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Overview of Meteorological and Sea Ice Conditions off Eastern Canada during 1997

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ABSTRACT

A review of meteorological and sea ice conditions off eastern Canada during 1997 is presented. Air temperatures throughout the northwest Atlantic generally cooled relative to 1996. In the Labrador Sea area, temperatures still remained much warmer than the minima in the early 1990s. On the southern Labrador coast and in the Gulf of St. Lawrence they were near normal while along the Atlantic coast from St. John's to Cape Hatteras annual air temperatures were below normal. From the Gulf of St. Lawrence north, temperatures went from extremely warm during the first part of the winter to very cold in the latter half. The NAO index for 1997 was below normal for the second consecutive year but above that recorded in 1996. Although the sea ice on the southern Labrador and Newfoundland shelves generally appeared late and left early resulting in a shorter duration than usual, the areal extent in 1997 was greater than in 1996. In addition, the number of icebergs reaching the Grand Banks increased over 1996 by over 60% but still remained well below the large number of icebergs reported in the early 1990s. In the Gulf of St. Lawrence, the ice typically appeared late but remained longer than expected. While the ice also lasted longer than normal on the Scotian Shelf and seaward of Cabot Strait, its areal coverage was lower than normal.

RÉSUMÉ

L'article présente les résultats d'un examen des conditions météorologiques et des conditions des glaces au large de la côte est du Canada en 1997. Les températures de l'air dans tout l'Atlantique nord-ouest ont généralement été inférieures à celles de 1996. Dans la mer du Labrador, les températures sont demeurées beaucoup plus élevées que les minimums observés au début des années 1990. Elles se rapprochaient de la normale sur la côte sud du Labrador et dans le golfe du Saint-Laurent, mais les températures annuelles ont été inférieures à la normale le long de la côte de l'Atlantique, de St. John's au cap Hatteras. À partir du golfe du Saint-Laurent, en direction nord, elles ont été extrêmement chaudes pendant la première partie de l'hiver, mais très froides pendant la deuxième partie. L'indice NAO pour 1997 a été inférieur à la normale pour la deuxième année consécutive, mais supérieur à celui de 1996. Bien que les glaces de mer des plateaux du sud du Labrador et de Terre-Neuve soient généralement apparues tardivement et disparues tôt, ce qui a donné lieu à une période d'englacement plus courte que la normale, la superficie notée en 1997 a été supérieure à celle de 1996. En outre, le nombre d'icebergs qui ont atteint les Grands Bancs a été supérieur de 60 % à celui de 1996, mais nettement inférieur au nombre important signalé au début des années 1990. Dans le golfe du Saint-Laurent, les glaces sont généralement apparues tardivement, mais sont demeurées plus longtemps que prévu. Les glaces sont aussi demeurées plus longtemps que la normale sur le plateau néo-écossais et dans la partie donnant sur la mer du détroit de Cabot, mais la superficie couverte a été inférieure à la normale.

INTRODUCTION

This paper examines the meteorological and sea ice conditions during 1997 off eastern Canada (Fig. 1). Specifically, it discusses air temperature trends, atmospheric sea level pressures and associated winds, sea ice coverage and iceberg drift. It compliments the oceanographic reviews of the waters in and around Newfoundland, the Gulf of St. Lawrence, Scotian Shelf and Gulf of Maine, which together constitute the annual physical environmental overviews to DFO's Fisheries Oceanography Committee. 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, and where the data permit, the latter have been standardized to a 30-yr (1961-90) base period in accordance with the convention of meteorologists and the recommendations of the Northwest Atlantic Fisheries Organization (NAFO). Having a standardized base period allows direct comparison of anomalies both between sites and variables.

METEOROLOGICAL OBSERVATIONS

Air Temperatures

The German Weather Service publishes monthly air temperature anomalies relative to the 1961-90 means for the North Atlantic Ocean in their publication *Die Grosswetterlagen Europas*. During January, positive anomalies covered most of our area of interest with values reaching 4°C in Baffin Bay off West Greenland (Fig. 2). Air temperature anomalies on the northern Labrador Shelf exceeded 1°C. Rapid cooling during February resulted in very cold air temperatures over the Labrador Sea with anomalies exceeding -3°C. The air temperatures in the Gulf of St. Lawrence and the Newfoundland area were also below normal but of lower magnitude than over the Labrador Sea. South of Nova Scotia air temperature anomalies were above normal by as much as 3-4°C around the Cape Cod to New York region. Colder-than-normal conditions continued to cover most of the region during the late winter and spring. In March temperatures over the Gulf of St. Lawrence were 2-4°C below normal. In June, the Labrador Sea was covered by air that was above normal while from the Gulf of St. Lawrence south air temperatures were below normal by up to 2°C. During the summer months, the air temperatures varied spatially and from month to month between above and below normal. In September, however, warm air pervaded the region. Over the Labrador Sea, temperatures generally remained above their long-term means through to the end of the year. From Newfoundland south, however, air temperatures were colder-than-normal during October and November but warmed to near normal or above by December.

Monthly air temperature anomalies for 1996 and 1997 relative to their 1961-90 mean at eight sites in the northwest Atlantic from Godthaab 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 air temperature sites were available from the *Canadian Climate Summaries* published by the Atmospheric Environment Service and for non-Canadian locations from the NOAA publication *Monthly Climatic Data for the World*. The warm air temperatures in the northern sites during

January noted above are a continuation of the warm air conditions that were established in December of 1996 (Fig. 3). This was followed by a rapid decline in temperature anomalies in February. Temperatures remained colder-than-normal at most northern sites for another month or two before returning to above normal values by the spring. From then until autumn, air temperature anomalies from Cartwright north were predominately above normal, while those from Sable Island south were below normal. The cold conditions at the latter stations followed a winter, which in contrast to the northern regions, was warmer-than-normal. At St. John's and the Magdalen Islands, air temperatures from the spring to the end of the year showed no strong trends, fluctuating about the long-tern normal.

The annual mean air temperatures for 1997 were above normal at the northern most sites of Iqaluit (anomaly of 1.0°C) and Godthaab (0.2°C). At Cartwright and the Magdalen Islands they were normal while at St. John's and the remaining stations the annual anomalies were negative. The maximum negative anomaly was at St. John's (-0.6°C), followed by Sable Island (-0.4°C) and then Boston and Cape Hatteras (-0.3°C).

The 1997 annual temperature anomalies at seven of the eight sites declined from the local maximua in 1996, the exception being Cape Hatteras where the annual mean temperature was similar to that recorded in 1996 (Fig. 4). Note that the interannual variability since 1960 at Godthaab, Iqaluit, Cartwright, and, to a lesser extent, St. John's have been dominated by the large amplitude fluctuations with minima in the early 1970s, early to mid-1980s and the early 1990s, suggesting a quasi-decadal period. Indeed, the recent rise in temperature is consistent with a continuation of this near decadal pattern. Since 1970, temperature anomalies at these sites were predominantly below normal due to a general downward trend in temperatures that was occurring at the same time as the near decadal oscillations. Temperature anomalies at the Magdalen Islands and Sable Island have been of much lower amplitude than those to the north and show no signs of the declining temperatures since 1970. They do, however, contain minima in the early 1970s (both sites), the mid-1980s (Sable Island only) and in the 1990s (Magdalen Islands only). At Boston and Cape Hatteras, there has also been decadal variability in air temperatures but they have generally been out of phase with the temperature fluctuations in the Labrador region. Thus, for example, when the temperatures were very cold in Labrador during the early 1990s, they were relatively warm along the US seaboard (Fig. 4).

Sea Surface Air Pressures

Climatic conditions in the Labrador Sea area are closely linked to the large-scale pressure patterns and atmospheric circulation. Monthly mean 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 1997, relative to the 1961-90 means, are shown in Fig. 5. Winter includes December 1996 to February 1997, spring is March to May, and summer is June to August.

In winter, a positive air pressure anomaly developed over the western North Atlantic with a maximum (exceeding 3 mb) centred south of Newfoundland. A ridge of high pressure anomalies extended from there to the northeast covering eastern Greenland. This ridge separated two areas of negative anomalies, one centred over Foxe Basin in eastern Canada (-2.6 mb) and the other near the Azores (near -3 mb). This pressure pattern suggests stronger than normal offshore winds off Labrador and northern Newfoundland but anomalous southerly winds along the Middle Atlantic Bight to the Gulf of St. Lawrence. Western Greenland experienced greater amounts of south-westerly winds. In the spring of 1997, a negative anomaly formed over most of the northern North Atlantic with the center (-4.9 mb) east of Newfoundland. To the east over Europe, a positive (5.6 mb) anomaly developed peaking over France and a negative (-3.3 mb) anomaly centred off northern Norway. In contrast to the winter, the winds off Labrador and northern Newfoundland were more onshore, while they were from the northwest in the Gulf of St. Lawrence and offshore over the Scotian Shelf to the Middle Atlantic Bight. Both the winter and spring pressure patterns show more meridional flow than normal. In the summer, a broad band of negative anomalies stretched from North America across the Atlantic into Europe. The largest negative anomaly (near -3 mb) was recorded over south-western Ireland. To the north and south of this band of below normal pressures were positive anomalies, with again the maximum values being located on the eastern side of the Atlantic. The centre of the positive anomalies to the north was located over northern Norway whereas to the south it was situated just off West Africa. Over eastern North America, this pressure pattern resulted in a predominance of easterly to north-easterly winds. The autumn pattern is similar to that of summer but more intense. The negative pressure anomaly extended latitudinally both north and south with the center located to the southeast of Newfoundland (-5.3 mb). The center of the positive anomaly remained over northern Greenland (7.7 mb). This pattern results in anomalously winds from the east and southeast in the Labrador coast and Labrador Sea regions and from the northeast between Newfoundland and the Middle Atlantic Bight.

NAO Index

The North Atlantic Oscillation (NAO) Index is the difference in winter (December, January and February) sea level 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 an intensification of the Icelandic Low and 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 annual NAO index is derived from the measured mean sea level pressures at Ponta Delgada 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 1961-90 mean.

In 1997, the NAO anomaly was below normal for the second consecutive year but was above that observed in 1996 (Fig. 6). These two years contrast with the very high NAO anomalies that had persisted since the late 1980s and indicates the possibility of a significant shift in the large-scale atmosphere circulation. However, this decline also fits the pattern of near

decadal variability that has persisted since the 1960s, and was therefore expected, although its amplitude was much greater than predicted based upon past variability.

SEA ICE OBSERVATIONS

Information on the location and concentration of sea ice is available from the daily ice charts published by Ice Central of Environment Canada in Ottawa. The long-term medians, maximum and minimum positions of the ice edge (concentrations above 10%) based on the composite for the years 1962 to 1987 are taken from Coté (1989).

Newfoundland and Labrador

At the end of 1996, sea ice lay off the southern Labrador coast in the vicinity of Hamilton Inlet resulting in an areal coverage that was slightly less than the long-term median for that time of the year (Fig. 7a). This was in part due to above normal air temperatures during the second half of December that slowed ice formation. By the beginning of January, the ice extent along the south Labrador coast was approximately two weeks later than normal. By mid January, the ice had extended south to Belle Isle Strait but remained much closer inshore than normal. This resulted in much less ice covered than usual and was again caused by much warmer than normal air temperatures, especially off southern Labrador. By the first of February, ice coverage was back to near median values as air temperatures cooled to below normal. Continuing cold air temperatures and moderate to strong northwesterly winds during February pushed the ice pack southward and offshore, increasing the areal coverage to between median and maximum values by the beginning of March. Cold, windy conditions prevailed throughout March. These left the sea ice again intermediate between median and maximum extent by 1 April (Fig. 7b). Ice off northern Newfoundland was positioned offshore keeping many of the harbours and coast communities ice clear. By 1 May, strong northeasterly winds over southern Labrador and northern Newfoundland packed the ice inshore from St. John's north. Retreat of the ice proceeded during May resulting in ice coverage near the long-term median by 1 June. There was, however, an isolated patch of ice off northern Newfoundland between Notre Dame and White bays at this time. Ice remained off the mouth of Hamilton Inlet through June and was still there on 1 July. By 10 July all traces of ice had disappeared from southern Labrador.

