C above normal at Sable Island. There was about 20% less ice coverage than normal during the ice season (December 2002–May 2003) for the southern Labrador-Newfoundland shelf region. In the Gulf of St. Lawrence the season long coverage was about 10% above the long-term mean, the first year above normal since 1995. The Scotian Shelf had twice the long-term January-May coverage and was dominated by March, when coverage approached the long-term maximum. This also was the first year since 1995 with the ice season coverage above the long-term mean. The number, 927, of icebergs that reached the Grand Bank was about equal to the 877 counted in 2002. The analysis of satellite data indicates a north-south gradient of sea surface temperatures with above normal annual anomalies (to 1.2^{o}C) to the northeast Newfoundland Shelf and Flemish Pass and generally below normal values on the Grand Banks, in the Gulf of St. Lawrence and over the Scotian Shelf.

Acknowledgements

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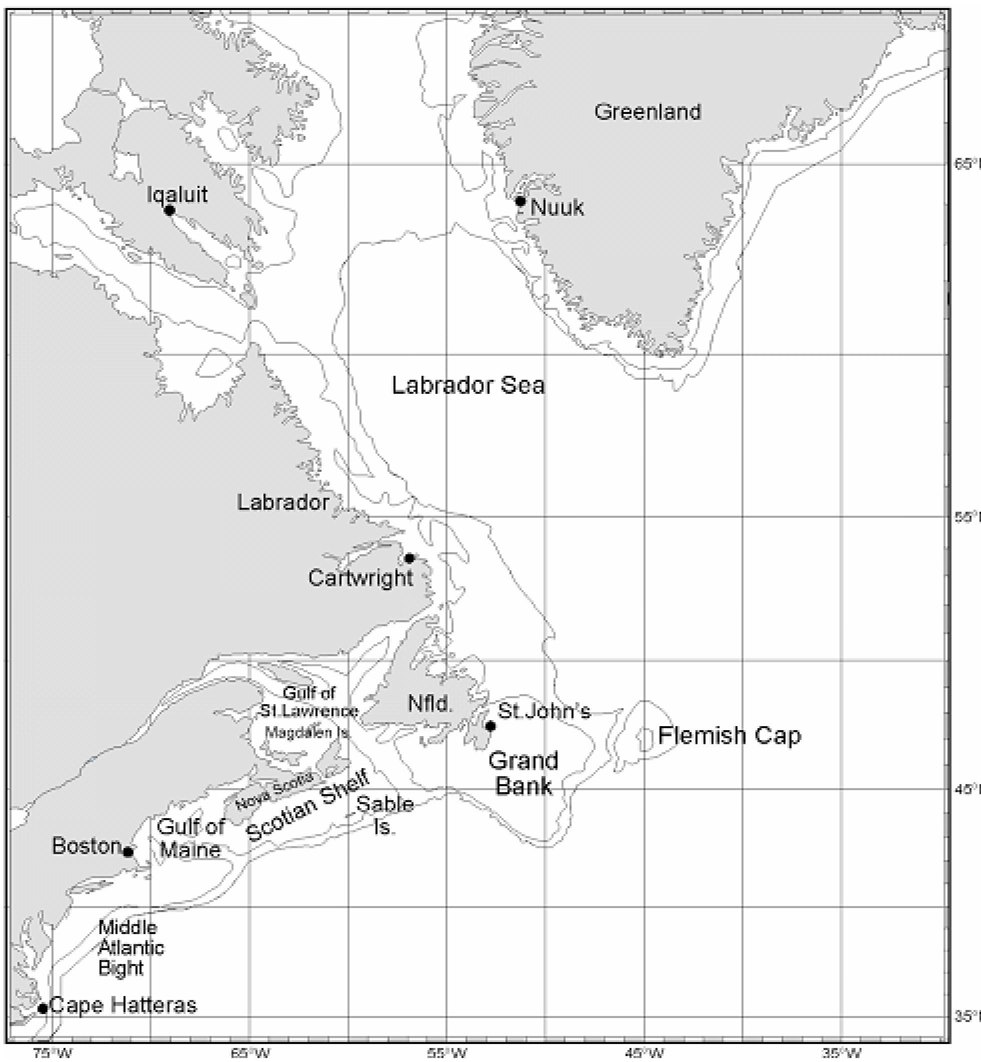

Fig. 1. Northwest Atlantic showing coastal air temperature stations. The thin lines denote the 200 m and 1000 m isobaths.

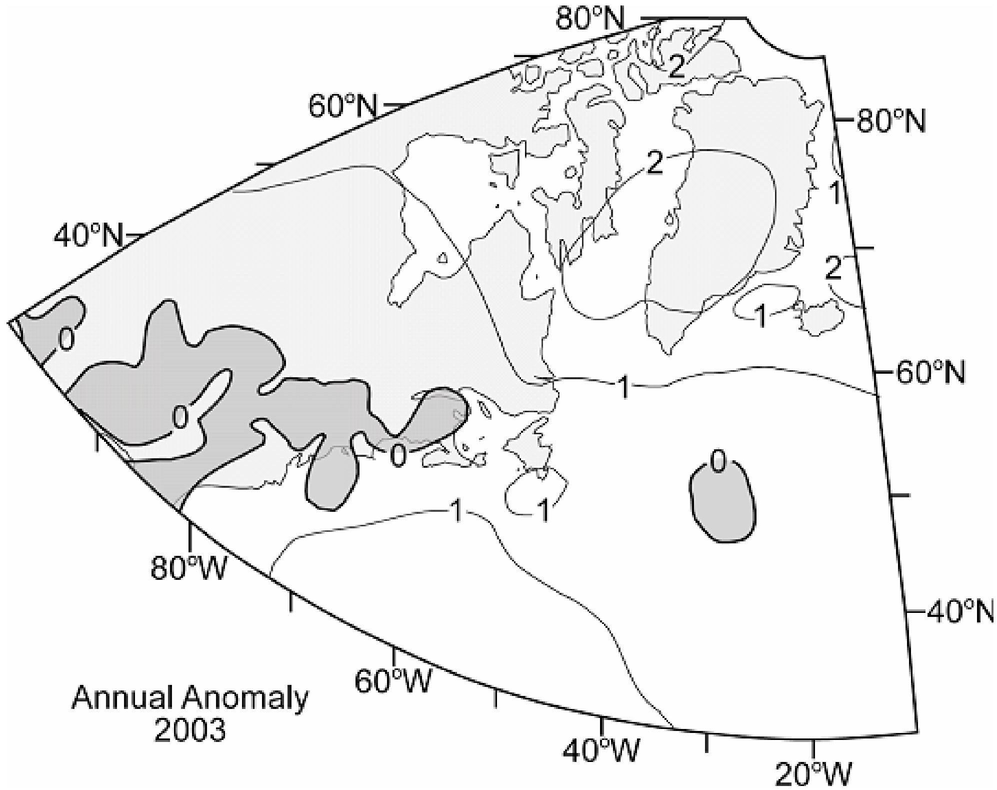

Fig. 2A. The 2003 annual anomaly of air temperature (°C) over the Northwest Atlantic relative to the 1961-1990 means. The darker shaded areas are colder-than-normal. (Redrawn from Grosswetterlagen Europas).

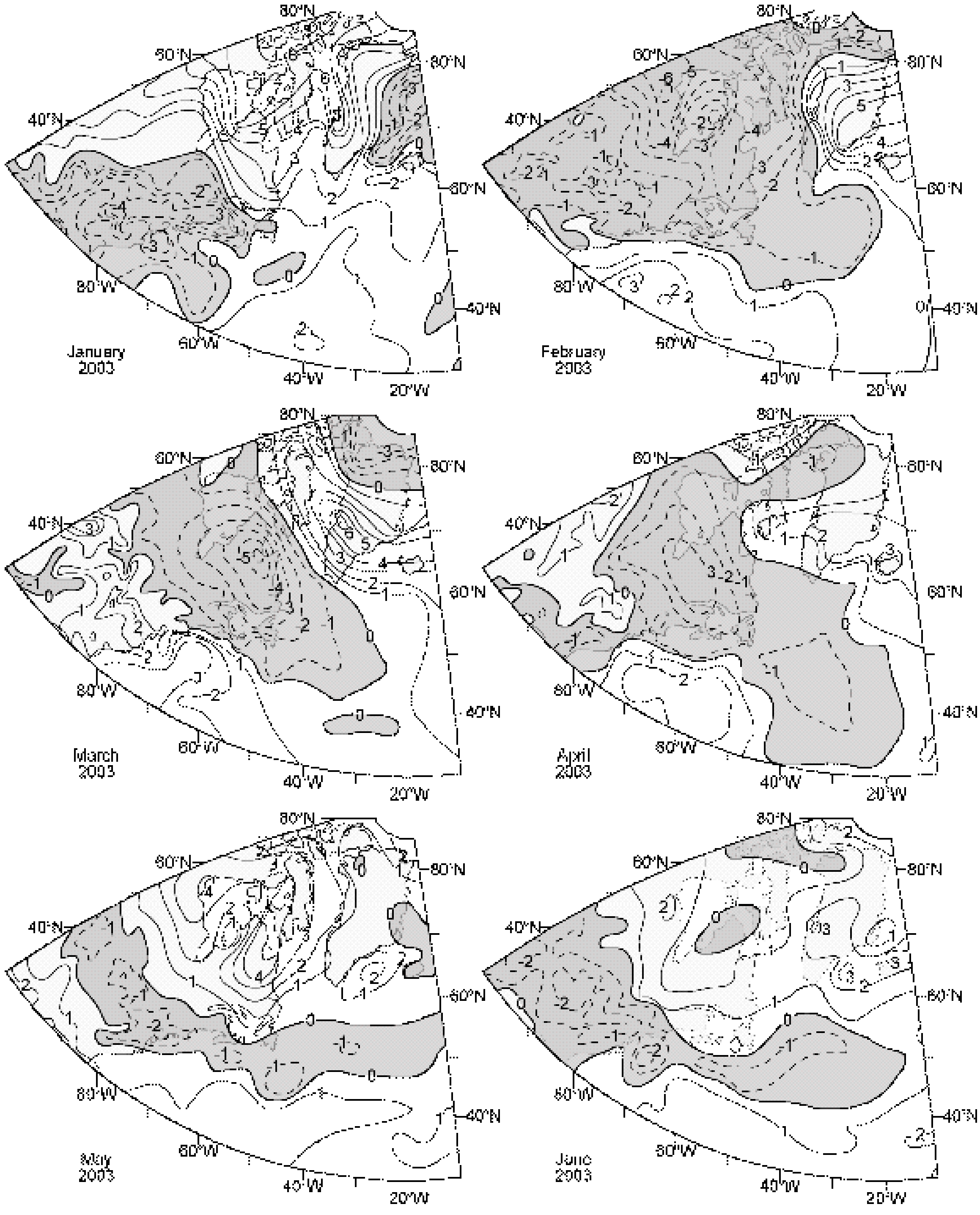

Fig. 2B. Monthly air temperature anomalies (^{o}C) over the Northwest Atlantic from January to May of 2003 relative to their 1961-1990 means. The darker shaded areas are colder-than-normal. (Redrawn from *Grosswetterlagen Europas*)

