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STEENSBY INLET IRON ORE SHIPPING PROJECT

Fixed wing survey - June 2023

2023-VIC_Baffinland Project B

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Introduction

Viking Ice Consultancy (VIC) was during the autumn of 2023 approached by Baffinland to continue and extend previous ice studies for the new Steensby shipping route. VIC proposed several project parts, one of the proposed project parts for the extended ice study was an overflight with fixed wing to observe ice and ice dynamics, (Project part B).

Purpose

The purpose of the fixed wing survey was to gather high resolution data describing the ice conditions along the maritime route utilized to access Steensby Inlet.

Currently much of the previous work done by VIC is based on utilizing ice information provided by the Canadian Ice Service (CIS). The data is categorized utilizing the WMO ice code (Egg code)in SIGRID format. Due to the categorization of ice types/thicknesses utilized in this approach, many details of ice conditions that affect the logistical assessment are lacking.

The accuracy of the ice charts provided by CIS have in this project not been verified or subjected to quality control. The aim of the survey is to get a snap-shot of the current governing ice conditions along the sea route, and compare these with the description provided by the Canadian Ice Service through their ice charts.

General description of the governing ice conditions

The shipping route to the Steensby Inlet is going from the Labrador Sea, through the Hudson Strait and further crossing the Foxe Basin before entering the Steensby Inlet. The route is stretching over a large geographical area, covering several climatic zones, with associated local metocean conditions. There is about 400 nautical miles from the northern parts to the southern parts of the route. The large distance in the North/South direction causes the degree of summer melting of the sea ice to be highly variable between the northern and the southern sections of the route, this was clear during the period the survey was taking place.

Due to the large variation in the melting processes, the ice conditions are highly variable at this time of the year. Some areas have open water, while other areas have 100% ice coverage.

The space generated by melting ice resulting in open water enables significant movement of the dynamic ice pack within the area. A consequence of this is that local observations differ from the ice charts provided by the Canadian Ice Service (CIS) due to the time lag from when the ice charts are developed until the observations are made. This makes the verification of CIS ice charts difficult.

During the winter, ice develops over the whole area, trapping the leftover sea ice from previous years, in addition to the ice of land origin.

Conduction of survey

The survey was conducted out of Iqaluit utilizing a KingAir plane for PAL. All crew, including radar operator and FLIR-image operator were PAL employees.

Knut Espen Solberg participated as a representative of Viking Ice Consultancy.

The survey was conducted during the period from 28.06.2023 to 01.07.2023.

Conduction of an aerial ice survey requires a high cloud base at the area of interest to enable visual observations. In addition, it will require a relatively high cloud base (depending on airframe and landing site) at a primary and at a secondary landing site.

Due to the KingAir being equipped with a belly mounted-radar and a belly-mounted FLIR camera, landing on gravel air strips is not a recommended option. The closes alternative paved airstrip to Iqaluit is located in Quebec, about 200 nautical miles to the south of Iqaluit. Due to safety concerns additional fuel had to be carried at times to ensure a flight-range adequate for reaching the alternative paved airstrip. This significantly reduced the practical operational range of the aircraft.

Every morning was started with a planning meeting, adapting the original plan to the governing weather conditions. This included not only the governing weather conditions in the survey area, but also at Iqaluit airport and at an alternative airstrip. If flying was not considered feasible, update meetings were conducted throughout the day and evening. Continuous monitoring of weather conditions was carried out in both during the planning and during the execution phases of the operation.

Activities

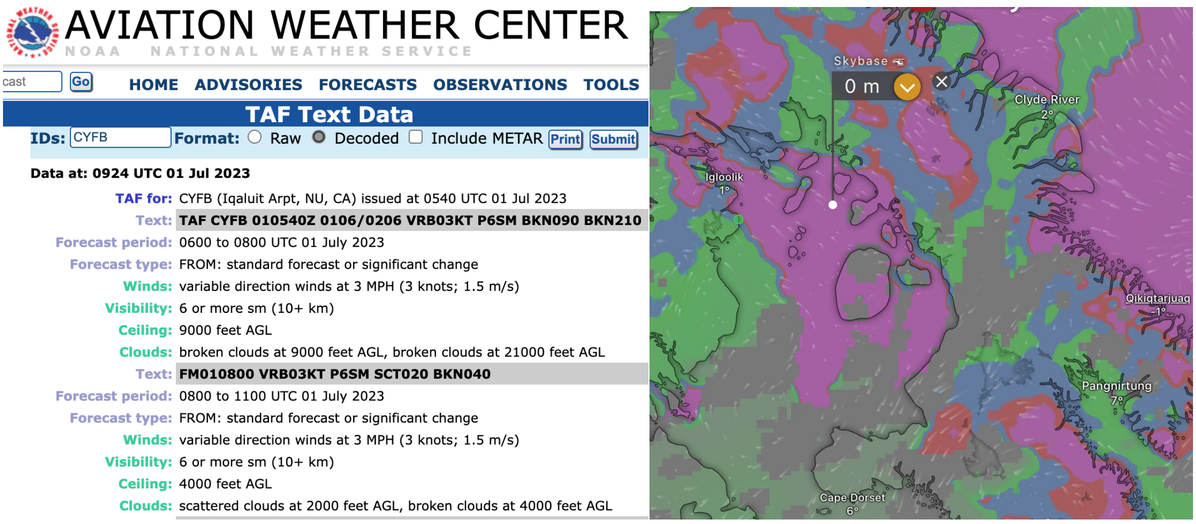
The scheduling of activities was based on the official aviation weather forecasts that were issued every 6 hours. For the flights to take place it was required to have a VFR conditions, implying a cloud ceiling of more than 500 feet AGL at both the primary airport and at the secondary airport. It was also required to have a cloud ceiling of preferably 3000 feet in the survey area to enable proper ice observations, and at the same time maintain flight safety.

Due to the limitations imposed on the operation, a high degree of improvisation was required to utilize the flight time in a cost-efficient way, and at the same time obtain high quality data. This required close cooperation between the flight crew, the sensor operators, and the representative from Viking Ice. It also proved important to have a common situational understanding related to all aspects of the operation.

Along the lines described above, the following activities were conducted.

Date	Activity conducted
28.06.2023	Flight covering Eastern parts of Hudson Strait (Zone 6 and partly Zone 5 and Zone 7).
29.06.2023	Flight covering Foxe Basin (Zone 3 and Zone 4).
30.06.2023	Flight covering Stensby Inlet and approaches (Zone2) – Cancelled due to low cloud cover at Stensby Inlet.
01.07.2023	Flight covering Stensby Inlet and approaches (Zone2) – Cancelled due to TEMPO (temporary cloud base (500 feet) warning) at Iqaluit and at alternate airport. Flight covering Zone 7, Baffin Bay and approaches to Hudson Strait conducted.

The official aviation forecast provided input for determination of access to landing strips. Due to remoteness in the area of operation, no official weather reports are to be found for the survey areas. Websites like Windy and Meteoblue provided an overview of parameters like the cloud ceiling visibility and wind in the survey areas.



Methodology

To enable a non-biased assessment of the prevailing ice conditions, automation of the process is a preferred approach. The approach consisted of the following steps:

1. Image gathering - Images were gathered at regular intervals. 3 sectors were covered, to the starboard of the plane, to the port of the plane and directly under the plane. This provided 3 individual datasets. The interval of 25 seconds was chosen as this gives a spatial resolution of less than 2 nautical miles along the route (depending on air speed), and at the same time keeping the data load on the hardware within acceptable limits. The 3 individual datasets and high spatial resolution provided a high flexibility with regards to analysis later in the project.

2. Image pre-processing – The images from each sector was cropped to cover only the area of interest. The blue color band was extracted and the image was converted to a 8-bit black and white image. Based on the features/size of a known object, each image sequence was calibrated to the right scale.

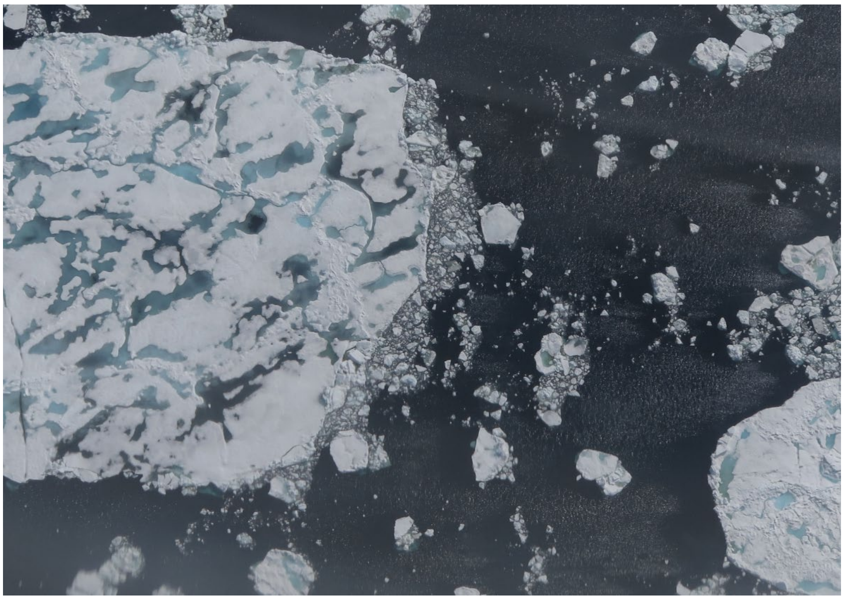


Figure 1: Raw image captured during the flights.

3. Image processing – Based on adjustment of threshold levels, each stack of images was converted to a binary dataset. The threshold adjustment defined what part of the image that was to be identified as ice, and what part of the image that was identified as water.

