Homeland Security
United States Coast Guard

Report of the International Ice Patrol in the North Atlantic

2013 Season
Bulletin No. 99
CG-188-68

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Season of 2013

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Forwarded herewith is Bulletin No. 99 of the International Ice Patrol (IIP), describing the Patrol's services and ice conditions during the 2013 season. With only 13 icebergs drifting into the transatlantic shipping lanes, 2013 was the 11th lightest ice season on record since 1900. The Ice and Environmental Conditions section presents a discussion of the meteorological and oceanographic conditions that set up this light season.

In 2013, IIP focused on innovations and efficiencies in iceberg reconnaissance. We collected and analyzed sweep width data from the HC-130J ELTA-2022 radar which allowed us to open up our track spacing to 30 nautical miles in calm conditions. This track spacing expansion will allow us to maximize our flight hours under these conditions beginning in 2014. We also worked with the Canadian Ice Service to implement a North American Ice Service (NAIS) Reconnaissance Strategy. This strategy allowed both services to eliminate redundancies in reconnaissance flights and maximize coverage by sharing all post-flight data between the services. Looking toward the future, we finalized our report on benchmark testing conducted in 2011 and 2012 that compared ground truth iceberg and ship data with simultaneous satellite imagery for direct comparison. This technical report, which will lay the groundwork for an IIP Satellite Reconnaissance Concept of Operations, is included in Appendix B.

While working to improve our reconnaissance, IIP also strived to improve its service to mariners. We contracted Shearwater Systems, LLC to conduct a study to identify IIP customers in the shipping industry, assess their use of current IIP iceberg products, and obtain input on additional or future customer needs in terms of types of information, format, accessibility, and timeliness. The results of this study will help IIP to provide its customers with the most relevant iceberg warning products.

In April, Ice Patrol commemorated 100 years of service to the North Atlantic mariner. We marked this event with a ceremony held at the Mystic Aquarium in Mystic, CT where a display within the Aquarium's TITANIC Exhibit was dedicated to the IIP.

On behalf of the dedicated men and women of IIP, I hope that you enjoy reading this report on the 2013 season.

G. G. McGrath, CDR

G. G. McGrath
Commander, U. S. Coast Guard
Commander, International Ice Patrol

International Ice Patrol
2013 Annual Report

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Cover art: International Ice Patrol Centennial.

Abbreviations and Acronyms

AIS	Automated Information System
APN-241	HC-130J Tactical Transport Weather Radar
AVHRR	Advanced Very High Resolution Radiometer
BAPS	iceBerg Analysis and Prediction System
CCG	Canadian Coast Guard
C-CORE	Center for Cold Ocean Resources Engineering
CG-257	USCG Office of Intelligence
CIS	Canadian Ice Service
CONOPS	Concept of Operations
CSAR	Classification Synthetic Aperture Radar
CSK	COSMO-SkyMed satellite
D1	Coast Guard First District
ECAS	Air Station Elizabeth City
ELTA	ELTA Systems Ltd., a group and a wholly-owned subsidiary of IAI (Israel Aerospace Industries) specifically referring to the ELM-2022A Airborne Maritime Surveillance Radar aboard the HC-130J
EOIR	Electro-Optical/Infrared
FNMOC	Fleet Numerical Meteorology and Oceanographic Center
FOUO	For Official Use Only
FY	Fiscal Year - October through September
HC-130J	Long Range Surveillance (LRS) Maritime Patrol Aircraft (MPA)
ICC	Intelligence Coordination Center
IDS	Iceberg Detection Software
IIP	International Ice Patrol
IRD	Iceberg reconnaissance Detachment
ISAR	Inverse Synthetic Aperture Radar
KTS	Knots
KIAS	Knots Indicated Air Speed
LRC	Lateral Range Curves
MANICE	Manual of Standard Procedures for Observing and Reporting Ice Conditions
MCTS	Marine Communications and Traffic Service
MIFC LANT	Maritime Intelligence Fusion Center Atlantic Area

NAFO	Northwest Atlantic Fisheries Organization
NAIS	North American Ice Service
NAO	North Atlantic Oscillation
NGA	National Geospatial-Intelligence Agency
NIC	National Ice Center
NL	Newfoundland and Labrador, Canada
NM	Nautical Mile
NOAA	National Oceanographic and Atmospheric Administration
NWS	National Weather Service
NTM	National Technical Means
OPAREA	Operational Area
OPCEN	Operations Center
PAL	Provincial Aerospace Limited
POD	Probability of Detection
RADAR	Radio Detection and Ranging (also radar)
RCS	Radar Cross-Section
RDC	Research and Development Center
RMS	Royal Mail Steamer
RSA2	RADARSAT-2 satellite
R/T	Radar Target
SAIC	Science Applications International Corporation
SAR	Synthetic Aperture Radar
SOLAS	Safety of Life at Sea
SS-##	ELTA Sea Surveillance mode at ## nautical mile range
SST	Sea Surface Temperature
SVP	Surface Velocity Program
TCPED	Tasking Collection Processing Exploitation and Dissemination
TENCAP	Tactical Exploitation of National Capabilities
TSX	TerraSAR-X satellite
USCG	United States Coast Guard
W	Sweep Width
WOCE	World Ocean Circulation Experiment

Introduction

This is the 99th annual report of the International Ice Patrol (IIP). The report contains information on IIP operations, environmental conditions, and iceberg conditions in the North Atlantic between February and August of 2013. 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 near the Grand Banks of Newfoundland and has broadcast the Iceberg Limit to the maritime community. The activities and responsibilities of IIP are delineated in U.S. Code, Title 46, Section 80302 and the International Convention for the Safety of Life at Sea (SOLAS), 1974.

IIP was under the operational control of Commander, U.S. Coast Guard First District. Iceberg reconnaissance Detachments (IRD) conducted aerial reconnaissance from St. John's, Newfoundland to search for icebergs in the North Atlantic and Labrador Sea. 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 a daily ice chart and text bulletin in 2013 under the North American Ice Service (NAIS) Collaborative Arrangement. In addition to these routine broadcasts, IIP responded to individual requests for iceberg information.

RDML Daniel B. Abel was Commander, U.S. Coast Guard First District.

CDR Lisa K. Mack was Commander, International Ice Patrol until relieved by CDR Gabrielle G. McGrath on 01 August 2013.

For more information about the International Ice Patrol, including historical and current ice bulletins and charts, visit our website at www.navcen.uscg.gov/IIP.

Summary of Operations

IIP monitors the iceberg danger near the Grand Banks of Newfoundland (**Figure 1**) and provides the Iceberg Limit to the maritime community as mandated by SOLAS. IIP works within a collaborative arrangement with the Canadian Ice Service (CIS) and the U.S. National Ice Center (NIC) formally titled the North American Ice Service (NAIS). The mission of NAIS is to leverage the strengths of the three services to monitor and provide the highest quality, timely and accurate ice analyses, to meet the needs of maritime interests in North America. NAIS agencies continued to work together during 2013 to improve the products to the transatlantic mariner.

Historical Perspective

The 2013 season was the 11th lightest on record since 1900. To determine the severity of the Ice Season, IIP uses two traditional measurements. The first measurement is the number of icebergs crossing south of 48°N latitude. This number includes icebergs initially sighted or detected south of 48°N as well as those originally sighted or detected further north and drifted south, as modeled by BAPS. In 2013, 13 icebergs (not including bergy bits or growlers) crossed south of 48°N. **Figure 2** shows the historical variability from 1900-1913 for this measurement (blue columns) along with the five year running

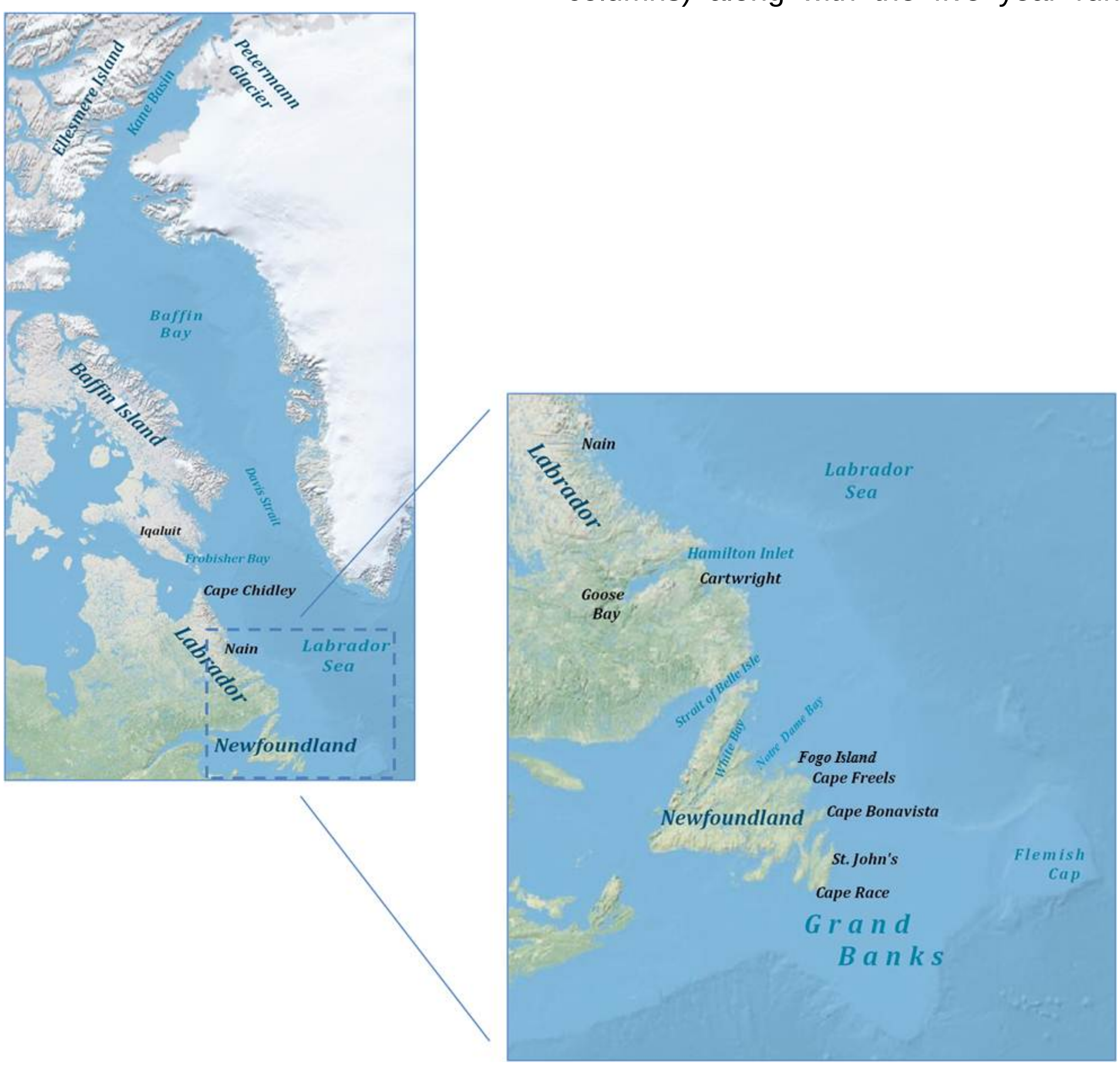

Figure 1. International Ice Patrol Operational Area (OPAREA).

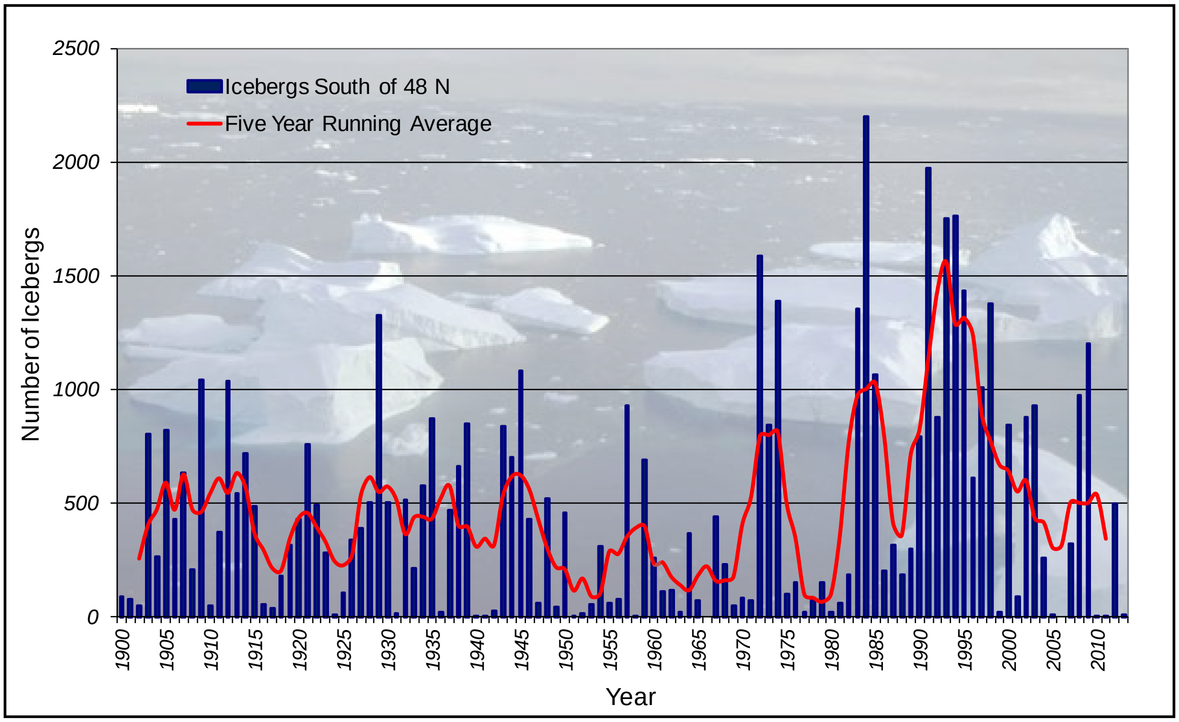

Figure 2. Icebergs crossing 48°N and five-year running average (1900-2013).

average (red line). The second factor is season length, measured in the number of days icebergs were present south of 48°N. In 2013, IIP recorded icebergs south of this latitude from 01 March through 20 May 2013 (81 days). IIP's modern aerial reconnaissance era is defined as the time period from 1983 through the present day when the use of aircraft equipped with radar for iceberg detection became standard. The average number of icebergs sighted or modeled south of 48°N during this period is 751, and the average season length during this time period is 121 days. In 2013, iceberg hazards only minimally impacted the transatlantic shipping lanes.

Products and Broadcasts

IIP strives for accurate and timely reports to the maritime community. In 2013, IIP transmitted scheduled NAIS Iceberg Bulletins every day with 99.7% reaching SafetyNET and Navigational Telex (NAVTEX) on time (prior to 0000Z). SafetyNET is a satellite-based, worldwide maritime safety information broadcast service. One hundred percent of the Simplex Teletype Over Radio (SITOR) service bulletins via Communications Station Boston were delivered on time.

Rarely, IIP will receive a report of an iceberg or radar target (R/T) outside of the published limit which challenges the accuracy of the NAIS products and is a threat to safe navigation. Although IIP receives reports of icebergs by other means, the Canadian Coast Guard Marine Communications and Traffic Service (MCTS) St. John's receives most iceberg reports. If MCTS determines an iceberg or R/T is outside of the published limit, MCTS generates and transmits a Notice to Shipping (NOTSHIP). The NOTSHIP is automatically forwarded to the National Geospatial-Intelligence Agency (NGA), and the information is disseminated through a NAVAREA IV warning. A NOTSHIP is the primary means of relaying critical iceberg information to the transatlantic mariner and allows time for IIP watch standers to produce and transmit a revised product during IIP Operations Center working hours. It also ensures the information is disseminated immediately. During the 2013 Ice Season, IIP received two NOTSHIPs: one transmitted in error by MCTS that required no product revision and one reporting an R/T outside of the published limit. Because IIP does not set the Iceberg Limit based on R/Ts, the Iceberg Limit accuracy for the 2013 Ice Season was 100%.

Iceberg Reports

A critical factor contributing to IIP's successful safety record is the support received from the maritime community. This support is measured annually by the number of voluntary iceberg reports IIP receives in a fiscal year (FY). In order to more efficiently serve the maritime community, IIP modified the reporting process in 2012. Due to the availability of reliable oceanographic information resources, IIP ceased requests for stand-alone sea surface temperature reports and solely requested iceberg reports. Iceberg reports from ships remain a critical source of information, and IIP encourages vessels transiting within or near the Grand Banks of Newfoundland to report iceberg sightings in a timely manner. Receiving on-scene and near real-time information further enhances the accuracy of IIP products.

As described above, 2013 was one of the lightest on record. Throughout the season, the iceberg population was mainly concentrated near the Canadian coast. This fact is clearly represented in the number of iceberg reports received from traditional sources. The IIP OPCEN received, analyzed, and processed 208 iceberg sighting messages, primarily via MCTS as shown in **Figure 3** (left bar graph). The number of reports was approximately 44% less than the 370 iceberg messages received in 2012 which can be attributed to light iceberg conditions. The Canadian Government, including Canadian Coast Guard vessels and Canadian Forces aircraft, combined to deliver 55 (26%) messages. Commercial aerial reconnaissance conducted by Provincial Aerospace Limited (PAL) provided 52 (25%) messages. Merchant ships provided 47 (23%). Satellite reconnaissance was responsible for 35 (17%), and IIP aerial

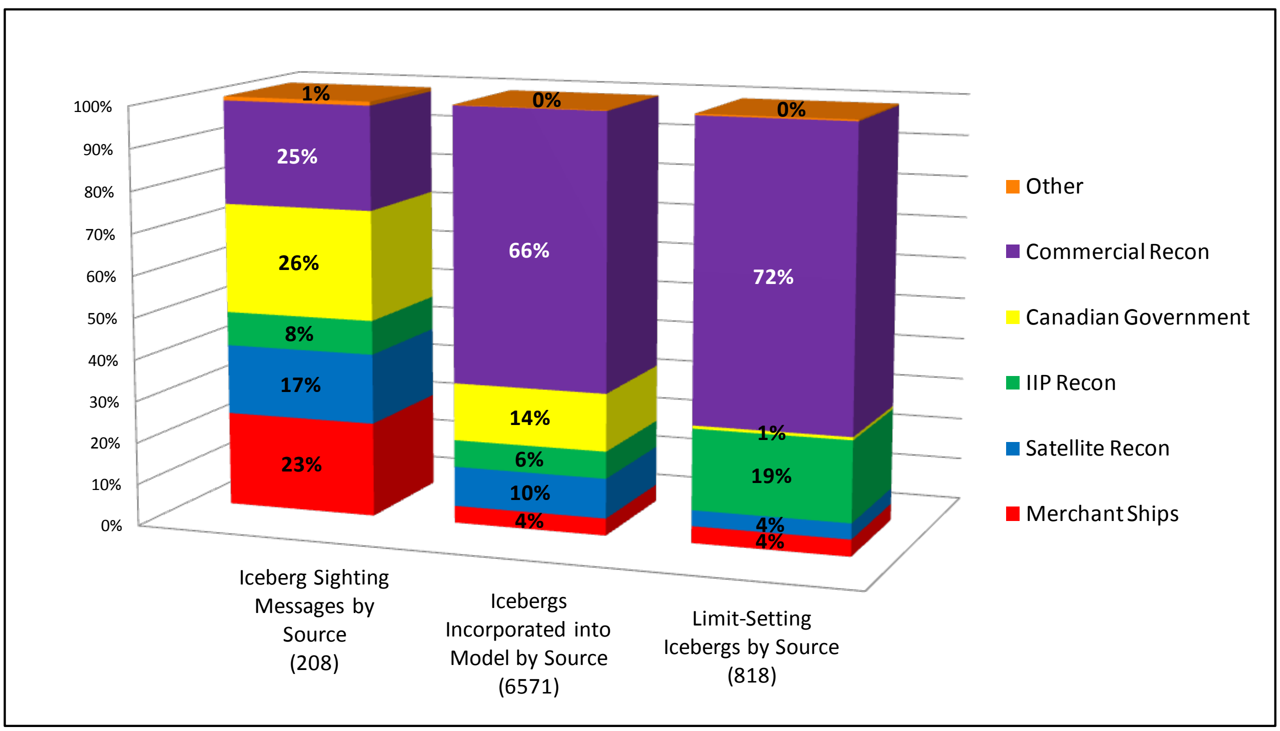

Figure 3. Percentage of iceberg messages, icebergs incorporated into model, and limit-setting icebergs by reporting source in 2013.

reconnaissance flights provided 17 (8%) ice reports. A scientific research vessel and a fishing vessel relayed the remaining two (1%) iceberg reports.

These iceberg sighting messages contained a total of 6774 icebergs, growlers, bergy bits or R/Ts. Prior to entry into the BAPS iceberg drift and deterioration model, IIP watch personnel evaluated all messages for accuracy and viability. After this process, 6571 of the original 6774 icebergs were incorporated (added or re-sighted) into BAPS. Several factors were considered 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, to ensure accurate iceberg products are being broadcast to the maritime community. The percentage of updates to BAPS by reporting source is portrayed in the middle bar graph of **Figure 3**. Commercial flights (66%) provided the majority of the icebergs incorporated into BAPS this year. These flights were conducted in support of the oil and gas industry operating on the Grand Banks and the Canadian Government. IIP reconnaissance reported 6% of the total number of icebergs entered into BAPS in 2013. This is consistent with the extremely light iceberg conditions observed during the 2013 season.

Icebergs used to establish the limit are of critical importance because they define the boundary for ice-free ship navigation. As a result, IIP's reconnaissance flights normally focus on this boundary and typically provide the highest percentage of limit-setting iceberg reports. However, this year the southernmost iceberg only drifted to 47°02'N, and the Iceberg Limit never extended significantly past the oil rigs on the nose of the Grand Banks, well within the range of PAL reconnaissance. Consequently, as shown in the right bar graph of **Figure 3**, commercial flights made the most significant contribution to the number of limit-setting iceberg sightings at 72% and allowed the U.S. Coast Guard (USCG) to utilize these flight hours for other missions. IIP flights accounted for 19% of all limit-setting iceberg sightings or detections.

Satellite Reconnaissance Research

In an effort to build confidence in using iceberg data from satellite reconnaissance, IIP partnered with the USCG Research and Development Center (RDC) under a two-year research and development project titled "Alternative Asset Iceberg Reconnaissance". IIP worked with RDC analysts to coordinate image collection under the USCG's Tactical Exploitation of National Capabilities (TENCAP) program through the USCG's Office of Intelligence (CG-257). Under this project, RDC collaborated with the USCG Intelligence Coordination Center (ICC) in Suitland, MD to acquire and analyze classified data from National Technical Means (NTM). After time-consuming and largely unsuccessful attempts at manually detecting iceberg targets from satellite imagery, ICC analysts applied an automated detection algorithm which dramatically improved their ability to identify iceberg targets. Data from these images were not used operationally due to time latency and classification but represented an initial proof-of-concept attempt at using this data source. Under this project, IIP also acquired two commercial unclassified RADARSAT-2 images from the NGA at no additional cost to the USCG.

IIP attempted ground truth collections during IRDs in May and June. Coordination attempts in May were unsuccessful due to persistent low visibility in St. John's and poor OPAREA weather which caused flight cancellations on five consecutive days. Two additional flight cancellations occurred due to aircraft maintenance. In June, IIP conducted two under-flights on 13 and 16 June for both commercial and government satellite assets. Commercial satellite acquisitions included RADARSAT-2 on both 13 and 16 June (Wide-Fine mode) and TerraSAR-X (TSX) (ScanSAR mode) on 16 June only. The TSX image was provided by the Astrium-Airbus company, a German corporation operating the TSX satellite. Despite further problems with poor visibility in the OPAREA and inoperative aircraft radar for portions of the flights, IIP collected some limited ground truth data on these two dates.

For unclassified, commercial image processing and analysis, IIP contracted the Centre for Cold Ocean Research Engineering (C-CORE), a not-for-profit research organization located in St. John's, Newfoundland. C-CORE uses a computer algorithm called the Iceberg Detection Software (IDS) which automates iceberg detections from commercial synthetic aperture radar (SAR) imagery. C-CORE provided the IIP OPCEN a report in Manual of Standard Procedures for Observing and Reporting Ice Conditions *(*MANICE) format based on IDS output. MANICE is the standard developed by CIS, for observing all forms of Sea, Lake and River Ice, as well as Ice of Land Origin. It describes the standard procedures for observing, recording and reporting ice conditions. C-CORE processed and analyzed both RADARSAT-2 images on 13 and 16 June and the TSX image on 16 June. In addition, ICC processed and analyzed the RADARSAT-2 images, and Astrium-Airbus processed and analyzed the TSX image using independent, automated algorithms. While the individual algorithms matched closely, results indicated only marginal correlation (between 37 and 44%) between satellite and aerial observations.

Detailed results from this project will be reported separately by RDC following the 2014 season. Lessons learned thus far have illuminated the need for IIP to test the overall Tasking, Collection, Processing, Exploitation and Dissemination (TCPED) process. The RDC project will continue in 2014 by thoroughly exercising the TCPED process over an extended period during the Ice Season. As operations allow, IIP will continue ground truth efforts in conjunction with normally scheduled IRDs and will focus on the operational impact of satellite-derived detections. Detailed results from 2011 and 2012 validations efforts are documented in Appendix B of this report.

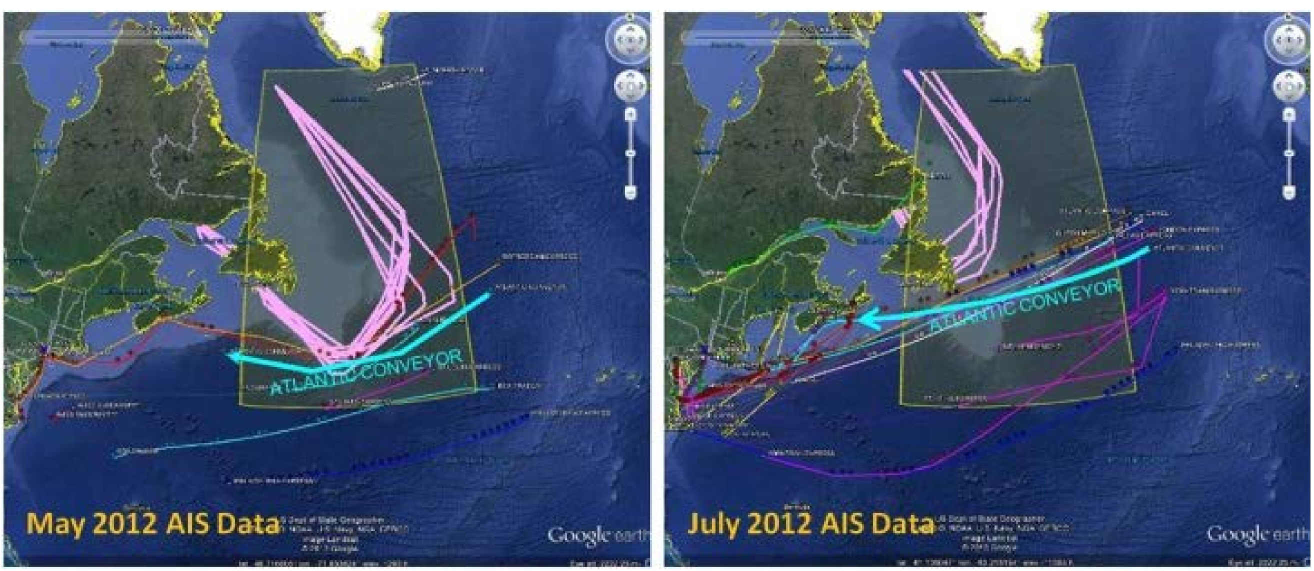

Figure 4. Example vessel tracks from 2012 AIS data.

In addition to the focused ground truth efforts described above, IIP received multiple reports from C-CORE through their Iceberg Finder program. C-COREs satellite derived messages from the Iceberg Finder Program contained 934 reports of icebergs, 13.8% of the total icebergs reported in 2013. These reports were initially quality-controlled by the IIP OPCEN and then sent to the Maritime Intelligence Fusion Center Atlantic (MIFC LANT) for further vetting. IIP incorporated 614 of the original 934 in its iceberg database. Of these, 47 eventually became limit-setting icebergs (5.2% of all Iceberg Limit setters).

Customers

To identify customers and improve understanding of their behavior, IIP contracted Shearwater, LLC to conduct a full-scale study.

Several times per week, Shearwater staff downloaded ship positions from a publicly-available ship tracking internet site called 'Sailwx.info' (SAILWX, 2013). In some instances, vessels appeared to maneuver to remain outside of the Iceberg Limit while others sailed through the warning area. With only 13 icebergs drifting south of 48°N latitude in 2013, the Iceberg Limit did not significantly impact the transatlantic shipping route. It was difficult to draw any strong conclusions about transatlantic ship behavior in response to IIP's Iceberg Limit during 2013 since the normal great circle route, passing just south of Newfoundland, closely coincided with the southern Iceberg Limit during April and May.

Shearwater also analyzed the 2012 Ice Season, a moderate season when 499 icebergs drifted south of 48°N. **Figure 4** provides an excerpt from the Shearwater analysis that shows several transatlantic ship tracks in May 2012 (left panel) compared to July 2012 (right panel). One vessel track, M/V ATLANTIC CONVEYOR (cyan-colored track) transited the area during both time frames and clearly diverted south by over 200 NM in May compared to July. On both voyages, the vessel was bound for Halifax, Nova Scotia. Results of this study are available and will be used to provide better support to our customers. (Shearwater, 2013)

Canadian Support

The Canadian Government continued to provide excellent support, particularly in product and process harmonization efforts. CIS freely shared valuable reconnaissance data, environmental data from the Canadian Meteorological Centre, iceberg and information reports from Canadian Coast Guard and Canadian Forces assets, and expertise regarding icebergs and sea ice. In addition, Canadian Coast Guard vessels deployed two satellite-tracked drifting buoys that provided key current data for BAPS model predictions.