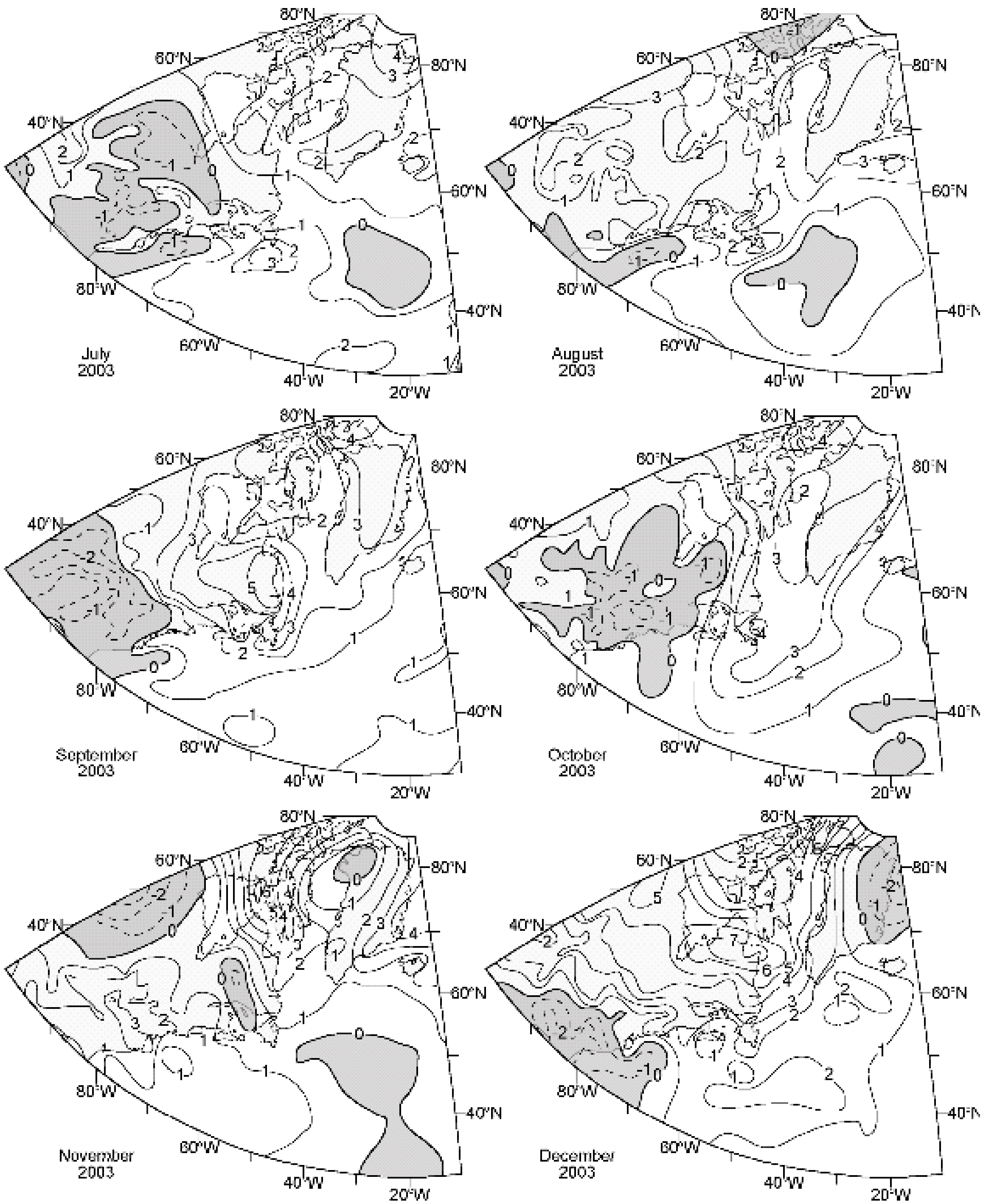

Fig. 2C. Monthly air temperature anomalies (°C) over the Northwest Atlantic from July to December of 2003 relative to their 1961-1990 means. The darker shaded areas are colder-than-normal. (Redrawn from *Grosswetterlagen Europas*)

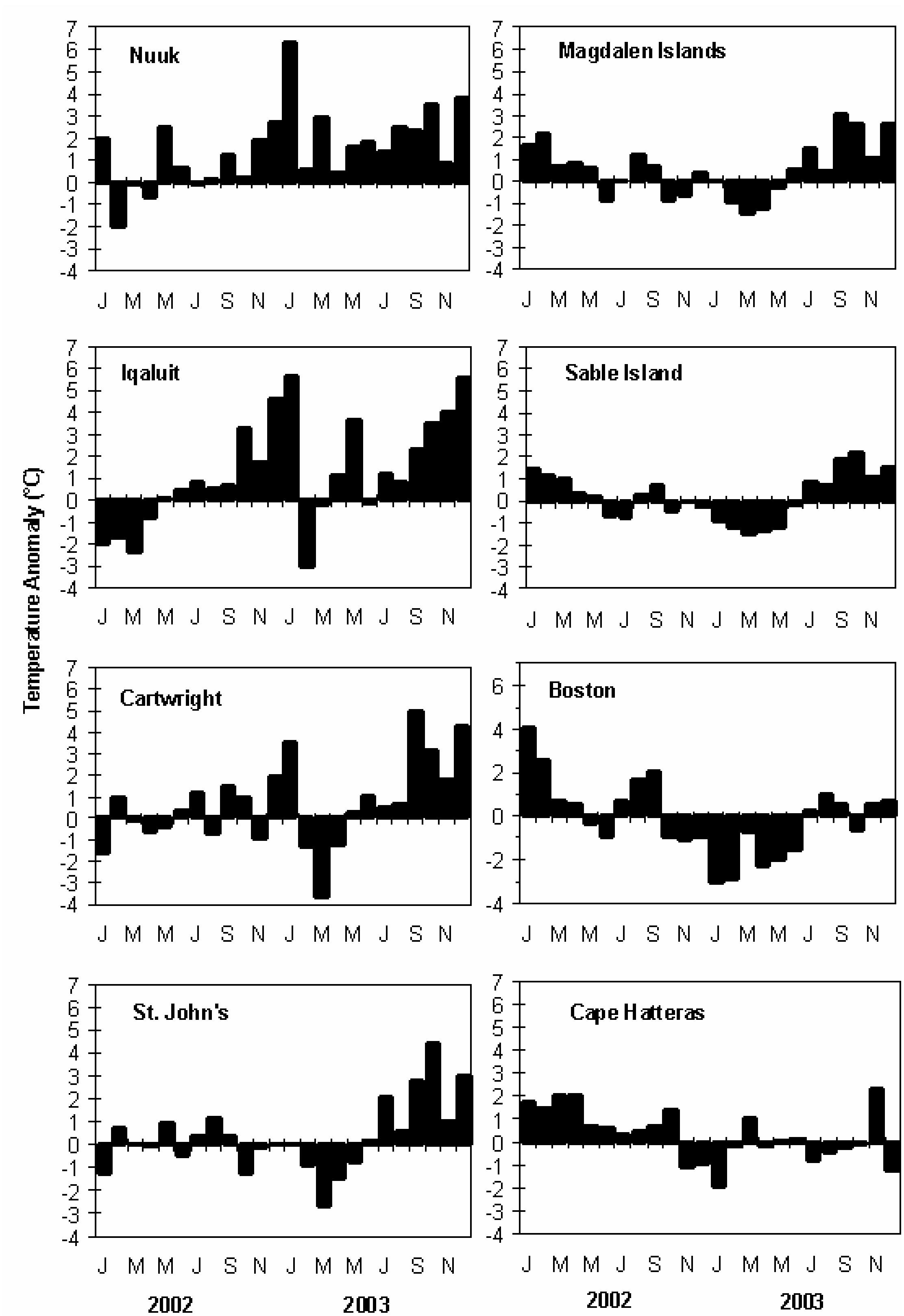

Fig. 3. Monthly air temperature anomalies in 2002 and 2003 at selected coastal sites (see Fig. 1 for locations).

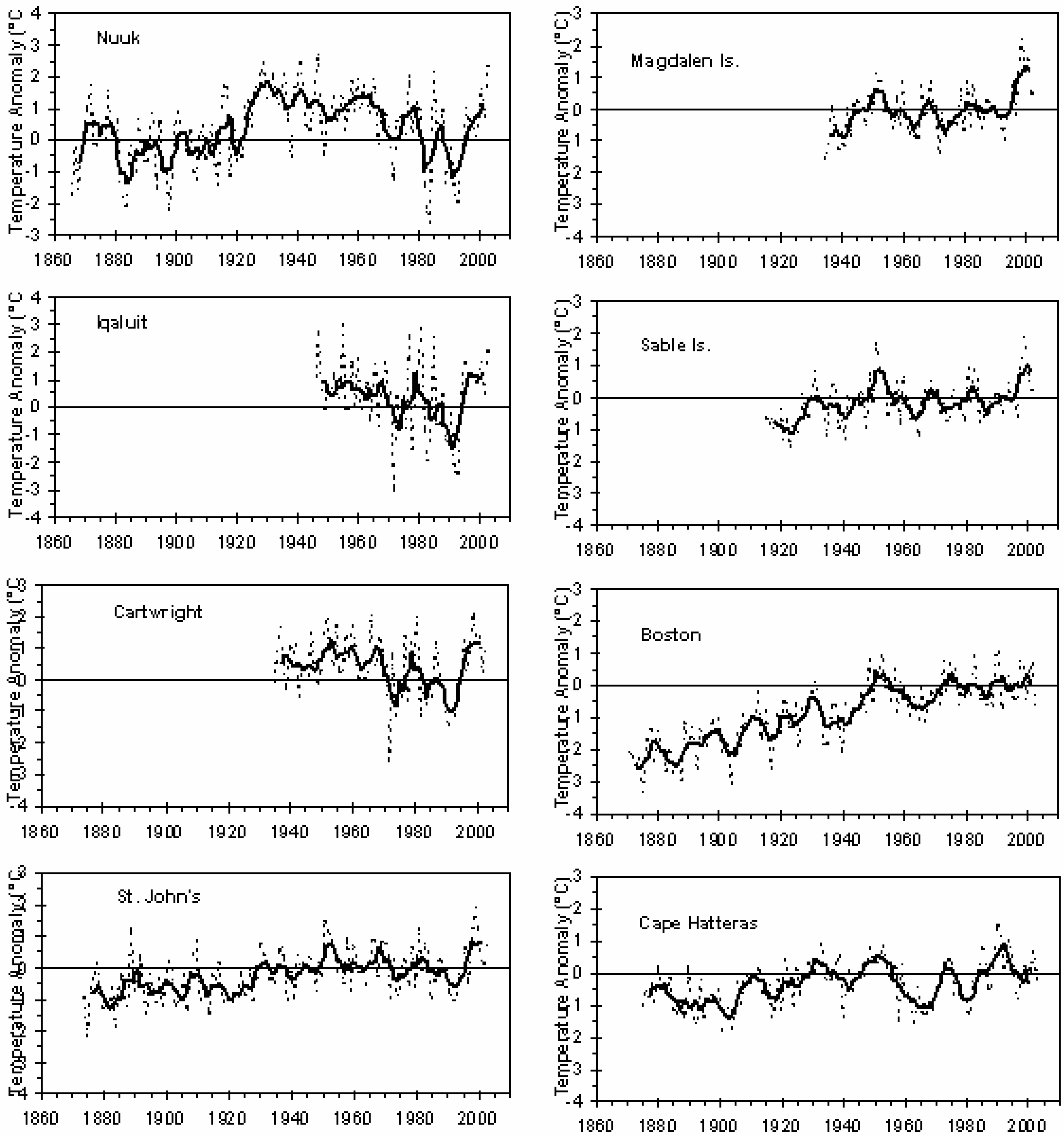

Fig. 4. Annual air temperature anomalies (dashed line) and 5-yr running means (solid line) at selected sites.

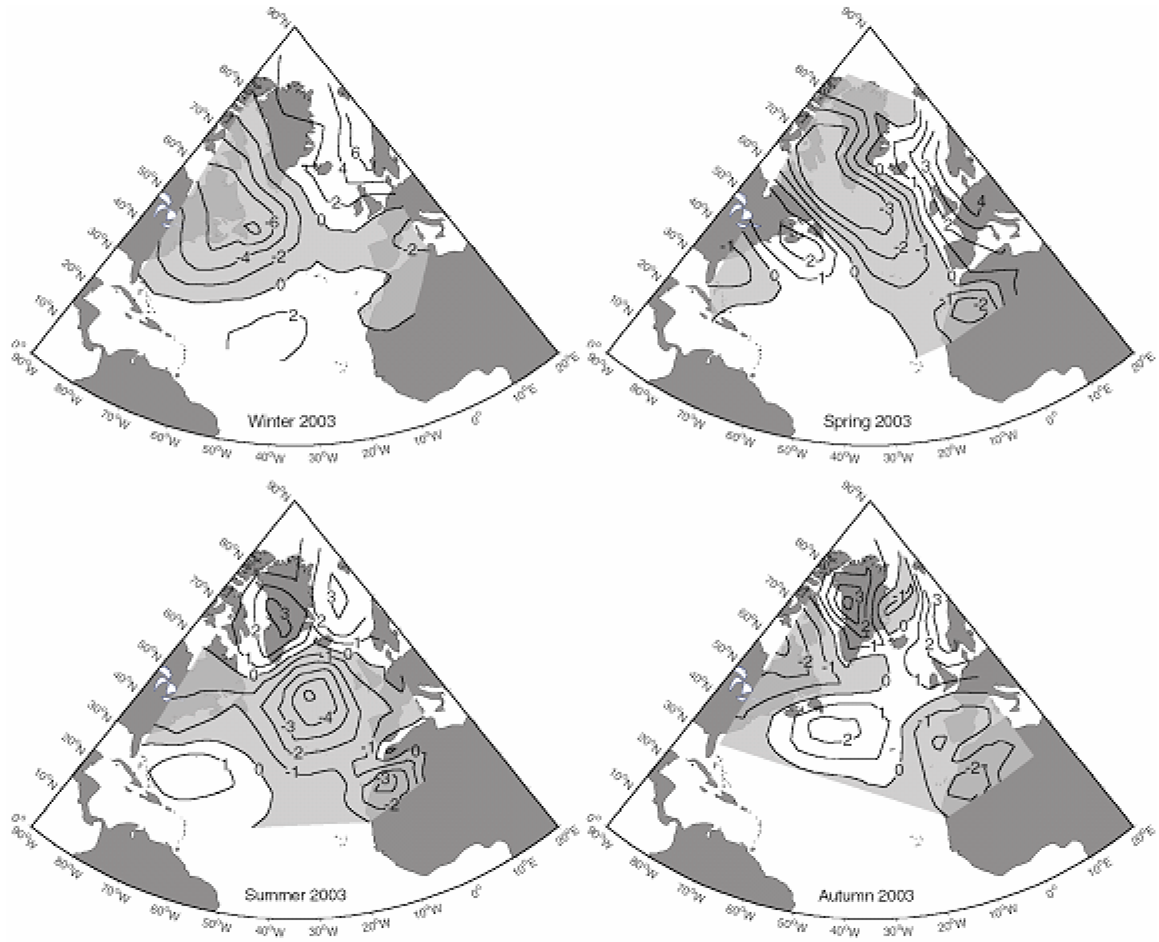

Fig. 5. Seasonal sea-surface air pressure anomalies (mb) over the North Atlantic in 2003 relative to the 1971-2000 means.