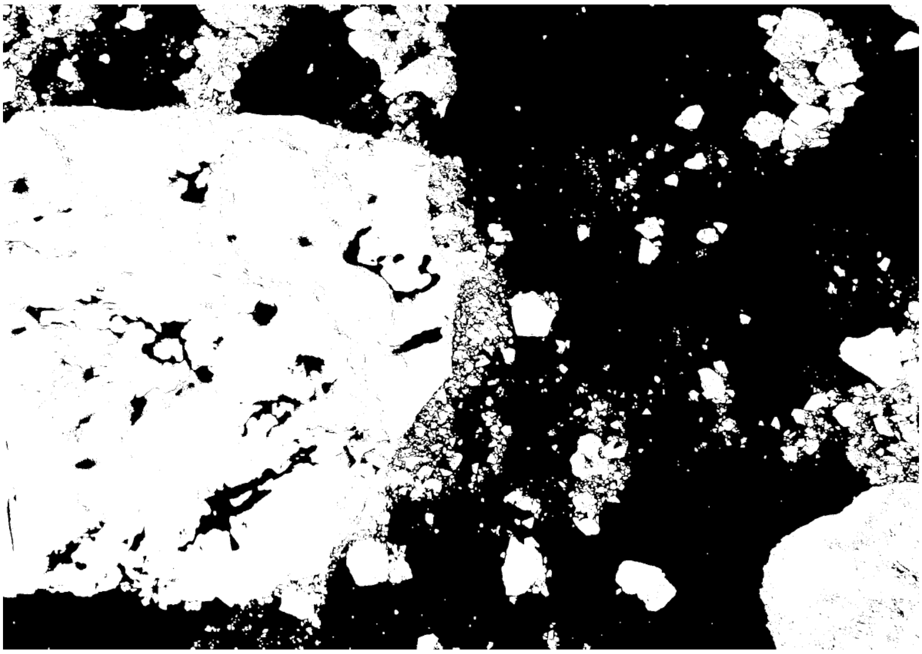


Figure 2: RGB image with adjusted thresholds and converted to a binary image file.

4. Particle analysis – A particle analysis was conducted on each of the individual images in the binary stacks. This generated statistical information for every individual ice floe. Within an image, all the statistical information for each of the individual ice floes was combined, generating a summary report for that specific image.

Figure 3: Binary image particle analysis.

Each ice floe was assigned a unique identification number. To reduce the strain on the computer hardware, only ice floes with visual footprint of more than 4 square meters were identified in the analysis.

Figure 4: An extract of the particle analysis with identification and assignment of a unique identification number to each individual ice floe.

Besides automation of the data gathering, visual ice observations were made through out the flights. The visual observations provided a good indication of the variation of the ice cover in the areas surrounding our flight path.

Ridge information was tried to be identified, utilizing both the radar and visual observations. No ridges were identified. This was mainly due to the break-up/melting process already taking place in a majority of the survey area. There were also limitations on the ability of the radar to identify ridge structures in fields of pack-ice.

Icebergs were identified visually or through the utilization of the onboard radar. The radar had a good capacity for identification of icebergs in open water. Identification of icebergs in pack ice proved challenging due to the numerous reflections from other sea ice features. As a result, a majority of the icebergs identified in this study are located in open water.

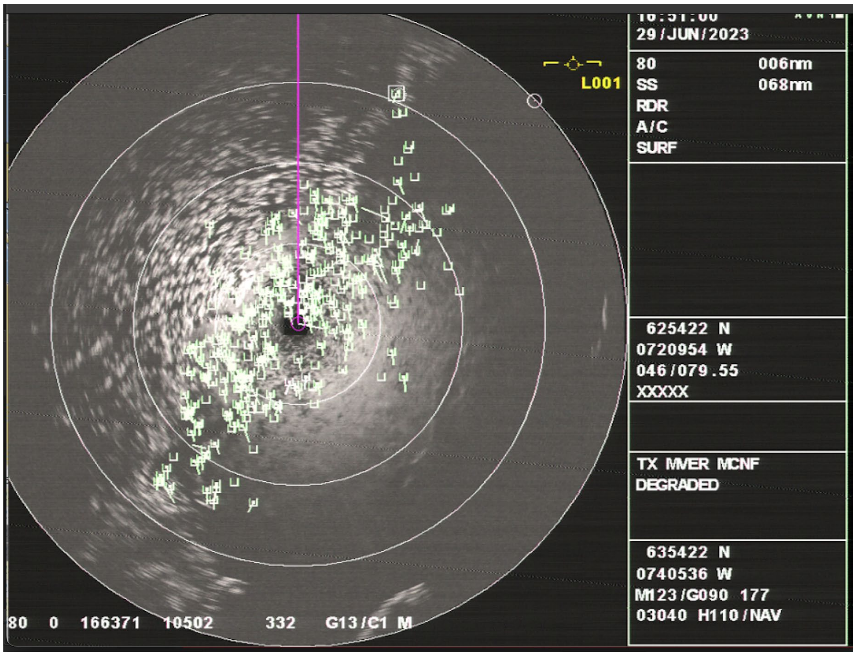


Figure 5: Sea ice echos, masking possible ice bergs.

Equipment utilized.

For conduction of the data gathering the following equipment was utilized:

- Canon G16 positioned on a tripod, utilizing an external capture timer kit (Hahnet) for automatic capturing of images at regular intervals. The camera covered the port sector of the plane.
- Richo GX200 positioned on a tripod, covering the starboard sector of the plane.
- Onboard camera
- Onboard radar
- Visual observations/binoculars.

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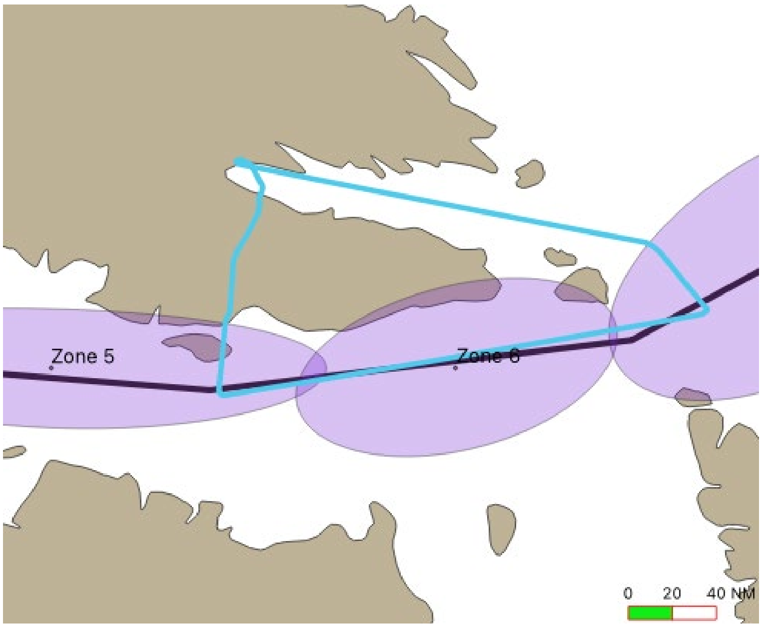
Results

Flight 1

Parameter	Description
Area of operation	Hudson Strait eastern part (Western part of Zone 7, Zone 6 and Eastern part of Zone 5).
Flight plan	From Iqaluit the plane flew South through Frobisher Bay until reaching the drifting ice pack at the mouth of Hudson Strait. The flight continued Eastwards along the shipping route, towards Big Island, outside Kimmirut. When reaching the open water to the West of Big Island, the plane broke off and returned to Iqaluit. During the survey part of the flight, the plane maintained an altitude of 3500 feet.
Departure time	28.06.2023 at 12.00
Weather	Overcast in the Northern and North-Eastern parts. No precipitation.
Cloud base	3000 meter declining during the last part of the flight to avoid low cloud cover.
Flight path	

Data gathered

In the eastern parts of the route (western part of Zone 7 and Eastern part of Zone 6) areas of ice with a concentration of about 70% ice concentration was observed. Between these areas of denser ice, large areas of open water was identified. In some areas strips of ice was stretching out, originating from the denser areas. The large variation in ice cover concentration over a relatively small area indicates a highly dynamic ice pack being affected by both wind and current, not being restricted by land.

As the plane moved westwards, the ice loosened, and at the center of Zone 6 average ice concentrations of less than 20% was experienced. At Big Island (Eastern Part of Zone 5) the ice vanished, and a large stretch of open water stretched out in an western direction.