The time series of the areal extent of ice on the Newfoundland and southern Labrador shelves (between 45-55°N; I. Peterson, personal communication, Bedford Institute) show the peak extent during 1997 increased relative to 1996 and was near but slightly below that of the early 1990s (Fig. 8). The average area during the period of general advancement (January to March) and retreat (April to June) also increased from 1996. These values indicate that the areal coverage on average, however, was less than the early 1990s and was extremely low during the time of retreat. The monthly means plotted separately show that in 1997 ice coverage was typically more than that observed in 1996 but less than during the early 1990s (Fig. 9). These data indicate 1997 was an average to lighter-than-average ice year on the Labrador and Newfoundland shelves. Note that during January through April there has been a general increase in the area of ice over the past 30 y but no such trend exists during May through July. Variations of

ice area reflect similar changes in ice volume as the two are reasonably well correlated based on studies we have carried out in the Gulf of St. Lawrence.

Past reviews included an analysis of the time of onset, duration and last presence of sea ice in eastern Canadian waters based upon data from 24 sites located off southern Labrador, the east and north coasts of Newfoundland and in the Gulf of St. Lawrence. Up to and including 1994, the data were provided by Ice Central of Environment Canada in Ottawa, afterwhich we continued the analysis. During this last year, these analyses were undertaken using more comprehensive sea-ice databases maintained at the Bedford Institute of Oceanography. The weekly concentration and types of ice within 0.5° latitude by 1° longitude areas were recorded through the ice season. The date of the first and last appearance of ice within these areas as well as the duration of ice were determined. The databases begin in the early 1960s and persist to the present. Long-term means (30-years, 1964-1993) of each variable were determined (using only data during the years ice was present) and subtracted from the 1997 values to obtain anomalies. In 1997, ice first appeared north of Hamilton Bank off southern Labrador in late December, and gradually spread southward with ice first appearing on the northeastern Grand Bank in mid-March (around day 70, Fig. 10). Relative to the long-term mean, ice generally appeared slightly later-than-normal throughout most of the shelf with the exception of some offshore locations where it arrived on schedule or slightly earlier (Fig. 10, note positive anomalies indicate ice formed late which is generally associated with warmer conditions). Ice began to disappear from some of the of the offshore and southern sites in March (Fig. 11). Ice began to retreat from northern Newfoundland waters during April, from southern Labrador in May but lasted in the region south of Hamilton Inlet until 8 June. Over most of the region ice disappeared earlier-than-normal (positive anomaly, generally associated with warm conditions), greater than 30 days early off southern Labrador and northern Newfoundland. The only exceptions were small areas along the coast of Newfoundland and in the extreme offshore areas where ice was observed later-than-normal. The duration of the ice season ranged from less than a month off the northern Grand Banks and offshore to over 170 days north of Hamilton Inlet on the southern Labrador (Fig. 12). Note that the duration is not simply the date of the first presence minus the last presence because the ice may disappear for a time and then reappear. The ice duration was shorter-than-normal (negative anomaly) over most of the Labrador and Newfoundland waters. The duration off southern Labrador and northern Newfoundland was over 1 month shorter-than-normal. Exceptions included the White Bay area of northern Newfoundland and the far offshore regions, especially off southern Labrador, where the duration was slightly longer-than-normal by upwards of 10 days or more in some locations.

Icebergs

The number of icebergs that pass south of 48°N latitude in each year is monitored by the International Ice Patrol Division of the United States Coast Guard. Since 1983, data have been collected with SLAR (Side-Looking Airborne Radar). During the 1996/97 iceberg season (October to September), a total of 1011 icebergs were spotted south of 48°N. The monthly totals for February to August were 10, 475,162, 238, 80, 43, and 3 (Fig. 13). No icebergs were spotted between October, 1996, and January, 1997, inclusive, or in September, 1997. In 1997, 98.7% of the icebergs were observed during the primary iceberg season of March to July, higher than the mean in

1983-97 of 91%. Almost 50% of the total number of icebergs during the 1996/97 season penetrated south of 48°N in March, proportionally more then on average during the years icebergs have been detected using SLAR (1983-96). Indeed, almost 50% of the icebergs in 1996 arrived in April. The total number of icebergs in 1997 was above the long-term mean and up from 1996 but was lower than the earlier years of the 1990s (Fig. 13). The decline in iceberg numbers matches the decline in sea ice extent and follows from the warmer air temperatures and reduced northwest winds. Note that periods of large number of icebergs reaching south of 48°N occurred in the early 1970s, the mid-1980s and the early to mid-1990s, all periods of cold air temperatures, strong NW winds and extensive ice cover. This relationship is believed to be due primarily to reduced melting from the colder temperatures and sea ice protecting the bergs from breaking waves (Marko et al., 1994).

Gulf of St. Lawrence

At the end of December 1996, no ice was present in the Gulf of St. Lawrence and upper St. Lawrence Estuary due to warmer-than-normal air temperatures which delayed ice formation (Fig. 14). By mid-January, ice had formed by along the coast from Gaspe Peninsula to Nova Scotia including most of Northumberland Strait. Ice had also appeared along most sections of the north shore of Quebec from Anticosti Island to the Strait of Belle Isle. The ice was approximately two weeks behind schedule and the areal coverage was much less than the long-term median. This again was primarily due to the air temperatures remaining above normal through the first half of January. During the second half of the month, northwesterly winds and below normal temperatures over the northwestern portion of the Gulf resulted in rapid spreading of the ice such that the coverage was only slightly less than the long-term median by the beginning of February. The ice was thinner than normal at this time, however. Cold air and strong northwest winds continued during February and by 1 March the Gulf was ice covered except for St. Georges Bay in Newfoundland. The ice edge was very near to its median position at this time. Ice retreated during March so that 1 April it had left the Estuary and many of the coastal areas of the south western Gulf. There was more ice than normal in the Gulf at this time. Ice continued to retreat through April and by 1 May ice was only located in the southern Magdalen Shallows and in the northeast near the Strait of Belle Isle but there was more of it than normal. The ice from the southern Gulf disappeared by the 17 May but remained in the northern Gulf until 3 June. The last ice to disappear was located north of Anticosti Island.

During 1997, an ice database for the Gulf of St. Lawrence and Scotian Shelf was completed and a more comprehensive analysis of the first and last appearance of ice and the ice duration was carried out. The Gulf and Scotian Shelf was divided into 130 areas of dimensions 0.5° latitude by 1° longitude. As with the Newfoundland database, the weekly concentration and types of ice within each area were recorded through the ice season. The date of the first and last appearance of ice within these areas as well as the duration of ice were determined. Optimal estimation of the gridded data were used to smooth the data. The database begins in the early 1960s and persists to the present. Long-term means (30 years, 1964-1993) of each variable were determined (using only data during the years ice was present) and subtracted from the 1997 values to obtain anomalies. During 1997 within the Gulf (landward of Cabot Strait), ice formation ranged from

near the beginning of the year (prior to day 15) along the north shore of Quebec, the St. Lawrence Estuary and the western Magdalen Shallows to after mid-February (day 45) off southwestern Newfoundland (Fig. 10). Except around the eastern end of Anticosti Island, this represented a later-than-normal appearance of ice, typically by 10 days to over 20 days with the later occurring off western Newfoundland. The date of last appearance shows the typical pattern of ice lasting longest in the southern Magdalen Shallows and along the north shore of Quebec through to the Strait of Belle Isle (Fig. 11). Over most of the region this represented later-than-normal disappearance although in the outer St. Lawrence Estuary and part of the Magdalen Islands the ice actually left earlier than normal. Note the late disappearance of ice north of Anticosti Island where it remained for over 60 days later than usual. The duration of ice ranged from less 60 days off southwestern Newfoundland to over 130 days along the Quebec north shore (Fig. 12). Relative to the long-term mean during years when ice was present, ice lasted longer than normal throughout the eastern Gulf, around Anticosti Island and the southern Magdalen Shallows. In contrast, there were fewer days of ice over the rest of the Magdalen Islands and in most of the St. Lawrence Estuary. The maximum anomaly in duration of ice was around 20 days, off eastern Prince Edward Island and smaller areas off southwestern Newfoundland and the Quebec north shore.

Scotian Shelf

Sea ice normally flows out of the Gulf of St. Lawrence through Cabot Strait, pushed by northwest winds and the mean ocean current pattern. Seaward of Cabot Strait, ice first appeared during the first half of February and continued to spread over the northeastern Scotian Shelf through March and appeared off the Atlantic coast of Nova Scotia south of Chedabucto Bay in mid-April. This was later-than-normal by 10 to over 50 days. Most of this ice had disappeared during the later half of April which is 10 to 30 days later than normal. The duration of ice south of Cabot Strait ranged from 90 days off Cape North on Cape Breton Island to 10 and less on the northeastern Scotian Shelf and off southern Newfoundland. Note that a duration of less than 10 days are not plotted in Fig. 18. The duration of ice in 1997 was similar to that of the long-term means (Fig. 15).

The monthly estimates of the ice area seaward of Cabot Strait since the 1960s shows that less ice than normal was transported onto the Scotian Shelf during 1997 but it was greater than in 1996 (Fig. 16). While there were more days than usual when ice was present seaward of Cabot Strait, the integrated ice area (summation of the area times the number of days) was less than normal. This suggests that the ice conditions on the Scotian Shelf, although it remained for a long time was not as severe as usual. Note that based upon data collected since the 1960s, the furthest south that the ice penetrates is along the Atlantic coast of Nova Scotia to just past Halifax. Historical records, albeit incomplete, suggest that in the past ice penetrated much further south, for example in the late 1800s sea ice was observed in the Gulf of Maine (A. Ruffman, Halifax, personal communication).

SUMMARY

During 1997, the wintertime large-scale atmospheric circulation (Icelandic Low and Bermuda-Azores High) remained weaker-than-normal for the second consecutive year. This resulted in a lower-than-average NAO index, and well below the high values of the earlier 1990s. Associated with the weakening of the Icelandic Low, the northwest winds were weaker-than-normal over the Labrador Sea which would account for the wintertime air temperatures being, on average, warmer-than-normal. The NAO index and the Icelandic Low strengthened relative to 1996, which resulted in lower air temperatures than the previous year. Notable was the significant change in air temperatures during the winter from very warm during the first half of the season to very cold in the latter half. The warm air temperatures and weaker winds early in the winter resulted in later-than-normal ice formation, but as very cold conditions and strong northwest winds developed during the latter half of the winter the ice formed and spread quickly. Ice lasted longer than normal in much of the Gulf and on the Scotian Shelf but not on the Newfoundland and Labrador shelves. In spite of the long lasting ice the areal extent of ice on the Scotian Shelf was below normal. The number of icebergs reaching the Grand Banks in 1997 was up from 1996 but below the large numbers recorded in the earlier years of the 1990s. In 1997, the air and sea ice conditions were more severe (colder and larger ice extent) than in 1996 but not as severe as the early 1990s.

