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Overview of Meteorological and Sea Ice Conditions off Eastern Canada during 1998

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ABSTRACT

A review of meteorological and sea ice conditions off eastern Canada during 1998 is presented. Annual mean air temperatures throughout the northwest Atlantic warmed relative to 1997 and were warmer than the long-term normal by between 0.4° to 1.5°C. The maximum air temperature anomaly, and largest increase relative to 1997, was in the Gulf of St. Lawrence. Seasonally, air temperatures in most areas of the northwest Atlantic were above normal in at least 10 out of the 12 months of 1998. The North Atlantic Oscillation (NAO) index for 1998 was slightly above normal, reversing the trend of below normal values of the previous two years. There was, however, only a slight increase in the index relative to 1997 but these lay well above the 1996 index. This indicates that the large-scale atmospheric circulation, including the Icelandic Low, has been intensifying relative to events in 1996. The sea ice on the southern Labrador and Newfoundland shelves generally appeared late and left early, resulting in a shorter duration of ice than usual. The ice coverage in these areas during 1998 was less than in 1997 and lower than average. The number of icebergs reaching the Grand Banks in 1998 was 1384, which represents a 36% increase over the 1997 numbers. This large number of bergs in 1998 was unexpected given the reduced sea-ice extent and the relatively warm wintertime air temperatures. Still, it remained below the large number of icebergs reported in the early 1990s. In the Gulf of St. Lawrence, the sea-ice appeared late and disappeared early, resulting in a lower than normal duration. Little to no ice reached the Scotian Shelf proper and the areal coverage of ice in the Sydney Bight area off eastern Cape Breton was much less than normal.

RÉSUMÉ

Un examen des conditions météorologiques et des conditions des glaces de mer au large de la côte est du Canada en 1998 est présenté. La température annuelle moyenne de l'air dans tout le nord-ouest de l'Atlantique a augmenté par rapport à 1997 et était supérieure de 0,4 à 1,5 ^{o}C à la normale à long terme. L'anomalie maximale de la température de l'air, et la plus grande augmentation par rapport à 1997, a été notée dans le golfe du Saint-Laurent. Par rapport à la saison, la température de l'air de la plupart des zones du nord-ouest de l'Atlantique a été supérieure à la normale pendant au moins 10 des 12 mois de 1998. L'indice de l'oscillation nord-altlantique (ONA) de 1998 était légèrement supérieur à la normale, et renversait ainsi la tendance de valeurs inférieures à la normale notées au cours des deux années précédentes. L'indice n'était que légèrement supérieur à celui de 1997, mais bien supérieur à celui de 1996. Cela montre que la circulation atmosphérique à grande échelle, y compris la dépression d'Islande, s'est intensifiée par rapport à 1996. La glace de mer des plateaux du sud du Labrador et de Terre-Neuve est généralement apparue tardivement et disparue hâtivement, de sorte que la période d'englacement a été plus courte que normalement. La couverture de glace de ces zones en 1998 a été inférieure à celle de 1997 et à la moyenne. Le nombre d'icebergs qui ont atteint les Grands Bancs en 1998 a été de 1 384, ce qui représente une augmentation de 36 % par rapport à 1997. Ce nombre élevé n'avait pas été prévu étant donné la faible couverture de glace de mer et la température de l'air en hiver relativement élevée. Il est cependant inférieur aux nombres importants signalés au début des années 1990. Dans le golfe du Saint-Laurent, la glace de mer est apparue tardivement et est disparue tôt, de sorte que la période d'englacement a été plus courte que la normale. Peu ou pas de glaces ont atteint le plateau Scotian et la superficie couverte par les glaces dans la grande baie de Sydney, au large du Cap-Breton, a été de beaucoup inférieure à la normale.

INTRODUCTION

This paper examines the meteorological and sea ice conditions during 1998 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 complements 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 between 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* (Deutscher Wetterdienstes, 1998). Data up to and including November were available at the time of writing. Warmer-than-normal temperatures dominated most regions of the northwest Atlantic during 1998. In January, they covered the continental shelves off West Greenland and from southern Labrador to the Middle Atlantic Bight, the latter reaching anomalies of > 3°C (Fig. 2a). In contrast, over the central Labrador Sea, northern Labrador, Baffin Island and off eastern Newfoundland, temperatures in this month were below normal. Mild conditions continued for the remainder of the winter over the region south of Labrador with anomalies between 2°-4°C during February and March. The most intense cold during the year appeared over Davis Strait and extended from Baffin Island to Greenland and Iceland in February, with negative anomalies reaching -7°C. Springtime temperatures were above normal in most regions, the notable exception being the Middle Atlantic Bight. These lower-than-average temperatures in the vicinity of the Bight remained until August. During the summer of 1998, temperatures remained above normal in most regions although the amplitudes were lower than those observed earlier in the year (Fig. 2b). However, the colder-than-normal temperatures off the Middle Atlantic Bight extended further northward to cover large portions of the Gulf of Maine, especially during June and July. In September, a small area off eastern Newfoundland experienced below average air temperatures while most of the rest of the northwest Atlantic continued the higher-than-normal temperatures. Much of the Labrador Sea experienced above normal air temperatures in October although slightly below or near average values spread over the Scotian Shelf, Gulf of Maine and off southwestern Greenland. These conditions also extended into November, with the cold conditions expanding slightly to include the Gulf of St. Lawrence and the Middle Atlantic Bight.

Monthly air temperature anomalies for 1997 and 1998 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 sites were available from the Environment Canada website and for non-Canadian locations from *Monthly Climatic Data for the World* (NOAA, 1998). The predominance of warmer-than-normal air temperatures during 1998, noted above, are clearly evident (Fig. 3). At Cartwright, all months were above normal and at the Magdalen Islands and Sable Island all months but one (November). The cold conditions in the northern Labrador Sea during February are clearly seen at Godthaab and Iqaluit with anomalies at both sites near -4°C. At Iqaluit, cold conditions were observed in January and March as well. The highest monthly air temperature anomalies in 1998 tended to occur in the winter months at Godthaab, Cartwright, the Magdalen Islands and on Sable Island with the maximum value on the Magdalens (3.4°C). At St. John's the highest monthly air temperature anomalies occurred in May and August. The highest monthly anomaly recorded at all sites in 1998 was at Iqaluit in November (4.2°C).

The annual mean air temperatures for 1998 were above normal at all sites. The annual anomalies decreased from a maximum value of 1.5°C at the Magdalen Islands near the center of the study area, to 0.4°C at the northern (Godthaab) and southern (Cape Hatteras) extremes. The second highest anomaly was at Cartwright (1.2 °C). At all of the sites except Godthaab and Cape Hatteras, anomalies exceeded 0.8°C. At Boston, 1998 was within the top 5% of the warmest years in over 100 years of records. From Sable Island north to Cartwright, 1998 annual mean air temperatures were within the warmest 8-16% on record.

The 1998 annual temperature anomaly increased relative to 1997 values at all sites except Iqaluit (Fig. 4). From Cartwright to Boston, the change in annual mean air temperature was over 1°C with a maximum of over 1.5°C at the Magdalen Islands in the Gulf of St. Lawrence. Note that the interannual variability in air temperatures since 1960 at Godthaab, Iqaluit, Cartwright, and, to a lesser extent, St. John's, have been dominated by 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. 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). Air temperatures at Boston and Cape Hatteras has also exhibited decadal variability 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). Also note that all sites where data are available, cold conditions (relative to the 1961-90 mean) existed throughout the late 1800s and early 1990s. Temperatures rose to above normal values between the 1910s and 1950s, the actual timing being site-dependent.

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 1998, relative to the 1961-90 means, are shown in Fig. 5. Winter includes December 1997 to February 1998, spring is March to May, and summer is June to August.

In winter, a negative air pressure anomaly extended throughout most of the North Atlantic with minima over the southeastern seaboard of the United States (-4.9 mb) and south of Iceland (-3.7 mb). Strong positive anomalies persisted from eastern Canada north of Newfoundland, across to Greenland and to Svalbard, the islands east of Greenland, with maxima (≥ 3.5 mb) centered over Hudson Bay and north of Svalbard. A ridge of high pressure anomalies also existed in the southeastern region with maxima over western Europe and north Africa. This pressure pattern suggests stronger than normal onshore winds along the Labrador coast and Newfoundland and anomalous easterly winds over the Maritime provinces through to the Middle Atlantic Bight. These winds could have contributed to the generally warmer-than-normal air temperatures.

In the spring of 1998, a positive air pressure anomaly formed over most of the northern North Atlantic with centres east of Newfoundland (2.9 mb) and off the northeastern tip of Greenland (3.6 mb). Another high pressure anomaly was observed over the extreme southeast of the study area in north Africa. To the east over northern Europe and in the west over the eastern seaboard of the United States, weaker negative anomalies formed with centres over Norway and the southern United States. In contrast to the winter, the air pressure patterns suggest that the winds during spring over much of the Labrador Sea, Newfoundland and the Gulf of St. Lawrence were primarily from the south to southwest. These would have contributed to the warmer-than-normal air temperatures over the region. Over the Gulf of Maine, the winds in springtime were from the southeast.

In the summer, a broad band of negative anomalies stretched from North America across the Atlantic into Europe. The largest negative anomaly (-2.9 mb) was recorded over northern Norway and another (-2.5 mb) over the southeastern United States. Both to the north and southeast of this band were positive pressure anomalies, with maximum values again being located on the eastern side of the Atlantic. The centre of the positive anomalies in the north was located over northeastern Greenland whereas in the south it was situated near the Azores. Over eastern North America, this pressure pattern resulted in a predominance of easterly to southeasterly winds.

The autumn air pressure pattern bears some resemblance to that of summer. The negative pressure anomaly across the northern North Atlantic had intensified but still had two minima. The western most centre shifted slightly northward, relative to summer, with a minimum value of -3.4 mb

off Nova Scotia. Positive pressure anomalies again lay to the north and southeast with the largest change compared to summer being in the intensity of the anomalous high centered over northern Greenland (11.9 mb). The autumn pressure pattern resulted in anomalously winds from the east and southeast in Newfoundland, along the Labrador coast, and over the southern Labrador Sea. These would have contributed to the warmer-than-normal air temperatures during the autumn months.

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 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 1998, the NAO anomaly was near normal (+1.2 mb) and had increased only slightly from the 1997 value which was just below normal (Fig. 6). The 1998 value was, however, significantly above the low index registered in 1996 but well below the very high NAO anomalies of the first half of the 1990s. The recent NAO indices fit the pattern of near decadal variability that has persisted since the 1960s.

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 median, 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). As in last year's review (Drinkwater et al., 1998), we include an analysis of the time of onset, duration and last presence of sea ice in eastern Canadian waters based upon up-to-date comprehensive sea-ice databases maintained at the Bedford Institute of Oceanography (Peterson and Prinsenberg, 1990; Drinkwater et al., 1999). The weekly concentration and types of ice within 0.5º latitude by 1º 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 continues into 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 1998 values to obtain anomalies.

