Homeland Security

United States Coast Guard

Report of the International Ice Patrol in the North Atlantic

2010 Season
Bulletin No. 96
CG-188-65

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Season of 2010

CG-188-65

Forwarded herewith is Bulletin No. 96 of the International Ice Patrol, describing the Patrol's services and ice conditions during the 2010 season. With only one iceberg crossing 48° N, this was one of the lightest seasons on record, and the third time in the last six years that icebergs did not threaten transatlantic shipping lanes.

Ice Patrol vigilantly monitored iceberg danger and issued weekly products but conditions never warranted issuing daily products. The Ice and Environmental Conditions section presents a discussion of the meteorological and oceanographic conditions that contributed to the light season. Transatlantic shipping benefited by saving hundreds of miles per voyage compared to an average season transit. Vigilant monitoring was fundamental to ensuring the safe passage of hundreds of vessels.

During 2010, Ice Patrol, the Canadian Ice Service, and the U.S. National Ice Center signed a new collaborative agreement, formalizing their international partnership as the North American Ice Service. Ice Patrol and the Canadian Ice Service evaluated a new iceberg model as described in Appendix C. Also in 2010, the first ice reconnaissance detachment using the U.S. Coast Guard's new HC-144A aircraft deployed to Newfoundland for testing and evaluation of the platform for iceberg reconnaissance as described in Appendix D.

On behalf of the dedicated men and women of the International Ice Patrol, I hope you enjoy reading this report on the 2010 season.

L. K. Mack
Commander, U. S. Coast Guard
Commander, International Ice Patrol

International Ice Patrol
2010 Annual Report

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Cover Photograph: HC-144A Maritime Patrol Aircraft. In 2010, the HC-144A was used for the first time for the Ice Patrol mission. See Appendix D for the Platform Evaluation.

Abbreviations and Acronyms

AIS	Automated Information System
AOR	Area of Responsibility
ATC	Aviation Training Center
BAPS	iceBerg Analysis and Prediction System
C-130J	Non-missionized C-130 long-range reconnaissance aircraft
CALIB	Compact Air-Launched Ice Beacon
CAMSLANT	Communications Area Master Station Atlantic
CCG	Canadian Coast Guard
CIS	Canadian Ice Service
D1	First Coast Guard District
ECAS	Air Station Elizabeth City
ELTA	Brand name of radar system on HC-130J
GMES	Global Monitoring for Environment and Security
HC-130J	Missionized C-130 long-range reconnaissance aircraft
HC-144A	Medium-range Maritime Patrol Aircraft
HF	High Frequency
HMCS	Her Majesty’s Canadian Ship
IIP	International Ice Patrol
IRD	Ice Reconnaissance Detachment
KT	Knot or Nautical Mile Per Hour
LAKI	Limit of All Known Ice
M	Meter
MB	Millibar
MCTS	Marine Communications and Traffic Service
M/V	Motor Vessel
NAFO	Northwest Atlantic Fisheries Organization
NAIS	North American Ice Service
NAO	North Atlantic Oscillation
NIC	National Ice Center
NM	Nautical Mile
NTIS	National Technical Information Service
NWS	National Weather Service
OPCEN	Operations Center
PAL	Provincial Aerospace Limited
RADAR	Radio Detection and Ranging (also radar)
RMS	Royal Mail Steamer
SAIC	Science Applications International Corporation

Abbreviations and Acronyms (continued)

SOLAS	Safety of Life at Sea
SST	Sea Surface Temperature
TAC	Total Accumulated Ice Coverage
WOCE	World Ocean Circulation Experiment

Introduction

This is the 96th annual report of the International Ice Patrol (IIP). IIP was under the operational control of Commander, U.S. Coast Guard First District. The report contains information on IIP operations, environmental conditions, and iceberg conditions in the North Atlantic during 2010. The Ice Patrol was formed after the RMS Titanic sank on 15 April 1912. Since 1913, except for periods of World War, Ice Patrol has monitored the iceberg danger on and near the Grand Banks of Newfoundland and has broadcast the Limit of All Known Ice (LAKI) to mariners. The activities and responsibilities of IIP are delineated in U.S. Code, Title 46, Section 738, and the International Convention for the Safety of Life at Sea (SOLAS), 1974.

IIP conducted aerial reconnaissance from St. John's, Newfoundland to search for icebergs in the southeastern, southern, and southwestern regions of the Grand Banks. In addition to IIP reconnaissance data, Ice Patrol received iceberg reports from other aircraft and mariners in the North Atlantic. At the Operations Center (OPCEN) in New London, Connecticut, personnel analyzed iceberg and environmental data and used the iceBerg Analysis and Prediction System (BAPS) computer model to predict iceberg drift and deterioration. Based on the model's prediction, IIP produced the ice chart and text bulletin once per week in 2010 due to very light ice conditions. In addition to these routine broadcasts, IIP responded to individual requests for iceberg information.

RADM Joseph L. Nimmich was Commander, U.S. Coast Guard First District until May 2010 when he was relieved by RADM Daniel A. Neptun. CDR Scott D. Rogerson was Commander, International Ice Patrol until June 2010 when he was relieved by CDR Lisa K. Mack.

For more information about the International Ice Patrol, including historical and current ice bulletins and charts, visit our website at www.uscg-iip.org.

Summary of Operations

As mandated by SOLAS, IIP monitors the iceberg danger near the Grand Banks of Newfoundland from 15 February to 01 July. This period is regarded as the Ice Season and has traditionally been defined as such because the Grand Banks are generally free of icebergs from August through January. While the SOLAS Ice Season extends from February through July, IIP reporting services traditionally commence whenever iceberg populations pose a threat to the primary shipping routes between Europe and North America and continue until the threat has passed. IIP's weekly product distribution is scheduled to commence the first Friday following 15 February and continues until ice conditions are severe enough to necessitate transmission of daily products or until season end. Although the Ice Season timeframe typically references IIP's busiest operational period, the IIP OPCEN processes ice information year-round. These activities are evidenced by the large number of voluntary information reports IIP receives from merchant vessels each year. These reports are sent in response to a long-standing IIP request for captured within the Ice Year timeframe that is marked from 01 October of the previous year until 30 September of the current year.

During the 2010 Ice Year, IIP actively monitored the iceberg danger to transatlantic shipping in its Area of Responsibility (AOR), defined as the region bounded by 40°N, 50°N, 39°W, and 57°W (**Figure 1**). IIP began issuing weekly products on Friday, 19 February. Due to unusually light ice conditions, only weekly products were distributed through 23 July. Iceberg populations were such that daily products were not required in 2010.

Information and Ice Reports

A critical factor contributing to IIP's successful history is the support received from the maritime community. This support includes information on weather conditions, sea

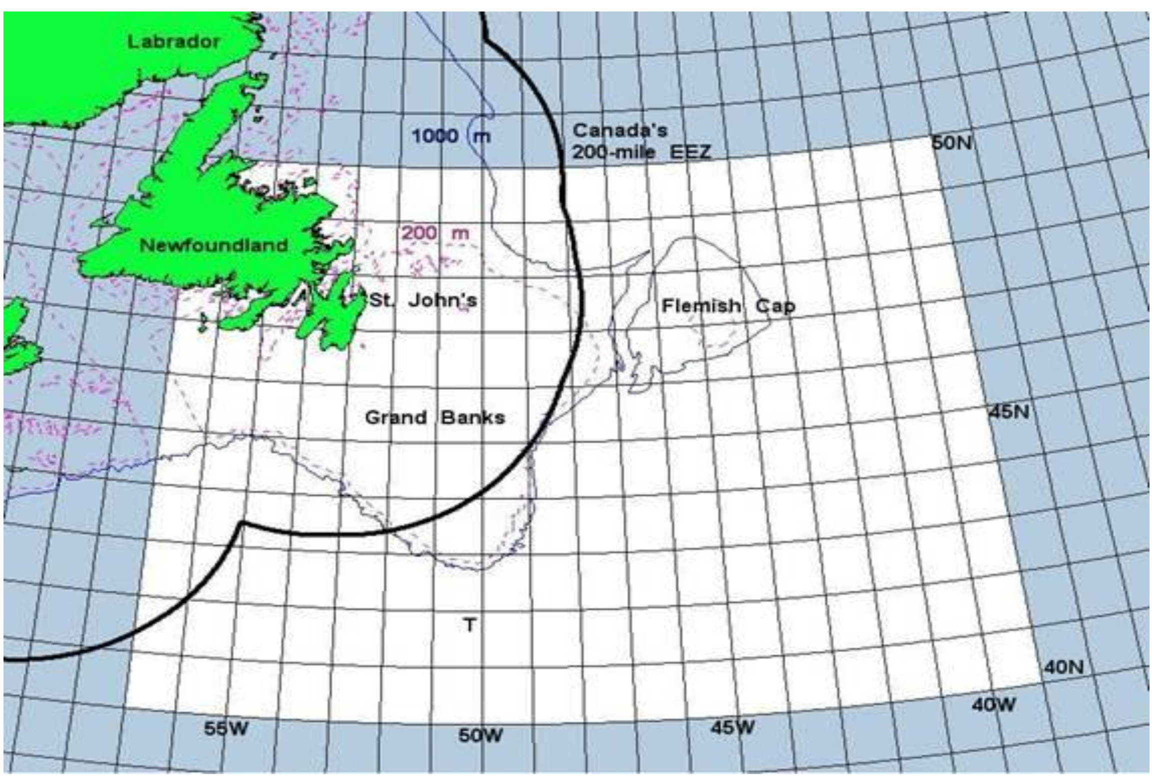

Figure 1. IIP's Area Of Responsibility. **T** indicates the location of the sinking of *Titanic*.

surface temperatures, and ice sightings from any vessel transiting within or near the Grand Banks of Newfoundland. Receiving on-scene and near real-time information helps ensure the accuracy of IIP products. All ships that provided reports including weather, sea surface temperature, ice, and/or stationary radar target reports during the 2010 Ice Year are listed in Appendix B. Although a majority of the reports were received from merchant vessels, IIP also received valuable information from several other sources. **Figure 2**, **Column 1** provides the breakdown of the various sources for all information reports received throughout the 2010 Ice Year.

During the 2010 Ice Year, the IIP OPCEN received, analyzed, and processed 791 information reports concerning oceanographic, atmospheric, and/or ice conditions throughout IIP's AOR. These reports were generated by various land, sea, air, and space platforms including: merchant ships and Canadian Coast Guard vessels operating within or near the Grand Banks of Newfoundland, IIP reconnaissance flights, commercial aerial reconnaissance contracted by the Canadian Ice Service (CIS) and provided by Provincial Aerospace Limited (PAL), and satellite data processed by C-CORE, a private company based in St. John's.

Of the 791 information reports received by IIP, 238 reports contained some type of ice information (i.e. reporting sizes, shapes, and/or positions of icebergs and stationary radar targets). Commercial reconnaissance was responsible for the greatest number of ice reports with 153 (64%) reports. Merchant ships tallied the second highest number with 45 (19%) ice reports. IIP aerial iceberg reconnaissance flights provided 13 (6%) ice reports. The Canadian Government, including Canadian Coast Guard vessels, Canadian Forces aircraft, and the Canadian Ice Service, combined to deliver 19 (8%) ice reports. Various other sources, including scientific research vessels, fishing vessels, and one passenger vessel combined to relay the remaining eight (3%) ice reports. The breakdown by reporting source of all ice reports processed by IIP in 2010 is illustrated in **Figure 2**, **Column 2**.

The 238 ice reports identified 3,284 individual objects including icebergs, bergy bits, growlers, and stationary radar targets. Although 3,284 individual objects were reported to IIP, only 402 objects were merged (added or re-sighted) by IIP to the iceBerg Analysis and Prediction System (BAPS) iceberg drift and deterioration model.

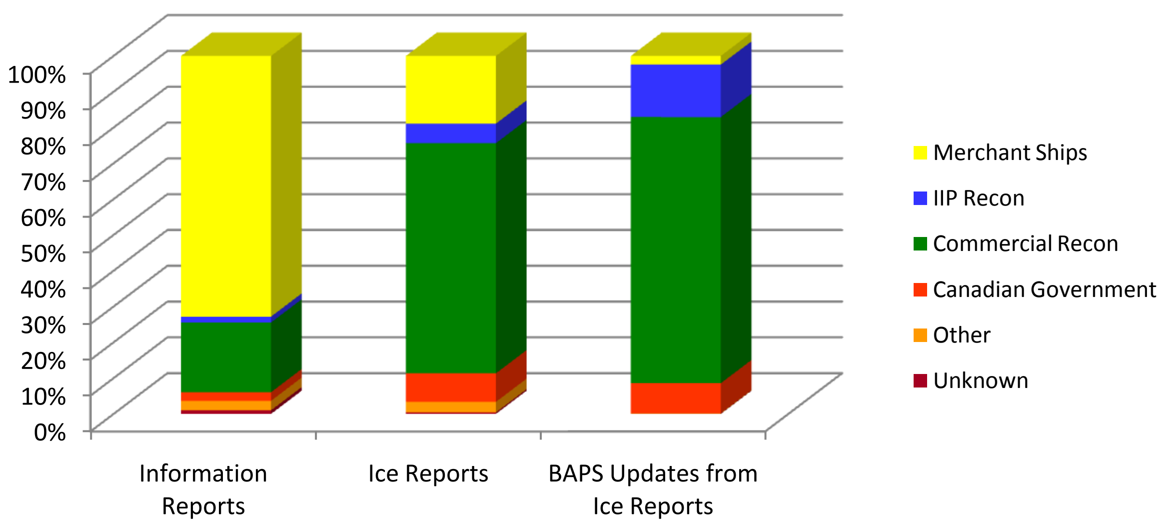

Figure 2. Distribution of information reports processed, by reporting source, during the 2010 Ice Year.

The disparity between the number of reported and merged objects illustrates two important points regarding IIP operations.

First, each ice information report is judged for accuracy and timeliness to ensure that only the most reliable information is used to populate the iceberg drift and deterioration model and to generate IIP products. Several factors come into play during this evaluation, including atmospheric and oceanographic conditions, recent reconnaissance in the area, method of detection, and any other amplifying information relayed with the ice report. This standard is applied to all ice reports, even IIP's own reconnaissance. Second, because of the unusually light ice conditions throughout 2010, most icebergs were detected and drifted solely within CIS's AOR, i.e. the area north of 50°N and/or west of 55°W and were added or re-sighted to BAPS by CIS personnel. CIS's efforts to monitor the iceberg dangers around northern Newfoundland, the Strait of Belle Isle, and along the Labrador coast resulted in 2,322 icebergs, bergy bits, growlers, and radar targets being merged to BAPS.

In total, the work of both ice operations centers (IIP and CIS), accounted for 2,724 updates to BAPS throughout the 2010 Ice Year (**Figure 2**, **Column 3**). The 2,724 updates to the model represented 2,383 distinct icebergs, bergy bits, growlers, and radar targets (i.e. those objects assigned a unique number in the BAPS iceberg database) owing to the fact that some individual objects may have been sighted or detected multiple times. Only 50 distinct objects were sighted, detected, or predicted to have drifted into IIP's AOR.

LAKI Iceberg Sightings

In order to meet SOLAS mandates, IIP develops a LAKI in order to inform the mariner of the southern, eastern, southeastern, and southwestern limit of the iceberg population. During the 2010 Ice Season, IIP did not create a LAKI or distribute daily products. Iceberg populations were light within IIP's AOR throughout the season, and only one iceberg was modeled to have drifted south of 48°N, the latitude that marks the nominal northern extent of the trans-Atlantic shipping lanes.

Products and Broadcasts

IIP issued a weekly ice chart and bulletin each Friday from 19 February to 23 July stating that IIP was monitoring iceberg conditions. In addition, the chart numerically displayed the current iceberg population density in each one degree of latitude by one degree of longitude. In 2010, IIP transmitted 23 scheduled ice bulletins via Inmarsat-C. All scheduled bulletins reached Inmarsat-C SafetyNET on time or prior to 1200Z. The on-time delivery percentage for Ice Charts was 100%. Ice Charts were broadcast three times daily at 0438Z, 1600Z, and 1810Z.

Note: Information concerning product format and distribution methods can be found in IIP's annual Announcement of Services, on the IIP webpage at www.uscg-iip.org, or in NGA Publication 117.

Safety Broadcasts

Any report of an iceberg or stationary radar target near or beyond the published LAKI challenges the accuracy of IIP products and is a potential threat to safe navigation. When such a report is received, IIP transmits an unscheduled safety broadcast to mariners to report the location and type of object (iceberg or radar target) sighted or detected. During the 2010 Ice Season, IIP did not establish a LAKI. Therefore, no Safety Broadcasts were required.

Historical Perspective

To determine the severity of the Ice Season, IIP uses two traditional measurements. The first is season length, measured by the number of days daily products are issued. The second measurement is the number of icebergs crossing south of 48°N. This number includes icebergs initially sighted or detected south of 48°N as well as those originally sighted or detected further north that drifted south of 48°N, as modeled by BAPS.

Due to light iceberg conditions, the 2010 Ice Season did not warrant daily products. In 2010, only one iceberg (not including bergy bits or growlers) was estimated to have drifted south of 48°N. This is the fourth time since 1983 (1999, 2005, 2006, and 2010) that ice conditions have not necessitated the release of daily ice warnings. 1983 through present day represents IIP's modern aerial reconnaissance era when using aircraft equipped with radars for iceberg detection became standard. In terms of the number of icebergs crossing south of 48°N, the 2010 Ice Season is among the lowest. Only in 2006, when no icebergs were modeled south of 48°N, did IIP track fewer icebergs into the transatlantic shipping lanes (**Figure 3**, **Blue Columns**).

Historically speaking, since 1900, the 2010 Ice Season was one of the lightest recorded. As calculated from 110 years of iceberg data, 2010 ice conditions were well below the seasonal average of 483 icebergs drifted or detected south of 48°N. For the period from 1900 until present, 2010 is tied with 1940 and 1958 as the third lightest ice season.

Canadian Support

As they do every year, the Canadian Government generously supported IIP during 2010. CIS shared valuable reconnaissance data, including iceberg and information reports from Canadian Coast Guard and Canadian Forces assets, critical environmental data from the Canadian Meteorological Centre, and most importantly, their sea ice and iceberg expertise. The synchronized iceberg-modeling database, now in its fifth year of operation, continued to ensure that all ice information received by IIP or CIS was quickly merged and accurately reflected on both organizations' ice products.

IIP also appreciated the critical support from PAL who continued to share valuable ice observation data throughout the 2010 Ice Season. Their reconnaissance flights for CIS and the Canadian Department of Fisheries and Oceans provided critical information on the iceberg population.

IIP thanks C-CORE for continuing to provide satellite-derived iceberg data and for their ongoing efforts to improve their iceberg detection capabilities. IIP looks forward to working with C-CORE in 2011 to operationally implement RADARSAT-2 data.

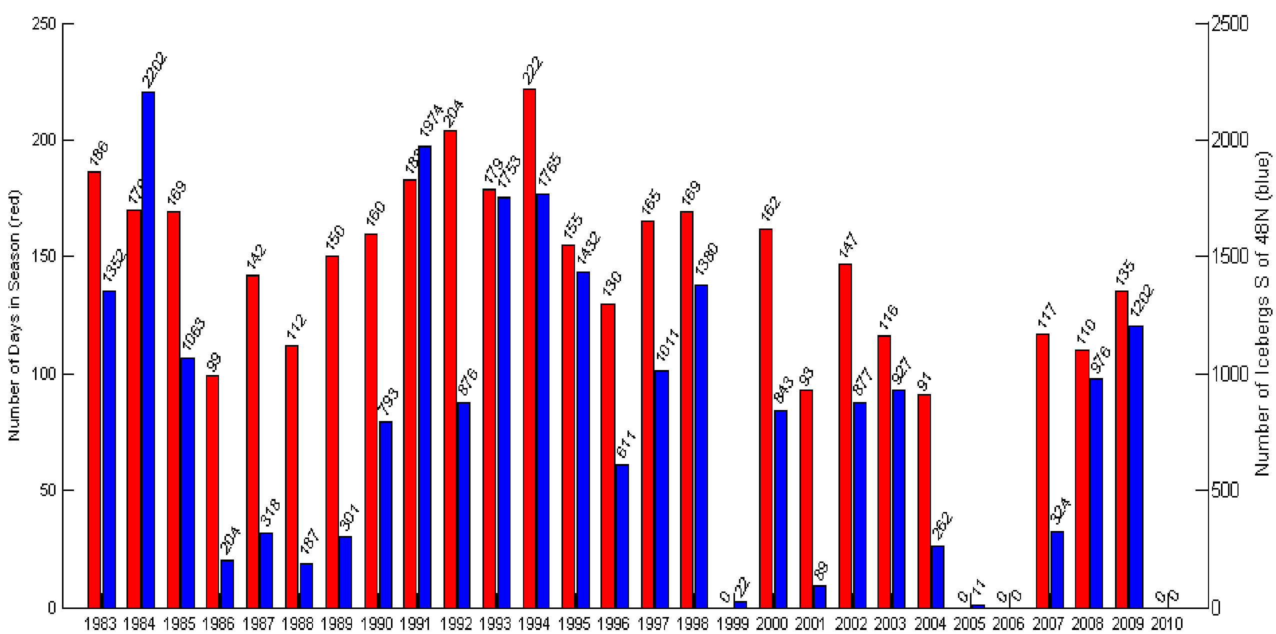

Figure 3. 1983-2010 Season Severity Chart. Ice Season length (red) is measured by the number of days IIP issued daily products. Note: Daily products were not transmitted in 1999, 2005, 2006, and 2010 due to very light ice conditions. The number of icebergs south of 48°N (blue) does not include bergy bits or growlers.

Iceberg Reconnaissance and Oceanographic Operations

Ice Reconnaissance Detachment

The Ice Reconnaissance Detachment (IRD) is a sub-unit under Commander, International Ice Patrol which is partnered with Coast Guard Air Station Elizabeth City (ECAS). During the 2010 Ice Season, seven IRDs deployed to observe and report icebergs, sea ice, and oceanographic conditions on and near the Grand Banks of Newfoundland. All observations were transmitted to the IIP OPCEN in New London, CT where they were entered into BAPS and processed. IIP's ice products were created and distributed to mariners operating in IIP's area of responsibility as described in the **Summary of Operations** chapter.

The Pre-Season IRD departed on 16 February to conduct official meetings with IIP partners in Elizabeth City, NC and St. John's, NL and to determine the early season iceberg distribution. The Post-Season IRD was conducted in mid-July, concluding 2010 IIP deployments to Newfoundland.

Throughout the 2010 Ice Season, IRDs operated primarily out of IIP's forward operating base in St. John's for a total of 45 days conducting 14 iceberg patrols. IRD 4 operated out of Halifax, Nova Scotia for a total of three days to conduct the Titanic Memorial ceremony and out of Goose Bay, Labrador for a total of three days conducting one iceberg reconnaissance patrol due to inclement weather in St. John's. A summary of 2010 IRD operations is provided in **Table 1**.

Aerial Iceberg Reconnaissance

A detailed description of IIP's reconnaissance strategy is provided on IIP's website at http://www.uscg-iip.org in the FAQ section. Due to the consistently inclement environmental conditions in IIP's AOR, detecting and classifying targets is a perpetual challenge for IRDs. It is for this reason that the use of radar is critical to IIP operations. In times of reduced visibility, IIP relies heavily on the detection and classification capability of the ELTA-2022 radar as the primary means of conducting iceberg reconnaissance. In no-visibility conditions, the ELTA's imaging capability is relied upon as the primary means of classifying targets.

IRD	Deployed Days	Iceberg Patrols	Transit Flights	Logistics Flights	Flight Hours
PRE	9	2	3	0	35.3
1	Cancelled				
2	9	3	2	1	18.7
3	Cancelled				
4	6	1	4	0	22.0
5	8	3	2	0	31.8
5.5	6	2	2	0	29.9
6	Cancelled				
7	8	3	2	0	33.0
8	Cancelled				
9	Cancelled				
10	Cancelled				
11	Cancelled				
12	Cancelled				
13	Cancelled				
14	Cancelled				
POST	4	1	2	0	20.7
TOTAL	**50**	**15**	**17**	**1**	**191.4**

Table 1. 2010 IRD Summary.

