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Ice risk management for drilling operations in the Southern Barents Sea

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ABSTRACT

The probability of sea ice or glacial ice intrusions in the area open to petroleum activity in the Norwegian Barents Sea is low. Still, drifting ice represents a non-negligible risk to drilling operations that needs to be managed. Within the past decade, Equinor has been operator for exploration and production drilling campaigns in the Norwegian Barents Sea that have required ice risk management. The basic philosophy has been to ensure ice avoidance by implementing an ice risk management system (IRMS) in close collaboration with the drilling contractor. The IRMS encompasses monitoring of ice conditions, ice risk management training, alerting and procedures for responding to threatening ice. The Norwegian Government's management plan for the Barents Sea also dictates that no drilling in oil-bearing layers shall take place when sea ice is closer than 50 km from the well location. A secondary objective with the IRMS has therefore been to ensure that this requirement is met. The paper presents how sea ice and iceberg risks affect drilling operations in normally ice-free waters. Further, the paper explains how ice risk management has been implemented in practice, covers the ice monitoring system, training of offshore/onshore personnel and organization of ice risk management activities. Relevant experiences from ice risk management during the drilling campaigns are also summarized. In an adjoining paper, the area in the Barents Sea where drilling operations need to consider glacial ice is defined (Eik et al., 2023).

KEY WORDS: Ice risk management; Barents Sea; Ice Surveillance.

INTRODUCTION

The Southern Barents Sea is normally free of both sea ice and glacial ice, due to the warm, Atlantic water masses entering the Barents Sea from south-west. In the Northern Barents Sea, sea ice forms locally every winter over the shallow banks surrounding the Svalbard and Franz

Josef Land archipelagos. In addition, there is occasional influx of sea ice from the Arctic Ocean, which could bring multi-year ice into the area. Icebergs are calved from the tide-water glacier fronts in Svalbard (SB), Franz Josef's Land (FJL) and Novaya Zemlya (NZ). The Atlantic water, entering the Barents Sea from South-west, acts as a buffer that efficiently melts sea ice and icebergs that may cross the oceanic polar. The polar front is the transition zone between the colder and fresher arctic water masses over the shallow shelf areas to the north and the warmer and more saline Atlantic water. Still, under the influence of sustained wind and currents from the north, both sea ice and icebergs may occasionally advance into the south-western Barents Sea and pose a risk to Mobile Offshore Drilling Units (MODUs) performing drilling operations. The NORSOK N-003 standard (NORSOK N-003, 2017) on actions and action effects on offshore structures and provides guidance on the extent of the area where sea ice and icebergs may occur with an annual probability > 10^{-4} (Figure 1). The iceberg areal density and subsequent encounter probability have been analyzed further in several recent studies summarized by Eik et al. (2023). NORSOK N-003 states that all operations planned within areas where sea ice or icebergs are encountered with an annual probability >10^{-4} need to implement an ice risk management system (IMRS) to reduce the associated risks. Possible adverse consequences of ice-structure interaction are damage to the hull with subsequent loss of stability and/or loss of position. Use of a disconnectable structure that can move off location like a Dynamic Positioning (DP) or moored drilling rig is considered a part of the ice management system. The relevant ISO standards (ISO 35104 and ISO 19906) also puts out the principles, requirements, and guidance for establishing an IRMS, but are in general focused towards areas with more frequent ice occurrence than in the southern Barents Sea. Figure 1 shows the well locations where the IRMS described in the present paper was implemented (2017-2021). All the wells are within the 10^{-4} annual encounter probability for both sea ice and icebergs, but the ice frequency increases towards the northernmost drilling locations in the east (Dezecot and Eik, 2015). Furthermore, the Norwegian Government's integrated management plan for the Barents Sea (Meld. St. 20., 2019-2020) states that no drilling in oil-bearing layers should take place closer than 50 km from sea ice.