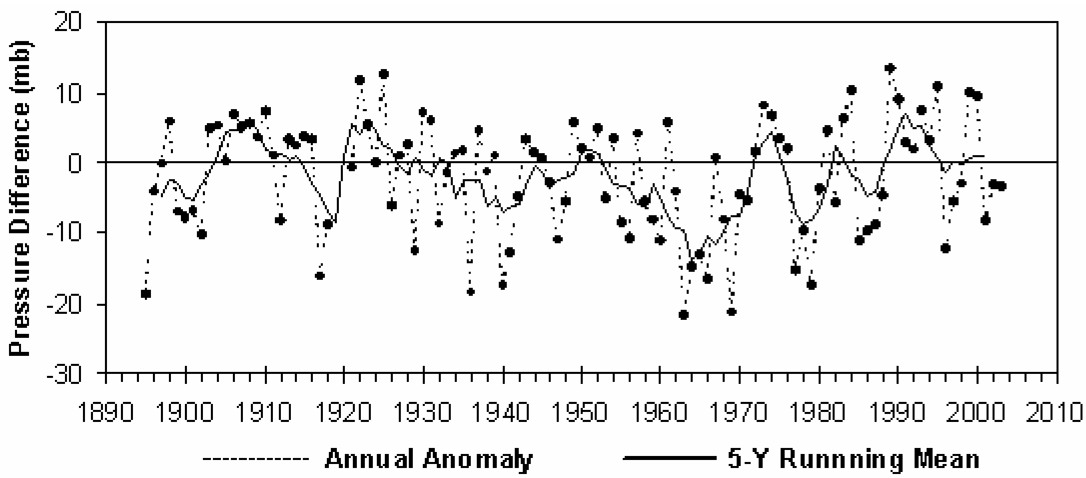

Fig. 6. Anomalies of the North Atlantic Oscillation Index, defined as the winter (December, January, February) sea level pressure difference between the Azores and Iceland, relative to the 1971-2000 mean.

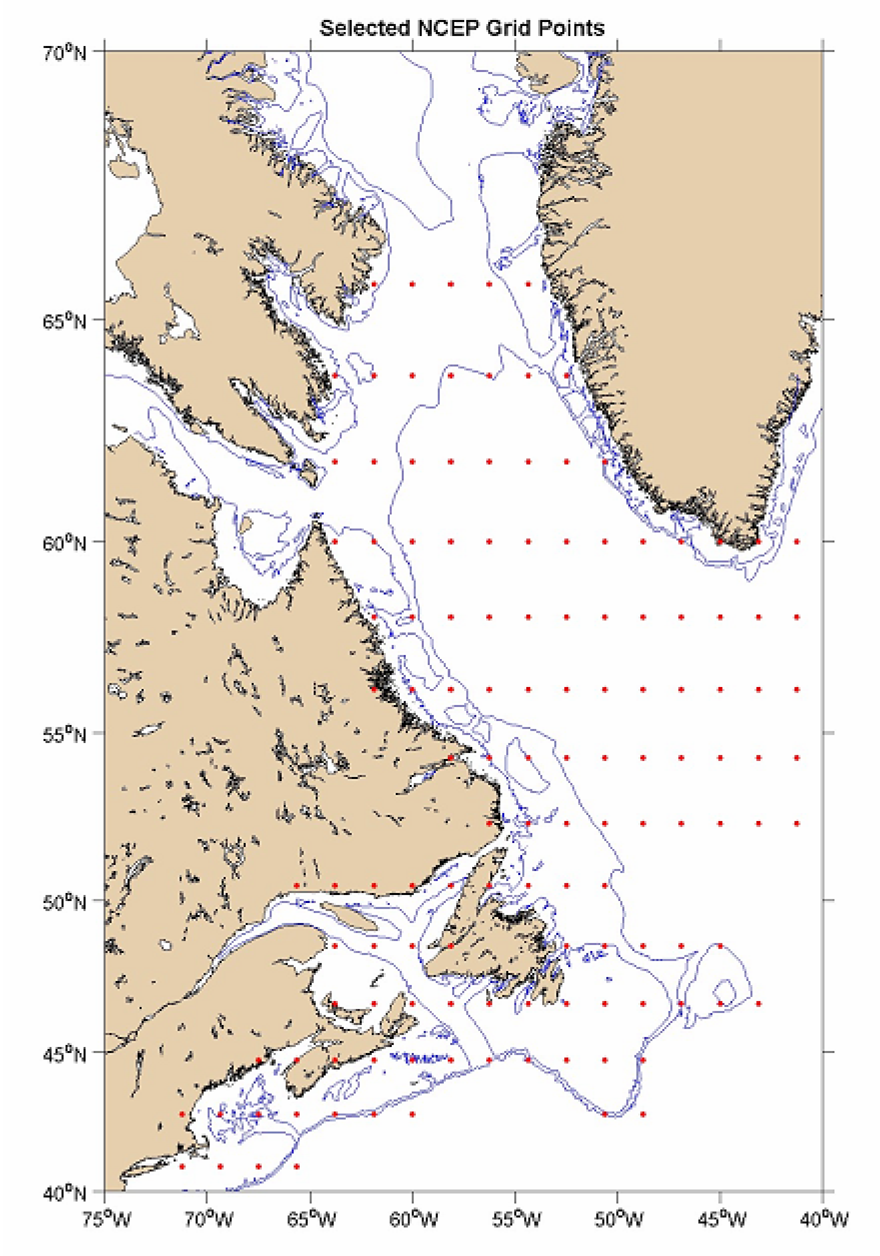

Fig. 7. The Northwest Atlantic showing the NCEP wind grids used in our study.

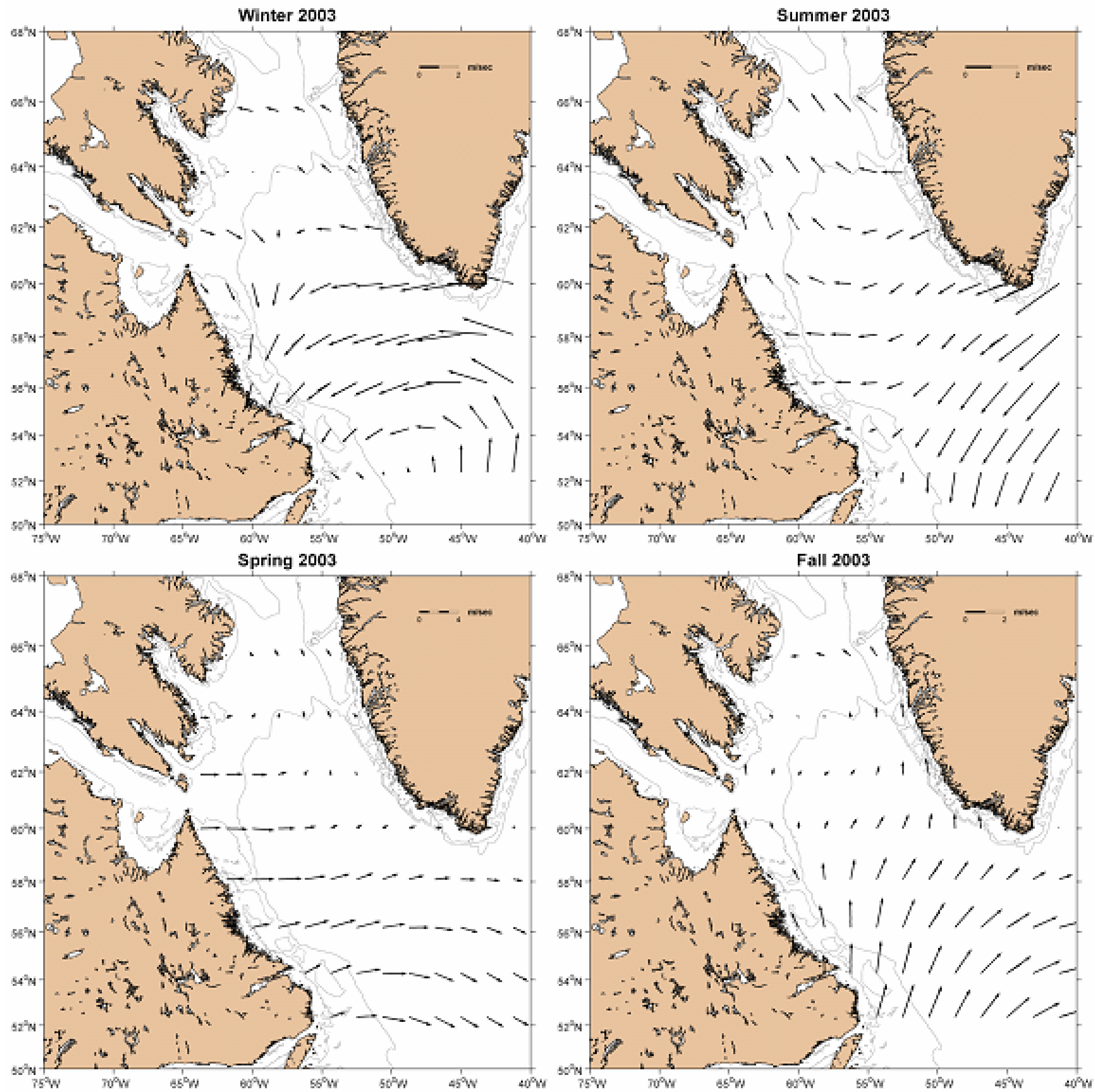

Fig. 8. The seasonal wind anomalies for the northern region during 2003.

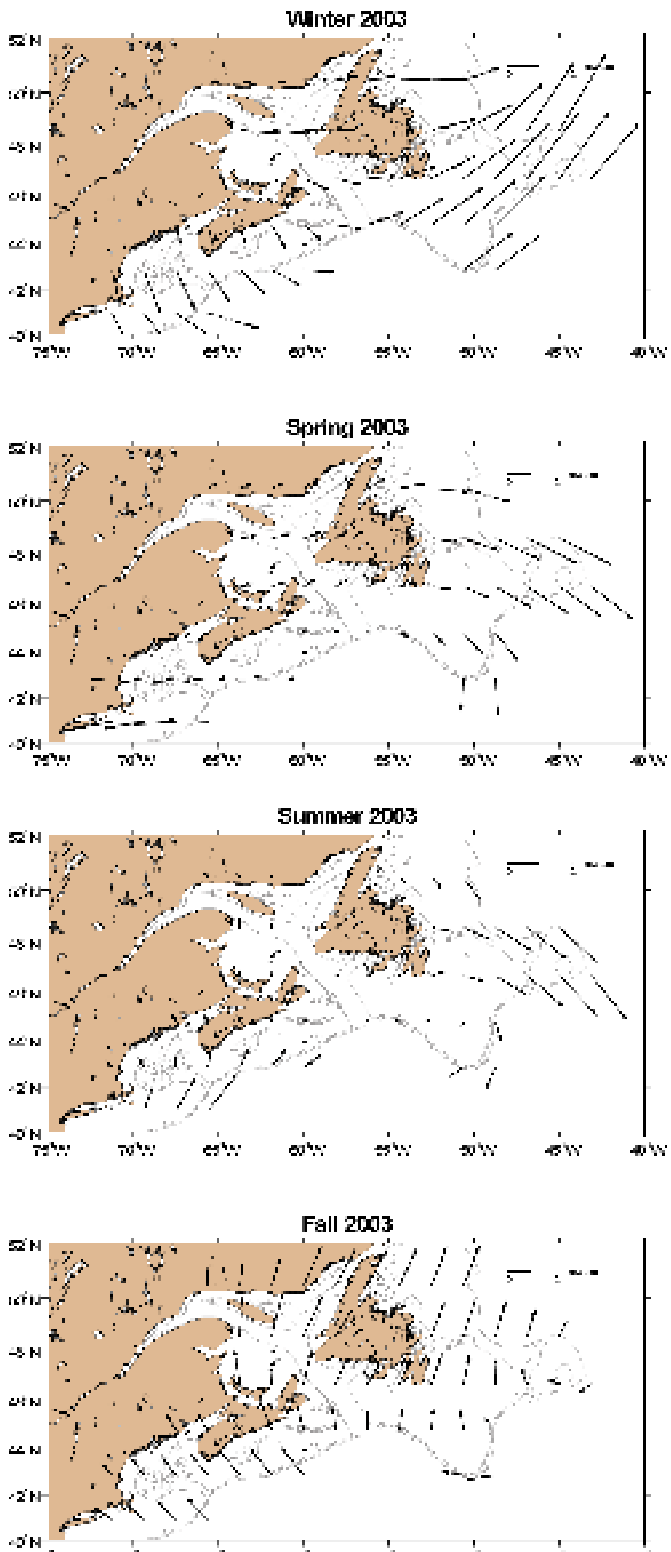

Fig. 9. The seasonal wind anomalies for the southern region during 2003.

