Report of the International Ice Patrol in the North Atlantic

2018 Season
Bulletin No. 104
CG-188-73

INTERNATIONAL
ICE PATROL

Bulletin No. 104
Report of the International Ice Patrol in the North Atlantic
Season of 2018
CG-188-73

Forwarded herewith is Bulletin No. 104 of the International Ice Patrol (IIP) describing the Patrol's services and ice conditions during the 2018 season. With 208 icebergs drifting into the transatlantic shipping lanes, the 2018 Ice season was designated as a "Light" Ice Season, the first since 2013. While pre-season predictions forecasted 2018 to be a moderate year, the population of icebergs proved to be smaller than predicted. The Ice and Environmental Conditions section presents a discussion of the meteorological and oceanographic conditions that created this light season.

Throughout 2018, IIP continued to embark on a new reconnaissance era. For the second year, IIP used commercial synthetic aperture radar satellite reconnaissance for iceberg detection and identification. Shifting the focus of satellite reconnaissance south to areas with less sea ice presented new challenges of distinguishing icebergs from vessels, marine life, fishing gear, and other targets. To improve methodology for satellite imagery analysis, more than one-third of IIP's flights included areas coincidental with recent satellite passes. These validation flights, made possible by the light and more compact ice season compared to recent years, served to enhance the ability to positively classify targets from satellite imagery. In addition, IIP implemented a dedicated Satellite Day Worker to download, process, and analyze multiple frames per day, resulting in a three-fold increase in frames processed and greater analyst proficiency.

In reviewing previous Annual Reports, it is interesting to note the 1968 season opened on 14 February, closed on 21 July, and saw 219 icebergs in the shipping lanes. Fifty years later the season opened on 6 February, closed on 5 July, and saw 208 icebergs in the shipping lanes. While the statistics are similar, IIP reconnaissance operations have certainly changed. In the appendices, we present a new definition of Season Severity to account for these changes in reconnaissance.

To honor events inextricably linked with IIP history, three memorial services and wreath dedication ceremonies were held. To commemorate the 106th anniversary of the sinking of RMS Titanic, IIP held ceremonies in New London, CT and Halifax, Nova Scotia. The final ceremony commemorated the sacrifices of those that were a part of the Greenland Patrol during World War II.

This report was prepared by all members of the IIP team. On behalf of the dedicated men and women of IIP, I hope that you enjoy reading this report on the 2018 season.

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

International Ice Patrol
2018 Annual Report
Table of Contents

Previous IIP Annual Reports may be obtained from the following sources:

- IIP website: http://www.navcen.uscg.gov/?pageName=IIPAnnualReports
- Printed and bound Annual Reports (1963 – 2015) can be ordered from the National Technical Information Service (NTIS) website at http://www.ntis.gov.

Cover art: Image of an iceberg as seen from aerial reconnaissance using a high definition camera (top) and satellite reconnaissance in a coincident Sentinel-1 image (inset) on 04 May 2018. Bottom row from left to right: US Revenue Cutter on International Ice Patrol, HU-16 Albatross, HC-130J Super Hercules, and ESA's Sentinel-1A Satellite, representing the four eras of reconnaissance in International Ice Patrol operations.

1. Introduction

This is the 104th annual report of the International Ice Patrol (IIP) describing the 2018 Ice Season. It contains information on IIP operations and environmental and iceberg conditions in the North Atlantic from October 2017 to September 2018, focusing on the Ice Season (February to August 2018). To conduct aerial reconnaissance, IIP deployed 10 Ice Reconnaissance Detachments (IRD) to detect icebergs in the North Atlantic and Labrador Sea. The IRD's used HC-130J aircraft from U.S. Coast Guard (USCG) Air Station Elizabeth City (ASEC) and primarily operated from St. John's, Newfoundland. In addition to this reconnaissance data, IIP received iceberg reports from commercial aircraft and mariners in the North Atlantic. Further, IIP continued the progression toward incorporating satellite data into standard reconnaissance operations. IIP personnel analyzed iceberg and environmental data using iceberg drift and deterioration models within the iceBerg Analysis and Prediction System (BAPS) at the IIP Operations Center (OPCEN) in New London, Connecticut. In accordance with the North American Ice Service (NAIS) Collaborative Arrangement, IIP used BAPS to produce an iceberg chart and a text bulletin using the model output. These iceberg warning products were then distributed to the maritime community. IIP also responded to individual requests for iceberg information in addition to these routine broadcasts.

IIP was formed after the RMS TITANIC sank on 15 April 1912. Ever since 1913, with the exception of periods of World War, IIP has monitored the iceberg danger in the North Atlantic and broadcast iceberg warnings 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.

For the 2018 Ice Season, IIP was under the operational control of the Director of Marine Transportation (CG-5PW), Mr. Michael D. Emerson. CDR Kristen L. Serumgard was Commander, IIP (CIIP).

For more information about IIP, including historical and current iceberg bulletins and charts, visit our website at www.navcen.uscg.gov/IIP.

2. Ice and Environmental Conditions

Operational Area

IIP is responsible for guarding the southeastern, southern, and southwestern limits of the region of icebergs, in the vicinity of the Grand Banks of Newfoundland. In conjunction with other North American Ice Service (NAIS) partners, the Canadian Ice Service (CIS), the United States National Ice Center (USNIC), and the Danish Meteorological Institute (DMI), IIP examines environmental, meteorological, and climatological data to develop accurate iceberg warning products in the IIP Operational Area (OPAREA) (**Figure 2-1**). The extent and concentration of sea ice from January through March in the OPAREA plays a critical role in the number of icebergs that present a hazard to transatlantic shipping. Further, the confluence of the cold Labrador Current and warm Gulf Stream/North Atlantic Current, make this area especially challenging for both shipping and iceberg reconnaissance due to frequent fog and the presence of small-scale oceanographic features. This section describes the ice and environmental conditions during the 2018 Ice Year.

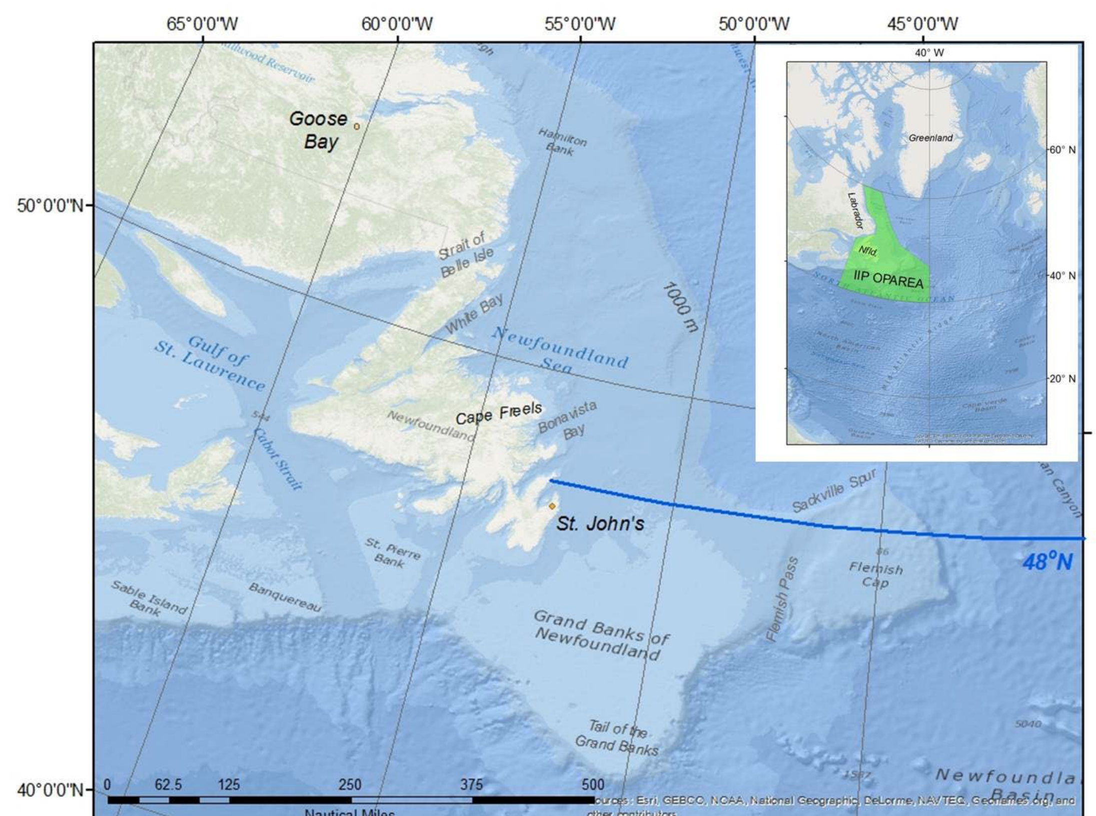


Figure 2-1. International Ice Patrol Operational Area (OPAREA) in green. The latitude of 48°N is typically considered the northern boundary of the transatlantic shipping lanes. IIP measures season severity based on this line.

Ice Year Summary
Season Severity

For the first time since 2013, IIP classified iceberg conditions during the 2018 Ice Year as “Light” based on the number of icebergs crossing south of 48°N (IIP, 1994). By definition, the Ice Year spans the time period between 01 October of the previous year and 30 September of the current year. During the 2018 Ice Year, 208 icebergs (not including the smallest iceberg sizes e.g., bergy bits or growlers) crossed south of 48°N. The average number of icebergs south of 48°N from 1900-2017 is 492. **Figure 2-2** shows the historical variability for this measurement from 1900 to 2018 (blue columns) along with the five-year running average (red line). Variations arise due to actual changes in iceberg conditions and modifications to sighting methods.

Other season severity indicators include Season Length and Iceberg Distribution. Season length is defined as the number of days icebergs were present south of 48°N. In 2018, icebergs were present south of 48°N for a total of 146 days, the lowest number since 2013.

Iceberg distribution is related to the area encompassed by the Iceberg Limit south of 48°N. As with the previous two metrics, the Iceberg Limit area (and therefore iceberg distribution) was the lowest since 2013 and consistent with a “Light” Ice Year.

Figure 2-3 compares the maximum extent of the southern and eastern Iceberg Limit for 2018 with 2017. The Iceberg Limit reached its southernmost extent on 15 June at 42°N (**Figure 2-3**, left panel). Note: 2017 was an anomalous year with respect to the timing of the

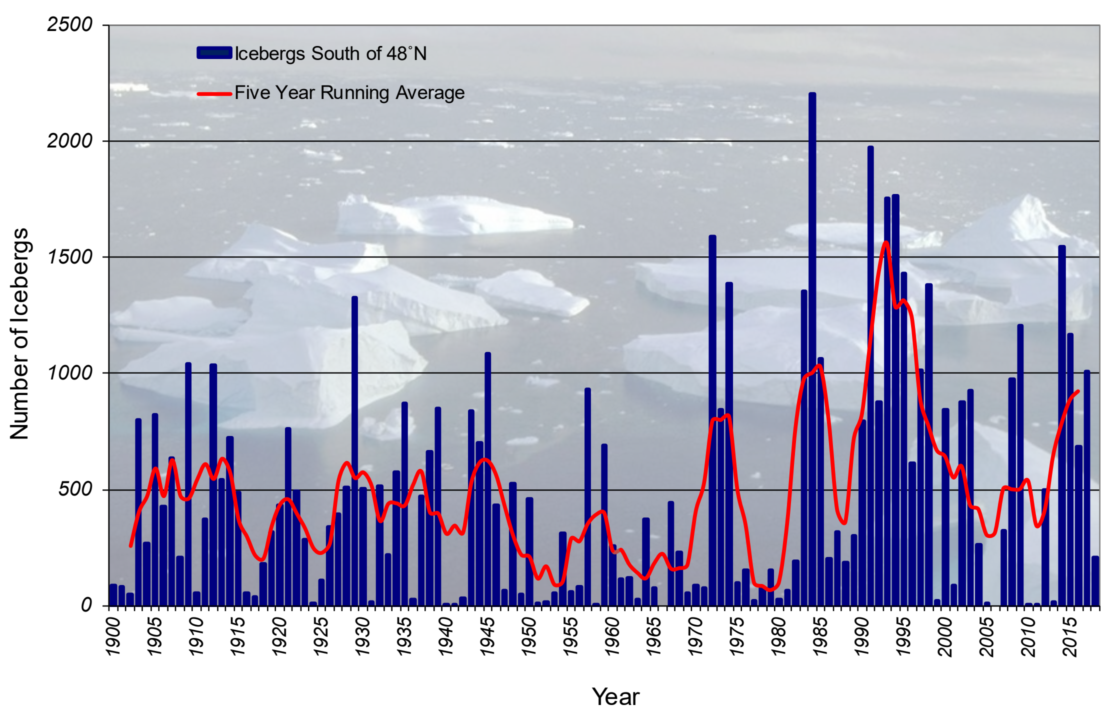


Figure 2-2. Icebergs crossing 48°N and five-year running average (1900-2018).

maximum because the southernmost extent of the Iceberg Limit normally occurs in late May or early June. The 2018 Iceberg Limit reached its easternmost extent of 43°30'W longitude on 03 May (**Figure 2-3**, right panel) and its westernmost extent of 62°31'W on 15 June (not shown). In contrast to the previous five years, iceberg distribution south of 48°N in 2018 was closely confined to the Grand Banks and Flemish Cap, covering a significantly smaller area than the previous four "Extreme" years. In addition to reducing the impact on transatlantic shipping routes, the 2018 iceberg distribution had important consequences for both aerial and satellite reconnaissance that are described more fully in Section 4 of this report.

The introduction of surface search radar on aerial reconnaissance platforms, coupled with increased use of numerical drift and deterioration models has motivated IIP to review season severity metrics. The prevalence of "Extreme" Ice Years using iceberg season severity definitions from 1994 is striking (IIP, 1994). Indeed 21 of the past 35 years were defined as "Extreme". Appendix B examines a new way to interpret season severity metrics accounting for changes in reconnaissance operations and methodology over more than a century of IIP operations. This Appendix also proposes new definitions to describe iceberg season severity.

Pre-season Predictions

At IIP's Annual Partner Meeting on 14 December 2017, CIS provided a seasonal outlook for expected sea ice and iceberg conditions for 2018. With forecasted La Niña conditions and a predicted positive North Atlantic Oscillation Index (NAOI), CIS expected near normal sea ice extent for the Canadian East Coast. Based on their sea ice forecast, surface air and sea temperatures, along with the location of the known iceberg population, CIS projected a near normal iceberg population with the majority of

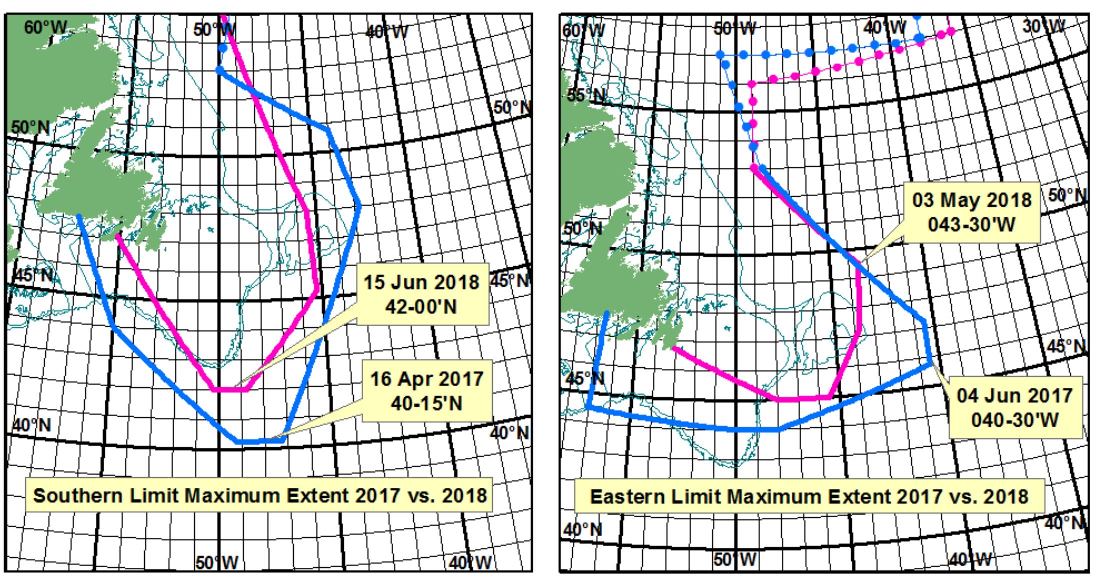


Figure 2-3. Southern and eastern maximum Iceberg Limit extent for 2018 (magenta) and 2017 (blue).

the icebergs arriving into the main shipping lanes near 48°N in mid-March (CIS, 2017a,b).

Ice Year Environmental Conditions Overview

The CIS prediction for iceberg timing proved accurate, but the population was smaller than expected. This smaller number is attributed to a rapid decline in sea ice from late February through early March; the presence of sea ice during these months is critical to the survival and ultimate location of the iceberg population.

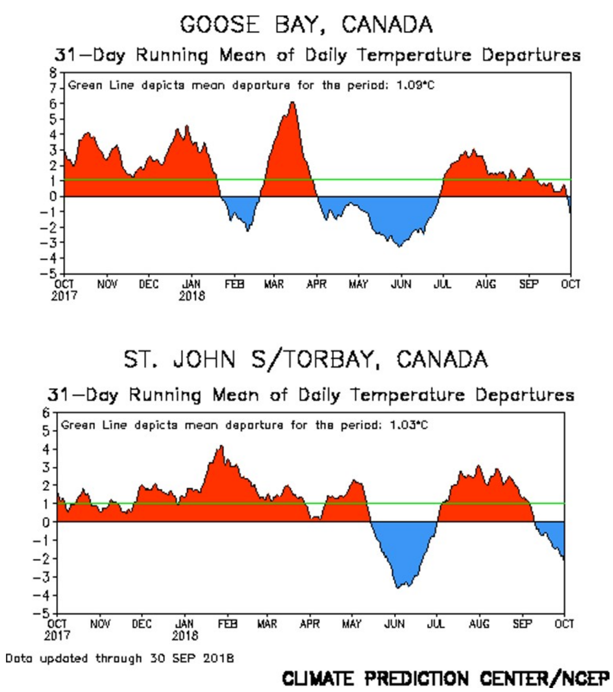


Figure 2-4. 31-day running mean of daily temperature departures for Goose Bay (top) and St. John's, Newfoundland (bottom). (NOAA/NWS, 2018a)

Air temperature anomalies significantly influenced sea-ice growth and retreat across the OPAREA. **Figure 2-4** shows the daily air temperature departures from mean throughout the Ice Year at two key locations along the Canadian East Coast: Goose Bay, Labrador (top panel) and St. John's, Newfoundland (bottom panel) (NOAA/NWS, 2018a). Above normal air temperatures from October throughout January (**Figure 2-4**) resulted in below normal sea-ice growth throughout IIP's OPAREA during the first quarter of the Ice Year. A brief cooling period from mid-January to mid-February in Goose Bay supported near normal sea ice growth during that time. Significantly higher than normal air temperatures in both locations returned from mid-February throughout the entire month of March. These temperatures, coupled with a series of powerful low pressure systems, drove sea ice growth below the median level beginning in late February (**Figure 2-5**). The storms caused rapid destruction of sea ice that exposed icebergs to the open sea, accelerating their destruction and ultimately limiting the number of icebergs entering the offshore branch of the Labrador Current. While cold temperatures returned in Goose Bay and St. John's in April through June, enabling the remaining sea ice to persist, the sea ice extent never recovered from the late winter storms and remained below median throughout the rest of the year.

As in prior years, IIP observed a correlation between the NAOI and the number of icebergs crossing south of 48°N (e.g., IIP, 2016). The NAOI represents the dominant pattern of winter-time atmospheric variability in the North Atlantic, fluctuating between positive and negative phases. Generally, a positive phase of the NAOI is associated with offshore winds that supply cold air from Newfoundland and Labrador, promoting seaward sea ice growth. Onshore winds, associated with a negative phase of the NAOI, inhibit seaward sea ice growth, leaving icebergs exposed to open waters and causing grounding events which limit iceberg movement toward the offshore branch of the Labrador Current.

On 26 February, the daily 500mb-based NAOI reversed sharply from positive to negative and remained near zero until mid-April when it reversed again, remaining positive until early June. The timing of the initial negative reversal resulted from the storm systems that tracked through the OPAREA bringing persistent onshore winds to the region.

To illustrate the impact of the reversal of NAOI (and predominant wind direction), **Figure 2-5** shows the CIS sea ice coverage for the Southern Labrador Sea and East Newfoundland for 2018. The inset chart shows the daily 500mb-based NAOI for 06 January through 04 May. The red box highlights the period from 26 February through 02 April for both sea ice coverage and NAOI. The decline in sea ice coverage appears closely correlated with the NAOI reversal and underscores the importance of this measurement for explaining sea ice growth.

Mean station-based NAOIs are also calculated using the difference in normalized sea-level atmospheric pressure between Lisbon, Portugal and Stykkisholmu/Reykjavik, Iceland (Hurrell, 2018). The winter-time, station-based NAOI for December through March each year provides a good indicator for sea ice growth conditions in the IIP OPAREA. In 2018, the NAOI was slightly positive at +0.3. However, the timing of the March

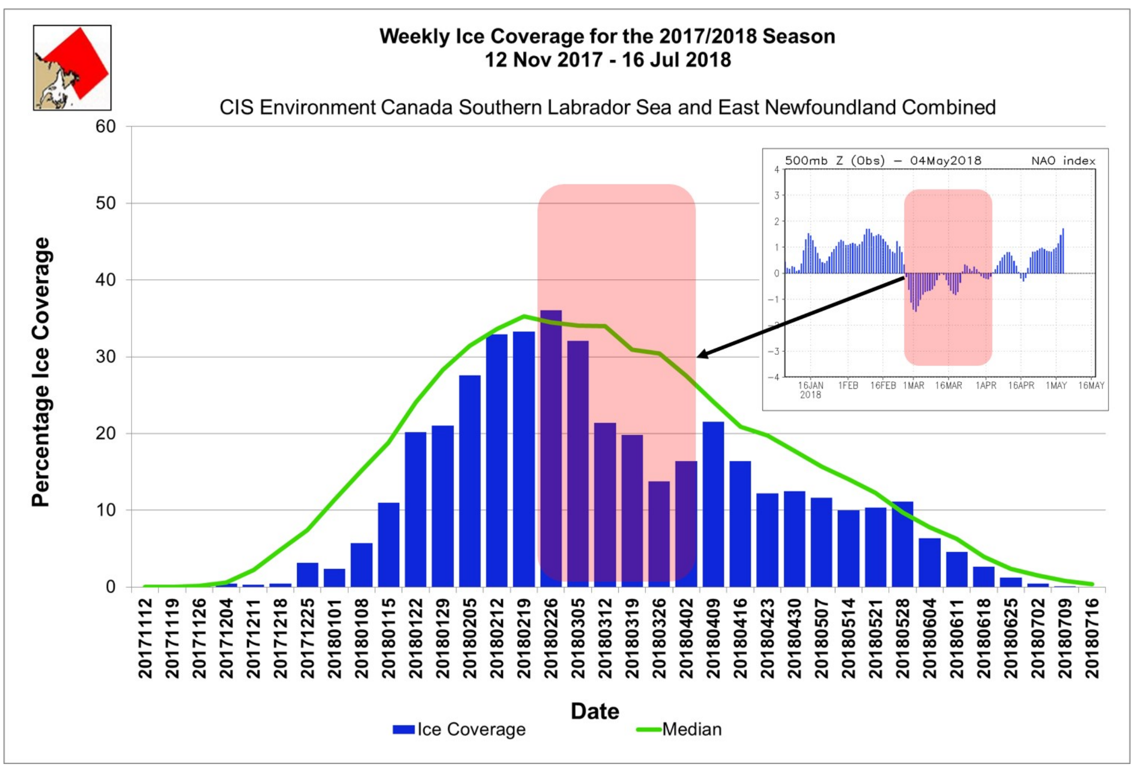


Figure 2-5. Weekly ice coverage for East Newfoundland and Southern Labrador Sea waters for 2017-2018. The percent coverage is relative to the area shaded in red in the upper left map of this figure (CIS, 2018a; NOAA, 2018b).

storm events and NAOI reversal proved crucial to sea ice development and iceberg survival. This situation is described in greater detail in the quarterly summary for January through March.

Quarterly Environmental Summaries October – December 2017

The Ice Year started with air temperatures higher than the climatological median due to predominant southwesterly low level atmospheric flow. This caused a delay in the beginning of the formation of the sea ice in the region. The first sea ice began forming in the western parts of Lake Melville (Labrador) approximately two weeks later than normal. Beginning in mid-December, sea ice began forming along the Labrador coast but did not extend as far offshore as observed in previous years. (CIS, 2018b)

At the beginning of the Ice Year, CIS had responsibility for monitoring iceberg danger and disseminating daily Iceberg Limit warning products. At this time, CIS was tracking 14 icebergs in the iceBerg Analysis and Prediction System (BAPS). A single iceberg near the Northern Peninsula of Newfoundland set the southern Iceberg Limit near 51ºN. Further north at 55ºN, the Iceberg Limit extended eastward to 52ºW. The majority of the icebergs tracked by CIS were along the northern part of the Labrador coast. The Iceberg Limit retracted northward until it reached 54ºN in the middle of October. The iceberg population declined, but the Limit began gradually extending further south and east throughout November and December. By the end of December, only nine icebergs remained on the daily warning product. An isolated iceberg set the southern Limit at just below 51ºN. Three icebergs established the eastern Limit at 47º30'W, approximately 300NM east of the Strait of Belle Isle. No icebergs were sighted or drifted south of 48ºN during the first quarter of the Ice Year.

January - March 2018

Prolonged above normal air temperatures during the entire month of January resulted in below normal sea ice development along the Labrador coast and into the eastern Gulf of St. Lawrence. The sea ice condition can be seen in the CIS departure from normal sea ice concentration graphic for 08 January (**Figure 2-6)**. On this date, sea ice extended offshore to approximately 50NM along the Labrador coast. Normal extent is closer to 100NM during early January (CIS, 2018b).

The slow start in the growth of sea ice along the Labrador coast exposed icebergs drifting southward along the 1000m depth contour to open sea waves. In early January, a CIS-funded aerial reconnaissance flight into the Strait of Belle Isle, along the southern Labrador coast, and offshore to the 1000m depth contour detected no icebergs. With this information, CIS brought the Iceberg Limit north to 54ºN. CIS transferred responsibility for creating and distributing NAIS Iceberg Limit products to IIP on 24 January. NOTE: Semi-monthly NAIS Iceberg Limit products for January to September are included in Section 7 of this report.

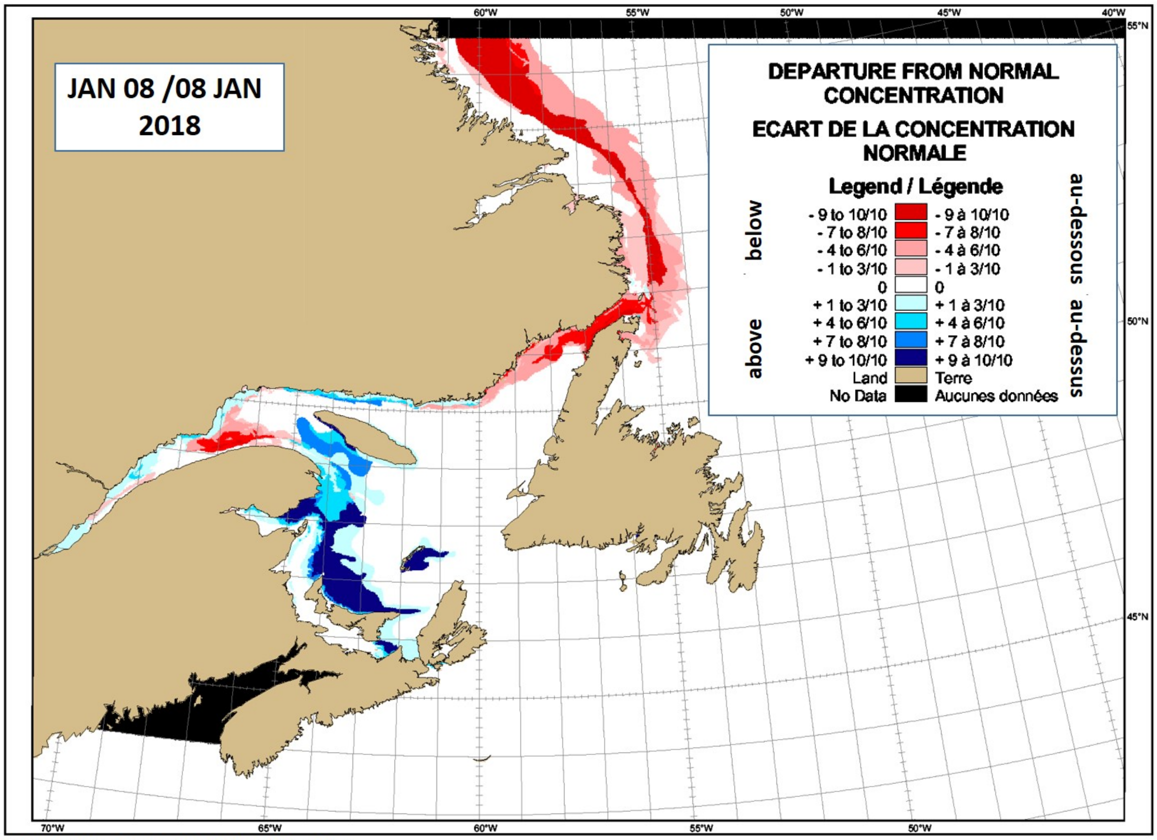


Figure 2-6. CIS Departure from Normal Concentration for 08 Jan 2018 (CIS, 2018c).

By the end of January, sea ice development returned to near normal concentration and extent due to a brief cooling in Goose Bay. Because of the known challenges of locating icebergs in sea ice, the IIP Commander (CIIP) directed extension of the Iceberg Limit to encompass all sea ice resulting in expansion of the Iceberg Limit southward.

IIP sent its first Ice Reconnaissance Detachment (IRD) to Newfoundland on 06 February, focusing its patrols along the 1000m depth contour. On four separate patrols, IIP located 105 icebergs all north of 51ºN and mostly confined within sea ice. Since the iceberg population did not threaten transatlantic shipping and PAL Aerospace began more frequent flights, CIIP elected to cancel the second IRD scheduled in February.

February average sea level pressure over the Labrador Sea resulted in persistent offshore winds, supporting continued sea ice growth (**Figure 2-7**, left panel). Sea ice development continued to increase and by 26 February, reached its highest concentration for the year, slightly above median concentration for the southern Labrador Sea and Newfoundland waters. This situation is consistent with a positive NAOI throughout the region during February. By the end of the month, sea ice coverage exceeded the 30-year climatological average for the first time during the season.

This condition did not last long, as sea ice significantly and rapidly retracted due to four consecutive low pressure systems that passed through the region in March. **Figure 2-7,** (right panel) shows the sea level pressure for March with the approximate resulting wind vector (annotated by IIP) for the month. Sea ice also extended well into the Strait of Belle Isle due to the strong northeasterly winds caused by the passing storms. Sea ice extent typically continues southward through the middle of March. However, this season sea ice reached its southernmost extent (just below 47ºN) on 26 February.

The change in sea ice conditions over the two-week period from 26 February through 12 March was remarkable. The CIS Weekly Regional Ice Analyses for the Canadian East Coast for 26 Feb and 12 March show this dramatic ice destruction quite well (**Figure 2-8**). The impact of this diminished sea ice was clearly seen through the spring and into the summer in the reduced iceberg population encountered by IIP.

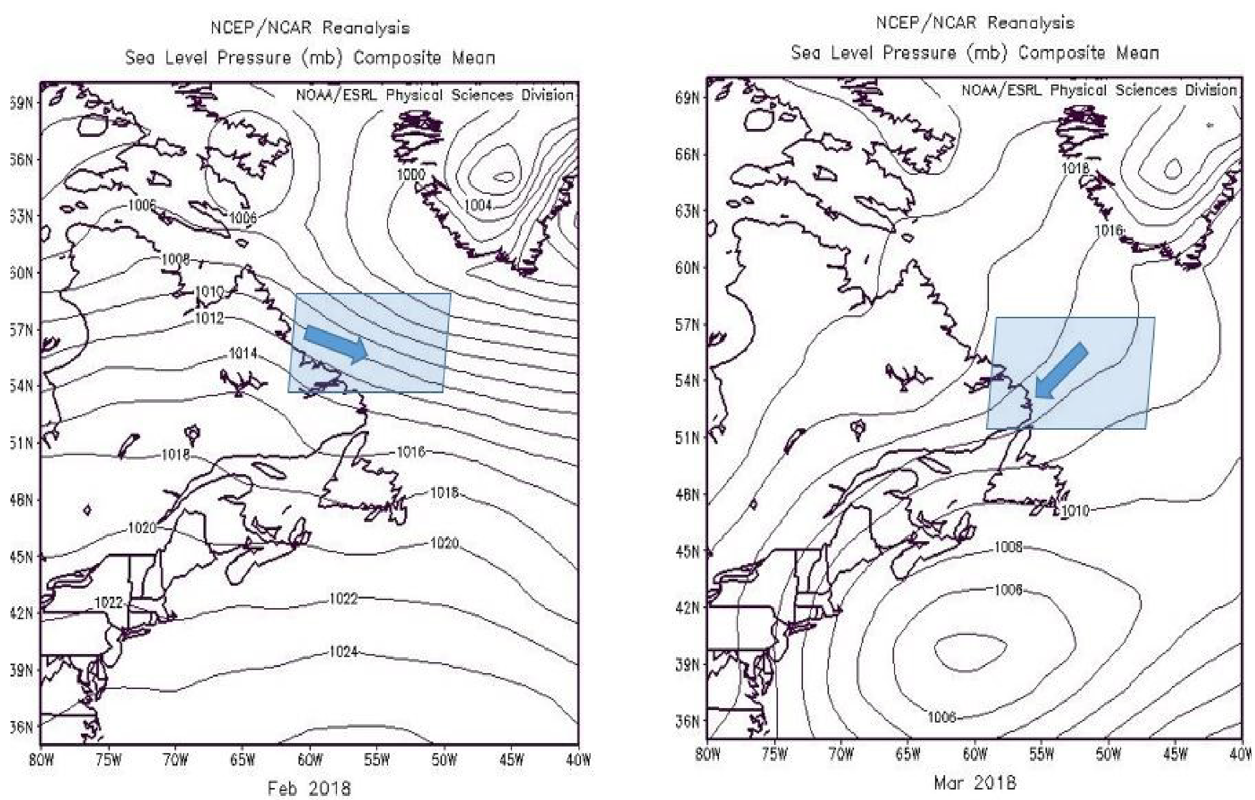


Figure 2-7. Composite Mean Sea Level Pressure for February (left panel) and March (right panel) from NOAA's Earth Systems Research Laboratory (ESRL). IIP annotated this figure by adding approximate wind directions, indicated by an arrow within the blue shaded regions. (NOAA/ESRL, 2018)

By the end of the quarter, the Iceberg Limit extended southward to 45º30’N and eastward to 45ºW. The Iceberg Limit remained well within the median for the end of March. During this quarter, 58 icebergs were sighted or drifted south of 48ºN.

April – June 2018

A low pressure system that tracked towards southern Greenland during the second week of April brought strong offshore winds along the Labrador and Newfoundland coasts with a corresponding increase in NAOI. This resulted in a return to near-normal sea ice concentration for Labrador and Newfoundland in mid-April (**Figure 2-5**). Sea ice initially cleared from the Strait of Belle Isle at the end of April, but was in and out of the strait for the rest of the quarter. Sea ice melted more slowly than the climatological median throughout May and June due to below normal temperatures in both St. John’s and Goose Bay in May and June (**Figure 2-4**).

The Iceberg Limit at the beginning of the quarter extended southward to 45ºN. An IRD flight on 06 April covered the southern and eastern Iceberg Limits. This patrol also searched approximately 60NM south of the Iceberg Limit to positively confirm that no icebergs escaped detection in the cold Labrador Current. Finding no icebergs, this flight led to a significant reduction of the Iceberg Limit.

IIP deployed another IRD in April and continued its reconnaissance flights throughout the remainder of the quarter, sending two per month. The majority of the icebergs detected were concentrated in the area north of 45º N and west of 45º W, along the Labrador and Newfoundland coasts. The Iceberg Limit never extended beyond IIP’s climatological median Limit throughout the quarter. This

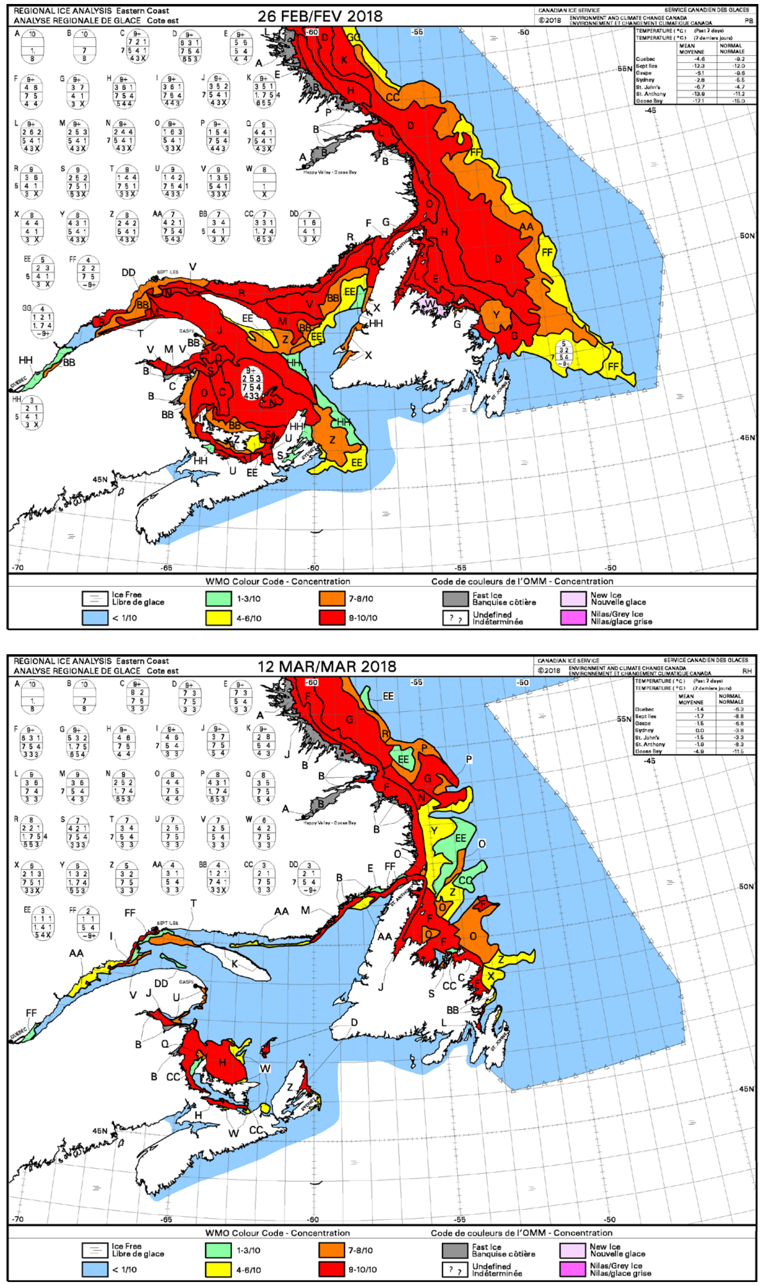


Figure 2-8. CIS Weekly Regional Ice Analyses for the Canadian East Coast for 26 Feb (top) and 12 March (bottom) showing significant reduction in sea ice following the passing of strong winter storms (CIS, 2018d).

compact distribution of the icebergs allowed for multiple southern and eastern Iceberg Limit reconnaissance flights, as well as dedicated satellite validation flights, which had been a challenge in prior years with more expansive limits. IIP conducted a single northern survey flight on 23 April that detected hundreds of icebergs along the Labrador coast up to 59ºN. However, few of these icebergs drifted into the offshore branch of the Labrador Current. This is likely due to the sea ice destruction observed during the previous quarter which left many of these icebergs exposed to open water, forcing them into the inshore branch of the Labrador Current. Many icebergs remained around Newfoundland, particularly near the eastern opening of the Strait of Belle Isle.

Infrared imagery depicting sea surface temperatures continued to show the presence of cold Labrador Current water along the eastern Grand Banks. Since this oceanographic feature serves as a possible transport mechanism for icebergs, IIP continued to extend its searches (five total during this quarter) beyond the southern Iceberg Limit. **Figure 2-9** shows an image from the

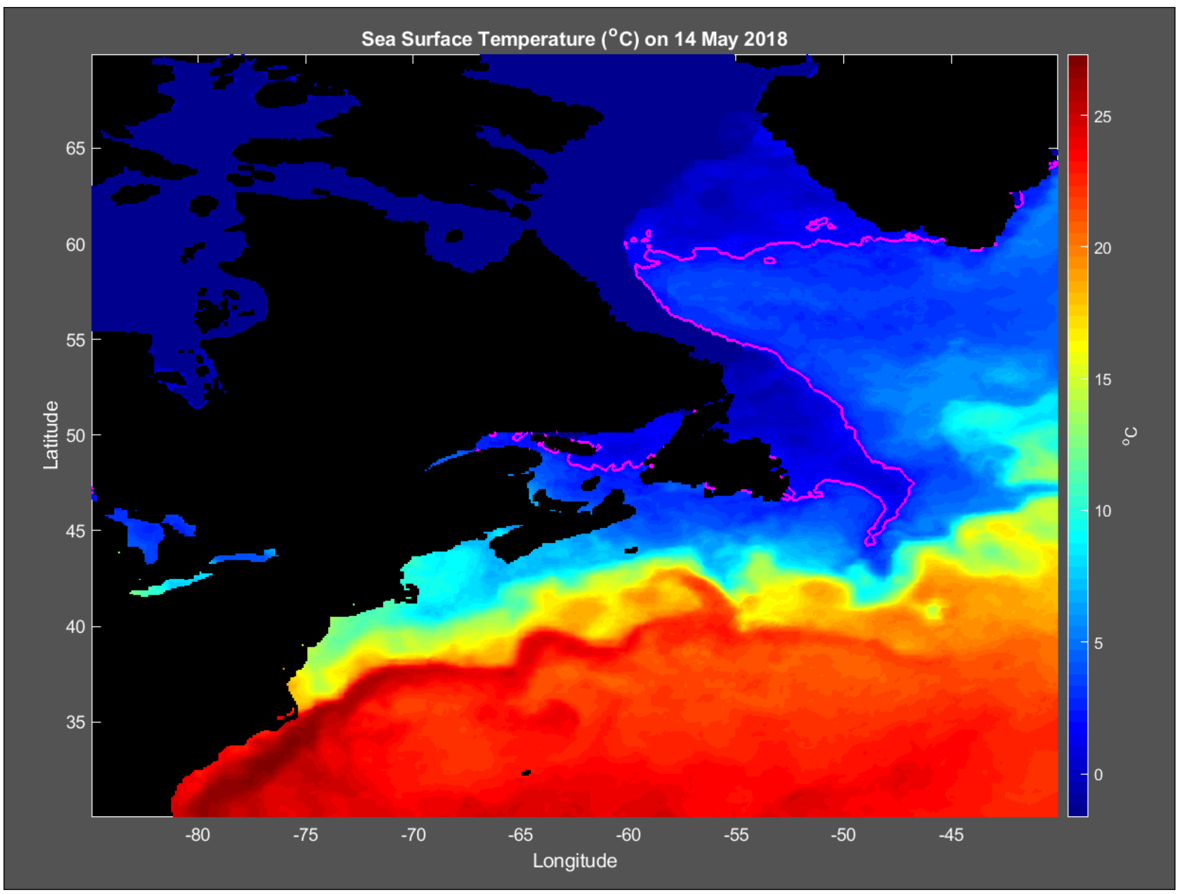


Figure 2-9. Group for High Resolution Sea Surface Temperature (GHRSST) image for 14 May 2018. The magenta contour shows cold water (<2°C) of the Labrador Current as it flows around the Grand Banks through Flemish Pass. Data were obtained from the NASA Earth Observing System Data and Information System Physical Oceanography Distributed Active Archive Center at the Jet Propulsion Laboratory, Pasadena, CA. (RSS, 2017)

Group for High Resolution Sea Surface Temperature (GHRSST) of this feature on 14 May (RSS, 2017). These flights searched as far south as 42ºN to ensure that this critical region of the shipping lanes remained free of iceberg hazards.

On 05 June, IIP sighted the southernmost iceberg for the year at 45º38'N in the vicinity of the Labrador Current. This is the first time since 2013 that no icebergs were sighted south of 45ºN (the southernmost iceberg sighting in 2013 was at 47º09'N). The southernmost extent of the Iceberg Limit (42ºN on 15 June), resulted from the drift of an iceberg sighted by a vessel on 31 May. re-During this quarter 149 additional icebergs were sighted or drifted south of 48ºN for a total of 207 icebergs by the end of June.

