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Overview of Meteorological and Sea Ice Conditions off Eastern Canada in 1994

by

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ABSTRACT

A review of meteorological and sea ice conditions off eastern Canada during 1994 is presented. Annual air temperatures were slightly colder-than-normal but warmed in comparison to recent years. Seasonally, the winter temperature anomalies were below normal but conditions moderated as the year progressed. By the summer and through into the late autumn air temperatures were warmer-than-normal. The cold air temperatures in winter were related to stronger northwest winds which carried Arctic air masses further south. The stronger winds resulted from an intensification of the Icelandic Low which was reflected in high positive values of the NAO index. These colder-than-normal winter air temperatures and accompanying stronger-than-normal northwest winds caused ice to form early, be of greater areal extent than normal and last longer off Newfoundland and southern Labrador. In addition, there were large numbers of icebergs reaching the Grand Banks in 1994. Heavy ice conditions were also observed in the Gulf of St. Lawrence and on the Scotian Shelf. In February and March the ice edge extended as far south as Halifax on the Scotian Shelf. The warming in eastern Canada in the summer and autumn was due to increased westerly and southwesterly winds over much of the region. These brought warm air from southern regions and central Canada.

RÉSUMÉ

Une analyse des conditions météorologiques et glacielles au large de l'est du Canada en 1994 est présentée. Les températures annuelles de l'air ont été légèrement plus froides que les normales mais elles se sont réchauffées comparativement aux récentes années. Sur le plan saisonnier, les anomalies des températures hivernales ont été au-dessous des normales mais les conditions se sont modérées au fil des mois. Jusqu'à l'été et la fin de l'automne, les températures de l'air ont été plus chaudes que les normales. Les températures froides de l'air en hiver étaient associées à des vents nord-ouest plus violents qui ont transporté des masses d'air arctiques plus au sud. Les vents violents ont été causés par une intensification de la dépression d'Islande qui s'est traduite par des valeurs positives élevées de l'indice de l'oscillation nord-atlantique. Ces températures de l'air hivernal plus basses que les normales accompagnées de vents du nord-ouest plus forts que les normales ont provoqué la formation d'une glace plus précoce, plus étendue et plus durable au large de Terre-Neuve et du sud du Labrador. De plus, on a dénombré un grand nombre d'icebergs dans la région des Grands Bancs en 1994. On a en outre observé des conditions glacielles denses dans le golfe du St-Laurent et sur le plateau Néo-Écossais. En février et mars, la bordure de glace s'est prolongée jusqu'au sud de Halifax sur le plateau Néo-Écossais. Le réchauffement de l'est du Canada en été et en automne est dû à une augmentation des vents d'ouest et du sud-ouest sur une grande partie de la région. Ces vents ont apporté de l'air chaud des régions méridionales et centrales du Canada.

INTRODUCTION

This paper examines the meteorological and sea ice conditions off eastern Canada (Fig. 1) during 1994. Specifically, it discusses air temperature trends, atmospheric sea level pressures and associated winds, precipitation, sea ice coverage and iceberg drift. It compliments the oceanographic reviews of the Newfoundland, Gulf of St. Lawrence and Scotia-Fundy regions, which together constitute the annual environmental overview to the Fisheries Oceanography Committee. Environmental conditions are compared with those of the preceding year as well as the long-term means. Where possible, the latter have been standardized to a 30-yr (1961-90) base period in accordance with the convention of the World Meteorological Organization.

METEOROLOGICAL OBSERVATIONS

Air Temperatures

The Atmospheric Environment Service of Canada publishes the annual and monthly mean air temperature anomalies (relative to 1951-80) for Canada in their publication *Climatic Perspectives*. The 1994 annual anomalies were slightly colder-than-normal over most of eastern Canada and contrast with the warmer-than-normal temperatures in the west (Fig. 2). This pattern is similar to that observed in both 1993 and 1992, although this year's anomalies over eastern Canadian were not as cold as in the previous two years. The coldest anomalies in 1994 (between -0.5°C and <-1°C) were found along a narrow region encompassing the southern tip of Labrador, the northern Gulf of St. Lawrence and the St. Lawrence Estuary. Over most of the remainder of eastern Canada, the annual anomalies lay in the range of 0°C to -0.5°C, except on the Atlantic coast of Nova Scotia where annual temperatures were slightly above normal. All of the annual anomalies over eastern Canada were less than one standard deviation from their long-term means (Trites and Drinkwater, 1986).

The colder-than-normal air temperatures in eastern Canada did not persist throughout the year but rather were concentrated during the first five months (Fig. 3). During the latter half of 1994 the monthly anomalies were predominantly above normal but were not high enough to produce above average annual anomalies. Exceptions to the general warming in the second half of 1994 arose in August for areas north of central Labrador and in December over southern Labrador and Newfoundland where negative anomalies were observed. The largest negative anomalies during the year were reported in January and February when magnitudes exceeded -4 to -6°C along the Labrador coast and northern Newfoundland. Atlantic Canada experienced its 11th coldest winter in the past 100 years and it was the 10th winter in a row that temperatures were colder-than-average. The relatively warm conditions in eastern Canada during the autumn was the first in several years. The magnitude of the warming was higher in southern areas and weaker in the north, e.g. in the vicinity of southeastern Baffin Island only two of the last six months showed positive anomalies.

Monthly air temperature anomalies for 1993 and 1994 relative to their 1961-90 mean at five sites in eastern Canada and one on the west coast of Greenland for comparison (see Fig. 1 for locations) are shown in Fig. 4. The predominance of colder-than-normal air temperatures in the first few months of 1994 and warmer-than-normal during the latter half of the year is evident for all sites. At the two most northern sites, the wintertime temperatures were not as severe as 1993 whereas at Cartwright on the Labrador coast, and stations farther south, the winter air temperature anomalies were similar to last year. The warming in the latter part of the year was less evident or absent at Godthaab in West Greenland and at Iqaluit on Baffin Island compared to the more southerly stations. This warming was in contrast to events in 1993 (Fig. 4).

The time series of temperatures (25-month running means) show the warming in 1994 as a recent upward trend (Fig. 5). Note that the interannual variability since 1970 at Godthaab, Iqaluit, Cartwright, and, to a lesser extent, St. John's have been dominated by large amplitude fluctuations with periods of 5-10 yr with minima in the early 1970s, early to mid-1980s and the early 1990s. Indeed, the recent rise in temperature is consistent with a continuation of this decadal pattern. In addition, there has also been an overall downward trend causing temperature anomalies since 1970 to be predominantly below normal. Temperature anomalies at the Magdalen Islands and Sable Island have been of much lower amplitude and show no signs of a general downward trend 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).

Iqaluit recorded an annual air temperature of -9.7°C which was near normal (anomaly of -0.1°C) but represents a rise of 2.8°C over last year. At the remaining four stations in Fig. 5, annual air temperatures rose between 0.7° and 1.0°C. At Cartwright, 1994 was the 16th coldest year out of a total of 63, but at Sable Island it was the 13th warmest in 80 years. At the Magdalen Islands and St. John's, Newfoundland, temperatures were near normal.

Precipitation

Annual precipitation anomalies over the Atlantic provinces and along the southern Labrador coast during 1994 were wetter-than-normal by upwards of 25% (Fig. 6). This contrasts with the northern Labrador coast and Baffin Island, as well as the Hudson Bay region, where precipitation was slightly below normal. Below normal precipitation also extended throughout most of central Canada. Seasonally, wet conditions were observed over all of Atlantic Canada during the spring and over Newfoundland in the winter and summer as well. The autumn tended to be drier in all regions of Atlantic Canada expect for the northern shore of Newfoundland. Along the Labrador coast and Baffin Island, wet conditions were observed in the spring and summer and dry conditions in the winter and autumn. Dry conditions generally existed throughout most of central Canada, i.e. the drainage basin for the Great Lakes, in all seasons.

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* by the German Meteorological Service, Deutscher Wetterierst, in Offenbach, Germany. 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 1994, relative to the 1961-90 means, are shown in Fig. 7. Winter includes December 1993 to February 1994, spring is March to May, summer is June to August and autumn is September to November.

In winter, negative air pressure anomalies covered the northern North Atlantic with peak values (exceeding -9 mb) centred slightly south of Iceland. This suggests an intensification and slight shift southward in the position of the Iceland Low. In contrast, a center of positive anomalies (maximum of 5.8 mb) was observed over the southern North Atlantic and western Europe, consistent with a strengthening of the Bermuda-Azores High. Another anomalous high pressure pattern formed over northern Greenland. The resultant air pressure patterns would have strengthened the westerly winds across the North Atlantic and shifted them slightly southward. The winds over East Greenland were much stronger-than-normal and may have contributed to an increased transport of both the East Greenland Current and ice out of the Arctic into the Greenland Sea. NW winds would have been reduced over Baffin Bay but increased over the southern Labrador Sea. The latter tends to bring cold Arctic air masses farther south. The anomalous winds over Newfoundland and the Gulf of St. Lawrence would have also been from the northwest while over the Scotian Shelf and the Gulf of Maine they would have been more easterly. In spring and summer negative anomalies again dominated the atmospheric pressure pattern in the northern North Atlantic with positive anomalies in the southern North Atlantic. This resulted in a continuation of stronger-than-normal westerly winds across the Atlantic at mid-latitudes. Anomalous winds across the Scotian Shelf and in the Gulf of St. Lawrence would have been more southwesterly to westerly carrying with them warmer air. Note that the magnitude of the anomalies decreased with season. In autumn, a strong negative anomaly developed over the North Atlantic with a peak minimum value of -6 mb centred just to the east of Newfoundland. This would have brought anomalous easterly winds to Newfoundland. In contrast, anomalous westerly winds blew over northern Labrador in autumn which may have contributed to the above normal air temperatures.

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). Strong NW winds, cold temperatures and heavy ice in the Labrador Sea area are also associated with a strong positive NAO index. 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 (Fig. 8). The small number of missing data was filled using pressures from nearby stations. The NAO anomalies were calculated by subtracting the 1961-90 mean. In 1994, the NAO anomaly was strongly positive but slightly below last year's value. This continues a trend of above average NAO

anomalies that has existed since the late 1980s. Over the past 30 years there has been large decadal variability superimposed upon a general upward trend from a minima in the mid-1960s. Note that the timing of the three most recent peaks in the NAO index corresponds to the periods of cold air temperature anomalies in the Labrador Sea (Fig. 5).