The majority of 2010 aerial iceberg reconnaissance operations were conducted using HC-130J (missionized) long-range reconnaissance aircraft provided by ECAS. Due to schedule constraints resulting in reduced HC-130J availability, the reconnaissance during IRD 5.5 was conducted using the HC-144A medium-range reconnaissance aircraft provided by Coast Guard Aviation Training Center (ATC) Mobile, AL. A detailed description of this IRD is provided in Appendix D of this report.

The HC-130J aircraft is equipped with the ELTA-2022 360° X-Band Radar capable of detecting and classifying surface targets and the APN-241 Weather Radar capable of detecting surface targets but not classifying them. The HC-130J is also equipped with an Automated Information System (AIS) receiver

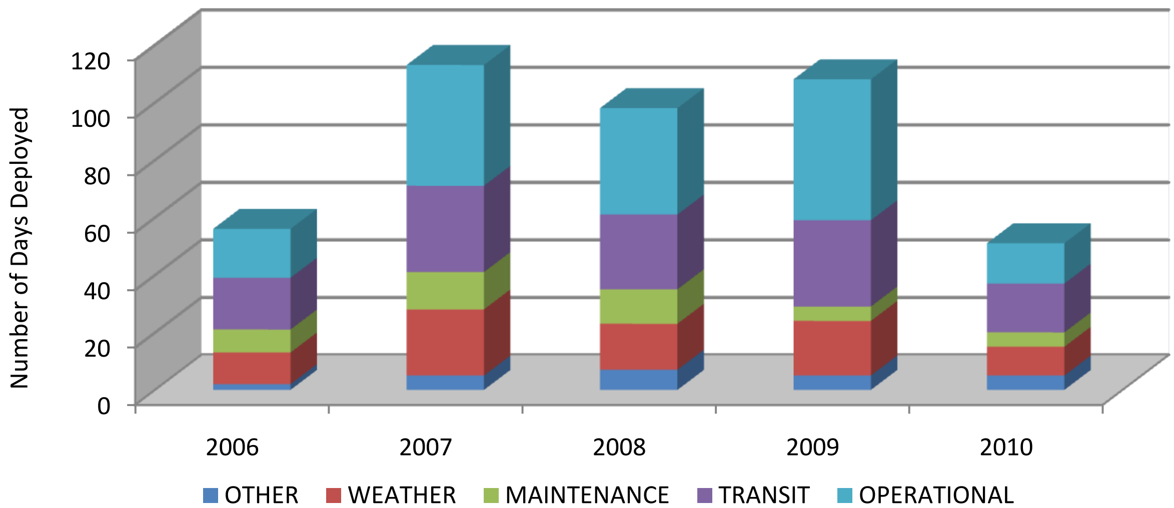

Figure 4. Five-year IRD Deployment Day Summary.

as an integrated component of the HC-130J mission system to assist in target discrimination. The HC-144A aircraft is equipped with a Telephonics APS-143 360° Radar capable of detecting and classifying surface targets, and is also equipped with an AIS receiver in a similar configuration as the HC-130J to assist in target discrimination.

2010 marked the completion of the missionization process for all six ECAS C-130J aircraft. However, maintaining full functionality of the new mission system on all aircraft has proven challenging due to the limited availability of replacement parts. Despite these challenges, as a result of the outstanding support provided by ECAS, IIP accrued only four maintenance days during the 2010 Ice Season, the same number of maintenance days accrued in 2009. **Figure 4** provides a five-year breakdown of IRD deployment days.

The increased functionality of the HC-130J mission system during the 2010 season greatly enhanced reconnaissance effectiveness. IIP conducted 15 radar and visual patrols and no visual only patrols. This is a marked improvement from the 2009 season in which 36 of 53 patrols were conducted using only visual reconnaissance. **Table 2** shows a five-year radar/visual patrol comparison. **Table 3** shows a five-year comparison of yearly totals for track miles flown and area coverage.

Year	Number of Radar and Visual Patrols	Number of Radar Only Patrols	Number of Visual Only Patrols	Total Number of Patrols
2006	17	0	0	17
2007	38	2	0	40
2008	34	3	0	37
2009	16	0	37	53
2010	15	0	0	15

Table 2. Five-year Radar and Visual Only Patrol Comparison.

Year	Primary Platform	Planned Track Spacing	Total Track Miles Flown (nautical miles)	Total Area Coverage (square miles)
2006	HC-130H	30 NM	18,130	1,087,800
2007	HC-130H	30 NM	52,977	3,178,626
2008	HC-130H	30 NM	53,690	3,221,370
2009	C-130J	10 NM	80,677	1,883,778
2010	HC-130J	20 NM	20,451	818,040

Table 3. Five-year Track Mile and Area Coverage Comparison.

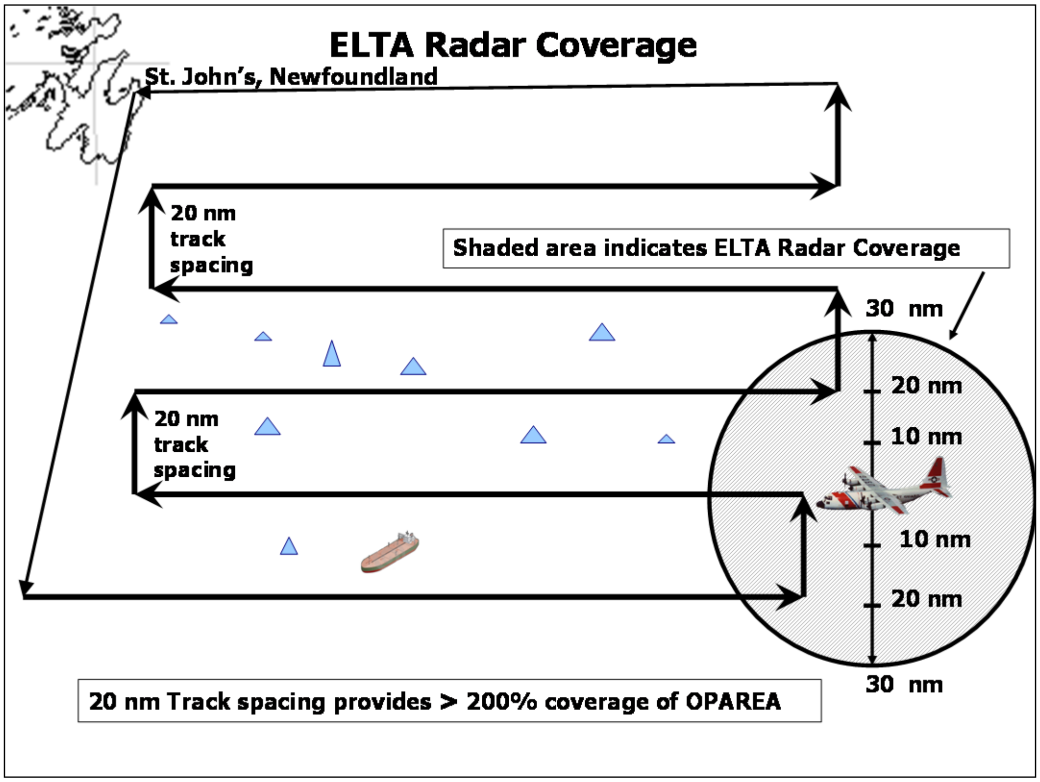

Figure 5. IIP Radar Reconnaissance Plan.

In 2010, availability of 360° coverage provided by the ELTA Radar allowed IIP to use 20 NM track spacing operating the radar in the 30NM range to achieve greater than 200% radar coverage on each patrol leg (**Figure 5**). IIP maintained 20 NM track spacing throughout the season in an effort to maintain the integrity of patrols until further data analysis and probability of detection testing of the ELTA-2022 radar can be conducted.

In 2010, IRDs detected a total of 351 icebergs. Nearly 35% of the icebergs were detected by both radar and visually. The remaining icebergs were either detected by radar only (37%) or by visual means only (28.5%) (**Figure 6**). Icebergs can be detected by visual means only on both visual only patrols (patrols with visibility but no working radar) and radar and visual patrols (patrols with visibility and a working radar). **Figure 7** displays the number and types of targets that IRDs detected during 2010.

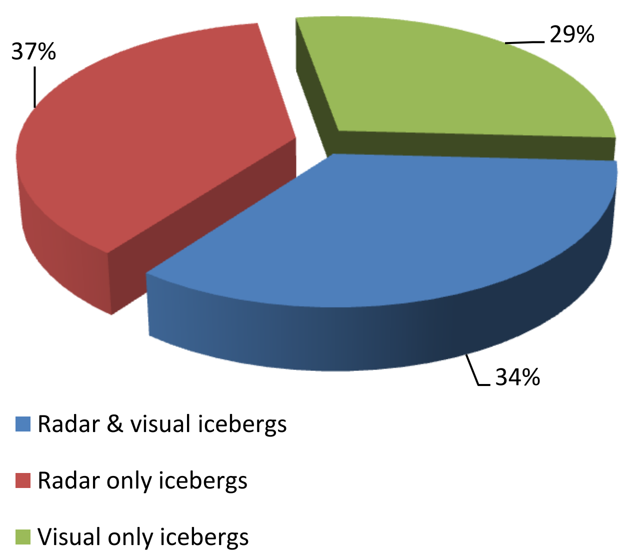

Figure 6. Breakdown of icebergs by detection method.

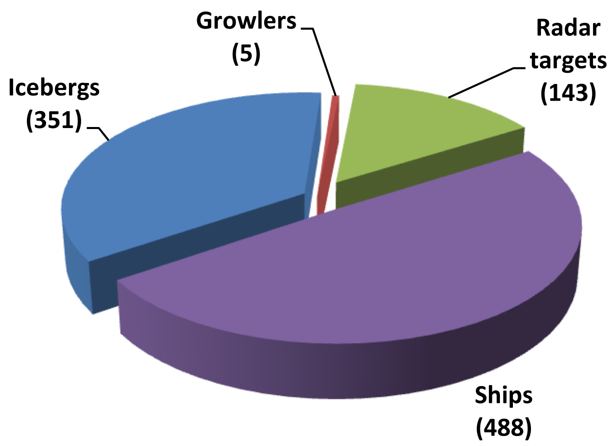

Figure 7. Breakdown of target type and number detected.

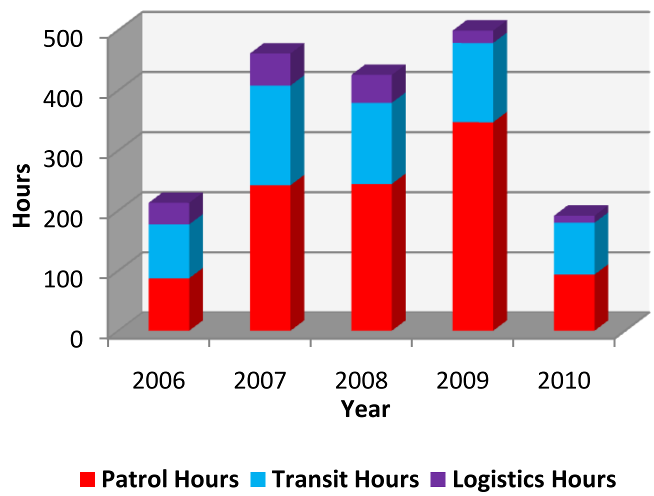

Figure 8. Summary of flight hours (2006-2010).

2010 Flight Hours

In addition to the 15 IRD iceberg patrols flown during the 2010 Ice Season, 17 transit flights were conducted from ECAS to and from St. John's. Three transit flights were conducted during the Pre-Season IRD to conduct training and meetings at ECAS in preparation for the commencement of the Ice Season. Four transit flights were conducted during IRD 4 due to a mechanical problem encountered in Halifax, Nova Scotia. The original aircraft deployed on IRD 4 had to be returned to ECAS and exchanged for a different aircraft to provide a platform capable of conducting iceberg reconnaissance. **Figure 8** shows the breakdown of the 191.7 flight hours used during the 2010 Ice Season for IIP operations. It is important to note the drastic reduction in patrol hours from 2009 to 2010. The combination of extremely light ice conditions with a fully functioning radar explains this significant reduction. A comparison of flight hours to number of icebergs that drifted south of 48°N from 2001 to 2010 is shown in **Figure 9**. During the 2010 Ice Season, First Coast Guard District (D1) did not request IIP to conduct Northwest Atlantic Fisheries Organization (NAFO) patrols that were conducted in 2009. In addition, there were no radar test flights conducted in 2010.

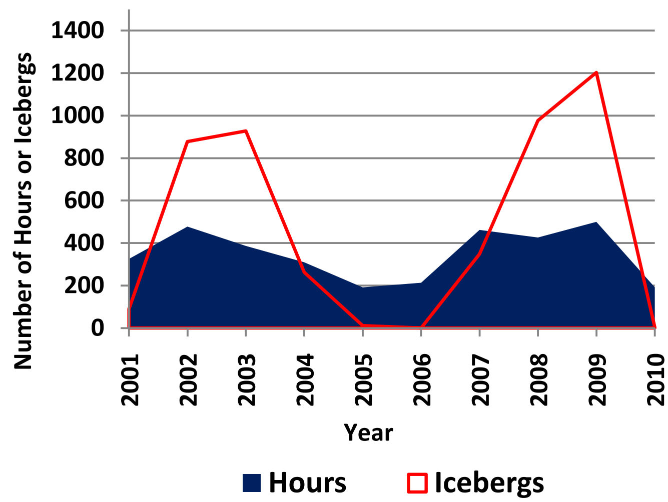

Figure 9. Flight hours versus icebergs south of 48°N (2001-2010).

Reconnaissance Challenges

The Grand Banks are a productive fishing ground frequented by fishing vessels, ranging from 20 to over 70 meters in length. Determining whether an ambiguous radar contact is an iceberg or a stationary vessel is particularly difficult with small targets in low sea states. These contacts often present similar radar returns and cannot easily be differentiated. Therefore, when a radar image does not present distinguishing features, IIP classifies the contact as a radar target (R/T) in hopes of being able to identify it on a subsequent pass or patrol.

The Grand Banks region continues to be rapidly developed for its oil reserves with new exploration conducted daily and many prospects of future exploration in the region. The escalated drilling has increased air and surface traffic in IIP's AOR, further complicating target identification. However, this difficulty is offset by the information reports this traffic provides. Reports from ships, aircraft, and drilling platforms greatly aid IIP in the creation of a LAKI that is as accurate and reliable as possible.

Satellite Iceberg Reconnaissance

IIP continued to cooperate with C-CORE in the analysis and verification of iceberg detections using RADARSAT II satellite imagery. Although there were no opportunities to use coincident reconnaissance flights to validate satellite detection data using ice detections, C-CORE was able to make improvements to their detection algorithm by correlating satellite detections with non-ice targets in the area. C-CORE is affiliated with Memorial University in St. John's, NL and has been working in cooperation with IIP since 2003. IIP will continue to evaluate satellite information provided by C-CORE during the 2011 Ice Season.

IIP initiated a space-borne reconnaissance study in the summer of 2010 to analyze the availability and feasibility of using commercial satellites to supplement future IIP operations and reduce IIP's dependence on USCG aircraft. A detailed report will be provided to IIP by Science Applications International Corporation (SAIC), the government contractor hired to conduct the study. A summary of the findings will be provided in the 2011 Annual Report.

Oceanographic Operations

IIP deploys World Ocean Circulation Experiment (WOCE) drifting buoys on and near the Grand Banks of Newfoundland. WOCE drifting buoys provide near real-time ocean current information that is used to modify the historical current database within BAPS to improve the accuracy of the iceberg drift calculated by the model. They also provide sea surface temperature (SST) information that is incorporated into SST models used by the U.S. Navy. The combined data is used by the BAPS along with other environmental data described in the **Summary of Operations** chapter to forecast the drift and deterioration of icebergs on and near the Grand Banks of Newfoundland. Updates are performed by the IIP OPCEN daily when WOCE data is available in the area. WOCE drifting buoys are air-deployed using Coast Guard aircraft and ship-deployed through cooperation with the CCG and merchant vessels operating in the area. Air-deployed WOCE drifting buoys are purchased by IIP and prepared and deployed through cooperative efforts by IIP and ECAS personnel. Buoy deployments are conducted in conjunction with IRD iceberg reconnaissance operations when flying patrols near desired drop locations, usually in the offshore branch of the Labrador Current. Air-deployments are normally conducted to deploy WOCE drifting buoys drogued at 50m, but are occasionally conducted to deploy WOCE drifting buoys drogued at 15m.

Ship-deployed WOCE drifting buoys are purchased and prepared by IIP personnel and deployed by vessels of opportunity, usually CCG vessels operating out of St. John's, NL. As part of a volunteer operation, these vessels of opportunity deploy WOCE drifter buoys at locations requested by IIP, usually in the inshore branch of the Labrador Current and on the Grand Banks. Ship-deployments are normally conducted to deploy WOCE drifting buoys drogued at 15m, but are occasionally conducted to deploy WOCE drifting buoys drogued at 50m. The ship deployments save significant amounts of flight time and money.

In 2010, IIP air-deployed three WOCE drifting buoys from USCG HC-130J aircraft. No WOCE drifting buoys were deployed from CCG vessels during the season due to the extremely light ice conditions, marking 2010 the first time since 1982 that shipboard buoy deployments were not utilized. The three air-deployed WOCE drifting buoys were deployed on the Grand Banks of Newfoundland in the offshore branches of the Labrador Current. All three buoys functioned properly and transmitted oceanographic data for sufficient durations, ranging from two to nine months.

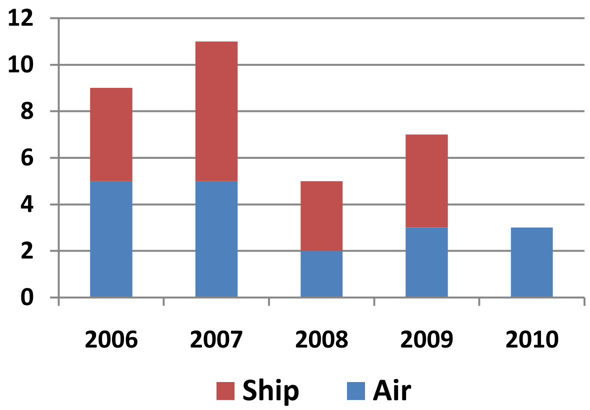

Figure 10. WOCE Drifting Buoy deployments (2006-2010).

Figure 10 shows 2006-2010 air and ship WOCE drifting buoy deployments. **Figure 11** depicts composite drift tracks for the WOCE drifting buoys deployed in 2010. Detailed WOCE drifter information is provided in IIP's 2010 WOCE Buoy Track Atlas, available upon request from IIP.

IIP continued support for the development of the Arctic buoy deployment program in cooperation with Coast Guard Air Station Kodiak, the University of Washington, and the National Science Foundation. Additional deployment and buoy rigging procedures and deployment equipment sources of supply were provided by IIP and ECAS personnel.

Commemorative Wreath Deployments

In conjunction with reconnaissance operations, IIP air-deployed several wreaths in 2010 to commemorate the sinking of the RMS TITANIC and those lives lost in the execution of the Greenland Patrol. Three wreaths commemorating the 98th anniversary of the sinking of the TITANIC were deployed on IRD 5, and one wreath honoring the Greenland Patrol was deployed on IRD 7.

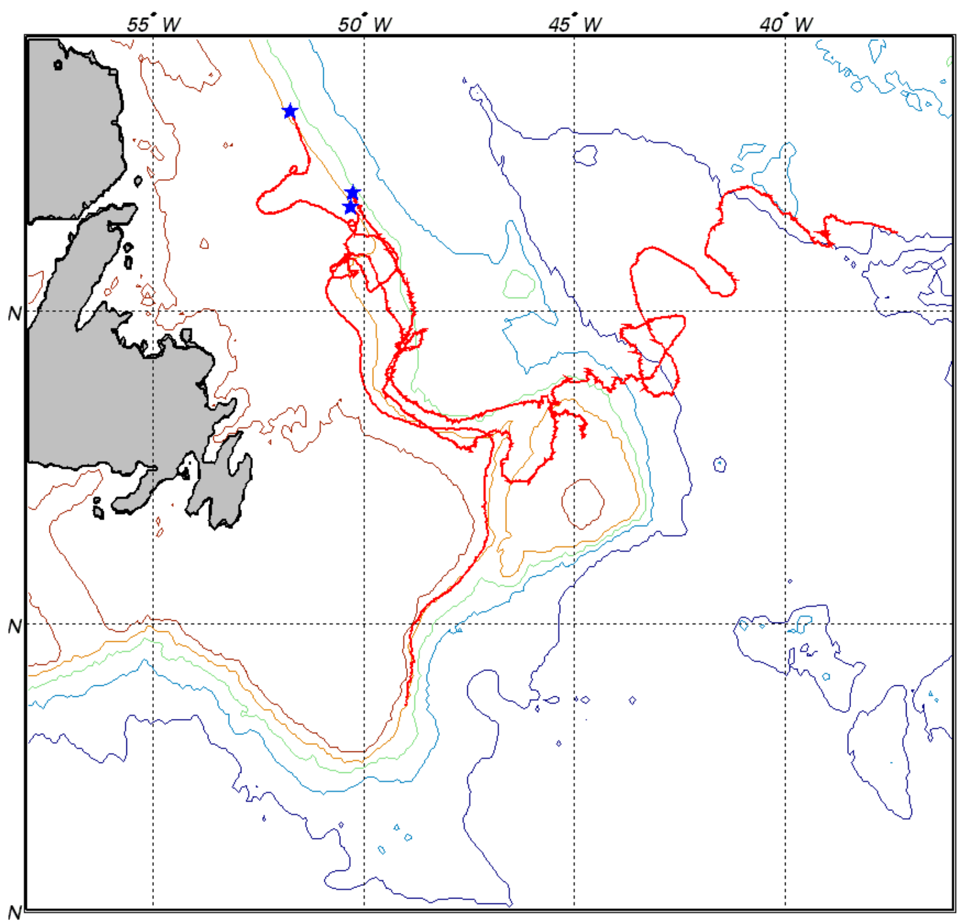

Figure 11. Composite buoy tracks. Blue stars represent drop locations of air-deployed buoys.

Ice and Environmental Conditions

Introduction

For the third time in the last six years, no significant iceberg population moved into the North Atlantic shipping lanes. Environmental conditions during the ice year were dominated by exceptionally warm air temperatures in Labrador and southern Baffin Island. The year was also marked by a particularly stormy period in February in which strong onshore winds along the Labrador coast caused extensive sea-ice destruction and compaction. In 2010, no icebergs were detected south of 48°N, although one iceberg was estimated by BAPS to have reached 47°-55.21’N 51°-43.36’W on 24 June. As a result, IIP did not produce daily warnings to mariners.

This section describes the progression of the ice year and the accompanying environmental conditions. The following month-by-month narrative begins in December 2009 as new ice began forming in the bays along the Labrador coast and concludes in mid-July when IIP’s last reconnaissance detachment returned from St. John’s, NL.

The narrative draws from several sources, including the *Seasonal Summary for Eastern Canada, Winter 2009-2010* (Canadian Ice Service, 2010a); sea-ice and iceberg analyses provided by CIS and the U. S. National Ice Center (NIC); sea surface temperature anomaly plots provided by the National Oceanic and Atmospheric Administration’s National Weather Service (NOAA/NWS, 2010a); and, finally, summaries of the iceberg data collected by IIP.