Newfoundland and Labrador

At the end of 1997, sea ice lay off the southern Labrador coast in the vicinity of Hamilton Inlet resulting in an areal coverage that matched closely the long-term median for that time of the year (Fig. 7a). This was in part due to above normal air temperatures during the first half of December that had initially slowed ice formation in the region. By early January, however, the ice

had spread to the southern tip of Labrador and by mid-month, the ice edge lay just south of the Strait of Belle Isle. It was closer inshore than normal which resulted in less ice coverage in spite of colder-than-normal air temperatures during the first half of the month. By the first of February, ice coverage was back to near normal values and by 1 March, the southern most ice edge lay near but slightly north and west of the long-term median line. On 1 April, the ice edge still was very close to its long-term median position (Fig. 7b). By mid-April (not shown) the ice was south of the median but only in the inshore regions off eastern Newfoundland. The ice retreated at approximately the long-term mean rate such that the ice edge on 1 May lay near the long-term median location except in the nearshore regions of White Bay and Notre Dame Bay where it was further south than usual. By June, the ice was limited to an area off Hamilton Inlet and was still near its long-term median position. Ice remained off Hamilton Inlet until mid-June and by 1 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^{o}N; I. Peterson, personal communication, Bedford Institute) show the peak extent during 1998 decreased relative to 1997 and was near that of 1996 (Fig. 8). The average area during the period of general advancement (January to March) fell slightly relative to 1997 and during the period of retreat (April to June) it was similar to 1997. During both advance and retreat periods, the average ice area was below the long-term mean and was much less than the early 1990s. The monthly means show that in 1998 ice coverage was less than that observed during 1997 in February and March and more only in April (Fig. 9). In the remaining months, the ice coverage was similar in the two years. The data indicate 1998 was generally a lighter-than-average ice year on the Labrador and Newfoundland shelves. Variations of ice area generally reflect changes in ice volume as the two are reasonably well correlated based on studies carried out in the Gulf of St. Lawrence (Drinkwater et al., 1999).

In 1998, ice appeared along the southern Labrador coast in late December, and gradually spread southward to northeastern Newfoundland waters by mid-March (Fig. 10). Only small quantities of ice reached the northern Grand Bank (around day 75). Relative to the long-term mean, ice generally appeared later-than-normal throughout most of the shelf area, the only exceptions being on the extreme outer shelf. Ice began to disappear from the offshore and southern sites by early April (day 105; Fig. 11). Ice did not began to retreat from northern Newfoundland waters and southern Labrador until May but lasted in the region north of Hamilton Inlet until near mid-June. Over most of the region, ice disappeared earlier-than-normal (negative anomaly, generally associated with warm conditions), more than 15 days early over all of southern Labrador waters. The only regions where ice departed later-than-usual was off White Bay and the outer half of the shelf to the northeast of Bonavista Bay. The duration of the ice season ranged from less than a month off northeastern Newfoundland 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 almost all of the Labrador and Newfoundland waters. Off northeastern Newfoundland, southern Labrador and northeast of Hamilton Inlet, the duration was over 1 month shorter-than-normal. Only off the White Bay area of northern Newfoundland and northeast of Bonavista Bay was the duration longer-than-

normal, and there it was within a few days of normal.

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 1997/98 iceberg season (October 1997 to September 1998), a total of 1384 icebergs were spotted south of 48°N. The monthly totals for January to July were 1, 8, 26, 70, 1017, 247, and 15 (Fig. 13). No icebergs were spotted between October and December, 1997, inclusive, or in August or September, 1998. In 1998, 99.3% of the icebergs were observed during the primary iceberg season of March to July, higher than the mean in 1983-98 of 91%. Over 73% of the total number of icebergs during the 1997/98 season penetrated south of 48°N in May, the highest percentage of the total annual number in any one month during the past 5 years. The total number of icebergs in 1998 was up from 1997 by 36% and above the long-term mean but was still below the numbers recorded in the earlier years of the 1990s (Fig. 13). The relatively large numbers of icebergs in 1998 was somewhat unexpected given the lower amount of sea ice, warm air temperatures and reduced northwest winds during the winter. In the past, such environmental conditions have usually resulted in low numbers of icebergs (Marko et al., 1994). Note, for example, that the years when large number of icebergs passed south of 48°N, such as the early 1970s, the mid-1980s and the early to mid-1990s, were 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 1997, ice was only present in the St. Lawrence Estuary and along the eastern coast of the Magdalen Shallows in the Gulf of St. Lawrence due to warmer-than-normal air temperatures which delayed ice formation (Fig. 14). By mid-January, ice had formed throughout the Estuary, along the north shore of the Gulf and spread eastward on the Magdalen Shallows to surround all of Prince Edward Island. The ice edge lay shoreward of its median position. During the second half of January, ice spread such that the coverage was near the long-term median by the beginning of February. By 1 March the areas north of Cape Breton and off western Newfoundland still remained ice free and the ice coverage was less than usual. Ice retreated during March and by 1 April it had left the Estuary and many of the coastal areas of the southwestern Gulf. There was generally less ice than normal in the Gulf at this time although there was more ice along the north shore of Quebec around Anticosti Island. Ice continued to retreat through April and by 1 May ice was only located in the Strait of Belle Isle. The ice disappeared from the northern Gulf around 20 May.

During 1998 within the Gulf (landward of Cabot Strait), first ice formation ranged from the beginning of the year (day 0) along the St. Lawrence Estuary and the western Magdalen Shallows to after mid-February (day 45) off southwestern Newfoundland (Fig. 10). This

represented a later-than-normal appearance of ice, over 15 days in some areas of the central Gulf. The date of last appearance shows the typical pattern of ice lasting longest over the southern Magdalen Shallows and along the north shore of Quebec through to the Strait of Belle Isle (Fig. 11). In 1998, there was an earlier-than-normal disappearance over the Magdalen Shallows and the eastern Gulf, up to 45 days off western Newfoundland. A later than normal departure was observed in the Estuary and around Anticosti Island. The duration of ice ranged from less than 30 days off southwestern Newfoundland to over 120 days in the Strait of Belle Isle (Fig. 12). Relative to the long-term mean using only years when ice was present, ice duration was less than normal throughout the entire Gulf, except for a small area to the west of Anticosti Island. Near Cabot Strait, the duration of ice was 50 days less than the long-term mean while much of the Gulf had durations of at least 30 days less-than-normal.

Scotian Shelf

Sea ice is generally transported out of the Gulf of St. Lawrence through Cabot Strait, pushed by northwest winds and the mean ocean currents. In 1998, ice first appeared seaward of Cabot Strait during the first half of January (Fig. 10) approximately 15 days later-than-normal, and maintained a relatively constant presence through into March. This ice was primarily restricted to the Sydney Bight area with little to no ice reaching the Scotian Shelf proper. Most of this ice had disappeared by the end of March with small amounts remaining until the later half of April (Fig. 11). This departure was over a month to a month and half earlier-than-normal. The duration of ice south of Cabot Strait ranged from 50 days off Cape North on Cape Breton Island to 10 days or less around the eastern most point and southern coast of Cape Breton Island, which was less than the long-term mean by 30 to 50 days in most areas (Fig. 12). Note that a duration of less than 10 days is not plotted in Fig. 12.

The monthly estimates of the ice area seaward of Cabot Strait since the 1960s shows that much less ice than normal was transported onto the Scotian Shelf during 1998 compared to either 1997 or the long-term mean (Fig. 15, 16). There were fewer days than usual when ice was present seaward of Cabot Strait and the integrated ice area (summation of the area times the number of days) was the third lowest on record, after 1969 (when no ice was observed outside of the Gulf) and 1983 (Fig. 15). Thus, 1998 was a very light ice year seaward of Cabot Strait. 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 prior to 1960, albeit incomplete, suggest that during heavy ice years, it occasionally penetrated much further south, for example in the late 1800s sea ice was observed in the Gulf of Maine (A. Ruffman, Geomarine Associates Ltd., Halifax, personal communication).

SUMMARY

During 1998, the NAO index was near its long-term mean indicating an intensification of the

Icelandic Low and Azores High relative to 1996 but weaker than the early 1990s. The index rose only marginally compared to 1997 but just enough to revert back to positive anomalies compared to the negative values registered during the past 2 years. Air temperatures over most of the northwest Atlantic were above normal continuing the warming trend of the past 2 years. Indeed, from the Labrador coast, through Newfoundland and the Gulf of St. Lawrence, to the Gulf of Maine, 1998 ranked within the top 5-15% of the warmest years on record, the exact value depending on location. Almost all months in 1998 experienced warmer-than-normal temperatures, the major exception being February in the northern Labrador Sea and Baffin Island regions. The warmer-than-normal winter temperatures resulted in less ice than normal off Newfoundland and Labrador, and in the Gulf of St. Lawrence. Ice typically arrived late and left early, causing fewer days of ice in most areas. Little to no ice reached the Scotian Shelf proper and seaward of Cabot Strait, the amount of ice was the 3rd lowest in the 37-year record. In spite of the reduced amount of sea ice and warmer temperatures, the number of icebergs that reached the northern Grand Banks increased relative to 1997, up by 36%. The number of icebergs was greater than the long-term average but below the record numbers of the early 1990s.

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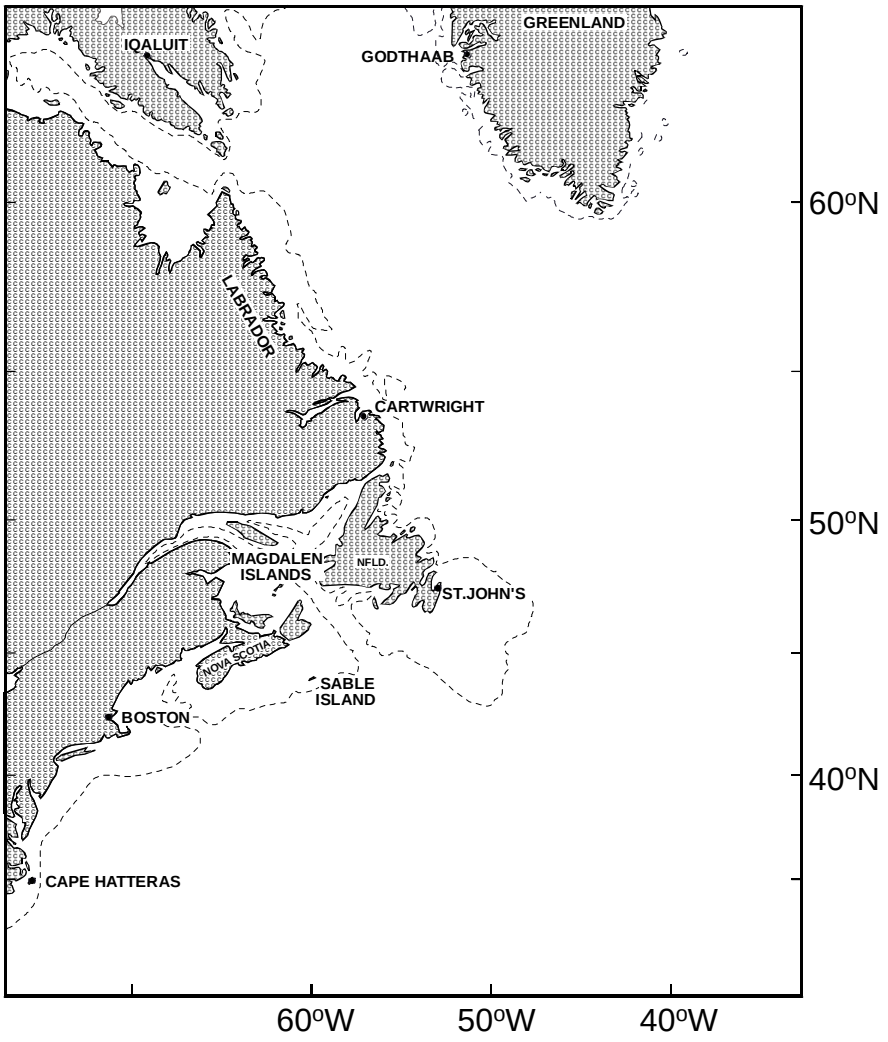

Fig. 1. Northwest Atlantic showing coastal air temperature stations. The dashed line denotes the 200 m isobath.