SEA ICE OBSERVATIONS

Newfoundland and Labrador

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).

Near seasonal air temperatures and light to moderate NW winds during the second half of December 1993 resulted in near normal ice coverage by the end of the month. The southern limit of the ice edge lay near the Strait of Belle Isle (Fig. 9). The ice edge continued to move southward during early January at a rate consistent with its normal progression due to continuing seasonal temperatures and winds. However, in the latter half of January extremely cold air temperatures and strong NW winds accelerated the rate of southward movement. By the beginning of February the ice coverage lay between the long-term median and maximum. Cold weather and strong winds in February continued to push the ice south and offshore so that by the beginning of March the ice edge was close to the long-term maximum. The ice began to retreat along the coast of Newfoundland later in March and by April 1 the ice had shifted eastward, freeing most of the coastal communities of Newfoundland of ice. The offshore ice edge, however, still lay near its long-term maximum extent. Through April the ice moved back inshore along northern Newfoundland and remained there into June. It finally disappeared from the region around mid-June.

The Ice Climatology and Applications Division of Environment Canada also undertakes an annual analysis of ice conditions off the east coast of Newfoundland and southern Labrador and in the Gulf of St. Lawrence by determining the time of onset, duration and last presence of ice at 24 grid sites (Fig. 10). For each site, the extracted data include ice duration in weeks for the 1993/1994 season, mean duration for all years of record, as well as minimum, maximum and mean duration for years when ice was present (Table 1). Almost without exception in the area east of Newfoundland and southern Labrador, the ice appeared early and left late (Fig. 11, 12). The ice typically appeared 2 weeks early (Fig. 11). In the inshore areas it left 1-2 weeks late but offshore it lasted 3-7 weeks longer-than-normal (Fig. 12). This resulted in a much longer period of ice duration especially in the offshore region (Fig. 13). Note that ice duration is not simply the difference between the first and last presence of ice because ice may disappear for a time after first presence or before last presence. A new record for the date of the last appearance of ice was established in 1994 at the farthest offshore sites east of the Avalon Peninsula (N112 and N114). The appearance of ice at N114 was unusual in that ice has only been observed at this site in 5

out of the 35 years of record. Ice was not observed at sites N25, N27 or N70; however, ice has never appeared at sites N27 and N70 and only reached N25 in 2 out of 35 years.

The monthly time series of the areal extent of ice on the northern Newfoundland and southern Labrador shelves (between 45-55°N) from 1963 to 1994 are shown in Fig. 14. In January through April there has been a general increase in the area of ice over the past 30 y. In addition, there are maxima in the early 1970s, the mid-1980s and the 1990s, corresponding to air temperature minima at Iqaluit and Cartwright (Fig. 5) and maxima in the NAO index (Fig. 8). The 1994 areas from January to May were well above average and often near maximum values. In February 1994 the ice coverage was the maximum on record. These data further support 1994 being a heavy ice year on the Labrador and Newfoundland shelves.

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 1993/94 iceberg season (October to September), a total of 1765 icebergs were spotted south of 48°N. The monthly totals for February to August were 79, 529, 208, 377, 387, 161, and 24 (Fig. 15). No icebergs were spotted between October, 1993, and January, 1994, inclusive, or in September, 1994. In the primary iceberg season of March to July, 1662 icebergs were observed which represents 94% of the annual total which is slightly higher than the 1983-1994 average of 89%. The percentage of the total number of icebergs by month for the 1993/94 season shows that proportionally a larger number than normal penetrated south of 48°N in March. The total number of icebergs in 1994 were similar to 1993, although last year more icebergs appeared earlier in the season. A recent analysis by the U.S. Coast Guard (G. Trivers, personal communication) has indicated that earlier concerns of the SLAR estimating a larger number of icebergs than previous methods appears to have been unfounded. Thus we have presented the time series of iceberg counts during March to July beginning in 1945 when aerial reconnaissance was first established (Fig. 15). In the 1990s the number of icebergs has been much higher than normal. Other periods of large number of icebergs reaching south of 48°N occurred in the mid-1980s, and the early 1970s, all periods of cold air temperatures, strong NW winds and extensive ice cover. These same conditions are believed to have contributed to the relatively high number of bergs in 1994.

Gulf of St. Lawrence

During December, 1993, air temperatures were below normal over the Gulf and along the western coast of Newfoundland. This led to rapid ice formation along the north shore of Quebec, in the St. Lawrence Estuary and off eastern New Brunswick. Ice extent was above normal for this time of year (Fig. 16). During the first half of January, air temperatures dropped well below normal and the entire Magdalen Shallows became covered with ice by the middle of the month. In the eastern Gulf along the north shore the ice edge was near its long-term median position. Continuing cold temperatures and strong NW winds caused the entire Gulf to be ice covered by the beginning of February. The ice also moved out onto the Scotian Shelf, reaching as far south

as Halifax along the Atlantic coast of Nova Scotia and beyond the 1962-1987 long-term maximum. The ice edge remained near its maximum extend throughout February and early March. By April 1, ice had begun to retreat with open areas in the western Gulf. Ice still remained in the Cabot Strait region and at the extreme northeastern end of the Scotian Shelf at this time. By the beginning of May only the northeastern Gulf was ice covered. The Strait of Belle Isle contained ice through to late May and early June.

As off Newfoundland and Labrador, ice in the Gulf of St. Lawrence appeared early (by 1-3 weeks; Fig. 11) and left late (also by 1-3 weeks; Fig. 12). A new record was set for the latest date of the last presence of ice on the Magdalen Shallows off Baie des Chaleurs (site G22; Fig. 10). The ice duration (Fig. 13) was longer-than-normal (by over 2 weeks) throughout most of the Gulf. Ice duration records were set on the northern Magdalen Shallows (G22) and equalled off Cape Breton (G33, G87) and in the northeastern Gulf (G10).

OUTLOOK FOR 1995

The air temperatures in January along the Labrador coast were below normal while those over the Gulf of St. Lawrence and the Scotian Shelf were above normal. As a result ice in January in the Gulf of St. Lawrence was lighter and less extensive than normal whereas off Newfoundland it was two weeks ahead of normal. Colder and windy conditions in February resulted in a rapid increase in ice coverage so that by the beginning of March in the Gulf of St. Lawrence and off Newfoundland, the areal extent exceeded the normal but was much less than that of the past several years. Based upon the decadal variability in the NAO index, it might be expected that the atmospheric conditions in Labrador and Newfoundland during winter may moderate over the next few years. This would produce warmer air temperatures, weaker winds and less ice than were experienced in the early years of the 1990s.

SUMMARY

During 1994, wintertime air temperatures over eastern Canada were generally colder-than-normal. This was associated with the high positive value of the NAO index caused by the intensification of the Icelandic Low and Azores High. This resulted in strong NW winds over the region which brought cold Arctic air further south. The cold conditions and stronger NW winds resulted in early ice formation, greater areal extent of ice and a longer presence of ice, both on the Labrador/Newfoundland shelves and in the Gulf of St. Lawrence/Scotian Shelf. The cold temperatures, strong winds and heavy ice all contributed towards a large number of icebergs reaching the Grand Banks. As the year progressed, air temperatures moderated and by summer and through into autumn anomalies rose above normal. The maximum warming occurred in the south and decreased in amplitude towards Baffin Island. This warming appears to be related to strong southwesterly to westerly winds. Although the warming was not sufficient to raise annual air temperatures above normal except along the Atlantic coast of Nova Scotia, it resulted in an increase in the annual anomaly relative to last year by between 1-3°C.

ACKNOWLEDGEMENTS

We wish to thank those who provided data or helped in the preparation of this paper, including; P. Coté of the Ice Centre of Environment Canada in Ottawa for the data on the duration and presence of first and last ice; I. Peterson and S. Prinsenberg for the monthly areal ice extent data for the Newfoundland region; and G. Trivers of the U.S. Coast Guard for the iceberg data.

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Trites, R.W. and K.F. Drinkwater 1986. Overview of environmental conditions in the Northwest Atlantic in 1984. NAFO Sci. Coun. Studies 10: 21-34.

TABLE 1. Historical data on presence and duration of sea ice at 24 sites off eastern Canada and ice duration at these sites in the 1992/93 (October-September) ice year with 1991/92 data in parentheses.

				Ice Duration (in weeks)				
				When ice present				
Site	Seasons Studied	# of Yrs	Yrs of ice	Min	Max	Mean	Overall Mean	93/94 (92/93)
G-7	67/68-93/94	27	27	6	16	10.7	10.7	14 (13)
G-10	76/77-93/94	18	18	3	17	12.1	12.1	15 (17)
G-12	67/68-93/94	27	27	2	15	11.6	11.6	12 (13)
G-22	76/77-93/94	18	18	7	15	12.2	12.2	15 (15)
G-31	68/69-93/94	26	25	8	17	12.6	12.2	13 (15)
G-33	71/72-93/94	23	23	2	14	10.8	10.8	13 (14)
G-35	59/60-93/94	35	19	1	11	3.5	1.9	4 (1)
G-86	76/77-93/94	18	18	6	23	16.6	16.6	20 (19)
G-87	70/71-93/94	24	23	1	12	7.6	7.3	8 (9)
N-19	66/67-93/94	28	28	17	32	23.9	23.9	25 (25)
N-21	67/68-93/94	27	27	5	28	18.6	18.6	23 (25)
N-23	59/60-93/94	35	29	1	17	5.2	4.3	5 (12)
N-25	59/60-93/94	35	2	1	1	1.0	0.1	0 (0)
N-27	59/60-93/94	35	0	0	0	0.0	0.0	0 (0)
N-62	67/68-93/94	27	27	8	27	18.8	18.8	20 (23)
N-64	59/60-93/94	35	34	3	25	13.2	12.8	18 (21)
N-66	59/60-93/94	35	29	1	17	8.7	7.2	16 (17)
N-68	59/60-93/94	35	16	1	10	3.5	1.6	3 (3)
N-70	60/61-93/94	34	0	0	0	0.0	0.0	0 (0)
N-108	59/60-93/94	35	29	1	17	6.2	5.1	6 (15)
N-110	59/60-93/94	35	28	1	16	5.6	4.5	10 (16)