Iceberg Reconnaissance and Oceanographic Operations

Iceberg Reconnaissance Detachment

The IRD is a sub-unit under Commander, IIP, which is partnered with U.S. Coast Guard Air Station Elizabeth City (ECAS). During the 2013 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 the maritime community.

Throughout the 2013 Ice Season, IRDs operated out of the IIP's base of operations in St. John's, Newfoundland for a total of 53 days and conducted 16 iceberg patrols. The first IRD departed for St. John's on 07 February, and the last IRD returned to New London on 10 July. Twenty-one flights were cancelled due to weather, and two flights were cancelled for aircraft maintenance. A summary of IRD operations is provided in **Table 1**.

IRD	Deployed Days	Iceberg Patrols	Transit Flights	Logistics Flights	Flight Hours
1	7	1	2	0	15.6
2	6	2	2	0	21.7
3	8	1	2	0	15.7
4	8	4	2	0	30.7
5	10	1	2	0	26.7
6	8	4	2	0	41.3
7	6	3	2	0	29.1
Total	**53**	**16**	**14**	**0**	**180.8**

Table 1. Summary of IRD Operations.

Aerial Iceberg Reconnaissance

The 2013 aerial iceberg reconnaissance operations were conducted using the HC-130J, a long-range surveillance maritime patrol aircraft, from ECAS. The aircraft is equipped with two radars and an Automatic Identification System (AIS) integrated into the mission system suite. The ELTA-2022 360° X-Band (ELTA) radar is capable of detecting and discriminating surface targets. The APN-241 Weather Radar is capable of detecting surface targets but not discriminating them. The AIS receives information transmitted by ships and is used in conjunction with the radar to differentiate vessels from icebergs.

Due to frequent poor weather in IIP's OPAREA, detecting and discriminating targets is an ongoing challenge for IRD personnel. This makes the use of radar critical to IIP operations. The IRD relies heavily on the detection and discrimination capability of the ELTA radar as the primary means of conducting iceberg reconnaissance. In conditions where there is no visibility to the surface, the IRD relies solely on the ELTA's imaging capability as the primary means of classifying targets.

IRDs conducted 16 patrols for a duration of 99.8 patrol hours and experienced 12.5 hours of ELTA radar casualties. Radar casualties resulted in two visual-only patrols. IRDs operated without working radar for 12.5% of total patrol time. This is an 11.9-hour increase from the 2012 Ice Season which had a total of only 0.6 hours of ELTA down-time.

The availability of 360° coverage provided by the ELTA radar supports the use of 25 NM track spacing for patrol planning (**Figure 5**). This decision is based in part, on limited detection data collected in 2008 and reported in the HC-130J Ice Patrol

Suitability Test Report of 20 February 2009. While this report recommended 22 NM track spacing to achieve 95% cumulative probability of detection (POD), it also recognized the need for further sensor performance testing. For the 2011-2013 seasons, IIP employed 25 NM track spacing to increase patrol coverage and reduce flight hours while accepting the possibility that 95% cumulative POD may not be achieved under certain environmental conditions. Testing the 25 NM tracking spacing became a high priority for 2013. IIP dedicated five patrols to collect detection data in concert with regular reconnaissance. Results from these tests are summarized later in this section.

As described in the Summary of Operations section, 6,571 icebergs were incorporated into the BAPS model. IRD personnel detected 523 icebergs which accounted for 8% of the total. Icebergs are detected in one of three ways: (1) combination of radar and visual, (2) radar only, or (3) visual only. This year, 46% of the icebergs were detected by both radar and visual sightings. The remaining icebergs were either detected only by radar (17%) or only by visual sighting (37%) (**Figure 6**). The number of visual only sightings decreased slightly from the previous year (43% in 2012) while the radar only sightings increased (10% in 2012).

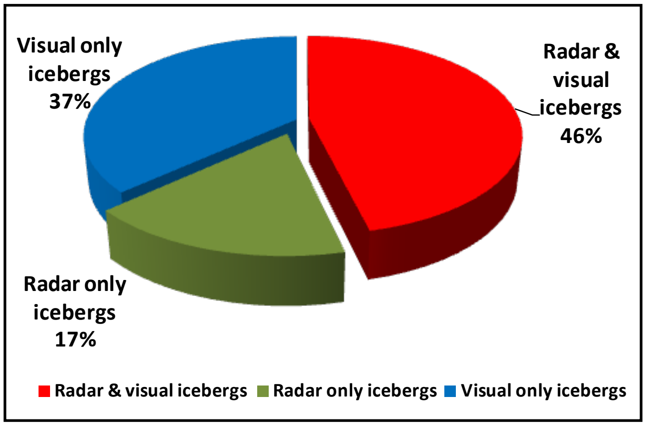

Figure 6. Iceberg sightings by method.

IIP is working to improve radar detection of icebergs in sea ice by evaluating the ELTA radar's Strip SAR mode in this environment and by modifying search altitudes for the best radar performance. However, distinguishing icebergs in sea ice remains a challenge because the radar automatically detects hundreds of targets, and the system operator does not have time

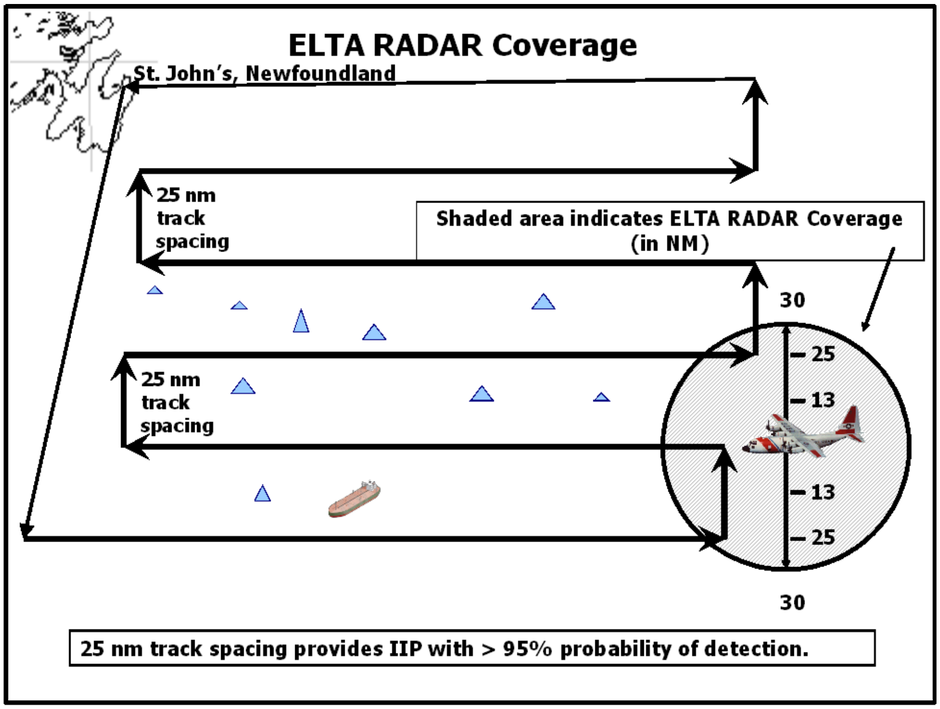

Figure 5. Radar Reconnaissance Plan.

to image and discriminate all of them. This underscores the value of visual observers when patrolling in sea ice.

2013 Flight Hours

In addition to the 16 iceberg patrols flown during the 2013 Ice Season, ECAS conducted 14 transit flights to and from St. John's. **Figure 7** shows the breakdown of the 180.8 flight hours used during the 2013 Ice Season for IIP operations. The flight hours are broken into three categories; transit hours, patrol hours, and logistics hours. Transit hours are the hours that the aircraft transited to and from specific locations in support of the IIP mission. There were 72 hours used this season for transits to and from St. John's. During the 2013 season, there were no requests to conduct concurrent First Coast Guard District (D1) Northwest Atlantic Fisheries Organization (NAFO) patrols during IIP transit flights. Patrol hours are the hours used for iceberg reconnaissance. IIP flew 99.8 patrol hours this season. Logistics hours are the hours used to support the overall mission of IIP, but do not fall into the previous two categories. Logistics hours are generally used to transport parts for an aircraft designated for use in the execution of the IIP mission. This year, nine logistics hours were used to transport aircraft parts from ECAS to the IRD in St. John's.

The number of flight hours needed for IIP to monitor iceberg danger to transatlantic mariners is closely linked to the number of icebergs observed or drifted south of 48°N. **Figure 8** shows a comparison of flight hours to number of icebergs drifted south of 48°N from 2003 to 2013. The red line indicates the IIP total flight hours. The blue bars indicate the number of icebergs observed or drifted south of 48°N.

Sweep Width Testing

The primary goal of Sweep Width Testing (SWT) was to validate the current use of 25 NM track spacing and to identify situations which warrant a change in track spacing (either increase or decrease) under given environmental conditions. During 2013, IIP collected iceberg detection data to measure the effectiveness of the ELTA radar. An increase in track spacing could improve sortie efficiency by reducing the number of sorties and/or flight hours required to conduct the mission as well as the personnel deployment days for IIP and ECAS personnel. Results from this testing are summarized here. A more comprehensive, For Official Use Only (FOUO) report provides a detailed description of these testing procedures, results, and analysis (SAIC, 2014).

Test data were collected during five separate sorties under similar environmental

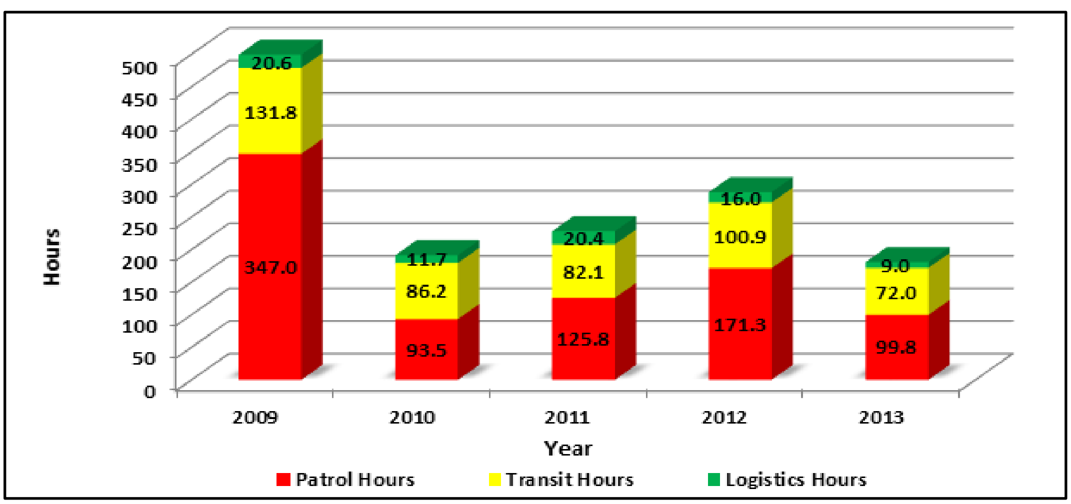

Figure 7. Summary of flight hours (2009-2013).

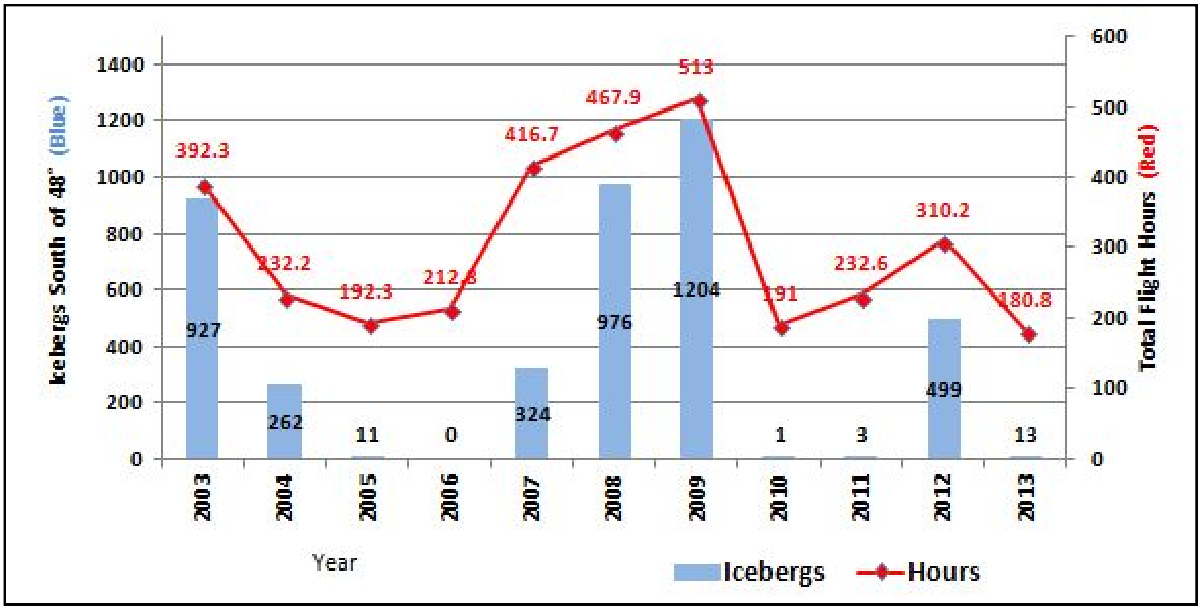

Figure 8. Flight hours versus icebergs south of 48°N (2003-2013).

conditions (generally light winds, with few or no white-caps). On test days, the aircraft first completed a normal ice surveillance sortie to locate suitable test targets and other icebergs in the operating area. All data were collected using operational flight parameters of 2,500 feet altitude at 250 knots unless on-scene conditions dictated otherwise. The ELTA Sea Surveillance at 40 NM range (SS-40) mode was employed for all searches. The automatic track initiation feature of the ELTA radar was employed during all testing. Test targets included icebergs that were located during the reconnaissance portion of each flight. A parallel search was designed in flight to generate both radar detections and misses on the select group of targets. During the test portion of the flight, the radar operator reported targets to a dedicated data collector who recorded time, position, track number, and any pertinent information in a paper log. Concurrently, the radar operator collected Inverse SAR (ISAR), and Classification SAR (CSAR) images of each target, while another operator recorded video of the target from the aircraft Electro-Optical/Infrared (EOIR) camera system. When visibility allowed, Ice Observers stationed at scanner windows took digital photographs of icebergs within view and, using binoculars with calibrated optics, recorded size and shape data. Post-test analysis included reconstructing detection data of approximately 150 total detection opportunities to create lateral range curves (LRCs) (POD vs. lateral range from aircraft) and resulting sweep width values for ‘small’, ‘medium’, and ‘large’ icebergs encountered during testing. Analysis used sweep width data to estimate the cumulative POD against a ‘small’ iceberg target over a range of track spacing options.

The sweep width (W) data collected in this test provided justification for IIP to increase the standard track spacing under environmental conditions where wind speed is less than 10 knots with calm seas. Data collected for ‘small’ icebergs were limited to low sea states only (winds less than 10 knots). The presence of whitecaps appeared as a statistically significant variable. LRCs were computed for ‘no’ observed whitecaps (W = 75 NM) and ‘few’ observed whitecaps (W = 65 NM). Under these conditions, 95% POD can be achieved

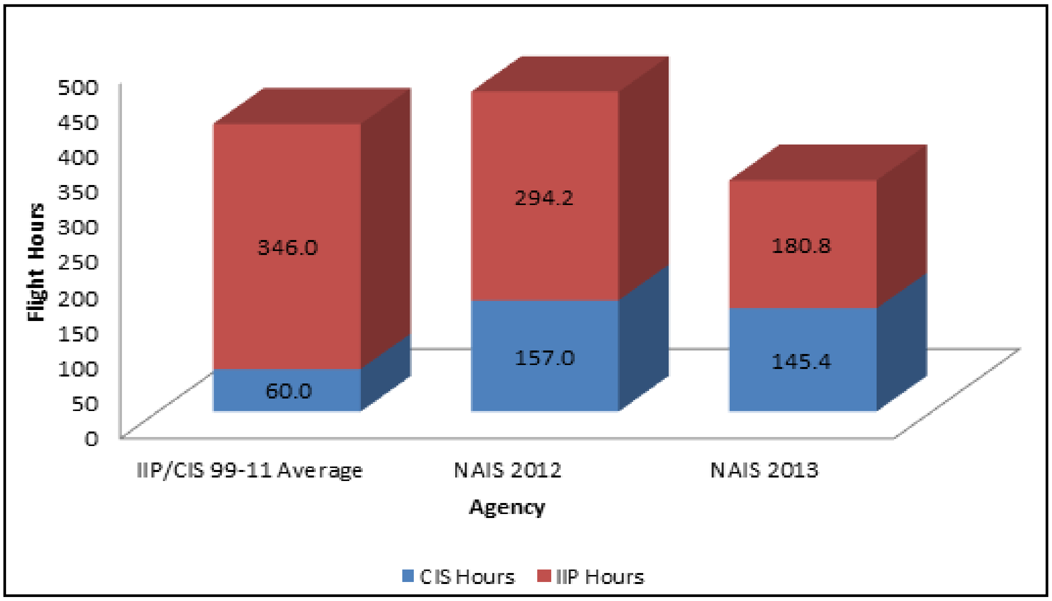

Figure 9. NAIS Flight Hours.

using the ELTA SS-40 mode at 2500 feet altitude and 25 NM track spacing against 'small' icebergs. ELTA model performance predictions suggest better performance in higher wind speeds by using the SS-30 mode and by searching at 1500 feet altitude to reduce the effects of sea clutter. (SAIC, 2014).

The Science Applications International Corporation (SAIC) report also provided recommendations for additional data collection. To validate model predictions, detection data should be collected at 1500 feet in SS-30 mode under low wind conditions and in both SS-30 and SS-40 with wind speeds greater than 13 knots. Finally, this report provided an approach to approximate the Radar Cross-Section (RCS) for a small iceberg based on a limited amount of optical iceberg length measurements. The RCS is a key input into the radar performance model. Additional optical measurements for 'small' icebergs along with simultaneous RCS measurements using the ELTA radar range profiling display should be collected to validate and improve the RCS estimate.

NAIS Reconnaissance Results

NAIS agencies determined this partnership should be leveraged to maximize aerial reconnaissance resources. By coordinating flight planning, redundant reconnaissance can be eliminated. This section describes how actual reconnaissance aligned with these efforts. **Figure 9** depicts the NAIS flight hours. Data provided includes hours flown for each service. In 2013, coverage of the Iceberg Limit was a joint effort between CIS and IIP. IIP flew 16 patrols for a total of 99.8 patrol hours. CIS contracted 22 patrols with PAL for a total of 122.5 hours. Six iceberg patrols totaling 22.9 hours were conducted by Transport Canada for CIS. The combined total is 44 patrols for 326.2 hours in support of NAIS. On average, from 1999 to 2011, IIP and CIS combined for a total of 406 hours each year to conduct iceberg reconnaissance. These numbers are included in **Figure 9**.

Note: Ice Patrol flight hours (indicated in red) include transit and logistics hours. CIS flight hours do not include separate transit hours because the patrol aircraft are based close to the area of operations. In 2013, transit and logistics hours accounted for 45% (81 hours) of IIP flight time. 99.8 flight hours (55%) were used for iceberg reconnaissance.

Figure 10 depicts the NAIS Coverage Strategy. The NAIS region is divided into five areas based on the risk of iceberg collision for vessels in the transatlantic shipping lanes. Areas “A” and “B” are monitored to determine the overall iceberg population early in the season and to predict the continued threat of icebergs drifting south in the Labrador Current. Once the Iceberg Limit has extended into areas “C”, “D”, and “E,” iceberg reconnaissance flights are focused in these regions as the iceberg distribution dictates and with the frequency indicated.

Reconnaissance Challenges

The Grand Banks are a productive fishing ground frequented by fishing vessels ranging from 20 meters to over 70 meters in length. Even in low sea states, determining whether an ambiguous radar contact is an iceberg or a stationary vessel is particularly difficult. These contacts (small vessels and icebergs) often present similar radar returns and cannot easily be differentiated. When a radar image does not present a distinguishable feature, the IRD classifies the contact as an R/T in hopes of being able to identify it on a subsequent pass or patrol. During the 2013 Ice Season, the IIP did not record any R/Ts.

Additionally, the oil industry continues to develop and explore the Grand Banks region for its oil reserves. The escalated exploration and drilling have increased aircraft and vessel traffic in the IIP’s OPAREA, further complicating target identification. Although the presence of these additional targets complicates IIP operations, these platforms also provide on-scene iceberg information reports which greatly aid IIP in the creation of an Iceberg Limit that is as accurate and reliable as possible.

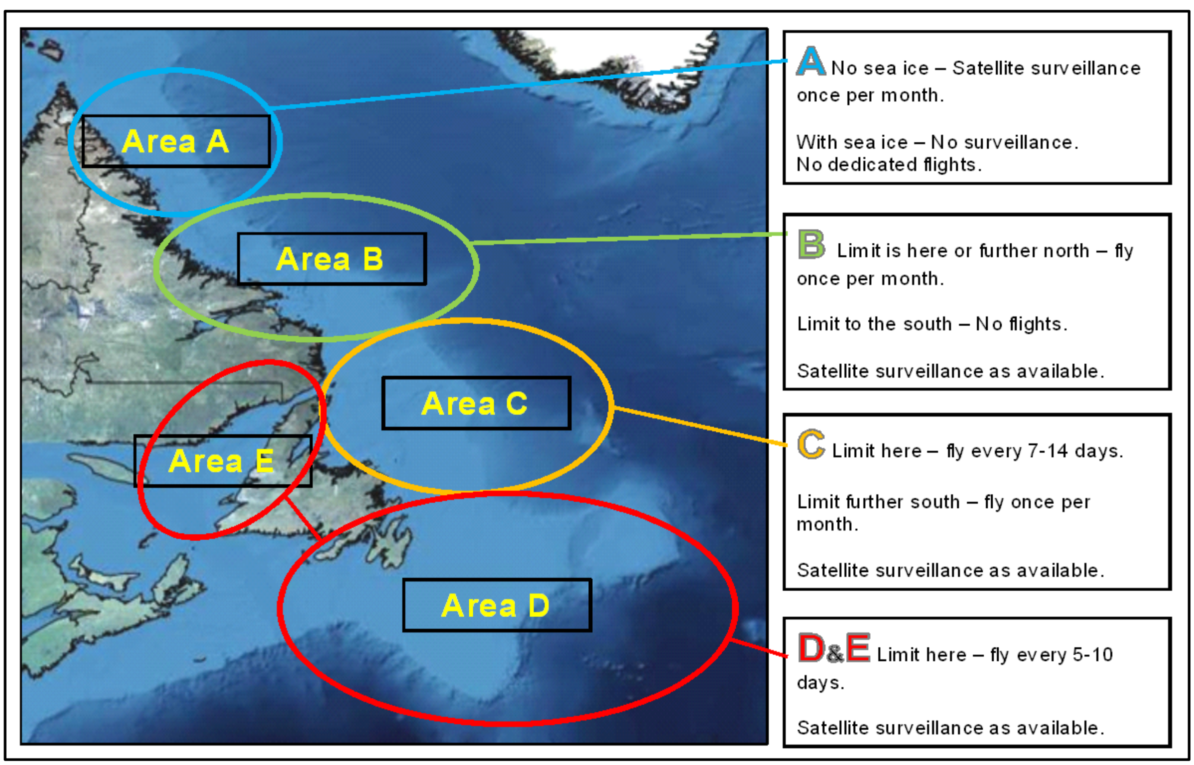

Figure 10. NAIS Coverage Strategy.

At the beginning of the 2013 Ice Season, IIP reduced IRD manning to four Ice Patrol members in an effort to reduce costs. This reduction, in conjunction with the light ice season, had a negative impact on the training, qualification, and proficiency of IIP members. In an effort to minimize the impact of reduced manning on training, the IIP conducted extensive "simulation" training for all personnel. As a direct result of this training, three new personnel were able to qualify as Ice Observers on their first IRD. For the 2014 Ice Season, IIP plans on sending five members on each IRD.

On two IRDs, patrols were conducted during the transit from Groton to St John's in order to cover the Western Iceberg Limit. One of these patrols was conducted in conjunction with a Public Affairs opportunity.

Two IRDs conducted multiple missions during the same patrol. These missions included a typical iceberg reconnaissance patrol, radar sweep width testing, and a satellite under-flight. All three of these missions were accomplished successfully due to the dedication of IRD personnel. However, conducting multiple missions simultaneously has the potential to over-saturate the crew which could result in inaccurate data.

Oceanographic Operations

IIP deployed drifting buoys on and near the Grand Banks of Newfoundland in order to collect near real-time ocean current information. The data were used to modify the historical ocean currents database within BAPS and improved the accuracy of the model-calculated drift for each iceberg. The drifting buoys also collected Sea Surface Temperature (SST) information that was incorporated into the SST analysis product developed by the U.S. Navy Fleet Numerical Meteorology and Oceanography Center (FNMOC). BAPS used both the current data and SSTs along with other environmental data to forecast the drift and deterioration of icebergs.

IIP used drifting buoys of the Surface Velocity Program (SVP) design. These buoys were formerly used for the World Ocean Circulation Experiment (WOCE). The buoys deployed in 2013 were drogued at 15m and 50m. The drifters with drogues centered at 50m were deployed in deep waters of the North Atlantic, most frequently in the offshore branch of the Labrador Current. This current brings icebergs southward along the edge of the continental shelf and into the shipping lanes. The drifting buoys with the drogue centered at 15m, the standard SVP drogue depth, were used to measure the currents in the shallower waters on the Grand Banks and in the inshore branch of the Labrador Current.

IIP used reconnaissance aircraft and ships of opportunity to deploy the drifting buoys. Air deployments were conducted during reconnaissance missions using an air-drop package prepared by IIP and ECAS personnel. Ship deployments were conducted on or near the Grand Banks through a cooperative arrangement with Canadian Coast Guard vessels operating out of St. John's, NL. Air deployments were conducted offshore in regions outside of the range of the Canadian Coast Guard vessels.

In 2013, IIP deployed six SVP drifting buoys. Four 50m buoys were air-deployed, and two buoys were ship-deployed: one 15m buoy and one 50m buoy. All were successfully deployed without incident. IIP used the Argos system to track buoy positions and transmit data to the IIP OPCEN. The Argos system is a worldwide satellite-based system used to collect Doppler-based position data from special transmitters that are built into the drifting buoys. The buoys were tested, and transmission was verified through Argos prior to deployment. Following deployment,

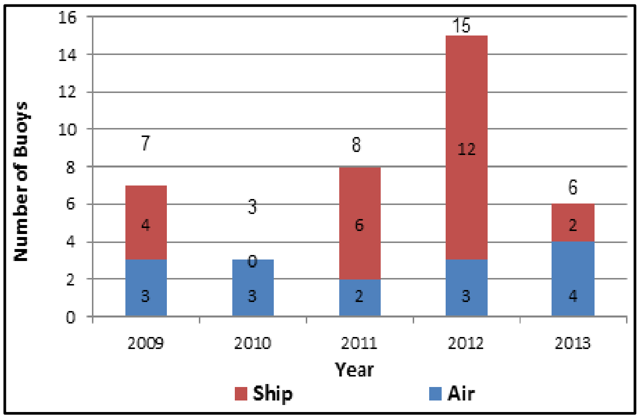

Figure 11. SVP Drifting Buoy deployments (2009-2013).

three buoys functioned properly and transmitted oceanographic data until they drifted out of the IIP OPAREA. However, the other three buoys failed for various reasons. The first two never sent a transmission or only sent information intermittently once deployed. The third failed buoy was only active for 30 days before ceasing transmissions. The reason for this failure was unknown.

Figure 11 shows 2009-2013 air and ship SVP drifting buoy deployments.

Figure 12 depicts composite drift tracks for the SVP drifting buoys deployed in 2013. Detailed SVP drifting buoy information is provided in IIP's 2013 SVP Drifting Buoy Track Atlas, available upon request from IIP.

Commemorative Wreath Drops

Each year, IIP drops commemorative wreaths in conjunction with reconnaissance operations in remembrance of the sinking of the RMS TITANIC. This year, IIP deployed three commemorative wreaths during IRD 4.