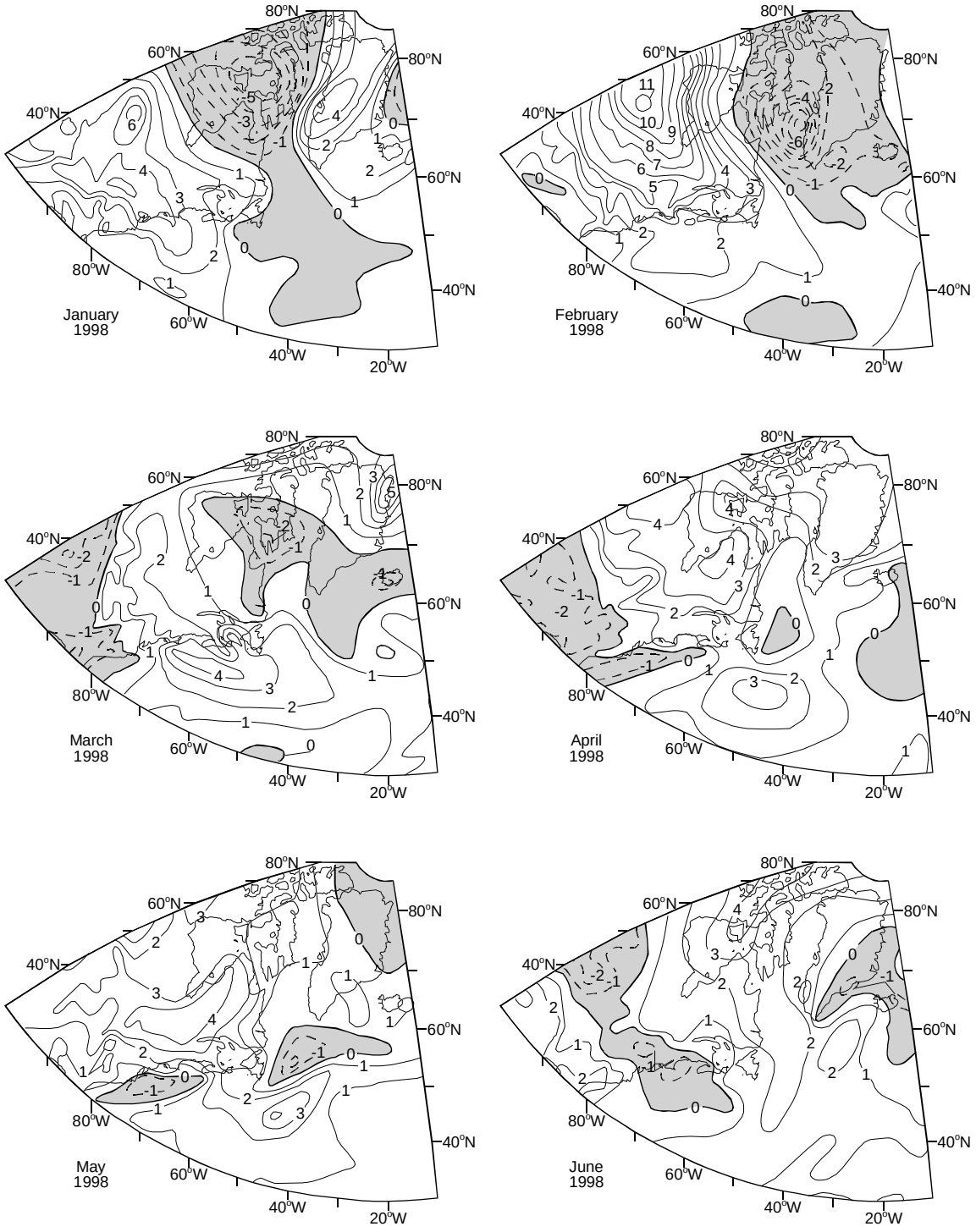

Fig. 2. Monthly air temperature anomalies (°C) over the Northwest Atlantic and eastern Canada in 1998 relative to the 1961-90 means. Shaded areas are colder-than-normal. (From *Grosswetterlagen Europas*)

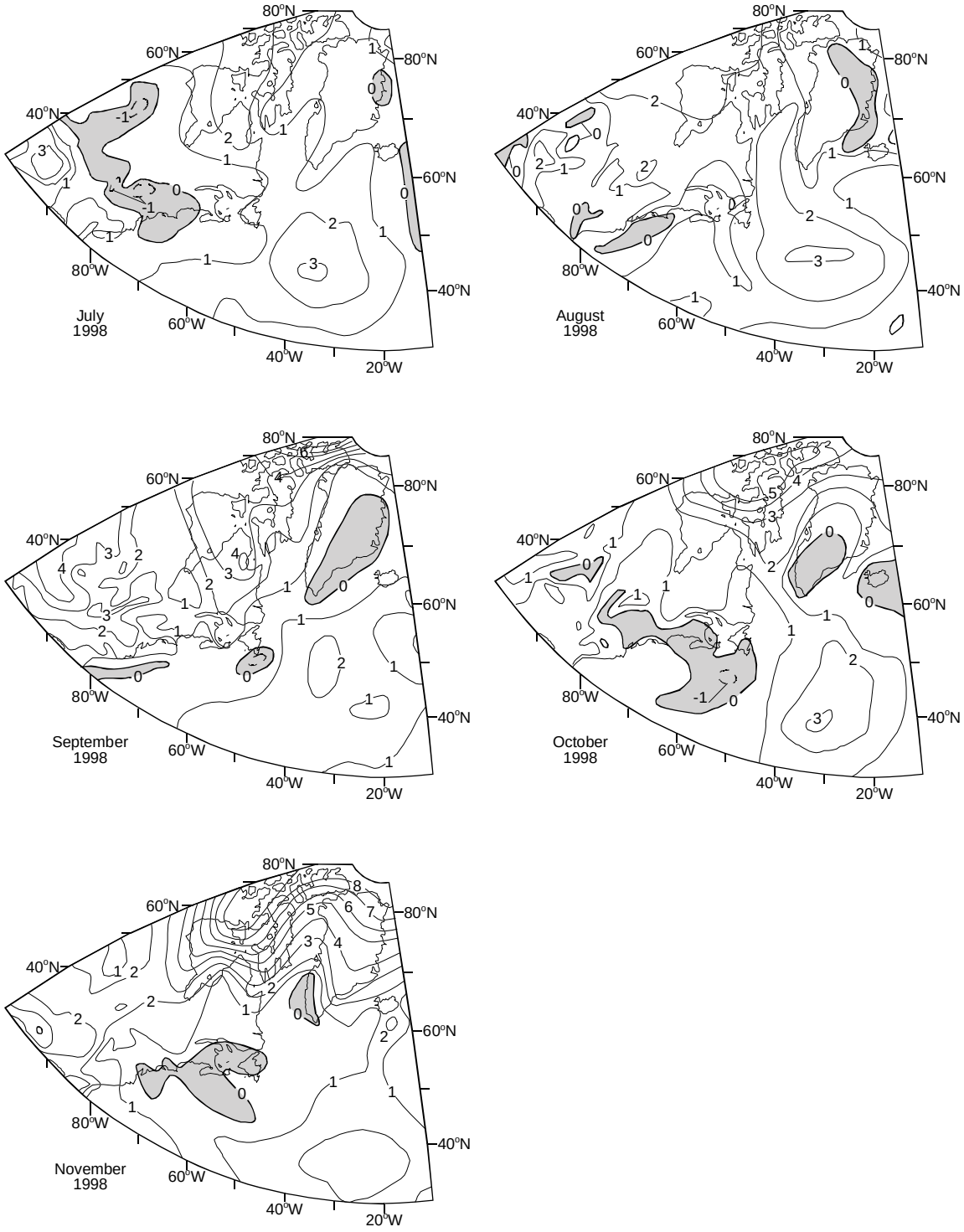

Fig. 2 (continued). Monthly air temperature anomalies (°C) over the Northwest Atlantic and eastern Canada in 1998 relative to the 1961-90 means. Shaded areas are colder-than-normal. (From *Grosswetterlagen Europas*)

