Homeland Security

United States Coast Guard

Report of the International Ice Patrol in the North Atlantic

2022 Season
Bulletin No. 108
CG-188-77

INTERNATIONAL ICE PATROL

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Forwarded herewith is Bulletin No. 108 of the International Ice Patrol (IIP), describing the Patrol's services and ice conditions during the 2022 Ice Year. In 2022, 58 icebergs drifted into transatlantic shipping lanes, marking the third consecutive “Light” Ice Season, following one iceberg in 2021 and 169 in 2020. This was preceded by an “Extreme” season in 2019, which saw 1,515 icebergs impacting IIP’s Iceberg Limit. While the impact of climate change to the iceberg danger in the North Atlantic is of keen interest to IIP and its partners, seasonal variability remains a reality and IIP anticipates future heavier seasons. For example, in 1975, IIP experienced seven consecutive “Light” seasons followed by an “Extreme” season which saw more than 2000 icebergs. The Ice and Environmental Conditions section presents a discussion of the meteorological and oceanographic conditions that resulted in this year’s light season.

In 2022, IIP detected the majority of icebergs using commercial satellites, as opposed to C-130 aircraft, continuing the trend begun in 2020. IIP’s first operational use of satellite imagery for iceberg detection occurred in 2017, which is considered the beginning of the “modern era” for IIP reconnaissance. IIP remains committed to the short-term elimination of the need for costly aircraft hours. Following IIP’s 2021 relocation to the National Capital Region, IIP deepened partnerships with federal agencies involved in geospatial intelligence and information systems. These partnerships allow IIP to access systems and training that will be a key part of the transition to satellite-only reconnaissance.

IIP relied on satellite reconnaissance in providing tailored decision support to two non-ice-strengthened Coast Guard cutters, as well as foreign partner vessels, off Greenland, supporting the growing demand for iceberg warning products to enable increased Arctic engagement. IIP anticipates growing demand for these product lines.

Each year, IIP honors events inextricably linked to our history, holding memorials and wreath dedications honoring the loss of RMS TITANIC in Washington, DC, and Halifax, Nova Scotia. This is followed by a commemoration of the Greenland Patrol, honoring its sacrifices during WWII. For the first time since 2019, IIP was able to host its traditional RMS TITANIC remembrance ceremony in Halifax, attended by dignitaries and members of the public, concluding with a visit to the TITANIC cemetery and aerial wreath drop over the site of the sinking.

This report was prepared by all members of the IIP team. On behalf of all of us, I hope that you enjoy reading this report of the 2022 season.

M. T. Hirschberg
Commander, U. S. Coast Guard
Commander, International Ice Patrol

International Ice Patrol
2022 Annual Report
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Previous IIP Annual Reports may be obtained from the IIP website:

http://www.navcen.uscg.gov/?pageName=IIPAnnualReports

Cover art: A collection of several images highlighting different operations throughout the 2022 Ice Season. The top image is the entire International Ice Patrol crew in front of a C-130, taken at the start of the season. The bottom left image depicts a Sentinel-2 true color image of a large iceberg in sea ice. The image second from the left is a C-130 on the tarmac in St. John's, Newfoundland, taken during the first IRD. The third image on the bottom is USCGC Escanaba taken during operation NANOOK. The bottom right image is the new building for the International Ice Patrol, the NOAA Satellite Operations Center located in Suitland, MD.

1. Introduction

This is the 108th annual report of the IIP describing the 2022 Ice Year. It contains information on North Atlantic environmental and iceberg conditions and IIP operations from October 2021 to September 2022 with a focus on the Ice Season (February to August 2022). To conduct aerial reconnaissance, IIP deployed seven Ice Reconnaissance Detachments (IRD) to detect icebergs in the North Atlantic and Labrador Sea. These IRDs used HC-130J aircraft from U.S. Coast Guard (USCG) Air Station Elizabeth City (ASEC).

In addition to this reconnaissance data, IIP received iceberg reports from commercial aircraft and mariners in the North Atlantic. IIP personnel analyzed iceberg and environmental data using iceberg drift and deterioration models within the iceBerg Analysis and Prediction System (BAPS). This work was performed at the IIP Operations Center (OPCEN) in the National Capital Region's National Oceanic and Atmospheric Administration (NOAA) Satellite Operations Facility. In accordance with the North American Ice Service (NAIS) Collaborative Arrangement, IIP used BAPS to produce a daily iceberg chart and a text bulletin from 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.

While aviation missions will continue in 2023, IIP remains committed to transitioning all reconnaissance to space-based systems in the near future. Although aircraft remain the most accurate method of sighting small icebergs, developments in commercial imagery and access to interagency partnerships and expertise make satellite-only reconnaissance a viable option in the short term for IIP. During the 2023 Season, IIP will conduct validation tests of an automatic correlator for vessels Automatic Identification Systems (AIS) transmitters. Differentiating vessels from icebergs in synthetic aperture radar (SAR) imagery is one of IIP's primary challenges, and automation of this process will add analyst capacity to address more complex oceanographic and technical challenges.

In May, approximately halfway through the reconnaissance season, the five remaining IRD's were canceled due to an urgent need for C-130 aircraft to support safety of life at sea amid a surge in dangerous maritime migration and loss of life. IIP pivoted to satellite reconnaissance alone, leveraged lessons learned from pandemic-reduced reconnaissance, and modified the daily Iceberg Limit to reflect increased uncertainty. IIP also relied on its partnership with the Canadian Ice Service (CIS) to ensure adequate coverage of the Iceberg Limit, highlighting the critical importance of this long-standing relationship.

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 2022 Ice Season, IIP was under the operational control of the Director of Marine Transportation (CG-5PW), Mr. Michael D. Emerson. CDR Marcus T. Hirschberg 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

This section describes the ice and environmental conditions throughout IIP's Operational Area (OPAREA) during the 2022 Ice Year. International Ice Patrol (IIP) is responsible for guarding the southeastern, southern, and southwestern Iceberg Limits near the Grand Banks of Newfoundland. In conjunction with IIP's 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 monitors environmental, meteorological, and climatological data to develop accurate iceberg warning products in the OPAREA (**Figure 2-1**). This section documents the atmospheric, oceanographic and sea ice conditions that influenced iceberg conditions during the 2022 Ice Year.

Ice Year Summary
Season Severity

With 58 icebergs crossing south of the 48th parallel (not including bergy bits or growlers), IIP classified 2022 as a "Light" year for the third year in a row. The Ice Year spans the period between 01 October of the previous year and 30 September of the current year. IIP recognizes 48˚N as the latitude where icebergs intersect the great circle route between

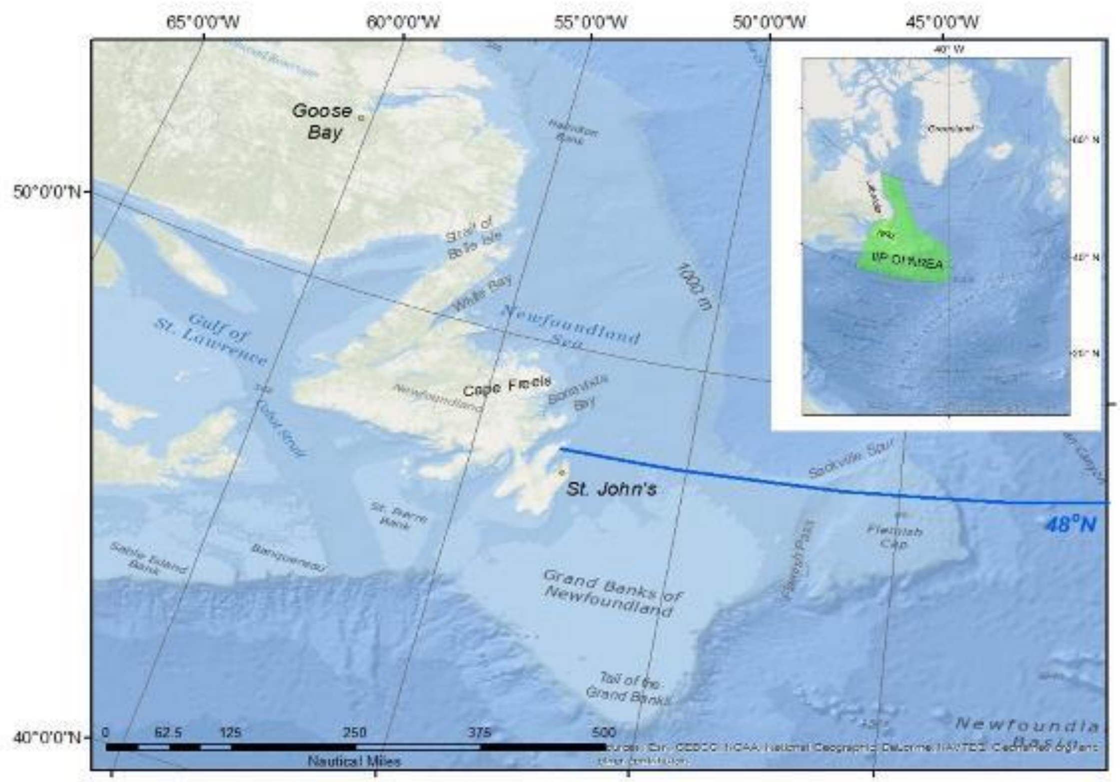


Figure 2-1. International Ice Patrol Operational Area (OPAREA) in green. IIP considers the latitude of 48°N as the northern boundary of the transatlantic shipping lanes and measures season severity based on the number of icebergs crossing this line.

Europe and North America, making them particularly hazardous to transatlantic shipping. Using revised season severity metrics, normalized to account for varying observational methods. The 2022 Ice Year ranks as 103rd out of 118 in terms of icebergs crossing south of 48˚N. (IIP, 2018)

From 1900 to present, IIP has documented significant inter-annual variability in the number of icebergs drifting south of 48°N. This variability is caused both by variation in environmental conditions and by modifications to sighting methods (**Figure 2-2**). The mean number of icebergs south of 48°N throughout IIP's entire iceberg data record prior to 2021 (1900-2020) is 488. The average number of icebergs crossing 48°N for the modern reconnaissance era (1983-2020) is 741. IIP characterizes the 'modern era' by IIP's use of aircraft with sophisticated airborne radar systems, ship reports, and satellite reconnaissance. During the 'modern era', IIP also began including results from iceberg drift and deterioration modeling. In 2017, IIP began incorporating satellite imagery into its routine operations. While this was a significant milestone, its impact on the number of icebergs crossing of 48°N remains unclear. IIP will continue to report this year and subsequent years under the modern reconnaissance era but acknowledges 2017 as the potential start of a fourth reconnaissance era.

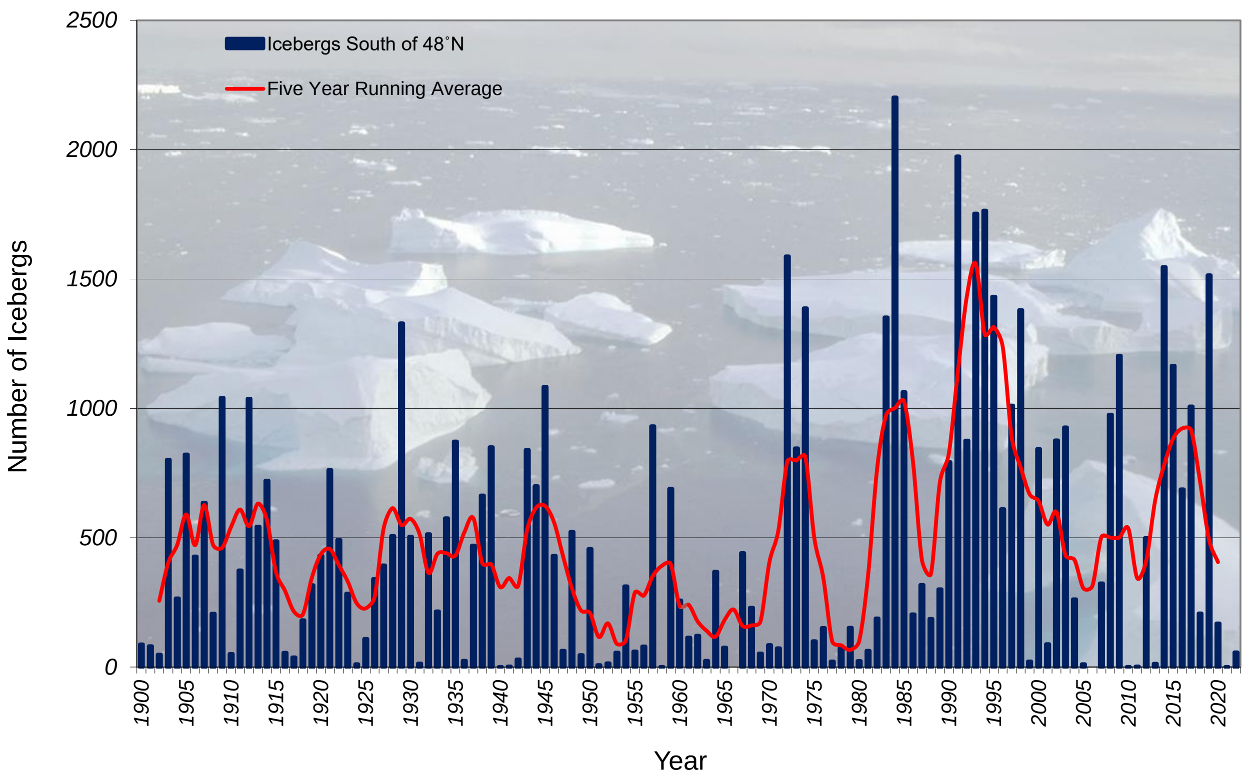


Figure 2-2. Icebergs crossing 48°N by year (blue bars) and five-year running average for 1900-2020 (red line).

Ice Year Environmental Conditions Overview

The CIS outlook for Winter 2022 forecasted above normal air temperatures over Newfoundland and near normal air temperatures over the southern Labrador coast. Forecasted air temperatures, coupled with above normal sea-surface temperatures along the Labrador Coast prompted a ‘below normal’ outlook for sea ice growth and iceberg activity in 2022 (CIS, 2021a). Throughout the IIP OPAREA this projection generally held true. However, sea ice growth along the Labrador Coast exceeded median levels from early February through mid-March, while the opposite occurred further south off Newfoundland. Throughout the season, IIP observed a sizeable iceberg population but relatively few icebergs survived into the shipping lanes. The air temperature anomaly throughout the region during the first two quarters of the Ice Year showed colder than normal conditions over the northern Labrador Sea and warmer than normal air temperatures further south over the Grand Banks and Newfoundland Sea (**Figure 2-3**). This resulted in below normal sea ice coverage in the southern part of IIP’s OPAREA near Newfoundland and above normal sea ice coverage along the Labrador Coast.

The correlation between sea ice coverage and iceberg season severity is well established. Sea ice offers protection from exposure to the open seas for icebergs, thereby slowing their melt. The extent of sea ice from the Newfoundland (NL) coasts can also impede the shoreward movement of icebergs, keeping them in the offshore branch of the Labrador Current. Above normal sea ice coverage along the Labrador Coast supported a sizeable iceberg population upstream, however below normal sea ice conditions off of Newfoundland accelerated iceberg melt, resulting in a relatively low number of icebergs surviving into the shipping lanes.

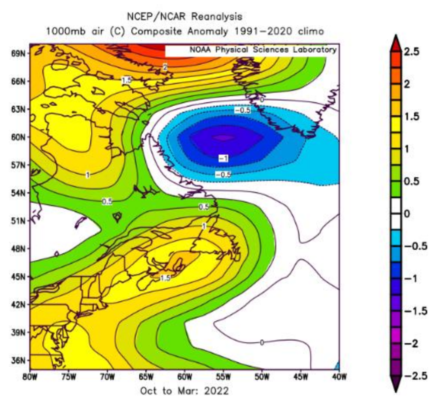


Figure 2-3. National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Surface Air Temperature Composite Anomaly for October 2021 – March 2022. (NOAA/ESRL PSD, 2022)

Below normal sea ice coverage off Newfoundland limited both the number of icebergs drifting into the shipping lanes and the maximum areal extent of the Iceberg Limit. The Iceberg Limit reached its easternmost longitude on 01 April and southernmost latitude on 14 April. Based on data collected over the past 10 years, these milestones normally occur in mid-May. The maximum eastward and southward extent of the Iceberg Limits for 2022 remained well inside of the climatological Iceberg Limit extremes for early and mid-

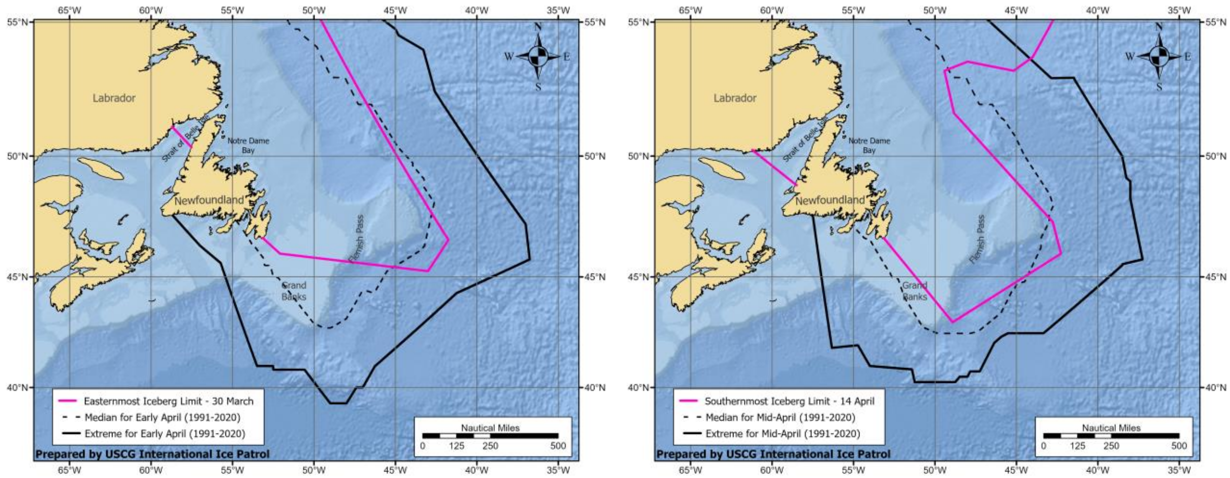


Figure 2-4. Easternmost (left panel) and Southernmost (right panel) Iceberg Limits for 2022 (magenta). Easternmost Iceberg Limit reached the pictured location on 01 April and the southernmost on 14 April. Extreme and Median climatological Iceberg Limits based on 1991-2020 are plotted for comparison.

April, respectively. The maximum eastward extent exceeded the median due to the drift of a single iceberg. The southernmost extent remained well within both median and extreme climatological limits (**Figure 2-4**).

IIP also closely monitored the wintertime North Atlantic Oscillation Index (NAOI). A positive NAOI typically favors an environment for sea ice growth, resulting in an elevated count of icebergs crossing south of 48°N. However, NAOI during the critical sea ice formation months from January through early March remained consistently though weakly positive (**Figure 2-5**). This positive NAOI appeared to promote predominant westerly (offshore) wind direction along the northern Labrador Coast and above normal sea ice development in the

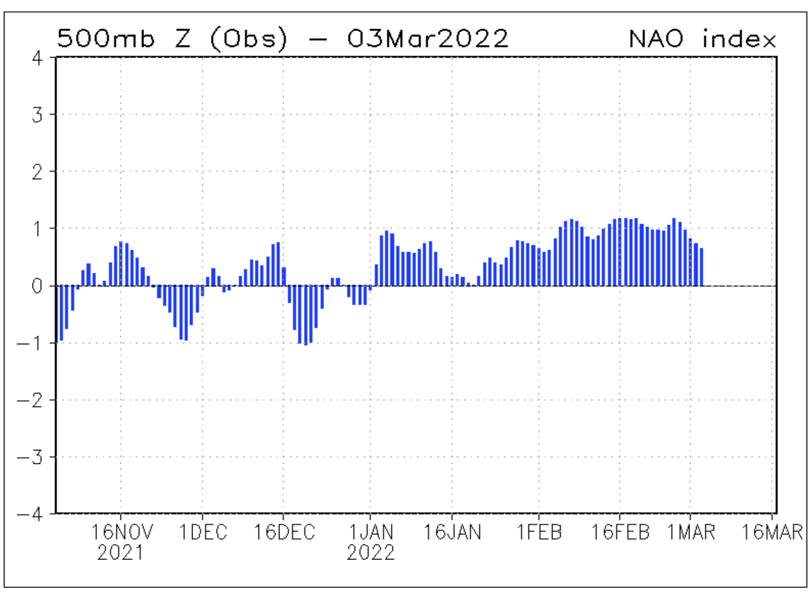


Figure 2-5. NAO Index from 05 November 2021 to 03 March 2022.

northern part of IIP's OPAREA. Above normal air temperatures and rapid destruction in April after individual storm tracks, particularly near the Grand Banks dominated the sea ice growth pattern and iceberg counts further south.

Quarterly Environmental Summaries

October – December 2021

Throughout the first quarter of the Ice Year, sea ice concentration remained at about 1/10 and below CIS' new ice climate normals for 1991-2020 (CIS, 2022b). By mid-December, 1-3/10ths sea ice concentration began to form along the Labrador Coast. This slow start to sea ice development can be attributed to above normal air temperature conditions in the region. Of note, the air temperature anomaly in Davis Strait exceeded 5°C above normal (**Figure 2-6**).

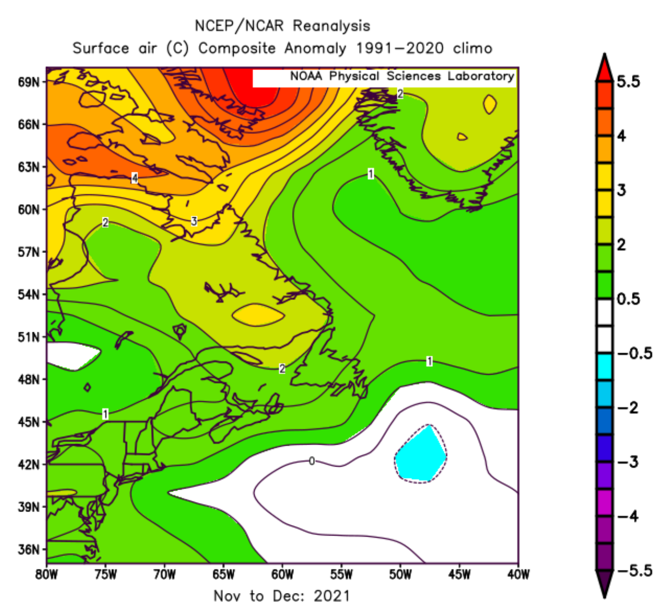


Figure 2-6. National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Surface Air Temperature Composite Anomaly for November-December 2021. (NOAA/ESRL PSD, 2022)

This situation resulted in a slower than normal freeze-up throughout the region. (CIS, 2022c).

At the beginning of the Ice Year, CIS had primary responsibility for issuing the NAIS daily Iceberg Limit warnings and were monitoring 81 icebergs in the iceBerg Analysis and Prediction System (BAPS). All except one iceberg were north of 54°N and most were within 120 NM of the Labrador coast. CIS leaned heavily on Radarsat Constellation Mission (RCM) images, acquiring 1137 images and analyzing 294 of these through mid-November (CIS, 2021a).

The iceberg population remained at around 50 through early November. By mid-November, the population declined to 31 though isolated icebergs drifting southeastward caused the iceberg limit to expand south of 52°N and east of 50°W. CIS established a western Iceberg Limit across the Strait of Belle Isle in mid-November due to a single iceberg drifting toward the strait along the southern Labrador Coast. The known iceberg population continued to decline throughout December with the majority of icebergs remaining north of 52°N. An isolated iceberg at 55°N caused the Iceberg Limit to expand to the east of 50°W at that latitude. Otherwise, icebergs remained within 120 NM of the Labrador coast. Section 7 of this report contains IIP and CIS semi-monthly iceberg charts, issued on the 1st and the 15th of each month. These charts depict the Iceberg and Sea Ice Limits, along with an estimate of the number of icebergs contained in a one-degree-by-one-degree latitude/longitude grid cell.

As sea ice developed along the Labrador Coast, satellite reconnaissance focused on areas outside of the sea ice edge, which may explain the observed decrease in the number of icebergs appearing on the daily warning product. By the end of December, 18 icebergs remained with the majority outside of the sea ice edge. The Iceberg Limit expanded southward, close to 51°N. The western Iceberg Limit moved back to the Labrador Coast as no icebergs threatened the Strait of Belle Isle. No icebergs were sighted or drifted south of 48°N during the first quarter of the Ice Year.

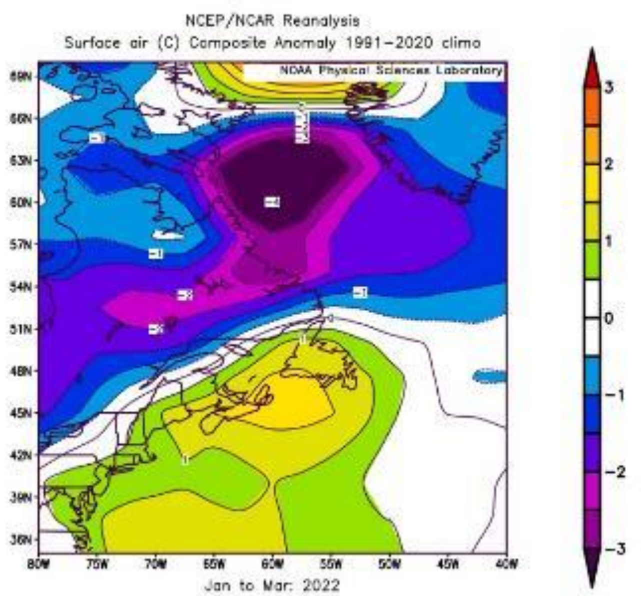


Figure 2-7. National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Surface Air Temperature Composite Anomaly for January –March 2022. (NOAA/ESRL PSD, 2022)

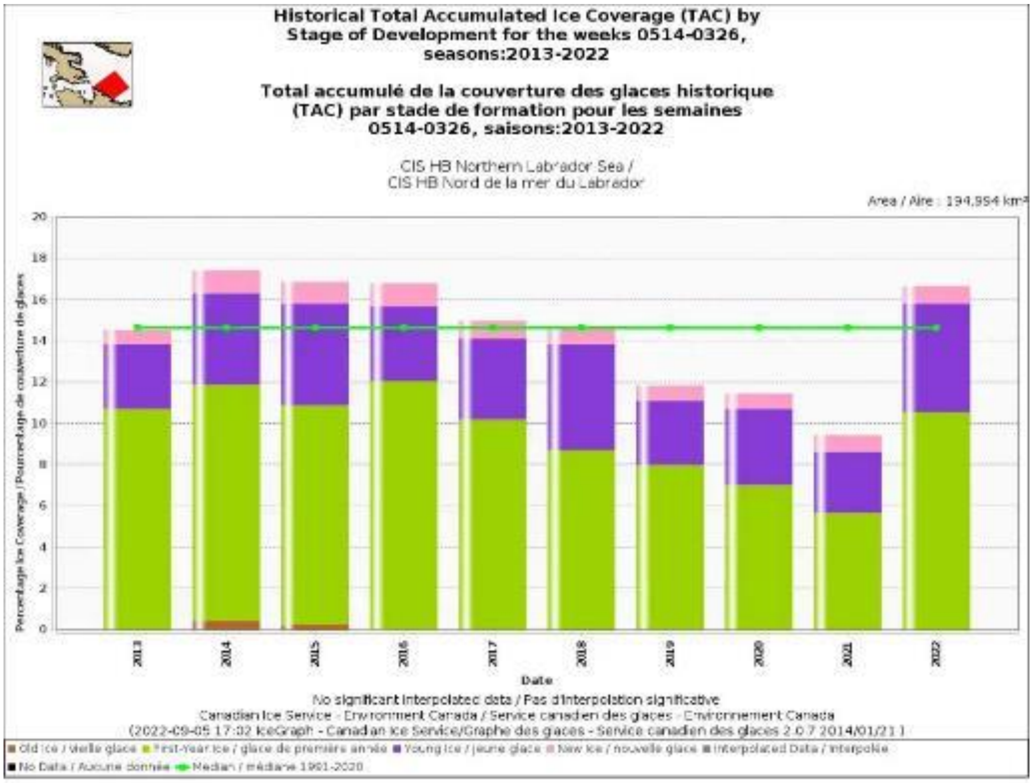
January-March 2022

Sea Ice Development

In January, below-normal air-temperatures appeared in the northeastern Labrador Sea and remained throughout the quarter. The atmospheric pressure pattern, consistent with a positive NAOI, promoted offshore winds in the northern part of IIP's OPAREA (**Figure 2-7**). These conditions, combined with below normal sea surface temperature (SST) supported above normal sea ice growth along the northern portion of the Labrador Coast.

Supported by predominant southwesterly winds during the same period, warmer than normal air temperatures persisted over Newfoundland. The elevated air temperature and near normal SST kept sea ice growth over the Grand Banks well below normal from January through March.

Comparing sea ice Total Accumulate Coverage over the past 10 years illustrates the variation in sea ice coverage between the northern Labrador Sea and east Newfoundland waters (**Figure 2-8**). With exception of last year's record-setting ice coverage, the ratio of new ice formation (pink color in the bar chart of **Figure 2-8**) was the lowest since the 2012/2013 Ice Year.



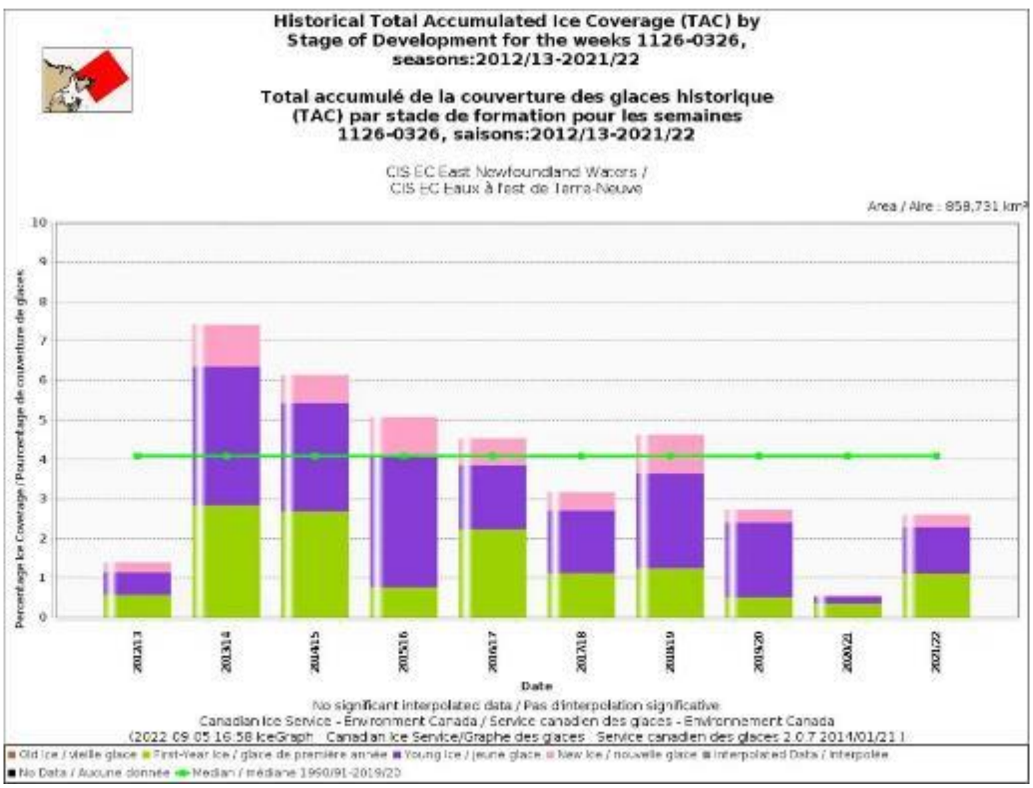


Figure 2-8. Ten years of Total Accumulated Ice Coverage by State of Development through 26 March for the Northern Labrador Sea (top) and for East Newfoundland Waters (bottom). (CIS, 2022d)

Iceberg Conditions

On 18 January, IIP resumed primary responsibility for creating and distributing Iceberg Limit products from CIS. Satellite reconnaissance continued throughout the quarter. PAL Aerospace reported 16 icebergs on 31 January, all within 100 NM of the Labrador Coast and inside the sea ice edge. PAL continued to provide iceberg reports throughout the season, both while conducting iceberg reconnaissance on behalf of CIS and the oil and gas industry as well as flights dedicated to other mission area.

The iceberg population remained light throughout January with distribution scattered along the Labrador coast and generally north of 54°N. By the end of the month, IIP estimated that 26 icebergs were scattered along the Newfoundland coasts. A single iceberg, drifting southeastward, caused the Iceberg Limit to expand to the south of 51°N and east of 48°N. The Strait of Belle Isle remained iceberg-free throughout January and no icebergs crossed south of 48°N in January.

IIP returned to St. Johns, Newfoundland on 10 February and conducted its first flight of the year on 11 February. This southern Iceberg Limit flight, designed to locate the single limit-setting iceberg observed in January, did not detect any icebergs. However, poor on-scene conditions and radar issues significantly degraded iceberg reconnaissance. As a result, the limit-setting iceberg remained in IIP's database and caused the Iceberg Limit to expand southeastward due to forecasted drift.

IIP flew three additional reconnaissance patrols during the third week of February that focused on the 1000-m contour (offshore branch of the Labrador Current), the Strait of Belle Isle and eastern Gulf of St. Lawrence. These flights detected 17 icebergs in the Newfoundland Sea and inside of the sea ice edge. All but one of the icebergs were shoreward of the offshore branch of the Labrador Current and therefore not in position to drift southward. The *Iceberg Reconnaissance Operations* section of this report (Section 4) provides a detailed narrative of each deployment for the year. No icebergs crossed south of 48°N in February. On average, 28 icebergs drift south of this latitude by the end of February based on iceberg sighting data collected during the modern era (1983-2021).

IIP conducted 6 aerial reconnaissance flights in March. These detected 179 icebergs that included a northern survey flight along the Labrador Coast to 60°N on 25 March. The primary purpose of this flight was to evaluate the iceberg population both with respect to quantity and condition of icebergs. This patrol located 59 icebergs with the majority (50) reported as 'Small' or 'Medium". IIP's Tactical Commander onboard the aircraft reported that most observed icebergs were already in an advanced state of deterioration. With slow sea ice growth over the Grand Banks, it became clear by the end of March that 2022 would be another 'Light' season.

On 12 March, a PAL Aerospace flight located the southern limit-setting iceberg and a second iceberg approximately 5 NM outside of the Iceberg Limit. These icebergs were the first to cross south of 48°N in 2022. At the end of March, IIP estimated that 150 icebergs were present throughout the OPAREA. Over half were ‘Small’ (less than 60 meters in length) and appeared to be in an advanced state of deterioration. In March, 13 icebergs crossed south of 48°N. On average, 153 icebergs drift south of this latitude by the end of March.

April - June 2022

Sea Ice Development

With exception of the northern Labrador Sea north of 60°N, above normal air temperatures persisted throughout the OPAREA during this quarter. Further, above normal air pressure in the Labrador Sea with below normal pressure over the central Atlantic for April created a strong pressure gradient (**Figure 2-9**) that supported onshore winds throughout the month (**Figures 2-9** and **2-10**). Slow sea ice development in the previous quarter, combined with these atmospheric conditions set the stage for rapid sea ice retreat in early April.

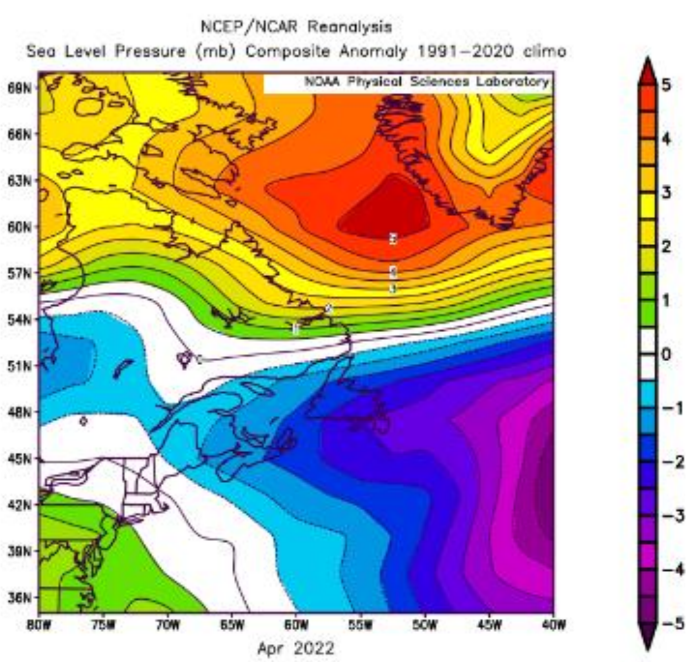


Figure 2-9. Sea Level Pressure anomaly in millibars for April 2022. (NOAA/ESRL PSD, 2022).

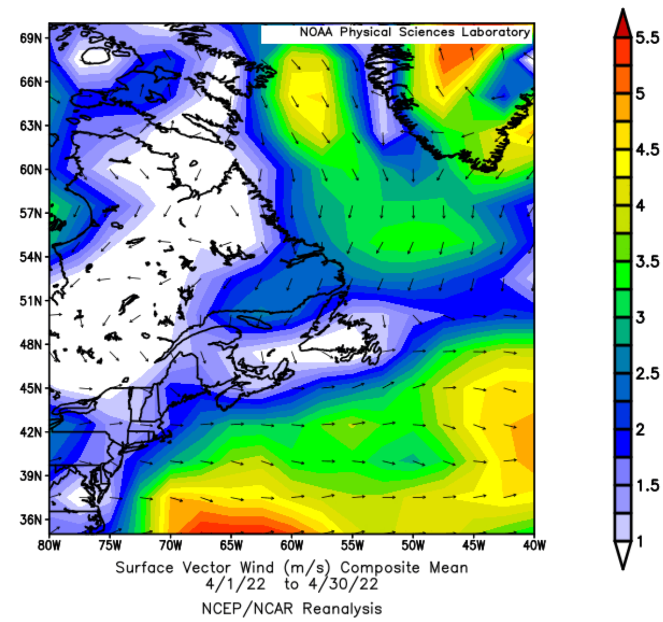


Figure 2-10. Mean Surface Vector Winds for April 2022. Color shading represents wind speed in meters per second; arrows show the mean wind direction. (NOAA/ESRL PSD, 2022).

For example, a 972-millibar low pressure system (**Figure 2-11**) tracked across Newfoundland during the second week of April bringing strong onshore winds and heavy seas that accelerated sea ice destruction in the region. Regional sea ice coverage for 04 April compared to 18 April illustrates the impact of the prevailing atmospheric conditions and this storm on sea ice coverage in early April (**Figure 2-12**).