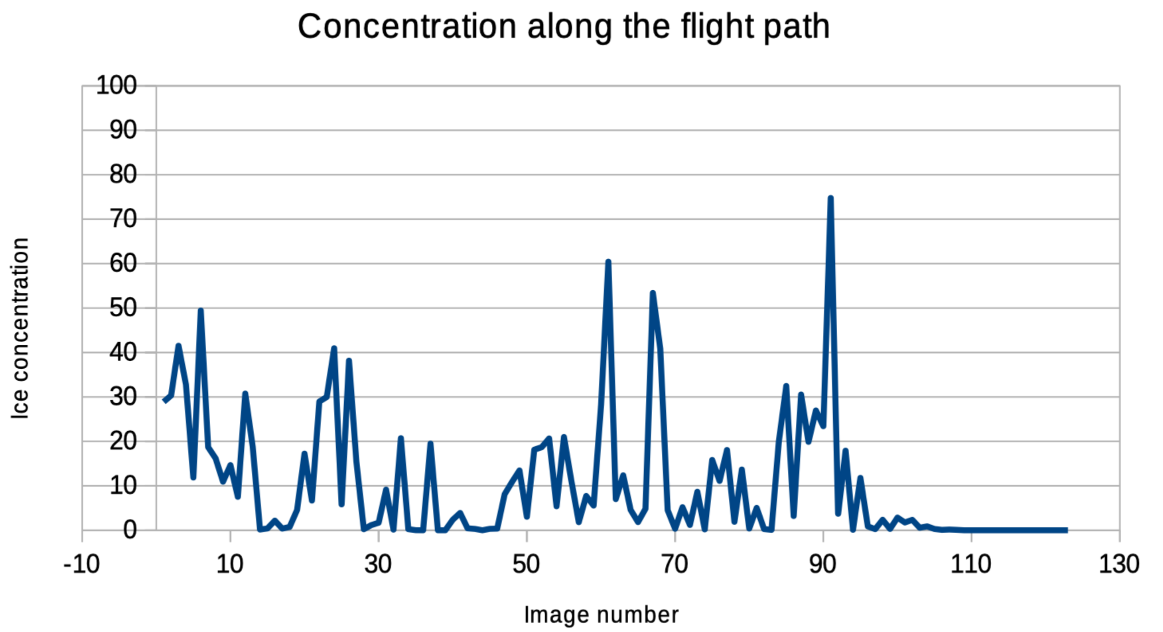
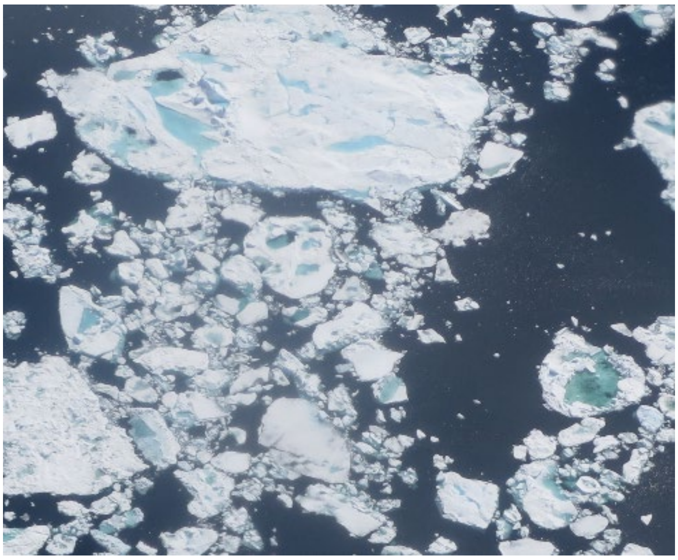
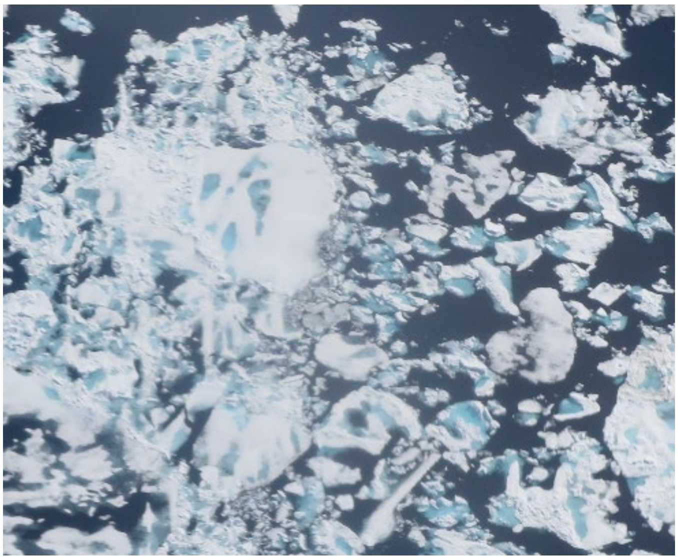


Figure 6: Ice concentration identified along the flight path.

The flow sizes/level of deformation did not seem to significantly change through out the survey area.

Ice observations, Flight 1	
	Ice observed at the Eastern end, at Zone 6.
	Ice observed between Zone 5 and Zone 6. This type of ice conditions was typically representative for the strips of ice observed.
	Ice observed South of Big Island, Zone 5. The ice mainly consisted of bergy bits, with the odd larger flow.

Comparison with ice charts provided by CIS

The ice charts from Canadian Ice Service (CIS) provides a static picture of the ice conditions. Based on the weekly charts provided, the flight was to transverse ice fields ranging from more than 90% ice coverage to open water. The chart was produced on 26.06, and the flight took place on 28.06. Based on the data gathered both sources of information harmonize, and the general picture provided by CIS is the same as observed from the plane. However, during the time from production of ice charts to our survey the ice have shifted, altering the concentrations on a local level.

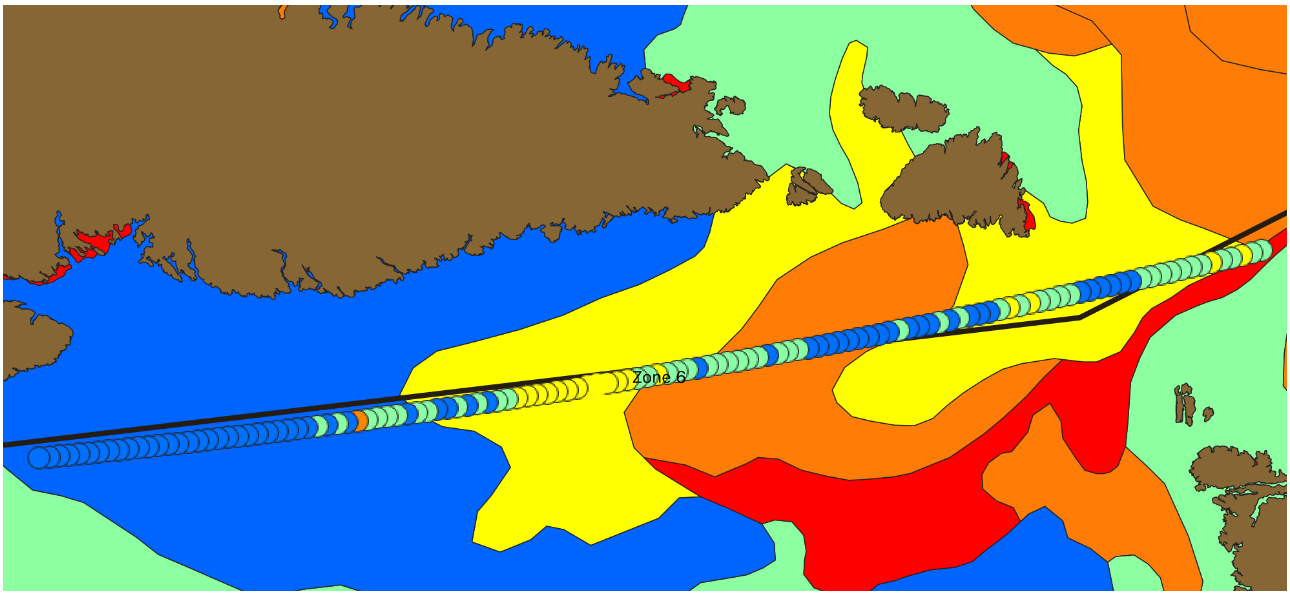


Figure 7: Observed ice conditions (Colored circles) overlayed with CIS ice chart. (Ice concentrations: Blue less than 10%, Green-between 10% and 40%, Yellow-between 40% and 70%, Orange-between 70% and 90%, Red above 90%.

At the time of the survey areas identified in the CIS ice charts as between 70% and 90% ice cover had dissipated, and mainly areas of concentrations below 50% was identified.

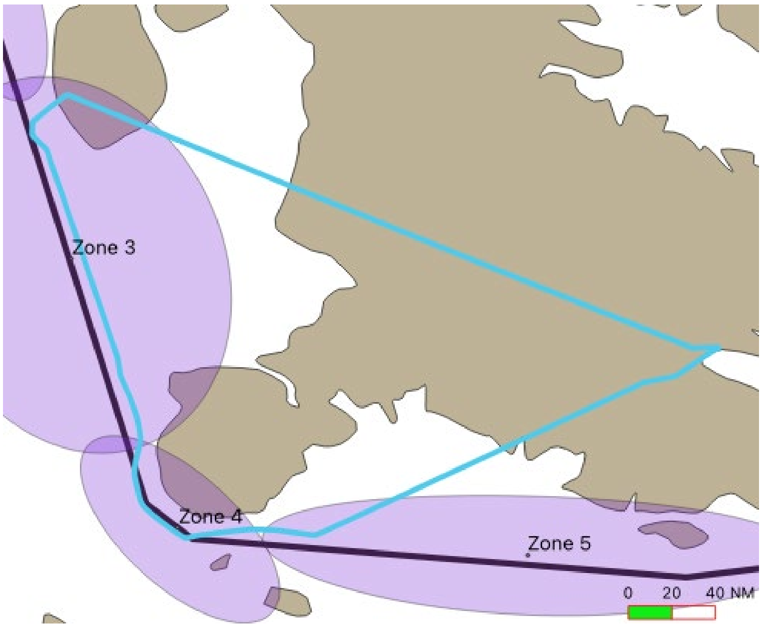
Considerations for marine activities

The effect of the time lag from production of CIS ice charts is visible in the Hudson Strait area as the ice is highly dynamic. Ice concentrations ranging from open water to more than 90% coverage is found within a distance of less than 40 nm.

The main driving forces are wind, ocean currents going in and out of Hudson Strait and the South moving current moving along the western coast of Baffin Bay. Prediction of the combined effect of these forces is highly complicated and ice concentrations/ice edges are should be expected to move at speeds up to 2 knots. As a result it is not expected to find concentrations during our survey that are identical to the concentrations indicated by the CIS ice chart.