The progress of the 2010 Ice Year (October 2009 through September 2010) is compared to observations from the historical record. The sea-ice historical data are derived from the *Sea Ice Climatic Atlas, East Coast of Canada, 1971-2000* (CIS, 2001), which provides a 30-year median of ice concentration at seven-day intervals for the period from 26 November through 16 July. The average number of icebergs estimated to have drifted south of 48°N for each month was calculated using 110 years (1900 through 2009) of Ice Patrol records (IIP, 2010). Sea level pressure data are from NCEP/NCAR Reanalysis dataset

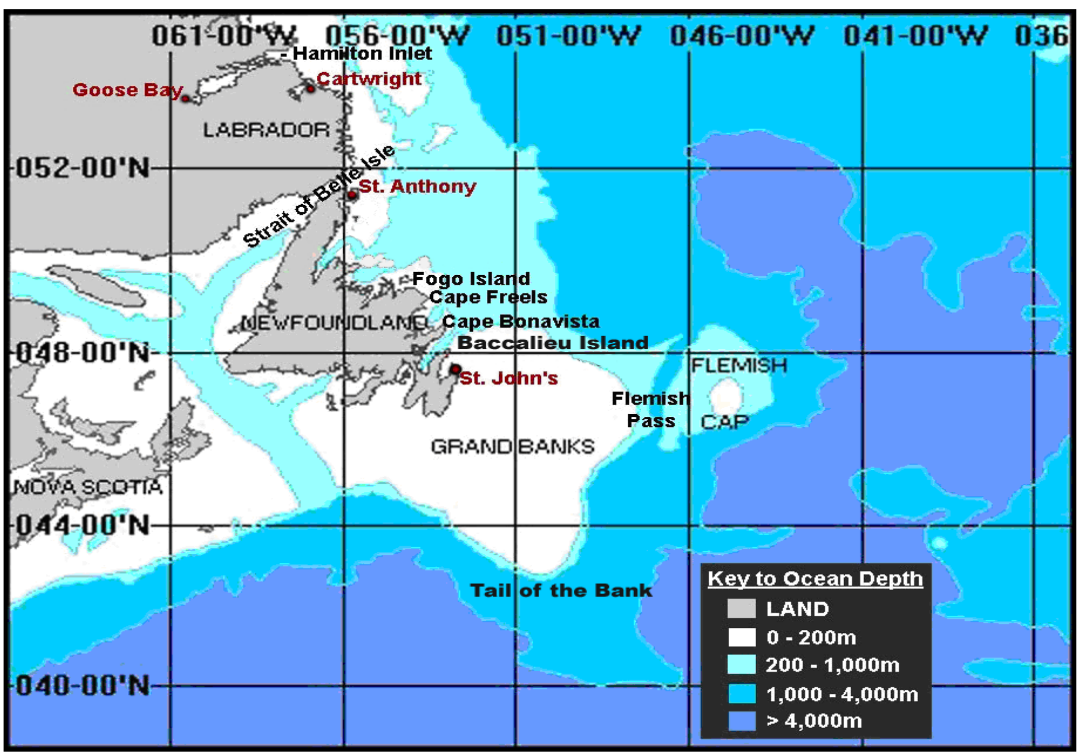

Figure 12. Bathymetry of the Grand Banks.

(Kalnay et al., 1996) and the United Kingdom's Meterological Office (Met Office, 2010).

Pre-Season Predictions

The Pre-Season sea-ice forecast for east Newfoundland waters (CIS, 2009), issued on 04 December 2009, predicted somewhat above average sea-ice extent and thickness at the peak of the season and a one to two week delay in the annual retreat. This forecast was based on the seasonal temperature forecast that predicted below-normal temperatures over Newfoundland waters for the first two months of the year. The forecast predicted that the southern ice edge would:

- reach Fogo Island in the third week of January and Cape Freels a week later.
- move southward to the approaches to St. John's during the third week of February.
- possibly move south to 45°N in the cold water of the offshore branch of the Labrador Current in late March and early April.
- begin to retreat in early April.

From 04-21 October 2009, CIS conducted a census of the iceberg population off the south coast of Baffin Island. It was based on radar images from two satellites, RADARSAT-I and ENVISAT (Desjardins, 2009). The resulting iceberg count was 146, the lowest CIS fall iceberg count in the ten years of the survey's history. Based on the forecast of greater than normal sea ice extent on the Grand Banks and an atmospheric flow parallel to the Labrador coast, Desjardins (2009) predicted an active iceberg season.

December 2009

Labrador and southern Baffin Island experienced extraordinarily warm conditions in December. Iqaluit, Nunavut observed a monthly average air temperature anomaly of 9.3°C, while Nain, NL and Cartwright, NL were 6°C above normal (Environment Canada, 2010).

Early in the month, sea ice began forming in the bays along Labrador's coast, but its development was slowed dramatically by the warm conditions. By month's end, about four weeks later than normal, the southern edge of the main pack moved past Labrador's northernmost point, Cape Chidley. Near-normal sea surface temperature conditions persisted along the Labrador coast throughout the month (NOAA/NWS, 2010a).

January 2010

Exceptionally warm conditions persisted along the Labrador coast throughout January. Average temperatures for the month were from 7°C to 8°C above normal (e.g. **Figure 13**) in Nain, Goose Bay, and Cartwright. The warm temperatures are consistent with the January mean sea-level pressure pattern (**Figure 14**) which shows an onshore flow bringing relatively mild temperatures to Labrador.

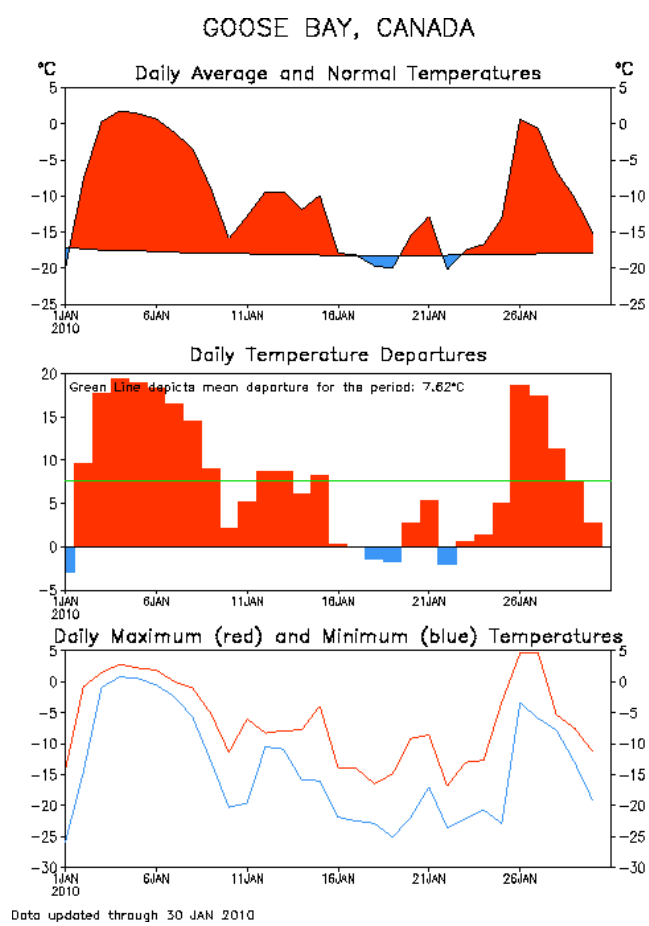

Figure 13. January 2010 air temperature in Goose Bay, Labrador. NOAA/NWS, Climate Prediction Center (NOAA/NWS, 2010).

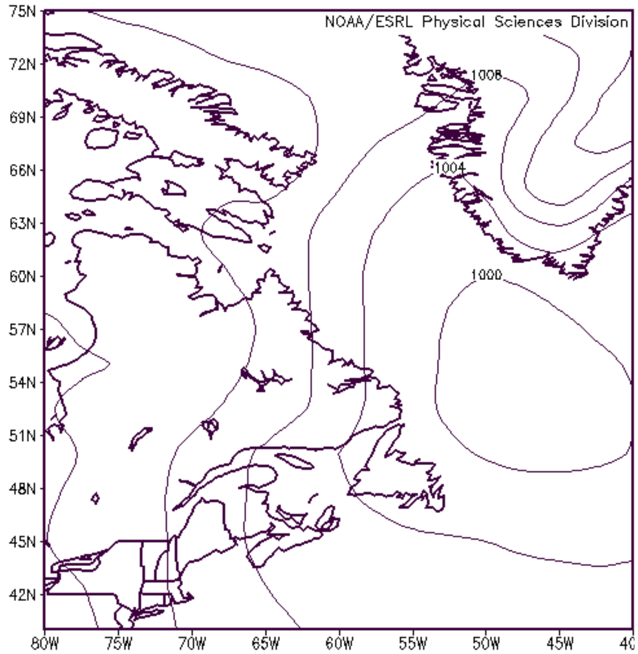

Figure 14. Mean sea-level pressure for 01 to 31 January 2010. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

Throughout the month, the leading edge of the main ice pack moved southward along the Labrador coast, arriving in the northern reaches of the Strait of Belle Isle during the third week. This was about four weeks later than normal. **Figure 15** shows the departure of sea ice from its normal extent on 25 January 2010. In most years, ice conditions in the vicinity of the Strait of Belle Isle prompt the CCG to recommend in late January that the strait not be used by transatlantic shipping until the ice departs. The mild sea ice conditions in 2010 made this recommendation unnecessary.

In mid-January, two iceberg reconnaissance flights conducted by PAL under CIS sponsorship, found no icebergs in the sea ice off the central Labrador coast. The areas east of the sea ice edge were not searched.

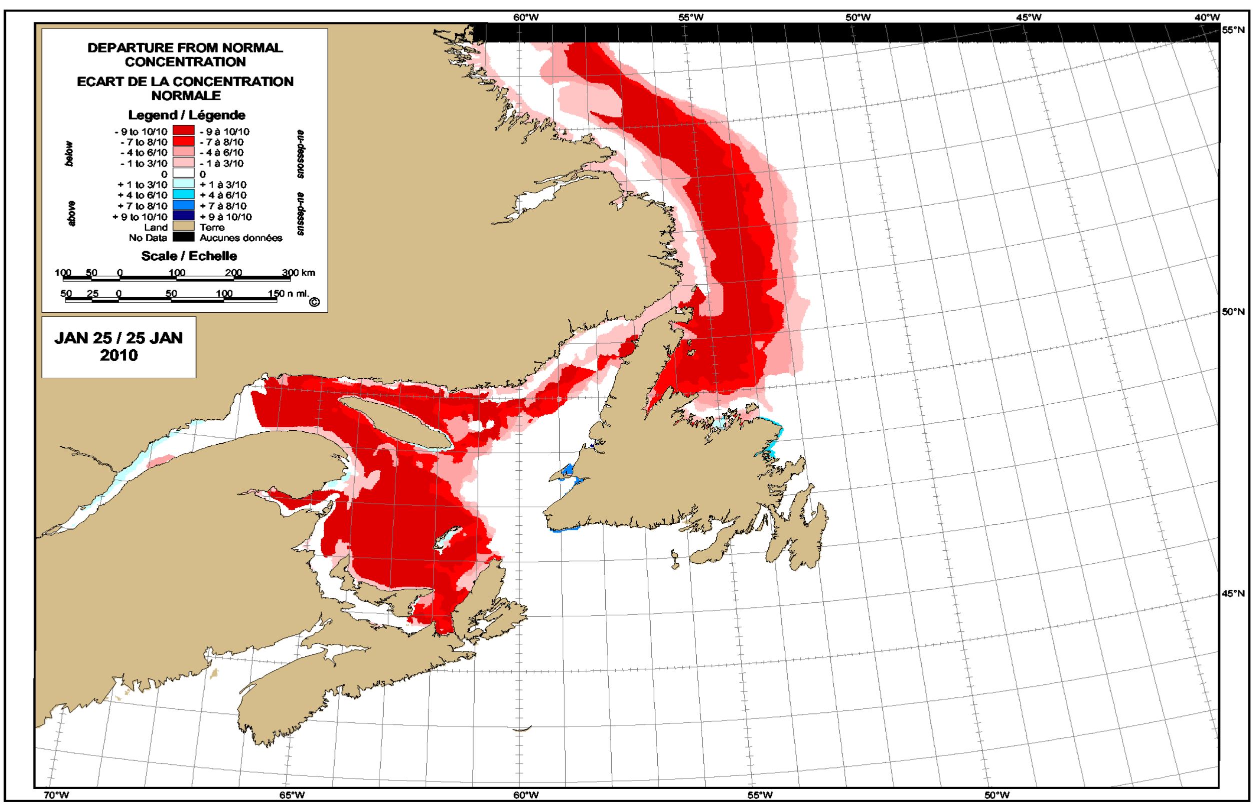

Figure 15. Departure of sea ice from normal on 25 Jan 2010. The various shades of red indicate areas where there was less sea ice than normal. The white areas near shore indicate regions of normal sea-ice concentrations. Map Courtesy of the Canadian Ice Service.

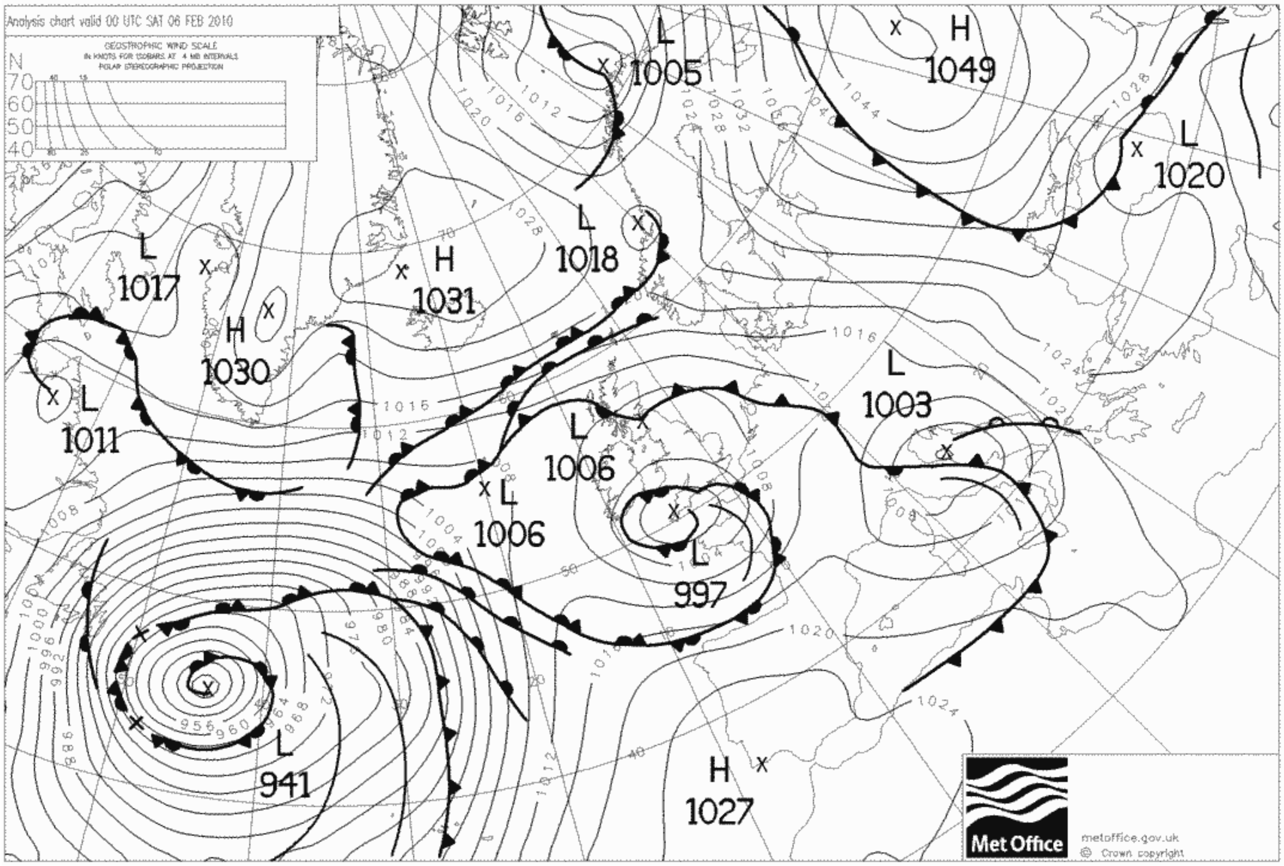

Figure 16. Sea-level pressure for 00Z 06 February 2010. Plot courtesy of Met Office, Bracknell, UK.

February 2010

During February, the abnormally high air temperatures in Labrador and southern Baffin Island peaked. In Iqaluit, the monthly average air temperature was 10.6°C above normal, while in Labrador the anomaly ranged from a low of 9.7°C in Cartwright to 12.8°C in Nain.

In early February, the ice edge moved quickly from the vicinity of the Strait of Belle Isle southward, reaching Fogo Island on 06 February, about two weeks later than forecast (CIS, 2009). Its normal position for the date is about 100 NM to the southeast of Fogo Island. This was the southernmost position of the sea ice edge for the 2010 Ice Year.

February was a particularly stormy period in the North Atlantic. During the first half of the month, seven cyclones intensified into hurricane force lows in the North Atlantic. The most intense of these deepened rapidly as it moved southeast of Newfoundland. By 00Z on 06 February, the central pressure deepened to 941 MB (**Figure 16**), the lowest pressure of any cyclone in either the North Atlantic or North Pacific during the 2009/2010 winter. This storm eventually turned west into the Labrador Sea bringing strong onshore winds to the coast (Bancroft, 2010). For the next two weeks, a series of lows moved off the U. S. mid-Atlantic coast south of New England and stalled southeast of Newfoundland. Some backed into the Newfoundland and Labrador coasts bringing persistent and strong easterly and southeasterly winds to region. **Figure 17** shows the mean sea level pressure for the 15-day period 06-20 February.

The storms had a dramatic and immediate effect on the extent of the sea ice north of Newfoundland. Over the 14-day period from 06-20 February, virtually all sea ice disappeared from the east Newfoundland waters. Indeed, there was no appreciable sea ice remaining south of Belle Isle, and the sea ice along the southern and central coast of

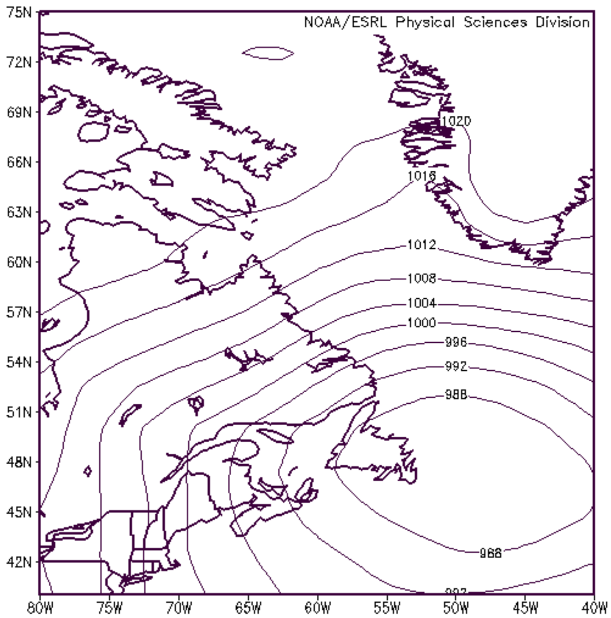

Figure 17. Mean sea-level pressure for 06-20 February 2010. Image provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

Labrador was compacted near shore. **Figure 18** compares the observed and normal ice extent for 22 February.

From 22-24 February, three airborne reconnaissance patrols, two by IIP's Pre-Season IRD and one by PAL, searched from the northern Grand Bank to northern Labrador. They located a very small iceberg population north of Hamilton Inlet, Labrador. All of the icebergs were within the sea ice (**Figure 19**).

March 2010

The extraordinarily warm conditions abated somewhat in March, but Labrador remained much warmer than normal throughout the month. Nain, Goose Bay, and Cartwright recorded monthly mean air temperatures 3.1°C, 3.4°C, and 2.7°C above normal, respectively. On the island of Newfoundland, St. John's registered 2.2°C above normal for the month.

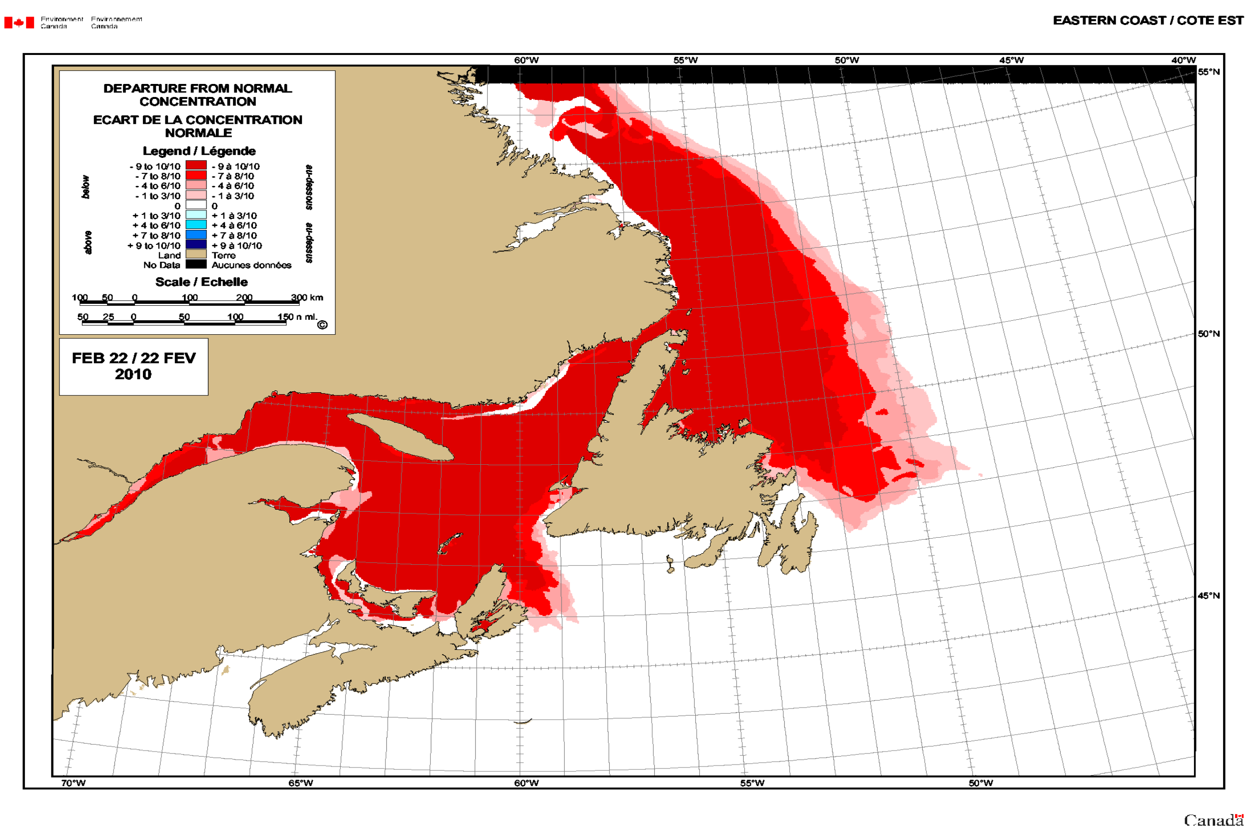

Figure 18. Departure of sea ice from normal on 22 Feb 2010. The various shades of red indicate areas where there was less sea ice than normal. The white areas near shore indicate regions of normal sea-ice concentrations. Map courtesy of the Canadian Ice Service.