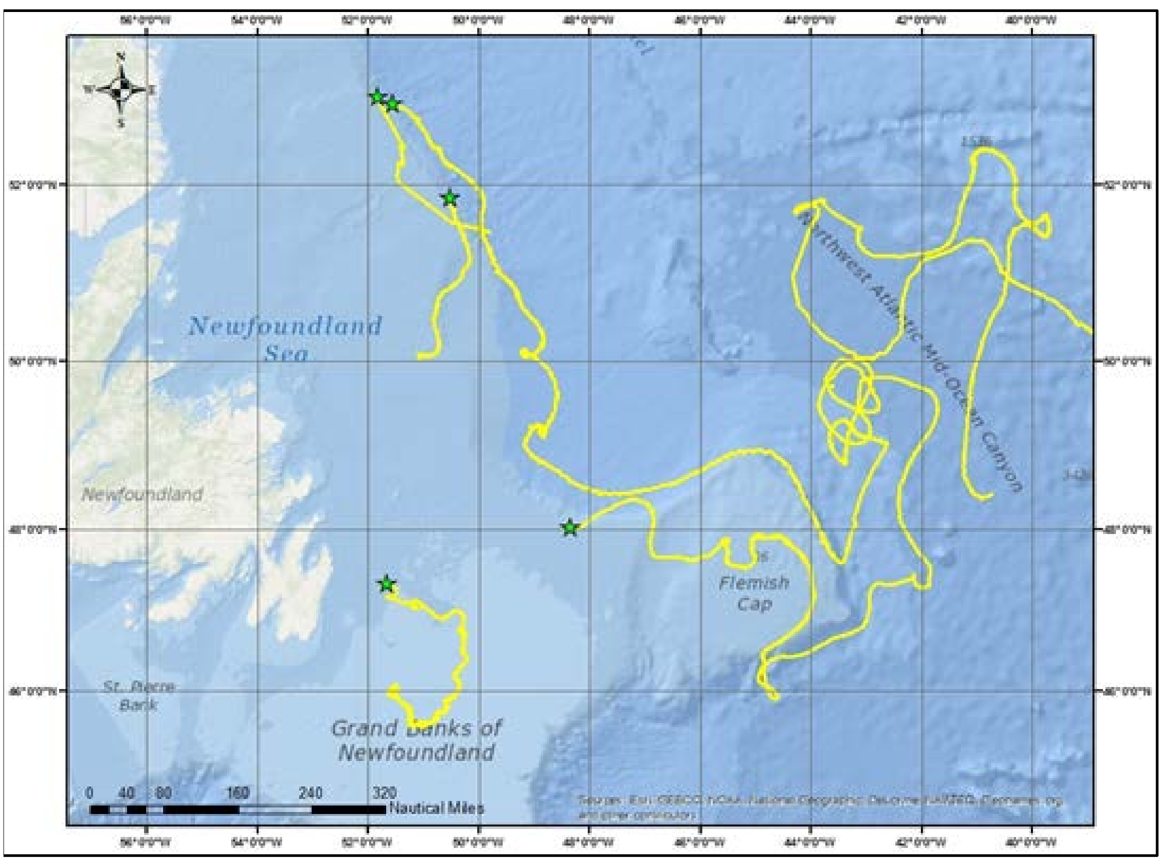

Figure 12. Composite buoy tracks. Green stars indicate Argos-tracked SVP buoy deployment positions. Yellow tracks indicate individual SVP buoy paths.

Ice and Environmental Conditions

Introduction

The 2013 Ice Year (October 2012-September 2013) began with warmer than normal air temperatures from November to mid-January throughout Labrador and Newfoundland. Near normal air temperatures from January to mid-February supported average sea-ice growth over the region. From mid-February through April, air temperatures were above normal. Air temperature patterns coupled with persistent onshore winds starting in mid-February impeded sea-ice growth such that the maximum sea-ice extent occurred on 25 February 2013 and also limited the number of icebergs entering the offshore branch of the Labrador Current. Consequently, only 13 icebergs were sighted or drifted south of 48ºN. This section describes the progression of the 2013 Ice Year and the accompanying environmental conditions in the waters off of the Newfoundland and Labrador coasts. The following narratives are summarized by quarter beginning in October 2012. This summary continues through the summer of 2013.

The narrative draws from several sources, including sea-ice and iceberg analyses provided by CIS and NIC; SST anomaly plots provided by the National Oceanic and Atmospheric Administration's National Weather Service; and summaries of the iceberg data collected by IIP.

The progress of the ice year 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, 1981-2010* (CIS, 2011). The average number of icebergs estimated to have drifted south of 48ºN for each month was calculated using 113 years (1900 through 2012) of IIP records (IIP, 2012). Monthly mean wind vectors are from the National Oceanic and Atmospheric Administration's National Weather Service (NOAA/NWS, 2013a).

Pre-season Predictions

CIS presented a forecast for the 2013 Ice Season at the IIP Annual Conference on 06 December 2013 in Boston, MA (CIS, 2012). For this outlook, CIS analyzed air and SST anomalies for the preceding fall

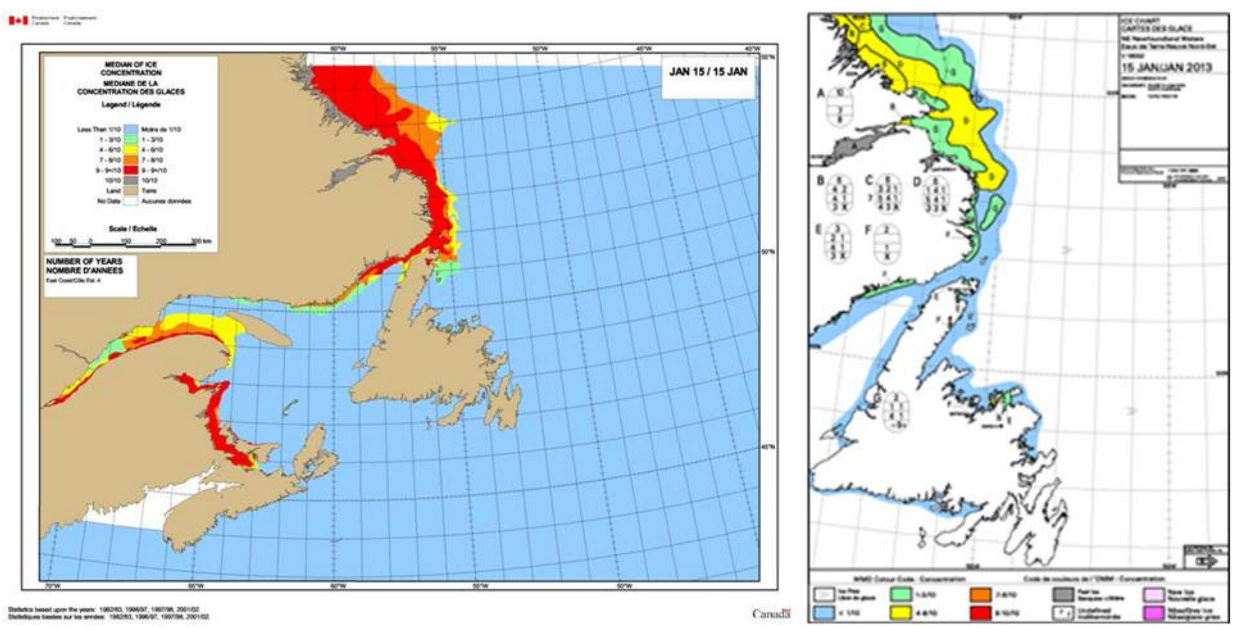

Figure 13. Expected (left panel) and Observed (right panel) sea ice for 15 January 2013. (CIS, 2012)

and then applied Canadian Meteorological Centre temperature forecasts for December through February to project sea-ice growth for the 2013 season. CIS forecasted a late freeze-up and normal ice conditions in waters off eastern Newfoundland and southern Labrador. CIS also projected over 60% more ice than the 2012 season for Newfoundland waters and only a slightly larger extent than the 2012 season for Labrador waters. CIS forecasted an ice extent greater than the ten-year mean in both locations, but less than the 1981-2010 climatological mean. **Figure 13** compares the expected sea ice conditions based on the previous four years (left panel) with observed sea ice for 15 January. As shown in this figure, sea ice grew as predicted through the month of January and early February. However, persistent onshore wind patterns, beginning in mid-February and lasting through March, impeded both eastward and southward ice expansion. As a result, ice extent for the season proved much less than predicted.

For icebergs, CIS predicted a delayed population south of 48°N due to a warmer than normal SST anomaly in October. CIS described the presence of many Petermann Ice Island fragments upstream as “mini-iceberg factories” and forecasted more icebergs (than in recent years) with a longer season but added the caveat that if predicted wind patterns prevailed, then offshore industries (and transatlantic shipping) would experience significant iceberg hazards. As described below, predicted wind patterns did not prevail. While IIP flights observed a notable population of icebergs through early July, these were largely confined to the inshore branch of the Labrador Current system and did not pose a significant threat to offshore industries or transatlantic shipping.

Quarterly Environmental Summaries

Conditions affecting sea-ice growth and iceberg distribution are summarized below. Much of the early ice growth was influenced by mean air temperature along with changes of the mean wind speed and direction in central and southern Labrador early in the year and over Newfoundland as the year progressed.

Figure 14 shows the temperature fluctuations from January through December 2013 in Goose Bay, Labrador (NOAA/NWS, 2013b). Of note, temperatures in Goose Bay were above normal during the winter months, particularly during the period between mid-February and late March. This period coincided with a predominantly onshore wind flow along the Labrador and Newfoundland coast, ultimately causing a very light iceberg season.

October – December 2012

A relatively small iceberg population was present along the southern Labrador coast during early October with the Iceberg Limit at approximately 53°N. The Iceberg Limit continued to move north to 56°N in

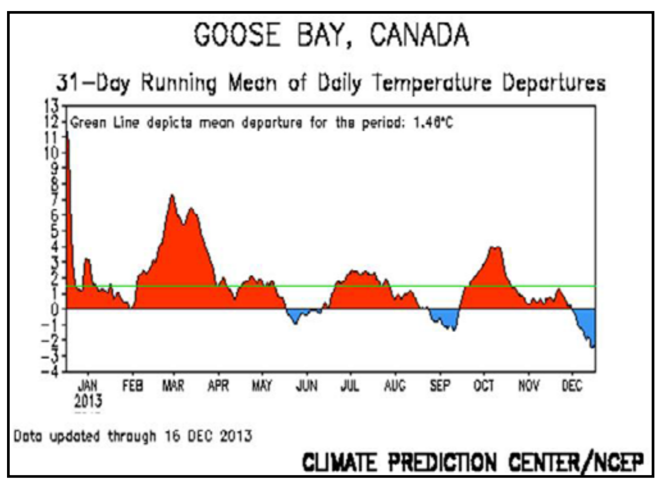

Figure 14. 31-day running mean of daily temperature departures for Goose Bay, Canada. Courtesy of the National Center for Environmental Prediction, Climate Prediction Center (NOAA/NWS, 2013b)

early November. Though new ice began forming along the Labrador coast and in the Newfoundland bays one to two weeks ahead of normal, the average air temperatures for the October-December period were above normal resulting in below normal ice coverage by the end of December. This temperature pattern set the stage for continued slow sea-ice growth throughout the season. (CIS, 2013).

January – March 2013

Near-normal air temperatures and SSTs (**Figure 15**) favored sea-ice development along the Labrador coast, the shallow bays of Newfoundland, and into the Strait of Belle Isle, covering the strait by the third week of January (CIS, 2013a). CIS contracted PAL to begin iceberg reconnaissance flights on 15-16 January along the central Labrador coast up to 58°N. The first PAL flights reported 11 small and medium icebergs in sea ice. Between 01-03 February, PAL conducted additional iceberg reconnaissance flights that ranged from 52°N up to approximately 60°N. PAL observed over 100 icebergs during these flights (PAL, 2013). This sizable population of icebergs coupled with sea-ice growth under normal air/water temperatures and

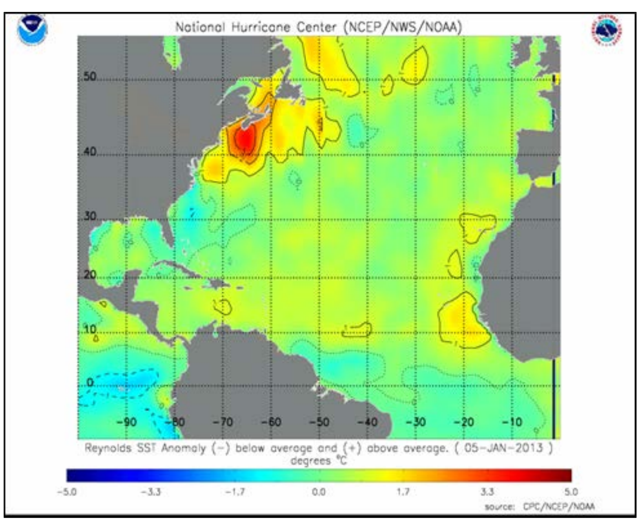

Figure 15. SST Anomaly for 05 January 2013. (NOAA/NWS, 2013c)

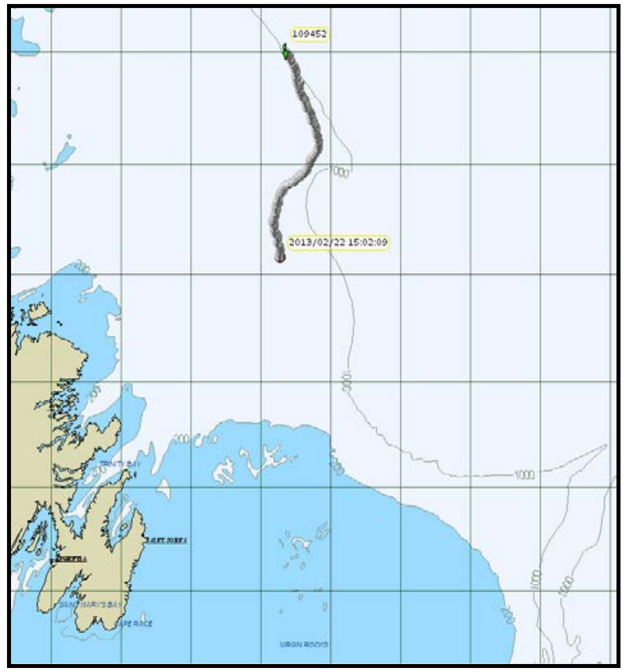

Figure 16. IIP 50-m Drogue Drifting Buoy Trajectory.

predominantly offshore winds appeared to set the stage for another moderate to severe iceberg season.

IIP conducted its first reconnaissance on 12 February. This patrol straddled the 1000 m depth contour to assess iceberg conditions up to 53°N in the offshore branch of the Labrador Current. IIP detected 20 icebergs and growlers, and deployed an SVP drifting buoy with 50 m drogue at 52°00’N, 50°40’W in the vicinity of one of the icebergs sighted. The buoy drifted in a generally southward direction following the 1000 m depth contour at approximately 0.5 knots (**Figure 16**). Speed and direction were consistent with IIP mean currents in this area suggesting normal current flow in the offshore branch of the Labrador Current and a mechanism to transport icebergs south into the shipping lanes.

PAL continued its reconnaissance in February focusing most flights in the waters near Newfoundland and the Strait of Belle Isle (PAL, 2013). IIP conducted two more patrols on 23 and 24 February concentrating

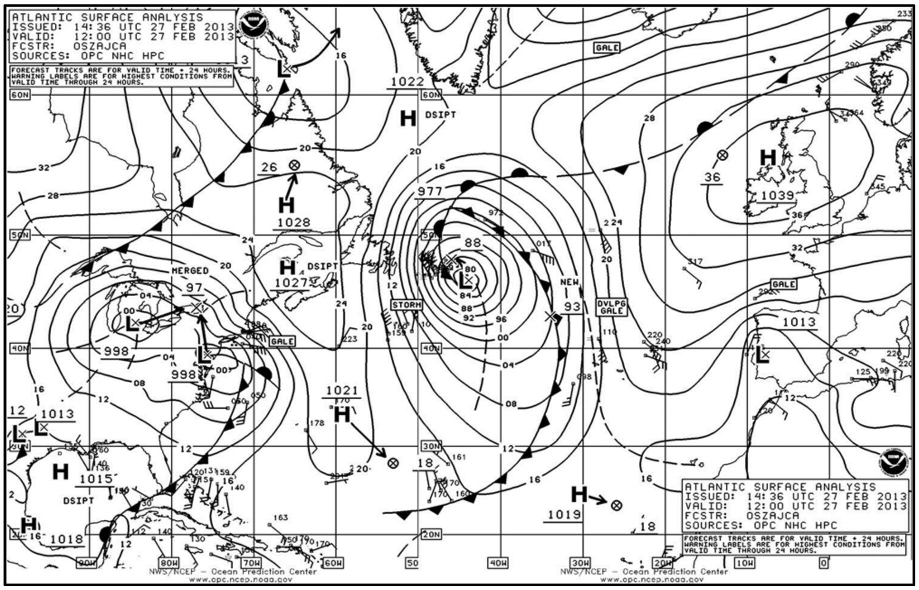

Figure 17. Surface pressure analysis for 27 Feb 2013. (UKMO Met Office, 2013)

on the southeastern and northeastern Iceberg Limit. By 22 February, the sea-ice limit and Iceberg Limit for 2013 very closely approximated the preceding 2012 season when 499 icebergs were observed or drifted south of 48°N.

While all ingredients were in place for another active iceberg year, a series of low pressure systems dramatically reversed this trend beginning in February. **Figure 17** illustrates an example of one of these systems (Met Office, 2013). This intense, 977 mb low pressure system and others that followed compacted sea ice and confined icebergs to the east coast of Canada. The sea-ice edge reached its maximum extent on 26 February, nearly one month ahead of the 1981-2010 climatologic median (**Figure 18**) (CIS, 2011).

Onshore wind patterns continued throughout March frequently pushing the ice edge to within 30-50 miles of the

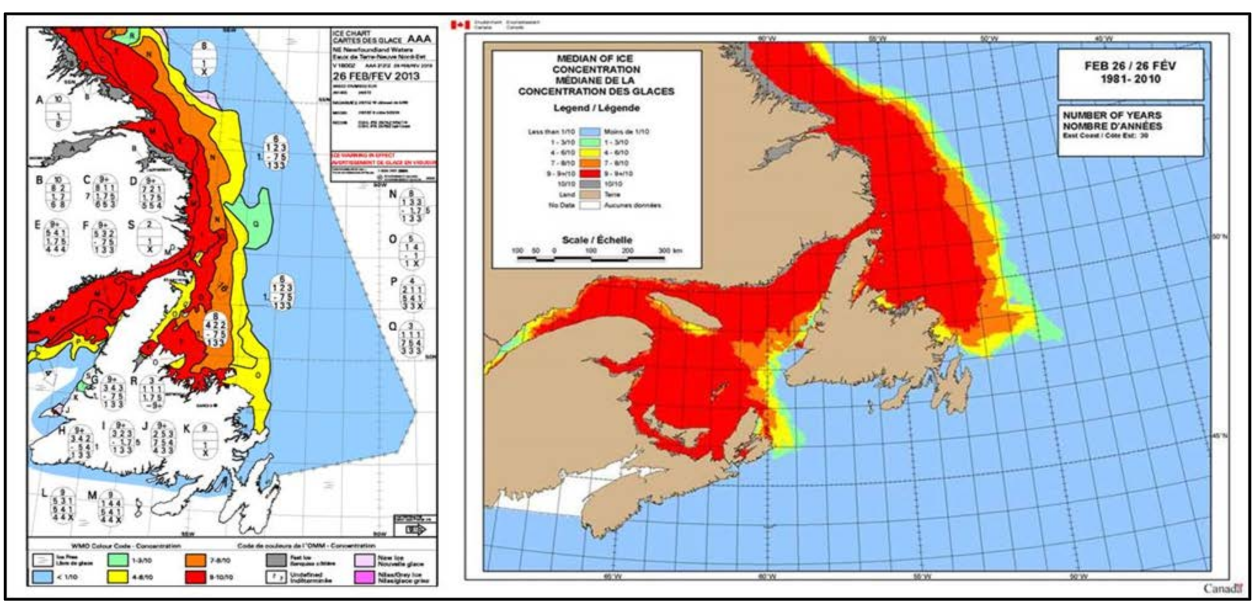

Figure 18. Observed sea ice conditions on 26 February 2013 at its maximum extent (left) compared with 1981-2010 Ice Concentration Climatology for February 26 (right). (CIS, 2011)

Newfoundland and Labrador coasts (CIS, 2013a). With very few icebergs threatening the transatlantic shipping lanes, IIP canceled the scheduled reconnaissance detachment for early March. On 21 March, IIP flew one patrol that covered both the southern and eastern Iceberg Limit out to the 1000 m depth contour. This flight did not detect a single iceberg in the offshore branch of the Labrador Current.

PAL conducted reconnaissance flights during March in the area along the southern Iceberg Limit (between 47°N and 48°N) and near the Esquiman channel on the western side of Newfoundland. While the offshore iceberg population was sparse, PAL located dozens of icebergs that had been forced through the Strait of Belle Isle (PAL, 2013). The presence of icebergs and compacted sea ice created a hazardous situation for shipping through the Strait. For the most part, vessel traffic in this area was minimal with one notable exception: M/V OOCL BELGIUM became beset in the ice on 28 February while on a voyage from Montreal to northern Europe. This "ice-class" container ship required a Canadian icebreaker escort to navigate heavy sea ice and numerous icebergs through Cabot Strait and around the southern side of Newfoundland delaying the voyage by several days.

By the end of March, it became clear that 2013 would be a light ice season in terms of icebergs drifting south of 48°N. During the month, only four icebergs drifted or were sighted south of this latitude. For the 113-year period from 1900-2012, the average number of icebergs passing south of 48°N for the month of March was 61.

April - June 2013

Weather patterns shifted in early April to a predominantly offshore wind, and this pattern continued throughout the remainder of the month. Sea ice began to move offshore along Newfoundland and the southern Labrador coast (CIS, 2013a). However, a 2-3°C warmer than average SST anomaly also developed at

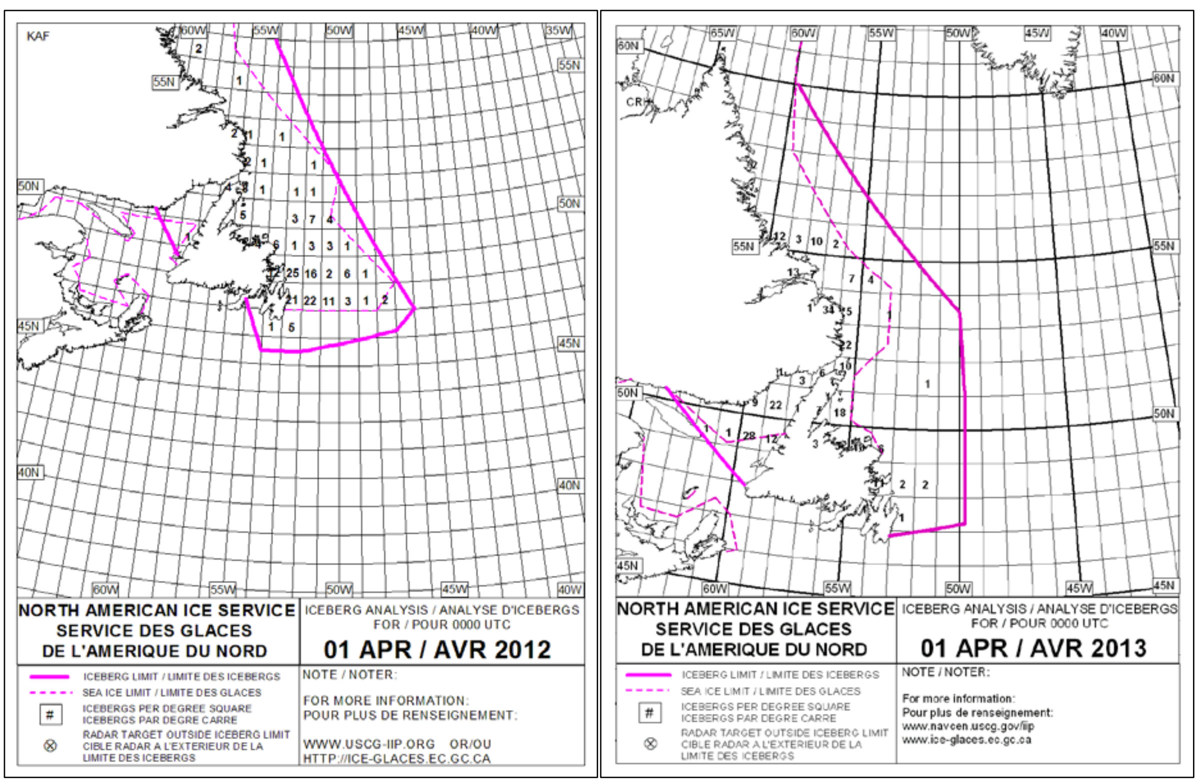

Figure 19. NAIS Iceberg Limit for April 01 2012 (left) and April 01 2013 (right).

Extreme Icebergs	Source	Sighted			Modeled		
		Date	Lat	Long	Date	Lat	Long
Southern	IIP C130	18-Apr-13	47-09.0N	51-48.0W	23-Apr-13	47-02.3N	51-32.7W
Eastern	Provincial Aerospace Ltd.	11-Apr-13	50-30.9N	54-22.0W	22-May-13	48-17.5N	46-51.8W
Western	Provincial Aerospace Ltd.	1-Apr-13	49-45.4N	61-27.6W	1-Apr-13	49-45.4N	61-27.6W

Table 2. 2013 Extreme iceberg positions with sighting dates and locations.

approximately 50°N, 50°W and may have hastened iceberg destruction offshore limiting the number of icebergs entering the offshore branch of the Labrador Current.

Figure 19 shows the NAIS Iceberg Limit products for 01 April 2012 on the left and 01 April 2013 on the right. Both the position of the Iceberg Limit and the distribution of icebergs are markedly different between the 2012 and 2013 seasons. (Note the difference in scale between the two products). With only one iceberg south of 48°N and in the inshore branch of the Labrador Current, IIP canceled the scheduled reconnaissance for early April. During the first part of April, PAL continued numerous flights both for CIS and in support of the offshore industry (PAL, 2013). An IIP reconnaissance detachment returned to Newfoundland from 17-25 April completing four patrols of the southern, northeastern, western and southeastern Iceberg Limit. Both PAL and IIP observations showed the same pattern of very few icebergs offshore and a relatively large population along the northern Newfoundland and southern Labrador coasts and to the west of Newfoundland. Of note, the western Iceberg Limit approached Anacostia Island in the Gulf of St. Lawrence on 01 April, reaching its westernmost longitude of 61°28'W on that date.

By the end of April, eight new icebergs drifted or were sighted south of 48°N, making the season cumulative total 12 icebergs. For the 113-year period from 1900-2012, the average number of icebergs passing south of 48°N for the month of April was 123. The Iceberg Limit reached its southernmost extent of 47°02'N for the 2013 season on 23 April 2013.

During the first part of May, remaining sea ice along the northern arm of Newfoundland and southern Labrador coastlines shifted to the north and offshore. Sea-ice concentrations diminished rapidly throughout May. The Iceberg Limit reached its easternmost extent of 46°52'W at 48°17'N on 22 May 2013. By the end of May, one new iceberg had drifted south of 48°N. For the 113-year period from 1900-2012, the average number of icebergs passing south of 48°N for the month of May was 148. **Table 2** provides a summary of the extreme iceberg sightings, sources, and modeled positions for the 2013 Ice Year.

During June, the remaining sea ice continued to move north and deteriorate. A

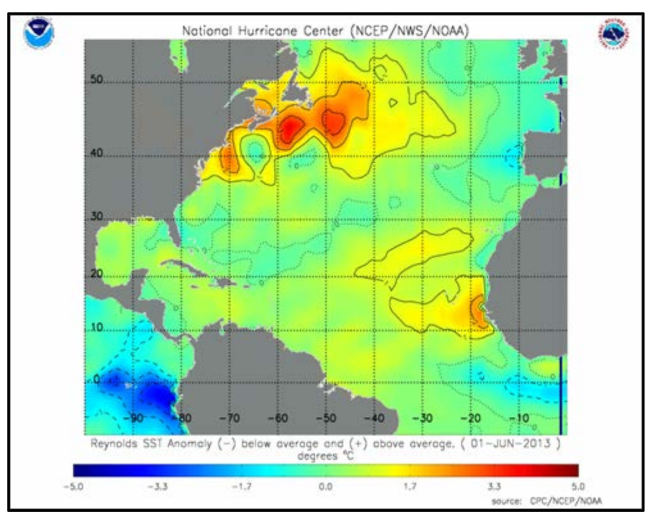

Figure 20. SST Anomaly for 01 June 2013 (NOAA/NWS, 2013c).

few individual icebergs kept the limit south of 50°N. The warm SST anomaly observed during May exceeded 3°C and moved south over the Grand Banks (**Figure 20**), significantly reducing any further southward iceberg drift. IIP conducted one reconnaissance detachment with four patrols in June. These flights combined eastern and southern Iceberg Limit patrols with radar sweep width and satellite underflight testing. IIP reconnaissance detected a sizable population - all north of 50°N with scattered icebergs offshore near the 1000 m contour. No icebergs were sighted or drifted south of 48°N during the month of June. For the 113-year period from 1900-2012, the average number of icebergs passing south of 48°N for the month of June was 83.

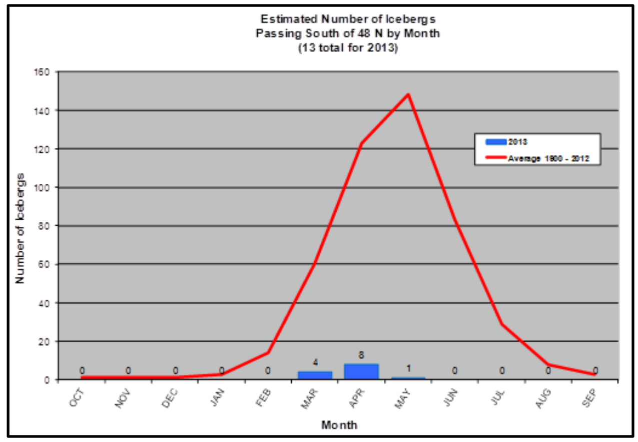

Figure 21. Number of icebergs passing south of 48ºN by month.

July - September 2013

During July through September, seasonal warming throughout the region caused the iceberg population to diminish rapidly. IIP conducted its final reconnaissance flights from 05-10 July. Four patrols during this time verified the western, southern, and eastern Iceberg Limits. IIP reconnaissance confirmed that there were no ice hazards south of 48°N or west of Newfoundland, and located a small population of icebergs near the offshore branch of the Labrador Current. PAL also conducted two flights in support of CIS, detecting a very large number of icebergs all within 100 NM of the Newfoundland and Labrador coasts (PAL, 2013). As in June, no icebergs were sighted or drifted south of 48°N latitude for the remainder of the season.