ACKNOWLEDGEMENTS

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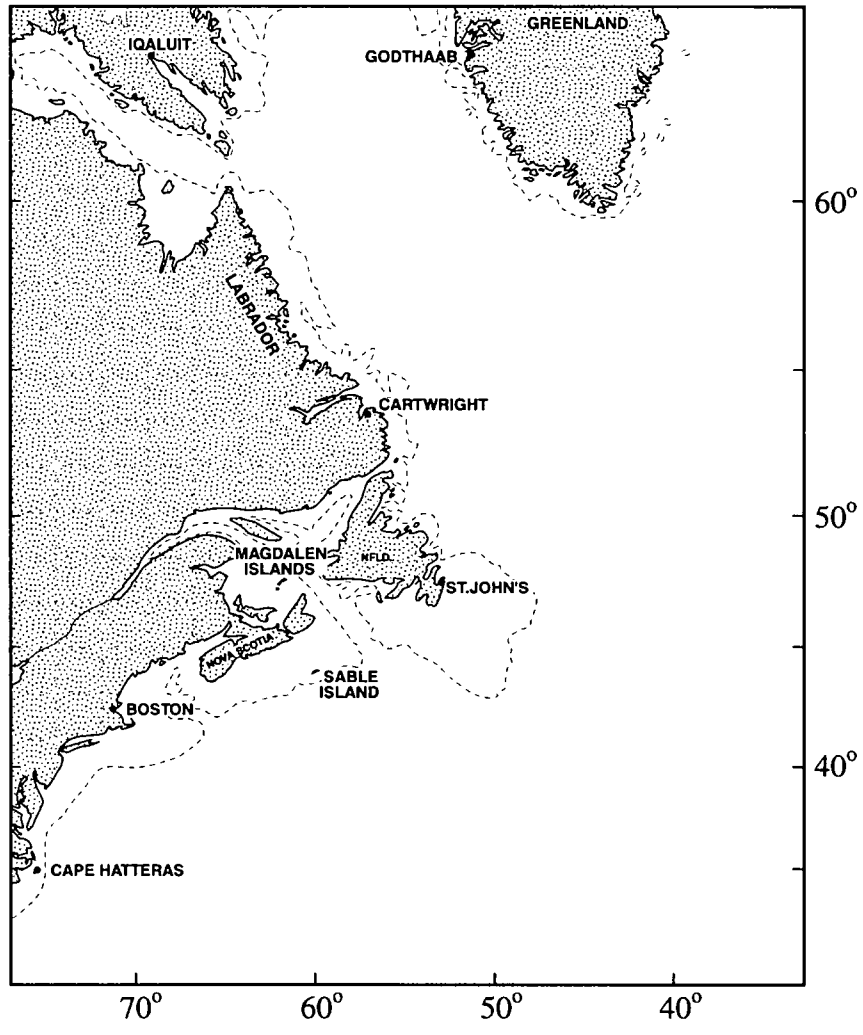

Fig. 1. Northwest Atlantic showing coastal air temperature stations.

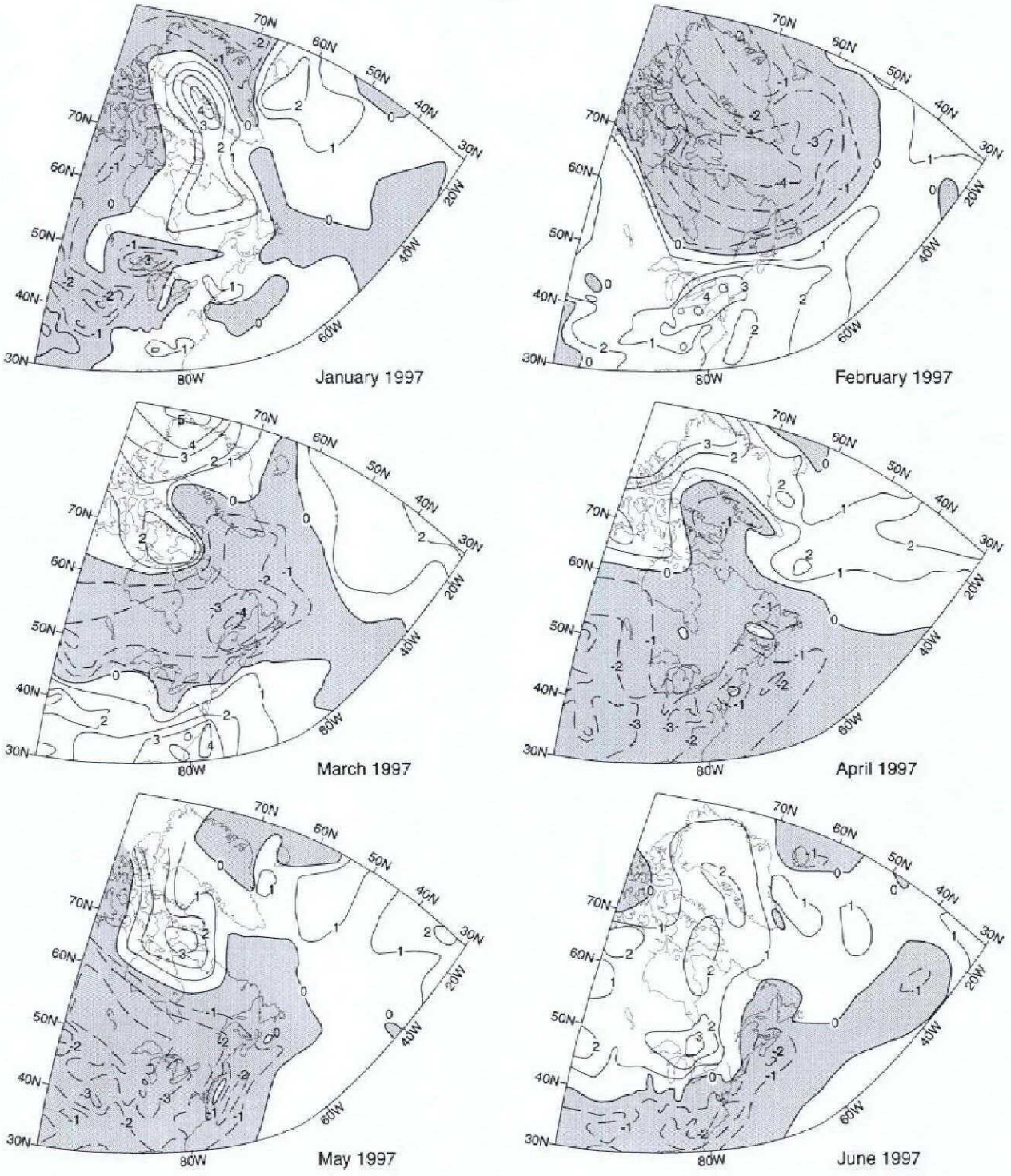

Fig. 2. Monthly air temperature anomalies (°C) over the Northwest Atlantic in 1997 relative to the 1961-90 means. Shaded areas are negative anomalies. (From *Grosswetterlagen Europas*)

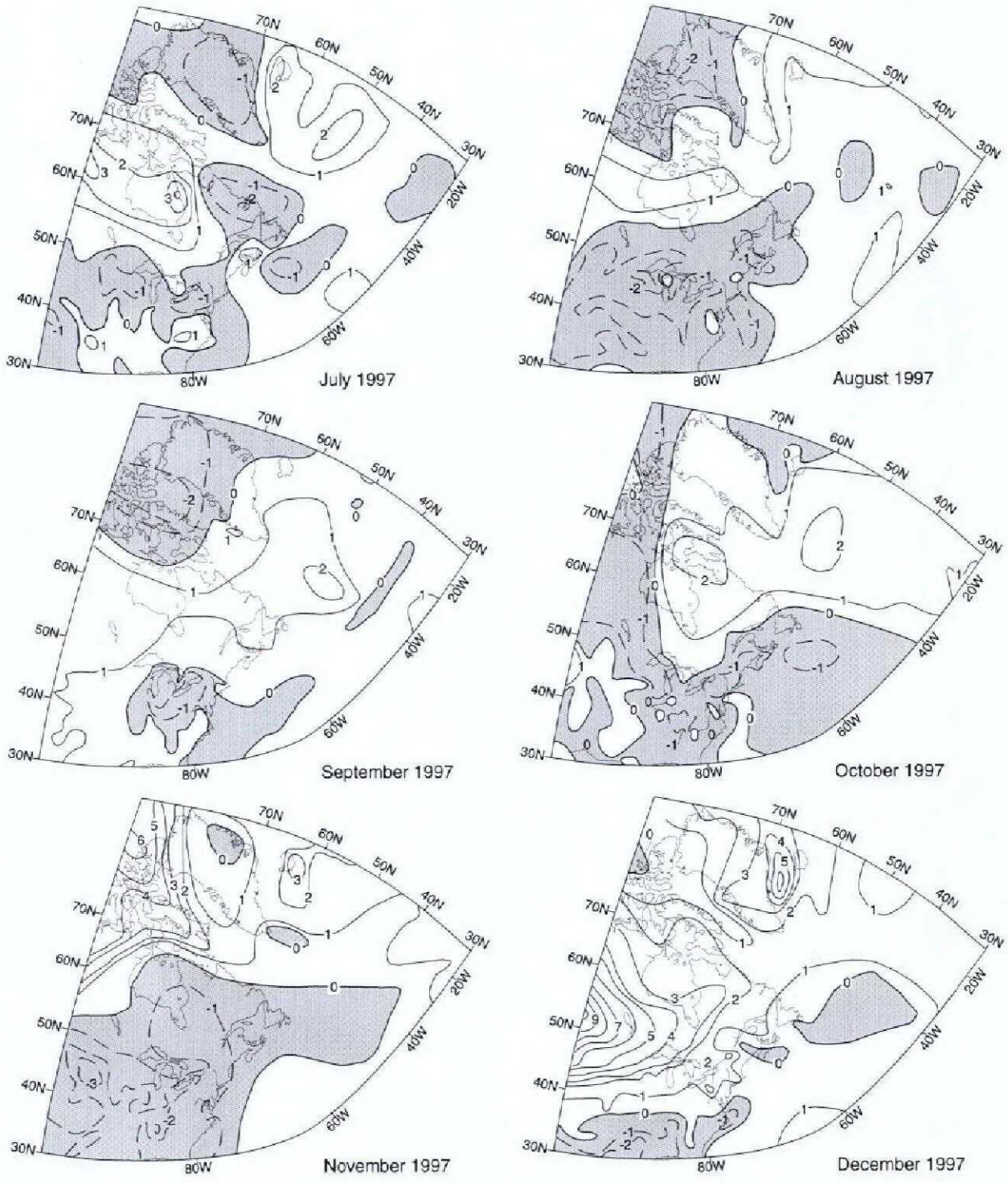

Fig. 2. (continued). Monthly air temperature anomalies (°C) over the Northwest Atlantic in 1997 relative to the 1961-90 means. Shaded areas are negative anomalies. (From *Grosswetterlagen Europas*)