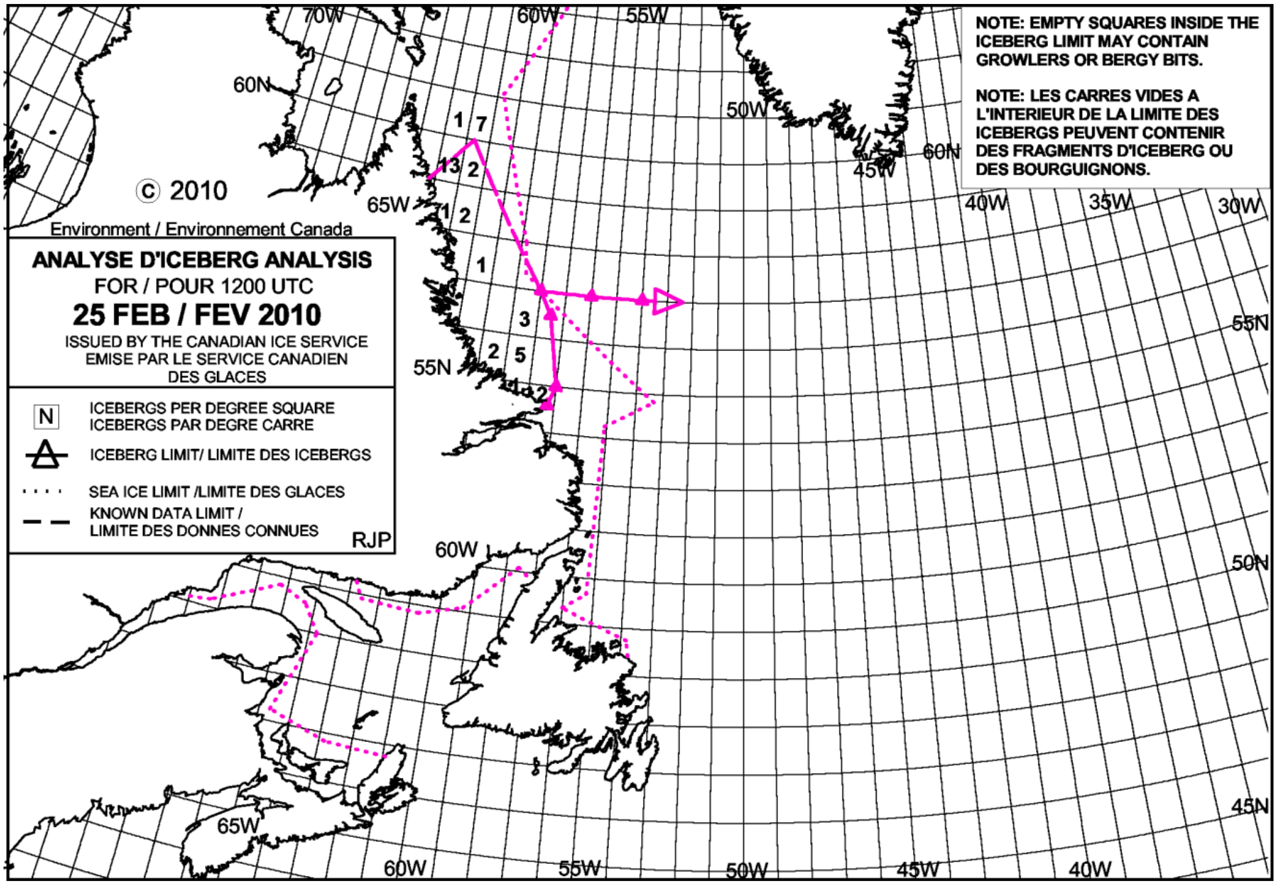

Figure 19. Iceberg distribution on 25 February 2010. The numbers indicate the number of icebergs and radar targets within a 1° of latitude by 1° of longitude bin. Map courtesy of the Canadian Ice Service.

Sea-ice coverage in northeast Newfoundland waters continued to be far less than normal. In mid-March, the southern ice edge normally reaches its southernmost position, which is typically near St. John's. In mid-March 2010, it was at 51°N, approximately 300 NM northwest of its normal position.

Throughout March, CIS-sponsored PAL and IIP IRD reconnaissance flights continued to monitor icebergs in northeast Newfoundland waters and along the southern Labrador coast. The number of icebergs being tracked remained small. Most were within the sea ice and near the Labrador coast.

April 2010

Monthly-averaged air temperatures in Newfoundland and Labrador remained well above normal for the month, with Nain, Cartwright, and St John's reporting 4.9°C, 4.5°C, 2.2°C, respectively.

By the second half of April, the little remaining sea ice south of 52°N began to retreat northward, and by month's end, there was no appreciable ice east on Newfoundland's northern peninsula.

Three reconnaissance flights, two CIS-sponsored PAL patrols (11 and 12 April) and one by the IIP IRD (18 April) documented a large iceberg population extending from the northern reaches of the Strait of Belle Isle to 57°N (**Figure 20**). In addition, ships entering the Strait of Belle Isle started reporting numerous icebergs in the strait.

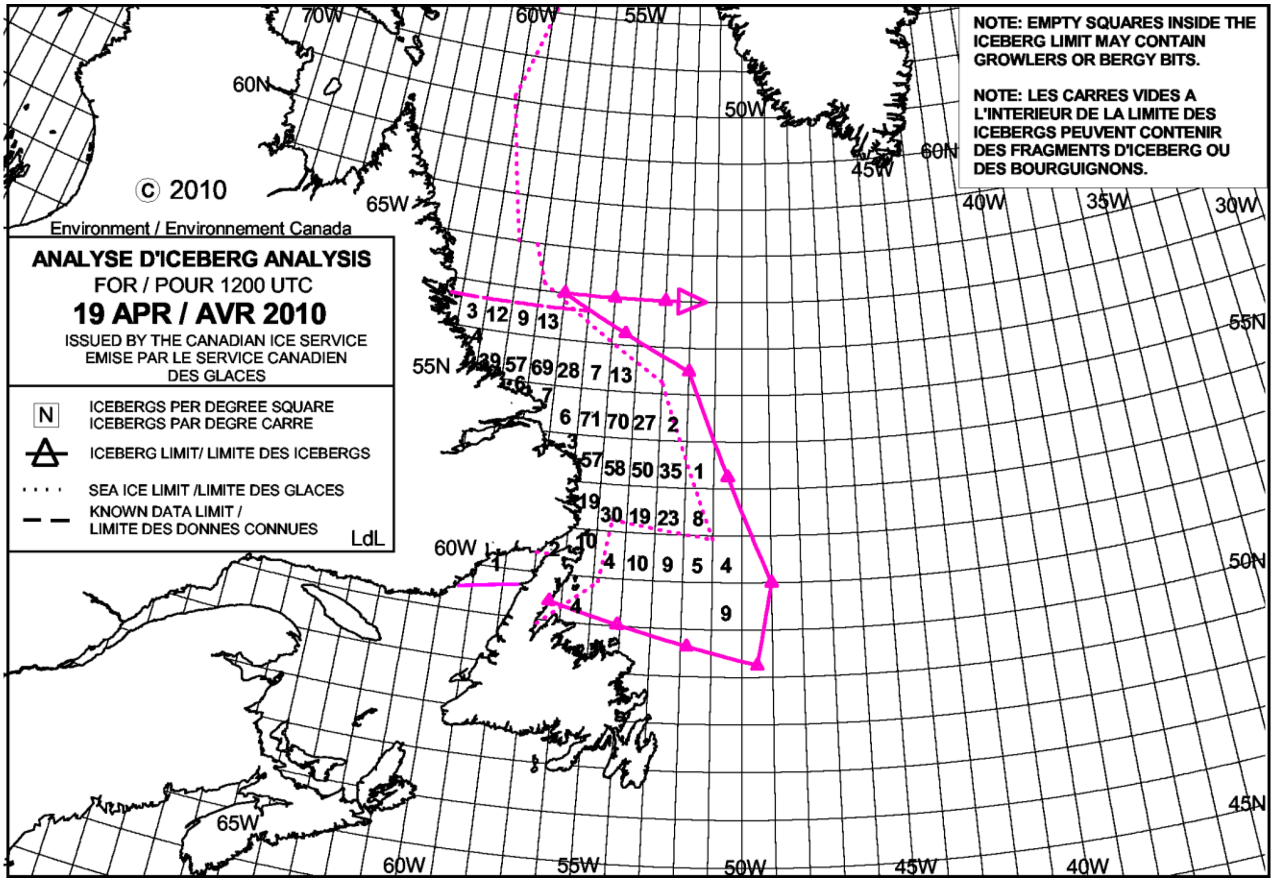

Figure 20. Iceberg distribution on 19 April 2010. The numbers indicate the number of icebergs and radar targets within a 1° of latitude by 1° of longitude bin. Map courtesy of the Canadian Ice Service.

May 2010

In May, the air temperatures in Newfoundland and Labrador began to return to near-normal conditions. Cartwright and St. John's experienced average monthly temperatures of 0.6°C and -0.6°C, respectively. Farther north, Nain and Iqaluit remained well above normal with positive anomalies of 1.5°C and 2.7°C, respectively.

During the first half of May, the sea ice continued its northward retreat. By mid-May 2010, the southern ice edge moved to Cartwright, where it lingered for the remainder of the month. The 30-year median position of the southern ice edge for the end of May is 52°N (CIS, 2001), about 60 NM south of 2010's position.

The number of icebergs being tracked by IIP and CIS declined steadily throughout May, although a large number remained in the Strait of Belle Isle and its eastern and western approaches. During the second half of the month, there were few icebergs south of 52°N, and most of them were close to Newfoundland's shore. There were no icebergs south of 48°N.

June and July 2010

In June, near-normal conditions prevailed in Newfoundland and Labrador. The monthly mean air temperature in Cartwright was 0.5°C above normal, while St. John's was 0.1°C below.

By the last week of June 2010, only a small amount of ice remained along the central Labrador coast, and by the end of the first week of July, all of the sea ice had disappeared.

Two IIP reconnaissance flights, one on 05 June and the other on 08 June, documented a large number of icebergs from 52° to 57°N.

On 22 June, IIP's BAPS model estimated that one iceberg moved south of 48°N. On 24 June, it reached 47°-55.21N, 51°-43.36W.

A substantial number of icebergs lingered within and near the approaches to the Strait of Belle Isle throughout June and the first half of July. These icebergs were seen frequently by CIS-sponsored aerial reconnaissance and vessels traversing the strait, including the CCG icebreaker Des Groseilliers. During the second half of July, seasonal warming took a toll on the iceberg population reducing it to a sparse distribution, which eventually disappeared by late August.

On 17 July, IIP's IRD conducted its last patrol of the 2010 Ice Year.

Discussion

By the end of December, it was becoming evident that the 2009-2010 Ice Year would be far from normal. Extraordinarily warm conditions (**Figures 21** and **22**) in Labrador and southern Baffin Island resulted in sea-ice development that was a month behind normal. The same conditions persisted in January, delaying the arrival of sea ice into east Newfoundland waters by a month. The storms of February, which destroyed most of the sea ice in east Newfoundland waters and compacted sea ice against the Labrador coast, put the final stamp on a sea-ice season for the record books. Without the protection sea ice affords the southward-moving icebergs and the likelihood that many icebergs were driven toward shore, the iceberg season was also remarkable. In 2010, one iceberg was estimated to have passed south of 48°N

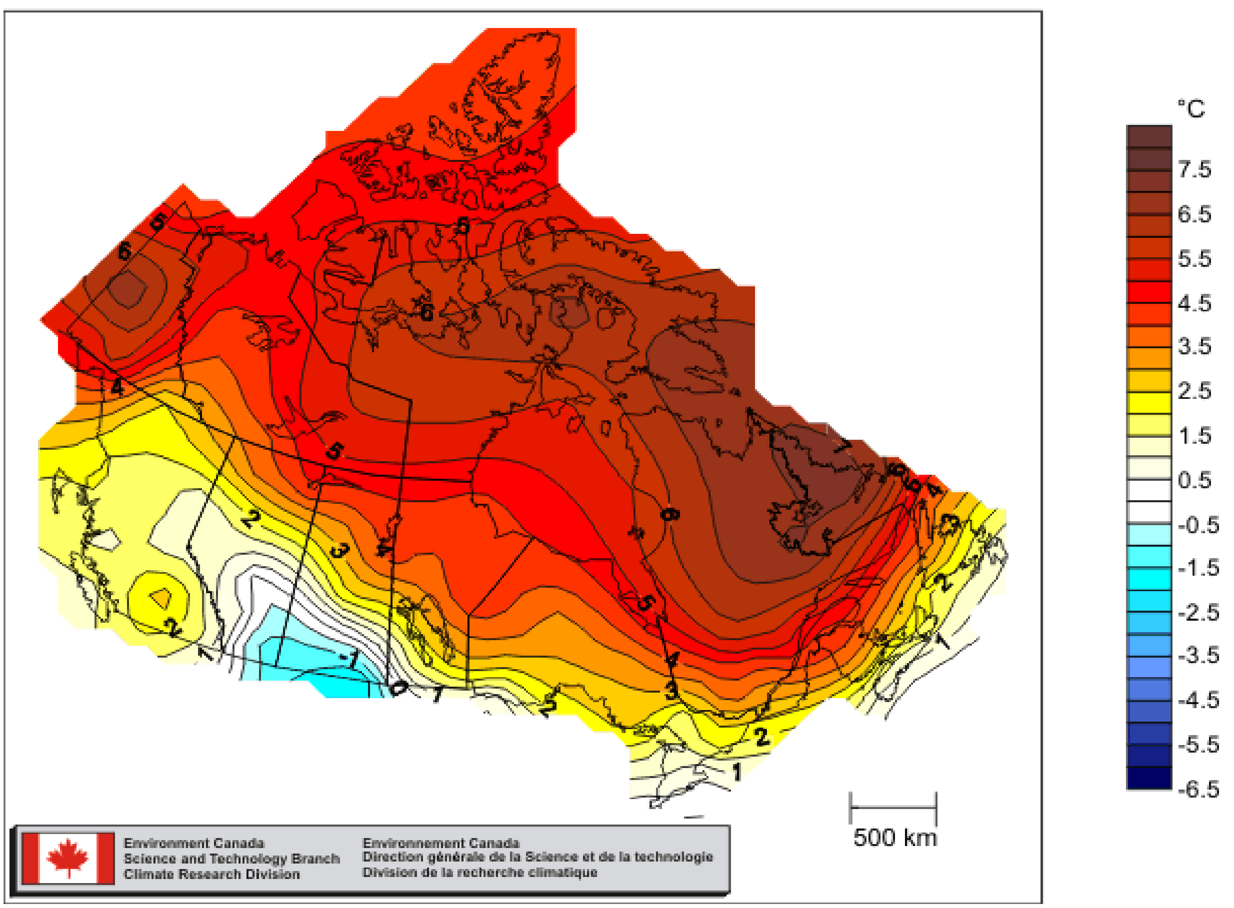

Figure 21. Temperature Departures from Normal - Winter (Dec, Jan, Feb) 2009/2010.

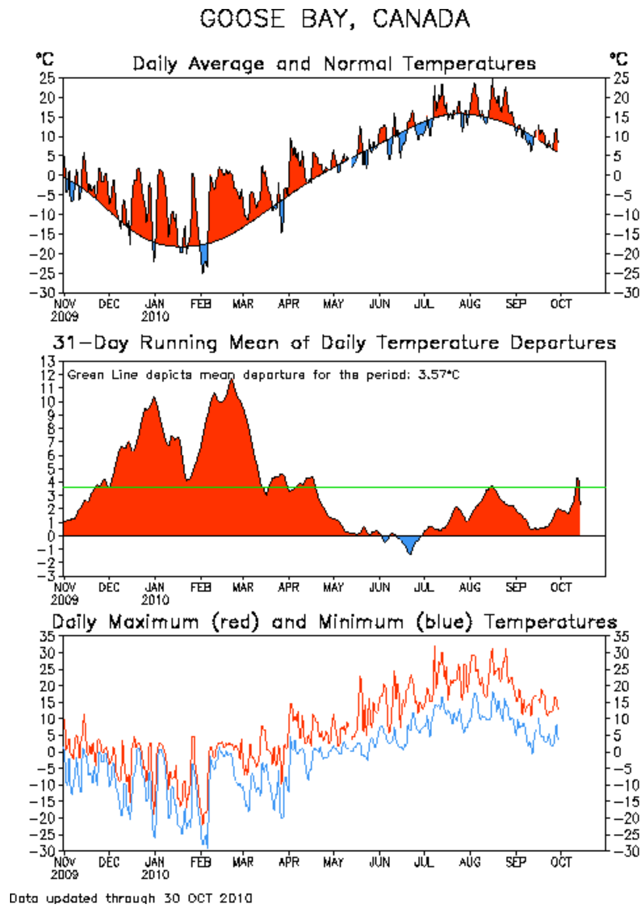

Figure 22. November 2009 – October 2010 air temperature in Goose Bay, Labrador. NOAA/NWS, Climate Prediction Center (NOAA/NWS, 2010).

During the winter, many storms coming off of North America encountered high-latitude atmospheric blocking in the central or eastern North Atlantic Ocean (Bancroft, 2010), resulting in extended episodes of southeasterly or southerly flow in the northwest Atlantic Ocean. This brought onshore winds and relatively warm maritime air to Labrador.

The impact of these conditions on the sea-ice distribution was striking (**Figure 23**). The combined Grand Banks and Southern Labrador coast sea-ice coverage was well below average for the entire winter. What little ice growth that took place in late January and early February was destroyed or compacted along the coast during the stormy middle of the month. The ice extent in east Newfoundland waters never recovered, and by the end of February, for first time since 1969, there was virtually no sea ice in area. In fact, a new record low for total accumulated ice coverage (TAC) in east Newfoundland waters was established in 2010. The Gulf of Saint Lawrence also set a record for low TAC in 2010, breaking the previous record set in the winter of 1968-1969 (CIS, 2010a).

The high-latitude blocking, warm Labrador air temperatures and mild sea-ice conditions are characteristic features of a negative phase of the North Atlantic Oscillation (NAO). The NAO, the dominant pattern of winter atmospheric variability in the North Atlantic, fluctuates between positive and negative phases. NAO dynamics have been extensively described by Hurrell et al. (2003). The winter 2010 (December 2009 through March 2010) NAO Index was very strongly negative, -4.64 (Hurrell, 2010). This value, called the winter station-based NAO index, is calculated using the difference in normalized sea-level atmospheric pressure between Lisbon, Portugal and Stykkisholmur/Reykjavik, Iceland. The data record for the station based NAO index extends back to 1864. Only once in that period has there been a lower index, -4.89 in 1969. Remarkably, 1969 was the previous record holder for minimum TAC in east Newfoundland waters and the Gulf of St. Lawrence.

Conditions associated with the negative phase of the NAO are also unfavorable to the movement of icebergs toward the shipping lanes. The lack of sea ice exposes icebergs to wave-induced deterioration, and the onshore wind moves them toward the shallower waters near the coast, where they can run aground or become trapped in bays.

With the estimate that one iceberg passed south of 48°N, the 2010 Ice Year enters a three-way tie for third place for the lowest number of icebergs in a year (**Table 4**). Most, but not all, of the low iceberg counts were in years with strongly negative NAO indices. While it is tempting to argue that strongly negative conditions lead to low iceberg counts, the relationship is more complex than it appears. Two of the ten years, 1931 and 2005, were neutral NAO years. In addition, other years have diverged more dramatically from the simple relationship that a low NAO index results in a low iceberg count. For example, in 1996, the NAO index was -3.78, but 611 icebergs passed south of 48°N, a very active

RANK	YEAR	NAO INDEX	ICEBERGS SOUTH OF 48° N
1 (Tie)	2006	-1.09	0
1 (Tie)	1966	-1.69	0
3 (Tie)	2010	-4.64	1
3 (Tie)	1940	-2.86	1
3 (Tie)	1958	-1.02	1
6	1941	-2.31	3
7	1951	-1.26	8
8 (Tie)	2005	0.12	11
8 (Tie)	1924	-1.13	11
10	1931	-0.16	14

Table 4. Years with the lowest number of icebergs estimated to have drifted south of 48°N and North Atlantic Oscillation Index. Note: The iceberg-count data reflects the current definition of the ice year. 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 during the year. One of these icebergs passed south of 48°N in November 1940 and was originally counted as a 1940 observation. It is now counted as a 1941 observation. Thus, in 1940 there is one iceberg listed, and in 1941, three.

year for icebergs. On the other hand, there have been years in which there were few icebergs, but a strongly positive NAO index. In a recent example, 1999 had a strongly positive NAO (1.7), but few icebergs, 22, passed south of 48°N.

The inter-annual variability in the western North Atlantic iceberg counts remains impressive and difficult to understand and predict. Although the NAO index offers some help, it is clear that there are other mechanisms at work. The most likely mechanisms are related to the ocean and atmospheric circulation patterns north of the shipping lanes. Although IIP estimated only one iceberg moved south of 48°N in 2010, there were numerous icebergs not far to the north. In April and early May, there was a large population off southern Labrador. This population did not make its way to the shipping lanes. Rather, the icebergs lingered in the vicinity of the Strait of Belle Isle through early July, when seasonal warming of the surface waters finally began to destroy the population.

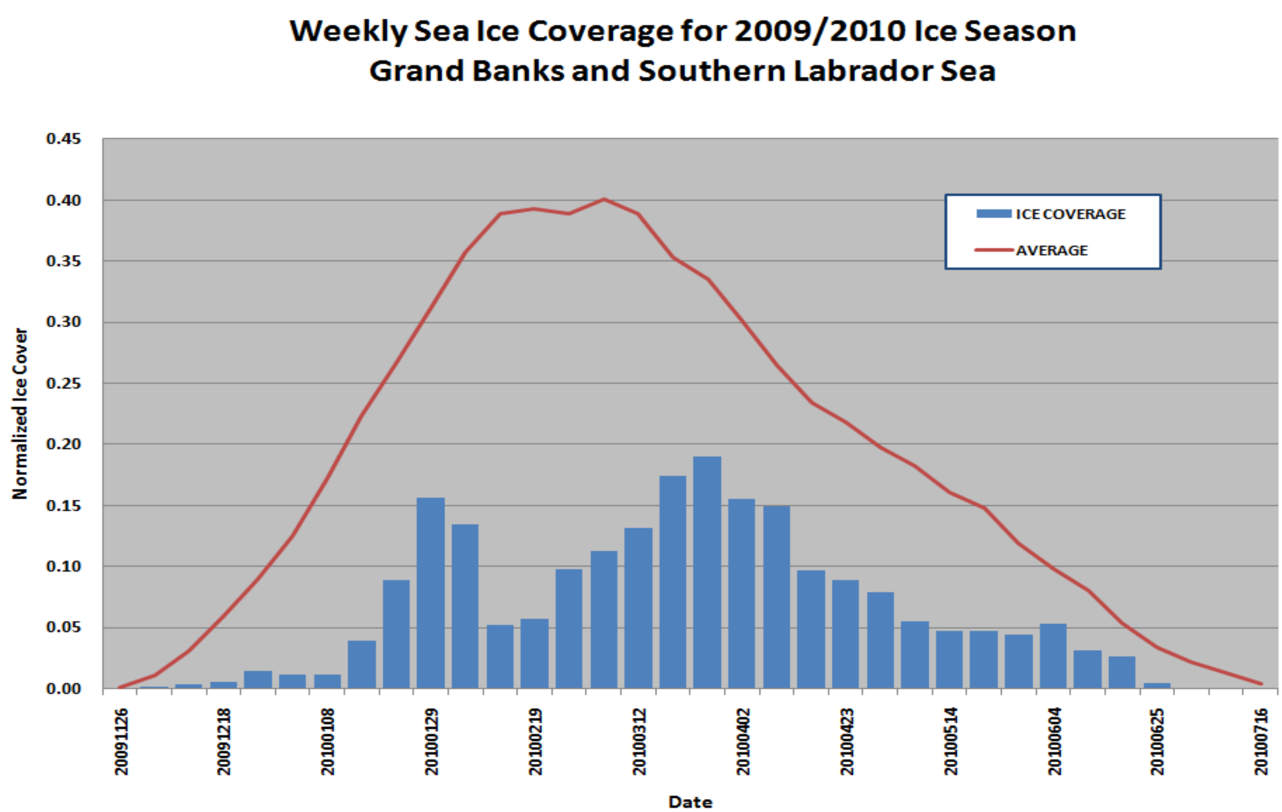

Figure 23. Weekly ice coverage on the Grand Banks and along the Southern Labrador coast for the 2010 Ice Season. The ice coverage is normalized to the total area of the Grand Banks and Southern Labrador coast regions. (CIS, 2010b).

