U.S. Department
of Transportation

United States
Coast Guard

Report of the International Ice Patrol in the North Atlantic

1999 Season
Bulletin No.85
CG-188-54

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REPORT OF THE INTERNATIONAL ICE PATROL IN THE NORTH ATLANTIC

Season of 1999

CG-188-54

Forwarded herewith is Bulletin No. 85 of the International Ice Patrol, describing the Patrol's services, ice observations and conditions during the 1999 season. 1999 proved to be an unusual year, with only 22 icebergs finding their way below the 48th parallel north. While not the "lightest" iceberg season on record, the low numbers do earn 1999 a tie with the 1977 season as the ninth-mildest iceberg season in Ice Patrol history. This document chronicles this unusual and fascinating season.

R. L. DESH
Commander, U. S. Coast Guard
Commander, International Ice Patrol

International Ice Patrol
1999 Annual Report

Contents

List of Abbreviations and Acronyms

AXBT	Air-deployed eXpendable BathyThermograph
BAPS	iceBerg Analysis and Prediction System
CAMSLANT	Communications Area Master Station Atlantic
CIIP	Commander, International Ice Patrol
CIS	Canadian Ice Service
DFO	Department of Fisheries and Oceans (Canada)
FLAR	Forward-Looking Airborne RADAR
FNMOC	Fleet Numerical Meteorology and Oceanography Center (USN)
IRD	Ice Reconnaissance Detachment
IGOSS	Integrated Global Ocean Services System
IIP	International Ice Patrol
LAKI	Limit of All Known Ice
MCTS	Marine Communications and Traffic Service (Canada)
NIC	National Ice Center
SOLAS	Safety Of Life At Sea
SST	Sea Surface Temperature
SLAR	Side-Looking Airborne RADAR

Introduction

This is the 85th annual report of the International Ice Patrol (IIP). It contains information on Ice Patrol operations, environmental conditions, and iceberg conditions for the 1999 IIP season. The U. S. Coast Guard conducts the Ice Patrol in the North Atlantic under the provisions of the U. S. Code, Title 46, Sections 738, 738a through 738d, and the International Convention for the Safety of Life at Sea (SOLAS), 1974. The IIP is supported by 17 member nations (Appendix A). It was initiated shortly after the sinking of the RMS TITANIC on April 15, 1912 and has been conducted yearly since that time with the exception of brief periods during the two World Wars.

Commander, International Ice Patrol (CIIP) is under the operational control of Commander, Coast Guard Atlantic Area. CIIP directs the Ice Patrol from its Operations Center in Groton, Connecticut. In addition to its own ice reconnaissance, IIP receives iceberg location reports from ships and planes transiting its patrol area. We salute *M/V Berge Nord* who provided the most ship reports during the 1999 ice year. IIP conducts aerial Iceberg Reconnaissance Detachments (IRD) to survey the southeastern, southern, and southwestern regions of the Grand Banks of Newfoundland for icebergs. Ice Patrol's IRDs were based in St. John's, Newfoundland, Canada during the 1999 season. IIP analyzes ice and environmental data and employs an iceberg drift and deterioration model to produce twice-daily iceberg warnings, which are broadcast to mariners as ice bulletins and radiofacsimile charts. IIP also responds to requests for iceberg information.

The cover is a picture from the ramp of a U. S. Coast Guard Air Station Elizabeth City HC-130H flying over an iceberg near the Grand Banks of Newfoundland while conducting Ice Patrol reconnaissance. Photo by AVT1 Kevin Daniels.

Vice Admiral Kent H. Williams was Commander, U.S. Coast Guard Atlantic Area. CDR Stephen L. Sielbeck was Commander, International Ice Patrol.

For more information concerning the U. S. Coast Guard International Ice Patrol, including daily iceberg bulletins and facsimiles, see IIP's website at http://www.uscg.mil/lantarea/iip/home.html.

Summary of Operations

The 1999 ice year (1 October 1998 to 30 September 1999) marked the 85th anniversary of the International Ice Patrol, which was established on 7 February 1914 with the signing of the SOLAS agreement. IIP's operating area is enclosed by lines along 40°N, 52°N, 39°W and 57°W (Figure 1).

IIP's first aerial Ice Reconnaissance Detachment (IRD) of the year departed on 20 January 1999. IIP flew subsequent reconnaissance flights throughout the traditional ice season, to continue to monitor the iceberg severity. However, iceberg conditions never warranted the opening of a regular season to provide Ice Patrol services. IIP suspended routine reconnaissance for the year with the return of IRD #6 on 4 June.

IIP's Operations Center in Groton, Connecticut analyzed the iceberg observations from the IRDs, ships, Canadian Ice Service (CIS) sea ice/iceberg reconnaissance flights, and other sources. IIP received 185 reports of ice, containing 5831 targets (Figures 2 and 3), of which 3033 were entered into the iceBerg Analysis and Prediction System (BAPS) model.

The major source of reported targets in 1999 came from Canadian government and industry, including targets transferred from the CIS model to IIP's BAPS and aerial reconnaissance conducted by CIS and Provincial Airlines (PAL), a private supplier of ice reconnaissance services. Together, they accounted for 76% of all observed targets.

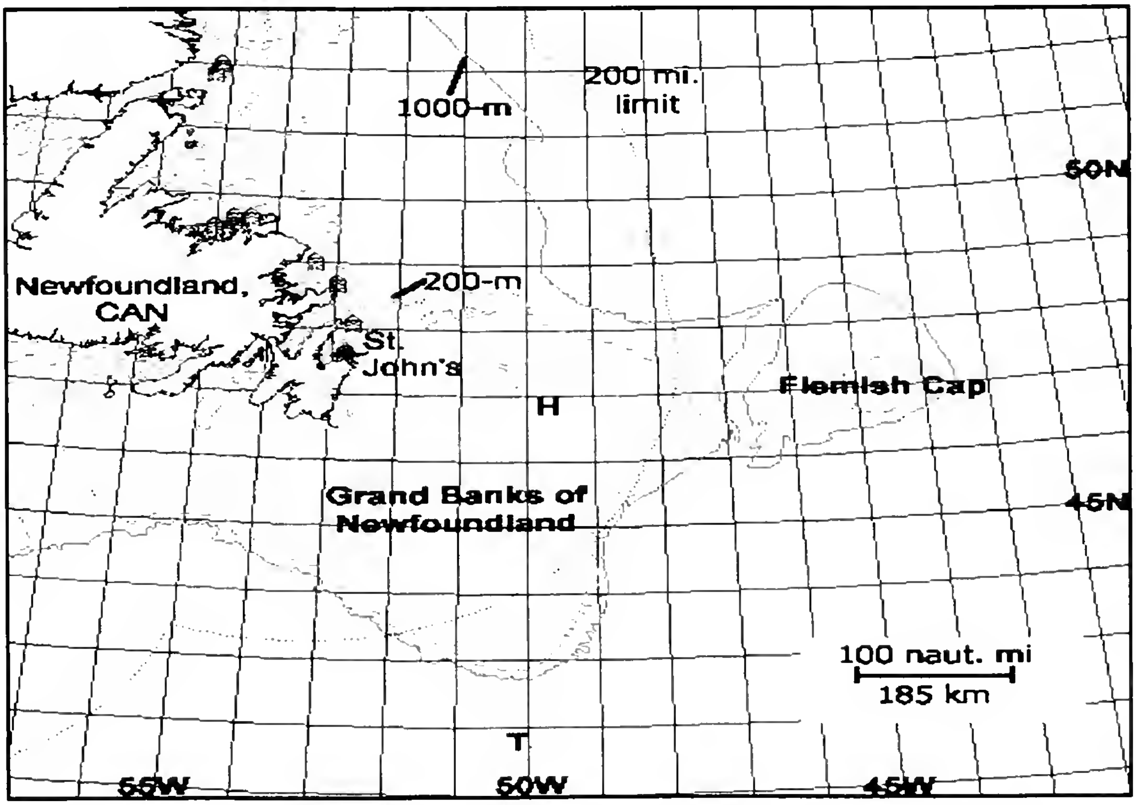

Figure 1. IIP operations area on the Grand Banks. "H" shows the location of the Hibernia Gravity-Based Structure and "T" shows the location of the TITANIC sinking.

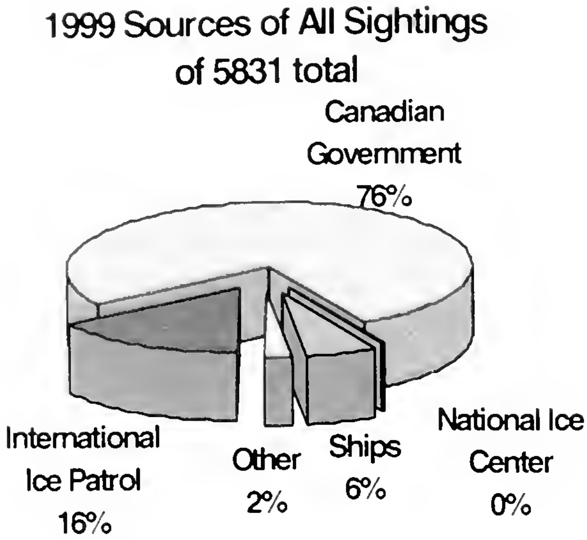

Figure 2. Total number of reports for 1999, including ice, "no ice", and SST reports

Nearly half of the Canadian observations were BAPS transfers, which means the target was originally detected north of the demarcation between IIP and CIS operations areas, 52°N latitude, and then drifted southward with the Labrador Current and entered IIP's area of responsibility. In 1999, this process was automated, so no ice reports were generated during the transfer process. Thus, although the BAPS transfer category accounted for 37% of merged targets in 1999, it did not represent any ice reports submitted to IIP.

Canadian government and industry aerial reconnaissance accounted for the remainder of the Canadian observations. CIS conducts its own ice reconnaissance using a SLAR-equipped Dash-7 airplane, which focuses its attention on sea ice and icebergs in the Canadian economic zone. PAL provides contract reconnaissance services to the Canadian government and the offshore oil industry. They monitor the activities of fishing vessels for Canada's Department of Fisheries and Oceans (DFO) throughout the year, sometimes covering areas with high iceberg concentrations. PAL also conducts contract ice reconnaissance for CIS. Finally, PAL conducts extensive ice reconnaissance in support of the offshore oil industry.

IIP aerial patrols were responsible for 15% of all reports and 16% of the targets detected in 1999. IIP flew 29 sorties, detecting 671 targets that were entered into the BAPS model. The 671 targets accounted for over 22% of the targets entered into Ice Patrol's model. IIP's reconnaissance was conducted using RADAR-equipped HC-130H aircraft based at Coast Guard Air Station Elizabeth City, North Carolina and forward deployed to St. John's, Newfoundland. Because IIP is mandated to determine the limit of all known ice (LAKI), their reconnaissance flights are conducted far offshore in international waters, typically in the vicinity of the 1000 m bathymetric contour (Figure 1). These areas are populated with few icebergs, but those icebergs form the LAKI. Generally, IIP detects about 50% of the limit-setting icebergs during an ice season.

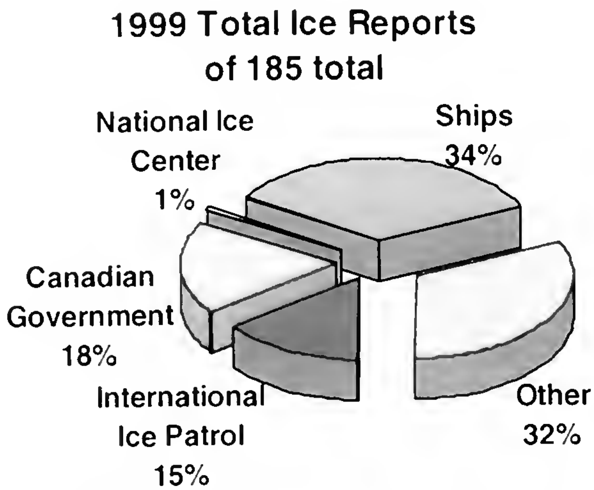

Figure 3. Reporting sources for 1999 ice reports.

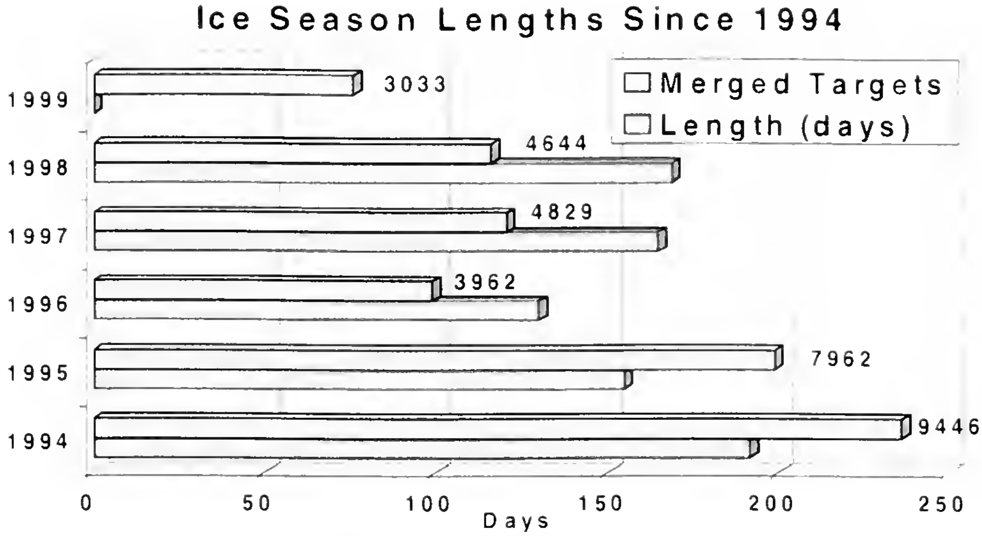

Figure 4. Ice season lengths since 1994

[Since IIP never opened the iceberg season in 1999, there were no formal LAKI broadcasts.] The different areas of operation of the Canadian and IIP aerial reconnaissance provides for excellent complementary coverage of the entire Grand Banks region. This combined system allows for better coverage than either organization could achieve separately.

Table 1. Newfoundland Lighthouse Iceberg Reports

Lighthouse	Number of Reports
Surgeon's Cove	28
Bacalhao	16
Twillingate	14
Bell Island	1
Total	**59**

In 1999, the North Atlantic shipping community continued its traditional high level of support to Ice Patrol's operations. They accounted for 34% of the reports and 6% of the targets received by IIP. The low number of targets provided by shipping is a clear indication of the mild 1999 ice year. Vessels continued to provide many "reports of no ice", which is extremely valuable information to IIP. Ships also provide weather and sea surface temperature observations when operating in IIP's area of responsibility. In all, 23 ships of 18 different nations provided ice information to Ice Patrol. Appendix B lists all the ships that provided iceberg sighting reports, including reports of stationary RADAR targets. Each year, Ice Patrol presents an award to the vessel that provides the greatest number of reports. In 1999, the award went to the *M/V Berge Nord*, which sent 25 reports. The continued high level of participation by the entire shipping community indicates the value they place on IIP's service.

The "Other" category, which provided 2% of the targets detected in 1999, includes reports from less-frequent or irregular ice reporting sources. For example, Ice Patrol receives reports from operators on lighthouses along the Newfoundland coast (Table 1), from commercial transatlantic airliners and from the operators of various exploratory petroleum platforms in the IIP operations area.

Finally, the National Ice Center (NIC), which is a joint U. S. Navy, National Oceanographic and Atmospheric

Administration, and U. S. Coast Guard facility located in Suitland, Maryland, provided less than 1% of the targets and approximately 1% of the reports in 1999. NIC is Ice Patrol's partner and provides ice information it obtains from various sources.

Regardless of the numbers and percentages reported above, the continued success and viability of the Ice Patrol service in the North Atlantic depends heavily on all the contributors of ice reports.

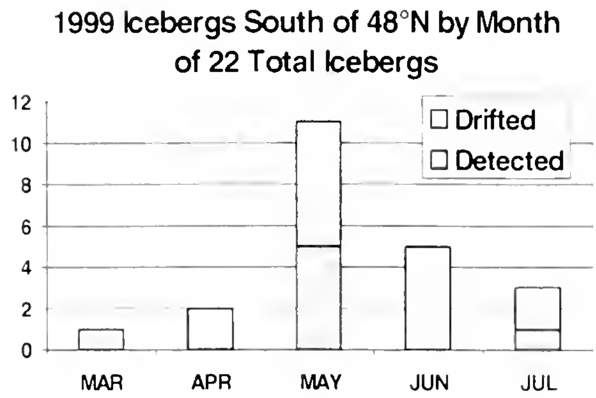

Figure 5. Icebergs South of 48°N for 1999, excluding growlers, bergy bits and radar

To compare with previous year's ice seasons, 1999 was negligible in terms of season length and number of merged targets (Figure 4). In previous years, IIP has used the number of icebergs south of 48°N as a metric for ice season severity (Figures 5 and 6). This metric includes both icebergs detected south of 48°N and those that are predicted to have drifted south of 48°N. The icebergs south of 48°N measurement is generally preferred by IIP because it places the emphasis on icebergs that represent a significant hazard to transatlantic shipping. In addition, IIP may not necessarily merge all reported targets into its database: sightings of targets outside IIP's area of responsibility and coastal icebergs are usually not merged as they represent little threat to transatlantic shipping. Thus, total merged targets is not necessarily an objective and unbiased measurement from year to year.

Admittedly, season length is related to icebergs south of 48°N, as Commanders of the International Ice Patrol consider this measurement in decisions on when to open and close seasons. Various authors have discussed the appropriate metric for ice season severity (Alfultis, 1987; Trivers, 1994; Marko, *et al.*, 1994). Comparing 1999 to the past five years and measuring the statistics against historical standards in various papers, 1999 was remarkable in its tameness, both in terms of its lack of an ice season and in terms of the paltry number of icebergs south of 48°N. A moderate season length is defined as between 105 and 180 days. Extreme for icebergs is defined as greater than 600 icebergs south of 48°N (Trivers, 1994; Marko, *et al.*, 1994).

During an average season, IIP prepares and distributes ice bulletins at 0000Z and 1200Z daily to warn mariners of the southwestern, southern, and southeastern limits of ice. U. S. Coast Guard Communications Area Master

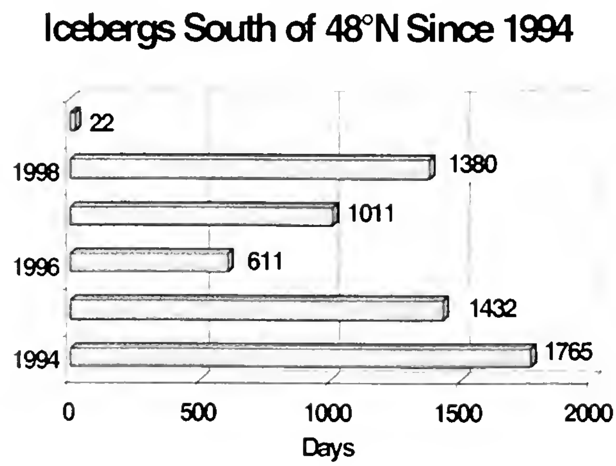

Figure 6. Icebergs South of 48°N since 1994, excluding growlers, bergy bits and radar targets.

Station, Atlantic (CAMSLANT)/NMF in Chesapeake, VA and Canadian Coast Guard Marine Communications and Traffic Service (MCTS) St. John's Newfoundland/VON are the primary radio stations responsible for the dissemination of the ice bulletins. In addition, ice bulletins and safety broadcasts are delivered over the INMARSAT-C SafetyNET via the Atlantic east and west satellites. Other transmitting stations for the bulletins include Canadian Coast Guard MCTS St. Anthony Newfoundland/VCM and Radio Station Bracknell, UK/GFA. IIP also prepares a daily ice chart, depicting the 1200Z limit of all known ice, for broadcast via radiofacsimile at 1600Z and 1810Z daily. CAMSLANT and the National Weather Service (NWS) assist with the transmission of the daily ice chart. The bulletin and chart are also placed on the World Wide Web on IIP's website. In addition, CAMSLANT and MCTS St. John's provide special broadcasts as required.

Table 2. Iceberg and Sea Surface Temperature (SST) Reports

Type/Source	Number or Date
Ships Furnishing Reports	34
Total Reports Received	133
Ships Furnishing Reports with SST	6
Reports Received without SST	83
Commencement of Ice Monitoring	20JAN99
Conclusion of Ice Monitoring	9JUL99
Length of Season	0

Because IIP never offered regular service in 1999, no bulletins or charts were distributed. IIP sent six season status reports advising mariners of the IIP's ice observations near the Grand Banks of Newfoundland.

As part of its season status report broadcasts, International Ice Patrol requested that all ships transiting the area of the Grand Banks report ice observations, weather, and sea surface temperatures to IIP via CAMSLANT, Canadian Coast Guard Radio Station St. John's/VON, or INMARSAT-C or INMARSAT-A using code 42. Ships are encouraged to make reports even if "no ice" is sighted (reports with "no ice" are included in IIP's statistics as ice reports). Knowledge of where ice is not found is very important to IIP. IIP tabulated the number of reports received and the start/end date of the 1999 ice season (Table 2). IIP received information via the following communications and operations centers during the 1999 ice year: Canadian Coast Guard Ice Operations St. John's; Canadian Coast Guard Marine Communications and Traffic Services Halifax/VCS; Canadian Coast Guard Marine Communications and Traffic Services St. John's/VON; Canadian Ice Centre Ottawa; U.S. Coast Guard Atlantic Area Command Center; and U.S. Coast Guard Automated Mutual-assistance VEssel Rescue (AMVER) System/ Operations Systems Center, Martinsburg, WV. Commander, International Ice Patrol extends a sincere thank you to all stations and ships which contributed reports during the 1999 ice year.