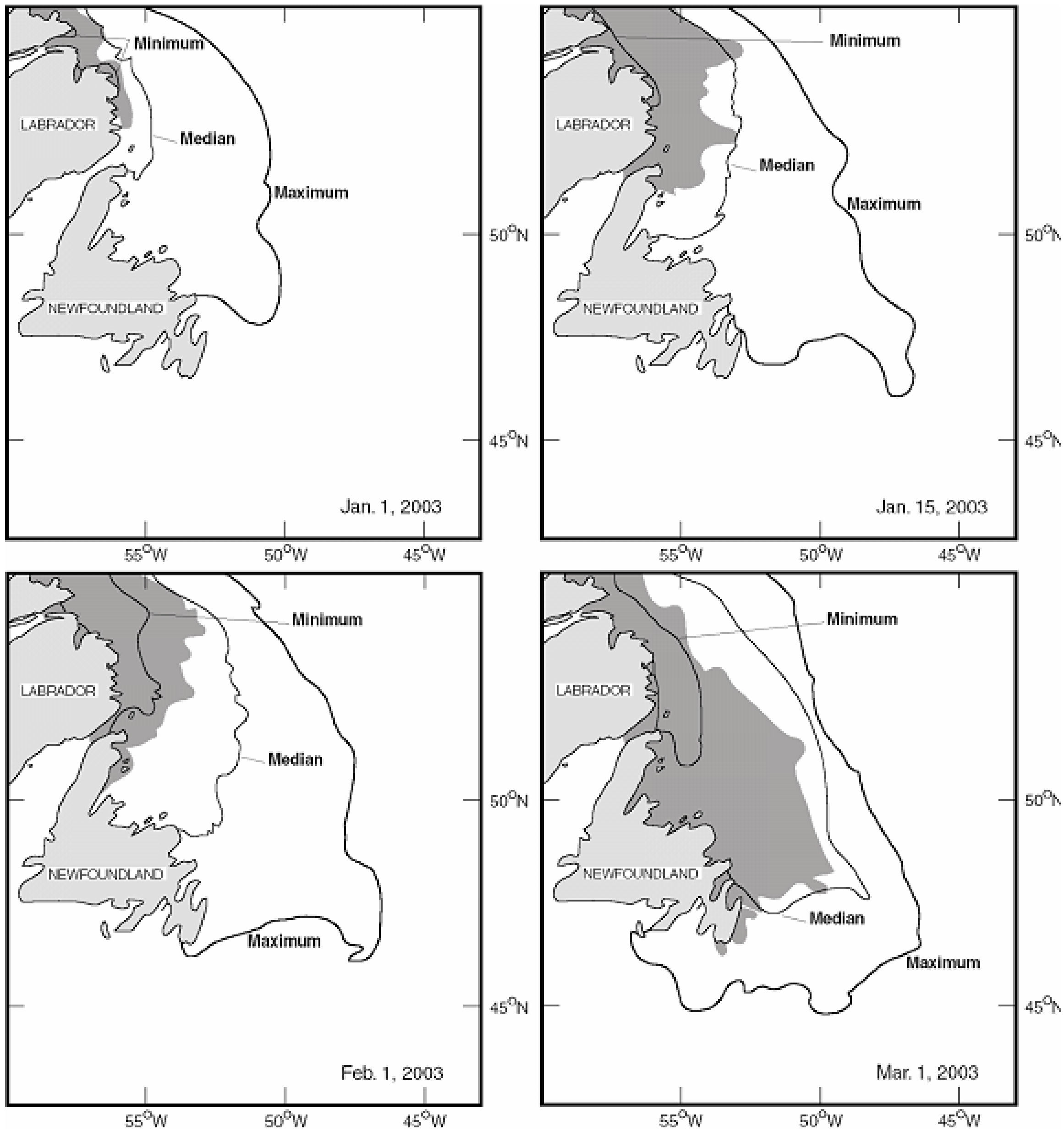

Fig. 10A. The location of the ice (shaded area) between January and March 2003 together with the historical (1971-2000) minimum, median and maximum positions of the ice edge off Newfoundland and Labrador.

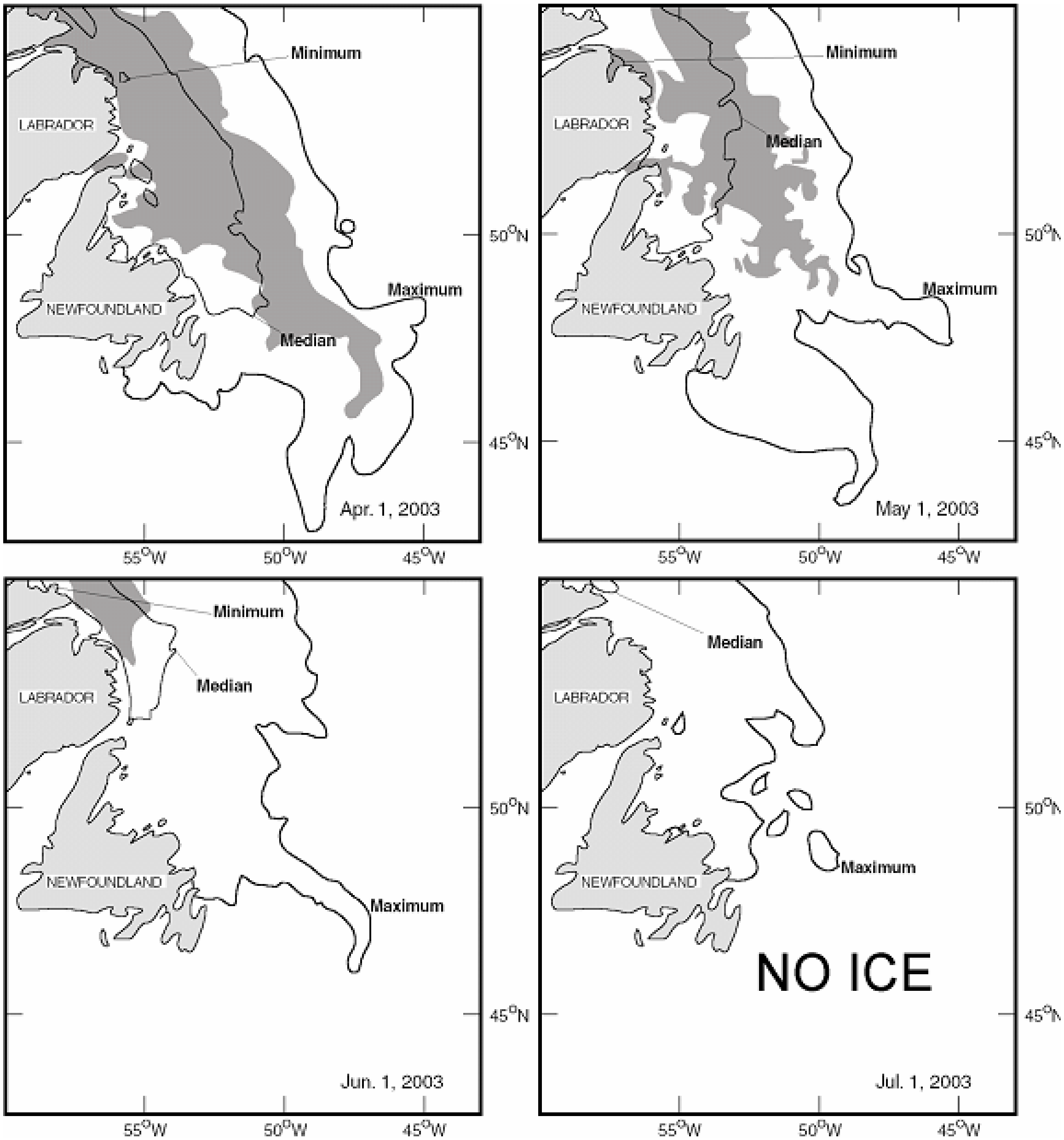

Fig. 10B. The location of the ice (shaded area) between April and July 2003 together with the historical (1971-2000) minimum, median and maximum positions of the ice edge off Newfoundland and Labrador.

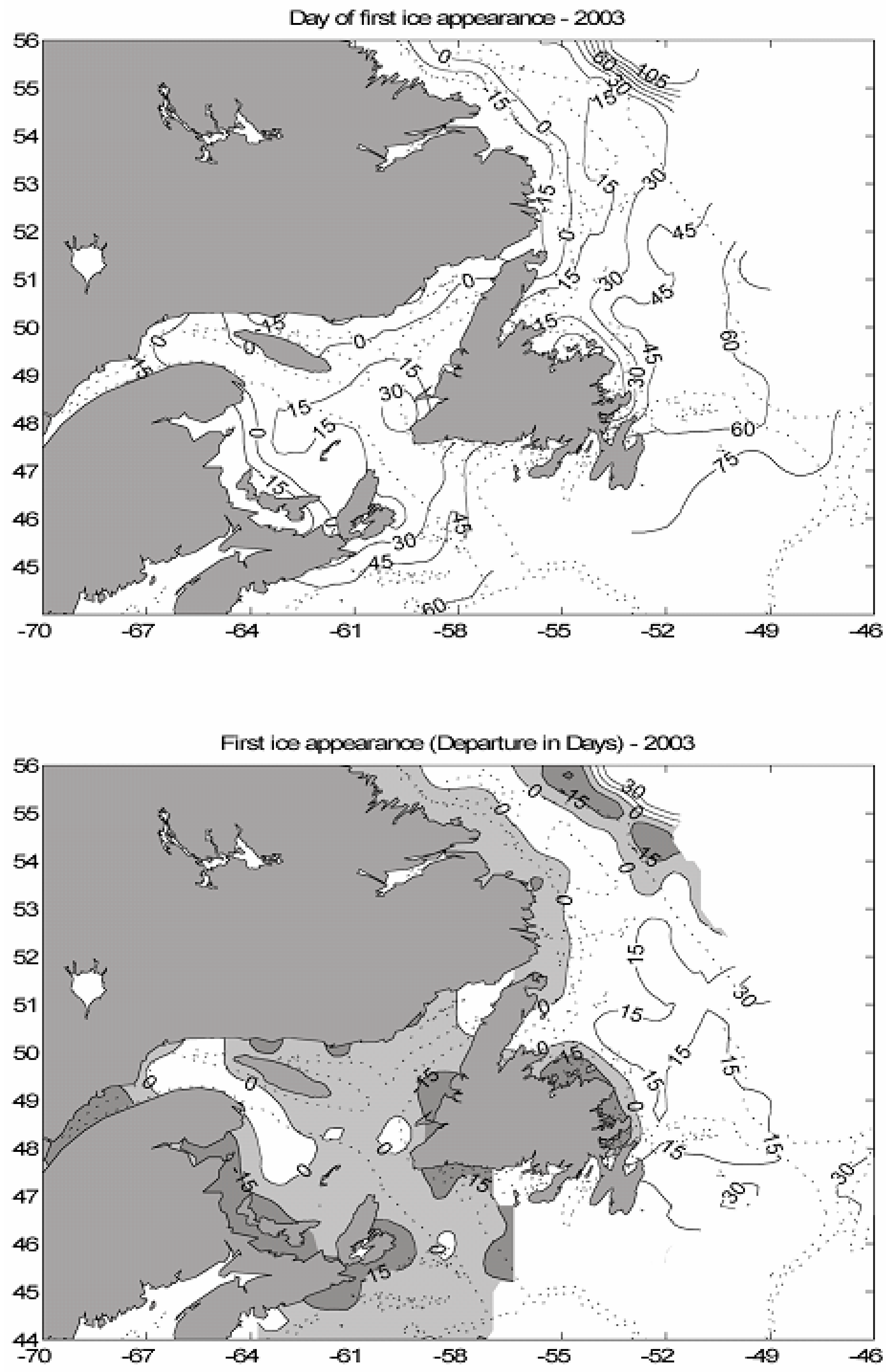

Fig. 11. The time when ice first appeared during 2003 in days from the beginning of the year (top panel) and its anomaly from the 1971-2000 mean in days (bottom panel). Negative anomalies, indicating earlier than normal appearance, are shaded.