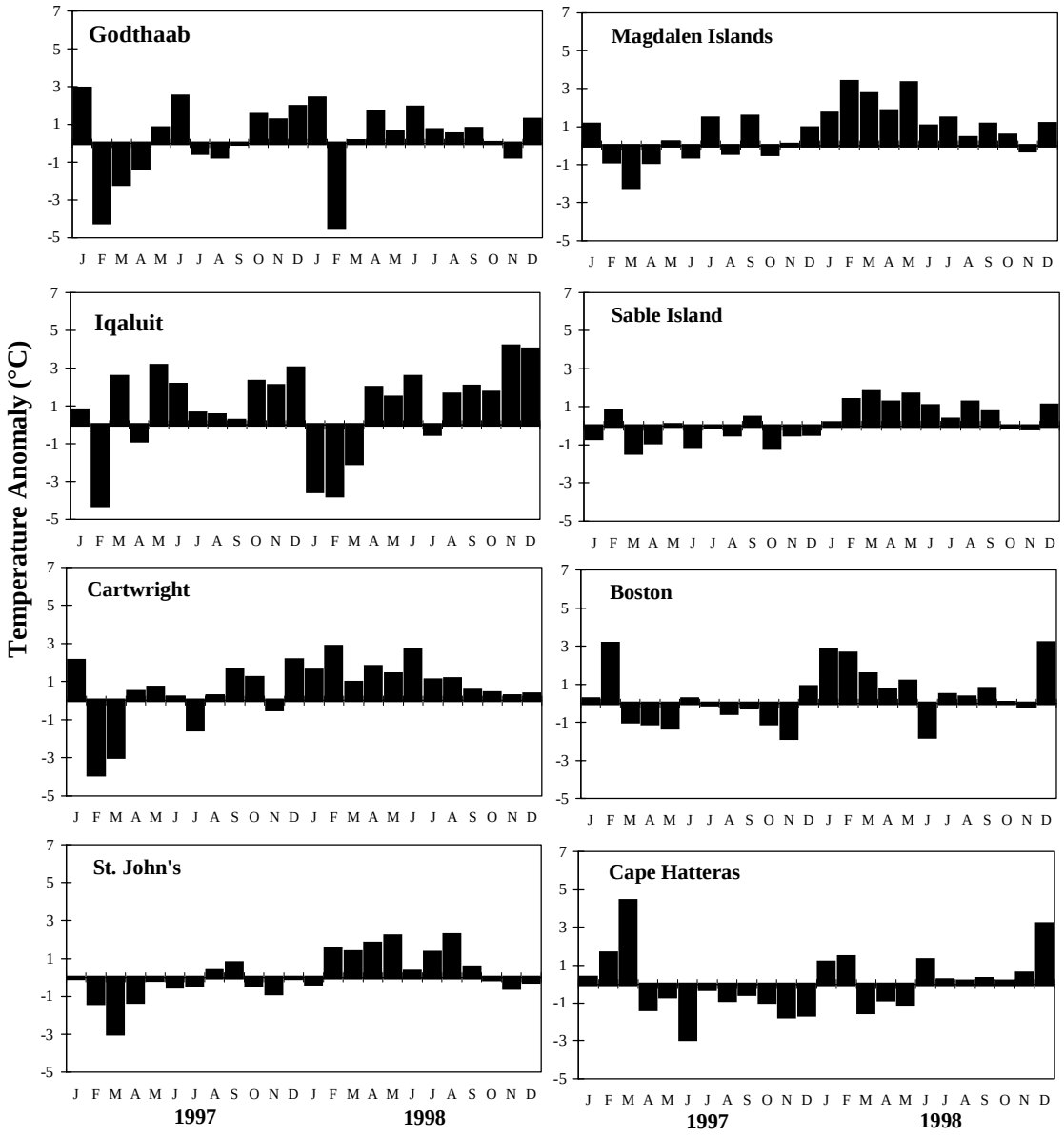

Fig. 3. Monthly air temperature anomalies in 1997 and 1998 at selected coastal sites (see Fig. 1 for locations).

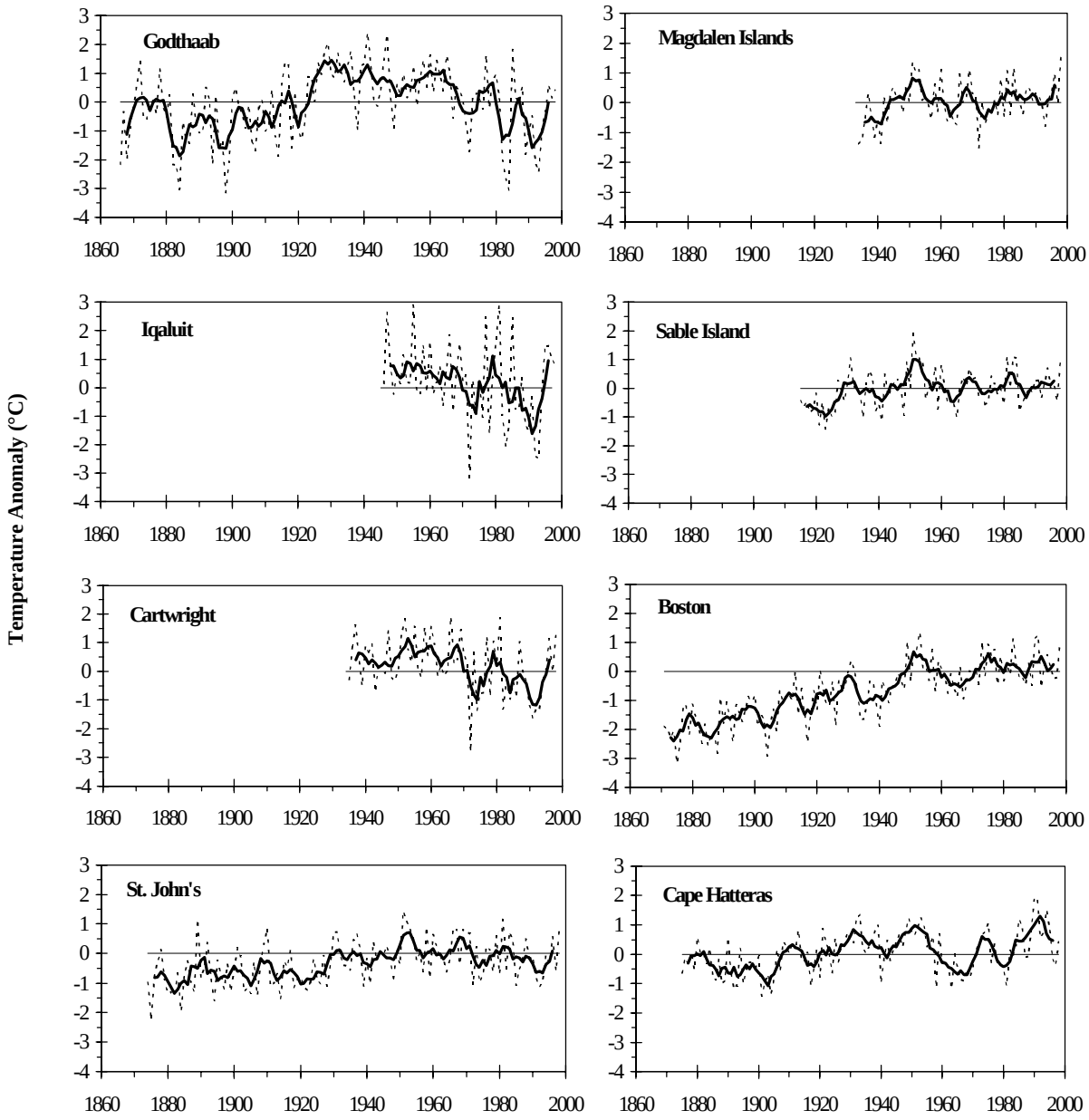

Fig. 4. Annual air temperature anomalies (dashed line) and 5-yr running means (solid line) at selected sites.

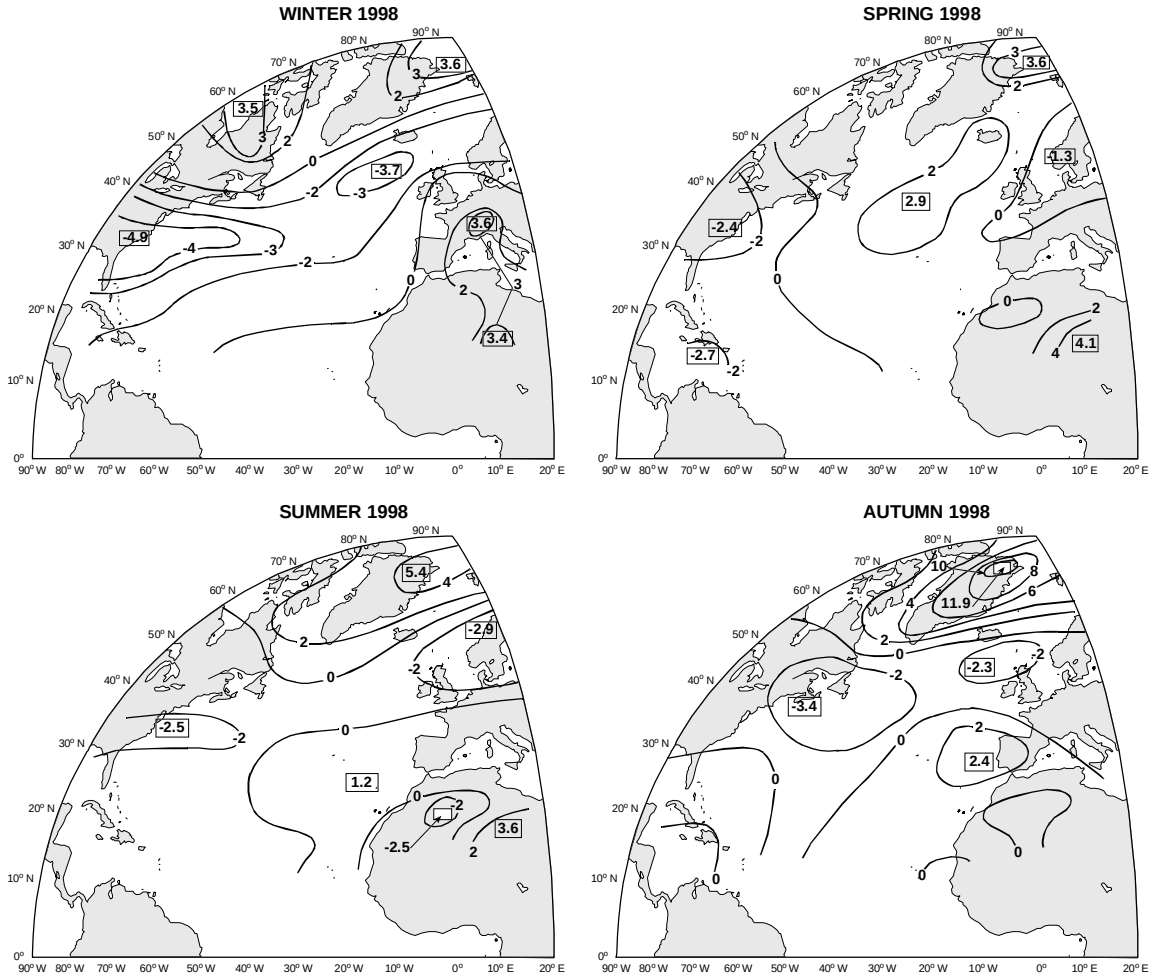

Fig. 5. Seasonal sea-surface air pressure anomalies (mb) over the North Atlantic in 1998 relative to the 1961-90 means.

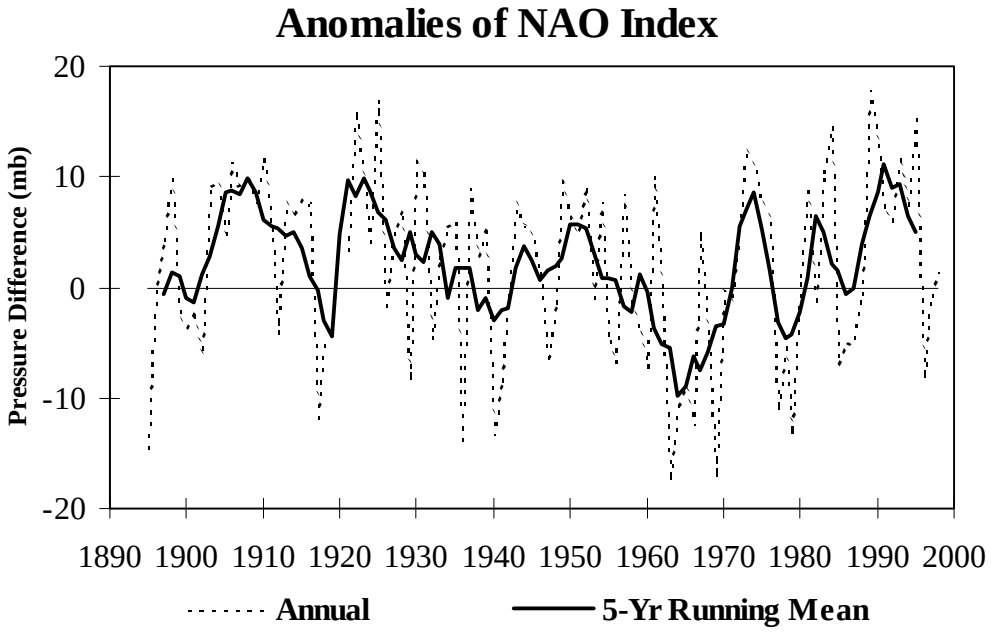

Fig. 6. Anomalies of the North Atlantic Oscillation Index, defined as the winter (December, January, February) sea level pressure at Ponta Delgada in the Azores minus Akureyri in Iceland, relative to the 1961-90 mean.