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Iceberg Reconnaissance & Oceanographic Operations

Reconnaissance Operations

The U. S. Coast Guard International Ice Patrol formally begins its seasonal ice observation and Ice Patrol service whenever icebergs threaten primary shipping routes between Europe and North America. This usually occurs in the month of February and the threat usually extends through July, but the Ice Patrol is flexible and commences operations when iceberg conditions dictate. The 1992 season, the longest on record, ran from March 7th through September 26th, 203 days. By contrast, 1999 was an extremely light ice season with no icebergs threatening transatlantic shipping. Except during unusually heavy ice years, the Grand Banks of Newfoundland are normally iceberg free from August through January. The activities of the International Ice Patrol are delineated by treaty and U.S. law to encompass only those ice regions of the North Atlantic ocean that affect transatlantic shipping routes. Fixed-wing Coast Guard aircraft conduct the primary reconnaissance work for the Ice Patrol. Ice reconnaissance flights are made on the average of five days every other week during the ice season. The mainstay of the Ice Patrol flights for the past 20 years has been the Hercules HC-130H aircraft.

A USCG HC-130H long-range surveillance aircraft equipped with a Motorola AN/APS-135 Side-Looking Airborne RADAR (SLAR) and a Texas Instruments AN/APS-137 Forward-Looking Airborne RADAR (FLAR) is used to conduct iceberg reconnaissance and monitor the location of iceberg threats to the transatlantic mariner. U. S. Coast Guard aircraft are the

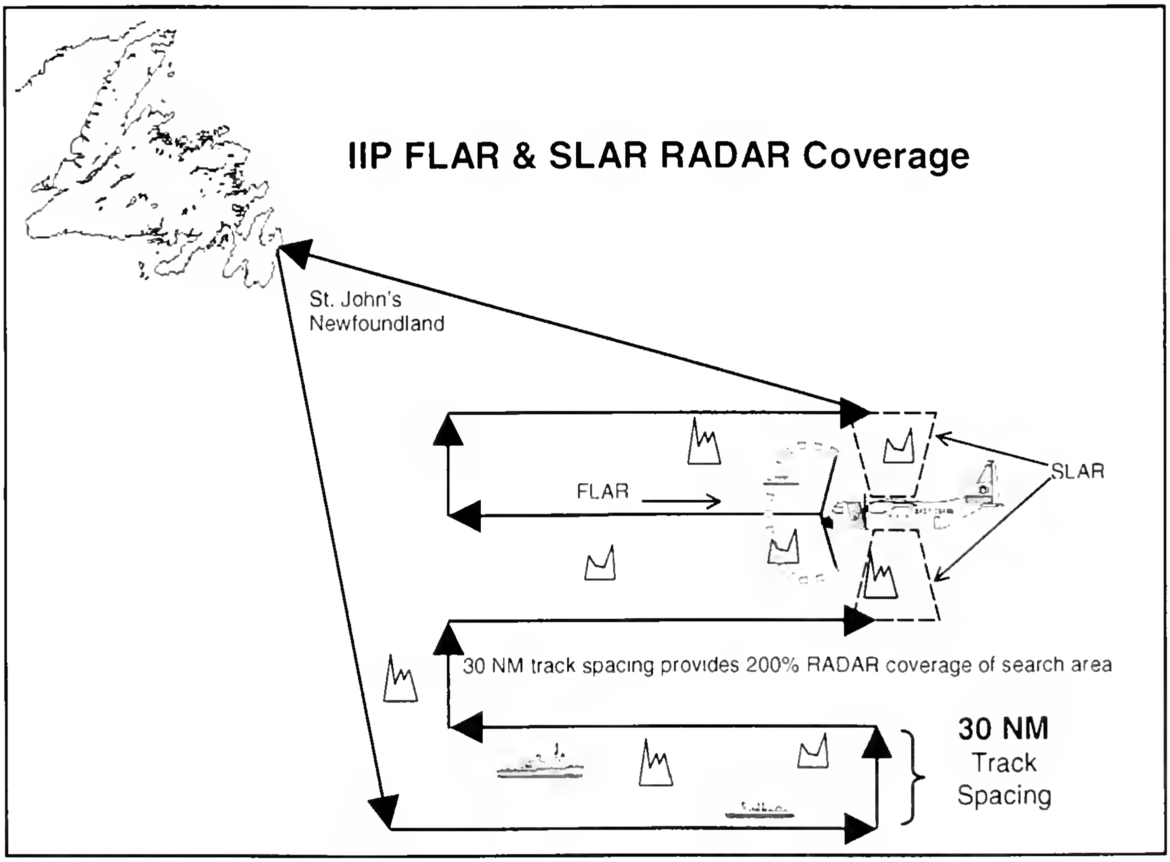

Figure 7. IIP RADAR reconnaissance plan.

primary means of detecting icebergs that form the limit of all known ice (LAKI). When iceberg reconnaissance is not being conducted, IIP relies on computer modeling of the iceberg drift and deterioration to determine iceberg position and size updates. The computer model ingests ice observations, environmental data, and ocean current data to predict iceberg drift and deterioration. The LAKI is based on the model output.

The Ice Reconnaissance Detachment (IRD) is a sub-unit under Commander, International Ice Patrol with Commanding Officer, Coast Guard Air Station Elizabeth City providing the aircraft platform. The IRD is deployed to observe and report the ice and oceanographic conditions in the vicinity of the Grand Banks of Newfoundland. Commander, International Ice Patrol, disseminates this ice information to shipping as per Title 46, USC Section 738a and the Convention on the Safety of Life at Sea. Oceanographic observations are used for operational and research purposes at IIP.

Environmental conditions are favorable for visual reconnaissance in the vicinity of the Grand Banks approximately 20-30% of the time during ice reconnaissance operations in the spring and early summer. Therefore, Ice Patrol relies heavily on its two airborne RADAR systems to detect and identify icebergs through fog and cloudy conditions.

The ability of the FLAR and SLAR RADAR combination on the HC-130H to detect and differentiate icebergs in the pervasive low visibility reconnaissance conditions allows IIP to minimize the number of flight hours required to adequately survey the ice limit. IIP has used the SLAR since 1983 and the FLAR since 1993. This RADAR combination also allows IIP to use a 30 nautical mile track spacing compared to a 10 nautical mile track spacing that was used prior to 1983. The HC-130H with SLAR and FLAR is able to cover a larger geographic area of ocean and still provide 200% RADAR coverage and 30 nm track spacing (Figure 7). The 30 nm track spacing allows IIP to cover approximately 400,000 nm^2 of ocean in good or poor visibility conditions as opposed to approximately 20,000 nm^2 with a 10 nm track spacing in only good visibility conditions. A more detailed description of IIP reconnaissance procedures is provided on Ice Patrol's web page: http://www.uscg.mil/lantarea/iip/home.html.

During 1999, 49 aircraft sorties were flown in support of IIP. Of these, 16 were transit flights to St. John's, Newfoundland, IIP's base of operations. There were 29 ice observation or patrol sorties conducted to locate the southwestern, southern and southeastern limits of icebergs. Four logistics flights were required to support and maintain the patrol aircraft operational status. Figure 8 shows IIP flight-hour usage for 1999. Ice Patrol typically schedules aerial reconnaissance every other week, however the lack of iceberg threat resulted in several scheduled deployments being cancelled.

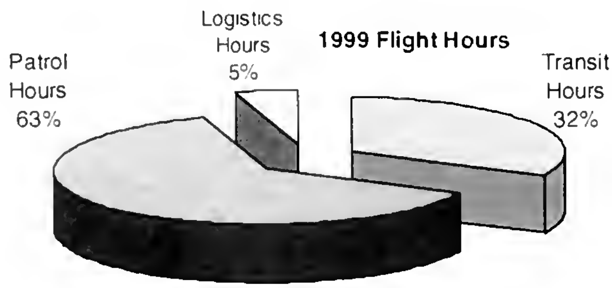

Figure 8. 1999 flight hour usage.

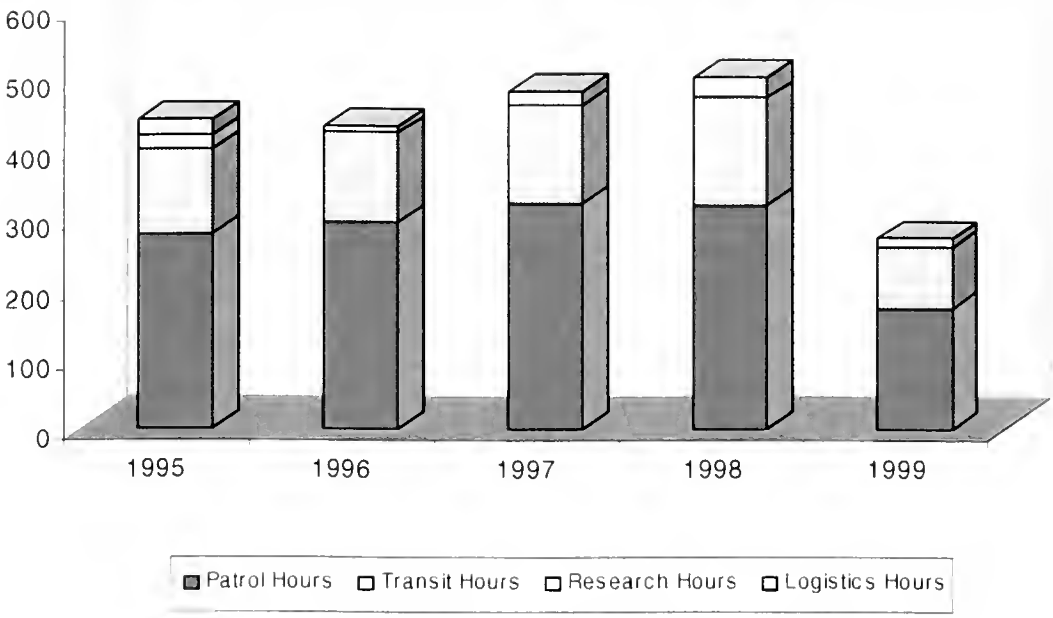

Figure 9. 1995 to 1999 flight hour use summary

Ice Patrol used 272 hours of HC-130H time in 1999, a 46% reduction from the 502 hours used in 1998 (Figure 9). The reason for this dramatic reduction was the early suspension of aerial reconnaissance due to the minimal iceberg threat in 1999. Mild iceberg seasons do not always lead to such impressive savings in aircraft usage. Figure 10 compares flight hours with the number of icebergs south of 48°N latitude since 1984. This graphic shows that, although the threat to the transatlantic mariner may vary, Ice Patrol must still expend a fairly consistent number of flight hours to ensure that the Grand Banks region of the North Atlantic ocean is safe for navigation. In some years, a few icebergs may greatly extend the LAKI even though there may not be a large number of icebergs passing south of 48°N. Therefore, Ice Patrol is often in the position of having to patrol a large area of ocean with widely spaced iceberg targets.

Distinguishing among the many types of targets that frequent the Grand Banks region is a continuing challenge for Ice Patrol's airborne reconnaissance. The visibility is notoriously bad, and frequently the identity of a target must be determined based solely on its RADAR image. Both the SLAR and the FLAR provide valuable clues about the identity of the targets; however, in most cases, the FLAR's superior imaging capability provides the definitive information.

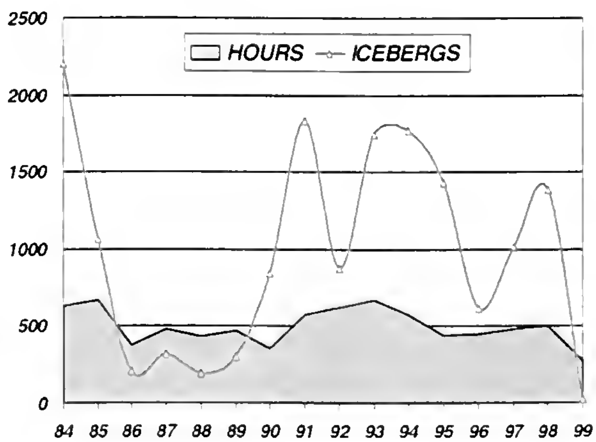

Figure 10. 1984 to 1999 comparison of the number of icebergs south of 48°N to IIP's total flight hours.

Figure 11 shows the numbers and types of targets detected during 1999 IIP reconnaissance patrols according to three general categories: icebergs, vessels and RADAR targets. When flying reconnaissance in low visibility conditions it is often difficult to determine whether a target is an iceberg or a vessel. The Grand Banks region is a major fishing area, frequented by fishing vessels ranging in size from 60 ft to over 200 ft. Occasionally, Ice Patrol will detect and confirm other types of targets such as

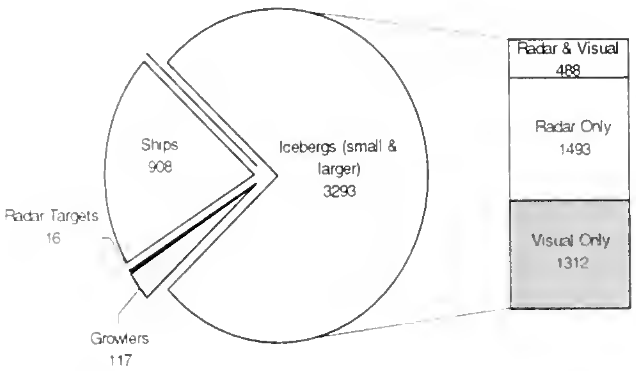

Figure 11. Breakdown of 1999 IIP reconnaissance targets

marine life, fishing markers, etc. Since 1997, the Grand Banks region has rapidly been developed for its oil reserves. In November 1997, Hibernia, the gravity-based oil production platform was set in position approximately 150 nm offshore on the northeastern portion of the Grand Banks. Each year, there have been several mobile drilling rigs in the nearby White Rose and Terra Nova oil fields. This increased development on the Grand Banks has increased air and surface traffic in IIP's search area, further complicating Ice Patrol's reconnaissance efforts. As previously mentioned, the addition of FLAR in 1993 provided IIP with a reliable method of discriminating targets without actually visually confirming the target. This method works well for larger targets but is very difficult with small vessels and small icebergs. Both present similar RADAR returns and, sometimes, cannot be differentiated. In the cases in which there are no clear distinguishing features, the target is simply classified as a RADAR target. Of the 3293 icebergs detected, 45% were detected and identified with RADAR only. This further emphasizes the need for FLAR and the continuing need to pursue technological innovations in reconnaissance equipment.

Oceanographic Operations

During the 86-year history of IIP, extensive oceanographic surveys were conducted in the Grand Banks and Greenland regions. Oceanographic operations peaked in the 1960's when the U. S. Coast Guard devoted substantial vessel assets solely for collecting oceanographic data. Two factors combined to change the nature of IIP's oceanographic operations. First, increased competition among the various Coast Guard missions for already scarce ship resources made it increasingly difficult for IIP to obtain ship-time. Second, there has been a vast improvement in the capability and reliability of oceanographic instruments that can be deployed from aircraft and volunteer ships. The instruments telemeter data to aircraft or satellites, and ultimately to Ice Patrol's operations center for analysis. Oceanographic data are collected using air-deployed satellite-tracked drift buoys and Air-deployed eXpendable BathyThermograph (AXBT) probes.

During 1999, Ice Patrol deployed 16 satellite-tracked drift buoys, nine from its reconnaissance airplane, and seven from volunteer ships. For drifter information, request IIP's 1999 Buoy Atlas. In addition, Ice Patrol drifter data are archived and available from the National Oceanographic Data Center.

IIP also drops AXBT probes to determine the water temperature profile down to approximately 300 meters. This information is coded into the standard JJYY format and sent to METOC Halifax Canada, the U. S. Navy's Fleet Numerical Oceanographic and Meteorological Center (FNMOC) and the Naval Oceanographic Center. At FNMOC, the data are processed, quality controlled and redistributed via FNMOC's oceanographic model products. For more information on FNMOC, see their web site at http://www.fnmoc.navy.mil/. Figure 12 shows how IIP's AXBT program has developed since 1994. The failures in 1998 were from flaws in IIP's AXBT receiver system. In 1999, IIP awarded a contract to replace the AXBT receiver with a rugged, reliable system to reduce AXBT failures.

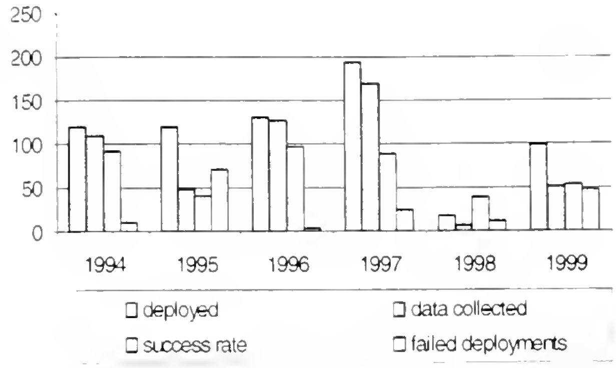

Figure 12. IIP AXBT statistics for 1994 through 1999.

Ice and Environmental Conditions

Introduction

The 1999 ice year will be recorded as one of the mildest in International Ice Patrol's history. In fact, it was so mild that Ice Patrol never formally opened the iceberg season and issued no formal iceberg warnings. What made the year even more remarkable was that repeated reconnaissance flights by IIP and the Canadian Ice Service and numerous reports from shipping documented a very large population north of 48°N. The icebergs south of 52°N were confined to the bight of Newfoundland (the area between Funk Island and Cape Bauld) and in the northern arm of the Gulf of St. Lawrence (Figure 13). Very few icebergs escaped this region, and ultimately they deteriorated in place.

For record keeping purposes, the IIP ice year extends from October through September. The following month-by-month narrative of the progress of the 1999 ice season begins as sea ice began forming along the Labrador coast in December 1998 and concludes in July 1999 as the last vestiges of the sea ice departed the Labrador coast. The narrative draws from several sources, including the Seasonal Summary for Eastern Canadian Waters, Winter 1998-1999 (Canadian Ice Service, 1999); sea ice analyses provided by the Canadian Ice Service and the National Ice Center; and the Integrated Global Ocean Services System Products (IGOSS) sea surface temperature anomaly (Climate Data Library, International Research Institute for climate prediction at Lamont-Doherty Earth Observatory of Columbia University); and, finally, summaries of the iceberg data collected by Ice Patrol and CIS.

Comparing the 1998-1999 sea ice and iceberg observations to the historical record emphasizes the departures from normal. For sea ice, Cote (1989) provides maximum, median, and minimum extent of

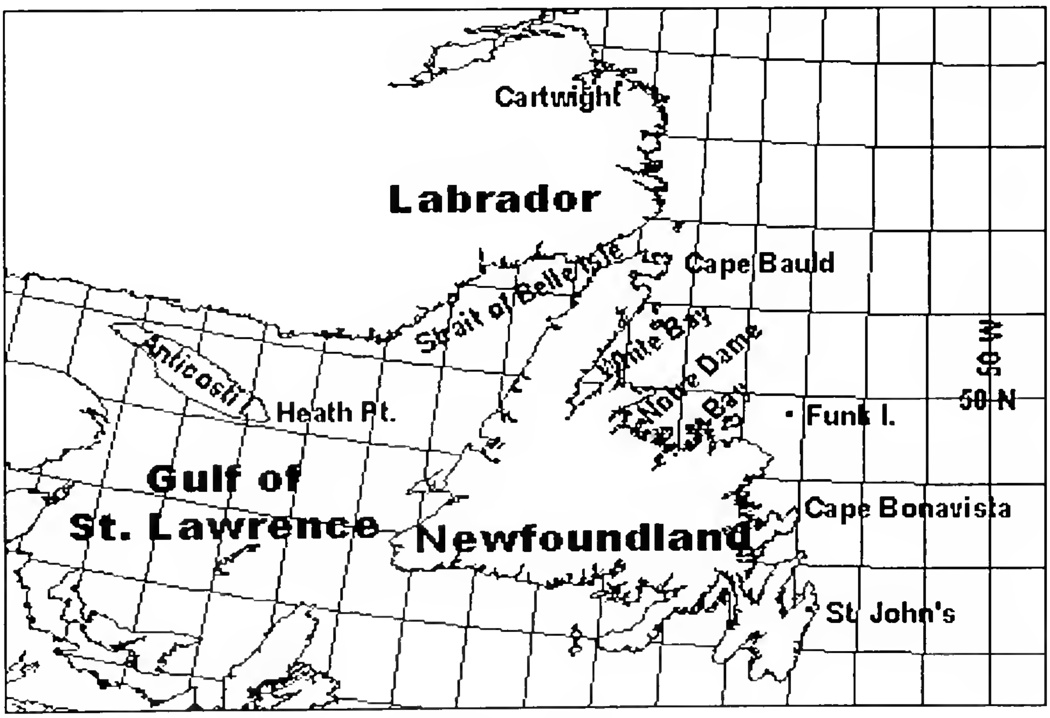

Figure 13. Area map.

sea ice cover along the eastern Canadian seaboard at weekly intervals from mid-November through the end of July. The maps are based on a 25-year record beginning in 1962. Viekman and Baumer (1995) present an iceberg limit climatology from mid-March to 30 July based on 21 years of Ice Patrol observations from 1975 through 1995. They provide the extreme, median, and minimum extent of the limit of all known ice (LAKI) for the period. Finally, the average number of icebergs estimated to have drifted south of 48°N for each month was calculated using 100 years (1900 through 1999) of IIP records.