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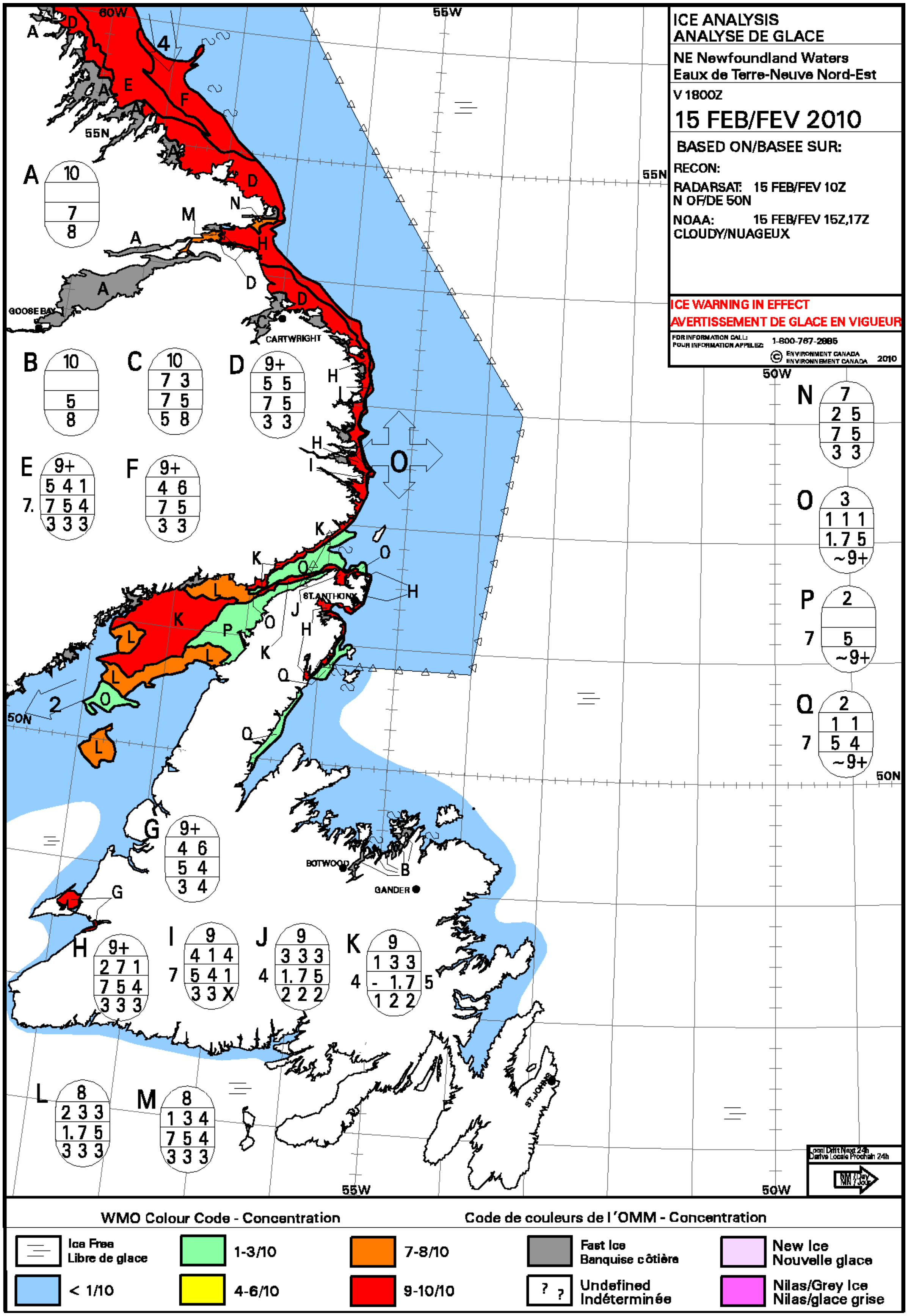
Monthly Sea-Ice Charts

Sea-ice charts are reprinted with permission of the Canadian Ice Service.

Click here for an explanation of sea-ice Egg Code courtesy of Environment Canada.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Eaux de Terre-Neuve Nord-Est
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2010
60W
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GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHN'S
WMO Colour Code - Concentration
Code de couleurs de l'OMM - Concentration
Ice Free
Libre de glace
< 1/10
1-3/10
4-6/10
7-8/10
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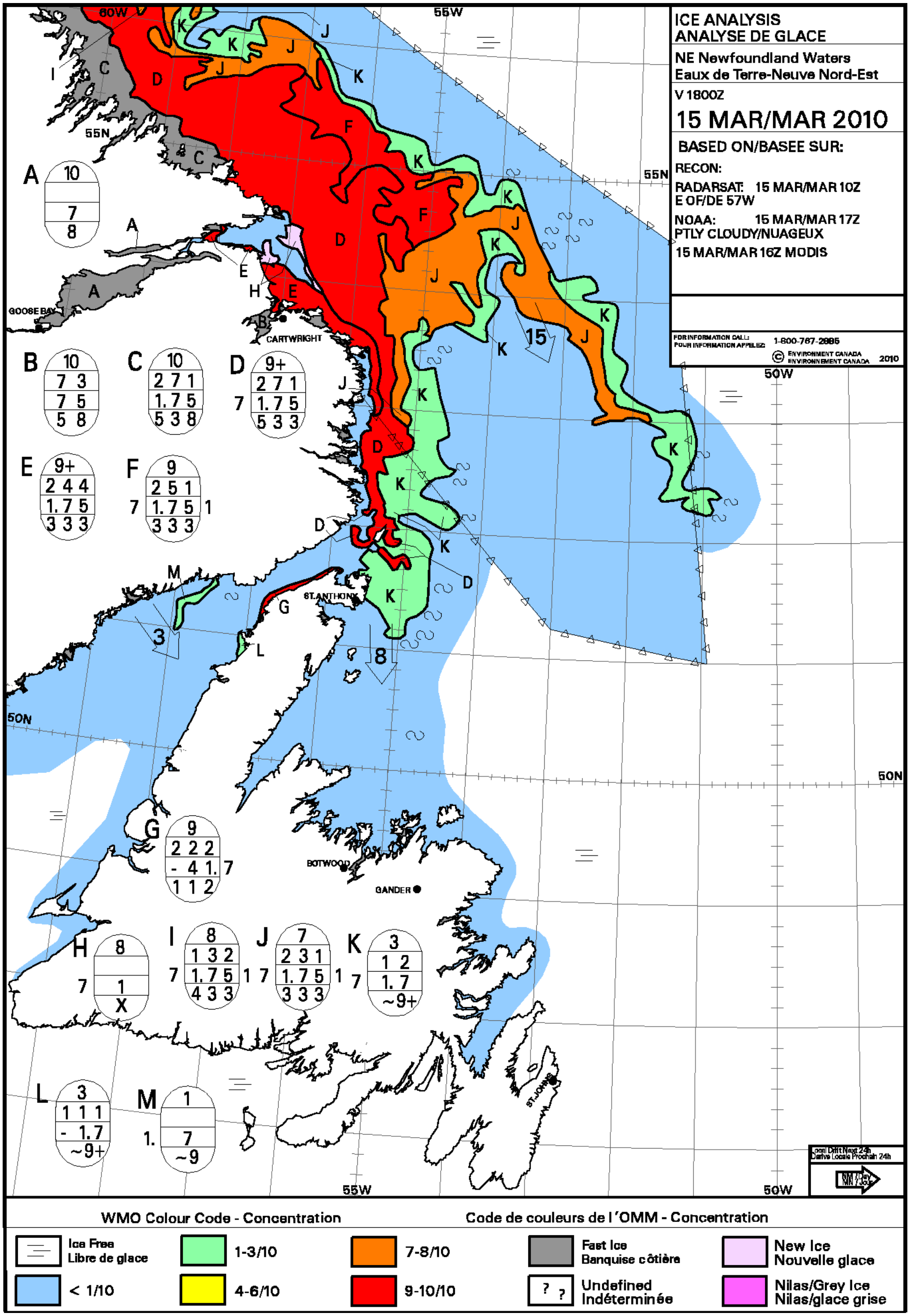
Fast Ice
Banquise côtière
Undefined
Indéterminée
New Ice
Nouvelle glace
Nilas/Grey Ice
Nilas/glace grise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GOOSE BAY
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ST.ANTHONY
BOTWOOD
GANDER
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WMO Colour Code - Concentration
Code de couleurs de l'OMM - Concentration
Ice Free
Libre de glace
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7-8/10
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Fast Ice
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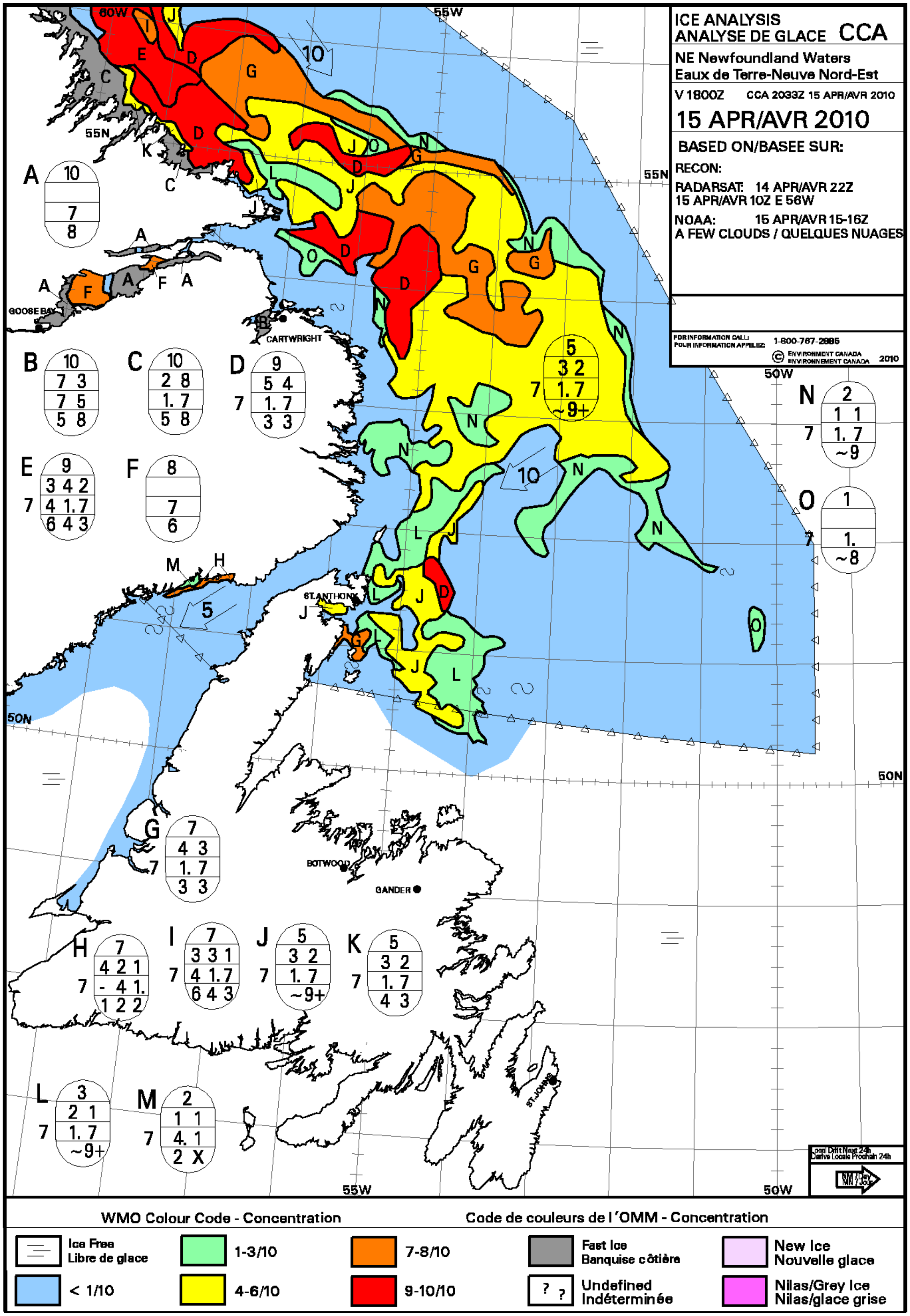
New Ice
Nouvelle glace
Nilas/Grey Ice
Nilas/glace grise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NOAA: 15 APR/AVR 15-16Z
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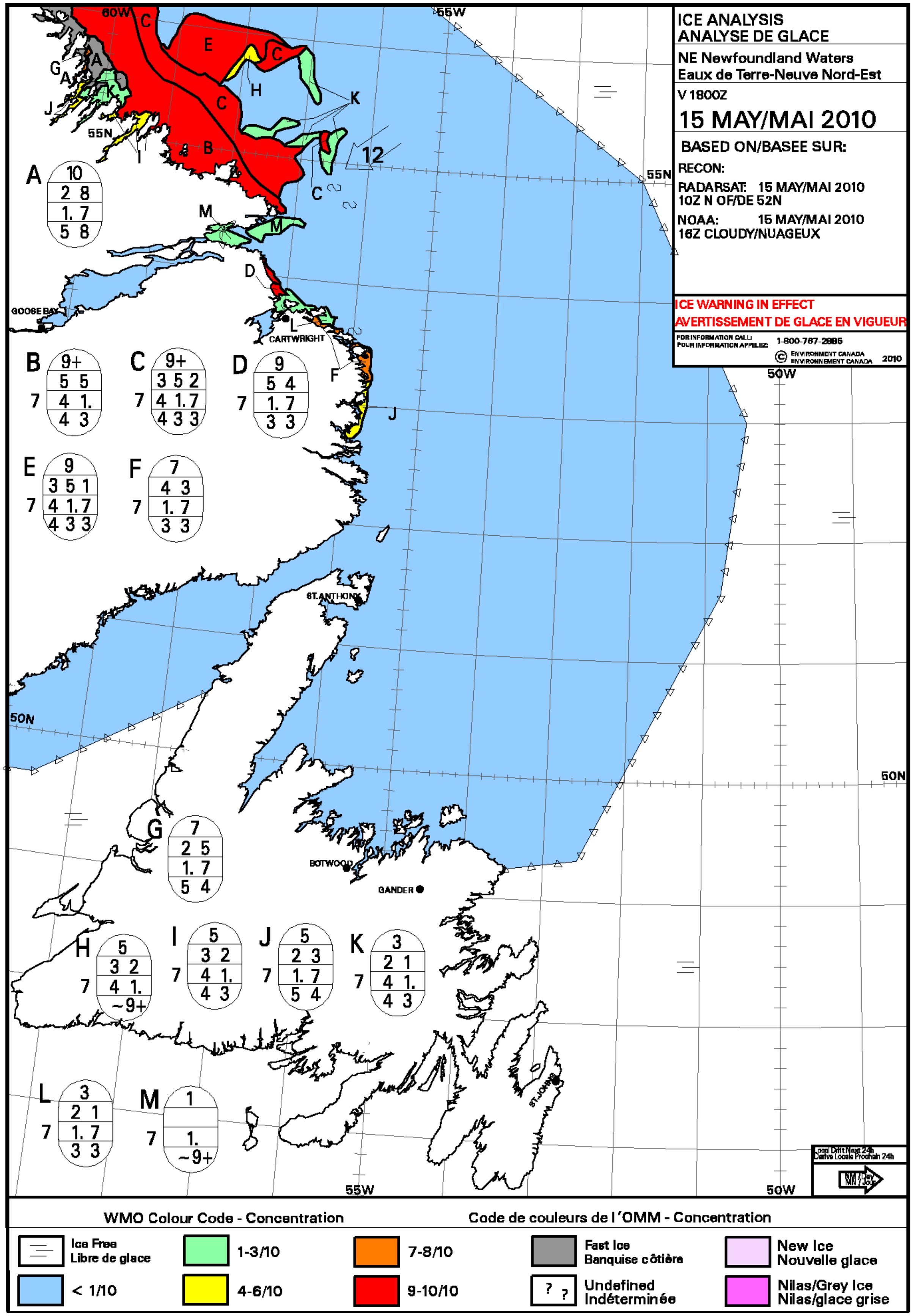
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
WMO Colour Code - Concentration
Code de couleurs de l'OMM - Concentration
Ice Free
Libre de glace
< 1/10
1-3/10
4-6/10
7-8/10
9-10/10
Fast Ice
Banquise côtière
Undefined
Indéterminée
New Ice
Nouvelle glace
Nilas/Grey Ice
Nilas/glace grise


ICE ANALYSIS
ANALYSE DE GLACE
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 MAY/MAI 2010
BASED ON/BASEE SUR:
RECON:
RADARSAT: 15 MAY/MAI 2010
10Z N OF/DE 52N
NOAA: 15 MAY/MAI 2010
16Z CLOUDY/NUAGEUX
ICE WARNING IN EFFECT
AVERTISSEMENT DE GLACE EN VIGUEUR
FOR INFORMATION CALL: POUR INFORMATION APPELEZ: 1-800-767-2885
ENVIRONMENT CANADA ENVIRONNEMENT CANADA 2010
60W
55W
50W
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50N
GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
12
WMO Colour Code - Concentration
Code de couleurs de l'OMM - Concentration
Ice Free
Libre de glace
< 1/10
1-3/10
4-6/10
7-8/10
9-10/10
Fast Ice
Banquise côtière
Undefined
Indéterminée
New Ice
Nouvelle glace
Nilas/Grey Ice
Nilas/glace grise