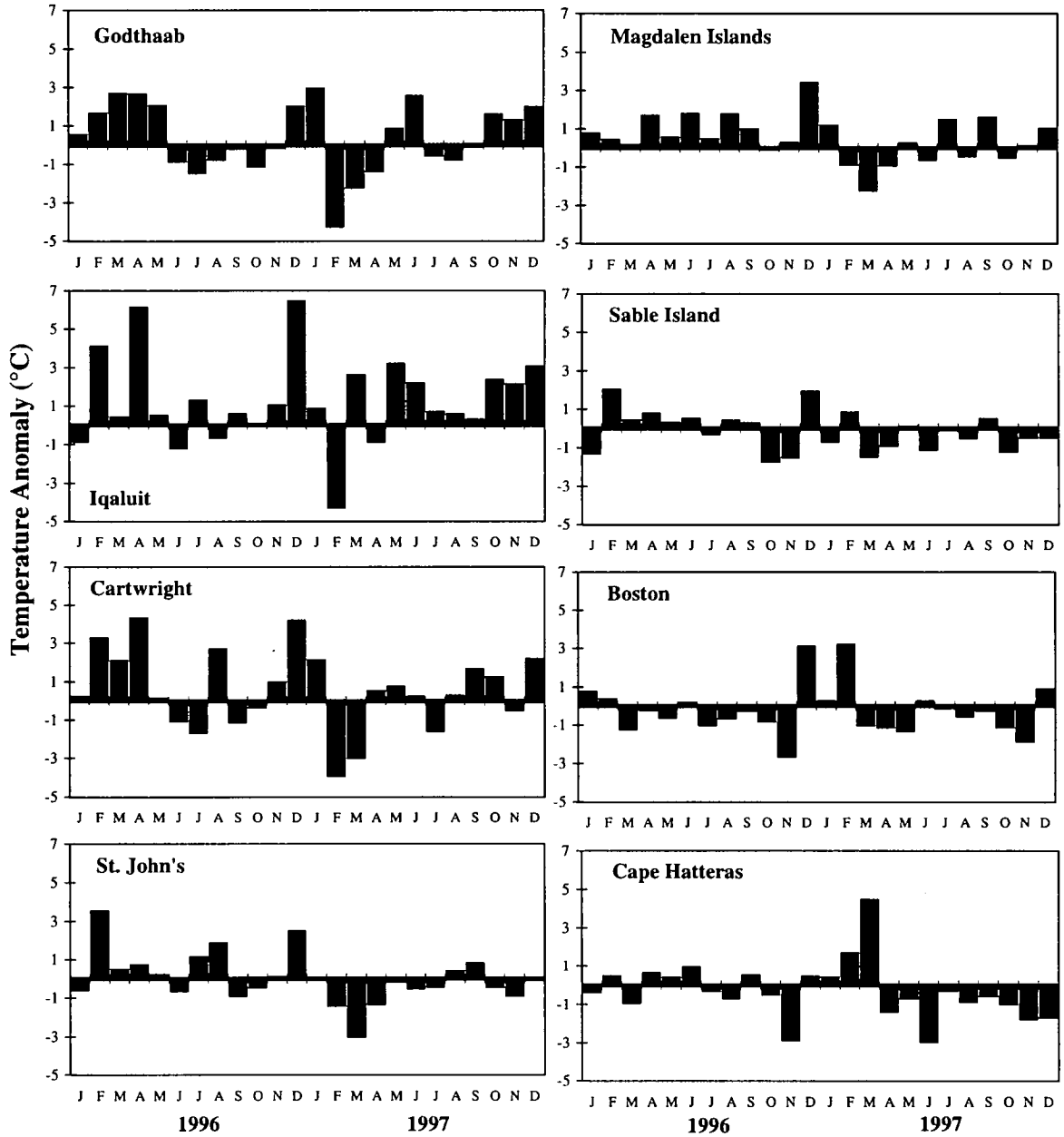

Fig. 3. Monthly air temperature anomalies in 1996 and 1997 at selected coastal sites (see Fig. 1 for locations).

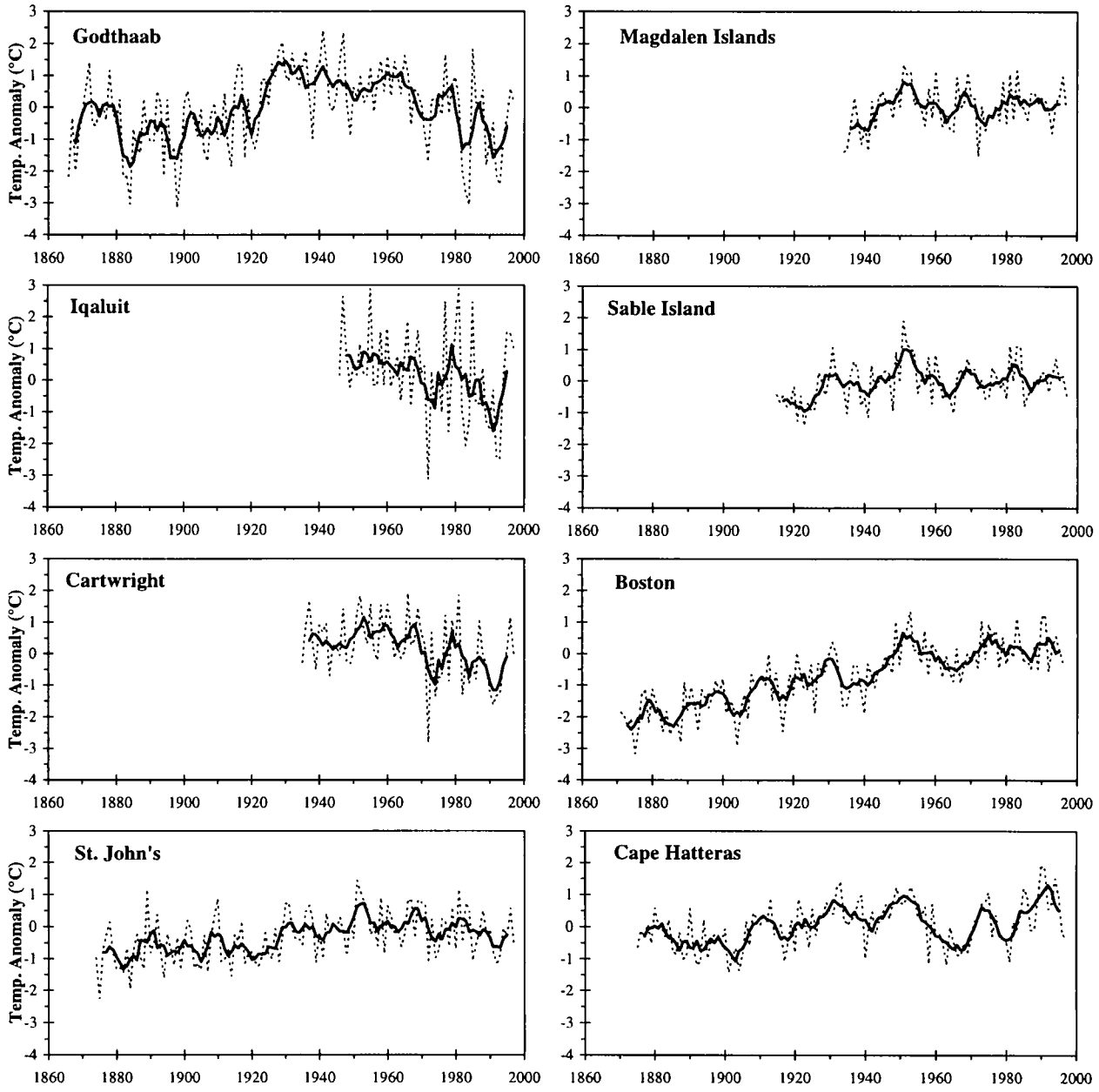

Fig. 4. Annual air temperature anomalies (dashed line) and 5-yr running means (solid line) at selected sites.

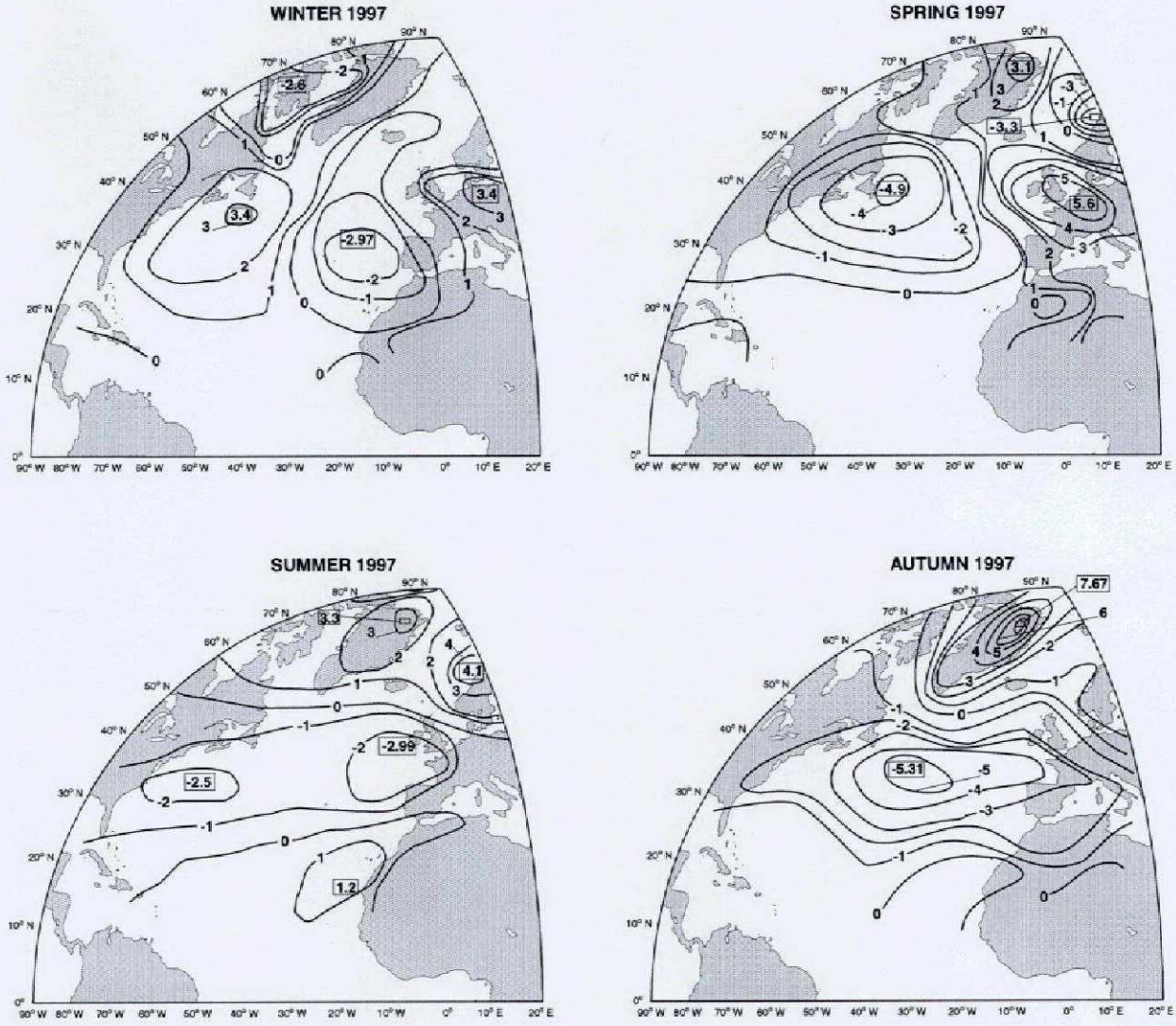

Fig. 5. Seasonal sea-surface air pressure anomalies (mb) over the North Atlantic in 1997 relative to the 1961-90 means.