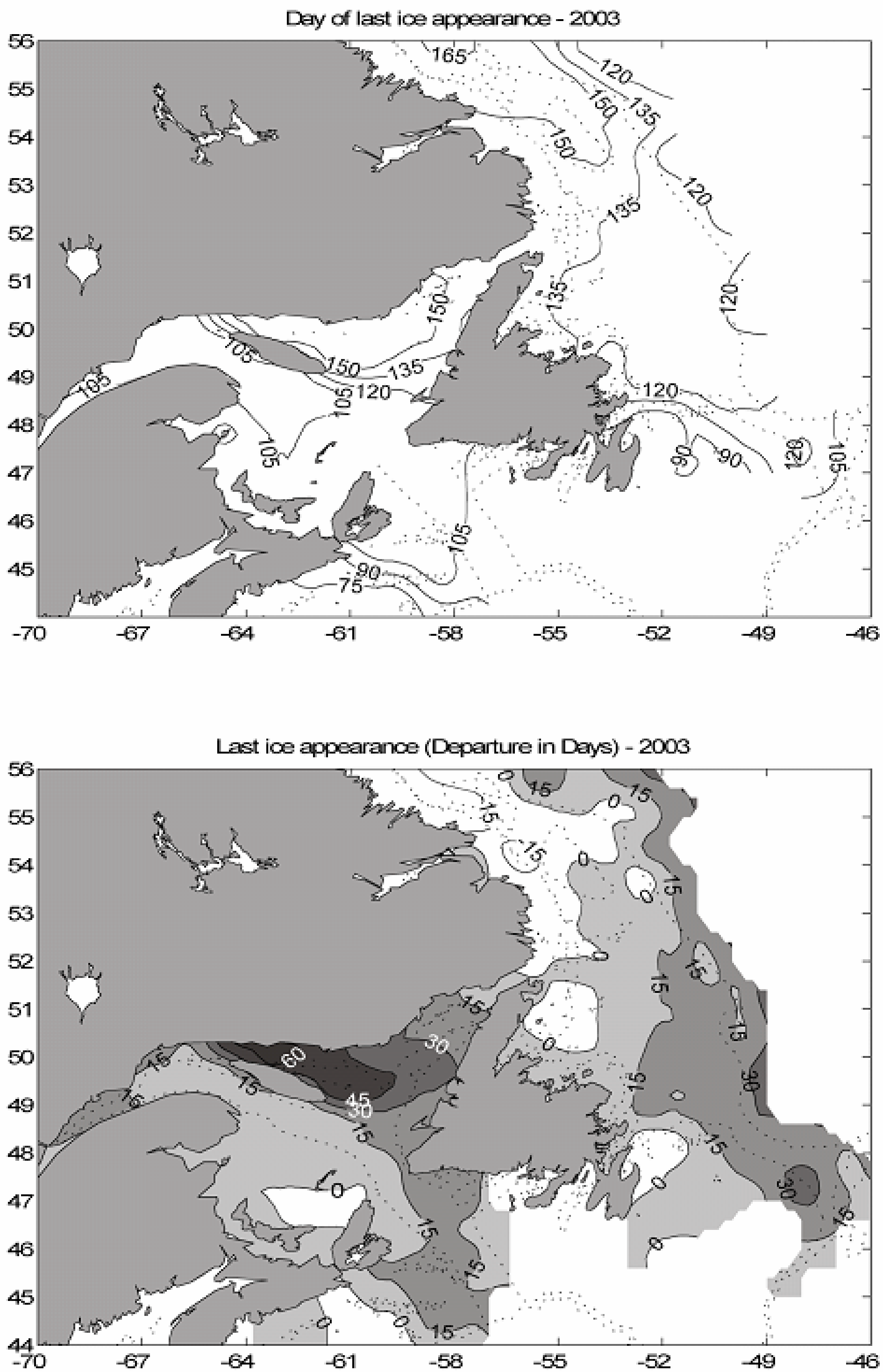

Fig. 12. The time when ice was last seen in 2003 in days from the beginning of the year (top panel) and its anomaly from the 1971-2000 mean in days (bottom panel). Positive anomalies, indicating later-than-normal disappearance, are shaded.

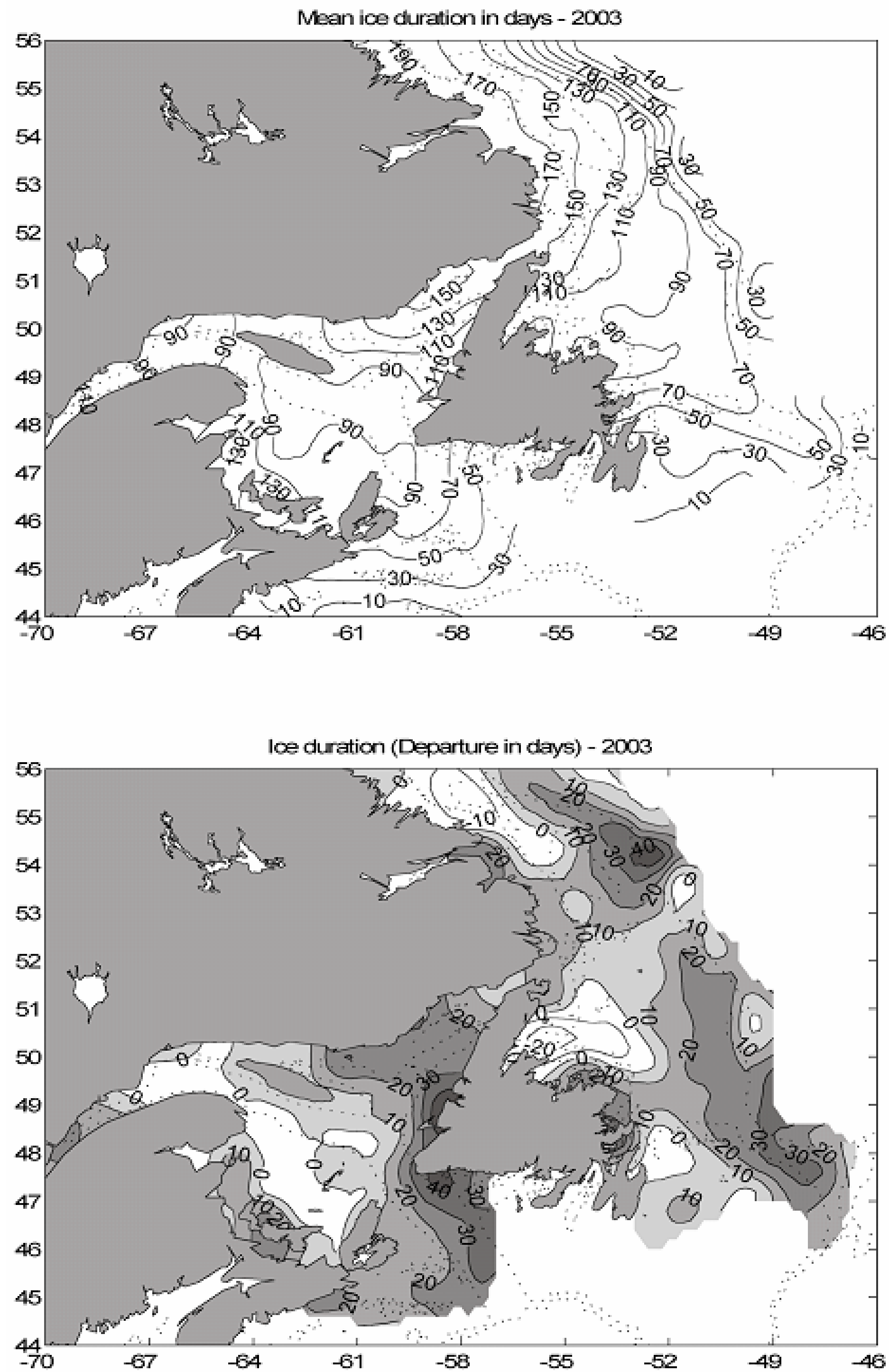

Fig. 13. The duration of ice in days (top panel) during 2003 and the anomalies from the 1971-2000 mean in days (bottom panel). Positive anomalies, which indicate durations longer than the mean, are shaded.

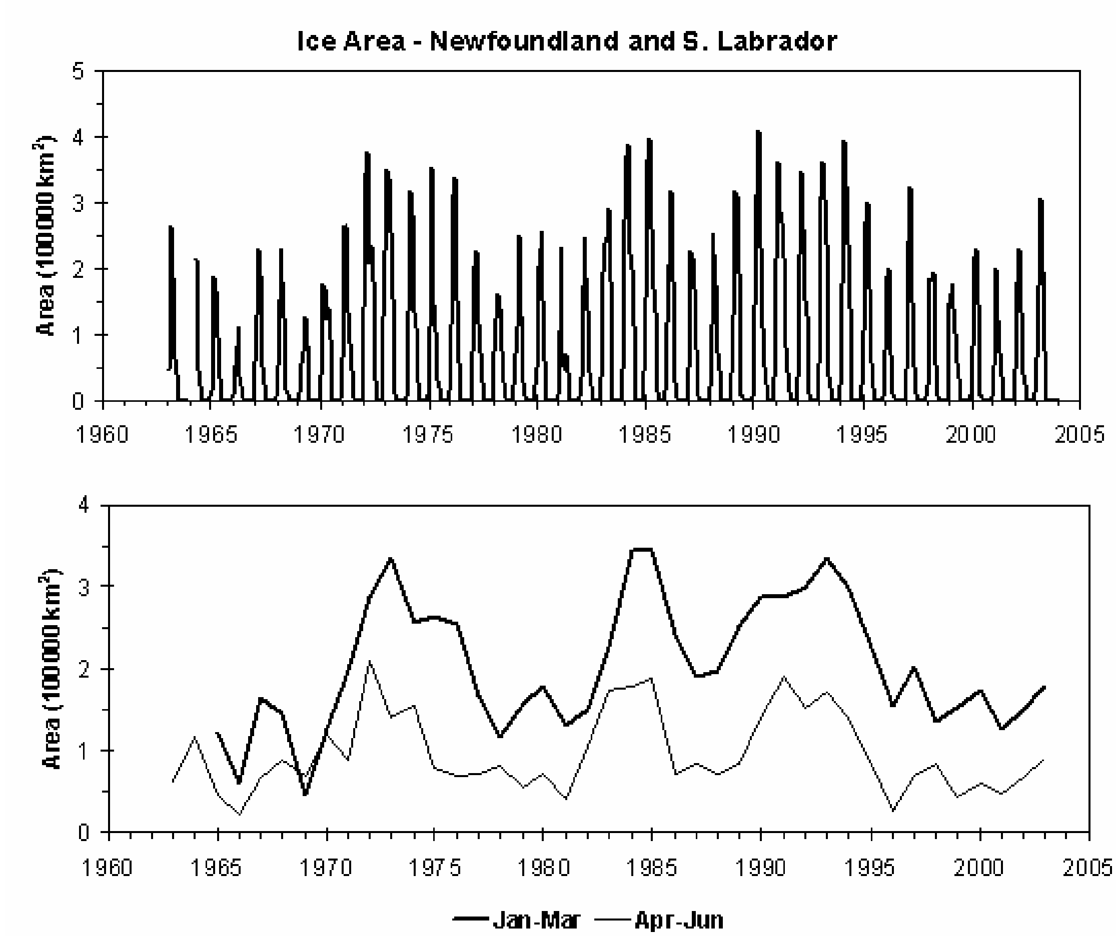

Fig. 14. Time series of the monthly mean ice area off Newfoundland and Labrador between 45°N-55°N (top panel) and the average ice area during the normal periods of advancement (January-March) and retreat (April-June) (bottom panel).

