Thin Ice Thickness Measured by Upward-Looking Sonar in a Marginal Sea

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ABSTRACT

Upward-looking sonar (ULS) has been used successfully to observe ice thickness in polar regions since the 1990s, but studies of applying ULS to the measurement of thin ice are rare. In the 2003/2004 winter, a ULS was deployed to measure ice thickness at an oil platform in Bohai Sea. The data, with a relatively high sampling frequency, were transmitted through a cable from the observation system and stored in a computer set on the platform and also sent to a remote computer in real time. A practical model to derive the thickness of thin ice in the marginal ice zones is developed. In the Bohai Sea, the tide is one of the significant hydrodynamic features. The role of tide in affecting the residual total error in the determined mean ice thickness is discussed. The results of sea ice thicknesses derived with the model were compared to observations and estimates from analysis of digital camera images. The model shows reasonable skill in detecting ice less than 0.5 m thick.

KEY WORDS: ULS; marginal sea; sea ice thickness, tide

1. INTRODUCTION

The sea ice cover and its variations in thickness in middle-high-latitude marginal seas are important factors affecting local shipping management, coastal engineering and the safety of oil platforms. Thin ice with a very short life cycle in marginal seas, such as in the Bohai Sea of China, is different from that in the polar regions. It occurs only in winter in the Bohai Sea. The ice conditions of the one-year old ice also show interannual variability, which is related to ENSO cycles (Bai et al. 2001). The Bohai Sea was almost entirely covered by ice in 1969; however the conditions have been mild in most of the years since 1986. With the tendency for global warming, the ice condition in Bohai Sea may provide an index of climate change. Ice measurements, such as ice thickness, ice concentration and ice area, are also important for the initial fields of the numerical sea ice forecast, for forecast verification, and for predicting extreme ice hazards.

Sea ice thickness is an element which is difficult and expensive to measure either directly or remotely. Thickness data observed directly from holes drilled through the ice are highly accurate, but generally have poor spatial and temporal coverage. Direct on-ice observations of thin ice conditions in marginal zones could be very dangerous and are 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 (ULSs) mounted on submarines have been measuring sea ice draft and ridging characteristics in the basins of the Arctic Ocean for several decades. Great efforts have been made recently in developing moored self-contained ULSs for detecting sea ice at fixed locations in the polar regions (Strass, 1998). Many ULSs have provided high quality sea ice draft estimates since the mid-1990s. A moored ULS has been developed to measure the underside topography of the polar pack ice (Melling et al., 1995). Fukamachi et al. (2003) examined the variability of 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 three ULS systems, deployed in the north-western Barents Sea for 2 years, it is suggested that the transport of ice from the Central Arctic into the Barents Sea appears to be associated with the large-scale 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). However, difficulties remain applying this technology for thin ice in marginal ice zones. This is mainly due to the fact that the sonar echo signal reflected from thin ice less than 0.7 m is very weak, so that the calculated ice thickness is not reliable. The relatively strong tidal currents in the marginal sea also affect the accuracy of this technology. For one-year old thin ice, few ULSs have been used successfully.

This paper is organized as follows: Section 2 describes the setup of a ULS system installed in Bohai Sea and the data recorded by the instrument; section 3 provides the data processing method, with an emphasis on the effect of the tides; it also compares the processed sea ice thickness data with the observations; the last section is the conclusion.

2. INSTRUMENTS AND DATA

A typical ULS system usually includes a sonar and a high precision