December 1998 through February 1999

Along the Labrador Coast and in east Newfoundland waters, the winter started out normally. In December and January, northwest and north winds dominated both areas; air temperatures, though variable along the Labrador Coast, were near normal elsewhere. In December, the SSTs were 2°C to 3°C colder than normal near Newfoundland and Labrador, but by February the ocean's surface had warmed to within a degree of normal. The extent of sea ice was normal in both areas for December and January.

By February, there were early indications of great changes to come. While northwesterly winds continued to dominate the Labrador Coast, east Newfoundland waters experienced southwesterlies in the beginning of the month and northeasterlies during the latter half of the month. In both areas, air temperatures were 2°C to 5°C warmer than normal for the entire month. Ice conditions in February were normal along the Labrador Coast and, although sea ice was seven to ten days late in developing in east Newfoundland waters, by month's end ice thickness and extent were normal. A late January IIP pre-season reconnaissance flight along the sea ice edge off the Labrador coast observed 26 icebergs near the ice edge between 52°N and 59°N. Adverse weather conditions prevented a survey of the iceberg population within the sea ice off the southern Labrador coast.

March

In March it became clear that 1999 would be an unusual ice year, maybe even an historic one. Both Labrador and east Newfoundland were dominated by moderate southwest winds and 4°C to 6°C warmer than normal air temperatures. In both areas, the thickness and areal extent of sea ice were much less than normal. Early in the month the sea ice reached its farthest southward extent of the year, barely reaching the area of Cape Bonavista, with an easterly extent that was much less than normal. Late in the month the sea ice started a rapid retreat, and at month's end it was restricted to the bight of Newfoundland. The SST on the northeast Newfoundland continental shelf remained within a degree of normal, but south of 45°N the ocean surface was 1°C to 2°C warmer than normal.

The first ice reconnaissance detachment deployed to St. John's from 4 to 11 March; four patrols documented a sparse iceberg population south of 52°N. By the end of March, however, there were reports of large numbers of icebergs in the sea ice east of the Strait of Belle Isle and along the southern Labrador coast. There were very few icebergs outside the sea ice, and those few were not far from the ice edge. During the month, one iceberg was estimated to have drifted south of 48°N. In an average season, 58 icebergs pass south of 48°N during March.

April

Both Labrador and east Newfoundland waters experienced strong northeast and north-northeast winds and above-normal air temperatures in April. The thickness and areal extent of the sea ice were less than normal in both areas. The SST on the northeast Newfoundland shelf was near normal but, as in March, the ocean surface south of 45°N was 1°C to 2°C warmer than normal (Figure 14). Throughout the month, the sea ice continued its rapid retreat, and by month's end was limited to the inner portions of White Bay and Notre Dame Bay and along the coast of the northern part of Newfoundland's northern peninsula. The overall areal extent of sea ice in southern Labrador and east Newfoundland waters was less than normal.

In the beginning of the month there were numerous icebergs within the sea ice along the southern Labrador coast and east of the Strait of Belle Isle. By mid-month some of these icebergs had entered the Gulf of St. Lawrence via the Strait of Belle Isle due, in part, to the vigorous and persistent northeast winds that dominated the entire area. Many others moved southward along the northern peninsula of Newfoundland, still mostly within the sea ice. By month's end, aerial reconnaissance observed large numbers of icebergs within and near the sea ice edge along Newfoundland's northeast coast between Funk Island and Cape Bauld. Also, there were numerous icebergs in the Strait of Belle Isle and in the northeast arm of the Gulf of St. Lawrence, as far east as Heath Point, the eastern-most point of Anticosti Island. Despite the large number of icebergs moving southward along the

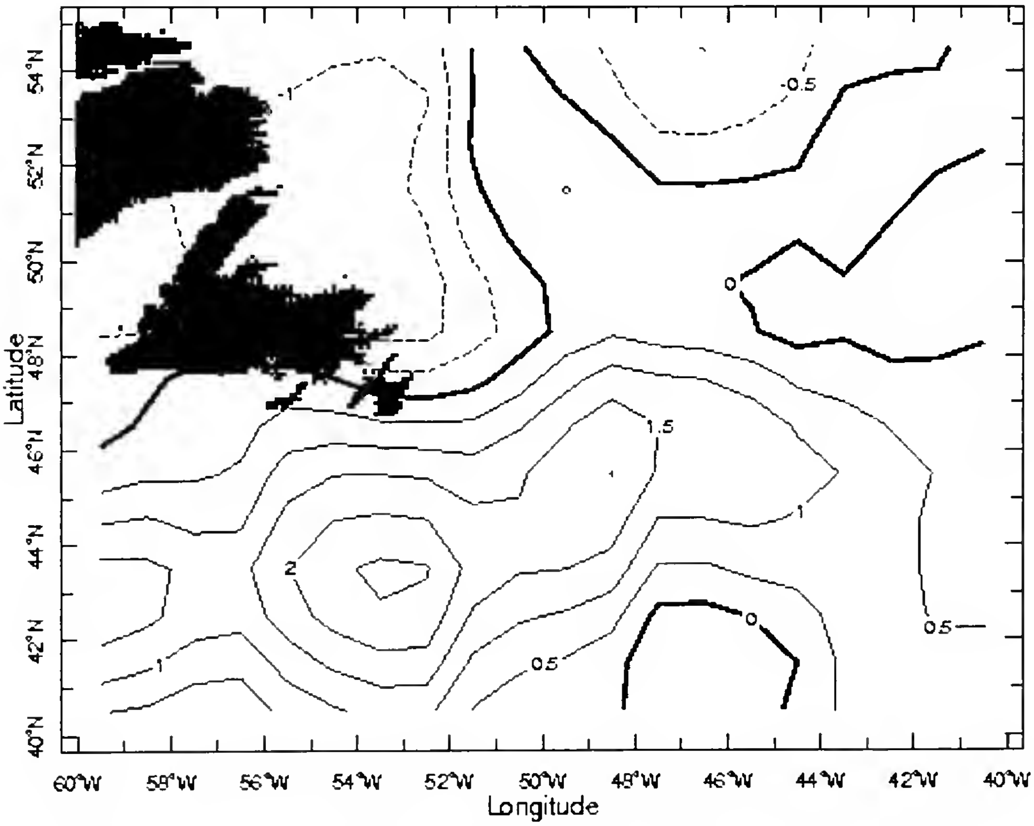

Figure 14. Monthly mean IGOSS sea surface temperature (SST) anomaly for April 1999. SSTs are in °C and are blended from ship, buoy, and bias-corrected satellite data.

Labrador coast and into east Newfoundland waters, only two icebergs were estimated to have moved south of 48°N during April. In an average April, 119 icebergs pass south of 48°N.

May

In May, both Labrador and east Newfoundland waters experienced moderate northwesterlies during the first half of the month and light and variable winds in the second half. In both areas, the air temperature was 4°C to 5°C warmer than normal in the first half of the month. In east Newfoundland waters and along the southern Labrador coast, the air temperature was about 3°C warmer than normal in the latter half of the month. In both areas, the ice thickness was less than normal for the month. In early May (Figure 15) the sea ice retreat continued, and by mid-month the areal extent of the sea ice in southern Labrador and east Newfoundland waters increased somewhat due to the ongoing break up of the sea ice upstream. However, south of Cartwright, the concentration was 2/10 or less in most areas. On May 25, the Strait of Belle Isle was declared open for ship traffic, and by the end of May, sea ice had nearly disappeared from southern Labrador and east Newfoundland waters. What remained was isolated in bays along the Northern Peninsula and southern Labrador coast.

In the 100 years (1900 through 1999) of IIP's database of icebergs passing south of 48°N, May is most frequently the month in which most icebergs are counted, with an average of 146. Despite the extraordinarily large numbers of icebergs immediately to the north, in May, only eleven icebergs were estimated to have passed south of 48°N. The southernmost iceberg seen by the Ice Patrol reconnaissance aircraft was a medium drydock sighted on May 17 at 47°28'N and 50°34'W.

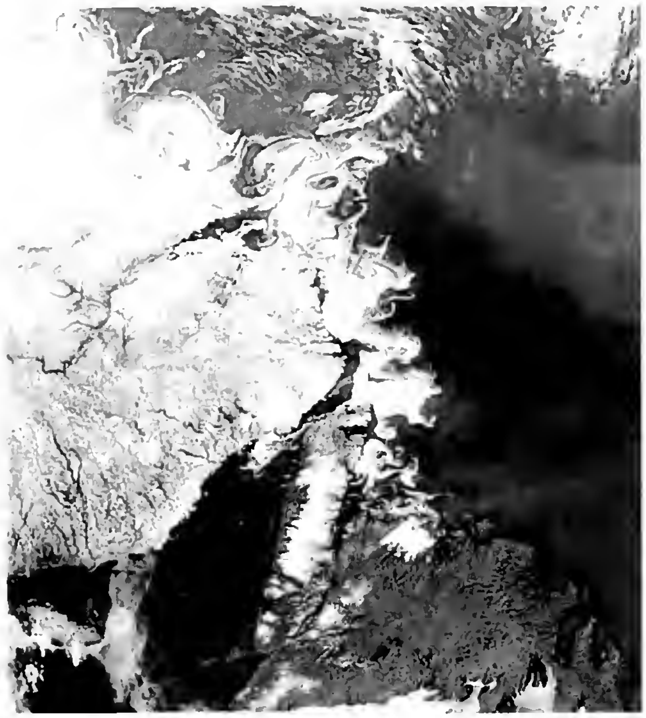

Figure 15. May 9, 1999 SeaWiFs image showing the sea ice distribution in east Newfoundland waters and along the Labrador coast. (Image provided by the SeaWiFs Project, NASA/Goddard Space Flight Center, and ORBIMAGE)

June and July

The early June disappearance of the sea ice from east Newfoundland waters was approximately consistent with mean conditions. However, the sea ice retreat left behind numerous icebergs east of Newfoundland between 49°N and 52°N and over 100 icebergs in the Gulf of St. Lawrence and Strait of Belle Isle.

Figures 16 and 17 show the 1999 iceberg distribution in early June and in early July. On June 3, CIS was tracking nearly 2000 icebergs off the northern Newfoundland peninsula and the Labrador coast; by July 2 that number had increased to over 3000 icebergs. Both figures show icebergs that had recently been detected by extensive aerial reconnaissance

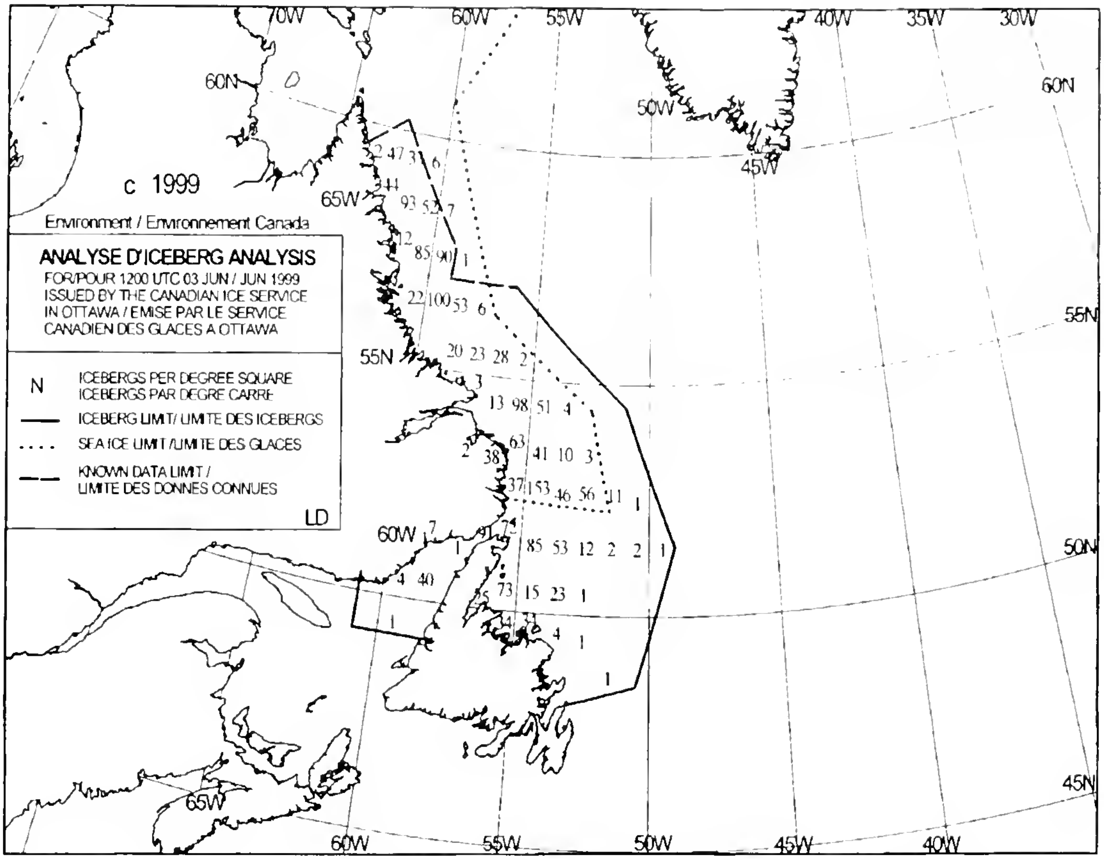

Figure 16. Iceberg distribution on June 3, 1999 from the iceberg analysis issued by the Canadian Ice Service. There are 1914 icebergs on this plot.

conducted in good to excellent visibility. On 1 to 2 June the IIP airplane detected nearly 1400 icebergs during two consecutive flights. Despite this large iceberg population, Ice Patrol estimated that just five icebergs drifted south of 48°N in June, much less than the monthly average of 87. The easternmost predicted iceberg drift for the year was on June 29, 1999 when an iceberg was estimated to have reached 48°26'N and 45°32'W.

Ice Patrol suspended its active aerial reconnaissance for 1999 after the return of Ice Reconnaissance Detachment #6 on June 4. However, Ice Patrol continued to receive ship and Canadian aerial reconnaissance reports throughout the next several months.

Over a seven-day period from June 25 through July 1, six Canadian reconnaissance flights, most with the CIS's reconnaissance airplane, observed over 2000 icebergs in east Newfoundland waters and along the Labrador coast. For the entire month of July, Ice Patrol estimated that three icebergs drifted south of 48°N, compared to a 100-year average of 31. The easternmost observed iceberg in 1999 was seen by a ship on July 14 at 47°56'N and 46°28'W. The southernmost predicted drift for the year was on July 11 when an iceberg was estimated to have reached 47°15'N and 46°07'W.

Summary

The factors that shape the severity of an iceberg season in the western North Atlantic ocean can be divided into three main categories. The first is the supply of icebergs to the southern Labrador coast, which is affected by iceberg calving

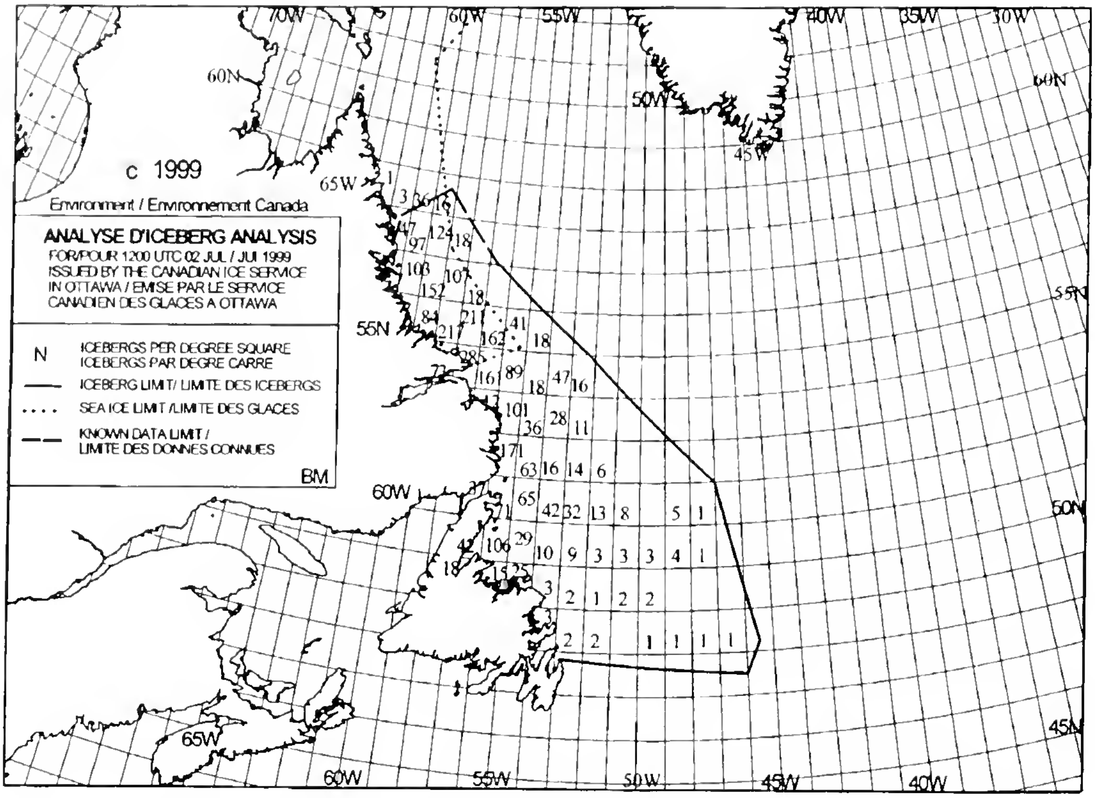

Figure 17. Iceberg distirbution on July 2, 1999 from the iceberg analysis issued by the Canadian Ice Service. There were 3165 icebergs in the CIS model on this date.

production at the various glaciers and deterioration processes in Baffin Bay that might destroy them before getting very far south. The second includes the mechanisms that contribute to iceberg destruction in east Newfoundland waters, such as the duration and areal extent of the sea ice cover, air and sea surface temperature, and storm tracks. The final category includes those factors relating to the movement of icebergs once they reach southern Labrador and east Newfoundland waters, primarily the ocean currents in the region, and to a lesser extent, winds.

During the 1999 ice year there was an ample supply of glacial ice to the southern Labrador coast and east Newfoundland waters. From mid-April through July many hundreds of icebergs surrounded the northern peninsula of Newfoundland. Although the icebergs eventually deteriorated in place, the deterioration process was a lengthy one, taking over two months, and few icebergs escaped to the south during it.

While icebergs were plentiful, the sea ice season was light compared with the median ice limits provided by Cote (1989). The sea ice reached its farthest southern extent in very early March, about two weeks earlier than usual. At its extreme, the areal extent was substantially less than normal, never reaching below 48°N latitude (the northern tip of the Avalon Peninsula). Its easterly extent was also much less than normal, and by mid-April there was very little sea ice east of 55°W longitude.

Thus, the dominant factor in 1999 was the ocean currents that drove the many icebergs that were present into the bight of Newfoundland and the Gulf of St. Lawrence, where they became immobilized and deteriorated in place.

With 22 icebergs estimated to have passed south of 48°N, 1999 enters into a tie with 1977 as the ninth-mildest iceberg season in Ice Patrol's history. In fact, the traditional scale Ice Patrol uses to gauge iceberg season severity (Trivers, 1994) is too coarse to be useful. Moreover, the monthly iceberg-climatology charts (Viekman and Baumer, 1995) are not useful because Ice Patrol issued no formal iceberg products and therefore never defined a limit of all known ice or LAKI in 1999. CIS did define ice limits for the 1999 season, and if those were compared to Viekman and Baumer's charts, the limits would be at or near the minimums for the entire ice season.