Biweekly Iceberg Charts

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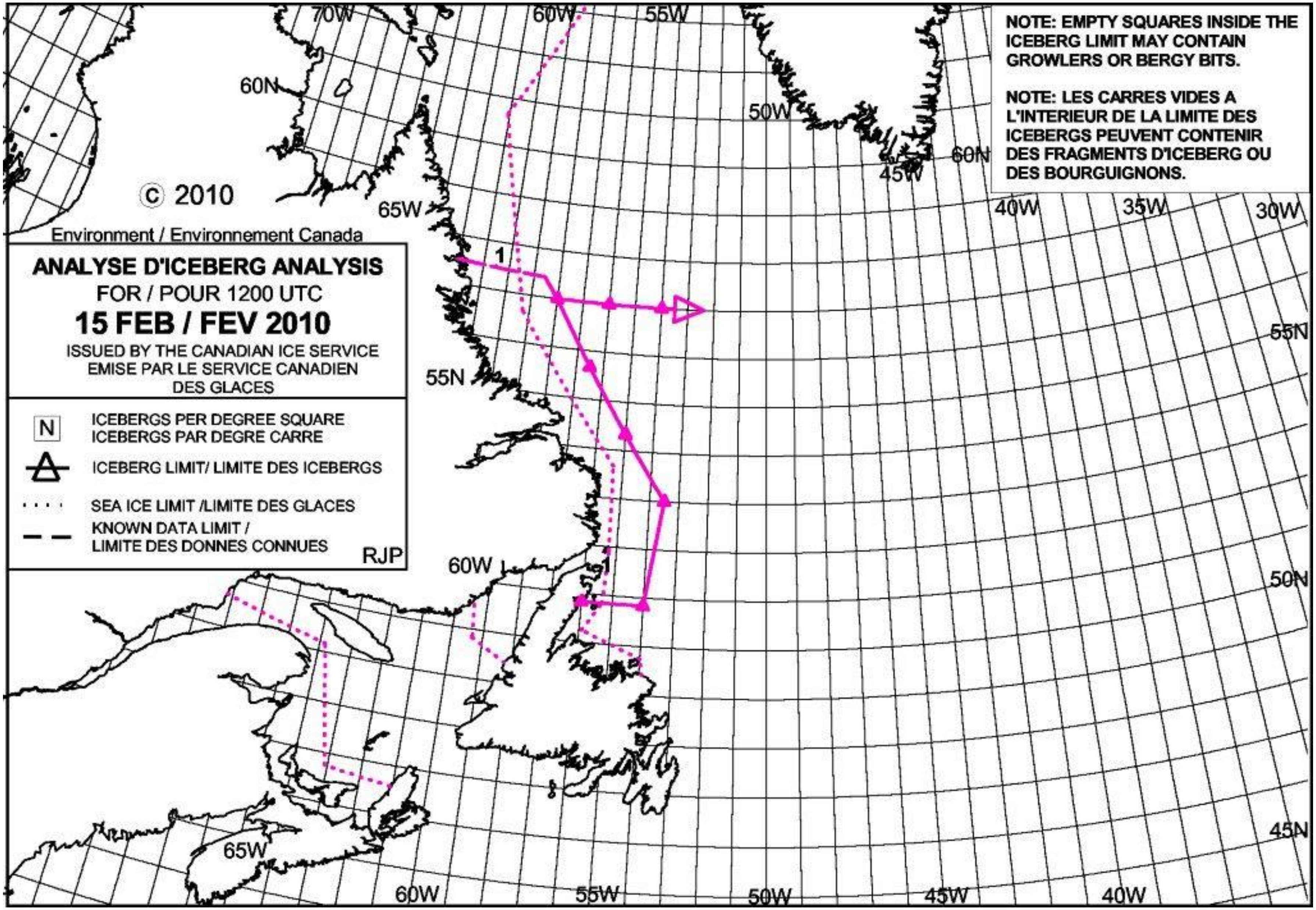
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N ICEBERGS PER DEGREE SQUARE / ICEBERGS PAR DEGRE CARRE
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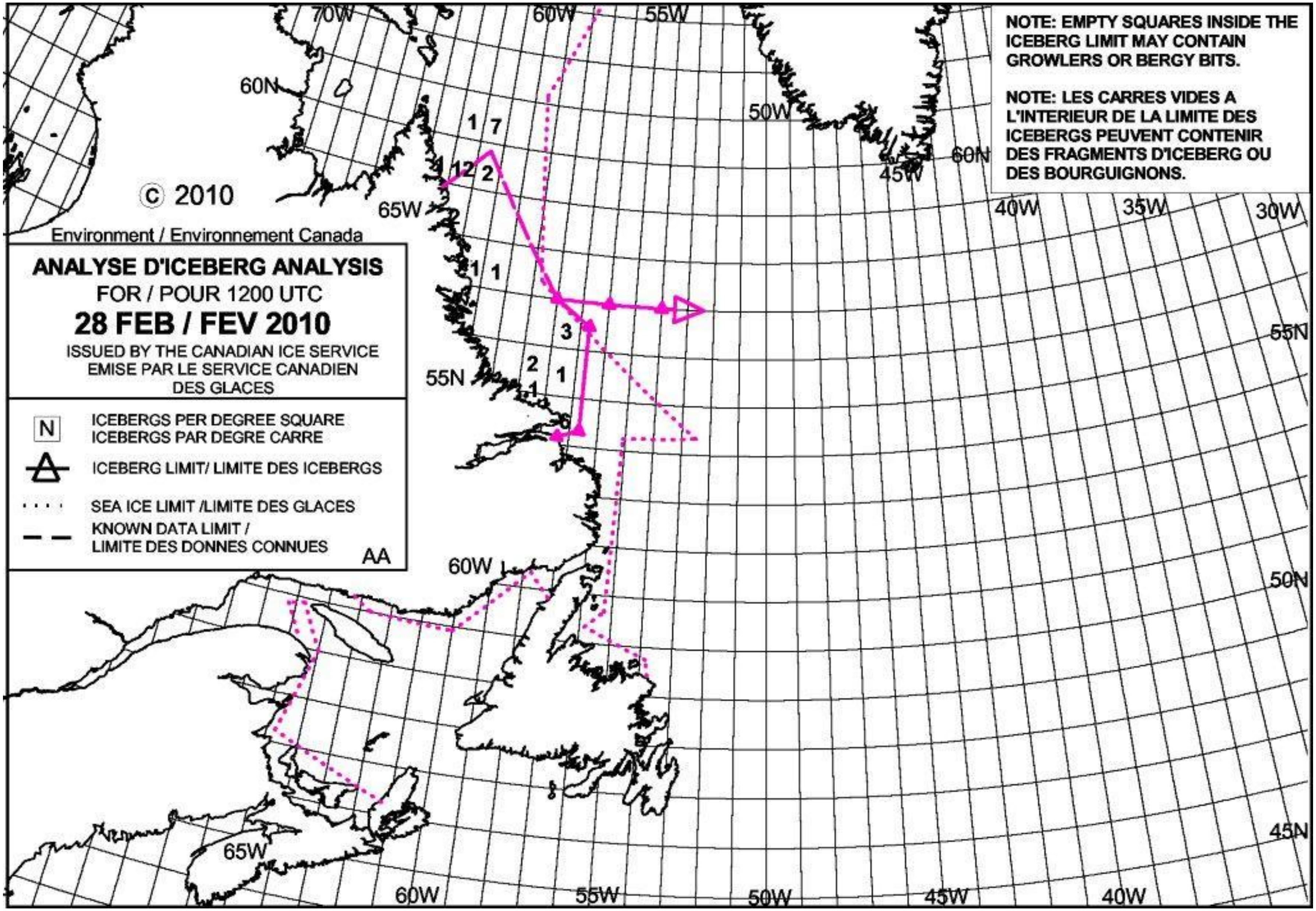
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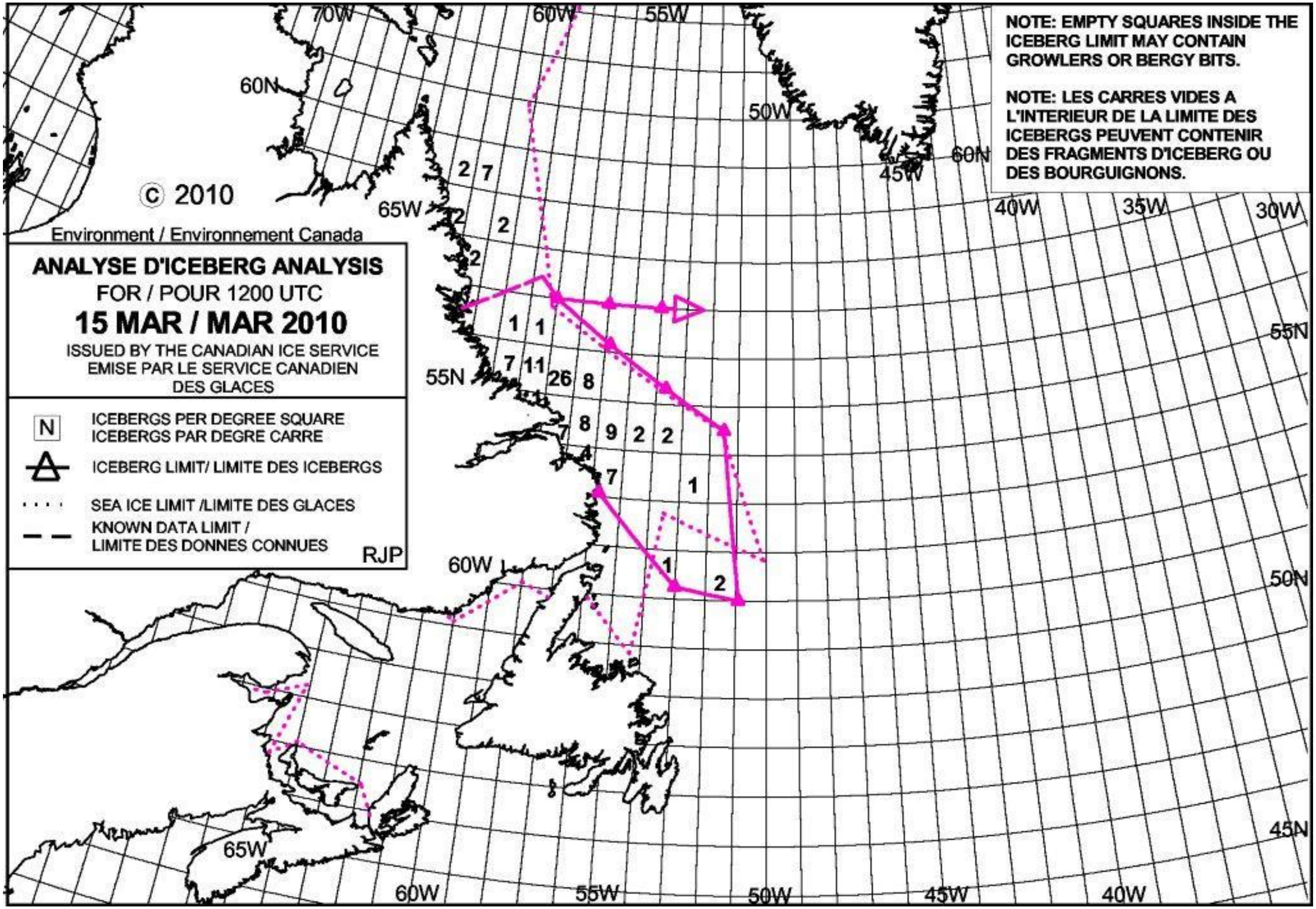
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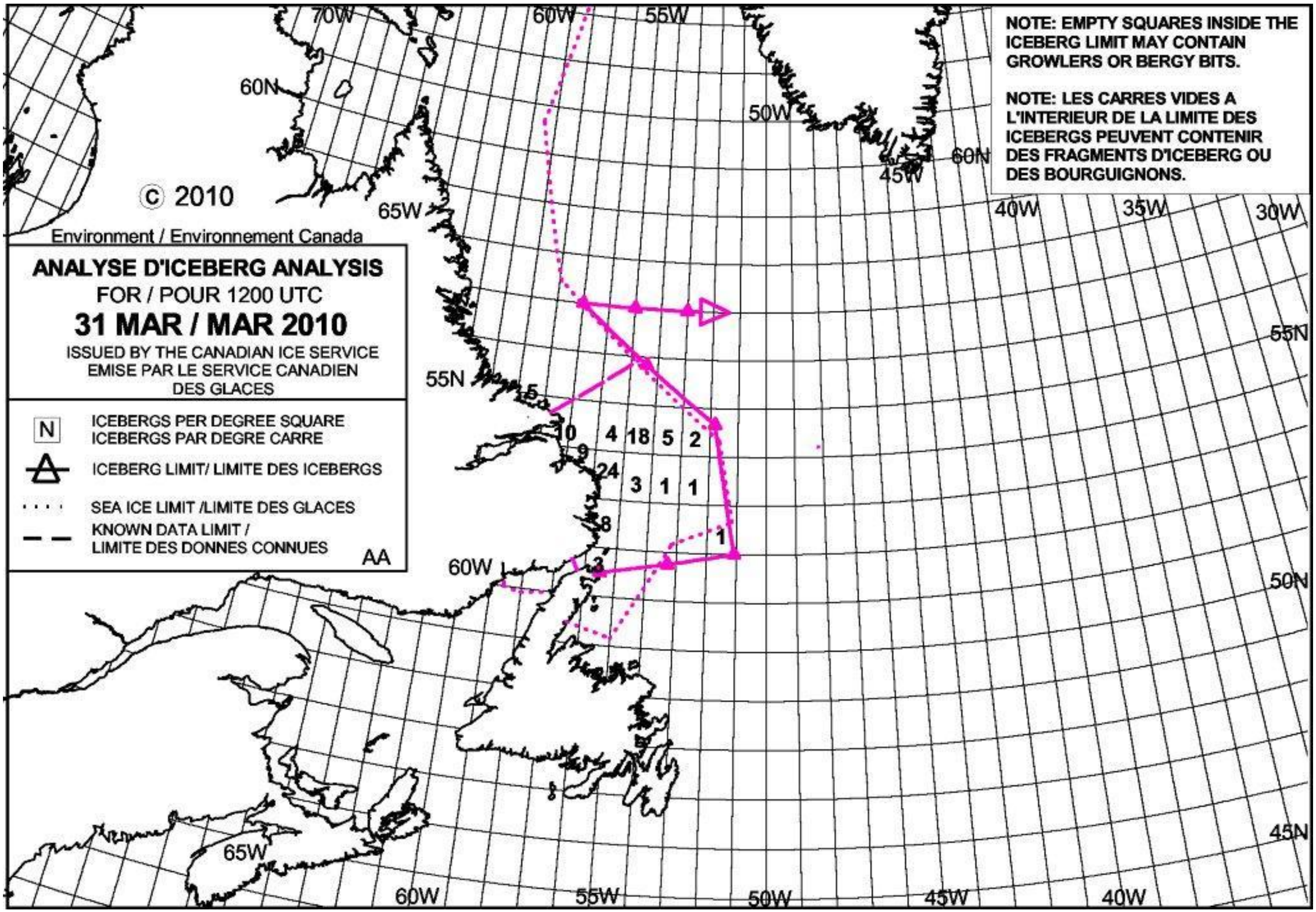
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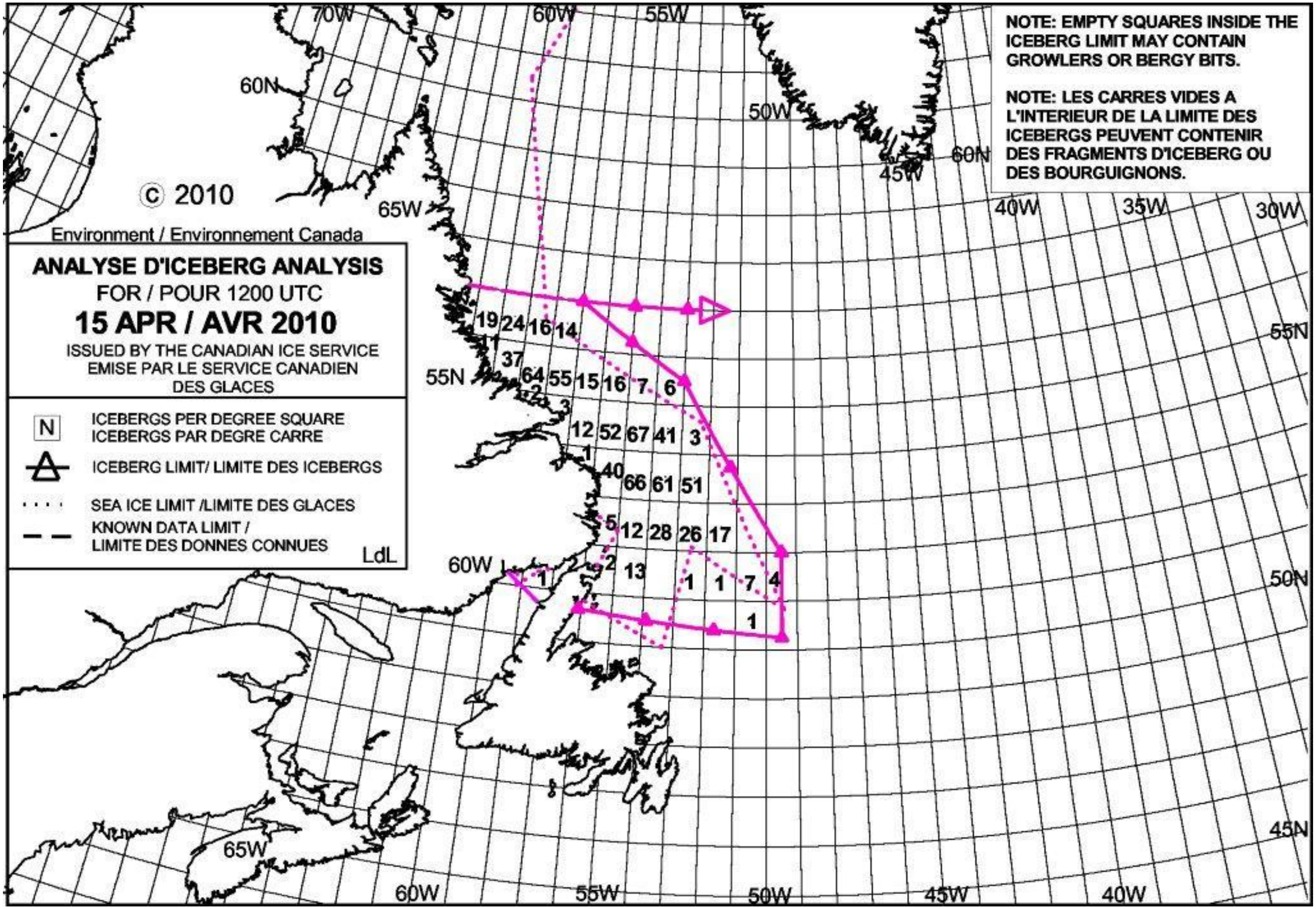