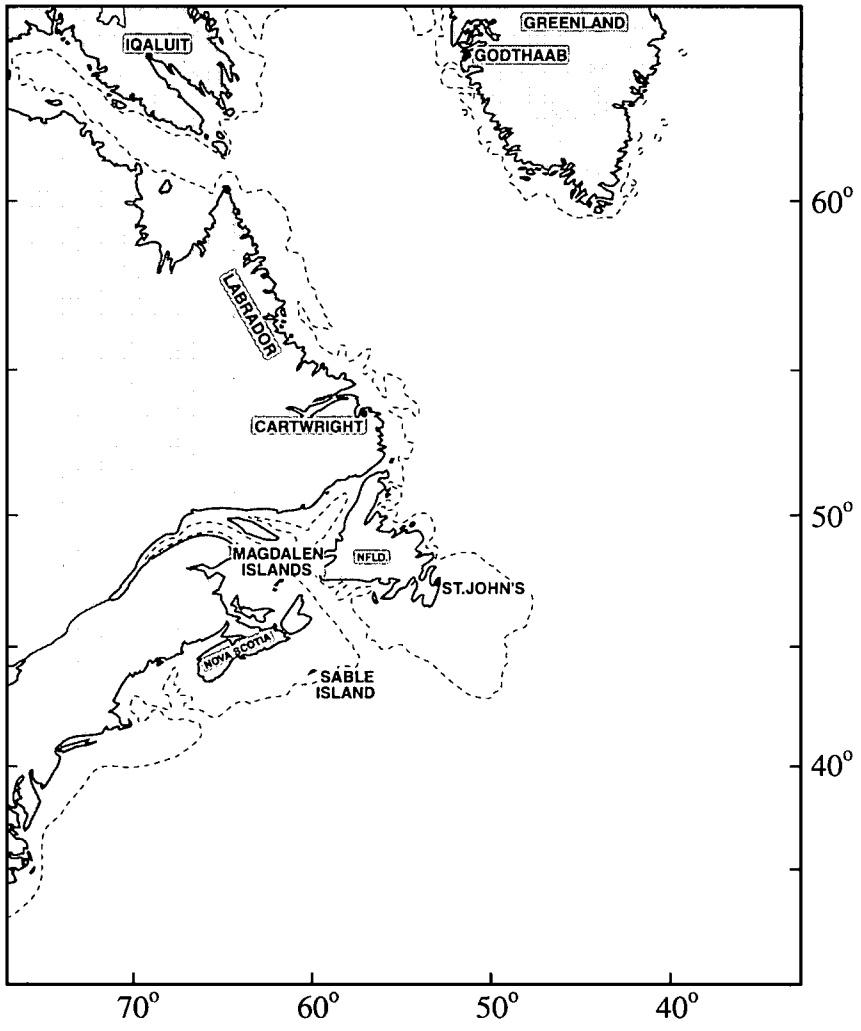

Fig. 1. Eastern Canada, showing coastal air temperature stations.

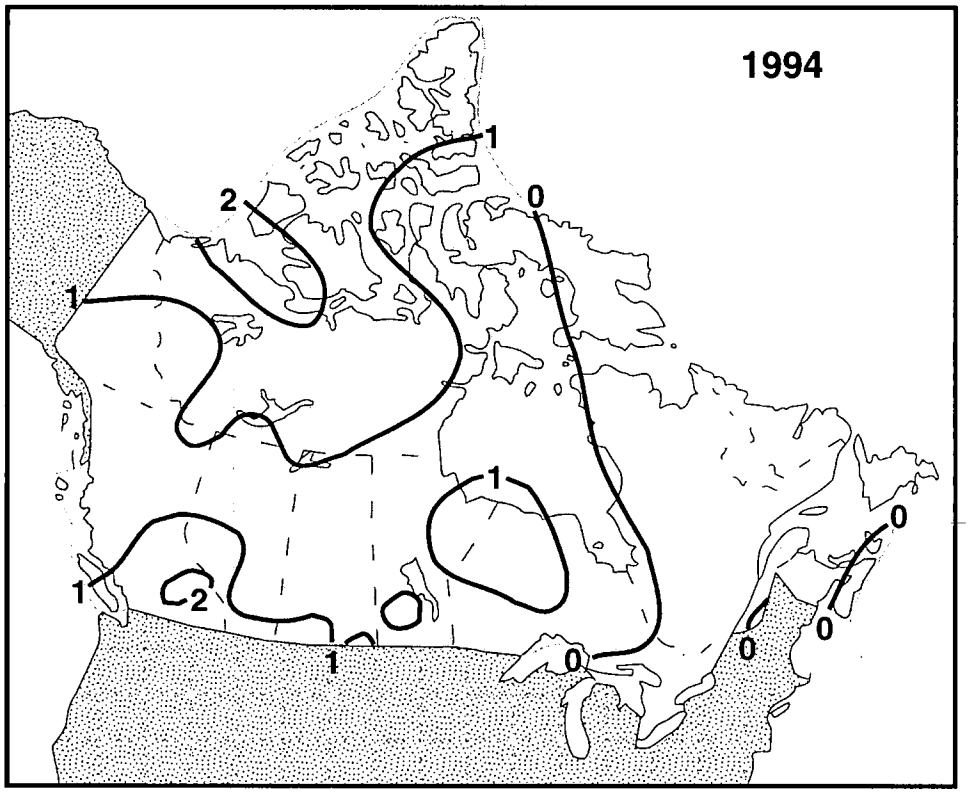

Fig. 2. Annual air temperature anomalies (°C) over Canada in 1994 relative to the 1951-80 means. Shaded areas are positive anomalies. (From Climatic Perspectives, Vol. 16)

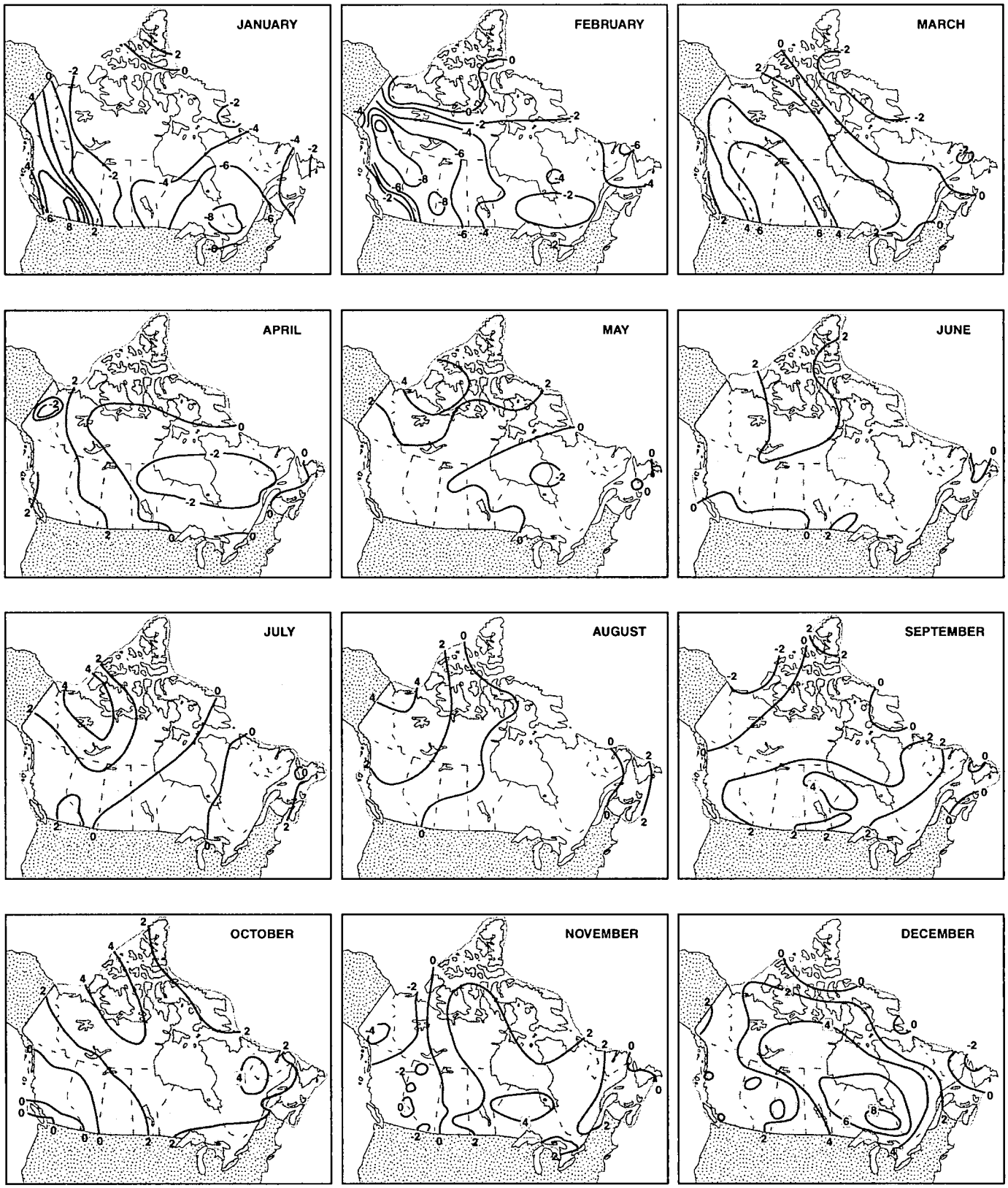

Fig. 3. Monthly air temperature anomalies (°C) over Canada in 1994 relative to the 1951-80 means. Shaded areas are positive anomalies. (From Climatic Perspectives, Vol. 15)