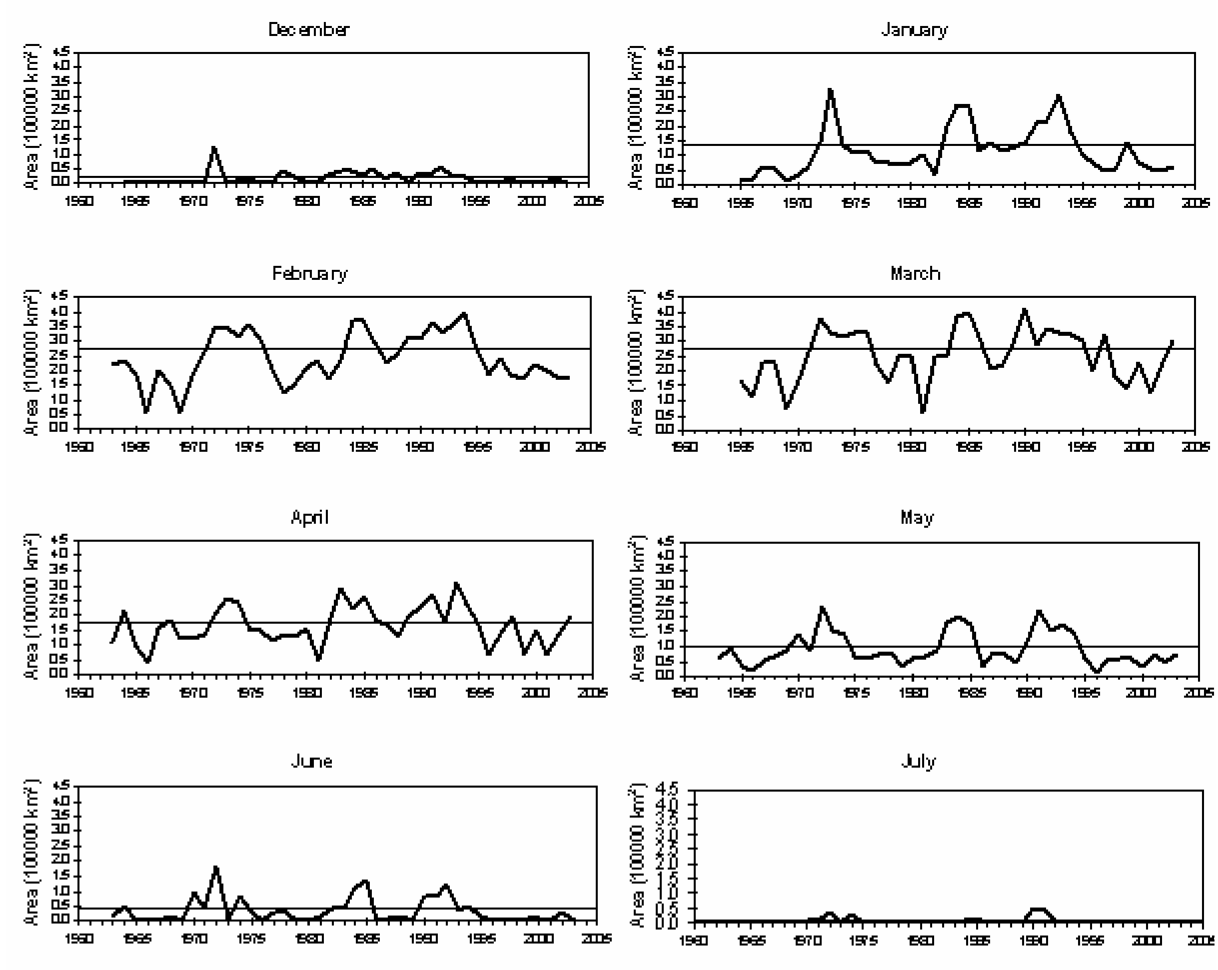

Fig. 15. The time series of ice area off Newfoundland and Labrador, by month. The horizontal lines represent the long-term (1971-2000) means.

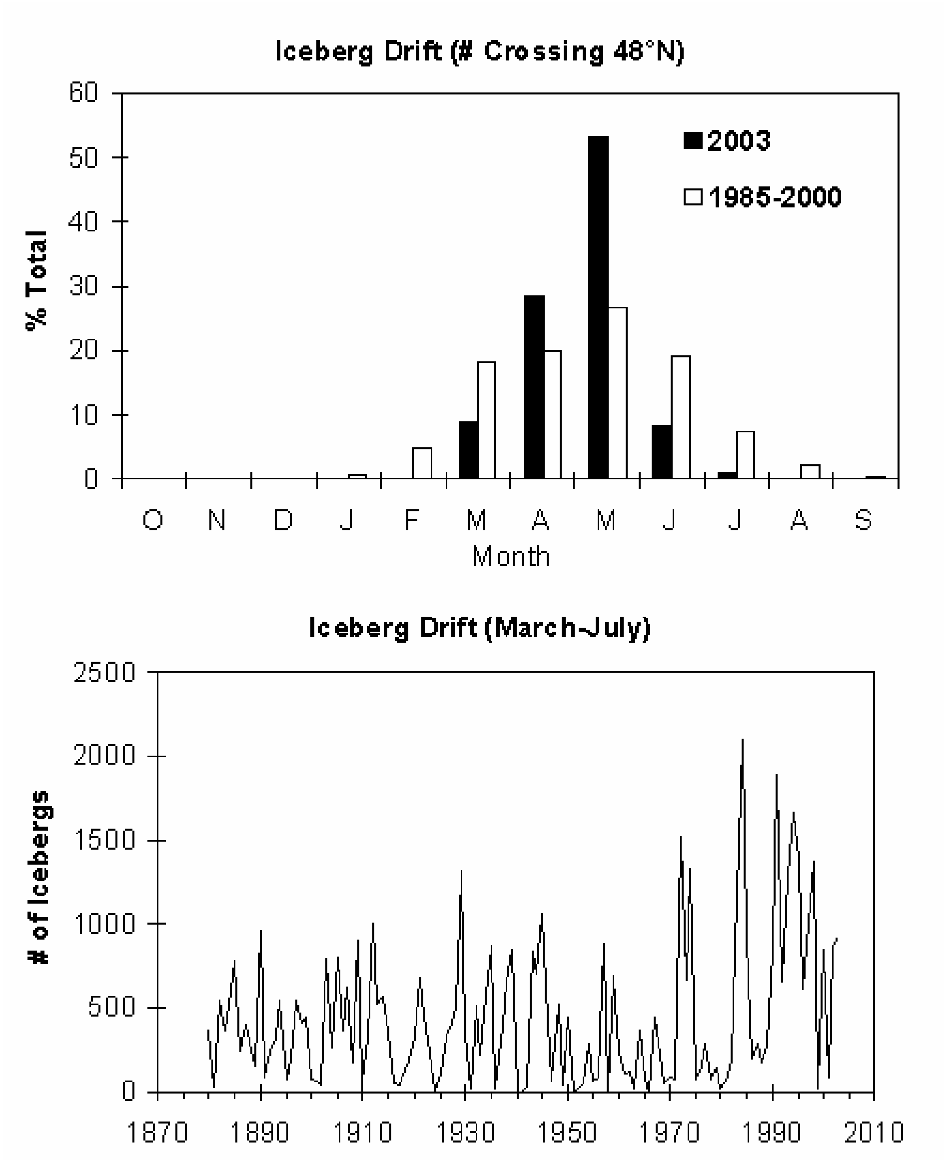

Fig. 16. The number of icebergs crossing south of 48°N during the iceberg season 2002/2003 expressed as a percent of the total by month compared to the mean during 1985-2000, the years SLAR has been used (top panel), and the time series of total number of icebergs observed during March to July (bottom panel).

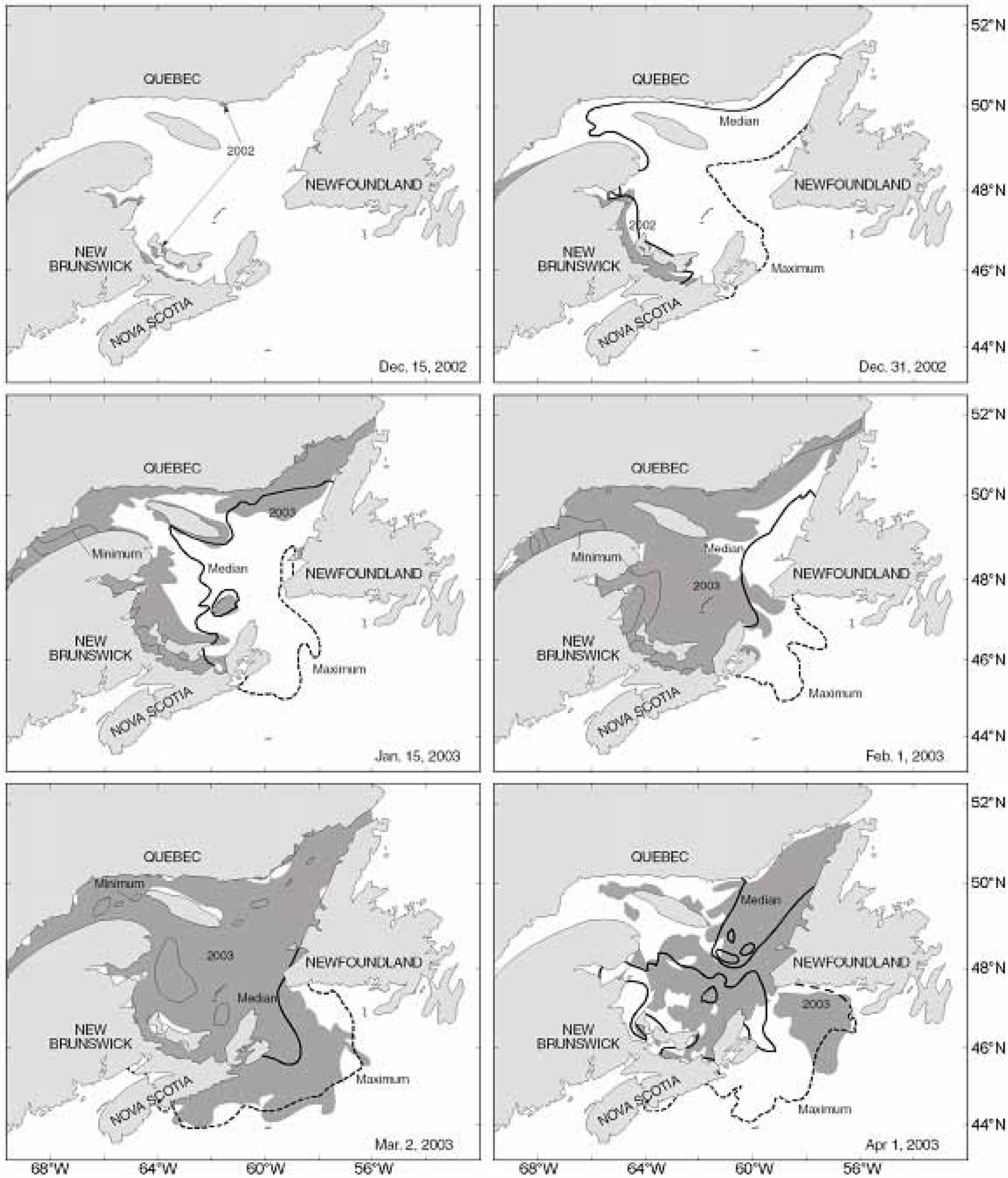

Fig. 17. The location of the ice (shaded area) between December 2002 and April 2003 together with the historical (1971-2000) minimum, median and maximum positions of the ice edge in the Gulf of St. Lawrence.

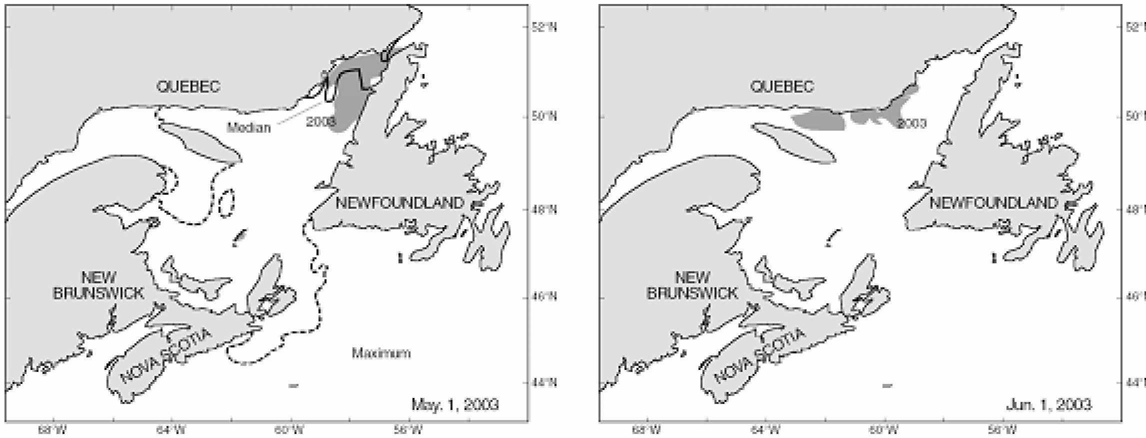

Fig. 17. Continued. The location of the ice (shaded area) between early May and June 2003 together with the historical (1971-2000) minimum, median and maximum positions of the ice edge in the Gulf of St. Lawrence.