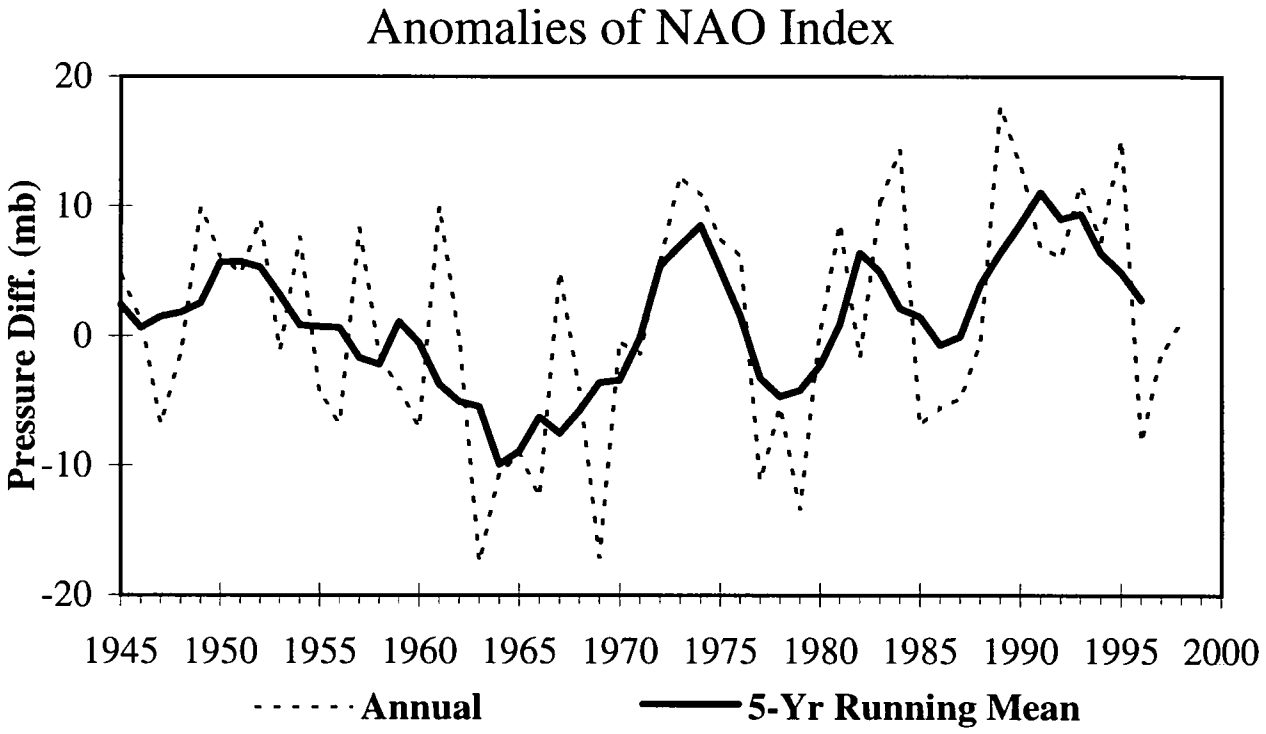

Fig. 6. Anomalies of the North Atlantic Oscillation Index, defined as the winter (December, January, February) sea level pressure at Ponta Delgada in the Azores minus Akureyri in Iceland, relative to the 1961-90 mean.

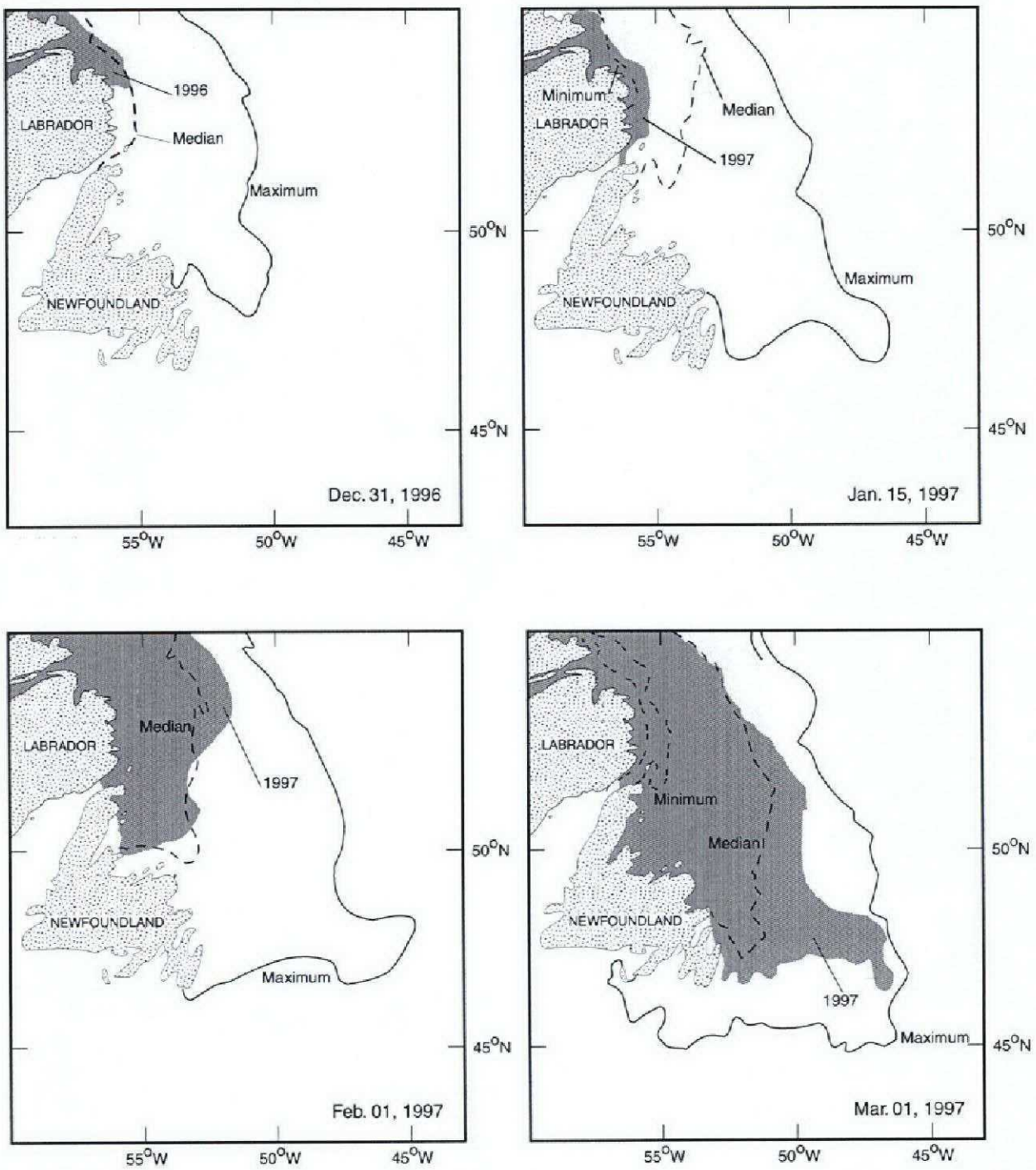

Fig. 7a. The location of the ice edge together with the historical (1962-1987) median and maximum positions off Newfoundland and Labrador between December 1996 and March 1997.

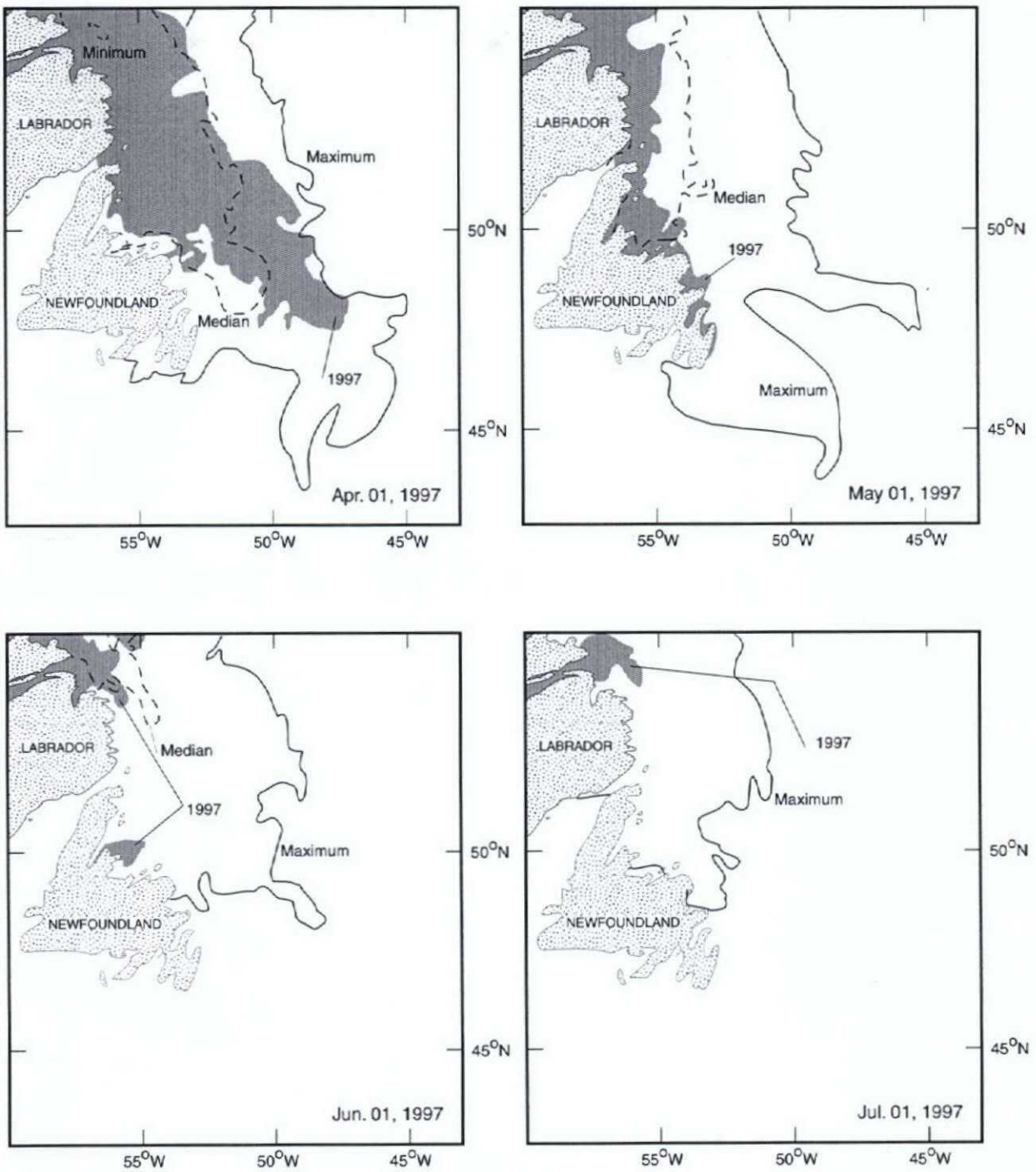

Fig. 7b. The location of the ice edge together with the historical (1962-1987) median and maximum positions off Newfoundland and Labrador between April and July 1997.