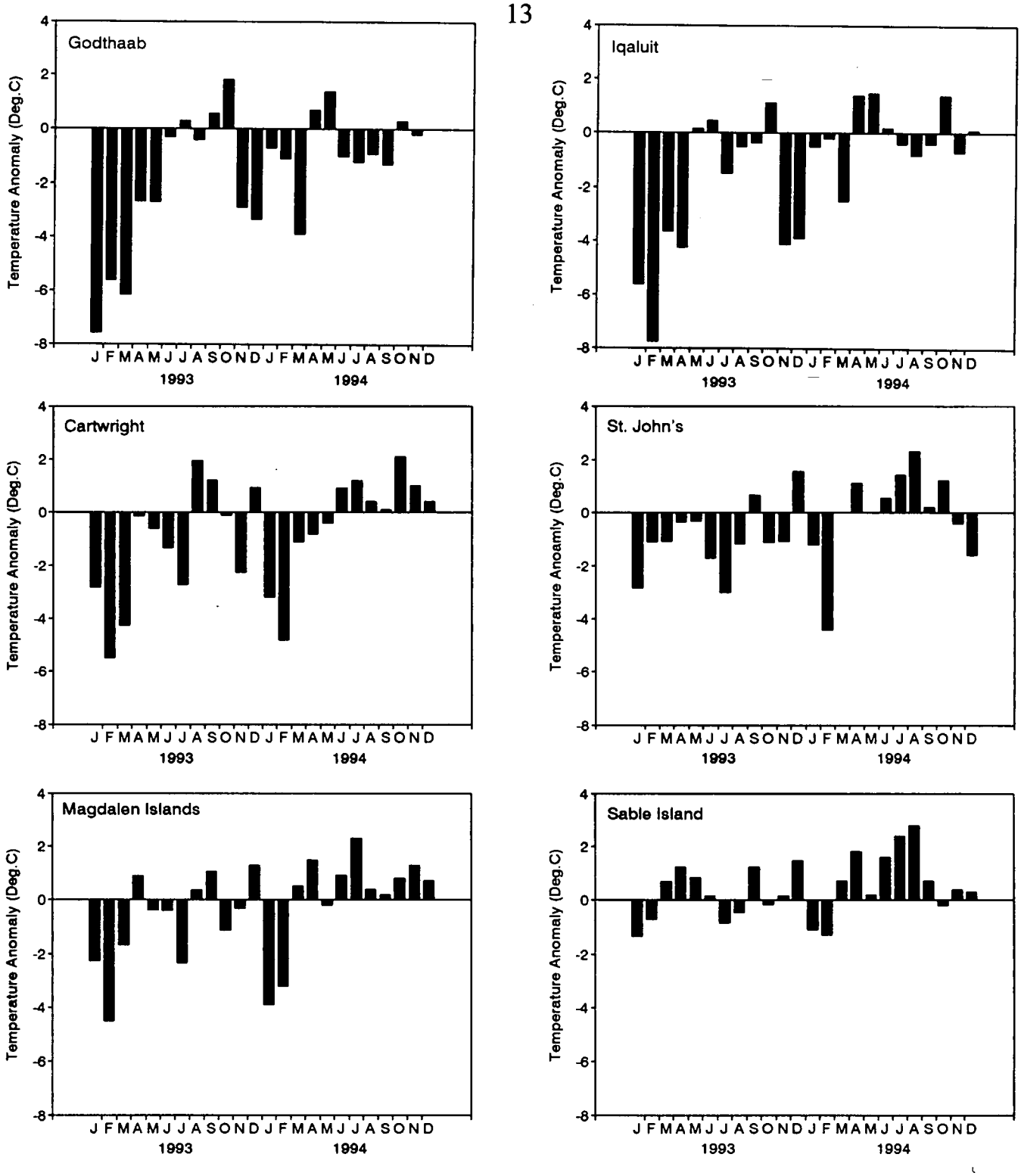

Fig. 4. Monthly air temperature anomalies in 1993 and 1994 at selected coastal sites (see Fig. 1 for locations).

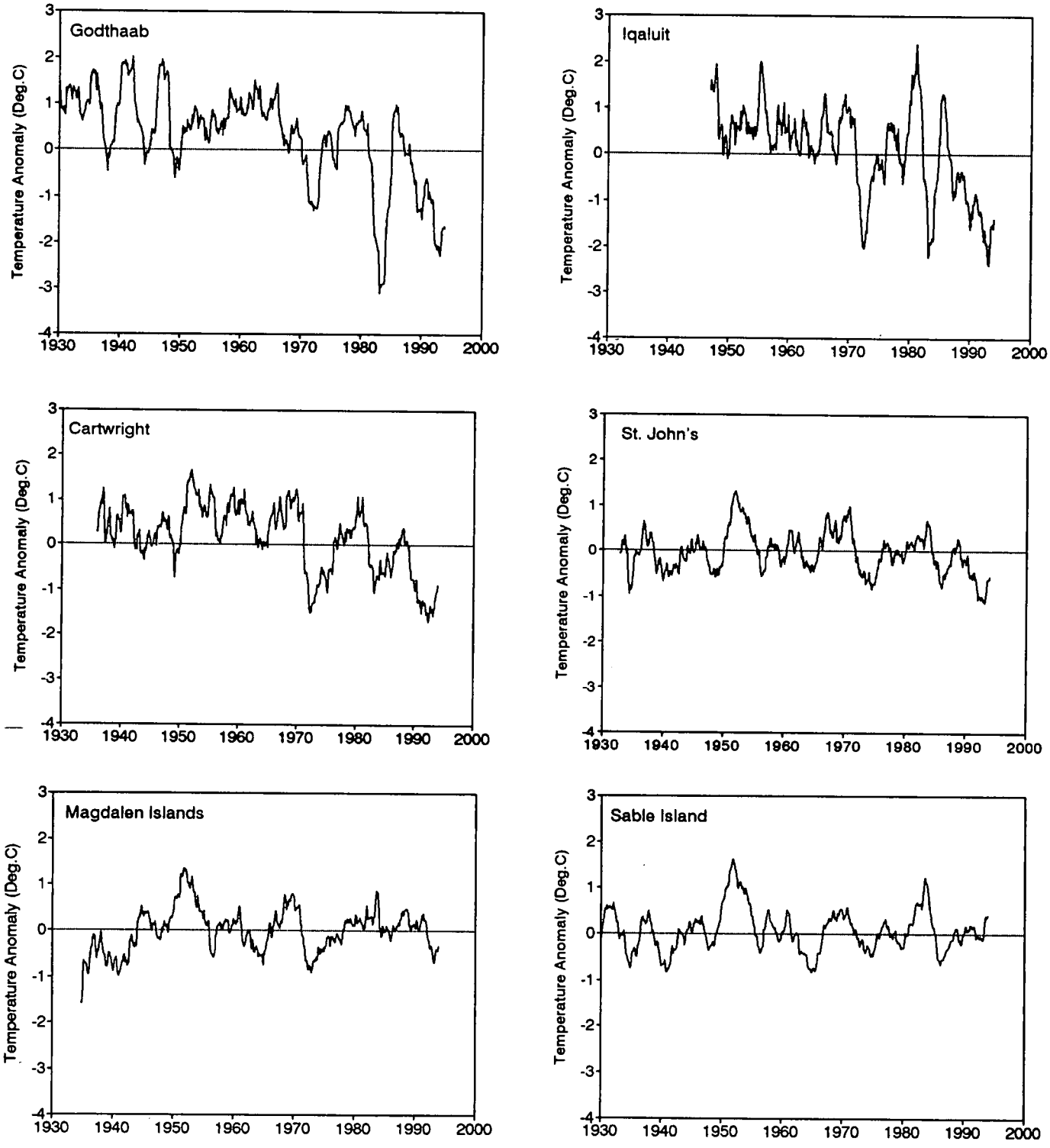

Fig. 5. Twenty-five month running means of monthly air temperature anomalies at selected sites.

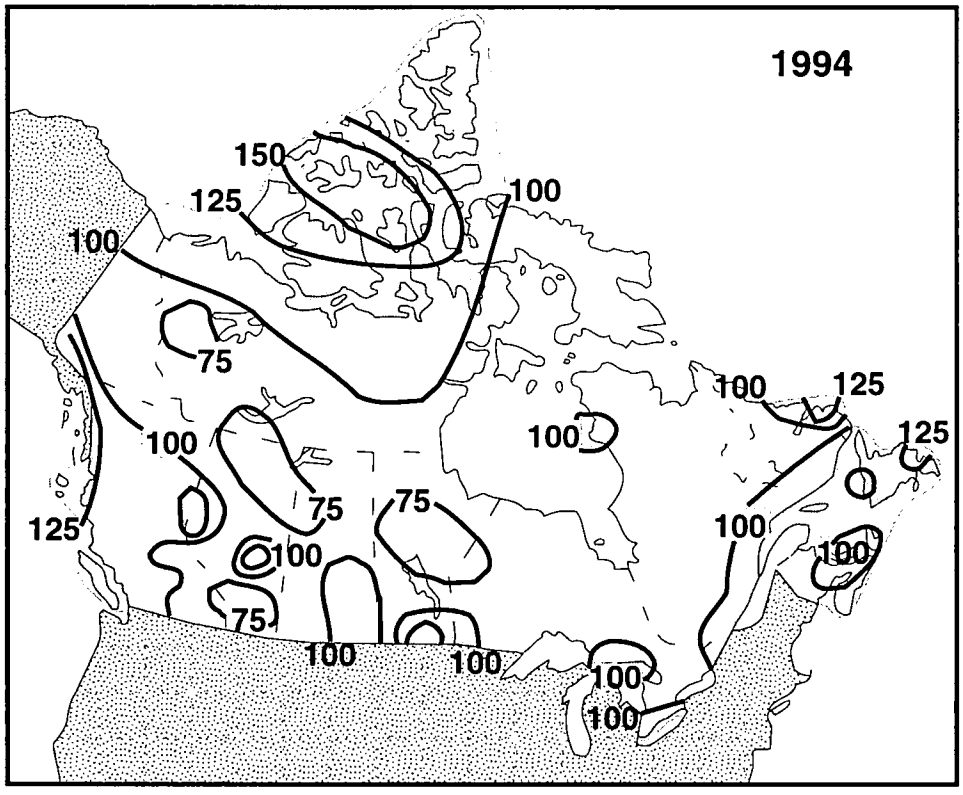

Fig. 6. Annual precipitation anomalies in percentage relative to the 1951-80 means (From Climatic Perspectives, Vol. 16)