Icebergs were observed along the route. Disclosing all the icebergs with the help of the radar from the plane was difficult, as patches of ice masked the iceberg echoes. Mariners are to pay close attention to both old ice and icebergs/ice of land origin as it is present in the area.

Flight 2

Parameter	Description
Area of operation	Western shores of Baffin Island to Prince Charles Island, further South to Cape Dorse (East of Zone 3, Zone 3 and Zone 4).
Flight plan	From Iqaluit the plane flew NorthWest to the western shores of Baffin Island, heading northwest, to the southern tip of Prince Charles Island. From Prince Charles Island (the northern part of Zone 3) the flight continued with a southerly course, parallel with the shipping route, towards Cape Dorset. Upon reaching Cape Dorset (Zone 4), the plane followed around the coast, into Hudson Strait, before it broke off towards Iqaluit. During the survey part of the flight, the plane maintained an altitude of 3500 feet, unless restricted by low cloud cover.
Departure time	29.06.2023 at 09.00
Weather	Overcast in Iqaluit and Hudson Strait, enabling VFR conditions. Low cloud cover and fog in the northern parts of the flight (northern part of Zone 3).
Cloud base	Cloud base at about 3000 feet in Iqaluit. In the northern part of the survey area (northern part of Zone 3), the cloud base was reduced to less than 500 feet.
	

Data gathered.

Zone 3

In the northern part of Zone 3 the visibility was obstructed by a low cloud ceiling. The low cloud ceiling made observations over a greater area difficult as the visibility was barely 1500 feet, straight down to the ice. Based on the observations conducted through the cloud cover, the ice was identified as thick first year ice. There was very little snow on the ice as it was all windblown, and the blue ice was visible. There was not observed any deformation of the ice in this area. There were no leads identified. In the ice charts from CIS, this is identified as a concentration of more than 9/10 and less than 10/10, with a stage of development of more than 120 cm.

As the plane moved further south, small leads full of broken ice were developing. At about the middle of the Zone 3, the ice edge to the western side of the route became visible. The ice edge was going about the same direction as the route. The close the ice edge approached, the more broken up the ice.

At the southern portion of Zone 3, patches of open water became visible. Leads stretching in the East/West direction dominated the ice regime on the approach of the intersection of Zone 3 and Zone 4. This is most likely the effect of the local tidal currents flowing along the coast.

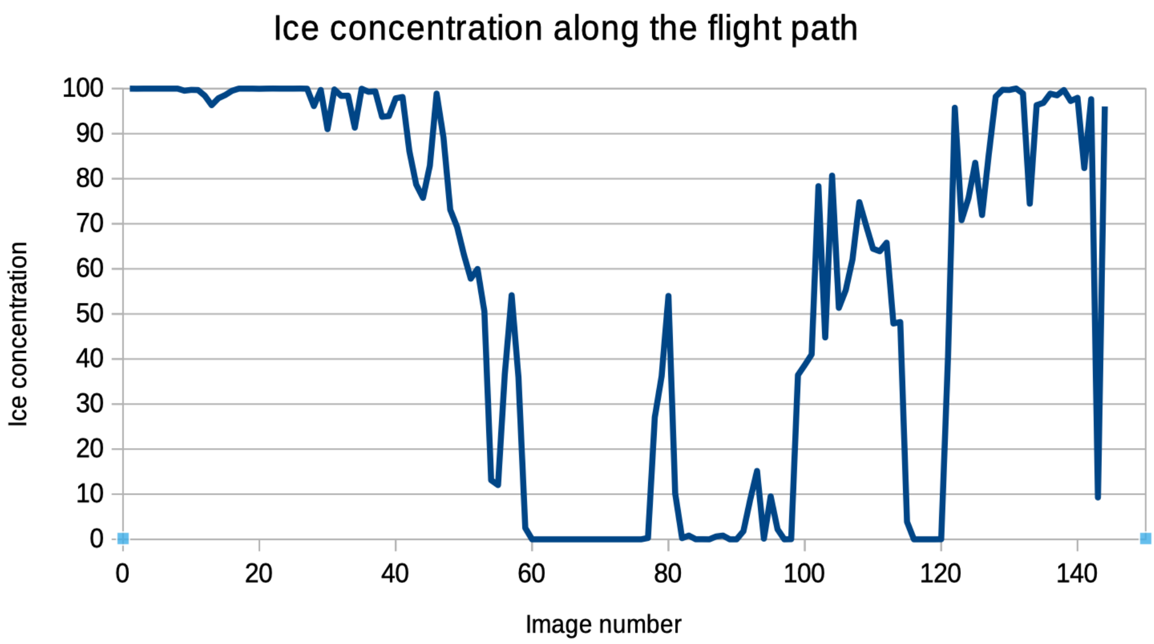
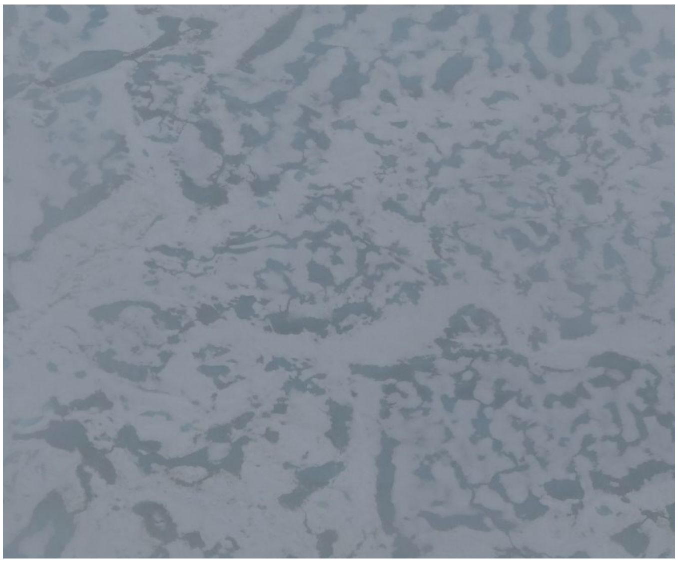
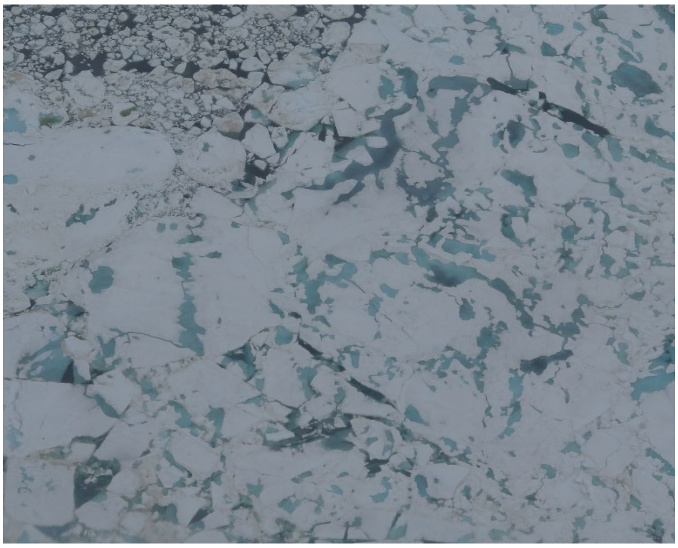
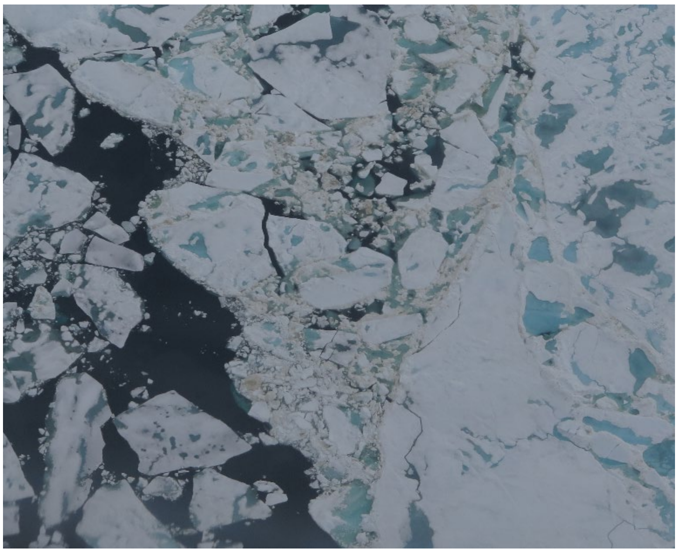


Figure 8: Ice concentration observed along the flight path.

Ice observations Zone 3, Flight 2	
	Solid ice with without leads of fractures observed at the Northern part of Zone 3.
	In the northern parts of central Zone 3, the ice had started to fracture and break apart. Very few large leads were identified. Open water was observed south of the central parts of Zone 3 as the ice edge had drifted eastwards,
	In the southern part of Zone 3, leads filled with rubble-ice had started to develop between the larger floes. The further South, the more open water.

Comparison with ice charts provided by CIS

The ice charts from Canadian Ice Service (CIS) provides a static picture of the ice conditions. Based on the weekly charts provided by CIS, the northern part of Zone 3 was to be covered by ice with a concentration of > 9/10 and < 10/10. The ice was to have a stage of development of >120 cm.