Sea ice steadily deteriorated, receding north of 52°N.A segment of above normal concentration remained offshore between 54°N and 56°N. By the end of June only a small patch of 7-8/10 thick first-year ice remained near 55°N. During this quarter and for the rest of the Ice Year, the presence of sea ice did not play a significant role in the iceberg conditions further south.

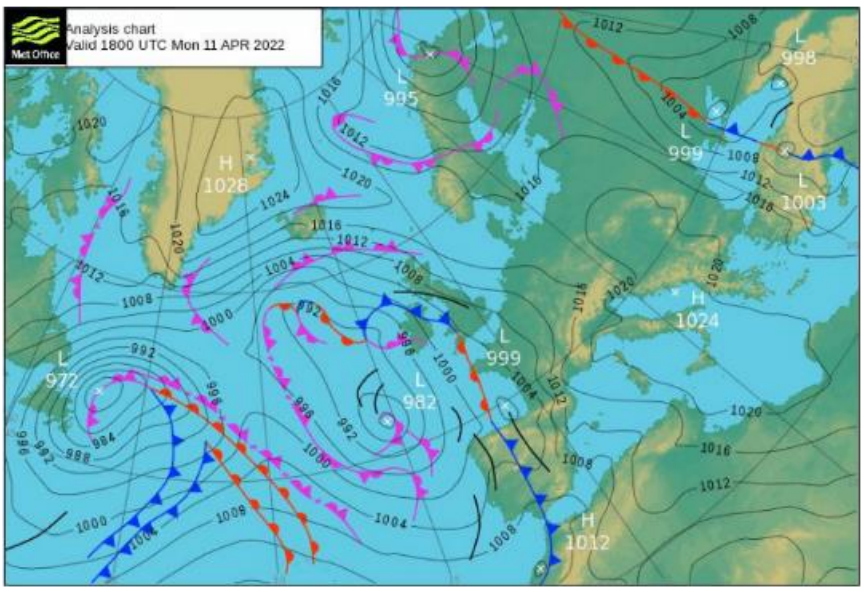


Figure 2-11. UK Meteorologic Office (UKMO) surface pressure analysis valid for 1800 UTC on Monday, 11 April 2022. Analysis shows a 972 millibar low pressure system off of Newfoundland (UKMO, 2022).

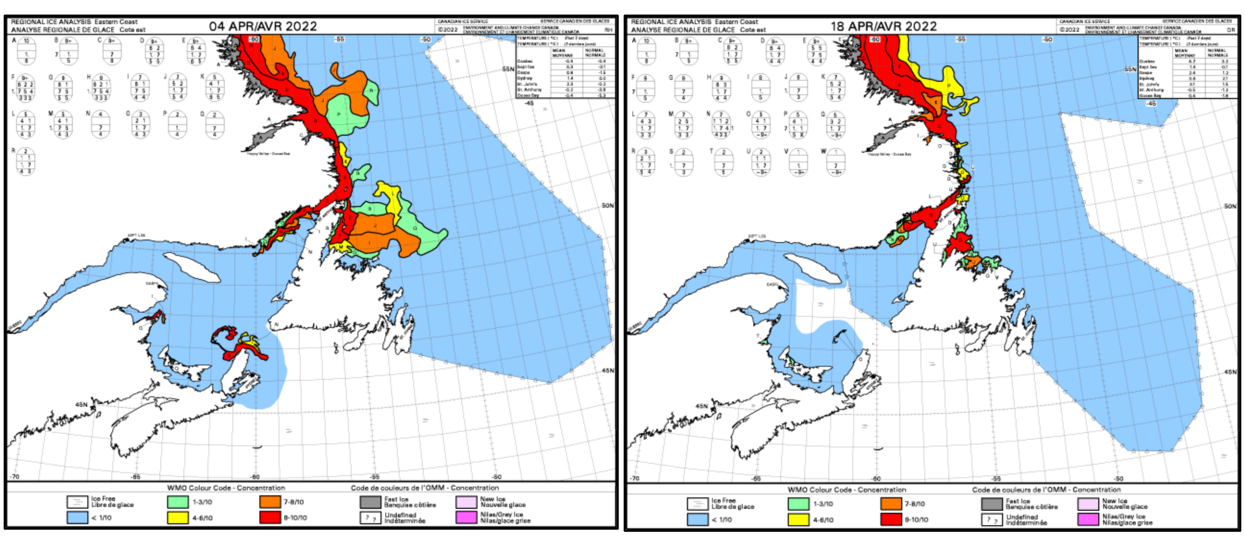


Figure 2-12. CIS regional Sea Ice Analysis on 04 April (left) and 18 April (right). (CIS, 2022a)

To summarize sea ice pattern in 2022, sea ice coverage in East Newfoundland waters remained well below normal for the entire year, with only a trace amount present in early May (**Figure 2-13**). In contrast, the Southern Labrador Sea had nine weeks of above normal sea ice coverage (**Figure 2-14**).

This sea ice coverage pattern significantly influenced the iceberg population drifting southward and played an important role in the light iceberg conditions observed in the shipping lanes in 2022.

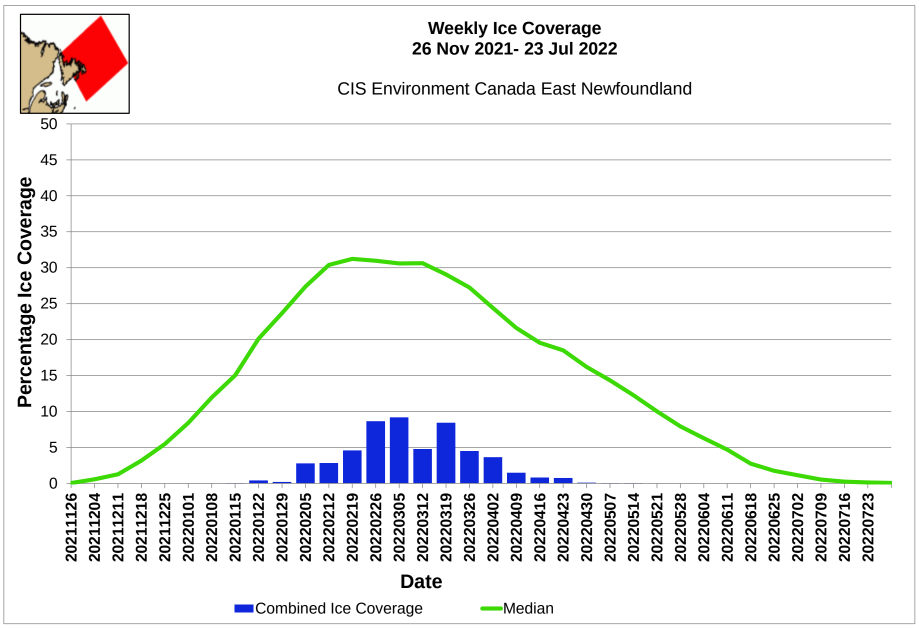


Figure 2-13. Weekly ice coverage for East Newfoundland waters for 2021-2022. The percent coverage is relative to the area shaded in red in the upper left map of this figure (CIS, 2022a).

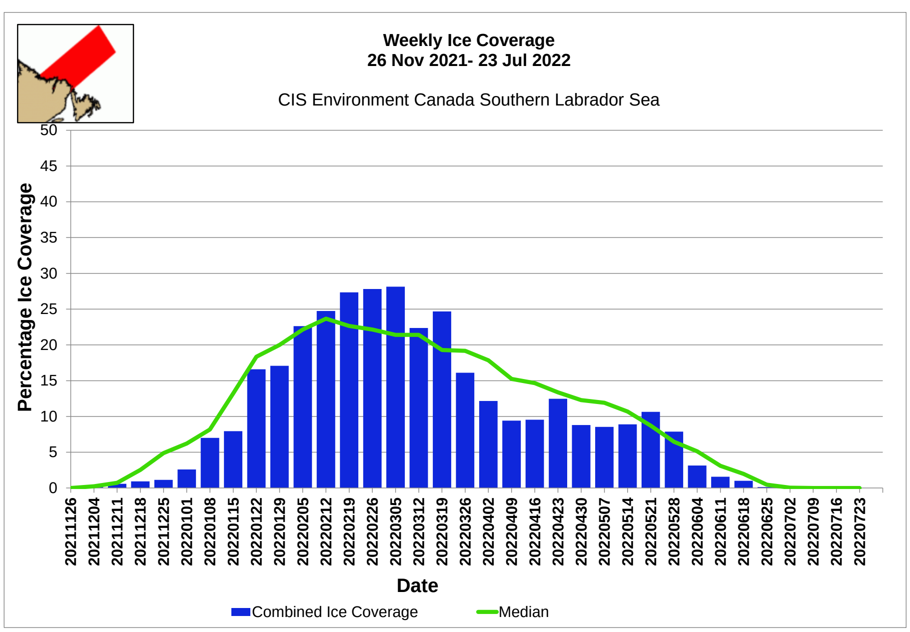


Figure 2-14. Weekly ice coverage for Southern Labrador Sea waters for 2021-2022. The percent coverage is relative to the area shaded in red in the upper left map of this figure (CIS, 2022a).

Iceberg Conditions

Satellite and aerial reconnaissance continued through April. IIP deployed two reconnaissance detachments in April that focused on the southern and western Iceberg Limits along with a northern survey patrol on 22 April along the Labrador Coast to 60°N. Like the March survey, the April survey flight detected 250 icebergs that were in an advanced state of deterioration. More than half (139) were estimated as 'Small' (less than 60 meters in length). The northern survey also noted that there were many tabular icebergs that appeared to be associated with a large ice island fragment near 58°N. While the northern survey detected a sizeable population of icebergs, the majority of these were north of 55°N. Light sea ice conditions to the south accelerated iceberg deterioration and reduced the probability of icebergs surviving into the shipping lanes.

PAL Aerospace conducted 18 iceberg flights on behalf of CIS and the oil and gas industry. These focused on the area surrounding the oil production facilities near the northern part of the Grand Banks and 1000-m contour. Most flights remained south of 49°N and near the 1000-m depth contour. Flight results were consistent with IIP's results showing a light iceberg distribution south of 48°N.

An isolated iceberg caused the Iceberg Limit to expand south of 45°N and two other icebergs drifted into Flemish Pass and south of Flemish Cap. These icebergs caused a southeastward expansion of the Iceberg Limit that exceeded the median for several days (**Figure 2-15**) and threatened the transatlantic shipping lanes. Forecasted drift of these icebergs caused the Iceberg Limit to reach its southernmost and

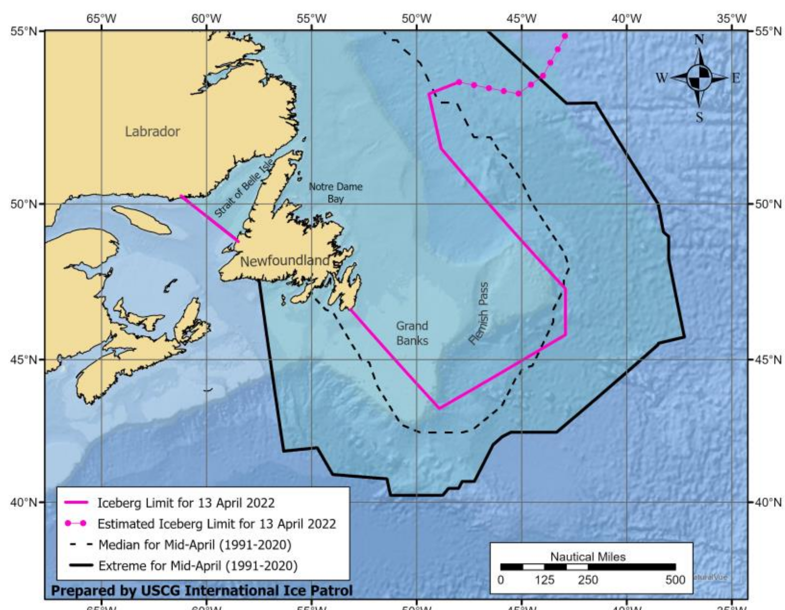


Figure 2-15. IIP Iceberg Limit for 13 April with median (dashed line) and extreme Iceberg Limits based on 1991-2020 climatology data. Iceberg drift caused the limit to slightly exceed median but remained well within the climatological extreme.

easternmost extents on 01 and 14 April, respectively.

IIP established its westernmost Iceberg Limit based on a satellite target, interpreted as an iceberg, outside of the existing limit on 12 April. This target was located in an unusual location off of the southwest coast of Newfoundland. Despite attempts to confirm the presence of this target with aerial reconnaissance e.g., PAL Aerospace flight on 15 April, this target continued to establish the western Iceberg Limit through 01 May. IIP later determined that this persistent target may have been the result of a strong radar reflection in the interior of Newfoundland, causing a satellite radar ambiguity. This presents a challenging situation for SAR image analysts.

At the end of April, IIP was tracking 345 icebergs throughout the OPAREA. Most icebergs were along the Labrador Coast and relatively few were in a position to drift further southward in the Labrador Current. A total of 36 icebergs crossed south of 48°N in April, bringing the cumulative total to 49 for the year. On average, 355 icebergs drift south of this latitude by the end of April.

With continued airborne radar issues, generally light iceberg conditions and other higher USCG aircraft needs, IIP concluded its aerial reconnaissance for the year in early May with a final deployment to Newfoundland from 4-12 May. Without the use of radar, IIP conducted four patrols that focused on the southern and western Iceberg Limits, and the 1000-meter depth contour to assess the iceberg population in the Labrador Current. Flown at a reduced track spacing due to the lack of a radar, these flights verified that the isolated icebergs, were no longer present. As a result, the Iceberg Limit contracted northward and shoreward in early May.

PAL Aerospace continued its aerial reconnaissance, flying 12 times for the oil and gas industry in May. These flights continued to focus on the 1000-meter depth contour and upstream of the oil and gas facilities on the Grand Banks. PAL detected scattered icebergs south of 50°N in this region, confirming a light iceberg distribution in the southern part of IIP's OPAREA.

At the end of May, IIP estimated that there were 683 icebergs distributed throughout the OPAREA. The majority of these icebergs were located north of 54°N near a remaining section of sea ice along the Labrador Coast. Ten icebergs remained in the Strait of Belle and Gulf of St. Lawrence. Six additional icebergs crossed south of 48°N in May, bringing the cumulative total to 55 for the year. On average, 580 icebergs drift south of this latitude by the end of May.

With the conclusion of aerial reconnaissance in May, IIP continued to monitor iceberg danger throughout June using satellite reconnaissance. On 20 May, IIP began displaying the Iceberg Limit as 'estimated' on its daily chart due to the lack of aerial reconnaissance. The Iceberg Limit continued to contract and recede northward throughout the month and the threat of icebergs impacting transatlantic shipping steadily declined.

PAL Aerospace continued its aerial reconnaissance in June, conducting four ice flights on behalf of CIS and the oil and gas industry. These flights continued to confirm the lack of icebergs in the offshore branch of the Labrador Current but detected 16 icebergs near the Strait of Belle Isle and several other icebergs scattered throughout the Newfoundland Sea.

Using primarily satellite reconnaissance, IIP estimated that 1089 icebergs remained in the OPAREA. While a sizable population, most were confined to the Labrador Coast and in open water. Only one additional iceberg crossed south of 48°N in June, bringing the cumulative total to 57 so far for the year. On average, 702 icebergs cross south of this latitude by the end of June.

July – September 2022

Iceberg Conditions

Only a single iceberg drifted south of the 48th parallel in the last quarter (in August). The rest of the season and year were calm in terms of iceberg activity. On average, 758 icebergs threaten the North Atlantic shipping lanes by the end of September; in 2022, only 58 did. The iceberg limit correspondingly receded, shrinking to a southern extent at 51°N and an eastern extent at roughly 48°W by September 30. CIS resumed the production responsibility of the iceberg limit on September 10.

3. Operations Center Summary

The International Ice Patrol (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 Ice Reconnaissance Detachment (IRD) flights, commercial reconnaissance flights, satellite imagery, and vessel sighting reports. After these reports are received, sighted iceberg locations and properties are added to IIP's iceberg database and processed through the drift and deterioration models in the iceBerg Analysis and Prediction Software (BAPS). Iceberg Limits are then defined to contain the modeled iceberg positions and daily North American Ice Service (NAIS) warning products are created and distributed to mariners by various 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, Newfoundland (NL) and generating products. This is the time of year that icebergs are most likely to threaten the North Atlantic shipping lanes. This year, the Ice Season ran from 11 January to 07 September (while the deployment period was 09 February – 12 May). CIS published products for the remaining months of the year termed "out of season," when the iceberg population is typically found farther north along the Canadian coast.

The first product released daily by IIP is the NAIS-10 bulletin, which is a text bulletin that lists the latitude and longitude points along the Iceberg Limit and sea ice limits. The second product is the NAIS-65, which is a chart that 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 Chapter Seven 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 2022 Ice Season, 100% of iceberg warning products were released on time.

IIP publicly distributes the NAIS iceberg warning products via a variety of methods. The NAIS-10 iceberg bulletin is broadcast over SafetyNET, Navigational Telex (NAVTEX), Simplex Teletype Over Radio (SITOR), and posted online. The NAIS-65 iceberg chart is broadcast over radio facsimile (Radiofax) and posted online. Both products are available on IIP's website:

https://www.navcen.uscg.gov/north-american-ice-service-products

Additionally, the NAIS-65 iceberg chart is available on the National Weather Service (NWS) Marine Forecast and NOAA Ocean Prediction Center (OPC) sites:

https://www.weather.gov/marine/marsh

https://ocean.weather.gov/Atl_tab.php

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 compatible charting software. The daily Iceberg Limit is also a displayable layer within NOAA's Arctic Environmental Response Management Application (ERMA) mapping tool:

https://erma.noaa.gov/arctic

Product Changes for 2022

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 2022, DMI improved its ability provide an estimated iceberg limit for Greenland waters twice per week over the course of the whole year. This was an improvement over sending an estimated limit twice per week while in season only, and using climatological limits for the remainder of the year.

The 2022 season was a "normal" season when compared to the 2020 and 2021 seasons in that it was not significantly impacted by complications associated with the COVID-19 pandemic. Even though the main challenges associated with the pandemic were largely avoided this year, some of the adaptations that were made to the products persisted. During periods of reduced reconnaissance, a designated text bulletin was added to the iceberg chart and bulletin stating as much, and the iceberg limit symbology was changed to represent an estimated limit. IIP was deemed to be operating under reduced reconnaissance conditions when aircraft were not available during periods when they are normally available in season. After the seventh IRD of the season, aircraft usually assigned to IIP for iceberg reconnaissance were re-assigned by Coast Guard Headquarters to a higher priority law enforcement mission. Due to the lighter severity of the season, the assumed risk of reduced aerial iceberg reconnaissance was deemed acceptable by Headquarters when weighed against the risk to human life posed by the increased migrant traffic crisis off the coast of Florida.

Finally, several incremental changes were made to each agency's detection and classification algorithms for analyzing satellite imagery. A bi-monthly coordination meeting for Radarsat Constellation Mission imagery analysis was instituted, DMI incorporated an automated process into their target classification algorithm to remove known ship targets from satellite images based on Automatic Identification System (AIS) data, and IIP made improvements to internal procedures for processing images. IIP also began investigating the use of commercially-sourced satellite imagery to supplement open source data sources. That initiative is described in further detail in **Appendix B**.

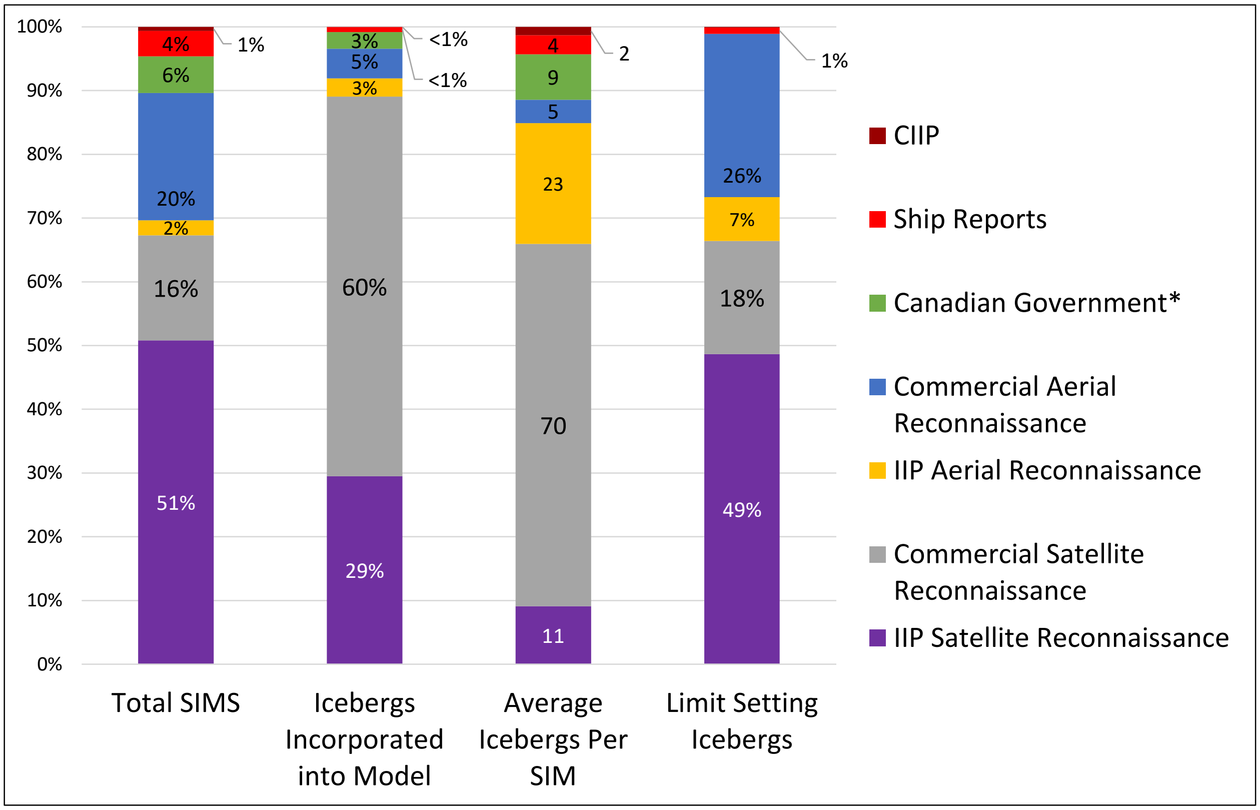


Figure 3-1. Detailed information of 2022 icebergs received from each SIM source.

Iceberg Reports

The IIP OPCEN received reports of icebergs from a variety of sources including IRD flights, commercial flights, ship reports, and satellite reconnaissance from IIP, CIS, and commercial sources (**Figure 3-1**). Collecting and processing iceberg reports from this wide variety of sources bolstered IIP's reconnaissance mission. An important source contributing to IIP's successful safety record were the reports received from mariners transiting through the OPAREA. A list of the individual ships that made voluntary iceberg reports during the 2022 Ice Season is compiled in **Appendix A**.

Iceberg reports were received in various formats and were converted into a standard iceberg message (SIM) that contained information on the reported iceberg's time of sighting, position, size, shape, and any other amplifying information. Depending on the reporting source and time of year, SIMs may have reported zero icebergs or hundreds of icebergs. Overall, during the 2022 Ice Season, IIP received, analyzed, and processed 804 SIMs, 517 of which included iceberg sightings. The majority of iceberg messages were IIP satellite imagery analysis (51%), followed by commercial aerial reconnaissance (20%). **Table 3-1** provides further detail on the number and types of SIMs received over the course of the season. Each reporting source is listed, along with the number of bergs sighted using that reconnaissance method. Also listed is a count of the limit-setting icebergs listed by source. Limit-setting icebergs are the bergs that are closest to the iceberg limit around which the limit is drawn. Because of the nature of how the limit is drawn, icebergs plotted closer to land or in the interior of the population do not affect the final product. Only the few (less than eight) icebergs that are located at the outer edge of the limit are responsible for its shape.

A total of 15,410 targets (icebergs, growlers, and radar targets) were incorporated into the model during the 2022 Ice Season. This is a massive 386% increase over 2021 (3,984 targets).

Observed icebergs that could be correlated with already modeled icebergs were "re-sighted" to the model. If they could not be re-sighted, they were added to the model. The number of adds corresponded to the number of unique sightings in the season. This season there were 4,295 additions to the model, which was 28% of all actions taken (add, delete, re-sight) for icebergs in SIMs received throughout the season

The reported icebergs that were not incorporated in the model included many that were coincident sightings where the OPCEN received reports of the same iceberg(s) from numerous sources at approximately the same time. In these circumstances, the OPCEN will only ingest the most recent position and most complete size information and take no action on older or less complete reports. In some cases, two agencies analyzed the same satellite frame and reported different results to IIP. In these cases, all unique targets between the two SIMs were incorporated into the model, and any duplicates were ignored.

Source	Total SIMS	Icebergs Incorporated into Model	Average Icebergs Per SIM	Limit Setting Icebergs
IIP Satellite Reconnaissance	407	4545	11	397
Canadian Government Satellite	0	0	0	0
Commercial Satellite Reconnaissance	132	9180	70	145
IIP Aerial Reconnaissance	19	441	23	56
Commercial Aerial Reconnaissance	160	721	5	209
Canadian Government*	46	400	9	0
Ship Reports	32	118	4	8
CIIP	5	8	2	1
Total	**801**	**15413**	**15**	**816**

Table 3-1. Detailed information of 2022 icebergs received from each SIM source.

*** The Canadian Government row does not include Government-funded Commercial Aerial Reconnaissance (which are included in the Commercial Aerial Reconnaissance source) and is mostly made up of Canadian Coast Guard reports.**

Satellite Reconnaissance

Table 3-1 and **Figure 3-1** show that the majority of icebergs, growlers, and radar targets incorporated into the model were from satellite reconnaissance (commercial and IIP satellite reconnaissance combined for a total of 13,725 icebergs, growlers, and radar targets added into the model from 539 SIMs). This significant increase in satellite targets over 2021 (3,273 targets) is largely attributed to increased activity by C-CORE, a St. John's based company that conducts satellite reconnaissance for icebergs in support of the oil and gas industry. C-CORE significantly increased reconnaissance off the coast of Northern Labrador using Radarsat Constellation Mission (RCM) imagery. That area is continuously and densely populated with icebergs, and the images collected in that area frequently included hundreds of iceberg targets. IIP and commercial satellite reconnaissance together accounted for 89% of the additions to the model, compared to 72% of the additions in 2021.

IIP continued to analyze Sentinel-2 multispectral imagery after incorporating the imagery source for the first time in 2020. Sentinel-2 is an incredibly useful resource for IIP satellite reconnaissance as it has higher resolution (10m) than Sentinel-1 (20m) and results in very high confidence iceberg classifications, especially for icebergs greater than 30m in length.

Aerial Reconnaissance

This season, IIP conducted 19 reconnaissance flights. These flights accounted for 441 icebergs, growlers, and radar targets added or re-sighted into the BAPS model. On average, 23 icebergs were observed per IRD flight. More information on IIP's aerial reconnaissance can be found in Chapter Four of this report.

Commercial aerial reconnaissance accounted for 721 icebergs added to the model over 160 reports. This is also a significant increase over 2021's 39 commercial aerial reports. It should be noted that IRD flights have a primary mission of iceberg reconnaissance on every sortie; this is not necessarily the case for commercial flights. The commercial aerial reconnaissance data in **Table 3-1** and **Figure 3-1** are from SIM reports made by PAL Aerospace, which was contracted

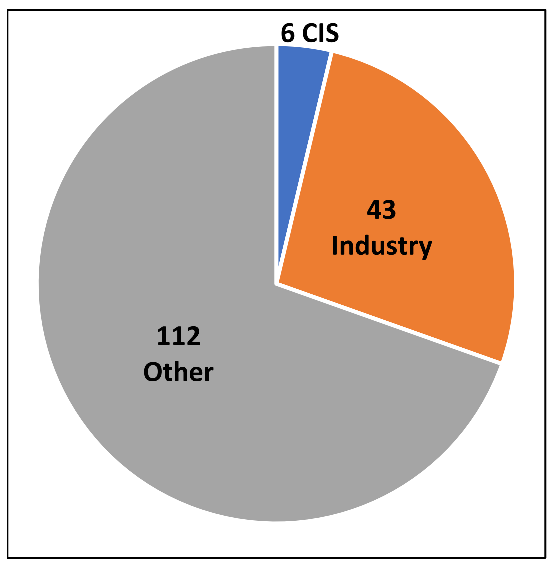


Figure 3-2. PAL Aerospace flights by primary mission type that reported icebergs. The "Other" category includes flights that reported icebergs but with a primary mission other than iceberg reconnaissance.

by multiple sources. **Figure 3-2** shows the 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. More than half (70%) 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, 4%, of PAL Aerospace flights that reported icebergs were funded by CIS specifically for iceberg reconnaissance in areas designated by either IIP or CIS. The 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.

Iceberg Deletions

After they were sighted, icebergs were added or re-sighted in the active iceberg database. They were then drifted and deteriorated via numerical models in BAPS. Icebergs were deleted from the active iceberg database as a result of modeled deterioration, time since last sighting, or IIP aerial reconnaissance results. This season, 26 icebergs were deleted based upon the results of IIP aerial reconnaissance as no icebergs were present in the vicinity of the modeled position when the flight flew overhead. In order to delete an iceberg from the database, its error circle must be cleared of icebergs. For satellite imagery, the error circle is almost always covered, but icebergs can be missed in imagery for a variety of reasons. For this reason, deletes are hardly ever executed based off of satellite imagery. Similarly, a commercial flight might fly overhead of a modeled position, but may not cover the error circle entirely, leaving a chance that the iceberg was missed. Again for this reason, deletes aren't typically executed based on commercial flights.

Given the high confidence associated with Sentinel-2 reconnaissance, IIP continued to rely on Sentinel-2 imagery to justify deletions in imagery with no cloud or sea clutter. This practice was only applied to the clearest frames that provided little chance of missing icebergs.

PAL Aerospace flew CIS-funded iceberg reconnaissance flights using IIP-drawn flight plans. This allowed IIP to plan commercial flights based on internal criteria for deleting modeled icebergs. This season, 42 modeled icebergs were deleted from CIS-funded PAL flights (compared to only eight in 2021).

Icebergs that were not deleted by reconnaissance were deleted either by time on drift or by predicted melt.

Limit-Setting Icebergs

Of all the icebergs sighted and modeled by IIP, the most important were the ones that defined the Iceberg Limit. Typically, an average of four icebergs (minimum of one and maximum of seven) set the Iceberg Limit at any time. At its maximum extent, the limit stretched 481 NM east of St. John's to an easternmost point of 47°-00N, 041°-00w on April 1st. Shortly after on April 14th, the limit reached its southernmost extent at 42°-55N, 048°-40W, a point 336 NM south of St. John's.

Reconnaissance from satellite imagery was the leading source for spotting limit-setting icebergs at 49% of limit setting icebergs. This is consistent with 51% from 2021.

Although a large number of icebergs incorporated into the model and setting the Iceberg Limit were observed by satellite, satellite reconnaissance using Synthetic Aperture Radar (SAR) 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 not one. This can result in the needless expansion of the Iceberg Limit, negatively impacting shipping without a corresponding increase in safety.

However, of greater concern are false-negatives, in which it is determined there are no icebergs where icebergs do, in fact, 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 these errors through increased understanding of the impact of satellite parameters, image quality, and environmental conditions on valid positive detection and classification of targets.

Given these considerations, the more reliable method for monitoring the Iceberg Limit remains 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. **Appendix B** discusses IIP's progress in procuring commercially-available satellite imagery to supplement government imagery sources.

IIP Protocol for Icebergs Reported Outside of the Iceberg Limit

In the event that an iceberg or radar target is reported outside the published Iceberg Limit, the OPCEN Duty Watch Stander (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 Navigational Warning (NAVWARN) which is the primary means of relaying critical iceberg information to the transatlantic shipping community and provides the IIP watch standers with time to transmit revised products. The NAVWARN is sent via Navigational Telex (NAVTEX) and forwarded to the U.S. National Geospatial-Intelligence Agency (NGA). NGA broadcasts the message as a Navigational Area (NAVAREA) IV warning message over satellite (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 OPCEN 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.

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 feature remains a challenge. SAR returns are quite open to interpretation. IIP takes a conservative approach to ensure that the maritime community receives a timely warning of any possible target outside of the limit and keeps the target plotted in the model until subsequent reconnaissance could verify its status. IIP relies on coordination with other data sources such as vessel AIS and a collaborative exchange with Coast Guard Intelligence to help classify ambiguous targets as icebergs or ships.

In past seasons, several cases of icebergs outside the limit were closely linked with the sea ice limit, where icebergs had been undetected within the sea ice limit, but outside the Iceberg Limit in “open drift” sea ice concentrations or greater (four-tenths sea ice concentration or more) of gray or gray-white ice. In response to this, IIP and CIS worked closely together from December to February tracking the leading edge of the gray and gray-white sea ice drifting south from Baffin Bay. This sea ice makes identification of icebergs from satellite challenging and is very likely to include icebergs. Therefore, this leading edge was included within the iceberg limit as if it contained icebergs.

Cases of Icebergs Detected Outside of the Iceberg Limit

February 24, 2022 (Figure 3-3)

The OPCEN received an email from PAL regarding a target spotted in an RCM2 satellite image. The target was 100 NM south of the current iceberg limit measuring 60-70 meters. PAL did not find any corresponding AIS data and wanted IIP to take a second look at the frame to assess if it was an iceberg or not. IIP could not correlate the target with

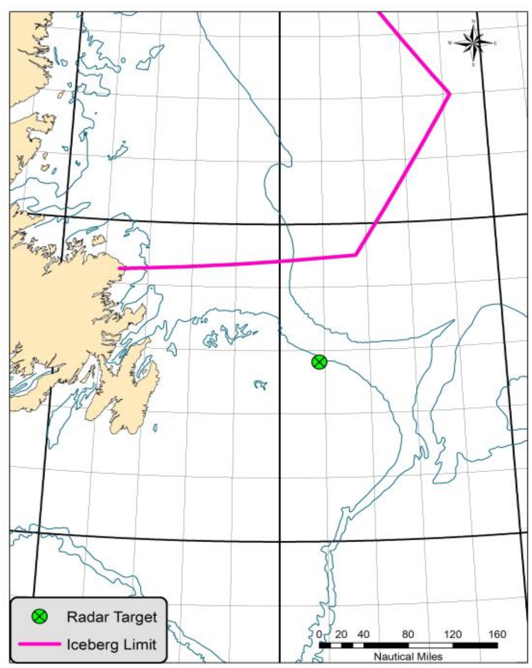


Figure 3-3. Iceberg outside of the limit case, 24 February 2022

AIS after requesting information from the Coast Guard Maritime Intelligence Fusion Center (MIFC). IIP contacted CIS to notify them of the target outside limit and to see if they could find any vessels in the area using the Canadian Vessel Monitoring System (VMS). CIS did not see any ships within 50 NM of the suspected target, nor did any track history pass through the area. Based on this information and the fact that the radar image was inconclusive, IIP decided to call it a radar target. MCTS Port-aux-Basques and NGA were contacted to issue warnings but they would not issue warnings for targets that weren't confirmed. IIP added the radar target to the chart and text bulletin and issued products on time.

March 13, 2022 (Figure 3-4)

The OPCEN received an iceberg message from a PAL industry flight. The target was 6NM east of the valid iceberg limit measuring 15-60 meters across with a dome shape. IIP could not correlate the sighting with AIS. IIP contacted CIS to notify them of the iceberg outside the limit and warnings were issued via MCTS and NGA. IIP revised products to reflect the new iceberg sighting and redistributed products.

April 08, 2022 (Figure 3-5)

The OPCEN received an iceberg message from a PAL industry flight. The target was 1 NM west of the valid western iceberg limit measuring 15-60 meters across. IIP watch standers made proper standard notifications and warnings were issued. IIP revised products to reflect the new iceberg sighting and redistributed products.

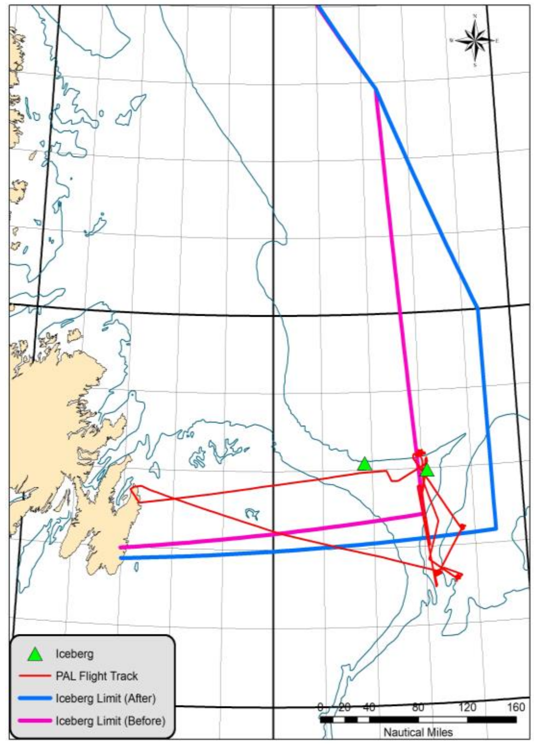


Figure 3-4. Iceberg outside of the limit case, 13 March 2022

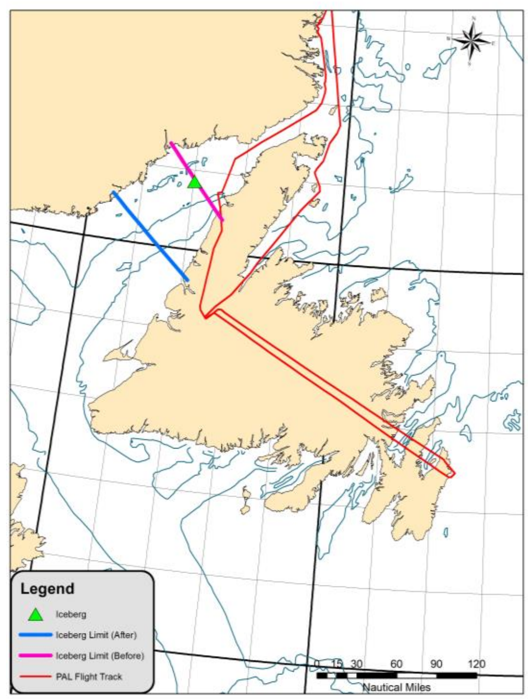


Figure 3-5. Iceberg outside of the limit case, 08 April 2022

April 13, 2022 (Figure 3-6)

The OPCEN received an iceberg message from the IIP Satellite Duty Watch Stander. The iceberg detected was 31 NM outside of the valid western iceberg limit, measuring 178 meters across. Duty Watch Standers attempted to correlate AIS information with MIFC and VMS but could not correlate the target with any vessels in the area. Warnings were issued, but IIP did not create updated products because the sighting came only one hour before the release of standard products. The change was reflected in the new daily chart and bulletin. This target was later discovered to be an anomalous artifact present in the exact same position in each of the repeat Sentinel-1 frames acquired in that position.