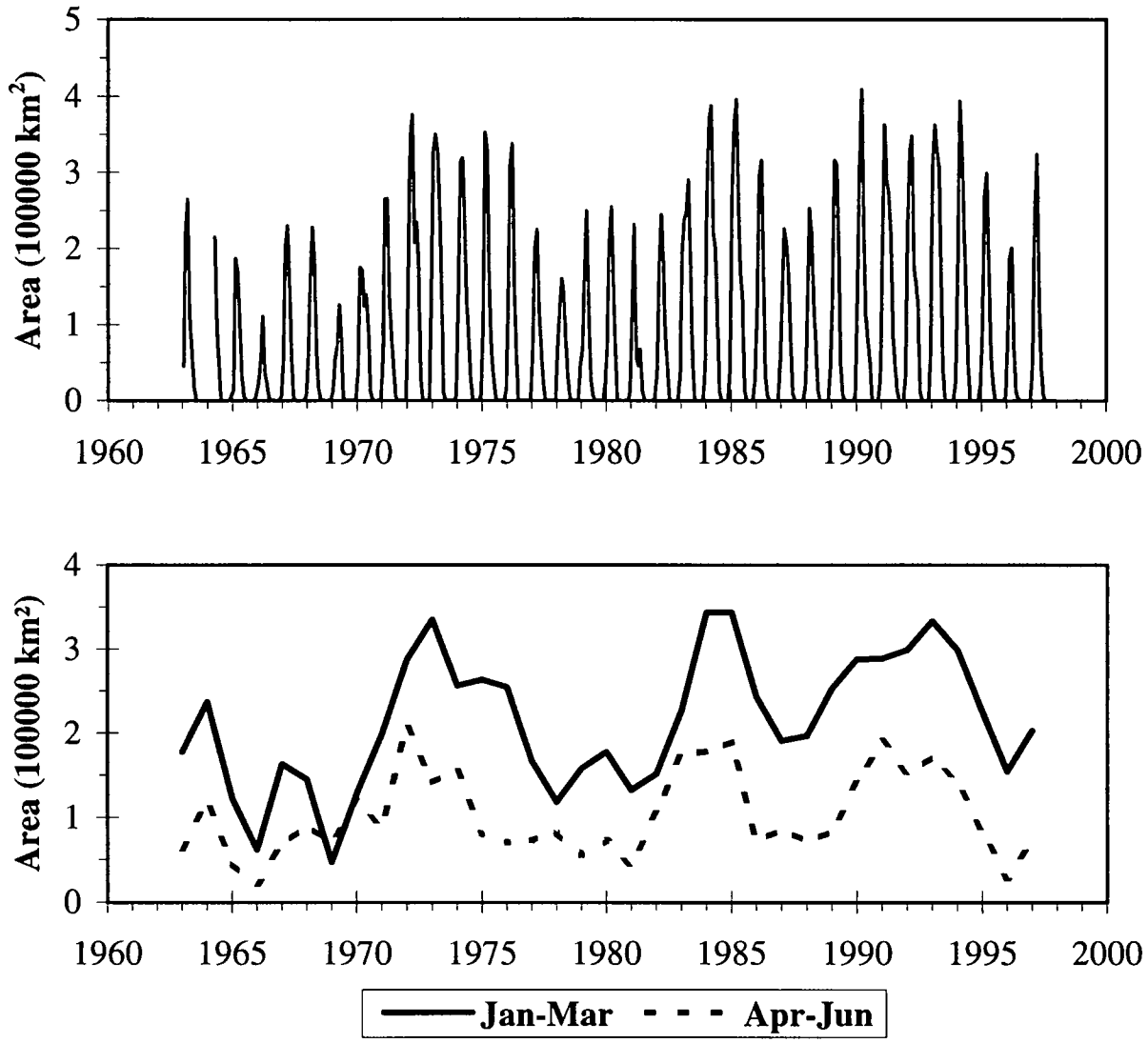

Fig. 8. Time series of the monthly mean ice area off Newfoundland and Labrador between 45°N-55°N (top) and the average ice area during January-March and April-June (bottom).

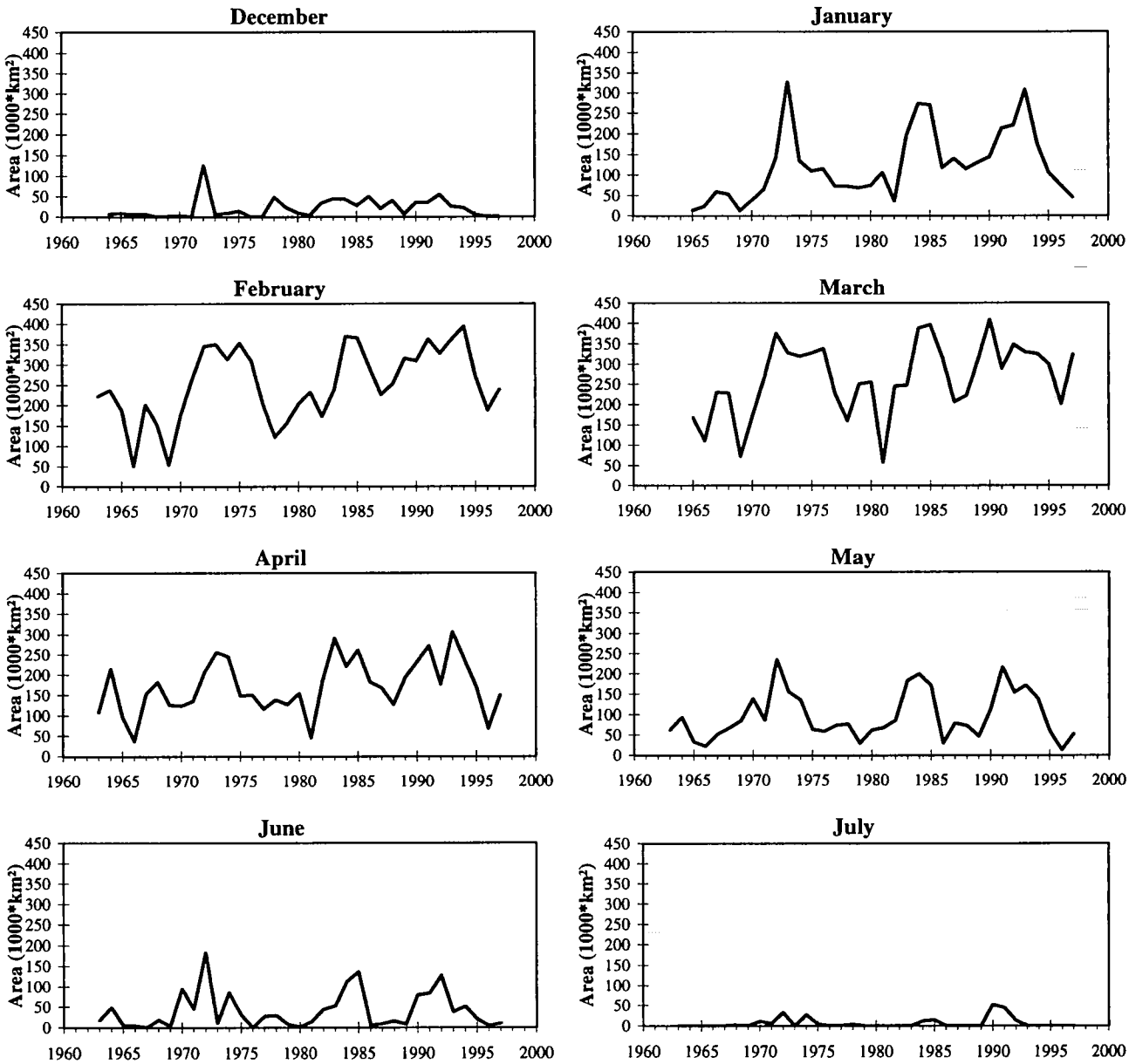

Fig. 9. The time series of ice area off Newfoundland and Labrador, by month.

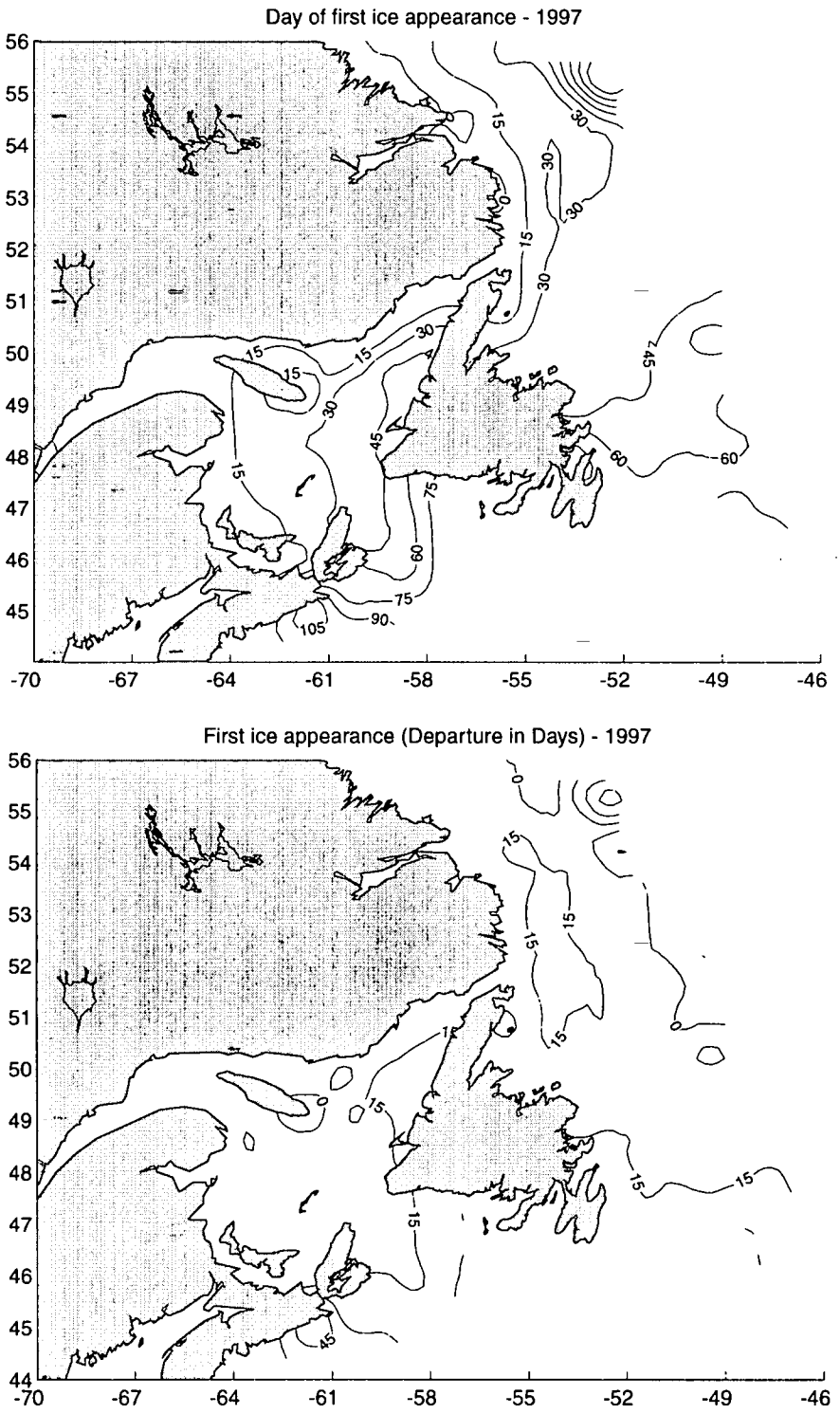

Fig. 10. The day of first presence of ice in 1997 (top panel) and their anomalies relative to the long-term mean in days (bottom panel). Negative anomalies represent ice that appeared earlier than usual.

