Iceberg Detection and Characterization Capabilities: Field Trials in the Arctic Seas

Alexander V. Nesterov, Yuri G. Gavrilov, Igor V. Buzin*, Andrey A. Skutin and Yuri P. Gudoshnikov
Arctic and Antarctic Research Institute (AARI)
St. Petersburg, Russia

Konstantin A. Kornishin, Yaroslav O. Efimov and Petr A. Tarasov
Department of Marine Operations, Arctic Research Centre
Moscow, Russia

This article discusses various issues involved in identifying icebergs and their fragments using visual contrasts, an infrared camera, and an ice radar. The basis for this article is the research expeditionary work carried out in 2012–2017 in the waters of the Barents, Kara, and Laptev seas. The results of the expeditions revealed a significant effect of the size of the observed objects, wind speed and wave height, ship speed, and other parameters on the detection probability. Estimates for the maximum detection range of icebergs and the probability of their detection depending on the size and environmental parameters are presented. Recommendations for the optimal technological performance of a vessel for detecting icebergs and comparison with satellite and helicopter-based methods are formulated.

NOMENCLATURE

\[ D \] Distance of detection with given probability (km)  
\[ D_0 \] Horizontal visibility range (km)  
\[ D_{\text{max}} \] Limitation on the distance of detection (km)  
\[ H_s \] Significant wave height (m)  
\[ h_1, h_2 \] Distance of the observer and the iceberg above the sea level (m)  
\[ L \] Distance of detection with given probability (km)  
\[ L_0 = \Delta x \cdot 1.3 \] Minimum length of iceberg detectable from satellite images of the radar band (m)  
\[ P \] Probability of detection (km)  
\[ R_0 \] Range of the vessel’s radar (km)  
\[ \Delta x \] The “pixel size” of the satellite image  
\[ H_{01}, k \] Constants equal to 1.6 m and 2.3 m, respectively

INTRODUCTION

Detection of icebergs and correct assessment of the capabilities of detection tools and equipment are integral components to ensure safety during marine operations in iceberg waters. A feature of the icebergs of the northern hemisphere is their smaller size compared to the Antarctic icebergs. At the same time, an ice feature with above-water dimensions of only tens of meters can pose a danger to offshore facilities. In recent years, great progress has been made in algorithms of iceberg detection using satellite images. For example, the results of such interpretation were used to map icebergs on the Greenland shelf (http://ocean.dmi.dk/saliens). Within Google Earth Engine, automated workflow has been developed for the detection of icebergs using high spatial resolution timestamped Arctic Digital Elevation Model strip data.

(Shiggins et al., 2023). Based on data from Sentinel-1 medium-resolution satellite images, new algorithms are being developed to identify Arctic icebergs in conditions of sea noise and signals from ships (Heiselberg et al., 2022). This activity is often organized as different “hackathons” (Jang et al., 2017).

At the same time, the problem of detecting icebergs with characteristic sizes of tens to hundreds of meters during iceberg management activities should be solved using all available effective detection tools.

The paper presents the results of field trials on iceberg detection carried out in eight locations in the Kara and Barents Seas between September 12, 2017 and October 13, 2017: at four locations off the northern island of the Novaya Zemlya archipelago and at four locations off different outlet glaciers of the Franz Josef Land archipelago.

Some information was also used from other expeditions, conducted since 2012, aimed at research of metocean and ice conditions of the Russian Arctic shelf. Iceberg detection from a vessel using ice radar Rutter Sigma S6, visual observations, an infrared camera, and airborne reconnaissance were considered.

Practical considerations of applicability are discussed for each case, and correlation formulas for estimating the probability of iceberg detection as a function of iceberg size, environmental conditions, and distance are also presented.

RANGE LIMITS OF ICEBERG DETECTION

The theoretical limit on the detection distance to the object can be calculated from the height of the observer as

\[ D_{\text{max}} \approx 3.57 \cdot (\sqrt{h_1} + \sqrt{h_2}) \]  \hspace{1cm} (1)

where the distance \( D_{\text{max}} \) is measured in kilometers, and the heights \( h_1 \) and \( h_2 \) of the observer and the iceberg, respectively, above the sea level are in meters. According to the theoretical limitation above, with a navigation bridge height of about 20 m and an average iceberg height of about 10 m, the maximum iceberg detection range will be about 15 nautical miles (28 km).

At the same time, it should be noted that at this distance, the observer or the device is able to detect only the tip of the iceberg.