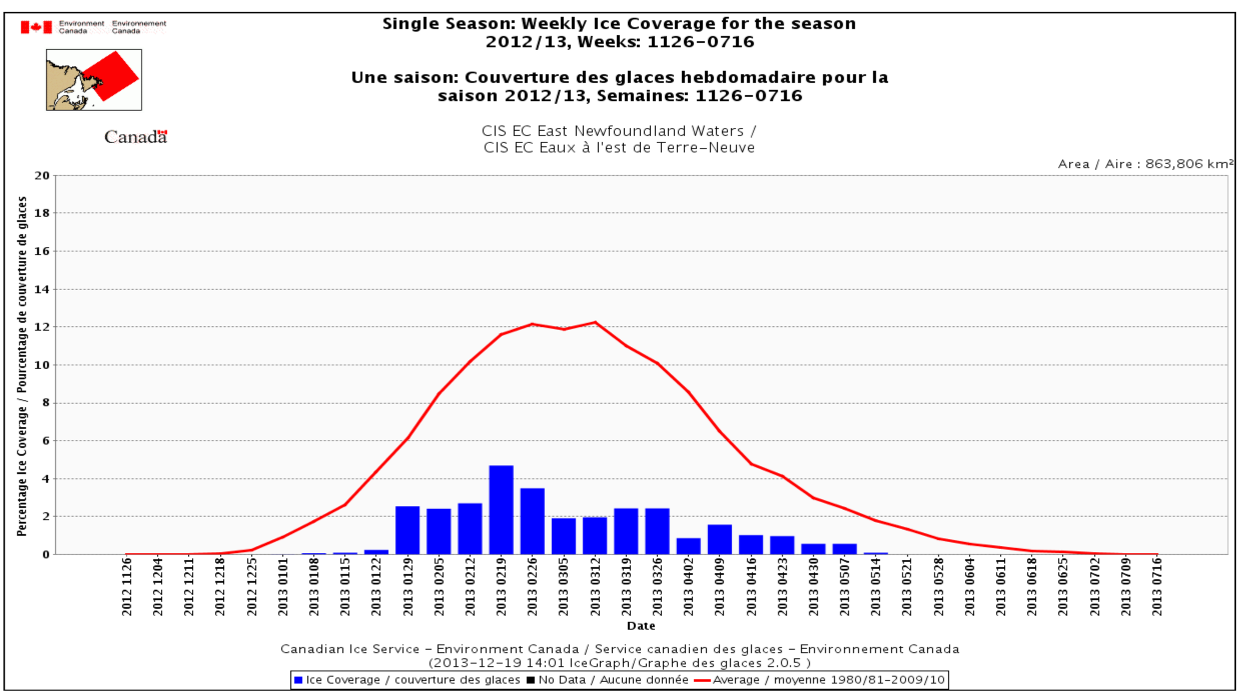

Figure 22. Weekly ice coverage for East Newfoundland Waters. The percent coverage is relative to the area shaded in red in the upper left map of this figure. (CIS, 2013b)

At the end of August, IIP transferred responsibility for creating and distributing the daily NAIS products to CIS. **Figure 21** graphically summarizes the 2013 Ice Season showing the number of icebergs drifting south of 48°N by month. **Figure 22** shows the weekly and average sea-ice coverage for East Newfoundland waters. Both the number of icebergs south of 48°N and the sea-ice coverage for the year are dramatically less than average.

Atmospheric and Oceanographic Discussion

The 2013 Ice Year was the 11th lightest season on record. Though a large population of icebergs was present along the Labrador and Newfoundland coasts, only 13 icebergs drifted south of 48°N. As discussed in prior reports (IIP, 2012), the number of icebergs that drift south of 48°N is closely related to sea-ice coverage and the predominant wind direction over IIP's OPAREA during the winter months (December-March). The southern extent of the Iceberg Limit further depends on both the number of icebergs that reach the northern Grand Banks after the sea ice retreats and the strength and position of the Labrador Current south of Flemish Pass.

Once again, the North Atlantic Oscillation (NAO) proved to be a reliable indicator of season severity. The NAO index represents the dominant pattern of winter atmospheric variability in the North Atlantic, fluctuating between positive and negative phases. NAO dynamics have been extensively described by Hurrell et al. (2003).

Persistent onshore winds in Labrador during winter are characteristic features of a negative phase of the NAO. The winter time station-based NAO index (December 2012 through March 2013) was strongly negative at -1.97. This value is calculated using the difference in normalized sea-level

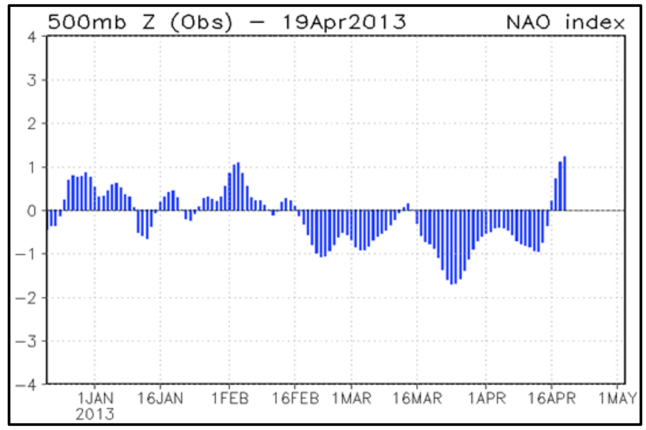

Figure 23. Station Based NAO Index for late December through mid April (NOAA/NWS, 2013d).

atmospheric pressure between Lisbon, Portugal and Stykkisholmu/Reykjavik, Iceland (Hurrell, 2013). Over several seasons, the NAO index during these winter seasons the NAO has shown some correlation to the severity of the iceberg season. The 2010, 2011, and 2013 winter-time NAO indices were all strongly negative, consistent with very light iceberg conditions for each of these years.

Figure 23 and **Figure 24** illustrate the relationship between NAO index and mean wind direction for January through April. **Figure 23** shows a slightly positive NAO index from late December until around February 16. The NAO index then reversed for the remainder of February, March, and the first half of April. Shifts in wind directions are clearly shown in **Figure 24** with predominant offshore winds in January with respect to the Newfoundland and Labrador coasts (top, left panel) transitioning in February to winds from the north (top, right) and then onshore for the month of March (bottom, left). By April, winds had shifted back to a predominantly offshore direction (bottom, right), but the icebergs were already confined to the inshore region resulting in very few icebergs entering the offshore branch of the Labrador Current. While not a predictive tool, the NAO index provides insight into the mechanisms influencing the number of icebergs moving into the offshore branch of the Labrador Current.

With the large population of icebergs sighted off of Newfoundland and southern Labrador throughout the season, 2013 had the potential to significantly impact the transatlantic shipping lanes. Analysis of IIP's drifting buoy trajectories along with SSTs derived from Advanced Very High Resolution Radiometer (AVHRR) imagery show a well-defined, southward flowing Labrador Current that extends to about 42°N (red circle in **Figure 25**).

To put the 2013 Ice Season in context, **Table 3** shows the 11 lightest Ice Seasons in terms of the number of icebergs sighted or drifted south of 48°N with the corresponding NAO index.

Rank	Year	NAO Index	Icebergs South of 48°N
1 (tie)	1966	-1.69	0
1 (tie)	2006	-1.09	0
3 (tie)	1940	-2.86	1
3 (tie)	1958	-1.02	1
3 (tie)	2010	-4.64	1
6 (tie)	1941	-2.31	3
6 (tie)	2011	-1.57	3
8	1951	-1.26	8
9 (tie)	1924	-1.13	11
9 (tie)	2005	0.12	11
11	**2013**	**-1.97**	**13**

Table 3. The 11 lightest Ice Seasons on record.

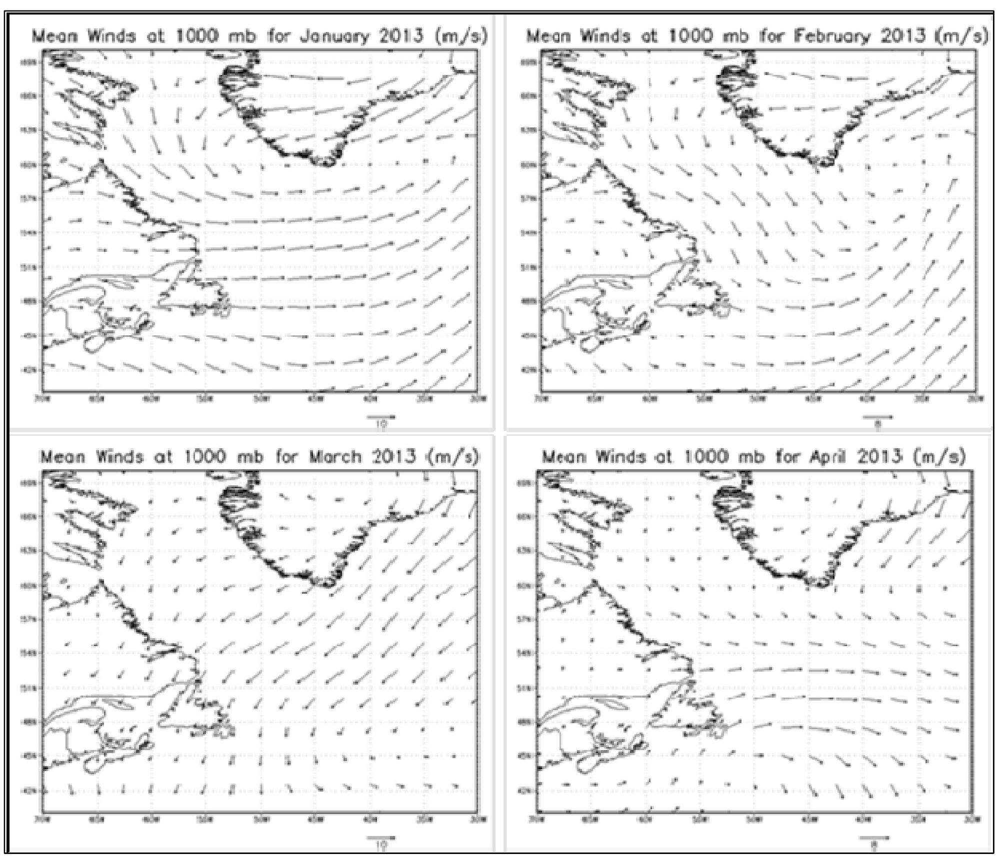

Figure 24. Mean winds at 1000 mb for January - April 2013 (NOAA/NWS, 2013a).

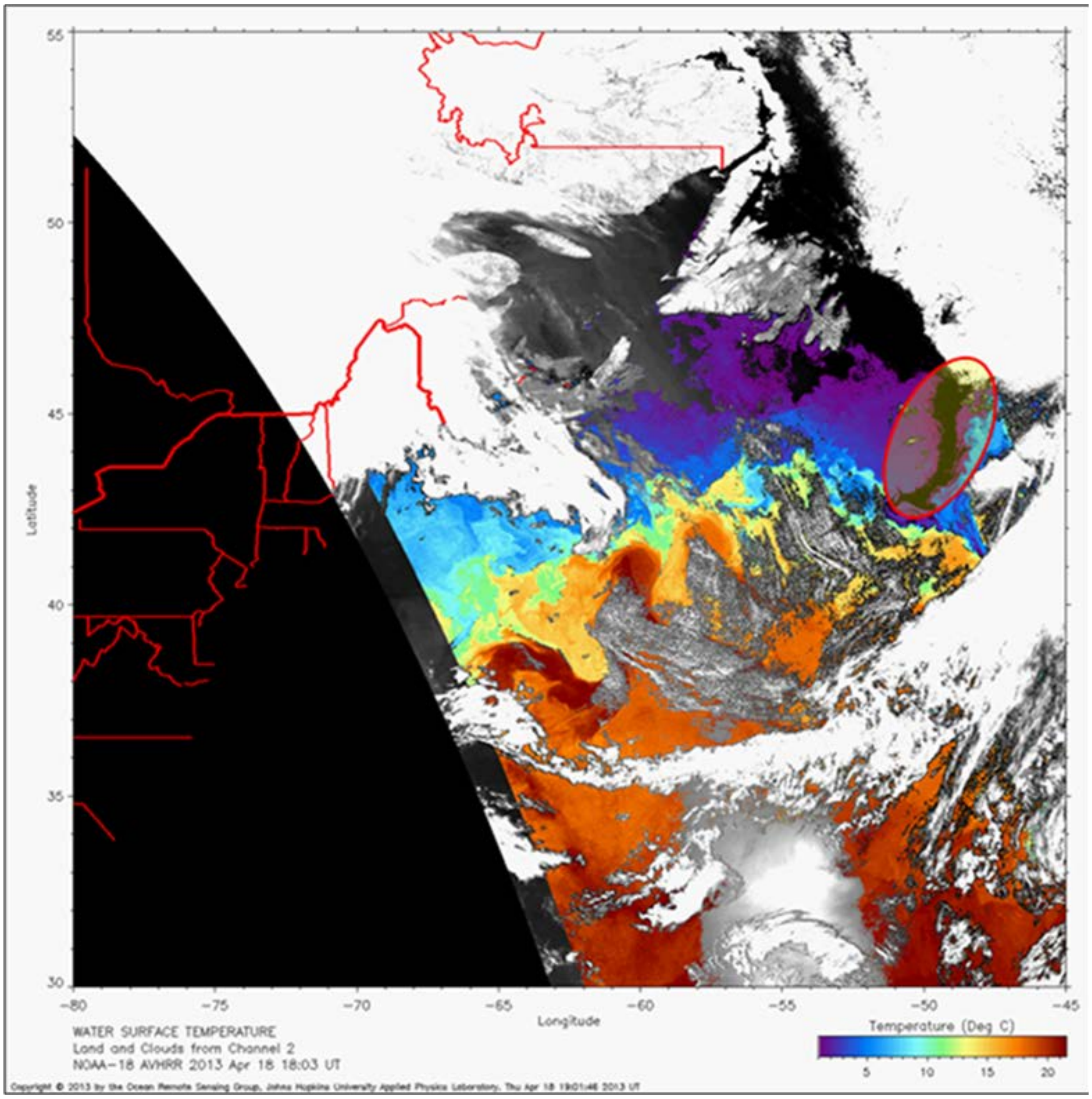

Figure 25. AVHRR Sea Surface Temperature Imagery for April 18, 2013. (JHU, 2013)

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Monthly Sea-Ice Charts

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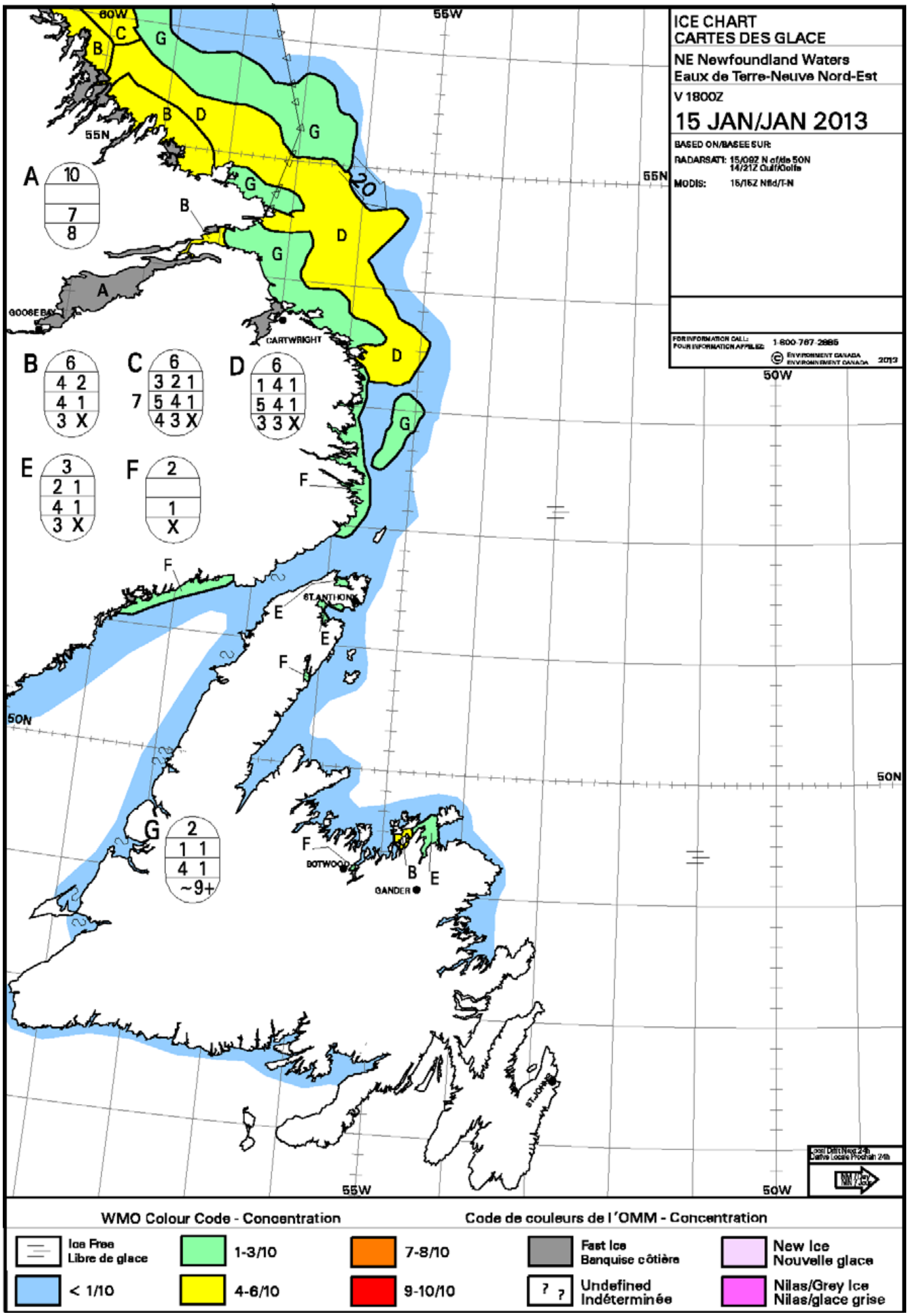
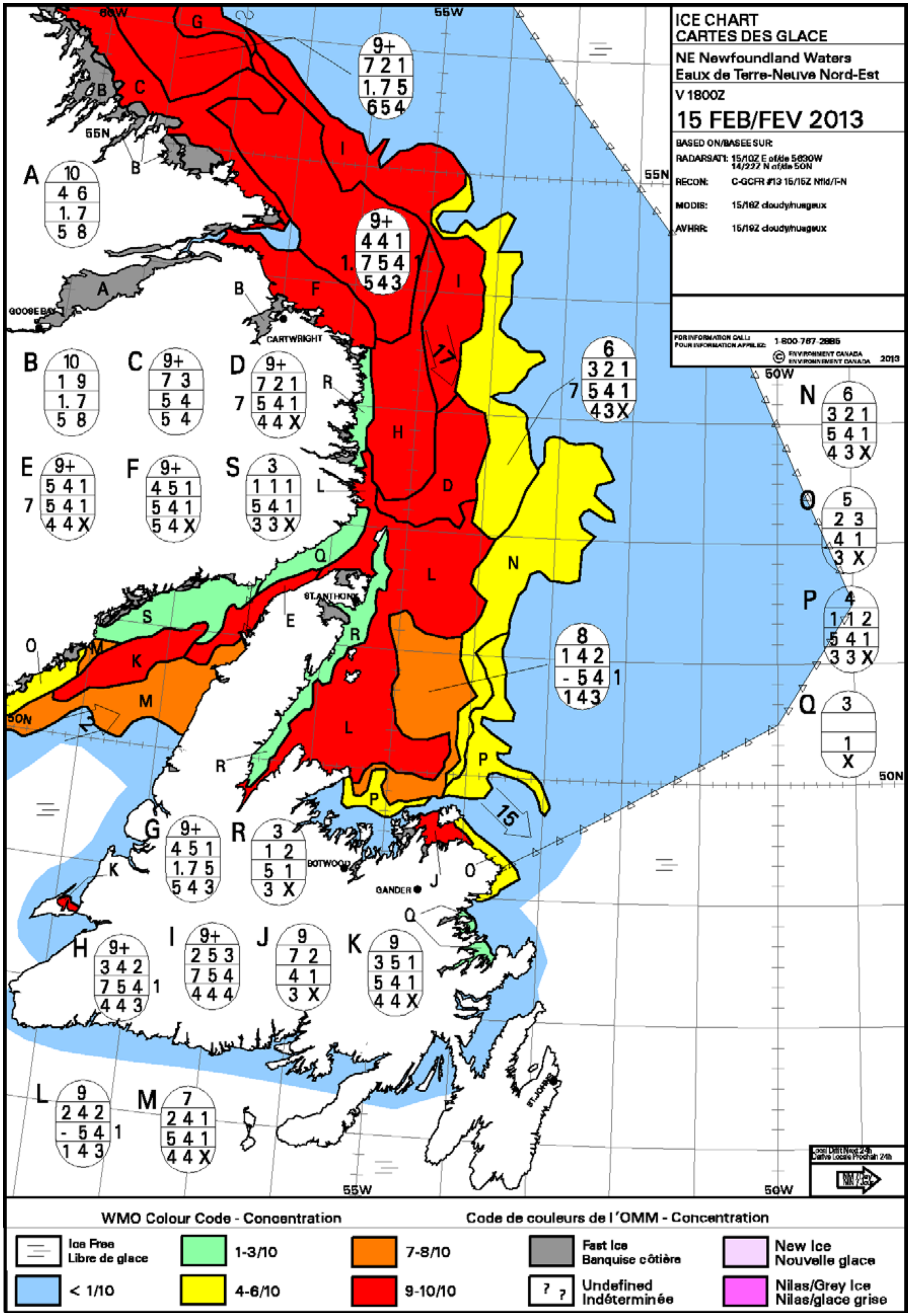
Sea ice symbols are in accordance with the World Meteorological Organization.


ICE CHART
CARTES DES GLACE
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 JAN/JAN 2013
BASED ON/BASEE SUR:
RADARSAT: 15/09Z N of/de 50N
14/21Z Gulf/Golfe
MODIS: 15/15Z Nfld/T-N
FOR INFORMATION CALL:
POUR INFORMATION APPELEZ:
1-800-787-2885
ENVIRONMENT CANADA
ENVIRONNEMENT CANADA
2013
60W
55W
50W
55N
50N
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
9-10/10
Fast Ice
Banquise côtière
Undefined
Indéterminée
New Ice
Nouvelle glace
Nilas/Grey Ice
Nilas/glace grise


ICE CHART
CARTES DES GLACE
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Eaux de Terre-Neuve Nord-Est
V 1800Z
15 FEB/FEV 2013
BASED ON/BASEE SUR:
RECON: C-GCFR #13 15/15Z Nfld/T-N
MODIS: 15/16Z cloudy/nuageux
AVHRR: 15/19Z cloudy/nuageux
1-800-767-2885
CARTWRIGHT
GOOSE BAY
ST.ANTHONY
BOTWOOD
GANDER
WMO Colour Code - Concentration
Code de couleurs de l'OMM - Concentration
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Libre de glace
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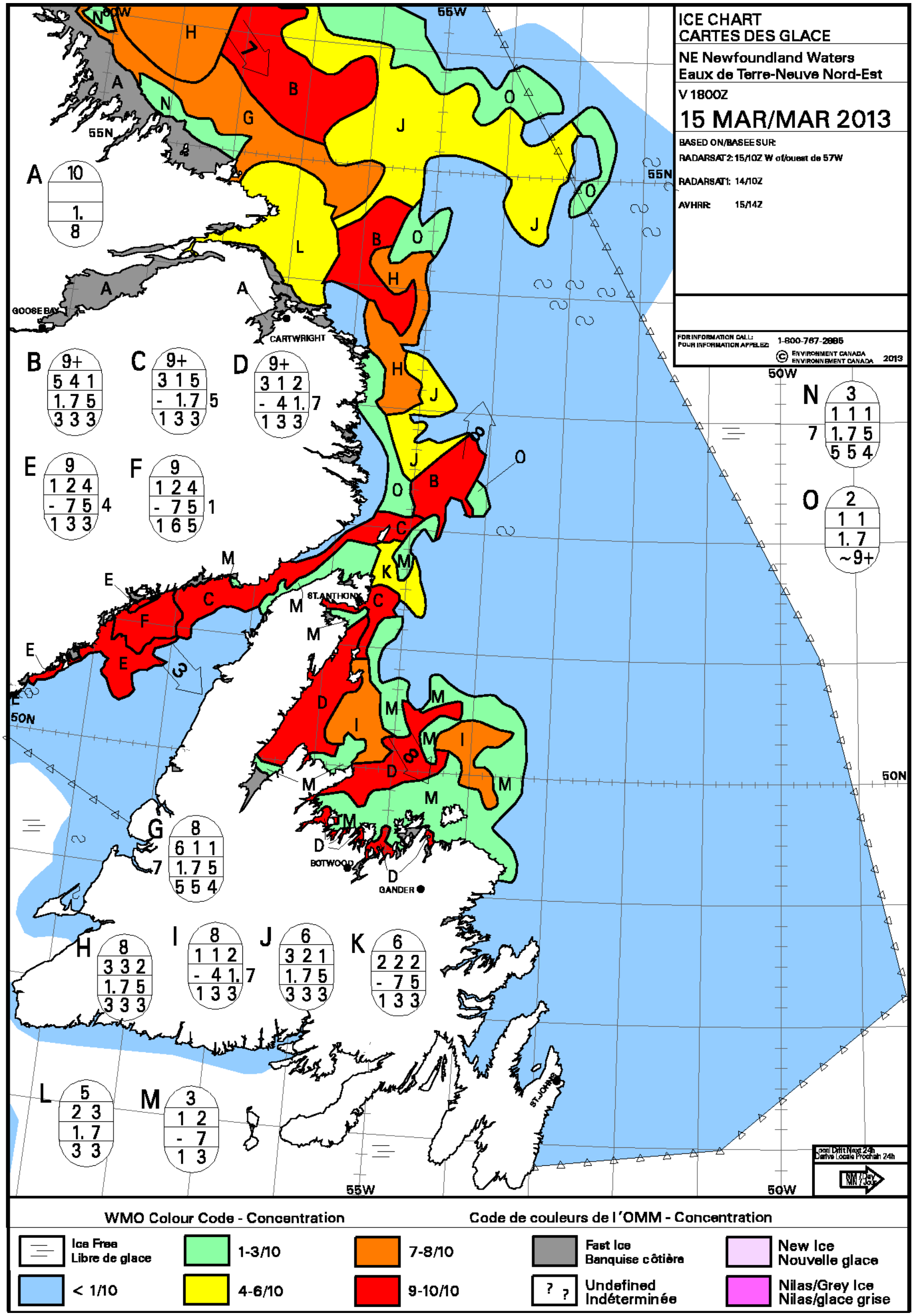
New Ice
Nouvelle glace
Nilas/Grey Ice
Nilas/glace grise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Eaux de Terre-Neuve Nord-Est
V 1800Z
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RADARSAT1: 14/10Z
AVHRR: 15/14Z
FOR INFORMATION CALL: POUR INFORMATION APPELEZ: 1-800-767-2885
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GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHN'S
55W
50W
55N
50N
Local Drift Next 24h
Dérive Locale Prochain 24h
WMO Colour Code - Concentration
Code de couleurs de l'OMM - Concentration
Ice Free
Libre de glace
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Nilas/Grey Ice
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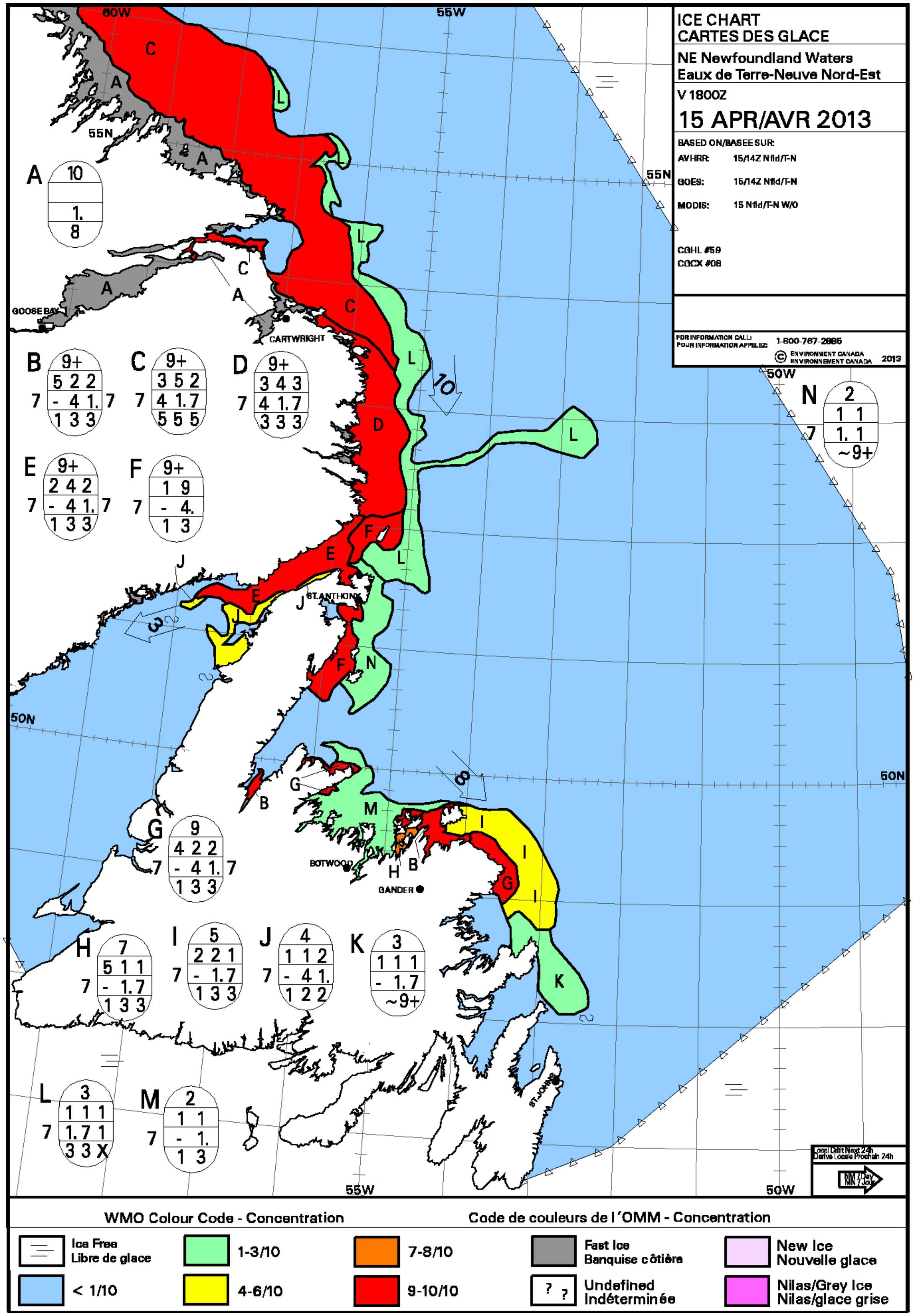
ICE CHART
CARTES DES GLACE
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 APR/AVR 2013
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MODIS: 15 Nfld/T-N W/O
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CGCX #08
FOR INFORMATION CALL: POUR INFORMATION APPELEZ: 1-800-767-2885
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GOOSE BAY
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BOTWOOD
GANDER
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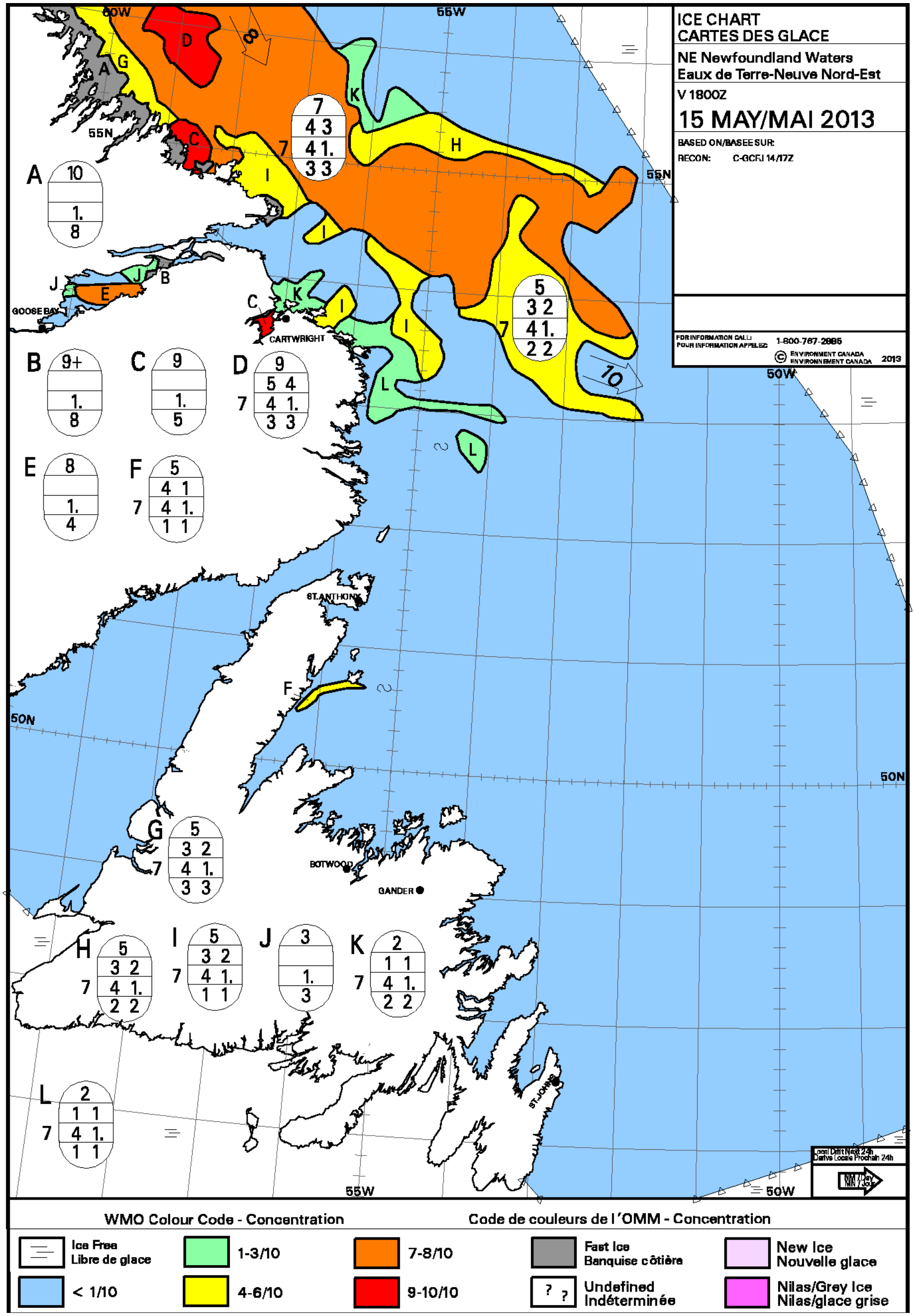
New Ice Nouvelle glace
Nilas/Grey Ice Nilas/glace grise