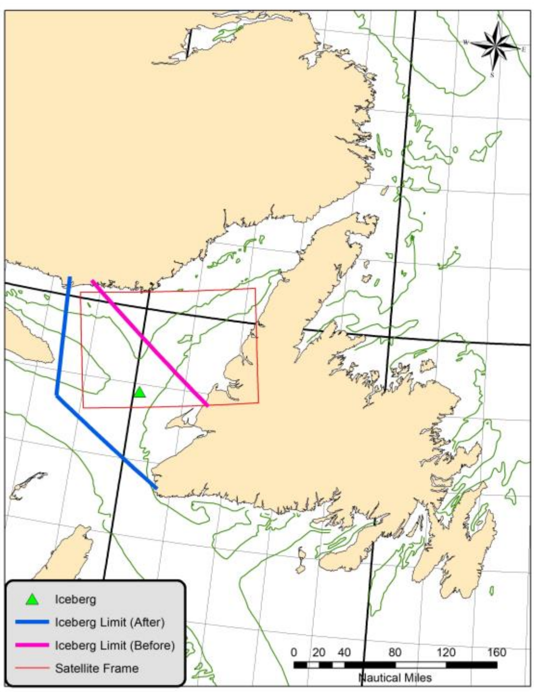


Figure 3-6. Iceberg outside of the limit case, 13 April 2022

July 3, 2022 (Figure 3-7)

C- CORE reported an unknown radar target from Sentinel-1 imagery 104NM outside the valid iceberg limit. MIFC was contacted to attempt to correlate the target with vessel traffic and CIS assisted by checking Canadian VMS, but there were no known vessels in the area. IIP Watch Standers decided to also manually analyze the frame in question, and determined that a radar target should be added to the plot outside of the limit. MCTS and NGA were contacted and a warning was issued. Revised products were issued shortly thereafter.

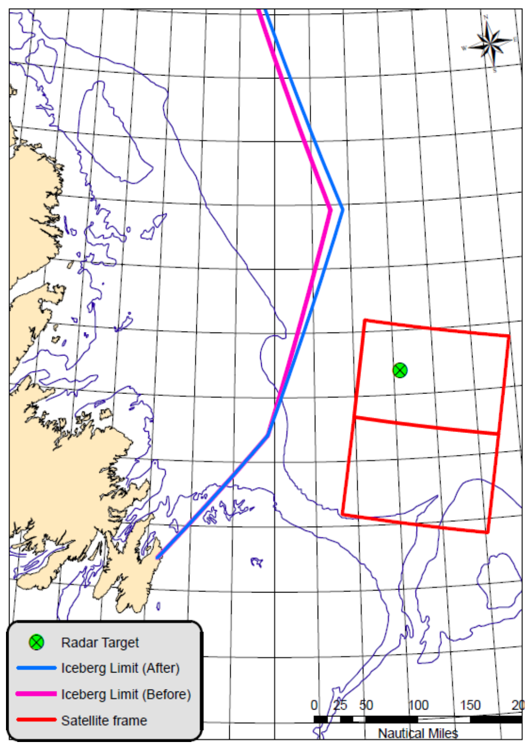


Figure 3-7. Iceberg outside of the limit case, 03 July 2022

18 August 2022 (Figure 3-8)

Watch standers received a report of two icebergs from PAL Aerospace for a recent flight off the east coast of Newfoundland. The two icebergs were spotted about 60 NM outside the valid iceberg limit. Standard notifications were made with warnings issued by NGA and MCTS, and products were revised with an expansion of the limit of 110 NM.

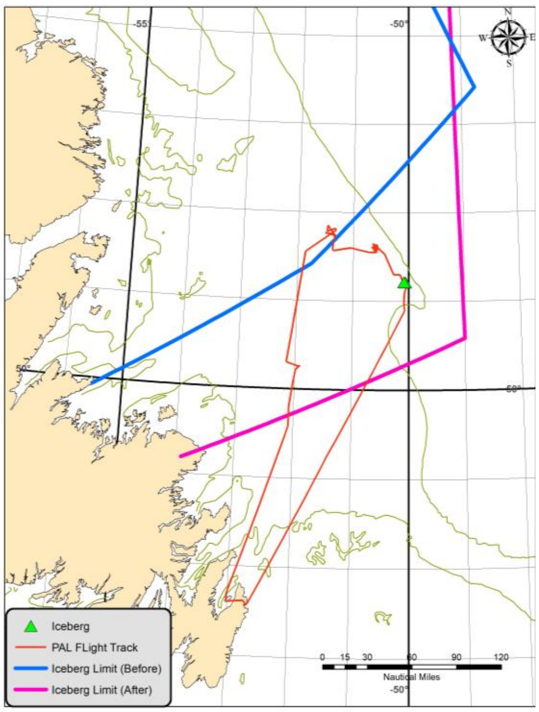


Figure 3-8. Icebergs outside of the limit case, 18 August 2022

29 August 2022 (Figure 3-9)

IIP received two flight messages from PAL Aerospace dated August 25th and 26th. The flight from the 25th had located four icebergs on the 1,000m bathymetric contour at about 52ºN, less than 30 miles from the iceberg limit. After adding the icebergs to the plot and running the analysis, the icebergs or their error circles had drifted outside of the limit. Shortly after running that analysis, another flight message from PAL was received valid from that same morning on August 29th. That flight found three grounded icebergs on the east coast of Newfoundland, all outside of the limit and between 47ºN and 49ºN. Due to the proximity in time of the reports, both reports were treated as a single case of icebergs reported outside the limit. A NAVWARN message was released about 20 minutes after contacting MCTS and a NAVAREA IV message was released about 90 minutes after contacting the NGA watch. Products were revised and released at 1700Z.

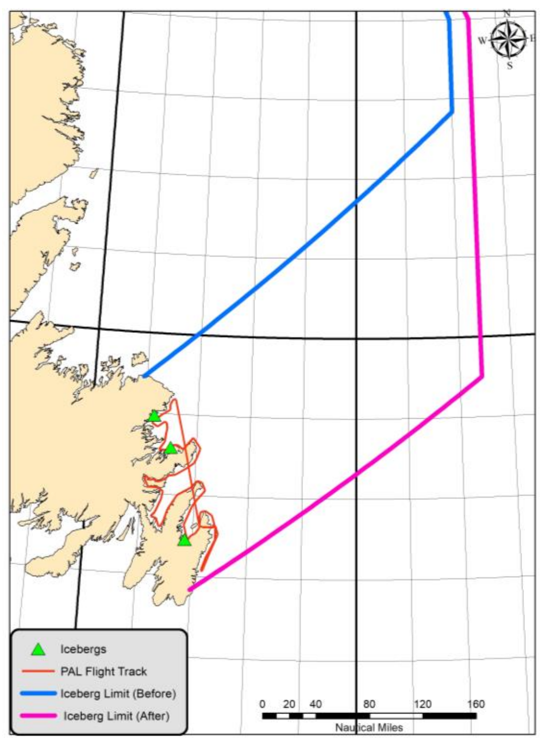


Figure 3-9. Icebergs outside of the limit case, 29 August 2022

Risk-Based Iceberg Products and Tailored Support

IIP continued support specific customers transiting north to eastern Canada and western Greenland. Two U.S. Coast Guard Cutters (USCGC) participated in operations in the waters of the Labrador Sea and Baffin Bay over the course of the 2022 summer. CGC OAK is a 225-ft sea-going buoy tender with an ice-strengthened hull, and CGC BEAR is a 270-ft medium endurance cutter with no ice strengthening. Neither crew had useful experience operating in icebergs, and depended on IIP for daily updates on the iceberg population in their respective operating areas. Each cutter received a daily iceberg hazard chart depicting iceberg proximity, and by proxy, density, that could be used to make risk assessments concerning their intended movements. This product is the "Isolated/Few/Many" product.

The Isolated/Few/Many (IFM) product remains a novel endeavor for IIP, but one that continues to gain popularity and relevance. Whereas in the 2021, only three analysts at IIP were qualified to produce such a chart, that number increased to 11 qualified analysts due to a concentrated training effort executed at the beginning of the season. This chart uses three distance thresholds (>45 NM, <45 NM and >10NM, and <10 NM) to indicate how close plotted icebergs are to each other, and draw corresponding contours around regions that correspond with each distance threshold. **Figure 3-10** depicts an example of this product.

This capability is the result of much effort and collaboration between IIP and the Danish Meteorological Institute (DMI), as well as through other government and commercial agencies through the International Ice Charting Working Group (IICWG). In these two cases of customized support, IIP relied heavily on its NAIS partnership with DMI. DMI employs an automated iceberg detection and classification algorithm that quickly and accurately sorts through satellite images to find the thousands of icebergs in its waters. IIP relied on the output of that automated process to create IFM products. Taking those points, IIP drifted the icebergs using the NAIS drift and deterioration model to predict where relevant icebergs might be when cutters were transiting nearby. Proximity contours were then drawn around the results of the model, with the final results being sent out daily to the supported cutters.

USCGC OAK participated in the annual search and rescue exercise ARGUS with units representing France, Denmark, and Greenland. 15 products were produced by seven different analysts between 27 June and 15 July, and OAK's Commanding Officer credited IIP's products as being "critical to safe navigation."

USCGC BEAR represented the U.S. contingent in the annual Operation NANOOK along with vessels from France, Canada, England, and Denmark. 19 products were produced by eight different analysts between 03 August and 24 August. Also of note, since the list of participating vessels was published ahead of the exercise, IIP offered and delivered products to all the participating units in the exercise. This included

HMCS HARRY DEWOLF, HMCS MARGARET BROOKE, HMCS GOOSE BAY, HDMS TRION, FS RHONE, and the Meteorology and Oceanography Operations center in Halifax. BEAR's after action report read, "Products provided by the International Ice Patrol were helpful and on-point."

IIP predicts the demand signal for tailored support to grow as more Navy and Coast Guard assets not accustomed to ice navigation begin to push farther and farther north.

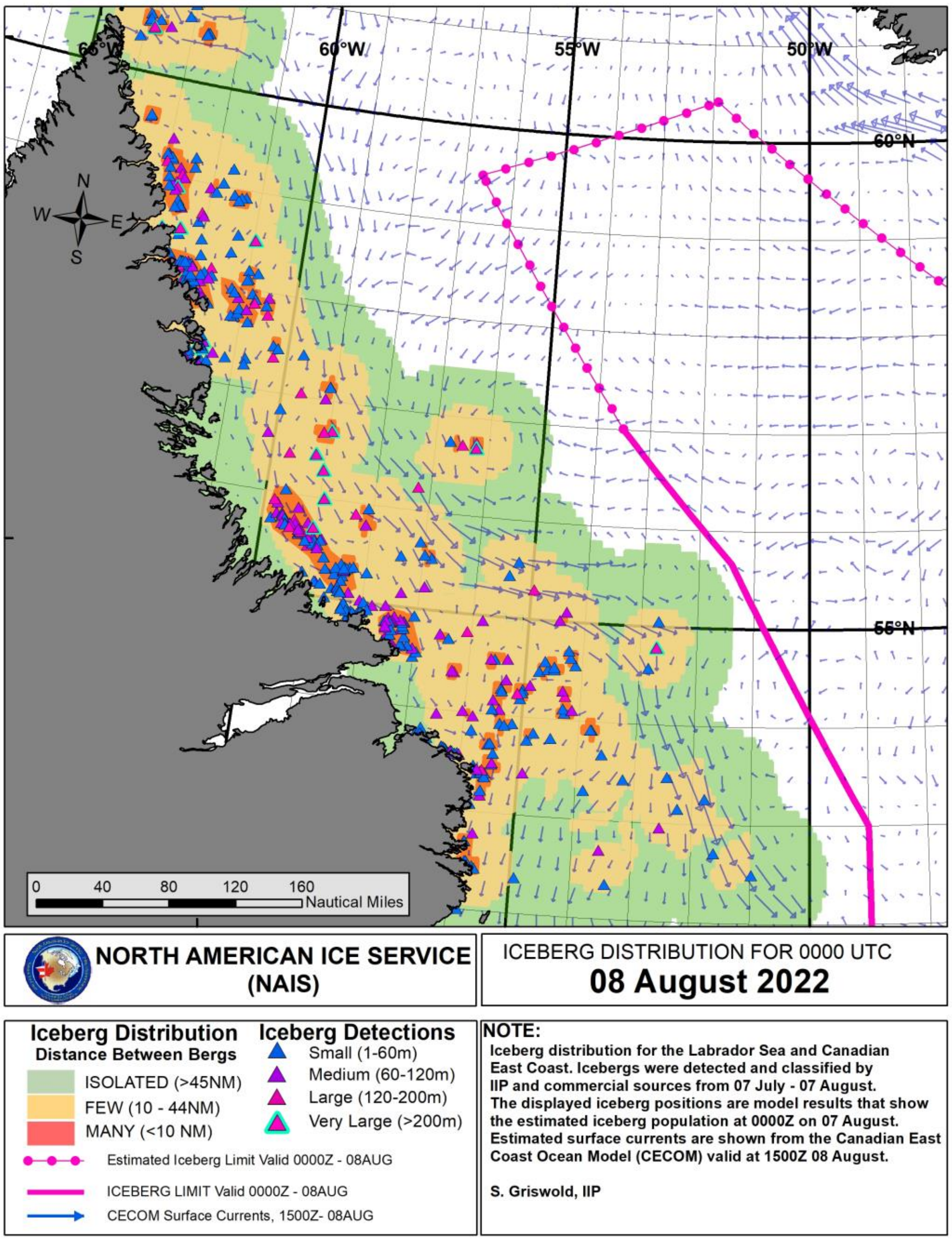


Figure 3-10. Isolated/Few/Many Product sent to CGC BEAR valid for 08 August, 2022

4. Iceberg Reconnaissance Operations

Ice Reconnaissance Detachment

The Ice Reconnaissance Detachment (IRD), a sub-unit under the International Ice Patrol (IIP), partners with Air Station Elizabeth City (ASEC) to conduct aerial iceberg reconnaissance. During the 2022 Ice Season, seven IRDs deployed to observe and report icebergs, sea ice, and oceanographic conditions in the North Atlantic Ocean. All observations from the IRDs were transmitted to the IIP Operations Center (OPCEN) in Suitland, MD for processing and entry into the iceberg Analysis and Prediction Model (BAPS). These observations provided critical information used by the IIP OPCEN to create the Iceberg Limit and North American Ice Service (NAIS) iceberg warning products that are distributed to the maritime community on a daily basis. Chapter 7 has examples of these products distributed throughout the season.

IIP classified 2022 as a 'light' season with respect to the number of icebergs crossing south of 48ºN (only 58 icebergs), and also with respect to the total area encompassed by the iceberg limits. The 2022 season was the first since 2019 that flew all of its patrols out of St. John's due to COVID-19 protocols.

Over the 2022 Ice Season, IIP and ASEC crews deployed for 52 days, conducting 19 iceberg reconnaissance sorties on HC-130J aircraft. The 2022 flight season spanned 92 days; 46 days shorter than the five-year (2017-2021) average of 138 days. The first IRD departed on 10 February, with the last IRD returning on 12 May. The number of sorties flown this season decreased from 24 to 19, a 21% decrease. The shorter deployment season and decrease in number of sorties was due to the unavailability of HC-130J aircraft late in the season. Aircraft normally allocated for the ice patrol mission were re-assigned to other higher priority missions by Coast Guard Headquarters. **Table 4-1** contains a summary of operations for each IRD.

Aerial Iceberg Reconnaissance Equipment

HC-130J aircraft equipped with two radars and an Automatic Identification System (AIS) integrated into the

IRD	Deployed Days	Iceberg Patrols	Transit Flights	Patrols en Route	Logistics Flights	Flight Hours
1	7	1	2	0	0	14.0
2	8	4	2	0	0	32.8
3	8	3	1	1	0	33.0
4	5	1	2	0	0	19.0
5	8	2	1	1	0	26.7
6	7	2	2	0	0	23.8
7	9	4	2	0	0	41.5
Total	**52**	**17**	**12**	**2**	**0**	**190.8**

Table 4-1. An overview of days and flight hours used during the scheduled IRD's for the 2022 Ice Season.

mission system suite were used to conduct aerial iceberg reconnaissance. The ELTA-2022 360° X-Band (ELTA) surface search radar is capable of detecting and discriminating surface targets (iceberg, ship, other). The HC-130J Tactical Transport Weather Radar (APN-241) is capable of detecting surface targets, but cannot discriminate or classify targets as an iceberg, ship, or other object. The AIS receives information transmitted by AIS-equipped ships for positive identification, and is used to differentiate vessels from icebergs on the ELTA radar.

The 360° coverage provided by the ELTA radar supports the use of up to 30 NM track spacing for patrol planning. In the 2022 season, IIP planned 74% of flights at 30 NM while still maintaining a 95% probability of detection (POD) of small icebergs (15 to 60m). The remaining flights were planned at 10 NM track spacing due to inoperable radar on the aircraft.

When the ELTA radar was inoperable, the IRD drew flight plans under "visual-only" specifications using 10 NM track spacing, covering 40% less area in a given time period. Good reconnaissance conditions (at least 50% visibility and few to no white caps) are required for visual-only patrols, and those conditions are a rarity in IIP's meteorologically active OPAREA.

During the 2022 Ice Season, all IRDs were flown with Minotaur Mission System (MMS)-equipped aircraft. The MMS is a software and hardware suite that allows for onboard networking of cameras, radar sensors, navigational instruments, and communications.

IRD crews also utilized the Inverse Synthetic Aperture Radar (ISAR) onboard the HC-130J. This technique generates a high-resolution image of a target using the movement of the target to create an image frame. ISAR imagery is analogous to the SAR imagery IIP receives from satellites in that it is a still image created from radar energy pulses. The key difference between the two technologies is that SAR sensors onboard orbiting satellites rely on the movement of the sensor in orbit to create a "synthetic" image, while the ISAR uses the movement of the target to generate the image. This technology has proven extremely useful for identifying icebergs and distinguishing between icebergs and non-AIS ships in poor visibility.

Deployment Season Summary

Figure 4-1 shows a breakdown of IIP's deployment days during the 2022 Ice Season in six categories: Operational, Transit, Patrol/Transit, Weather, Maintenance, and Crew Rest. Examples of days in the "other" category include time taken for partner meetings, higher priority tasking of the aircraft (i.e. search and rescue) while on an IRD, and logistics flights. In accordance with USCG regulations, the IRD normally takes one crew rest day as well as one maintenance day per nine day deployment; otherwise, the intent is to fly every day. Operational time took up the largest fraction of deployment days in 2022 (33%).

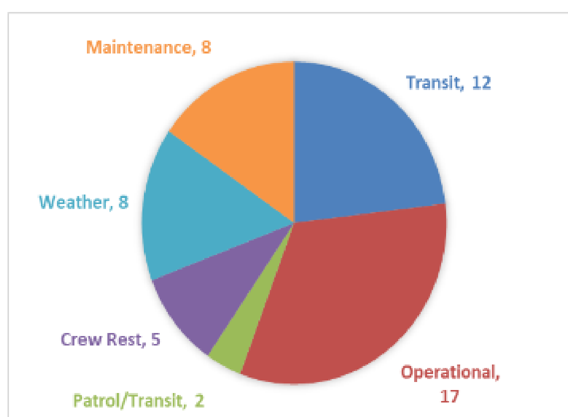


Figure 4-1. Utilization of days for the 2022 Ice Season.

The prevailing OPAREA weather contributed significantly to the number and effectiveness of reconnaissance patrols. In 2022, weather conditions prevented patrols on 15% of the days deployed. When deployed to St. John's, the IRD crew capitalized on poor weather opportunities whenever possible to meet the required crew rest and maintenance days, in order to maximize operational iceberg reconnaissance on favorable weather days.

Unscheduled maintenance and mechanical issues proved to be a much smaller issue than the previous year. Four out of the 52 days were allotted to unscheduled maintenance or waiting for replacement parts to arrive at the deployment location. Like in past seasons, IRDs based out of St. John's saw significant logistics challenges with transporting spare parts to the deployed aircraft.

Table 4-2 shows a further breakdown of the crew rest and maintenance days into days taken when the weather conditions did not permit flights (opportunity days), days taken when conditions permitted flights, but required crew rest or maintenance had to be taken (scheduled) or days taken because of crew or maintenance issues (unscheduled).

	Crew Rest	Aircraft Maintenance
Opportunity (Weather)	4	4
Scheduled	1	0
Unscheduled	0	4
Total	5	8

Table 4-2. Crew rest and aircraft maintenance days for the 2022 Ice Season.

IRD Summaries

IRD1 - The first IRD of 2022 began on 09 February. Due to inclement weather at St. John's (airport code CYYT), the flight was delayed by one day. On 10 February, the aircrew from Elizabeth City (airport code KECG) departed and picked up the IIP crew at their new location of Joint Base Andrews (airport code KADW). The following day, 11 February, a patrol of the Southern Limit was conducted. The patrol was completed as visual only due to the discovery of an inoperable ELTA during the transit flight from KADW to CYYT. Portions of the planned flight plan had to be cut off due to poor on-scene conditions which made searching by visual means unachievable. This first patrol detected zero icebergs and zero ships. On 12 February, the IIP crew was grounded because of severe turbulence and low level wind shear at CYYT. On 13 February, the patrol was cancelled for poor reconnaissance conditions which made a visual only patrol not viable. An opportunity maintenance day was conducted in place of the planned patrol. A crew rest day was taken the following day, 14 February. On 15 February, the planned patrol was cancelled due to persistent poor on-scene weather conditions. Later that afternoon, the aircrew departed on the HC-130J to conduct a search and rescue mission off the coast of Newfoundland to assist in the Canadian-led search for the Spanish fishing vessel Villa de Pitanxo. Forecasted conditions at CYYT were predicted to worsen throughout the week and the decision was made to return the crew home one day early on 16 February.

IRD2 - IRD 2 was scheduled to begin on 23 February but was delayed one day due to a significant low pressure system bringing high winds and snow to Newfoundland. On 25 February, a patrol of the interior down to the south of Hamilton Bank was conducted and identified a total of 10 icebergs and two ships. The following day, a planned patrol of the Western Limit and Hamilton Bank was flown which detected seven total icebergs and eight ships. On 27 February, an unscheduled crew rest day was taken due to unfavorable reconnaissance conditions in the OPAREA. On 28 February, takeoff was delayed by five hours to allow a low pressure to move through, allowing for a short patrol of the Southern Limit. No targets were identified during the patrol and a previously unverified radar target was able to be deleted from the model. High winds at CYYT prevented the hangar from being opened on 01 March and an opportunity maintenance day was taken. On 02 March a Northern Survey was flown and had identified just one iceberg when the aircraft experienced a mechanical casualty. Due to the nature of the casualty, the IRD crew returned directly to KECG the following day. IIP crew returned to Suitland, MD via government vehicles facilitated by AIRSTA Elizabeth City.

IRD3 - Poor visibility and icing conditions along the entire east coast delayed the start of IRD 3 by one day. On 10 March, a patrol en route of the Strait of Belle Isle between KADW and CYYT was conducted, identifying three icebergs located at 50°N inside the 1000 M contour. On 11 March, a planned patrol of the Southern Limit was flown and a total of nine icebergs were spotted. The next day a patrol of the 1,000 meter contour and interior was flown with nine icebergs and one ship detected. On 13 March, an opportunity crew rest day was taken due to high winds at CYYT. Winds continued over the next two days and kept the plane grounded until 16 March when a patrol of the interior and Hamilton Bank was flown and identified a total of 20 icebergs and three ships. The IRD crew returned home the following day.

IRD4 - On 23 March, the crew of IRD 4 arrived in St. John’s. The next day, sustained winds of 35 kts prevented the plane from leaving the hangar. On 25 March a Northern Survey was flown and 59 icebergs were spotted, the most of any patrol of the season to date. Upon returning to CYYT, a significant mechanical issue was discovered and IRD 4 was cancelled. The IRD crew was unable to depart the following day due to snowfall, high winds, and freezing rain. On 27 March the IIP crew returned directly to KECG. That evening the IIP crew returned to Suitland, MD via government vehicles.

IRD5 - IRD 5 began on 06 April with the IRD crew arriving at CYYT. Due to low ceilings and freezing precipitation, the IRD was grounded on 07 April. The following day, a patrol of the Southern Limit and the Flemish Cap found zero icebergs and 14 ships. On 09 April, a patrol of Sackville Spur and the 1,000 meter contour was flown and detected two icebergs and 12 ships. An opportunity crew rest day was taken on 10 April due to forecasted icing and low ceilings in the OPAREA. The next day, 11 April, a maintenance day was taken due to a low pressure system over Newfoundland and the OPAREA bringing extremely inclement weather. On 12 April, the patrol was cancelled again due to high winds at CYYT. The IRD crew returned to KADW a day early with a patrol en route of the Western Limit. This decision to end the deployment one day early was based on forecasted thunderstorms along the east coast that would have prevented the aircraft from landing. During the patrol en route a total of eight icebergs and four ships were spotted in the Strait of Belle Isle.

IRD6 - On 20 April, IRD 6 began with an arrival in Halifax, Nova Scotia for the first Titanic Ceremony there since 2018. The official ceremony took place on 21 April and was attended by numerous dignitaries, the IRD crew, as well as members from CG Headquarters and Public Affairs. Later that afternoon, the IRD crew departed for CYYT and conducted a patrol as well as a ceremonial wreath drop over the resting place of the RMS Titanic **(Figure 4-2)**. No targets were identified en route to CYYT. On 22 April a Northern Survey was flown in addition to the aerial deployment of a SVP buoy. That flight saw the most icebergs of any flight throughout the season, having spotted 239 icebergs and five ships. On 23 April the planned patrol was cancelled due to a communications failure on the aircraft and an unscheduled maintenance day was conducted instead. Due to low ceilings and visibility at CYYT on 24 April, the planned patrol was cancelled. The following day testing was unable to reestablish communication on the aircraft and the IRD was cancelled. On 26 April, the IRD crew returned two days early.

Figure 4-2. U.S. Coast Guard Capt. (ret.) Kevin Kiefer, lays a memorial wreath over the resting place of the RMS Titanic on April 21, 2022.

IRD7 - 04 May marked the start of IRD 7 and what would later be determined to be the last deployment of the season. A Southern Limit patrol was conducted on 05 May, with five icebergs spotted during the patrol along with 20 ships. The following day, 06 May, 11 icebergs and eight ships were detected during a patrol of the Western Limit and Strait of Belle Isle. On 07 May, low ceilings and high seas in the OPAREA prevented the patrol from taking place. Opportunity maintenance was conducted in lieu of flying. During maintenance checks, a mechanical issue was discovered and the aircraft was grounded awaiting replacement parts from KECG. The IRD crew was prevented from flying from 08-09 May while awaiting for the parts to arrive. On 10 May, a patrol of the Southern Limit and Flemish Pass was flown which did not detect any icebergs but saw 71 ships during its flight. 11 May saw a patrol of the 1,000 meter contour and Hamilton Bank which included the accompaniment of media personnel from the Canadian Broadcasting Corporation (CBC). A total of 92 icebergs and five ships were identified during what would be the final patrol of the 2022 IRD season. This marked the earliest end to the flying season since 1985, when those statistics began being tracked.

IRD Iceberg Detections

IRD personnel detected 475 icebergs over the seven IRDs in the 2022 Ice Season. Of the 475 icebergs sighted, 441 were incorporated into BAPS, which accounted for 3% of the total icebergs incorporated into the drift and deterioration model during the 2022 Ice Season. No action was taken on a total of 34 icebergs. This was either due to the reconnaissance occurring outside the boundaries of the model, or conflicts with other reconnaissance the same day. The 3% of icebergs incorporated into BAPS from IRDs is significantly lower than the 18% in 2021, which saw a larger number of deployments and patrols than in 2022.

During IRDs, icebergs were detected in one of three ways: (1) both visually and electronically (radar or camera), (2) radar only, or (3) visual only. Iceberg detections made with the Electro-Optical Infrared (EOIR) camera are counted as electronic reconnaissance because of the camera's ability to see much farther than the human eye and its ability to use infrared imaging to find targets. It can also identify exact latitude and longitude positions on the earth's surface, unlike window observers who only calculate estimated positions based on range and bearing. This year, 38% of the icebergs were detected by concurrent radar observations and visual sightings (69% in 2021). 2% of the remaining icebergs were detected by radar only (8% in 2021), and 60% were detected visually only (23% in 2021) **(Figure 4-3 and Table 4-3).**

Visual-only detection accounted for a significantly higher than average portion of total icebergs sighted. Five sorties were flown in spite of known radar issues which resulted in more visual detections than is typical for a deployment season.

IIP personnel employed a two-tiered approach in areas of favorable environmental conditions, focusing visual observations close to the aircraft and radar observations away from the flight path enabling maximum detection efficiency. This tactic often resulted in visual-only iceberg detections within the range of the radar (and even detected on radar), but in those scenarios observers were recording high volumes of icebergs and there was not a need to have the exact radar position or detection information recorded.

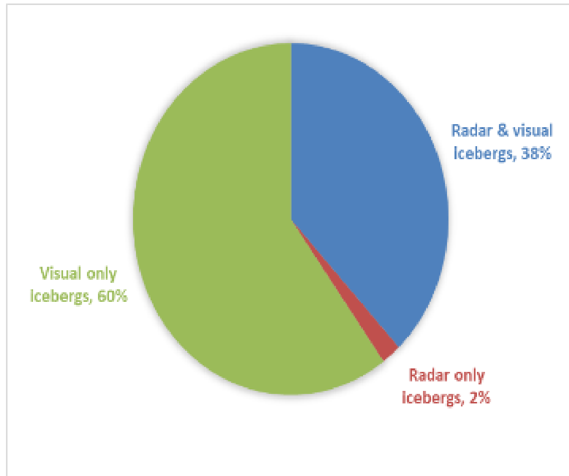


Figure 4-3. Ice Reconnaissance Detachment iceberg detection methods for the 2022 Reconnaissance Season.

Year	Radar & visual icebergs	Radar only icebergs	Visual only icebergs
2013	46%	17%	37%
2014	43%	5%	52%
2015	29%	45%	26%
2016	20%	32%	48%
2017	21%	39%	40%
2018	24%	31%	45%
2019	44%	26%	30%
2020	67%	3%	30%
2021	69%	8%	23%
2022	38%	2%	60%

Table 4-3. IRD iceberg detections by method from over the last ten years (2013-2022).

2022 Flight Hours

As in previous seasons, IIP was allotted 500 Maritime Patrol Aircraft flight hours for its operation during the 2022 Ice Season. IIP used 190.8 total hours in 2022. This total includes patrol, transit, and logistics hours attributed to the IIP mission. **Figure 4-4** shows the breakdown of these hours for 2022 compared to the past four seasons into three categories: transit hours, patrol hours, and logistic hours.

Transit hours are the hours the aircraft is transiting to and from specific locations in support of the IIP mission, without conducting reconnaissance. These flights were between Elizabeth City, NC and St. John's, NL, with a brief stop at Joint Base Andrews in Prince George's County, MD to load IIP person nel and equipment. There were 72.4 hours used this season for transits.

Patrol hours are those hours associated with iceberg reconnaissance including the flight time to and from the reconnaissance area. IIP flew 118.4 patrol hours this season. When a patrol is conducted during a regularly planned transit flight, such as a patrol while transiting back to Joint Base Andrews, the hours are split accordingly. There were two patrols en route during this season. In 2022, 37.2 hours out of the logged 118.4 patrol hours (31%) were used for flying to/from the OPAREA. On average, it took two hours to fly to and from the OPAREA when operating out of St. John's. This return to standard transit times was a significant improvement over the 6+ hours it took to fly to and from the OPAREA when patrols took off out of Cape Cod, MA in 2019 and 2020. **Figure 4-5** depicts a breakdown of flight hours for the 2022 season by IRD.

Logistics hours are the hours used to support the IIP mission, but do not fall into the previous two categories. Logistic hours accrue when a Coast Guard aircraft is used to transport parts for an aircraft deployed on an IIP mission. This

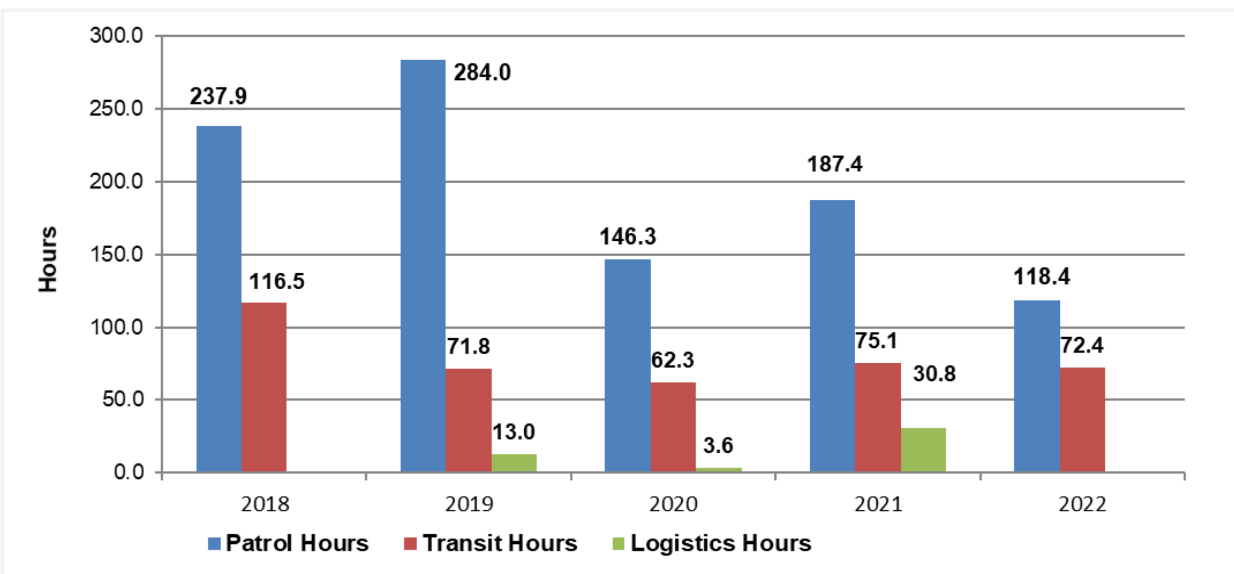


Figure 4-4. Flight hours broken down by patrol, transit, and logistics hours over the past five years.

Figure 4-5. 2022 Flight hours broken down by IRD. FBO refers to a Fixed Base of Operations, the staging area for reconnaissance flights.

season there were no logistics flights since all repairs were completed using commercial shipments or via commercial courier.

The spatial and temporal distribution of icebergs, as well as the quantity of icebergs drifting south of 48ºN, all contribute to the amount of reconnaissance needed to effectively monitor the iceberg danger and provide relevant warning products. **Figure 4-6** shows a comparison of flight hours to the number of icebergs that drifted south of 48ºN from 2013 to 2022. IIP flew 190.8 hours and saw only 58 icebergs drift south of 48ºN. This was a light season, with 58 icebergs being well below the average for the modern reconnaissance era (1983 – 2020) of 758 icebergs.

Satellite Reconnaissance

IIP satellite reconnaissance during the 2022 Iceberg Season focused on development of analysts and the pursuit of new capabilities. The majority of frames analyzed by IIP in 2022 remained to be from the European Commission's SAR satellites Sentinel-1A. IIP continues to rely on Sentinel-1A imagery by following a consistent collection schedule and accessing open source, no-cost imagery available online in near real-time. However, it is worth noting the Sentinel-1B failure in December 2021 hindered IIP's satellite capabilities tremendously, as satellite passes are no longer as frequent in covering the AOR, which made consistent satellite analysis more difficult. This season also continued operational use of imagery from the Canadian Space Agency's Radarsat Constellation Mission (RCM), a direct result of the important partnership between IIP and CIS. Finally,

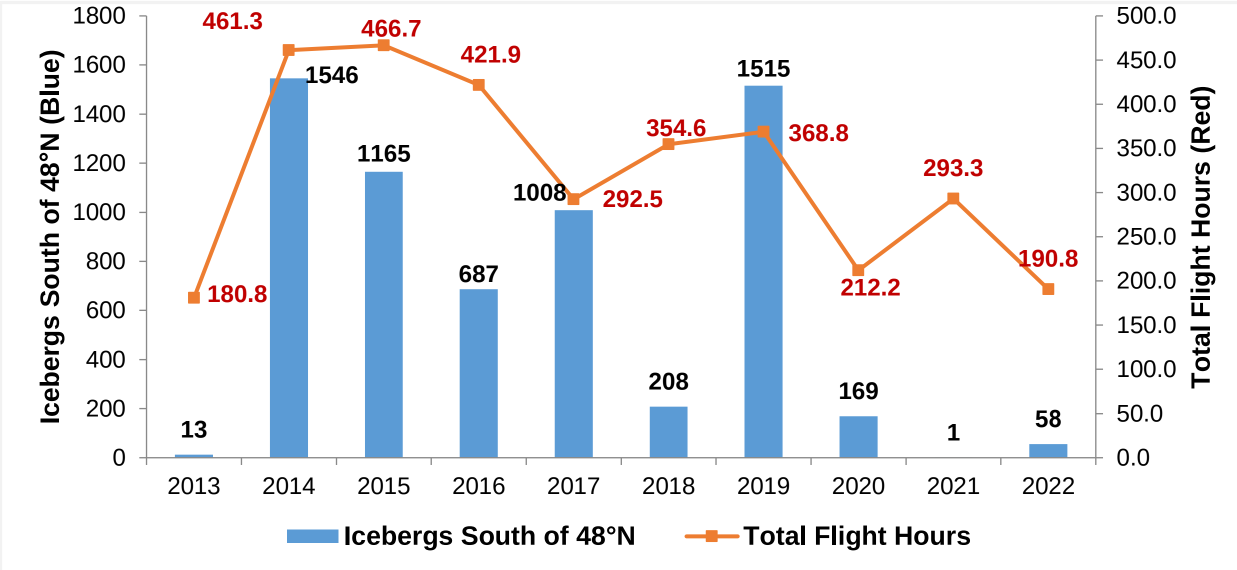


Figure 4-6. Comparison between total IRD flight hours per season and season severity, measured by number of icebergs sighted or drifted below 48ºN for the past 10 years. More icebergs south of 48ºN may require increased reconnaissance efforts.

IIP continued to utilize Sentinel-2A/B multispectral imagery in 2022.

IIP analyzed 682 individual satellite frames for 408 total SIMS during the 2022 Ice Season. These 682 satellite frames were comprised of 327 Sentinel-1 frames (279 SIMS), three RADARSAT-2 frames (three SIMS), 290 Sentinel-2 frames (73 SIMs), 46 RCM frames (46 SIMS), 15 ISPY frames (four SIMS), two Planet SIMS (unknown number of frames used), and one Capella frame (one SIM). IIP's Satellite Day Worker (SDW) analyst identified 4,541 icebergs in the 682 analyzed frames, of which 3,992 were added or resighted in BAPS. A further breakdown of satellite iceberg reports received from all sources and the total number of satellite icebergs entered into BAPS can be found in **Table 3-1**. The total number of frames analyzed in-house by IIP increased from the 410 frames in 2021 to 682 frames in 2022. The increase can be attributed to the decreased flight hours in 2022 season. This is similar to the 2020 Ice Season, where IIP operated with reduced flight hours due to the COVID-19 pandemic, thereby deploying fewer members, and enabling the employment of multiple satellite analysts per day. Furthermore, the small number of icebergs within the IIP OPAREA over the last three ice seasons constrained the Iceberg Limit and reduced the number of satellite frames available for relevant analysis. This discussion is reflected in **Figure 4-7**, which shows the total percentage of satellite-identified icebergs (from all sources).

