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Near field ice detection using infrared based optical imaging technology

Hazem Abdel-Moati [a,*], Jonathan Morris [b], Yousheng Zeng [b], Martin Wesley Corie II [b], Victor Garas Yanni [c]

[a] ExxonMobil Research Qatar, Qatar Science and Technology Park, PO Box 22500, Doha, Qatar
[b] Providence Photonics LLC, 1201 Main Street, Baton Rouge, LA 70802, United States
[c] ExxonMobil Upstream Research Company, 22777 Springwoods Village, Spring, TX 77389, United States

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ABSTRACT

If not detected and characterized, icebergs can potentially pose a hazard to oil and gas exploration, development and production operations in arctic environments as well as commercial shipping channels. In general, very large bergs are tracked and predicted using models or satellite imagery. Small and medium bergs are detectable using conventional marine radar. As icebergs decay they shed bergy bits and growlers, which are much smaller and more difficult to detect. Their low profile above the water surface, in addition to occasional relatively high seas, makes them invisible to conventional marine radar.

Visual inspection is the most common method used to detect bergy bits and growlers, but the effectiveness of visual inspections is reduced by operator fatigue and low light conditions. The potential hazard from bergy bits and growlers is further increased by short detection range (<1 km). As such, there is a need for robust and autonomous near-field detection of such smaller icebergs. This paper presents a review of iceberg detection technology and explores applications for infrared imagers in the field. Preliminary experiments are performed and recommendations are made for future work, including a proposed imager design which would be suited for near field ice detection.

1. Introduction

If not detected and characterized, icebergs can potentially pose a hazard to oil and gas exploration, development and production operations in arctic environments as well as commercial shipping channels. Largely prompted by the sinking of the RMS TITANIC, the International Ice Patrol (IIP [1]) was established in 1914 in order to track icebergs in shipping lanes in the North Atlantic Ocean using various methods, including but not limited to, satellites, airborne and ship-borne surveillance systems. Table 1 shows the iceberg size classifications established by IIP.

In general, very large bergs are tracked and predicted using models or satellite imagery. Their location can be determined while they are still a long distance from the production facility or shipping lane (>15 km). Small and medium bergs are generally detectable using conventional marine radar and are generally detected at shorter distances (1–15 km). As icebergs decay, they shed bergy bits and growlers, which are much smaller and more difficult to detect. Their low profile above the water surface, in addition to occasional relatively high seas, makes them invisible to conventional marine radar. Visual inspection is the most common method used to detect them, but the effectiveness of visual inspections is reduced by operator fatigue and low light conditions (fog and nighttime), which are not uncommon in many arctic regions. The potential hazard from bergy bits and growlers is further increased by the short detection range (<1 km) As such, there is a need for a robust and autonomous near-field detection of these smaller icebergs. This paper presents the current state of the art in iceberg detection and explores applications for infrared imagers in near-field ice detection.

Campbell et al. [2] has shown that satellite data, including high resolution visible images and Synthetic Aperture Radar (SAR), is generally used to discriminate open water from sea ice and large scale ice drift patterns. Although satellite data has demonstrated the ability to detect icebergs as small as 10 m, there are some significant limitations. Revisit times between satellite data windows can limit the effectiveness for near field ice detection. There is also a tradeoff to be made between resolution and footprint which can limit the coverage of satellite data. Data availability for satellite coverage can also be limited by multiple requests for data in different regions. Proliferation of smaller, dedicated satellites have the potential to address these limitations and provide better ice monitoring.

Stein Sandven [3] proposes using a multi-sensor approach by combining Synthetic Aperture Radar (SAR) and high resolution

* Corresponding author.
E-mail addresses: hamoati@gmail.com, hazemm.abdelmoati@exxonmobil.com (H. Abdel-Moati).

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Table 1
Iceberg size categories per IIP classification.

	Height (m)	Length (m)	Detection method
Growler	<1	<5	Visual Observation
Bergy Bits	1–4	5–14	Visual Observation
Small	5–15	15–60	Shipborne Radar
Medium	16–45	61–122	Shipborne Radar
Large	46–75	123–213	Airborne Radar, Satellites
Very Large	>75	>213	Prediction Models, Airborne Radar, Satellites

optical images that has the potential to detect small icebergs (horizontal extents >10 m). Fig. 1 shows one such study in the northern Barents Sea, highlighted by Kloster and Spring [4] and Sandven et al. [5], that investigated 15 icebergs ranging in size from 50 m to 400 m using imager fusion from Landsat visible satellite imagery and ENVISAT SAR data.

Stein Sandven [3] points out that more advanced and higher resolution optical satellite data and SAR data should be able to reduce the detectable iceberg size to approximately 10 m but detection capability will be limited by cloud cover, fog and the backscatter of the surrounding sea ice or open water.

Modelling, or forecasting, is a technology for predicting the location of and drift of icebergs over time. It is not a real-time method to detect the presence of ice in a specific location as clarified by Kubat et al. [6]. Drift of icebergs is modeled by considering the various forces that act on each iceberg, and solving the linear movement equations.

Sensitivity studies performed by Kubat et al. [6] were able to define the sensitivities in the model as follows: Water current has the most pronounced effect on the forecasts, then the waterline length of the iceberg. Waves might have an important role but more data collection is needed. Values of water and air drag coefficients had the smallest effect on the forecasts.