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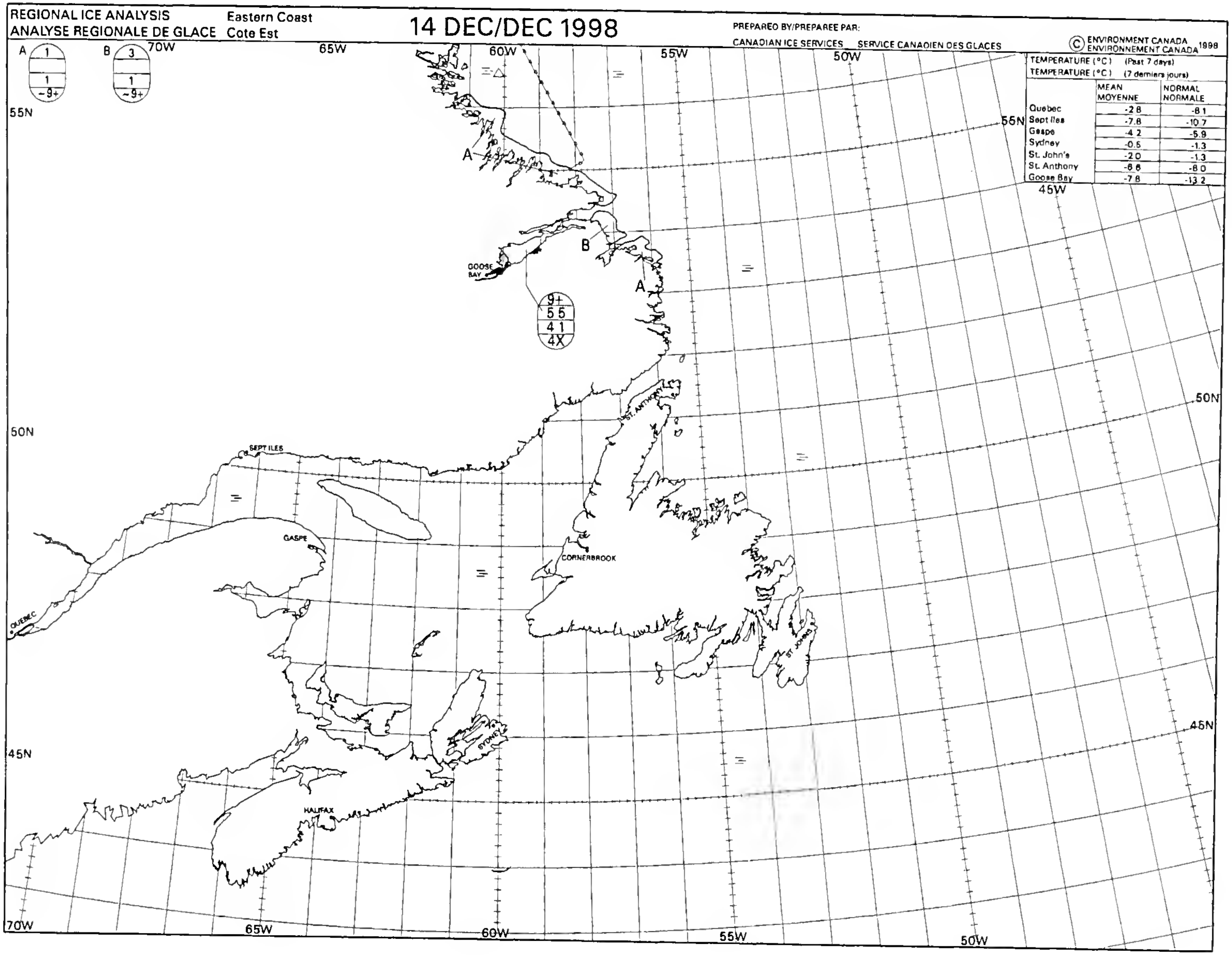
Monthly Sea Ice Charts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ANALYSE REGIONALE DE GLACE
Eastern Coast
Cote Est
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SERVICE CANADIEN DES GLACES
© ENVIRONMENT CANADA
ENVIRONNEMENT CANADA 1998
TEMPERATURE (°C) (Past 7 days)
TEMPERATURE (°C) (7 derniers jours)
MEAN MOYENNE
NORMAL NORMALE
Quebec -2.8 -8.1
Sept Iles -7.8 -10.7
Gaspe -4.2 -5.9
Sydney -0.5 -1.3
St. John's -2.0 -1.3
St. Anthony -6.6 -8.0
Goose Bay -7.8 -13.2
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GOOSE BAY
SEPT ILES
GASPE
QUEBEC
CORNERBROOK
ST. ANTHONY
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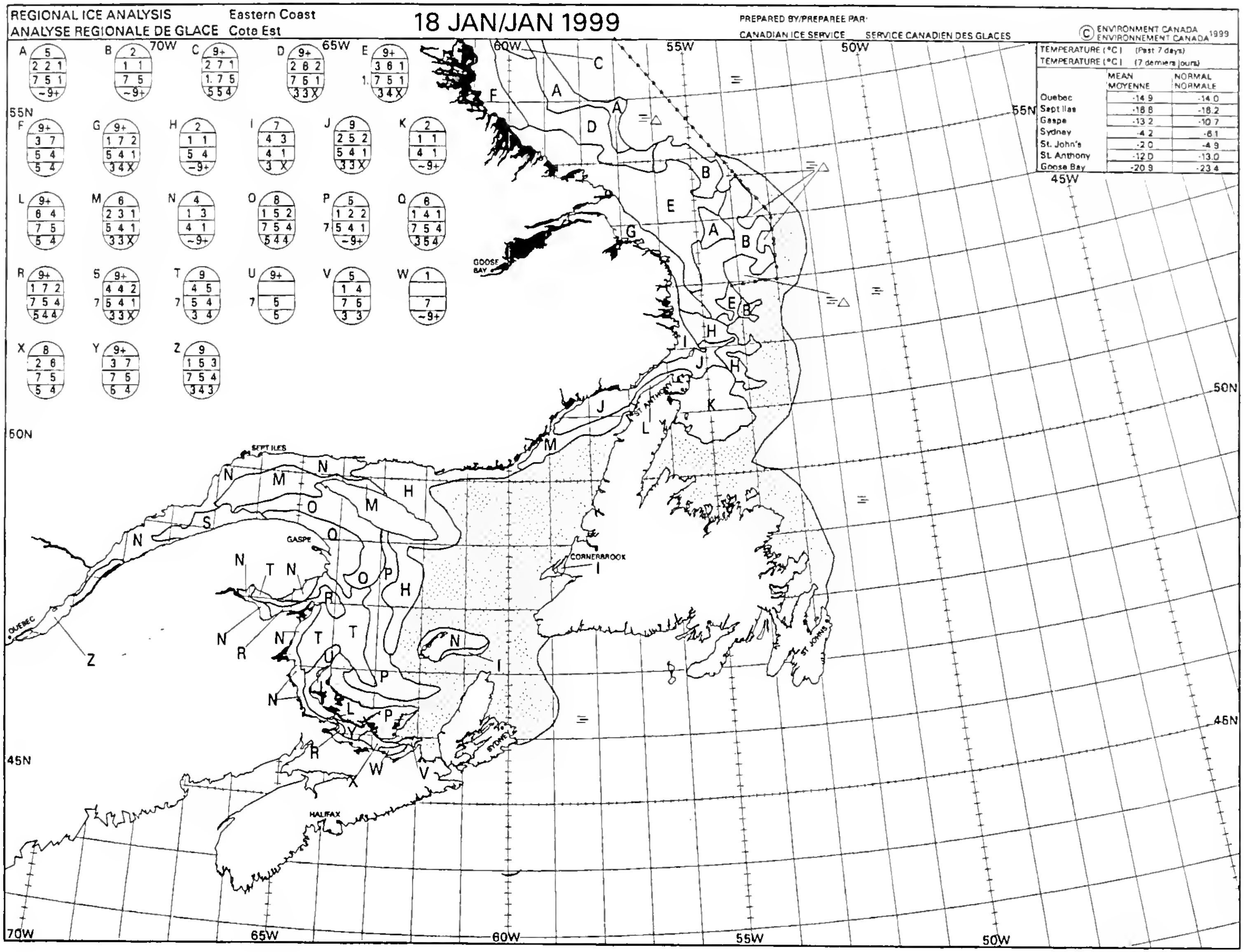
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SERVICE CANADIEN DES GLACES
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ENVIRONNEMENT CANADA 1999
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TEMPERATURE (°C) (7 derniers jours)
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Sept Iles -18.8 -18.2
Gaspe -13.2 -10.7
Sydney -4.2 -6.1
St. John's -2.0 -4.9
St. Anthony -12.0 -13.0
Goose Bay -20.9 -23.4
SEPT ILES
GASPE
GOOSE BAY
CORNERBROOK
ST ANTHONY
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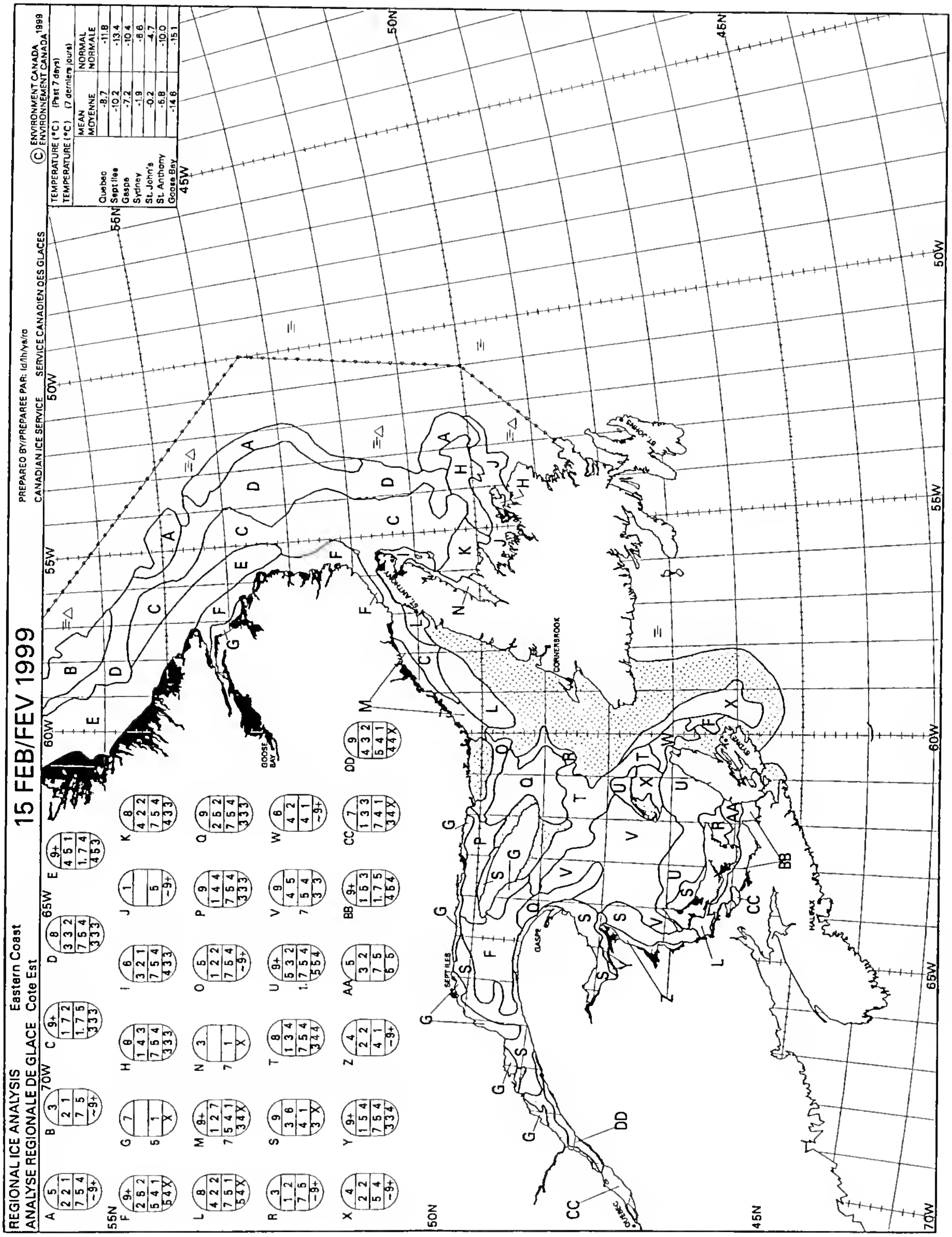
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TEMPERATURE (°C) (7 derniers jours)
MEAN MOYENNE
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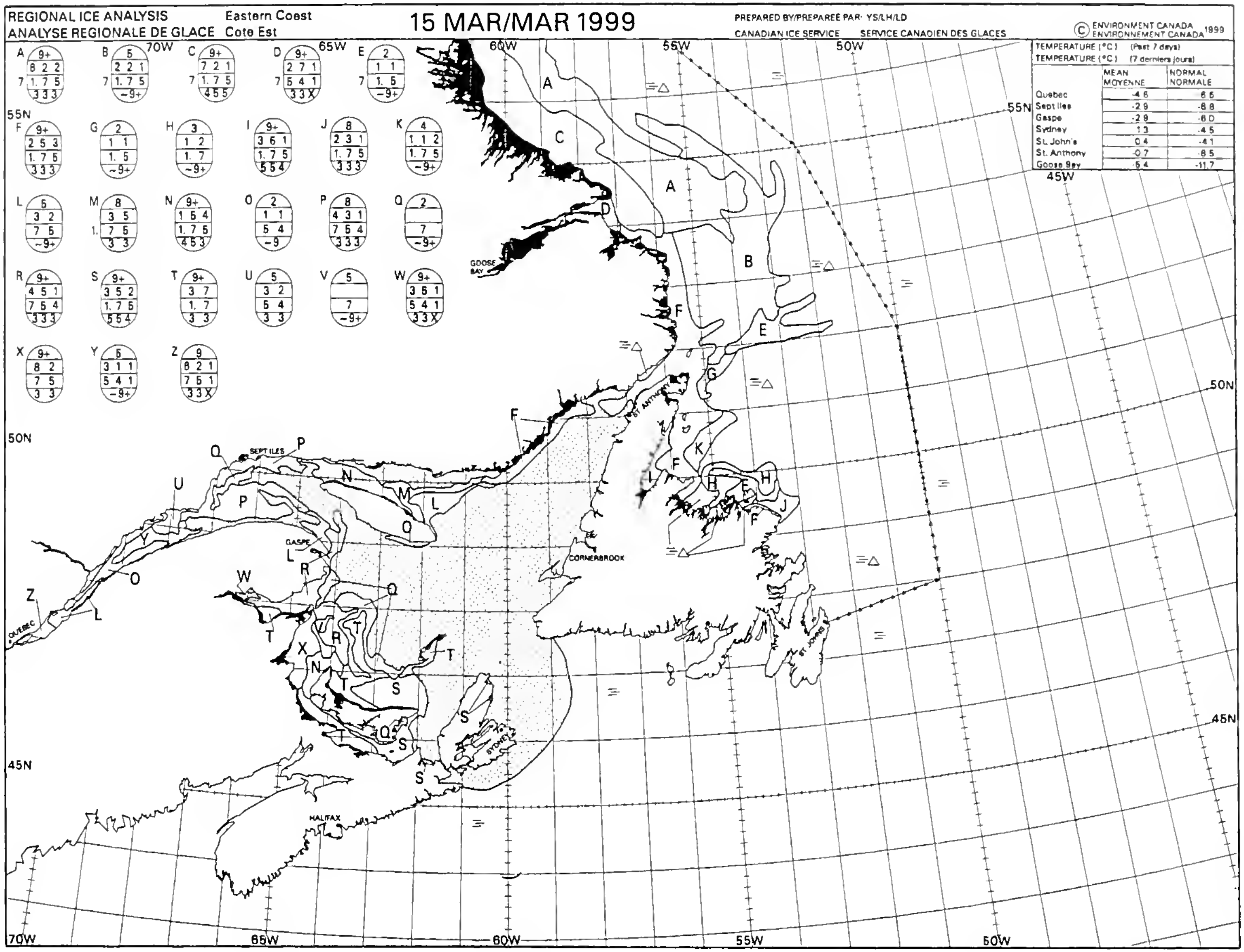
SEPT ILES
HALIFAX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Gaspe -2.9 -8.0
Sydney 1.3 -4.5
St. John's 0.4 -4.1
St. Anthony -0.7 -8.5
Goose Bay -5.4 -11.7
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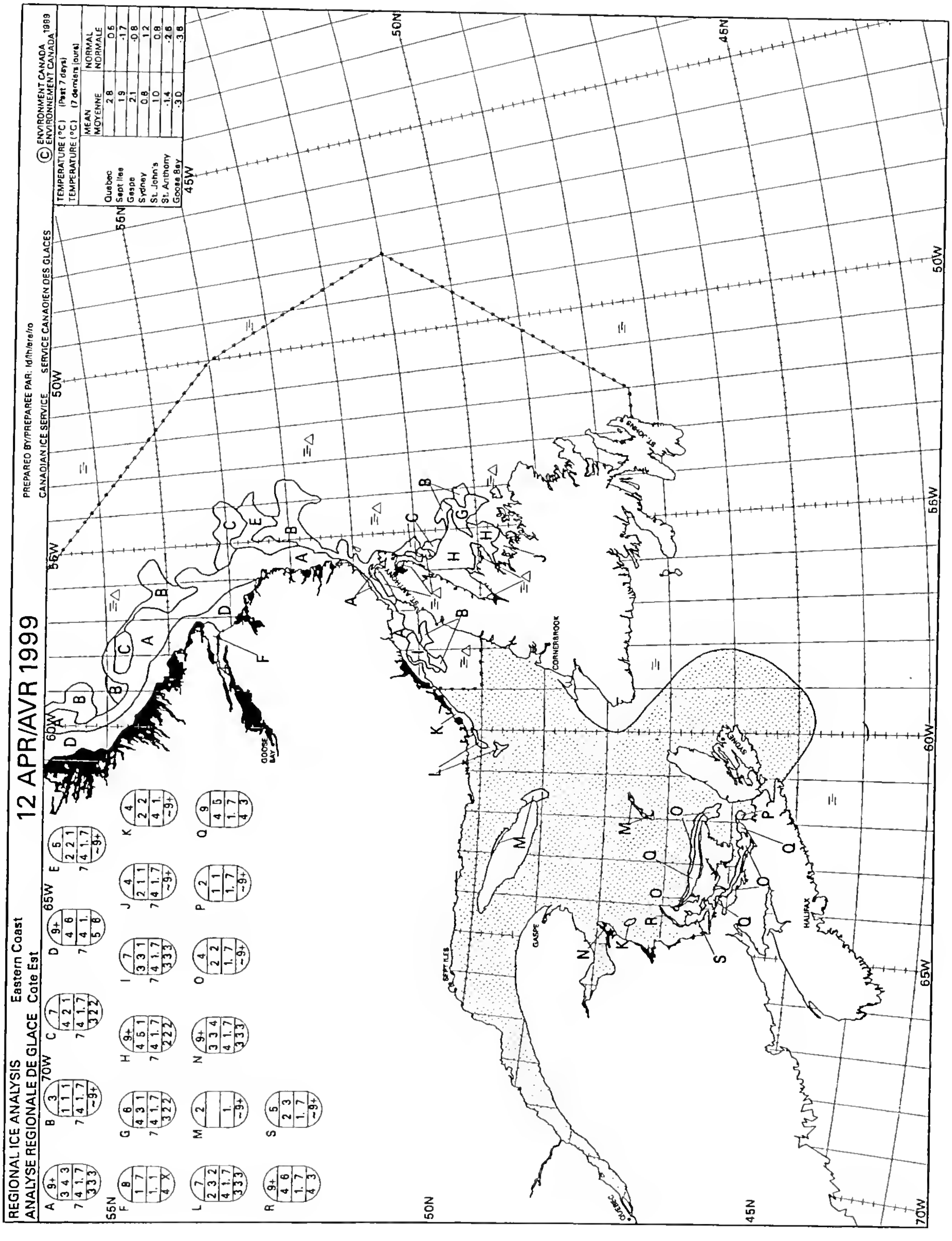
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TEMPERATURE (°C) (7 derniers jours)
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Sept Iles 1.9 -1.7
Gaspe 2.1 -0.8
Sydney 0.8 1.2
St. John's 1.0 0.8
St. Anthony -1.4 -2.8
Goose Bay -3.0 -3.8
GOOSE BAY
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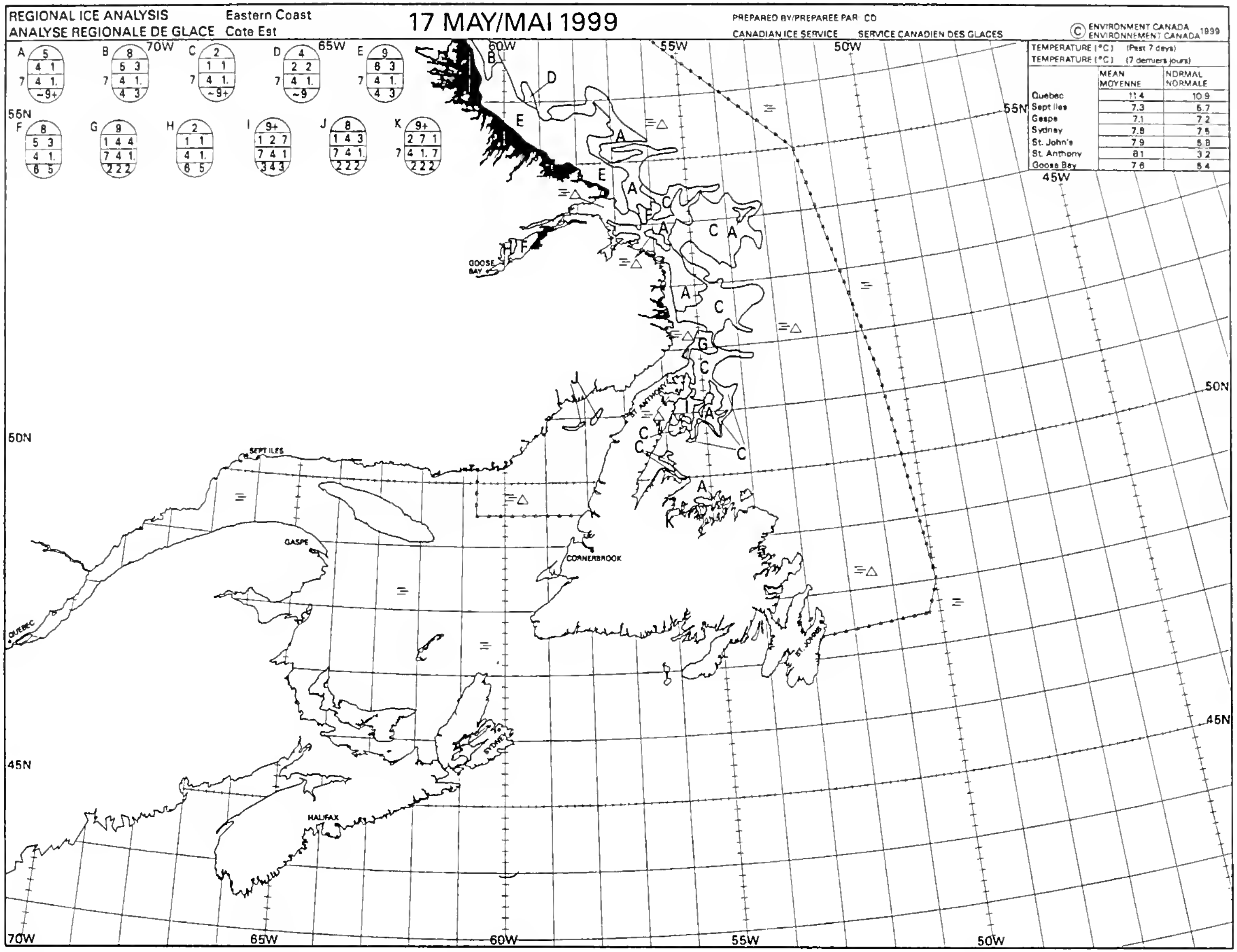
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TEMPERATURE (°C) (7 derniers jours)
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Gaspe 7.1 7.2
Sydney 7.8 7.5
St. John's 7.9 5.8
St. Anthony 8.1 3.2
Goose Bay 7.6 5.4
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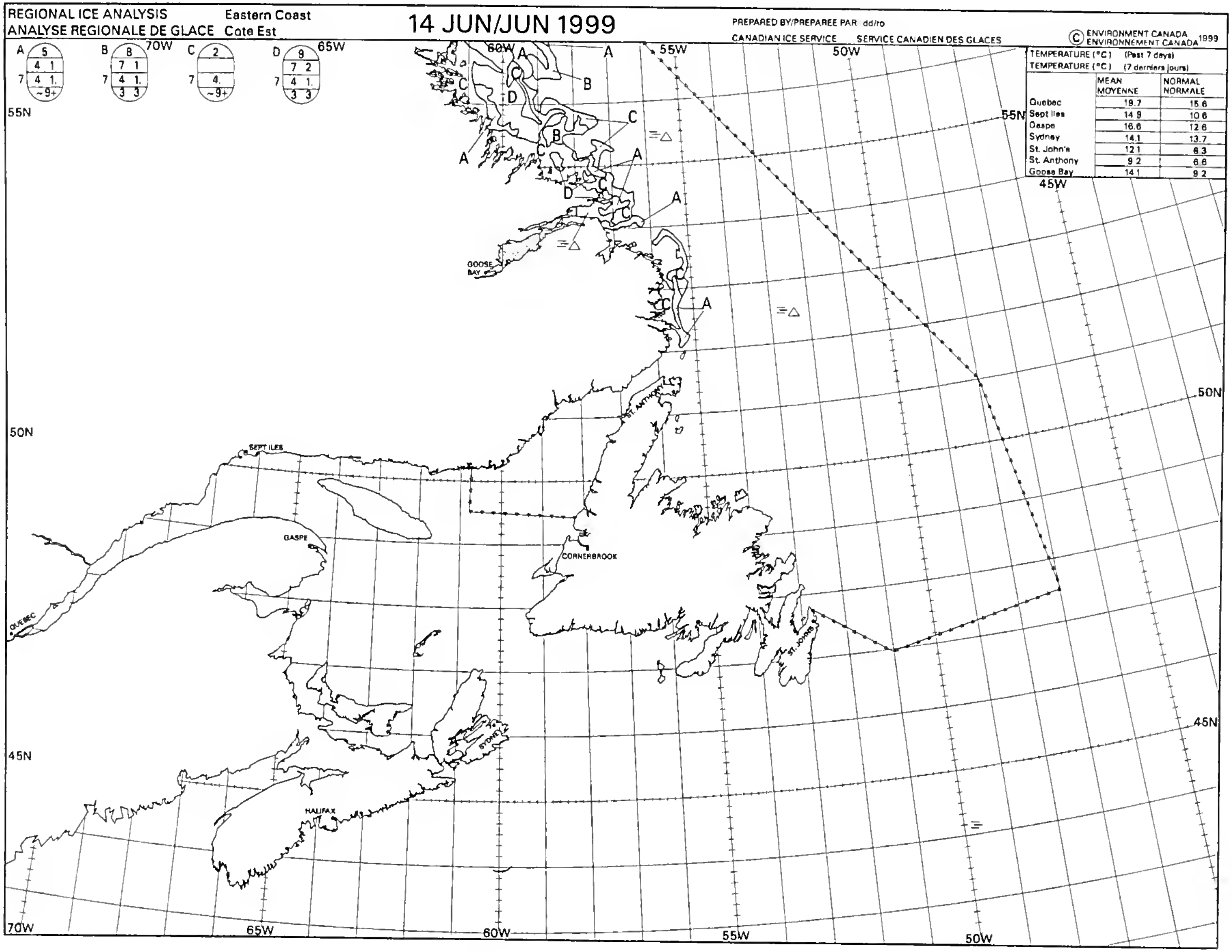