The ALARP (As Low As Reasonably Practicable) principle is embodied in the Framework regulations for petroleum activities in Norway (Petroleum Safety Authority, 2011), which states that *"In reducing the risk, the responsible party shall choose the technical, operational or organisational solutions that, according to an individual and overall evaluation of the potential harm and present and future use, offer the best results, provided the costs are not significantly disproportionate to the risk reduction achieved"*. For ice risk management in areas with very low probability of encountering ice, adhering to the ALARP principle implies that measures that further reduces the ice risk should still be implemented if the associated cost is not unreasonable (Ruud, 2019). The present paper describes how this was done in practice for the 2017-2021 exploration wells in the southern Barents Sea (Figure 1).

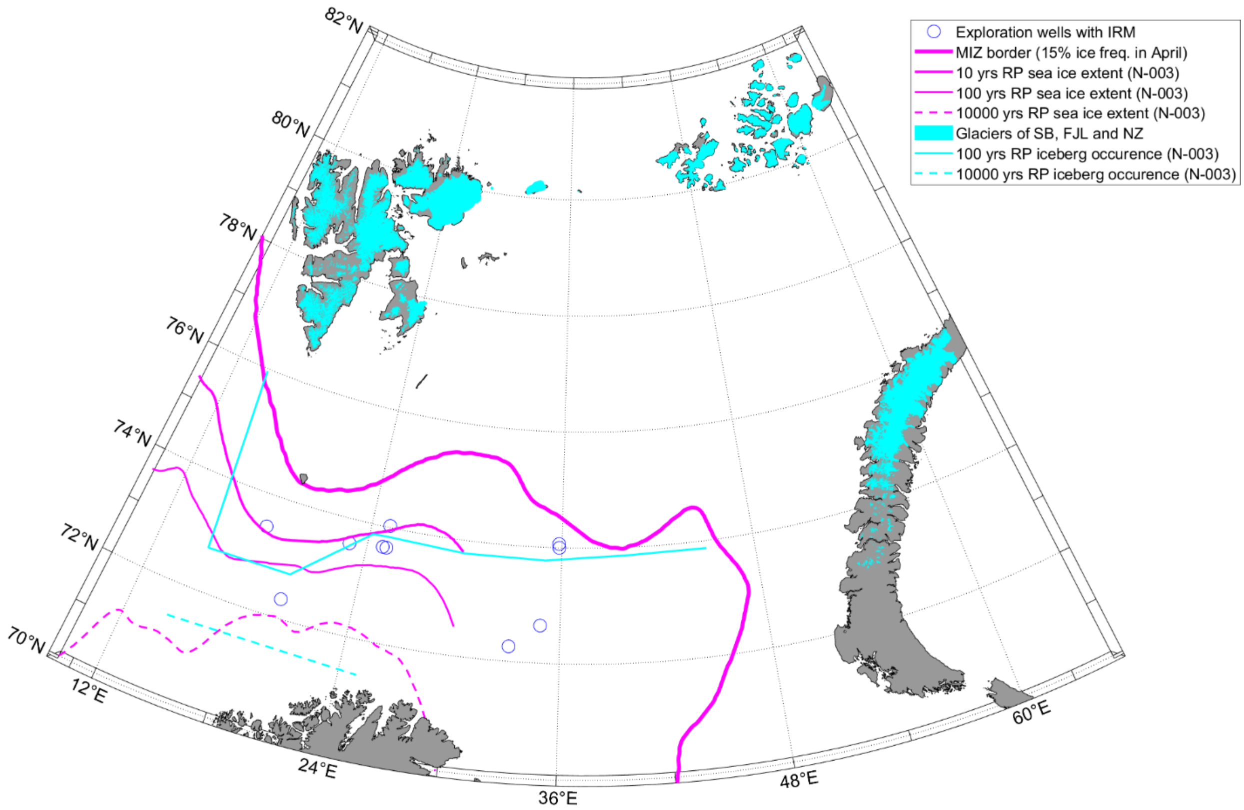

Figure 1. Map of the Barents Sea, showing drilling locations (2017-2021) where ice risk management was implemented, the border of the Marginal Ice Zone (Meld. St. 20. (2019-2020), p. 33), sea ice extent and iceberg occurrence at different return periods as defined by (NORSOK N-003, 2017).