Northern Survey Efforts

In December 2021, IIP's Satellite Reconnaissance Branch conducted a satellite Northern Survey between 65°N and 70°N along the coast of Labrador, east coast of Baffin Island, and southwestern Baffin Bay. The goal was to estimate the "upstream" iceberg population found in sea ice that could drive aerial reconnaissance decision-making

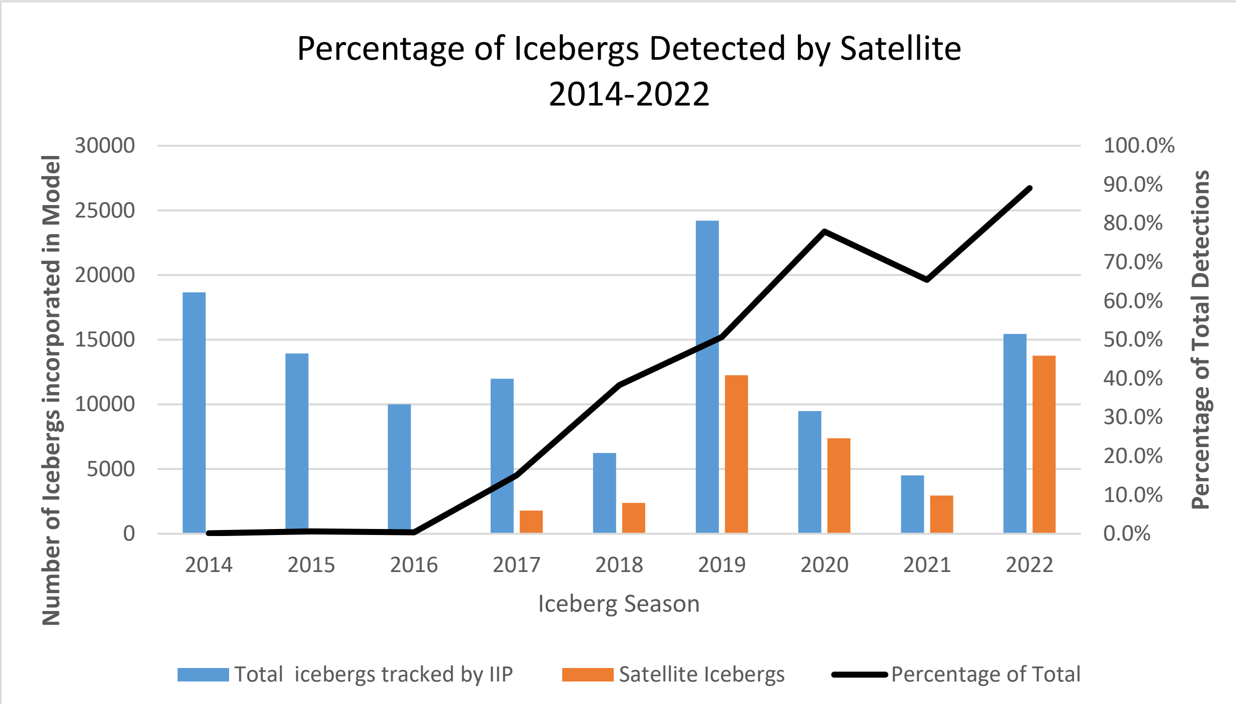


Figure 4-7. Comparison of the number of satellite iceberg detections (all sources) incorporated into the model at IIP and the total number of iceberg sightings from 2014-2022. The black line shows the percentage of total iceberg sightings merged to the model by IIP that were from satellite sources.

in the early part of IIP's iceberg reconnaissance season. The survey looked at 15 frames derived from Sentinel-1 and RCM from 02-09 December 2021, detecting a total of 84 icebergs **(Figure 4-8)**. Most of these icebergs were detected in sea ice. The sea ice helps to insulate the icebergs from sea waves that quickly cause them to melt otherwise. For that reason, these icebergs were deemed likely to drift south through the winter, and potentially down in to shipping lanes with the movement of the sea ice.

The methods for conducting this survey differed significantly between the first iteration of the study that was conducted in December, 2020. IIP's satellite analysts aim to standardize the methodology for surveying the area north of 65ºN, and to build a data set that may be useful in correlating season severity (number of icebergs detected south of 48ºN) with icebergs detected during a Northern Survey. Such a data set would be useful for attempting to predict season severity several months before the peak of the iceberg season (typically March each year).

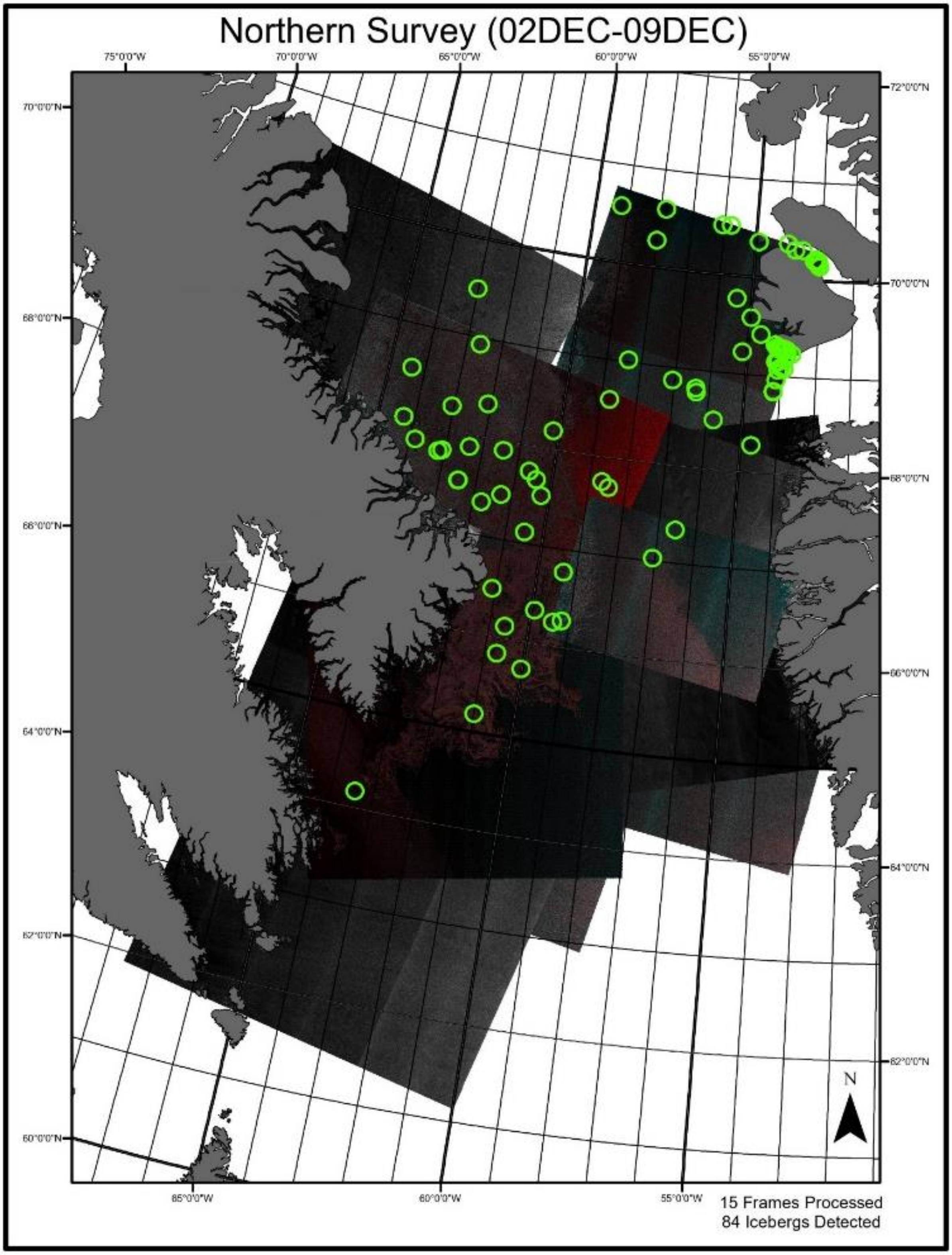


Figure 4-8. Results of the 2021-2022 Northern Survey showed 84 high-confidence targets contained within sea ice flowing through Baffin Bay.

Other Reconnaissance Activities

NAIS Collaboration

In order to maximize aerial iceberg reconnaissance in the North Atlantic, IIP continued to leverage its NAIS partnership with CIS. IIP coordinated flight plans with CIS during periods when IRDs were not deployed to St. John's, NL during the season. **Figure 4-9** depicts the NAIS flight hours for 2022. Data provided includes hours flown by each service. CIS contracted PAL Aerospace for 28.8 patrol hours, and IIP flew 81.2 patrols hours (with all transit time removed), which resulted in a combined total of 110 patrol hours in support of NAIS reconnaissance.

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 the vicinity of the aircraft, and direct calls to vessels identified by AIS. The information from the individual vessels is especially useful during periods of reduced visibility, or when numerous small vessels not equipped with AIS are present in the reconnaissance area. Vessel observations are valuable for confirmation of data provided by the aircraft's radar. During the 2022 season, IRDs made 16 general sécurité broadcasts and 26 direct vessel callouts. Out of all vessels contacted directly, 50% responded to callouts.

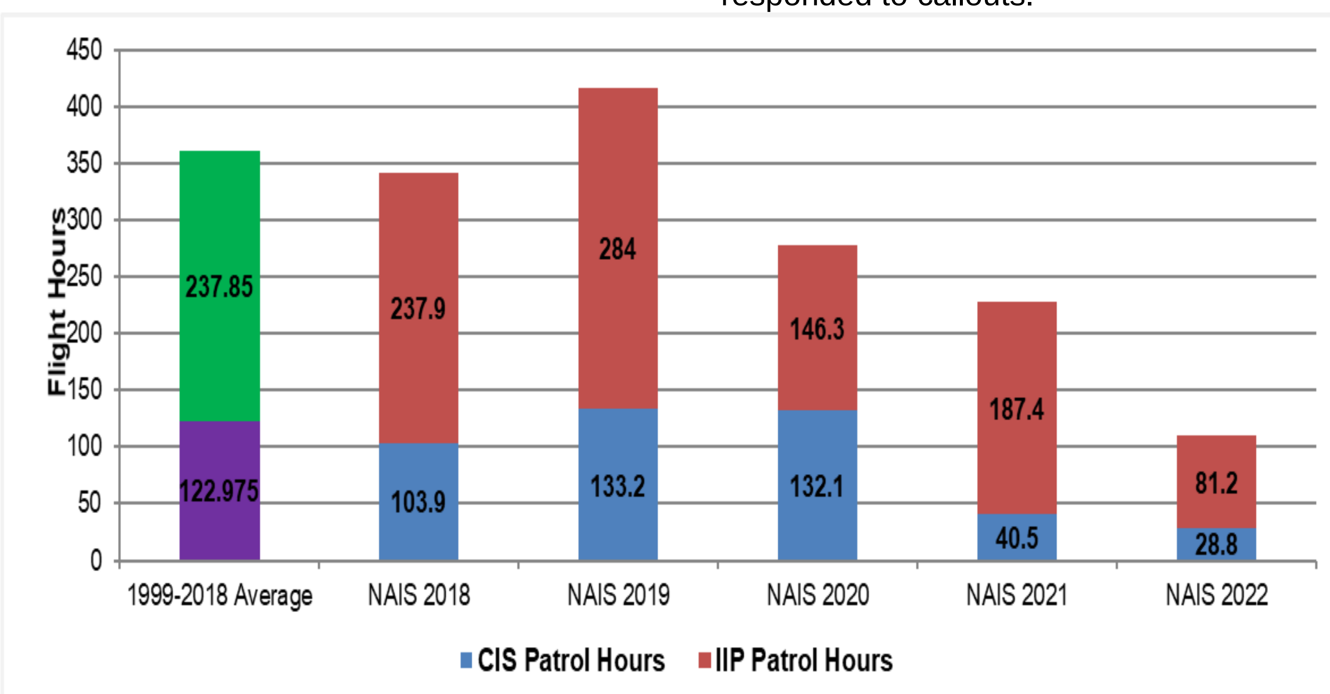


Figure 4-9. NAIS flight hours, a combination of IIP patrol hours and CIS funded PAL Aerospace patrol hours compared to the previous 6-year average.

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
CBC	Canadian Broadcasting Corporation
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
CCG	Canadian Coast Guard
CIIP	Commander, International Ice Patrol
CIS	Canadian Ice Service, an operational unit of the Meteorological Service of Canada
CYYT	St. John's International Airport
DMI	Danish Meteorological Institute
DWS	Duty Watch Stander
ELTA	ELTA Systems Ltd., a group and a wholly-owned subsidiary of Israel Aerospace Industries specifically referring to the ELM-2022A Airborne Maritime Surveillance Radar aboard the HC-130J
EOIR	Electro-Optical Infrared
ERMA	Environmental Response Management Application, NOAA
ESA	European Space Agency, owner of the Sentinel-1a satellite
ESRL PSD	Earth Systems Research Laboratory Physical Science Division
GHRSST	Group for High Resolution Sea Surface Temperature
HC-130J	U. S. Coast Guard Long Range Surveillance Maritime Patrol Aircraft
HD	High Definition
IDS	Iceberg Detection Software
IICWG	International Ice Charting Working Group
IFM	Isolated, Few, Many: in reference to the tailored support product
IIP	U. S. Coast Guard International Ice Patrol

IRD	Ice Reconnaissance Detachment
ISAR	Inverse Synthetic Aperture Radar
KADW	Joint Base Andrews Airport
KECG	Elizabeth City Airport
KML	Keyhole Markup Language
kts	knots
m	meter
mb	millibar
MCTS	Marine Communications and Traffic Service, Canadian Coast Guard
MD	Maryland
MIFC	Coast Guard Maritime Intelligence Fusion Center
MMS	Minotaur Mission System
M/V	Motor Vessel
N	North (Latitude)
NAIS	North American Ice Service
NAOI	North Atlantic Oscillation Index
NAVAREA	Navigational Area
NAVTEX	Navigational Telex
NAVWARN	Navigational Warning
NC	North Carolina
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction
NGA	U. S. National Geospatial-Intelligence Agency
NL	Newfoundland and Labrador, Canada
NM	Nautical Mile
NOAA	National Oceanographic and Atmospheric Administration
NSIDC	National Snow and Ice Data Center
NWS	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-2	Canadian C-Band SAR satellite system, owned and operated by MacDonald, Dettwiler, and Associates. (also abbreviated RS-2)
RCM (1, 2, or 3)	Radarsat Constellation Mission, Canadian Government C-Band SAR satellite system
Radiofax	Radio Facsimile
RMS	Royal Mail Steamer
SafetyNET	Inmarsat-C Safety Net, automated satellite system for promulgating marine navigational warnings, weather, and other safety information.
SAR	Synthetic Aperture Radar
SDW	Satellite Dayworker
shp	Shape File
SIM	Standard Iceberg Message
SITOR	Simplex Teletype Over Radio
SOLAS	Safety of Life at Sea
SRB	Satellite Reconnaissance Branch
SST	Sea Surface Temperature
SVP	Surface Velocity Program
UKMO	United Kingdom Meteorological Office
U.S.	United States
USCG	U. S. Coast Guard
USCGC	U. S. Coast Guard Cutter
USNIC	U. S. National Ice Center
VMS	Canadian Vessel Monitoring System
W	West (Longitude)
WWNWS	World Wide Navigation Warning System
Z	Zulu – Coordinated Universal Time

6. References

Canadian Ice Service. (2021a). Sea Ice and Iceberg Seasonal Outlook 2020-2021. Presented at IIP Annual Conference on 17 November 2020

Canadian Ice Service. (2021a). "Seasonal Summary for Eastern Canada – Winter 2020-2021."

Canadian Ice Service. (2021b). Weekly Regional Ice Charts – WMO Colour. Retrieved 18 September 2021 from: http://iceweb1.cis.ec.gc.ca/Archive/?lang=en

Canadian Ice Service (2022b). 30-Year Ice Climate Normals for 1991-2023. Accessed on 05 September 2022 from https://iceweb1.cis.ec.gc.ca/30Atlas/page1.xhtml?lang=en

Canadian Ice Service (2022c). Seasonal Summary North American Arctic Waters, Spring 2022.

Canadian Ice Service. (2021c). Departures from Normal Concentration for 22 March 2021. Retrieved 29 March 2021 from: https://www.canada.ca/en/environment-climate-change/services/ice-forecasts-observations/latest-conditions.html

Canadian Ice Service. (2021d). Single Season: Weekly Ice Coverage for the season 2020/2021. Created with CIS IceGraph program on 18 September 2021: http://iceweb1.cis.ec.gc.ca/IceGraph/page1.xhtml?lang=en

International Ice Patrol. (2018). Report of the International Ice Patrol in the North Atlantic (2018 Season), Bulletin No. 104, Appendix B.

Marko, J.R., D. Fissel, P. Wadhams, P. Kelly, and R. Brown (1994). Iceberg Severity off Eastern North America: Its Relationship to Sea Ice Variability and Climate Change. *J. Climate*, **7**, 1335–1351.

National Oceanic and Atmospheric Administration/Earth Systems Research Laboratory. (2021a). Physical Science Division. Air Temperature Composite Anomaly. Interactive Plotting and Analysis Pages. Retrieved 23 September 2021 from: http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/plot20thc.v2.pl

National Oceanic and Atmospheric Administration/Earth Systems Research Laboratory. (2021b). Physical Science Division. Sea Level Pressure Composite Anomaly. Interactive Plotting and Analysis Pages. Retrieved 20 September 2021 from: http://www.esrl.noaa.gov/psd/cgi-bin/data/composites/plot20thc.v2.pl

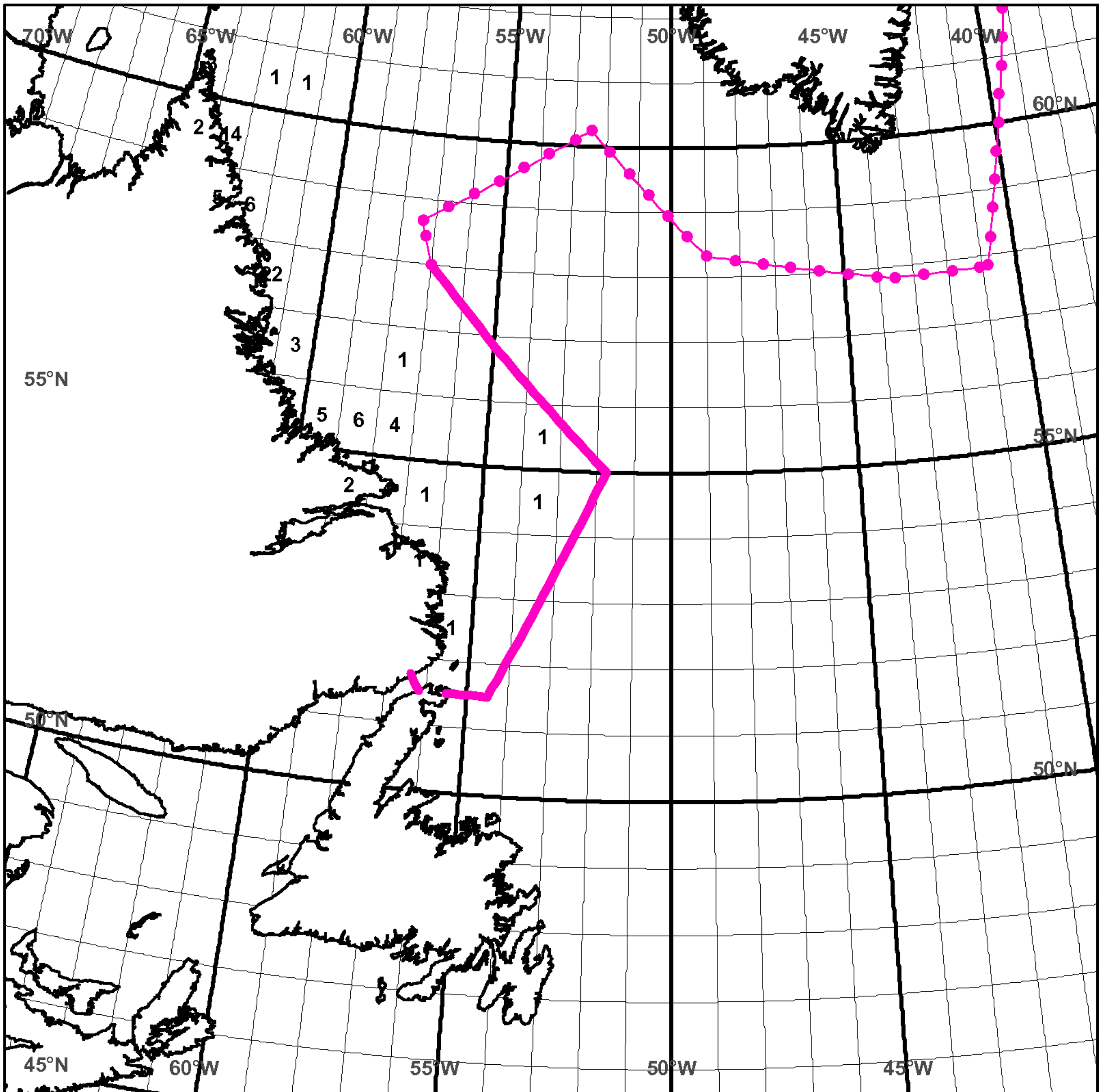
National Oceanic and Atmospheric Administration/Earth Systems Research Laboratory (2021c). Physical Science Division. Surface Vector Winds, Composite Mean. Interactive Plotting and Analysis Pages. Retrieved 20 October 2021 from: https://psl.noaa.gov/data/composites/day/

National Oceanic and Atmospheric Administration/National Weather Service (2021). NOAA Climate Prediction Center, Daily NAO Index. Retrieved 01 May 2021 from: http://www.cpc.ncep.noaa.gov/products/precip/CWlink/pna/nao_index.html

National Oceanic and Atmospheric Administration/National Center for Environmental Information (2022). NOAA Climate Prediction Center, Daily NAO Index. Retrieved 04 September 2022 from: https://www.ncei.noaa.gov/access/monitoring/nao/

UK Met Office. (2021). GHRSST Level 4 Operational SST and Sea Ice Analysis (OSTIA) Global Foundation SST Analysis (GDS version 2). Ver. 2.0. PO.DAAC, CA, USA. Dataset accessed on 13 October 2021 from: https://doi.org/10.5067/GHOST-4FK02

7. Semi-Monthly Iceberg Charts



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 OCT 2021

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

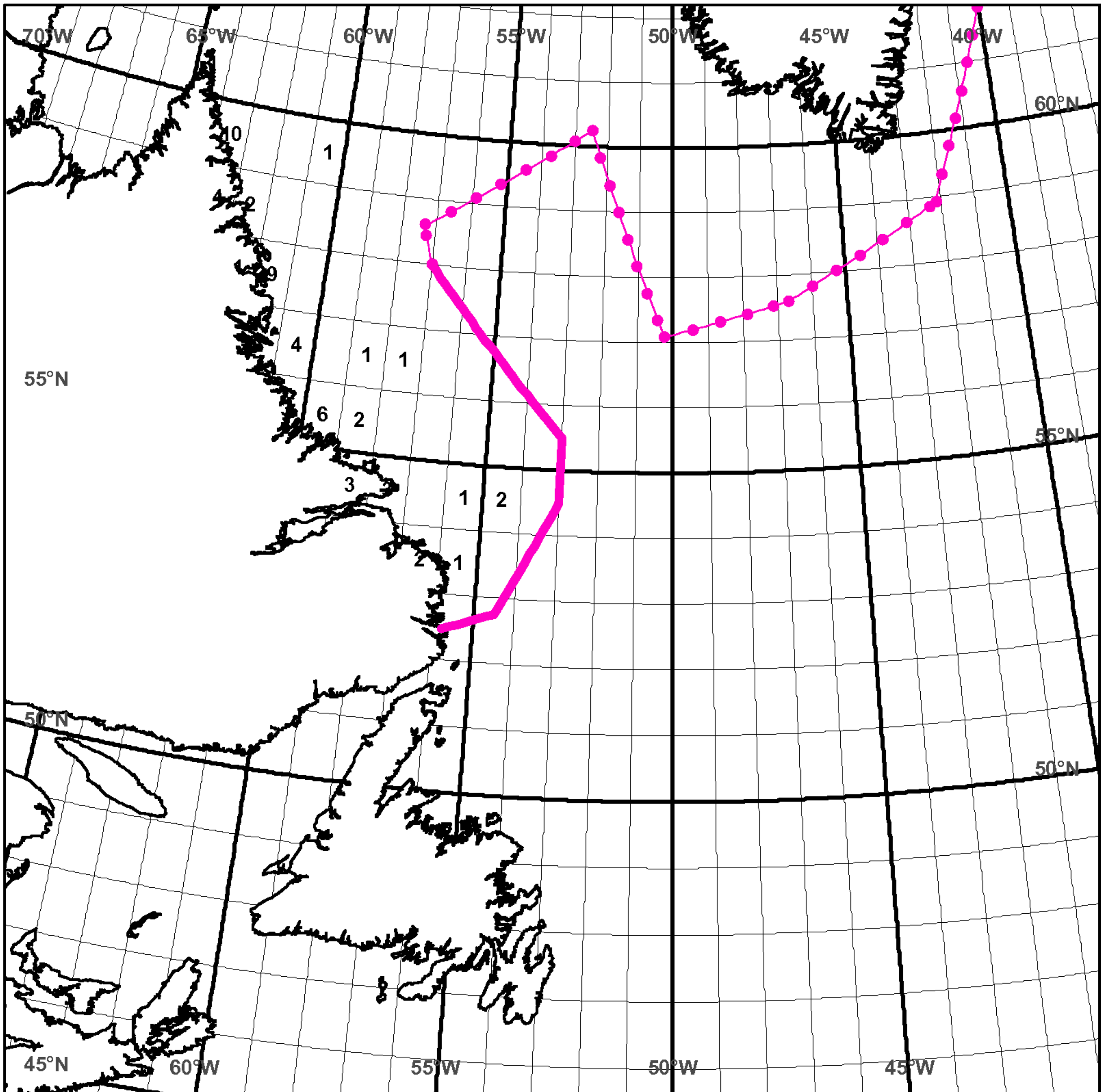
SEA ICE LIMIT

\# 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 29SEP21.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 OCT 2021

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

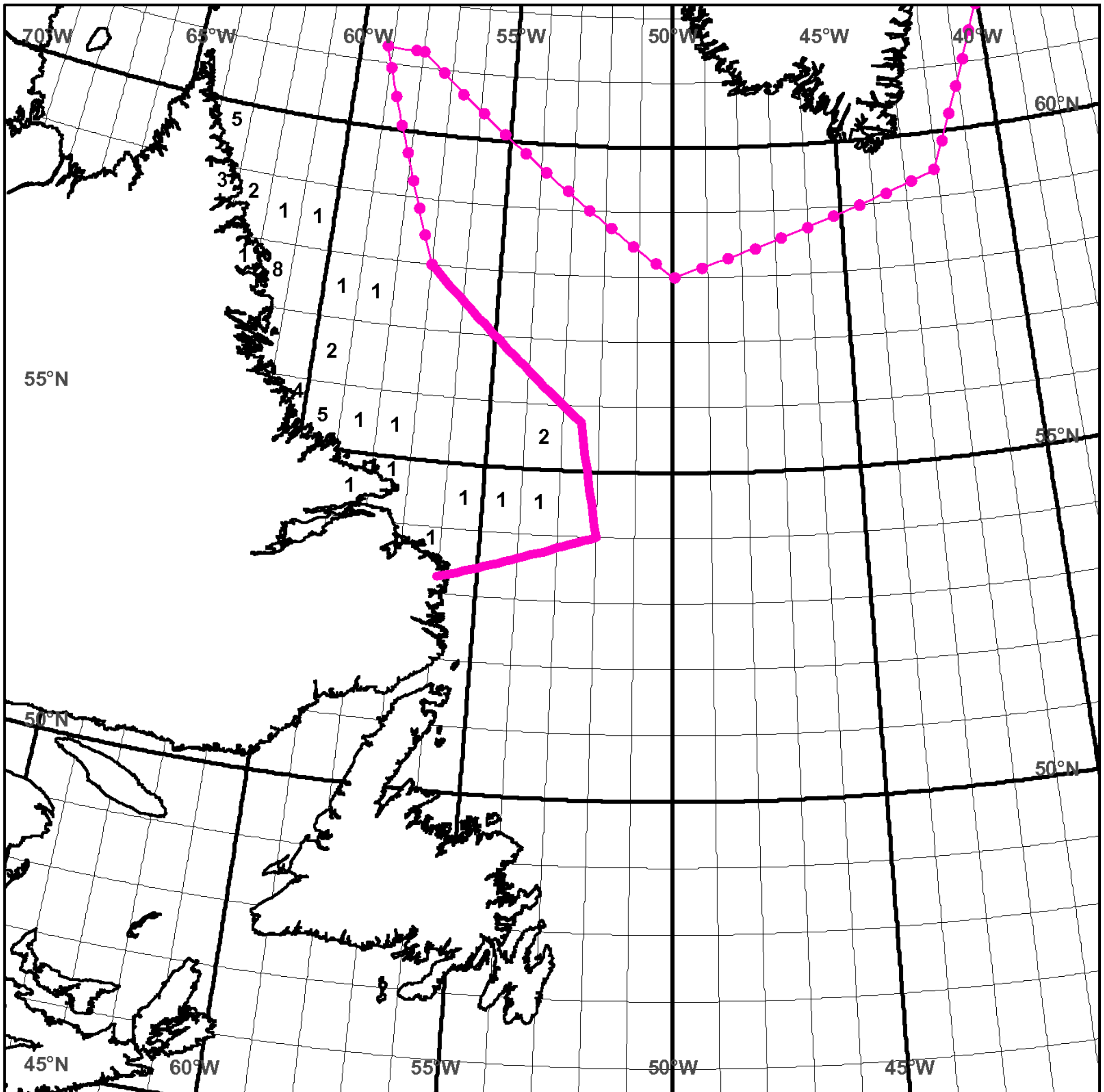
SEA ICE LIMIT

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 04OCT21.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 NOV 2021

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

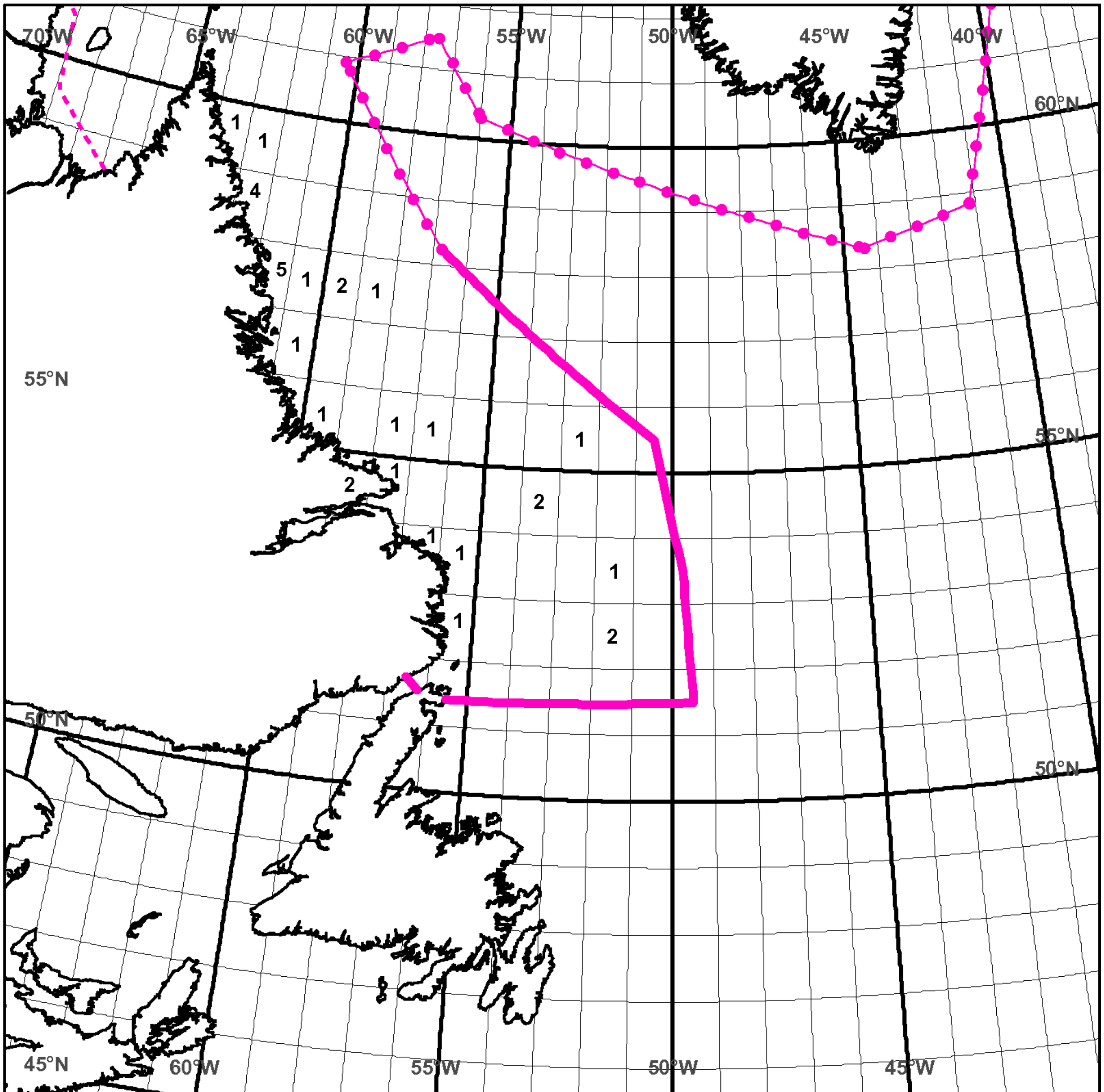
ICEBERGS PER DEGREE SQUARE

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 Satellite Pass 31OCT21.