July – September 2018

Temperatures throughout the quarter in both St. John's and Goose Bay remained well above average (**Figure 2-4**) which contributed to continued sea ice retraction and melt. July started with the southern sea ice edge at approximately 53ºN, and sea ice was completely absent from the Labrador coast by the beginning of August. By the beginning of July, IIP tracked 417 icebergs in BAPS. Approximately 100 of these were located in the Strait of Belle Isle, and the rest were distributed along the Newfoundland and Labrador coasts, and eastward to 48ºW. Due to a lack of recent reconnaissance along Northern Labrador, only four icebergs were being tracked north of 55ºN. A northern survey flight on 02 July up to 58ºN, detected numerous icebergs that were added to the warning product. By the end of the quarter, sea surface temperatures along the Newfoundland coast were slightly above the climatological median, contributing to the accelerated melt of the icebergs.

IIP conducted its final flight for the year on 05 July. Commercial aerial reconnaissance continued through CIS-funded ice reconnaissance flights by PAL Aerospace. Benefitting from the NAIS partnership with CIS, IIP provided input for target areas and suggested flight plans to meet IIP standards for probability of detection. The Iceberg Limit started at 46ºN and gradually receded northward with warmer air and sea temperatures. Notably, on 09 August, a ship reported an iceberg outside of the published Iceberg Limit, which caused the limit to extend south by two degrees, from 49º to 47º N. This situation is described in greater detail in the Operations Center Summary section.

IIP transferred responsibility for creating the iceberg limit products to CIS on 28 August. On 30 September, CIS was tracking 54 icebergs in BAPS, with isolated icebergs between 50ºN and 55ºN, and many north of 55ºN along the Labrador coast. By the end of the quarter and the 2018 Ice Year, the Iceberg Limit extended from Cape Freels, Newfoundland approximately 300NM offshore to 50ºN, 46ºW. With one additional iceberg drifting south of 48ºN in August, and none in July or September, the total number of icebergs sighted or drifting south of 48ºN was 208.

In summary, **Figure 2-10** graphically shows the number of icebergs estimated to have drifted south of 48°N by

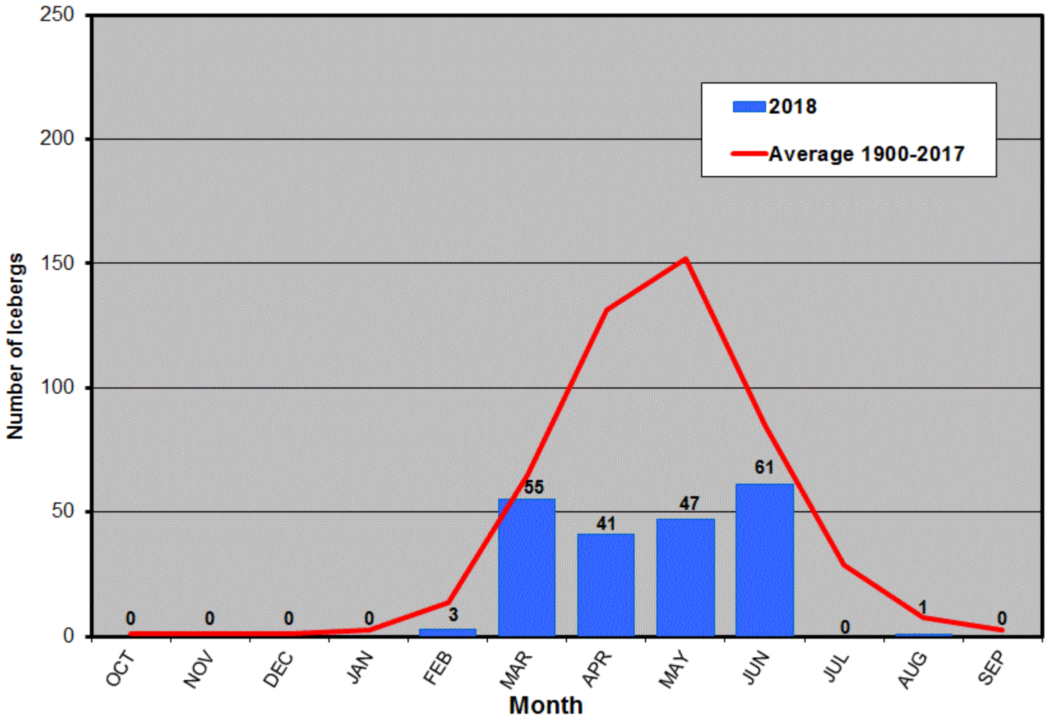


Figure 2-10. Icebergs south of 48°N by month for 2018 (208 total).

month for the 2018 Ice Year. The monthly average was calculated using 118 years (1900 through 2017) of IIP records and is plotted as a solid red line for comparison. This year, the number of icebergs that crossed 48°N remained relatively constant from March through June.

The average peak normally occurs in May. The pattern this year is related to the dramatic sea ice destruction in March that reduced the population of icebergs in the offshore branch of the Labrador Current for the successive months. The relative increase of icebergs in June can be attributed to below normal air temperatures in both Labrador and Newfoundland, and a positive NAOI from mid-May to mid-June, as seen earlier in **Figures 2-4** and **2-5.** A summary of extreme iceberg positions, both sighted and drifted by modeling, along with the sighting source, is presented in **Table 2-1.**

Oceanographic Operations

Due to budgetary uncertainty and administrative delays, IIP did not procure Surface Velocity Program (SVP) drifting buoys for deployment in 2018. Fortunately, the "Light" Ice Year minimized the impact of the lack of buoy deployments. Additionally, IIP extensively used iceberg drift model comparisons to modify flight plans to cover model uncertainties. In addition, Advanced Very High Resolution Radiometer (AVHRR) sea surface temperature imagery and US Navy Oceanographic Office Ocean Features Analysis products, guided searches of cold water features south of Flemish Pass. IIP has an inventory of buoys for deployment in 2019, and intends to continue to collect this data for incorporation into BAPS.

2018 Extreme Icebergs	Sighted				Drifted			
	Source	Date	Latitude	Longitude	Source	Date	Latitude	Longitude
Southern	IIP HC-130J	05-Jun-18	45-38.1N	47-03.1W	Vessel	15-Jun-18	42-52.4N	49-36.4W
Eastern	IIP HC-130J	23-May-18	47-35.0N	46-39.0W	IIP HC-130J	02-May-18	48-59.0N	45-08.7W
Western	Satellite (Sentinel-1a)	31-May-18	50-33.2N	59-15.5W	Satellite (Sentinel-1a)	01-Jun-18	50-33.2N	59-16.0W

Table 2-1. 2018 Extreme sighted and drifted (modeled) iceberg positions by original sighting source and date. Note: Western icebergs listed were those used to set the Iceberg Limit in the Gulf of St. Lawrence.

3. Operations Center Summary

The IIP Operations Center (OPCEN) is the hub of IIP's information processing and dissemination. IIP OPCEN watch standers receive iceberg reports from a variety of sources, process the information, and create daily iceberg warning products that are distributed to mariners. Iceberg reports are received from IRD flights, Commercial Reconnaissance flights, Synthetic Aperture Radar (SAR) satellite imagery, and vessel sighting reports. After these reports are ingested, icebergs are added to IIP's iceberg database and processed through the drift and deterioration models on BAPS. Iceberg Limits are then defined to contain the modeled iceberg positions and daily NAIS warning products are created and distributed to mariners via numerous means.

Products and Broadcasts

IIP and CIS partner to create and distribute two versions of the daily Iceberg Limit in a text and graphic format. IIP's defined Ice Season encompasses the time IIP is actively deploying to St. John's, NL and IIP is producing products; typically when icebergs threaten the transatlantic shipping lanes. This year, the Ice Season ran from 24 January to 28 August (while the deployment period ran 06 February to 05 July). During the remainder of the 2018 Ice Year, CIS created products as the iceberg population is typically found farther north along the Canadian coast.

The text version, NAIS-10 bulletin, lists the latitude and longitude points of the Iceberg Limit and sea ice limits. The graphical version, NAIS-65 graphic, shows the forecasted Iceberg Limit and estimated concentrations of icebergs in 1˚x 1˚ latitude x longitude gridded bins. Examples of the NAIS-65 iceberg charts can be found in Section 7 of this report. Both products include information regarding the most recent reconnaissance, including the date, type, and coverage area. These two products are released between 1830Z and 2130Z and are valid for 0000Z the following day. During the 2018 Ice Season, all broadcast schedules were met with 100% of iceberg warning products released on time.

IIP publicly distributes the NAIS iceberg warning products by a variety of methods. The NAIS-10 iceberg bulletin is broadcast over SafetyNET, Navigational Telex (NAVTEX), Simplex Teletype Over Radio (SITOR), and posted on the internet. The NAIS-65 iceberg chart is broadcast over radio facsimile (Radiofax) and posted online. Both products are posted on IIP's website (https://www.navcen.uscg.gov/?pageName=iipProducts). Additionally, the NAIS-65 iceberg chart is available on the National Weather Service (NWS) Marine Forecast (http://tgftp.nws.noaa.gov/fax/marsh.shtml) and NOAA Ocean Prediction Center (OPC) (www.opc.ncep.noaa.gov/Atl_tab.shtml) websites. Keyhole Markup Language (KML) files and ArcGIS shapefiles of the Iceberg Limit and sea ice limit are available on the IIP website for use with any mapping software. The daily Iceberg Limit is also a displayable layer within NOAA's Arctic Environmental Response Management Application (ERMA) mapping tool, (https://response.restoration.noaa.gov/maps-and-spatial-data/environmental-response-management-application-erma/arctic-erma.html).

Product Changes for 2018

Each year IIP, in conjunction with CIS and the Danish Meteorological Institute (DMI), reviews products, procedures, and processes to improve content, delivery, and value to the mariner. For 2018, no major changes were implemented but improvements made in 2017 continued to be refined. These included the incorporation of the estimated sea ice limit around Greenland into the daily iceberg products. In addition to the climatology based Iceberg Limit, IIP and CIS are currently working with DMI to prototype the inclusion of DMI satellite-derived iceberg data around Greenland into BAPS and the NAIS product.

Iceberg Reports

The International Ice Patrol OPCEN received reports of icebergs from a variety of sources including IRD flights, PAL Aerospace flights, ship reports, and satellite reconnaissance (**Figure 3-1**). Collecting and processing iceberg reports from this wide array of sources augments IIP's reconnaissance mission. An important factor aiding IIP's successful safety record are the reports received from the maritime community transiting through the OPAREA. A list of the individual ships that made voluntary iceberg reports during the 2018 Ice Season is compiled in **Appendix A**.

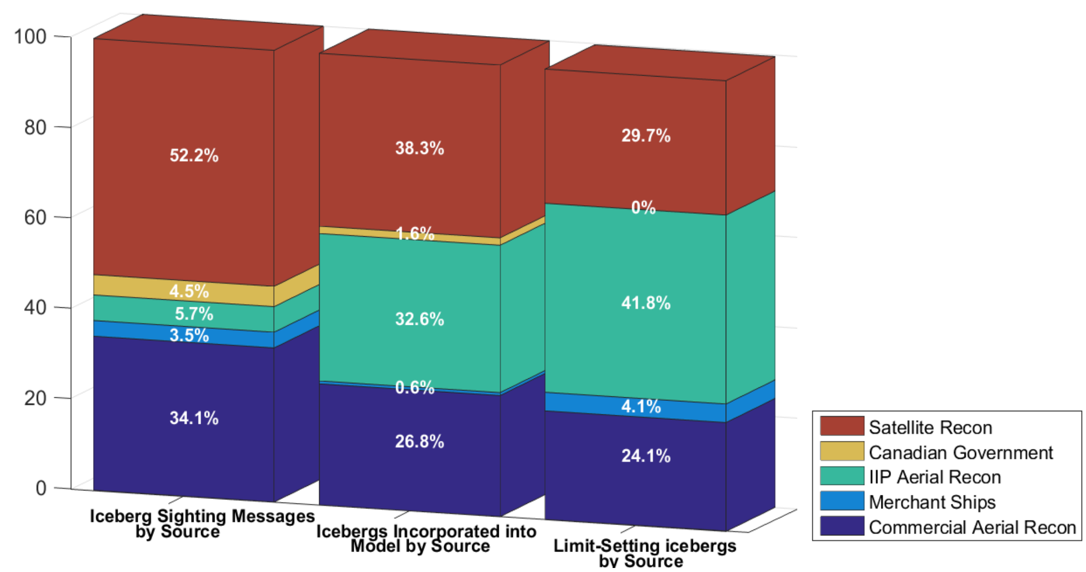


Figure 3-1. 2018 Standard Iceberg Message (SIM) information. The first bar (left) shows the percentage of SIMs received from each source. The second bar (center) shows the percent contribution from each source to the total number of iceberg observations that were included into the model. The third bar (right) shows the percentage of limit-setting icebergs reported by each SIM source. Here, the Satellite Recon category includes commercial and IIP analyses and the Canadian Government data does not include government funded commercial reconnaissance.

Overall, during the in-season period from 24 January to 28 August, IIP received, analyzed, and processed 690 standard iceberg messages (SIMs), 502 of which included iceberg sightings, approximately a 20% decrease in SIMs with icebergs from the 2017 Ice Season. **Figure 3-2** provides a ten-year summary showing the number of SIMs received compared with the number of icebergs that drifted south of 48˚N for each year. The first columns of **Figure 3-1** and **Table 3-1** show the distribution of these iceberg messages by reporting source.

During the 2018 Ice Season, IIP continued to incorporate the analysis of satellite imagery within IIP's OPAREA to the watch routine, refining the procedures and methodology through lessons learned in 2017. Almost-daily satellite passes over the IIP OPAREA were processed and analyzed for targets that could be icebergs. IIP watchstanders then added high confidence targets that did not correlate with ship traffic into the iceberg model. Further details regarding the incorporation of satellite reconnaissance into IIP's operations are addressed in **Section 4** and **Appendix C**.

A total of 8,001 icebergs, growlers, and radar targets were reported to IIP during the 2018 Ice Season. Of these, 6,248 (78%) were incorporated into the model. IIP watchstanders reviewed each report for accuracy and validity before the data was entered into BAPS. This included reviewing environmental conditions, other recent reconnaissance, and the detection method of each report.

Table 3-1 and **Figure 3-1** show that the majority of icebergs, growlers, and radar targets incorporated into the model were from aerial reconnaissance

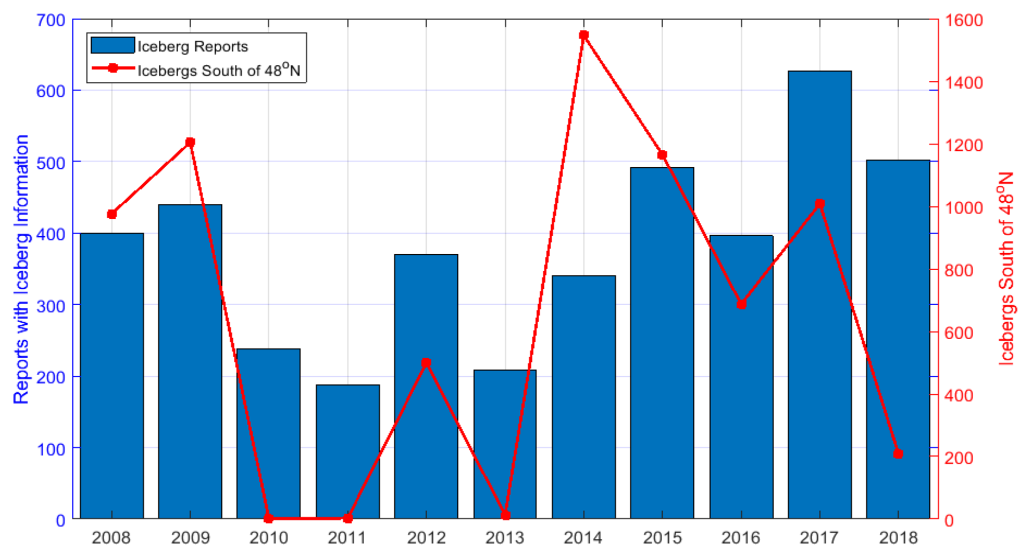


Figure 3-2. Ten-year record of the number of SIMs received that contained iceberg information (blue bars) and the number of icebergs observed south of 48˚N (red line). Note that 2018 had the second highest number of SIMs containing iceberg information despite the fourth lowest number of icebergs passing south of 48˚N.

Source	Total SIMs	Icebergs Incorporated into Model	Average Icebergs Per SIM	Limit Setting Icebergs
Satellite* Reconnaissance	361	2391	7	253
Canadian Government**	31	102	3	0
IIP Aerial Reconnaissance	39	2039	52	356
Merchant Ships	24	40	2	35
Commercial Aerial Reconnaissance	235	1676	7	205
Total	**690**	**6248**	**14**	**849**

Table 3-1. Detailed information of 2018 icebergs received from each SIM source. * Note that the Satellite Reconnaissance row includes both IIP and Commercial satellite reconnaissance. ** The Canadian Government row does not include Government-funded Commercial Aerial Reconnaissance and mostly is made up of Canadian Coast Guard reports.

(Commercial reconnaissance and IRD flights combined for a total of 3,715 added into the model). This season, IIP conducted 39 reconnaissance flights, which accounted for 2,039 icebergs and growlers added or re-sighted into the BAPS model.

On average, 52 icebergs were observed per IRD flight. Commercial reconnaissance accounted for 1,676 icebergs, an average of seven icebergs per flight. It should be noted that IRD flights have a primary mission of iceberg reconnaissance on every sortie while this is not the case for the commercial flights.

The Commercial Aerial Reconnaissance data in **Table 3-1** and **Figure 3-1** is from SIM reports made by PAL Aerospace, which was contracted by multiple sources. **Figure 3-3** shows the percentage of PAL Aerospace flights that were dedicated ice flights (funded by CIS or by the oil and gas industry) and other flights that reported icebergs as a byproduct of various other missions. Two thirds of the total PAL Aerospace flights which reported icebergs were flown for primary missions other than iceberg reconnaissance. 26% of flights that reported icebergs were funded by the oil and gas companies concerned with icebergs in the vicinity of the offshore oil rigs. The smallest portion, 5%, of PAL Aerospace flights that reported icebergs were funded by CIS specifically for iceberg reconnaissance in areas designated by either IIP or CIS. This willingness of PAL Aerospace to identify and share iceberg reconnaissance information regardless of funding source demonstrates a notable and significant commitment to maritime safety across the region.

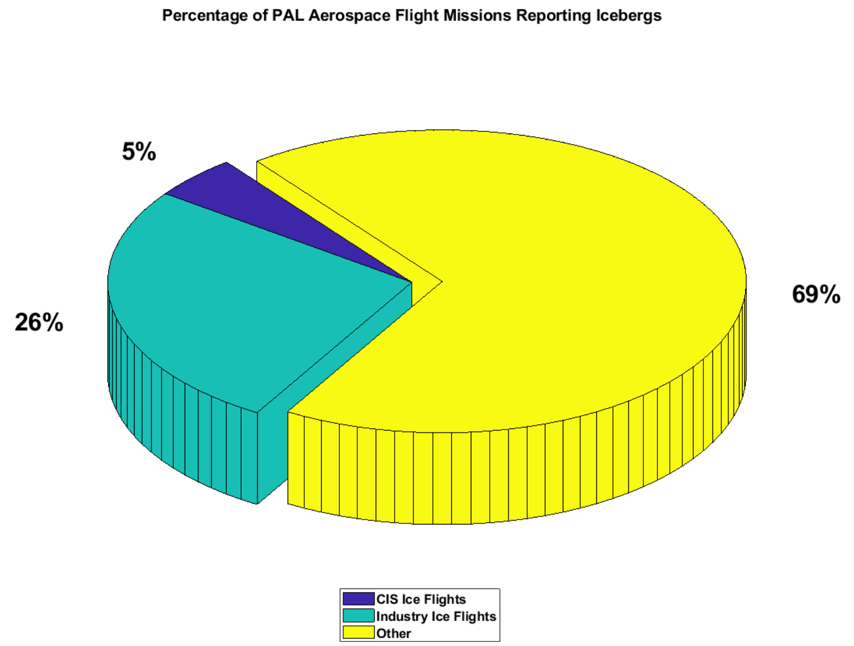


Figure 3-3. The percentage of PAL Aerospace flights by primary mission type that reported icebergs. The "Other" category includes flights that reported icebergs but with a primary mission other than iceberg reconnaissance.

Identifying icebergs is only one part of the process. Once identified, icebergs are added or resighted in the active iceberg database, then they are drifted and deteriorated via numerical models. Icebergs are removed or deleted from the active iceberg database as a result of modeled deterioration, recency of last sighting, or IIP aerial reconnaissance results. This season, 459 of the 6,248 icebergs added to the model were deleted based upon the results of IIP aerial reconnaissance indicating that no icebergs were present in the region identified by the modeled position. Currently, commercial aerial reconnaissance and satellite reconnaissance do not meet necessary probability of detection standards to enable deleting icebergs from the database. In July and August, IIP began working with PAL Aerospace during CIS-funded iceberg reconnaissance flights to quantify environmental conditions, visibility, and radar range, in order to facilitate deleting modeled icebergs from commercial reconnaissance results. In this last portion of the season, nine modeled icebergs or growlers were deleted from dedicated PAL Aerospace iceberg flights, highlighting the capacity for future improvement in coordination of commercial reconnaissance. The remainder of the modeled icebergs were typically deleted due to predicted melting and deterioration.

Also noteworthy this season was the 2,391 icebergs integrated into the model from 361 satellite reconnaissance SIMs. The Satellite Reconnaissance percentage in **Figure 3-1** is comprised of 305 satellite images that were processed and analyzed entirely by IIP staff. The remaining 56 SIMs, consisting of 186 satellite image frames, were processed and analyzed by C-CORE in support of the oil and gas industry. Of the 2,391 satellite-detected icebergs that were incorporated into the model, 1,273 were from IIP satellite SIMs and 1,118 were from C-CORE satellite SIMs.

Of all the icebergs sighted and modeled by IIP, the most important are the ones that define the Iceberg Limit. Typically, between three and seven icebergs set the Iceberg Limit at any time. In the 2018 Ice Season the limit stretched approximately 369NM east of St. John's at its maximum extent of 043˚30'W on 03 May, and approximately 350NM south of St. John's to 42˚00'N on 15 June.

Compared to 2017, PAL Aerospace flights decreased as a reporting source of limit setting icebergs from 40% to 24%, and IIP aerial reconnaissance increased from 29% to 42%. Reconnaissance from satellite imagery accounted for nearly 30% of limit setting icebergs, compared to 22% in 2017 and only 2.1% in 2016.

Although a large number of icebergs incorporated into the model were observed by satellite, at this time, satellite reconnaissance is unable to reliably determine ice-free conditions due to low confidence in the ability to avoid false-positives and false-negatives. A false-positive result is one in which a target is determined to be an iceberg where, in fact, there is none. This can result in the needless expansion of the Iceberg Limit, negatively impacting shipping without a corresponding increase in safety. However, much more insidious occurrences are false-negatives in which it is determined there are no icebergs where, in fact, icebergs exist. This situation is especially dangerous and can result in the Iceberg Limit not encapsulating the iceberg hazard and placing ships in harm's way. Continued development of satellite imagery analysis is aimed at reducing false positive and negative conditions through positively identifying iceberg hazards.

Given these considerations, the primary method for monitoring the Iceberg Limit is aerial reconnaissance. Observing the exact location of limit-setting icebergs, especially those in the vicinity of transatlantic shipping lanes, continues to be a critical part of completing IIP's mission. As shown in the Outside the Limit cases in this section, two-thirds (six of nine) of the targets reported outside of the limit were derived from satellite reconnaissance. For four of these six, aerial reconnaissance quickly proved that no iceberg was there, helping to ensure that the maritime community received the most accurate and practical warning products.

IIP Protocol for Icebergs Reported Outside of the Iceberg Limit

In the event that an iceberg or radar target is reported outside the published NAIS Limit, the OPCEN Duty Watchstander (DWS) takes prompt action to ensure that the maritime community is quickly notified and the NAIS products are updated.

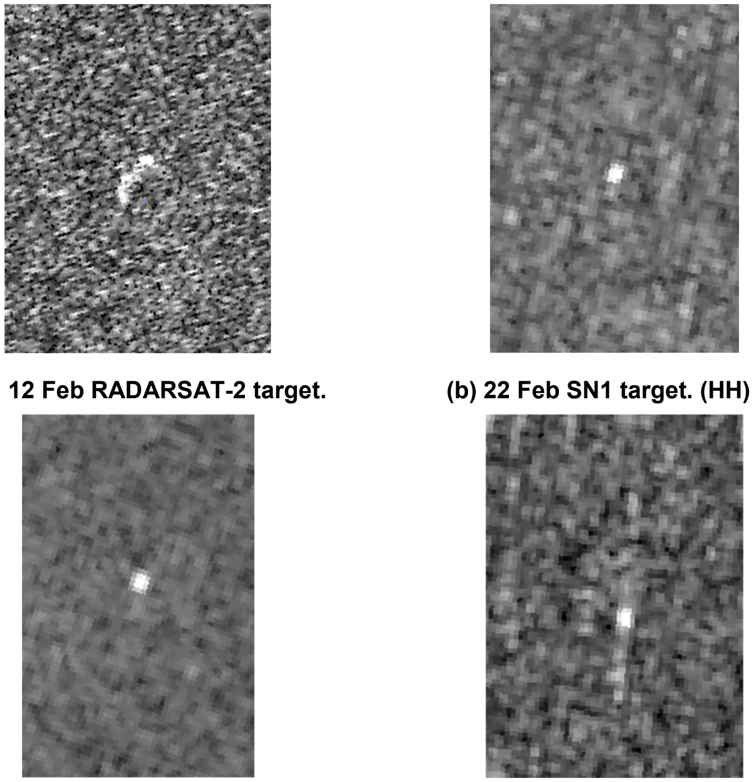
Typically, the first step is for the DWS to notify the Canadian Coast Guard Maritime Communication and Traffic Service (MCTS) Port aux Basques. In turn, MCTS issues a Notice to Shipping (NOTSHIP) which is the primary means of relaying critical iceberg information to the transatlantic shipping community and provides the IIP watchstanders with time to transmit revised products. The NOTSHIP is sent via NAVTEX and automatically forwarded to the U.S. National Geospatial-Intelligence Agency (NGA). NGA broadcasts the message as a Navigational Area (NAVAREA) IV warning message over SafetyNET and posts it to their website. NAVAREA IV is one of 21 Navigational Areas, designated by the World Wide Navigational Warning Service (WWNWS); the United States is the coordinator for NAVAREA IV.

If the report of an iceberg or radar target outside the limit is received by IIP during office hours (1200Z – 0000Z), products will be immediately revised by the DWS valid for 1200Z or 0000Z depending on the time received. If the report reaches IIP after office hours, products will be revised no later than 1400Z the following morning valid for 1200Z.

A total of nine reports of icebergs or radar targets outside the published Iceberg Limit were received throughout the 2018 Ice Year: eight while IIP was producing products and one when IIP was not. Only three were determined to be icebergs with the remainder being radar targets. Six were satellite-observed targets that could not be correlated to vessel traffic, a result of expanded use of satellite imagery especially in and around the Iceberg Limit. In four of these cases, aerial reconnaissance was conducted in close temporal proximity to the satellite observation and, in all instances, did not find an iceberg. These cases highlight the challenges associated with the increasing use of space-borne reconnaissance. While SAR satellites have proven to be able to detect icebergs, classifying targets as an iceberg, vessel, or another item such as marine life, fishing gear, or weather features remains a challenge. **Figure 3-4** shows four of these targets that were detected in single polarization only, and, though they were classified as "High Confidence" targets through the Iceberg Detection Software (IDS), their SAR returns are quite open to interpretation. In all, IIP took a conservative approach to ensure that the maritime community received a timely warning of any possible target outside of the limit and kept the target plotted in the model until subsequent reconnaissance could verify its status. The next section provides detailed information on each instance of an iceberg outside of the established Iceberg Limit. In each case, IIP relied on coordination with other data sources such as vessel Automated Identification System (AIS) and a collaborative exchange with a Coast Guard analysis center to help classify ambiguous targets as icebergs or ships. Access to this data and partnerships will continue to be key factors in space-borne reconnaissance efforts.

In-Season Icebergs and Radar Targets outside the Iceberg Limit

1. On 05 February 2018, a Sentinel 1 (SN1) B satellite frame from 03 February was processed and a target was detected approximately 50NM from the



(a) 12 Feb RADARSAT-2 target.

(b) 22 Feb SN1 target. (HH)

(c) 25 Apr SN1 target. (HH)

(d) 07 Jun SN1 target. (HH)

Figure 3-4. Examples of SAR targets detected in single polarization that resulted in targets outside of the established Iceberg Limit in 2018.

published Iceberg Limit (**Figure 3-5**). The target could not be correlated to ship activity. Due to the timing of the report, products were not revised and the iceberg was included in the current day's iceberg product, which resulted in a significant expansion of the Iceberg Limit. **Figure 3-6** shows the SAR target returns in HH and HV polarization as detected by SN1B.

2. On 14 February 2018, a RADARSAT-2 image from 12 February was processed and revealed a target approximately 100NM outside of the published Iceberg Limit (**Figure 3-7**). The target was detected with single polarization only (**Figure 3-4a**) and could not be correlated to ship activity. It was incorporated into the next day's iceberg product as a radar target outside the limit. An IRD patrol was conducted the next day to verify the sighting. No targets were reported in the vicinity of the radar target and it was subsequently deleted.

3. On 22 February 2018, a SN1B satellite frame was processed and revealed a target 0.5NM outside of the published Iceberg Limit (**Figures 3-8** and 3-**4b**). The target could not be correlated to ship activity. PAL Aerospace was consulted as they had flown an industry ice flight in the area two hours after the satellite pass and did not report any icebergs. They informed IIP that weather conditions and a high sea state significantly degraded the detection capability of the flight. The target was added as an iceberg in the current day's iceberg product and a NOTSHIP was issued.

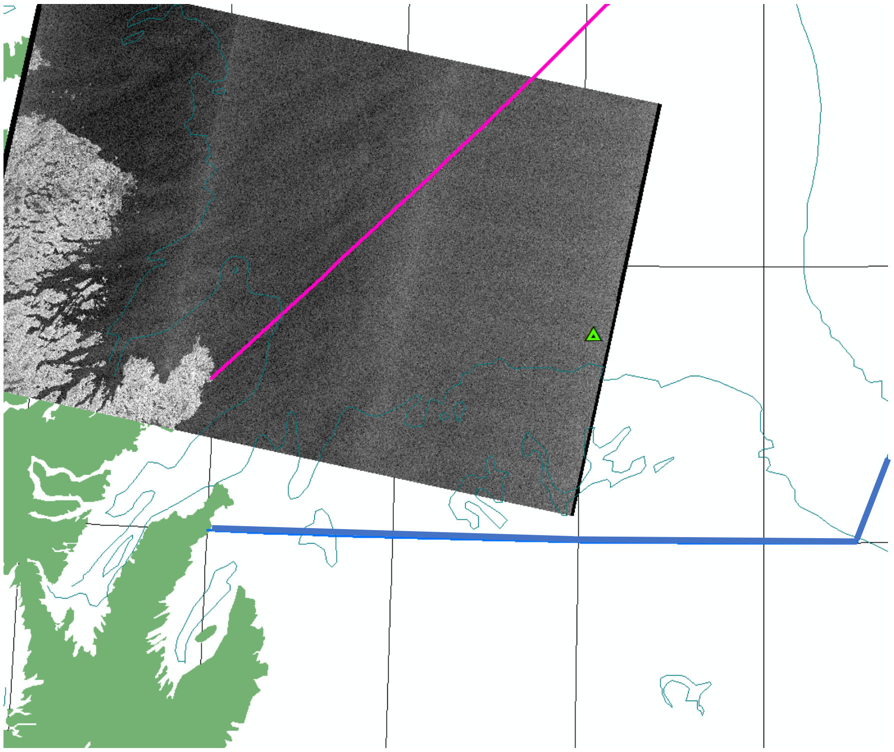
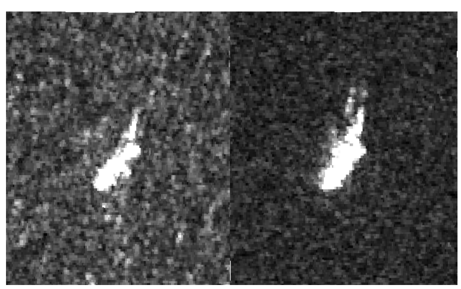


Figure 3-5. On 05 Feb 2018, an iceberg was detected outside the limit by analysis of Sentinel 1 imagery from 03 Feb. The magenta line represents the limit prior to the detection of the target (green triangle). The blue line denotes the significant expansion of the iceberg limit valid at 0000Z on 06 Feb.



(a) HH (b) HV

Figure 3-6. Sentinel 1 imagery from 03 Feb 2018 of the target in Figure 3-5 that was identified outside of the published Iceberg Limit during analysis on 05 Feb.

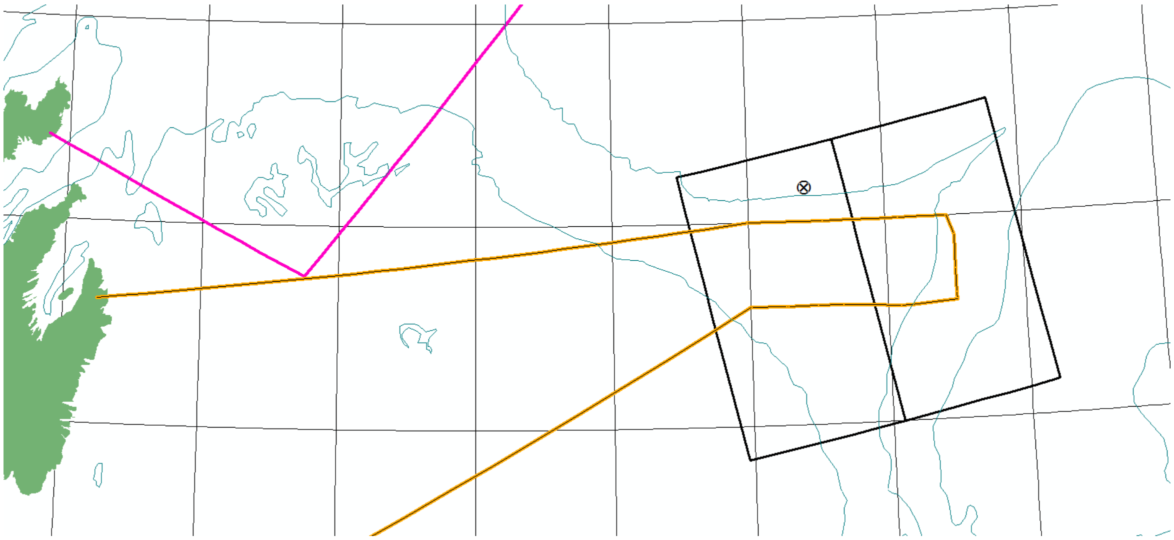


Figure 3-7. 14 Feb 2018 iceberg outside the limit detected by RADARSAT-2 imagery from 12 Feb. The target was approximately 100NM outside of the published Iceberg Limit (magenta line). The black box represents the RADARSAT-2 frame extent and the black circle with an "X" represents the location of the target. The gold line represents the IRD reconnaissance flight on 15 Feb that observed no icebergs.

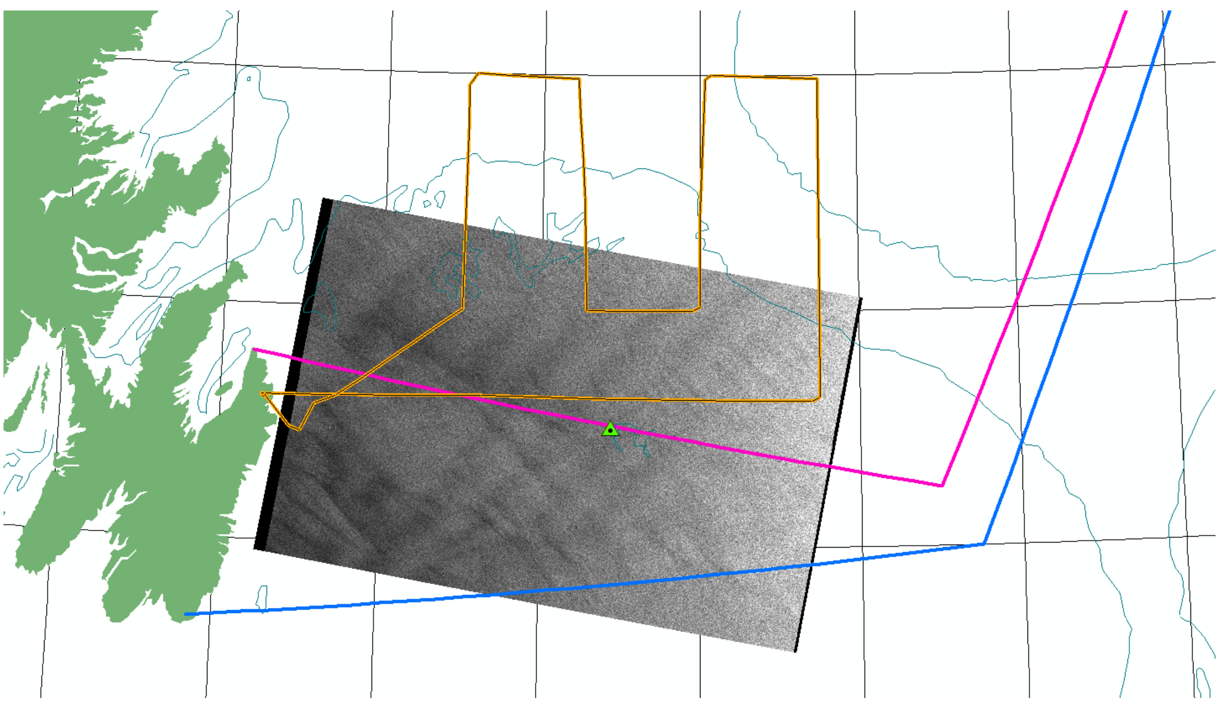


Figure 3-8. On 22 Feb 2018, a target (green triangle) was detected 0.5NM outside of the established iceberg limit (magenta line) by analysis of Sentinel 1 imagery. A PAL Aerospace industry funded ice flight patrolled the area approximately two hours after the satellite pass (gold line) and reported no icebergs but high seas that could have reduced their probability of detection. The Iceberg Limit was extended to the blue line effective at 0000Z on 23 Feb.

4. On 26 April 2018, a SN1A satellite image from 25 April was processed and a target was detected approximately 16NM from the published Western Iceberg Limit (**Figures 3-9** and **3-4c**). The target could not be correlated to ship activity. PAL Aerospace had flown a fisheries flight over the area of the target approximately two hours earlier and had sighted several ships in the vicinity, but no icebergs. It was incorporated in the current day's iceberg product as a radar target outside the limit and a NOTSHIP was issued.

5. On 07 June 2018, a satellite frame from the SN1B satellite was processed and a target was detected 7NM east of the published Iceberg Limit (**Figures 3-10** and **3-4d**). The target could not be correlated to ship activity. It was incorporated in the current day's iceberg product as a radar target outside the limit and a NOTSHIP was issued.

6. On 23 July 2018, IIP received a SIM from a fisheries flight conducted by PAL Aerospace on 21 July reporting an iceberg east of the published Iceberg Limit (**Figure 3-11**). PAL Aerospace conducted two flights on 21 July that passed this area within approximately an hour of each other. A CIS-funded iceberg flight passed near the target location on three legs of a flight plan aimed at searching for icebergs and did not report an iceberg in the area, but sighted several ships. IIP received the CIS-funded flight results on 22 July and deleted two icebergs which significantly reduced the Iceberg Limit. Upon receiving the second report on 23 July, that included an iceberg, IIP contacted PAL Aerospace and spoke with

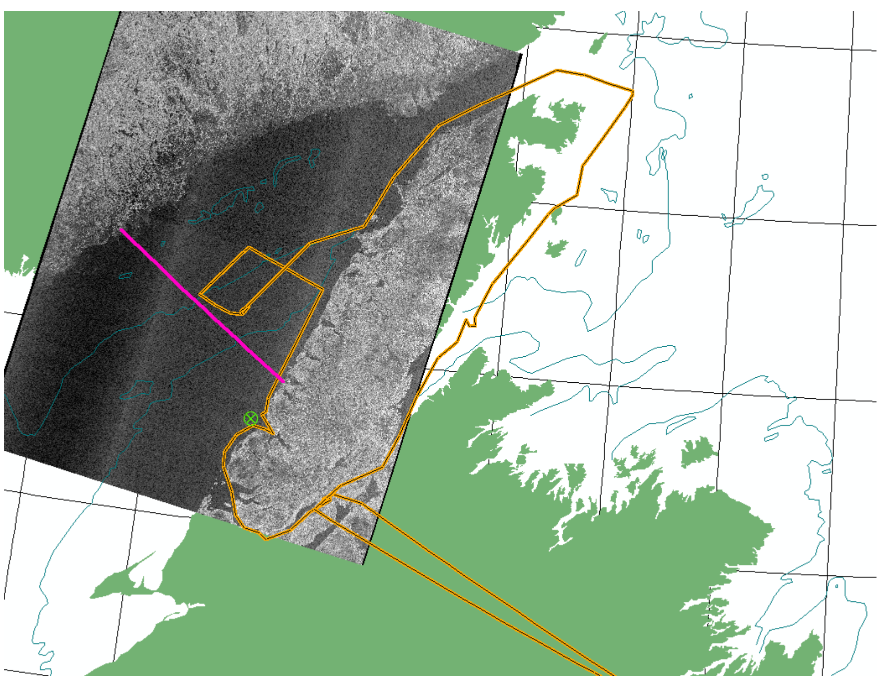


Figure 3-9. On 26 Apr 2018, a target (green circle with "X") was detected 16NM outside of the established Western Iceberg Limit (magenta line) by analysis of Sentinel 1 imagery from 25 Apr. A PAL Aerospace fisheries flight passed over the area approximately two hours before the satellite pass (gold line) and reported no icebergs. The contact was added as a radar target.

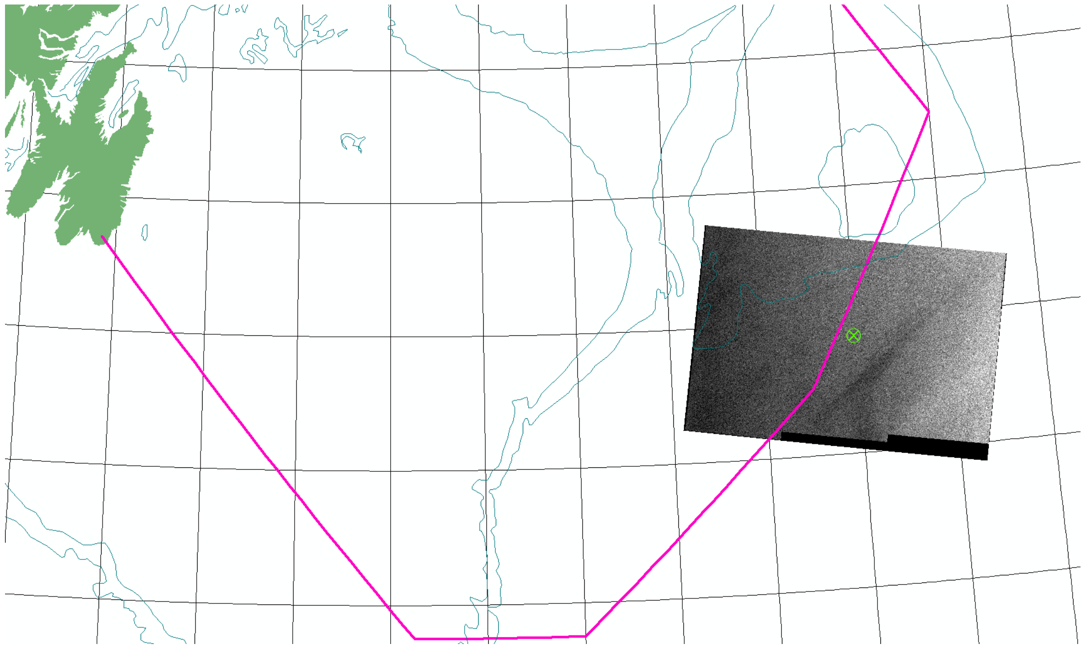


Figure 3-10. On 07 Jun 2018, a target (green circle with "X") was detected 7NM outside of the established Iceberg Limit (magenta line) by analysis of Sentinel 1 imagery. The contact was added as a radar target.