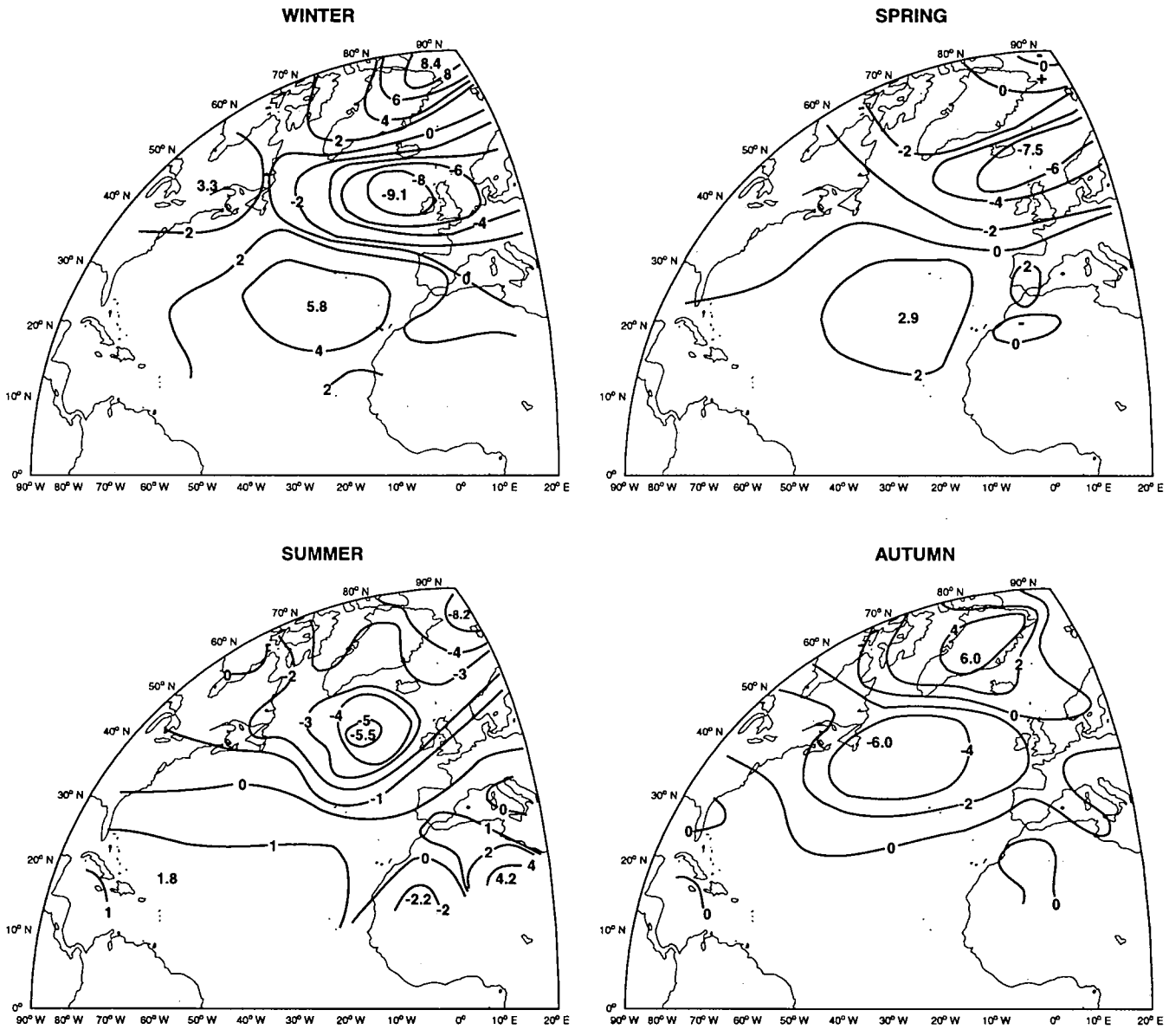

Fig. 7. Seasonal sea-surface air pressure anomalies (mb) over the North Atlantic in 1994 relative to the 1961-90 means.

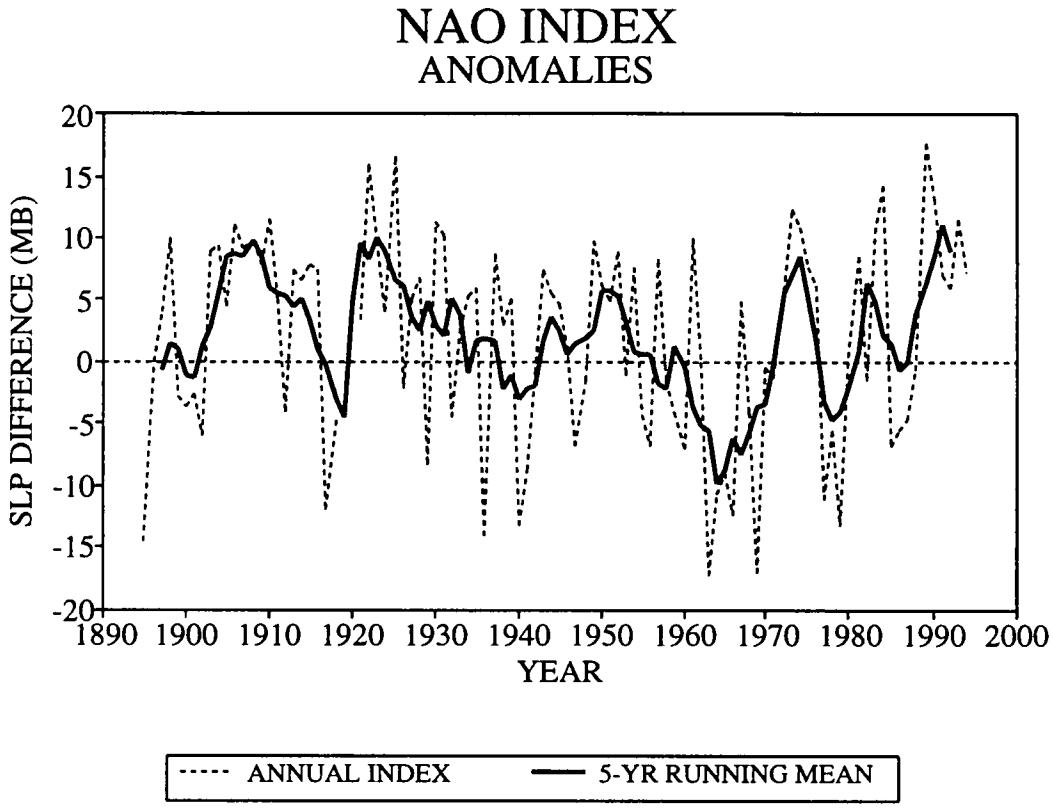

Fig. 8. The North Atlantic Oscillation Index defined as the winter (December, January, February) sea level pressure at Ponta Delgada in the Azores minus Akureyri in Iceland.

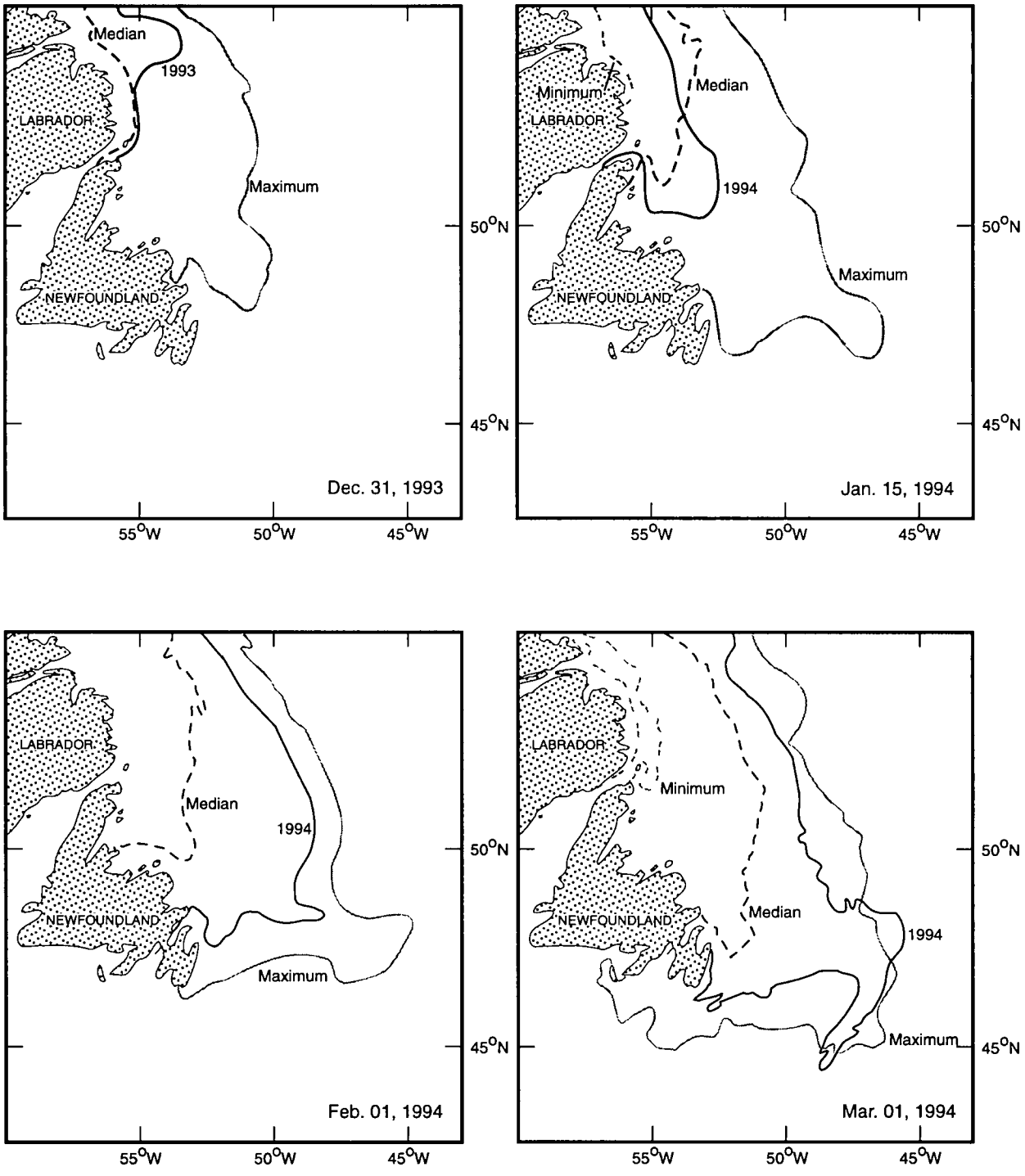

Fig. 9a. The location of the ice edge together with the historical (1962-87) median and maximum positions off Newfoundland and Labrador between December 1993 and March 1994.