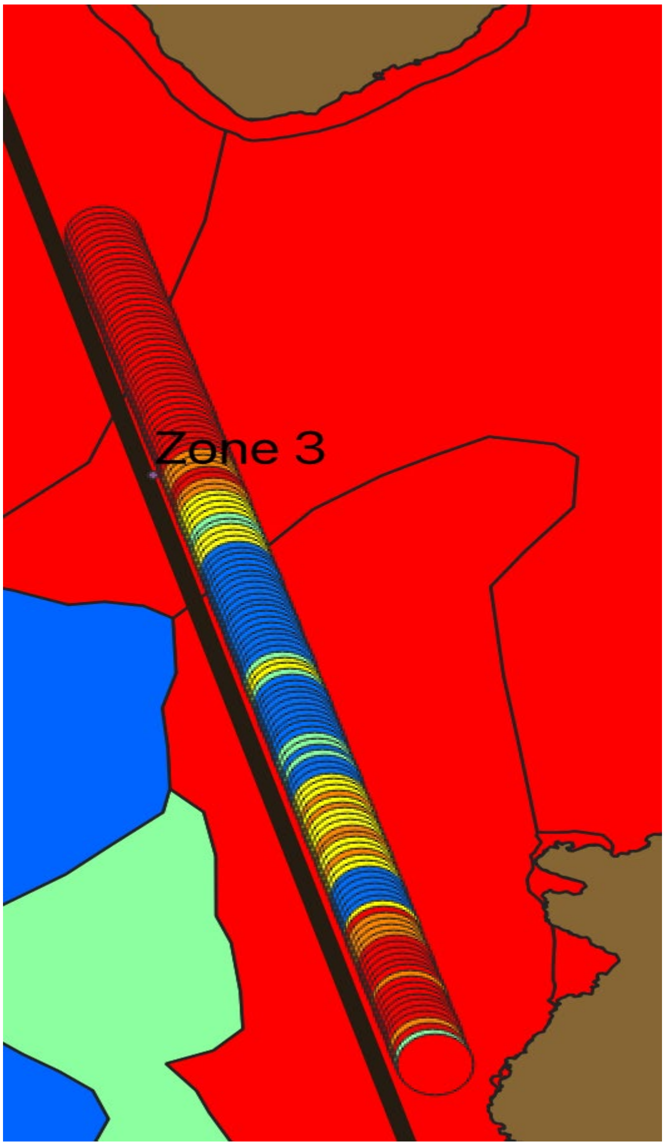


Figure 9: Observed ice conditions (Colored circles) overlayed with CIS ice chart. (Ice concentrations: Blue less than 10%, Green-between 10% and 40%, Yellow-between 40% and 70%, Orange-between 70% and 90%, Red above 90%.

Due to the low cloud base the plane was not able to obtain a good overview of the northern areas. The visual observations of the heavy ice conditions conducted through the cloud layers, harmonized with the data provided by CIS. Clean, blue ice, with snow spindrift was observed. No leads or fractures were identified. This indicates solid, hard (cold) ice of significant thickness, where the summer melt process not yet has had any significant impact.

As the flight proceeded south, and at the center of Zone 3 fractures and leads full of rubble ice was observed. This harmonizes well with the indications given by CIS.

Based on the observations it was evident that the ice cover had drifted further East during the time from when the ice chart was generated until our survey. A large open water polynya stretched eastwards across the flight path.

At the southern part of Zone 3 the CIS ice chart showed concentrations 90%, mainly consisting of thick first year ice. This harmonized with our observations. Very little open water was present, and all leads were filled with ice rubble.

Zone 4

In Zone 4 the ice followed the coastline. No shore leads were observed on the northern and the westerns side of the peninsula, while on the southern side a shore lead had developed. The northern part of Zone 4 was highly affected by the ice conditions prevailing in the Foxe Basin, while the southeastern corner of Zone 4 was affected by the ice condition prevailing in the Hudson Strait. As a result the ice conditions in varied from high concentrations in the northern sections to very light, including large areas of open water, in the southeastern section.

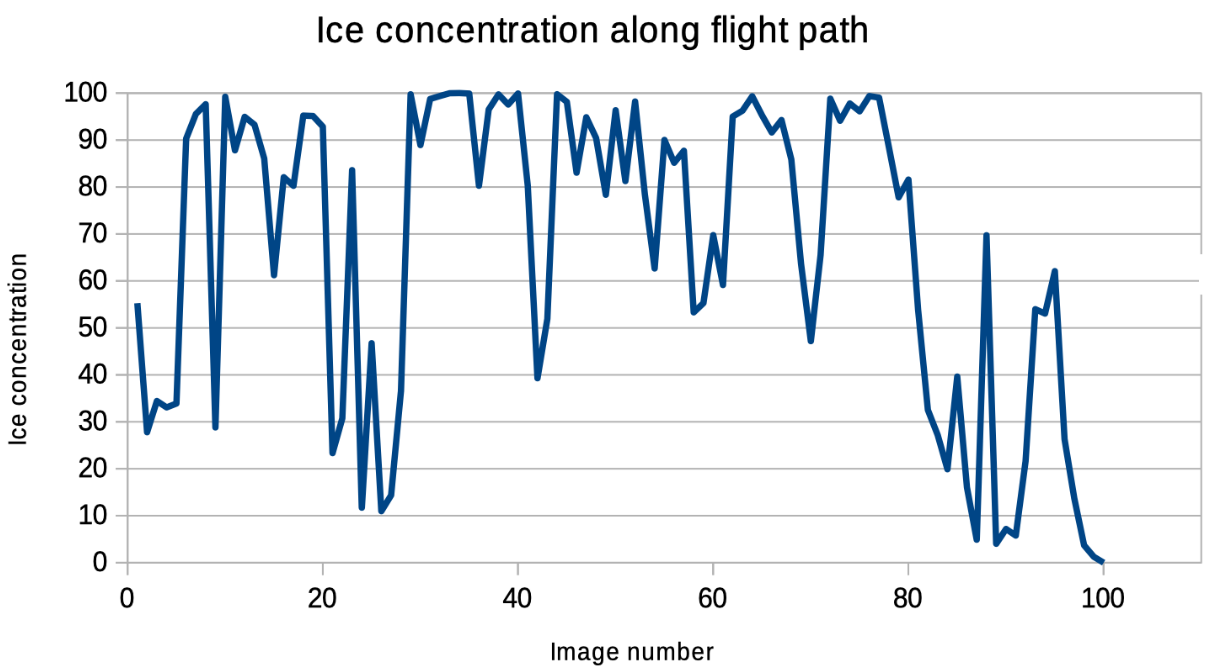
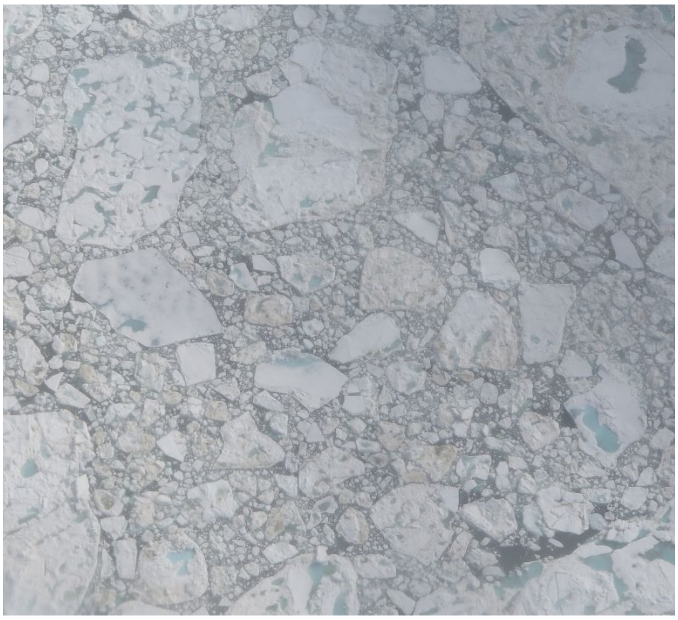
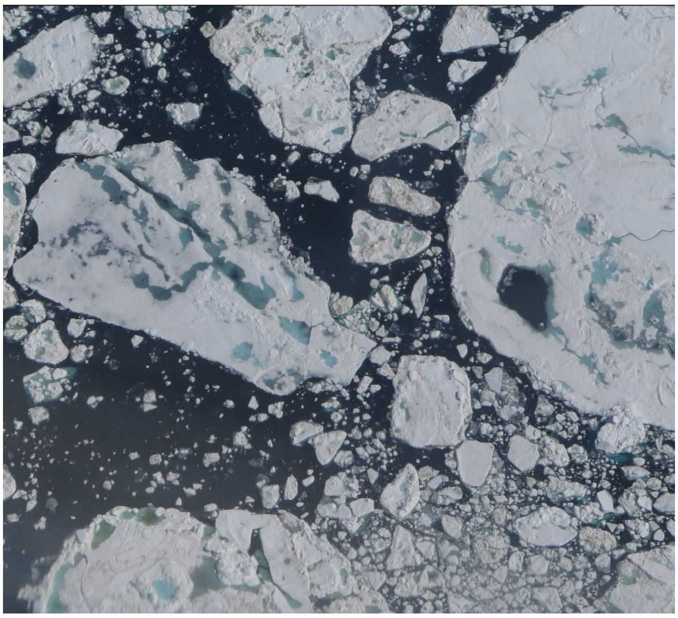
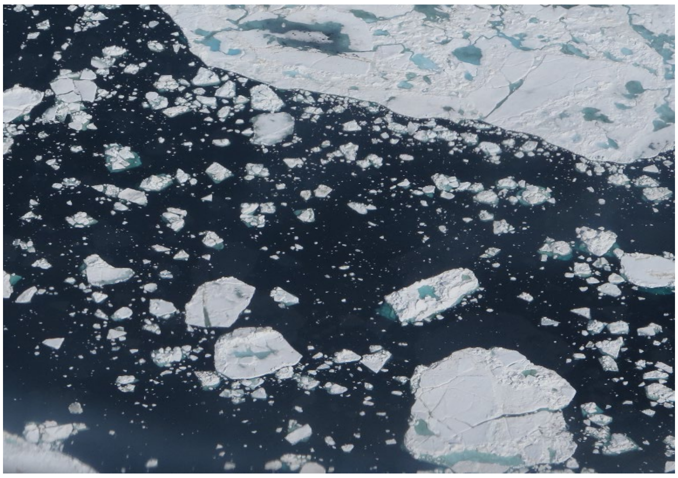


Figure 10: Ice concentration observed along the flight path.