NORTH AMERICAN ICE SERVICE (NAIS)

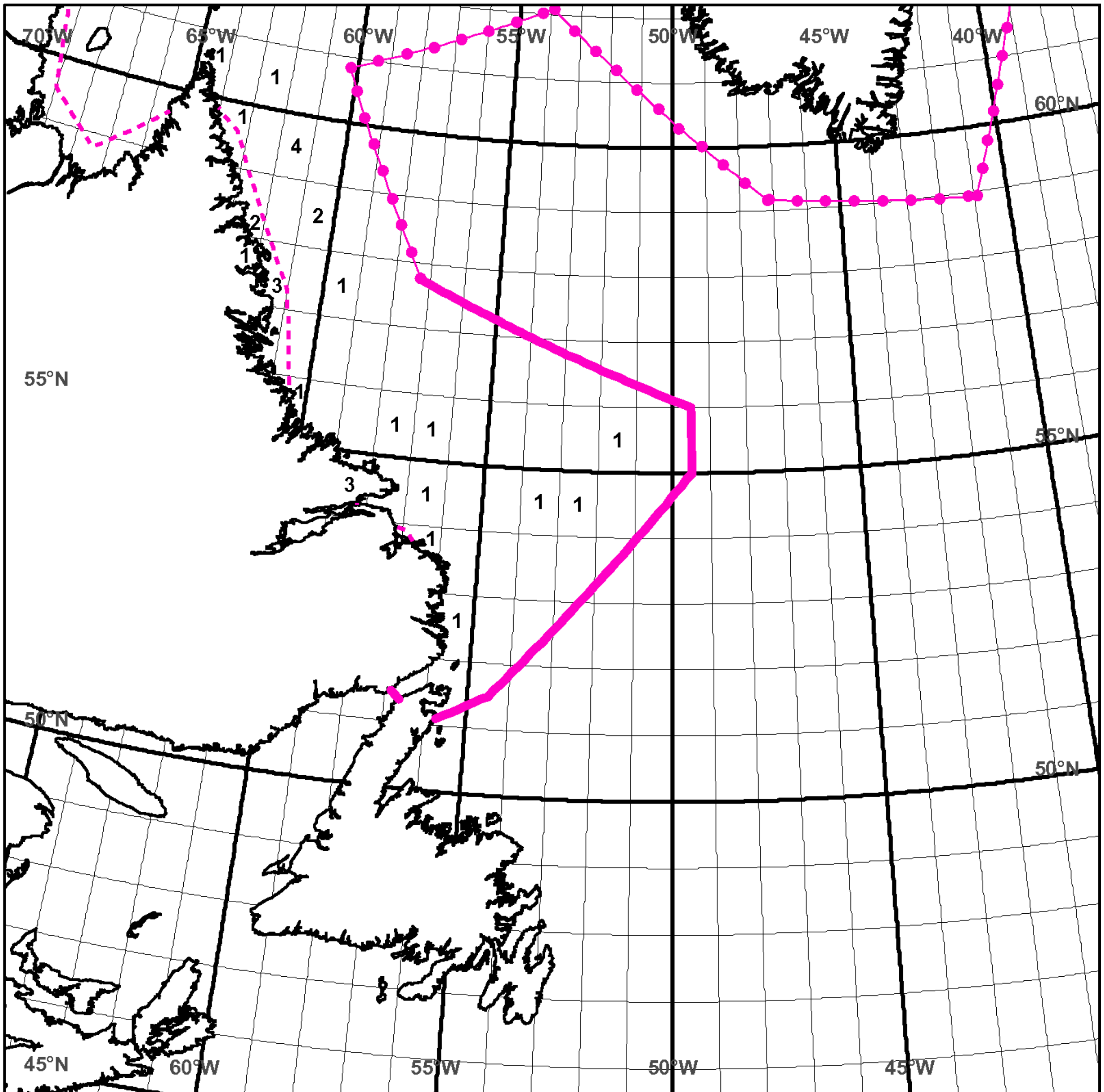
ICEBERG ANALYSIS FOR 0000 UTC

15 NOV 2021

- 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 Satellite Pass 14NOV21.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 DEC 2021

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

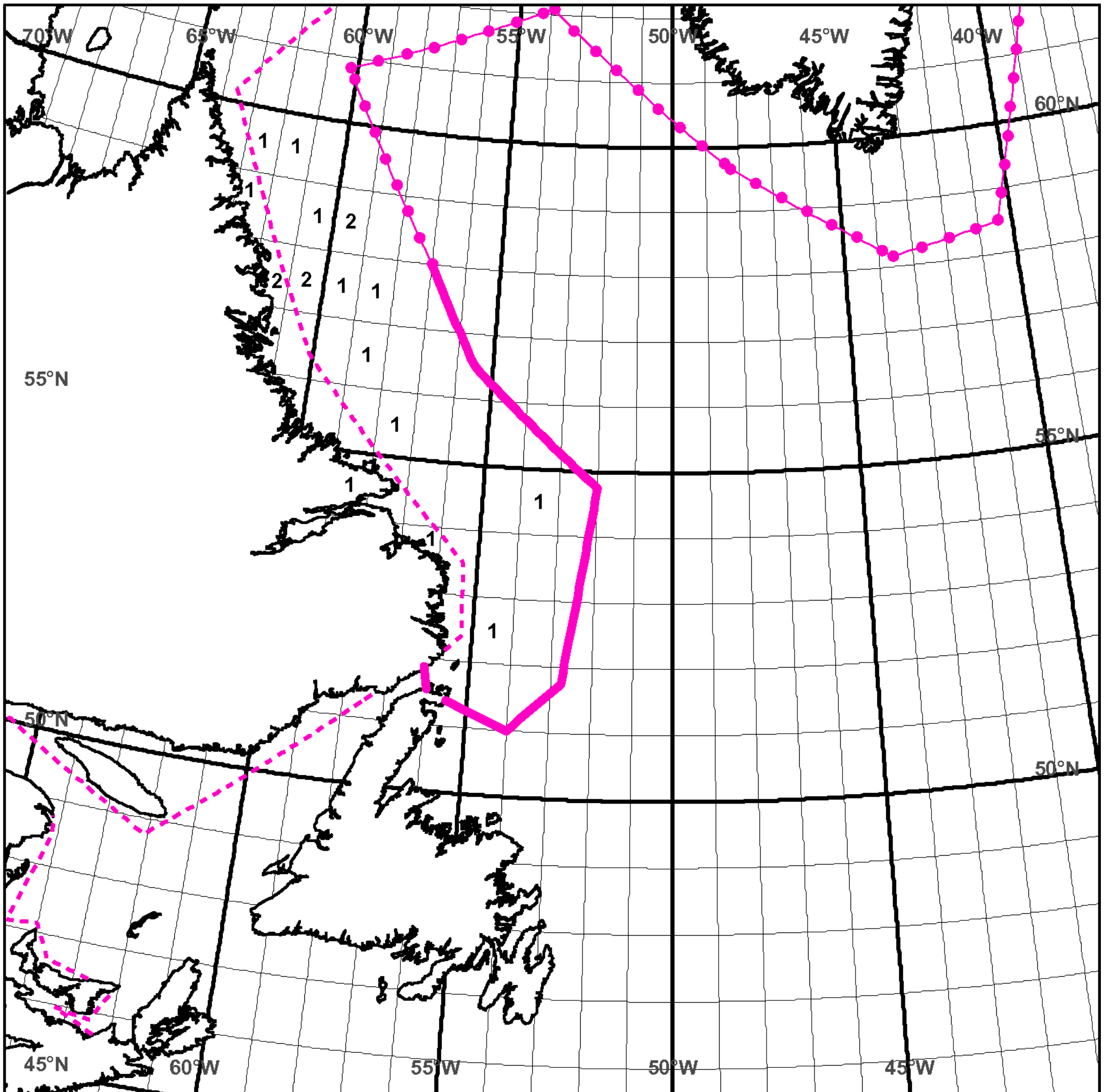
SEA ICE LIMIT

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 Satellite Pass 30NOV21.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 DEC 2021

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

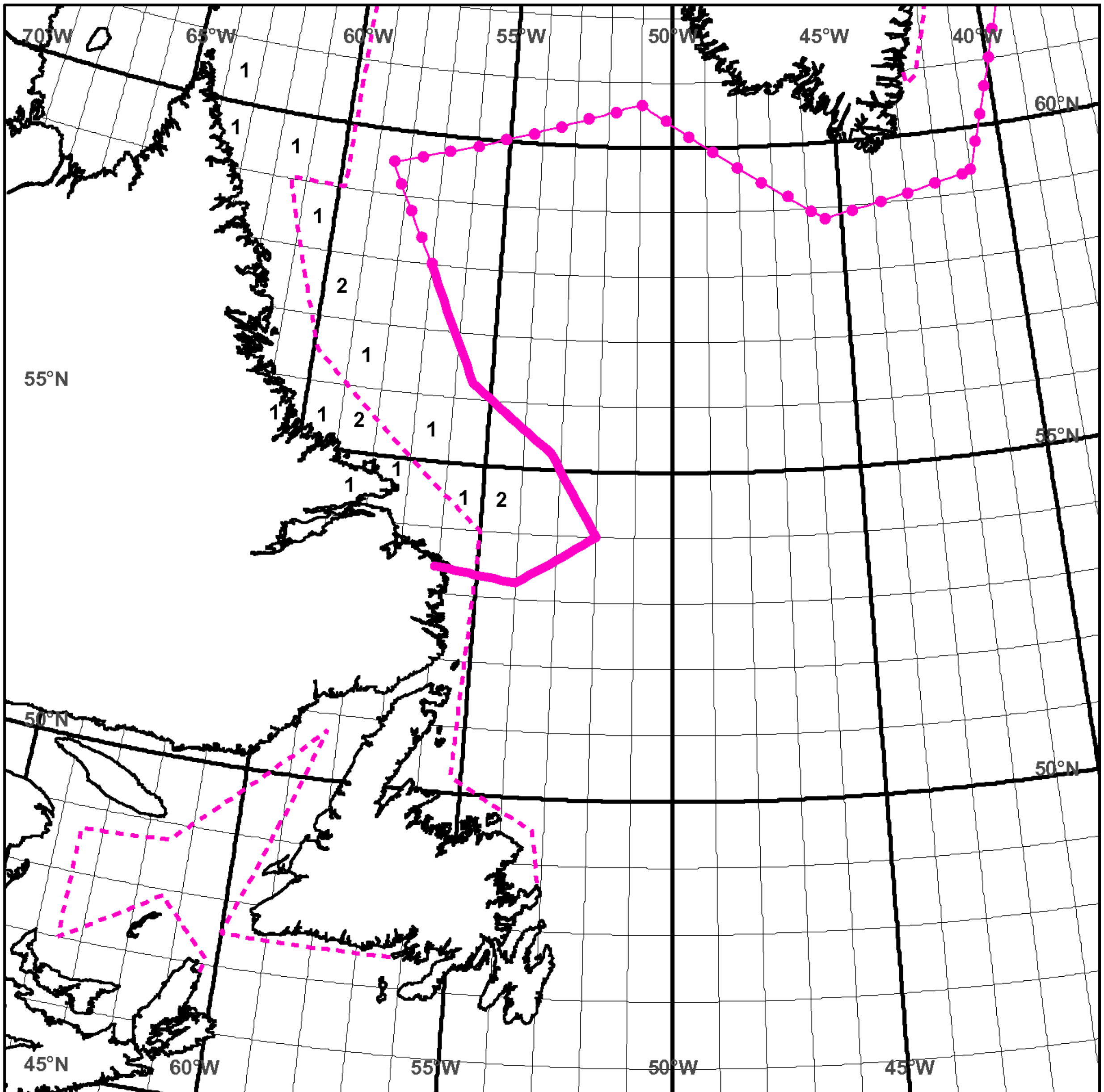
SEA ICE LIMIT

\# 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 Satellite Pass 13DEC21.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 JAN 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

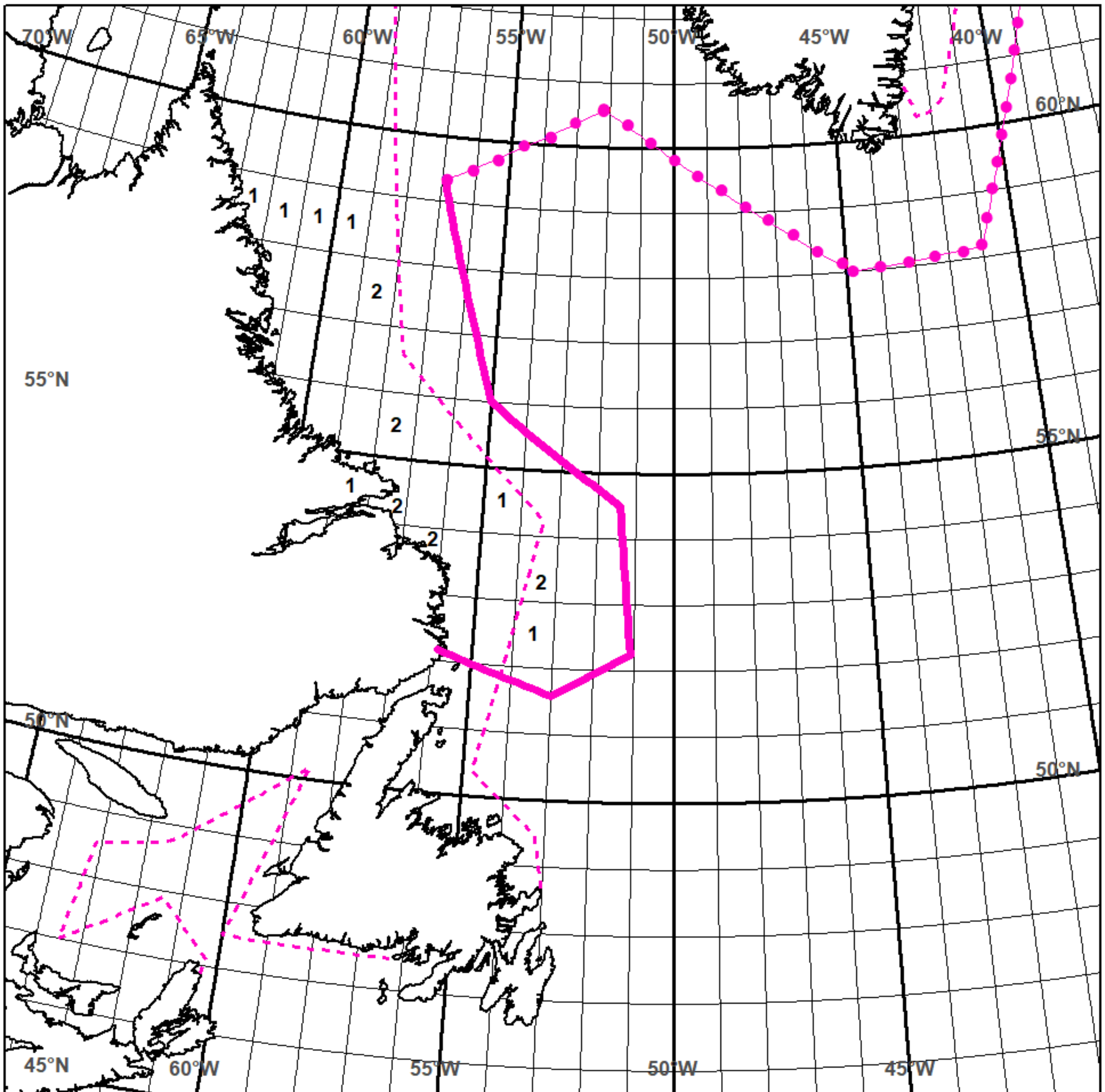
ICEBERGS PER DEGREE SQUARE

⊗ 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 30DEC21.



NORTH AMERICAN ICE SERVICE (NAIS)

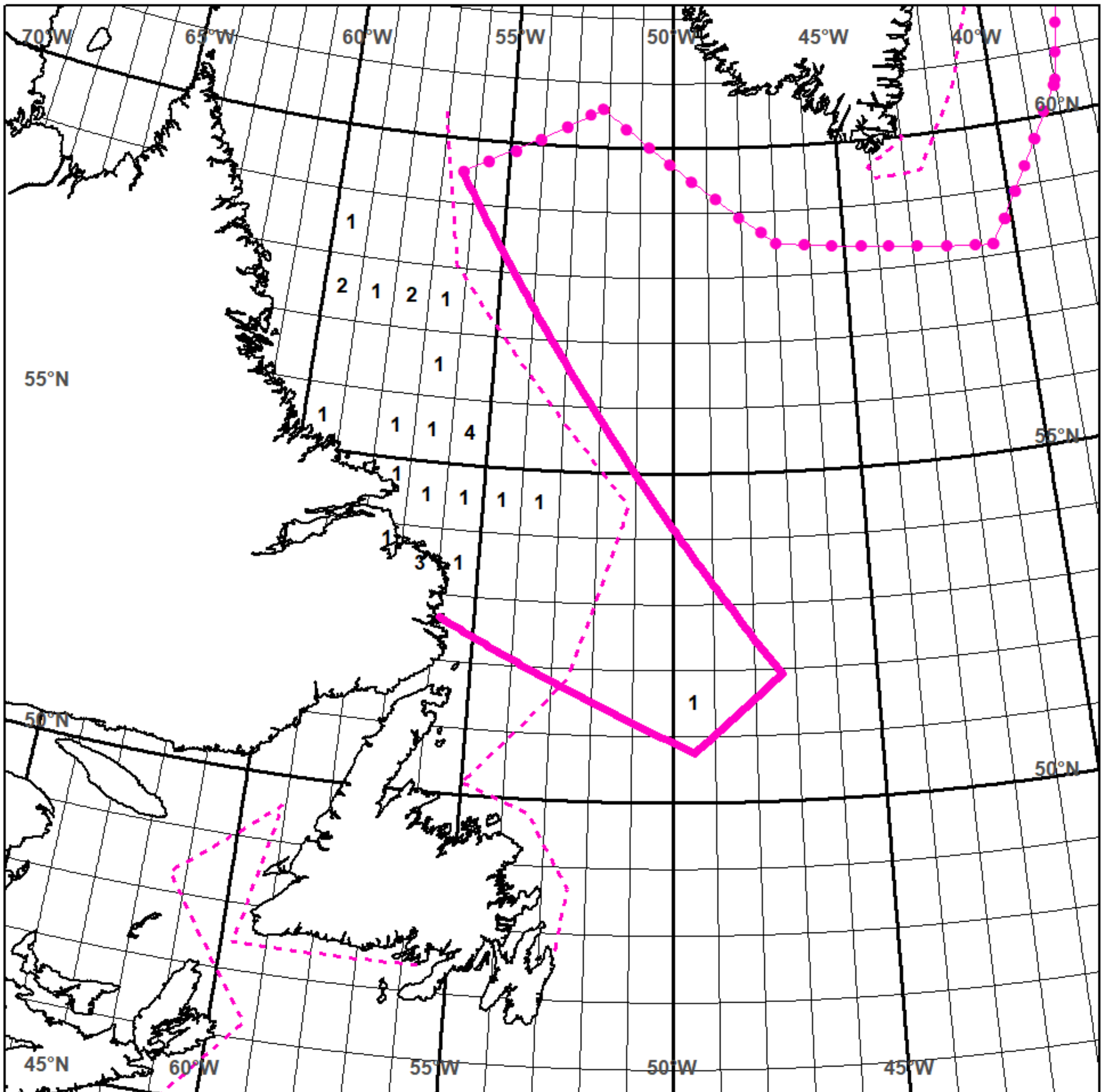
ICEBERG ANALYSIS FOR 0000 UTC

15 JAN 2022

●-●-●	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 Satellite Pass 12JAN22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 FEB 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

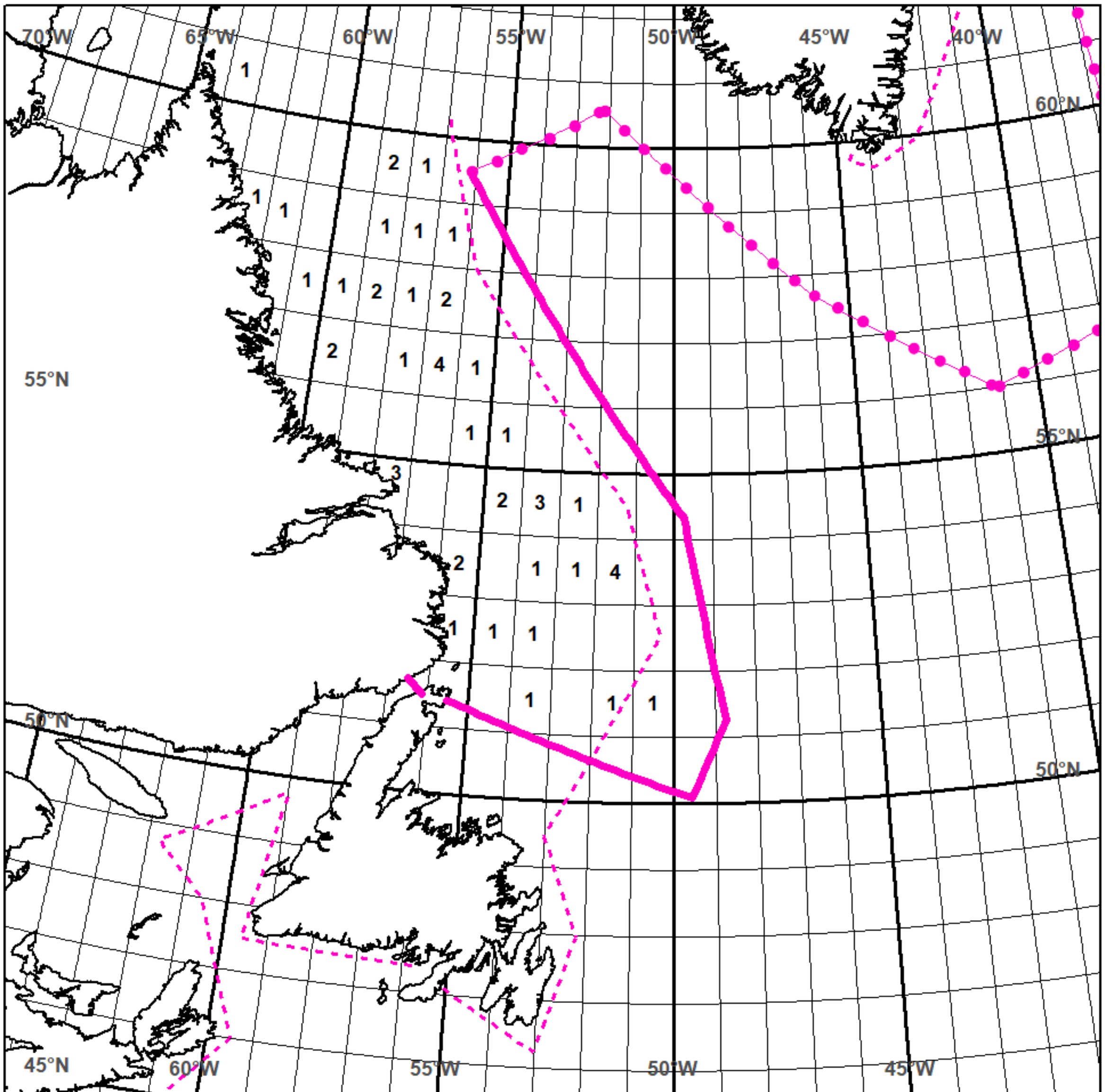
SEA ICE LIMIT

\# 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 Satellite Pass 29JAN22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 FEB 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

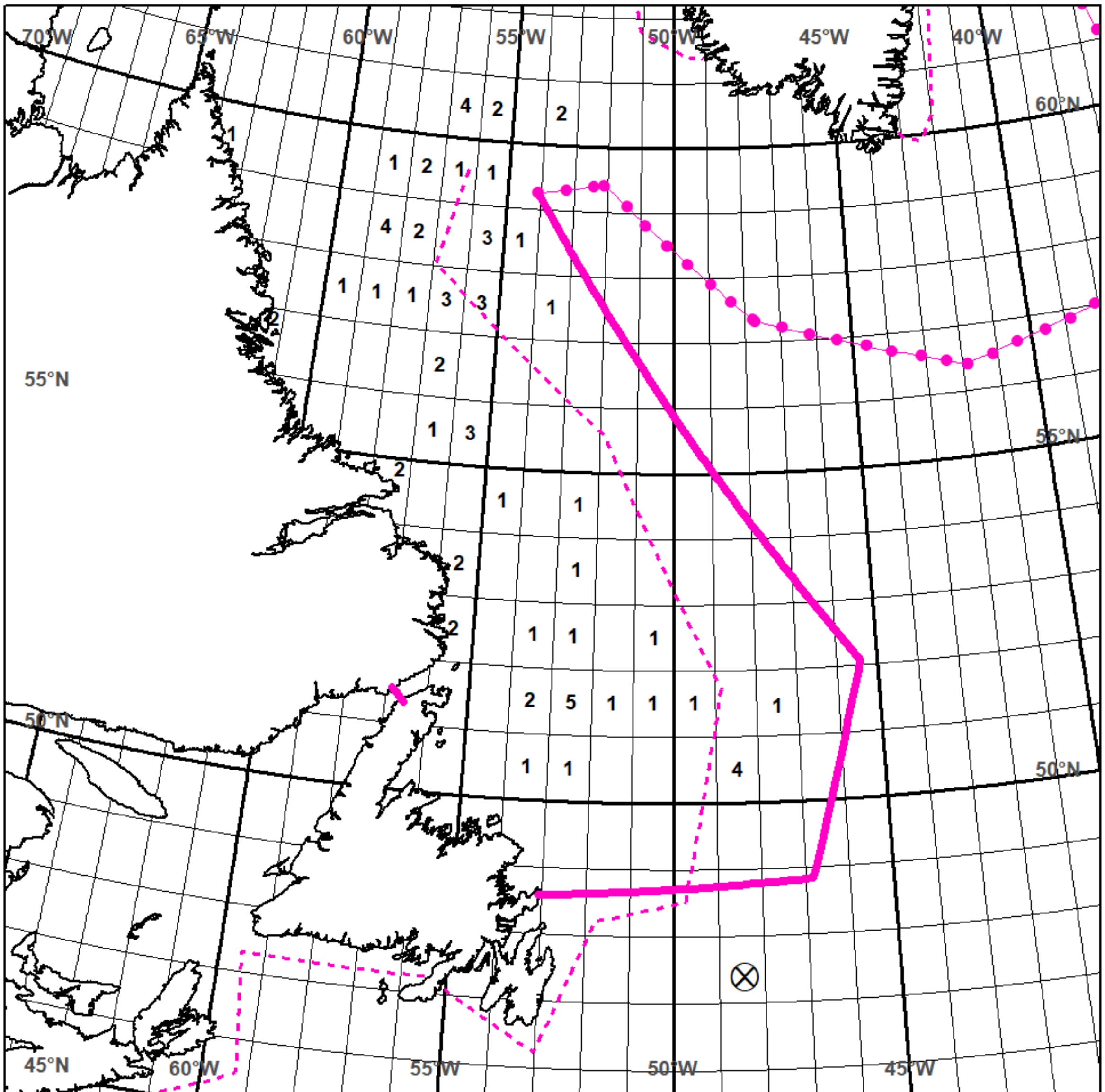
\# ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

Significant reduction of iceberg limit due to recent reconnaissance (predicted deterioration).

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Western Limit Satellite Pass 14FEB22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 MAR 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

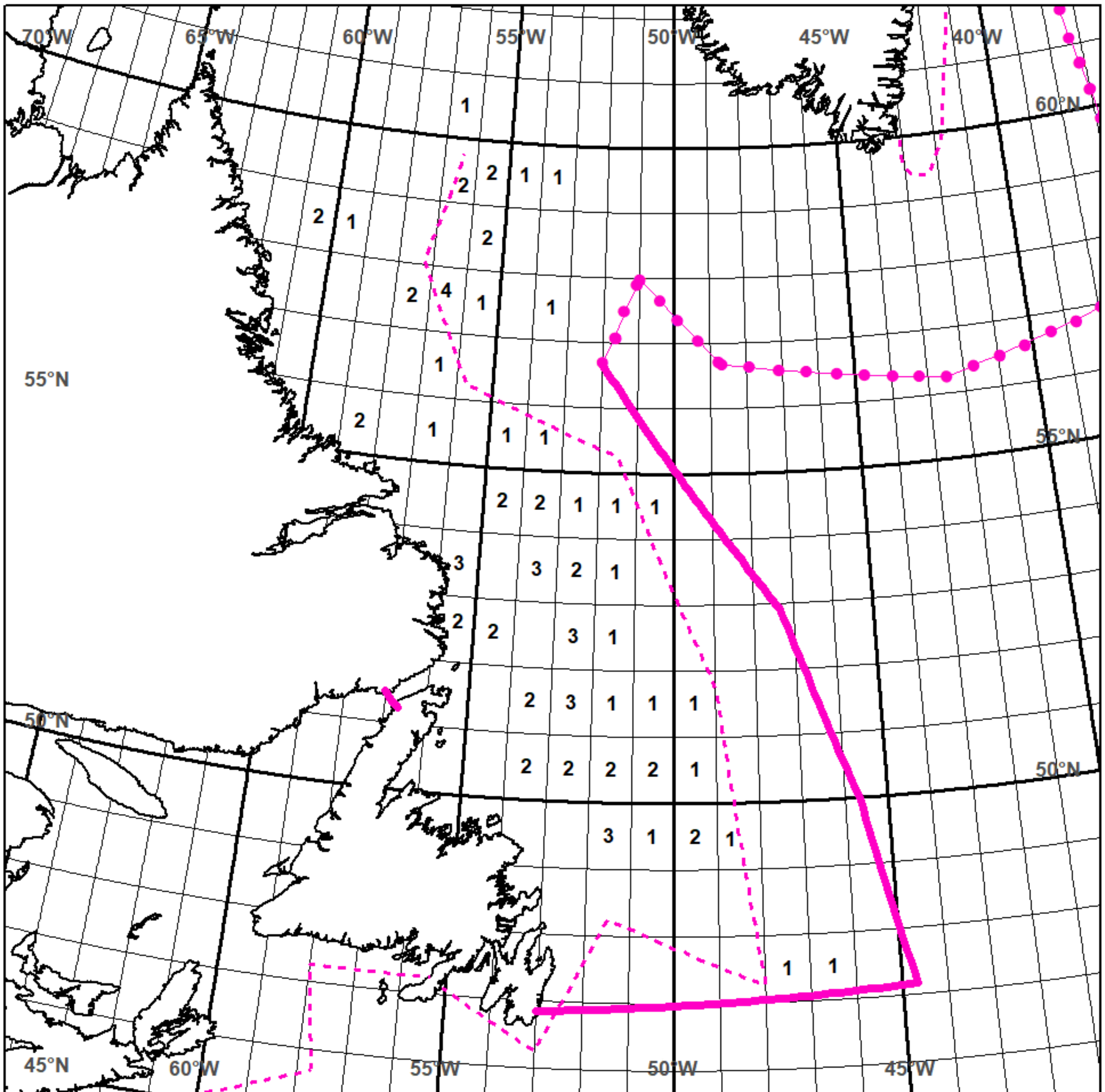
SEA ICE LIMIT

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 26FEB22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 MAR 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

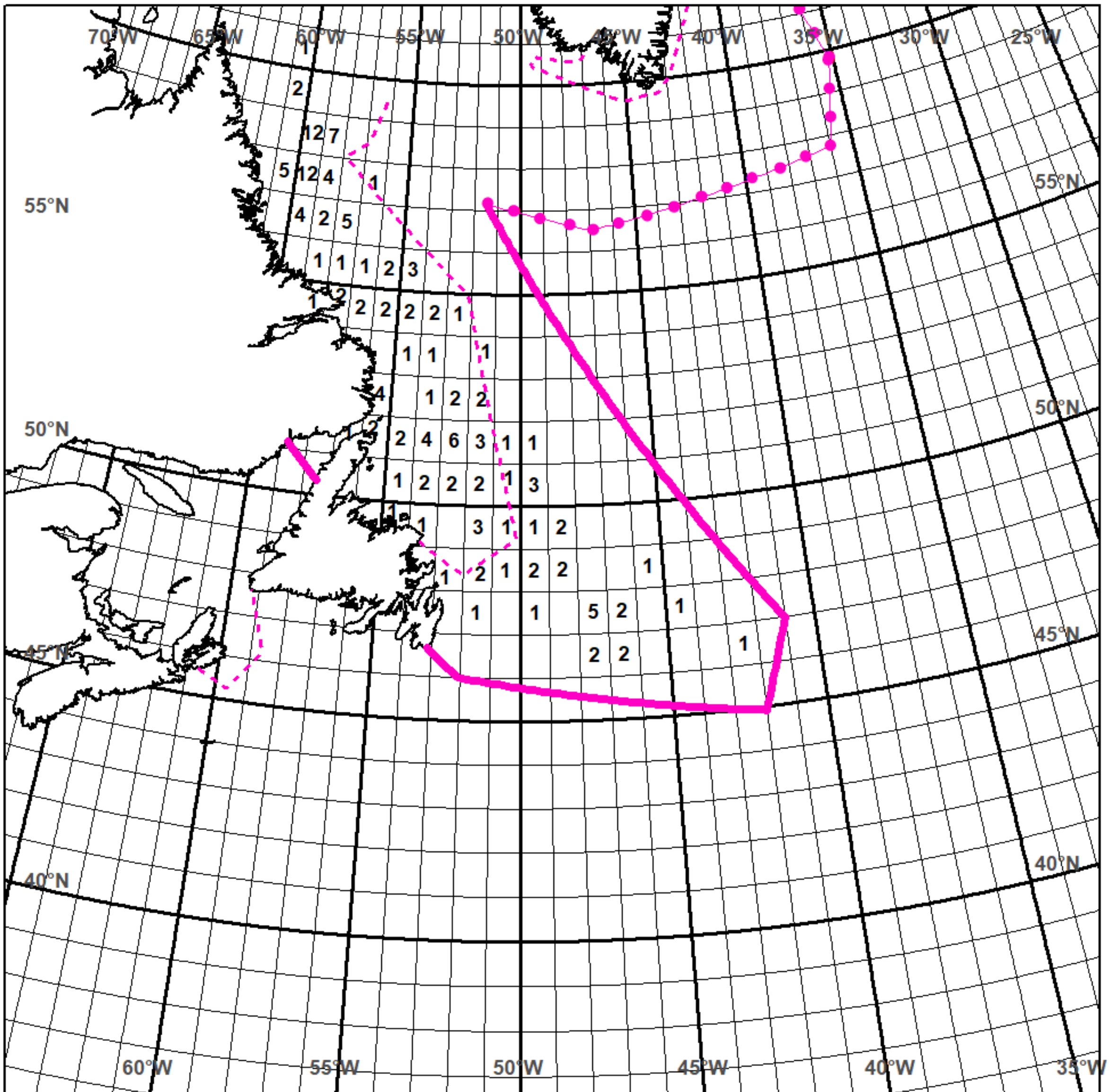
SEA ICE LIMIT

\# 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 General Flight 12MAR22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 APR 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

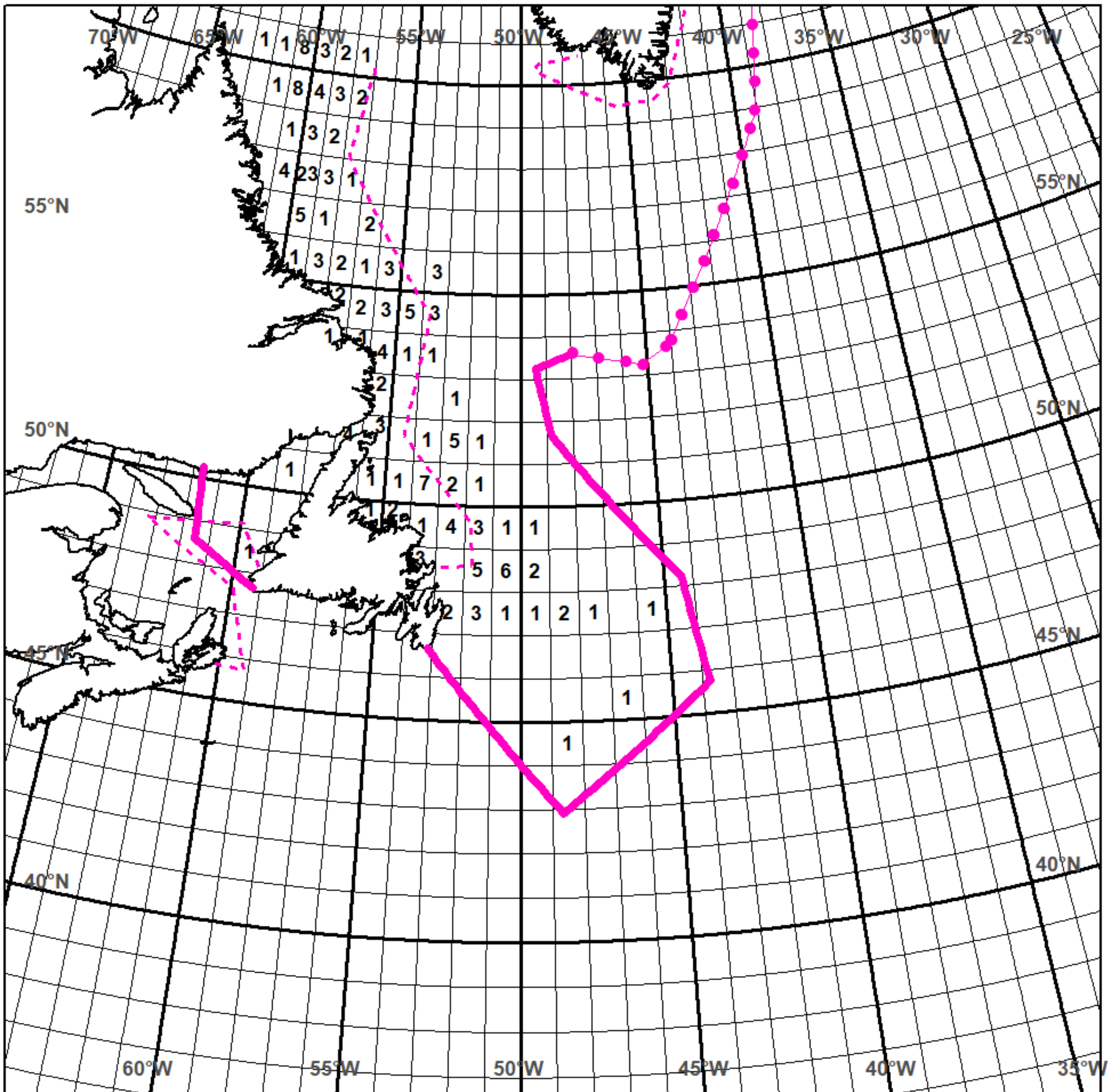
SEA ICE LIMIT

\# 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 31MAR22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 APR 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

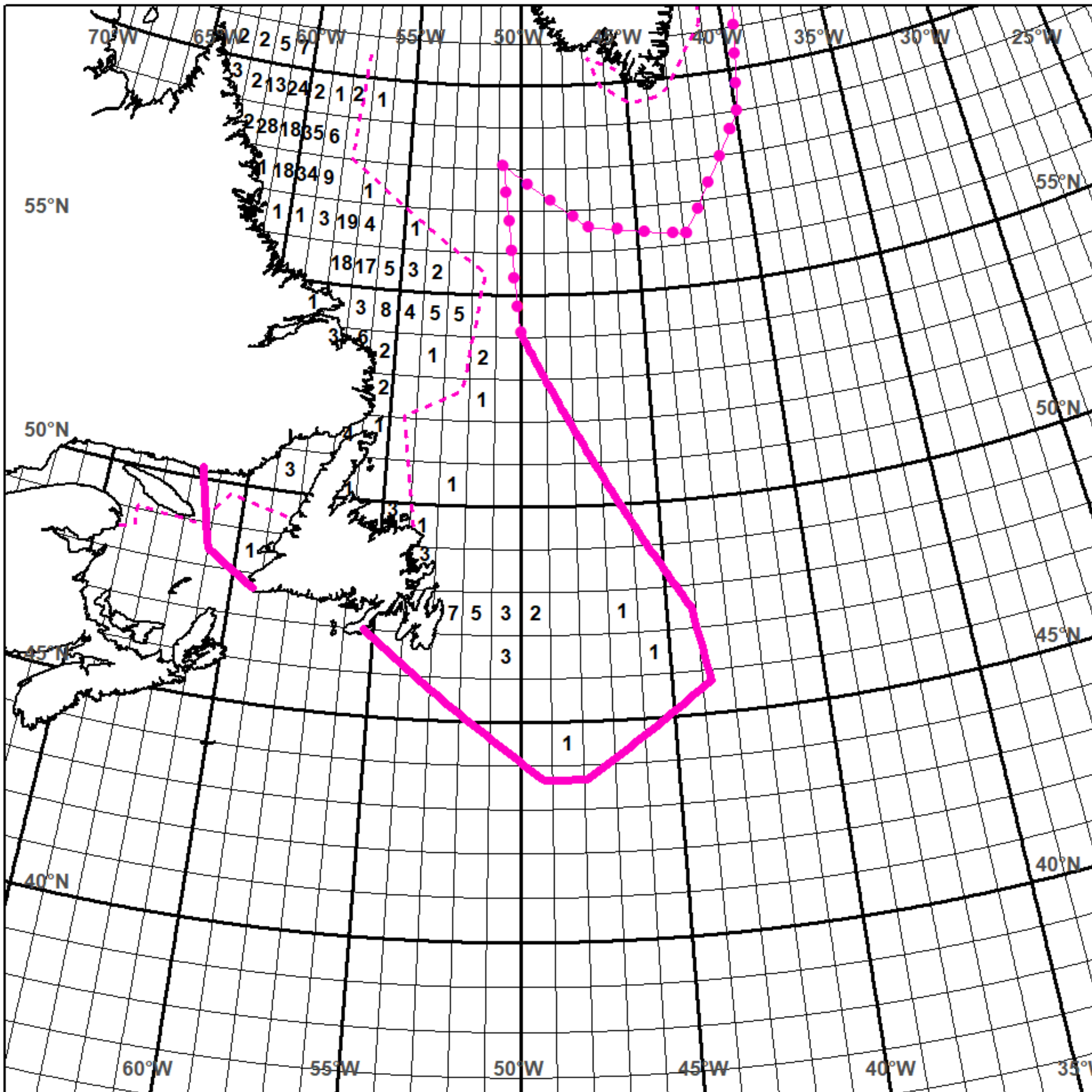
\# ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

Today we commemorate the 110th 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:
Western Limit Iceberg Flight 13APR22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 MAY 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