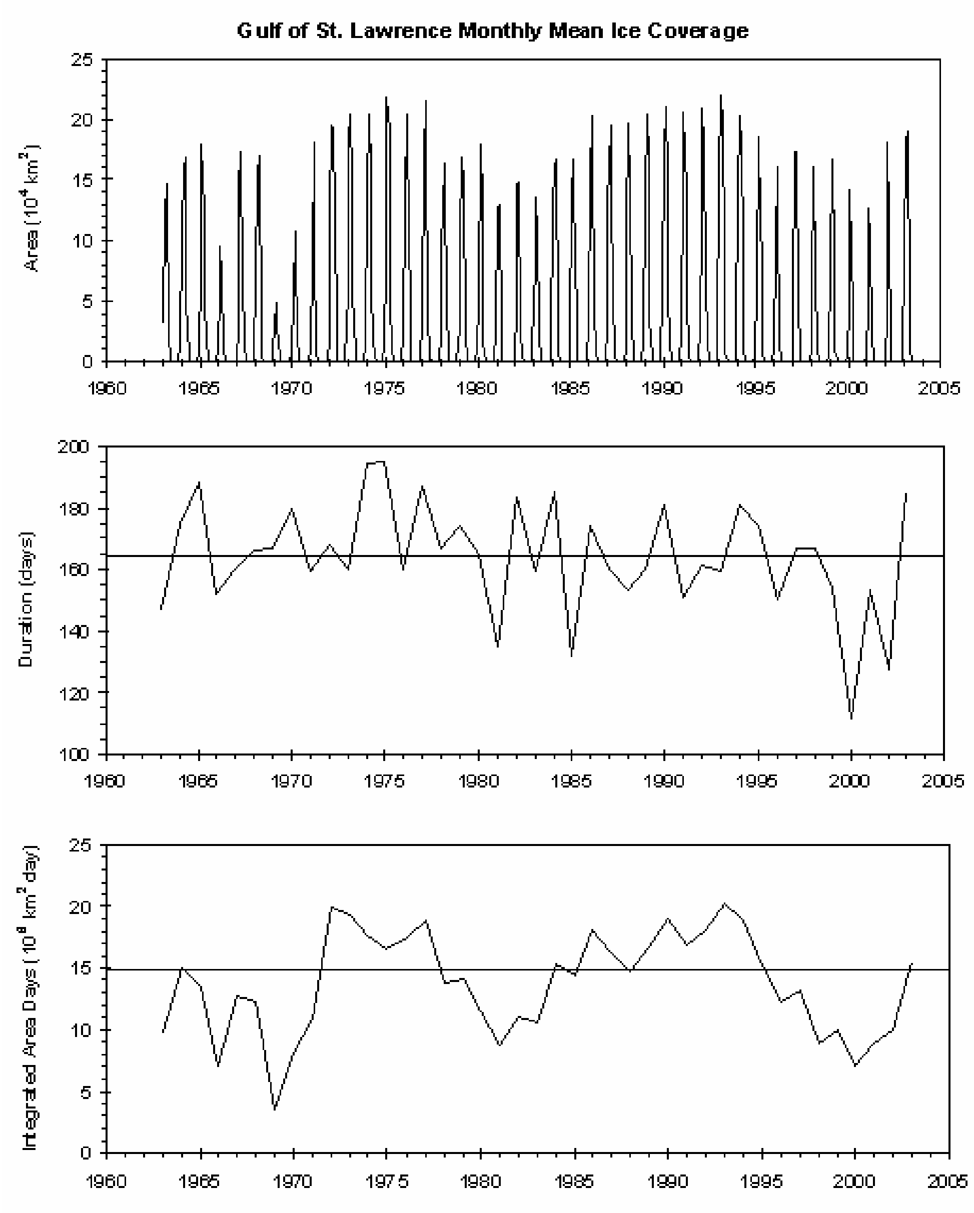

Fig. 18. For the Gulf of St. Lawrence, the time series of the monthly mean ice area (top), the duration of ice (middle) and the annual integrated ice area (summation of the area times the number of days). The horizontal lines represent the long-term (1971-2000) means.

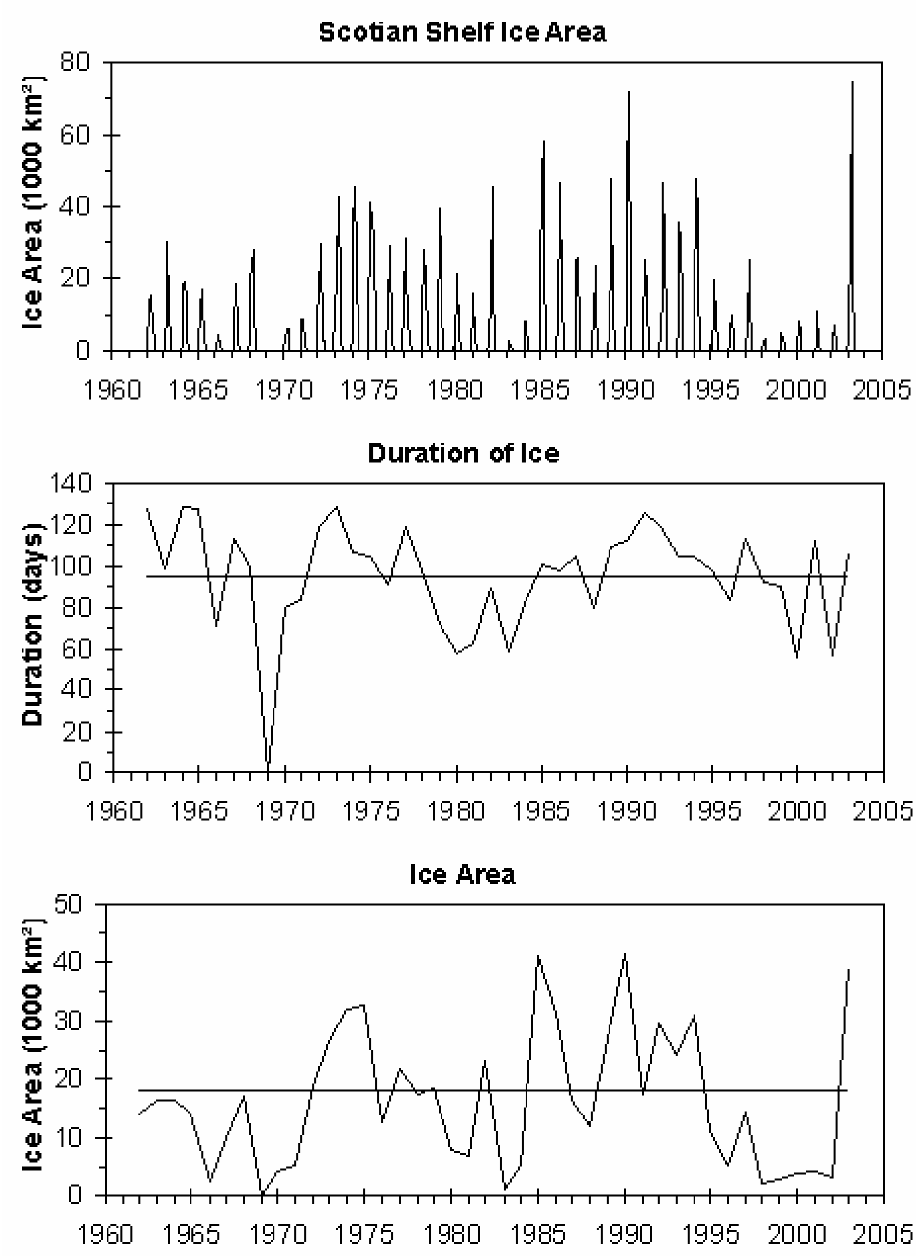

Fig. 19. For the region seaward of Cabot Strait, the time series of the monthly mean ice area (top), the duration of ice (middle) and the annual integrated ice area (summation of the area times the number of days). The horizontal lines represent the long-term (1971-2000) means.

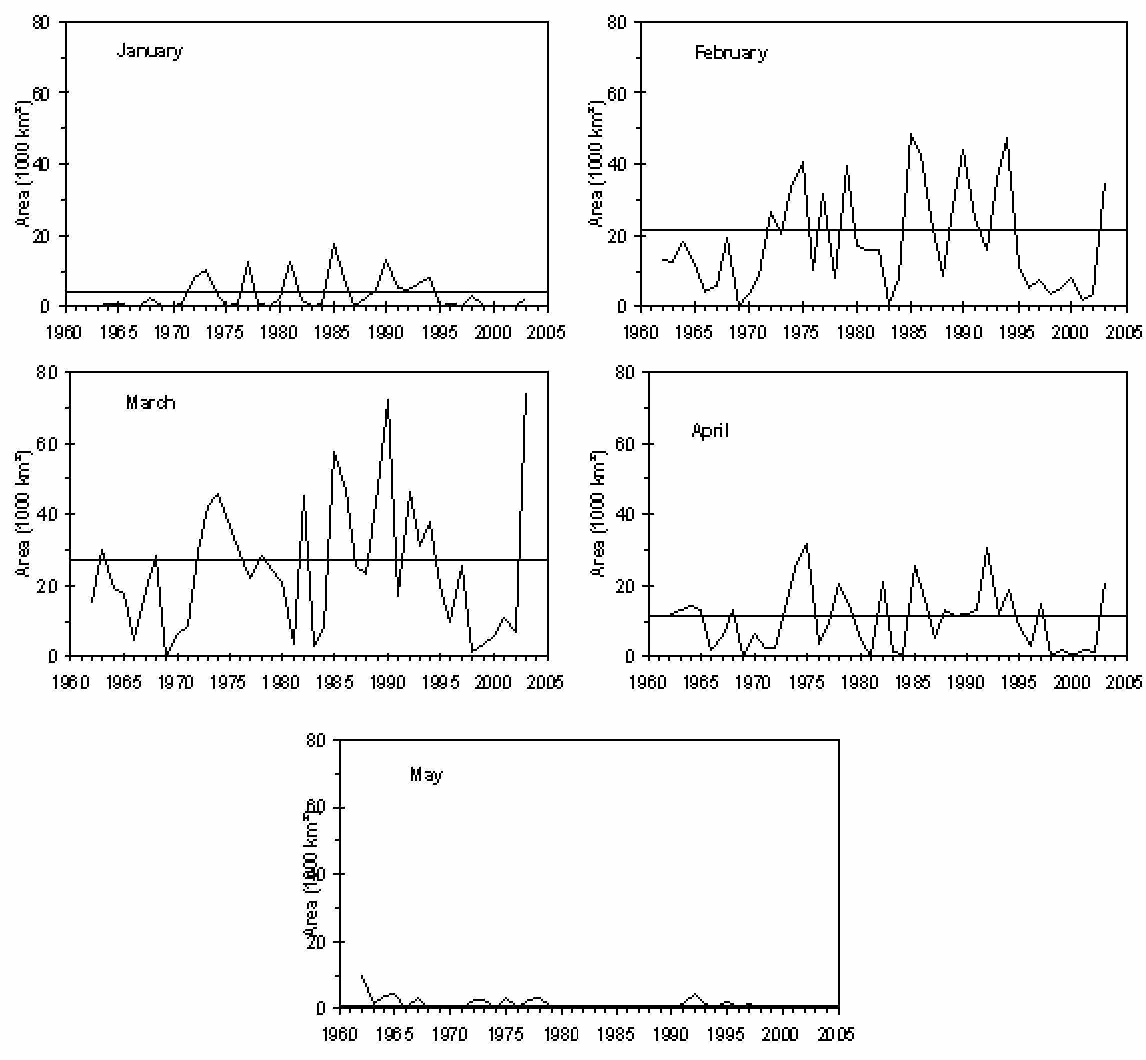

Fig. 20. The time series of ice area seaward of Cabot Strait, by month. The horizontal lines represent the 1971-2000 means.