ICE RISK MANAGEMENT SYSTEM (IRMS)

The overall ice risk management strategy for the exploration drilling campaign was to avoid any physical contact with ice. This was achieved by implementing an IRMS as described in the ice risk management plan for the different wells and MODUs. The IRMS would ensure a timely suspension of operation and, if required, a temporary move from the drilling location. In Figure 2, a schematic of the different components of the IRMS is shown. The cycle of adapting to the ice situation by updating the use of the different surveillance resources to inform the decision making resembles Boyd's OODA (Observe Orientate Decide Act) loop (see e.g. (Richards, 2020)).

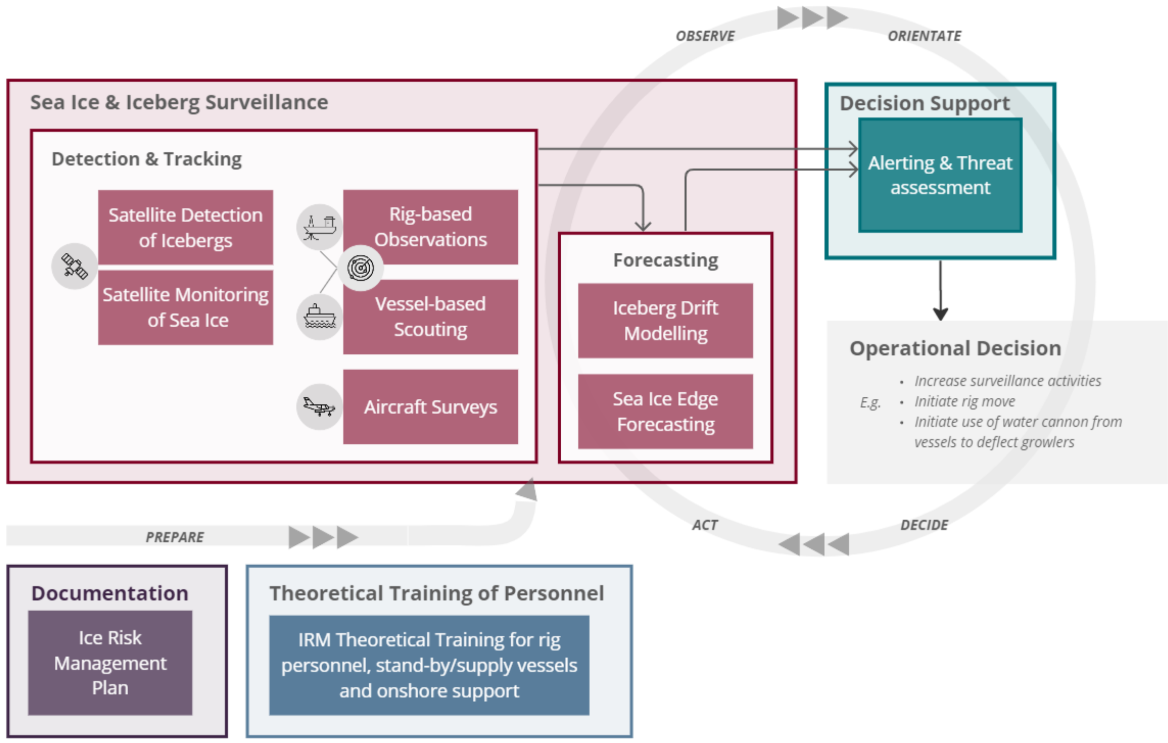

Figure 2. Components of the IRMS and Boyd's OODA loop.