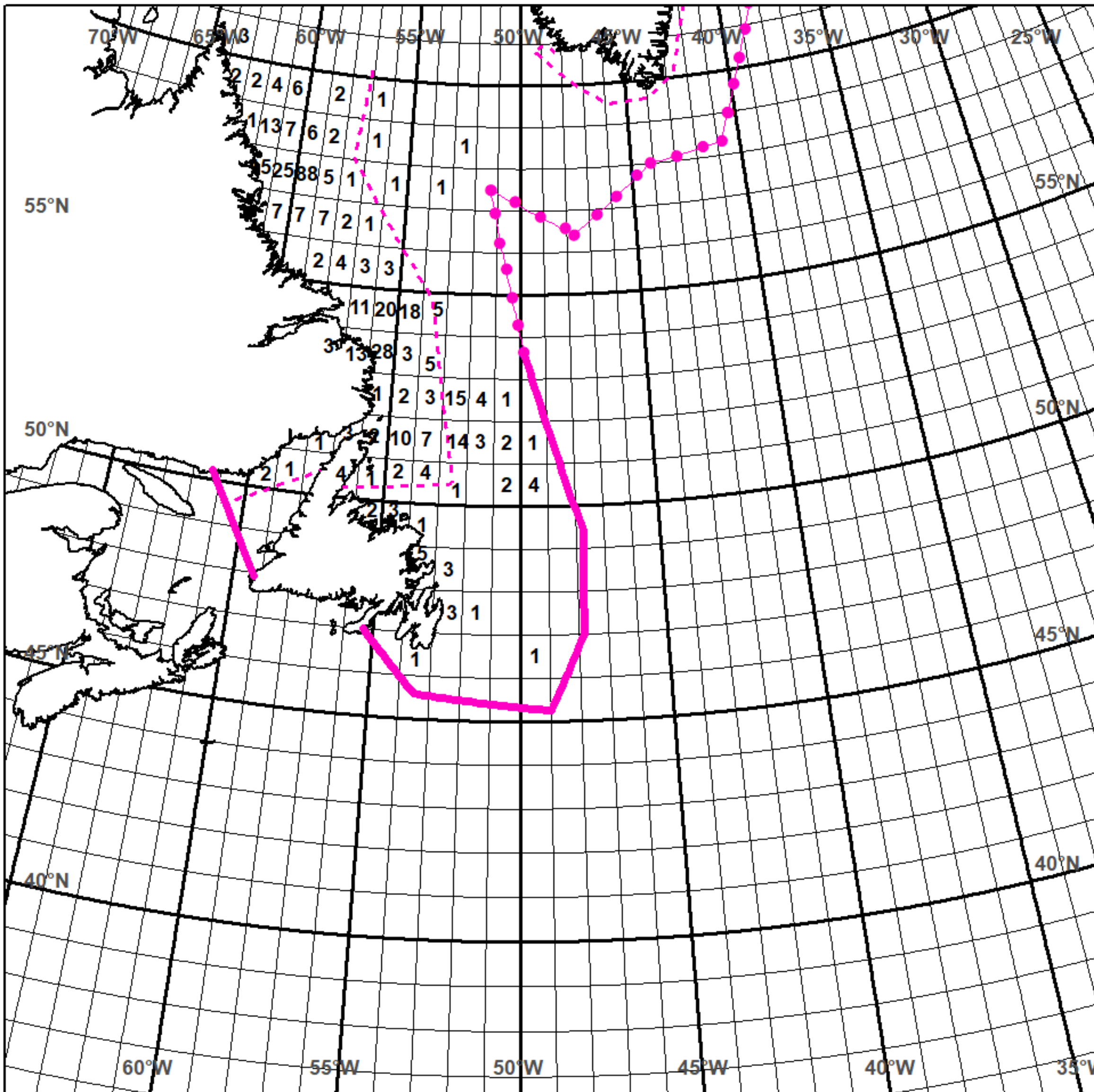
SEA ICE LIMIT

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 27APR22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 MAY 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

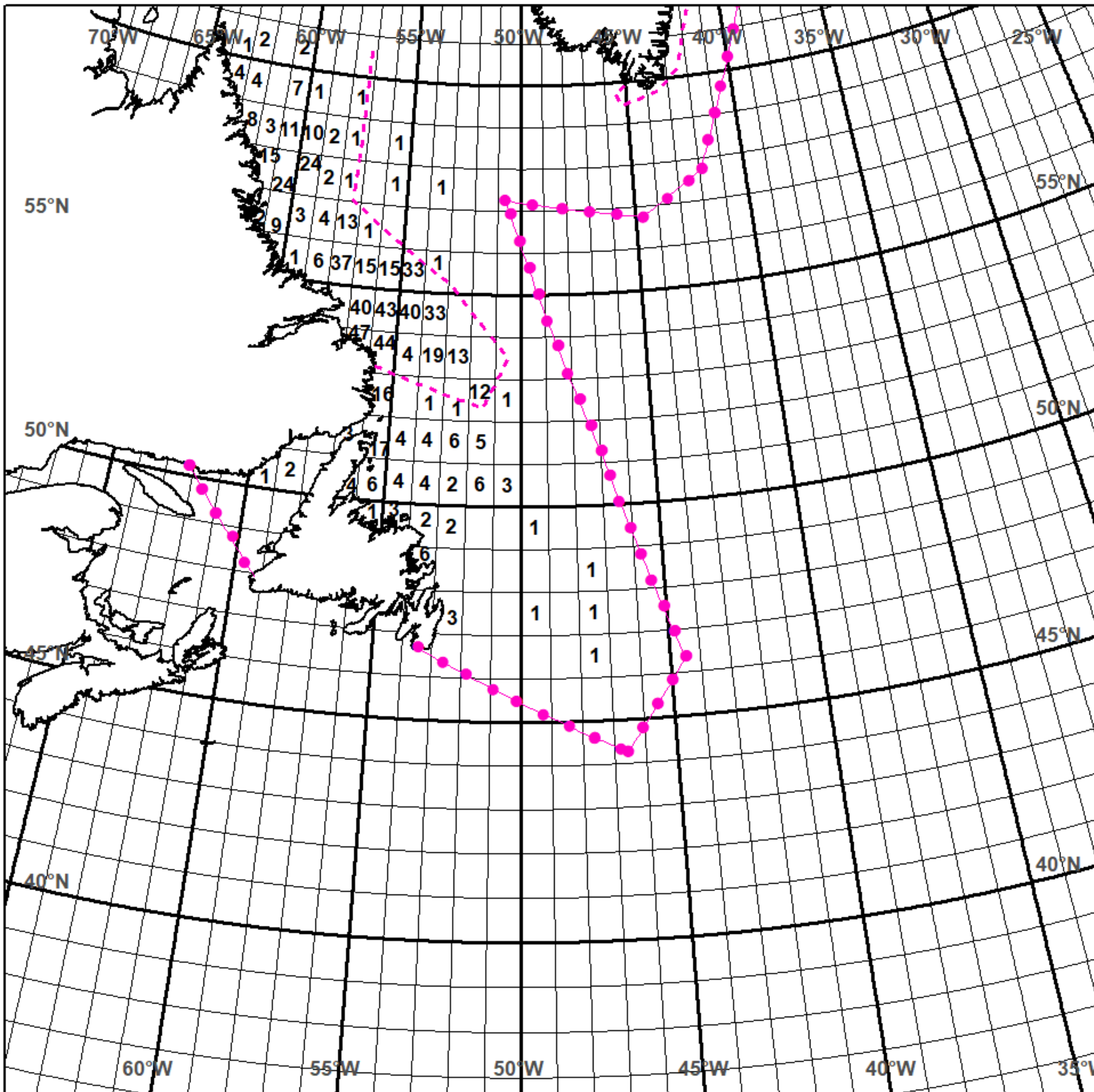
SEA ICE LIMIT

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 13MAY22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 JUN 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

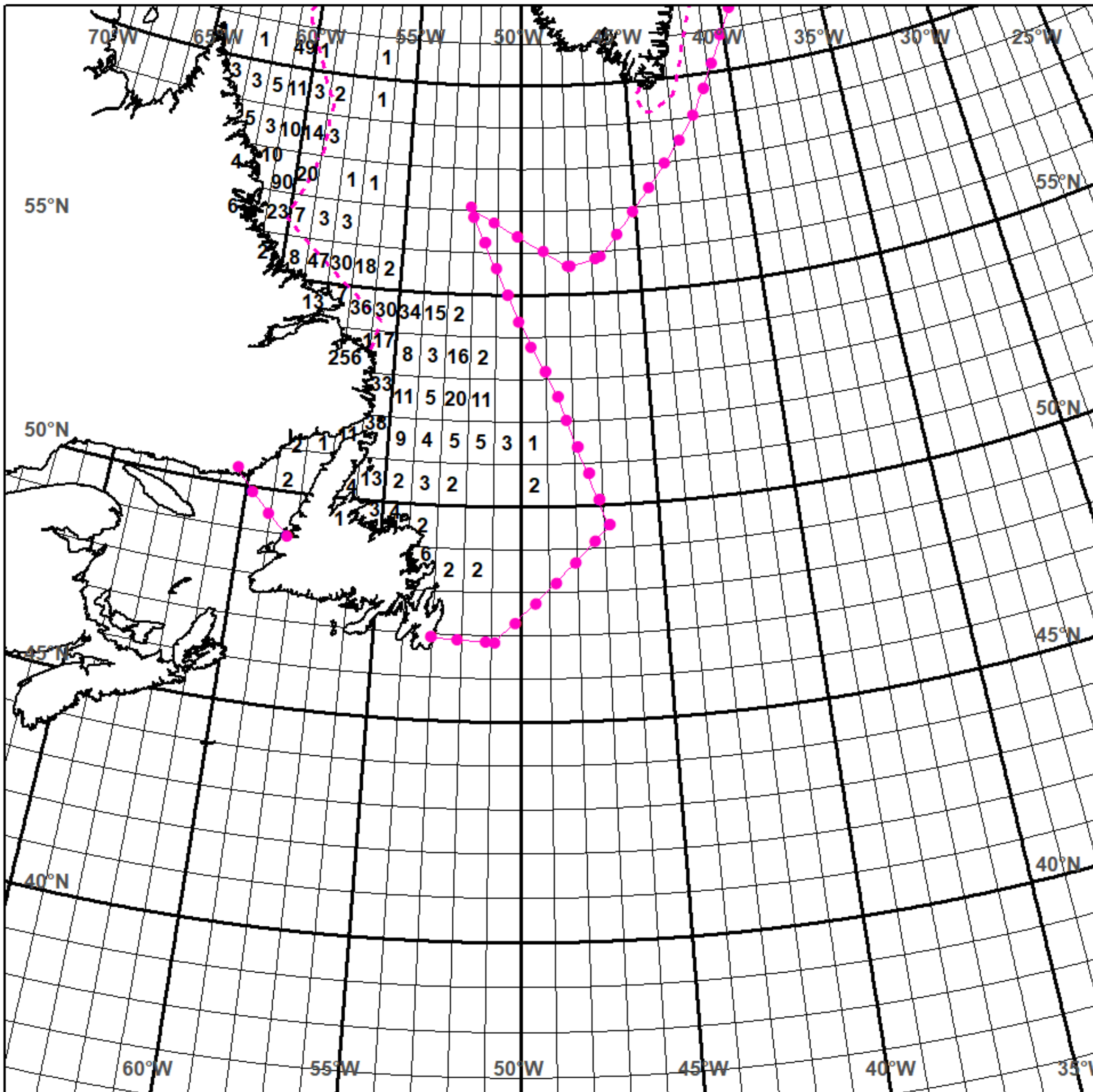
\# ICEBERGS PER DEGREE SQUARE

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 27MAY22.

WARNING! The International Ice Patrol is experiencing reduced iceberg reconnaissance. Please navigate with caution.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 JUN 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

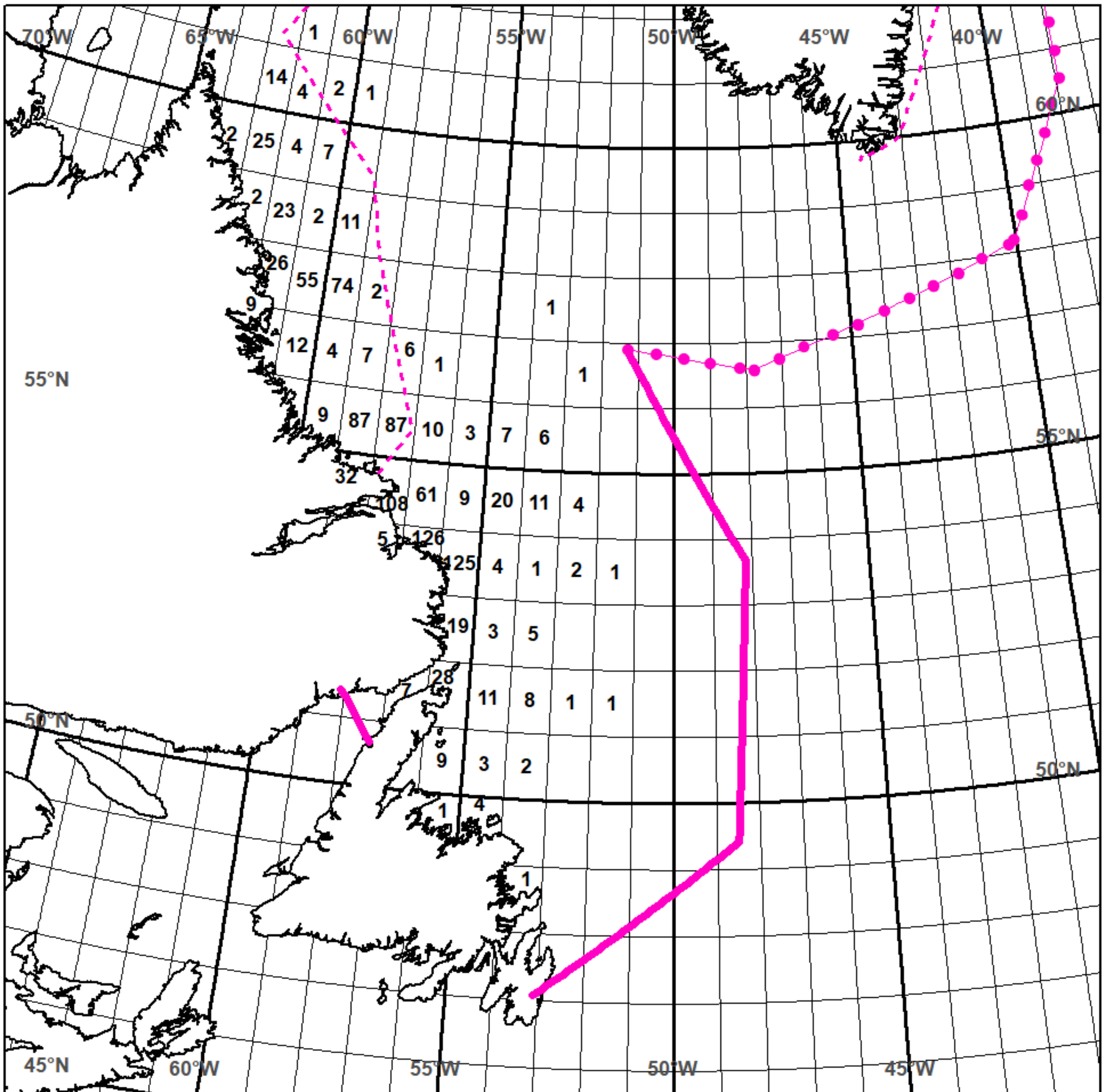
ICEBERGS PER DEGREE SQUARE

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

WARNING! The International Ice Patrol is experiencing reduced iceberg reconnaissance. Please navigate with caution.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

01 JUL 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

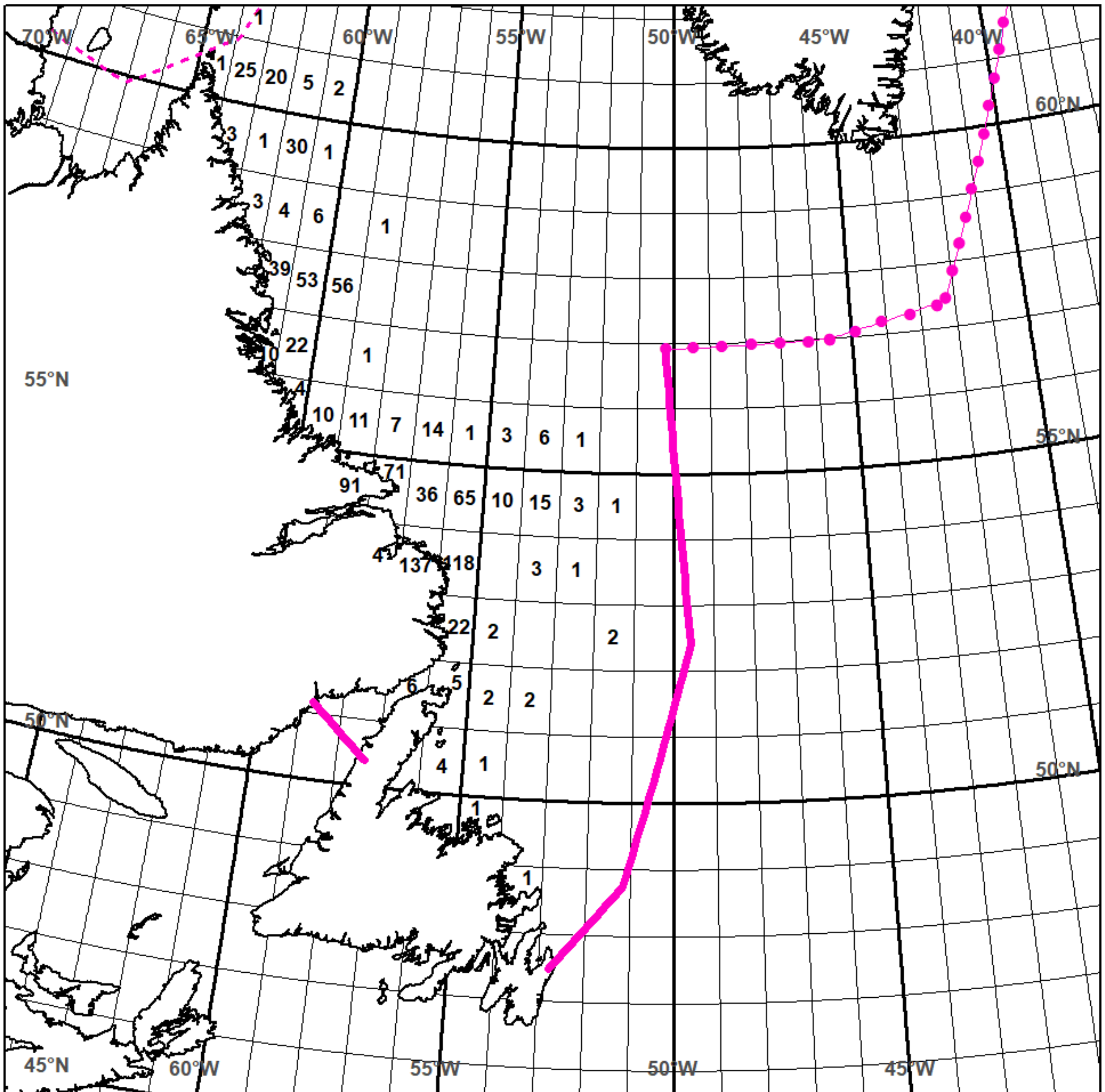
\# ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

NOTE:

Significant reduction of iceberg limit due to predicted deterioration.

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Western Limit Iceberg Flight 26JUN22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 JUL 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

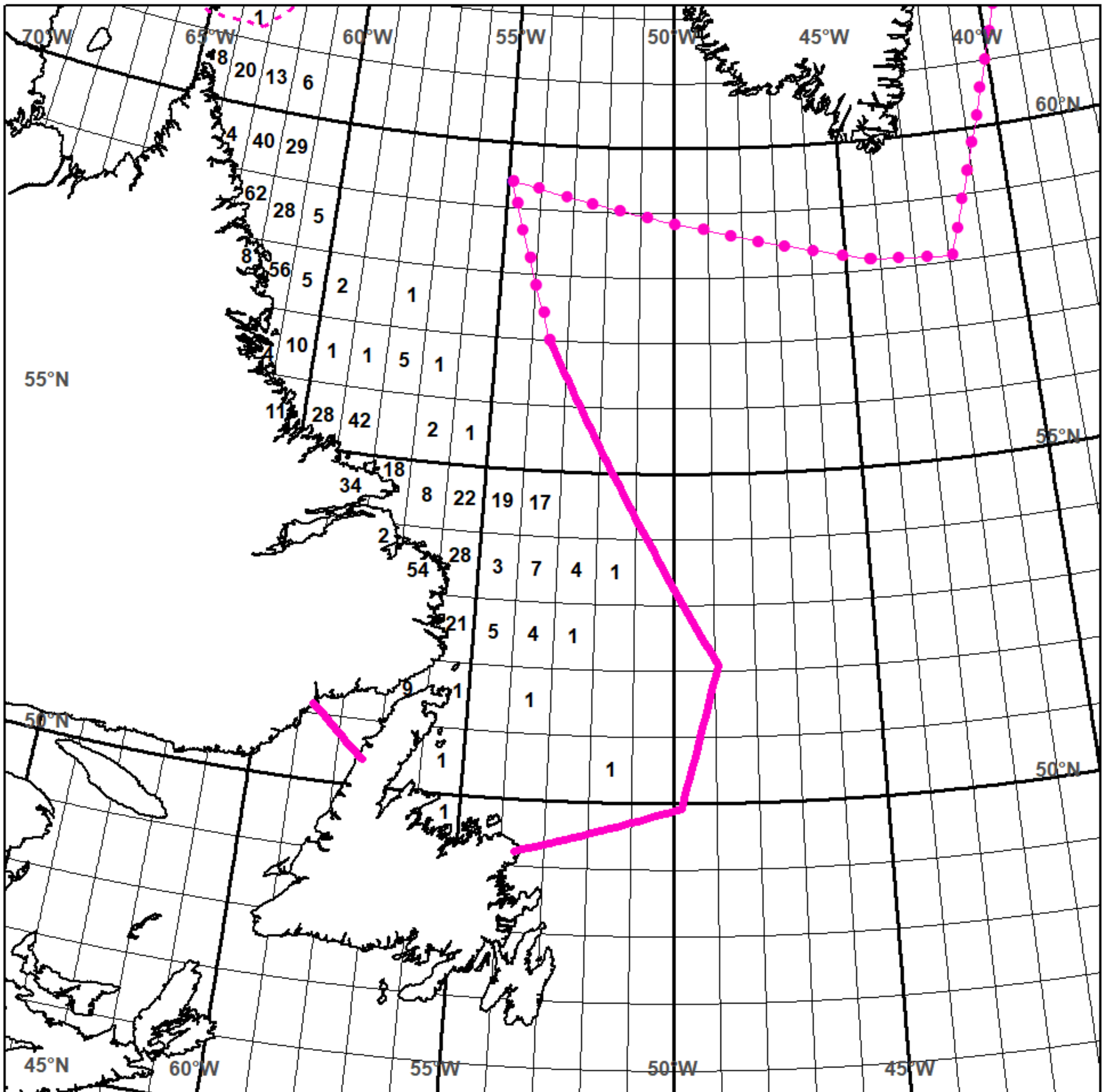
SEA ICE LIMIT

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 Satellite Pass 14JUL22.



NORTH AMERICAN ICE SERVICE (NAIS)

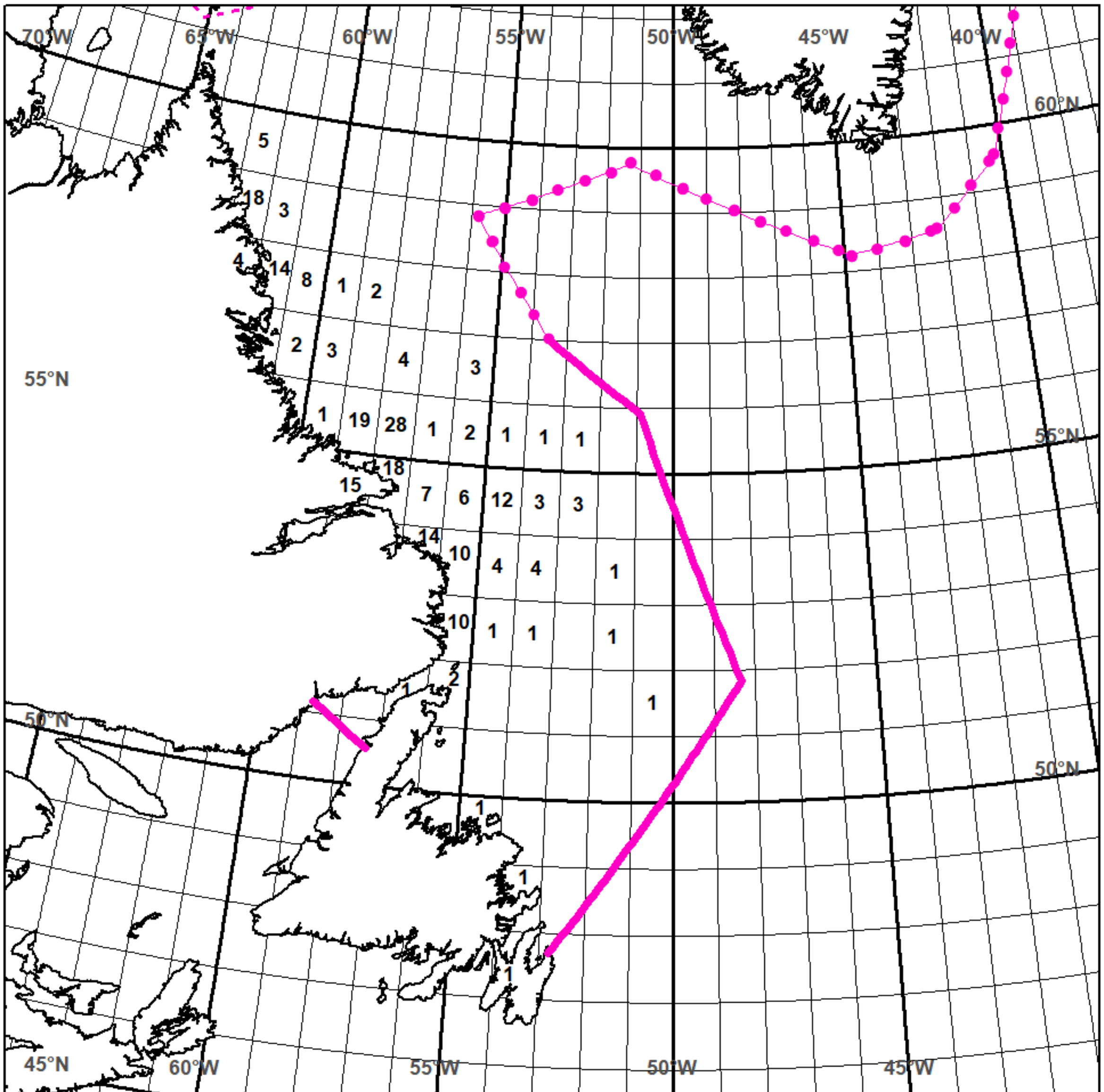
ICEBERG ANALYSIS FOR 0000 UTC

01 AUG 2022

- 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 31JUL22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 1200 UTC

15 AUG 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

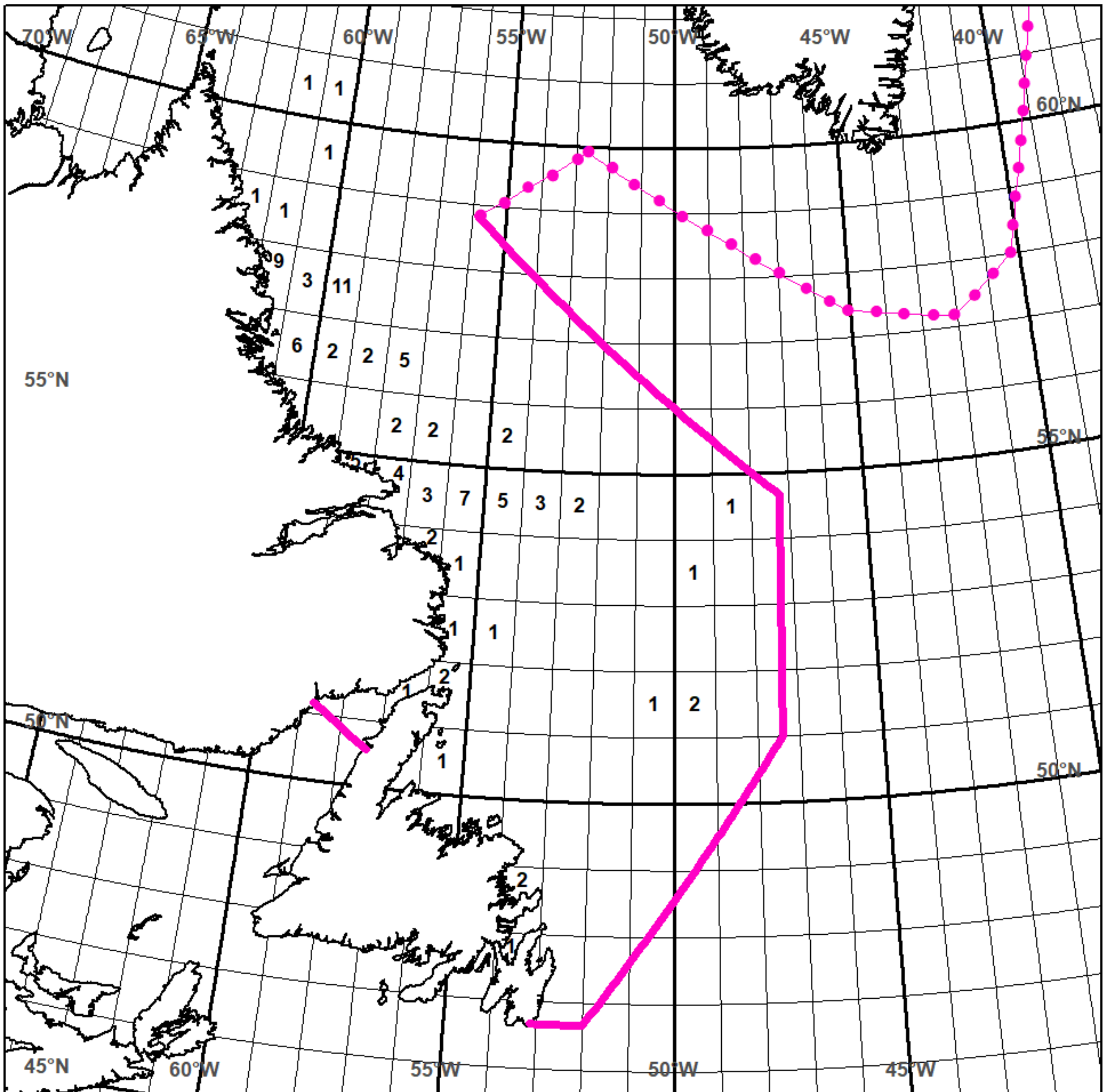
SEA ICE LIMIT

\# 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 Satellite Pass 12AUG22.



NORTH AMERICAN ICE SERVICE
(NAIS)

ICEBERG ANALYSIS FOR 0000 UTC
01 SEP 2022

ESTIMATED ICEBERG LIMIT

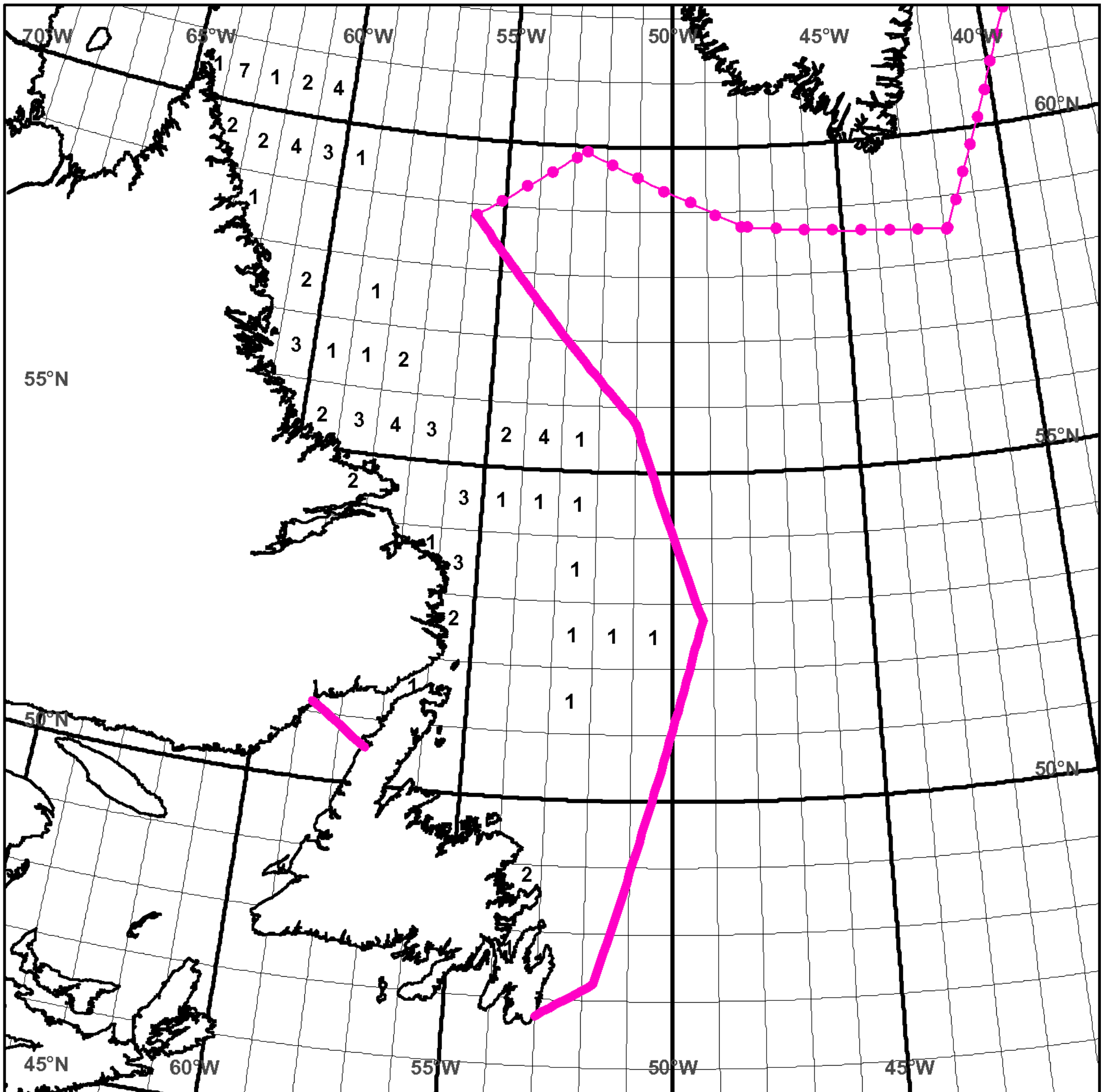
ICEBERG LIMIT

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 31AUG22.



NORTH AMERICAN ICE SERVICE (NAIS)

ICEBERG ANALYSIS FOR 0000 UTC

15 SEP 2022

ESTIMATED ICEBERG LIMIT

ICEBERG LIMIT

SEA ICE LIMIT

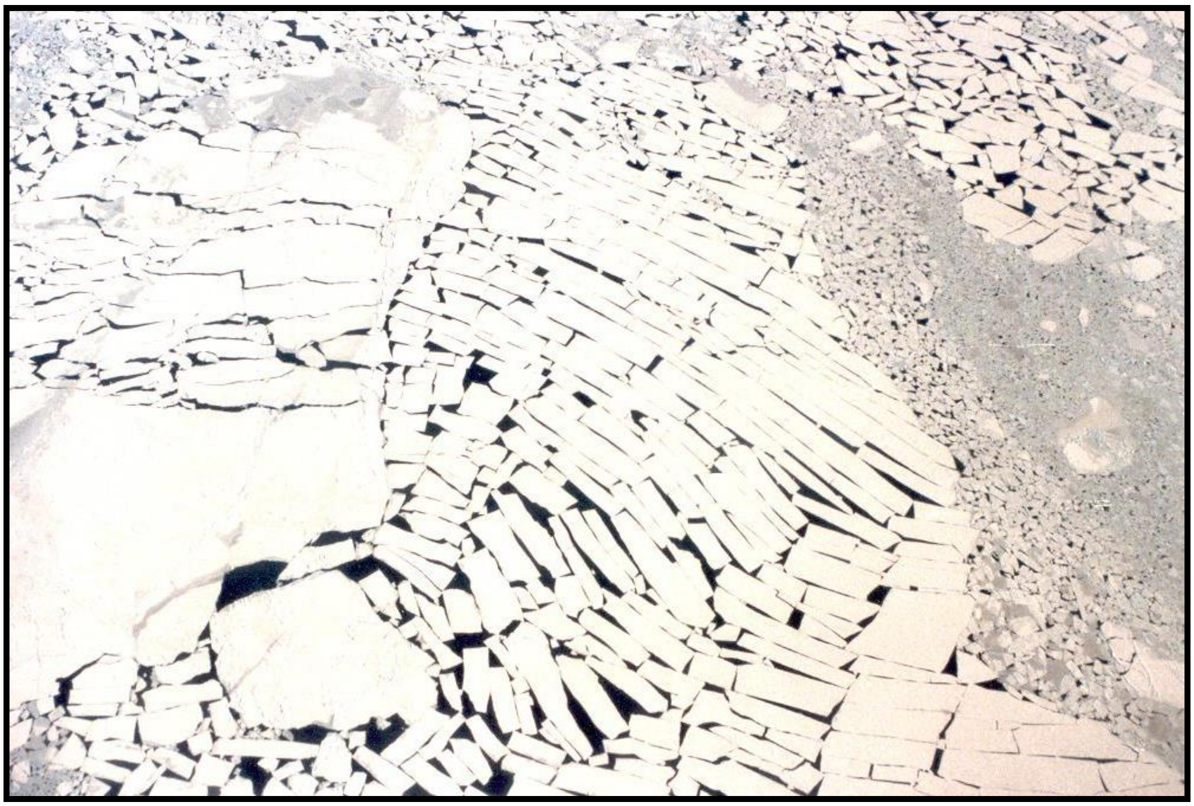
ICEBERGS PER DEGREE SQUARE

RADAR TARGET OUTSIDE ICEBERG LIMIT

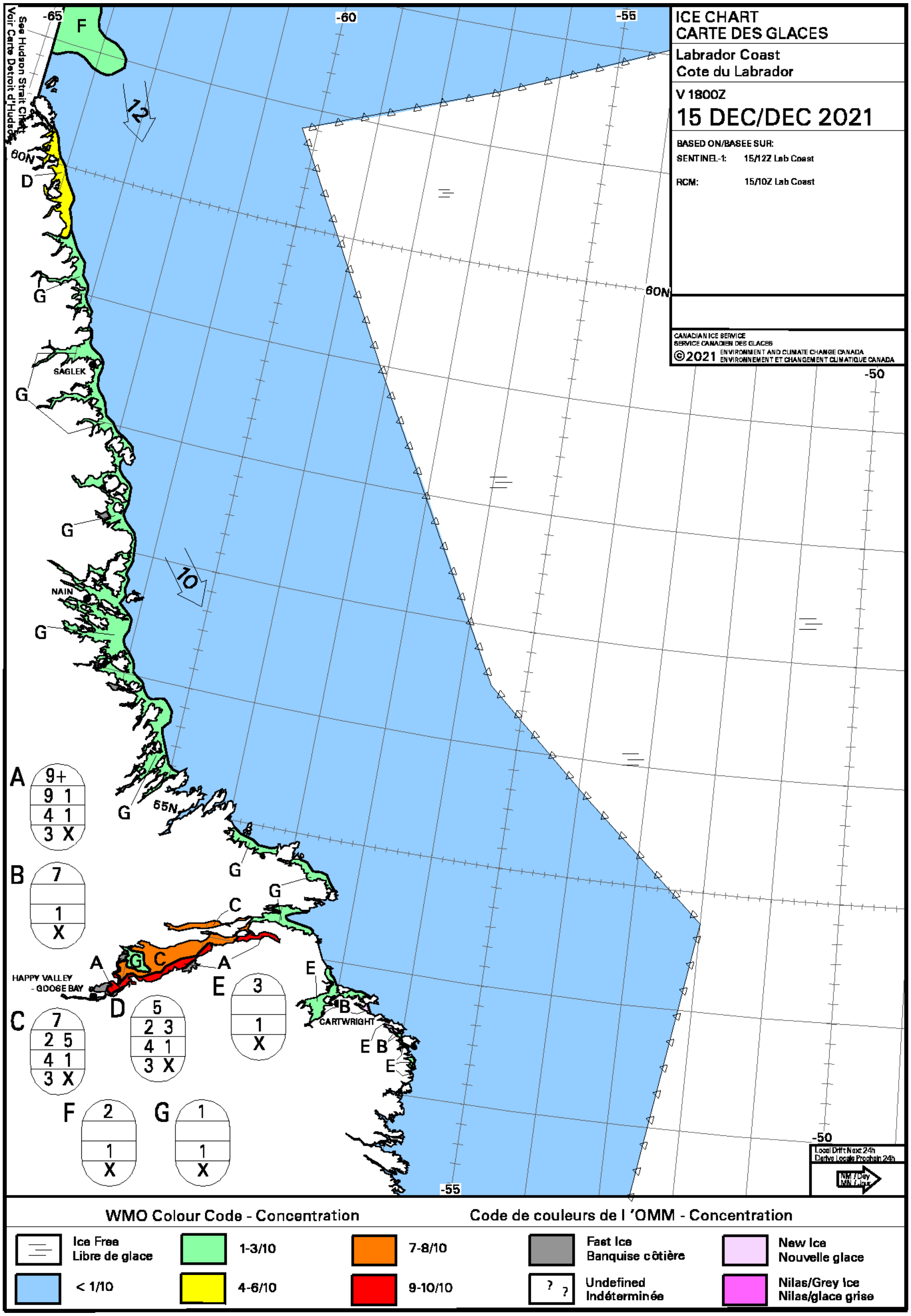
NOTE:

For more information:
www.navcen.uscg.gov/iip
www.ice-glaces.ec.gc.ca
Most Recent Reconnaissance:
Northern Survey General Flight 13SEP22.