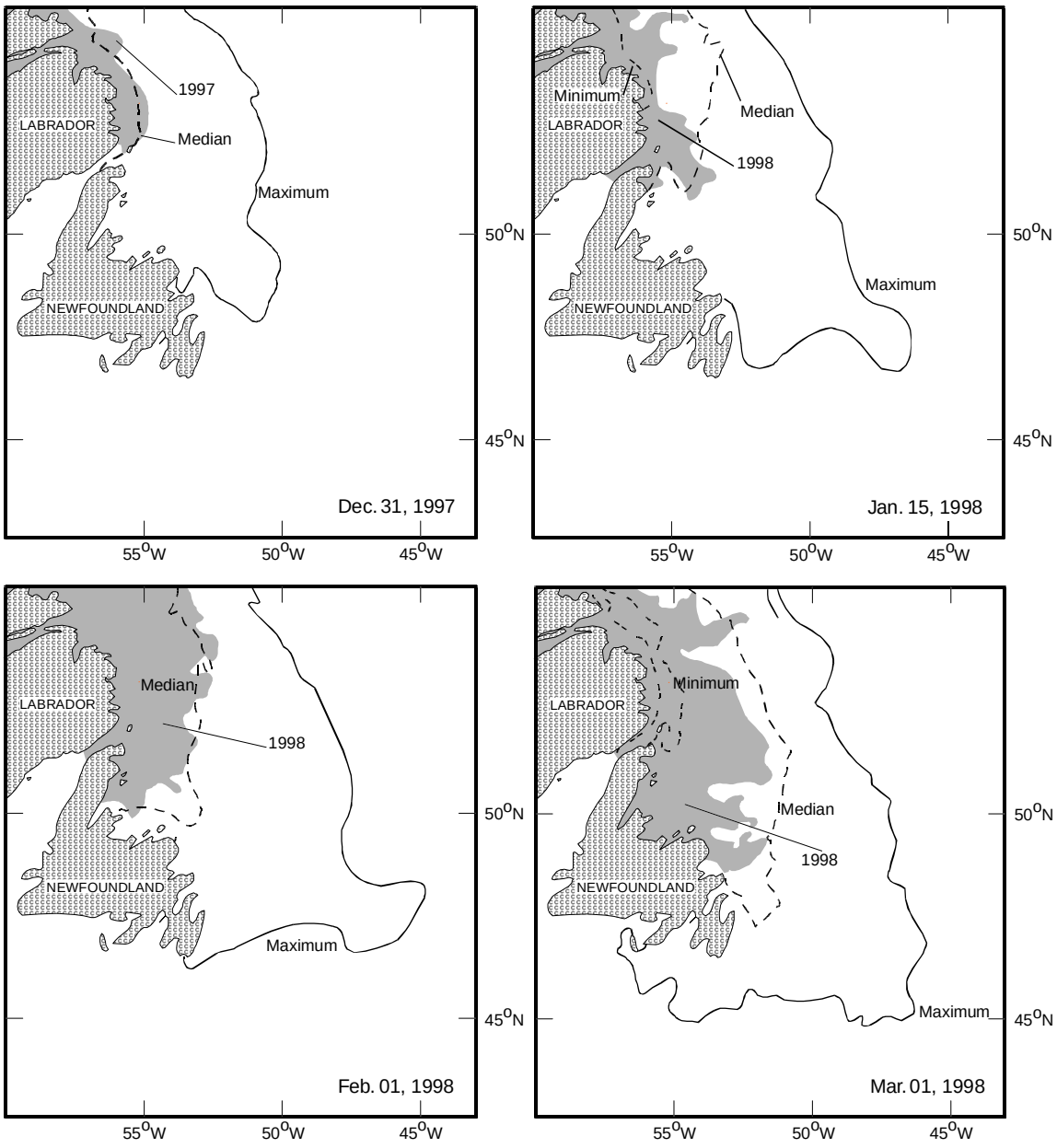

Fig. 7a. The location of the ice (shaded area) between December 1997 and March 1998 together with the historical (1962-1987) minimum, median and maximum positions of the ice edge off Newfoundland and Labrador.

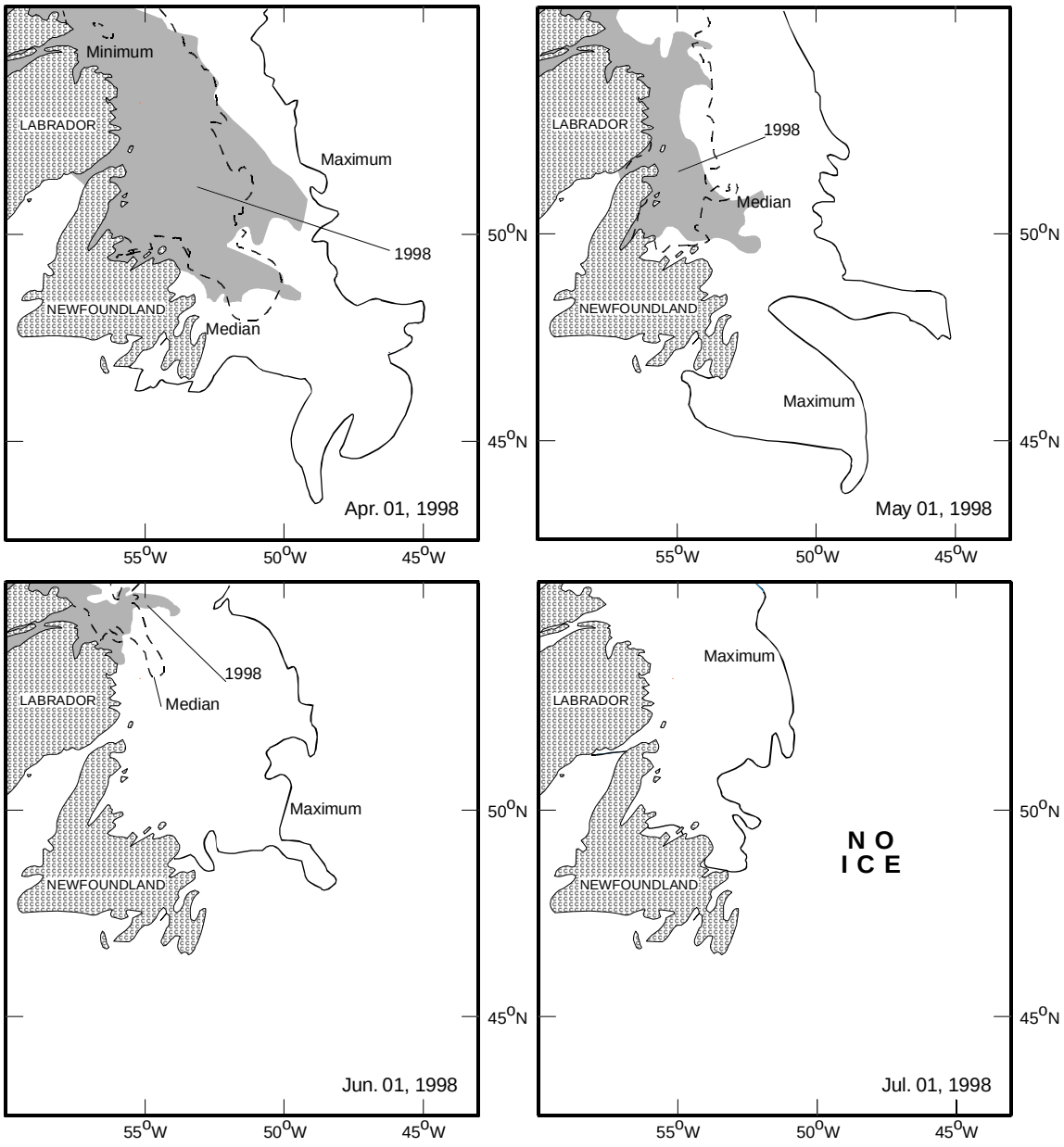

Fig. 7b. The location of the ice (shaded area) between April and July 1998 together with the historical (1962-1987) minimum, median and maximum positions of the ice edge off Newfoundland and Labrador.

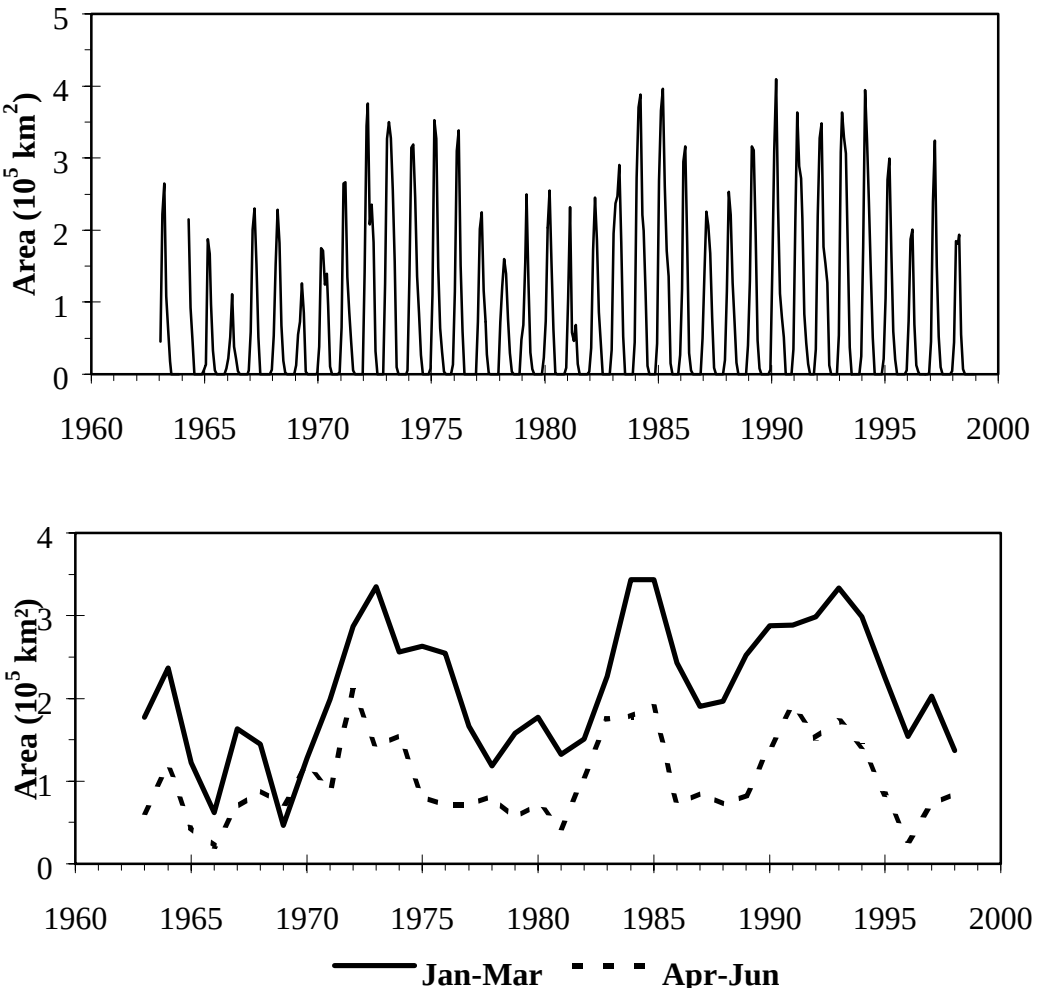

Fig. 8. Time series of the monthly mean ice area off Newfoundland and Labrador between 45°N-55°N (top panel) and the average ice area during the normal periods of advancement (January-March) and retreat (April-June) (bottom panel).