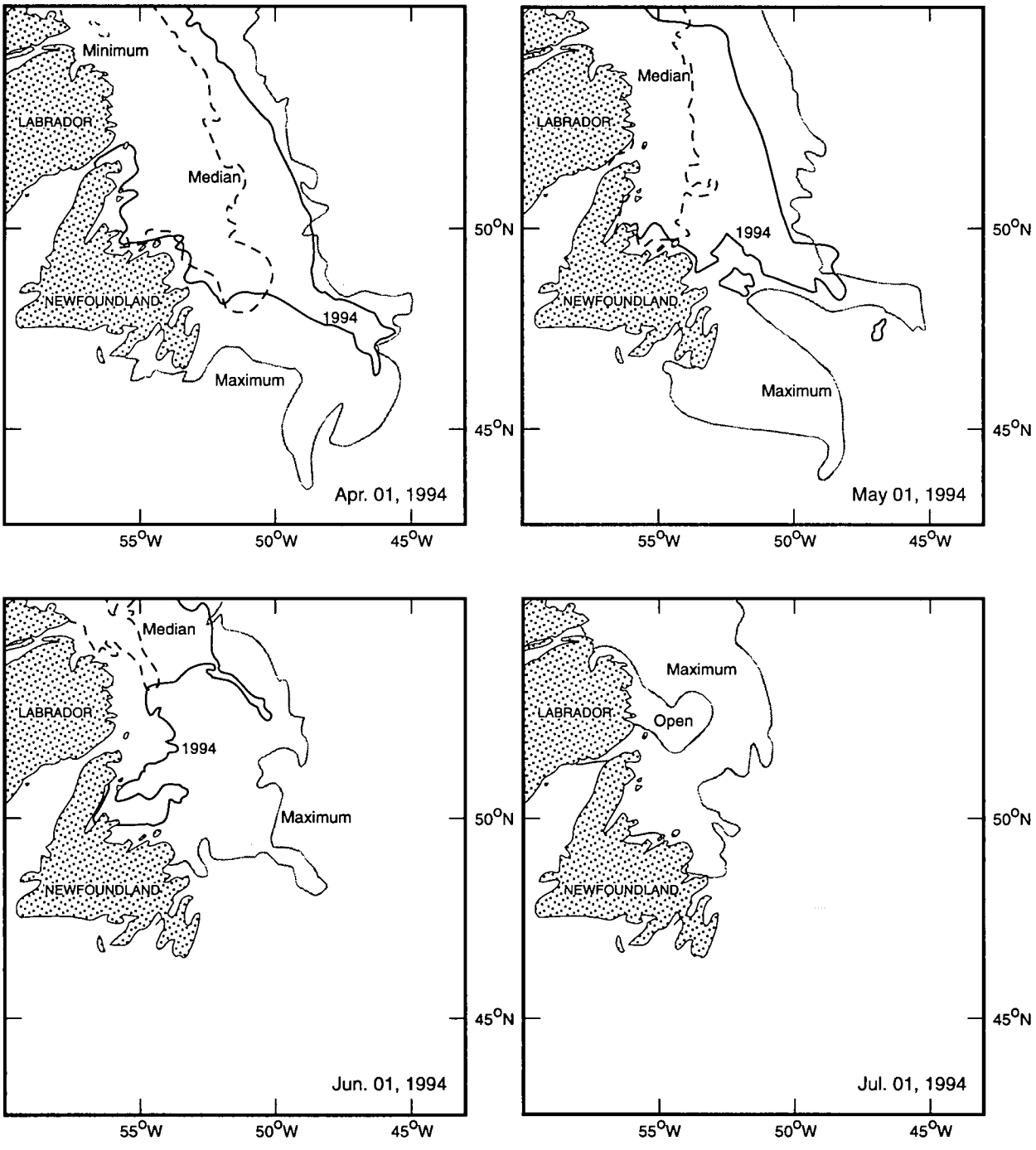

Fig. 9b. The location of the ice edge together with the historical (1962-87) median and maximum positions off Newfoundland and Labrador between April and July 1994.

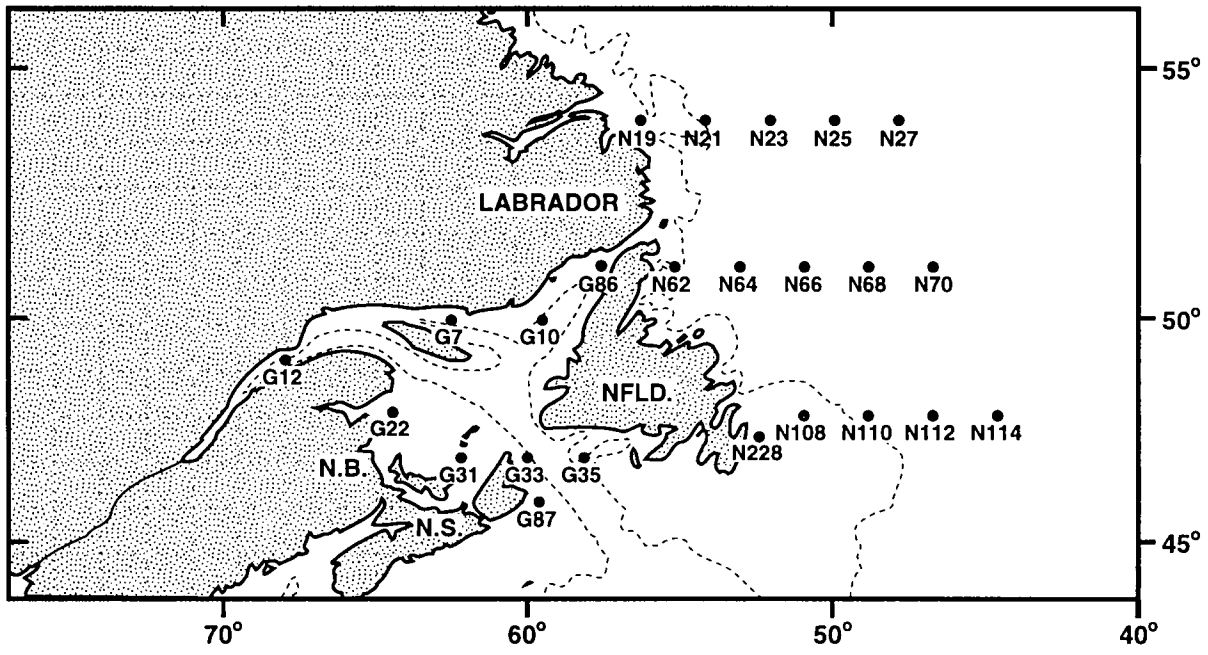

Fig. 10. Location of 24 grid points in the Northwest Atlantic where ice statistics have been extracted from ice charts.

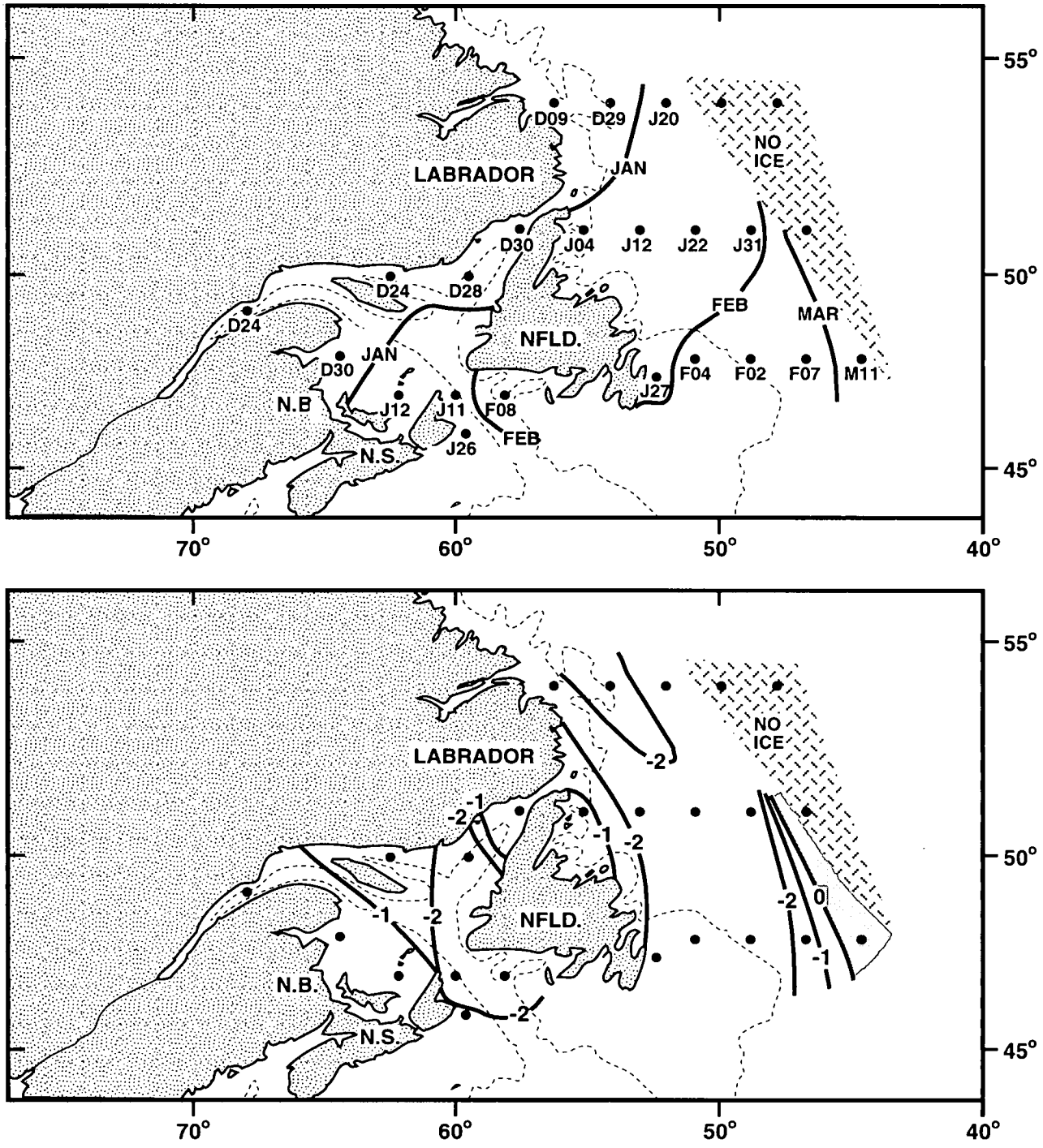

Fig. 11. The date at which first ice appears at the grid points in Fig. 10 (top) and their anomalies from the long term mean in weeks (bottom). A negative anomaly indicates ice appeared earlier than normal.