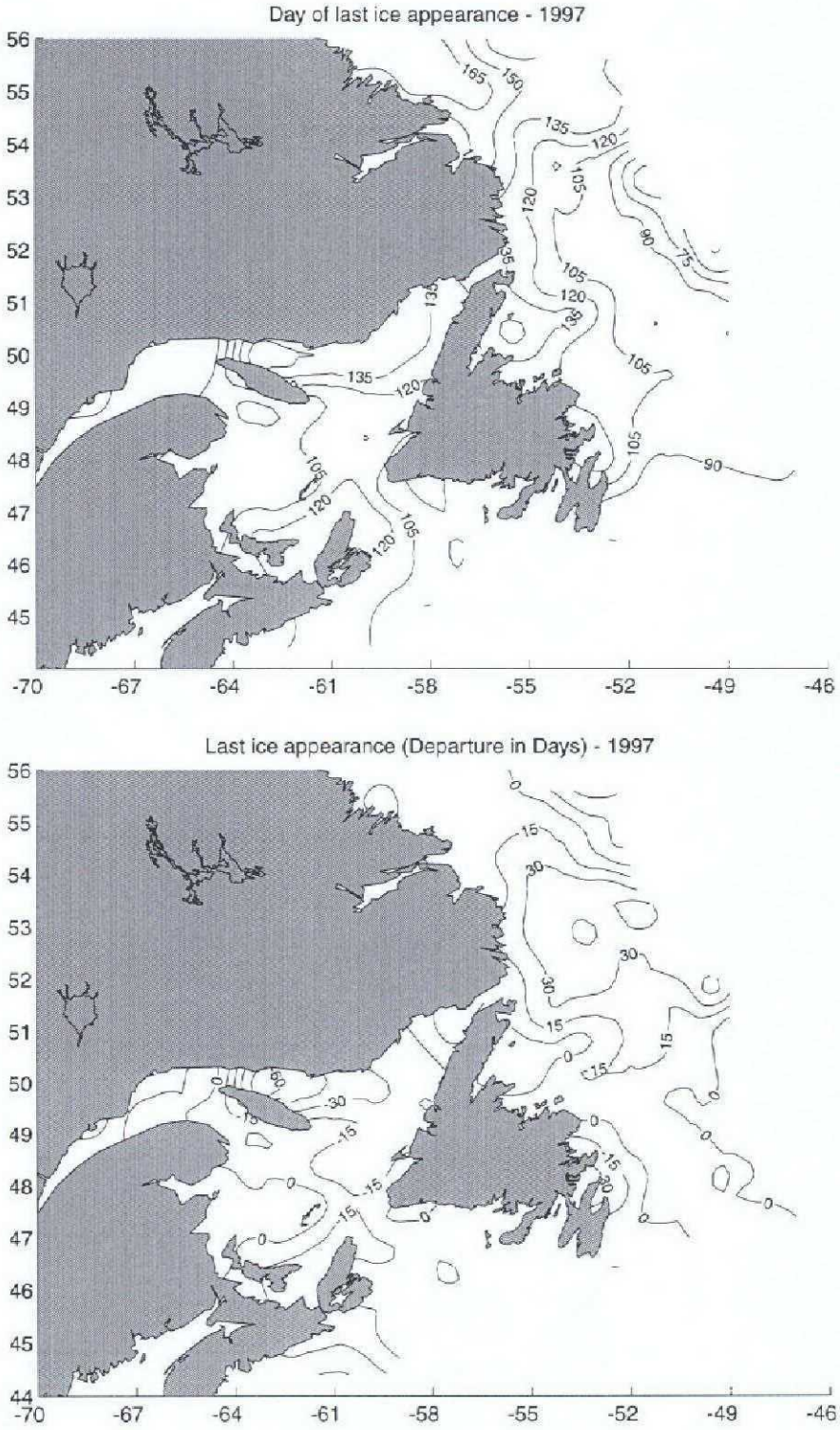

Fig. 11. The day of last appearance of ice in 1997 (top panel) and their anomalies relative to the long-term-mean in days (bottom panel). Negative anomalies represent ice that left later-than normal.

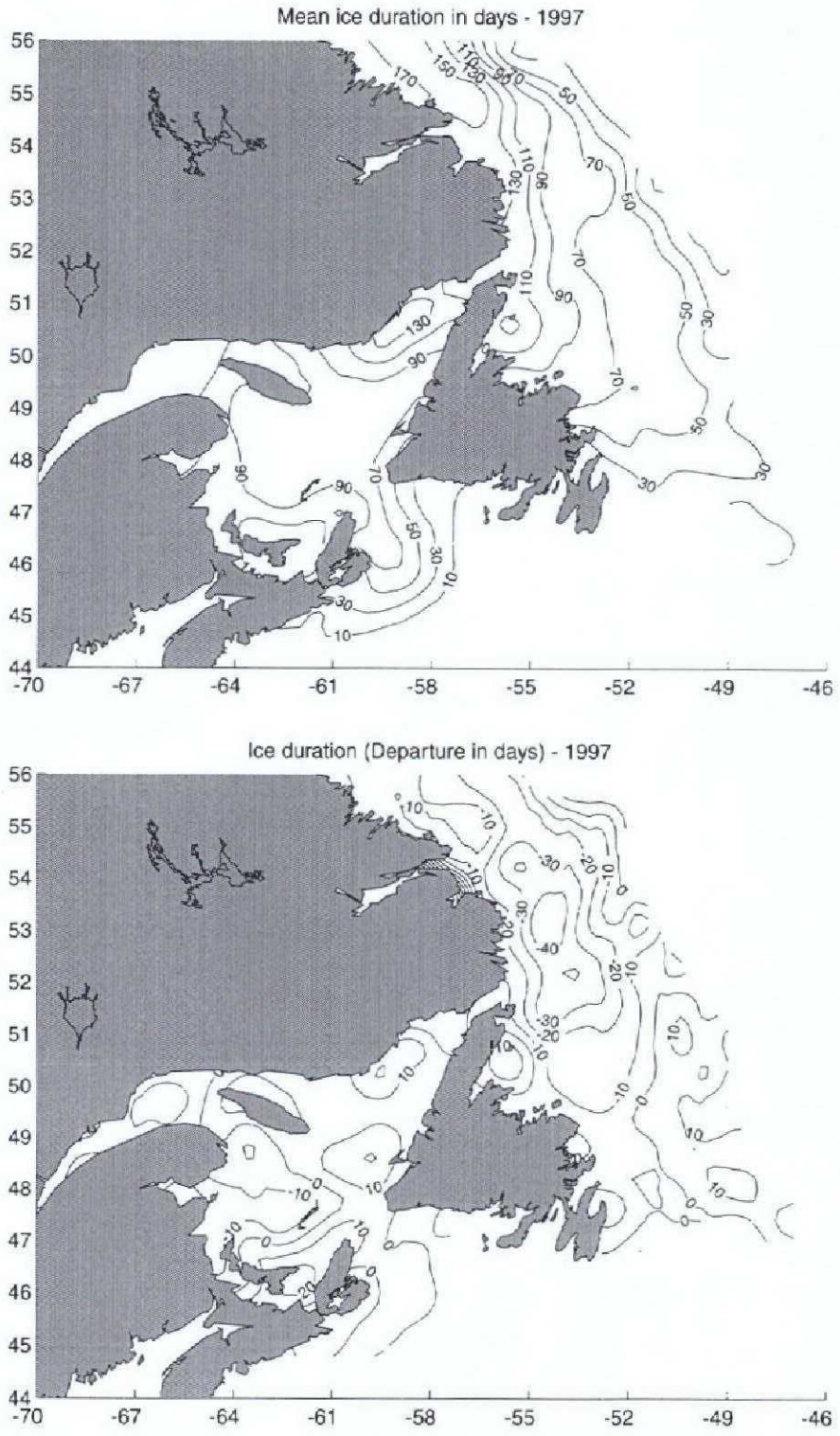

Fig. 12. The duration of sea ice in 1997 (top panel) and their anomalies relative to the long-term mean in days (bottom panel). Negative anomalies represent an ice duration that is shorter-than-normal.

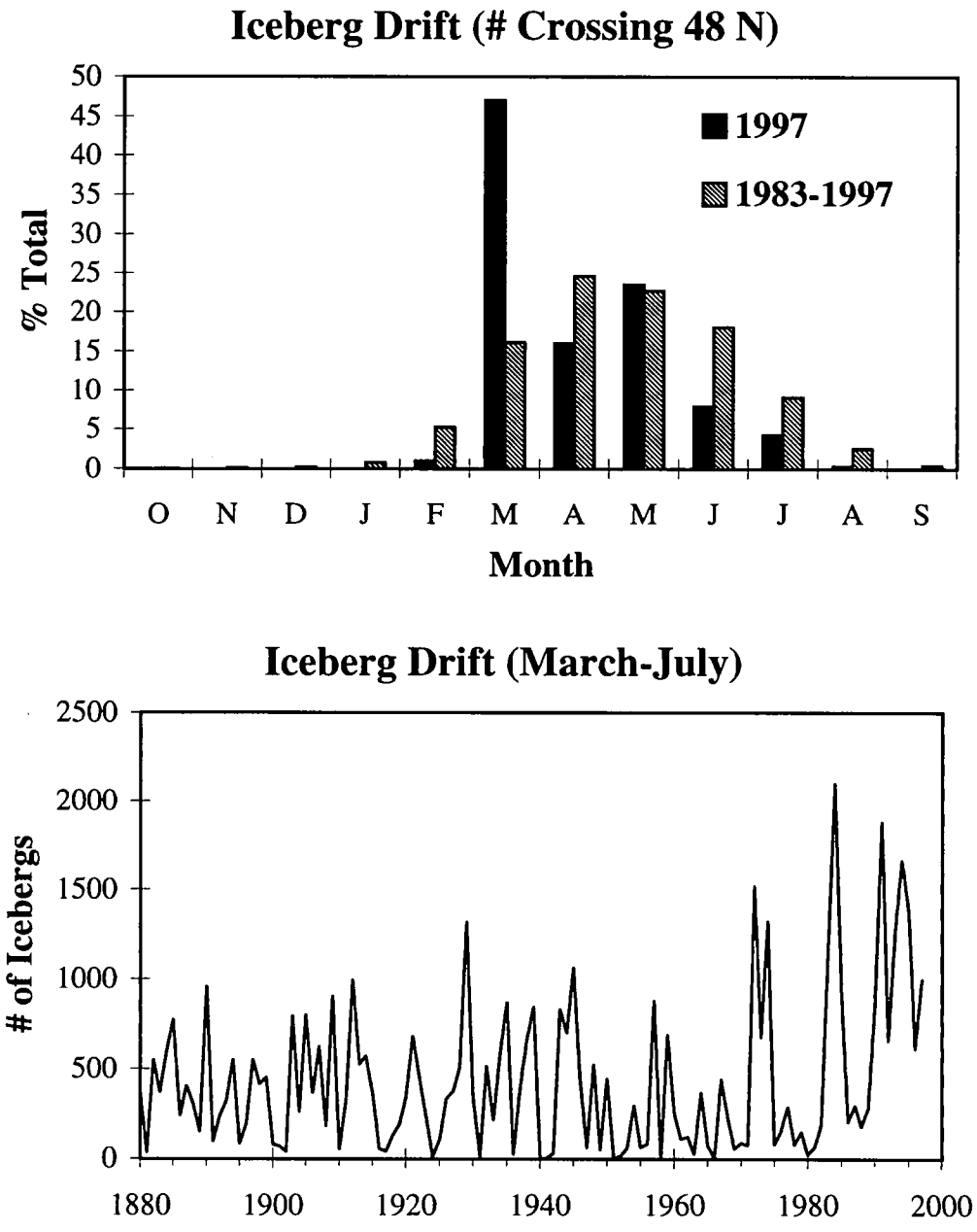

Fig. 13. The number of icebergs crossing south of 48°N during the iceberg season 1996/97 expressed as a percent of the total by month compared to the mean during 1983-97, the years SLAR has been used (top panel) and the time series of total number of icebergs observed during March to July (bottom panel).