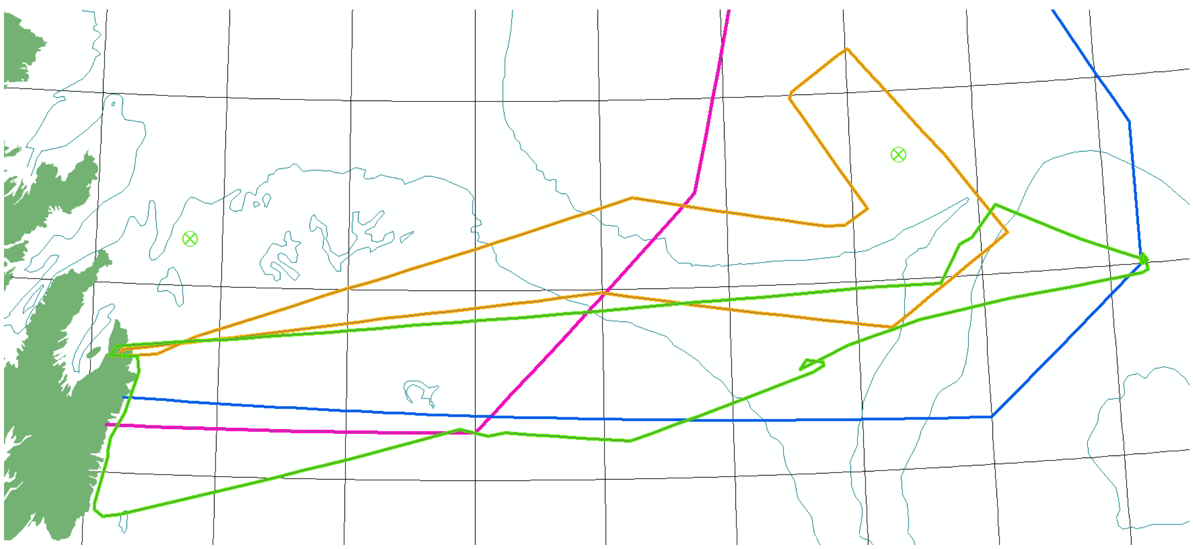


Figure 3-11. Two PAL Aerospace flights were conducted on 21 Jul 2018. The gold line above represents a CIS-funded iceberg reconnaissance flight to investigate the modeled positions of two icebergs. The green line represents a fisheries flight that was in the area at approximately the same time. The iceberg flight found no icebergs while the fisheries flight reported one unidentified target on radar at a range of 40NM (the green circle with an "X"). The blue line depicts the Iceberg Limit for 0000Z on 22 Jul. After receiving the results on 22 Jul of the dedicated iceberg reconnaissance flight (gold line) reporting no icebergs during their patrol, the limit was significantly reduced to the magenta line valid at 0000Z on 23 Jul. At approximately 1200Z on 23 Jul, IIP received the information from the fisheries flight (green line) reporting the iceberg that was now outside of the limit. Due to the conflicting reports from the same time and the fact that the iceberg reconnaissance flight passed much closer to the reported contact, it was added as a radar target.

the pilot of the fisheries flight who stated that the target was not seen visually. Due to the fact that the target was squarely within the search pattern conducted by the CIS-funded iceberg flight, which reported only ships in the area, while the fisheries flight's closest point of approach to the target was approximately 40NM south and only reported an uncorrelated radar target, it was added as a radar target and a NOTSHIP was issued.

7. On 09 August 2018, IIP watch personnel noticed a NOTSHIP on the USCG Navigation Center (NAVCEN) website warning mariners of an iceberg outside the published Iceberg Limit (**Figure 3-12**). On 07 August, the M/V RANFORM STERLING reported the target to Vessel Traffic Service (VTS) Placentia who then sent the report to MCTS Port Aux Basques. IIP watch personnel contacted the M/V RANFORM STERLING and spoke with the Third Officer who had reported the target. He informed IIP that the iceberg had been spotted visually on 05 August but was never reported. He also stated that the target reported on 07 August was seen only on radar but based on the target location in reference to the target sighted on 05 August, he believed it to be the same target. IIP watch personnel entered the 05 August report into the model and confirmed that the 07 August observed location matched the drift predicted by the model. Analysis of SN1 imagery from 05 August confirmed the

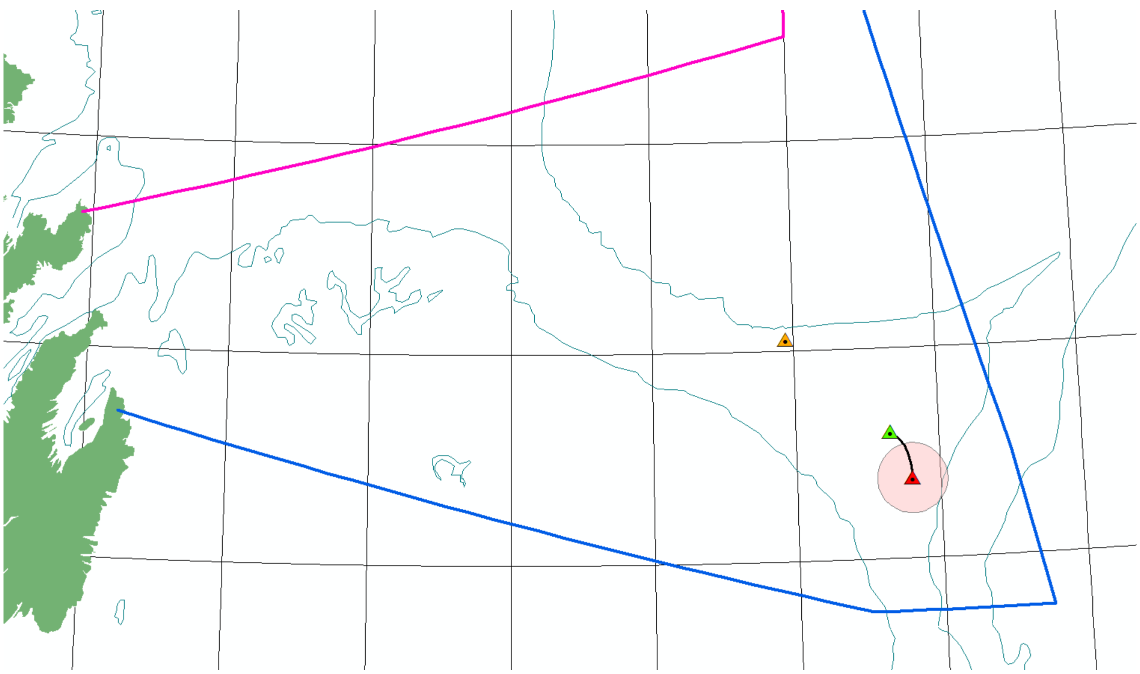


Figure 3-12. On 09 Aug 2018, IIP received a report of an iceberg 118NM outside of the established Iceberg Limit (magenta line). The orange triangle represents the first sighting of the iceberg by the M/V RANFORM STERLING on 05 Aug and the green triangle represents the location of the second sighting on 07 Aug. After the second sighting, RANFORM STERLING made an iceberg report to VTS Placentia at which point the notification process that resulted in the release of a NOTSHIP was started. The magenta line depicts the NAIS Iceberg Limit as of 0000Z on 09 Aug. The blue line is the location of the updated Iceberg Limit to account for the drift (black line), modelled position (red triangle), and modeled error (red shaded circle) of the iceberg at the time the limit was updated (1200Z on 09 Aug).

sighting with a verified AIS contact nearby a "High Confidence" large iceberg. The target was added as an iceberg and the NAIS Iceberg Limit was revised. Discussion with the Third Officer revealed that the crew did not report the iceberg on 05 August because they were not sure who to notify and what information to report.

8. On 18 August 2018, IIP watch personnel were attempting to locate the iceberg reported on 09 August with satellite imagery from 17 August and identified two targets located 36NM outside of the established Iceberg Limit that did not correlate with AIS vessel traffic or with vessel activity (**Figure 3-13**). Given the large amount of vessel traffic in the area and a pending iceberg flight, the two targets were added to the model as radar targets and a NOTSHIP was released. IIP watch personnel requested updated tasking for PAL Aerospace via CIS to include coverage of the two radar targets. PAL Aerospace executed the flight plan on 20 August and did not report any targets in the area leading to the subsequent deletion of the two targets.

Out of Season Icebergs and Radar Targets outside the Iceberg Limit

1. On 26 October 2017, the M/V VIKINGBANK reported an iceberg 93NM outside of the estimated Iceberg Limit located in position 56˚25’N, 043˚12’W, 210NM south of Cape Farewell, Greenland (**Figure 3-14**). The vessel observed

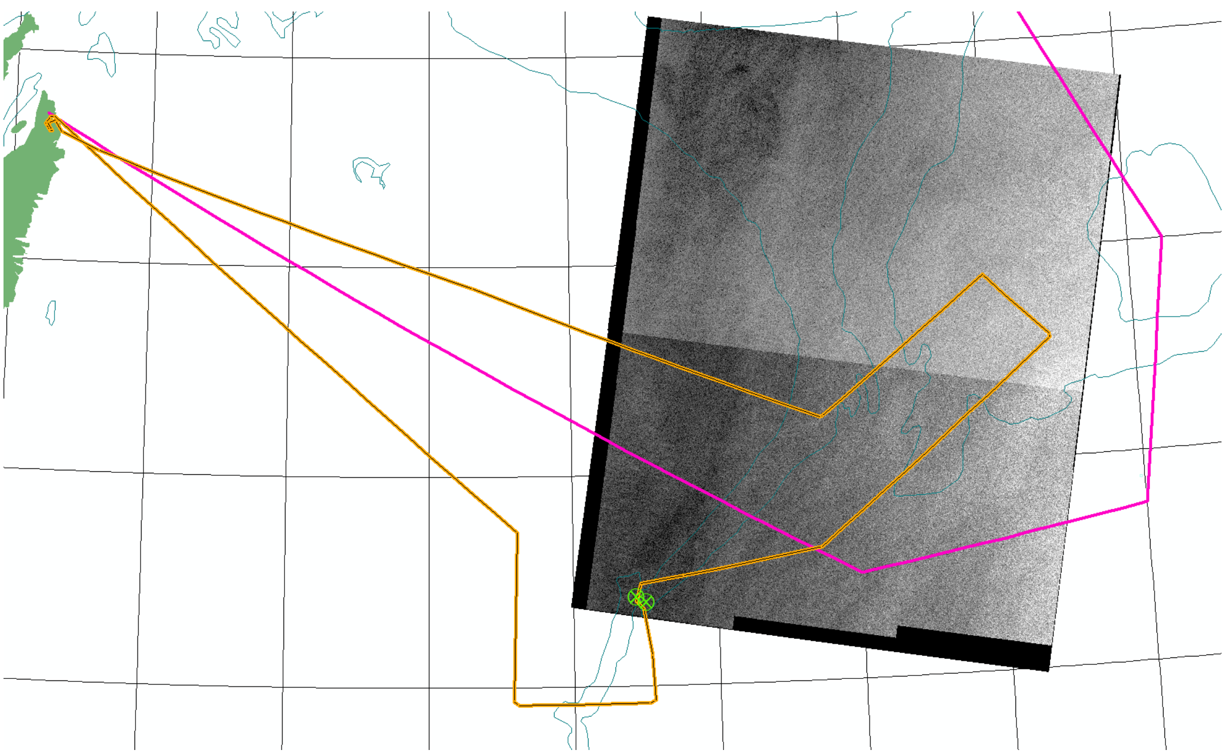


Figure 3-13. On 18 August 2018, IIP watch personnel were attempting to locate the 09 Aug iceberg (Figure 3-12) with satellite imagery from 17 Aug and identified two targets (green circles with "X"s) located 36NM outside of the established Iceberg Limit (magenta line) that could not be correlated with vessel traffic. PAL Aerospace executed a dedicated ice reconnaissance flight plan (orange line) on 20 Aug in the vicinity of their predicted positions and did not report any icebergs in the area, but several ships.

the iceberg both visually and by radar. CIS added the iceberg to the iceberg database and issued a significant expansion of the estimated Iceberg Limit. Because of the location of the iceberg a NOTSHIP was not issued and the report was forwarded to DMI.

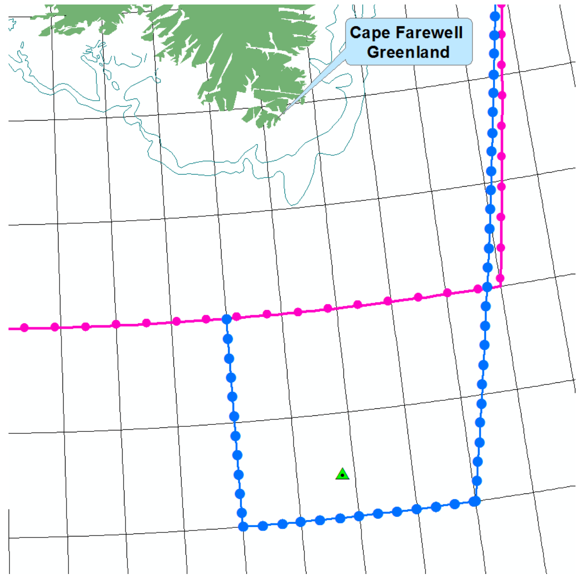


Figure 3-14. On 26 October 2017, the M/V VIKING-BANK reported an iceberg (green triangle) 93NM outside of the estimated Iceberg Limit (magenta line with circles) and 210NM south of Cape Farewell, Greenland resulting in a significant expansion of the estimated limit (blue line).

4. Iceberg Reconnaissance Operations

Ice Reconnaissance Detachment

The IRD, a sub-unit under CIIP, partners with ASEC to conduct aerial iceberg reconnaissance. During the 2018 Ice Season, ten IRDs deployed to observe and report icebergs, sea ice, and oceanographic conditions in the North Atlantic Ocean. The IRDs transmitted all observations to the IIP OPCEN in New London, CT for processing and entry into BAPS. The IIP OPCEN used these observations to create the NAIS iceberg warning products that are distributed to the maritime community.

Over the 2018 Ice Season, IIP and ASEC crews deployed for 93 days conducting 39 ice reconnaissance patrols on HC-130J air assets. As part of the first IRD, ASEC flew to Groton, CT to pick up six IIP personnel who returned to ASEC with the aircraft and provided pre-season training for ASEC personnel the following day. The 2018 flight season spanned 150 days, which is 8.2 days shorter than the five-year (2014-2018) average of 158.2 days. The first IRD departed on 06 February, and the last IRD returned on 05 July. **Table 4-1** contains a summary operations for each IRD.

Aerial Iceberg Reconnaissance

HC-130J aircraft were used to conduct aerial iceberg reconnaissance. USCG HC-130J aircraft are 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 HC-130J Tactical Transport Weather Radar (APN-241) is capable of detecting surface targets but not identifying them. The AIS receives information transmitted by AIS-equipped ships for positive identification and is used to differentiate vessels from icebergs on the radar.

IRD	Deployed Days	Iceberg Patrols	Transit Flights	Patrol Enroute	Logistics Flights	Flight Hours
1	11	3	3	1	0	36.2
2	8	3	2	0	0	25.9
3	11	0	2	1	0	12.5
4	9	4	3	0	0	40.4
5	9	5	2	0	0	46.7
6	9	5	2	0	0	43.1
7	9	4	2	0	0	35.5
8	9	3	1	1	0	32.2
9	9	2	1	2	0	39.7
10	9	4	1	1	0	42.4
Total	**93**	**33**	**19**	**6**	**0**	**354.6**

Table 4-1. Summary of 2018 operations broken down by IRD.

The ability to employ ELTA radar significantly enhances reconnaissance capabilities. The 360° coverage provided by the ELTA radar supports the use of 25NM track spacing for patrol planning. Under calm sea states, IIP is able to expand track spacing to 30NM, while maintaining a 95% probability of detection (POD) of small icebergs (15 to 60m). Conditions supporting expanded track spacing did not occur during any of the IRD patrols in the 2018 Ice Season.

When the ELTA radar is inoperable, the IRD must fly patrols under "visual-only" specifications using 10NM track spacing covering 40% less area in a given time period. Further, patrols are limited to areas with pristine environmental conditions; clear skies and visibility to the surface are requirements for visual-only patrols which rarely occur in IIP's meteorologically active OPAREA. Notably, in 2018, there were no ELTA radar casualties that required reduced track spacing.

In 2017, the HC-130J fleet began its Minotaur Mission System (MMS) upgrade. The MSS architecture is used on multiple platforms across the U.S. Departments of Defense and Homeland Security. Missionization with the MMS Suite involves modifying the aircraft to incorporate the radar; sensors; and remaining command, control, communications, computers, intelligence, surveillance and reconnaissance equipment that allows aircrews to gather and process information for transmission to surface and shore operators.

During the 2018 Ice Season, seven IRDs were flown with MMS equipped aircraft. When flying on MMS equipped aircraft, IIP and ASEC personnel worked together to improve effectiveness of the new radar detection algorithm. Challenges arose when flying over areas of heavy sea ice concentrations, where the radar detection algorithm, unable to differentiate between rough sea ice and icebergs, would saturate with possible targets. Additionally, during the first half of the season, the ability to use the Inverse Synthetic Aperture Radar (ISAR) feature on a possible iceberg target was limited, resulting in a heavy reliance on the aircraft's camera to confirm targets as icebergs. Updates to the systems appeared to improve the ability to use ISAR to detect icebergs during the last two IRDs.

As shown in **Figure 4-1**, IIP recorded an increased number of visually observed icebergs during the 2018 Ice Season, compared to the 2017 Ice Season **(Table 4-2)**. This increase in visual-only icebergs and subsequent decrease in radar-only and radar and visual detections can be partially attributed to the difficulties of the MMS identifying targets in areas of heavy sea ice concentrations. Additionally, IIP continued to employ a two-tier approach in areas of good visibility and high iceberg concentrations, focusing visual observations close to the aircraft and radar observations further away.

Year	Radar & visual icebergs	Radar only icebergs	Visual only icebergs
2014	43%	5%	52%
2015	29%	45%	26%
2016	20%	32%	48%
2017	21%	39%	40%
2018	24%	31%	45%

Table 4-2. Historical IRD iceberg detection method by year for the past five Ice Seasons (2014-2018).

IRD Operational Summary

The first IRD of 2018 began on 06 February when ASEC crew flew to Groton, CT planning to conduct egress training and gear check with IIP crewmembers. Unexpected snow in Groton canceled the egress training, but the ASEC HC-130J with six IIP crewmembers were able to depart and return to ASEC to conduct scheduled IRD training with ASEC personnel on 07 February. IRD 1 arrived in St. John's on 08 February and conducted opening season partner meetings on 09 February. The first patrol on 10 February flew northeast to approximately 50°N 48°W to confirm a radar target outside the southern Iceberg Limit, then headed northwest and flew along the 1000m depth contour. This initial flight confirmed that a reported satellite radar target was not an iceberg outside the limit and detected 16 icebergs north of 51°N near the 1000m contour. A second flight on 13 February patrolled between 53°N

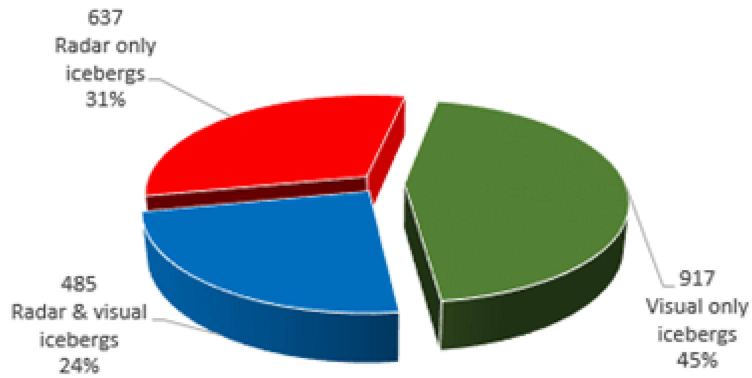


Figure 4-1. Percentage of icebergs detected by radar-only, visual-only, or both radar and visually on IRD flights during the 2018 deployment season.

and 55°N from the northeastern Iceberg Limit to the southern Labrador coast. This flight detected 15 icebergs inside the 1000m contour. The third flight of this IRD on 14 February was a northern survey flight that flew to 60°N and identified 74 icebergs. The final flight of this IRD flew to the east over the Flemish Cap where a possible iceberg was detected from a RADARSAT-2 image, however, no targets were detected by the IRD. IRD 1 confirmed the main population of icebergs remained well north of the transatlantic shipping lanes after IRD 1.

With the iceberg population well north of the transatlantic shipping lanes, CIIP determined IRD 2 would not return to St. John's until 07 March. Three patrols were conducted during this IRD and, due to a major winter storm moving into the area, the IRD ended a day early to avoid being grounded in St. John's. The first patrol searched the eastern Iceberg Limit to 45°W and confirmed that no icebergs were adrift in the Labrador Current through Flemish Pass, Sackville Spur, or over the Flemish Cap. In addition, this patrol flew over the footprint of both a RADARSAT-2 and a Sentinel-1 satellite passes; no icebergs were detected. The second patrol, on 09 March, searched the southern Iceberg Limit down to 46°30'N. This patrol detected one iceberg that verified the location of the limit. The final patrol of IRD 2, on 13 March, was a western Iceberg Limit and satellite validation flight, patrolling through the Strait of Belle Isle and along the Labrador coast. The original flight plan was modified in flight because of a prolonged issue with the electronic global positioning system failing to connect with the MMS. Seventeen icebergs were detected during this patrol.

During IRD 3, from 21 to 30 March, persistent inclement weather and unscheduled aircraft maintenance forced the cancelation of a patrol enroute on 21 March and kept the aircraft grounded in St. John's throughout the remainder of the scheduled deployment. In order to take advantage of a forecasted break in the inclement weather, IRD 3 remained in St. John's for an extra day and conducted a Southwestern Limit patrol enroute home on 30 March. This patrol detected three icebergs and verified the location of the southwestern Iceberg Limit. Upon landing in Groton, CT to drop off IIP crewmembers, the cloud layer descended below safe minimums for take-off. The resulting delay caused ASEC aircrew to exceed their allowable accrued flight hours. The aircrew remained overnight and returned to Elizabeth City, NC on 31 March.

IRD 4 arrived in Halifax, Nova Scotia (NS) on 04 April to conduct partner meetings and to participate in the RMS TITANIC remembrance ceremony at Fairview Lawn Cemetery. A planned patrol while transiting from Halifax to St. John's was canceled on 05 April due to deteriorating conditions at the airport in St. John's.

The first patrol on 06 April covered the eastern Iceberg Limit and south to approximately 43°30'N to verify no icebergs drifted outside the limit in the cold-water tongue of the Labrador Current or cold-water 'feature'. No icebergs were detected on this flight, but IIP deployed three wreaths to commemorate the RMS TITANIC. The second patrol for IRD 4, a Western Limit and satellite validation flight, occurred on 08 April. The flight detected 37 icebergs and validated the location of the western Iceberg Limit. The third patrol flew over the southwestern limit and again under a Sentinel-1 satellite pass for validation. This flight detected 43 icebergs and confirmed there were no icebergs along the Avalon Peninsula, allowing a reduction of the southwestern portion of Iceberg Limit by half a degree. The fourth and final patrol on 11 April flew east to 45°W to cover the eastern Iceberg Limit and under a Sentinel-1 satellite pass. 13 icebergs were detected and the limit was shifted 1 degree to the west.

Between 18 and 26 April, IRD 5 flew five patrols. An eastern Iceberg Limit and cold-water feature patrol on 19 April detected nine icebergs, the easternmost iceberg at approximately 46°45'W; and no icebergs outside the limits in the cold-water feature. The second patrol on 22 April covered the western Iceberg Limit in the Strait of Belle Isle and coincided with a Sentinel-1 satellite pass. There were 138 icebergs detected in the northern portion of the Strait and along the eastern coast of Newfoundland and northern Avalon Peninsula. A northern survey flight the next day was conducted for understanding of the iceberg population that would potentially drift into the transatlantic shipping lanes later in the season. Along the northern Labrador coast between 52°N and 60°N, 264 icebergs were detected. The patrol on 24 April was a dedicated RADARSAT-2 satellite validation flight in the interior of the OPAREA between 51°N and 53°N. This flight detected 54 icebergs. The final flight of IRD 5 was an eastern and southeastern Iceberg Limit patrol that covered north of the Sackville Spur down through the Flemish Pass. This patrol found one iceberg near the southern end of the Flemish Pass and validated the southeastern Iceberg Limit.

IRD 6 conducted a total of five patrols between 03 and 09 May. The first patrol, flying over the western Iceberg Limit and northern Notre Dame Bay under a Sentinel-1 satellite pass found 188 icebergs and growlers. The next flight covered the interior area north of the Avalon Peninsula under a Sentinel-1 satellite pass. The patrol found 87 icebergs and growlers. The third patrol on 07 May searched the eastern Iceberg Limit focusing over the Flemish Cap, Flemish Pass, and south over a cold-water feature. No icebergs were detected on this flight. The fourth patrol of IRD 6 flew interior and along the 1,000m contour to the north east of St. John's. Fifty-three icebergs and growlers were found mainly to the west of the 1,000m contour. The final patrol, on 09 May, searched the eastern Iceberg Limit and cold-water feature areas, focusing to the east of the area covered by flight three. This flight found only two icebergs near the Sackville Spur, allowing for a slight reduction of the limit.

IRD 7 deployed to St. John's from 16 to 24 May and flew four patrols with one unscheduled maintenance day. The first flight validated the southwestern Iceberg Limit and conducted a Sentinel-1 satellite under flight finding eight icebergs on 17 May. The next flight covered the western Iceberg Limit and across to the 1,000m contour. It found 123 icebergs mainly along the Labrador coast and east to the 1,000m contour between 52 and 53° N. The third and fourth flights covered the eastern Iceberg Limit, Sackville Spur, Flemish Pass and Flemish Cap areas. The third flight, on 19 May, was also a Sentinel-1 satellite validation flight, while the fourth flight, on 23 May, traveled further to the south and covered the cold-water feature. Combined, 14 icebergs were detected and the location of the eastern Iceberg Limit was shifted to the west by one degree.

IIP deployed on IRD 8 between 30 May and 07 June. Weather in the OPAREA and at St. John's airport limited effective reconnaissance during this detachment. On 30 May the IRD transited to Halifax, NS instead of St. John's because of poor weather conditions at St. John's. The first patrol, on 31 May, covered the western Iceberg Limit and a Sentinel-1 satellite validation flight in Notre Dame Bay and found 115 icebergs. Low ceilings at the airport in St. John's forced the patrol to land in Stephenville, NL. The second patrol, starting from Stephenville, NL, was an interior and RADARSAT-2 validation flight, covering the area to the east of the entrance to the Strait of Belle Isle and across to the 1,000m contour. The flight detected 80 icebergs and was able to land in St. John's after ending the patrol early for deteriorating conditions at the airport. The third flight of IRD 8, on 05 June, covered the southern Iceberg Limit and cold-water feature. It found four icebergs and verified there was not an iceberg directly south of the Avalon Peninsula, allowing the southwestern limit to move north. The IIP's delayed receipt of a ship report, coupled with limited communication capabilities between the OPCEN and aircraft necessitated IRD 8 to execute a patrol enroute home on 07 June. The iceberg was reported just outside the area covered by the previous southern flight. The iceberg was not detected; however, poor on-scene weather conditions, including low ceilings and altocumulus castellanus clouds requiring vertical and horizontal diverts from the flight plan, ruled out removing the iceberg from IIPs model and reducing the southern Iceberg Limit.

IRD 9 deployed on 13 June, but diverted to ASEC due to a radio malfunction. After repairs were made, IRD 9 conducted a patrol enroute to St. John's on 14 June to verify the southern Iceberg Limit. No icebergs were detected and the limit was shifted three degrees to the north. Due to OPAREA weather and a crewmember injury, IRD 9 was only able to conduct three additional patrols, including a patrol during the transit back to the U.S. on 21 June. The second flight on 16 June, a Sentinel-1 satellite validation flight, found 32 icebergs along the eastern coast of Newfoundland. The next flight, on 20 June, was a western Iceberg Limit and interior flight. It found 291 icebergs around the entrance to the

Strait of Belle Isle, which was a higher than expected number of icebergs so late in the season. The final flight of IRD 9, on 21 June, covered the eastern Iceberg Limit in the vicinity of the Sackville Spur and Flemish Pass. On-scene weather conditions forced the patrol to be cut short; no icebergs were detected by this flight.

IIP conducted its final IRD of the 2018 Ice Season from 27 June to 05 July. This detachment conducted patrols of the eastern/southeastern, southwestern and western Iceberg Limits, and a northern survey. The eastern/southeastern flight found three icebergs near the 1,000m contour around 49°N 49°W. A second flight over the 1,000m contour, and eastern Iceberg Limit, on 01 July, found five icebergs, all north of 51°N. The third flight, on 02 July, a northern survey, found 282 icebergs along the northern Labrador coast. The penultimate IRD flight of the 2018 Ice Season covered the southwestern Iceberg Limit and interior area north of the Avalon Peninsula. This flight found no icebergs around the Avalon Peninsula and 77 icebergs to the north of 49°N. The final flight of the 2018 Ice Season, on 05 July, covered the western Iceberg Limit enroute from St. John's to Groton, CT. The flight found 43 icebergs, all mainly outside the mouth of the Strait of Belle Isle and along the eastern coast of Newfoundland. The distribution and total number of icebergs detected on IRD 10 enabled CIIP to cease IIP aerial deployments in early July.

Figure 4-2 shows a breakdown of IIP's deployment days during the 2018 Ice Season in six categories: Operations, Transit, Weather, Maintenance, Crew Rest, and Training. In accordance with USCG regulations, the IRD normally takes one crew rest day as well as one maintenance day per deployment; otherwise, the IRD plans to fly every day. However, the prevailing OPAREA weather contributes significantly to the number and effectiveness of reconnaissance patrols. In 2018, weather conditions prevented patrols on 27% of the days deployed. In order to maximize operational iceberg reconnaissance flight days, the IRD capitalizes on poor weather days to meet crew rest and maintenance requirements when possible. Using this paradigm, all required crew rest days and 90% of required maintenance days were completed when weather prevented operations. Unscheduled maintenance and crew rest due to illness/injury of crewmembers impacted operations less than 8% of total deployed days. Finally, patrols executed while transiting between the U.S. and St. John's, NL are counted as an operational day vice transit day.

IRD Iceberg Detections

IRD personnel detected 2,039 icebergs, which accounted for 32.6% of the total icebergs added to the IIP database during the 2018 Ice Season. During

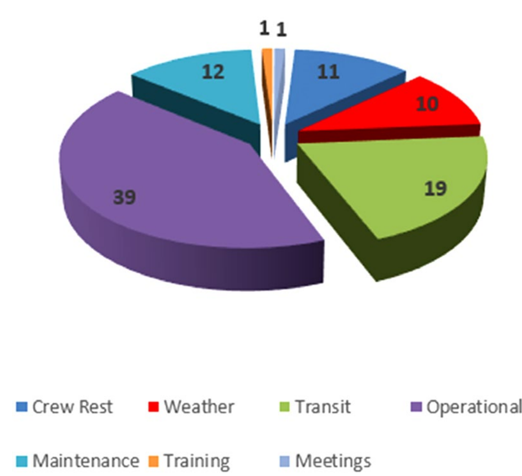


Figure 4-2: A breakdown of the 93 IRD deployment days in 2018.

aerial reconnaissance, icebergs are detected in one of three ways: (1) with both radar and visual, (2) radar only, or (3) visual only means.

This year, 24% of the icebergs were detected by both radar observations and visual sightings. The remaining icebergs were either detected only by radar (31%) or by visual detection alone (45%) (**Figure 4-1**). During dedicated satellite validation flights an increased effort was made to identify icebergs with radar or both radar and visually to record the most accurate position of the icebergs. However, visual-only detections remain a significant portion of the detection method as a result of optimizing reconnaissance resources while on patrol. In areas of high iceberg concentration with favorable environmental conditions, IRD's will focus visual-only observations close to the aircraft while employing radar only observations away from the flight path, enabling maximum detection efficiency. Additionally, on Minotaur-equipped aircraft flying over sea ice, there was a greater reliance on visual observations due to the radar detecting an overwhelming number of targets.

2018 Flight Hours

As in previous seasons, IIP was allotted 500 Maritime Patrol Aircraft flight hours for its operation during the 2018 Ice Season. IIP used 346.7 hours in 2018 compared to 292.5 in 2017. **Figure 4-3** shows the breakdown of these hours over the past four Ice Seasons into three categories: transit hours, patrol hours, and logistics hours. Transit hours are hours the aircraft transited to and from specific locations in support of the IIP mission without conducting reconnaissance operations. There were 108.6 hours used this season for transits. These flights are generally between Elizabeth City, NC and St. John's, NL. Transit hours for the 2018 Ice Season also include one planned and one unplanned flight to Halifax, NS; the

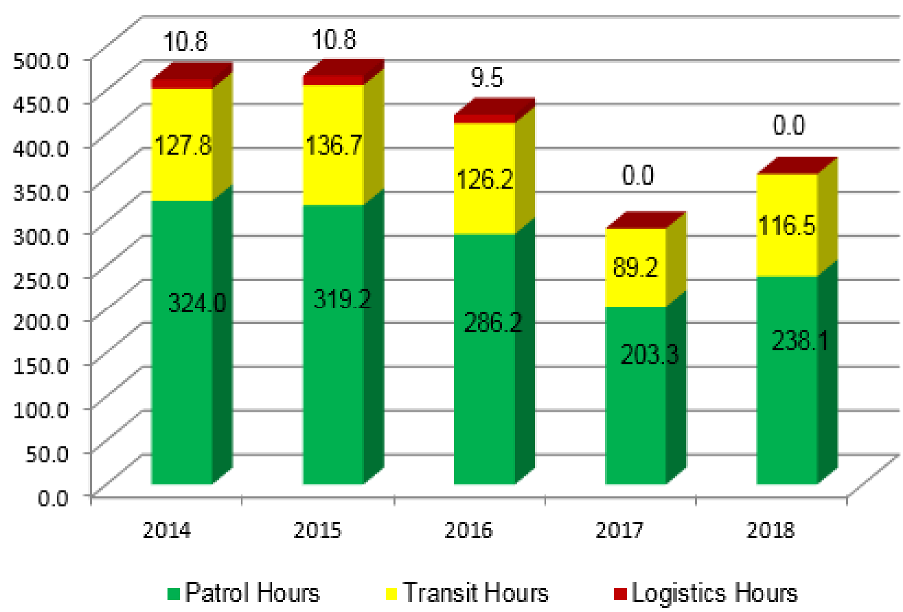


Figure 4-3. IRD flight hours broken down by type (patrol, transit, or logistics) over the past five years (2014-2018)

former in support of partner meetings and a Titanic Memorial Ceremony, and the later as a weather divert. Patrol hours are the hours associated with iceberg reconnaissance including flight time to and from the reconnaissance area. IIP flew 238.1 patrol hours this season. On six occasions, patrols were conducted during transits between the United States and St. John's, NL. Patrols conducted enroute to or from St. John's NL typically require longer transit times due to starting or ending reconnaissance positions north or east of St. John's, NL. Patrols during transit remain a mitigation tool for IIP to reduce the impact of poor weather or unplanned aircraft maintenance and to maximize IRD effectiveness. Logistics hours are the hours used to support the IIP mission, but do not fall into the previous two categories. Logistics hours accrue when a Coast Guard aircraft is used to transport parts for an aircraft deployed on an IIP mission. No logistics hours were accrued during the 2018 Ice Season.

The geographic and temporal distribution of icebergs, as well as the quantity of icebergs drifting south of 48°N, all contribute to the amount of reconnaissance needed to effectively monitor the iceberg danger and provide relevant warning products. **Figure 4-4** shows a comparison of flight hours to the number of icebergs that drifted south of 48°N from 2008 to 2018. The red line indicates IIP's total flight hours, the blue bars indicate the number of icebergs observed or drifted south of 48°N. Although the number of icebergs in the transatlantic shipping lanes in 2018 was much less than 2017, IIP expended more flight hours. IIP capitalized on the light season and more compact iceberg distribution to support satellite validation

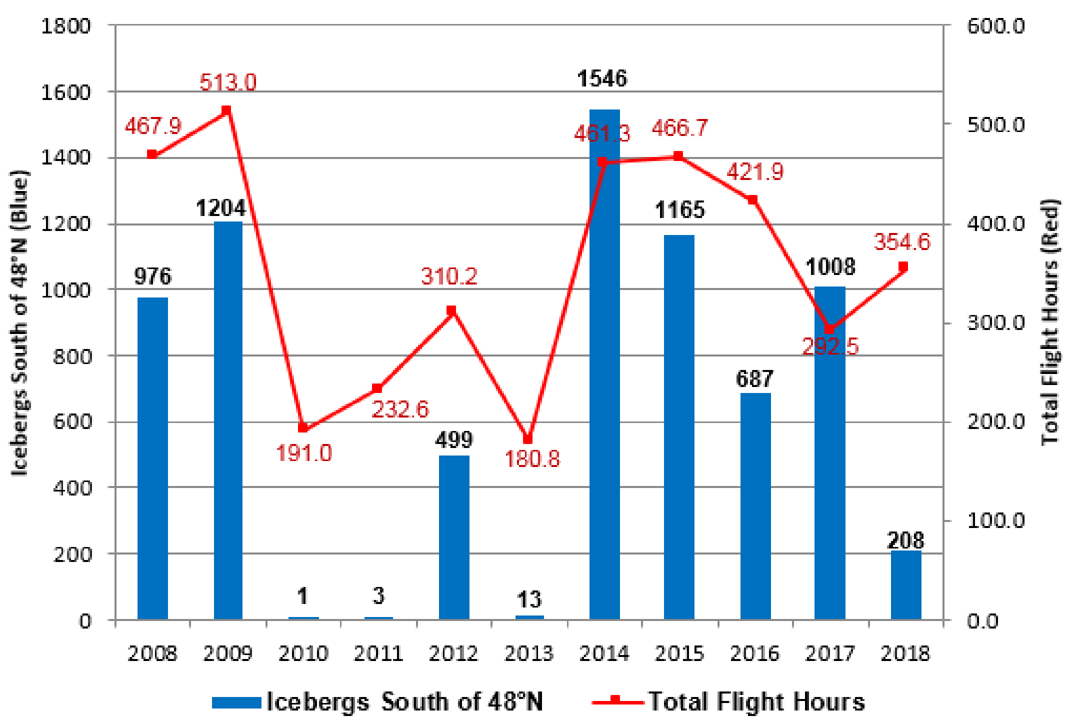


Figure 4-4. Flight hours used by IIP IRDs from 2008-2018 compared with the number of icebergs that drifted south of 48°N into the transatlantic shipping lanes.

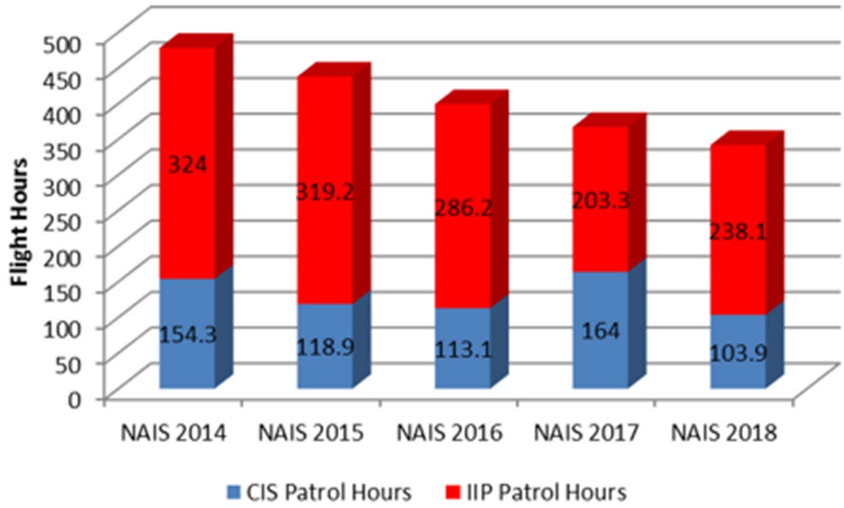


Figure 4-5. Comparison of NAIS iceberg reconnaissance flight hours over the past five years (2014-2018).

efforts; over 38% of the flight plans included coincident satellite coverage. The efforts during these satellite validation flights serve to improve satellite iceberg detection algorithms in support of transition to satellite reconnaissance and modernization of IIP. Refer to **Appendix C** for additional details on IIP's satellite reconnaissance modernization efforts.

Other Iceberg Reconnaissance Activities

NAIS Collaboration

In order to maximize aerial iceberg reconnaissance in the North Atlantic, IIP continued to leverage its NAIS partnership with CIS. **Figure 4-5** depicts the NAIS flight hours for 2018. IIP coordinated flight plans with CIS during periods when IRDs were not deployed to St. John's. Data provided includes hours flown by each service. CIS contracted PAL Aerospace for 103.9 patrol hours resulting in a combined total of 342 patrol hours in support of NAIS reconnaissance.

The NAIS region is divided into five areas based on the risk of iceberg collision for vessels in the transatlantic shipping lanes. Northern areas are monitored to determine the overall iceberg population early in the season and to predict the anticipated threat of icebergs drifting south in the Labrador Current. The focus of iceberg reconnaissance shifts as the iceberg population drifts south in early spring and retreats in late summer. To illustrate this tiered approach, **Figure 4-6** shows a one-day snapshot indicating the most recent reconnaissance coverage for areas across the NAIS region on 23 March.

Ship Interactions

IRD on-scene patrol time in the HC-130J aircraft is mainly focused on locating and classifying icebergs using visual and radar reconnaissance methods. However, during patrols, the IRD will also communicate directly with the maritime community to request recent iceberg sighting information. This communication takes two forms: a sécurité broadcast to all vessels in vicinity of the aircraft, and direct calls to vessels identified by AIS. The information from the individual vessels proves especially

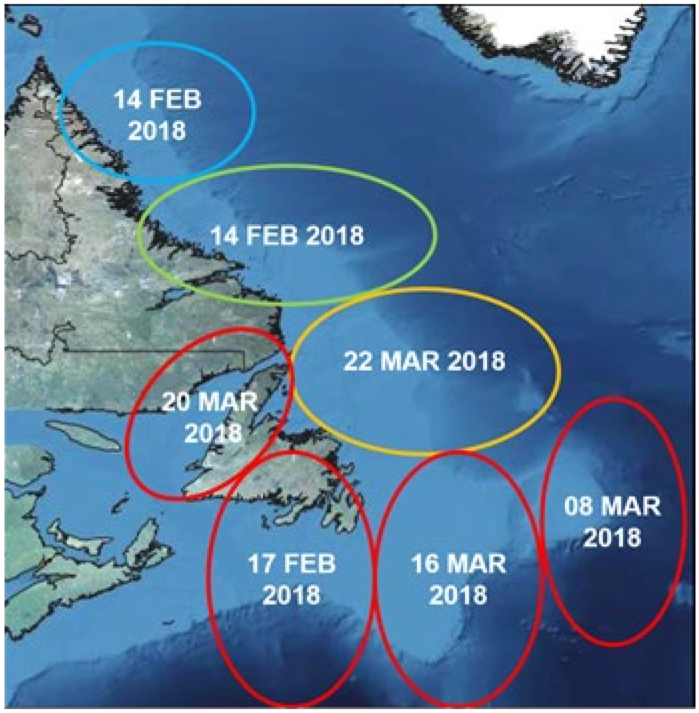


Figure 4-6. An Example of NAIS reconnaissance coverage from 23 March 2018. Circle color indicates the risk of iceberg collision for vessels in the transatlantic shipping lanes. Blue and green indicate areas where icebergs pose low risk and are monitored for iceberg population. Yellow indicated moderate risk and the area is monitored more frequently early and late in the Ice Season when the Iceberg Limit is within this area. Red indicated high risk of icebergs affecting transatlantic shipping, and reconnaissance is focused in these areas when the Iceberg Limit extends here.

useful during periods of reduced visibility, or when numerous small vessels not equipped with AIS are present in the reconnaissance area. Vessel observation information is also valuable for confirmation of data provided by the aircraft's radar. During the 2018 season, IRDs made 55 general sécurité broadcasts and 86 direct vessel callouts.

Satellite Reconnaissance

The 2018 Ice Season was the second year IIP incorporated OPCEN-analyzed satellite reconnaissance into its iceberg warning products. IIP continued to mainly use the European Space Agency's (ESA) Sentinel-1A and 1B satellites due to their consistent collection schedule, and open source, no-cost imagery available online in near real-time. IIP also used RADARSAT-2 satellite imagery throughout the season, but due to increased cost and competition associated with acquiring these frames, the opportunities for analysis were limited to a few days with planned coincident aerial reconnaissance.

Building upon lessons learned in 2017, IIP shifted focus of satellite reconnaissance to the southern portion of the OPAREA. Despite the higher volume of small, non-AIS transmitting vessel traffic, IIP made the strategic decision to analyze satellite frames outside the sea ice edge. Additionally, shifting emphasis from satellite CONOPS region A (IIP, 2016) provided greater opportunity for aerial reconnaissance coincident with satellite passes. To improve the processes and techniques used, and increase number of frames analyzed, IIP created a dedicated Satellite Day Worker (SDW) position to download, process and analyze multiple Sentinel-1 or RADARSAT-2 frames each work day. Additional details regarding IIP's modernization to space-borne reconnaissance can be found in **Appendix C**.

During the 2018 Ice Season, the OPCEN processed 361 SIMs resulting in 2,391 icebergs incorporated into BAPS. The newly established SDW resulted in a threefold increase in frames analyzed in-house, from 102 in 2017 to 305 in 2018. These efforts resulted in 925 iceberg re-sighted and 348 icebergs added to the model. Refer to the Operations Center Summary section of this report for a detailed breakdown of satellite SIM sources and number of modeled icebergs.

Five of the 305 satellite frames analyzed by IIP were acquired from Canadian C-Band SAR satellite system (RADARSAT-2) images. These were obtained in the 2018 Ice Season through IIP's partnership with NIC under the Northern View arrangement between NGA and Canada's Department of National Defense. Having a dedicated person at USNIC to manage RADARSAT-2 ordering requests continued to prove invaluable toward the smooth collection of data. IIP intended to use RADARSAT-2 imagery for validation purposes, and requested imagery coinciding with planned aerial reconnaissance; and scheduled Sentinel-1 passes to maximize validation efforts. However, due to weather and operational priorities, only three passes received aerial reconnaissance validation. These SIMs yielded 17 re-sights within the iceberg model.