ICE CHART
CARTES DES GLACE
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 MAY/MAI 2013
BASED ON/BASEE SUR:
RECON: C-GCFJ 14/17Z
FOR INFORMATION CALL:
POUR INFORMATION APPELEZ:
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CARTWRIGHT
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BOTWOOD
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ST.JOHNS
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WMO Colour Code - Concentration
Code de couleurs de l'OMM - Concentration
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New Ice
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Nilas/Grey Ice
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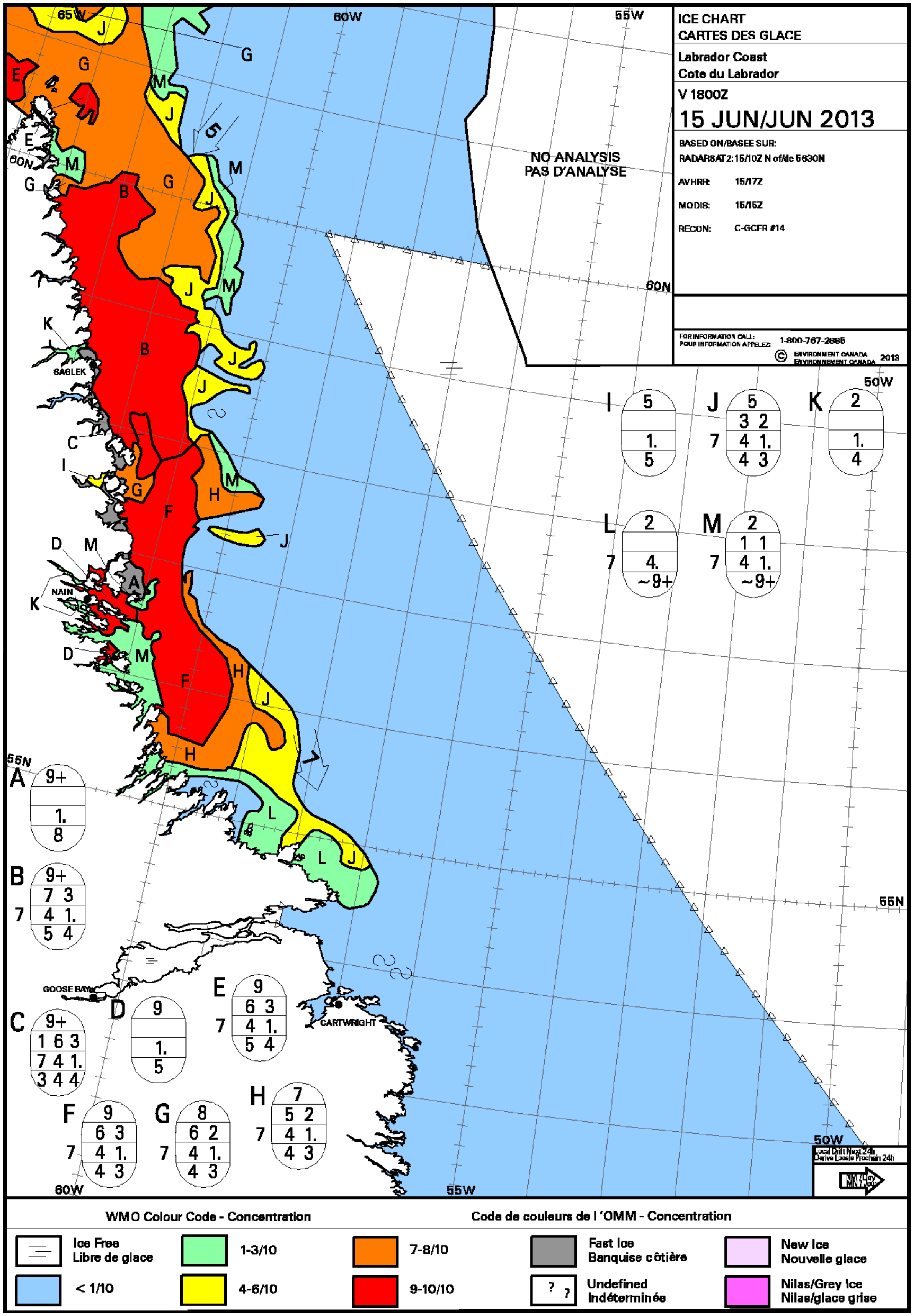
ICE CHART
CARTES DES GLACE
Labrador Coast
Cote du Labrador
V 1800Z
15 JUN/JUN 2013
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AVHRR: 15/17Z
MODIS: 15/15Z
RECON: C-GCFR #14
FOR INFORMATION CALL: POUR INFORMATION APPELEZ: 1-800-767-2885
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New Ice
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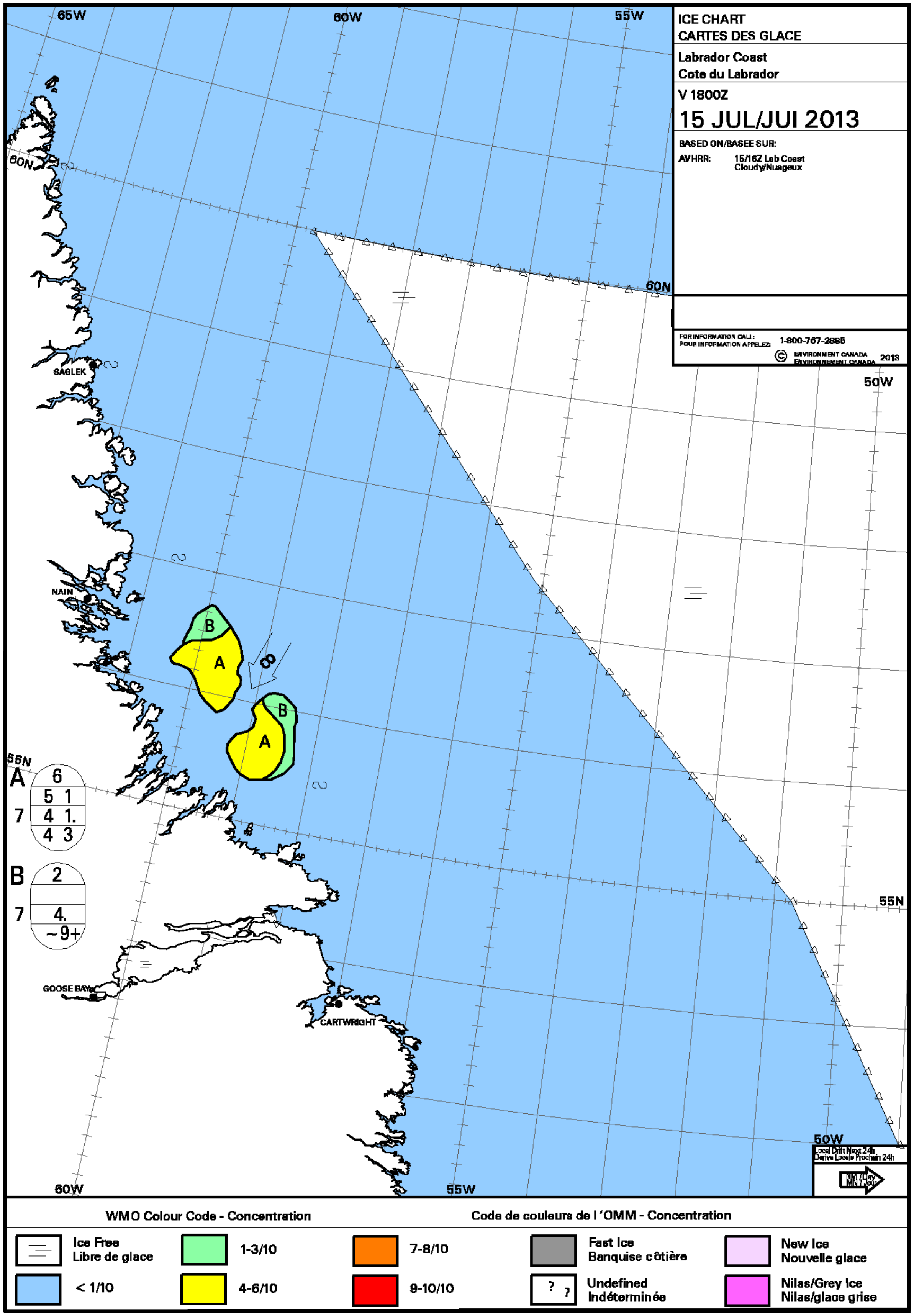
Nilas/Grey Ice
Nilas/glace grise


ICE CHART
CARTES DES GLACE
Labrador Coast
Cote du Labrador
V 1800Z
15 JUL/JUI 2013
BASED ON/BASEE SUR:
AVHRR: 15/16Z Lab Coast
Cloudy/Nuageux
FOR INFORMATION CALL:
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© ENVIRONMENT CANADA
ENVIRONNEMENT CANADA 2013
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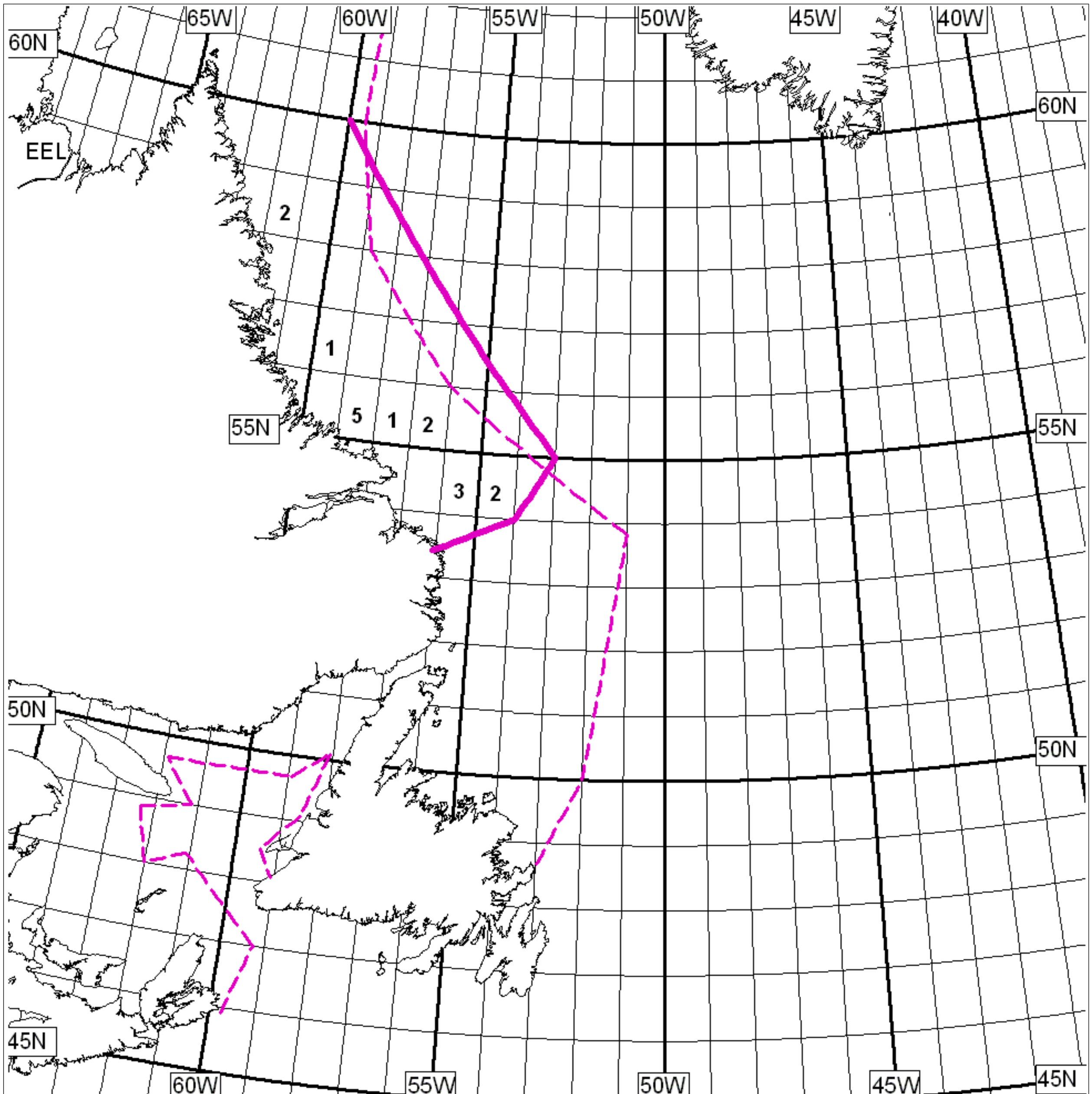
Nilas/glace grise

Semimonthly Iceberg Charts



NORTH AMERICAN ICE SERVICE
SERVICE DES GLACES
DE L'AMERIQUE DU NORD

ICEBERG ANALYSIS / ANALYSE D'ICEBERGS
FOR / POUR 0000 UTC UTC

01 FEB / FEV 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS

SEA ICE LIMIT / LIMITE DES GLACES

ICEBERGS PER DEGREE SQUARE
ICEBERGS PAR DEGRE CARRE

⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT
CIBLE RADAR A L'EXTERIEUR DE LA
LIMITE DES ICEBERGS

NOTE / NOTER:

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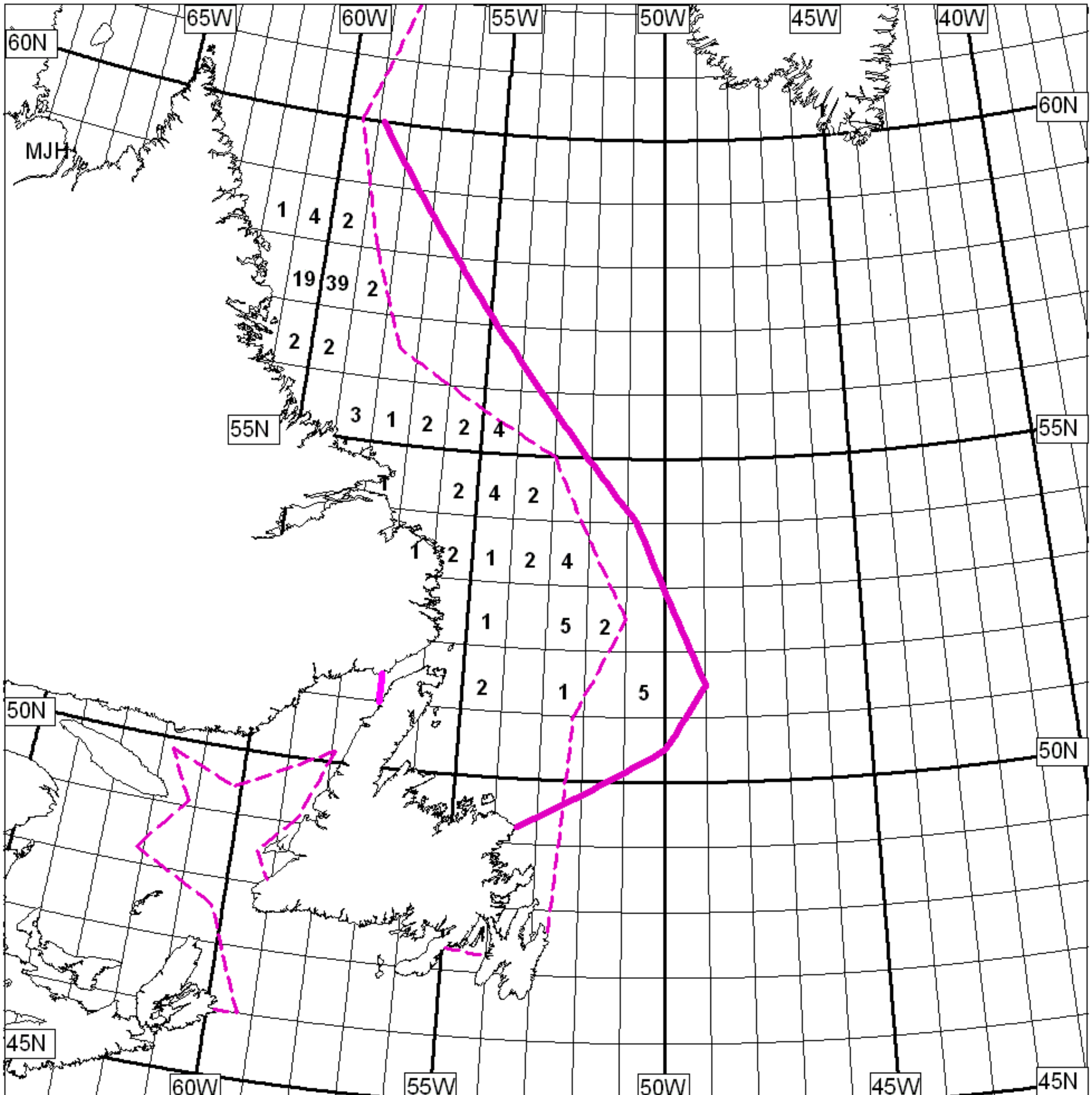
www.ice-glaces.ec.gc.ca



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15 FEB / FEV 2013

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ICEBERGS PER DEGREE SQUARE / ICEBERGS PAR DEGRE CARRE

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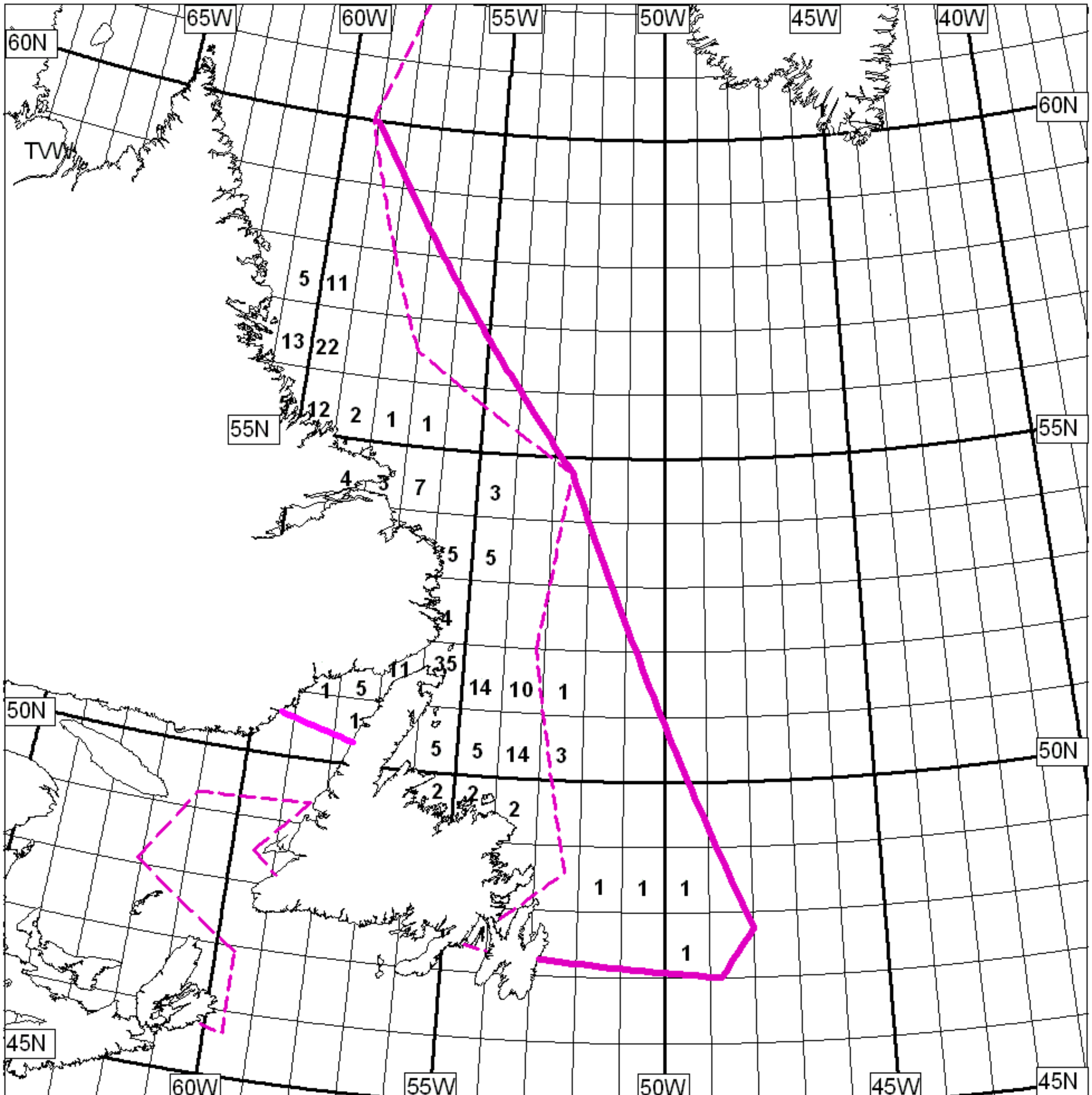

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01 MAR / MAR 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS

SEA ICE LIMIT / LIMITE DES GLACES

— ICEBERGS PER DEGREE SQUARE / ICEBERGS PAR DEGRE CARRE

⊗ — RADAR TARGET OUTSIDE ICEBERG LIMIT / CIBLE RADAR A L'EXTERIEUR DE LA LIMITE DES ICEBERGS

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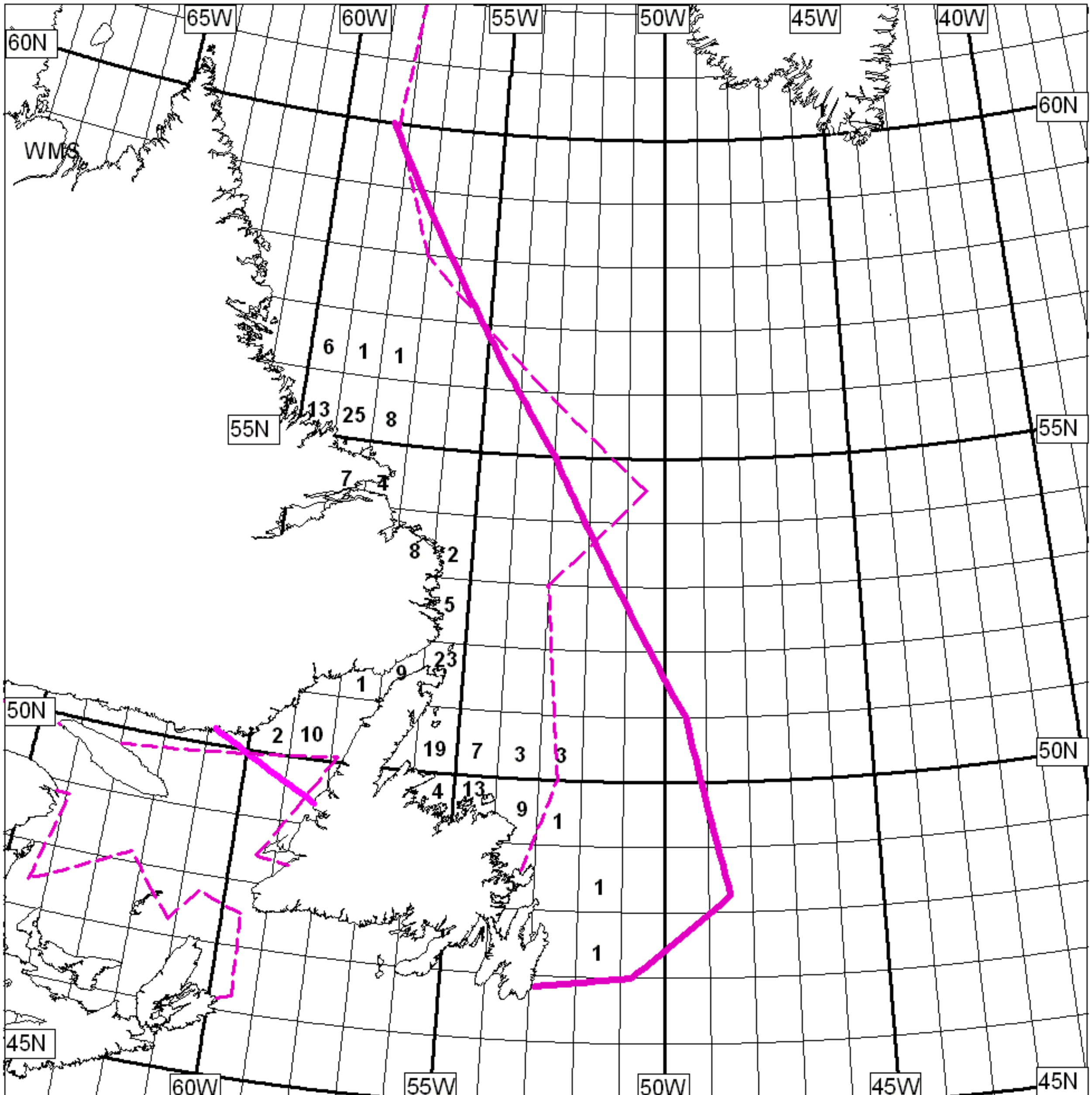