Ice Risk management plan

An ice risk management plan specific to each drilling rig and locations was prepared. This document gives an overview of how sea ice and iceberg hazards may affect drilling operations, details the procedures to deal with ice risks for operations, and specifies the organization and duties of personnel. The document was co-signed by both the drilling contractor and the operator. The different roles in the IRMS are illustrated in Figure 3. The Dynamic Positioning (DP) operators onboard the drilling rig took the role of ice advisors (IA). They would collate and evaluate information from ice and weather forecasts and observations from supply/standby vessels and ensure continuous radar surveillance from the MODU. The IA is responsible for continuously updating and communicating estimates on Threat Arrival Time and advise the Offshore Installation Manager (OIM) in establishing the Ice Alert Level. The OIM is the final authority with regards to safety on the rig and has the responsibility to leave the drill site in response to any ice hazard. Onshore support was provided by the Equinor Operation Centre for Logistics and Emergency preparedness (OPCLE). This centre is manned 24/7 as a part of the standard emergency preparedness organization and encompasses personnel with broad experience from maritime and offshore activities. OPCLE is the primary contact for support related to ice surveillance but may consult with the company's subject matter experts on ice risk management.

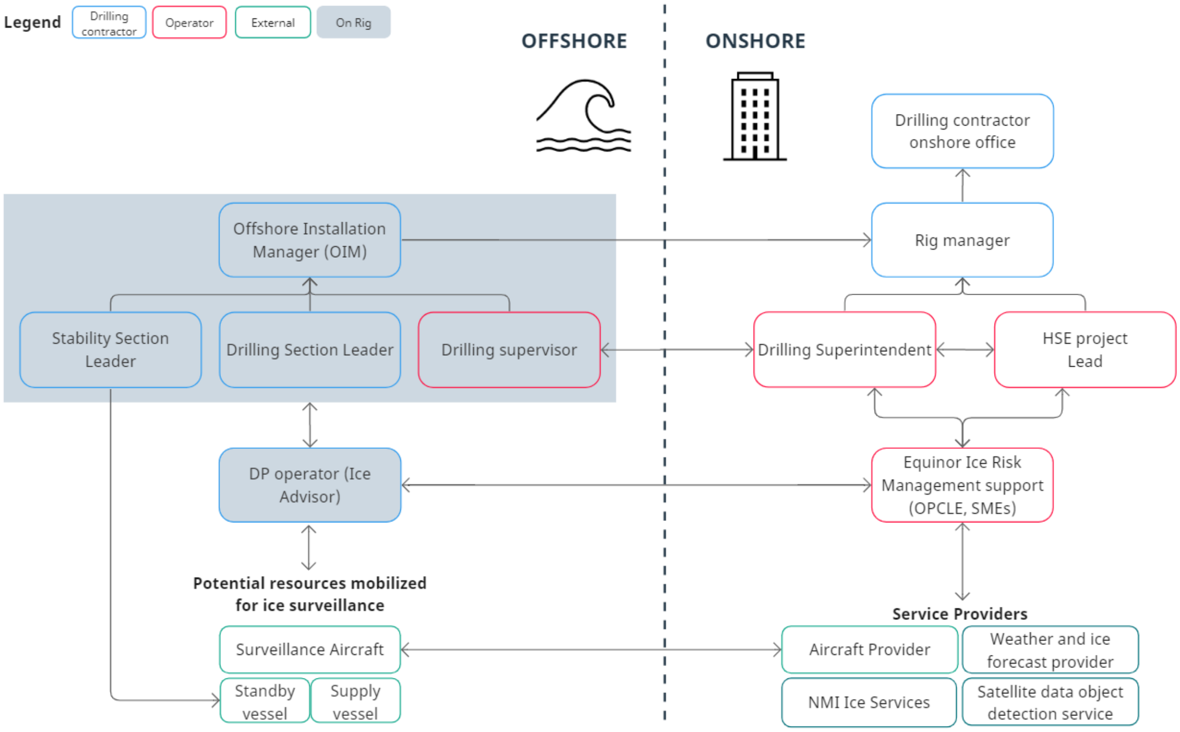

Figure 3. Overview of roles involved in the IRMS.