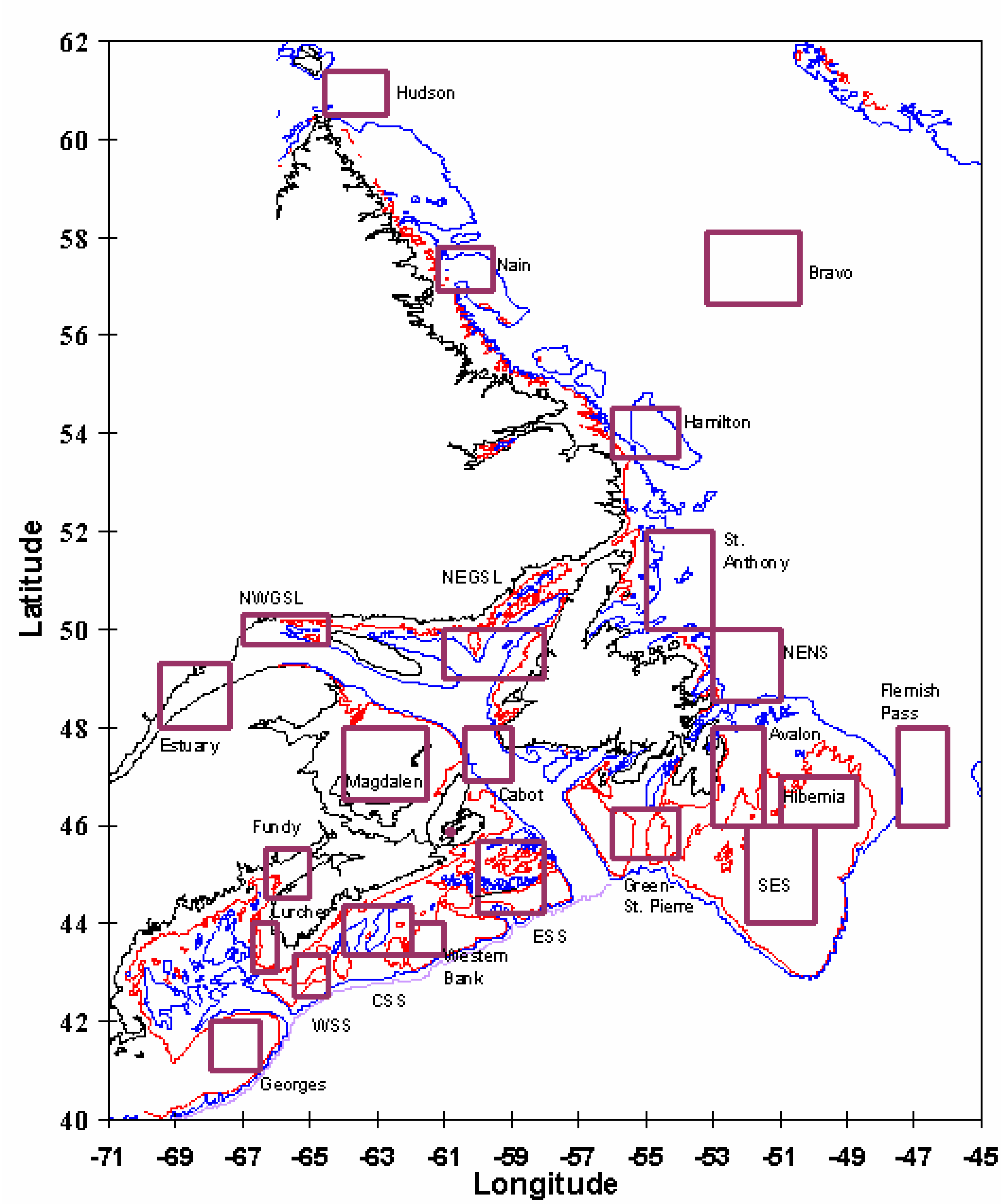

Fig. 21. The areas in the Northwest Atlantic used for extraction of sea-surface temperature.

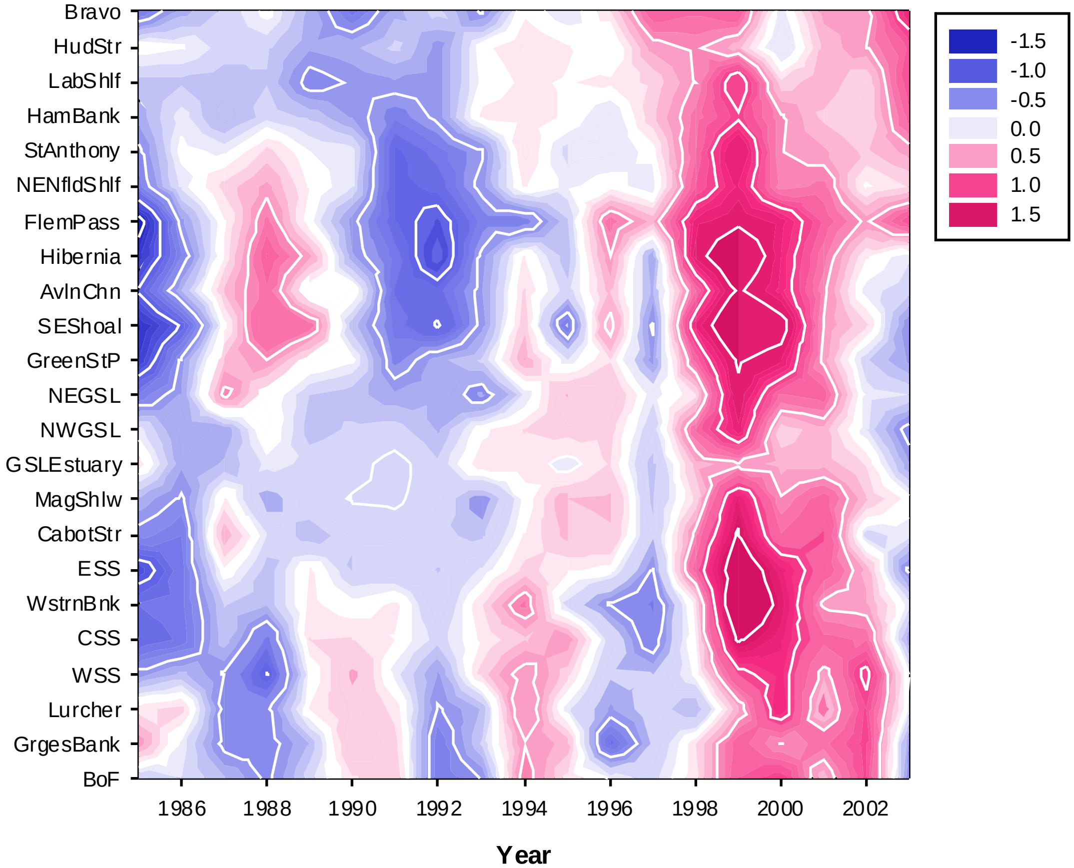

Fig. 22. The contoured time series of the annual sea surface temperature anomalies derived from satellite imagery compared to their long-term means.

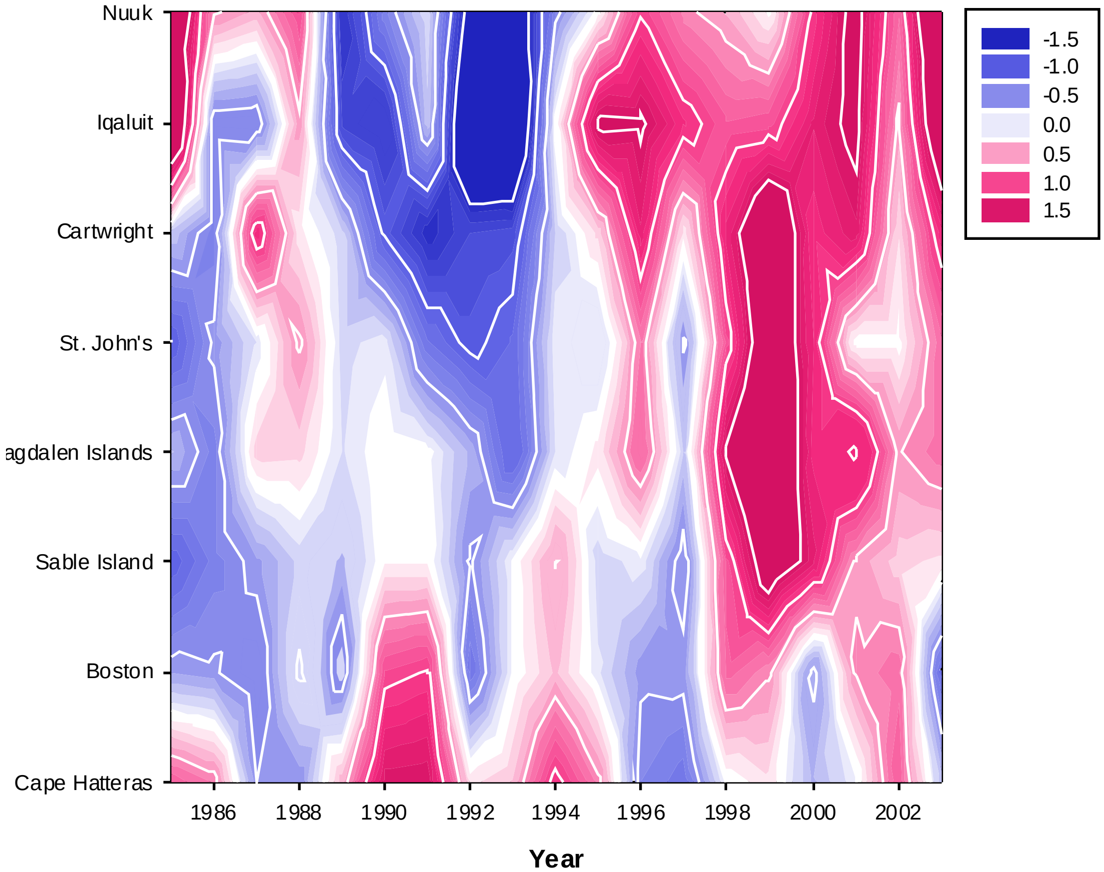

Fig. 23. The contoured time series of the annual air temperature anomalies based to their 1971-2000 means.

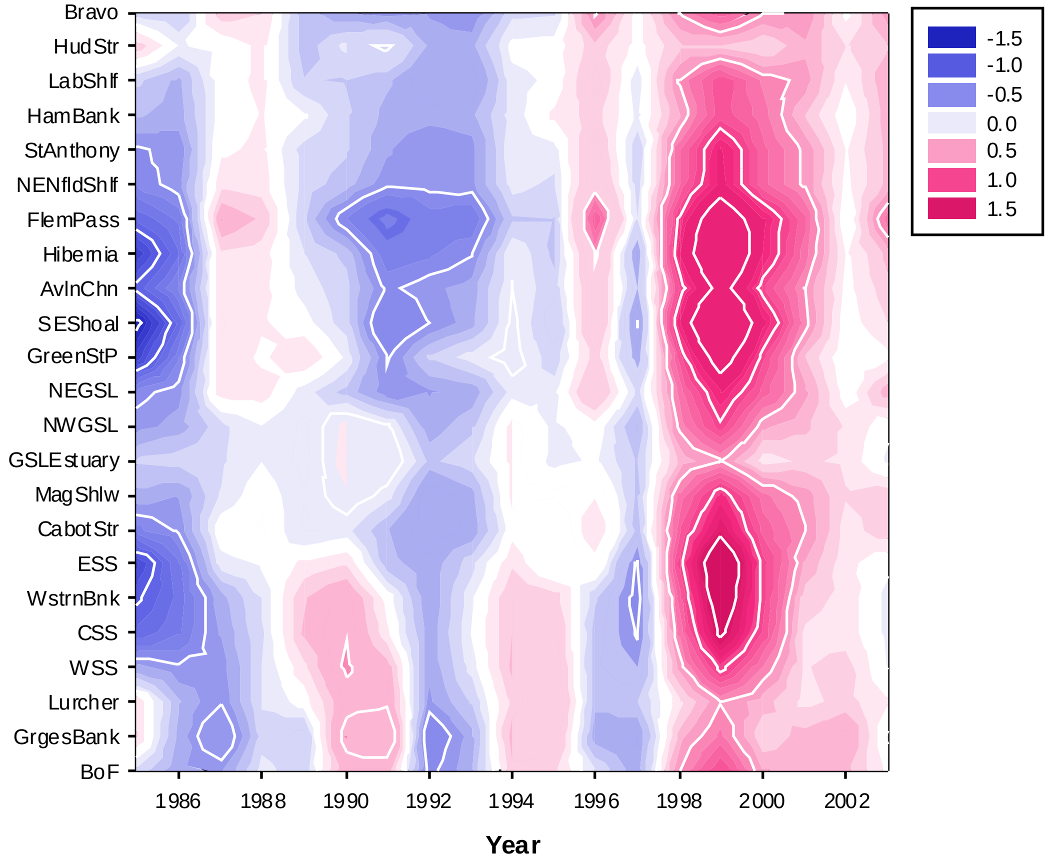

Fig. 24. The contoured time series of SST anomalies derived from regression of the 3 leading empirical orthogonal modes of air temperature and the NAO anomalies through multiple linear regression.