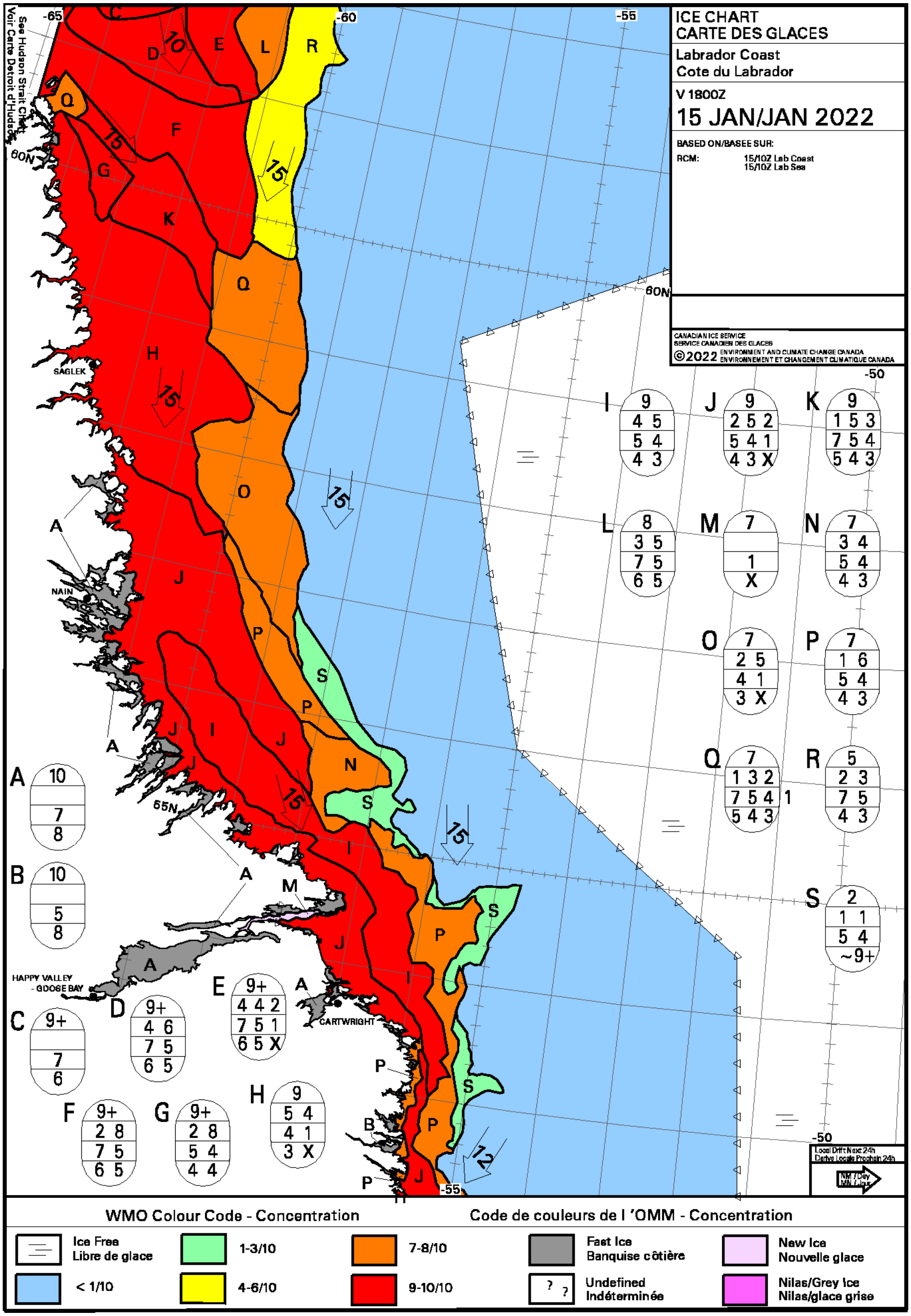
8. Monthly Sea-Ice Charts

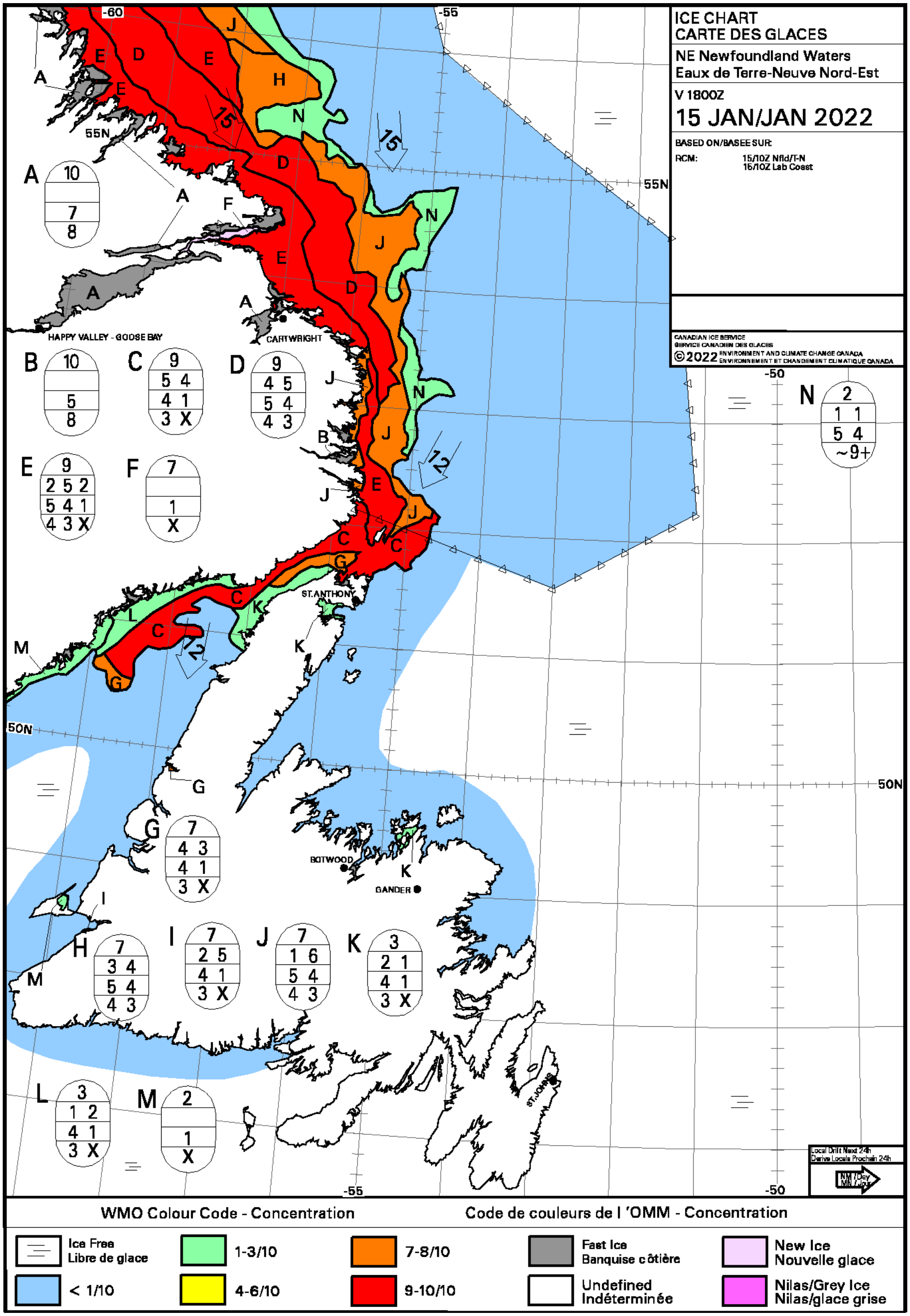


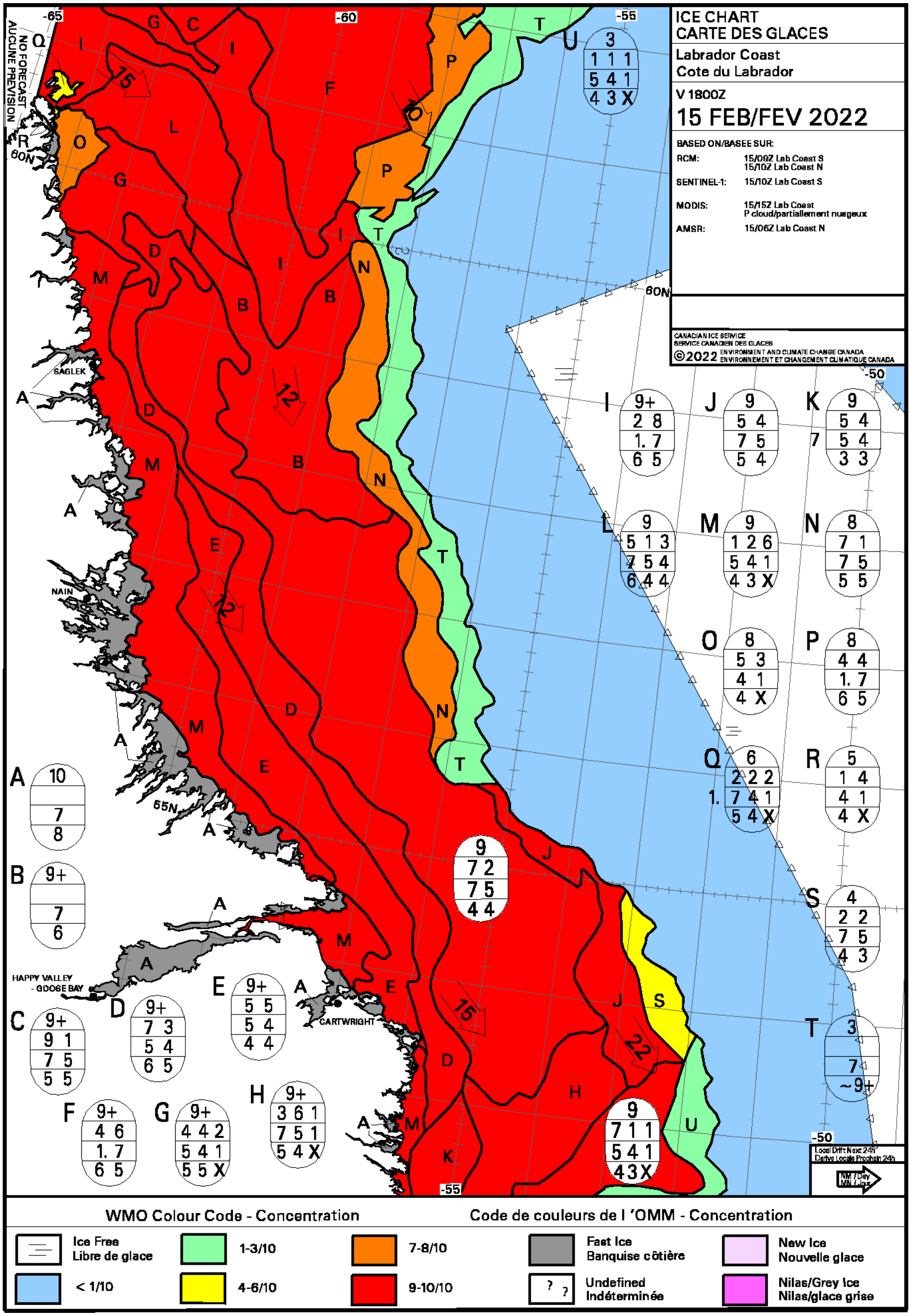
The following sea-ice charts for Northeast Newfoundland Waters are produced by the Canadian Ice Service. Months without measureable sea ice concentration on the charts were omitted.

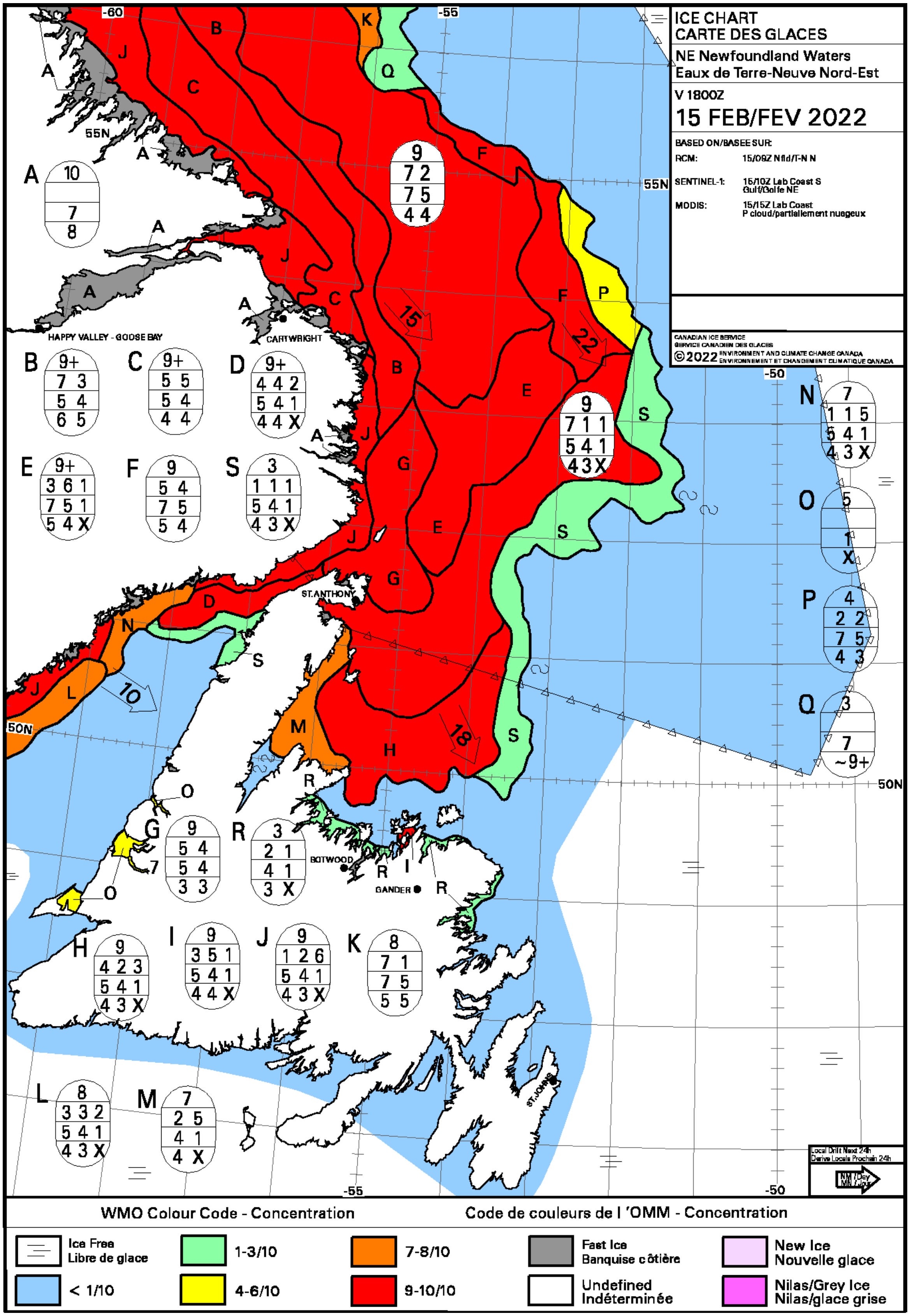


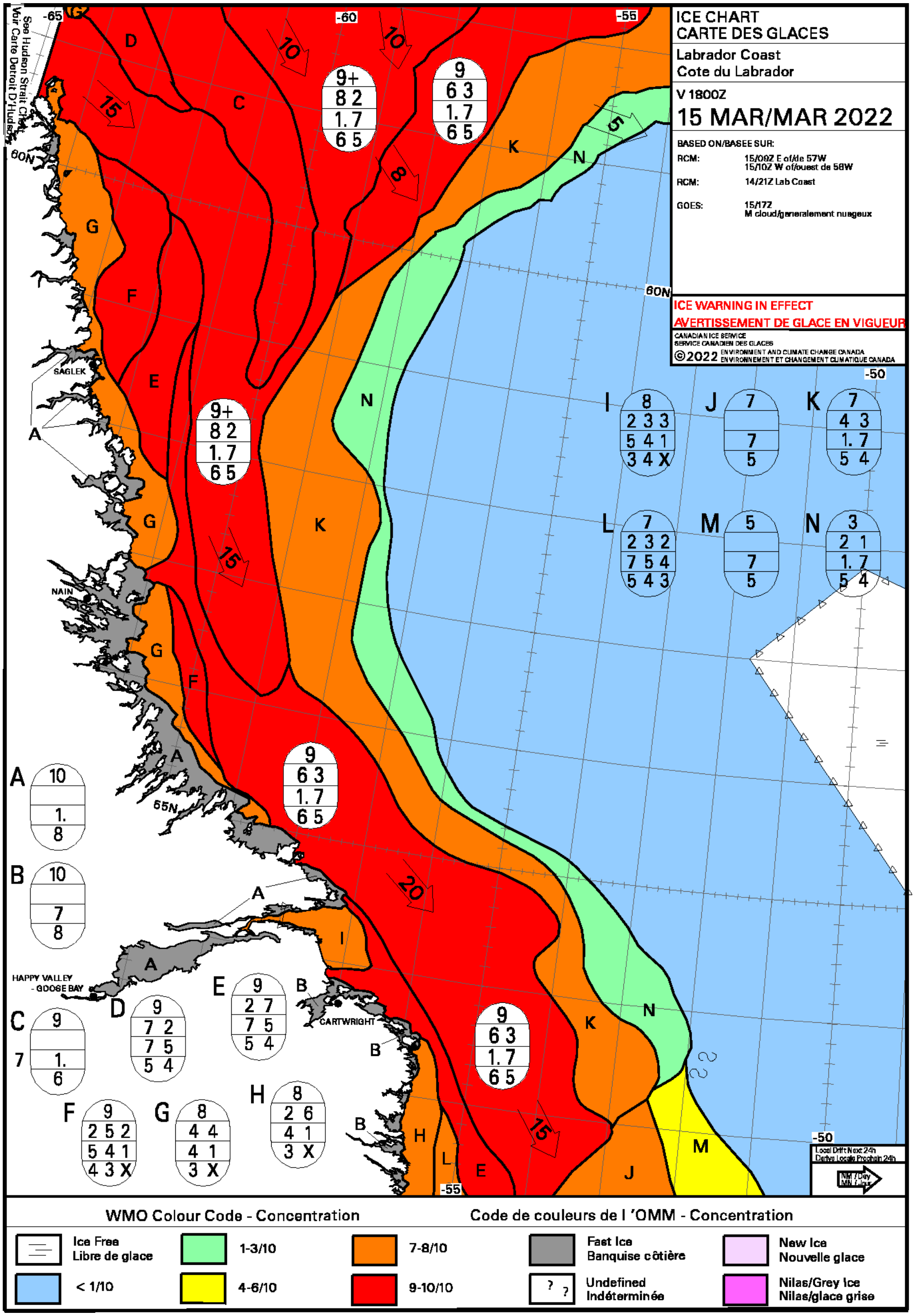
ICE CHART
CARTE DES GLACES
Labrador Coast
Cote du Labrador
V 1800Z
15 DEC/DEC 2021
BASED ON/BASEE SUR:
SENTINEL-1: 15/12Z Lab Coast
RCM: 15/10Z Lab Coast
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2021 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
See Hudson Strait Chart
Voir Carte Detroit d'Hudson
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
60N
55N
-65
-60
-55
-50
A 9+ 9 1 4 1 3 X
B 7 1 X
C 7 2 5 4 1 3 X
D 5 2 3 4 1 3 X
E 3 1 X
F 2 1 X
G 1 1 X
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

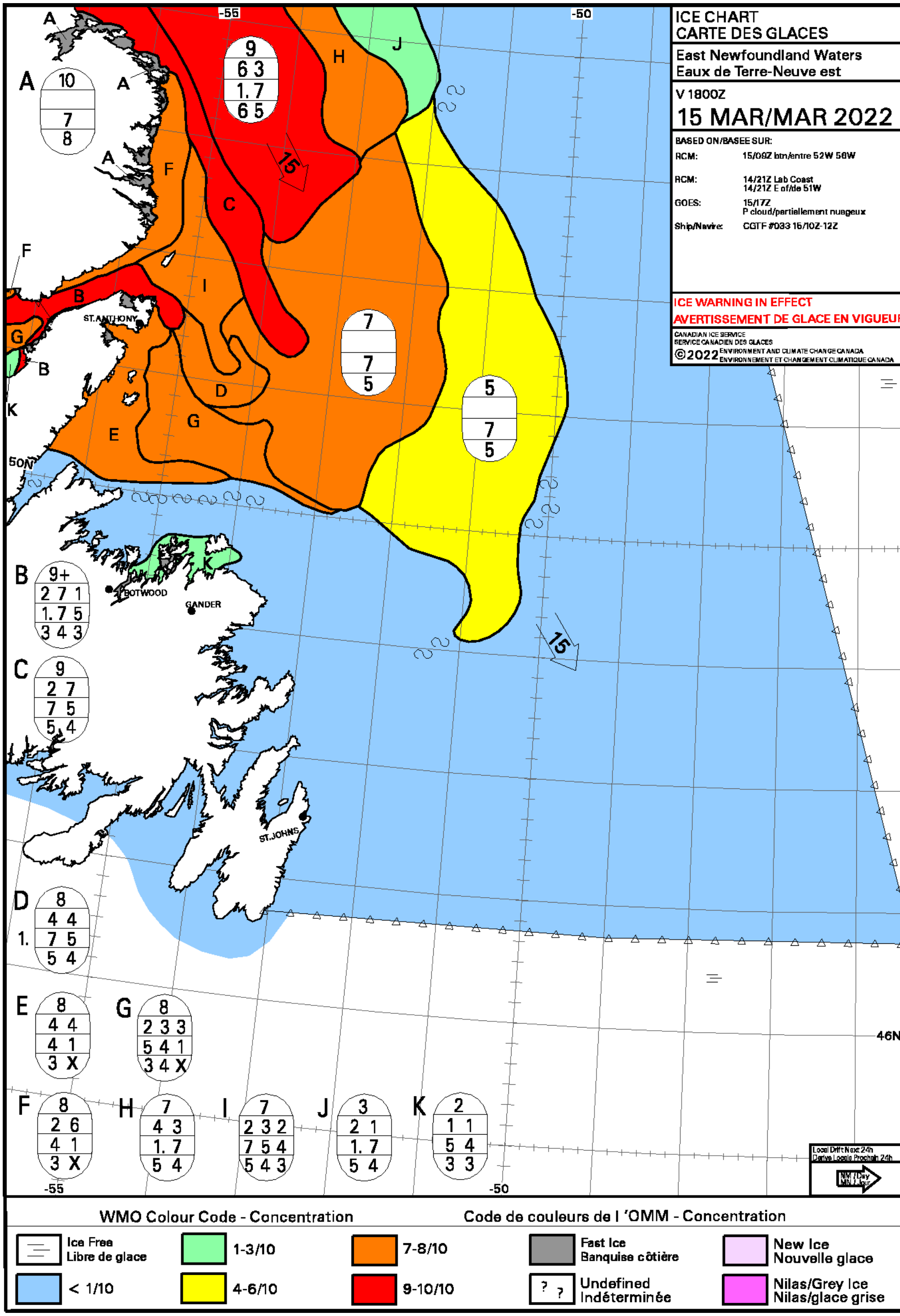

ICE CHART
CARTE DES GLACES
Labrador Coast
Cote du Labrador
V 1800Z
15 JAN/JAN 2022
BASED ON/BASEE SUR:
RCM:
15/10Z Lab Coast
15/10Z Lab Sea
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
See Hudson Strait Chart
Voir Carte Detroit d'Hudson
-65
-60
-55
-50
60N
55N
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
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 JAN/JAN 2022
BASED ON/BASEE SUR:
RCM: 15/10Z Nfld/T-N
16/10Z Lab Coast
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHN'S
55N
50N
-60
-55
-50
Local Drift Next 24h
Dérive 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

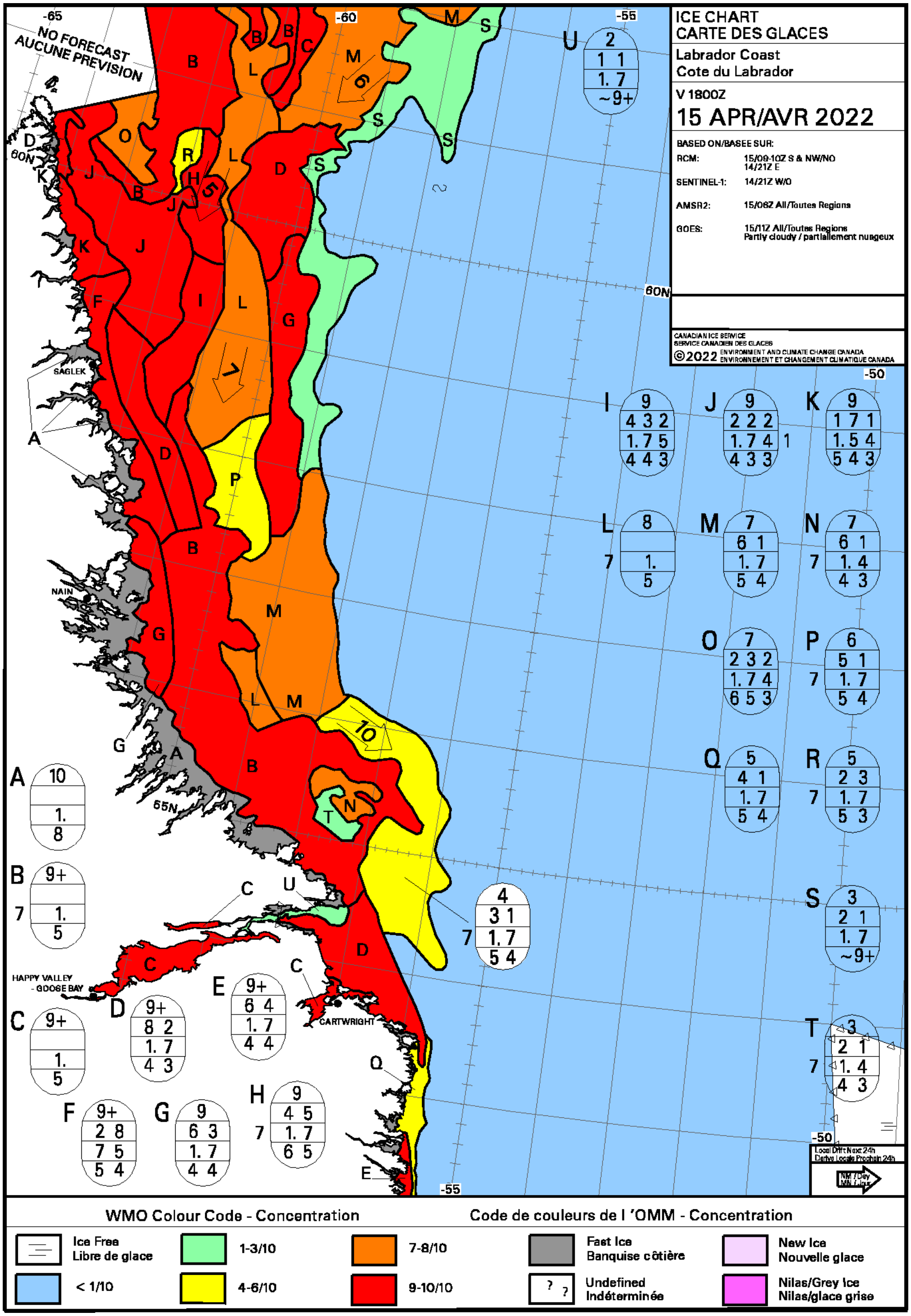

ICE CHART
CARTE DES GLACES
Labrador Coast
Cote du Labrador
V 1800Z
15 FEB/FEV 2022
BASED ON/BASEE SUR:
RCM: 15/09Z Lab Coast S
15/10Z Lab Coast N
SENTINEL-1: 15/10Z Lab Coast S
MODIS: 15/15Z Lab Coast
P cloud/partiallement nuageux
AMSR: 15/06Z Lab Coast N
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
NO FORECAST
AUCUNE PREVISION
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
60N
55N
-65
-60
-55
-50
Local Drift Next 24h
Dérive 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

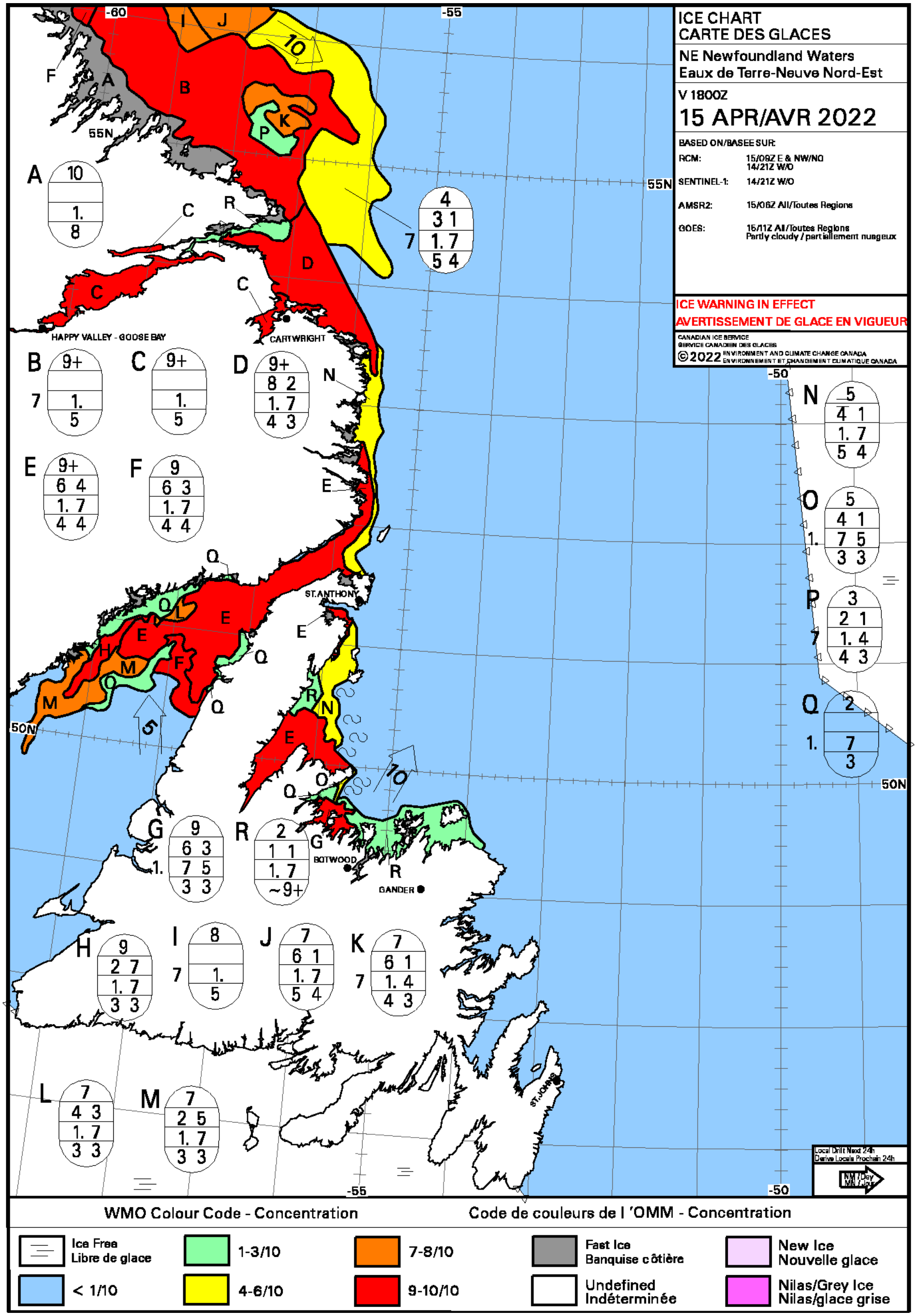

ICE CHART
CARTE DES GLACES
NE Newfoundland Waters
Eaux de Terre-Neuve Nord-Est
V 1800Z
15 FEB/FEV 2022
BASED ON/BASEE SUR:
RCM: 15/09Z Nfld/T-N N
SENTINEL-1: 15/10Z Lab Coast S Gulf/Golfe NE
MODIS: 15/15Z Lab Coast P cloud/partiellement nuageux
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHN'S
55N
50N
-60
-55
-50
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

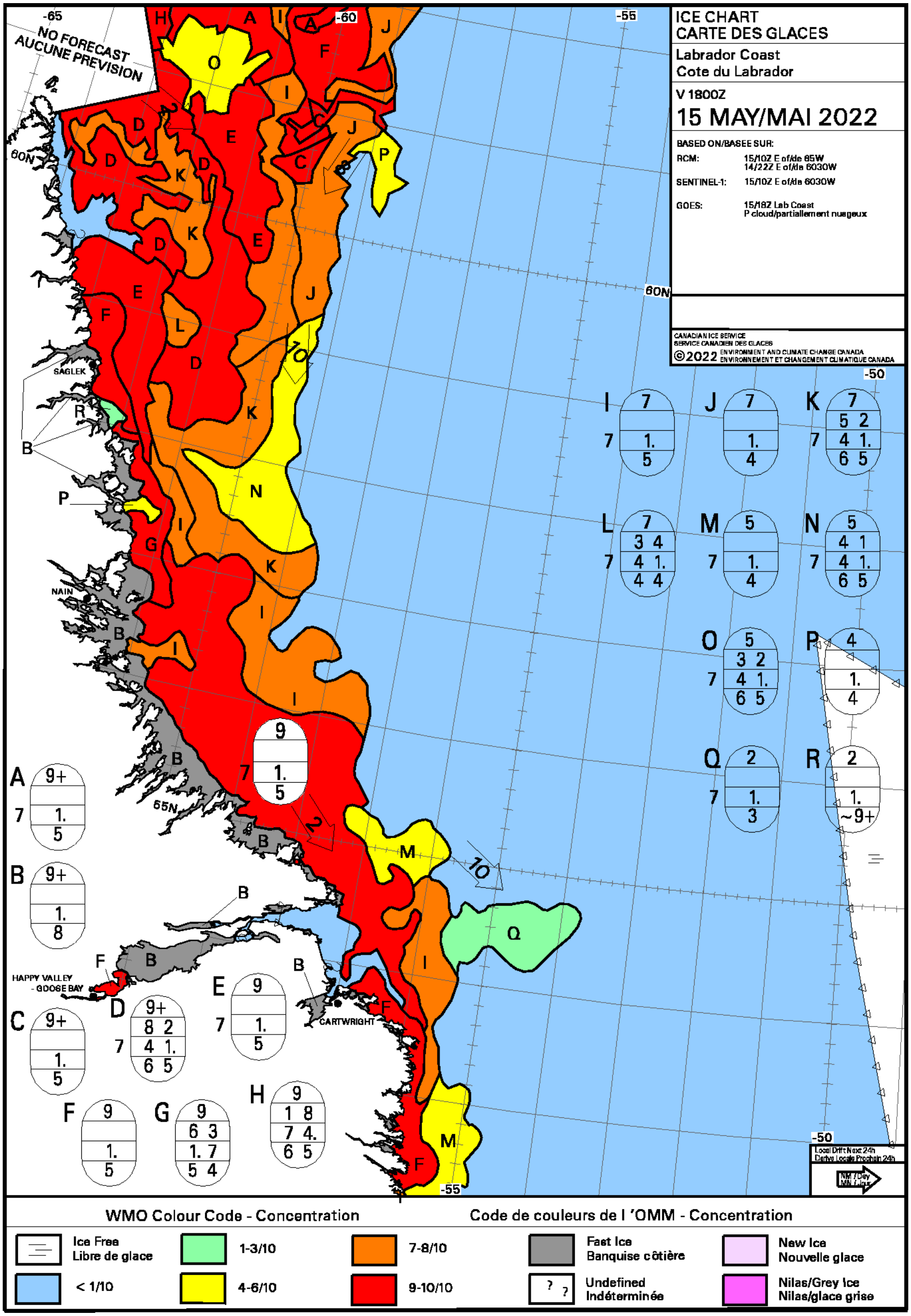

ICE CHART
CARTE DES GLACES
Labrador Coast
Cote du Labrador
V 1800Z
15 MAR/MAR 2022
BASED ON/BASEE SUR:
RCM: 15/09Z E of/de 57W
15/10Z W of/ouest de 58W
RCM: 14/21Z Lab Coast
GOES: 15/17Z
M cloud/generalement nuageux
ICE WARNING IN EFFECT
AVERTISSEMENT DE GLACE EN VIGUEUR
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
See Hudson Strait Chart
Voir Carte Detroit D'Hudson
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
60N
55N
-65
-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