Sea Ice and Iceberg Surveillance

The main components in the ice surveillance system are shown in Figure 4. For sea ice, the primary means of monitoring the situation is the daily ice charts issued publicly by the Norwegian Meteorological Institute (NMI). A GIS based tool had been developed to automatically keep track of the distance to the closest ice in the ice charts. For icebergs, the primary source of information was feature detection reports based on available satellite images covering a predefined area of interest around the well location. These detection reports were started around one week before the rig would arrive at the location and would be produced once per day during the winter season (January to June) and every third day during the summer season (July to December). Unknown detections (objects that could not be identified as a vessel from the AIS signal) automatically triggered an iceberg trajectory model to be run by the weather forecast provider. The satellite images also give a good confirmation of the location of the sea ice edge. In addition, prior to the rig moving into a new location, a surveillance flight with a fixed wing aircraft would be carried out to screen the area for small icebergs that had not been picked up by the satellite detection (Figure 5). Once at the location, the rig and standby/supply vessels would monitor their marine radars and keep visual outlook for potential ice. The standby/supply vessels were also used to do scouting of the upstream area when potential ice detections were made by satellite. The fixed wing aircraft could also be called upon to do verification of potential iceberg detections in satellite images, but this was never required throughout the drilling campaign. During the winter and spring months, when sea ice would be expand and be present further south in the Barents Sea, sea ice edge forecasts were ordered from the NMI, providing a five days' outlook for the position of the sea ice.

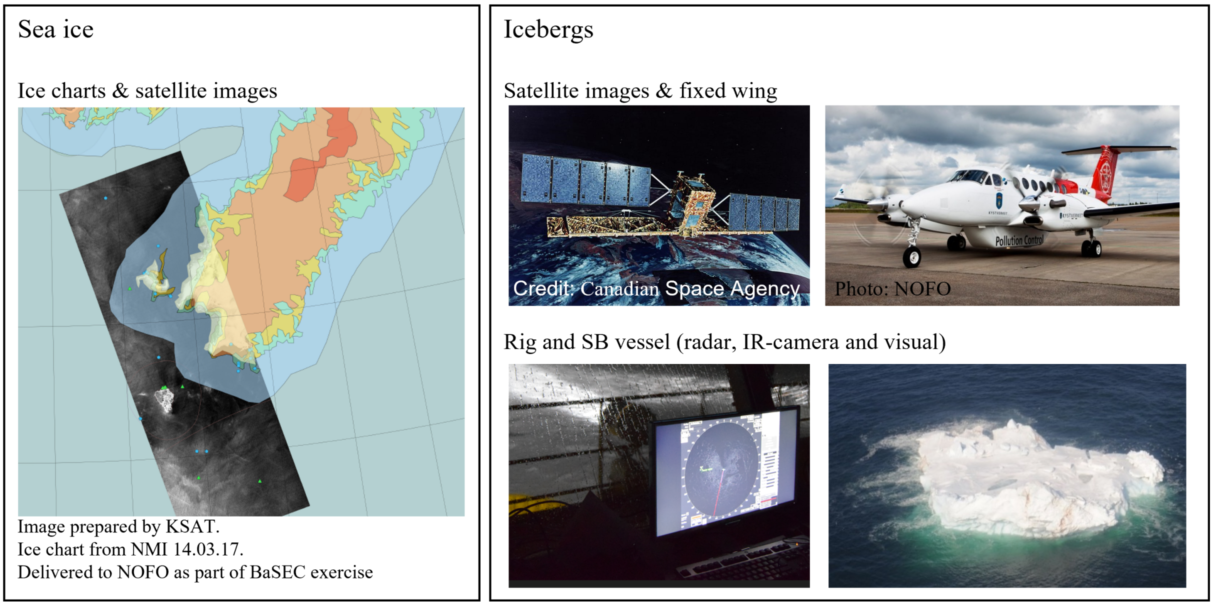

Figure 4. Ice surveillance components – a combination of different sensors and platforms for surveillance at different spatial scales and frequency. NOFO: The Norwegian Clean Seas Association for Operating Companies. BaSEC: Barents Sea Exploration Collaboration.