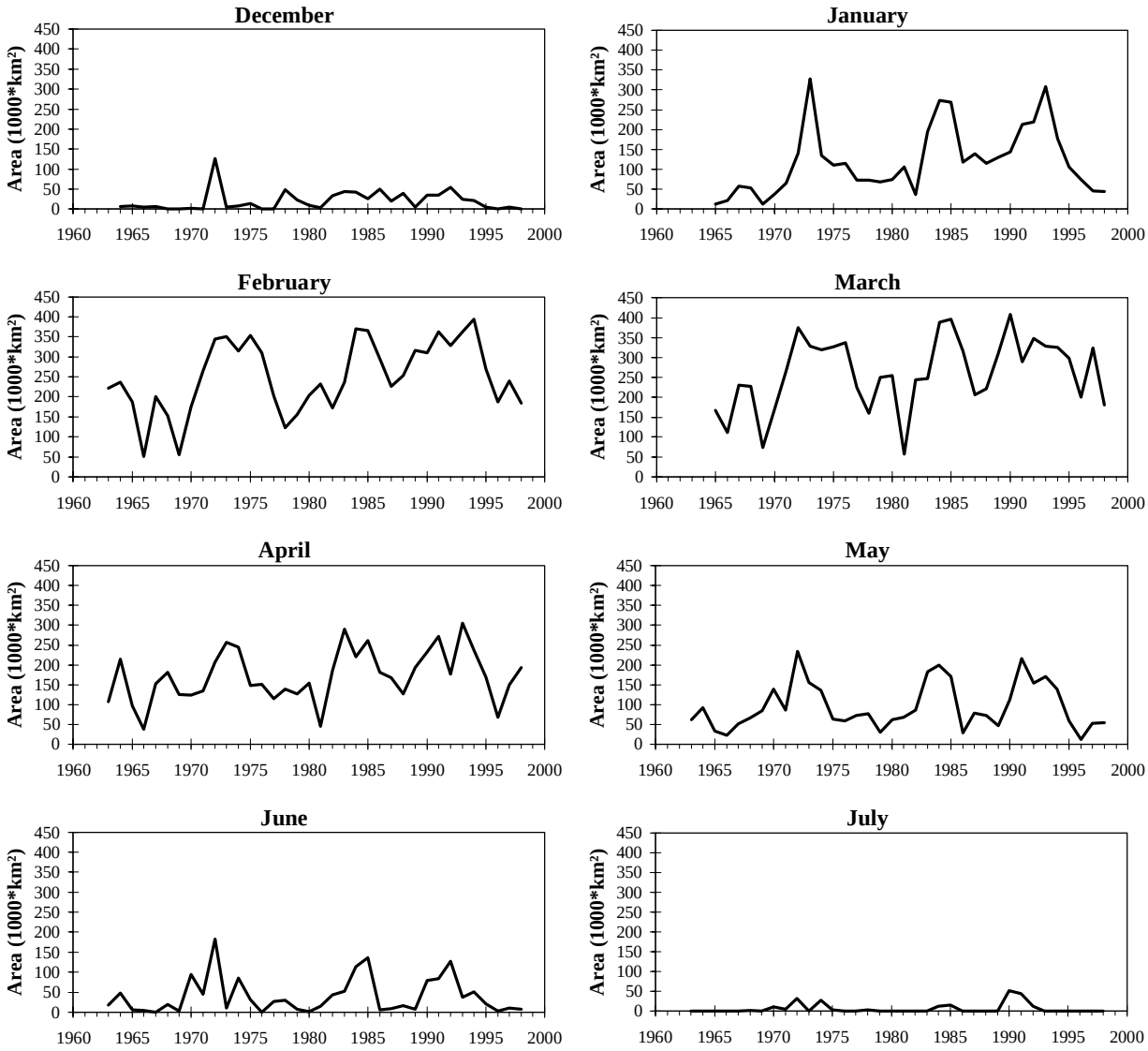

Fig. 9. The time series of ice area off Newfoundland and Labrador, by month.

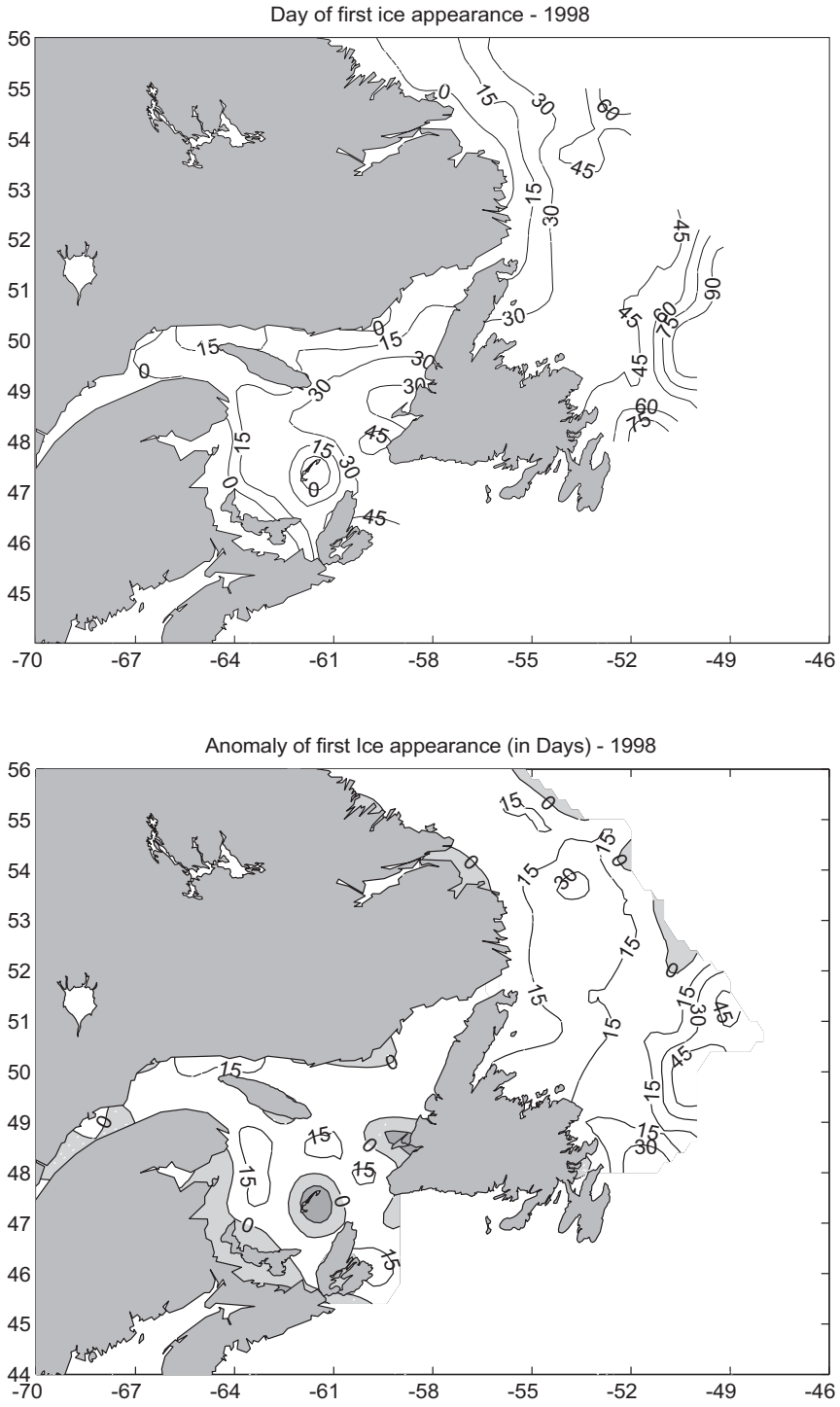

Fig. 10. The time when ice first appeared during 1998 in days from the beginning of the year (top panel) and their anomaly from the long term mean in days (bottom panel). The shaded negative anomaly indicates ice appeared earlier-than-normal which is generally associated with a cold year.