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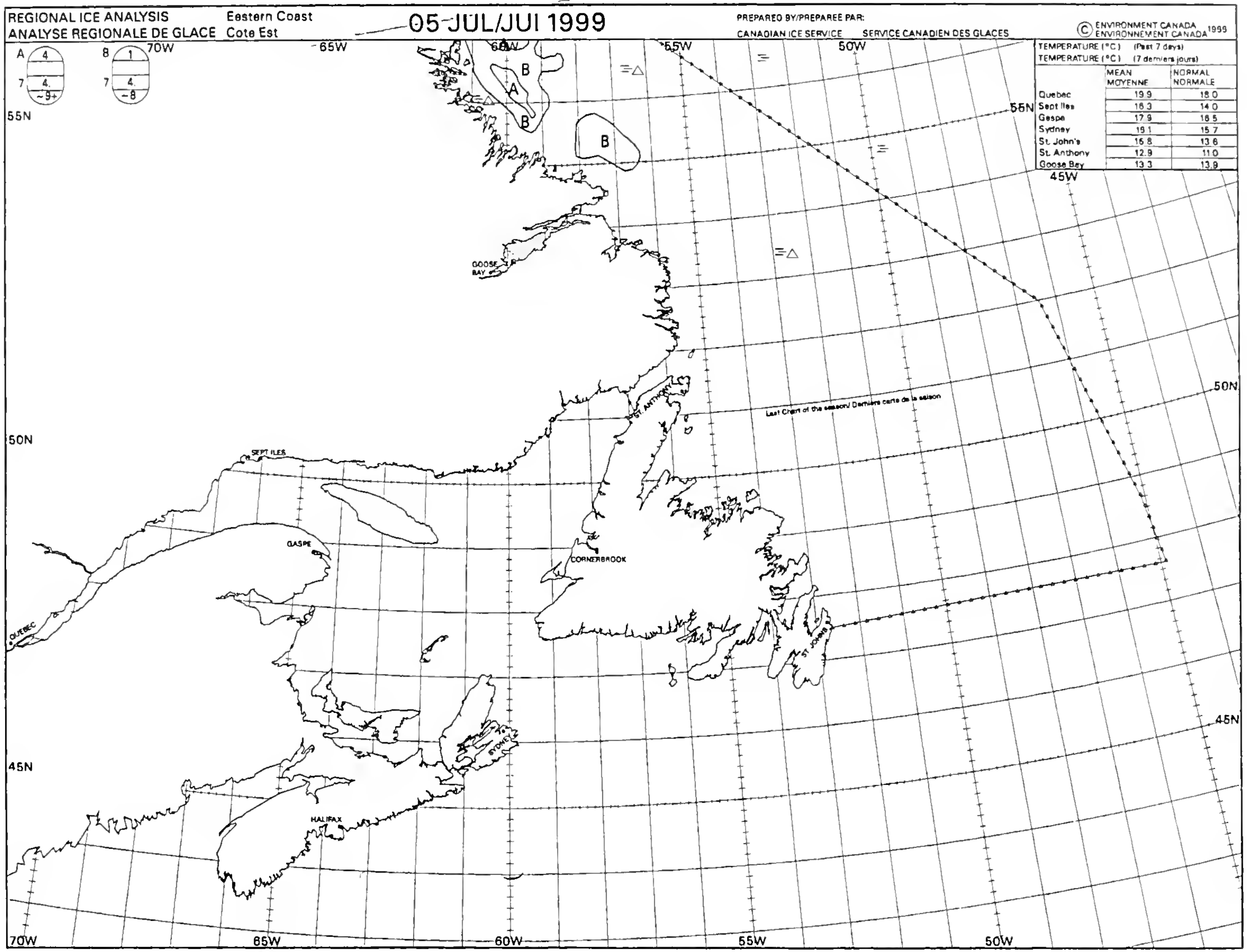
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TEMPERATURE (°C) (7 derniers jours)
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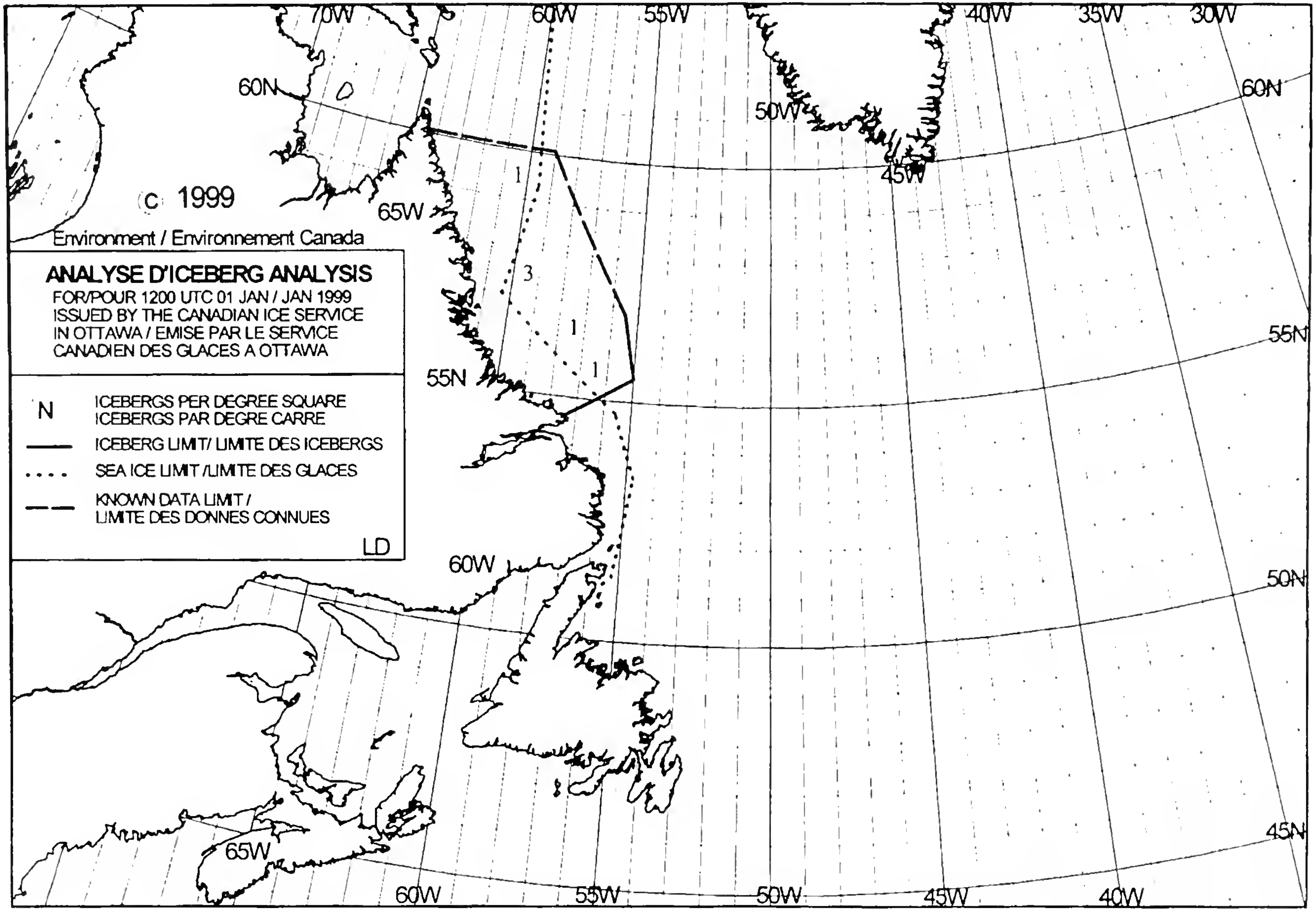
Biweekly Iceberg Charts

Note: International Ice Patrol did not distribute iceberg charts in 1999 due to an extremely light ice season. The following iceberg charts were provided by the Canadian Ice Service and are included for reference and continuity with past reports.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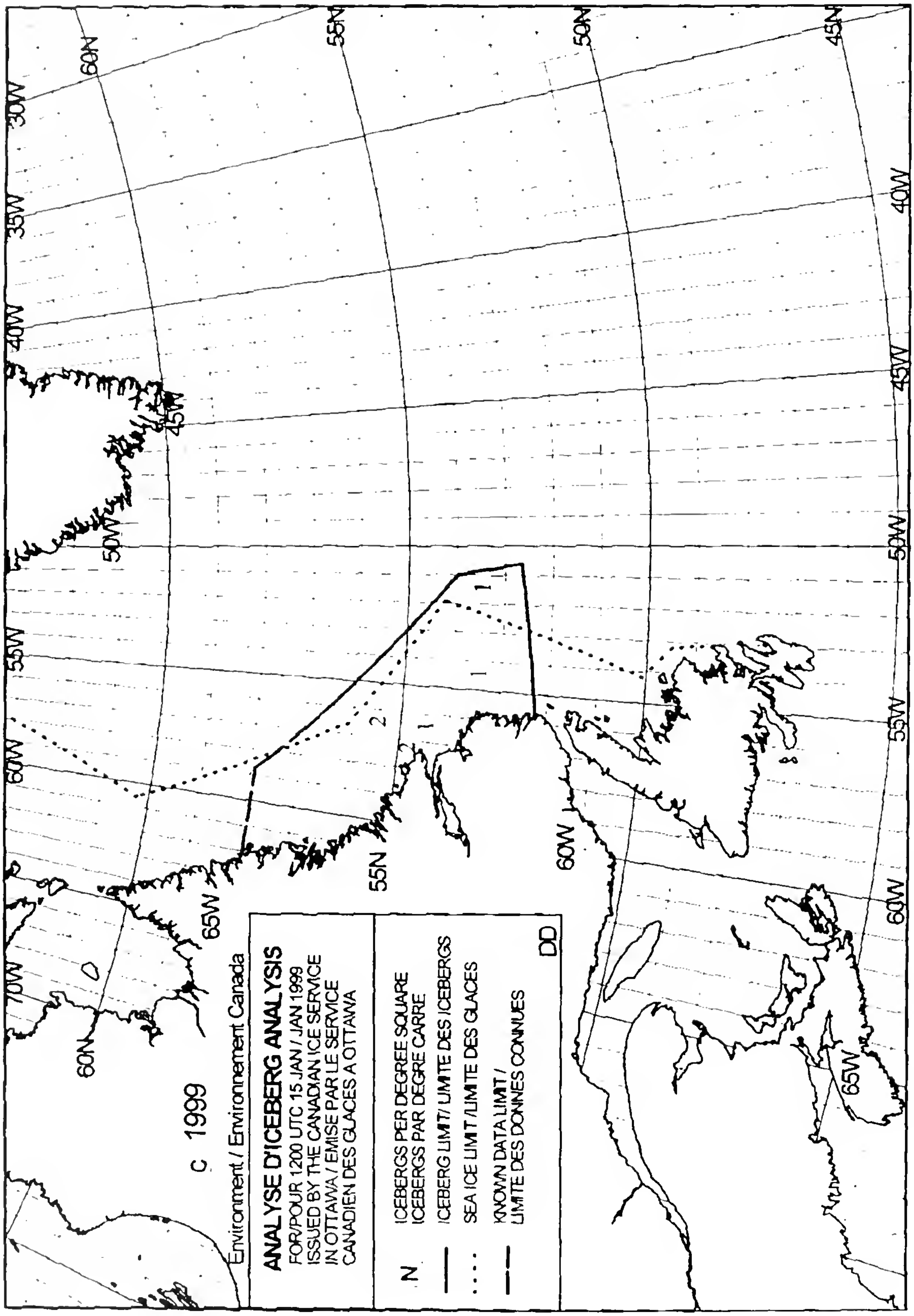
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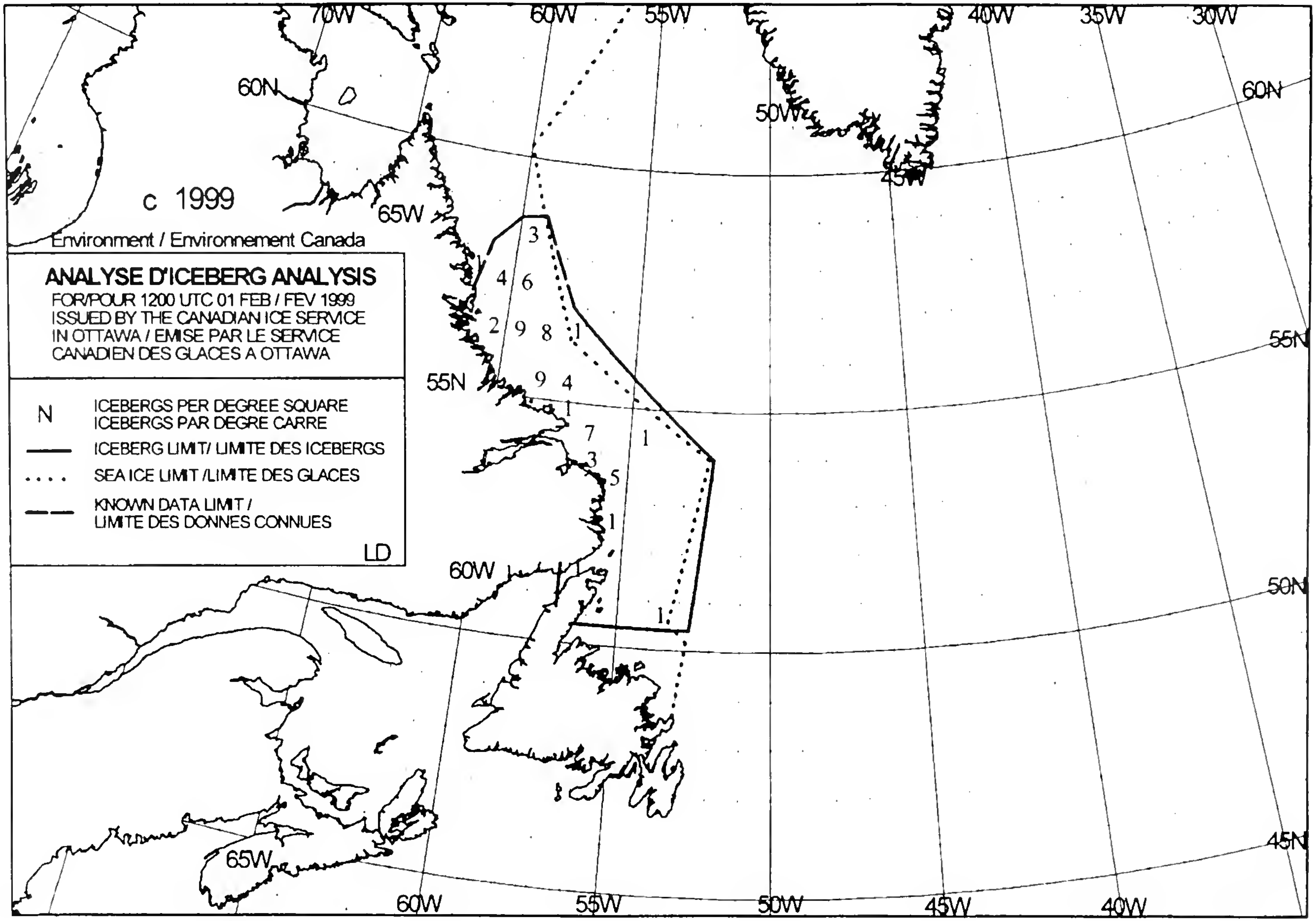