Commemorative Wreath Deployments

Each year, IIP deploys commemorative wreaths in conjunction with reconnaissance operations to remember the lives lost at sea in the North Atlantic Ocean. This year, IIP held two memorial

Figure 4-7. Titanic memorial wreaths before being deployed into the North Atlantic Ocean. These wreathes were dedicated at ceremonies in New London, CT and Halifax, NS to remember the lives lost during the tragic sinking of RMS Titanic.

services and wreath dedication ceremonies to commemorate the 106th anniversary of the sinking of RMS TITANIC. The first ceremony was held at IIP's office in New London, CT on the morning of 04 April. The second ceremony was held later that day at Fairview Lawn Cemetery in Halifax, NS. The cemetery is the final resting place for 120 victims of RMS TITANIC sinking. All three wreaths dedicated during the ceremonies were deployed from an HC-130J aircraft on 06 April (**Figure 4-7**). The wreaths were donated and dedicated to the victims of RMS TITANIC by the Titanic Society of Atlantic Canada, Ms. Monica Adorno, and Dr. Warren Ervine. Dr. Ervine dedicated the wreath in memory of his family member, RMS TITANIC engineer and victim, Albert G. Ervine.

On 11 June, IIP held a memorial ceremony at the Coast Guard Museum at the U.S. Coast Guard Academy in New London, CT commemorating the sacrifices of those serving as part of the Greenland Patrol during World War II. The wreath dedicated at the memorial service was deployed in the North Atlantic from an HC-130J aircraft on 02 July (**Figure 4-8**). The wreath was donated by the Bridgeport Council of the Navy League.

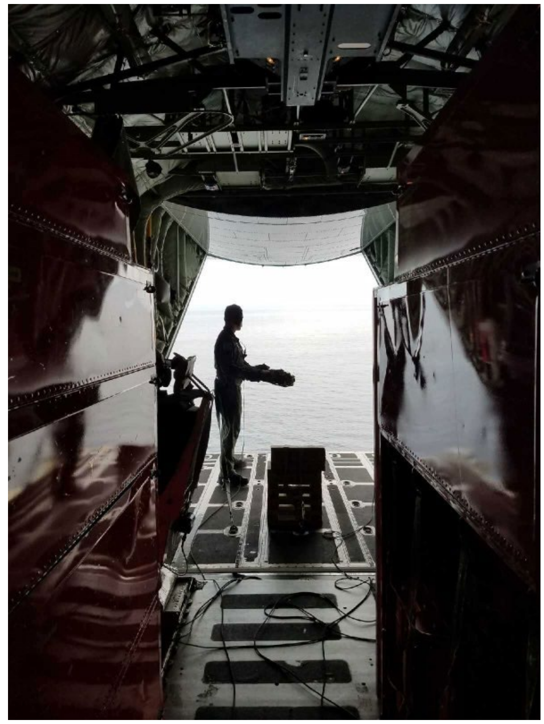


Figure 4-8. Petty Officer Menard preparing to deploy a dedicated wreath in the North Atlantic Ocean in remembrance of the Coast Guard Greenland Patrol operations in World War II.

5. Abbreviations and Acronyms

AIS	Automatic Identification System
APN-241	HC-130J Tactical Transport Weather Radar
ASEC	U. S. Coast Guard Air Station Elizabeth City
AVHRR	Advanced Very High Resolution Radiometer
BAPS	iceBerg Analysis and Prediction System
C	Celsius
C-CORE	A not-for-profit research and engineering organization in St. John’s, Newfoundland
CG-5PW	U. S. Coast Guard Director of Marine Transportation Systems
CCGS	Canadian Coast Guard Ship
CFAR	Constant False Alarm Rate
CIIP	Commander, International Ice Patrol
CIS	Canadian Ice Service, an operational unit of the Meteorological Service of Canada
CONOPS	Concept of Operations
Cosmo SkyMed	Italian X-Band Satellite System
CT	Connecticut
DHS S&T	Department of Homeland Security’s Science and Technology directorate
DMI	Danish Meteorological Institute
DWS	Duty Watch Stander
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
Envisat	European Space Agency C-Band SAR satellite system, inactive
EOSDIS	Earth Observing System Data and Information System
ERMA	Environmental Response Management Application, NOAA
ESA	European Space Agency, owner of the Sentinel 1A and 1B satellites
ESRL	Earth Systems Research Laboratory, Boulder, Colorado
GHRSST	Group for High Resolution Sea Surface Temperature
HH	Single Polarization Horizontal

HV	Cross Channel Polarization Horizontal
HC-130J	U. S. Coast Guard Long Range Surveillance Maritime Patrol Aircraft
IDS	Iceberg Detection Software
IIP	U. S. Coast Guard International Ice Patrol
IRD	Ice Reconnaissance Detachment
IS	Intelligence Specialist
ISAR	Inverse Synthetic Aperture Radar
km	kilometer
KML	Keyhole Markup Language
LAKI	Limit of All Known Ice
M/V	Motor Vessel
MANICE	Manual of Standard Procedures for Observing and Reporting Ice Conditions
m	meter
mb	millibar
MCTS	Marine Communications and Traffic Service, Canadian Coast Guard
MIFC LANT	U. S. Coast Guard Maritime Intelligence Fusion Center Atlantic Area
MMS	Minotaur Mission System
MSCOE	Modeling and Simulation Center of Excellence
MST	Marine Science Technician
N	North Latitude
NC	North Carolina
NAIS	North American Ice Service
NAIS-10	Iceberg Limit Bulletin
NAIS-65	Iceberg Limit Graphic
NASA	U. S. National Aeronautics and Space Administration
NASA JPL	NASA’s Jet Propulsion Lab
NAOI	North Atlantic Oscillation Index
NAVAREA	Navigational Area
NAVCEN	U. S. Coast Guard Navigation Center
NAVTEX	Navigational Telex
NGA	U. S. National Geospatial-Intelligence Agency
NL	Newfoundland and Labrador, Canada

NM	Nautical Mile
NOAA	U. S. National Oceanographic and Atmospheric Administration
NOTSHIP	Notice to Shipping
NS	Nova Scotia, Canada
NSSI	Normalized Season Severity Index
NWS	U. S. National Weather Service
OPAREA	Operational Area
OPC	Ocean Prediction Center
OPCEN	Operations Center
PAL Aerospace	Commercial aerial reconnaissance provider based in St. John's, Newfoundland.
POD	Probability of Detection
RADARSAT-1	Canadian C-Band SAR satellite system, inactive
RADARSAT-2	Canadian C-Band SAR satellite system, owned and operated by MacDonald, Dettwiler, and Associates.
Radiofax	Radio facsimile
RMS	Royal Mail Steamer
RSS	Remote Sensing Systems – Scientific Research Company
SafetyNET	Inmarsat-C Safety Net, automated satellite system for promulgating marine navigational warnings, weather, and other safety information.
SAR	Synthetic Aperture Radar
SDW	Satellite Day Worker
SN1	Sentinel-1 ESA C-Band SAR satellite system (A and B)
SIM	Standard Iceberg Message
SITOR	Simplex Teletype Over Radio
SOLAS	Safety of Life at Sea
TerraSAR-X	German X-Band SAR satellite system
USCG	U. S. Coast Guard
USNIC	U. S. National Ice Center
VTS	Vessel Traffic Service
VV	Single Polarization Vertical
VH	Cross Channel Polarization Vertical

W	West Longitude
WWNWS	World Wide Navigational Warning System
YN	Yeoman
Z	Time Zone designator for Coordinated Universal Time

6. References

Canadian Ice Service. (2017a). Seasonal Outlook, Gulf of St. Lawrence, East Newfoundland Waters and Labrador Coast, Winter 2017-2018. Issued by Canadian Ice Service of Environment and Climate Change Canada, 01 December 2017.

Canadian Ice Service. (2017b). Sea Ice and Iceberg Seasonal Outlook 2017-2018. Presented at IIP Annual Conference on 14 December 2017.

Canadian Ice Service. (2018a). Single Season: Weekly Ice Coverage for the season 2017/2018. Created with CIS IceGraph program on 22 October 2018: http://iceweb1.cis.ec.gc.ca/IceGraph/page1.xhtml?lang=en

Canadian Ice Service. (2018b). "Seasonal Summary for Eastern Canada – Winter 2017-2018." By the Canadian Ice Service of Environment and Climate Change Canada.

Canadian Ice Service. (2018c). Departure from Normal Concentration Chart for 06 January 2018. Retrieved on 09 January 2018 from: http://www.ec.gc.ca/glaces-ice/default.asp

Canadian Ice Service. (2018d). CIS Ice Charts of East Newfoundland Waters. Retrieved 22 October 2018 from: http://iceweb1.cis.ec.gc.ca/Archive/?lang=en

Hurrell, James & National Center for Atmospheric Research Staff (Eds). Last modified 04 Aug 2018. "The Climate Data Guide: Hurrell North Atlantic Oscillation (NAO) Index (station-based)." Retrieved from: https://climatedataguide.ucar.edu/climate-data/hurrell-north-atlantic-oscillation-nao-index-station-based.

IIP. (1994). Report of the International Ice Patrol in the North Atlantic (1994 Season), Bulletin No. 80, Appendix C.

IIP. (2016). Report of the International Ice Patrol in the North Atlantic (2016 Season), Bulletin No. 102, Appendix B.

IIP. (2017). Report of the International Ice Patrol in the North Atlantic (2017 Season), Bulletin No. 103.

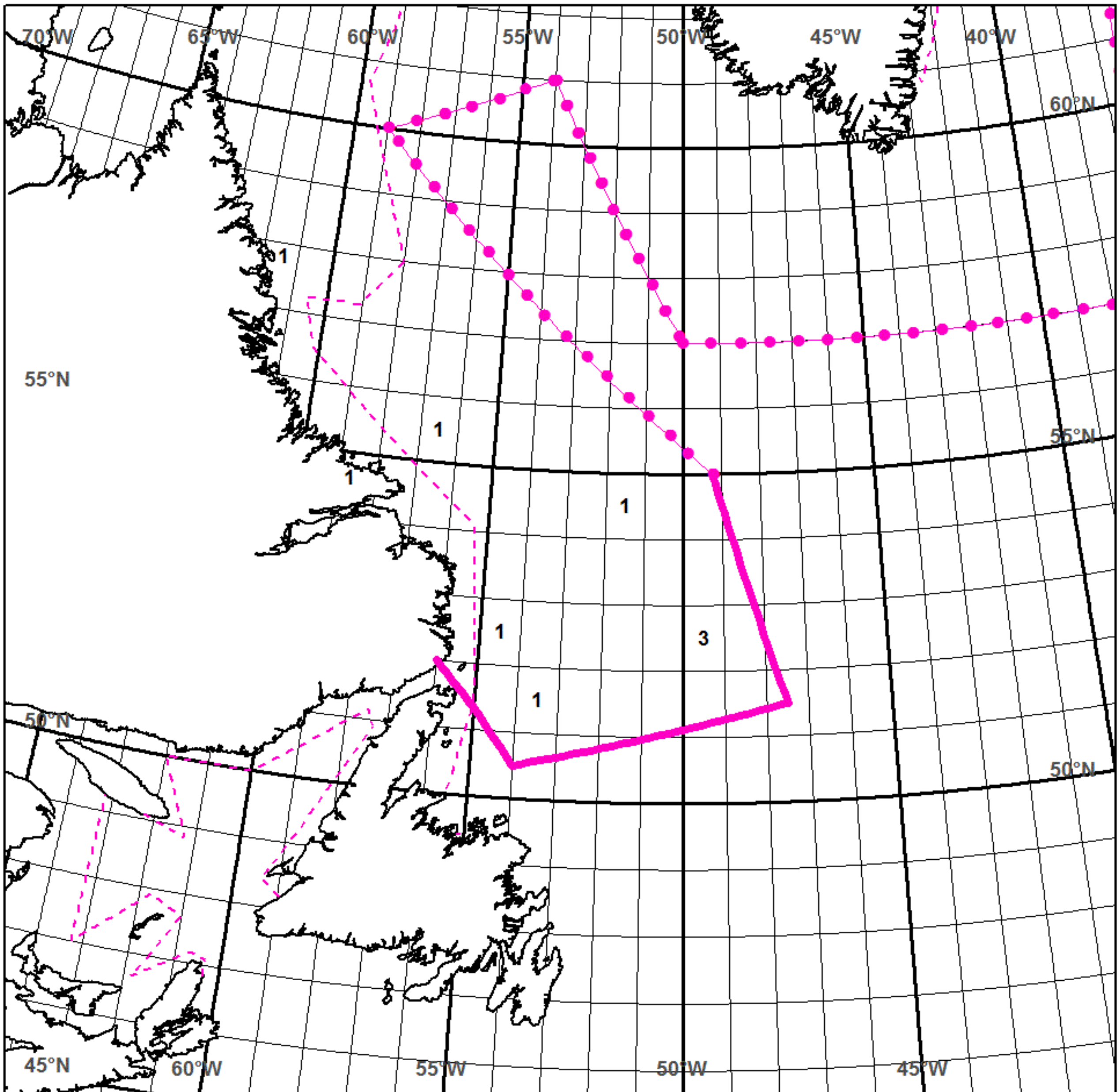
National Oceanic and Atmospheric Administration/National Weather Service. (2018a). Climate Prediction Center, Global Temperature Time Series. Retrieved 02 November 2018 from: http://www.cpc.ncep.noaa.gov/products/global_monitoring/temperature/ecanada_1yrtemp.shtml

National Oceanic and Atmospheric Administration/National Weather Service. (2018b). Climate Prediction Center, Daily NAO Index. Retrieved 04 May 2018 from: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_index.html

National Oceanic and Atmospheric Administration/Earth Systems Research Laboratory. (2018). Physical Science Division. Sea Level Pressure, Monthly Mean Composite. Interactive Plotting and Analysis Pages. Retrieved 22 October 2018 from: http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/plot20thc.v2.pl

Remote Sensing Systems. 2017. GHRSST Level 4 MW_IR_OI Global Foundation Sea Surface Temperature analysis version 5.0 from REMSS. Ver. 5.0. PO.DAAC, CA, USA. Dataset accessed 04 December 2018 at http://dx.doi.org/10.5067/GHMWI-4FR05.

7. Semi-Monthly Iceberg Charts



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 JAN 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

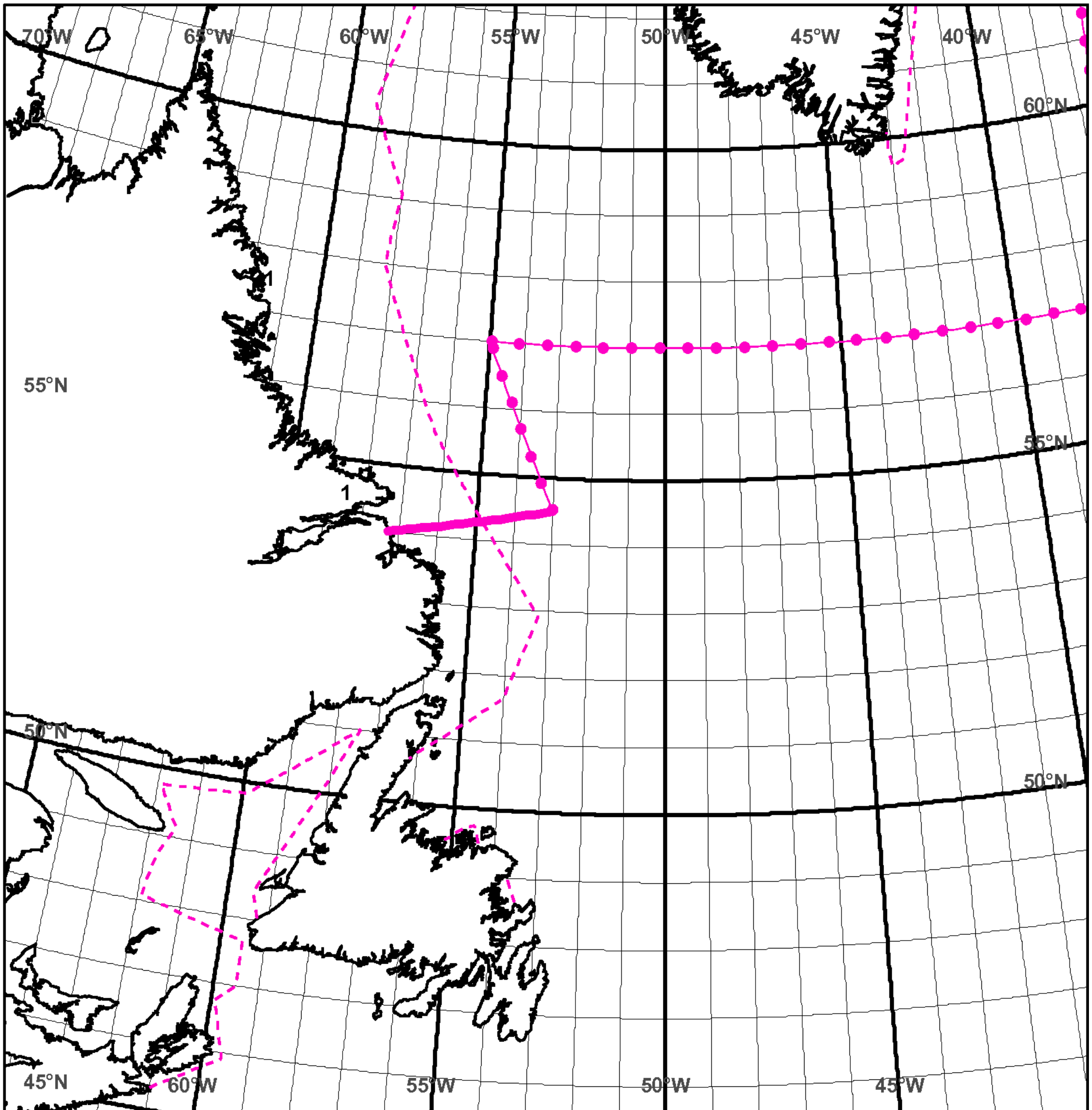
SEA ICE LIMIT

\# ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Southern Limit Iceberg Flight 19DEC17.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 JAN 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

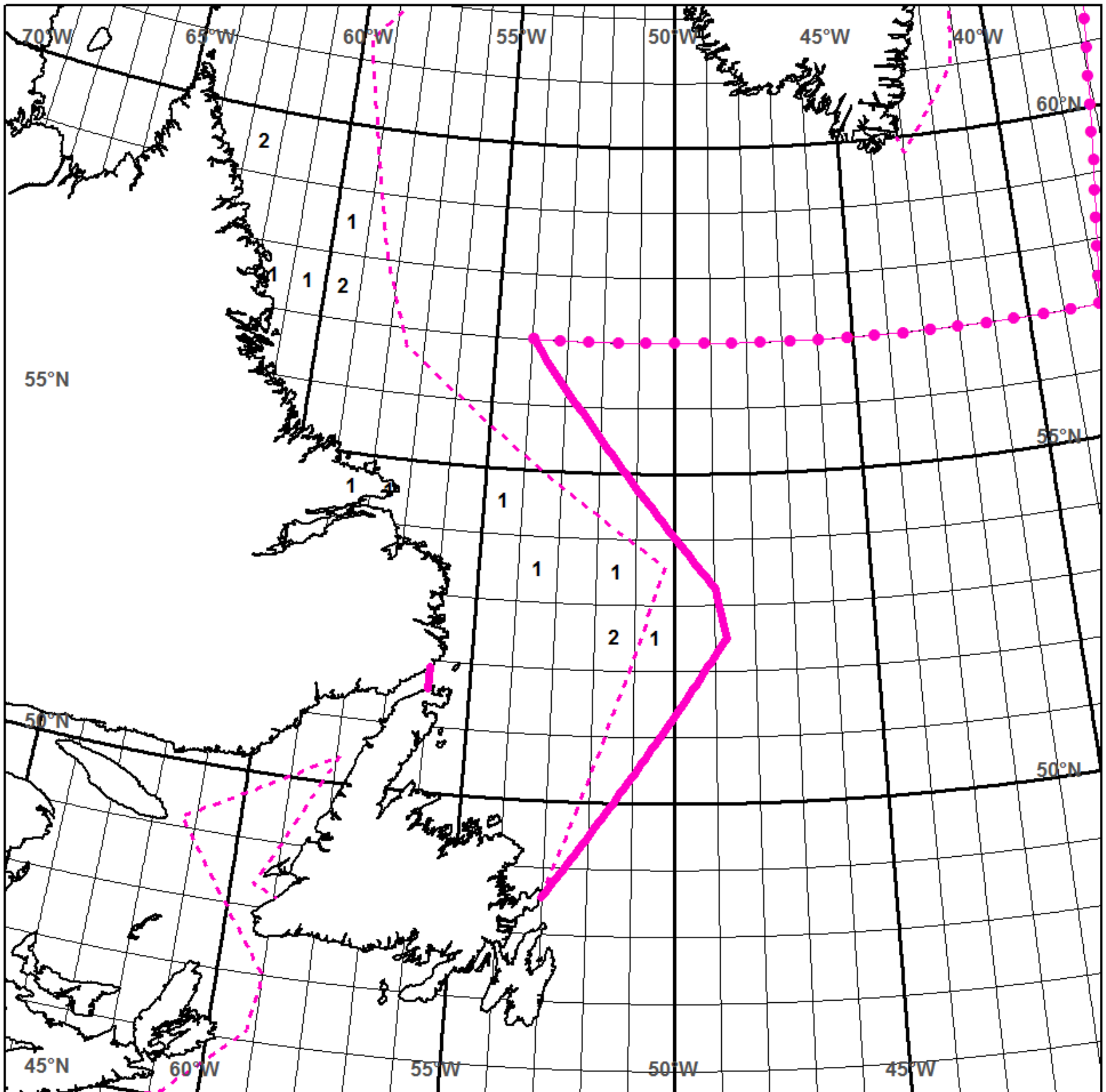
SEA ICE LIMIT

ICEBERGS PER DEGREE SQUARE

⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Southern Limit Iceberg Flight 04JAN18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 FEB 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

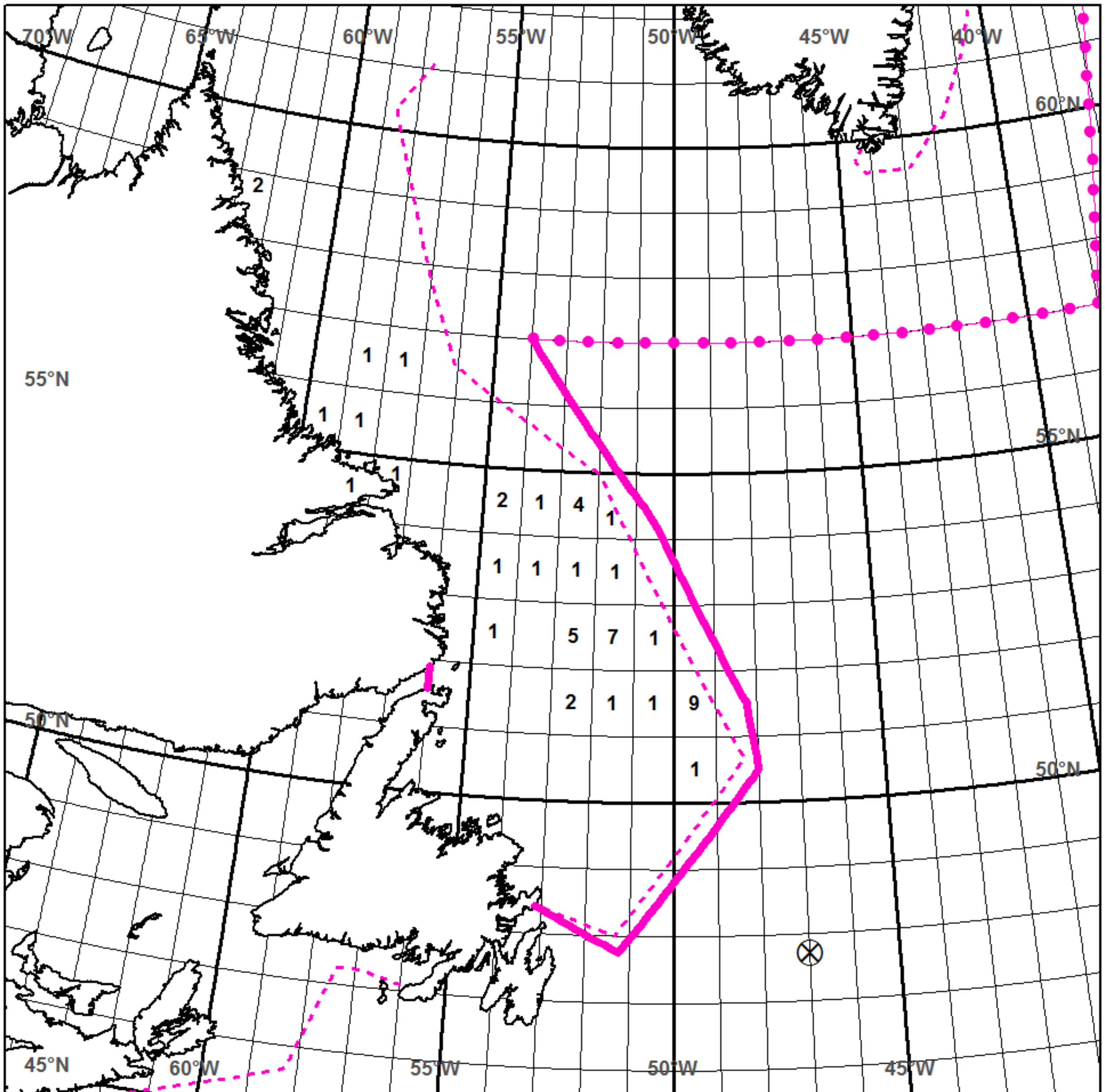
SEA ICE LIMIT

\# ICEBERGS PER DEGREE SQUARE

⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Interior Iceberg Flight 29JAN18.

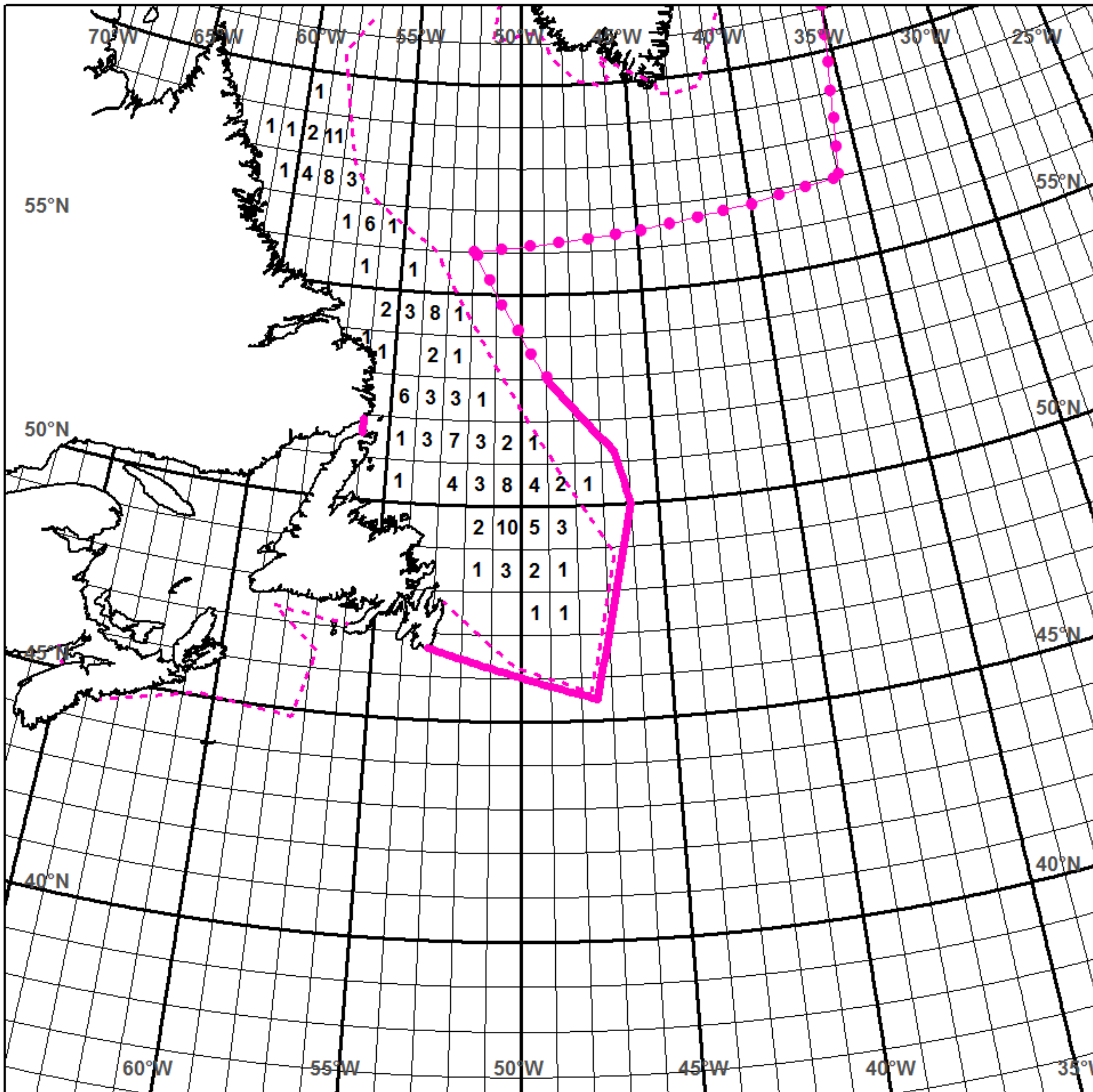


NORTH AMERICAN ICE SERVICE
(NAIS)

ICEBERG ANALYSIS FOR 0000 UTC
15 FEB 2018

ESTIMATED ICEBERG LIMIT
ICEBERG LIMIT
SEA ICE LIMIT
ICEBERGS PER DEGREE SQUARE
⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:
For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Interior Iceberg Flight 13FEB18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 MAR 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

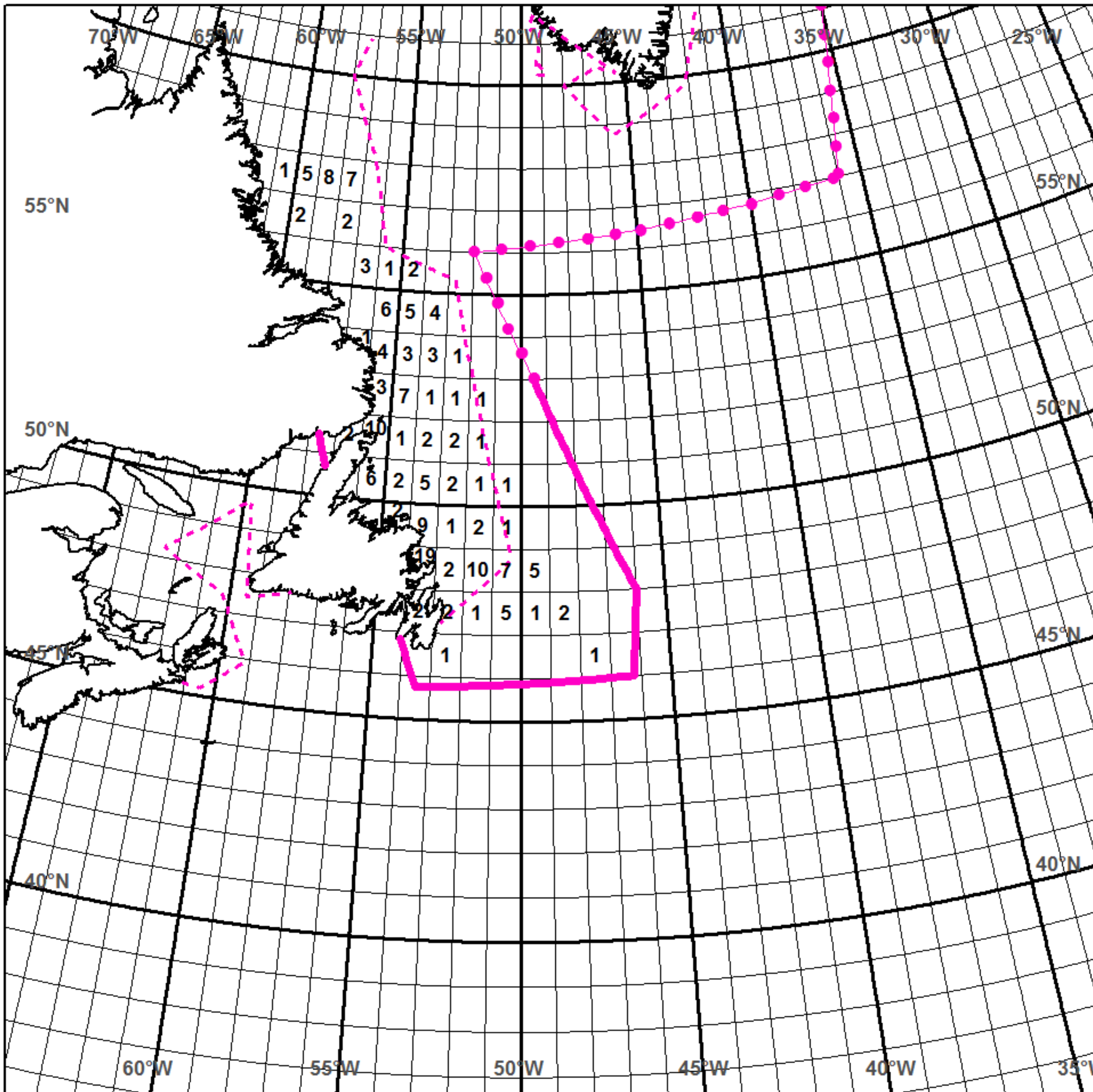
SEA ICE LIMIT

ICEBERGS PER DEGREE SQUARE

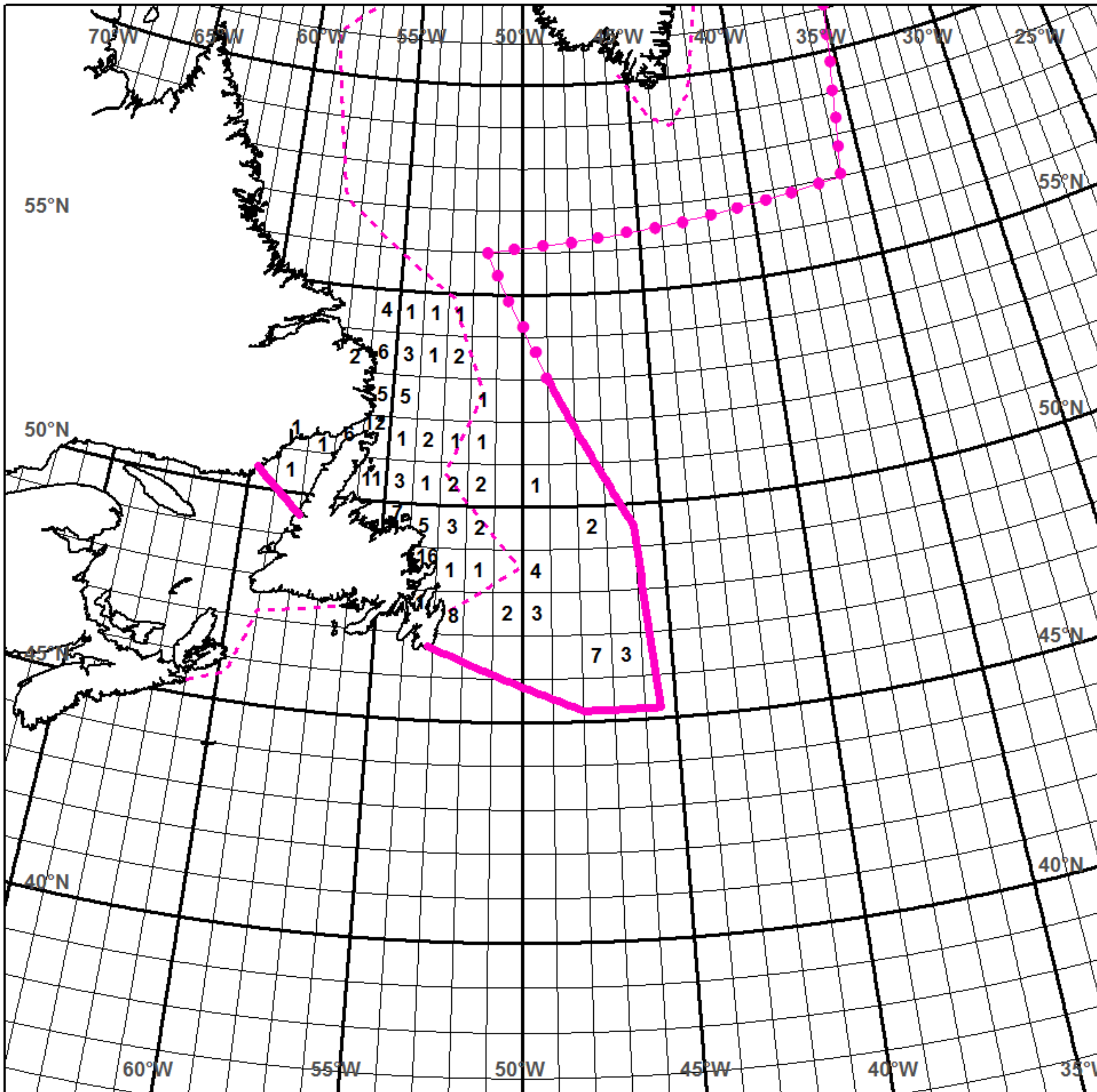
RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Interior General Flight 26FEB18.



NORTH AMERICAN ICE SERVICE (NAIS)	ICEBERG ANALYSIS FOR 0000 UTC **15 MAR 2018**
ESTIMATED ICEBERG LIMIT ICEBERG LIMIT SEA ICE LIMIT # ICEBERGS PER DEGREE SQUARE ⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT	**NOTE:** **For more information:** **www.navcen.uscg.gov/iip** **www.ice-glaces.ec.gc.ca** **Most Recent Reconnaissance:** **Western Limit Iceberg Flight 13MAR18.**



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 APR 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

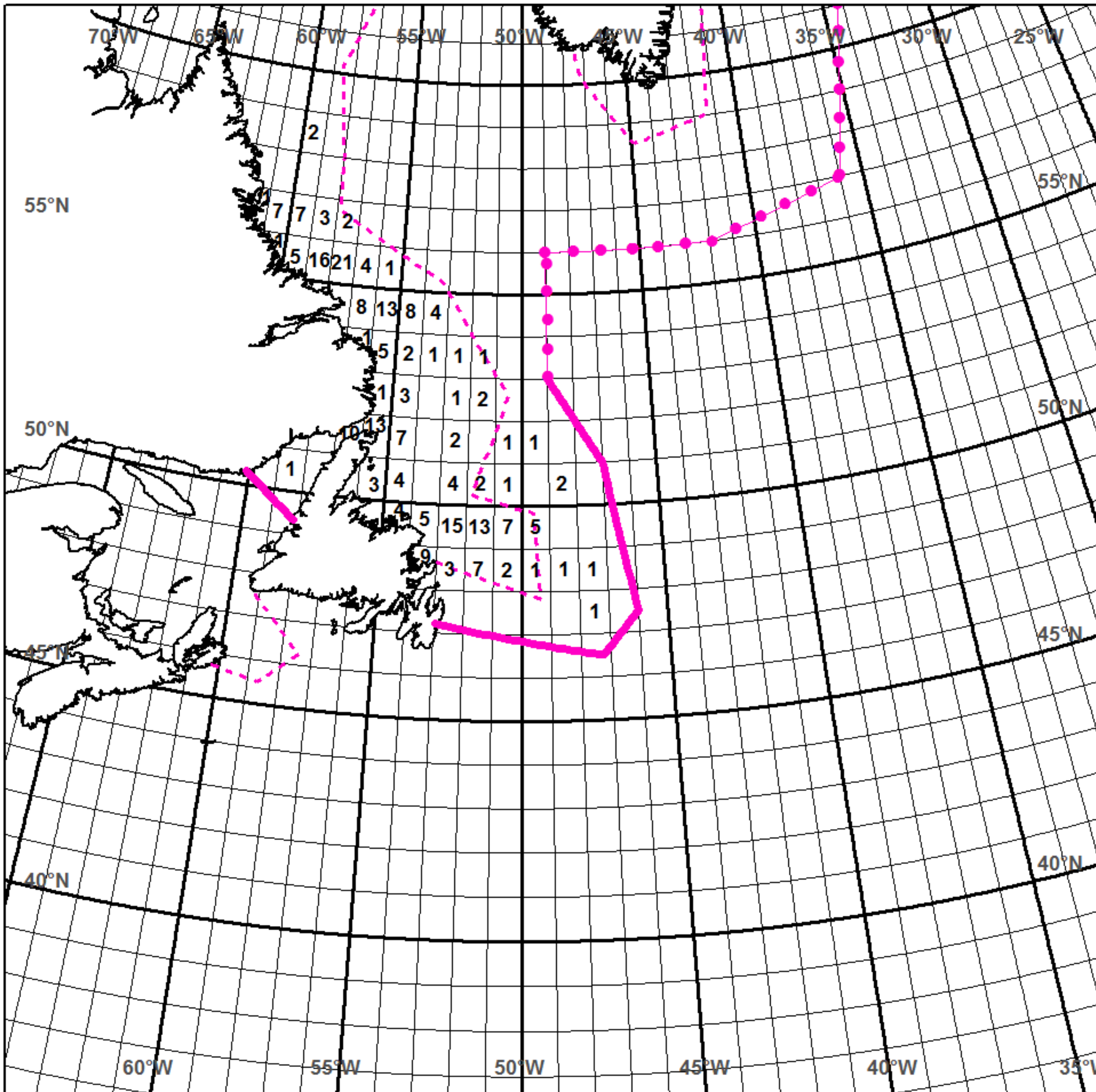
SEA ICE LIMIT

ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Interior Iceberg Flight 30MAR17.
Icebergs are likely present off of the Labrador Coast north of 55N, however, no numbers are charted due to limited reconnaissance.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

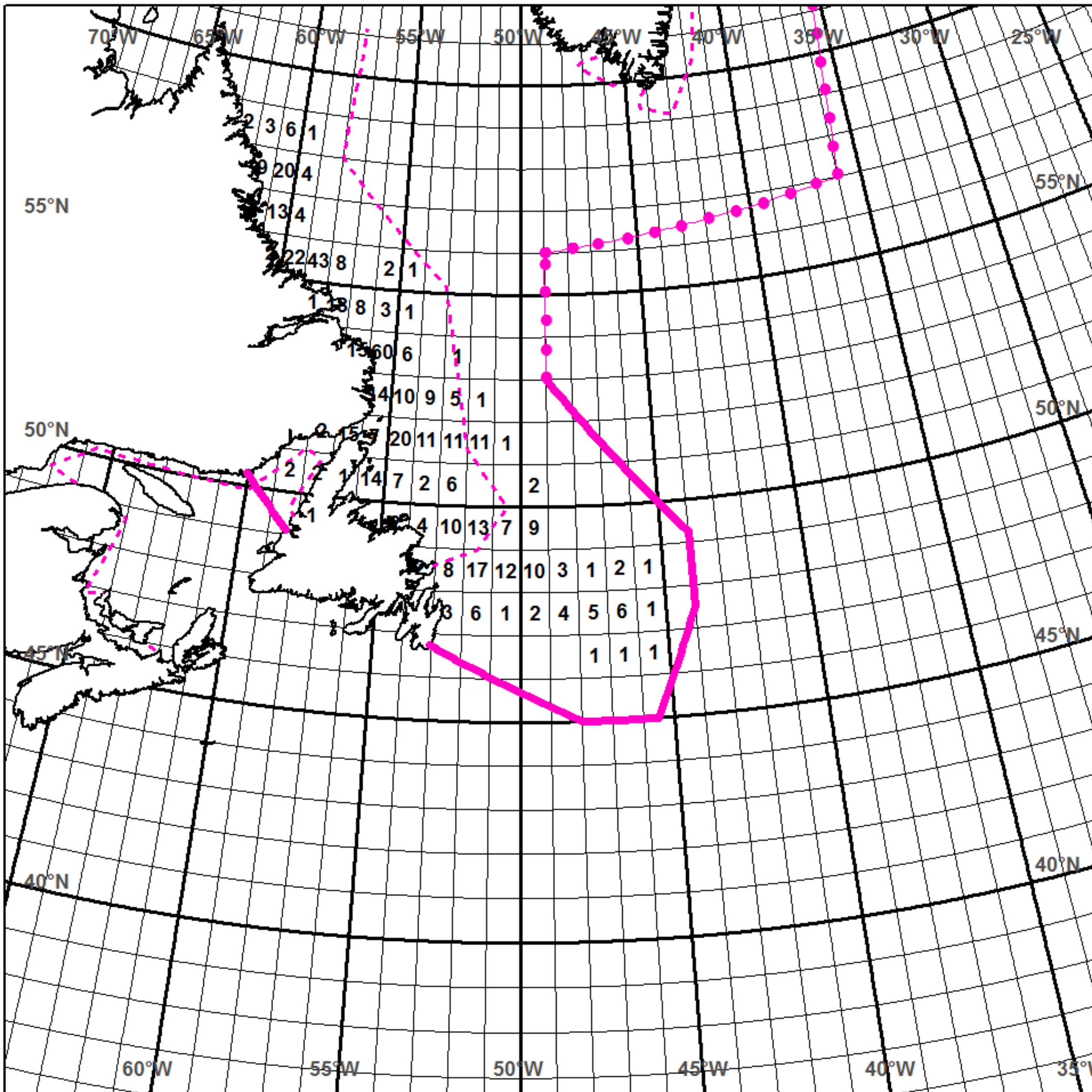
15 APR 2018

- ESTIMATED ICEBERG LIMIT
- ICEBERG LIMIT
- SEA ICE LIMIT
- # ICEBERGS PER DEGREE SQUARE
- ⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

Today we commemorate the 106th anniversary of the sinking of the RMS Titanic.