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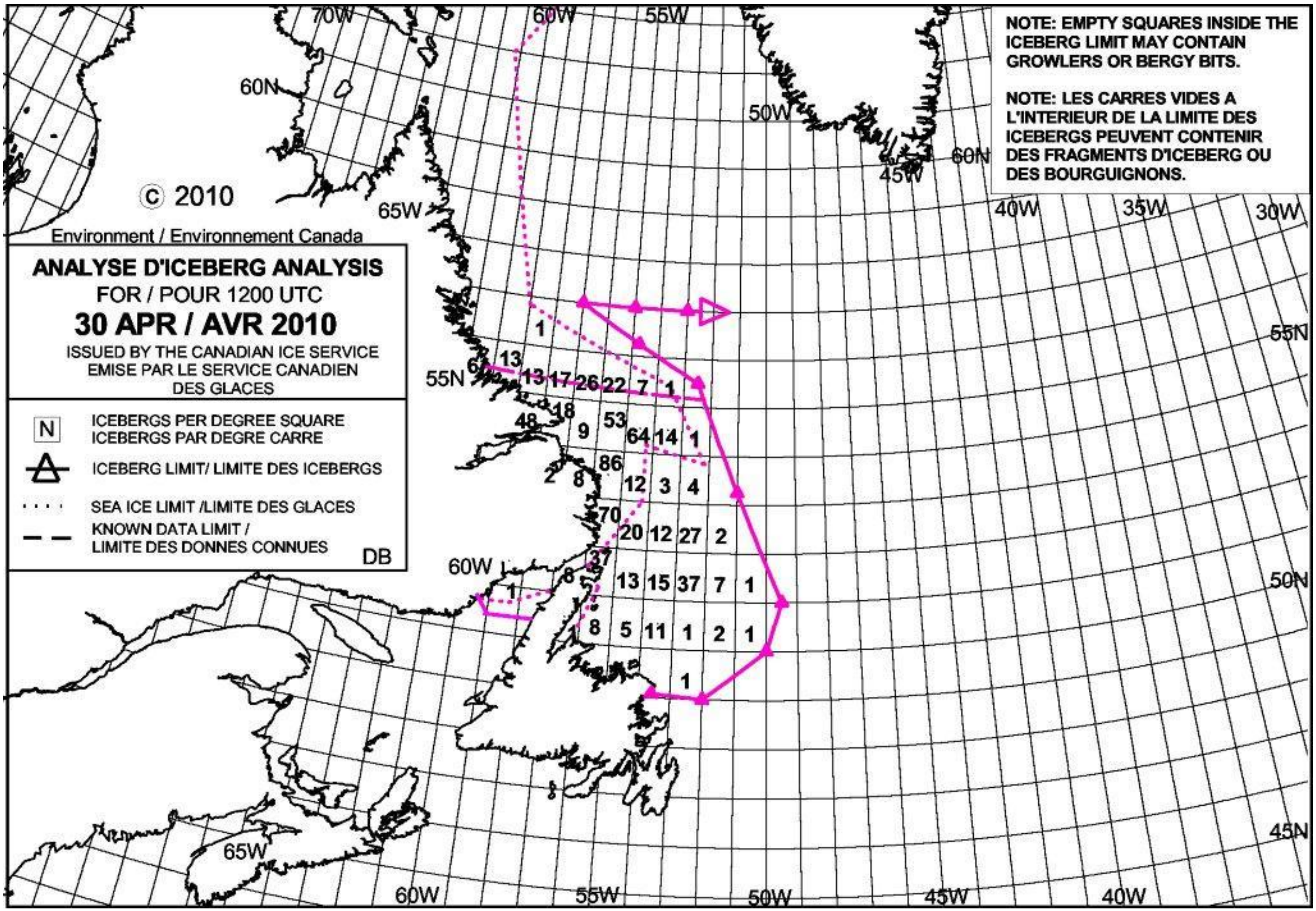
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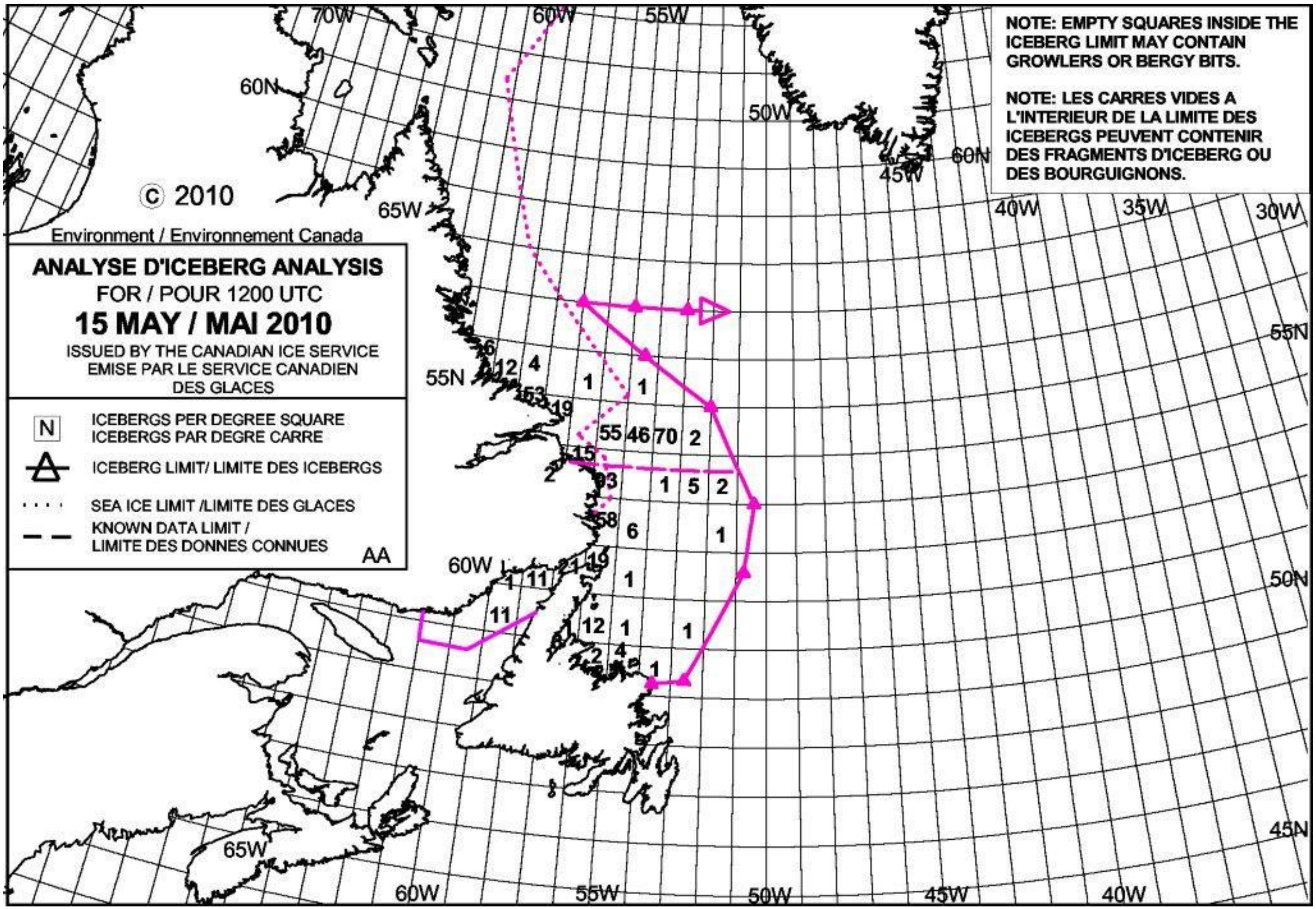
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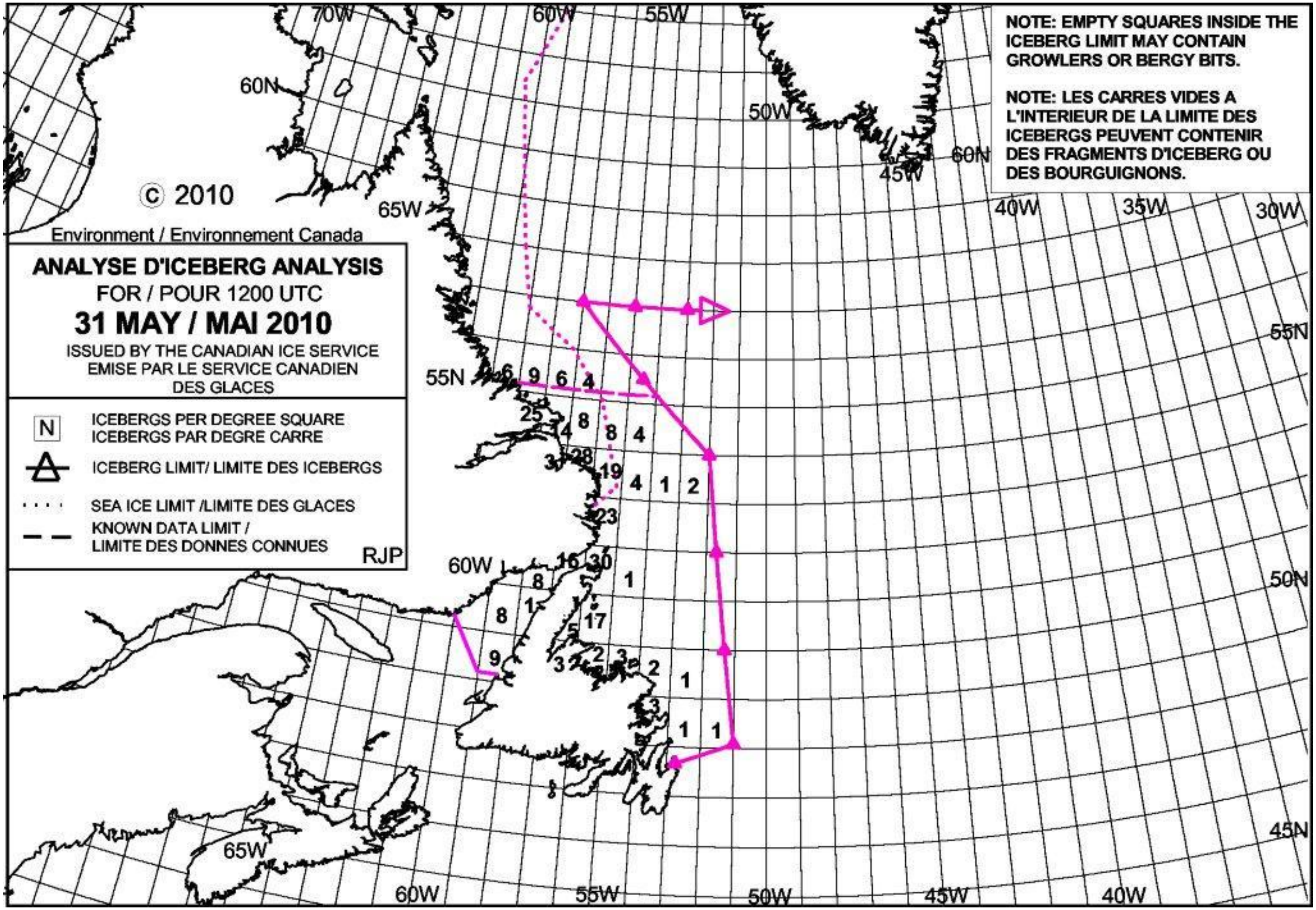
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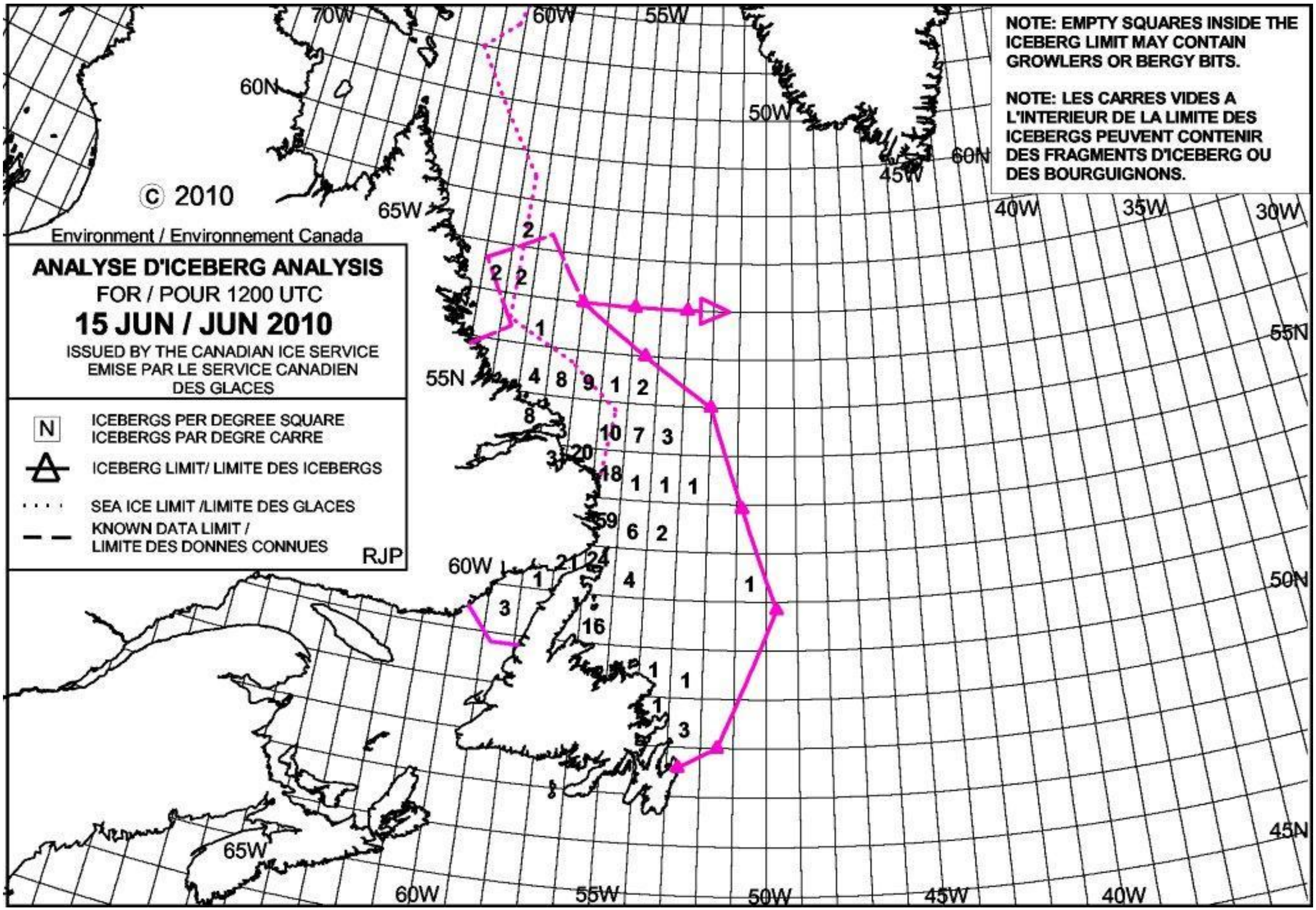
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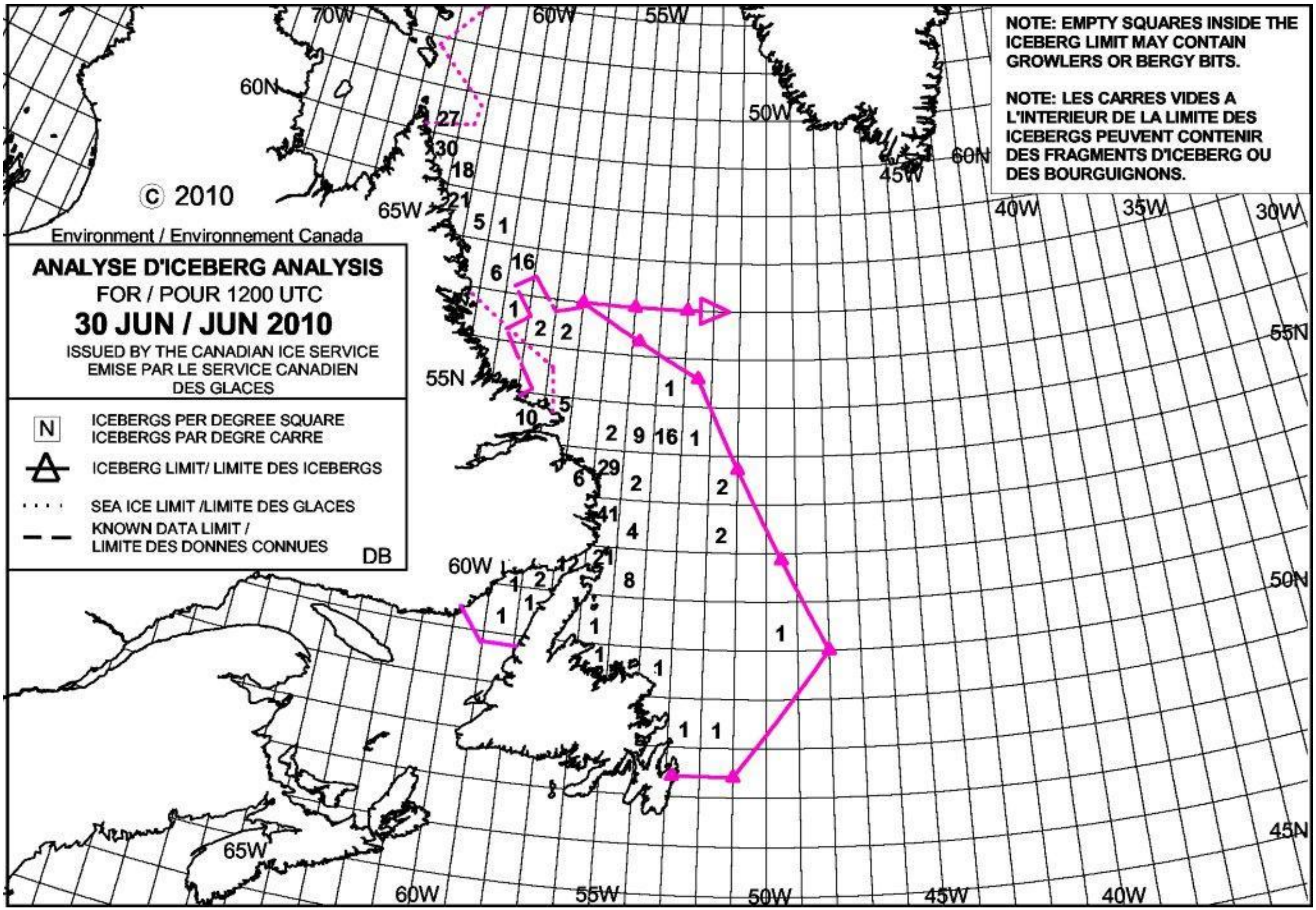
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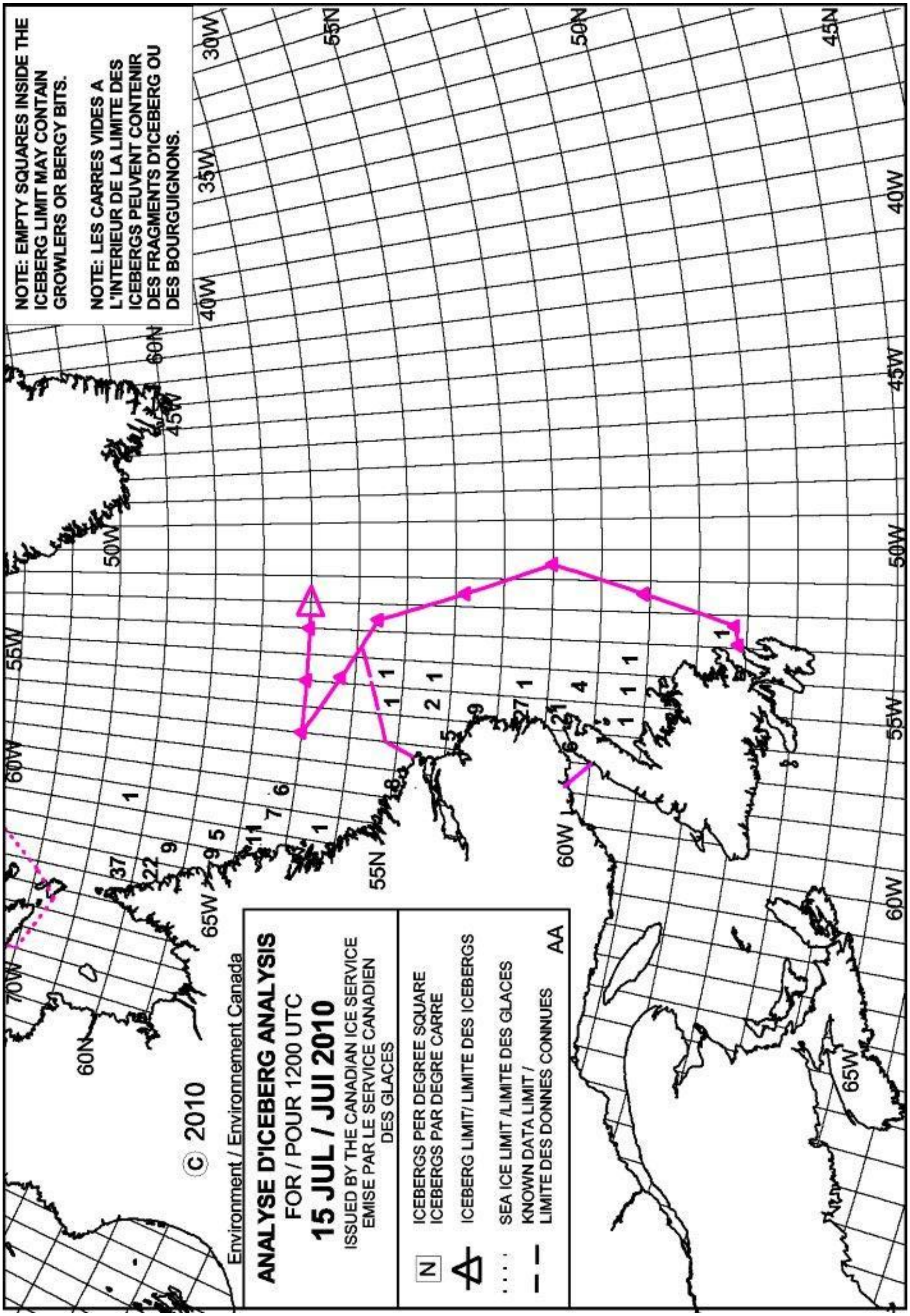
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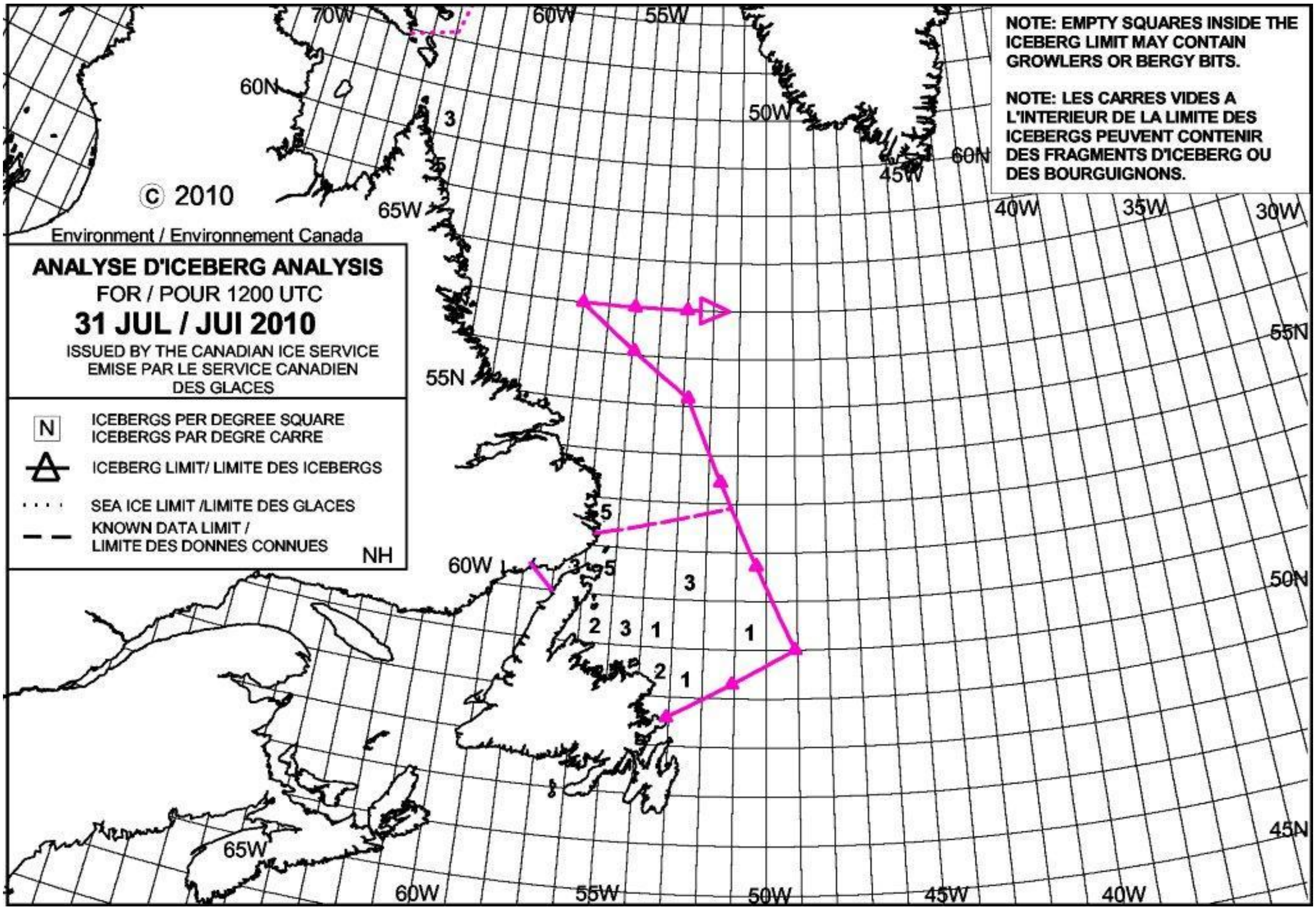
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Acknowledgements

Commander, International Ice Patrol acknowledges the following organizations for providing information and assistance:

Canadian Coast Guard
Canadian Forces
Canadian Ice Service
Canadian Maritime Atlantic Command Meteorological and Oceanographic Center
C-CORE
Department of Fisheries and Oceans Canada
German Federal Maritime and Hydrographic Agency
National Geospatial-Intelligence Agency
National Ice Center
National Weather Service
Nav Canada Flight Services
Provincial Aerospace Limited
U. S. Coast Guard Air Station Elizabeth City
U. S. Coast Guard Aviation Training Center Mobile
U. S. Coast Guard Atlantic Area Staff
U. S. Coast Guard Automated Merchant Vessel Emergency Response System
U. S. Coast Guard Communications Area Master Station Atlantic
U. S. Coast Guard First District Command Center
U. S. Coast Guard First District Staff
U. S. Coast Guard Headquarters Staff
U. S. Coast Guard Intelligence Coordination Center
U. S. Coast Guard Operations Systems Center
U. S. Coast Guard Research and Development Center
U. S. Naval Atlantic Meteorology and Oceanography Center
U. S. Naval Fleet Numerical Meteorology and Oceanography Center

It is important to recognize the outstanding efforts of the personnel assigned to the International Ice Patrol during the 2010 Ice Season:

CDR S. D. Rogerson
CDR L. K. Mack
LCDR G. G. McGrath
Dr. D. L. Murphy
Mrs. B. J. Lis
LT S. R. Houle
LT K. M. Nolan
MSTCS J. C. Luzader
YN1 I. O. Gonzalez
MST1 H. L. Brittle
MST1 W. W. Mendenhall
MST1 K. A. Farah
MST1 S. B. McClellan
MST2 G. J. Woolverton
MST2 S. A. Baumgartner
MST2 C. R. Hendry
MST2 W. N. Moran
MST3 M. M. Sanks
MST3 J. P. Orsini

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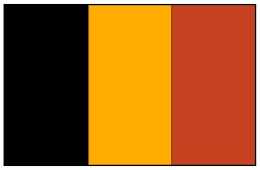
Appendix A

Contracting Nations

Belgium



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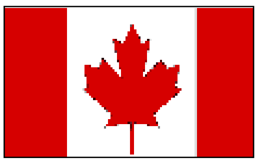

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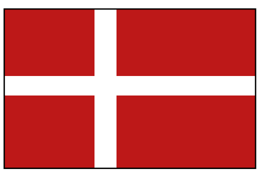

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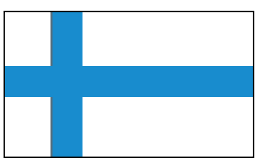

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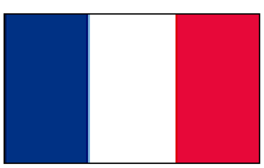
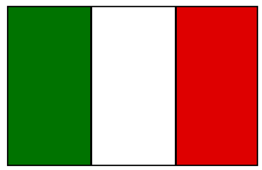


Germany

Greece

Italy



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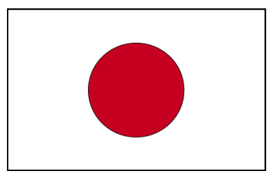

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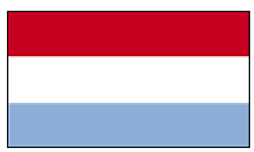

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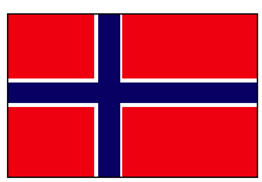

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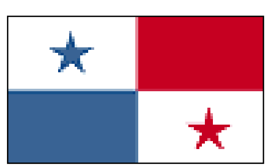

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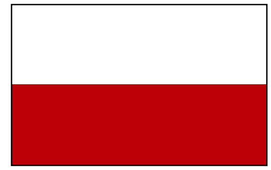
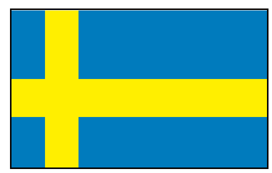
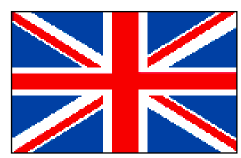


Spain

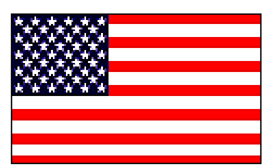
Sweden



United Kingdom



United States of America



Appendix B

Ship reports for Ice Year 2010
(Oct 1st, 2009 – Sep 30th, 2010)

Ships Reporting By Flag	Reports
ANTIGUA AND BARBUDA	
BBC GEORGIA	6
BAHAMAS	
AFRODITE	2
ARIADNE	1
BONNIE SMITHWICK	3
CLIPPER LEANDER	3
GREEN ICE	1
HANSEATIC	1
JAEGER ARROW	4
MAZURY	7
SEAROSE G	3
SEVEN SEAS VOYAGER	1
STENA CHRONOS	1
WARTA	10
BERMUDA	
STENA PERROS	1
STENA PROGRESS	7
CANADA	
ARCTIC	2
ASTRON	1
DUTCH RUNNER	1
MERSEY VENTURE (FISHING)	1
MOKAMI	1
NORTHERN EAGLE (FISHING)	1
OCEAN FOXTROT	1
OCEANEX AVALON	1
SIR ROBERT BOND (FERRY)	3
STRAIT EXPLORER (RESEARCH)	8
CHINA, PEOPLES REPUBLIC	
GOLDEN STRENGTH	2
CYPRUS	
FEDERAL PENDANT	1
FEDERAL POWER	7
INGRID GORTHON	8
ISADORA	22
ISOLDA	6
PRISCO ELIZAVETA	3

Ships Reporting By Flag	Reports
DENMARK	
ARINA ARCTICA	1
DTU AQUA	4
IRENA ARCTICA	1
MARY ARCTICA	3
NAJA ARCTICA	6
NUKA ARCTICA	3
ORATANK	6
OTILIA	1
TORM LENE	2
DOMINICAN REPUBLIC	
VESTLANDIA	4
FINLAND	
FUTURA	3
JURMO	2
NORDICA	3
PURHA	1
GERMANY	
SEACONGER	1
SEAMARLIN	6
SEATROUT	1
GIBRALTAR	
LS CHRISTINE	1
WESTON	1
GREECE	
CAP LARA	13
CAP PHILIPPE	7
CAP THEODORA	19
MINERVA JULIE	1
MINERVA SYMPHONY	34
HONG KONG	
CAPE OCEANIA	3
FEDERAL PROGRESS	3
FEDERAL SETO	4
FEDERAL VENTURE	1
GOLDEN OPPORTUNITY	1
GREAT QIN	4
NORDIC BARENTS	1

Ships Reporting By Flag	Reports
HONG KONG cont.	
OOCL BELGIUM	4
OOCL MONTREAL	5
SEATRANSPORT	6
ITALY	
COSTA ATLANTICA	15
MICHELE IULIANO	3
VALERIA DELLA GATTA	1
LIBERIA	
ADYGEYA	6
ANEMOS I	1
APL EGYPT	10
CMA CGM L'ETOILE	2
* EVA N	134
LOUISA BOLTEN	5
MCS MEXICO	5
OKTHA BRIDGE	1
TAMAN	2
LITHUANIA	
VENTA	2
MALAYSIA	
ALAM PADU	2
MALTA	
PESSADA	1
SOVI R	3
VOYAGER	1
WLOCLAWEK	2
MARSHALL ISLANDS	
IRON BILL	3
OVERSEAS JOSEFA CAMEJO	5
NETHERLANDS	
ASIABORG	1
FAIRLOAD	3
MAERSK PALERMO	3
MAERSK PENANG	3
TRANSPORTER	1
TRAVELLER	4
NETHERLANDS ANTILLES	
AMAZONEBORG	2
ARNEBORG	1
CFL PROUD	4
MAERSK PEMBROKE	1
PELAGIA	1
VARNEBANK	1

Ships Reporting By Flag	Reports
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A DUCKLING	2
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VANUATU	
LEGIONY POLSKIE	6
ORLETA LWOWSKIE	17

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Appendix C

A New Iceberg Drift and Deterioration Model for the North American Ice Service

Donald L. Murphy
U.S. Coast Guard
International Ice Patrol
and
Tom Carrieres
Environment Canada
Canadian Ice Service

Introduction

At the 8th annual meeting of the North American Ice Service (NAIS) in June 2010, the NAIS Co-Directors adopted a new iceberg drift and deterioration model, which was developed by the Canadian Ice Service (CIS). The Directors established a model transition team that will develop an implementation plan. Operational testing of the new model is expected to begin in 2011 and implementation is expected to occur in 2012. This appendix briefly describes motivation behind the change and the testing that formed the basis of this decision. The tests are described in more detail in Murphy and Carrieres (2010).

The operational iceberg drift and deterioration model used by International Ice Patrol (IIP) and CIS provides critical safety information to mariners navigating or operating in the western North Atlantic. The drift portion of the model, based on Mountain (1980), uses wind data from the Canadian Meteorological Center (CMC) and ocean current data from the IIP current database to estimate iceberg movement and develop operational products. The deterioration portion, which is based on White et al. (1980), was developed in 1983 (Anderson, 1983) and has changed little since. While the current operational iceberg drift and deterioration model has served IIP and CIS well, it has not been updated in many years. Thus, it is unable to take advantage of modern ocean current models, ensemble forecasting techniques, and other recent improvements.

Over the last several years, CIS has developed a new iceberg drift and deterioration model, which is documented extensively in Savage (1999), Kubat et al. (2005), and Kubat et al. (2007). It contains numerous improvements over the existing operational model. The drift algorithm, for example, includes a term for wave-induced iceberg drift. In addition, the CIS model is designed to take advantage of the multi-level currents provided by the new generation of ocean circulation models. Together with improved description of iceberg geometry, this results in superior representation of the stress on the submerged portion of the iceberg. The deterioration algorithm has several improvements as well, including the creation of small ice masses due to the calving of overhanging slabs and an improved estimate of wave erosion.