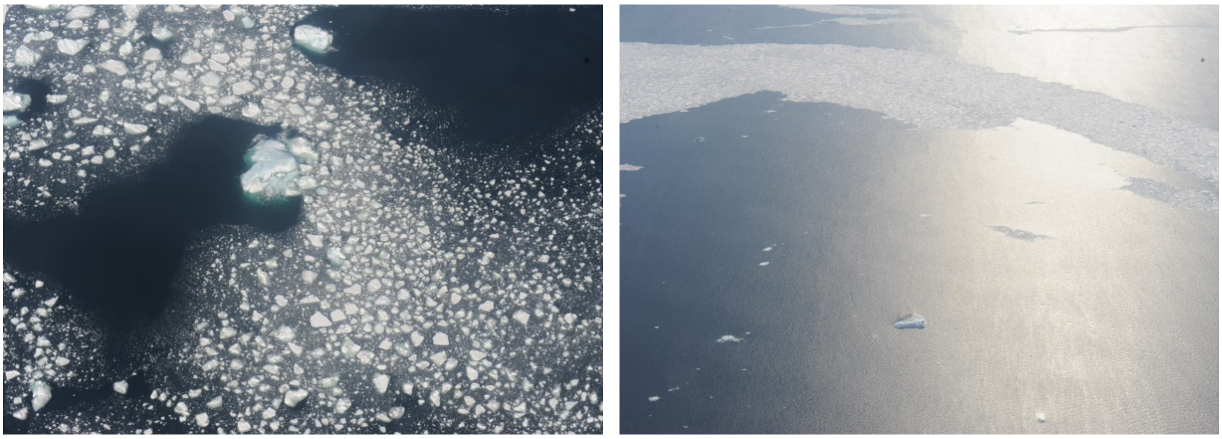

Figure 5. Pictures of patches of broken sea ice and an embedded iceberg (left) from a surveillance flight ~100 km to the north of one of the drilling locations.

Ice risk management training

The ice risk management training was organized as separate training sessions targeting groups with different roles in the IRMS:

- ✓ Drilling rig (one session per crew change – for personnel with ice risk management responsibilities)
- ✓ Support vessels
- ✓ Satellite data and weather forecast provider
- ✓ Equinor Operation Centre for Logistics and Emergency preparedness (onshore surveillance support)

- ✓ Equinor drilling management

The main topics covered in the training sessions were:

- ✓ Physical environment at well locations, with focus on sea ice and icebergs
- ✓ Ice risk management principles
- ✓ Content of Ice Risk Management Plan
- ✓ Practical exercises on ice threat assessment
- ✓ Learnings from past incidents
- ✓ Available forecasting services

The format of the training sessions was normally classroom sessions arranged by personnel with in-depth competence on cold climate. The duration of the session was 2-3 hours at a location close to the heliport operations. For personnel who were logistically difficult to gather (vessel personnel) or had more peripheral support functions (external providers of satellite data or weather forecasts), virtual classroom sessions were arranged.

LESSONS LEARNED

It is challenging to maintain awareness to ice risk in an area like the southern Barents Sea, where the frequency of ice intrusions is so low. As an example, in the satellite detection reports the number of false alarms will greatly outnumber the number of true iceberg detections. For permanent operations, this will require a high degree of automation.