Iceberg models of the Barents and Kara Sea, developed by Keghouche et al. [7], have suggested that icebergs originating from Franz Josef Land have the largest spread over the domain, even though lack of iceberg drift observations can make validation complicated. This information is useful for planning shipping routes and drilling locations, as iceberg mitigation operations are expensive as explained by Gusdal and Brostrom [8].

Radar radio detecting and ranging) is a standard sensor platform on ocean vessels, but conventional marine radar is unable detect small floes of ice, bergy bits, or growlers early enough to avoid collision. In 2006 and 2007, O'Connell [9] chronicled a series of trials that were performed on a new high-speed radar platform, called Ice Hazard Radar, with the goals of detecting the weaker targets earlier and improving display quality.

The Ice Hazard Radar system, whose images can be seen in Fig. 2, was able to provide a marked improvement in detection over traditional marine x-band radar as shown in Table 2 below.

These highly detailed images from Ice Hazard Radar enable better maneuvering around difficult areas, saving time and fuel, while minimizing risk of damage. Periods of extended night time, fog, and snow highlight the usefulness of this radar platform as mentioned by O'Connell [9].

Aerial surveys are another tool for detecting ice in Arctic waters, and due to frequent fog and poor visibility, onboard radar is relied upon heavily. The International Ice Patrol (IIP) [1] flies a USCG HC-130 H at altitudes of 1800 to 2500 m on its 120 nautical mile inspection swath, which takes approximately four flight days. IIP uses Side-Looking Airborne Radar (SLAR, seen in Fig. 3) and Forward-Looking Airborne Radar FLAR) in parallel in order to provide best coverage for iceberg detection and tracking as confirmed by Stoermer and Tootle [10].

There are shortfalls for both FLAR an SLAR in the realm of iceberg detection. SLAR seems to be highly dependent on the sea state for the ability to detect growlers and small pieces of ice. Large seas decrease the likelihood that SLAR will detect a growler. Additionally, target identification with SLAR is a skill, so observers are left with many ambiguous targets. Small vessels that are slow moving or stationary are difficult to differentiate from icebergs. On the other hand, FLAR has failed to detect small and medium icebergs at the same range at which SLAR had been highly effective. However, due to the increasing maintenance cost of these systems, Stoermer and Tootle [10] have shown that the IIP is not planning on integration of SLAR and FLAR, and is currently investigating more cost effective technologies to replace airborne radar for ice reconnaissance.

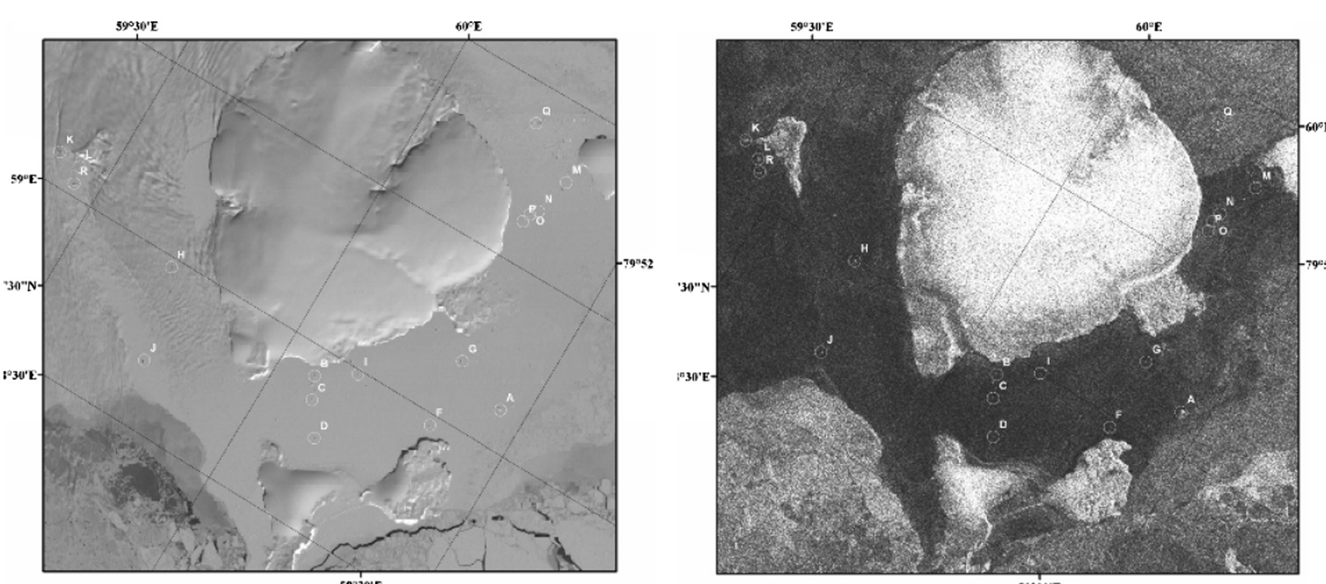

Fig. 1. Selection of icebergs with horizontal extents ranging from 50 to 400 m are identified in Landsat visible spectrum subimage (left) and ENVISAR Synthetic Aperture Radar (right).