Since 2007, CIS and IIP have been cooperating closely to compare the performance of the respective models. During the course of this research, both models have been tested under a wide variety of conditions. This effort culminated recently in an extensive inter-comparison of the performance of the two models using the observed drift of 137 icebergs. The inter-comparison was divided into two parts. In the first, the models were run under nearly identical conditions to show that, for the same winds and currents, the accuracy of both models was similar. This result gives confidence that the CIS model produces results that are as accurate as the IIP model if the same inputs are used. In the second test, the two models were run with the same wind data, but the IIP model used currents from the IIP database and the CIS model used currents from the ocean component of the Canadian East Coast Ocean Model (CECOM, Tang et al., 2008), an advanced 3-D circulation model for eastern Canadian waters. This test illustrates the potential accuracy improvements that can be achieved using better current data (of which CECOM is one example), which the CIS model is capable of ingesting.

In the following sections, the model used to create operational products is referred to as the IIP model. The new model, recently adopted as the NAIS iceberg model, is referred to as the CIS model.

Iceberg Drift

Comparison of Model Features

Model Features	IIP	CIS
Ocean currents	IIP current database, representing mean currents at one level, nominally 50 m.	The CIS model can use a wide range of numerical ocean circulation models, e. g., IIP currents, CECOM, and Mercator.
Wind-driven current	Ekman calculation added to mean current (uses time-dependent Ekman dynamics). The Ekman calculation gives depth-varying currents.	Included in data input from the numerical ocean circulation model; thus, not calculated in the CIS model.
Current data assimilation	Daily modification in the vicinity of buoys (Viekman and Wright, 1996).	No real-time currents used to update. CECOM can assimilate sea surface temperature (SST) data (Tang et al., 2008). Other ocean models also assimilate sea surface height.
Iceberg size and shape	Crude size and shape categories with cross-sectional area in each of four layers underwater, depending on the iceberg size and shape. In addition, the IIP model includes the bergy bit size category with growlers. Also, there is no distinction between large icebergs and very large icebergs in the IIP model.	More realistic underwater shapes to accommodate the multiple current levels and increasing knowledge of underwater iceberg shapes (Barker et al., 2004).
Numerical scheme	Fourth-order Runge Kutta, which is highly accurate but leads to convergence problems, which can cause growlers and small icebergs to go into a simple vector addition routine.	Implicit backward Euler (very stable solutions).
Input format for environmental data	Uses hard-coded formats for each environmental input (e. g., GRIB for wind data and ASCII for current data).	Accepts a wide variety of formats, including netCDF, GRIB, and ASCII.
Wave-forced movement	No wave-forced movement; wave data used only in the deterioration algorithm.	CIS model includes wave radiation stress that increases with the significant wave height squared; includes both wind and swell waves (Savage, 2007).
Ensemble forecasts: A collection of two or more deterministic forecasts valid at the same time; allows the incorporation of parameter uncertainties into a probabilistic iceberg drift.	Cannot create ensemble forecasts.	Capable of producing ensemble forecasts (Allison, 2008).

Table 1. Comparison between the features of the IIP and CIS iceberg drift models.

Comparisons of Model Performance

The observed iceberg tracks (**Figure 1**), against which the model results were compared, were obtained over the years 2002 - 2007 from several sources. Most of the iceberg tracks were collected by Provincial Aerospace Limited (PAL), a commercial ice reconnaissance provider, as part of their oil field support efforts. As a result, most of the data were collected in the eastern part of the Grand Banks, the location of the oil production and exploration platforms. Observations of iceberg location, size, and shape were entered into the two models. The results of the drift calculations were compared with subsequent iceberg observations.

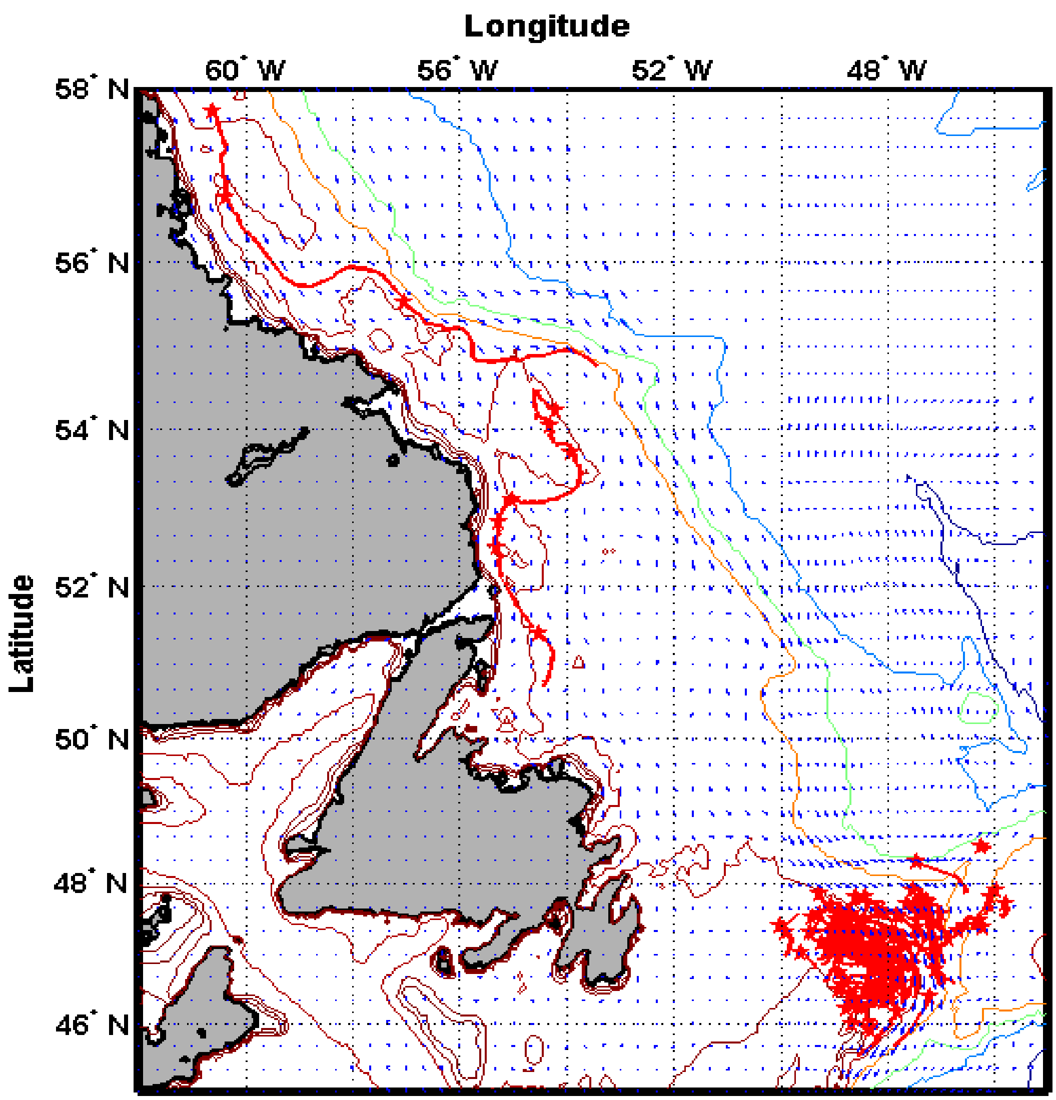

Figure 1. Observed iceberg tracks (red). There is a star at the beginning of the observed track. The blue vectors show the current vectors from the IIP current database.

Comparison of IIP and CIS Models for Identical Environmental Inputs (CMC Winds and IIP Currents)

A direct comparison between the IIP and CIS iceberg drift models was not possible because of the fundamentally different ways the two models include the effects of wind-driven currents. Currents in the IIP database are considered to be mean currents without wind effects. The IIP iceberg drift model uses an algorithm for time-dependent Ekman dynamics (Mountain and Mooney, 1979, and Mooney, 1978) to compute the wind-driven currents for four depth intervals and adds the result to the mean current value to arrive at the total water current for each level. However, the CIS model is designed to use currents from numerical ocean models that already include wind-driven current effects. Thus, the CIS model does not calculate wind-driven currents. IIP's attempt to create a version of the IIP model without the Ekman calculation to allow direct comparison was not possible because numerical solutions for many model runs became unstable.

As a result of the inability to modify the IIP model to eliminate the Ekman terms, the closest comparison that could be achieved was a comparison between the IIP model with wind-driven currents and the CIS model without wind-driven currents. The expectation was that the accuracy of the CIS model would be reduced due to the lack of a wind-driven component in the ocean forcing. Despite the lack of an exact match, it is useful to proceed with the comparison to get a sense of the scale of the differences between the two models. When all the iceberg sizes and locations are combined, the root mean square (RMS) errors of the IIP and CIS models were remarkably similar (**Figure 2**).

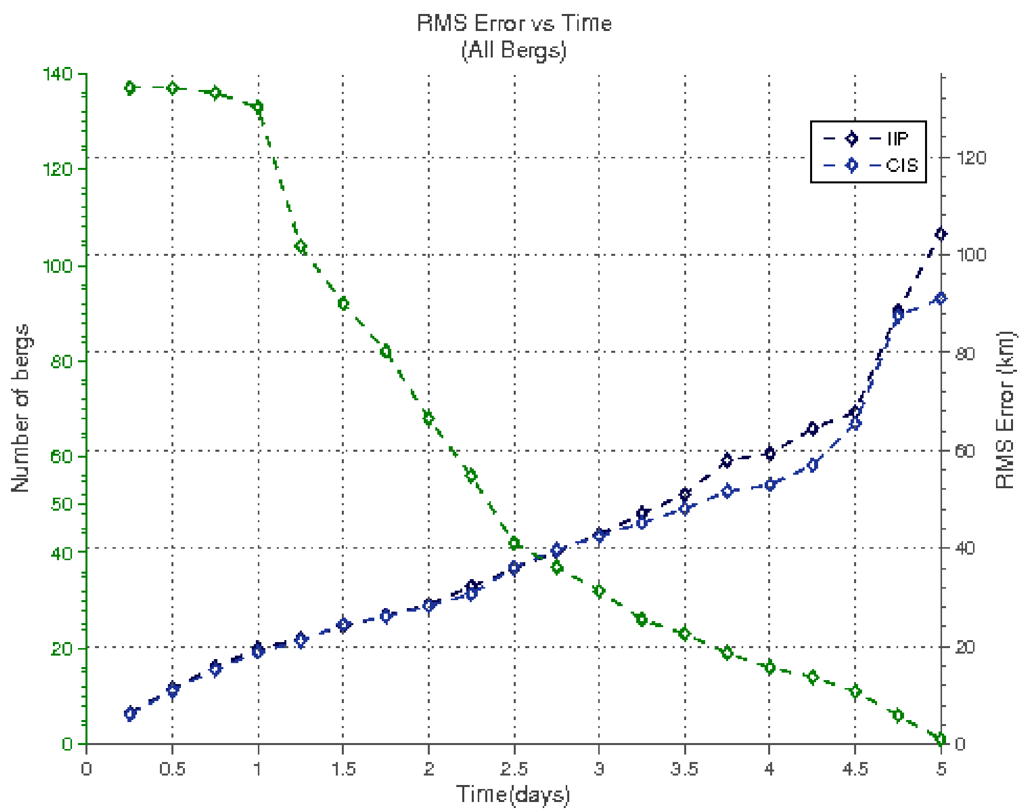

Figure 2. RMS error and number of icebergs with respect to time (Mongroo and Li, 2010).

In fact, the results are nearly identical up to 3.5 days, after which the number of icebergs declined significantly (below 30 icebergs The results showed that the IIP and CIS models, when run with identical environmental inputs, produce similar results. This may be considered surprising because the CIS model did not have a wind-driven component to the ocean currents. A likely explanation is that, for both models, the errors are dominated by errors in the mean currents.

Comparison of IIP Model using IIP Currents with the CIS Model using CECOM Currents

One of the major advantages of adopting the CIS model is its ability to use the new generation of ocean current models. This section describes the performance of the IIP model using the IIP current database to the CIS model with currents generated from the ocean component of the CECOM. The intent is to investigate the potential for improvement by moving from the IIP currents to an ocean model.

Several ocean current models could be used to drive the NAIS iceberg model, including:

- CECOM (Canadian East Coast Ocean Model), an advanced 3-D circulation model for eastern Canadian waters (Tang et al., 2008)
- HYCOM (HYbrid Coordinate Ocean Model), an ocean prediction system that is run daily at the Navy DoD Supercomputing Resource Center. http://www.hycom.org/
- Mercator Ocean's High-Resolution Atlantic and Mediterranean Model http://www.mercator-ocean.fr/

The currents from the CECOM ocean component were chosen for close examination because CIS will soon implement CECOM for its sea ice forecast program.

Description of IIP Currents and CECOM Currents

Feature	IIP Currents	CECOM
Source	Mean current measured by 243 satellite-tracked drifters (Murphy et al., 1996)	The ocean component of CECOM, which is the Princeton Ocean Model (2009) (Tang et al., 2008)
Horizontal resolution	1/3º latitude by 1/3º longitude except in the offshore branch of the Labrador Current where it is 1/3º by 1/6º	0.1º by 0.1º
Vertical resolution	None; represents the mean current in the upper ~ 50 m of the water column	CECOM has 20 layers, which are interpolated to 10 m layers for the iceberg model
Wind-driven currents	IIP currents do not contain a wind-driven component. The IIP iceberg drift model uses CMC (GEM) winds to calculate Ekman currents, which are added to the mean current.	CECOM dynamics include the effects of wind-driven current. CMC (GEM) winds are used by CECOM.
Wave forcing	None	Currents due to Stokes drift are calculated using surface winds (Tang et al., 2008).
Tidal Currents	None	Pawlowicz et al. (2002) tidal model calculates tidal current and elevation for the forecast period; results are linearly added.

Table 2. Comparison between IIP and CECOM currents.

The IIP ocean current database, created from many years of satellite-tracked drifter data (Murphy et al., 1996), represents the mean currents in the upper layer of the ocean (nominally 8 m to 50 m). The horizontal grid of the current database is coarse: 1/3° latitude by 1/3° longitude, except in the offshore branch of the Labrador Current where it is 1/3° latitude by 1/6° longitude. IIP deploys drifters to obtain near-real time data to use in updating the IIP currents.

The operational IIP model can use only the IIP currents while the CIS model is capable of using many different data sources.

Comparison Results

In this set of tests, the performance of the IIP model with CMC winds and IIP currents was compared to the performance of the CIS model with CMC winds and CECOM currents. Again, a set of 137 observed iceberg drift tracks was used for these tests.

South of 50ºN, using the CECOM currents resulted in a significant improvement in the performance of the CIS model, both with respect to the CIS model with IIP currents and the IIP model with IIP currents. The CIS model with CECOM currents had lower RMS error values than the IIP model with IIP currents.

North of 50ºN, using the CECOM currents in the CIS model resulted in a small improvement in the performance over the CIS model with IIP currents. Overall, however, there was a slight decline in the accuracy of the forecasts. There are several possible explanations for this observation. The results are based on a small dataset, which reduces the confidence. In addition, the CECOM model might not be producing accurate currents in the region, which is dominated by the complex bathymetry of Hamilton Bank.

Iceberg Deterioration

IIP conducted a series of numerical inter-comparison tests of the IIP and CIS iceberg deterioration models over a wide range of sea temperatures, wave heights, and wave periods. The primary goal was to gain an understanding of the differences between the deterioration estimates of the two models.

There are two major differences in the formulation of the two deterioration models. First, the CIS model includes a calving algorithm, which produces small ice masses as a result of the deterioration process. The second is a different formulation for calculating wave erosion, which results in CIS model having increased mass loss on the underside of the iceberg. In both cases, one would expect the CIS model to estimate faster iceberg destruction than the IIP model, which is not what the inter-comparison showed. Overall, the tests showed that IIP model melted icebergs faster than the CIS model. Perhaps IIP's simple approach to calculating wave erosion over-estimates its impact. Unfortunately, there aren't adequate field observations to determine which is correct.

The deterioration model provides IIP with a decision-making tool that helps indicate when an iceberg no longer poses a risk to mariners. When the model estimates that an iceberg has lost all its original length, it is removed from the plot and future simulations.

Recognizing the uncertainty of the deterioration estimate, IIP adds a safety factor that depends on the location of the iceberg. Near the Limit of All Known Ice (LAKI), the safety factor is very conservative. The iceberg is allowed to stay on plot until it melts 150% of its original length, 50% longer than the model estimated. Far within the LAKI, this is relaxed to 125% of the original length.

Conclusions

The following are the conclusions of the study:

- When the IIP and CIS models were run with identical wind and current data, the results were similar.
- South of 50^{o}N, the accuracy of the CIS model with CECOM currents was significantly better than the IIP model with IIP currents. North of 50^{o}N, the results were mixed. In some areas, the CIS model was more accurate. In other areas, the IIP model with IIP currents was.
- The CIS model has the ability to accept a wide variety of current data, including CECOM, HYCOM, IIP, and others as they become available.
- The CIS model has a flexible representation of iceberg geometry and has the ability to accept new iceberg size and shape data as they become available.
- The CIS model provides stable solutions to the model equations over a wide range of current and wind conditions.
- Numerical tests showed that the IIP deterioration model melted icebergs faster than the CIS model. There are insufficient field data to test the accuracy of the deterioration models.

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Appendix D

HC-144A Maritime Patrol Aircraft Platform Evaluation

LT Scott R. Houle
and
MST1 William W. Mendenhall

Introduction

In May 2010, due to unavailability of the HC-130J long-range aircraft to support iceberg reconnaissance operations, IIP was presented with an opportunity to supplement scheduled iceberg reconnaissance and conduct an operational evaluation of the Coast Guard's recently acquired HC-144A medium-range Maritime Patrol Aircraft and mission system. IIP was able to conduct a preliminary evaluation of the HC-144A's ability to detect and classify icebergs in accordance with current IIP reconnaissance requirements. The aircraft was deployed to St. John's, Newfoundland and conducted iceberg reconnaissance during Ice Reconnaissance Detachment (IRD) 5.5, named to minimize confusion with already scheduled IRDs. Because of the light ice conditions and minimal iceberg distribution, the HC-144A was able to successfully supplement the 2010 iceberg reconnaissance operations and allowed IIP to begin developing tactics to integrate the aircraft into IIP operations if needed in the future.

Aircraft History

The HC-144A was placed into operational use in 2009, charged with the task of replacing the Coast Guard's aging fleet of HU-25 Guardian (Falcon) jets. The aircraft is based on the Airbus Military CN235 tactical airlifter. This platform employs search radar, electro-optical and infrared cameras, an Automatic Identification System (AIS) for data collection from vessels at sea, and a specialized communications suite. It offers a rear ramp that allows for easy cargo operations and accommodates a roll-on-roll-off mission system pallet that the Coast Guard acquired separately (USCG Acquisition Directorate, 2010).

IIP Reconnaissance Requirements

IIP's primary area of responsibility (AOR) is described by SOLAS as "in the vicinity of the Grand Banks of Newfoundland," an area plagued by persistently poor weather conditions including low visibility. The current base of operations for IIP IRD's is St. John's, Newfoundland, chosen for its close proximity to the IIP AOR. IIP's Airborne Reconnaissance Requirements currently include an aircraft with a radar/sensor suite with the following capabilities:

- Search large geographical areas along the Limit of All Known Ice (LAKI) every 14 days.
- Detect icebergs and vessels in low and no visibility.
- Detect small icebergs (>15 meters in length and 5 meters in height) in 3 meter

seas (significant wave height), with a probability of detection of 0.95.
- Detect all vessels with a length of 10 meters or greater.
- Radar with an inverse synthetic aperture radar (ISAR) mode or other sensor(s) capable of discriminating between icebergs, vessels, and other objects in low and no visibility with qualified operators who can accurately interpret displayed signal returns.
- Real time display of target-data on the aircraft separate from pilot displays and with independent controls.
- Basic image enhancement techniques (zoom, filter, etc.) on specific targets.
- One window on each side of the aircraft large enough to give IIP's qualified Ice Observers a comprehensive view of the search area including below the aircraft.
- Aircraft navigational accuracy of +/- 250 meters.
- Integrated communications system (ICS) with isolated IIP mission circuit consisting of a minimum of 4 connections.
- Flight data must be transmitted to IIP operations center within 6 hours of landing time.

As a result of the evaluation conducted during IRD 5.5 from 10-15 May 2010, IIP was able to conclude that the HC-144A aircraft is capable of satisfying all of these requirements with the exception of the ability to "search large geographical areas" due to its limited range. This range is significantly shorter than the range of the HC-130J, the aircraft currently used to conduct IIP iceberg reconnaissance.

Aircraft/System Capabilities

The HC-144A is outfitted with two General Electric CT7-93C Turboprop engines capable of traveling 1,565 NM at a max cruise speed of 236 KTS, with an endurance of 8.7 hours. This is a notable contrast from the HC-130J which is capable of flying more than 12 hours at a max cruise speed of 335 KTS. The rear hydraulic operated ramp allows for easy cargo operations, providing a capability similar to that of the HC-130J for IIP buoy drops. However, the HC-144A has not yet been tested and approved to conduct IIP WOCE buoy drops, including no Standard Operating Procedures for the drop evolution. The aircraft also has two bubble style windows located near the rear of the plane with adjustable seating for aerial observers. This seating arrangement is a drastic improvement over the current observer configuration on the HC-130J.

The palletized mission system is composed of a pallet with two operating consoles. When installed, the mission system is linked to the mission equipment and sensors permanently integrated on the aircraft. The system can then provide mission data processing, video processing and display, sensor management and control, and communications capabilities. Systems include:

- APS-143C (V) 3 Multi Mode Radar (belly mounted for 360° surveillance)
- Automatic Identification System (AIS)
- Direction Finding (DF-430)
- Electronic Support Measure/Specific Emitter Identifier (ESM/SEI) AN/ALR-95
- Star Safire III Electro-Optical/Infrared (chin mounted EO/IR)

The HC-144A also provides off-aircraft communications via the following communications systems:

- ARC-210 VHF/UHF LOS
- RT-5000 P25 VHF/UHF LOS
- HF-9000
- INMARSAT
- ARC-210/1851 Warrior MILSATCOM (CGTO, 2010)

This combination of communications equipment offers the potential for real-time communications with the IIP Operations Center, a capability not previously available.

Summary

IIP's primary goal in conducting a preliminary operational evaluation of the HC-144A was to identify its ability to satisfy current IIP reconnaissance requirements during light ice seasons where an extended range is not needed to conduct effective iceberg reconnaissance. It was determined that the range of the HC-144A, which is significantly shorter than that of the HC-130J, is the most limiting factor for use of the aircraft. This platform is unable to meet current IIP reconnaissance requirements of approximately seven hour/ 1700NM iceberg reconnaissance patrols. These patrols also must factor in a consideration for an adequate fuel reserve required to land at alternate airport because of severe weather conditions frequently present in IIP's AOR . These challenges may render the aircraft ineffective in moderate to severe ice seasons where the extent of the ice population would exceed the aircraft's useful range. Another potential limitation that was identified but not sufficiently tested is the aircraft's ability to operate both mechanically and tactically in conditions that involve aircraft icing. The one opportunity to evaluate the aircraft in this manner proved challenging due to the lack of official procedures for icing conditions. In addition, incorporating a second aircraft with a completely different sensor package into IIP operations would significantly increase training requirements for IIP personnel.

The overall result of the evaluation indicated that the HC-144A is capable of conducting iceberg reconnaissance when Iceberg distribution is close to shore and would not require long transit legs to the search area. Historically these conditions are likely early and late in the season. It is noteworthy to mention that the HC-144A requires fewer crew members to operate than the HC-130J and has a fully-functioning mission system, a communications suite and aerial observer windows that are superior to what is currently installed on the HC-130J.

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1985	ADA259656
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1987	ADA259817
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1990	ADA256161
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1992	PB2002100029
1993	PB2002100028
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2000	PB2003100304
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2009	PB2011108676