An important principle in ice risk management is that the final decision on how to respond to an ice threat is taken by the offshore organization. Still, for the system to work, a good collaboration between offshore and onshore support is needed. An example of this from the exploration drilling campaign is how a situation with an unknown detection in the satellite report was dealt with (Figure 6). An unknown detection 38 km north of the drilling location was issued by the satellite object detection service. There were strong winds from the north and the automatic iceberg trajectory model run showed that the object would move closer to the rig if it was an iceberg. The DP operator/IA on the drilling rig consulted with the onshore operations centre and decided to request the stand-by vessel to position itself 5 nm north of the rig to keep a sharp lookout. In the subsequent detection reports, there was no unknown object, no objects were seen on the marine radar and the alert was eventually called off. Similar situations are likely to arise for permanent operations and to maintain alertness after checking many false detections without any real icebergs will be a challenge.

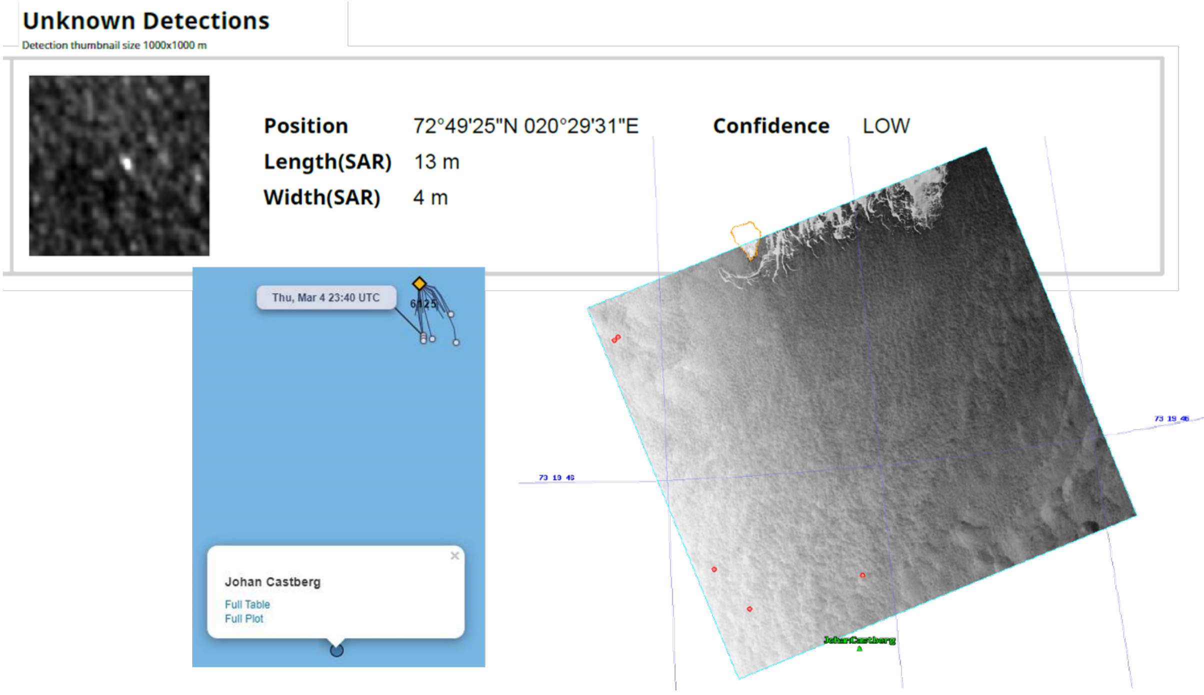

Figure 6. Unknown detection (top) 38 km to the north of one of the drilling locations in a SAR image (lower right). Iceberg drift trajectory modelling (shown in the lower left corner) was automatically initiated by the weather forecast provider.

SUMMARY

The drilling campaign (2017-2021) was carried out without any physical contact with ice and in compliance with the requirement that no drilling in oil-bearing layers should take place closer than 50 km from the observable ice edge. The IRMS for the drilling campaign was based on ALARP principles, using ice surveillance to keep track of any ice, and being prepared to move off location if any ice should approach, thus deliberately avoiding physical ice management due to the high cost and low overall risk. During operations, the drilling organizations had full control over ice presence and would have been ready to keep a safe distance to any ice if it was approaching drill location.

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