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ICEBERG ANALYSIS / ANALYSE D'ICEBERGS
FOR / POUR 0000 UTC UTC

15 MAR / MAR 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS

SEA ICE LIMIT / LIMITE DES GLACES

ICEBERGS PER DEGREE SQUARE
ICEBERGS PAR DEGRE CARRE

⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT
CIBLE RADAR A L'EXTERIEUR DE LA
LIMITE DES ICEBERGS

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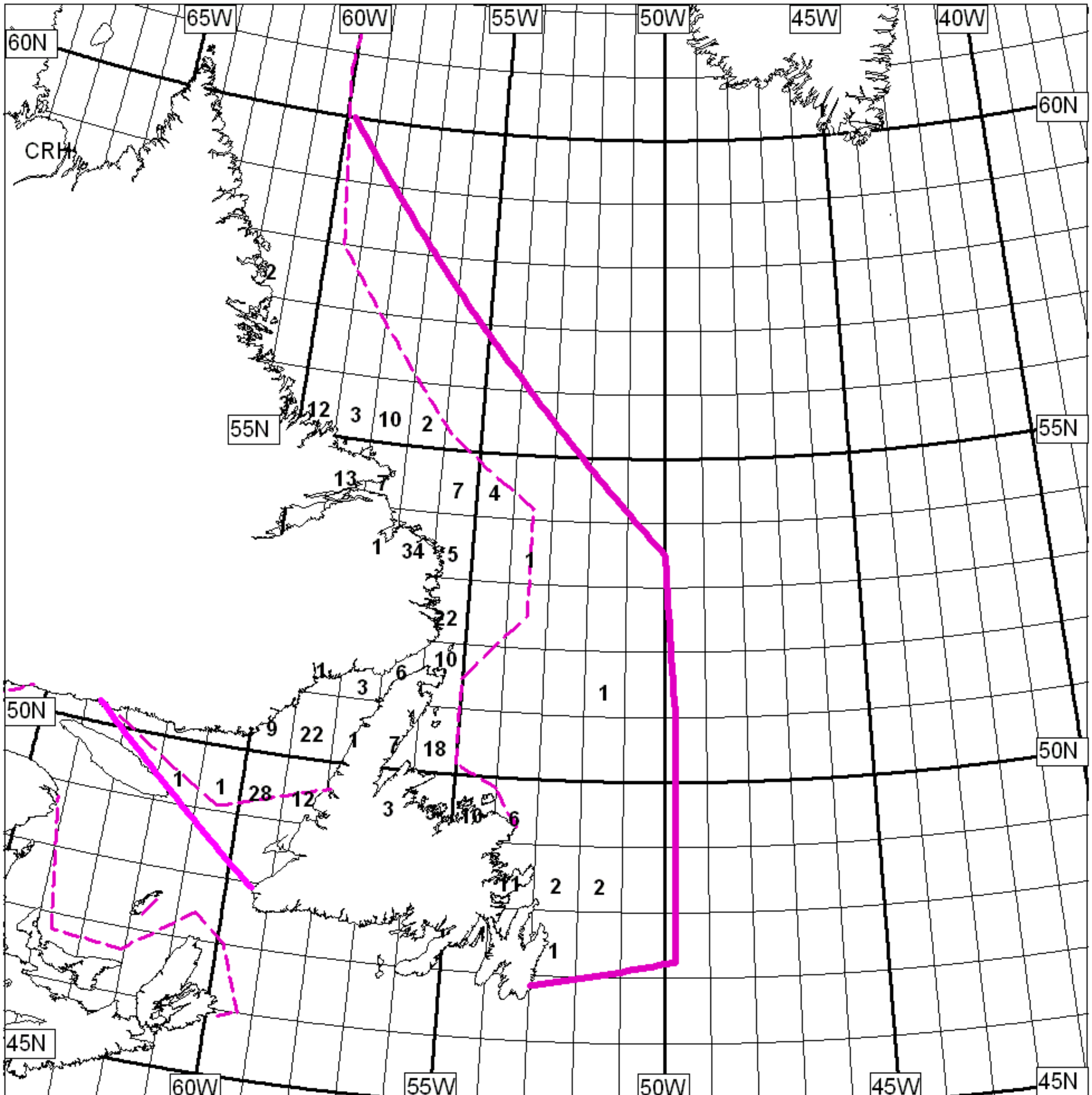

NORTH AMERICAN ICE SERVICE
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DE L'AMERIQUE DU NORD

ICEBERG ANALYSIS / ANALYSE D'ICEBERGS
FOR / POUR 0000 UTC

01 APR / AVR 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS

SEA ICE LIMIT / LIMITE DES GLACES

ICEBERGS PER DEGREE SQUARE
ICEBERGS PAR DEGRE CARRE

⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT
CIBLE RADAR A L'EXTERIEUR DE LA
LIMITE DES ICEBERGS

NOTE / NOTER:

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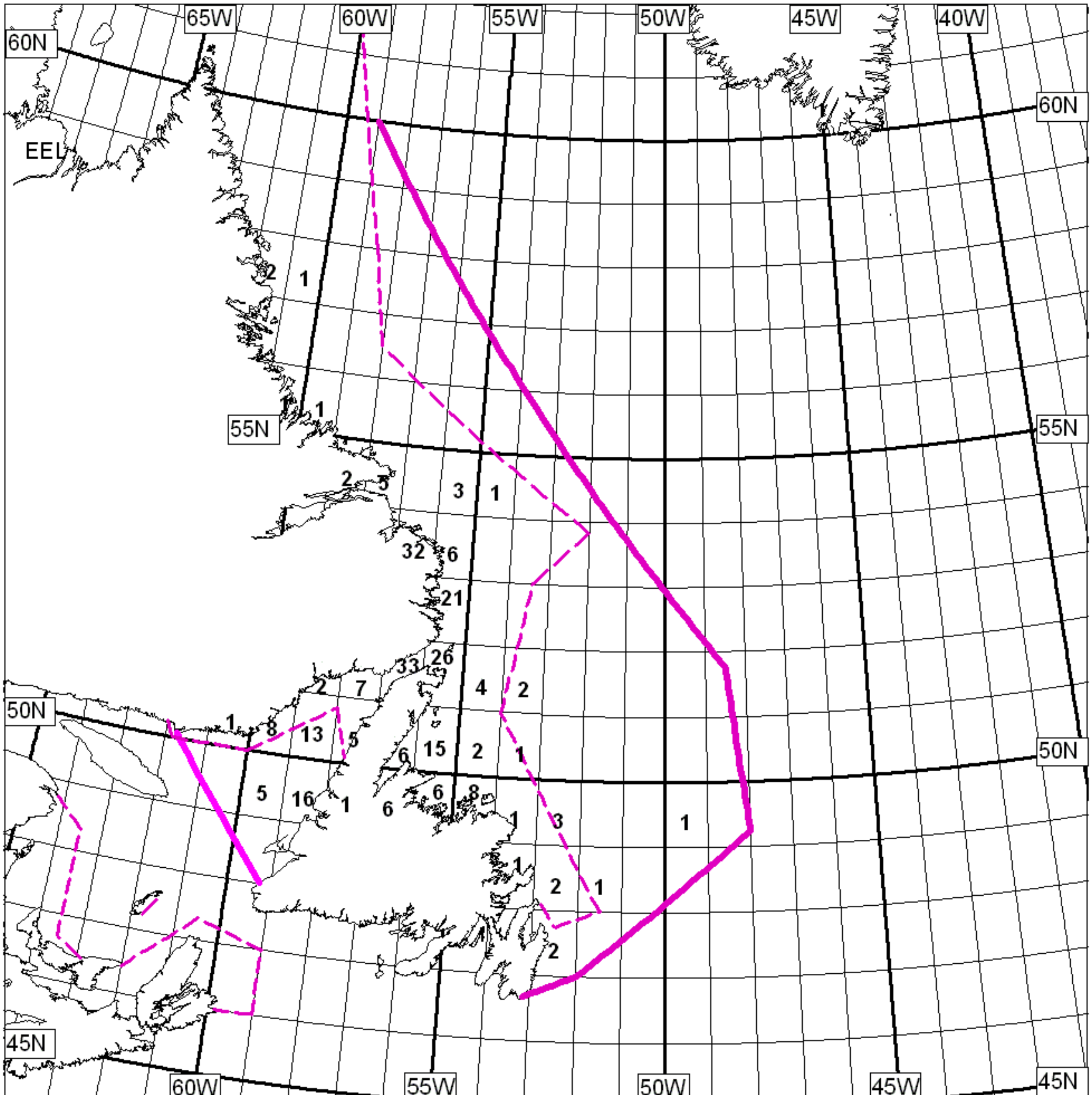
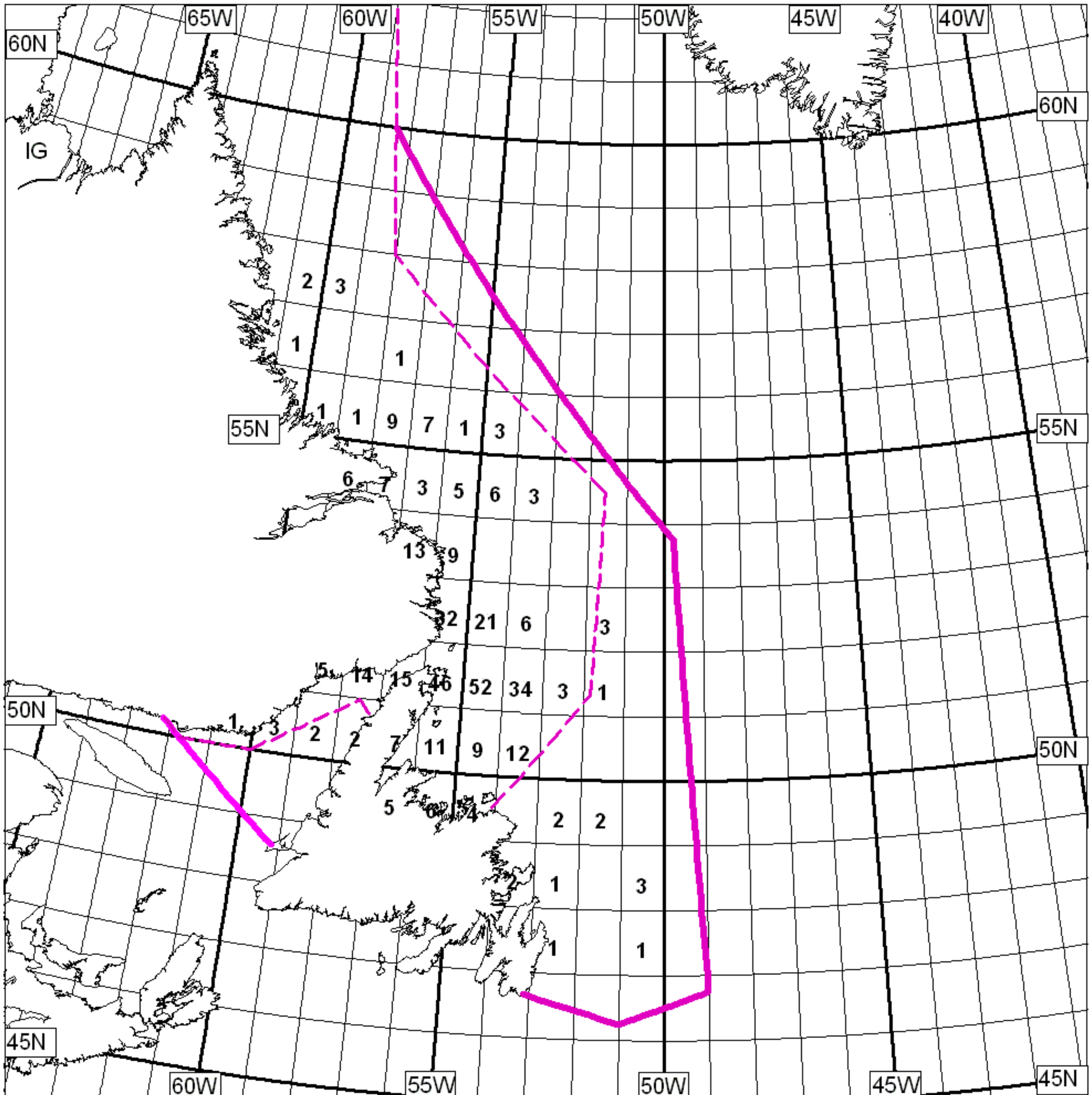


NORTH AMERICAN ICE SERVICE **SERVICE DES GLACES** **DE L'AMERIQUE DU NORD**	ICEBERG ANALYSIS / ANALYSE D'ICEBERGS FOR / POUR 0000 UTC **15 APR / AVR 2013**
ICEBERG LIMIT / LIMITE DES ICEBERGS SEA ICE LIMIT / LIMITE DES GLACES # ICEBERGS PER DEGREE SQUARE ICEBERGS PAR DEGRE CARRE ⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT CIBLE RADAR A L'EXTERIEUR DE LA LIMITE DES ICEBERGS	NOTE / NOTER: Today we commemorate the 101st anniversary of the sinking of the RMS Titanic. Aujourd'hui souligne le 101ième anniversaire du naufrage du RMS Titanic.



NORTH AMERICAN ICE SERVICE
SERVICE DES GLACES
DE L'AMERIQUE DU NORD

ICEBERG ANALYSIS / ANALYSE D'ICEBERGS
FOR / POUR 0000 UTC

01 MAY / MAI 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS

SEA ICE LIMIT / LIMITE DES GLACES

— ICEBERGS PER DEGREE SQUARE / ICEBERGS PAR DEGRE CARRE

⊗ — RADAR TARGET OUTSIDE ICEBERG LIMIT / CIBLE RADAR A L'EXTERIEUR DE LA LIMITE DES ICEBERGS

NOTE / NOTER:

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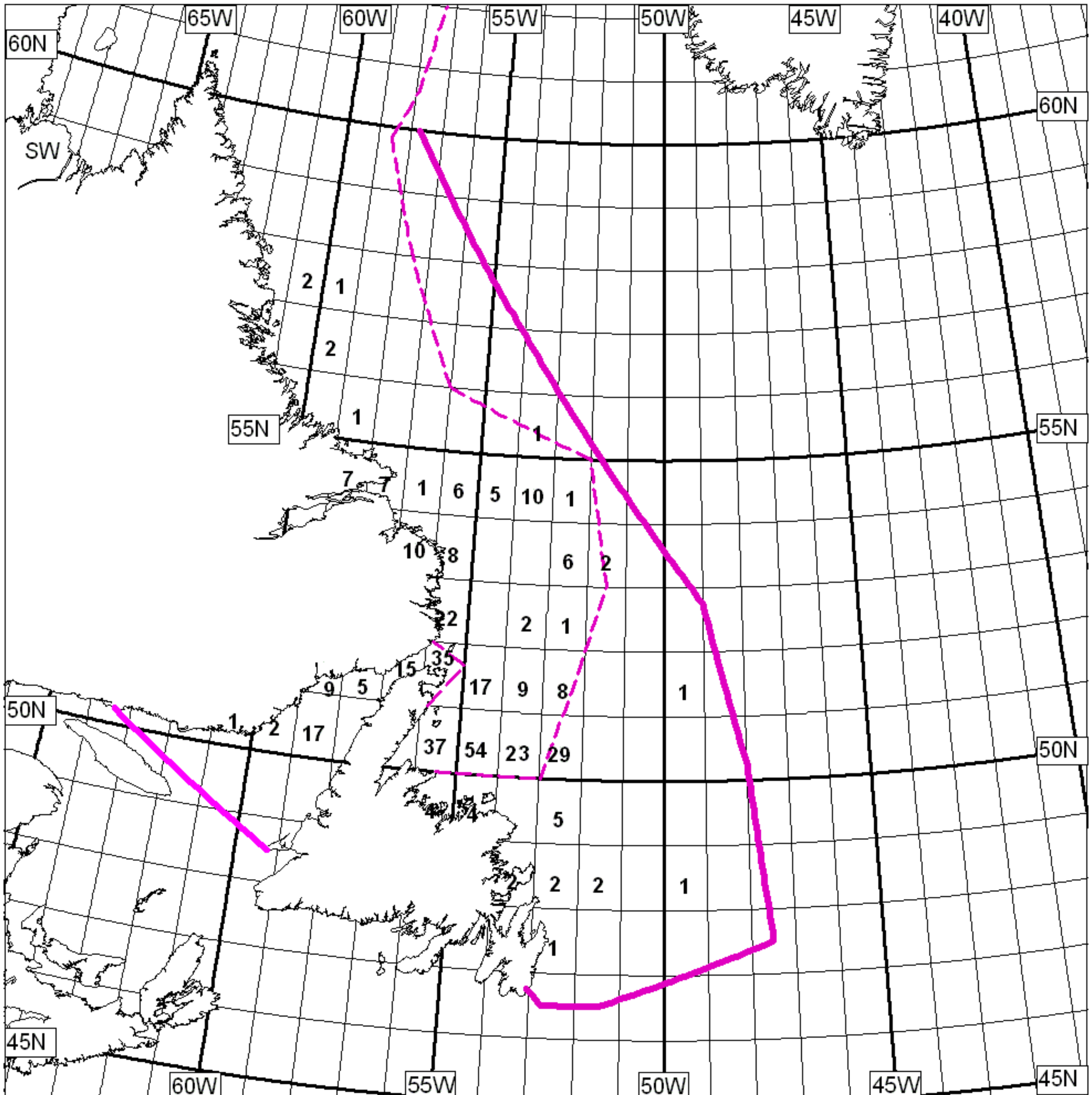
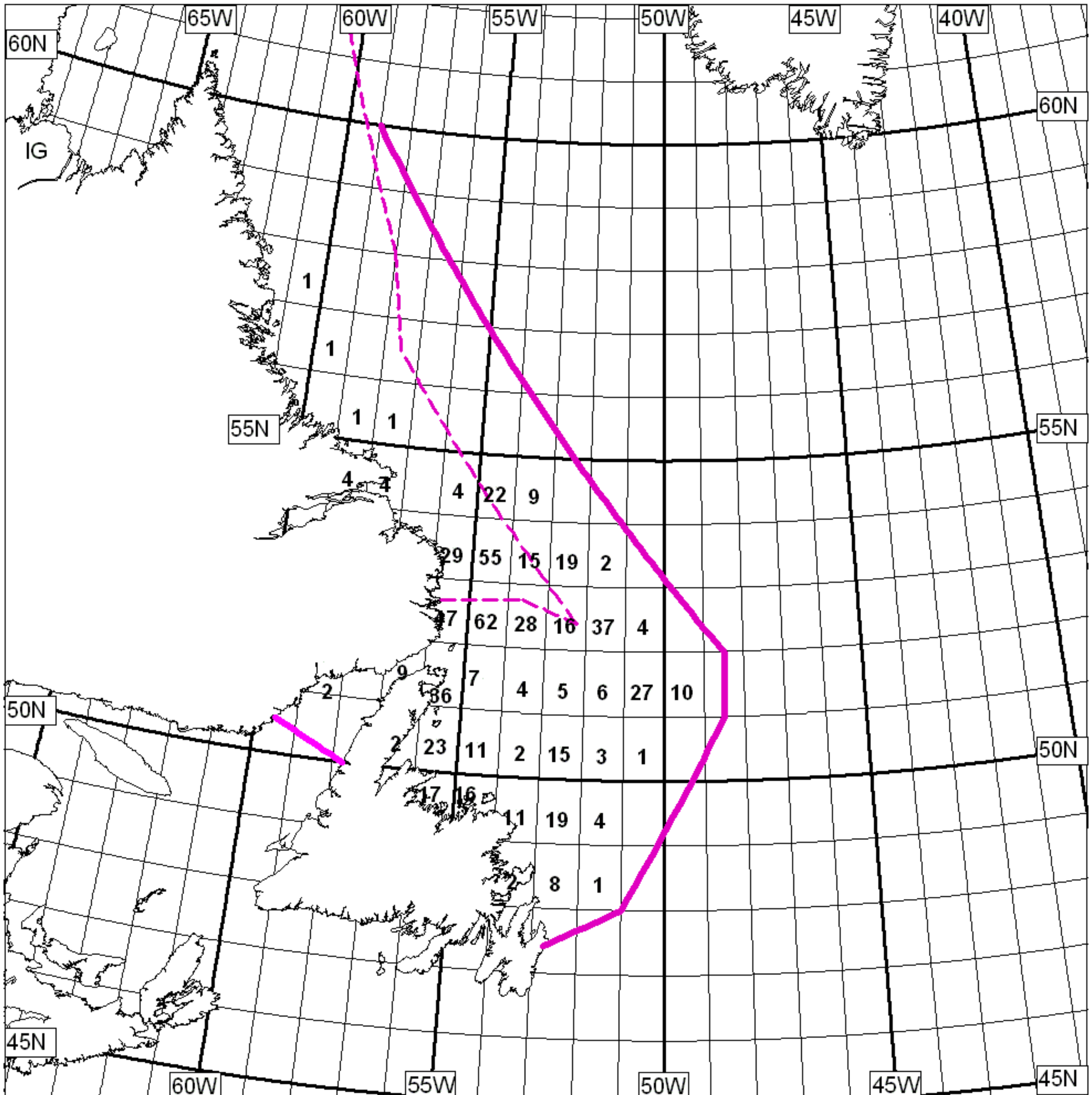
www.ice-glaces.ec.gc.ca



NORTH AMERICAN ICE SERVICE **SERVICE DES GLACES** **DE L'AMERIQUE DU NORD**	ICEBERG ANALYSIS / ANALYSE D'ICEBERGS FOR / POUR 0000 UTC **15 MAY / MAI 2013**
ICEBERG LIMIT / LIMITE DES ICEBERGS SEA ICE LIMIT / LIMITE DES GLACES # ICEBERGS PER DEGREE SQUARE ICEBERGS PAR DEGRE CARRE ⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT CIBLE RADAR A L'EXTERIEUR DE LA LIMITE DES ICEBERGS	NOTE / NOTER: For more information: Pour plus de renseignement: www.navcen.uscg.gov/iip www.ice-glaces.ec.gc.ca



NORTH AMERICAN ICE SERVICE
SERVICE DES GLACES
DE L'AMERIQUE DU NORD

ICEBERG ANALYSIS / ANALYSE D'ICEBERGS
FOR / POUR 0000 UTC

01 JUN / JUN 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS

SEA ICE LIMIT / LIMITE DES GLACES

\# ICEBERGS PER DEGREE SQUARE
ICEBERGS PAR DEGRE CARRE

⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT
CIBLE RADAR A L'EXTERIEUR DE LA
LIMITE DES ICEBERGS

NOTE / NOTER:

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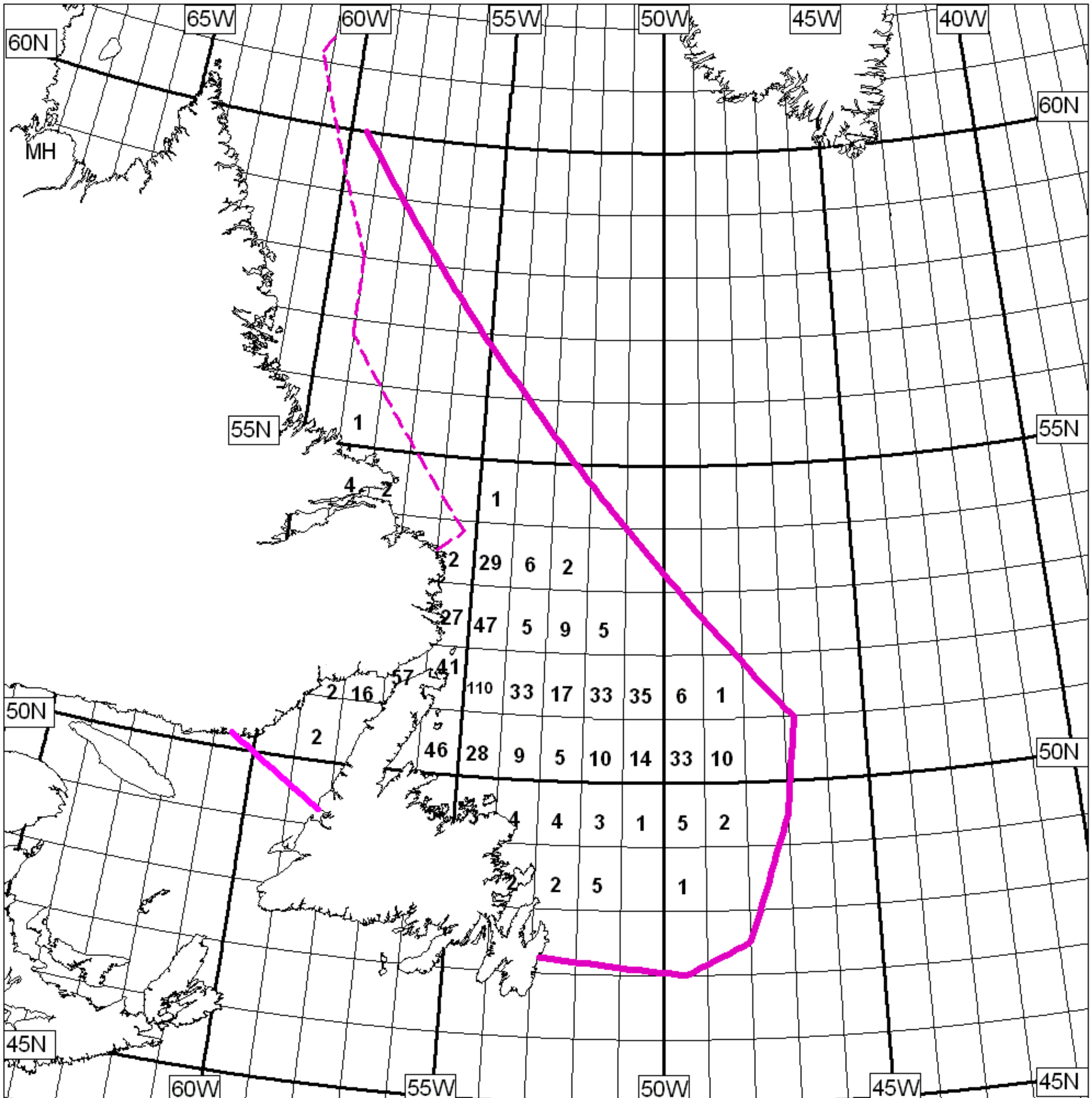

NORTH AMERICAN ICE SERVICE
SERVICE DES GLACES
DE L'AMERIQUE DU NORD

ICEBERG ANALYSIS / ANALYSE D'ICEBERGS
FOR / POUR 0000 UTC

15 JUN / JUN 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS

SEA ICE LIMIT / LIMITE DES GLACES

\# ICEBERGS PER DEGREE SQUARE
ICEBERGS PAR DEGRE CARRE

⨂ RADAR TARGET OUTSIDE ICEBERG LIMIT
CIBLE RADAR A L'EXTERIEUR DE LA
LIMITE DES ICEBERGS

NOTE / NOTER:

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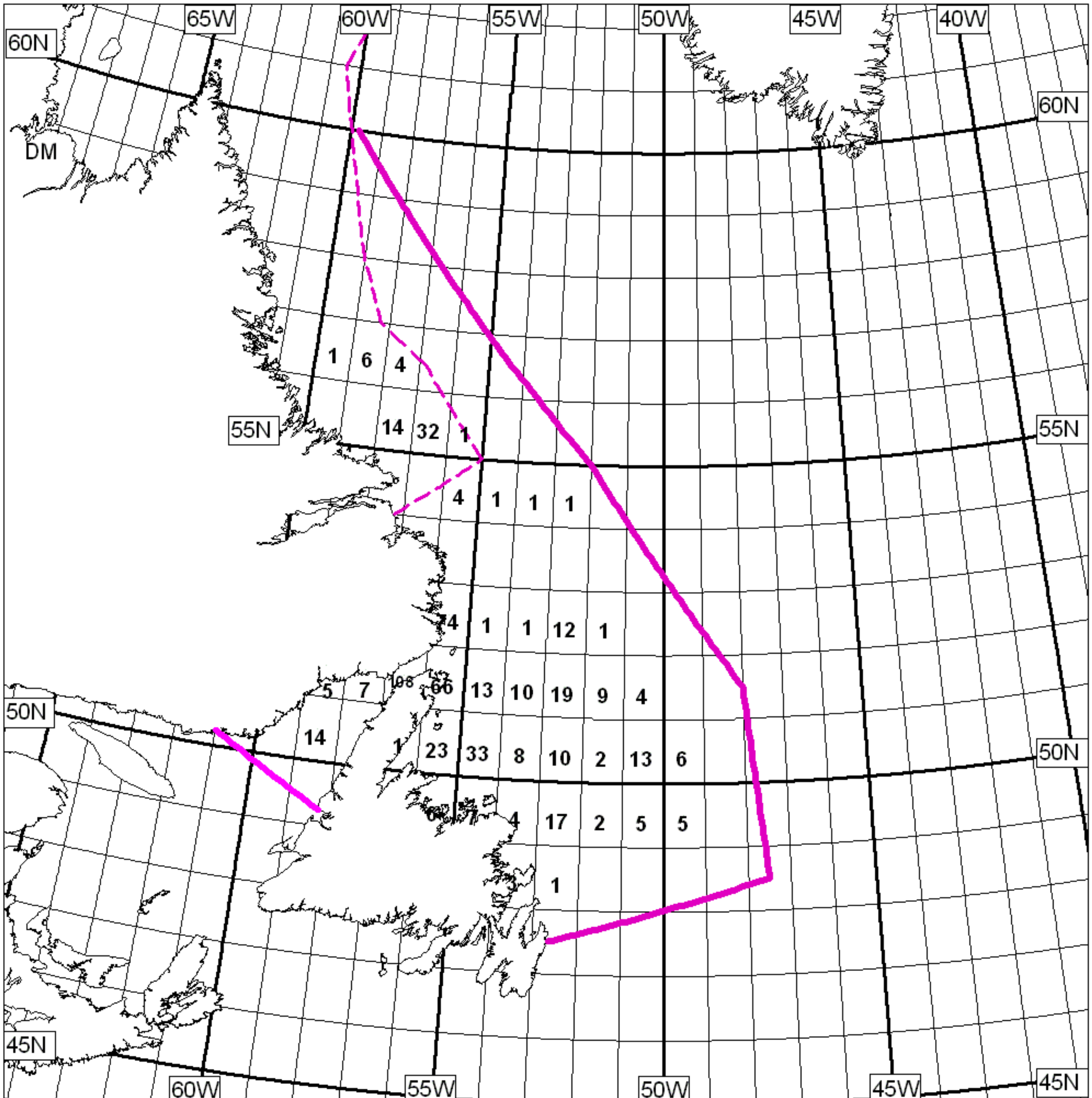

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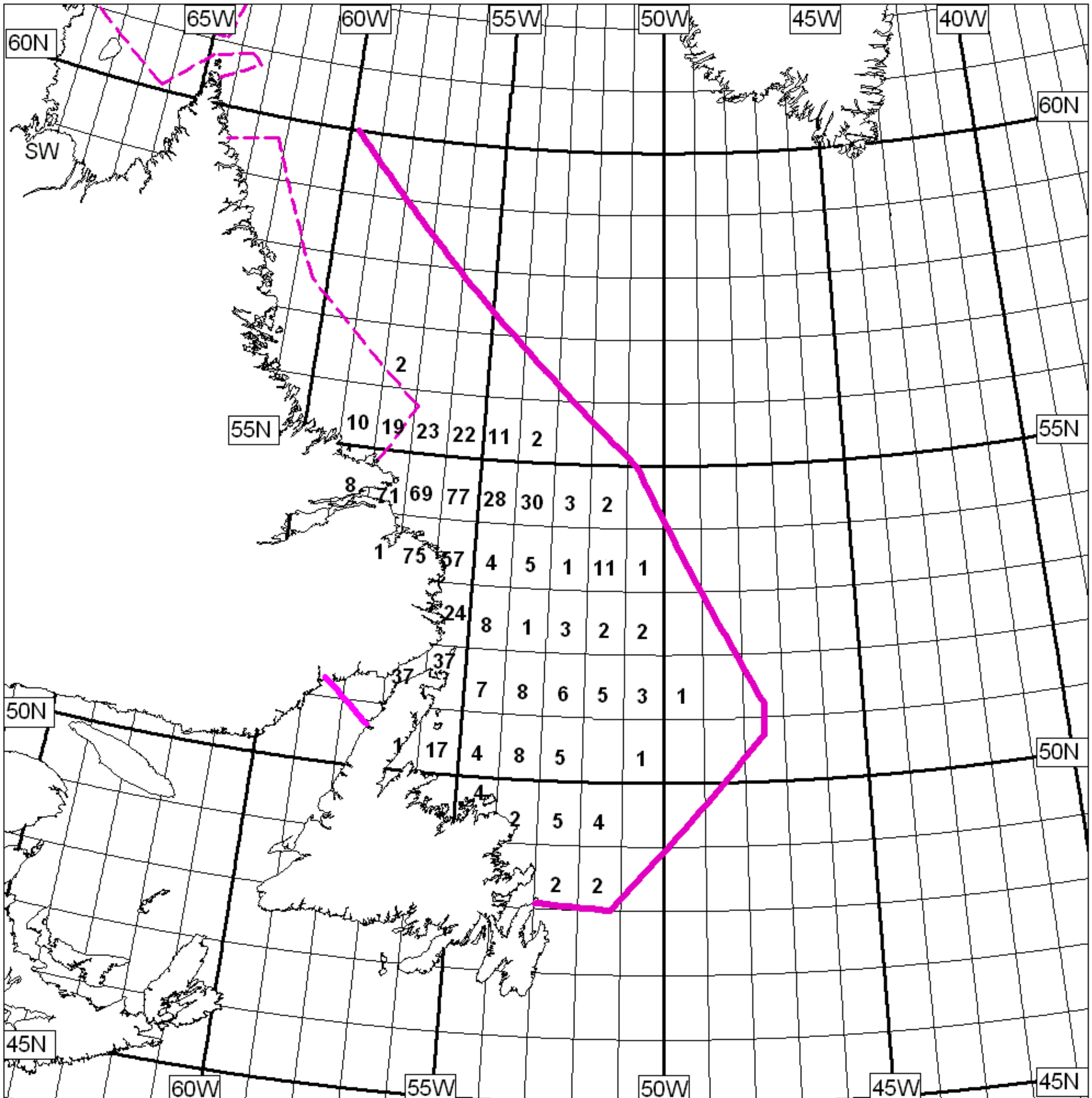
ICEBERG LIMIT / LIMITE DES ICEBERGS SEA ICE LIMIT / LIMITE DES GLACES # ICEBERGS PER DEGREE SQUARE ICEBERGS PAR DEGRE CARRE ⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT CIBLE RADAR A L'EXTERIEUR DE LA LIMITE DES ICEBERGS	NOTE / NOTER: For more information: Pour plus de renseignement: www.navcen.uscg.gov/iip www.ice-glaces.ec.gc.ca



NORTH AMERICAN ICE SERVICE
SERVICE DES GLACES
DE L'AMERIQUE DU NORD

ICEBERG ANALYSIS / ANALYSE D'ICEBERGS
FOR / POUR 0000 UTC

15 JUL / JUI 2013

ICEBERG LIMIT / LIMITE DES ICEBERGS
SEA ICE LIMIT / LIMITE DES GLACES
ICEBERGS PER DEGREE SQUARE
ICEBERGS PAR DEGRE CARRE
⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT
CIBLE RADAR A L'EXTERIEUR DE LA
LIMITE DES ICEBERGS

NOTE / NOTER:

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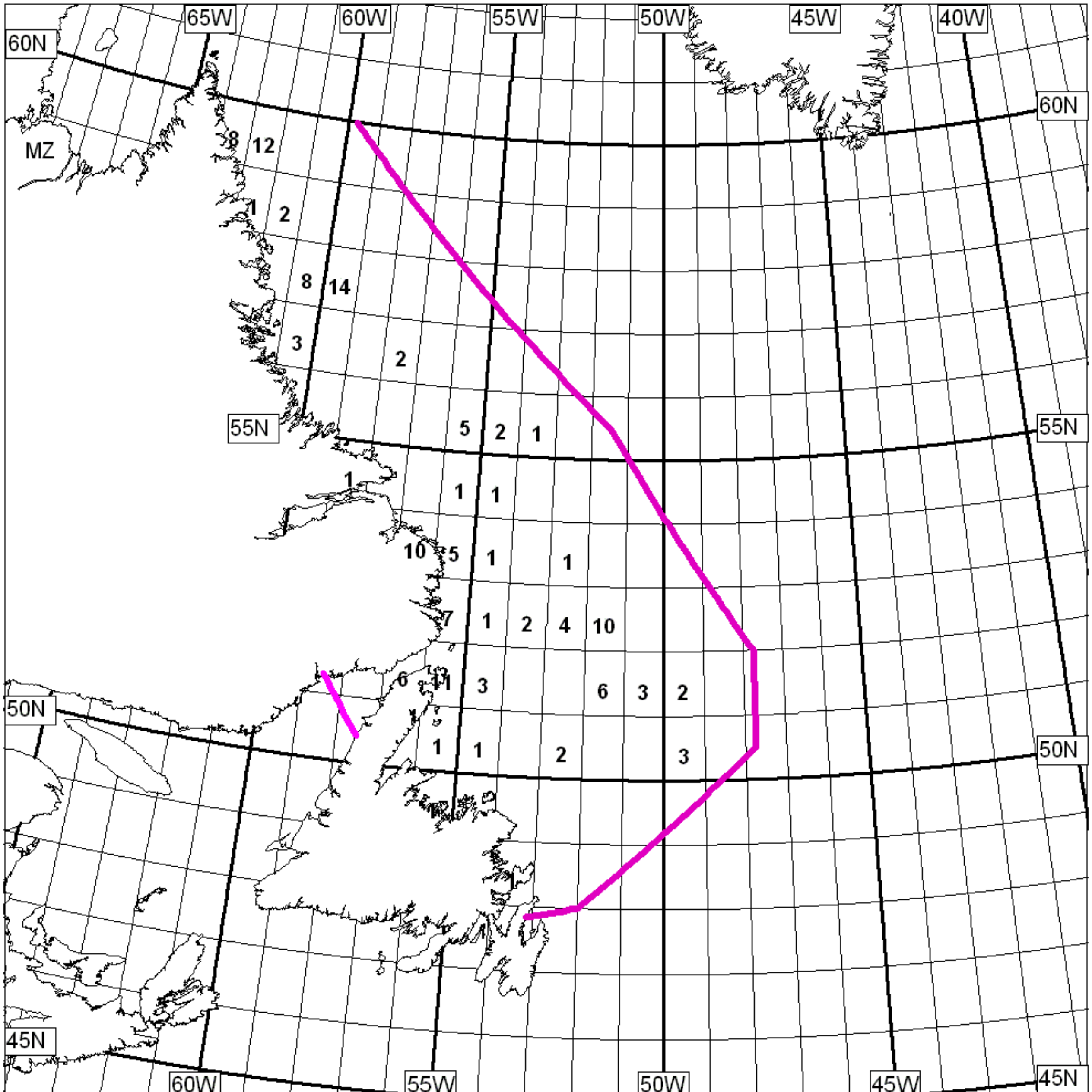
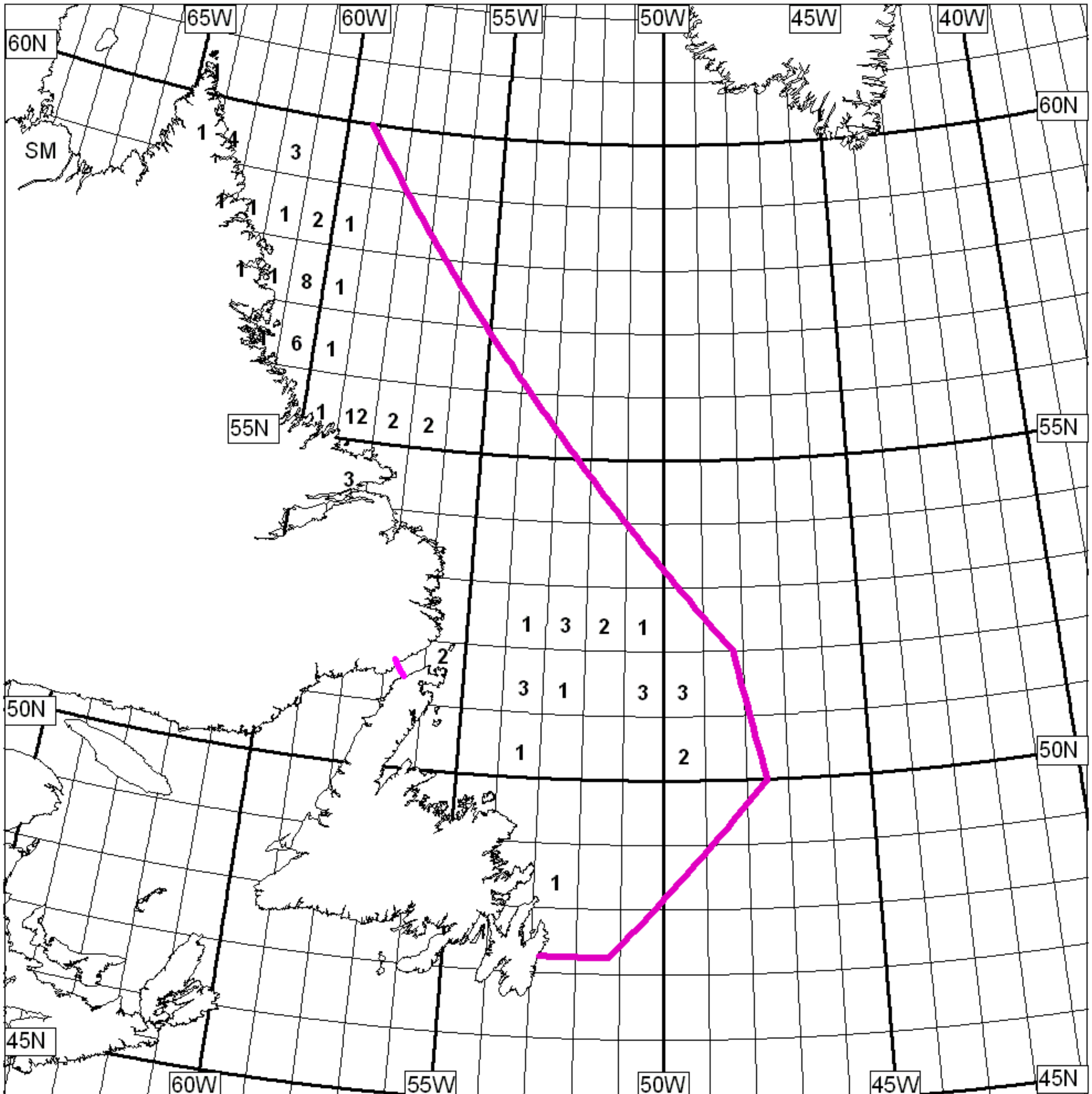


NORTH AMERICAN ICE SERVICE SERVICE DES GLACES DE L'AMERIQUE DU NORD	ICEBERG ANALYSIS / ANALYSE D'ICEBERGS FOR / POUR 0000 UTC **01 AUG / AOU 2013**
ICEBERG LIMIT / LIMITE DES ICEBERGS SEA ICE LIMIT / LIMITE DES GLACES # ICEBERGS PER DEGREE SQUARE ICEBERGS PAR DEGRE CARRE ⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT CIBLE RADAR A L'EXTERIEUR DE LA LIMITE DES ICEBERGS	NOTE / NOTER: For more information: Pour plus de renseignement: www.navcen.uscg.gov/iip www.ice-glaces.ec.gc.ca



NORTH AMERICAN ICE SERVICE SERVICE DES GLACES DE L'AMERIQUE DU NORD	ICEBERG ANALYSIS / ANALYSE D'ICEBERGS FOR / POUR 0000 UTC **15 AUG / AOU 2013**
ICEBERG LIMIT / LIMITE DES ICEBERGS SEA ICE LIMIT / LIMITE DES GLACES # ICEBERGS PER DEGREE SQUARE ICEBERGS PAR DEGRE CARRE ⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT CIBLE RADAR A L'EXTERIEUR DE LA LIMITE DES ICEBERGS	NOTE / NOTER: For more information: Pour plus de renseignement: www.navcen.uscg.gov/iip www.ice-glaces.ec.gc.ca

Acknowledgements

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

Canadian Coast Guard
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German Federal Maritime and Hydrographic Agency
National Geospatial-Intelligence Agency
National Weather Service
U. S. Coast Guard Air Station Elizabeth City
U. S. Coast Guard Atlantic Area Staff
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U. S. Coast Guard Maritime Fusion Intelligence Center Atlantic
U. S. Coast Guard Operations Systems Center
U. S. Coast Guard Research and Development Center
U.S. National Ice 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 2013 Ice Season:

CDR L. K. Mack	MST1 K. A. Farah
LCDR J. S. Worst	MST1 E. E. Lee
Mr. M. R. Hicks	MST1 W. M. Savage
Mrs. B. J. Lis	MST2 S. J. Weitkamp
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MSSD2 J. C. Luzader	MST2 T. V. Withers
YN1 I. O. Gonzalez	MST2 D. M. Morrisey

International Ice Patrol Staff produced this report using Microsoft® Office Word and Excel 2007.

Appendix A
Ship Reports for Ice Year 2013

Ships Reporting by Flag	Reports
ANTIGUA AND BARBUDA	
FEDERAL SAGUENAY	1
FEDERAL MAAS	1
BAHAMAS	
DELPHIN	1
CANADA	
CCGS GEORGE R. PEARKES *	12
UMIAK 1	5
ARCTIC	4
ROSAIRE A. DESGAGNES	1
CYPRUS	
FEDERAL DANUBE	1
HONG KONG	
OOCL MONTREAL	7
MALTA	
CAROL	7
UNITED KINGDOM	
MONTREAL EXPRESS	1

Appendix B
2011 and 2012 Satellite Coincident Analysis

Mr. Michael R. Hicks,
MST2 Thomas Withers,
and MST3 Megan M. Sanks
December 2013

Background

In 2010, the International Ice Patrol (IIP) contracted Science Applications International Corporation (SAIC) to assess the feasibility of using satellites to conduct iceberg reconnaissance. SAIC identified three commercial, satellite-based sensor systems that are capable of detecting icebergs using synthetic aperture radar reconnaissance and outlined possible employment strategies based on three time horizons defined as Present (2010), Intermediate (2015), and Long Term (2020). The SAIC study documented cost estimates for IIP's coverage requirements for RADARSAT-2 (RSA2), TerraSAR-X (TSX) and COSMO-SkyMed (CSK). (SAIC, 2011)

Findings from the SAIC report showed that none of the current satellite providers can fully meet IIP's spatial resolution and temporal requirements. The primary shortcoming is that the satellites studied cannot detect small icebergs with a sufficiently high probability of detection, particularly in high sea states. Distinguishing between icebergs and vessels remains a significant challenge. Cost estimates show that acquisition of satellite synthetic aperture radar (SAR) data for iceberg reconnaissance is competitive with aerial reconnaissance, though IIP is not currently funded to acquire or analyze satellite imagery. Further, purported relaxed data sharing policies of planned Canadian and European SAR missions should improve the availability and timeliness of SAR imagery to support the IIP mission. These facts, coupled with the increasing demand for costly HC-130J hours by other Coast Guard missions compelled further research into the use of both commercial and government SAR data to augment aerial iceberg reconnaissance.

The SAIC report recommended two key actions to advance the integration of satellite-based reconnaissance into IIP operations: (1) conduct benchmark testing that compares ground truth iceberg and ship data with simultaneous satellite imagery of the area of interest for direct comparison and (2) conduct a detailed financial analysis to estimate the cost of acquiring and operating the systems necessary to receive and analyze satellite image data. This technical report documents IIP's efforts during the 2011 and 2012 seasons to address the first SAIC recommendation. SAIC's second recommendation for a detailed financial analysis is necessary but beyond the scope of this report.

In addition to documenting results for these comparison efforts, the lessons learned during the 2011 and 2012 seasons provide valuable insight into the elements of a concept of operations (CONOPS) that will serve as a guide to routine incorporation of satellite data into future reconnaissance strategy. The CONOPS will seek to describe the most effective mix of satellite and aerial iceberg reconnaissance. CONOPS elements are included in the Recommendations section of this Appendix.

Data Collection Approach and Analysis Methods

The approach used to conduct this test required collection and processing of RSA2 and TSX imagery, as well as coordination of aerial reconnaissance at a coincident time over the same satellite footprint.

Costs for using satellite SAR in IIP operations arise not only from the cost of the image data itself but also from image processing that ultimately delivers an unclassified message coded with the Manual of Standard Procedures for Observing and Reporting Ice Conditions (MANICE) format so that data can be ingested into IIP's iceBerg Analysis and Prediction System (BAPS). In 2011, IIP received data from 81 RSA2 images for acquisition and processing. Iceberg data from these images were used both to execute the Ice Patrol mission and to conduct an assessment of the reliability of satellite reconnaissance. Images were acquired by C-CORE, a not-for-profit research organization located in St. John's, Newfoundland, through the support of Polar View. Polar View was an earth observation program funded by the European Space Agency that focused on the use of satellites for the Arctic and Antarctic regions. Additionally in 2011, the National Ice Center (NIC) funded procurement of the TSX images used in this study.

Since IIP has no organic capability to order, process or analyze raw SAR imagery, IIP contracted C-CORE, to perform these functions. Using considerable expertise in this field, C-CORE developed iceberg detection software (IDS) which automates iceberg detection and identification. IIP has been working with C-CORE since 1997 on similar SAR satellite validation projects.

The IIP also employed a process whereby satellite-derived data were sent to the USCG Maritime Intelligence Fusion Center, Atlantic (MIFC-LANT) as a means to assist in further target identification. While this process is an important element in the overall CONOPS for incorporating satellite data into the IIP's iceberg database, this Appendix focuses on coincident data from RSA2 and TSX satellite systems.

The 2011 data documents nine cases where RSA2 and TSX data were collected concurrently for comparison of these satellite systems. IIP analysis defined targets as coincident (and correlated) if the targets reported from each satellite were within one NM of each other. For 2011, satellite acquisition times were all within 29 minutes of each other so acquisition time differences were not considered a significant contributor to the observed correlations. Despite efforts to collect coincident ground truth data in 2011, a light season, combined with poor weather conditions, prevented any aerial validation.

In 2012, IIP collected data for four separate ground truth events for RSA2 only. Time differences between aerial flights and satellite passes varied between 43 minutes to 4.5 hours. Iceberg drift as a source of error was examined for the 4.5 hour difference event and is discussed in the Results section.

Results

2011

Table B-1 summarizes collection efforts during 2011. Results for 2011 compared coincident RSA and TSX satellite iceberg detections in an effort to gain insight on the level of agreement from two different remote sensing systems that were processed using C-CORE's IDS. All TSX images were acquired in ScanSAR mode (18 m resolution, 100 km swath). RSA2 images were acquired using Fine (8 m resolution, 50 km swath), Wide (8 m resolution, 150 km swath) and ScanSAR A/B (60 m resolution, 300 km swath).

			Radar Sat-2 Image Details					Terra SAR-X Image Details				
Date	Pass	Time Delta* (HH:MM)	Time	Beam Mode	Swath (km)	Resolution [Rng x Azimuth] (m)	Polar-ization	Time	Beam Mode	Swath (km)	Resolution (m)	Polar-ization
21-May-11	DSC	0:13	9:47:34	F3N	50	5.2 x 7.7	HH/HV	10:00:53	ScanSAR	100	16	HH
31-May-11	ASC	0:17	21:20:14	F2F				21:02:52				
7-Jun-11	DSC	0:00	9:51:26	F1				9:52:14				
10-Jun-11	ASC	0:08	21:28:14	SCNB	300	79.9 -37.7 X 60		21:19:30				
24-Jun-11	DSC	0:11	9:55:05	SCNA				9:43:46				
28-Jun-11	DSC	0:29	9:38:23	F6F	50	5.2 x 7.7		10:08				
30-Jun-11	ASC	0:08	21:45:53	SCNB	300	79.9 -37.7 X 60		21:54				
1-Jul-11	ASC	0:20	21:15:44	W1	170	13.5 x 7.7		21:36				
5-Jul-11	DSC	0:07	9:34:14	F6F	50	5.2 x 7.7		9:42				

*Time Delta represents the time difference between acquisition times for each satellite.

Table B-1: Summary of 2011 Collection Efforts

Figure B-1 graphically illustrates the areas covered by the two satellites and various RSA2 modes. Range and azimuth resolutions are outlined in **Table B-1** where resolution is

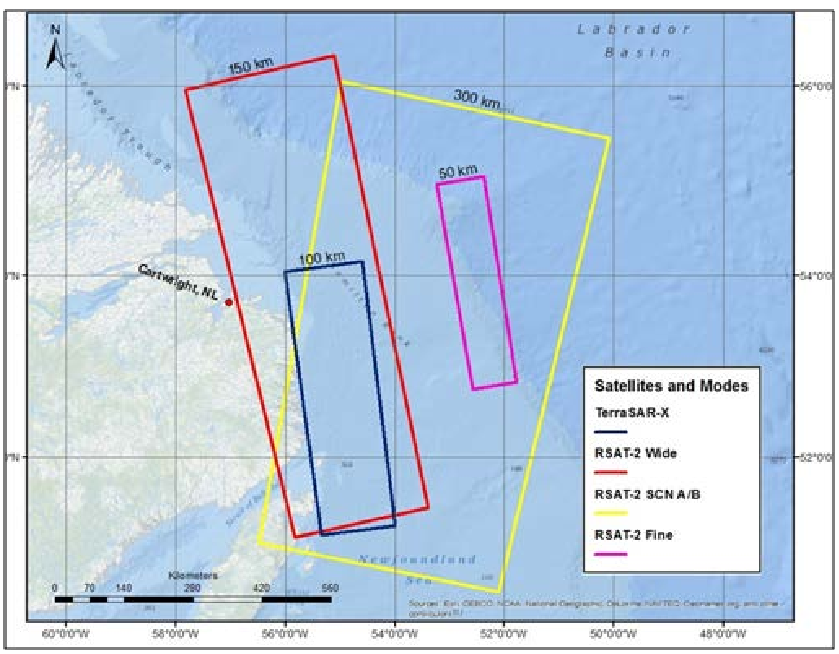

Figure B-1: Geographic coverage comparison of the various satellite modes analyzed during 2011 test.

defined as the minimum separation distance necessary to distinguish two unique targets. In general, resolution decreases as coverage area increases.

Without ground truth data to compare to satellite detections, analysis of the 2011 data sought to document the level of agreement between RSA2 and TSX by counting the number of targets that met the correlation criteria described earlier. To quantify agreement between the two systems, a ratio between the number of correlated iceberg and radar target (R/T) pairs for both systems and the total number of icebergs and R/Ts reported by both systems combined was computed. This approach assumed that each reported iceberg represented an opportunity for correlation. This analysis also counted R/Ts as coincident if one system reported an R/T and the other reported an iceberg.

Table B-2 presents results ranked by the percentage of agreement between the two satellite systems. These results do not show any clear correlation between the satellite mode and level of agreement e.g., the best agreement was on 07 June 2011 between RSA2 Fine mode (F1) and TSX ScanSAR where 38% of targets reported in the intersecting satellite footprints met the criteria for a correlated target. The worst agreement was on 28

Icebergs & Radar Targets							
	RSA2 Mode	TSX Mode	RSA2 Identified w/o TSX	TSX Identified w/o RSA2	Correlated Icebergs and R/Ts	Total Bergs and R/Ts	Agreement
7-Jun-11	Fine	ScanSAR	3	6	15	39	38%
30-Jun-11	SCN-B		6	132	115	368	31%
1-Jul-11	W1		12	93	84	273	31%
5-Jul-11	Fine		5	2	3	13	23%
24-Jun-11	SCN-A		1	47	15	78	19%
10-Jun-11	SCN-B		0	13	4	21	19%
21-May-11	Fine		23	4	7	41	17%
31-May-11	Fine		13	14	1	29	3%
28-Jun-11	Fine		49	7	1	58	2%
Totals			27	280	232	771	30%

Table B-2: Summary of Coincident Iceberg Detection Results from RSA2 and TSX

June 2011 also for RSA2 Fine mode and TSX ScanSAR where only 2% of the targets met these criteria. These results are shown graphically in **Figures B-2** and **B-3**.

An examination of the wind speed at Cartwright, NL for these dates may lend some insight into this observation. **Figure B-2** (top panel) shows the RSA2 and TSX satellite footprints with corresponding detections reported through the C-CORE IDS for 07 June 2011. TSX detections are in dark blue while RSA2 are in magenta. The coincident area is highlighted in gold; in this case, RSA2 Fine mode image is contained completely within the TSX footprint. The results for 07 June 2011 showed the highest percentage of coincident iceberg reports for all cases in 2011. A summary of key comparisons is contained inside

Figure B-2. On this day, 15 correlated iceberg matches were reported out of 39 total opportunities.

Figure B-2 (bottom panel) shows the hourly wind speed at Cartwright, NL. Acquisition times for each satellite system are plotted as vertical lines on the time scale. Winds at that station were relatively light, blowing from a south-southwesterly direction and peaking at approximately 12 kts at 0600 (local time), about one hour prior to the satellite acquisition time. The satellite passes were both descending resulting in westward satellite look-directions that were across the direction of wind. Prior research (Vachon et al., 1997) has shown that these two conditions (light winds and cross-wind satellite look direction) result in lower ocean backscatter (i.e., sea clutter) and leads to a higher probability of detection. Thus, these conditions may have supported better performance from both satellites.