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Eastern Limit Iceberg Flight 11APR18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 MAY 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

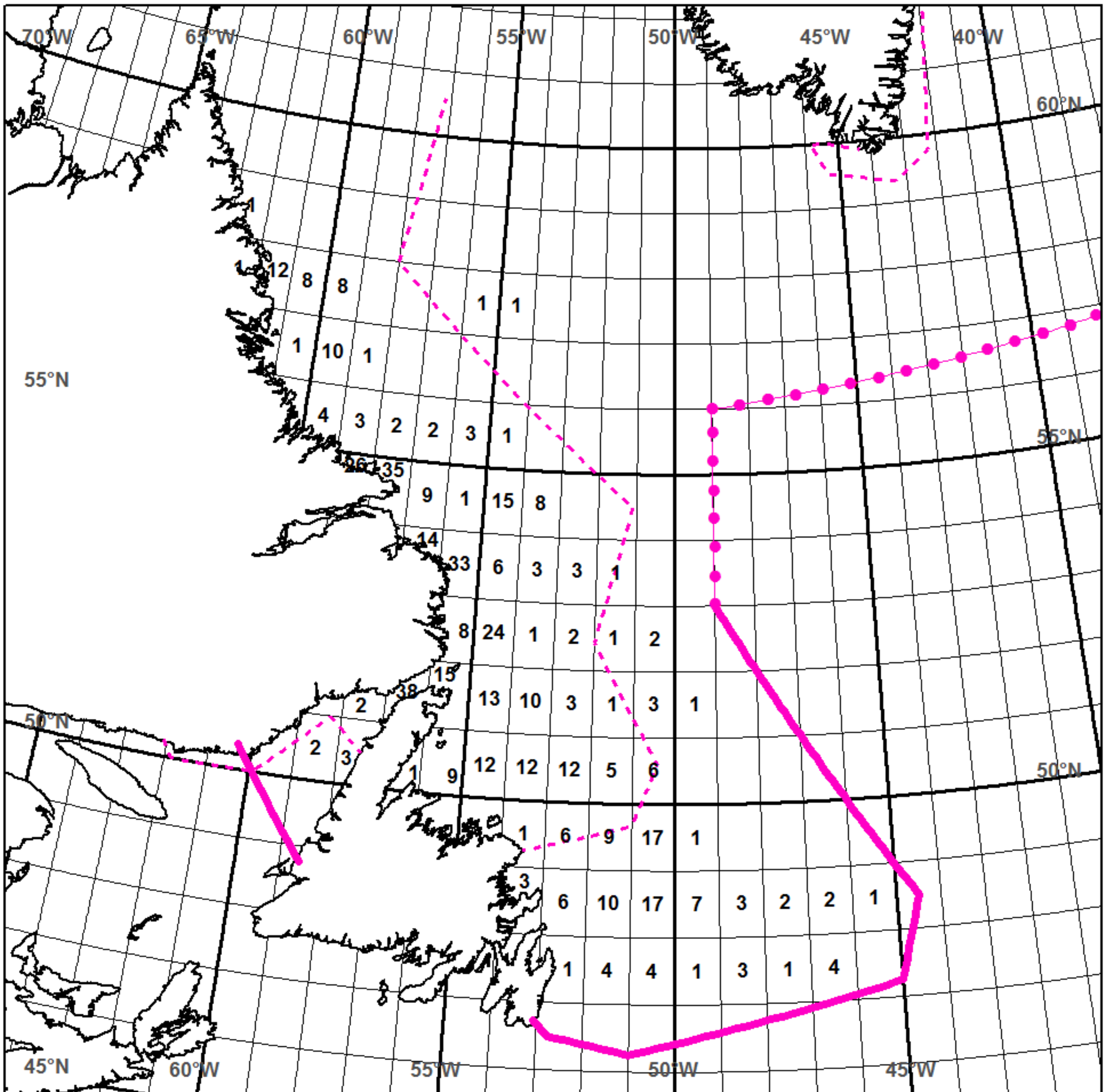
SEA ICE LIMIT

ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Eastern Limit Iceberg Flight 25APR18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 MAY 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

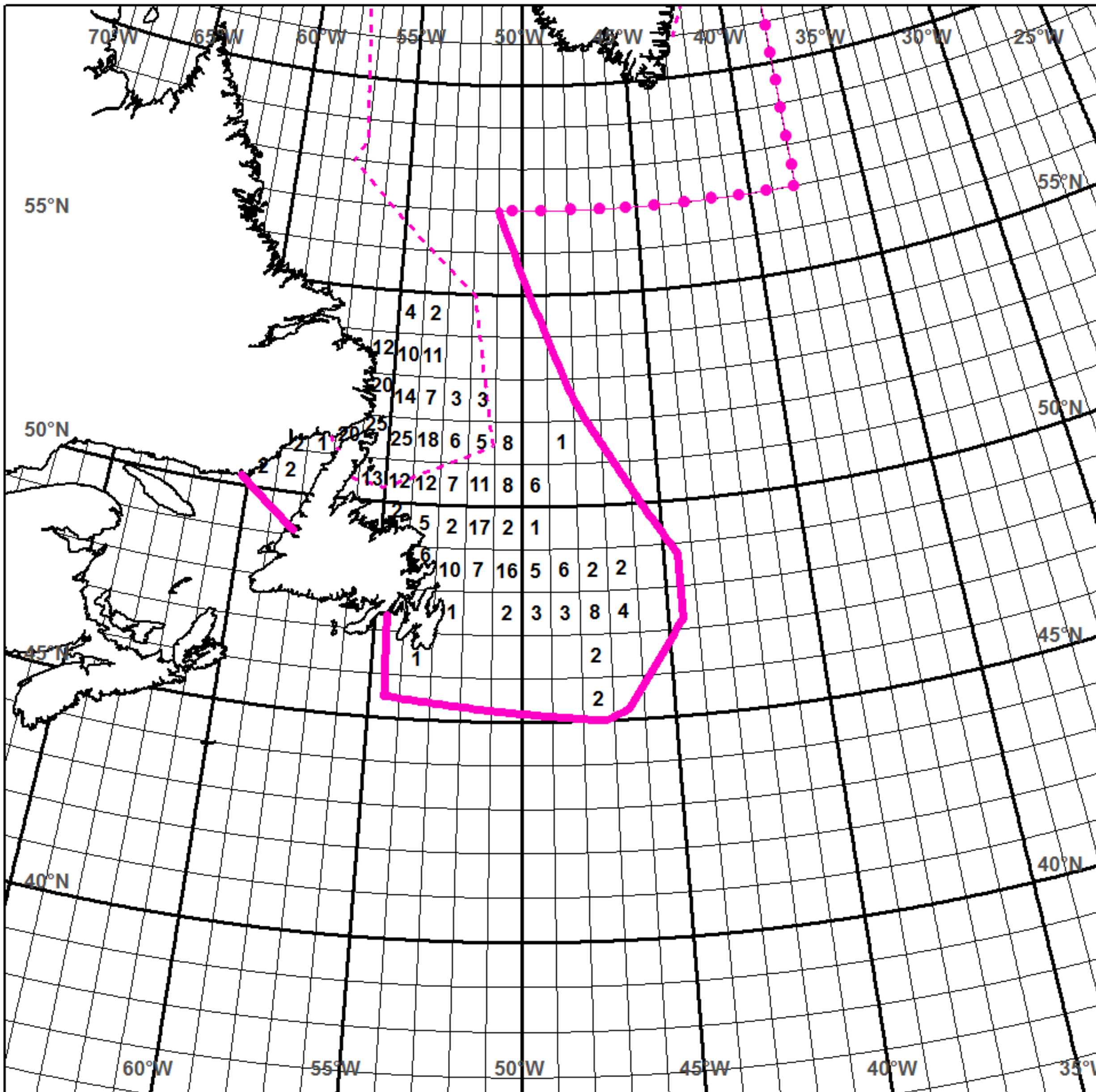
SEA ICE LIMIT

\# ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Southeastern Limit Iceberg Flight 09MAY18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

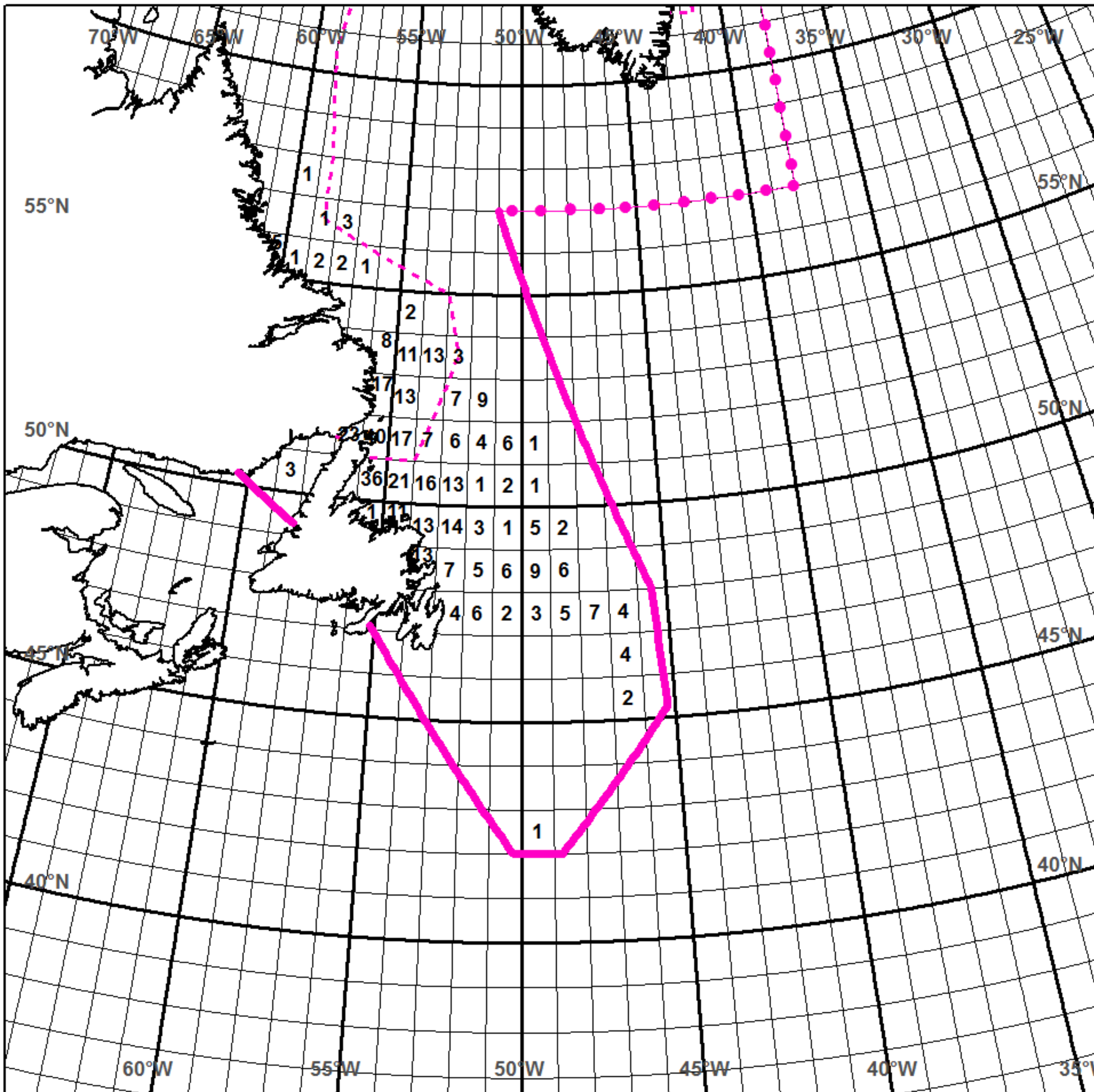
01 JUN 2018

ESTIMATED ICEBERG LIMIT	
ICEBERG LIMIT	
SEA ICE LIMIT	
#	ICEBERGS PER DEGREE SQUARE
⊗	RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Interior General Flight 29MAY18.

Icebergs are likely present off the Labrador coast north of 55N, however, no numbers are charted due to limited reconnaissance.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 JUN 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

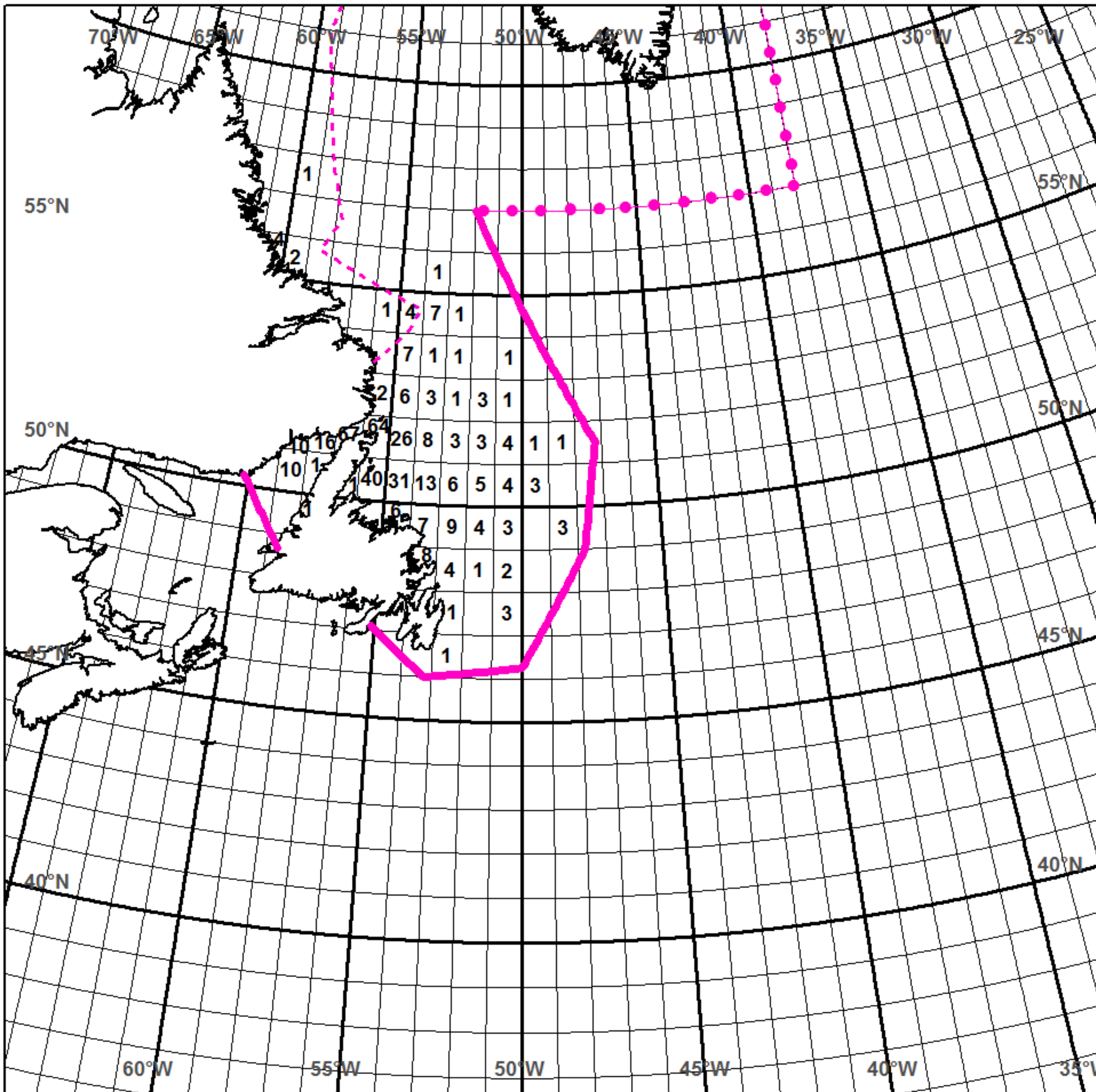
SEA ICE LIMIT

ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Southern Limit Iceberg Flight 07JUN18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 JUL 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

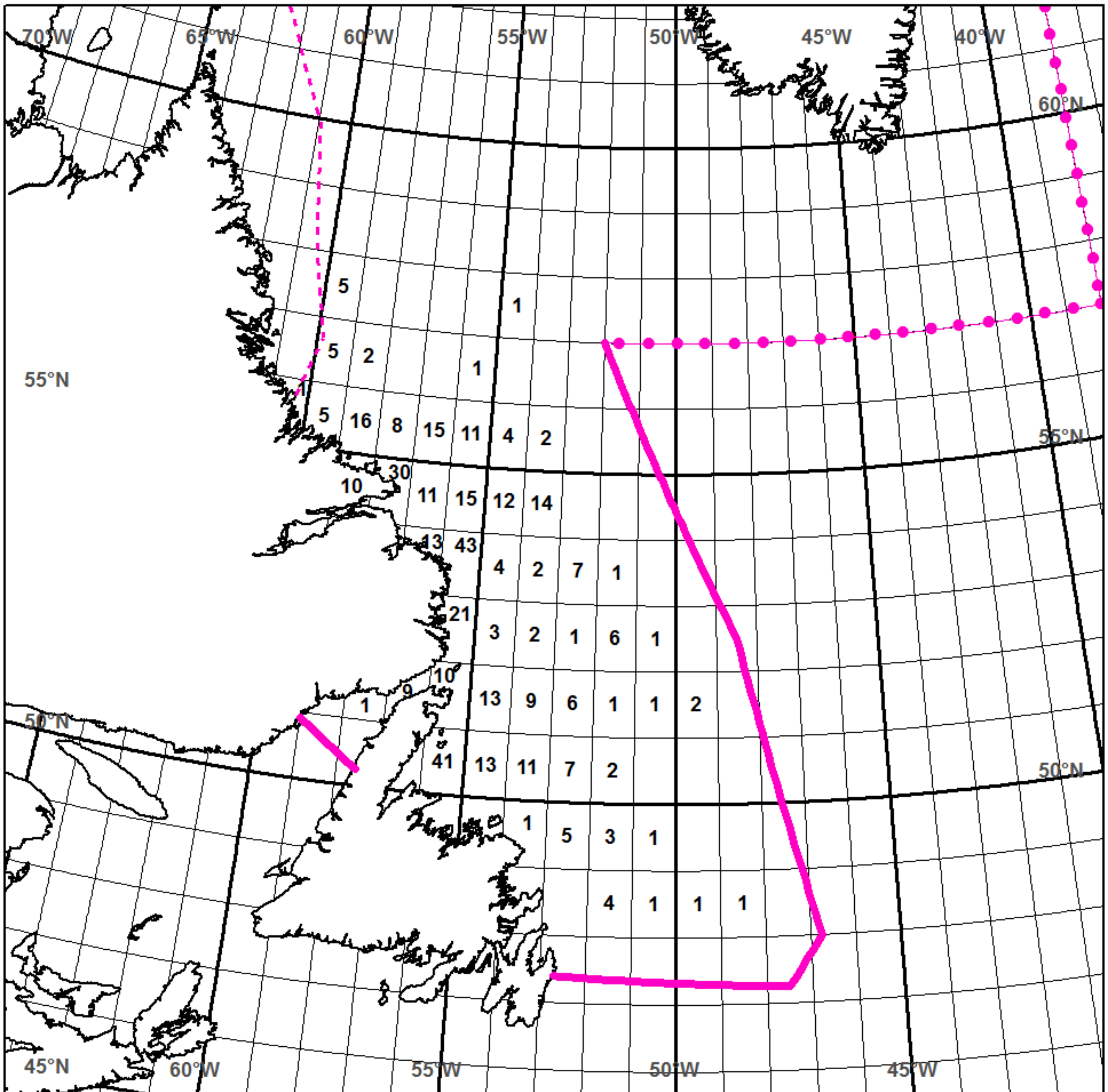
ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

Significant reduction of iceberg limit due to recent reconnaissance.

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Eastern Limit Iceberg Flight 29JUN18.



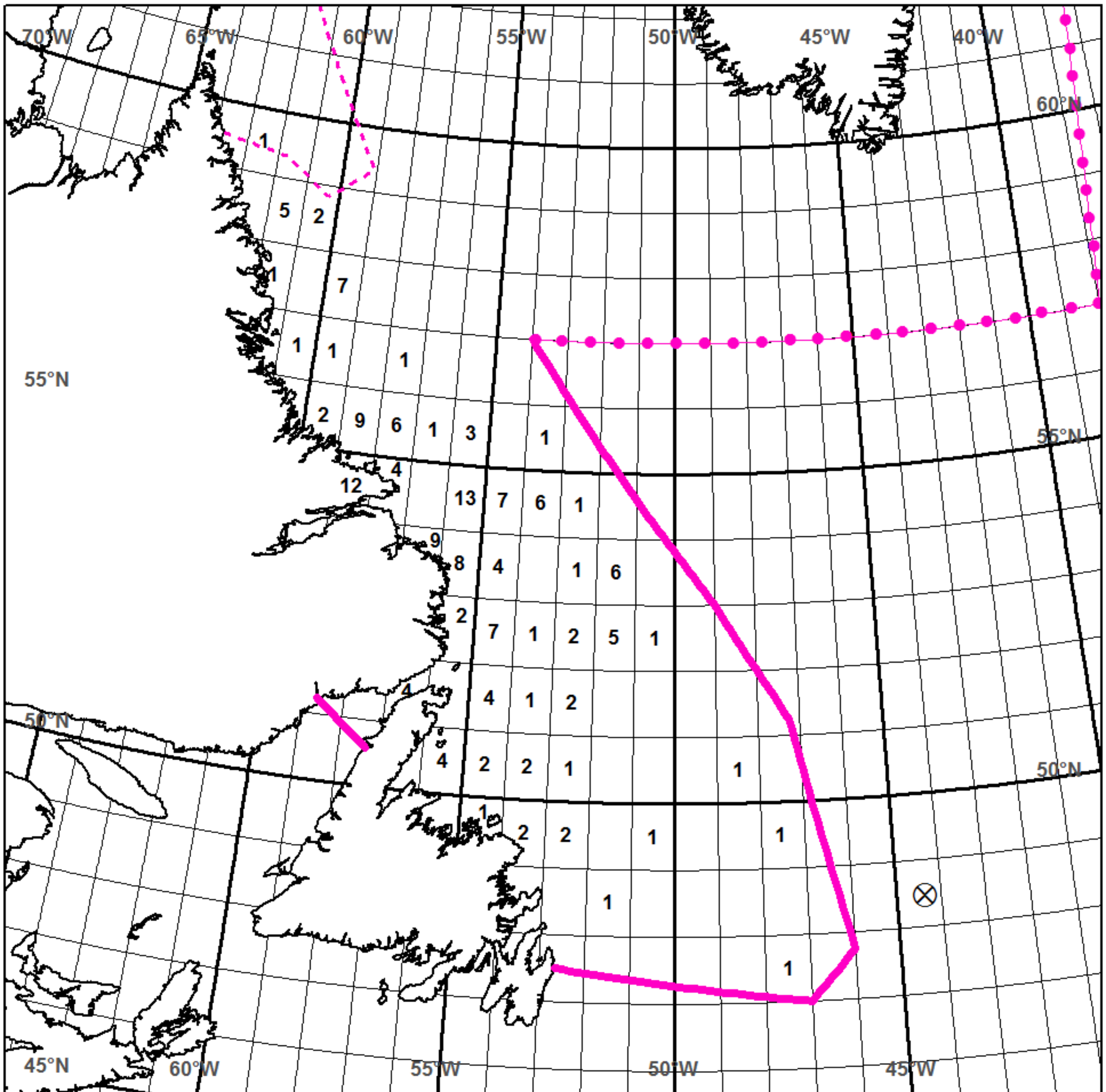
NORTH AMERICAN ICE SERVICE
(NAIS)

ICEBERG ANALYSIS FOR 0000 UTC
15 JUL 2018

ESTIMATED ICEBERG LIMIT	
ICEBERG LIMIT	
SEA ICE LIMIT	
# ICEBERGS PER DEGREE SQUARE	
RADAR TARGET OUTSIDE ICEBERG LIMIT	

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Eastern Limit Iceberg Flight 09JUL18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 AUG 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

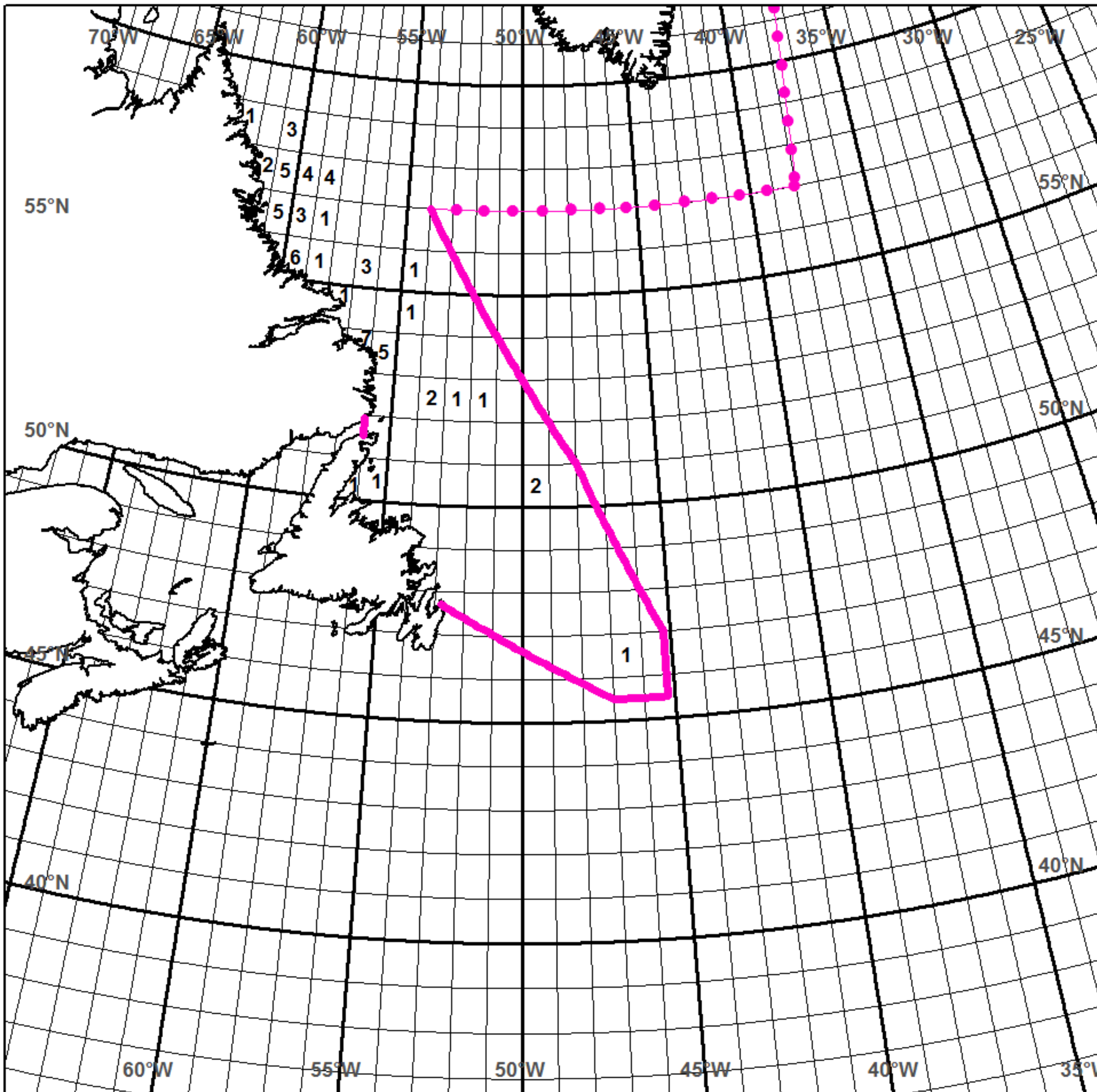
SEA ICE LIMIT

\# ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Interior General Flight 31JUL18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 AUG 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

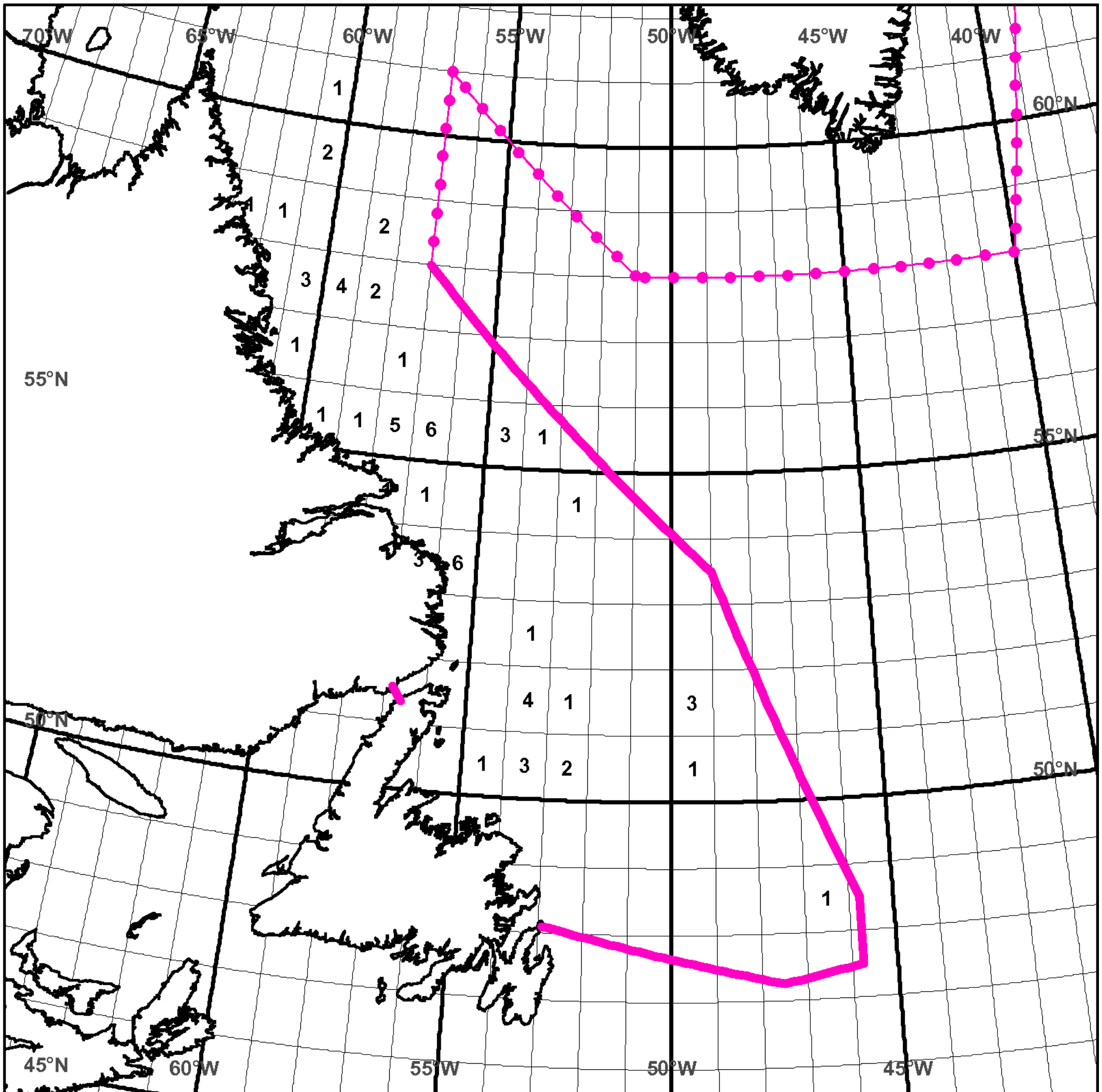
SEA ICE LIMIT

ICEBERGS PER DEGREE SQUARE

⊗ RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Eastern Limit Iceberg Flight 09AUG18.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 SEP 2018

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

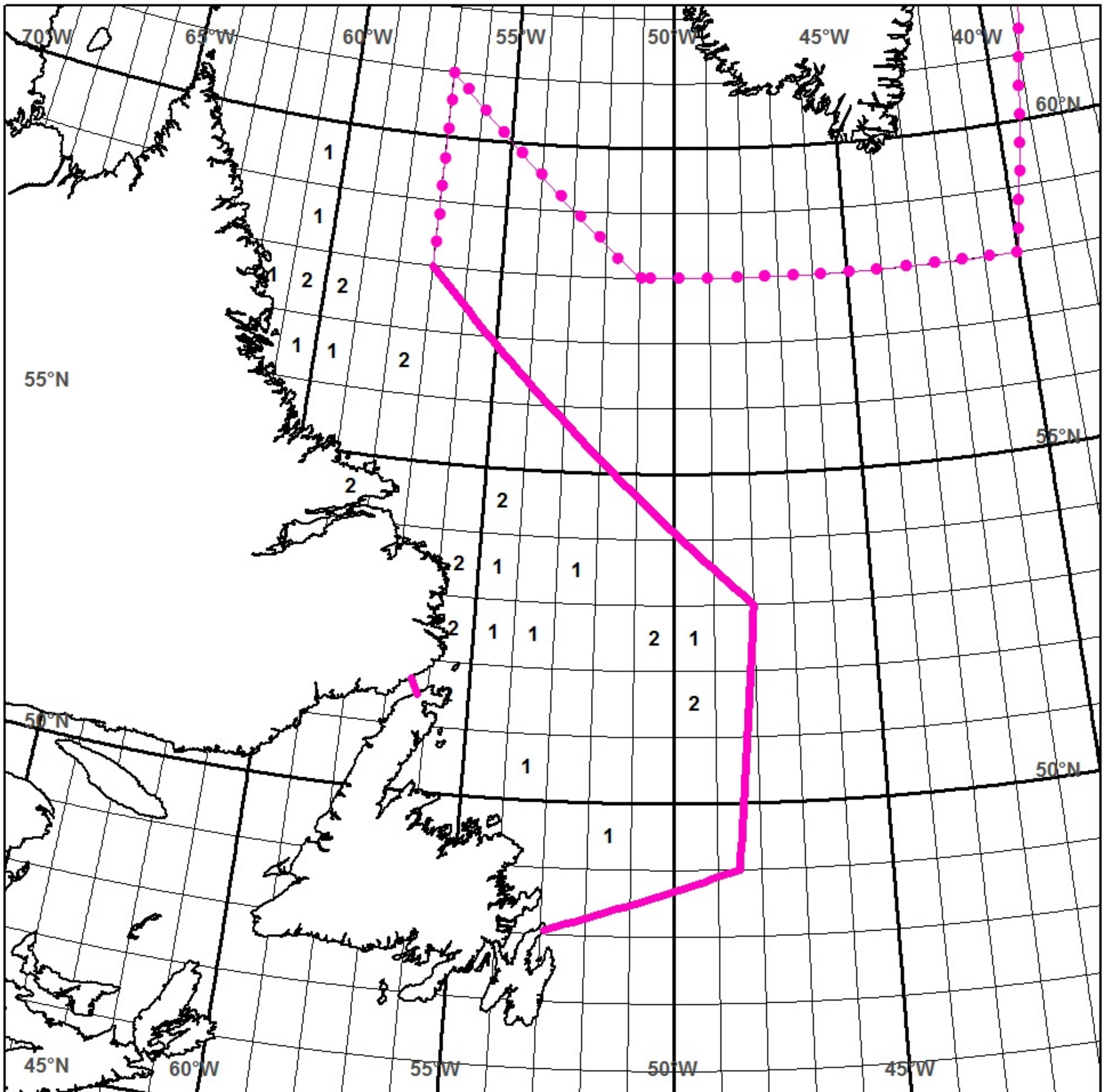
SEA ICE LIMIT

\# ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

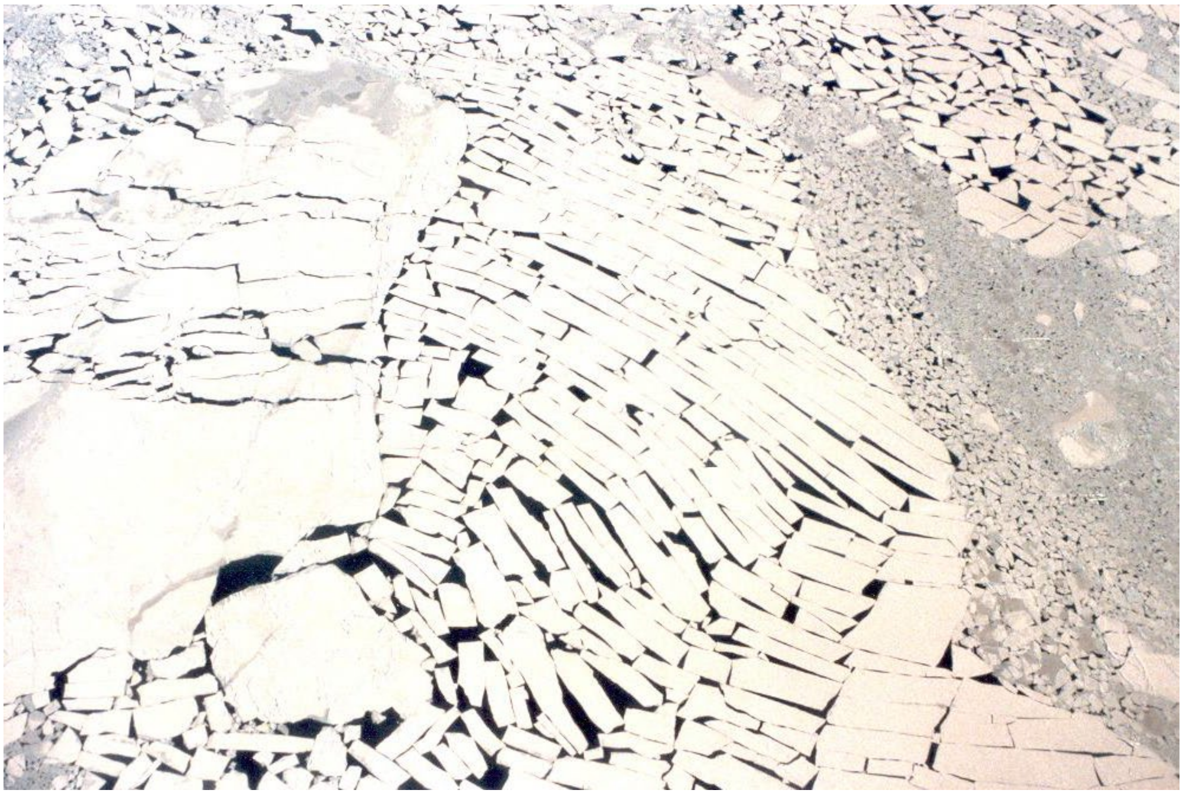
NOTE:

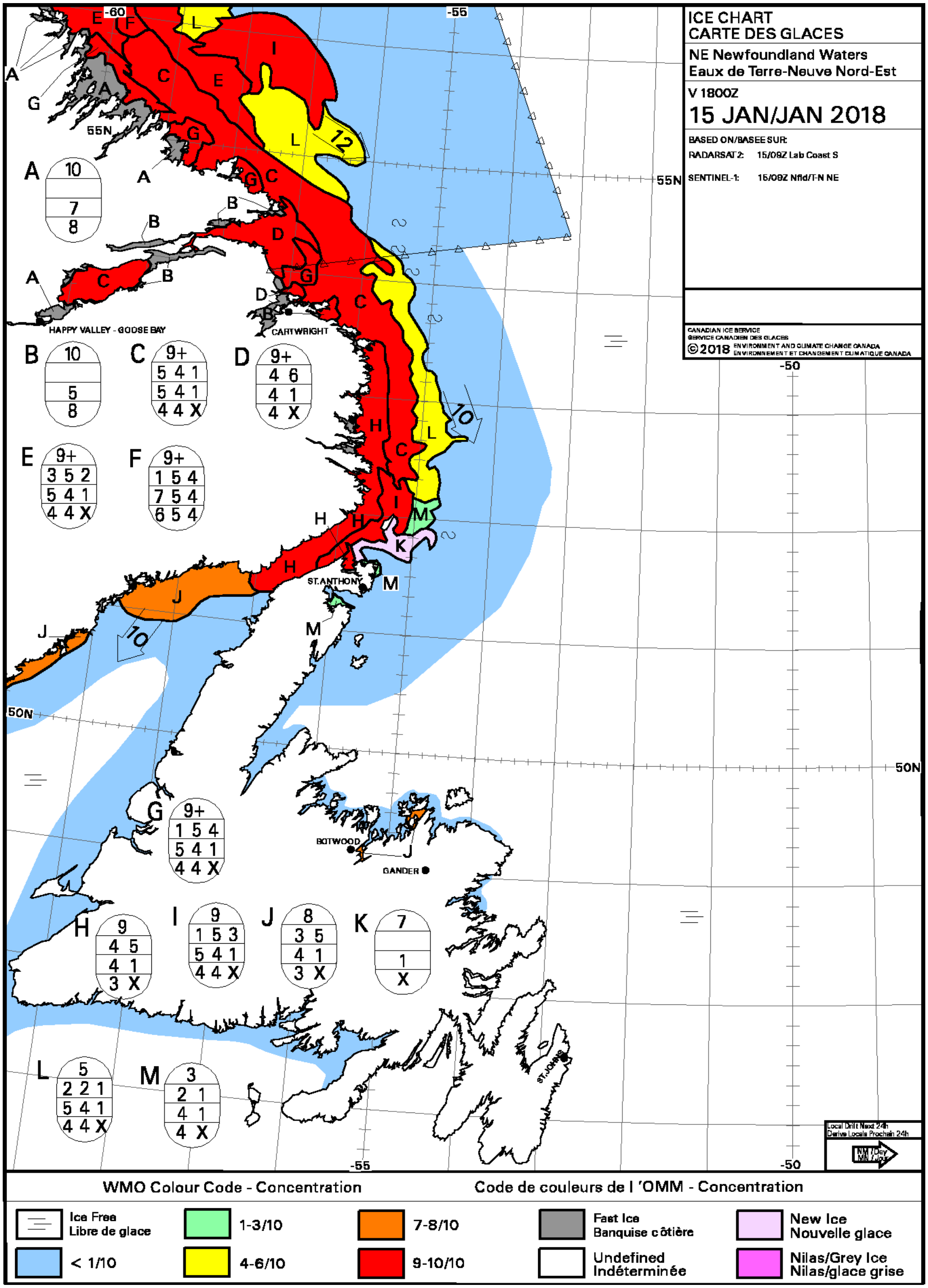
For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Interior Iceberg Flight 26AUG18.