To the West of the Zone there was open water visible through out the whole Zone. Based on radar observations, the ice was estimated to stretch about 20 nautical miles from the shore.

Due to the deformation/decaying of the ice, no pressure ridges were identified.

Ice observations Zone 4, Flight 2	
	The pieces of ice were in generally getting smaller and more deformed in the northern part of Zone 4 compared with the ice in the southern part of Zone 3. To the West of the track, open water was visible.
	In the central parts of Zone 4 the patches of open water increased.
	In the southeastern part of Zone 4 large areas of open water was found. There were still some large floes (more than 500 meters across) observed in the area.

Comparison with ice charts provided by CIS

In Zone 4 the ice charts provided by CIS indicated concentrations of above 90%. During the flights we observed these kind of conditions in the norther part of Zone 4, while in the southern parts the ice was considerably lighter. The predominant NE winds gives the ice a southerly drift vector. As there is open water in Hudson Bay, the ice has the room needed to drift southwards into these areas of open water. This generates an open water lead along the shores in the south part of Zone 4, and at the same time generates a relatively loose ice edge to the south of the route.

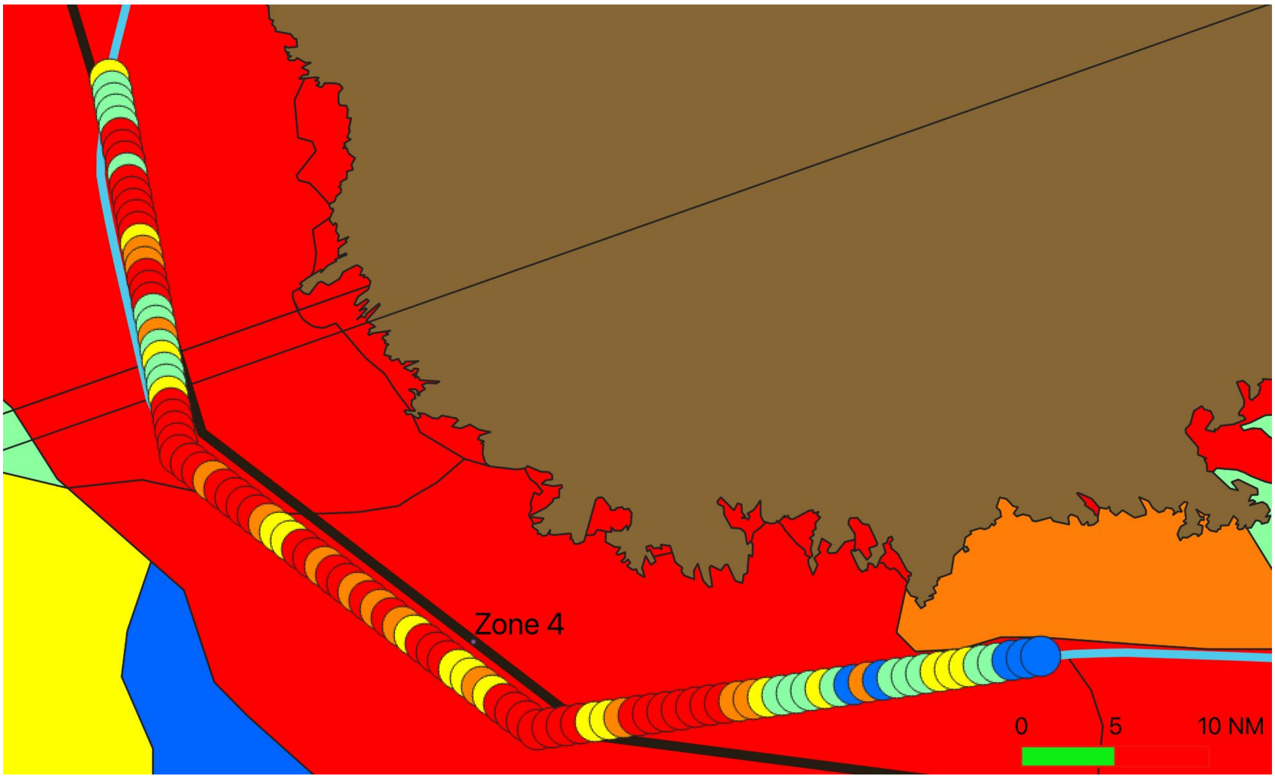


Figure 11: Observed ice conditions (Colored circles) overlayed with CIS ice chart. (Ice concentrations: Blue less than 10%, Green-between 10% and 40%, Yellow-between 40% and 70%, Orange-between 70% and 90%, Red above 90%.

For all of Zone 4, the pack ice stretched out, about 20 nautical miles from the shore. This is significantly further out than what is indicated on the ice charts. The ice charts indicates a distinct ice edge from 9/10 ice cover directly to open water. During our survey the ice edge was dispersed, and stretched significantly further westwards from the shore. This is assumed to be an effect of a reduced wind pressure/reduced currents enabling the slacking of the ice since the time when the ice charts were developed.

It was observed that the northerly winds had dispersed the ice along the southern shores of Baffin Island, generating open leads along the shoreline. As a result, higher ice concentrations were found in the more southern parts of Hudson Strait, possibly generating pressure zones around the island located in Hudson Strait/southern part of Zone 4.

Considerations for marine activities

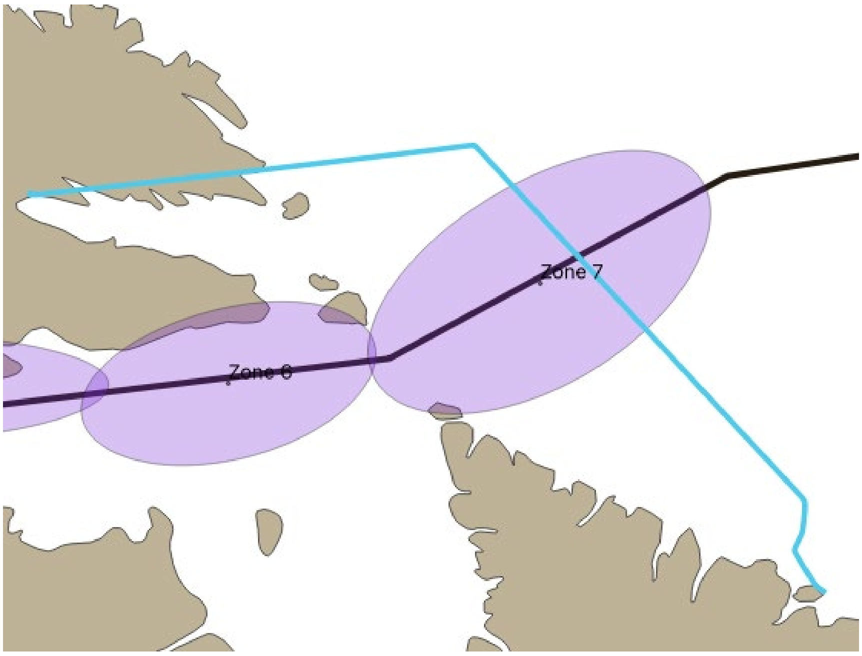
It is to be recognized that Zone 3 stretches in the North/South direction for about 200 nautical miles. The melt processes at the northern end is to be delayed by several weeks compared with the prevailing conditions in the southern end. At this time of the year it is to be expected large variations of the ice conditions within this area.

Operations in the northern end of Zone 3 will require high ice class vessels for the operation at this time of the year.

In Zone 4 and parts of Zone 3 avoidance of the ice is to a large degree possible by altering to a more westerly route.

It is believed that the northern part of Zone 3 (and Zone 1 and 2) to a large degree will dimension the ice requirements associated with a maritime operation along the route at this time of the year.

Flight 3

Parameter	Description
Area of operation	Baffin Bay and approaches to Hudson Strait (Zone 7).
Flight plan	From Iqaluit the plane flew due West through Frobisher Bay until reaching the drifting ice pack offshore in Baffin Bay. The flight continued south, intersecting the central parts of Zone 7. The area both north and south of Zone 7 is of interest as a north/south current causes the ice to move perpendicular through Zone 7. During the survey part of the flight, the plane maintained an altitude of 3500 feet.
Departure time	01.07.2023 at 08.00
Weather	Overcast and rain in the Northern parts. Sunshine along the Labrador coast.
Cloud base	Cloud base Iqaluit at about 700 feet. The low cloud base stretched to about 70 nautical miles offshore.
Flight path	

Data gathered

The ice observed on flight 3 was mainly consisting of small floes (less than 50 meters in diameter). The ice was greatly dispersed as light winds had dominated the area in the recent days. There were no clear edges of the drifting pack. Between the ice floes icebergs were present. Much of the ice observed have been generated at a more northerly location and is drifting south along the western shore of Baffin Bay. Much of the ice was identified as thick first year ice, with possible inclusions of old/glacial ice.

Figure 12: Strips of ice observed in Zone 7

Due to the effect of wind and current the higher concentration were mainly found as strips of ice. The strips were identified to stretch for many tenths of nautical miles. In the strips of ice the concentration was estimated to be about 30%. The strips had developed as a result of the governing wind and current conditions in the area. This would change with alterations in the weather conditions.