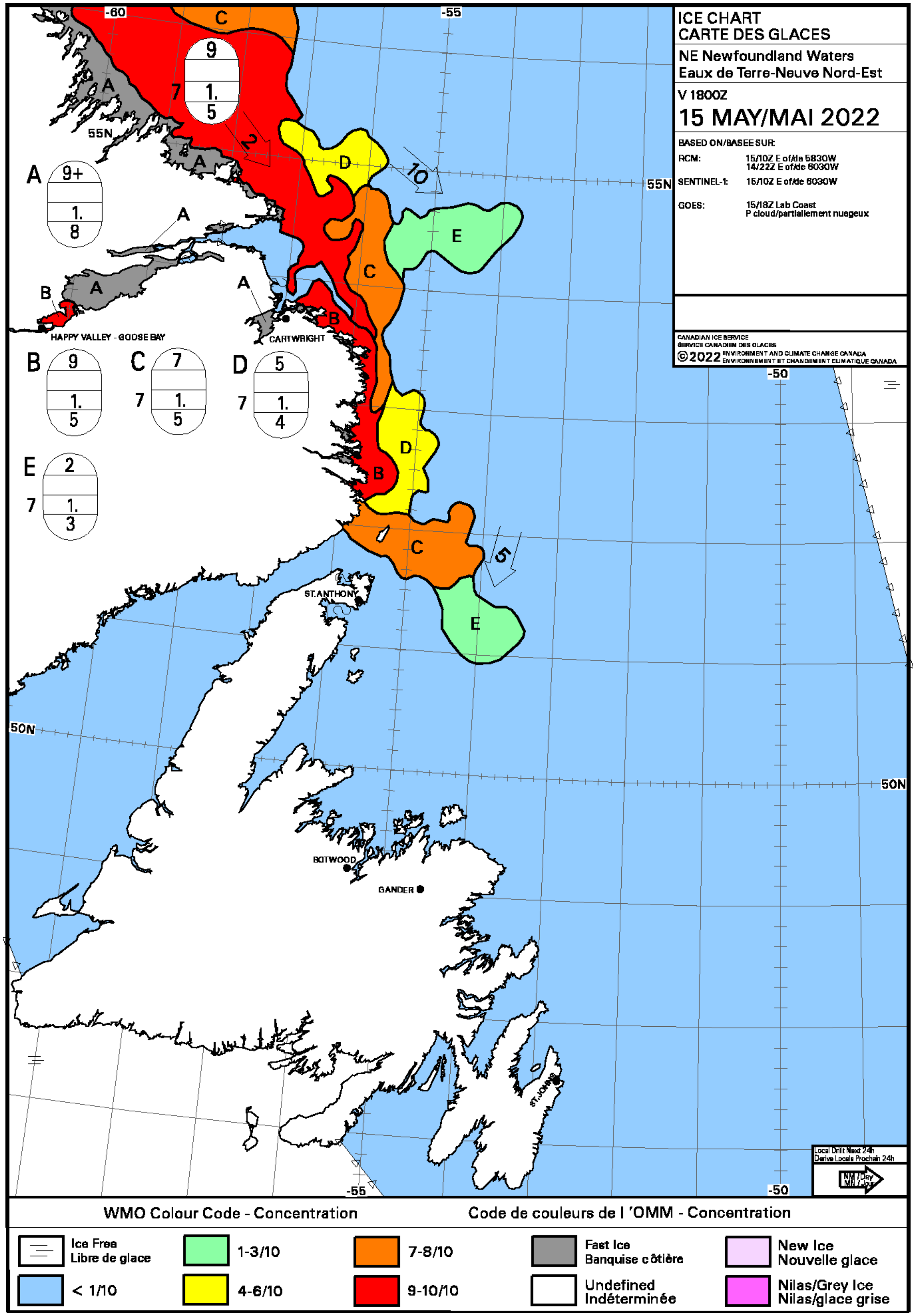


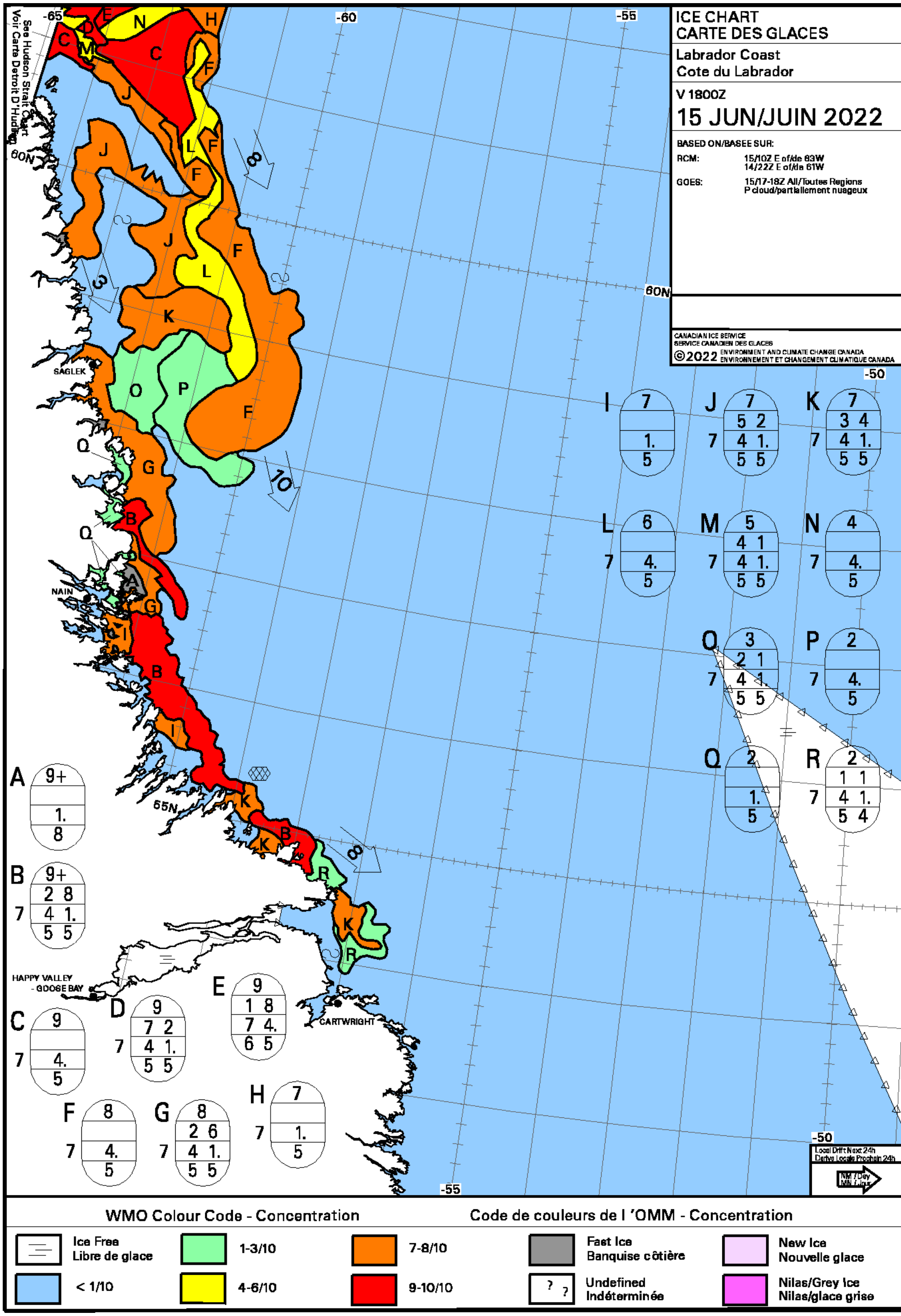
ICE CHART
CARTE DES GLACES
East Newfoundland Waters
Eaux de Terre-Neuve est
V 1800Z
15 MAR/MAR 2022
BASED ON/BASEE SUR:
RCM: 15/09Z btn/entre 52W 56W
RCM: 14/21Z Lab Coast
14/21Z E of/de 51W
GOES: 15/17Z
P cloud/partiellement nuageux
Ship/Navire: CGTF #033 15/10Z-12Z
ICE WARNING IN EFFECT
AVERTISSEMENT DE GLACE EN VIGUEUR
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
-55
-50
50N
46N
ST.ANTHONY
BOTWOOD
GANDER
ST.JOHNS
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

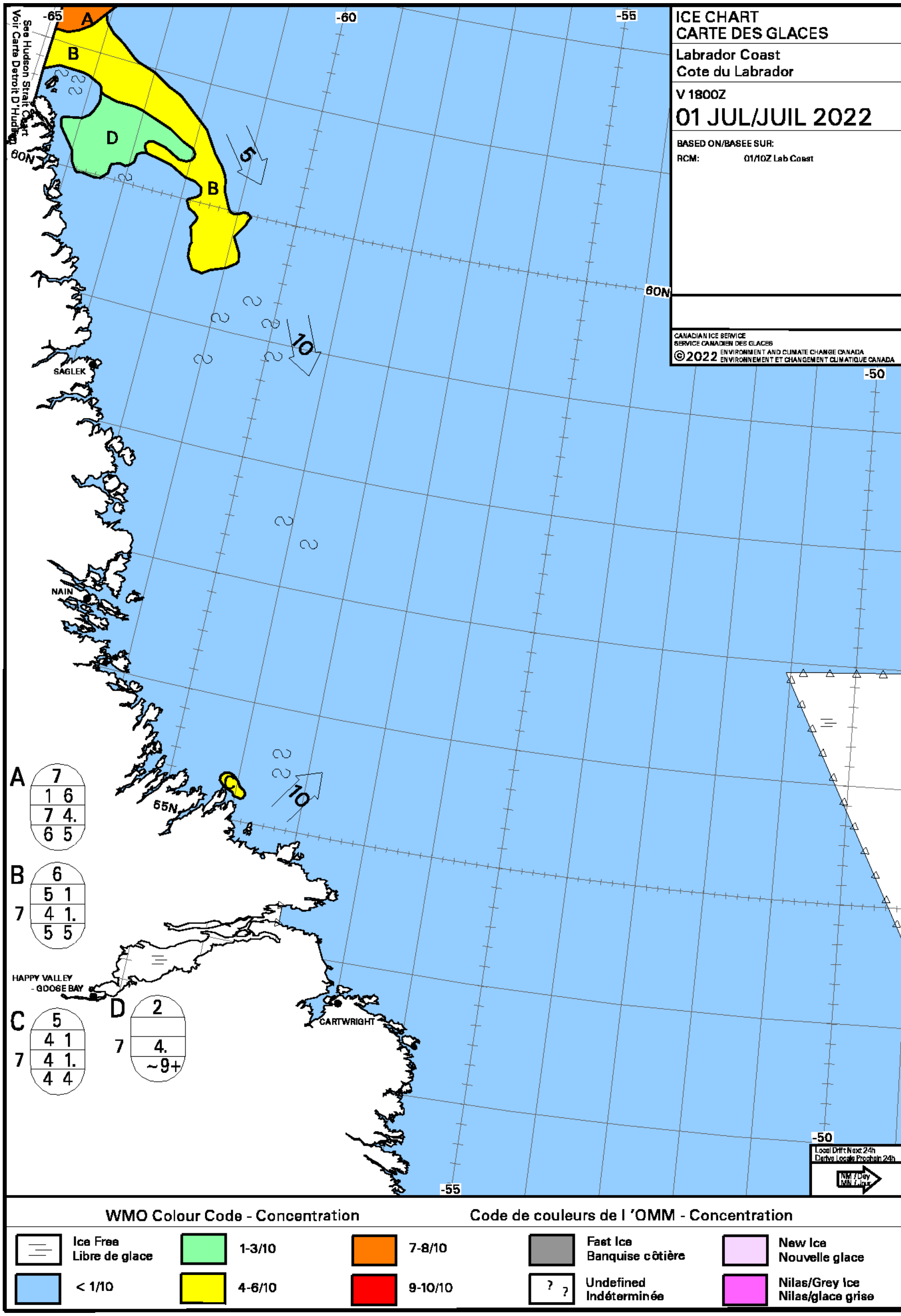

ICE CHART
CARTE DES GLACES
Labrador Coast
Cote du Labrador
V 1800Z
15 APR/AVR 2022
BASED ON/BASEE SUR:
RCM: 15/09-10Z S & NW/NO 14/21Z E
SENTINEL-1: 14/21Z W/O
AMSR2: 15/06Z All/Toutes Regions
GOES: 15/11Z All/Toutes Regions Partly cloudy / partiallement nuageux
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
NO FORECAST
AUCUNE PREVISION
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
60N
55N
-65
-60
-55
-50
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 2022
BASED ON/BASEE SUR:
RCM: 15/09Z E & NW/NO 14/21Z W/O
SENTINEL-1: 14/21Z W/O
AMSR2: 15/06Z All/Toutes Regions
GOES: 15/11Z All/Toutes Regions Partly cloudy / partiellement nuageux
ICE WARNING IN EFFECT
AVERTISSEMENT DE GLACE EN VIGUEUR
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 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
Labrador Coast
Cote du Labrador
V 1800Z
15 MAY/MAI 2022
BASED ON/BASEE SUR:
RCM: 15/10Z E of/de 65W 14/22Z E of/de 6030W
SENTINEL-1: 15/10Z E of/de 6030W
GOES: 15/18Z Lab Coast P cloud/partiellement nuageux
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
NO FORECAST
AUCUNE PREVISION
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
60N
55N
-65
-60
-55
-50
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 2022
BASED ON/BASEE SUR:
RCM: 15/10Z E of/de 5830W
14/22Z E of/de 6030W
SENTINEL-1: 15/10Z E of/de 6030W
GOES: 15/18Z Lab Coast
P cloud/partiellement nuageux
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 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
Labrador Coast
Cote du Labrador
V 1800Z
15 JUN/JUIN 2022
BASED ON/BASEE SUR:
RCM: 15/10Z E of/de 63W
14/22Z E of/de 61W
GOES: 15/17-18Z All/Toutes Regions
P cloud/partiellement nuageux
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
See Hudson Strait Chart
Voir Carte Detroit D'Hudson
SAGLEK
NAIN
HAPPY VALLEY - GOOSE BAY
CARTWRIGHT
60N
55N
-65
-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
Labrador Coast
Cote du Labrador
V 1800Z
01 JUL/JUIL 2022
BASED ON/BASEE SUR:
RCM: 01/10Z Lab Coast
CANADIAN ICE SERVICE
SERVICE CANADIEN DES GLACES
©2022 ENVIRONMENT AND CLIMATE CHANGE CANADA
ENVIRONNEMENT ET CHANGEMENT CLIMATIQUE CANADA
See Hudson Strait Chart
Voir Carte Detroit D'Hudson
-65
-60
-55
-50
60N
55N
SAGLEK
NAIN
HAPPY VALLEY
- GOOSE BAY
CARTWRIGHT
A
B
C
D
5
10
A 7 1 6 7 4. 6 5
B 6 5 1 7 4 1. 5 5
C 5 4 1 7 4 1. 4 4
D 2 7 4. ~9+
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

Appendix A

Ship Reports for Ice Year 2022

Ships Reporting by Flag	Reports
CANADA	
ALGOTERRA	1
ATLANTIC BEECH	1
CCGS HENRY LARSEN	10
CCGS LOUIS S. ST-LAURENT	2
CCGS MOLLY KOOL	2
CCGS PIERRE RADDISON	5
*CCGS TERRY FOX	16
HMCS MARGARET BROOKE	13
MIA DESGAGNES	1
NACC ARGONAUT	1
NORSE SPIRIT	2
NUKUMI	2
UMIAK 1	10
WESTERN TUGGER	1
DENMARK	
TORM THOR	1
LIBERIA	
WIGEON	2
MARSHALL ISLANDS	
FEDERAL EMS	1
NETHERLANDS	
ATLANTICBORG	1
IVER BRILLIANT	1
NORWAY	
FEDERAL KIVALINA	1
UNITED STATES OF AMERICA	
USCGC BEAR	1
USCGC OAK	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. Commercial Satellite Reconnaissance

LT Shelby K. Griswold

B-1. Introduction

The International Ice Patrol (IIP) started using satellite imagery to bolster iceberg reconnaissance in 2017. Since then, satellite imagery from Sentinel-1 (SN-1), Sentinel-2 (SN-2), RadarSat-2 (RS-2), and RadarSat Constellation Mission (RCM) have been used consistently and reliably to create Iceberg Warning Products. To continue improving IIP's satellite capabilities, IIP, along with its NAIS partners, have begun working with and analyzing both Synthetic Aperture Radar (SAR) and Electro-optical (EO) imagery from various commercial satellite providers, specifically Capella, ICEYE, and Planet.

B-2. Background

B-2-A Capella

Capella currently has a satellite constellation of 36 X-band SAR microsatellites. At an altitude of approximately 500 km, each of these satellites have an approximate 90 minute polar orbit with single-pol imaging polarizations HH (horizontal transmit and horizontal receive) and VV (vertical transmit and vertical receive). The main characteristics of the Capella SAR system are described in **Table B-1**.

Frequency Band	X- band (9.4-9.9 GHz)
Imaging Bandwidth	Up to 500 MHz
Imaging Modes	Spotlight Sliding Spotlight Stripmap
Imaging Polarizations	Single-Pol HH & VV
Imaging Orbit Directions	Ascending & Descending
Imaging Look Directions	Left & Right
Look Angle Ranges	25° - 40° (Standard Products) Up to 15° - 45° (Extended Products) Up to 5° - 45° (Custom Products)

Table B-1: Capella SAR system characteristics

Capella's SAR satellites support a wide range of look angles and can collect data in Spotlight (Spot), Sliding Spotlight (Site), and Stripmap (Strip) imaging modes. These imaging modes and their specifications are summarized in **Table B-2**. In the Capella console, the online interface used for tasking the satellites, there is an option to task stripmap images up to 200 km long and 20 km wide. Compared to the resolution of Sentinel-1 (20 meters), Capella provides <2 meter spatial ground resolution in all three mode products, as seen in **Table B-2** and compared to other satellite sensors in **Table B-3.**

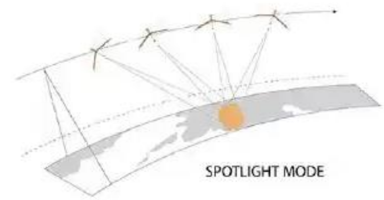
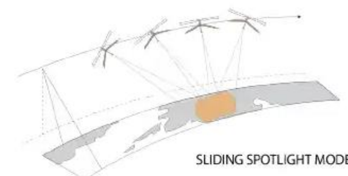
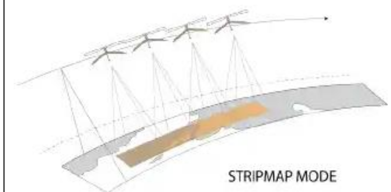
Image Product	Imaging Mode	Nominal Scene Size	Azimuth Resolution	Slant Range Resolution	Look Angle Range	Illustration
Spot SLC	Spotlight	5x5 km	0.5 m	0.3 m	25° to 40°	
Site SLC	Sliding Spotlight	5x10 km	1.0 m	0.5 m	25° to 40°	
Strip SLC	Stripmap	5x20 km Extended: 20 x 100 10 x 200	1.2 m	0.75 m	25° to 40°	

Table B-2: Imaging modes and specifications of the standard single look complex (SLC) Capella image product types.

	Capella	**ICEYE**	**SN-1**	**RCM**	**RS-2**
Swath Size	20 x 100 km	Scan: 100 x 100 km	IW: 250 x 250 km	GRD: 300 x 350 km	Wide-Fine: 150 km x 170 km
Resolution	1.2 m	15 m	20 m	50 m	8 m
Revisit Time	Tasked	Tasked	12 days*	4 day	24 days
Polarization	Single Pol HH & VV	VV	HH/HV	HH/HV	Single-Pol or Dual-Pol

Table B-3: Comparisons between different SAR satellite systems and capabilities.
**12-day repeat cycle with one satellite, 6-day repeat cycle with two satellites, prior to SN1-B failure*

For further information, please reference the Capella Space SAR Imagery Products Guide, Version 3.5, noted in the references.

B-2-B ICEYE

ICEYE has launched over 20 X-band SAR satellites since 2018, with 10+ more planned for 2022 and beyond. The constellation is on a sun-synchronous polar orbit with 17 days of ground track repeat cycle with 15 imaging orbits for day, and a VV polarization. The main characteristics of the ICEYE SAR system are described in **Table B-4**.

Carrier Frequency	X- band (9.65 GHz)
Maximum Bandwidth	600 MHz
Imaging Modes	Strip Spot Slea Scan
Polarization	VV
Look Directions	Left & Right

Table B-4: ICEYE SAR payload specifications.

The details of the ICEYE imaging modes are similar to Capella, with the main modes being Strip, Spot, and Scan mode, however the size of the footprint is quite large in comparison. The details for the ICEYE imaging modes are described and outlined in **Table B-5** and compared to other similar SAR sensors in **Table B-3**.

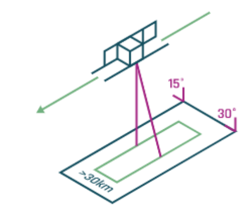
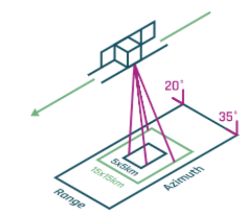
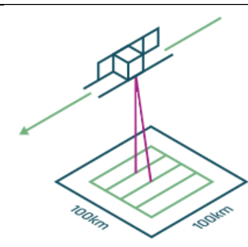
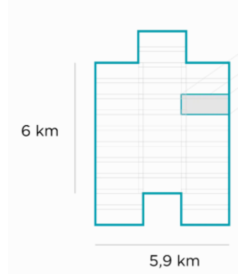
	Nominal Swath (Width x Length)	Nominal Collection Duration	Ground Range/ Azimuth Resolution	Incidence Angles	Maximum Image Length	Illustration
Strip	30 x 50 km	10 sec	3 x 3 m	15-30°	500 km	
Spot	5 x 5 km	10 sec	1 x 1 m	20-35°	N/A	
Slea (Extended Spot)	15 x 15 km	10 sec	1 x 1 m	20-35°	N/A	
Scan	100 x 100 km	15 sec	15 x 15 m	21-29°	500 km	

Table B-5: Specification of ICEYE imaging mode products.

B-2-C Planet

Planet has several satellite constellations, with over 150 satellites in orbit, collecting over 350 million square kilometers of imagery daily. IIP has utilized the SkySat constellation, which is comprised of 21 satellites and has the highest intraday revisit capability of any commercial provider globally, with insights up to 5-7 times a day in areas that are traditionally challenging due to low satellite capacity. This constellation produces EO imagery with ground resolution down to 50 centimeters and a swath size of 11 km x 6 km, in comparison to Sentinel-2 resolution of 10-meters. The specifications of the SkySat Constellation are detailed in **Table B-6**, compared to Sentinel-2, IIP's primary EO sensor used in iceberg detection.

<table>
<tr><th></th><th colspan="2">SkySat Collect</th><th>Sentinel-2</th></tr>
<tr><td>Image Type & Download Location</td><td colspan="2">Panchromatic, Multispectral:
ArcPro Add-In</td><td>Multispectral:
Level 1-C Scihub</td></tr>
<tr><td>Pixel resolution</td><td colspan="2">0.5 m</td><td>10 m (4-bands)
20 m (6-bands)
60 m (3-bands)</td></tr>
<tr><td>Tile/Swath Size</td><td>Scene:
1 x 2.5 km²

Collect:
~60 Scenes:
20 x 5.9 km²</td><td>
</td><td>100 x 100 km tiles

Combined tiles (w/ overlap) swath width: 290 km</td></tr>
<tr><td>Spectral Bands</td><td colspan="2">Blue 450-515 nm
Green 515-595 nm
Red 605-695 nm
Near Infra-Red (NIR) 740-900 nm
Pan 450-900 nm</td><td>10 m resolution bands:
B2 (Blue): 490 nm
B3 (Green): 560 nm
B4 (Red): 665 nm
B8 (NIR): 842 nm</td></tr>
<tr><td>Revisit Time</td><td colspan="2">Nadir: 28 days per spacecraft; sub-weekly per constellation
Off-Nadir: sub-weekly per spacecraft; intra-daily per constellation</td><td>Per satellite: 10 days;
Combined constellation:
5 days</td></tr>
</table>

Table B-6: Specifications of the Planet SkySat Constellation and Sentinel-2. (Nadir: directly perpendicular to Earth.)

Additionally, Planet has partnered with ESRI (Environmental Systems Research Institute, Inc.), the global market leader in Geographic Information Systems (GIS), integrating Planet data directly into GIS workflows. With the ArcGIS Pro Add-In, analysts can simply search, access, and analyze Planet's catalog of daily imagery directly from ArcGIS Pro, which will be further discussed in the results.

B-3. Results and Operational Use

B-3-A Capella

Initial test and evaluation efforts using Capella show great promise for operational use in the future. The Capella console itself has easy, self-tasking ability, and the constellation over the North Atlantic is frequent, timely, and high-quality. While our in-house Iceberg Detection System (IDS) code did not work to automatically detect icebergs in Capella imagery, icebergs were relatively easy to distinguish in the SAR imagery analyzed at IIP by the eyes experienced analysts.

Given that the nominal scene size of Capella frames are relatively small, two use cases were developed to test Capella's effectiveness for iceberg detection: 1) Single iceberg search, specifically "limit setting icebergs" and 2) monitoring known iceberg choke points, the Strait of Belle Isle and the Flemish Pass. An image of these use cases are seen in **Figure B-1**, where the green boxes are approximately 50 x 50 km.

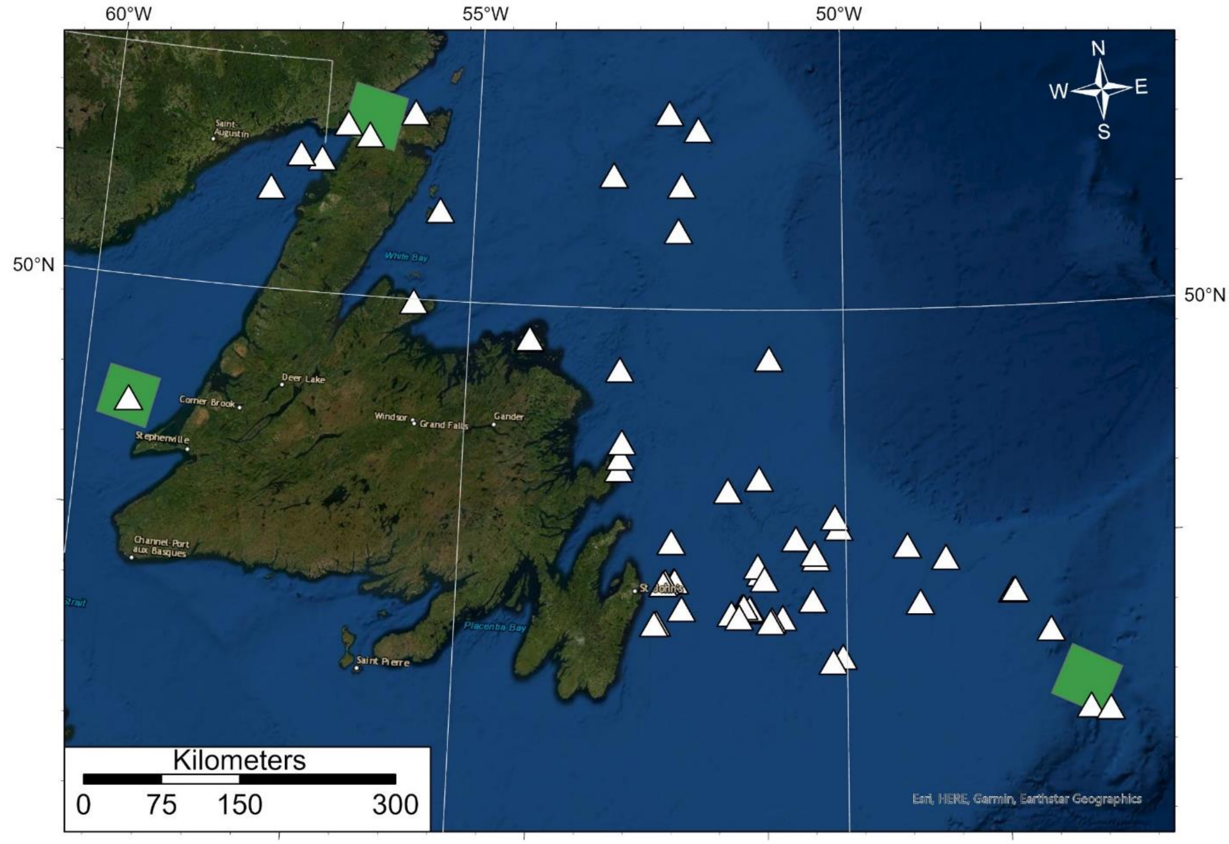


Figure B-1: Use cases for Capella imagery. Going left to right: 1) single iceberg search; 2) Strait of Belle Isle; 3) Flemish Pass

Because of Capella's fine resolution (1.2 m), this imagery could be used to detect and delete "limit-setting icebergs" from the iceberg model in the future. For limit-setting icebergs to be deleted, there are a few criteria established at IIP: 1) visually confirm the presence of no icebergs by aircraft in certain environmental conditions; 2) confirm the presence of no icebergs in cloud-free EO imagery, such as Sentinel-2; or 3) at CIIP's approval, typically after 30 days on drift or over 150% melt in the iceberg model.

Ideally, as IIP moves forward with remote sensing and away from aircraft, Capella may become a reliable source to use for iceberg deletions from the model. The error circle around the iceberg in the model has a radius of 30 Nautical Miles (NM), or 55.56 km, covering a total area of approximately 2800 square NM, or 9700 square km. This error circle compared to the size of a single 20x100 km stripmap can be seen in **Figure B-2**. To fully cover this area circle, approximately four to five 20x100 km stripmap images are needed within 48 hours of each other. This time frame is derived from the aircraft tasking standards, which dictates flight plans be redrawn after 48 hours due to iceberg drift and deterioration in time from their initial position. Whether this is a possibility, or if there are any changes to nominal scene size, will dictate if IIP will be able to use Capella imagery for these single iceberg searches for deletion.

Single "Limit-Setter" Iceberg Search

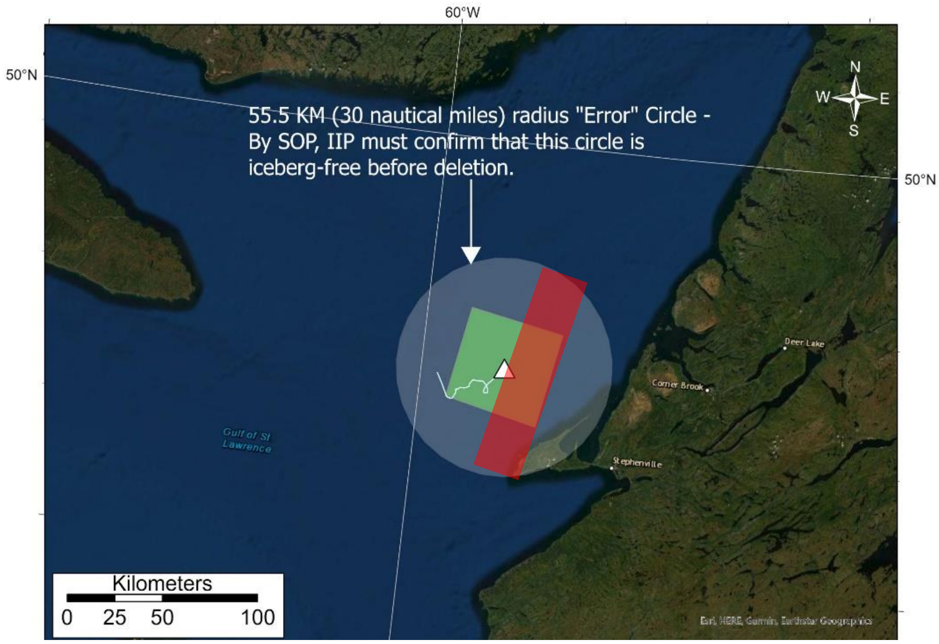


Figure B-2: An example of a "limit setting iceberg" with a radius of 30 NM, overlaid with an approximation of a 20x100 km stripmap.

There is another test and evaluation phase coming up at IIP for Capella to implement the method discussed above for limit setting icebergs. Testing will also be done in the known choke-points to try and establish the best orientation in the Strait of Belle Isle and Flemish Pass using the 20x100 km stripmaps.

B-3-B ICEYE

Initial test and evaluation results for ICEYE have produced mixed results in its capabilities to detect icebergs at IIP. At first glance, ICEYE would seem to be a solution to our limit setting iceberg challenge with Capella, due to its larger footprints and decent resolution (15 meters). However, in areas of open ocean with confirmed iceberg populations, ICEYE imagery did not detect the known icebergs.

The exact reason for these results are not exactly known. IIP's initial theory is due to the VV polarization and Bragg-Scattering. Bragg-Scattering explains the effects of the reflection of the SAR waves on structures whose distances are in the same wavelength; i.e. the wavelength of the radar is similar to the wavelength of small waves on the surface of the ocean, and these signals are reflected the strongest back to the radar, compared to the weak signal of an iceberg.

ICEYE imagery has also been used at the Danish Meteorological Institute (DMI) to test for iceberg detection in and out of sea ice in different locations, and DMI has produced extensive results from their study. DMI found that ICEYE was very sensitive to wind, even low winds, which reduced or eliminated signal from icebergs, the ice edge, or low concentration sea ice, which may be in part to the Bragg-Scattering theory. Interestingly, DMI found that ICEYE was useful for detecting icebergs in medium to high concentrations of sea ice, where there is less wave action competing with the signal of the surface waves.

While the usefulness of ICEYE for regular iceberg detections is uncertain, with more testing, it may prove useful for situational awareness in areas of high concentrations of sea ice, based on DMI's ICEYE results. If ICEYE implements horizontal polarizations, there may be greater chance for it to be more operationally relevant in open ocean.

B-3-C Planet

Planet has so far been a beneficial addition to IIP's satellite resources. IIP was able to establish an area of interest for Planet, so imagery is collected whenever the constellation is overhead the North Atlantic. While Planet hasn't been used for direct tasking, it already has been useful in iceberg validation. For example, IIP received a ship report of a 500-meter iceberg off the coast of Newfoundland that was not in the iceberg model or detected in SAR imagery. There happened to be Planet imagery from that day that confirmed the presence of this iceberg, and analysts were able to track the iceberg as it broke into smaller pieces in subsequent imagery.

Operationally, Planet may be useful for confirming iceberg and radar targets, confirming the presence of limit setting icebergs, or confirming icebergs outside the limit. Similar to Sentinel-2 though, the Planet constellation is not designed to monitor the open ocean, but rather the land mass and only captures coastal waters. Anything far from shore, potentially a limit setter or iceberg outside the limit, would not be able to be captured by Planet. Furthermore, the North Atlantic is known for its dense cloud cover, particularly in the winter, and this will also limit the usefulness of EO imagery.

The largest obstacle with Planet, for now, is the limitation placed on analysts for tile views and searches within the ArcGIS Pro Add-In. IIP shares a limited number of tile views with other agencies, and in one search off the coast of Labrador, used 107,000 scene tiles in one day, with a monthly allotment of 150,000 total for the community. Because the area in which IIP analysts are looking for icebergs is so large and expansive, and the scene size of a Planet image is relatively small, IIP learned a single iceberg search can quickly use up the shared monthly quota.

Furthermore, IIP is not downloading images from Planet, but "streaming" them within the ArcGIS Pro Add-In. While the resolution is reduced, streaming has not hindered analyst ability to detect icebergs greatly. The downside of streaming the images is increased tile views: zooming in or out and panning in the image adds to tile views, whether it is a repeat view or not. Additionally, there is no way to archive images locally. To go back and find an older image requires another search, counting more tile views against the quota.

B-4. Future Work

B-4-A SAR: Capella and ICEYE

The future of IIP lies in expanding our use of SAR satellites, and our ability to detect small icebergs in the open ocean. Capella, so far, has the best potential to bolster our satellite analysis. In the upcoming test and evaluation phase of Capella, IIP will assess the constellations capabilities to collect subsequent images over the same spot to cover the error circle of a "limit setting" iceberg. Additionally, IIP will test collect in the Strait of Belle Isle and Flemish Pass, since these locations are known iceberg chokepoints in-season.

As for ICEYE, IIP is limited in its use to only moderate to heavy sea ice, where the signal of the icebergs are not competing with the signal of the ocean waves. This may be potentially useful for situational awareness during the 2023 Northern Survey or in the northern AOR in-season. If ICEYE implements HH or HV polarizations, its practicality may increase to IIP.

B-4-B EO: Planet

Planet has great potential for IIP. With higher resolution than Sentinel-2, Planet would not only be useful for finding smaller icebergs near the coast, but also for filling in the temporal gaps of SN-2. However, for Planet to be more operational for IIP in the future, there would need to be a greater allotment of tile views or the capability to download imagery. Right now, Planet is used only for verification, if needed, or for training purposes at the end of the month when the monthly quota is not at risk for overage.

B-5. References

Capella Space, 14 Sept. 2021, https://www.capellaspace.com/.

"High-Resolution Imagery with Planet Satellite Tasking." Planet, 2022, https://www.planet.com/products/hi-res-monitoring/.

"ICEYE Missions Brochure." ICEYE, 2022.

"ICEYE SAR Data Brochure." ICEYE, 2022.

"Planet Labs PBC ." Planet Labs PBC Esri Partner, Esri, https://www.esri.com/partners/planet-labs-pbc-a2T5x000007udFsEAI.

Qvistgaard, Keld. "DMI ICEYE Presentation." Danish Meteorological Institute- Greenland Ice Service, 22 Aug. 2022.

"RADARSAT Constellation." Radarsat Constellation, Canadian Space Agency, 12 June 2012, https://www.eoportal.org/satellite-missions/rcm#rcm-radarsat-constellation-mission.

"Sar Imagery Products Guide." Capella Space, 2022, https://support.capellaspace.com/hc/en-us/articles/4626115099796-SAR-Imagery-Products-Guide.

"Satellite Missions." ICEYE SAR Satellites- Rapidly Delivered, ICEYE, 2022, https://www.iceye.com/satellite-missions.

"Sentinel-1 SAR User Guide." Sentinel Online, European Space Agency, https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar.

"Sentinel-2 - Missions- Resolution and Swath." Sentinel Online, European Space Agency, https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/instrument-payload/resolution-and-swath.

"Sentinel-2 MSI User Guide." Sentinel Online, European Space Agency, https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi.

SkySat, Planet Labs PBC, 2022, https://developers.planet.com/docs/data/skysat/.

“What Are Capella's Imaging Modes?” Capella Space, 2022, https://support.capellaspace.com/hc/en-us/articles/360059210171-What-are-Capella-s-imaging-modes-.

“What is Multi-Look Processing?” Capella Space, 2022, https://support.capellaspace.com/hc/en-us/articles/360058856552-What-is-multi-look-processing-

Wolff, Christian. “Radar Basics.” Bragg-Scattering , Radartutorial, https://www.radartutorial.eu/07.waves/wa52.en.html.