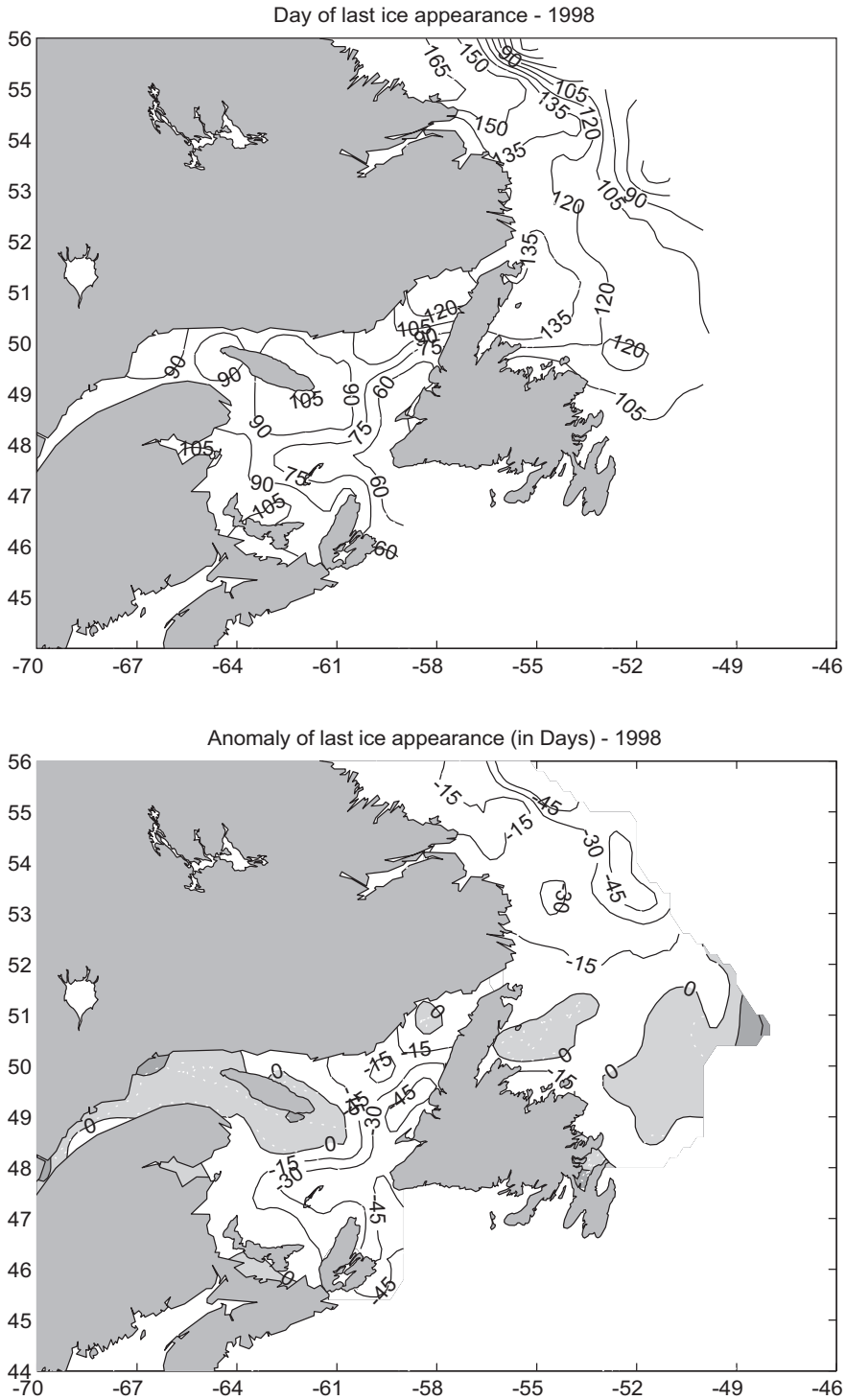

Fig. 11. The time when ice was last reported in days from the beginning of the year (top panel) and their anomaly from the long term mean in days (bottom panel). The shaded positive anomaly indicates ice lasted longer-than-normal which is generally associated with a cold year.

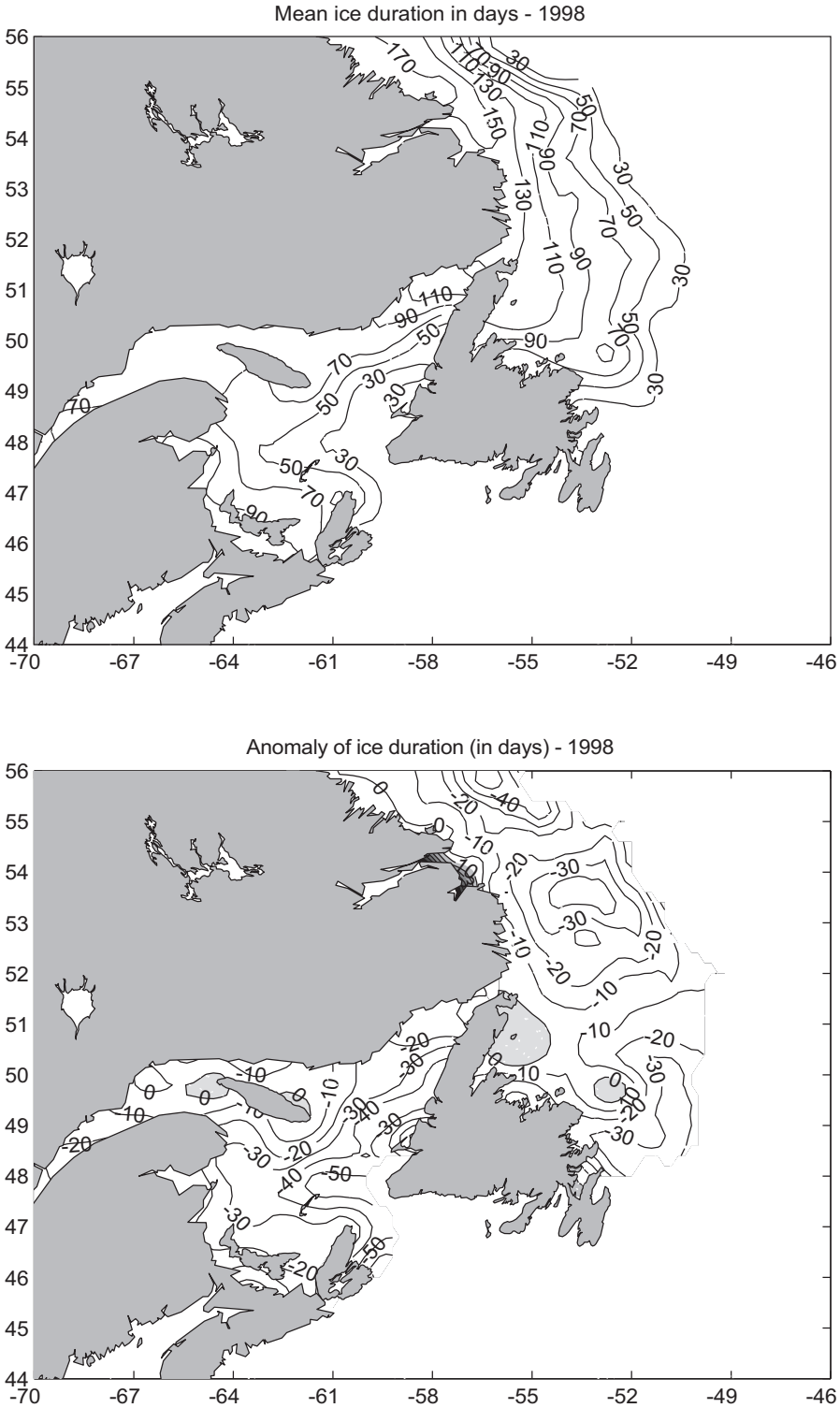

Fig. 12. The duration of ice in days (top panel) and their anomaly from the long term mean in days (bottom panel). The shaded positive anomalies indicate a duration longer than the mean which is generally associated with a cold year.

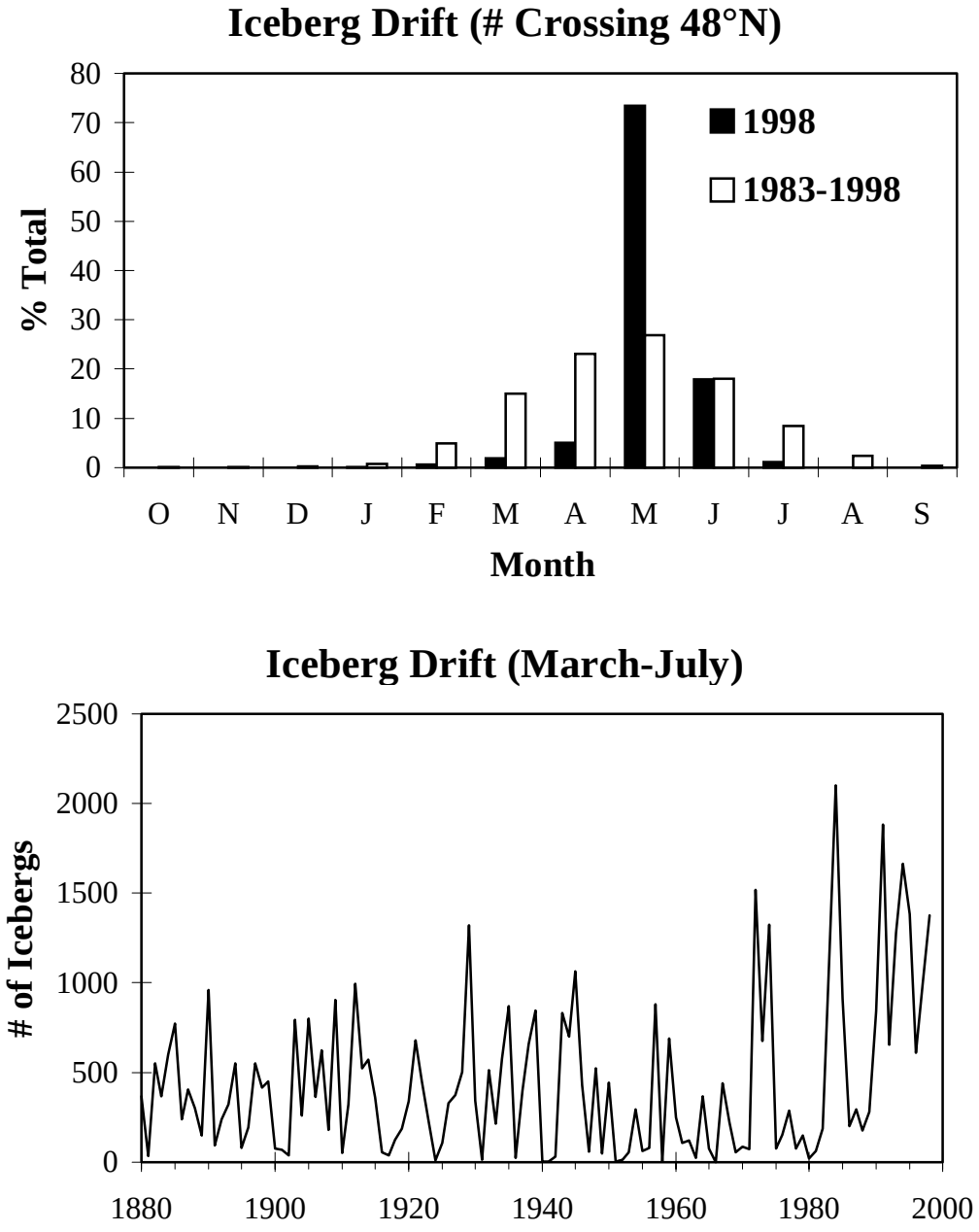

Fig. 13. The number of icebergs crossing south of 48°N during the iceberg season 1997/98 expressed as a percent of the total by month compared to the mean during 1983-98, the years SLAR has been used (top panel) and the time series of total number of icebergs observed during March to July (bottom panel).