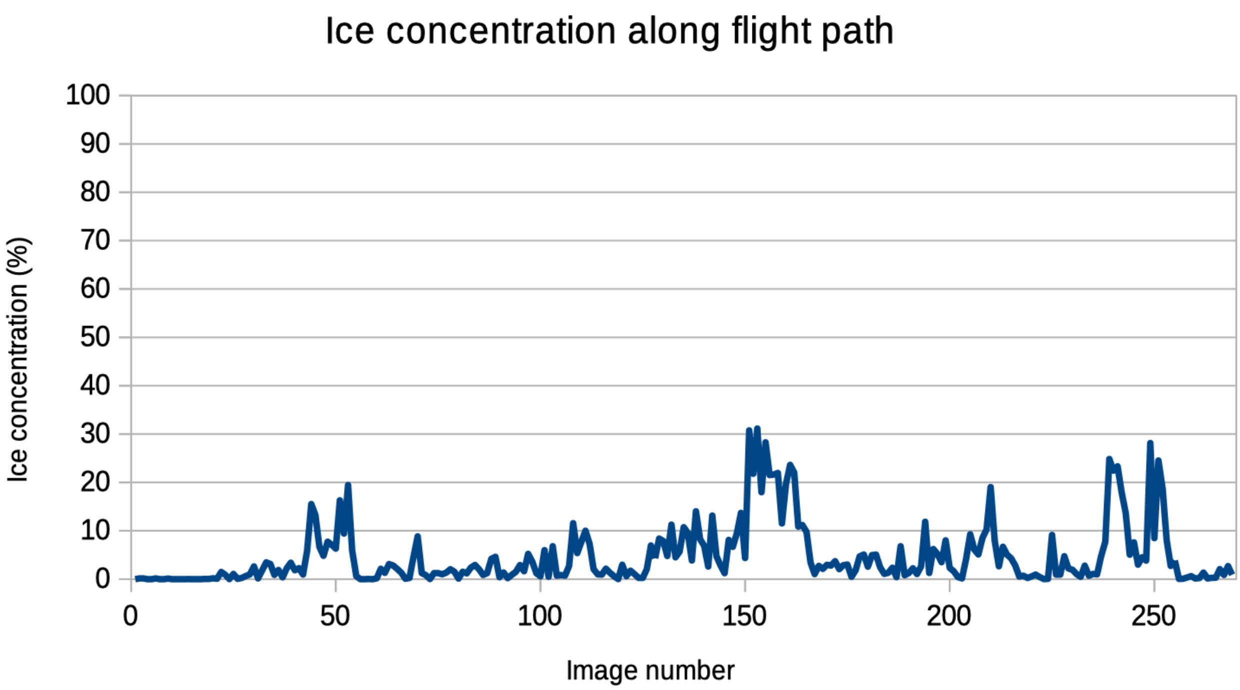
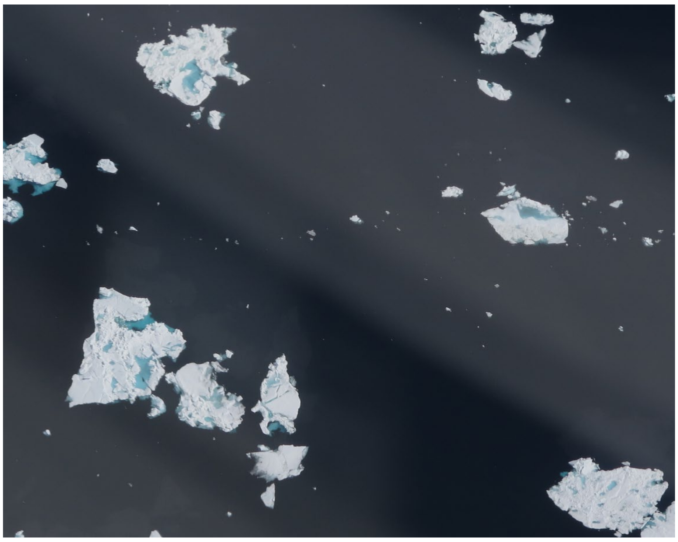
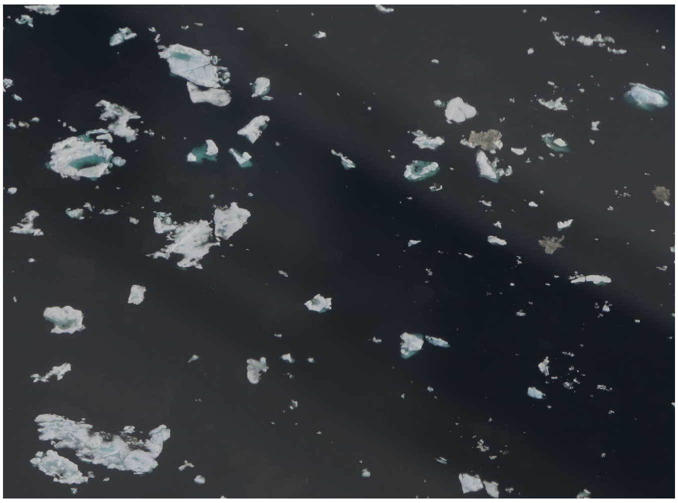


Figure 13: Ice concentration observed along the flight path.

Ice observations Zone 7, Flight 3	
	In the northern part of central Zone 7 there was observed very loose ice with with occasional larger (about 50 meters across) floes.
	In the middle of Zone 7 the occurrence and sizes of the flow had increased. The larger floes had a cross-section of about 100 meters. The higher ice concentration was usually found in strips.
	In the southern part of central Zone 7, loose drift ice was identified.

Icebergs

Due to the low ice concentration, the radar was able to identify numerous icebergs. The icebergs were mainly large, and had a tabular shape. The lack of identification of smaller icebergs/growlers is mainly due to the capacity of the onboard radar.

Comparison with ice charts provided by CIS

According to the weekly ice chart provided by CIS the ice concentration was identified to be about 70%, mainly consisting of thick first year ice (>120 cm thick), but with presence of old ice with a concentration of < 1/10. The ice observed had a significantly lower concentration than what was stated in the CIS ice charts.

The stage of development indicated by the ice charts seemed to be correct, despite of the ice having reached far in the decaying process.

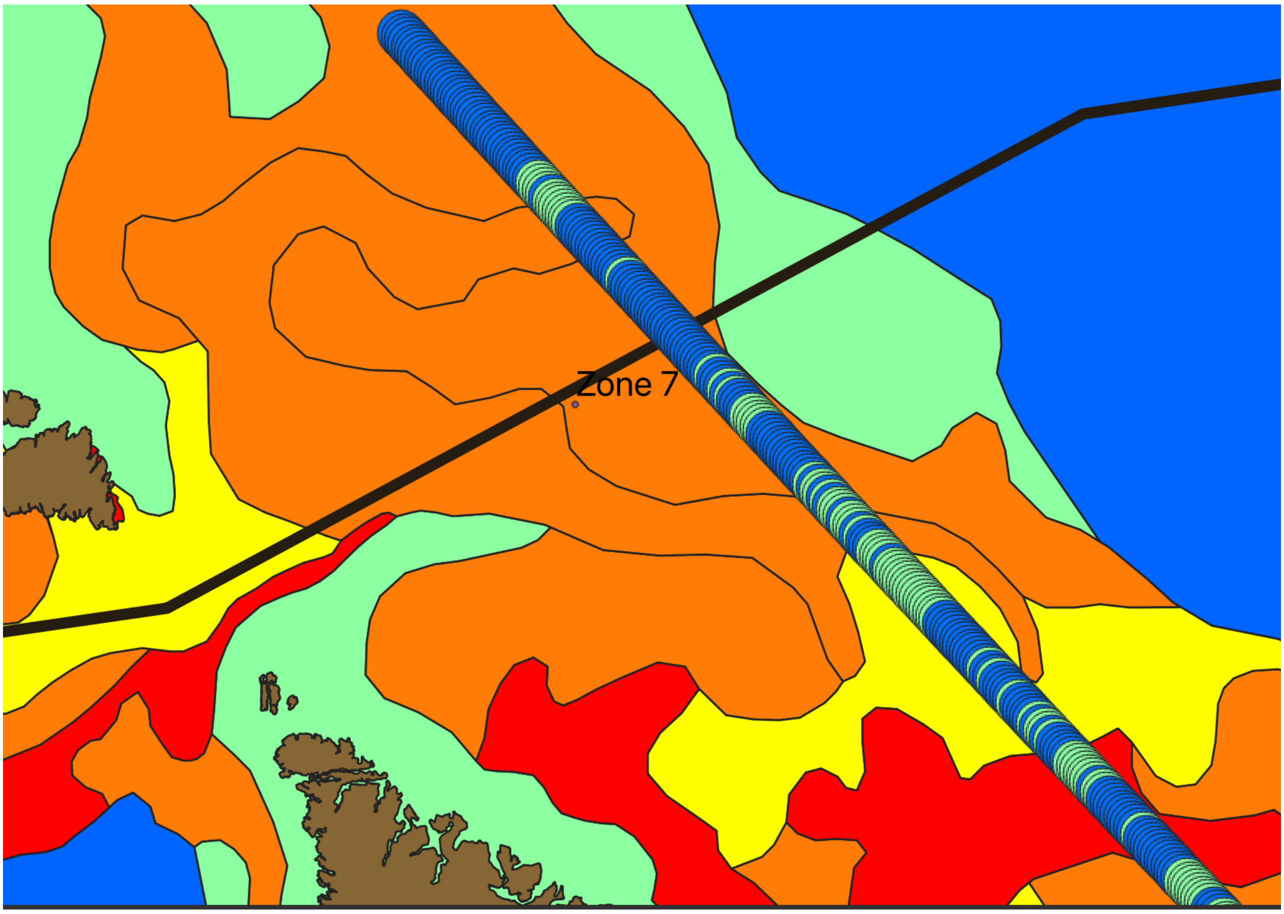


Figure 14: Observed ice conditions (Colored circles) overlayed with CIS ice chart. (Ice concentrations: Blue less than 10%, Green-between 10% and 40%, Yellow-between 40% and 70%, Orange-between 70% and 90%, Red above 90%.