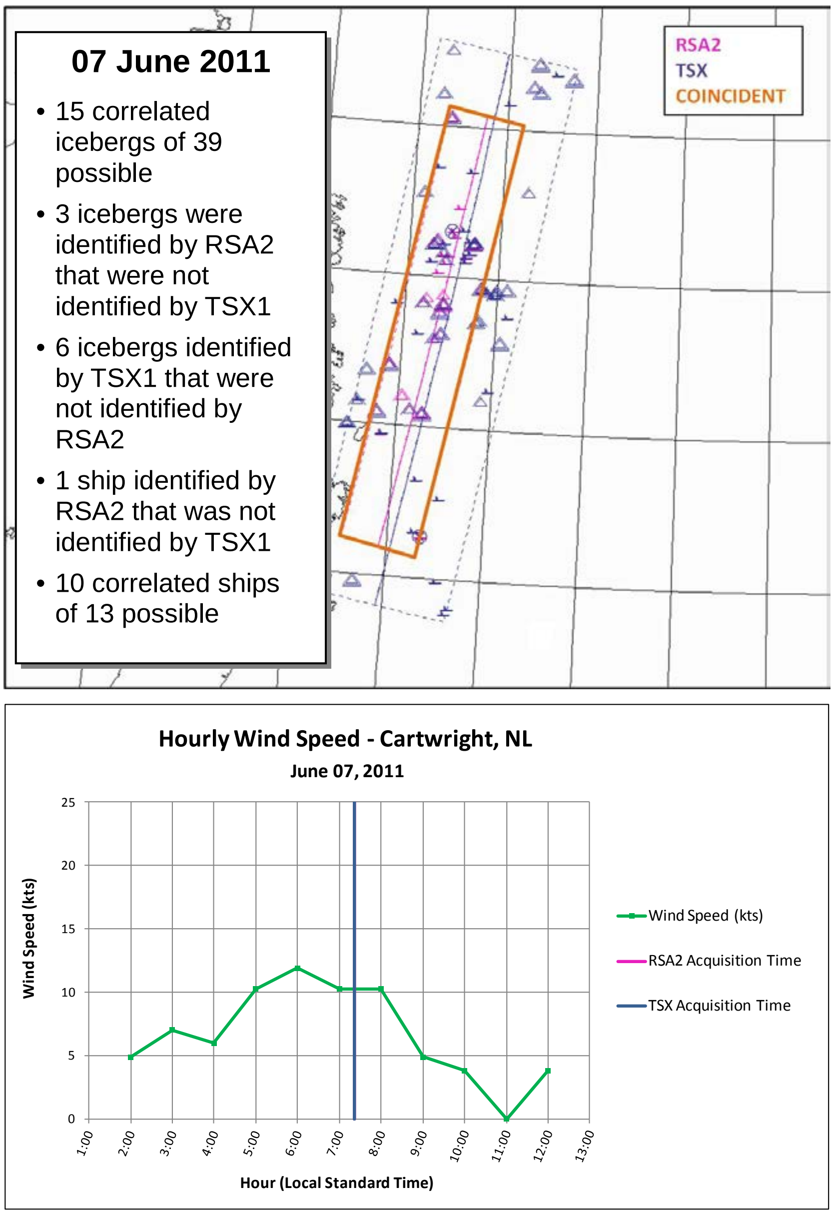

Figure B-2: Coincident areas and detections for RSA2 and TSX on 07 June 2011 (top) with hourly wind speeds at Cartwright, NL (bottom). (Wind data courtesy of Environment Canada).

By contrast, **Figure B-3** shows results from 28 June 2011. The RSA2 image was collected in Fine mode at the shallowest incident angle designated as ‘F6F’ at approximately the same time as the TSX ScanSAR image. On this date, the C-CORE IDS reported only one correlated match of 58 total opportunities (2%). Winds at Cartwright, NL during the time of acquisition were blowing from a northwesterly direction at greater than 22 kts. On a descending pass, the satellite look direction was more directly into the wind than on 07 June 2011. That, combined with a much higher sustained wind speed than on 07

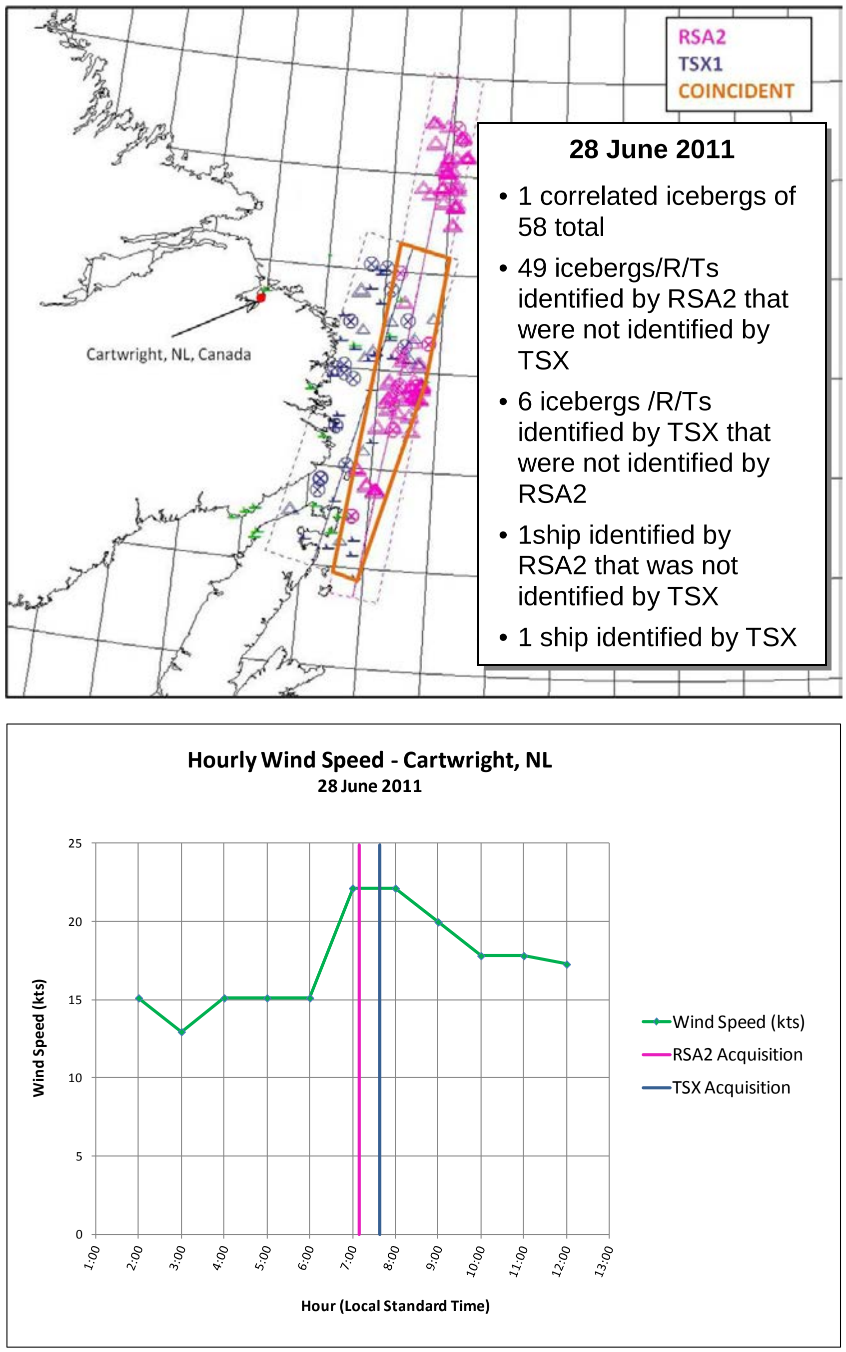

Figure B-3: Coincident areas and detections for RSA2 and TSX on 28 June 2011 (top) with hourly wind speeds at Cartwright, NL (bottom). (Wind data courtesy of Environment Canada).

June 2011 prior to and during the satellite acquisition time likely led to a higher ocean backscatter and reduced performance. In this case, the RSA2 Fine mode detected 42 targets while TSX only reported six. Of note, the BAPS model prognosis for 07 June 2011 estimated that 16 iceberg targets were within the intersecting footprint on that date. The BAPS model result was based on reconnaissance in the area on 05 June 2011, two days prior to the satellite acquisition. While this model result in no way qualifies as "ground truth" it does provide a rough indicator of the number of icebergs expected to be present in the area and suggests that RSA2 may have reported false targets – possibly due to a higher wind and ocean backscatter on this date. This result is not conclusive except to underscore the importance of understanding the environment under which satellite imagery is acquired when considering incorporation of satellite-derived data into the iceberg database.

Other results from 2011 efforts showed varying degrees of agreement between RSA2 and TSX that ranged from 3% to 31% coincident matches. Again, without ground truth data to state that one system detected an iceberg while another did not, it is not appropriate to draw any positive conclusions about the effectiveness of either satellite system. The data collected does provide some insight into the variables that must be considered when selecting and analyzing satellite-derived data such as mode, cross-polarization capability, radar transmit frequency (i.e., C-Band for RSA2 and X-Band for TSX), coverage area and specific application in IIP operations. For example, IIP may elect to use satellite detections to add iceberg targets into the database early in the season but rely on aerial reconnaissance to declare a critical area, such as the southern shipping lanes, free of ice hazards during the most active months of the year, typically mid-March through early June.

2012

Table B-3 summarizes ground truth collections and corresponding RSA2 modes. The coverage relationships for the RSA2 data are the same as those presented earlier in **Figure B-1** with exception of the single Wide-Fine acquisition on 26 May 2012 as previously discussed (shaded in blue) in **Table B-3**. The SAIC report based its RSA2 scenarios on the Wide-Fine mode which has a slightly larger swath (170 km) than Wide but has the same resolution as Fine Mode (8 m resolution). IIP conducted one under-flight coincident with Wide-Fine satellite acquisition in 2012. These results are discussed in the next section.

<table>
<tr><th>Date</th><th>Time Delta* (HH:MM)</th><th>Beam Mode</th><th>Swath (km)</th><th>Resolution [Rng x Aximuth] (m)</th><th>Polarization</th><th>Ground Truth</th></tr>
<tr><td>29-Apr-12</td><td>4:25</td><td>Fine (F6F)</td><td>50</td><td rowspan="4">5.2 x 7.7</td><td rowspan="4">HH/HV</td><td>PAL</td></tr>
<tr><td>26-May-12</td><td>1:37</td><td>Wide-Fine (FOW3)</td><td>170</td><td rowspan="3">IIP</td></tr>
<tr><td>9-Jun-12</td><td>2:02</td><td>Fine (F2)</td><td>50</td></tr>
<tr><td>8-Jul-12</td><td>0:43</td><td>Fine (F4)</td><td>50</td></tr>
<tr><td colspan="7">*Time Delta represents the time difference between satellite acquisition and time midway through ground truth flight.</td></tr>
</table>

Table B-3: Summary of RSA2 Satellite Acquisitions Coincident with Ground Truth data

During 2012, IIP collected ground truth data on four separate dates. A USCG HC-130J collected data for three of these four events. Though IIP planned for an HC-130J to collect data for all events, an air crew medical emergency prevented the aircraft from flying on the planned date. Fortunately, Provincial Aerospace Limited (PAL) flew in the area of the satellite pass within 4.5 hours of the acquisition time providing airborne radar coverage for the RSA2 footprint. IIP's analysis compared iceberg and ship detections reported by RSA2 satellite acquisitions with those detected by aerial reconnaissance. RSA2 Fine mode images (8 m resolution, 50 km swath) were acquired on three dates and Wide-Fine mode on one date (8 m resolution, 150 km swath).

Table B-4 summarizes results from the 2012 ground truth events. Fine mode acquisitions are shaded in light green while the Wide-Fine acquisition on 26 May 2012 is shaded in light blue. Due to time differences between satellite pass and aerial flight, vessels are not included in these results. To remain consistent with IIP's current reconnaissance requirement, only icebergs that were classified as 'small' (15-60 m in length) and larger were considered in this analysis. Growlers or bergy bits (less than 15 m in length) were not included. The last column in the table provides the percentage of correlated icebergs. IIP determined this correlation percentage by calculating the ratio of targets detected by RSA2 to detection opportunities (ground truth). It is important to note that this number is based on a very limited sample size and only provides a rough approximation of the effectiveness of the satellite. In general, RSA2 Fine mode performed better than Wide-Fine. On 29 April, RSA2 detected all bergs within the scene for 100% detection. Also, on 09 June an IIP flight verified that there were no icebergs in the scene. This flight was originally planned in an area where icebergs were present, but the Iceberg Limit receded rapidly in early June 2012 leaving no icebergs in the test area. It is encouraging to note that RSA2 did not report any icebergs as false targets on this occasion. **Figure B-4** through **Figure B-6** graphically depict comparative analyses on dates when icebergs were present for 29 April, 26 May and 8 July, respectively.

Date	Time Delta* (HH:MM)	RSA2 Mode (Beam)	Ground truth source	Wind Speed (kts)	Ground truth Bergs (length >15 m)	Number of Correctly Classified Bergs (length >15 m)	Percentage of Correlated Icebergs (length >15 m)
29-Apr-12	4:25	Fine (F6F)	PAL	25-30	3	3	100%
26-May-12	1:37	Wide-Fine (FOW3)	IIP	15	6	3	50%
9-Jun-12	2:02	Fine (F2)	IIP	11-15	0	0	no data
8-Jul-12	0:43	Fine (F4)	IIP	11-15	13	8	62%
Totals					**22**	**14**	**64%**
Fine Mode Total (50 km swath)					16	11	69%
Wide-Fine Mode Total (170 km swath)					6	3	50%

*Delta represents the time difference between satellite acquisition and time midway through ground truth flight.

Table B-4: Summary of 2012 RSA2 Coincident Analysis Results

Figure B-4 shows the results from 29 April 2012. As described above, a normally scheduled PAL flight provided the ground truth data for this date. Although the time difference between the PAL flight and RSA2 satellite pass was 4 hours and 25 minutes, the iceberg positions correlated remarkably well and were consistent with the expected drift of the icebergs based on wind and currents. PAL detected these icebergs by radar alone, so no size information was provided as ground truth. However, the C-CORE algorithm provided size estimates and drift characteristics for each size category reported that were consistent with environmental observations i.e., an iceberg classified by C-CORE as small drifted downwind while a large iceberg appeared to be influenced more by deeper currents and drifted perpendicular to the wind direction.

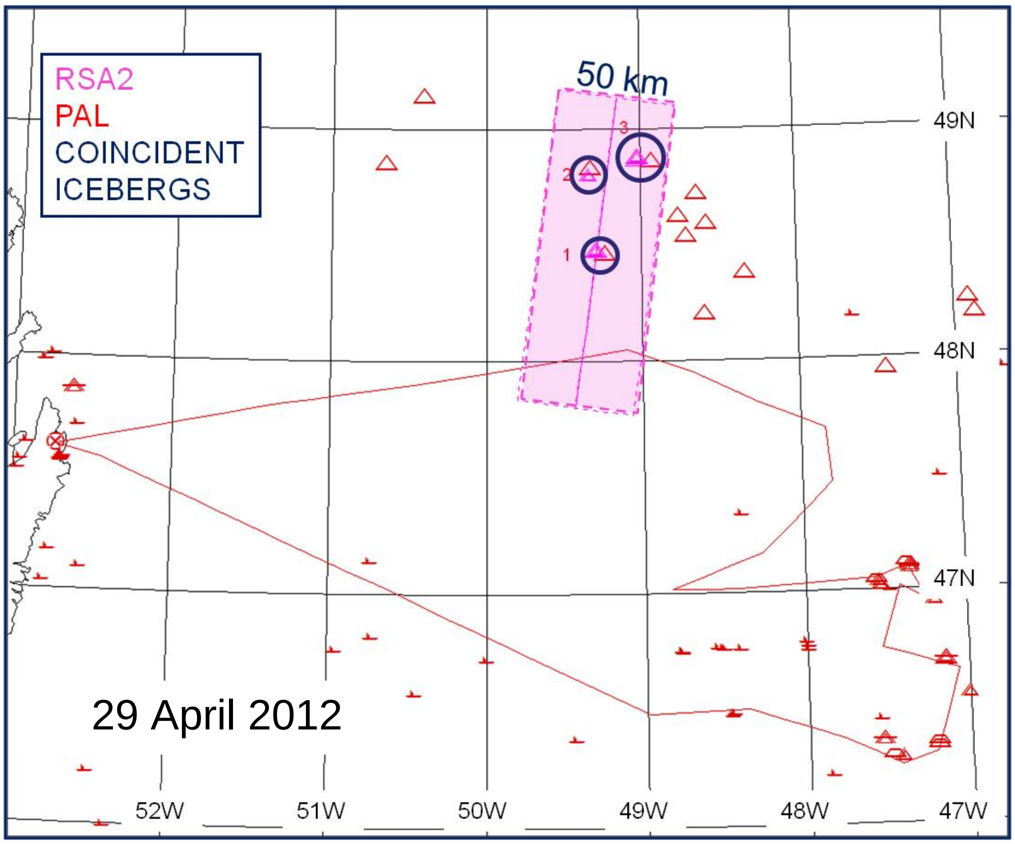

Figure B-4: Comparative analysis between PAL flight and RSA2 fine mode - 29 April

Figure B-5 shows results from the only Wide-Fine under-flight on 26 May 2012. With a 170 km (92 NM) swath, the Wide-Fine mode offers an attractive compromise between coverage area and resolution. While both Wide-Fine and Fine modes have the same resolution, the trade-off comes at the expense of added noise in the Wide-Fine mode which essentially means that the signal to noise ratio for a target must be higher for successful detections in this mode versus Fine mode. On this date, the C-CORE algorithm missed a total of six icebergs that were detected by the HC-130J. Of these six, three were classified visually as growlers (less than 5 m in length) by IIP reconnaissance. Of the three icebergs that were larger than growlers, two were 'small' (length of 15-60 m) and one, reported by radar only, was assigned a size of 'medium' (length of 61- 120 m) leaving three correlated matches of six opportunities. Thus, Wide-Fine mode yielded 50% correlation between ground truth and RSA2 targets for icebergs with a size of 'small' or larger. Of note, the requirement for IIP radar and visual reconnaissance is to detect icebergs that are of size 'small' (15 m length) and larger.

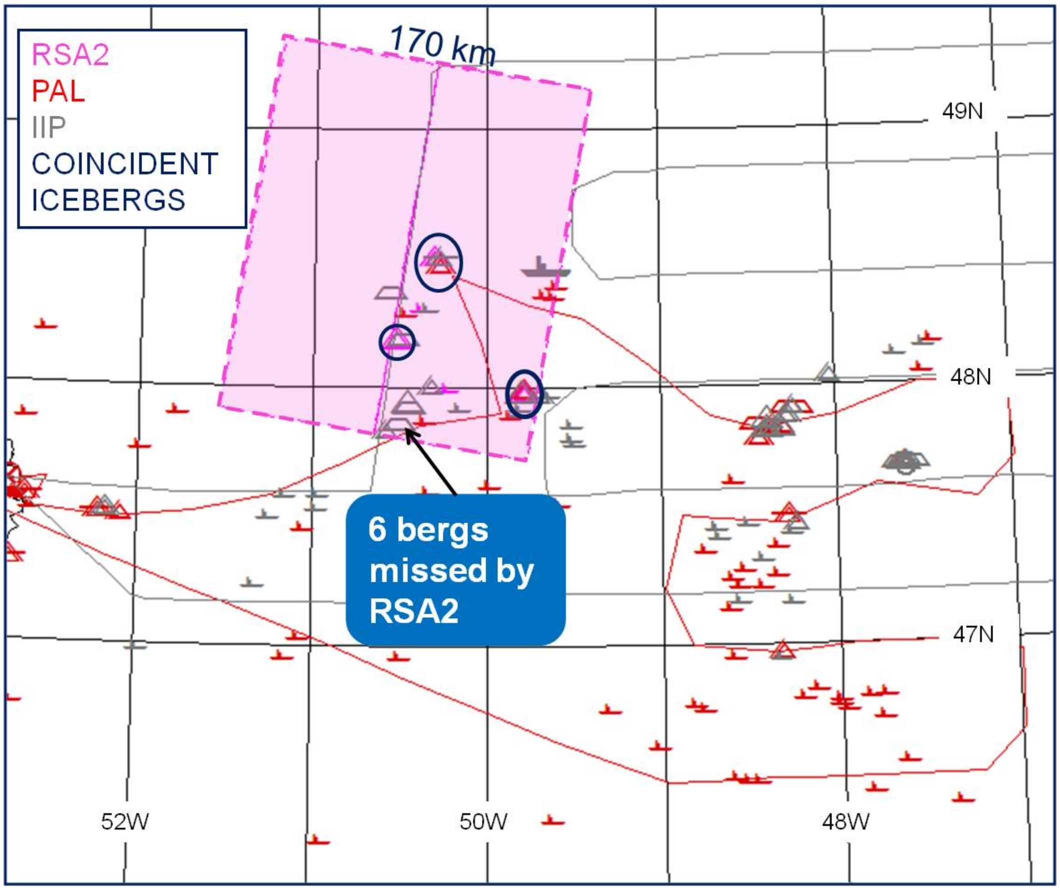

Figure B-5: Comparative analysis between IIP flight and RSA2 Wide-Fine mode - 26 May

Results from the 08 July 2012 under-flight for a RSA2 Fine mode image are shown in **Figure B-6**. This flight was conducted off of the southern Labrador coast with a sizable iceberg population. The flight occurred within 43 minutes of the satellite pass offering an excellent comparison opportunity. IIP detected 13 icebergs that were classified as 'small' or larger within the footprint of the RSA2 pass. Of these, eight were positively correlated with RSA2 icebergs. The C-CORE IDS reported one R/T in open waters that did not match IIP reconnaissance and three additional RSA2 icebergs that were very close to the coastline. These were not considered false positives due to the possibility that these were either not detected or not reported by IIP because of their proximity to the coast.

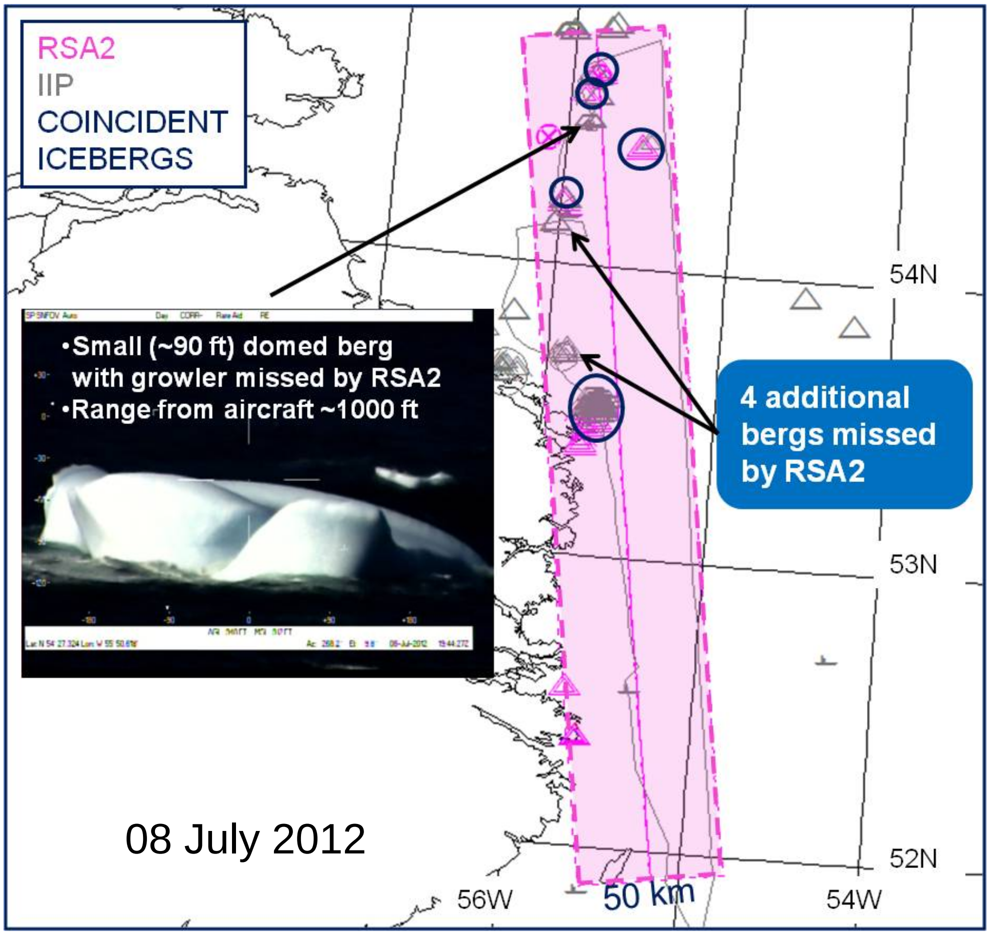

Figure B-6: Comparative analysis between IIP flight and RSA2 Fine mode – 08 July 2012

Summary and Discussion

This Appendix documents IIP's efforts during 2011 and 2012 to advance its understanding of the capabilities and limitations for incorporating satellite-derived iceberg detection data into its operations. It is important to note that IIP has been evaluating commercial satellite data since the mid-1990s and has been incorporating satellite iceberg reconnaissance data operationally via C-CORE's IDS since 2011. In 2012, 13.8% of all icebergs reported to IIP were via satellite and most recently in 2013, 16% of all icebergs were detected by commercial satellite. Prior to entry into BAPS, the IIP employs a process by which satellite-derived data is sent to the USCG MIFC-LANT as a means to assist in further target identification. This process is an important element in the overall concept of operations for incorporating iceberg data into IIP operations and will continue in the future.

Following SAIC's 2011 report recommendations, IIP acquired imagery at nearly the same time from both RSA2 and TSX (2011 only) to compare reported iceberg detections. 2011 efforts compared data from two different satellite systems that were processed through a common automated detection algorithm (C-CORE's IDS). All data were reported in

MANICE format and ingested into the IIP iceberg database through BAPS for analysis. Without ground truth data, results did not yield any conclusive information about the effectiveness of one system over another. This limited comparative value underscores the need for solid ground truth to build confidence in the proper use of satellite data in IIP operations.

The analysis of 2011 results revealed significant variability between the outputs from RSA2 and TSX satellite systems that are likely attributed to either the different resolution from various RSA2 and TSX modes or the availability to exploit horizontal and vertical polarization for RSA2 and not TSX. The impact of the environment (wind direction/speed and sea state) has been well-documented and likely contributed to the differences observed (Vachon et al., 1997).

In 2012, IIP coordinated four separate ground truth events that documented correlated iceberg detections with aerial ground truth for RSA2 Fine and Wide-Fine modes. All satellite data were processed using C-CORE's IDS automated algorithm and delivered in MANICE format. One of the events did not contain any icebergs, so a correlation percentage was not determined. Fine mode data showed higher correlation rates (69% average) than the Wide-Fine example (50%). While the sample size for this data set is small, these measurements are consistent with performance expectations that result when increasing the coverage area. In this case, the trade-off results from a higher noise floor level with the Wide-Fine mode compared to the Fine mode (MDA, 2011). The significance is that a signal must overcome a higher noise level in Wide-Fine vs. Fine to detect a target.

This trade-off between resolution (detection capability) and coverage area must be carefully considered when developing a concept of operations for routine incorporation of satellite data into IIP reconnaissance. While the use of RSA2 Fine mode may yield improved performance over a relatively small area, it is operationally impractical and cost-prohibitive to employ on a routine basis. Further, the likelihood of conflict with other users increases since most other applications can reliably use a much wider swath such as RSA2 ScanSAR mode with a 300 km swath and lower resolution e.g., sea ice detection (CIS, personal communication). RSA2 Wide-Fine (or comparable modes for other satellite systems) will provide the most realistic option for routine satellite operations in the future.

During the 2011 and 2012 seasons, IIP gained considerable experience in the use of satellite detections for operations. In 2013, IIP teamed with the USCG Research and Development Center (RDC) on a two year project to continue validation of commercial satellite systems and to investigate the feasibility of incorporating National Technical Means (NTM) for iceberg reconnaissance. Analysis for 2013 validation efforts will be combined with 2014 and documented in a separate RDC report. The 2013 and 2014 efforts will focus on continued validation and on data acquisition, processing, and analysis.

Follow-on testing during the 2013 Ice Season added to IIP's knowledge base, so that the benefits and challenges in transitioning from aerial to satellite reconnaissance can be more completely articulated. In November 2013, IIP met with key CIS and NIC personnel to begin discussing the elements for a concept of operations (CONOPS) document for the routine use of satellite-derived data for iceberg detection. A central recommendation from this report is that IIP should develop a CONOPS for routine use of satellite derived iceberg detections.

Recommendations

CONOPS development should be accomplished through continued close cooperation with IIP's NAIS partners. The CONOPS will serve as a basis for developing more formal operational requirements to transition from aerial to satellite reconnaissance. Lessons learned during the experiments documented in this report and through discussion with CIS and NIC partners highlight four broad categories that should be considered for CONOPS development:

Sensors & platforms

- Continue verification of existing commercial satellite systems with future ground truth collection experiments
- Determine viability of "no-cost" government NTM systems (examine performance, availability and security issues) through RDC project
- Explore opportunities to share commercial and NTM data with North American Ice Service (NAIS) partners

Data Acquisition

- Determine availability of existing U.S. government contracts with the National Geo-spatial-Intelligence Agency (NGA) and/or NIC for commercially produced satellite imagery
- Identify funding source and initiate budget request to procure commercial imagery to fill any gaps with "no-cost" government procured imagery
- Streamline process to order both commercial and government imagery
- Ensure a robust IT infrastructure exists at a suitable location to handle huge data files (or accept "black-box" MANICE product from 3rd party)

Data Analysis

- Assess existing automated iceberg detection algorithms – both commercial and/or government (U.S. or Canadian)
- Apply the proper balance between automated iceberg detection algorithm(s) and human analysis
- Determine the need to hire and train new image analysts
- Ensure output is delivered as an UNCLASSIFIED MANICE formatted product

Deployment Strategy

- Employ satellite detection data for early season iceberg additions vice mid-season deletions in critical areas in transatlantic shipping lanes

- Accept lower detection probability in favor of greater coverage when the Iceberg Limit is north of 48°N
- Maintain aerial reconnaissance capability – U.S. and Canadian government and/or commercial reconnaissance for critical regions
- Continue to work with NAIS partners to ensure that all iceberg reconnaissance is conducted in a complementary fashion.

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