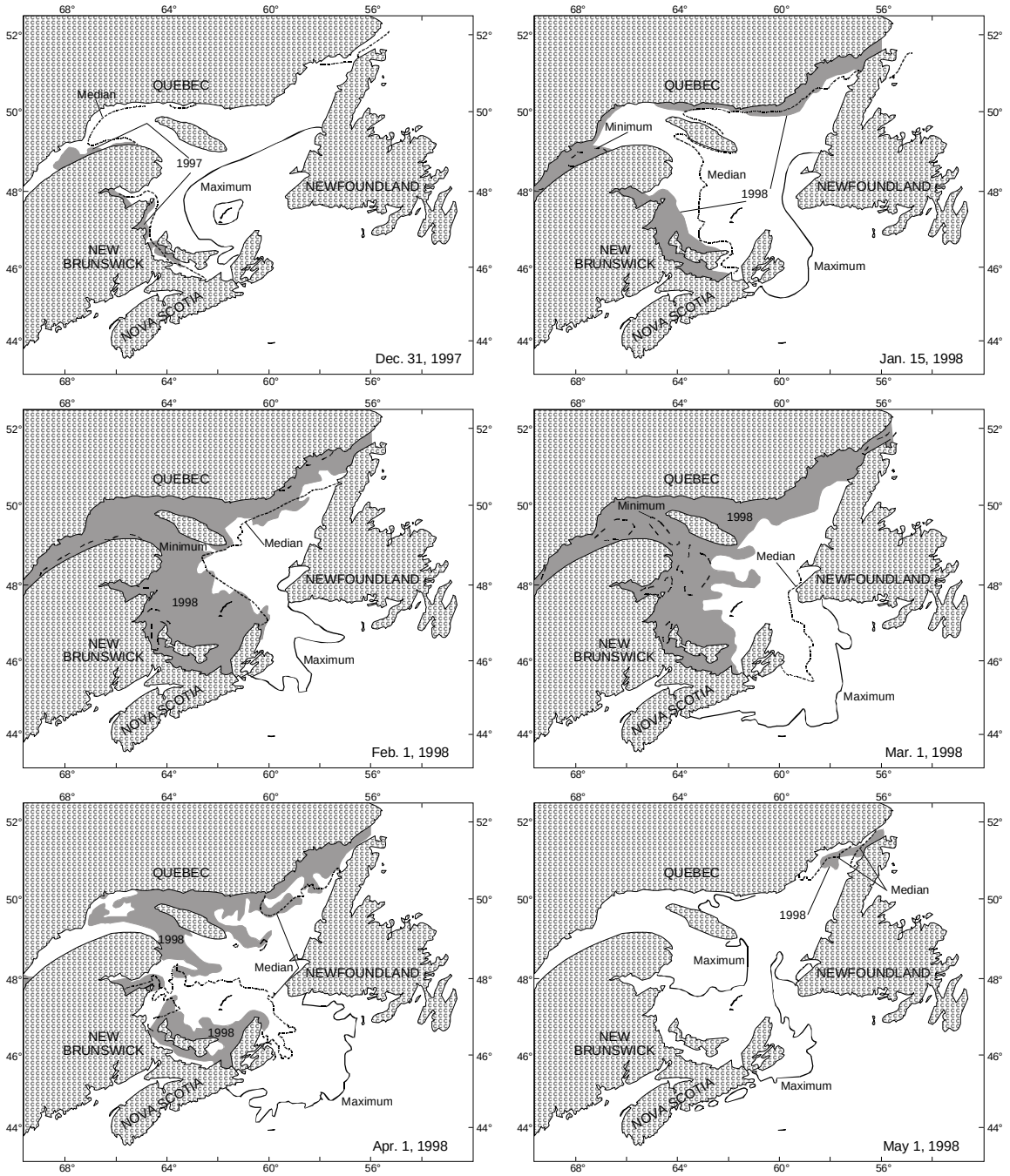

Fig. 14. The location of the ice (shaded area) between December 1997 and May 1998 together with the historical (1962-1987) minimum, median and maximum positions of the ice edge in the Gulf of St. Lawrence.

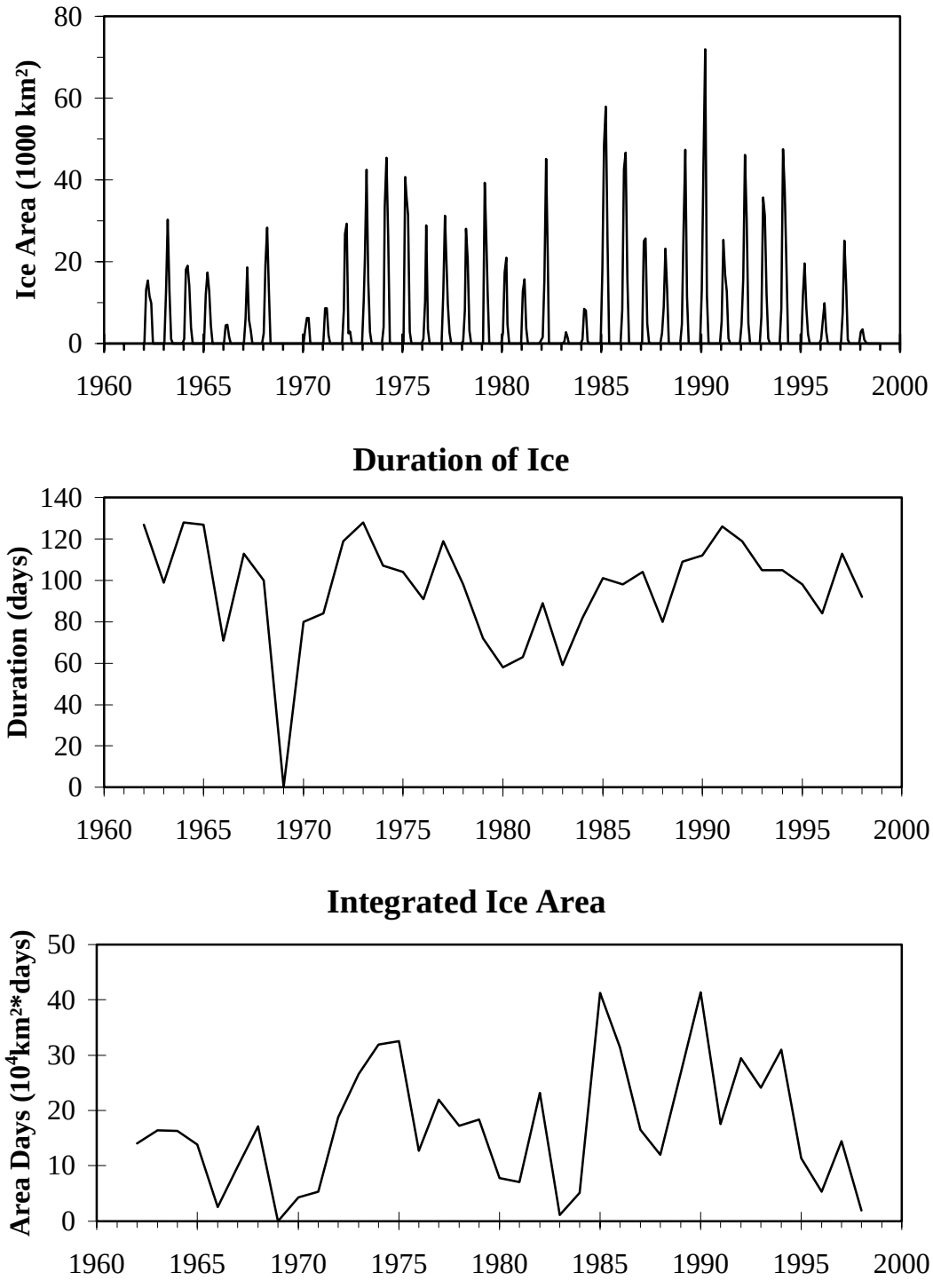

Fig. 15. For the region seaward of Cabot Strait, the time series of the monthly mean ice area (top), the duration of ice (middle) and the annual integrated ice area (summation of the area times the number of days).

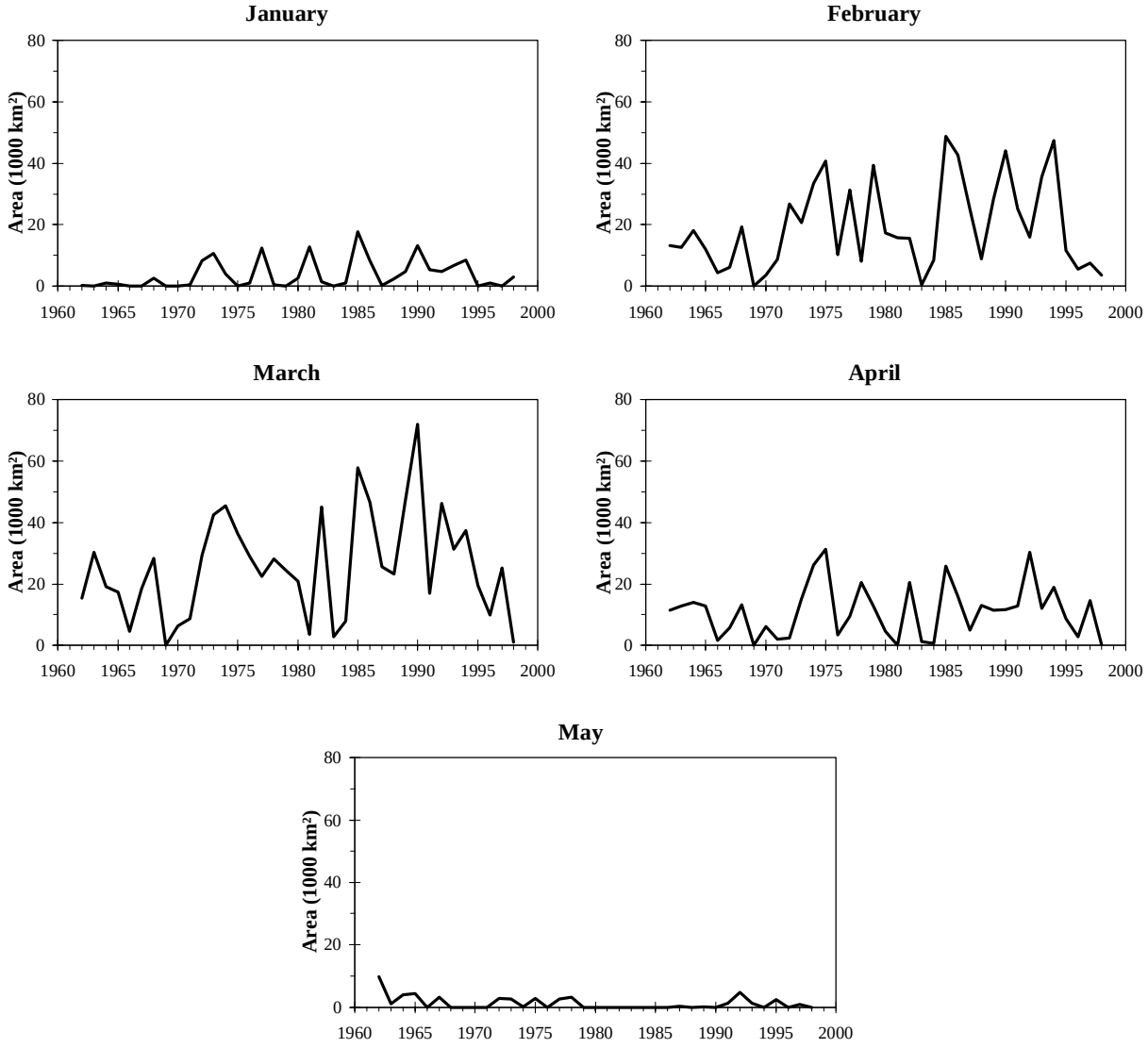

Fig. 16. The time series of ice area seaward of Cabot Strait, by month.