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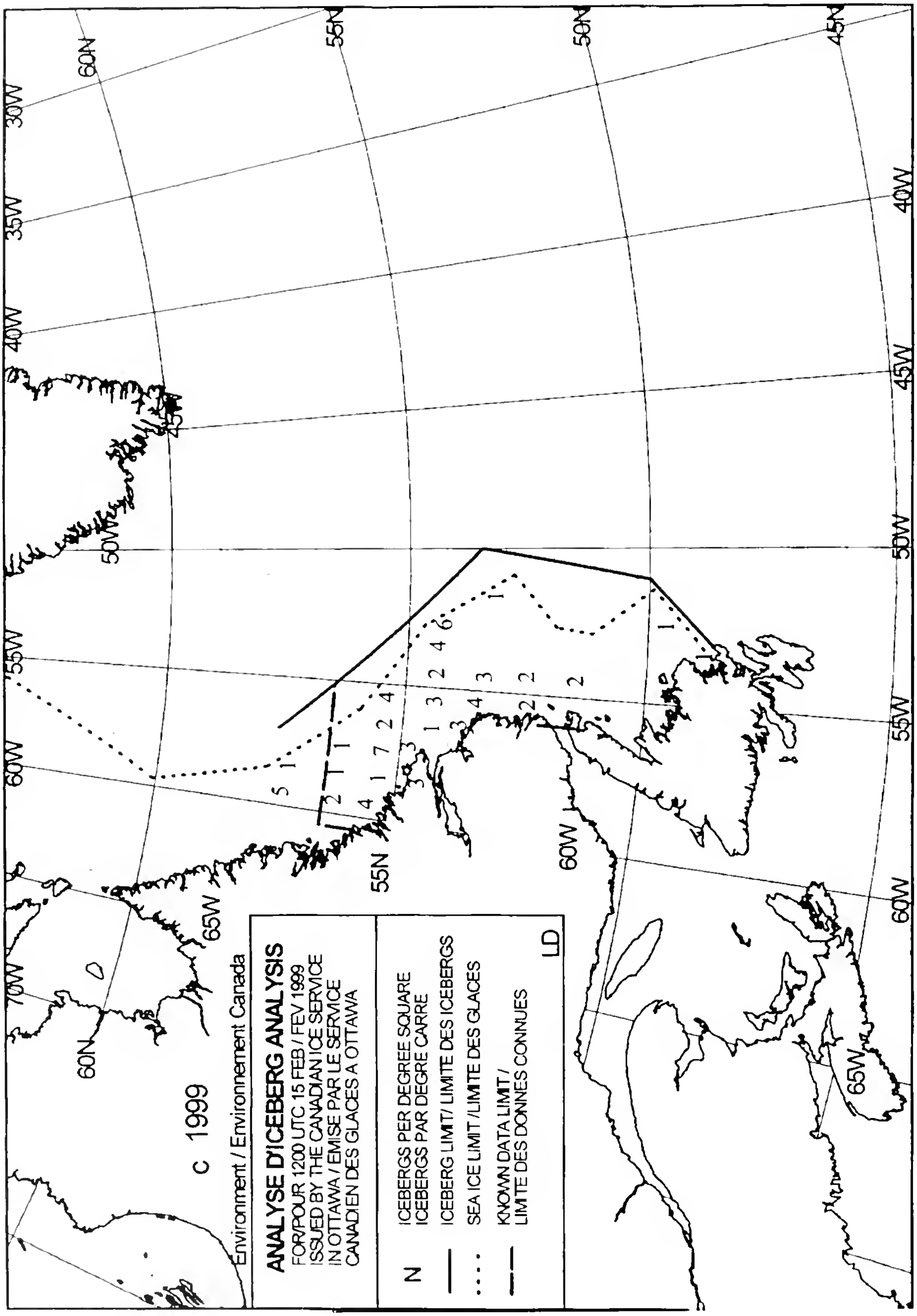
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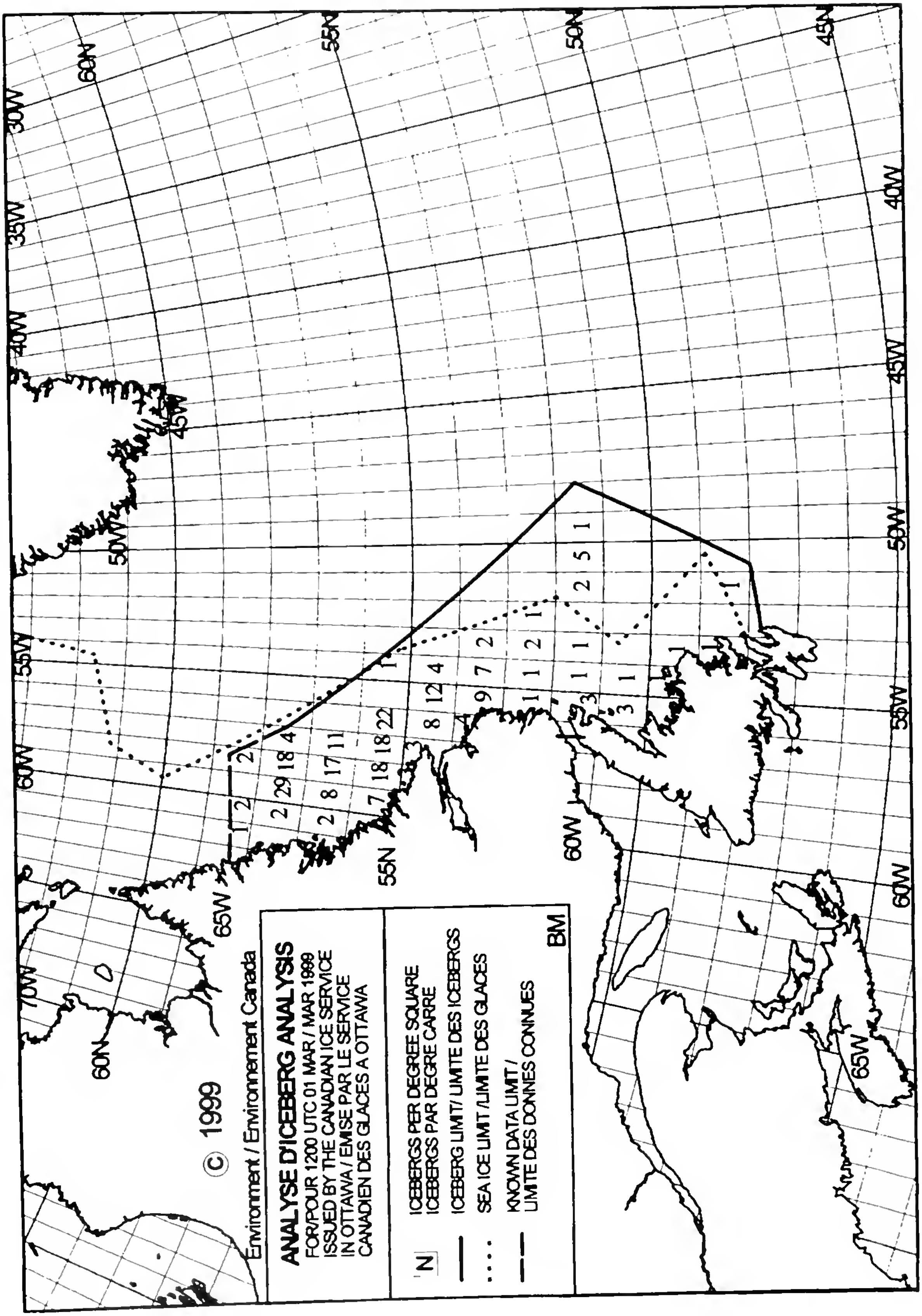
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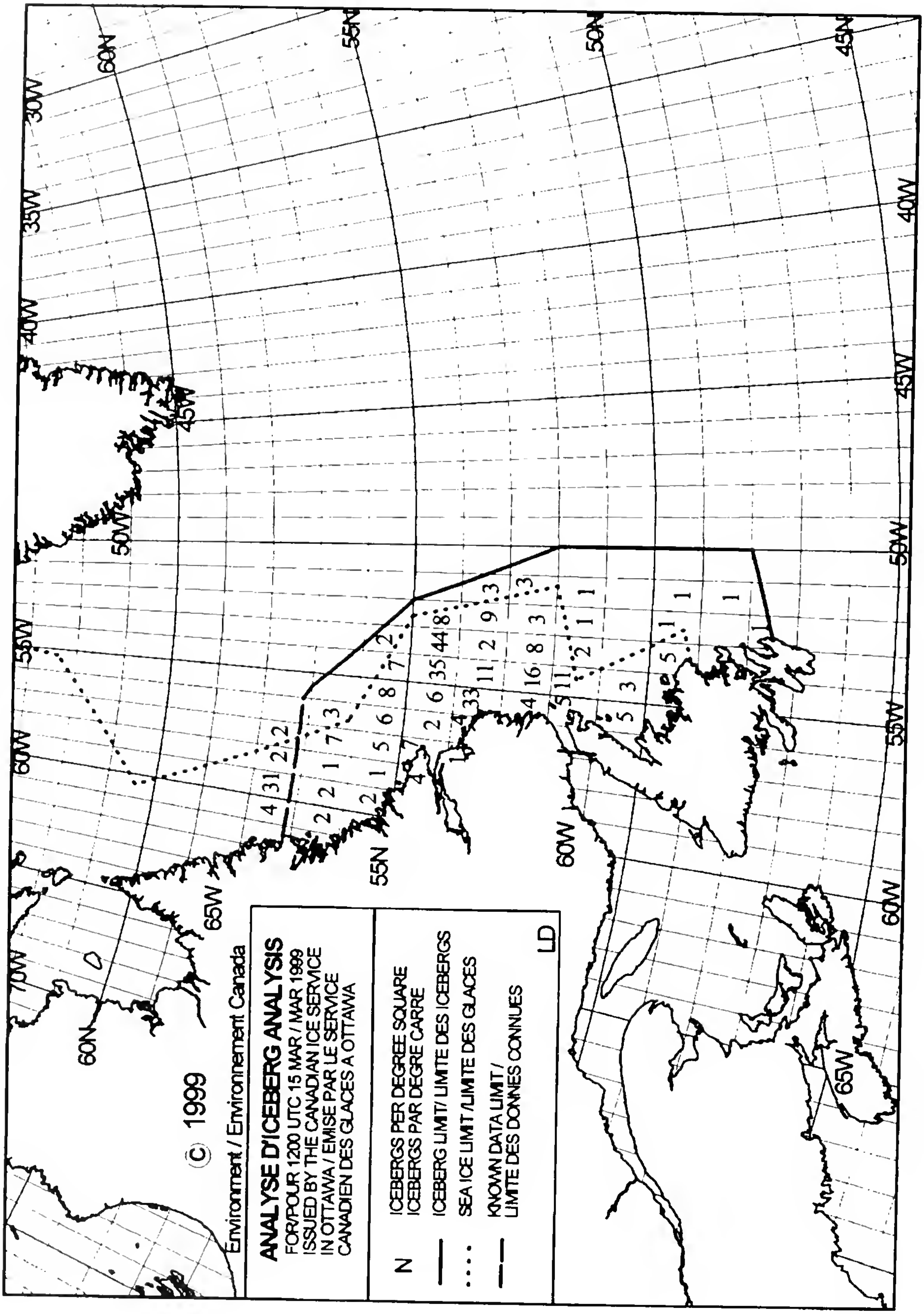
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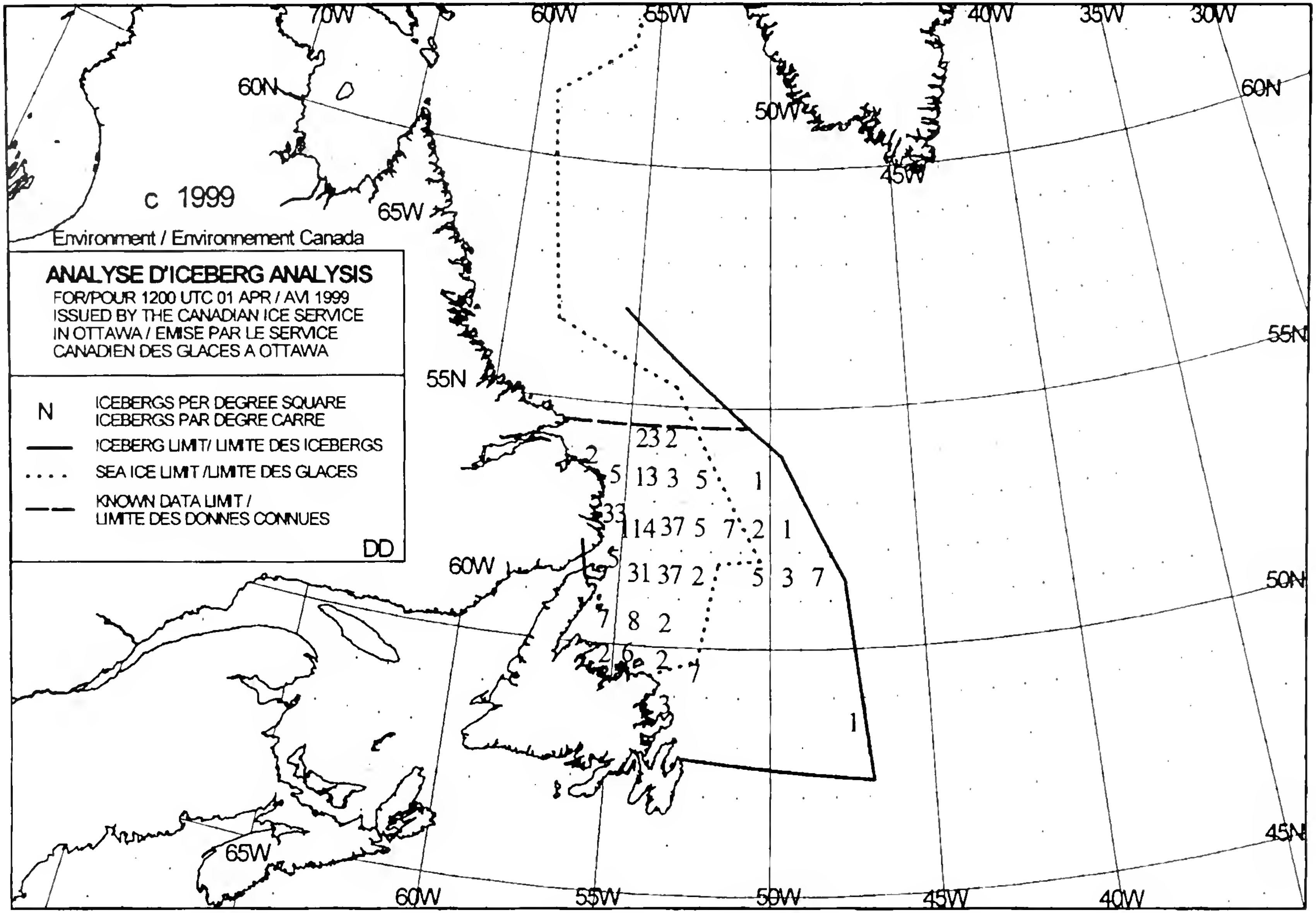
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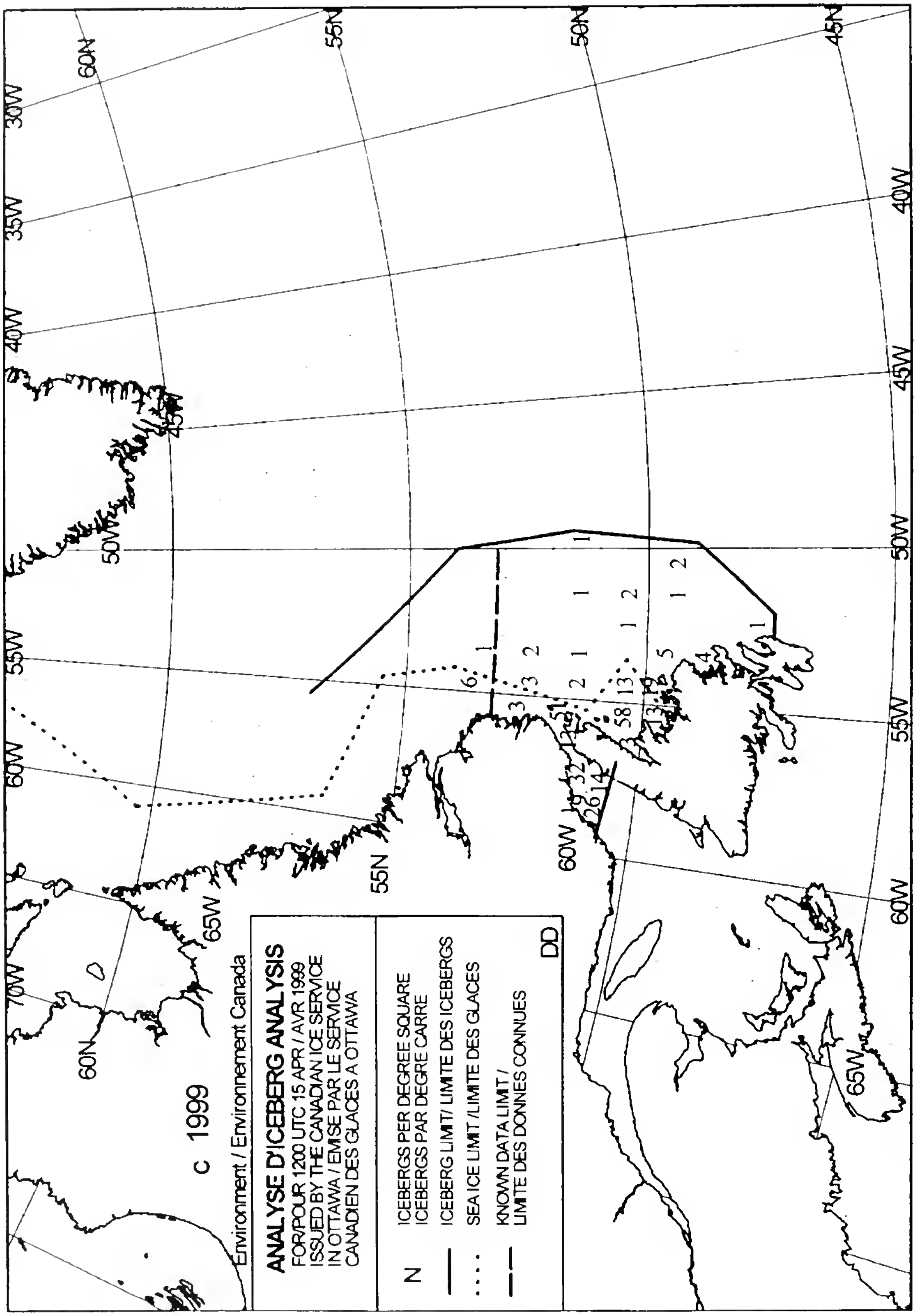