The ice charts issued by CIS were published on the 26.06, while the flight took place on 01.07. The ice drift taking place during the 5 days from the charts were issues to our observations is significant. Ice concentrations of 70 % had dispersed ans shifted into strips of ice with a concentration of about 30 %. In between the strips of ice there was mainly identified open water.

This indicates a highly dynamic ice pack resulting from a variation of forces induced by wind, ocean currents, tidal currents, wind induced currents and the Coriolis force.

Considerations for marine activities

The highly dynamic nature of the ice fields observed in Zone 7 shows the importance of maintaining up-to-date ice information in the operational phase.

The old ice and relatively high iceberg concentration to be present in the area represent a hazard for marine activities. Pieces of old ice and glacial ice can be relatively small, and challenging to identify at several hundred meters distance, from the bridge of a large bulk carrier. The combination of late detection, combined with the reduced maneuverability associated with large bulk carriers, will reduce the vessels ability to avoid impact. This type of ice is hard and is known to induce structural damage on inappropriately dimensioned the vessels.

Discussions

The survey provided a good impression of the governing conditions present in all Zones of the route, except Zone 1 and Zone 2 during the last part of June. Since the route covers a large area of water the fracture time varies significantly, e.g. in the more southern parts of the route there were large patches of open water, while in the northern part of the survey area few or no leads were identified.

It is believed that the charts provided by CIS gives a good overview of the governing conditions. However, there proved to be large local variations within areas identified as homogenous according to the CIS ice charts. As a maritime operation is to be dimensioned according to the most challenging conditions present in the area of operation, the large degree of local variation will demand flexibility and an ability to adapt an operation an operation to manage the dynamic conditions.

In general, the ice concentrations observed were lower than the conditions indicated by the CIS ice charts. The automated image analysis disregarded rubble ice with a floe size of less than 4 square meters. For the areas of severely deformed ice (e.g. Zone 7), the partial concentration of rubble ice could be relatively large. Our method of analysis could as a result calculate concentrations that were marginally lower than the real concentrations. This effect is however not big enough to alter the general impression of a lower ice concentration than what was indicated by the CIS ice charts.

In the southern parts of the route (Zones 4 to 7) the governing ice conditions at this time of the year proved to be relatively uncomplicated for marine operations. Despite relatively slack ice, both old ice and a relatively high iceberg concentration is believed to be present in much of the area. Conduction of maritime operations in ice covered areas containing both glacial ice and old ice requires appropriate dimensioning of the vessels to handle ice/vessel interactions. Operation of large vessels with limited maneuverability and large distances from the bridge to the ice cover in front of the vessel will increase the probability of impact between unfavored ice and the vessel hull. Ice breaker support can reduce the risk associated with an operation, but it will not eliminate the risk.

Based on the survey areas during the last part of June it is believed that the northern parts of the operational area (northern part of Zone 3, Zone 2 and Zone 1) will dimension the operation. Especially the area where the land fast ice meets the moving drift ice (Zone 2) will typically cause generation of ridges. The same is the possibly the case with the northern part of Zone 3. In these areas leads will open and close, and ridges will develop along the flow edges. These type of areas are also known to be important feeding grounds for marine mammals. Continuous vessel operations in these areas are expected to significantly alter the local ice regime.

Unfortunately the survey was not able to cover Zone 1, Zone 2 and the most northern part of Zone 3. This area, together with the presence of old ice and ice of land origin identified in all other Zones is believed to dimension a marine operation.

Considerations related to old ice and icebergs

Both old ice and ice bergs represent a type of ice that is hard, and it represent a hazard for marine activities. In general icebergs are easily identified, while growlers can be hard to identify. The larger icebergs produce growlers. The concentration of growlers is usually closely linked to the concentration of icebergs.

Smaller pieces of glacial ice, originating from decaying icebergs can be hard to identify during an areal survey, but the larger icebergs can be identified, and utilized as a proxy for identification of areas with a high probability of higher growler concentrations. It is also important to note that the radar onboard the plane predominantly picked up icebergs located in mainly open water. This means that numerous of icebergs embedded in sea ice was not captured by the survey.

Identification of old ice during an areal survey is challenging, especially if a relatively low concentration of old ice is embedded in larger ice fields of mainly thick first year ice.

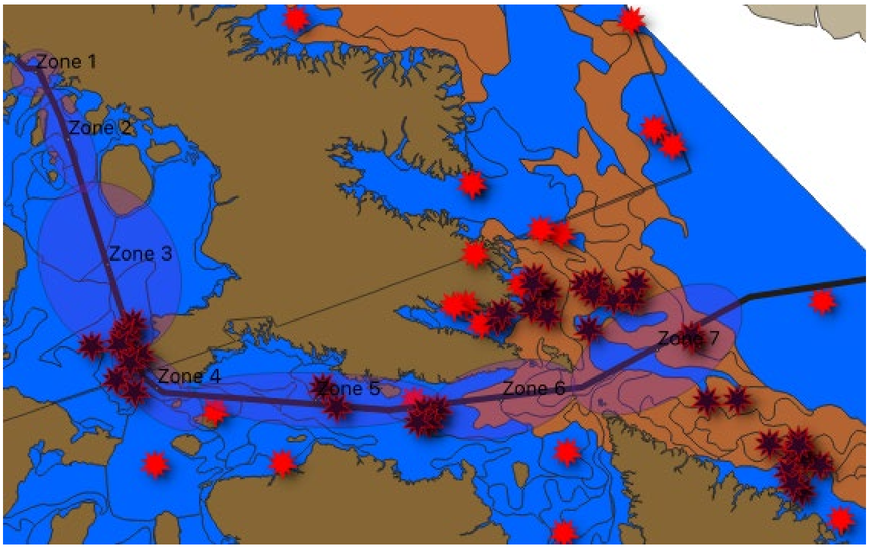


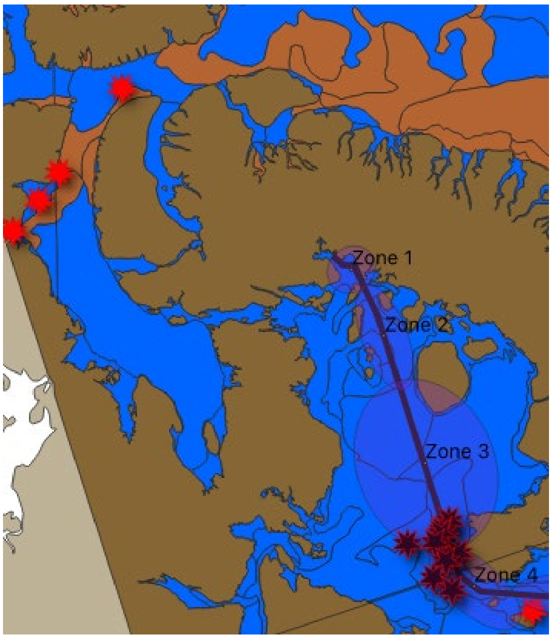
Figure 15: Red stars are icebergs identified by CIS, and the darker stars are icebergs identified during the areal survey. The sea ice marked in brown is old ice, with an ice concentration of less than 1/10.

The survey identified a significant number of icebergs not captured by the CIS ice charts. As seen in the figure above, relatively high concentrations of icebergs were present in all Zones surveyed. In Zone 6 and Zone 7, the tidal currents combined with the southerly currents in Baffin Bay, makes the ice regime highly dynamic. It is believed that all the icebergs identified south of Zone 7 have been drifting through Zone 7 earlier this spring.

The same effect is visible for the icebergs identified in Zone 3, Zone 4, and Zone 5. These icebergs have most likely drifted westward, from Baffin Bay through Hudson Strait.

In Zone 3, icebergs were only identified in the southern section. This was due to the ice cover masking the echos from the icebergs for the onboard radar. As a result, icebergs are assumed to also be present in the more northerly sections of Zone 3.

Old ice was only identified by CIS to stretch from Zone 7, into Zone 6. As some of the ice present in Hudson Strait originates from Baffin Bay, it is expected that old ice is also to be found further West, into Zone 4 and Zone 5.

	Currently no old ice or icebergs were identified in the central Foxe Basin. There is currently both old ice and icebergs identified in the northern sections of Prince Regent Inlet. This ice has earlier been known to drift south, through Fury and Hecla Strait, into Fox Basin. In the recent years this has been an infrequent occurrence, but should be considered as a possible option.

In the winter time, icebergs, growlers and old ice can be embedded in first year ice, with potential snow cover. This can make visual identification almost impossible. All vessels operating in especially Zone 3, 4, 5, 6 and 7 should be designed to handle the conditions described above.

Recommendations

To dimension a cost efficient logistic solution, in depth knowledge of the governing ice conditions during the time of operation is essential. The following actions are recommended to obtain a better understanding of the governing conditions:

- Conduction of aerial surveys at different parts of the year to capture seasonal variations throughout the route.
- Conduction of special aerial surveys during the winter months in Zone 1, Zone 2 and Zone 3 with a special focus on identification of ice-ride densities.
- Field measurements in Zone 1, Zone 2 and Zone 3 for verification of ice thickness and ridge thickness. This should preferably be conducted at a time of maximum ice thickness, e.g. spring time.