International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 23, No. 2, June 2013, pp. 96–103
http://www.isope.org/publications

Monitoring Thin Ice Thickness by Upward-looking Sonar in Bohai Sea

Jie Su, Bo Yang and Ling Du
Key Laboratory of Physical Oceanography, Ocean University of China
Qingdao, China

Shunying Ji
State Key Laboratory of Structural Analysis for Industrial Equipment
Dalian University of Technology, Dalian, China

The Bohai Sea is one of the lowest-latitude seas in the Northern Hemisphere where seasonal ice can be formed. The sea ice cover and thickness distribution are important factors affecting shipping navigation, coastal engineering and the safety operation of oil platforms. Upward-looking sonar (ULS) has been widely used to monitor ice thickness in polar regions since the 1990s, but studies of applying ULS to the measurement of thin ice have not been investigated thoroughly. During the winter of 2003-04, a ULS was deployed for the first time to measure ice thickness at an oil platform in the Bohai Sea. The data, collected at a relatively high sampling frequency, were obtained in real time. A practical processing method to derive thin ice thickness in the Bohai Sea, where there are strong tidal current, was developed. The role of the tide in affecting the residual total error in the determined mean ice thickness is discussed. The results of sea ice thicknesses derived were compared to observations and estimates from analysis of digital camera images. The correlation coefficient between the series was 0.67. The processing method shows reasonable skill in detecting thin ice.

INTRODUCTION

The Bohai Sea is the most northern area in the China Sea, bounded by latitudes 37°07′ to 41°0′N and longitudes 117°35′ to 121°10′ E. It is a semi-enclosed sea area surrounded by the Liaodong and Shandong Peninsulas, and it links with the Yellow Sea through the Bohai Strait. The Bohai Sea area covers 77,284 km^2, its average water depth is 18 m, and its maximum depth is 86 m. Every winter, sea ice appears due to the frequent invasion of the strong cold air. The ice season typically lasts for 3 to 4 months. The average level ice thickness could be from 20 to 40 cm depending on the weather conditions. Although the ice is thinner than in the polar regions, the overall ice condition is not necessarily mild. The tide and strong wind can pack the ice, causing a seriously difficult ice situation for ship navigation and inducing serious danger to the offshore oil/gas platforms. In 1969, the Bohai Sea was almost entirely covered by sea ice; in this severe ice condition, its tremendous force eventually collapsed 1 oil platform. Many ships were stacked in the ice for weeks (Bai et al., 1998). After 1969, ice monitoring and service began for the Bohai Sea, and the numerical sea ice forecasts started in the early 1990s (Wu, 1991). The monitoring of sea ice information, such as ice thickness, concentration and area, are also important for model validation. The real-time ice monitoring could help in issuing early warning of extreme ice hazards.

Sea ice thickness is an element which it is difficult and expensive to measure either directly or remotely. Thickness data observed directly from drill holes are highly accurate, but generally they have poor spatial and temporal coverage due to technical difficulties. Observations of thin ice conditions are very dangerous and highly dependent on weather and sea conditions. To measure sea ice thickness remotely, inductive radar is an option for multiyear ice floes, but still has challenges for unconsolidated first-year ice (Melling et al., 1995). Upward-looking sonars mounted on submarines have been measuring sea ice draft and ridging characteristics in the basins of the Arctic Ocean for several decades. Many ULS moored at fixed locations in the polar regions have provided high-quality sea ice draft estimates since the 1990s (Strass, 1998). Several ice-profiling sonars (IPS) have been deployed in the polar and subpolar regions (Birch et al., 1999). The IPS instruments were involved in many projects in all major global marine environments, including in areas east and north of Sakhalin Island, in the area off the northern coast of Sakhalin, in the Pechora Sea, in the St. Lawrence Seaway and Northumberland Strait (Melling et al., 1995; Birch et al., 2000; Fissel et al., 2008). Fukamachi et al. (2003) examined the variability of the sea-ice draft off Hokkaido in the Sea of Okhotsk based on the observations of a ULS along with an ADCP. Based on the observations of 3 ULS systems, deployed in the north-western Barents Sea for 2 years, it was suggested that the transport of ice from the Central Arctic into the Barents Sea appears to be associated with large-scale atmospheric variations such as the AO/NAO (Abrahamsen et al., 2006). The ULS was also used in examining the behavior of the Bering Sea St. Lawrence Island polynya, along with satellite imagery and salinity/temperature measurements (Drucker et al., 2003).

Although some ULS observational programs were carried out successfully in the shallow-depth waters (Drucker et al., 2003; Chave et al., 2004), difficulties remain applying this technology to very thin ice conditions in marginal ice zones. The relatively strong tidal currents in the Bohai Sea also affect the accuracy of this technology. During the winter of 2003-04, for the first time, a ULS was deployed to measure ice thickness in the Bohai Sea. The motivation was to build an ice observation system based on an oil platform and to obtain real-time sea ice data. A practical processing method to derive thin ice thickness is developed in this paper.

Received November 2, 2011; revised manuscript received by the editors February 16, 2013. The original version (prior to the final revised manuscript) was presented at the 20th International Offshore and Polar Engineering Conference (ISOPE-2010), Beijing, June 20–25, 2010.
KEY WORDS: ULS, Bohai Sea, sea ice thickness, tide.