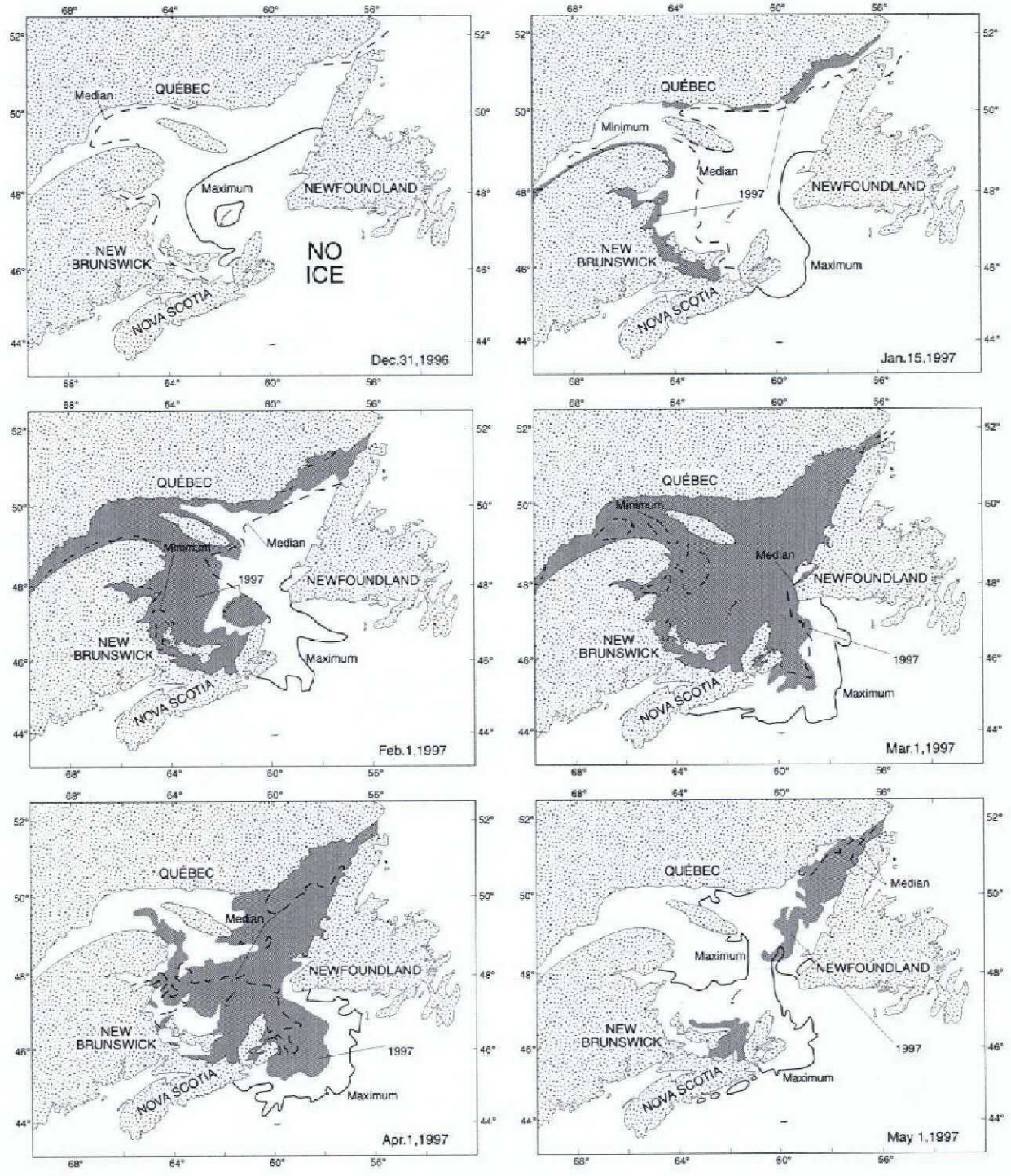

Fig. 14. The location of the ice edge together with the historical (1962-1987) median and maximum positions in the Gulf of St. Lawrence from December 1996 to May 1997.

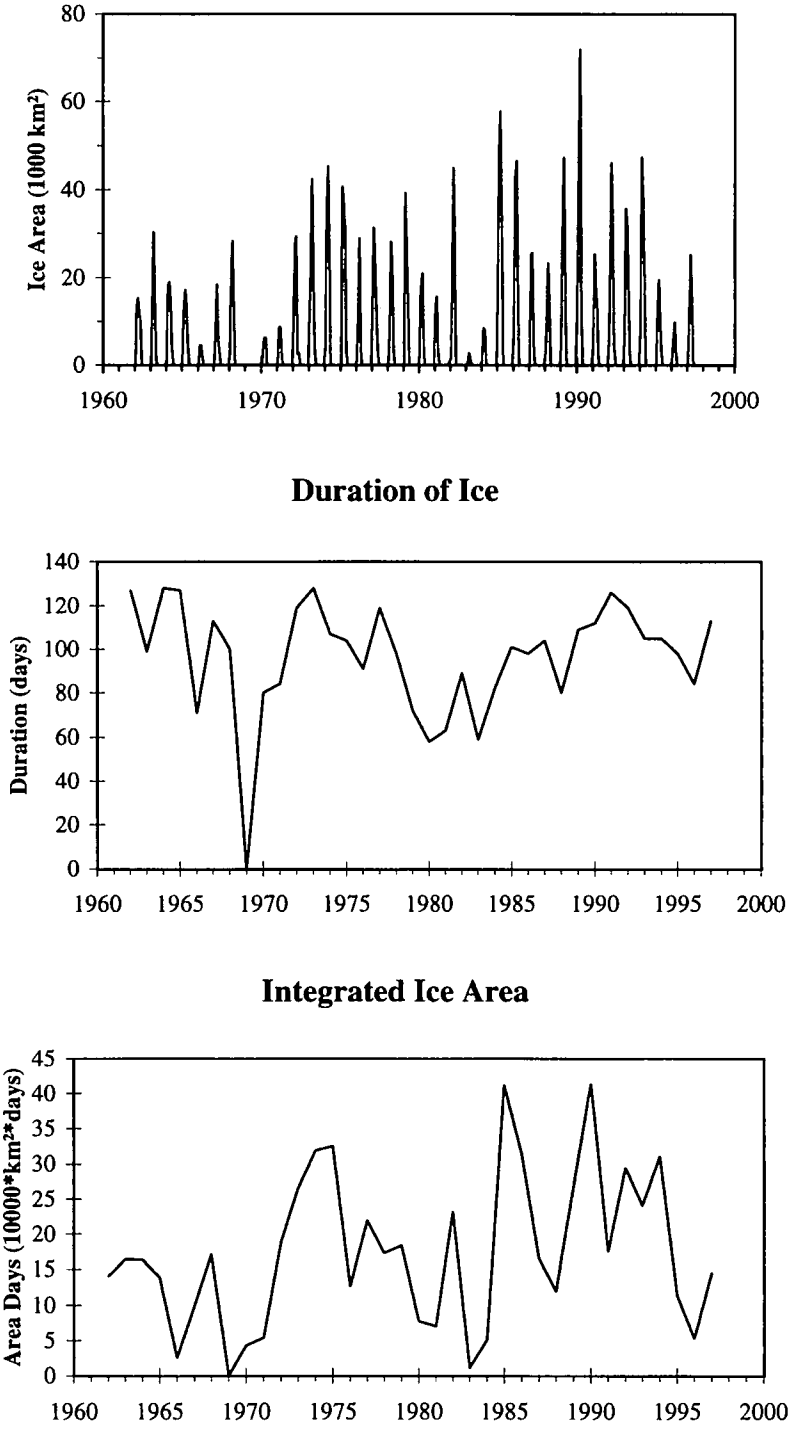

Fig. 15. For the region seaward of Cabot Strait, the time series of the monthly mean ice area (top), the duration of ice (middle) and the annual integrated ice area (summation of the area times the number of days).

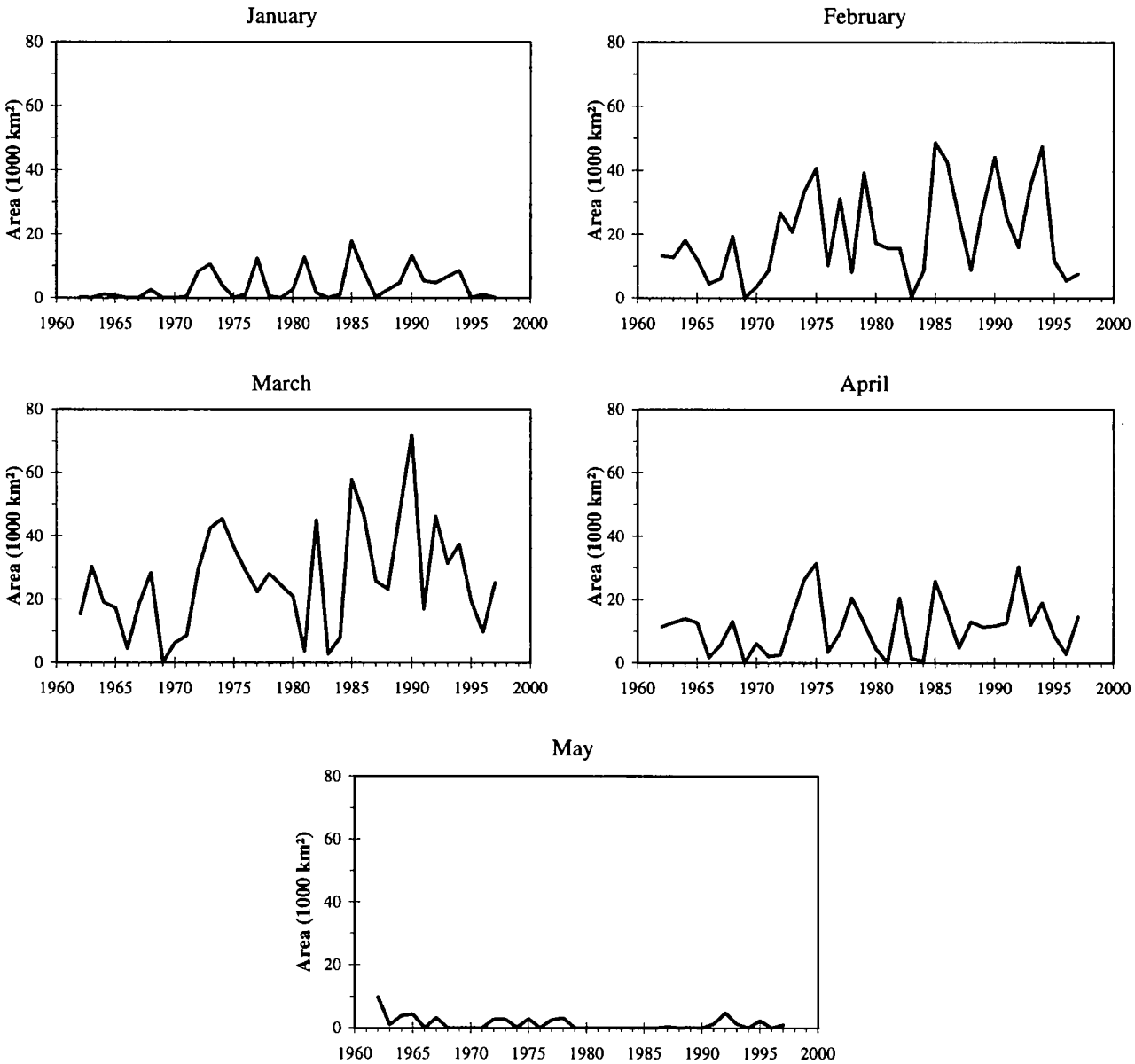

Fig. 16. The time series of ice area seaward of Cabot Strait, by month.