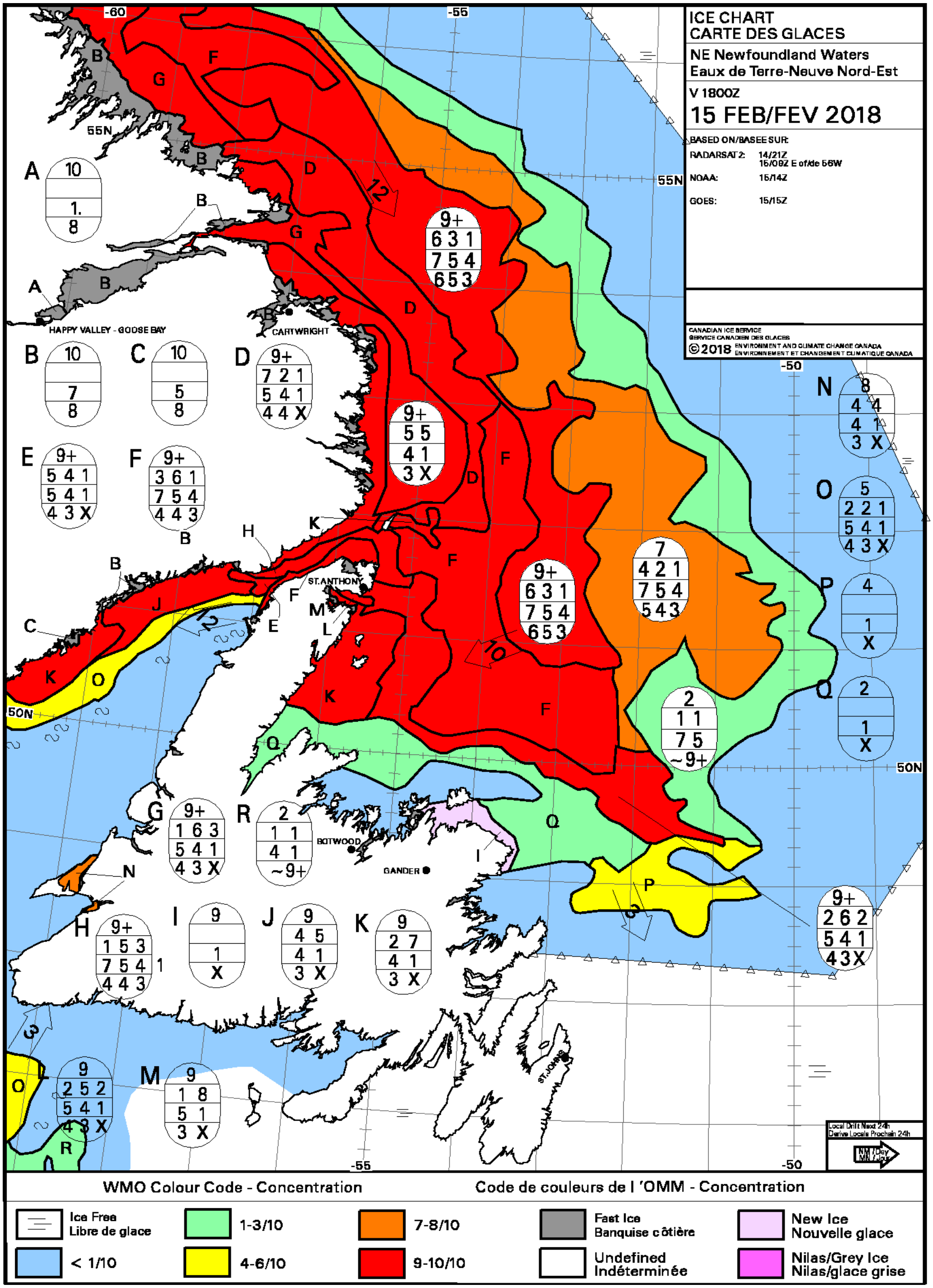


NORTH AMERICAN ICE SERVICE (NAIS)	ICEBERG ANALYSIS FOR 0000 UTC **15 SEP 2018**
ESTIMATED ICEBERG LIMIT ICEBERG LIMIT SEA ICE LIMIT # ICEBERGS PER DEGREE SQUARE RADAR TARGET OUTSIDE ICEBERG LIMIT	**NOTE:** **For more information:** **www.navcen.uscg.gov/iip** **www.ice-glaces.ec.gc.ca** **Most Recent Reconnaissance:** **Eastern Limit Iceberg Flight 07SEP18.**

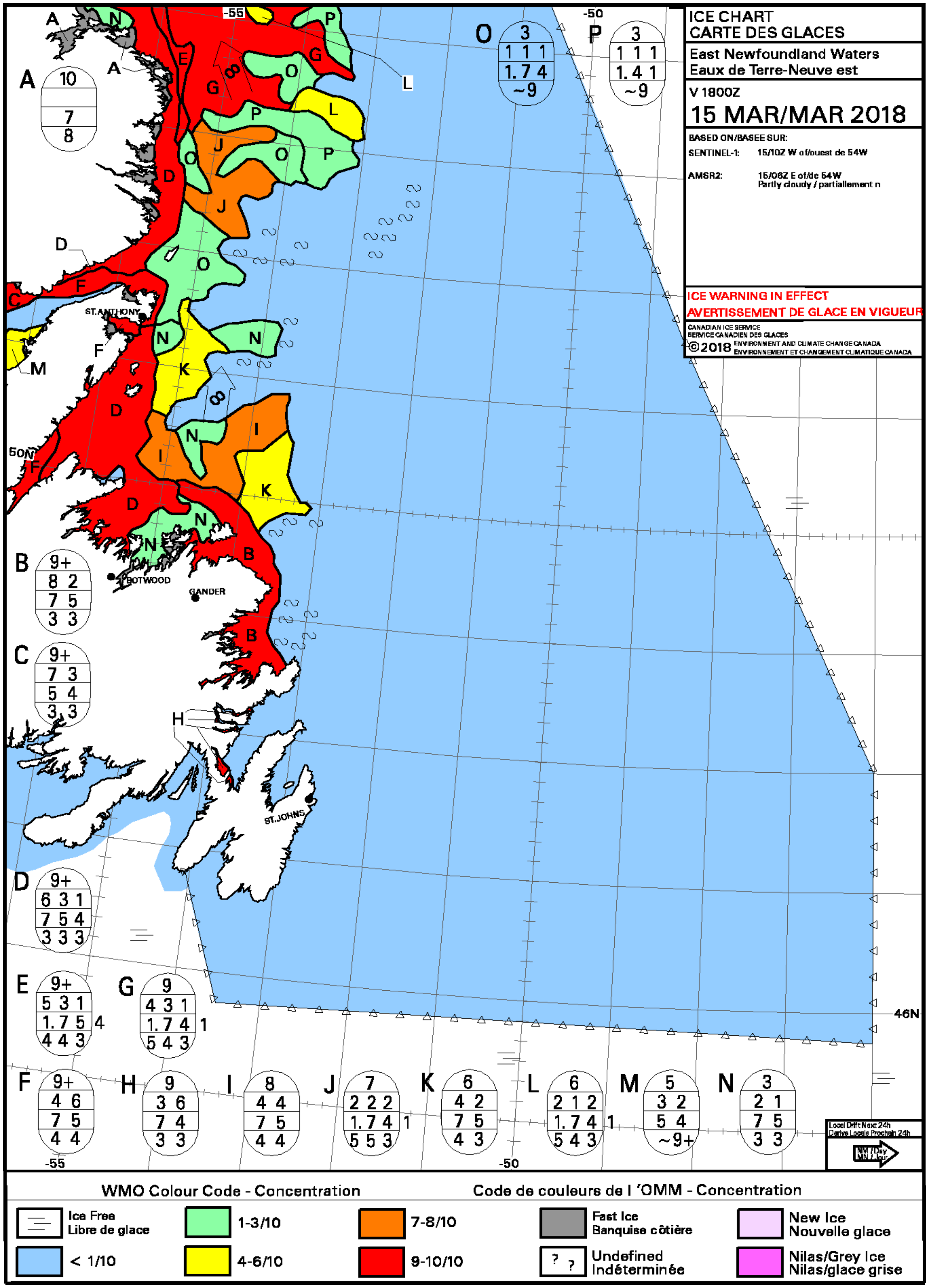
8. Monthly Sea-Ice Charts

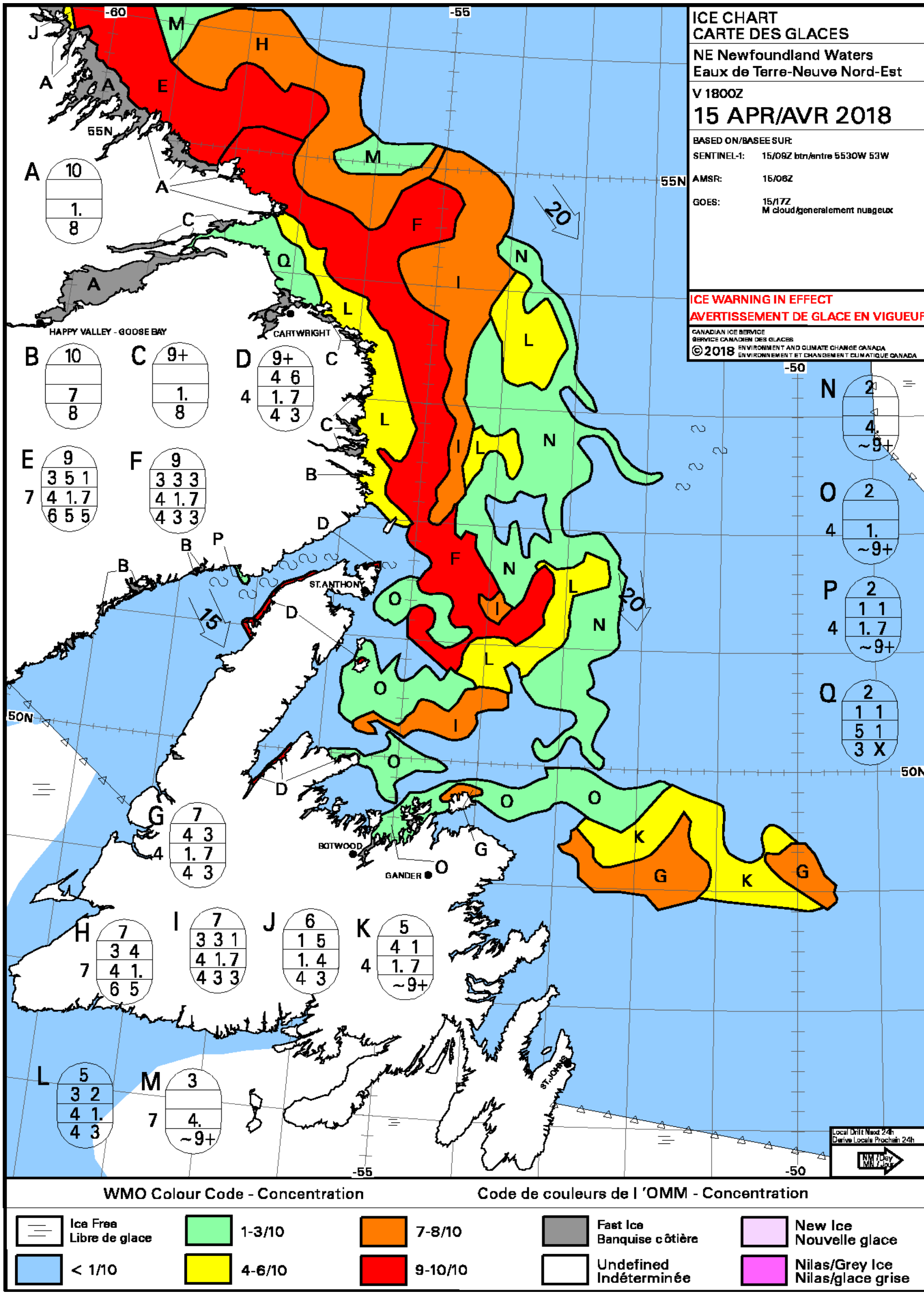


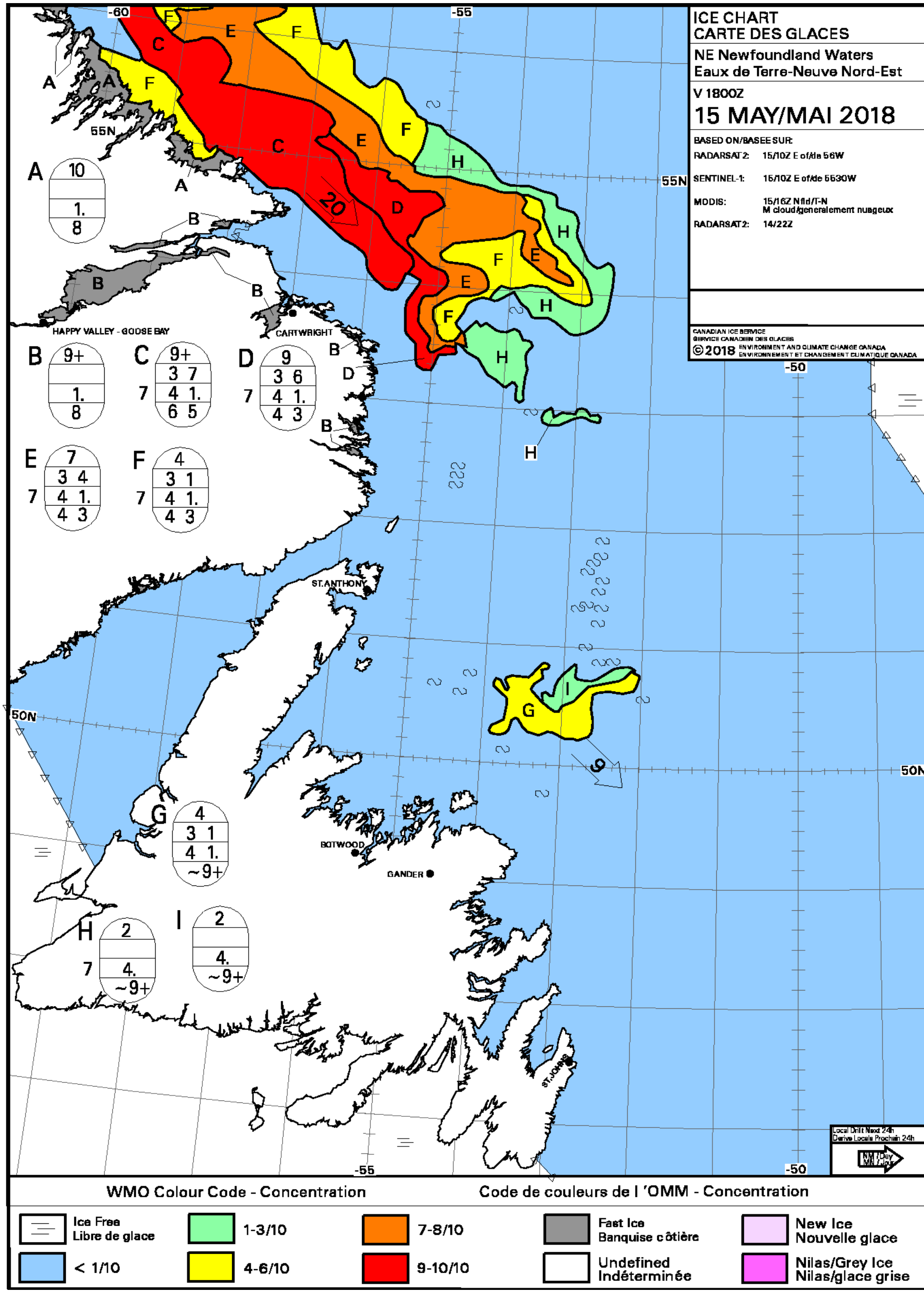

ICE CHART
CARTE DES GLACES
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 JAN/JAN 2018
BASED ON/BASEE SUR:
RADARSAT 2: 15/09Z Lab Coast S
SENTINEL-1: 15/09Z Nfld/T-N NE
©2018
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
WMO Colour Code - Concentration
Code de couleurs de l 'OMM - Concentration
Ice Free
Libre de glace
< 1/10
1-3/10
4-6/10
7-8/10
9-10/10
Fast Ice
Banquise côtière
Undefined
Indéterminée
New Ice
Nouvelle glace
Nilas/Grey Ice
Nilas/glace grise
Local Drift Next 24h
Dérive Locale Prochain 24h

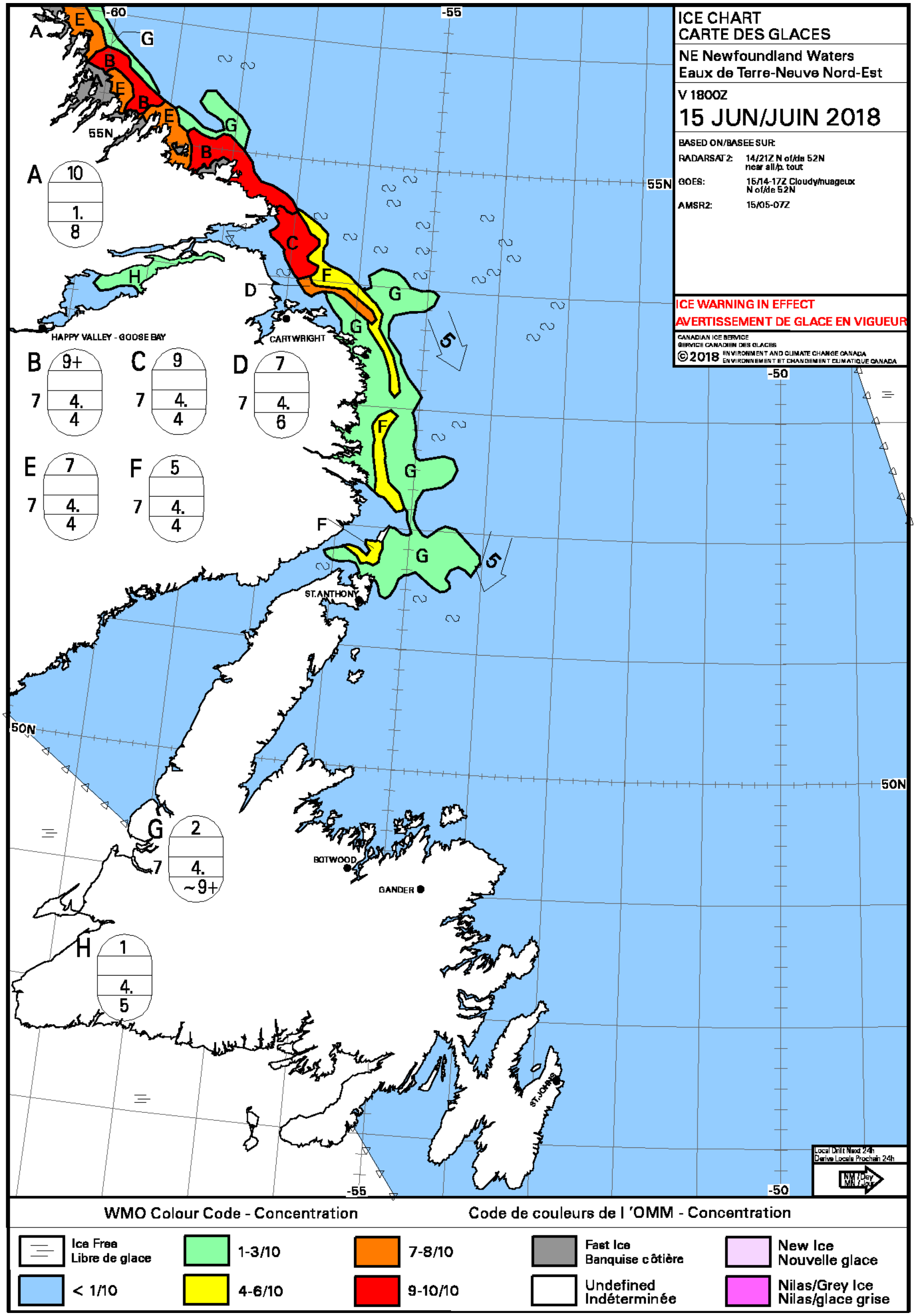


ICE CHART
CARTE DES GLACES
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 FEB/FEV 2018
BASED ON/BASEE SUR:
RADARSAT 2: 14/21Z
15/09Z E of/de 56W
NOAA: 15/14Z
GOES: 15/15Z
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2018 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
55N
50N
-60
-55
-50
Local Drift Next 24h
Derive Locale Prochain 24h
NM/Day
MN/Jour
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

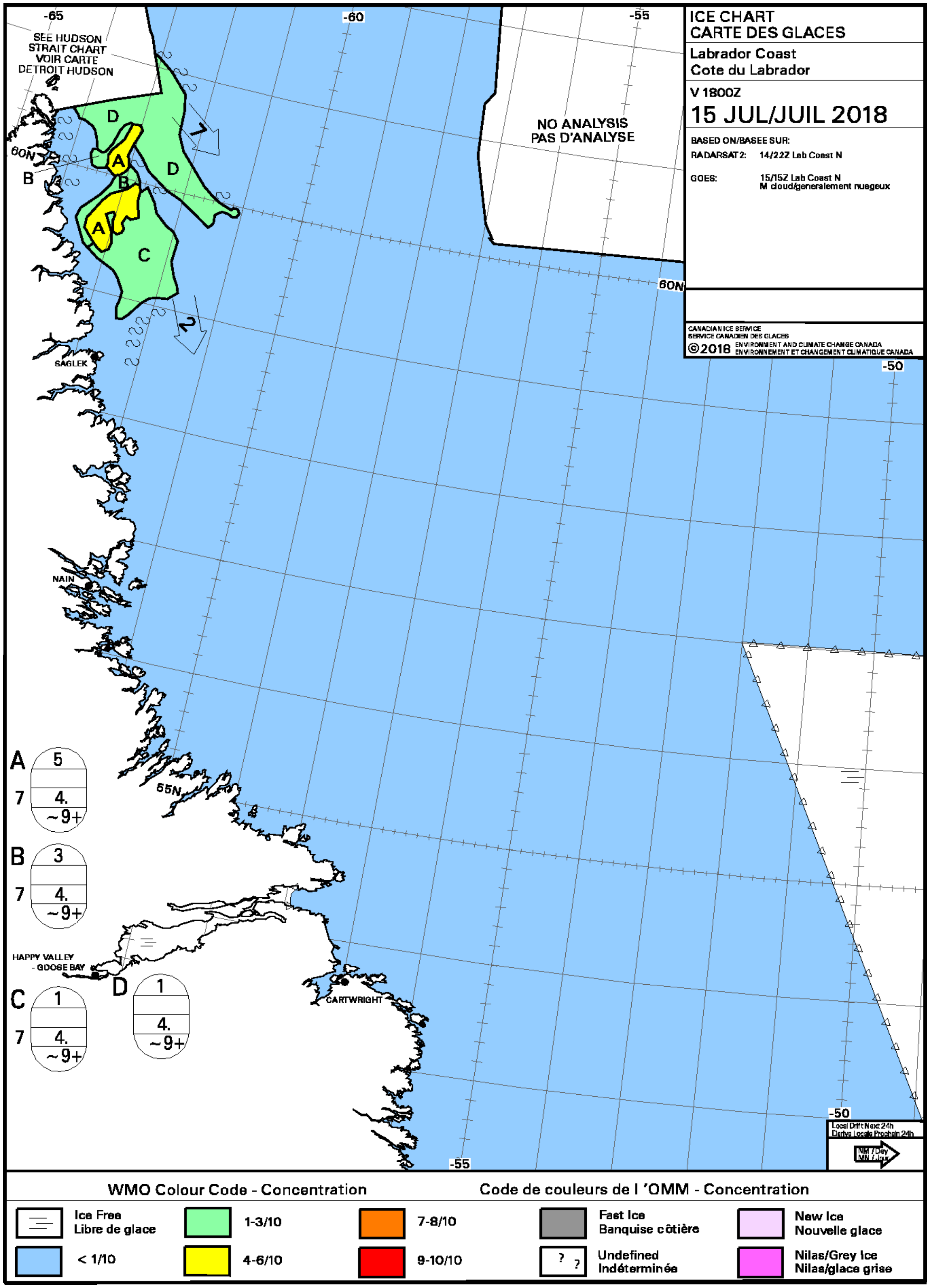

ICE CHART
CARTE DES GLACES
East Newfoundland Waters
Eaux de Terre-Neuve est
V 1800Z
15 MAR/MAR 2018
BASED ON/BASEE SUR:
SENTINEL-1: 15/10Z W of/ouest de 54W
AMSR2: 15/06Z E of/de 54W
Partly cloudy / partiallement n
ICE WARNING IN EFFECT
AVERTISSEMENT DE GLACE EN VIGUEUR
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2018 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
-55
-50
50N
46N
Local Drift Next 24h
Dérive Locale Prochain 24h
NM / Day
MN / Jour
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
CARTE DES GLACES
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 APR/AVR 2018
BASED ON/BASEE SUR:
SENTINEL-1: 15/09Z btn/entre 5530W 53W
AMSR: 15/06Z
GOES: 15/17Z
M cloud/generalement nuageux
ICE WARNING IN EFFECT
AVERTISSEMENT DE GLACE EN VIGUEUR
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2018 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
55N
50N
-60
-55
-50
Local Drift Next 24h
Dérive Locale Prochain 24h
NM / Day
MN / Jour
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
CARTE DES GLACES
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 MAY/MAI 2018
BASED ON/BASEE SUR:
RADARSAT2: 15/10Z E of/de 56W
SENTINEL-1: 15/10Z E of/de 5530W
MODIS: 15/16Z Nfld/T-N
RADARSAT2: 14/22Z
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2018
ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
55N
50N
-60
-55
-50
Local Drift Next 24h
Derive Locale Prochain 24h
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
CARTE DES GLACES
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 JUN/JUIN 2018
BASED ON/BASEE SUR:
RADARSAT 2: 14/21Z N of/de 52N near all/p. tout
GOES: 15/14-17Z Cloudy/nuageux N of/de 52N
AMSR2: 15/05-07Z
ICE WARNING IN EFFECT
AVERTISSEMENT DE GLACE EN VIGUEUR
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2018 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
55N
50N
-60
-55
-50
A 10 1. 8
B 9+ 7 4. 4
C 9 7 4. 4
D 7 7 4. 6
E 7 7 4. 4
F 5 7 4. 4
G 2 7 4. ~9+
H 1 4. 5
Local Drift Next 24h
Derive Locale Prochain 24h
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
CARTE DES GLACES
Labrador Coast
Cote du Labrador
V 1800Z
15 JUL/JUIL 2018
BASED ON/BASEE SUR:
RADARSAT 2: 14/22Z Lab Coast N
GOES: 15/15Z Lab Coast N
M cloud/generalement nuageux
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2018 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
SEE HUDSON STRAIT CHART
VOIR CARTE DETROIT HUDSON
NO ANALYSIS
PAS D'ANALYSE
-65
-60
-55
-50
60N
55N
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
A 5 7 4. ~9+
B 3 7 4. ~9+
C 1 7 4. ~9+
D 1 4. ~9+
Local Drift Next 24h
NM / Day
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

9. Acknowledgements

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

Canadian Coast Guard

Canadian Forces

Canadian Ice Service

Canadian Maritime Atlantic Command Meteorological and Oceanographic Centre

Canadian Meteorological Centre

C-CORE

Department of Fisheries and Oceans Canada

Danish Meteorological Institute

European Space Agency

German Federal Maritime and Hydrographic Agency

MacDonald, Dettwiler and Associates

National Geospatial-Intelligence Agency

Nav Canada Flight Information Center

PAL Aerospace

PAL Aviation Services

Transport Canada

USCG Air Station Elizabeth City

USCG Air Station Cape Cod

USCG Atlantic Area

USCG Aviation Training Center Mobile

USCG Director of Marine Transportation Systems

USCG Director of Intelligence and Criminal Investigations

USCG First District

USCG Maritime Fusion Intelligence Center Atlantic

USCG Navigation Center

USCG Research and Development Center

U.S. National Aeronautics and Space Administration – Jet Propulsion Laboratory

U.S. National/Naval Ice Center

U.S. Naval Fleet Numerical Meteorology and Oceanography Center

U.S. National Oceanic and Atmospheric Administration

U.S. National Weather Service

It is important to recognize the outstanding efforts of the personnel assigned to the International Ice Patrol during the 2018 Ice Year:

CDR K. L. Serumgard

CDR S. A. Koch

Mr. M. R. Hicks

Mrs. B. J. Lis

LCDR J. C. Gatz

LCDR C. B. Bell

LT D. W. Rudnickas

MSTCS K. E. Brockhouse

MST1 S. A. Baumgartner

MST1 M. A. Connell

MST1 R. M. Harings

YN1 J. I. Vega

MST2 J. Ambro

MST2 J. J. Menard

MST2 B. M. Reel

MST3 Z. P. Kniskern

MST3 J. L. Crocker

MST3 R. M. Hogan

MST3 J. J. Paulk

Appendix A

Ship Reports for Ice Year 2018

Ships Reporting by Flag	Reports
ANTIGUA AND BARBUDA	
HANSE GATE	1
BAHAMAS	
RANFORM STERLING	1
CANADA	
ARCTIC	1
ARGENTIA DESGAGNES	1
ATLANTIC HERON	1
ATLANTIC SHRIKE	1
CCGS PIERRE RADDISON	4
CCGS LOUIS S. ST-LAURENT	5
CCGS VLADYKOV	1
CCGS EDWARD COURNWALIS	2
COVENANT II	2
SIEM PILOT	1
*CCGS GEORGE R. PEARKES	13
CCGS HENRY LARSEN	6
OCEANEX CONNAIGRA	2
GREECE	
ARIS T	1
HONG KONG	
OOCL MONTREAL	1
BARCELONA EXPRESS	1
LIBERIA	
GLENDA MELANIE	2
MARSHALL ISLANDS	
KIBAZ	1
NETHERLANDS	
EXEBORG	2
STELLA POLARIS	1
DONAUGRACHT	1
UNIDENTIFIED SHIPS	3

*Denotes the CARPATHIA award winner.

IIP awards the vessel that submits the most iceberg reports each year. The award is named after the CARPATHIA, the vessel credited with rescuing 705 survivors from the TITANIC disaster.

Appendix B. Updated Iceberg Season Severity Definitions: Trends and Standardization

LT Don Rudnickas, CDR Kristen Serumgard

Introduction

In order to convey information about how an Iceberg Season impacts mariners and other stakeholders, it is useful to be able to assign a level of relative severity to each season. A traditional measure of Iceberg Season severity is the number of icebergs that travel south of 48˚N in a given year. This metric was first utilized by Smith (1926) and is still used today. The 48˚N line of latitude passes roughly between two well-known geographic features in the western North Atlantic: St. John's, Newfoundland and the northern point of the Flemish Cap. Below this line, icebergs are considered to pose a more significant threat to transatlantic shipping. Trivers (1994) provided the most extensive description of the record and we refer the reader there for a more comprehensive analysis of the history of this metric. The observed number of icebergs south of 48˚N is maintained and reported externally by the International Ice Patrol (IIP) to include the time period from 1900-present. Such data sets are rare in modern observational oceanography and identifying and explaining trends is a useful endeavor for patrol resource allocation and ship routing considerations.

Figure B-1 shows the record of the number of icebergs to drift south of 48˚N since 1900. Though the trend of these raw data shows an apparent overall increase in icebergs (indeed, the highest recorded numbers of iceberg sightings south of 48˚N on record have occurred since the mid-1980s), it is important to consider the changes in reconnaissance technology over more than a century of observations. In this Appendix, we will examine the long-term record of this iceberg count and compare it to the result of a normalization by reconnaissance period.

Aside from a long-term trend, it is relevant to discuss whether a season is more or less severe than previous ones. This requires a definition of season severity and enables IIP, as an operational unit, to plan the effective use of resources throughout the season. Due to the impact on transatlantic shipping below 48˚N, season severity is integrally related to this latitude.

Studies by Trivers (1994) and Marko et al. (1994) have shown a bilinear correlation between sea ice extent and iceberg numbers south of 48˚N. The current season severity definitions established by Trivers (1994) are based on this relationship (**Table B-1**).

Light	< 300 icebergs south of 48˚N
Moderate	300-600 icebergs south of 48˚N
Extreme	> 600 icebergs south of 48˚N

Table B-1. Iceberg Season severity definitions from Trivers (1994) based on correlations between sea-ice observations and iceberg populations up to 1994.

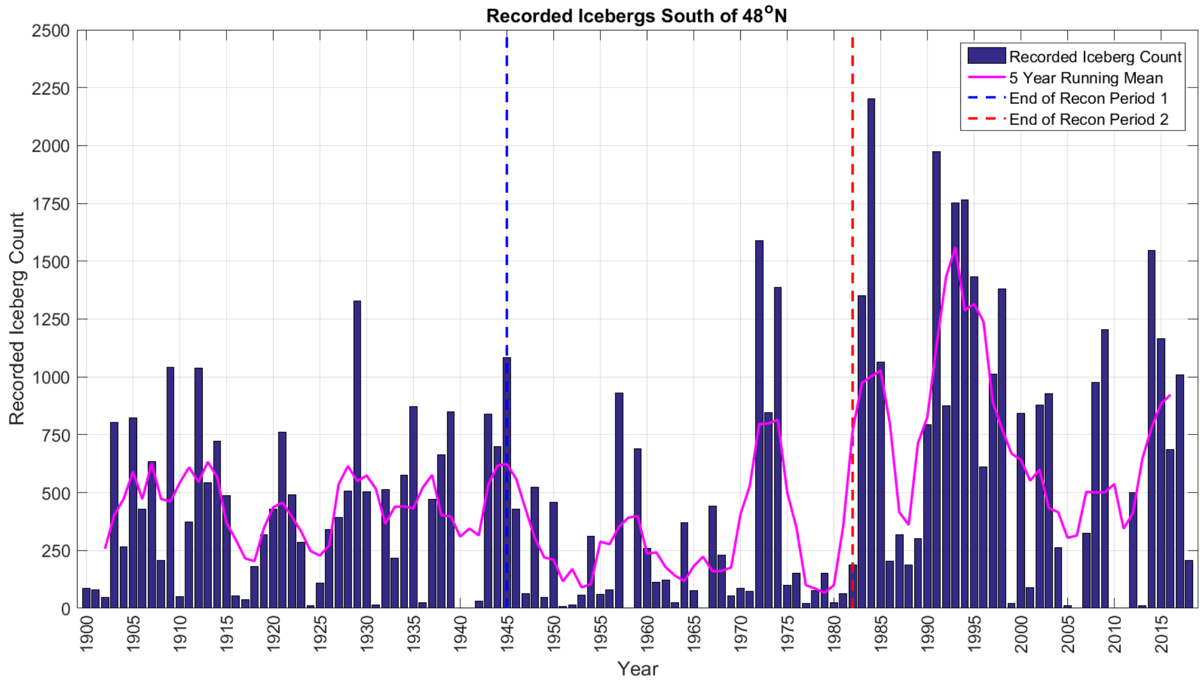


Figure B-1. Count of icebergs passing south of 48˚N from 1900 to 2018. The magenta line represents a five-year centered running mean used for a low pass filter and the dashed lines demark the break-points in reconnaissance periods.

Years with high January sea ice coverage off the Labrador coast are correlated with high iceberg counts because sea ice helps to protect icebergs from grounding, melting, and wave deterioration (Marko et al., 1994). In a dynamic global ocean, it is important to periodically evaluate the relationship between two variables. While sea ice certainly remains an important factor (if not the most important) in the preconditioning of an Iceberg Season, Trivers (1994) did not take into account the impact of changing reconnaissance methods (**Table B-2**) when determining the correlation between iceberg count and sea ice in the development of severity classes. Further, as we will show, since the establishment of the current definitions, there has been an increase in variance around the mean of icebergs passing south of 48˚N, though it is unknown whether this is due to the evolution of reconnaissance methods or a change in environmental factors. The impact of these factors on season severity resulted in 58% of the last 36 years being defined as "Extreme" iceberg seasons (**Table B-3**); we argue that this is not an accurate depiction. By separately considering the reconnaissance periods distinguished by reconnaissance method and statistically analyzing the iceberg metrics within each, we will show that Iceberg Seasons are not becoming more extreme but they are becoming more variable and will update the defining values of season severity.

Here, we examine season severity as a function of three measurements associated only with icebergs passing south of 48˚N without regard for other environmental variables, such as sea ice, understanding that these factors have determined the iceberg count to

Period 1	1900 - 1912	Prior to formation of IIP, icebergs sighted by vessels were reported to the U.S. Hydrographic Office.
	1913 - 1945	IIP established the surface distribution of icebergs from reports made by USCG Cutters and commercial vessels.
Period 2	1946 - 1982	IIP transitioned to aerial reconnaissance without radar (visual only) collected via aircraft augmented by commercial vessel reports.
Period 3	1983 - Present	Modern reconnaissance era characterized by use of aircraft with radar, ship reports, and satellite reconnaissance. Additionally, IIP began using iceberg drift and deterioration models to predict iceberg positions, so iceberg counts include both icebergs sighted and modeled to drift south of 48˚N.

Table B-2. History of iceberg reconnaissance.

Definition	Number of Seasons				% of Each Severity Class			
	All Years	Period 1	Period 2	Period 3	All Years	Period 1	Period 2	Period 3
Extreme (> 600)	40	14	5	21	34%	30.5%	14%	58%
Moderate (300 - 600)	24	14	6	4	20%	30.5%	16%	11%
Light (< 300)	55	18	26	11	46%	39%	70%	31%

	Distribution of Severity Classes			
		Period 1	Period 2	Period 3
Extreme Seasons		35%	12.5%	52.5%
Moderate Seasons		58%	25%	17%
Light Seasons		33%	47%	20%

Table B-3. Tabulation of season definitions resulting from Trivers (1994), Table B-1, considering the recorded count of icebergs south of 48˚N. The upper left pane shows the number of seasons classified as each severity definition in the whole time period ("All Years") as well as in each Reconnaissance Period defined in Table B-2. The top right pane shows the percentage of each time frame classified as each severity definition (i.e. 58% of Period 3 was determined to be made up of "Extreme" Iceberg Seasons) and the bottom left pane shows the percentage of each severity class that occurs in each timeframe (i.e. 52.5% of all extreme seasons were in Period 3). Note that this shows an increase in the number of "Extreme" seasons in Period 3 compared to the earlier years.

begin with. We evaluate the count of icebergs south of 48˚N, the length of the Iceberg Season, and the area south of 48˚N that is enclosed by the Iceberg Limit (also referred to as the Limit All Known Ice or LAKI). Previously, IIP has also considered a Normalized Season Severity Index (NSSI) that incorporated all three of these metrics as a possible option for defining and communicating season severity (Futch and Murphy, 2002). This appendix analyzes each of these metrics and defines four season severity classes: "Light", "Moderate", “Heavy”, and "Extreme" based on the statistics of each metric.

We will first examine the long-term trend of icebergs passing south of 48˚N, use that metric to statistically define Iceberg Season severity classes, and then examine the data and methods used for defining other season severity metrics. We statistically analyze these metrics to offer our conclusions on the future definition of Iceberg Season severity.

B-1. The Long-Term Count of Icebergs South of 48˚N

The International Ice Patrol has kept a count of the number of icebergs passing south of 48˚N since 1900. These data are displayed in **Figure B-1**. This simple metric is used to gauge the iceberg danger to the transatlantic shipping lanes. It is updated daily by the IIP Operations Center and, therefore, represents a near real-time estimation of season severity.

Reconnaissance Periods

The International Ice Patrol was officially formed in 1914 in response to the sinking of RMS TITANIC two years prior and has kept records of the Iceberg Season throughout its history. Prior to the creation of IIP, iceberg counts were culled from ship’s logs and government research back to 1900. Since 1926, the number of icebergs drifting south of 48˚N has been used to measure Iceberg Season severity and remains a valid metric. However, the methodology and ability to detect icebergs has dramatically improved over this time. Throughout these years, three broad reconnaissance periods have been identified (**Table B-2**). During Reconnaissance Period 1 (1900-1945), ship reports alone were used to monitor iceberg danger. For the US Coast Guard this involved one or two cutters patrolling the vicinity of the southern-most iceberg and reporting its position to mariners. Reconnaissance Period 2 (1946-1982) included the use of aircraft along with ship reports. Reconnaissance Period 3 (1983-Present) is the modern era and includes the use of Side Looking Airborne Radar and 360° Surface Search with Synthetic Aperture Radar (SAR) and Inverse SAR modes which allow for iceberg detection at a greater range and in more adverse weather conditions. Further, this period has utilized the Iceberg Drift and Deterioration Model (Mountain, 1980) to predict the motion of icebergs. Unlike Periods 1 and 2, in Period 3 these modeled positions of icebergs south of 48°N, in addition to observations, have been used to inform the severity metrics.

The current (Trivers, 1994) definitions of season severity do not account for changes in technology over the course of the iceberg record and show an increase in the number of “Extreme” seasons with time. We hypothesize that reconnaissance and count methods have impacted the number of recorded icebergs in the data with time such that if these recorded numbers are compared to each other without regard for these technological developments, the result could be erroneously skewed toward the assumption that Iceberg Seasons are becoming more severe (**Table B-3**).

Normalizing the Iceberg Record

To reduce the impact of changing reconnaissance and count methods, we endeavored to normalize this record. The recorded number of icebergs south of 48˚N was normalized by Reconnaissance Period to a range of 1 to 100 using a simple min-max normalization method (**Equation B-1**):

$$x' = min' + \frac{(x - min)(max' - min')}{(max - min)}$$

(**B-1**)

Where x' is the normalized value, x is the recorded value, $max'(min')$ is the maximum(minimum) values in the normalized distribution (100(1) for this case), and $max(min)$ are the maximum(minimum) values in the recorded distribution for each Reconnaissance Period. Each year's observed value was normalized to the range in the Reconnaissance Period to which it belonged. The results of this normalization are shown in **Figure B-2.**

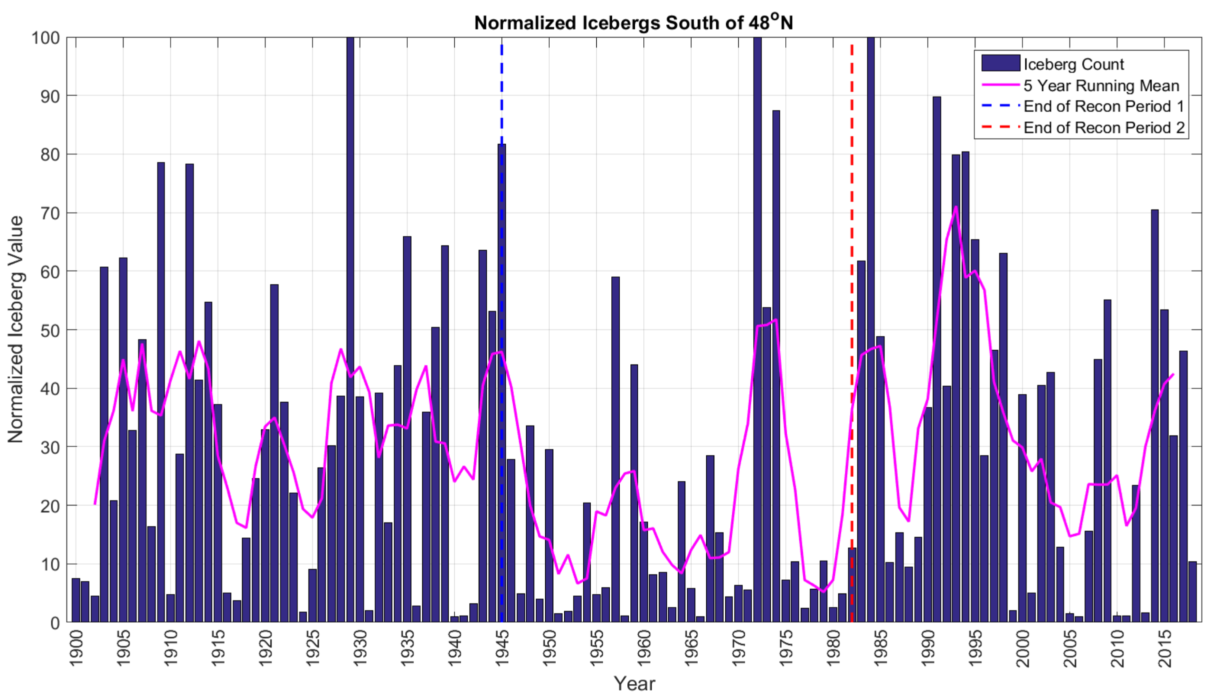


Figure B-2. The record of icebergs south of 48˚N normalized to each Reconnaissance Period by a min-max method (Equation B-1). The magenta line shows a five-year centered running mean and the dashed lines demark the break-points between the Reconnaissance Periods.

Long-Term Trend Analysis

To examine the long-term trend, a basic linear regression was used (**Equation B-2**) to determine a trend, b, within each Reconnaissance Period as well as over the entire iceberg record:

$$b = \frac{n(\sum_1^n(xy)) - (\sum_1^n(x) * \sum_1^n(y))}{n(\sum_1^n x^2) - (\sum_1^n x)^2} \quad \textbf{(B-2)}$$

Where n is the sample size (number of years) in the time period being considered, x is years, and y is the iceberg count data.

The results of this linear regression for the entire time period, as well as for each reconnaissance period for both the recorded and normalized iceberg counts, are shown in **Figure B-3** and **Table B-4.** Overall, the recorded iceberg count has a slope of 3.08

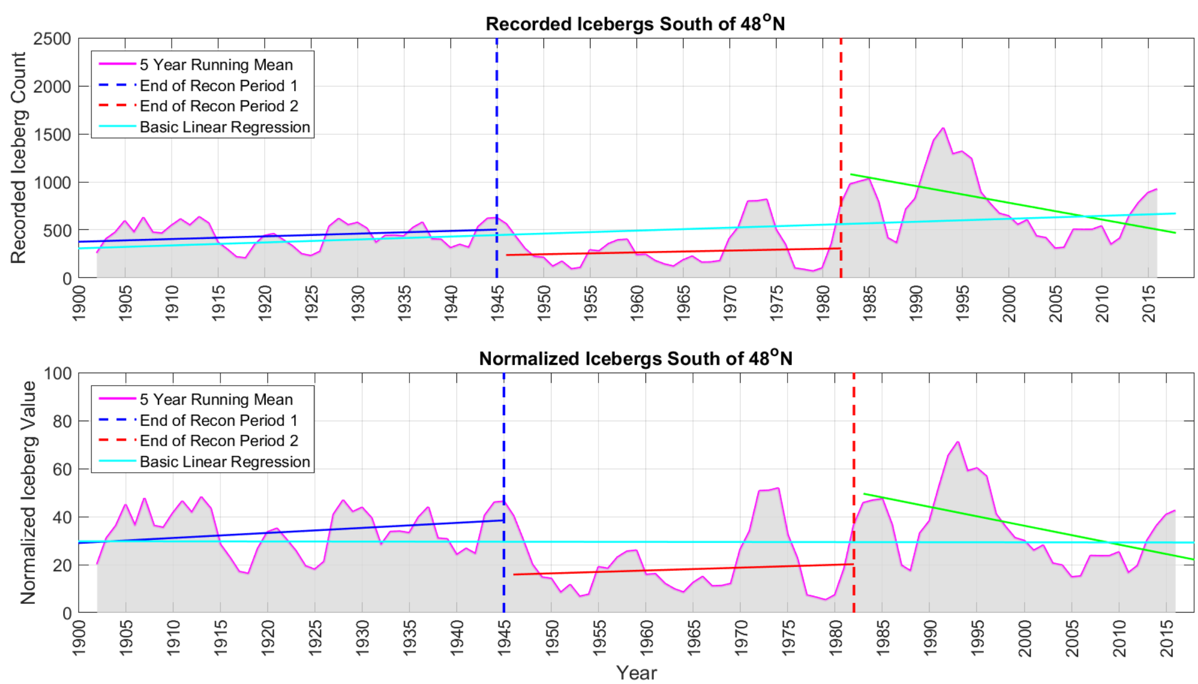


Figure B-3. The results of a simple linear regression calculated by the count of icebergs south of 48˚N through the entire observed record (top) and normalized to the Reconnaissance Period (bottom). The magenta line and grey shading represent the five-year running mean of the iceberg count and the vertical dashed lines indicate the break points in the Reconnaissance Periods. The cyan trend lines indicate the regression calculated from the entire time-period's record while the blue, red, and green trend lines show the regressions calculated from Reconnaissance Period 1, 2, and 3, respectively.

icebergs per year which, despite the interannual variability, could be interpreted as indicative of an increase in icebergs passing south of 48˚N over the time period. The normalized values, however, show a slope of -0.004: a scaled value indicative of a more stable average over time. This supports the assertion that the apparent increase in icebergs in recent years could be due to advances in reconnaissance technology. Note also that conducting a linear regression in this manner shows a decrease during the modern Reconnaissance Period. **Table B-4** also records the correlation coefficients between the linear regression and the running mean. It should be noted that these regressions show weak (at best) correlations with the mean iceberg count. This is not unreasonable given the interannual variability observed in the recorded data (**Figure B-1**) and the rapid increase in variance from the mean observed in **Figure B-4.** We include these regression lines not to provide a linear answer to an obviously nonlinear pattern, but to provide a simple diagnostic with which to discuss the long-term trend of the data.

