Icebergs detection and characterization capabilities: field trials in the Arctic Seas

Alexander V. Nesterov\textsuperscript{1}, Yury G. Gavrilov\textsuperscript{1}, Igor V. Buzin\textsuperscript{1}, Andrey A. Skutin\textsuperscript{1}, Yury P. Gudoshnikov\textsuperscript{1}, Konstantin A. Kornishin\textsuperscript{1}, Yaroslav O. Efimov\textsuperscript{2} and Petr A. Tarasov\textsuperscript{2}

\textsuperscript{1}Arctic and Antarctic Research Institute (AARI), St. Petersburg, Russia
\textsuperscript{2}Department of Marine Operations, Arctic Research Centre, Moscow, Russia

ABSTRACT

The article discusses various issues of 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 maximum detection range of icebergs, and probability of their detection depending on the size and environmental parameters are presented. Recommendations the optimal technological performance of a vessel for detecting icebergs, and comparison with satellite and helicopter based methods are formulated.

KEYWORDS: ice radar, iceberg detection; remote sensing;

NOMENCLATURE

\begin{align*}
D & \quad \text{distance of detection with given probability, km;} \\
D_0 & \quad \text{distance of detection with given probability, km;} \\
D_{\text{max}} & \quad \text{limitation on the distance of detection, km;} \\
H_s & \quad \text{significant wave height, m;} \\
h_1, h_2 & \quad \text{height of the observer and the iceberg above the sea level, m;} \\
L & \quad \text{distance of detection with given probability, km;} \\
L_0 & \quad \text{minimum length of iceberg detectable from satellite images of the radar band, m;} \\
P & \quad \text{probability of detection, km;} \\
R_0 & \quad \text{range of the vessel’s radar, kilometers} \\
\Delta x & \quad \text{the “pixel size” of the satellite image,} \\
\sigma_{\text{sat}} & \quad \text{and} \ k \text{ are constants equal to 1.6 m and 2.3 m, respectively.}
\end{align*}

INTRODUCTION

Detection of icebergs and correct assessment of 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 ones. At the same time an ice feature with above water dimensions of only tens of meters can have a mass of the order of hundreds of thousands of tons and pose a danger to offshore facilities. In recent years, great progress has been made in algorithms of icebergs detection using satellite images. For example, results of such interpretation were used to map icebergs on the Greenland shelf (http://ocean.dmi.dk/salienseas) 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 organised as different hackathons (Jang et al., 2022).

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 results of field trials on iceberg detection carried out in 8 locations the Kara and Barents Seas in autumn 2017 between 12.09.2017-13.10.2017: 4 locations off the northern island of the Novaya Zemlya archipelago and at 4 locations off different outlet glaciers of the Franz Josef Land archipelago.

Some information was also used from other expeditions aimed at research of metocean and ice conditions of the Russian arctic shelf, conducted since 2012. Icebergs detection from a vessel using ice radar Rutter Sigma-s6, visual observations, an infrared camera, as well as airborne reconnaissance were considered.

Practical considerations of applicability are discussed for each of the case, 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

In the wavelength range of visible light, infrared rays, radar devices of centimeter-range, the waves propagate almost rectilinearly. Then the theoretical limit on the detection distance to the object can be calculated from the height of the observer as:

\begin{equation}
D_{\text{max}} \approx 3.57 \cdot (\sqrt{h_1} + \sqrt{h_2})
\end{equation}