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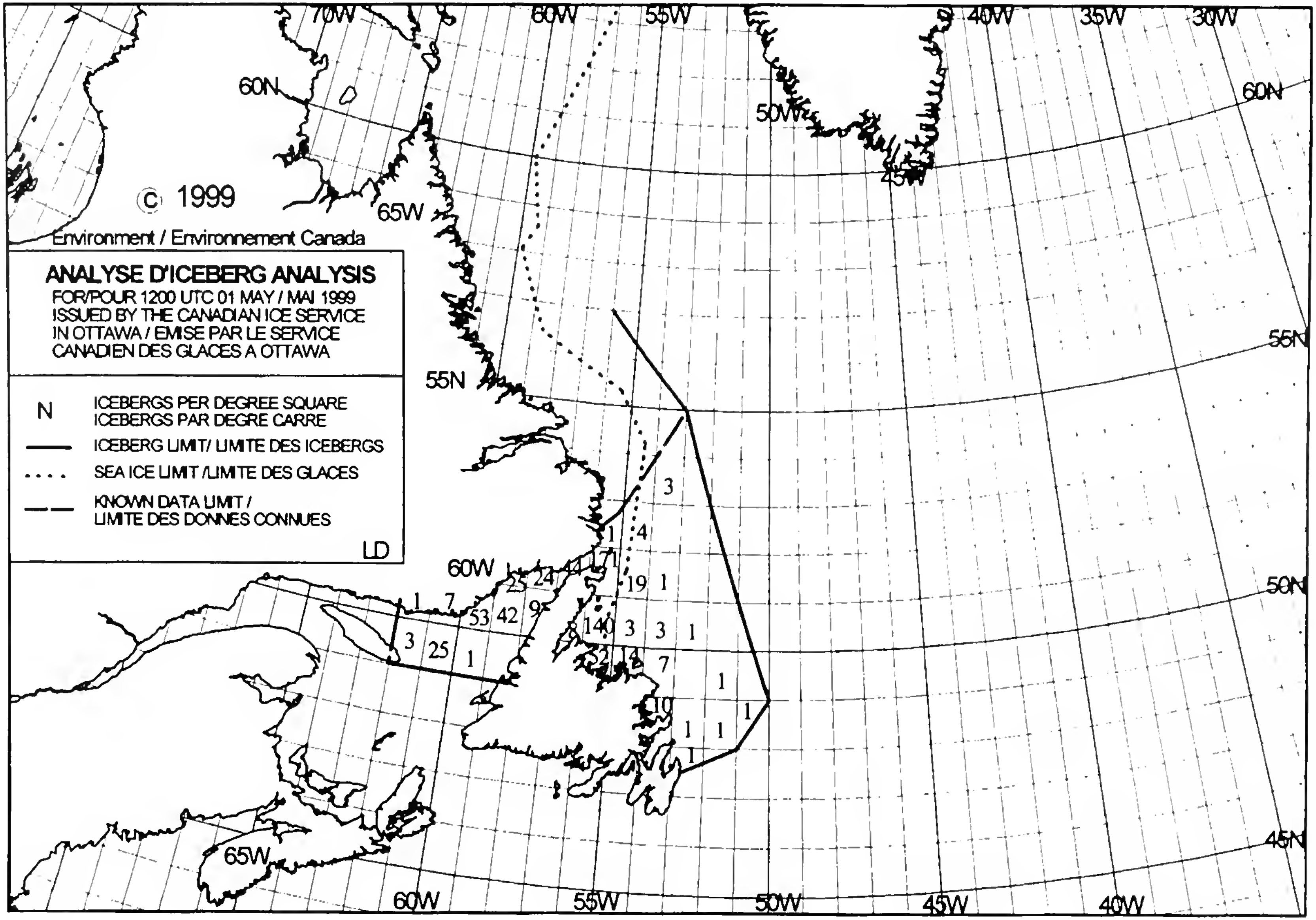
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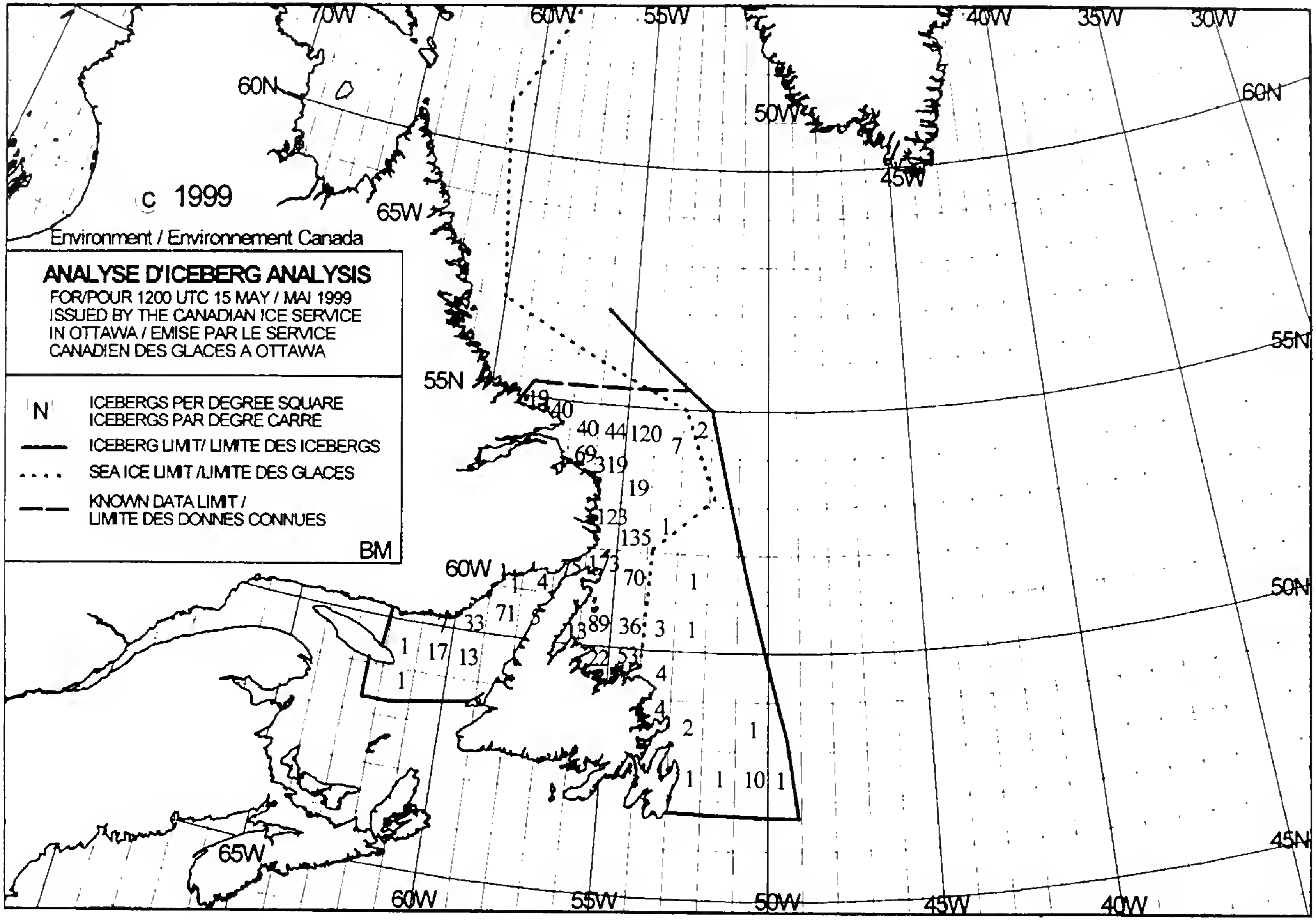
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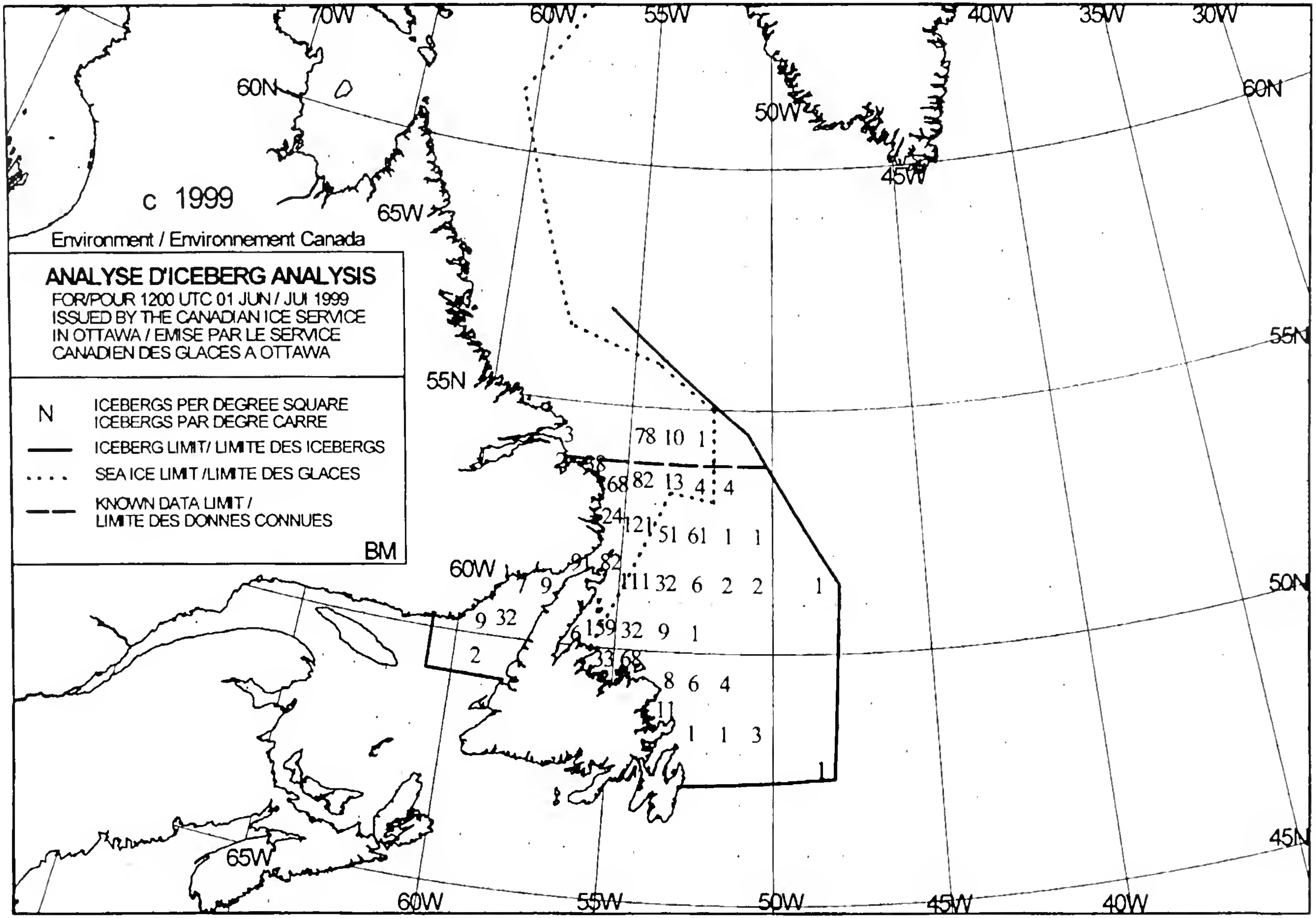
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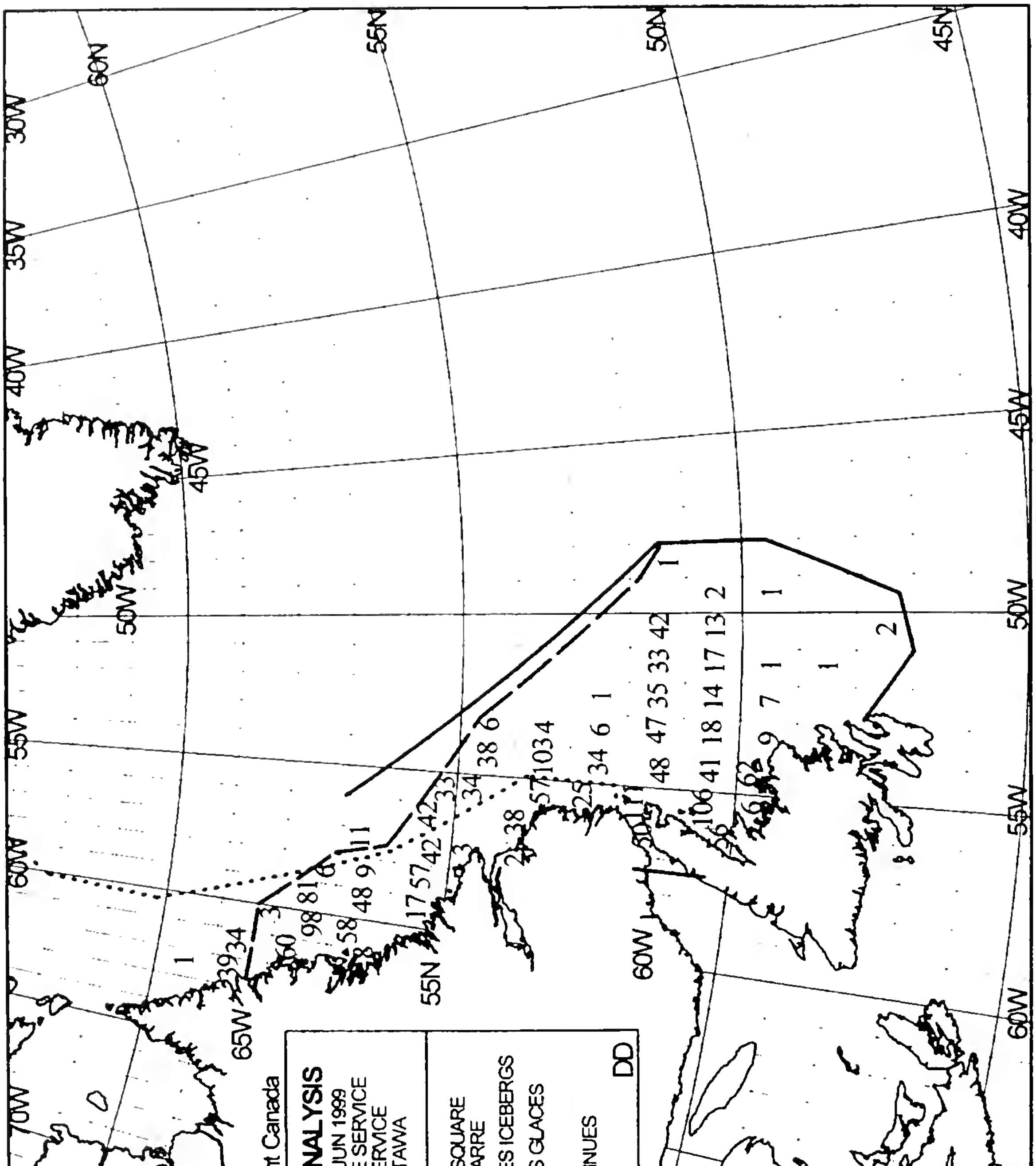

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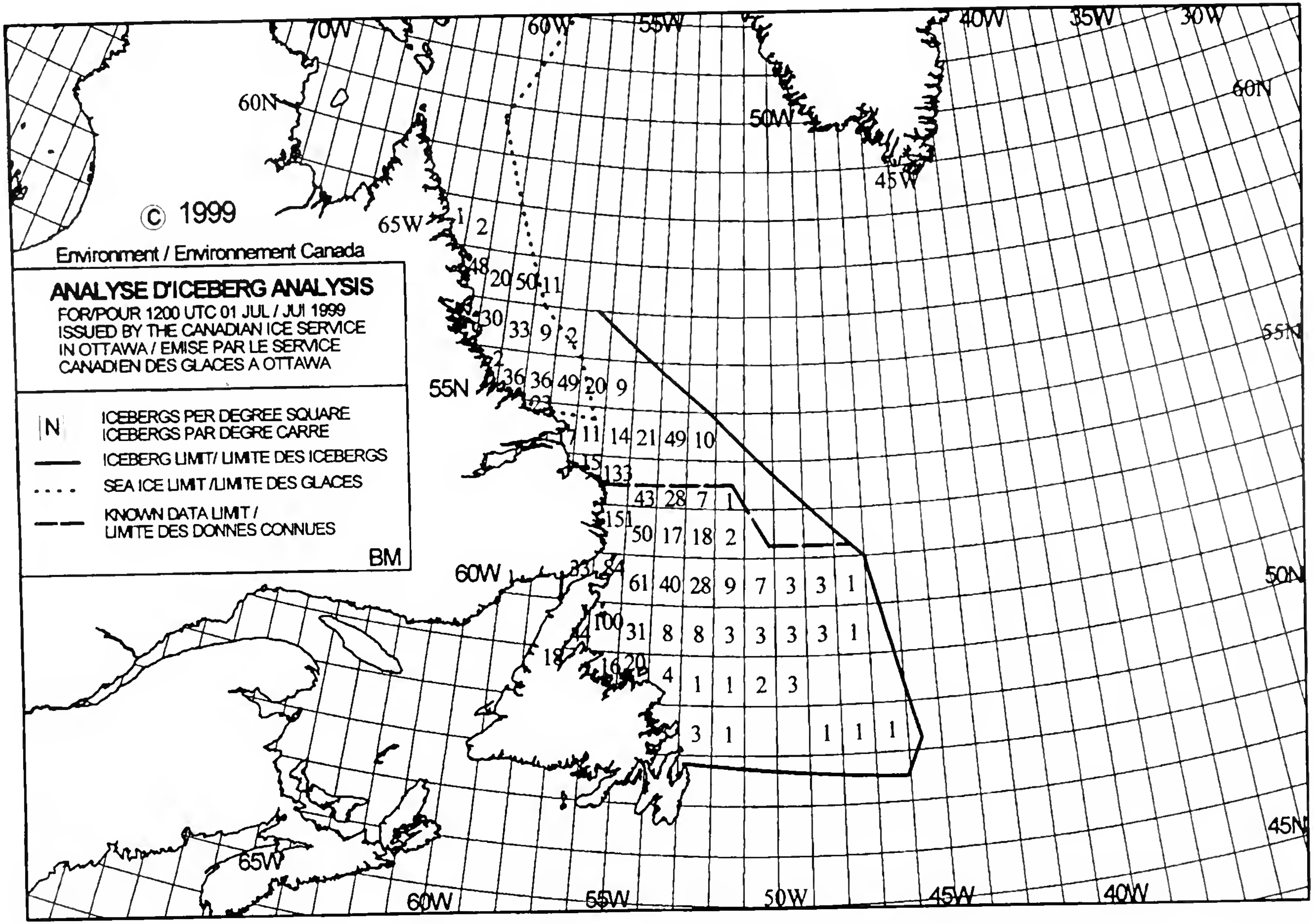

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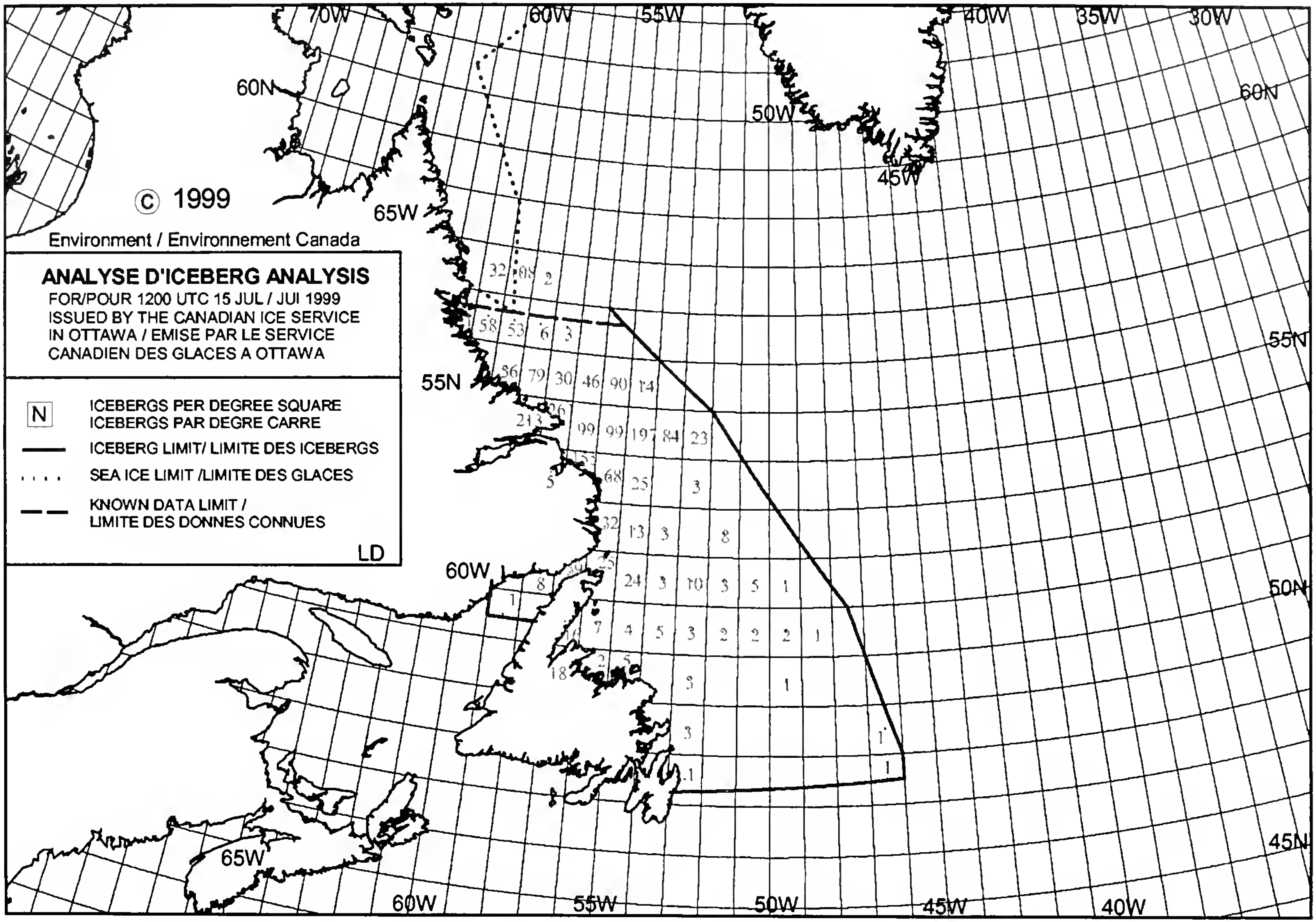
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Acknowledgements

Commander, International Ice Patrol acknowledges the assistance and information provided by:

Canadian Ice Service
Canadian Coast Guard
Navy / NOAA / USCG National Ice Center
U. S. Naval Fleet Numerical Meteorology and Oceanography Center
U. S. Naval Atlantic Meteorology and Oceanography Center
U. S. Coast Guard Research and Development Center
U. S. Coast Guard Atlantic Area Staff
U. S. Coast Guard Atlantic Area Command Center
U. S. Coast Guard Atlantic Area Master Communications Center

We extend our sincere appreciation to the staffs of these organizations for their excellent support during the 1999 International Ice Patrol season:

Canadian Coast Guard Radio Station St. John's, Newfoundland/VON
Ice Operations St. John's, Newfoundland
Air Traffic Control Gander, Newfoundland
Canadian Forces Gander and St. John's, Newfoundland
St. John's Flight Services Office
U. S. Coast Guard Air Station Elizabeth City, North Carolina
National Weather Service, Maryland

It is important to recognize the outstanding efforts of the personnel at the International Ice Patrol:

CDR S. L. Sielbeck
LCDR M. R. Hicks
Dr. D. L. Murphy
Mr. G. F. Wright
LT T. P. Wojahn
LT J. E. Andrews
MSTCM S. B. Bell
YN1 S. J. Hoss
MST1 M. J. O'Brien
MST1 L. L. Valliere
MST1 L. S. Howell
MST2 J. C. Luzader
MST2 H. R. Harbuck
MST2 T. T. Krein
MST2 P. J. Jenicek
MST3 M. L. Seeger

This report was produced using Microsoft® Word 97 and Excel 97 by International Ice Patrol staff.