	Recorded		**Normalized**	
	Slope	**Correlation (*r*)**	**Slope**	**Correlation (*r*)**
Whole Period	**3.08**	*0.33*	**-0.004**	*0.05*
Period 1	**2.81**	*0.12*	**0.21**	*0.11*
Period 2	**1.91**	*0.47*	**0.12**	*0.40*
Period 3	**-17.45**	*0.32*	**-0.78**	*0.34*

Table B-4. The slope (left) and correlation coefficient to the five-year running mean (right) of the basic linear regressions of the mean iceberg count south of 48˚N calculated by Equation B-2. This slope value for the recorded data is equal to the annual increase/decrease in the number of icebergs south of 48˚N. The normalized slope is a scaled value. Note the steep decrease in Period 3.

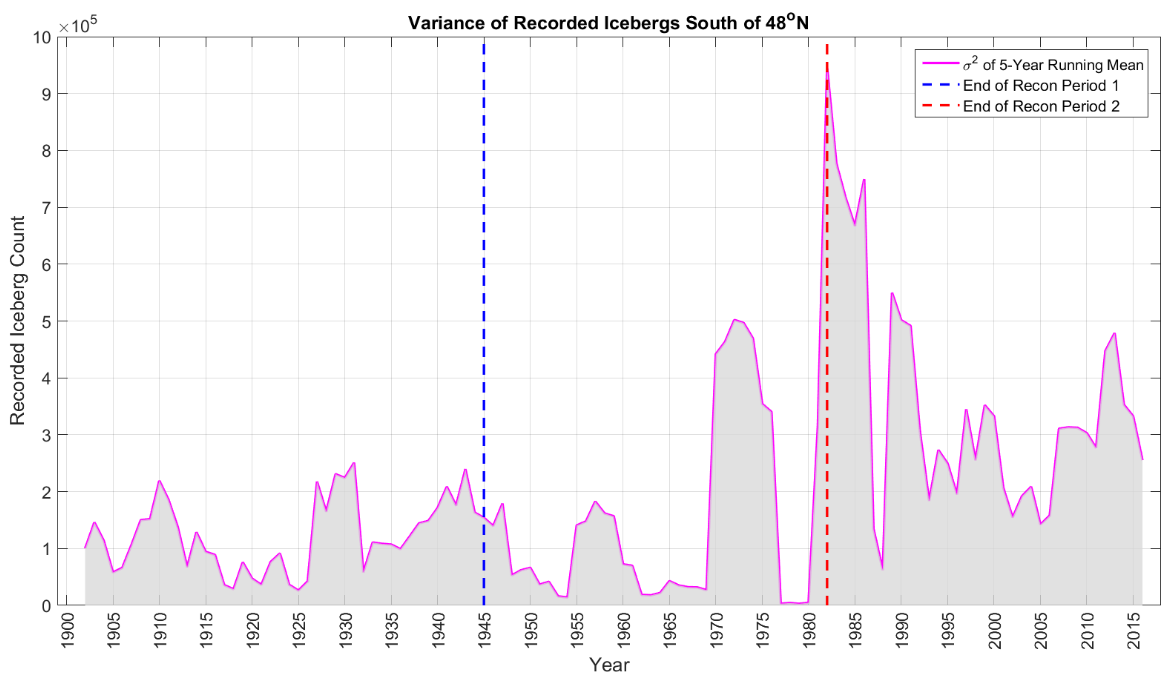


Figure B-4. Variance of the five-year running mean in the recorded record of icebergs south of 48˚N.

Through normalizing the data, the apparent increase in recorded numbers of icebergs south of 48˚N over time seen in **Figure B-1**, is shown to be an artifact of not considering the effect of increasing iceberg detection capability in each Reconnaissance Period. Though we assert that the number of icebergs passing south of 48˚N is not increasing as rapidly as the recorded count suggests, the variance of the number of icebergs from the mean from season to season has shown sharp increases in an episodic fashion after 1968 (**Figure B-4**). This means that the trend in the iceberg count should not be assumed to be linear over long time periods. Instead, the record is showing increasing variability at interannual and interdecadal timescales, making it harder to predict an Iceberg Season's severity based on prior seasons. Though beyond the scope of this Appendix, we hypothesize that this variance could be attributed to the relationship between the iceberg count and other dynamic environmental factors such as sea ice extent (i.e. Marko et al., 1994), variability in the Labrador Current (i.e. Palter et al., 2016; Fischer et al., 2010), or variability in the rate of icebergs calving off of the Greenland glaciers (i.e. Bigg et al., 2014).

To summarize, it is unreasonable to simply say that the number of icebergs passing south of 48˚N is increasing over time. The analysis showed two key points supporting this statement. First, the way that we detect and count icebergs has improved, resulting in instances of higher recorded numbers in recent years – supporting the use of a normalized scale with which to compare seasons. Second, the variability of Iceberg Seasons has increased such that recent years are characterized by more rapid shifts from seasons of higher to lower iceberg counts. In updating the manner in which we define season severity, it is important to consider these factors.

B-2. Defining Season Severity Classes

We used a statistical approach to define severity classes based on the normalized iceberg counts in Section B-1. Assuming a normal distribution, 68% of values will fall within one standard deviation (σ) of the mean, with 16% greater than 1σ and 16% lower. In a "Middle Fifty" statistical regime, 50% of values will fall within 0.67448σ, with 25% higher and 25% lower. Both of these regimes were examined, hereafter referred to as the 68% and 50% methods, respectively. While both methods produced statistically meaningful severity classes, the 68% method obscured interannual variability by encompassing more of the distribution around the mean and resulted in lost granularity in the season severity analysis. The 50% method more effectively preserved this granularity by allowing for more inclusive classes below and above the mean, providing more definitive severity classes. As such, here we only present the results of the 50% method.

The 50% standard deviation method was used to define four severity classes: "Light", "Moderate", "Heavy", and "Extreme" by setting thresholds based on the mean normalized value from 1900 to 2018 and 0.67448σ and 1.28σ. A metric value within the middle 50% of the distribution (mean $\pm$ 0.67448σ) was labelled a "Moderate" year. A value within the lower 25% of the distribution (< mean - 0.67448σ) was labelled a "Light" year. We further segregated the higher 25% values into two classes: the “Extreme” season class included the highest 10% of values (above 1.28σ) and the “Heavy” season class contained the 15% of values between 0.67448σ and 1.28σ. **Figure B-5** shows this method applied to the record of the iceberg count south of 48˚N from 1900 to 2018. **Table B-5** records the values used to define the thresholds.

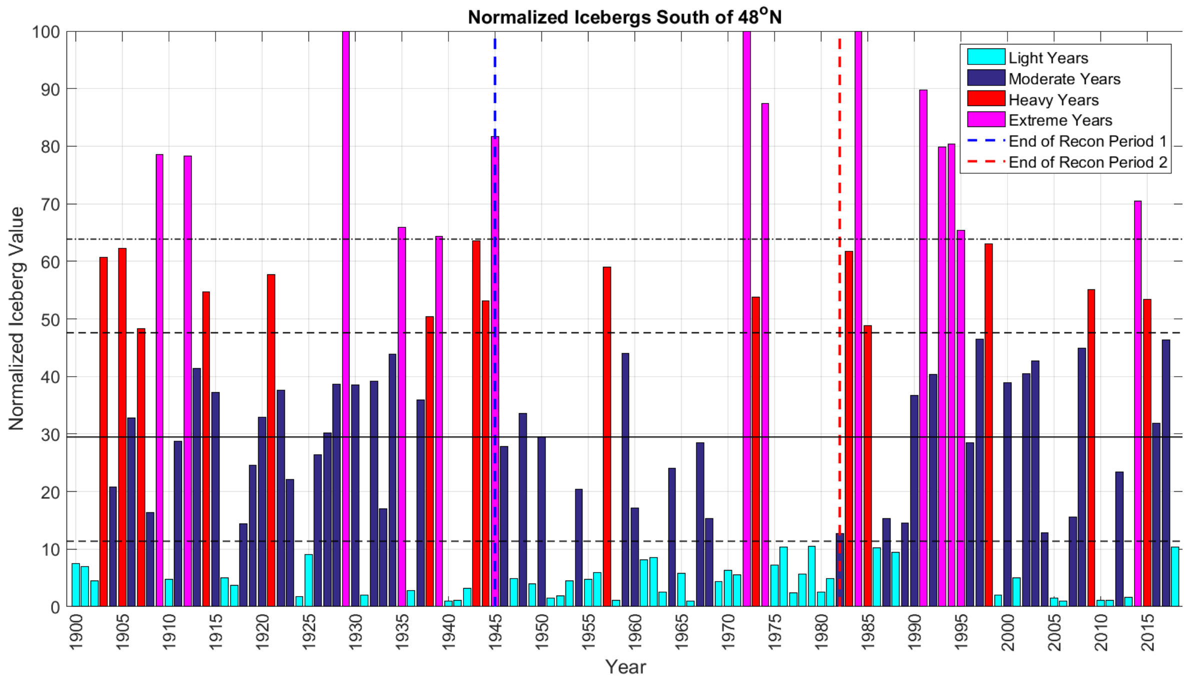


Figure B-5. The entire normalized iceberg record below 48˚N classified into four severity classes by the 50% standard deviation method with the top 10% being “Extreme”. Here, the 50% method was applied to the distribution of normalized values as determined by Equation B-1. The black, solid line denotes the mean normalized value over the time period while the dashed lines denote the ±0.67448σ (middle 50%) thresholds from the mean and the dot-dash line marks +1.28σ (top 10%).

While the normalized values are numerically interesting, we require a more operationally meaningful way to look at each season. Using the normalized value thresholds by the 50% method and the range of icebergs in each Reconnaissance Period, we calculated the number of icebergs passing south of 48˚N corresponding to each severity class threshold in each reconnaissance period. To do this, **Equation B-1** was solved for x, the observed number of icebergs, using each reconnaissance period’s range of observations, the normalized range (1 to 100), and the severity thresholds that were statistically calculated from the normalized values (top row of **Table B-5**) for x'. The resulting season severity classification definitions are shown in the Period 1, 2, and 3 rows of **Table B-5** and provide a meaningful way to define each season and compare them across reconnaissance periods based on our normalization technique.

		Mean	0.67448σ	1.28σ	Median	Light Range	Moderate Range	Heavy Range	Extreme Range
1900-2018	Normalized Values	29.48	18.10	34.35	22.76	0 - <11.4	11.4 - <47.6	47.6 - 63.8	>63.8
Period 1	Severity Class Definition (# of Icebergs)					0 - 140	141 - 625	626 - 843	≥ 844
Period 2	Severity Class Definition (# of Icebergs)					0 - 166	167 - 747	746 - 1008	≥ 1009
Period 3	Severity Class Definition (# of Icebergs)					0 - 230	231 - 1036	1037 - 1398	≥ 1399

Table B-5. Statistical analysis of the normalized iceberg count from 1900 to 2018. The top row shows the statistics and threshold values associated with the normalized iceberg values calculated from Equation B-1 and using the 50% method. The Period 1, 2, 3 rows show the number of icebergs in each Reconnaissance Period that correspond with the statistical thresholds for the four severity classes.

Definition	Number of Seasons				% of Each Severity Class			
	All Years	Period 1	Period 2	Period 3	All Years	Period 1	Period 2	Pe-riod 3
Extreme (> 63)	14	6	2	6	11.7%	13.0%	5.4%	16.6%
Heavy (47-63)	15	8	2	5	12.6%	17.4%	5.4%	13.9%
Moderate (11-47)	44	19	10	15	37.0%	41.3%	27.0%	41.7%
Light (0-11)	46	13	23	10	38.7%	28.3%	62.2%	27.8%
	Distribution of Severity Classes							
		Period 1	Period 2	Period 3				
Extreme Seasons		43%	14%	43%				
Heavy Seasons		53.3%	13.3%	33.3%				
Moderate Seasons		43%	23%	34%				
Light Seasons		28%	50%	22%				

Table B-6. Tabulation of season definitions considering the normalized values of icebergs south of 48˚N using the definitions based in Table B-5. The upper left pane shows the number of seasons classified as each severity definition in the whole time period ("All Years") as well as in each Reconnaissance Period defined in Table B-2. The top right pane shows the percentage of each timeframe classified as each severity definition (i.e. 16.6% of Period 3 was determined to be made up of "Extreme" iceberg seasons) and the bottom left pane shows the percentage of each severity class that occurs in each timeframe (i.e. 43% of all "Extreme" seasons were in Period 3).

Table B-6 shows the number of seasons that fall into each severity class under the normalized definition values. This set of values is derived from the statistics of the entire 1900-2018 dataset after the normalization process was carried out for each reconnaissance period. Compared to **Table B-3**, which showed the distributions of severity classes based on the Trivers (1994) definitions applied to the recorded iceberg count without normalization, we see a significant reduction in the number of "Extreme" years in

Reconnaissance Period 3 (from 58% to 17% of seasons identified as “Extreme”.) This bias in the 1994 definitions toward the extreme can be explained by the lack of regard for developing detection capabilities and count techniques. The new definitions set forth here take this into account and provide a more realistic use of the term “Extreme.” Introducing a fourth severity class, “Heavy”, gives us the ability to classify seasons that are above the average but not in the same noteworthy category implied by “Extreme.”

Another point to note is that the overall percentage of seasons classified as “Heavy” or “Extreme” has shifted in the new definitions (from 34% “Extreme” to 12% “Extreme” and 9% as “Heavy” under the new definition). Despite this, **Table B-6** still shows that nearly half of the seasons labelled “Extreme” occurred in Period 3, a fact which may be explained by the increased variance in recent years noted in Section B-1 of this Appendix. **Figure B-6** shows that the “Extreme” years in the modern period mostly occurred during two periods associated with increased variance in the mid-1980s and early-1990s (**Figure B-4**).

A Predictive Tool

In addition to the final tally of icebergs passing south of 48˚N in a given year, IIP tracks the value monthly over the Ice Year. To create a predictive tool, IIP examined Period 3 reconnaissance years corresponding to “Light”, “Moderate”, “Heavy”, and “Extreme” years by the new definitions, creating statistical benchmarks based on the cumulative monthly mean number of icebergs for each severity class. The mean and standard deviation of each severity class’ distribution for the cumulative number of icebergs in each month was calculated and used to find a monthly range for each severity class. **Figure B-6** shows the results of this calculation. The graph does not explicitly show the definitions, but the average total number of icebergs to have passed south of 48˚N in each month for seasons that fell within each severity class definition in Period 3. **Figure B-6** can be interpreted as showing that 68% of seasons defined as “Light”, “Moderate”, “Heavy”, or “Extreme” in the modern reconnaissance period had a cumulative number of icebergs within the corresponding shading at any given point in the year.

Applying this graph as a predictive tool could allow for mid-season predictions as to how severe a season may be based on historical statistics. For example, if 400 icebergs have entered the transatlantic shipping lanes by the beginning of March, the season is shaping up to be “Heavy” to “Extreme”. In comparison, if the total does not reach 400 until May, the season is most likely “Moderate”. Note that by June, all the severity class distributions are distinct of each other. To make the tool more robust with time, the statistics building this figure should be updated each year with the new season’s data.

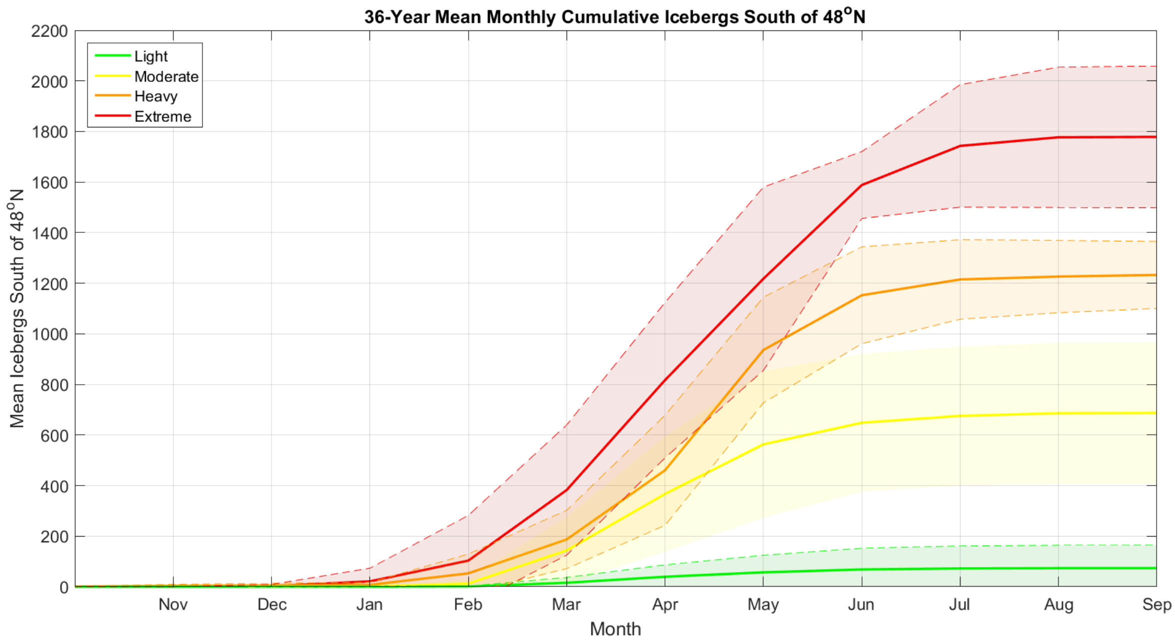


Figure B-6. A 36-year mean of monthly cumulative bergs south of 48˚N from 1983 - 2018. The seasons were defined using the normalized iceberg count and the 50% standard deviation method from Table B-5 as seen in Figure B-5. The solid lines indicate the mean number of icebergs that have passed south of 48˚N throughout the iceberg season in "Light" (Green), "Moderate" (Yellow), "Heavy" (Orange), and "Extreme" (Red) seasons. The dashed lines and shading indicate ±1σ from the mean.

B-3. Comparison to Other Metrics

As discussed in the introduction to this Appendix, the count of icebergs south of 48˚N is not the only metric that defines the impact of an Iceberg Season on transatlantic shipping. The Season Length and the Iceberg Limit area are also important factors. Each of these metrics impact maritime shipping in different ways: increased hazards within the limit, extended seasons in which the limit must be avoided, or greater distance required to transit outside of the limit. They also impact reconnaissance resourcing and planning. In order to explore new definitions of season severity, we used the same statistical approach (50% method described in Section B-2) applied to each of these metrics. We also considered the NSSI, which is a normalized measure that considers all three primary metrics combined.

While the count of icebergs south of 48˚N exists back to 1900, records for the other metrics do not. As such, in order to compare these metrics equitably, this section's analysis only considered Reconnaissance Period 3 (1983 – 2018). Each metric's mean and standard deviation were calculated within this time period and used to create the four season severity classes. This section will discuss each metric's history, determination techniques, and present the record in Period 3 as well as the results of the statistical

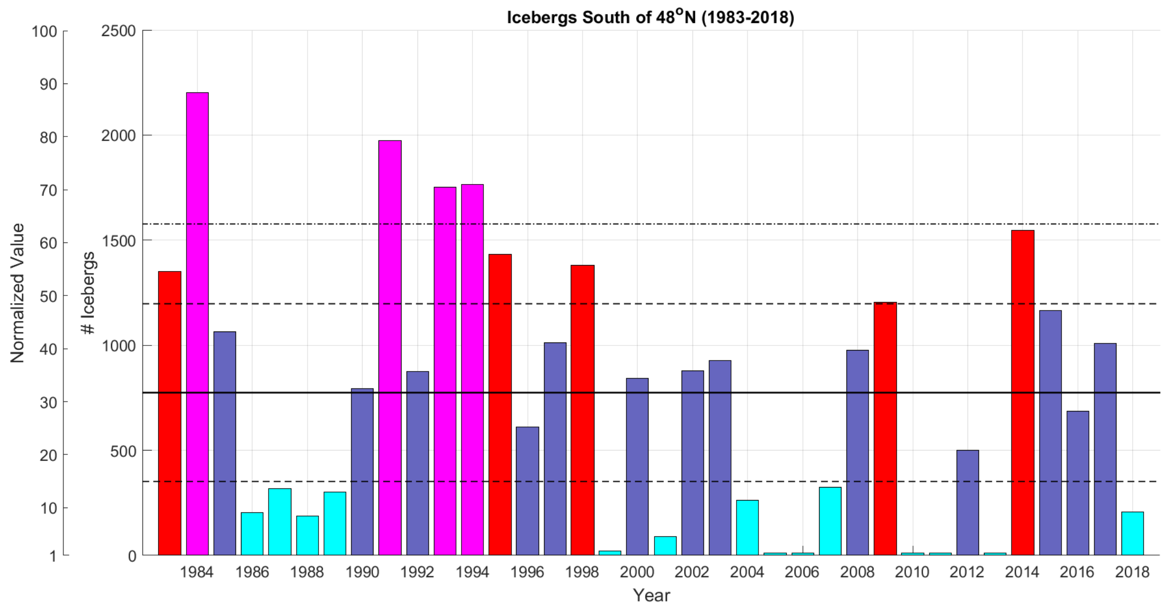


Figure B-7. The iceberg count below 48˚N count from 1983 – 2018 divided into four severity classes by the 50% standard deviation method with the top 10% being "Extreme". The cyan bars denote "Light", blue bars are "Moderate", red bars are "Heavy", and magenta bars are "Extreme" seasons. The black, solid line denotes the mean value over the time period while the dashed lines denote the ±0.67448σ (middle 50%) thresholds from the mean and the dot-dash line marks +1.28σ (top 10%). The y-axis contains the recorded iceberg count during the time period as well as the normalized values for this reconnaissance period as calculated by Equation B-1.

analysis in order to compare them as season severity measurement tools. **Figure B-7** shows the classes defined by the statistics of the normalized (and recorded) iceberg count in Reconnaissance Period 3. Note: The 50% method applied to only Period 3 iceberg counts results in different break points for severity classes than those derived in Section B-2. These break points are used in this section only to compare to other season severity metrics within Period 3, and not across the entire data set.

Iceberg Season Length

The Iceberg Season Length is an important measure of impact to shipping and to the effort expended by IIP to accurately determine the extent of the Iceberg Limit. Dangerous iceberg conditions that persist for long periods impede commercial shipping and require IIP to use a greater number of flight hours to assess the Iceberg Limits. IIP began recording Iceberg Season Length in 1975 and this measurement can be separated into two distinct eras:

1975 to 2010: Iceberg warning products were not released on a daily, year-round basis. The season was opened when IIP began releasing daily Iceberg Limit products at the discretion of Commander, IIP (CIIP) based upon the observed iceberg conditions. The day on which IIP began making products was marked Day 1 for the length of the Iceberg Season metric. The season ended when CIIP deemed the iceberg conditions no longer posed a significant threat to shipping and thus did not warrant daily release of IIP's products. This method inherently involves subjectivity based on the determination of the CIIP at the time.

2011-Present: In 2011, IIP harmonized its iceberg chart with the Canadian Ice Service. Daily iceberg products were released year-round which rendered the previous method of recording Season Length defunct. Under the new system, IIP determined that Season Length would be defined as the cumulative number of days with icebergs present south of 48˚N.

Figure B-8 shows the length of the Iceberg Season dating back to 1983. Note that only one "Extreme" season (2016) was identified and that four of the last five seasons have been "Heavy" or greater. There are several inherent inconsistencies between the two length measurement regimes. In the 1975 to 2010 record, there are instances when the season was never opened (i.e. 1999, 2005, 2006, and 2010). These correspond to years in the iceberg count (**Figure B-7**) in which very few icebergs (0-22) were observed

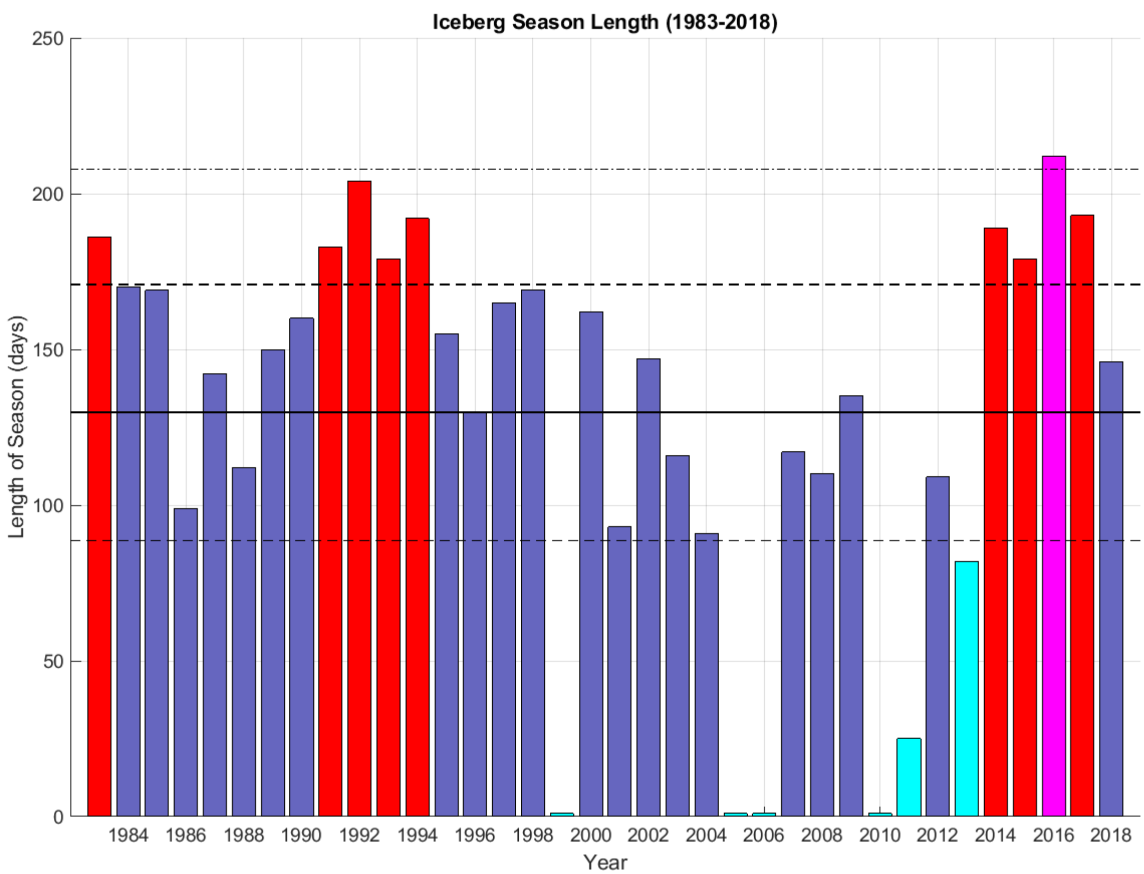


Figure B-8. Iceberg Season Length in days from 1983 - 2018 divided into four severity classes by the 50% standard deviation method with the top 10% being "Extreme". The cyan bars denote "Light", blue bars are "Moderate", red bars are "Heavy", and magenta bars are "Extreme" seasons. The black, solid line denotes the mean value over the time period while the dashed lines denote the ±0.67448σ (middle 50%) thresholds from the mean and the dot-dash line marks +1.28σ (top 10%).

south of 48˚N. In contrast, 2011 and 2013 both had season lengths of 25 and 82 days, respectively, with iceberg counts of 3 and 13, respectively. In the 2011 to 2018 record, there are several instances where icebergs drifted south of 48˚N after IIP's traditional Iceberg Season. For example, the 2015 value includes icebergs that were present south of 48˚N for a 12-day period from October to November 2014. The net result of these differences is that the current system for measuring Season Length tends to result in greater values than during the pre-2011 system as is evident by four of the last five years all being considered "Heavy" or "Extreme." Though the fact that this metric has been so subjective over its record and can only be finalized after the season is officially over limits its operational use, it is still a useful way to think about the impacts of a season and evaluate resource allocation and planning.

Iceberg Limit Area

The area encompassed by the Iceberg Limit is directly related to the obstruction to shipping caused by iceberg danger. Further, this metric provides crucial amplifying information on IIP's efforts during a given iceberg season as more flight hours are required to patrol a larger area. The impact of icebergs crossing south of 48˚N can be tempered by their frequency and distribution since icebergs confined to a smaller area or dispersed over a shorter time frame can require reduced resources to patrol.

IIP first recorded and calculated the seasonal average area encompassed by the Iceberg Limit south of 48˚N in 2002 (Futch and Murphy, 2002). At the time, the historical record was created back to the 1975 season. **Figure B-9** shows the limit area record dating back to 1983. The average value shown for each year represents the mean of a 17 data point average that includes the 15th day and the final day of each month, spanning from January 31 to September 30. As with Season Length, the Limit Area metric is also impacted by the transition to daily iceberg products. Prior to 2011, icebergs could have been present south of 48˚N but no product (and thus no Iceberg Limit) was created, though we found no evidence of this in the data set. There is also some subjectivity associated with this metric as how long a drifting (not resighted) iceberg remains part of the product and how large of a buffer to provide around the estimated position of the iceberg are at the discretion of CIIP. This could lead to a tendency for larger or smaller Iceberg Limits during the tenure of a given individual.

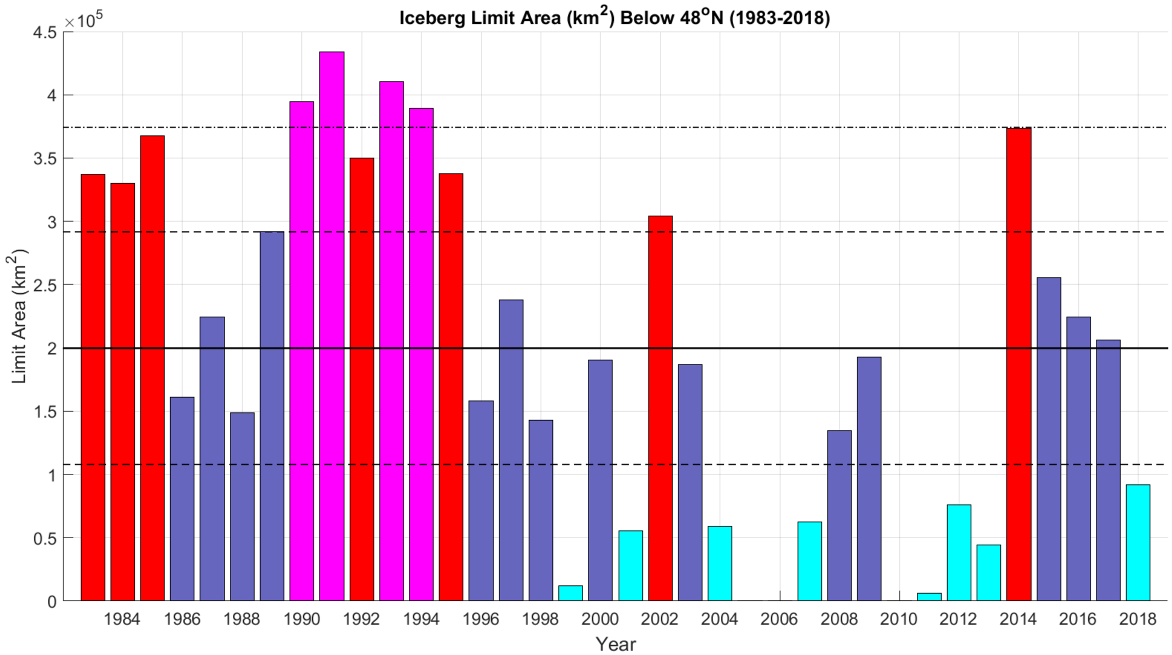


Figure B-9. The Iceberg Limit Area below 48˚N in km^2 from 1983 - 2018 divided into four severity classes by the 50% standard deviation method with the top 10% being "Extreme". The cyan bars denote "Light", blue bars are "Moderate", red bars are "Heavy", and magenta bars are "Extreme" seasons. The black, solid line denotes the mean value over the time period while the dashed lines denote the ±0.67448σ (middle 50%) thresholds from the mean and the dot-dash line marks +1.28σ (top 10%).

Normalized Season Severity Index

Combining these three metrics together, Futch and Murphy (2002) developed the Normalized Season Severity Index (NSSI):

$$NSSI = \frac{I}{\overline{I}} + \frac{L}{\overline{L}} + \frac{A}{\overline{A}} \tag{3}$$

Where I is the number of icebergs observed south of 48˚N, L is the season length, and A is the iceberg limit area. The overbar denotes the mean value for each metric during the considered time period. This method serves to normalize each metric to its own distribution and works to include the primary measurements evaluated at the end of a season in terms of iceberg impact to shipping lanes. The resulting value is a unit-less number allowing a relative comparison of seasons based on each season's relationship with each metric's mean. The NSSI was calculated for the period of 1983 to 2018 (**Figure B-10**) using the values of the three primary measurement metrics shown in **Figures B-7** to **B-9**.

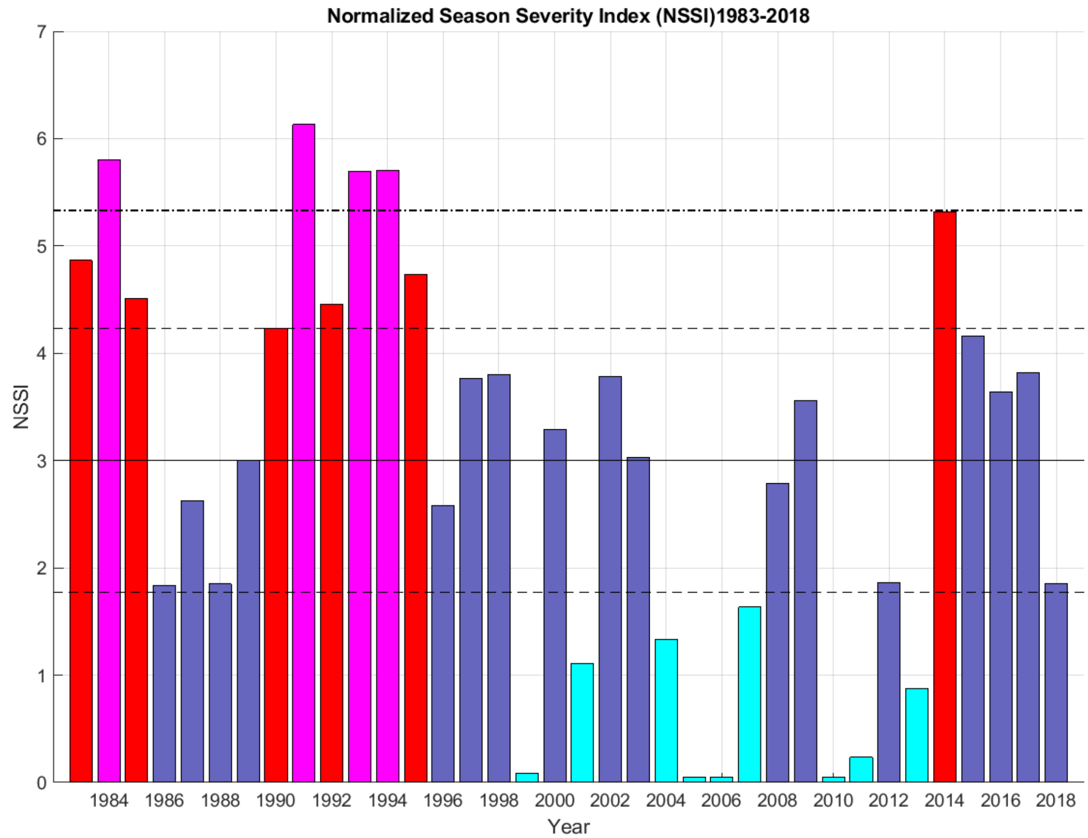


Figure B-10. The Normalized Season Severity Index (NSSI; Futch and Murphy (2002)) from 1983 - 2018 divided into four severity classes by the 50% standard deviation method with the top 10% being "Extreme". The cyan bars denote "Light", blue bars are "Moderate", red bars are "Heavy", and magenta bars are "Extreme" seasons. The black, solid line denotes the mean value over the time period while the dashed lines denote the ±0.67448σ (middle 50%) thresholds from the mean and the dot-dash line marks +1.28σ (top 10%).

Metric Comparison

Table B-7 shows the resulting severity definitions from the 50% standard deviation method applied to each of the metrics discussed in this section. It should be noted that the recorded and normalized severity class thresholds differ from those shown in Section B-2. This is because the statistics were determined from Reconnaissance Period 3 only as opposed to the definitions in **Table B-5** that were derived from the statistics of the normalized values from 1900 to 2018. To determine which of the metrics best fit our estimation of season severity, a series of cross correlations were conducted (not shown here), through which the NSSI was determined to have the best correlation (r = 0.97) to a combined severity index that incorporated every examined metric. Of the three primary measurements, NSSI was, itself, best correlated with the Limit Area (r = 0.95) but only slightly more strongly than to the icebergs south of 48˚N count (r = 0.94). In fact, the 48˚N count (recorded and normalized) had strong correlations with our combined index (r = 0.94). The NSSI had a slightly better correlation and is a useful tool because it includes each of the three primary severity measurements that each impact transatlantic shipping in their own way and normalizes each to their own distribution. However, the Season Length and Limit Area calculations are quite subjective with changing definitions over time. Each is subject to the changing Reconnaissance Periods as well as the interpretations of each season's CIIP. Additionally, as with Season Length and Limit Area, the NSSI cannot be calculated until the end of the season.

1983 - 2018 Metric Comparison								
Metric	Mean	0.67448σ	1.28σ	Median	Light Range	Moderate Range	Heavy Range	Extreme Range
Recorded (# bergs)	775	423	802	818	0 - <352	352 - <1197	1197 - 1577	> 1577
Normalized	35.83	19.01	36.08	37.78	0 - <17	17 - <55	55 - 72	> 72
Length (days)	129	41	78	146	0 - 88	89 - 170	171 - 207	> 207
Limit Area (km^2x10^5)	2.00	0.92	1.74	1.92	0 - <1.08	1.08 - <2.92	2.92 - 3.74	>3.74
NSSI	3.00	1.23	2.33	3.16	0 - <1.8	1.8 - <4.2	4.2 - <5.3	5.3 - 7.0

Table B-7. Results of the statistical analysis of each metric and definitions for "Light", "Moderate", "Heavy", and "Extreme" Iceberg Seasons by each in Period 3. It should be noted that the values listed here do not match those in Table B-5 or the definitions discussed in Section B-2. These are derived solely from the statistics of each metric within Period 3. While these values do not inform the severity classification definitions based on the normalization in Sections B-1 and B-2, they are shown here to explain the thresholds utilized for the metric comparison in this Section as observed in Figures B-7 to B-10.

Given these considerations, we assert that the iceberg count south of 48˚N provides the best measure of season severity. The subjectivity due to reconnaissance methods is known and can be corrected through normalization. Most importantly, it can be calculated daily to provide an in-season estimate of season severity throughout the year and is a practical number that is easily defined and communicated to stakeholders.

Conclusions

In this Appendix, we have analyzed and discussed the way in which season severity is measured and defined. The long-term trend analysis of iceberg counts south of 48˚N has shown that such a long data set is best considered with due regard for changes in technology. Our method of normalizing the iceberg count south of 48˚N to the Reconnaissance Period revealed two main results. First, that the generalized long-term trend of number of icebergs does not appear to be increasing as rapidly as the recorded count might suggest. Second, the results show that the variance has increased during the modern era. Given the scope of this appendix, it is unclear whether this increased variance is due to climatological factors or factors related to reconnaissance technology; but further analysis could probe this finding.

To determine normalized season severity class thresholds, we calculated the mean and standard deviation (mid-50% and top 10%) of the normalized data set from 1900 to 2018 and defined seasons that were "Light" (below the standard deviation threshold), "Moderate" (within the standard deviation threshold), “Heavy” (above the standard deviation threshold), or "Extreme" (top 10% standard deviation threshold). We then calculated the number of icebergs that corresponded to each value within a given Reconnaissance Period to provide the definitions presented in **Table B-8**. Using these standard deviation thresholds, we found that normalizing the iceberg count to the Reconnaissance Periods and then determining the statistical definition classes of severity resulted in a more realistic accounting of the number of recorded “Extreme” seasons.

	Severity Class Definition (# of Icebergs)			
	Light Range	Moderate Range	Heavy Range	Extreme Range
1900 - 1945	0 - 140	141 - 625	626 - 843	≥ 844
1946 - 1982	0 - 166	167 - 747	746 - 1008	≥ 1009
1983 - Present	0 - 230	231 - 1036	1037 - 1398	≥ 1399

Table B-8. The updated severity definitions extracted from Table B-5 for clarity. These are based on the statistics from the long-term normalization of the iceberg count to the Reconnaissance Periods.

In order to compare different severity metrics, we also applied this standard deviation scheme to the other season severity metrics in Reconnaissance Period 3 (from 1983 to 2018) where not only the number of icebergs south of 48˚N was recorded, but also the length of the iceberg season and the Iceberg Limit Area below 48˚N. Using these metrics, we compiled a Normalized Season Severity Index and calculated the statistical season severity thresholds for each data set. Conducting cross-correlations between the metrics, we found that the NSSI had the strongest correlation to a cumulative summary index but only slightly better than the iceberg count south of 48˚N.

While this analysis has shown that taking all three of the primary metrics and normalizing them to their own distributions (NSSI) is, statistically, the most accurate measure, this can only truly be done after the season has ended. Though this does not provide a near-real time ability to relate the season severity to stakeholders, it does provide the most accurate method of comparing the relative severity of seasons and includes three metrics of impact on transatlantic commerce. That said, it cannot replace the simplicity and practicality of the iceberg count south of 48˚N. The use of a more predictive tool, such as an in-season comparison to **Figure B-6**, would help to define the season severity in near real-time based on the monthly average count of icebergs that pass south of 48˚N and yield a statistically determined description throughout the season.

We assert that the NSSI, using the 50% standard deviation definition ("mid-fifty" scheme where the standard deviation threshold is set at ±0.67448σ), should be adopted as a useful post-season metric for analysis and comparison using the severity definitions in **Table B-7.** The count of icebergs south of 48˚N metric should continue to be maintained in real-time with our updated iceberg count definitions (**Table B-8**) based on normalizing the long-term iceberg record to reconnaissance technology periods. In-season comparison to the predictive mean of **Figure B-6** can provide a statistically meaningful and easily understandable basis for communications with stake-holders. Finally, by adding the "Heavy" severity classification, we have effectively preserved the use of the "Extreme" class for only the most severe seasons, providing a more understandable and practical method of sharing information with the maritime community.

The 2018 Iceberg Season		
Metric	**2018 Value**	**Severity Class**
Recorded 48˚N	208 bergs	Light
Normalized	10.35	Light
Length	146 days	Moderate
Limit Area	0.92 x10^5 km^2	Light
NSSI	1.9	Moderate

Table B-9. The values and severity definitions assigned to the 2018 Iceberg Season by each method described in this Appendix.

Our updated definitions for season severity by the iceberg count south of 48˚N are shown in **Table B-8** and the definitions for season severity by NSSI (as well as the other metrics considered here) are shown in **Table B-7**. By these definitions, 2018 was a "Light" season by iceberg count and a "Moderate" season by NSSI (**Table B-9**). **Table B-10** shows the ranking of all seasons comparing how the Trivers (1994) definitions and the full dataset normalized definitions would define and rank each season. 2018 ranks as the 49th lightest season on record by the 1994 definition and the 45th lightest by the 2018 normalized method.