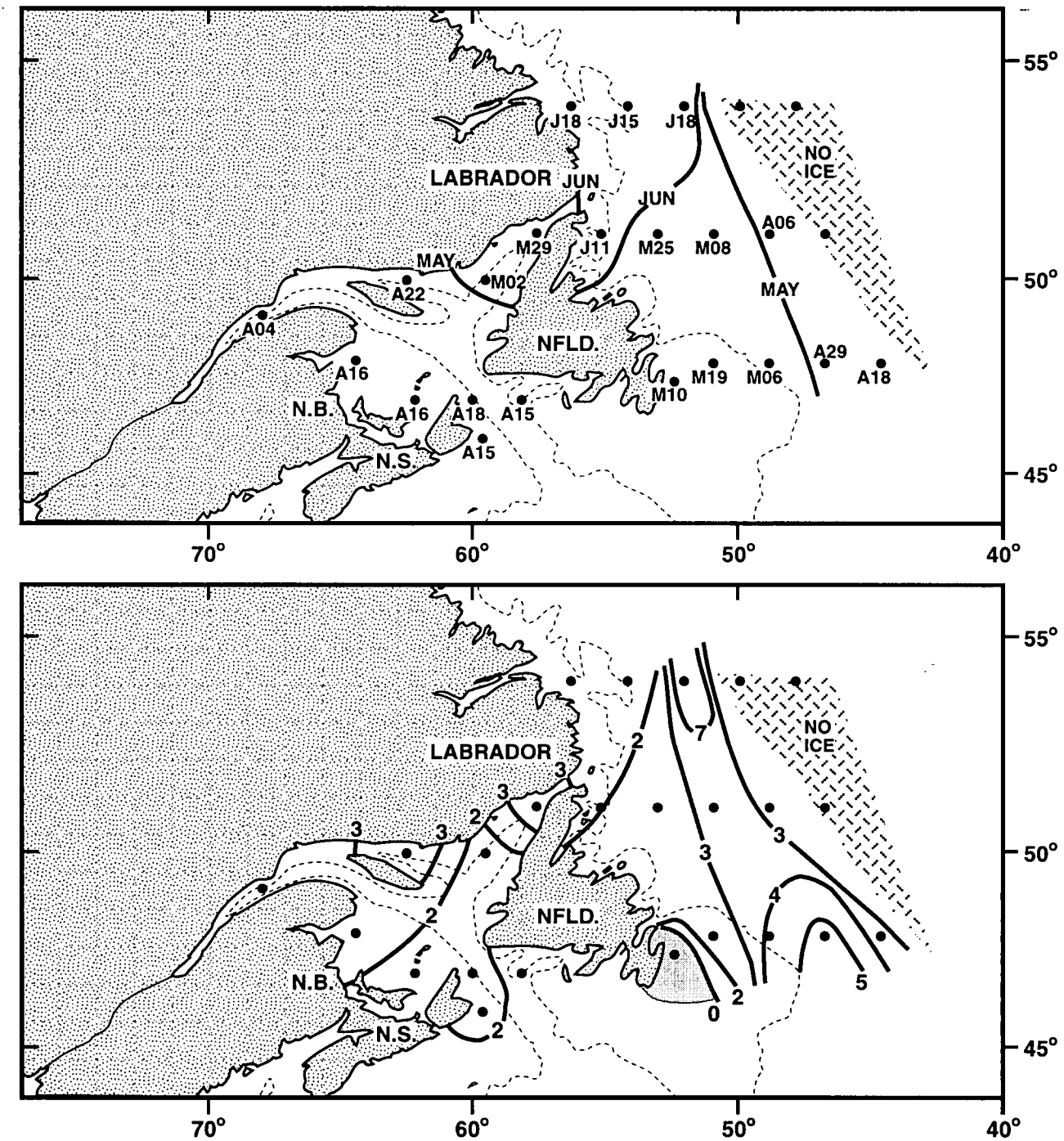

Fig. 12. The date at which last ice appears at the grid points in Fig. 10 (top) and their anomalies from the long term mean in weeks (bottom). A positive anomaly indicates ice lasted longer than normal.

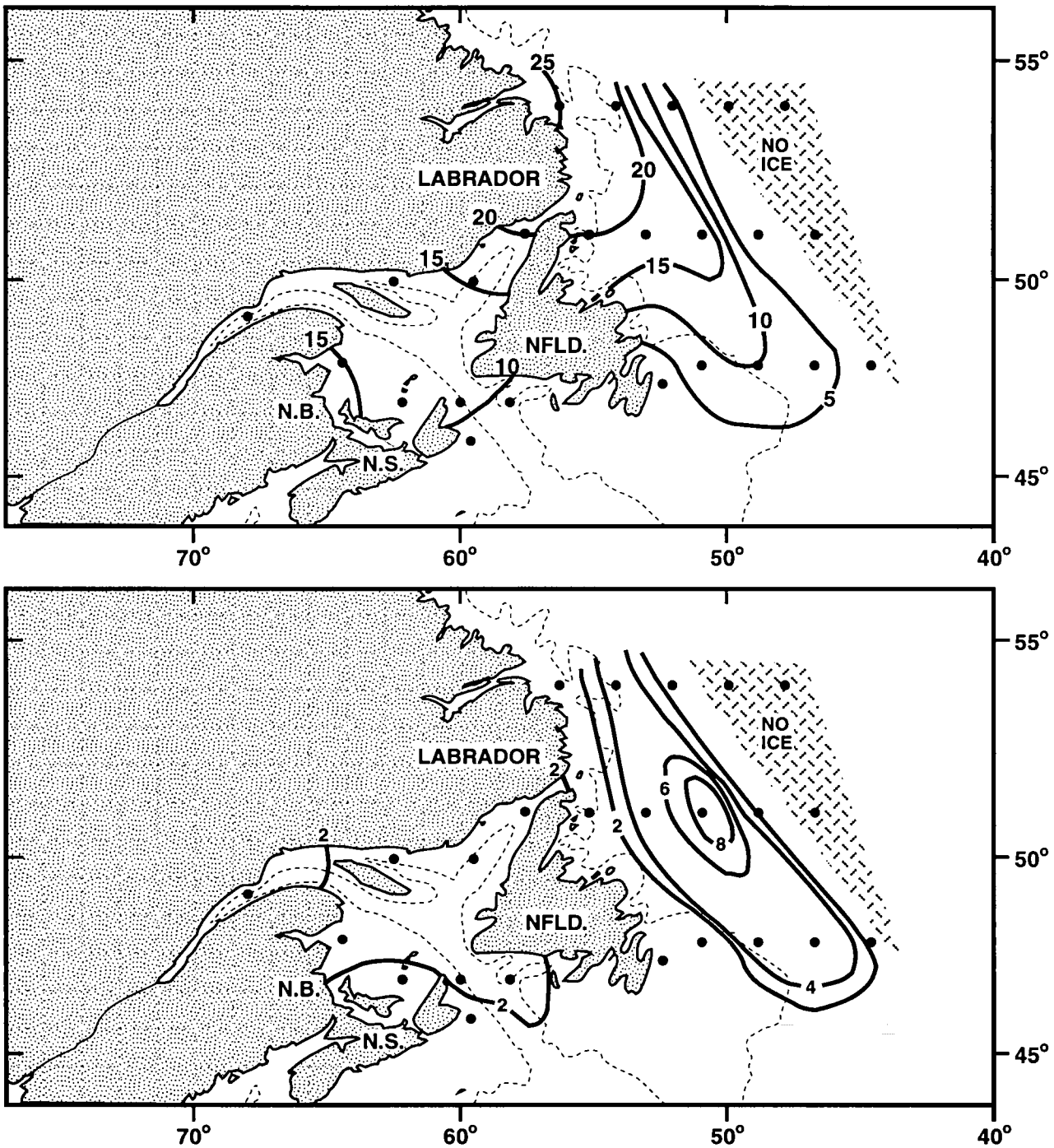

Fig. 13. The duration of ice (top) and its anomaly relative to the long-term mean in weeks (bottom). Positive anomalies indicate a duration longer than the mean.