Appendix A

Nations Currently Supporting International Ice Patrol

Belgium

Canada

Denmark

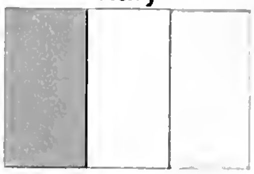
Finland

France

Germany

Greece

Italy



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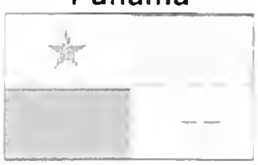
Netherlands

Norway

Panama



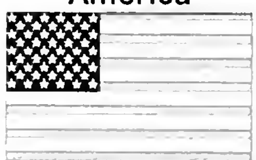
Poland

Spain

Sweden

United Kingdom

United States of America



Appendix B

Ship Reports

Ships Reporting By Flag	Reports
ANTIGUA & BARBUDA	
HANSEWELL	2
CANADA	
CGCS HENRY LARSEN	20
EMERALD STAR	3
FRANKLIN	2
IRVING ESKIMO	2
KALVIK	1
NORTHERN PRINCESS	3
SIBIL W	1
TERRY FOX	6
SIR HUMPHREY GILBERT	1
CYPRUS	
MAERSK TORONTO	21
PANAYIOTA	1
GERMANY	
ABITBI CLAIRBORNE	2
HONG KONG	
RIXTA OLDENDORFF	1
LIBERIA	
NATASHA III	1
LITHUANIA	
CAPE CIRCLE	1
MALAYSIA	
BUNGA ORKID LIMA	1
MARSHALL ISLANDS	
SEA-LAND FREEDOM	1
NETHERLANDS ANTILLES	
JO SPRUCE	1
NORWAY	
*BERGE NORD	25
BRUNTO	2
MACADO	1

Ships Reporting By Flag	Reports
NORWEGIAN INT. REGISTER	
GREEN BERGEN	6
MUNKSUND	1
PANAMA	
PARNASO	9
TRENCHSETTER	3
FEDERAL MCKENZIE	1
PHILIPPINES	
MOOR LAKER	1
RUSSIA	
AKADEMIK IOFFE	1
SINGAPORE	
AMAZON	1
SELFOSS	1
ST. VINCENT	
RHONE	7
SWEDEN	
BLUE CLIPPER	1
JOHN GORTHON	2

*DENOTES VESSEL PARTICIPATION AWARD WINNER

Appendix C

An Historical Perspective to the Mild 1999 Ice Year

Donald L. Murphy

Introduction

By any measure, the 1999 ice year was extraordinary. In an average year, nearly 500 icebergs pass south of 48°N, the traditional boundary below which icebergs are considered to be a menace to transatlantic shipping. In 1999, 22 icebergs passed south of 48°N. In a typical year, International Ice Patrol (IIP) issues routine iceberg warnings to mariners from February through July. In 1999, Ice Patrol issued no formal warnings. IIP's aerial reconnaissance usually extends well into August. In 1999, routine aerial reconnaissance was suspended after the return of Ice Reconnaissance Detachment #6 on 4 June 1999. The average iceberg season length is 147 days. There was no formal season in 1999. What made the 1999 iceberg season even more remarkable was the fact that there was no lack of icebergs in the western North Atlantic. Indeed, there were several thousand icebergs along the northern Newfoundland and Labrador coasts in May and June (See the Ice and Environmental Conditions section of this report), but only a few moved toward the shipping lanes.

This Appendix provides an historical context to the 1999 season. No attempt is made to answer the question "Why did so few icebergs pass south of 48°N in 1999?", though the review of the history provides several important clues. There is an extensive body of literature (Marko, *et al.*, 1994) by investigators who have struggled to explain the variability in the number of observed icebergs over the many decades that IIP has been keeping records.

1999's Place in History

The scarcity of icebergs passing south of 48°N latitude in 1999 is unusual, but not unprecedented. Ten times in Ice Patrol's history there have been fewer than 25 icebergs reported south of 48°N (Table 1). The 1999 ice season enters into a tie with the 1977 season as the ninth-mildest iceberg season in Ice Patrol's history.

Rank	Year	Icebergs
1	1966	0
2 (Tie)	1940	1
2 (Tie)	1958	1
4	1941	3
5	1951	8
6	1924	11
7	1931	14
8	1952	15
9	1977	22
10	1980	24

Table 1. Years with the lowest number of icebergs estimated to have drifted south of 48°N.

Note: Table 1 reflects the current definition of the ice year, which runs from October through September. At various times in Ice Patrol's history it has been defined differently, for example, in 1940 and 1941, the ice year was the calendar year. In both years, it was reported in IIP's annual reports that two icebergs passed south of 48°N. One of these icebergs passed south of 48°N in November 1940 and was originally counted as a 1940 observation. Here it is counted as a 1941 observation. This explains the minor differences between Table 1 and the original data in IIP annual reports.

Previous Mild Ice Seasons

This review was conducted using IIP's annual reports, which contain extensive narratives of ice and oceanographic conditions and tabulated and plotted data for each ice season. The environmental data came from a variety of sources, including oceanographic and meteorological data from IIP patrol and research vessels and volunteer reporting ships, which were asked to provide sea temperature and ice data every four hours. The sea surface temperature (SST) data were particularly useful. From these reports, IIP compiled twice-a-month SST charts, sometimes with 1000 or more reports, sometimes fewer than 100.

Prior to World War II, ice observation information was gleaned from conversations with mariners operating near Newfoundland and Labrador, especially those on sealing vessels. In fact, one of the first orders of business for an IIP vessel upon its arrival in St. John's, Newfoundland, was to visit the various vessels in port and discuss their observations. IIP also made use of an extensive network of shore observers, including Newfoundland Rangers, and coastal natives. After World War II, ice patrol used aerial reconnaissance to define the distribution of sea ice.

1924: The 1924 iceberg season was quite a surprise to IIP. Since the inauguration of the north Atlantic ice patrol shortly after the 1912 sinking of the RMS TITANIC, IIP became accustomed to active iceberg seasons. With the exception of the early World War I years of 1916 and 1917, when there were fewer reporting ships than normal, Ice Patrol had tracked several hundred to a thousand icebergs each year. In 1924, however, there was no meaningful iceberg threat to the transatlantic steamers; eleven icebergs passed south of 48°N. In April, one of the eleven reached 41°11'N latitude, but the remaining ten did not reach very far below 48°N.

The mild 1923-1924 winter led to late March sea surface temperatures over the Grand Banks that were about 3°C warmer than normal. With the exception of a few patches, there was no sea ice south of Newfoundland during the entire iceberg season. Observers on the northern Newfoundland and southern Labrador coasts reported field ice arrived a month later than normal and departed early, with a maximum extent that was far less than normal. The winds at Battle Harbor, Labrador prevailed from the east, and periods of northwesterly winds were of shorter duration than normal. There was remarkably little fog on the Grand Banks, and the patrol vessels reported good weather during the April and May cruises, a peculiar occurrence. In the latter part of May, Ice Patrol found large numbers of icebergs in the bight of Newfoundland, between Cape Bauld and Funk Island (Figure 1).

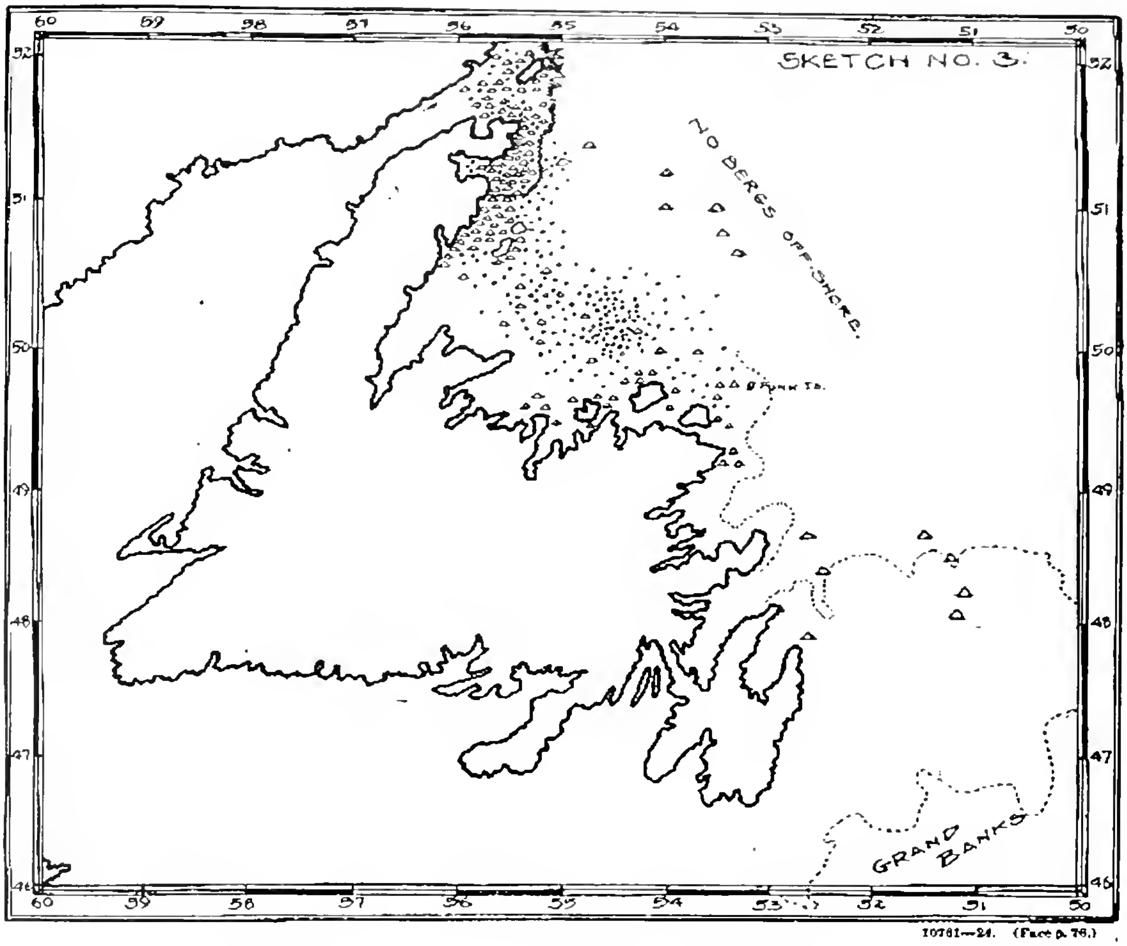


Figure 1. Distribution of icebergs in late May 1924.

1931: In 1931, 13 icebergs drifted south of 48°N, with the southernmost glacial ice seen on 3 May at 46°32'N near Cape Race. In fact, "...not a single iceberg menaced the United States-Europe steamship tracks throughout the season." As a result, continuous ice patrols were not put into effect. In February and early March, observers reported persistent, strong northeast winds blowing for 40 days. By the end of March, no pack ice or icebergs were seen drifting by St. John's. Observations made by the *General Greene,* IIP's oceanographic research vessel, in April and May 1931 indicated that in April the Grand Banks SSTs were generally warmer than normal. The May values were near normal.

By 10 April, the sea ice extended southward to the area of 60 miles east of Cape Bonavista, the southernmost extent of the season. Although no formal patrols were instituted, the *General Greene* monitored ice and oceanographic conditions near the Grand Banks throughout the spring and into the summer. The seven icebergs they saw east of Cape Bonavista during their early April cruise showed evidence of rapid deterioration. *General Greene* also conducted a research cruise to document ice and oceanographic conditions along the Labrador (4-24 July) and south Greenland coasts. In early July, they found numerous icebergs near the Strait of Belle Isle and modest numbers of icebergs within 65 miles of the

Labrador coast. While conducting eight cross-shelf oceanographic transects along the Labrador coast to the northern tip of Labrador, they found no sea ice along the Labrador coast. Their iceberg survey was somewhat hampered by poor visibility, so they believed that they did not conduct a very good iceberg census. From their discussions with natives and mariners, the ice season along the Labrador coast was light and there were prevailing onshore winds.

1940 and 1941: The early World War II years of 1940 and 1941 were each very light iceberg seasons, in both cases two icebergs were estimated to have passed south of 48°N (in the original IIP annual reports). In 1940, the southernmost glacial ice was seen at 47°42'N at the end of May. During these years, the usually extensive reporting network of transatlantic ships was largely absent. War disrupted customary transatlantic commerce, and most vessels, out of fear for their safety, did not provide radio reports of their position, course, speed, ice and environmental conditions. In neither year was it necessary to inaugurate a continuous surface vessel patrol. However, in both years, the *General Greene* carried out oceanographic measurements. Due to the lack of the normal surface patrol, they focused their attention on southern areas of the Grand Banks and the offshore branch of the Labrador Current. In 1940, *General Greene* found the Labrador Current had decidedly warmer minimum SSTs than normal, and surface waters on the Grand Banks were warmer than normal. In early July, a vessel reported many icebergs and growlers near the Strait of Belle Isle. Ice Patrol's annual report in 1941 suggests that Grand Banks sea temperatures were warmer than normal; however, there were insufficient SST data to draw charts. [Considering the risky operating environment, *General Greene's* presence on the Grand Banks in 1941 is a testament to the value IIP placed on oceanographic measurements. In fact, the *General Greene* served another role in May of that year when she picked up two lifeboats and 29 men from the *Marconi*, a steamer that had been torpedoed.]

1951: By the beginning of the 1951 iceberg season, the reporting network of volunteer ships had long since been re-established and Ice Patrol had been using aerial reconnaissance for several years. It was an extraordinary year, even among the ten extraordinarily light years of this review. Records from Argentia, Newfoundland and Goose Bay, Labrador show that the winter of 1950-1951 was one of the mildest on record with respect to snow and temperature. In February, aerial reconnaissance located few icebergs in the pack ice. In March, a series of easterly gales substantially reduced the areal extent of sea ice, which prior to that had been slightly less extensive than normal. The surface patrol vessels were placed on extended stand-by. Due in part to continued easterly winds, the April sea ice extent was well less than normal. An early April reconnaissance flight showed very meager (six small icebergs and several growlers) iceberg populations up to 56°N. Further reconnaissance in the Strait of Belle Isle showed only five icebergs and growlers. In all, six icebergs were estimated to have passed south of 48°N, and none crossed south of 46°N. Aerial reconnaissance confirmed that "...at no time during the season did there exist even a remote threat to the established steamer tracks." In May, aerial reconnaissance along the Labrador coast located fewer than 100 icebergs, most near shore. This is what makes the 1951 iceberg season so unusual. In both 1924 and 1931 there were indications of substantial iceberg populations in the bight of Newfoundland, the Strait of Belle Isle, and along the Labrador coast. The iceberg population in those areas was exceedingly sparse in 1951.

1952: For the second year in a row, surface patrol vessels were not used. The February and March sea ice extent was less than normal, and in early March, persistent easterly winds were reported. At the end of March, numerous icebergs were seen in the bight of Newfoundland. In April, many icebergs and growlers were reported in sea ice along the Labrador coast to Hamilton Inlet. Despite the presence of many icebergs north of Newfoundland and along the Labrador coast, only 12 passed south of 48°N in April, none of which moved south of 47°N. During the entire season, 14 icebergs passed south of 48°N. By May, there were no icebergs on the northern part of the Grand Banks, and only scattered icebergs in the bight of Newfoundland.

During March and April, numerous icebergs were seen in the vicinity of ocean station B at 56°30'N, 51°00'W by the Coast Guard cutters occupying the station. This was a very rare event. IIP speculated that these icebergs came from east of Cape Farewell rather than the Labrador side of the Labrador Sea, but, of course, the actual source is unknown.

1958: One iceberg passed south of 48°N in 1958. The year started with three months of persistent onshore winds along the Labrador coast and a mild Newfoundland winter. As a result, the extent of the sea ice near Newfoundland and Labrador was considerably less than normal and April SSTs were about 2°C warmer than normal on the Grand Banks. The surface patrol vessels were placed on standby. The southernmost extent of sea ice occurred on 29 April when a belt of broken block ice was sighted off Baccalieu Island. At the end of May, ships using the Strait of Belle Isle reported many large icebergs between 50°W and 52°W on their tracks (about 52°N). Many icebergs were reported throughout the month of June north of 50°N, and eastward for 200 miles. Between 10-21 February an ocean station Bravo vessel sighted and tracked three icebergs near 56°30'N, 51°00'W.

1966: This year is known as the year with no icebergs, with the southern most iceberg reported at 49°05'N. The December and January storm tracks were well south of normal, resulting in strong onshore winds and warmer than normal air temperatures in Newfoundland and southern Labrador. A major storm on 29 January brought hurricane force winds to the region causing much ice destruction. The maximum southward extent of the sea ice for the entire year was a narrow tongue to 47°30'N that occurred on 17 March. By April, there were only narrow sea ice bands between Newfoundland and Hamilton Inlet. Higher than average SSTs were observed all over the IIP oceanic areas of interest during the season. Onshore winds persisted through March and April, which resulted in above-normal air temperatures in Newfoundland and Labrador coastal areas. Two iceberg surveys conducted along the Labrador coast, one on 14 April and the other on 7 June, located 432 and 297 icebergs, respectively. The IIP oceanographic research vessel *Evergreen* completed the first of two hydrographic surveys on 8 April and found "...utter absence of any defined Labrador Current."

1977: Warmer than normal air temperatures and onshore winds along the Labrador coast in fall and early winter inhibited early sea ice development. Despite the slow start, at the end of January, the sea ice edge reached Cape Bonavista, which is approximately a normal southward extent. The eastward extent was less than normal for this time of year. A limited pre-season flight in January found 34 icebergs between 55°N and 60°N, while another from the end of February to early March found 145 medium and large icebergs south of 63°N, about half the size of the normal iceberg population for that time of year. From these observations, it was evident that the 1977 iceberg season was going to be light. A series of March storms broke up and spread out the sea ice, and at month's end a rapid retreat began, aided by above-average air temperatures and predominantly onshore winds along the Labrador coast. By late May, the sea ice edge had retreated to the vicinity of the Strait of Belle Isle, leaving a small iceberg population between 50°N and 52°N. In 1977, 22 icebergs passed south of 48°N, all before the end of April.

1980: The early winter of 1979/1980 was characterized by a series of intense storms, one of which brought record precipitation and hurricane force winds to the region. Prevailing northwest winds dominated Labrador. The early development of sea ice was slightly ahead of the norm, but by the end of January, sea ice conditions returned to normal. This year was unique in that the southernmost and easternmost iceberg for the entire season were seen very early in the year. In January, the southernmost iceberg was seen at 47°40'N, 47°40'W and the easternmost iceberg was seen at 48°10'N, 45°30'W. The sea ice began its retreat in early March, about a month earlier than usual, due in large part to the passage of two very strong storms that passed through the region. In 1980, 24 icebergs passed south of 48°N. Only 45 ice reports were received from ships during the entire season.

Common Characteristics of Mild Iceberg Years

Four factors characterize many of the mild iceberg years:

- mild winters in Newfoundland and Labrador
- persistent onshore winds in the winter
- warmer than normal sea surface temperatures
- sea ice arrives late, departs early and is not very extensive

These characteristics are usually associated with the negative phase of the North Atlantic Oscillation (NAO), which describes the dominant variability in the atmospheric circulation in the North Atlantic. (See, for example, Hurrell, 1995). A negative NAO phase is associated with a weakening of the Icelandic Low and the southward displacement of its mean position. In this state, the winter storms track south of Newfoundland, resulting in east and northeast winds and relatively warm, moist maritime air over Labrador and Newfoundland. Seven of the eleven mildest years in Ice Patrol's history had strongly negative (< -1.0) NAO index values (Table 2). Three years (1931, 1952, and 1980) were neutral NAO years, with the index between –1.0 and +1.0.

Many of the common factors of a mild season were present in 1999. For example, in March, air temperatures in Labrador and east Newfoundland were 4°C to 6°C warmer than normal, and the thickness and areal extent of sea ice were much less than normal. However, among the 11 mildest iceberg years in IIP's history, 1999 stands alone in one regard. Remarkably, the winter NAO index for 1999 was 1.70, indicating a positive NAO phase.

In the historical record, there appear to be two kinds of mild years: those in which very few icebergs are found near Newfoundland (1951 and 1966) and those with significant populations in the bight of Newfoundland and the Strait of Belle Isle (1924, 1931, 1952, and 1958). This suggests two fundamentally different processes, one related to the supply of icebergs to the Newfoundland area, and the other related to the movement once they are in the vicinity of the Strait of Belle Isle.

One thing is certain: an iceberg year like 1999 leads to a greater respect for the variability of the iceberg threat to transatlantic shipping and the complexity of causal factors.

RANK	YEAR	NAO INDEX*	ICEBERGS
1	1966	-1.69	0
2 (Tie)	1940	-2.86	1
2 (Tie)	1958	-1.02	1
4	1941	-2.31	3
5	1951	-1.26	8
6	1924	-1.13	11
7	1931	-0.16	14
8	1952	0.83	15
9(Tie)	1977	-2.14	22
9(Tie)	1999	1.70	22
11	1980	0.56	24

Table 2. Years with the lowest number of icebergs estimated to have drifted south of 48°N and winter (Dec-Mar) NAO index.

Note: The NAO Index used here is based on the difference of the normalized sea level pressures between Lisbon, Portugal and Stykkisholmur/Reykjavik, Iceland. (Source: University Corporation for Atmospheric Research Climate and Global Dynamics Division)

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