As discussed in other parts of this Annual Report, satellite reconnaissance is playing an increasing role in the detection and count of icebergs. We assert that 2017, when the IIP OPCEN implemented satellite reconnaissance into full operational use, marks the beginning of Reconnaissance Period 4. As such, subsequent updates to the severity definitions and evaluations of long-term trends should be done with due regard for the impact of changes in method, accuracy, and frequency of reconnaissance operations, as well as advances in modeling and changes in product development on the iceberg record.

Recorded Iceberg Numbers Trivers (1994) Definitions				Normalized Iceberg Values 2018 Definitions			
Year	Bergs	Def.	Rank	Year	Value	Def.	Rank
1984	2202	Extreme	1	1929	100.00	Extreme	1
1991	1974	Extreme	2	1972	100.00	Extreme	1
1994	1765	Extreme	3	1984	100.00	Extreme	1
1993	1753	Extreme	4	1991	89.75	Extreme	2
1972	1588	Extreme	5	1974	87.47	Extreme	3
2014	1546	Extreme	6	1945	81.66	Extreme	4
1995	1432	Extreme	7	1994	80.35	Extreme	5
1974	1387	Extreme	8	1993	79.81	Extreme	6
1998	1380	Extreme	9	1909	78.53	Extreme	7
1983	1352	Extreme	10	1912	78.31	Extreme	8
1929	1329	Extreme	11	2014	70.51	Extreme	9
2009	1204	Extreme	12	1935	65.93	Extreme	10
2015	1165	Extreme	13	1995	65.38	Extreme	11
1945	1083	Extreme	14	1939	64.29	Extreme	12
1985	1063	Extreme	15	1943	63.55	Heavy	13
1909	1041	Extreme	16	1998	63.04	Heavy	14
1912	1038	Extreme	17	1905	62.20	Heavy	15
1997	1011	Extreme	18	1983	61.78	Heavy	16
2017	1008	Extreme	19	1903	60.71	Heavy	17
2008	976	Extreme	20	1957	59.04	Heavy	18
1957	931	Extreme	21	1921	57.73	Heavy	19
2003	927	Extreme	22	2009	55.13	Heavy	20
2002	877	Extreme	23	1914	54.67	Heavy	21
1992	876	Extreme	24	1973	53.74	Heavy	22
1935	872	Extreme	25	2015	53.38	Heavy	23
1939	850	Extreme	26	1944	53.11	Heavy	24
1973	846	Extreme	27	1938	50.43	Heavy	25
2000	843	Extreme	28	1985	48.79	Heavy	26
1943	840	Extreme	29	1907	48.26	Heavy	27
1905	822	Extreme	30	1997	46.45	Moderate	28
1903	802	Extreme	31	2017	46.32	Moderate	29
1990	793	Extreme	32	2008	44.88	Moderate	30
1921	762	Extreme	33	1959	43.95	Moderate	31
1914	721	Extreme	34	1934	43.87	Moderate	32
1944	700	Extreme	35	2003	42.68	Moderate	33
1959	689	Extreme	36	1913	41.41	Moderate	34
2016	687	Extreme	37	2002	40.43	Moderate	35
1938	664	Extreme	38	1992	40.38	Moderate	36
1907	635	Extreme	39	1932	39.24	Moderate	37
1996	611	Extreme	40	2000	38.90	Moderate	38
1934	576	Moderate	41	1928	38.72	Moderate	39
1913	543	Moderate	42	1930	38.50	Moderate	40
1948	523	Moderate	43	1922	37.60	Moderate	41

Recorded Iceberg Numbers Trivers (1994) Definitions			
Year	Bergs	Def.	Rank
1932	514	Moderate	44
1928	507	Moderate	45
1930	504	Moderate	46
2012	499	Moderate	47
1922	492	Moderate	48
1915	487	Moderate	49
1937	470	Moderate	50
1950	457	Moderate	51
1967	441	Moderate	52
1920	430	Moderate	53
1946	430	Moderate	53
1906	428	Moderate	54
1927	393	Moderate	55
1911	374	Moderate	56
1964	369	Moderate	57
1926	341	Moderate	58
2007	324	Moderate	59
1987	318	Moderate	60
1919	317	Moderate	61
1954	312	Moderate	62
1989	301	Moderate	63
1923	284	Light	64
1904	266	Light	65
2004	262	Light	66
1960	258	Light	67
1968	230	Light	68
1933	216	Light	69
2018	208	Light	70
1908	207	Light	71
1986	204	Light	72
1982	188	Light	73
1988	187	Light	74
1918	181	Light	75
1979	152	Light	76
1976	151	Light	77
1962	121	Light	78
1961	114	Light	79
1925	109	Light	80
1975	100	Light	81
2001	89	Light	82
1900	88	Light	83
1970	85	Light	84

Normalized Iceberg Values 2018 Definitions			
Year	Value	Def.	Rank
1915	37.23	Moderate	42
1990	36.65	Moderate	43
1937	35.96	Moderate	44
1948	33.61	Moderate	45
1920	32.98	Moderate	46
1906	32.83	Moderate	47
2016	31.89	Moderate	48
1927	30.22	Moderate	49
1950	29.49	Moderate	50
1911	28.81	Moderate	51
1967	28.49	Moderate	52
1996	28.47	Moderate	53
1946	27.81	Moderate	54
1926	26.35	Moderate	55
1919	24.56	Moderate	56
1964	24.00	Moderate	57
2012	23.43	Moderate	58
1923	22.10	Moderate	59
1904	20.76	Moderate	60
1954	20.45	Moderate	61
1960	17.08	Moderate	62
1933	17.03	Moderate	63
1908	16.36	Moderate	64
2007	15.57	Moderate	65
1968	15.34	Moderate	66
1987	15.30	Moderate	67
1989	14.53	Moderate	68
1918	14.42	Moderate	69
2004	12.78	Moderate	70
1982	12.72	Moderate	71
1979	10.48	Light	72
1976	10.41	Light	73
2018	10.35	Light	74
1986	10.17	Light	75
1988	9.41	Light	76
1925	9.05	Light	77
1962	8.54	Light	78
1961	8.11	Light	79
1900	7.49	Light	80
1975	7.23	Light	81
1901	6.96	Light	82
1970	6.30	Light	83

Recorded Iceberg Numbers Trivers (1994) Definitions				Normalized Iceberg Values 2018 Definitions			
Year	Bergs	Def.	Rank	Year	Value	Def.	Rank
1901	81	Light	85	1956	5.99	Light	84
1956	80	Light	86	1965	5.74	Light	85
1965	76	Light	87	1978	5.68	Light	86
1978	75	Light	88	1971	5.55	Light	87
1971	73	Light	89	1916	5.03	Light	88
1947	63	Light	90	2001	5.00	Light	89
1981	63	Light	90	1947	4.93	Light	90
1955	61	Light	91	1981	4.93	Light	91
1953	56	Light	92	1955	4.80	Light	92
1916	55	Light	93	1910	4.73	Light	93
1969	53	Light	94	1902	4.50	Light	94
1910	51	Light	95	1953	4.49	Light	95
1902	48	Light	96	1969	4.30	Light	96
1949	47	Light	97	1949	3.93	Light	97
1917	38	Light	98	1917	3.76	Light	98
1942	30	Light	99	1942	3.16	Light	99
1936	25	Light	100	1936	2.79	Light	100
1963	25	Light	101	1963	2.56	Light	101
1980	24	Light	102	1980	2.50	Light	102
1977	22	Light	103	1977	2.37	Light	103
1999	22	Light	103	1999	1.99	Light	104
1952	15	Light	104	1931	1.97	Light	105
1931	14	Light	105	1952	1.94	Light	106
2013	13	Light	106	1924	1.75	Light	107
1924	11	Light	107	2013	1.58	Light	108
2005	11	Light	107	1951	1.50	Light	109
1951	8	Light	108	2005	1.49	Light	110
1941	3	Light	109	1941	1.15	Light	111
2011	3	Light	109	2011	1.13	Light	112
1940	1	Light	110	1958	1.06	Light	113
1958	1	Light	110	2010	1.04	Light	114
2010	1	Light	110	1940	1.00	Light	115
1966	0	Light	111	1966	1.00	Light	115
2006	0	Light	111	2006	1.00	Light	115

Table B-10. Ranking of iceberg seasons by the Trivers (1994) definitions applied to the recorded iceberg numbers (left) and the normalized definitions calculated from the statistics of all normalized years (right; using the definitions from the top row of Table B-5). Reconnaissance Period 1 years are highlighted in brown, Period 2 is highlighted in blue, and Period 3 is highlighted in purple. 2018 is highlighted in magenta.

References

Afultis, M. (1987). Iceberg Populations South of 48N Since 1900. *Report of the International Ice Patrol Services in the North Atlantic* Bulletin No. 73, Appendix B, pp 52-62.

Bigg, G.R., Wei, H.L., Wilton, D.J., Zhao, Y., Billings, S.A., Hanna, E., and Kadirkamanathan, V. (2014). A century of variation in the dependence of Greenland iceberg calving on ice sheet surface mass balance and regional climate change. *Proceedings of the Royal Society Part A.* 470: 20160662. http://dx.doi.org/10.1098/rspa.201.0662

Fischer, J., Visbeck, M., Zantopp, R., and Nunes, N. (2010). Interannual to decadal variability of outflow from the Labrador Sea. *Geophysical Research Letters,* 37. L24610, doi:10.1029/2010GL045321

Futch, V., and Murphy, D. (2002). Season Severity by Three Variable Index: LAKI Area, Length of Season, Iceberg Population below 48°N. *Report of the International Ice Patrol Services in the North Atlantic* Bulletin No. 88, Appendix E, pp 56-63.

Marko, J.R., Fissel, D.B., and Wadhams, P., Kelly, P.M., and Brown, R.D. (1994). Iceberg Severity off Eastern North America: Its Relationship to Sea-ice Variability and Climate Change. *Journal of Climate* 7, pp 1335-1351.

Mountain, D. (1980). On Predicted Iceberg Drift. *Cold Regions Science and Technology* 1, pp 273-282.

Palter, J.B., Caron, C.-A., Law, K.L., Willis, J.K., Trossman, D.S., Yashayaev, I.M., and Gilbert, D. (2016). Variability of the directly observed, middepth subpolar North Atlantic circulation. *Geophysical Research Letters* 42.

Smith, E. (1926). Summary of Iceberg Records In the North Western North Atlantic, 1880-1926. *Report of the International Ice Patrol Services in the North Atlantic* Bulletin No. 15, pp 75-77.

Trivers, G. (1994). International Ice Patrol's Iceberg Season Severity. *Report of the International Ice Patrol Services in the North Atlantic* Bulletin No. 80, Appendix C, pp 49-59.

Appendix C. International Ice Patrol Satellite Reconnaissance Modernization

LCDR Caroline Bell, Mr. Mike Hicks

Introduction

Since 1997, International Ice Patrol (IIP) has been actively involved with advancing the incorporation of satellite imagery analysis into its reconnaissance methods. Early work included evaluations of RADARSAT-1, RADARSAT-2, Envisat, and TerraSAR-X satellite synthetic aperture radar (SAR) systems, but validation efforts showed poor correlation between aerial observation and satellite detection results (IIP, 2015; IIP, 2016). Additionally, these commercial SAR sources proved cost-prohibitive until recently. In 2017, the shift from solely aerial reconnaissance to a combination of aerial and satellite reconnaissance became a reality for two specific reasons: (1) the launch of the European Space Agency's (ESA) Sentinel 1A and 1B SAR satellites with open source data, and (2) IIP's purchase of a license to operate Iceberg Detection Software (IDS), developed by C-CORE of St. John's, Newfoundland, in late 2016. Use of the IDS provided IIP staff members with a tool to analyze satellite imagery, and for the first time on January 24, 2017, incorporate satellite data derived entirely by IIP staff into the iceBerg Analysis and Prediction System (BAPS) and iceberg warning products.

IIP's proficiency in processing and analyzing SAR imagery has increased steadily since the 2017 milestone. Challenges, including the limitations of existing computer algorithms to reliably discriminate between icebergs, sea ice, and small vessels (without AIS transmitters), and the lack of formal SAR image training and limited proficiency for IIP staff, required a simple, conservative approach for initial satellite analysis efforts in 2017. With a year of experience and key process changes, 2018 resulted in a significant increase in the number of SAR images processed and icebergs detected by satellite compared to 2017. These changes include improved filtering methods, automated scripts to increase the efficiency of downloading and analyzing individual frames, and the creation of a dedicated Satellite Day Worker (SDW) from IIP's crew complement to work in the Operations Centers (OPCEN). IIP is continuing to refine satellite imagery processing and analysis procedures; learning from satellite validation under-flight results, and using relationships with industry partners, the Canadian Ice Service (CIS), the National Aeronautics and Space Administration (NASA) Jet Propulsion Lab (JPL) and the Danish Meteorological Institute (DMI). This appendix documents IIP's progress towards modernizing reconnaissance methods over the past two years. It concludes with a brief overview of IIP's satellite validation process, and a look towards machine learning solutions. While aerial reconnaissance remains the primary reconnaissance method, especially in the shipping lanes south of 48°N, IIP's work since 2017 has built a solid foundation for increasing the effectiveness of satellite iceberg reconnaissance.

2017 Initial Analysis and Reconnaissance Approach

A license for the C-CORE IDS tool was purchased by IIP and the CIS through our North American Ice Service (NAIS) partnership in 2016. IDS automates the initial step of SAR image analysis by detecting possible targets for further examination and classification by an analyst. IDS is capable of analyzing SAR satellite imagery from RADARSAT-1, RADARSAT-2, TerraSAR-X, Cosmo SkyMed, and Sentinel-1 sources. Through systematic scanning, IDS compares pixel brightness to that of the surrounding pixels, identifying a possible target when the difference reaches a predefined threshold. User defined settings can modify the sensitivity of targets detected through adjusting the level of false alarm tolerance through either a constant false alarm rate (CFAR) or standard deviation level. Additionally, applying a land mask to the IDS algorithm sets a buffer around coastline and island features to eliminate false positive land targets, which are brighter than surrounding water in a SAR image. **Figure C-1** shows the difference in IDS results with a land mask applied to Newfoundland and Labrador (right side of image), and without a land mask over Quebec (left side of image). The IDS outputs an ArcGIS compatible file of possible targets, which are analyzed further by IIP watchstanders and classified as either icebergs, ships, or false positive targets.

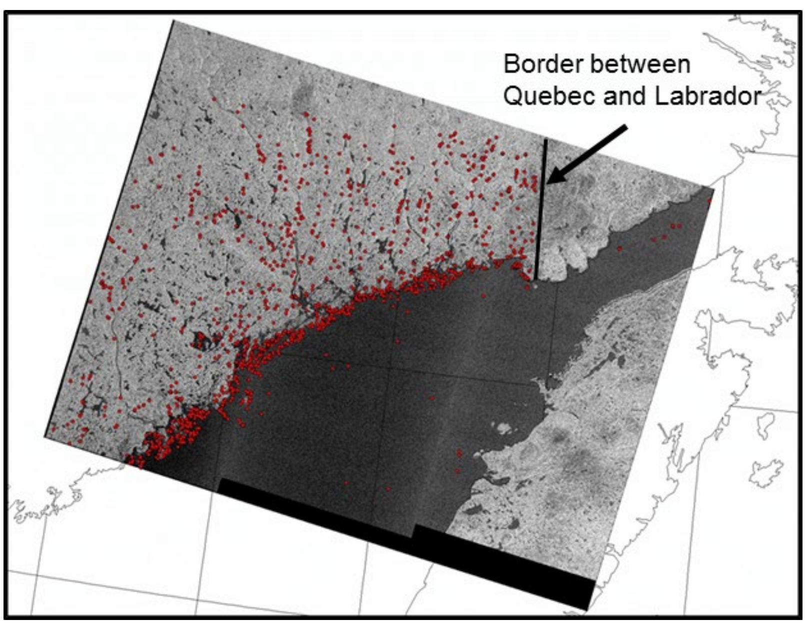


Figure c-1. Sentinel 1A image from 24 June 2018 in the Bay of Saint Lawrence and Strait of Belle Isle. Red dots are possible targets identified by IDS. A landmask filter has been applied in the IDS processing for Newfoundland and Labrador but not Quebec. IDS identified possible targets on land and islands in Quebec.

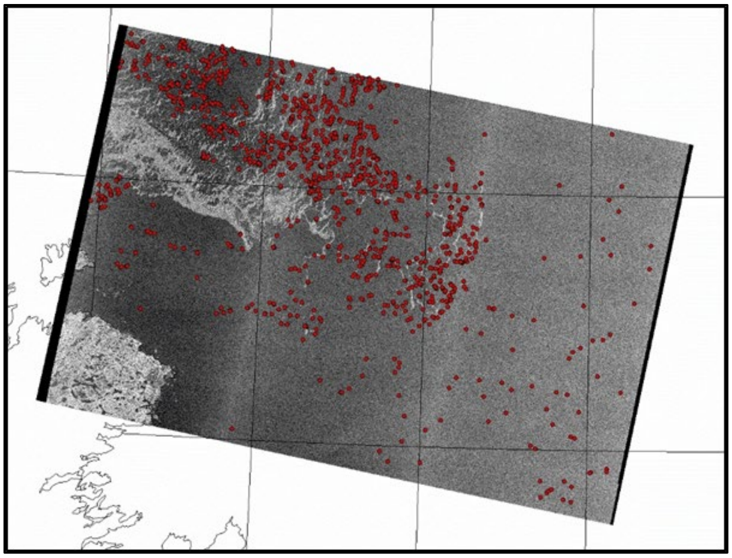


Figure C-2. An example of the initial target output (red dots) from a Sentinel 1A image processed through IDS.

Target detection with the IDS represents the first step in imagery analysis, and it typically results in hundreds to thousands of possible objects that meet the brightness threshold for consideration **(Figure C-2)**. Positively identifying candidate targets is a considerable challenge, especially for ambiguous targets with low signal strength, or for small vessels that do not transmit their location through AIS. Certain satellite sensors and modes have a built-in classification library in the IDS which aids in target identification. This enhancement, however, is not yet available for Sentinel 1A and 1B imagery.

In 2017, OPCEN watchstanders absorbed complex satellite image analysis tasks into their daily routine of processing iceberg reports, running iceberg models, creating daily warning products, and planning aerial reconnaissance for ice reconnaissance detachments (IRDs). To properly balance these new duties with existing responsibilities, IIP developed and followed a simple image analysis approach. Watchstanders only retained targets assigned a high confidence (target pixels greater than 10 decibels above background pixels) by the IDS and detected in dual polarizations, either HH + HV, or VV + VH. HH and VV are single polarization horizontal or vertical images respectively, and HV and VH are cross channel polarization images. This reduced the amount of possible targets IIP watchstanders needed to visually classify as icebergs. IIP watchstanders used AIS data from USCG's E-GIS database to assist in identifying vessels from the remaining high confidence dual-polarization targets.

As outlined in IIP's 2016 Satellite Reconnaissance CONOPS (IIP,2016), IIP focused the first year of in house satellite analysis on images well inside the iceberg limits in the northern portion of IIP's operational area; region A in **Figure C-3**. Region A, however, proved challenging because of the large areas covered by sea ice, which appear very similar to icebergs in SAR images. Also during the 2017 Ice Season, IIP incorporated icebergs from satellite reconnaissance imagery analyzed by C-CORE in support industry. Many of the C-CORE analyzed frames were from regions B and C, which resulted in a slight shift in focus from IIP's Satellite Reconnaissance CONOPS by incorporating data from the southern region of IIP's OPAREA into BAPS and the iceberg warning products.

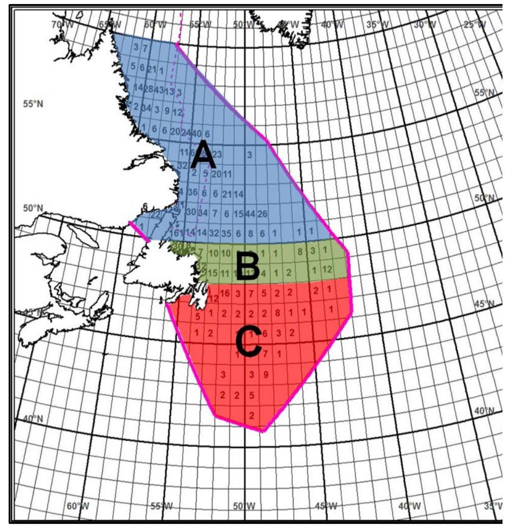


Figure C-3. IIP's satellite reconnaissance strategy regions from Satellite CONOPS.

During the 2017 Ice Season, IIP processed 185 satellite standard iceberg messages (SIMs), which resulted in 1,799 icebergs incorporated into BAPS. One hundred and two of those SIMs created from imagery were downloaded and analyzed in house by IIP watchstanders, adding 327 icebergs and re-sighting 367 icebergs into the model. The remaining 83 SIMs were created from images analyzed by C-CORE, in support of industry, adding 158 icebergs and re-sighting 947 icebergs in BAPS.

2018 Satellite Analysis and Reconnaissance Improvements

IIP received refresher training from C-CORE on SAR satellite imagery and the IDS program before the 2018 ice season. This training, combined with a year of experience analyzing satellite imagery positioned IIP with a better understanding of the variables affecting targets detection, and the roles they played in target discrimination. The key variables include image polarization, incidence angle, wind speed, and sea ice cover. With greater knowledge of the affect that these variables have on target identification, IIP developed new analysis procedures for the 2018 ice season. To better manage the workload, IIP created a Satellite Day Worker (SDW) position. IIP policy directed watchstanders and SDW's to examine all high confidence targets with either single or dual polarization. To reduce the impact of high winds or sea ice, which result in large numbers of false positive targets, IIP focused analysis in areas of low wind speed and sea ice concentration, using geo-referenced layer files provided by NOAA and CIS, respectively. IIP also applied an AIS layer file to eliminate vessels from the IDS results. The remainder of this section describes these improvements in greater detail.

Satellite Day Worker. In February 2018, IIP created a dedicated SDW position. Each day, an IIP crewmember filled the SDW role to download, analyze, and create a Manual of Standard Procedures for Observing and Reporting Ice Conditions (MANICE) SIM for selected satellite frames. Throughout 2017, satellite imagery processing and analysis fell on IIP's OPCEN watchstanders, which due to their other duties, limited the number of frames downloaded and analyzed for icebergs. Typically, the watch would process one to two satellite frames as they completed daily product creation, SIM processing, and aerial reconnaissance support. The SDW position was developed to increase the number of satellite frames downloaded and processed for icebergs, to continue to refine the target filtering procedures, and to validate satellite reconnaissance with aerial reconnaissance.

Another improvement to IIP's satellite analysis process came from collaboration with the US Coast Guard Research and Development Center's Modeling and Simulation Center of Excellence (MSCOE). Staff from the MSCOE developed a script to automate downloading satellite frames in a selected area on a specific day, and process them through the IDS. The script improved efficiency and productivity, limiting the manual inputs necessary by the SDW and minimizing the time spent monitoring the downloading and processing frames through the IDS. In addition to decreasing the inputs required by the SDW, the MSCOE script better utilized computing power by running multiple frames through IDS simultaneously. This automation process, combined with creation of the dedicated SDW position, resulted in a 200% increase in the number of satellite frames processed in house.

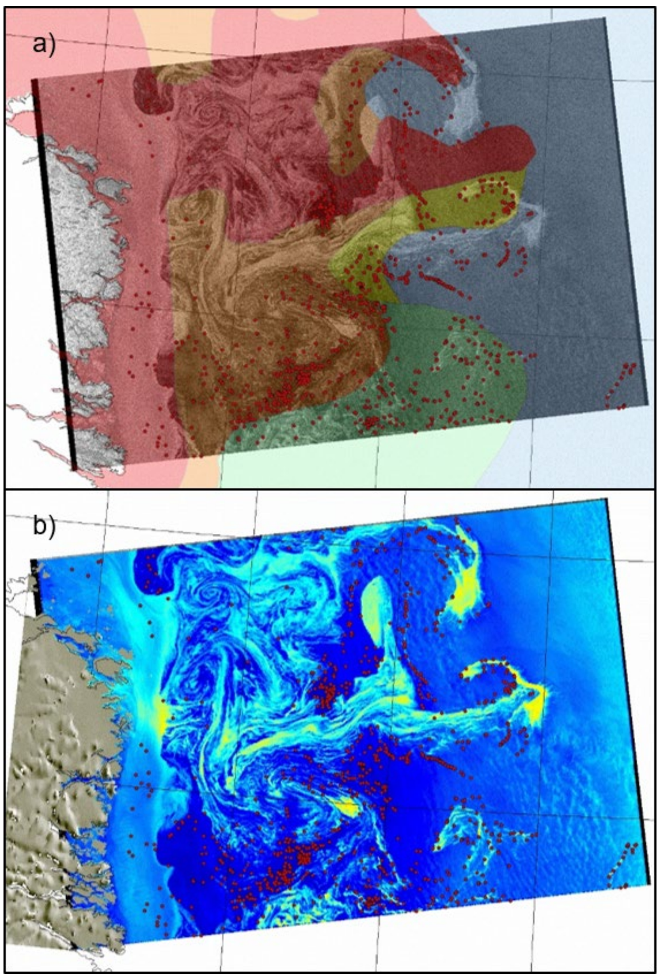


Figure C-4. Sentinel 1A image from 13 March 2018 a) overlaid with IDS targets (red dots) and sea ice shapefile (red, orange, yellow, and green shading) where red and orange shading are greater than 7/10 sea ice cover and b) overlaid with SAR wind data, where dark blue is 0 kt wind speed and yellow is 30 kt wind speed or areas covered by sea ice. Sea Ice shapefile is from https://iceweb1.cis.ec.gc.ca/Prod/page2.xhtml?CanID=11091&lang=en, SAR Wind overlay from https://www.ospo.noaa.gov/Products/ocean/sar/.

CIS Sea Ice Analyses. The presence of sea ice throughout IIP's OPAREA proves challenging to satellite imagery analysis, particularly from February through April. The texture of sea ice and similar composition to icebergs make it difficult to discriminate and positively identify icebergs contained in sea ice in SAR imagery. Both rough, compacted sea ice and icebergs show up brighter in SAR imagery, and are identified as possible targets in IDS outputs. To improve SDW's awareness of sea ice, IIP used daily sea ice shapefiles provided by CIS overlaid in ArcGIS with the satellite images and output targets from the IDS (CIS, 2018). **Figure C-4** (top panel) shows an example from 13 March 2018. With an understanding of the limitations in detecting icebergs in sea ice, IIP established policy for watchstanders to remove from consideration, all single polarization high confidence targets in greater than 7/10's sea ice coverage.

NOAA SAR Derived Winds. As with sea ice, detecting icebergs in areas with high surface wind speeds poses a challenge to SAR image analysis. Higher wind speeds impede SAR satellite's ability to detect actual targets because of increased ocean clutter; a phenomenon notably more pronounced in HH images (Dodge, 2017). An understanding of wind speed over the image area allowed IIP to further refine the filtering process. To assess wind speeds over the image area, IIP accessed, downloaded, and overlaid SAR-derived Wind Data provided by NOAA's Office of Satellite and Product Operations (NOAA, 2018). This NOAA product was developed using the same Sentinel-1 imagery that IIP used for analysis. As a result, areas of sea ice were depicted as high wind speeds due to increased ocean surface roughness (yellow areas in **Figure C-4b**). The bottom panel of **Figure C-4** shows the overlay of SAR winds from NOAA on IDS target output. By viewing both the sea ice and SAR Wind layers together, IIP watchstanders could easily distinguish between sea ice and open water. To address iceberg detection limitations in high winds, IIP policy directed the SDW to filter out targets in areas where the wind was greater than 15kts for both HH and VV images as indicated in the NOAA SAR Wind product. **Table C-1** summarizes the filtering methods used by IIP with respect to wind speed and sea ice concentration.

Confidence	Channels Detected	Wind Speed	Sea Ice Concentration
High	Dual Pol HH, HV or VV, VH	ANY	ANY
	* Single Pol HV or VH	ANY	<7/10
	Single Pol HH or VV	< 15 kts	<7/10
* Cross-channel polarizations will not appear as bright.			

Table C-1. Satellite analysis filtering guide for high confidence targets based on image polarization, wind speeds, and sea ice concentration

USCG AIS Data. As in 2017, IIP continued to classify targets as ships based on AIS data from USCG's E-GIS database. However, smaller ships which are not required to use AIS, such as fishing vessels, proved challenging to distinguish from icebergs. In certain situations, IIP watchstanders received support to identify ambiguous targets from the USCG's Maritime Intelligence Fusion Center Atlantic (MIFC LANT).

Throughout the 2018 Ice Season (February thru August), the SDW and OPCEN watch analyzed, processed, and incorporated 305 SIMs from satellite frames in-house; a threefold increase over the 102 IIP analyzed satellite SIMs during 2017. On average, about 2.5 frames were analyzed and added into BAPS per day by the SDW during the 2018 Ice Season. These 305 frames resulted in 1,255 icebergs added or re-sighted within BAPS. Pre-analysis, the iceberg detection algorithm in IDS identified anywhere between 5 and 18,000 possible targets per satellite frame, but averaged 557 target per frame. Of the possible targets detected by IDS, 0.719% were classified by IIP as icebergs, or an average of 4 icebergs per frame. This tiny percentage highlights one of the key challenges to satellite iceberg reconnaissance: target detection is only the first step; target classification requires continued advancement. Analyzing an average of 557 possible targets in a single SAR satellite frame to manually classify icebergs and ships is time consuming and subjective. Ongoing validation efforts are required to ground truth satellite data and provide feedback for machine learning processes and IDS classifiers for SAR images. **Figure C-5** shows the dramatic increase in the percentage of icebergs derived by satellite reconnaissance as compared to all iceberg sources.

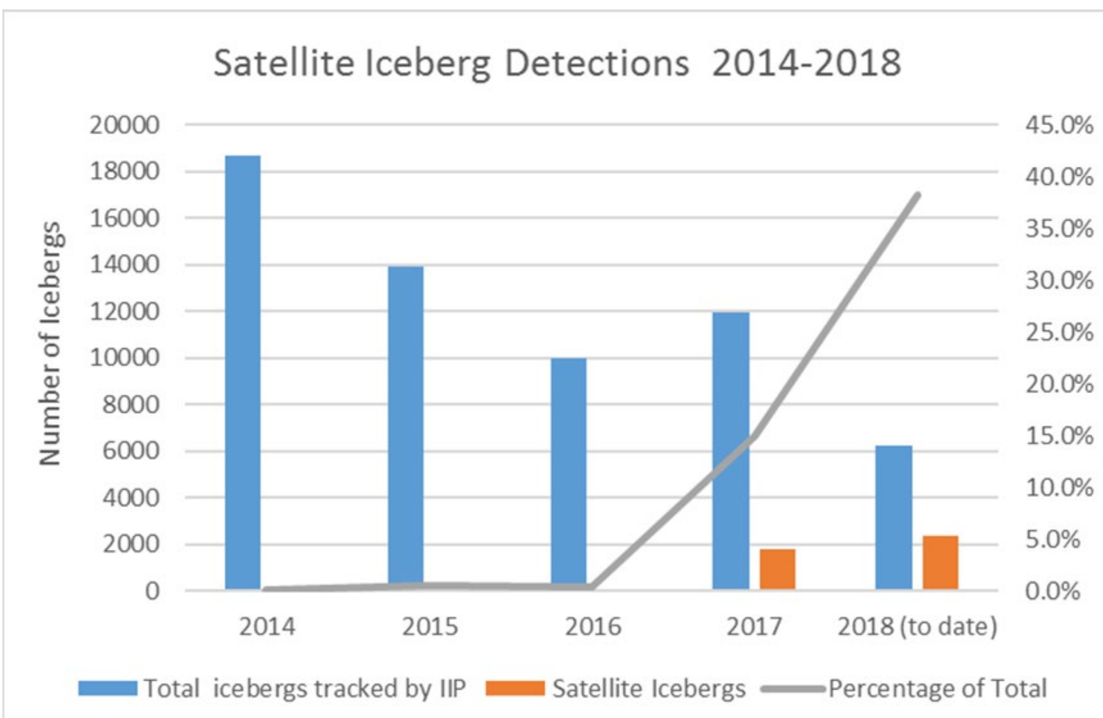


Figure C-5. Satellite Iceberg Detections from 2014 through 2018. The blue column represents icebergs from all satellite sources and the orange column are detections from satellites only. The grey lines shows the increase in the percentage of targets derived by satellite reconnaissance.

Satellite Image Analysis Validation. IIP prioritized satellite validation flights during IRDs when Iceberg Limit extent and iceberg conditions allowed over the 2018 ice season. 2018 was a light iceberg season with the maximum limit extent remaining near to St. John's, Newfoundland enabling satellite validation as at least a portion of the flight plan for 15 of 39 IRD flights. Satellite validation flights were planned to cover the area of that day or the previous day's satellite frame swath. On these flights IIP IRD crewmembers captured high definition camera images of each iceberg within the satellite frame, inverse synthetic aperture radar (ISAR) images from the Minotaur Mission System suite, and accurate position and size data of the iceberg through correlating visual icebergs with radar targets. ISAR provides a two dimensional image of a specific radar target and provides a way to distinguish between ships and icebergs in all visibility conditions. The 15 satellite validation flights correlated with a combination of 29 Sentinel 1A/B and RADARSAT-2 frames.

Future Efforts. At the end of the 2018 ice season, IIP shifted focus of the SDW position to compare data from satellite validation flights with targets from the corresponding satellite frames. This validation work is ongoing, but shows promise in providing IIP ground truth data on satellite targets correlated with visually identified icebergs. **Figure C-6** is an example of a camera image from an IRD flight and a correlated Sentinel 1 satellite target from reconnaissance on 04 May 2018. In addition to developing a database of satellite targets that correlate with verified icebergs, IIP is continuing to refine the

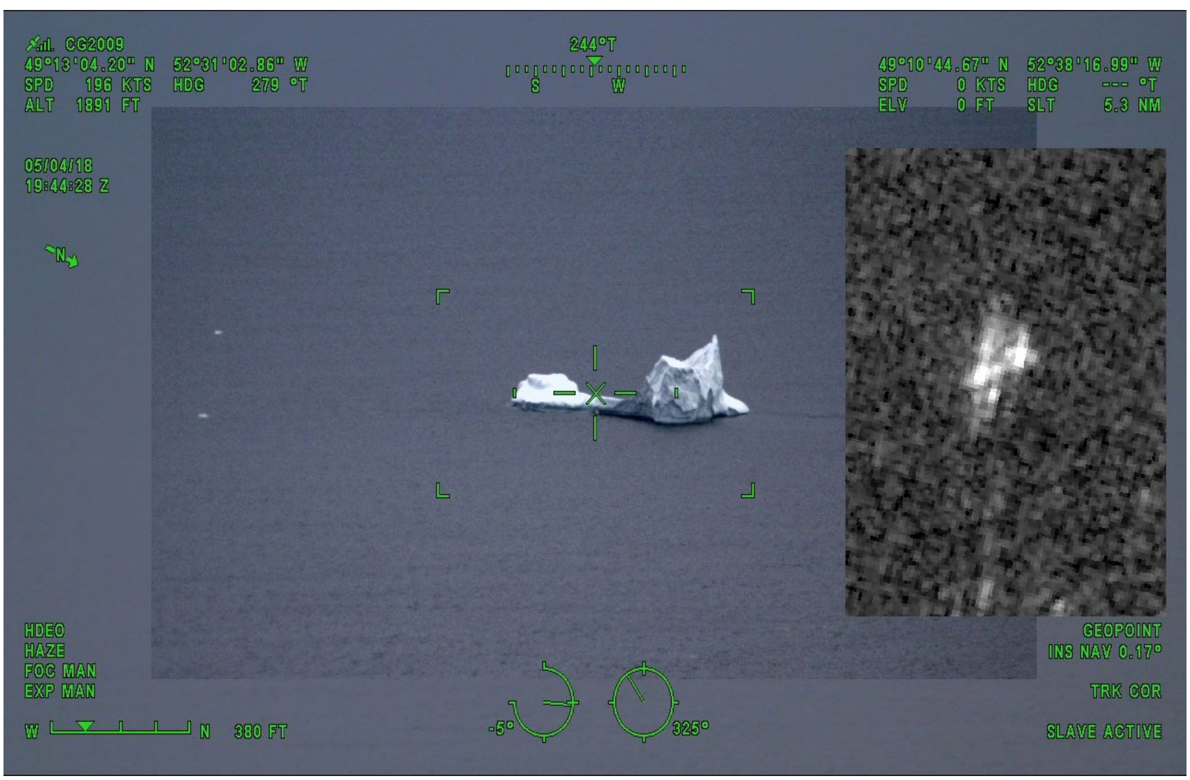


Figure C-6. Camera image of an iceberg detected on 04 May 2018 by an IIP IRD flight inset with the corresponding Sentinel 1 satellite image from.

filtering process for the 2019 ice season. IIP SDW's are testing the effects that different CFAR levels have on initial IDS targets detection and their correlation with icebergs identified by aerial reconnaissance. Using lower CFAR levels reduces the number of potential targets identified by IDS, reducing the number of items the SDW will have to analyze and classify, but may result in a greater number of false negative targets by not identifying small icebergs (15-60m in length) as possible targets.

Other Satellite Reconnaissance Improvement

In November 2017, IIP began working with a team from NASA's JPL to develop a remote sensing SAR analysis data system approach that employs machine learning to reliably detect and positively identify icebergs from other ambiguous targets. Data from IIP's validation flights will aid NASA JPL's machine learning project to improve the precision and automation of satellite iceberg reconnaissance. A team at NASA JPL has developed a cloud based machine learning technique that detects targets and distinguishes between icebergs and ships in SAR images. The proto-type model was developed using data from IRD flights from 2017 and positions of icebergs from IIP's iceberg database over several years. The initial results showed a greater than 90% cross-validation accuracy, but were completed on a small scale. In order to improve distinguishing the different signatures of icebergs and ships, validated satellite target data collected during 2018 will add to the database of images used for training the machine learning model. Additionally, IIP is pursuing an iceberg GPS-tagging campaign with the Department of Homeland Security's Science and Technology (DHS S&T) directorate for the 2019 Ice Season aimed at developing a more robust data set of validated iceberg satellite images.

A project with DMI shows the current challenge of relying only on satellite reconnaissance to develop an iceberg warning product in IIP's OPAREA. DMI provides an estimated limit of icebergs around Greenland to CIS and IIP for the NAIS iceberg warning products currently based on climatological data from 1981 and 2010. In 2018, DMI transitioned to soley using satellite reconnaissance and automated algorithms in the development of Danish Iceberg Charts. In their work, DMI provided IIP with a sample of the satellite iceberg detection results in IIP's OPAREA. **Figure C-7** shows a comparison between the DMI derived icebergs (left) and NAIS iceberg warning chart (right) for 13 August 2018. The satellite reconnaissance icebergs on DMI's graphic align with icebergs modeled on the NAIS chart north of 50°N. Icebergs in DMI's AOR and north of 50°N are typically large and less weathered, and easier to detect by SAR satellites, than those in IIP's AOR. Additionally the presence of small ships is less common, which makes it easier for an algorithm to differentiate between icebergs and ships. However, south of 50°N, especially over the Flemish Cap and Grand Banks, DMI's automated method does not distinguish well between icebergs and small ships. IIP's reconnaissance and model show one iceberg south of 50°N on 13 August, but the satellite reconnaissance detection

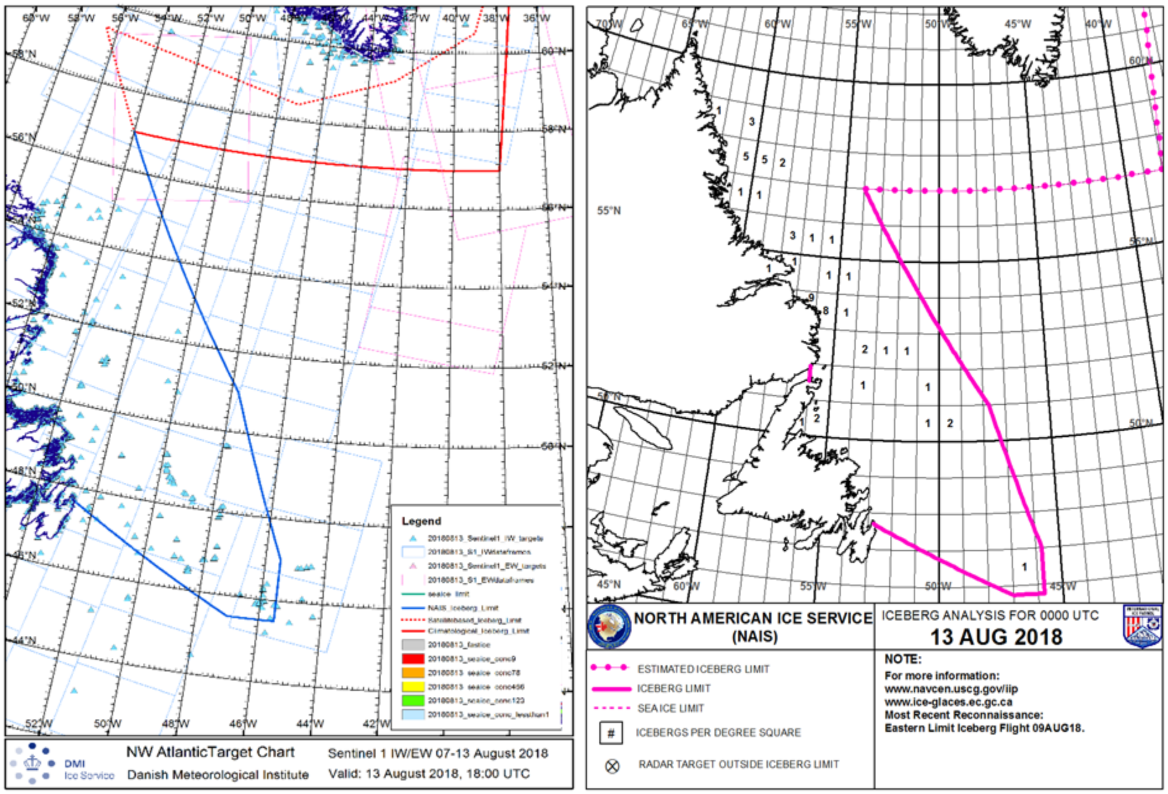


Figure C-7. Comparison between DMI satellite iceberg detection products (left) and IIP's NAIS iceberg warning product (right) for 13 August 2018. Small blue triangles in the left image represent targets identified by DMI that could be icebergs, which south of 50°N, do not align well with IIP's modeled iceberg positions. The challenge with satellite only detection south of 50°N is the greater presence of small ships that do not transmit over AIS and small icebergs.

methods show nearly a hundred targets. This example highlights the difficulty in distinguishing between small icebergs and ships in SAR satellite imagery. It also demonstrates how false positive targets would affect maritime transportation, the iceberg limit would be expanded unnecessarily by several degrees to the south and east if it were based solely on satellite reconnaissance. Validation flights collecting ground truth data to feed machine learning models and classifiers for the IDS tools are designed to lessen the small iceberg/small ship problem.

In addition to working with partners outside the Coast Guard, IIP is changing the makeup of its workforce to align the skills needed to analyze satellite reconnaissance. IIP enlisted workforce had historically consisted of Marine Science Technicians (MSTs) with backgrounds in meteorology and oceanography, and a Yeoman (YN) for administrative support. In the summer of 2019, IIP will transition 3 of 9 MST billets to Intelligence Specialists (IS) with advanced training in geospatial intelligence and satellite image analysis. The shift from all MST enlisted workforce to incorporate IS members will augment and improve IIP's satellite imagery analysis.

Conclusion

The availability and reliability of ESA's Sentinel 1 A/B polar orbiting satellites with open-source data, the partnership with C-CORE, and the licensing their IDS tool were game changers in the shift to satellite reconnaissance. With the assistance of numerous USCG, interagency, international government, and industry partners, IIP will continue to advance modernized reconnaissance methods through improving how satellite images are processed and analyzed. Incorporating results and process improvements learned from satellite validation under-flights, shared work with partner agencies to advance automatic iceberg detection, and updating IIP's workforce are all key strategic developments to advance satellite iceberg reconnaissance and modernizing the International Ice Patrol to meet the challenges of the next century of operations.

Over the 105-year history of IIP, the primary reconnaissance method has changed three times. From ships in 1913 to 1945, to aircraft in 1946 to 1982, and aircraft fitted with radar from 1983 to present. 2017 marked the shift to a new fourth era of reconnaissance with satellites. While much progress is still to be made before satellites replace aircraft, continued efforts by IIP and strategic partners show a promising future. As with each previous transition, there will be a period of overlap as IIP develops the protocol and procedures while improving trust and confidence in data and methodology to ensure we provide the most accurate information for the safety of those transiting the iceberg-rich waters of the North Atlantic.

References

Canadian Ice Service. (2018). CIS Ice Charts of East Newfoundland Waters. Retrieved 13 March 2018 from: https://iceweb1.cis.ec.gc.ca/Prod/page2.xhtml?CanID=11091&lang=en

Dodge, Kelley. (2017). IDS Training Questions. Powerpoint Presentation on 12 December 2017.

IIP. (2015). Report of the International Ice Patrol in the North Atlantic (2015 Season), Bulletin No. 101, Appendix B.

IIP. (2016). Report of the International Ice Patrol in the North Atlantic (2016 Season), Bulletin No. 102, Appendix C.

National Ocean and Atmospheric Administration. (2018). Operational SAR Derived Wind Products. Retrieved 13 March 2018 from: https://www.ospo.noaa.gov/Products/ocean/sar/