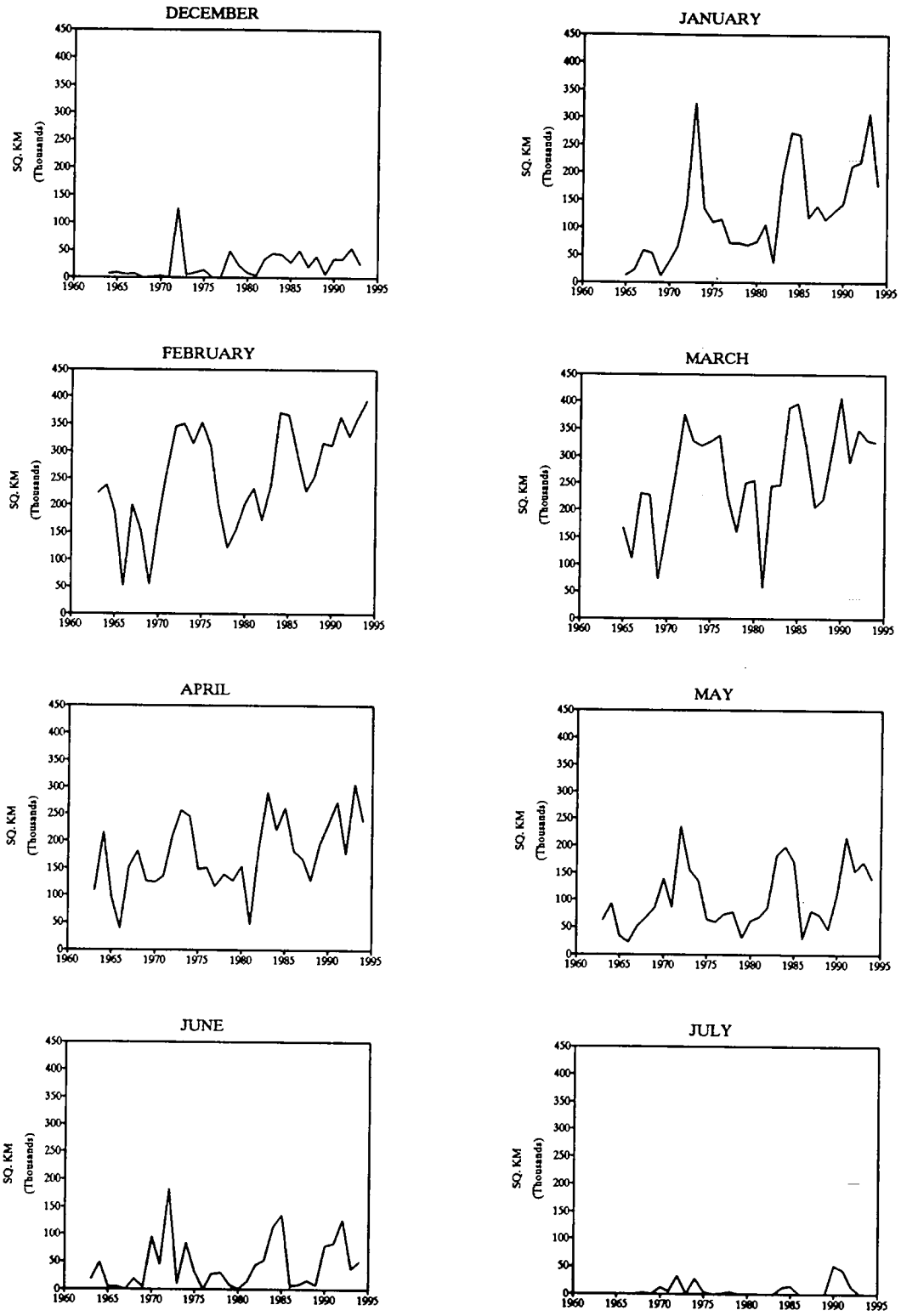

Fig. 14. The time series of ice area on the southern Labrador and northern Newfoundland shelves between 45°N-55°N by month.

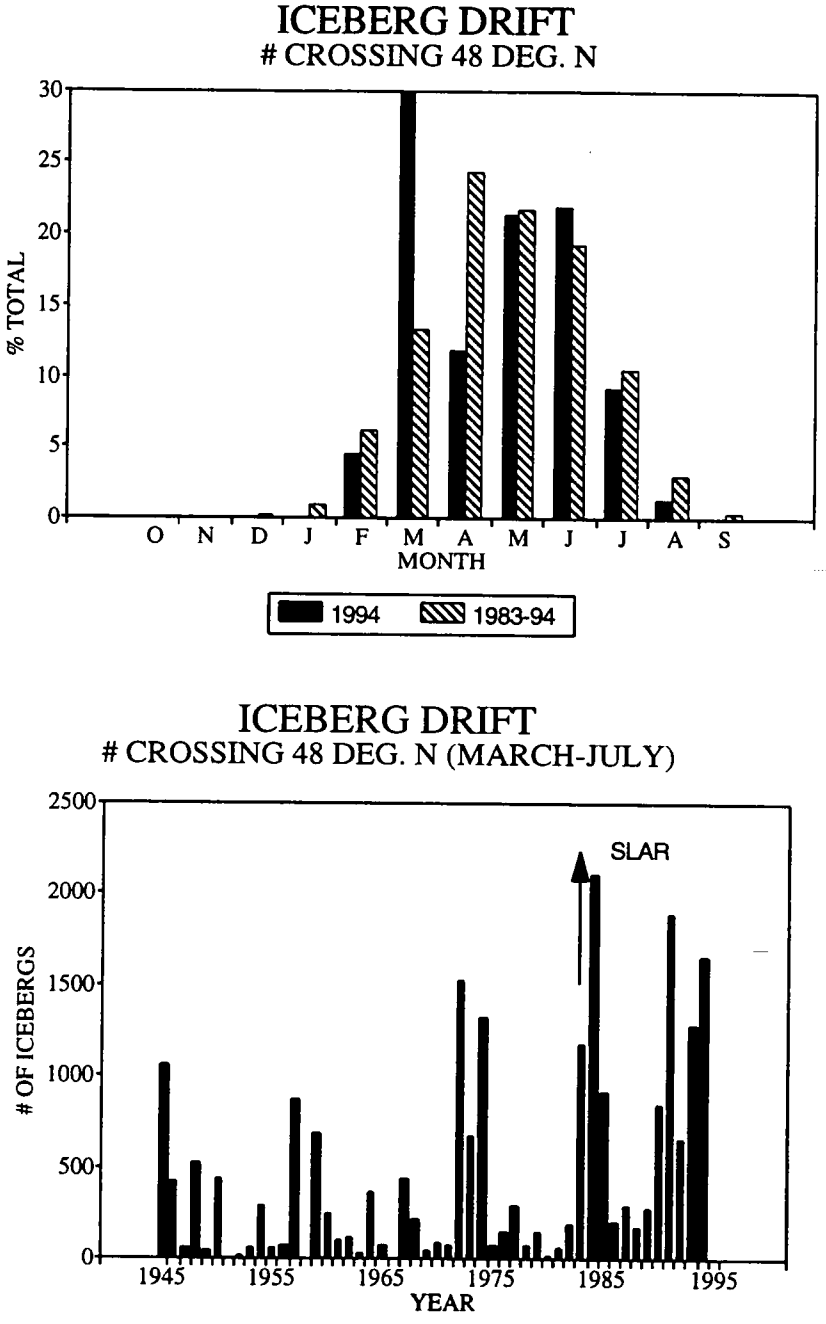

Fig. 15. The percentage of the total number of icebergs crossing south of 48°N by month during the iceberg season 1993/94 (top) and the number of icebergs during March to July from 1945 to 1994. The vertical arrow indicates the year they began to detect icebergs using SLAR.

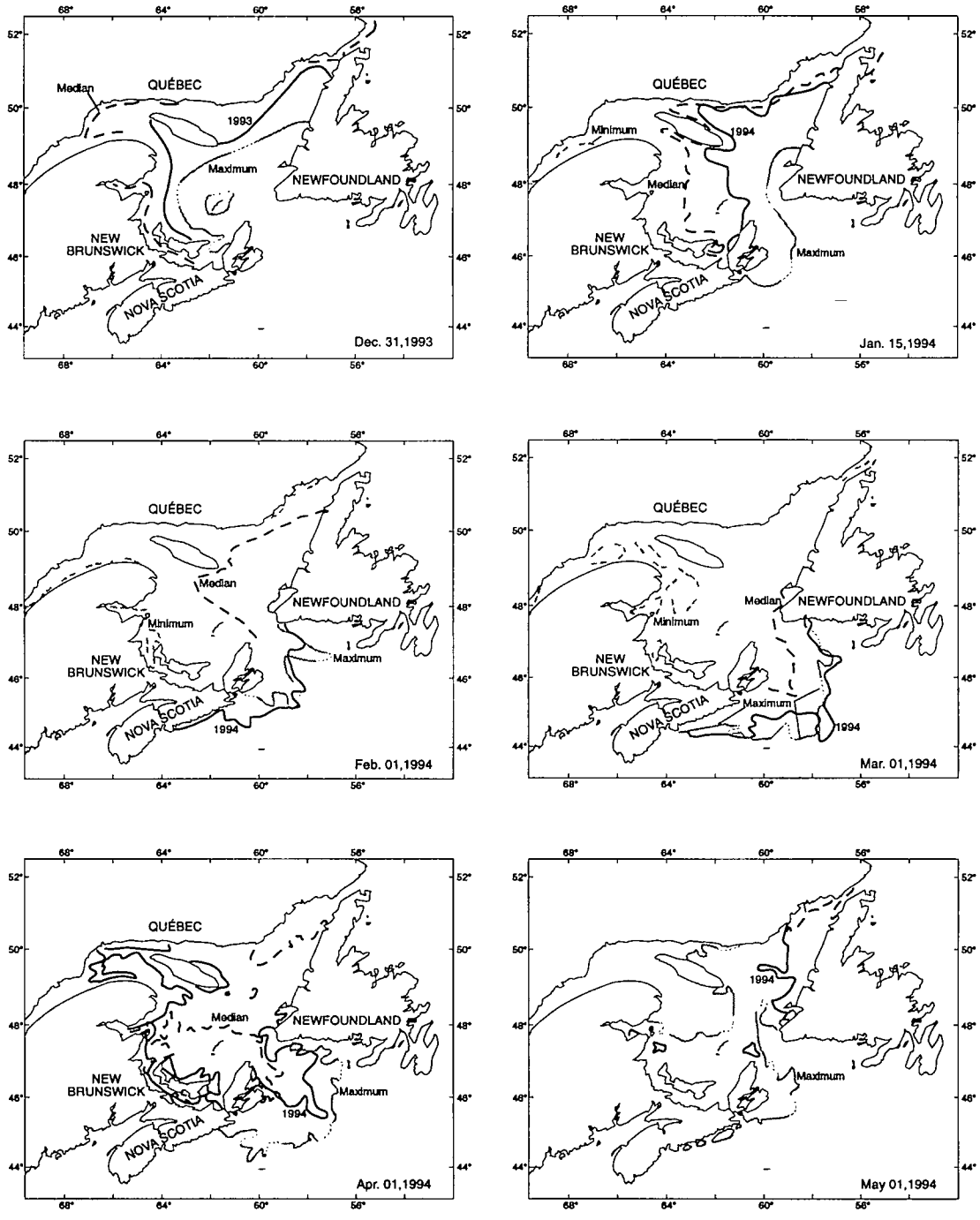

Fig. 16. The location of the ice edge together with the historical (1962-87) median and maximum positions in the Gulf of St. Lawrence between December 1993 and May 1994.