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Development of Accurate Ice Observation Technologies for Arctic Oil and Gas Developments and Verification by Field Campaigns

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ABSTRACT

Arctic is one of the most important areas for the future oil and gas development. However presence of ice is a serious hazard for safe, efficient and sustainable developments. The authors developed accurate ice observation technologies and verified their functions by field campaigns in Japan and Greenland. The "EM-BIRD" (airborne Electro-Magnetic induction sensor of ice thickness) was improved by installing a portable microwave radiometer (PMR) and a laser scanner for observing more comprehensive information including snow depth and surface geometry of ice. The authors developed the on-board pulse-doppler ice radar and the parametric sub-bottom profiler which are capable of measuring motions and distributions of sea ice, and gouging depth by massive ice features with high accuracy. The authors also developed ice database system containing satellite remote-sensing and field data measured by the developed sensors for the operability analysis of arctic facilities.

KEY WORDS: Ice observation; EM-BIRD; Pulse doppler radar ; Sub-bottom profiler

INTRODUCTION

Arctic is one of the most important areas for the future oil and gas development. For its safe, efficient and environmental-friendly developments, it is indispensable to accumulate and analyse ice information with high accuracy. Nowadays, satellite remote sensing by passive microwave radiometers is capable of providing sea ice information such as concentration, thickness and motion of sea ice on a regular basis. However, from the engineering point of view, sea ice information with higher special resolution and higher accuracy is required for the rational design and safe operation of arctic facilities. JOGMEC (Japan Oil, Gas and Metals National Corporation) conducted an R&D project on accurate ice observation technologies and ice database for offshore oil and gas development. Three Japanese universities, one research institute and one company joined the project. The authors established advanced sensor technologies for observing ice geometry and motion, and ice gouging on seabed with high accuracy. The authors also developed an ice database system to support the decision-making for industries to go into Arctic oil and gas developments. The main results of this project are summarized in the paper.

HIGH-ACCURATE ICE OBSERVATION SENSORS

Development of Advanced EM-BIRD

EM-BIRD (airborne Electro-Magnetic induction sea ice thickness profiler) is one of the most sophisticated technologies for measuring sea ice thickness with high accuracy in wide area (Haas and others, 2009). The first EM-BIRD in Japan was developed by Kitami Institute of Technology (KIT) in FY2011 under the support from JOGMEC. In the present R&D project, KIT and National Maritime Research Institute (NMRI) further improved the functions of the EM-BIRD by 1) installing a portable microwave radiometer (PMR) and a 2D laser scanner for observing more comprehensive information including snow depth and surface geometry of ice, 2) supplying electric power via a battery system, while it is supplied from helicopter for the original EM-BIRD. Figure1 shows the sensor part of the advanced EM-BIRD, the portable microwave radiometer stored inside the EM-BIRD and the test flight using the battery system.

Figure1. Development of Advanced EM-BIRD

KIT and NMRI conducted the field campaigns at Saroma Lagoon in the northern Japan and Qaanaaq in Greenland. From the field campaign in Saroma Lagoon performed from 25th February to 6th March in 2016 (right hand side of Figure2), it was verified that the EM-BIRD could measure the total thickness (ice plus snow thickness) of first-year ice ranged from 0.3 to 0.8m with a root-mean-square error (RMSE) of 0.05m against drill-hole measurements. It means that accuracy is about 10% of the total thickness of ice.

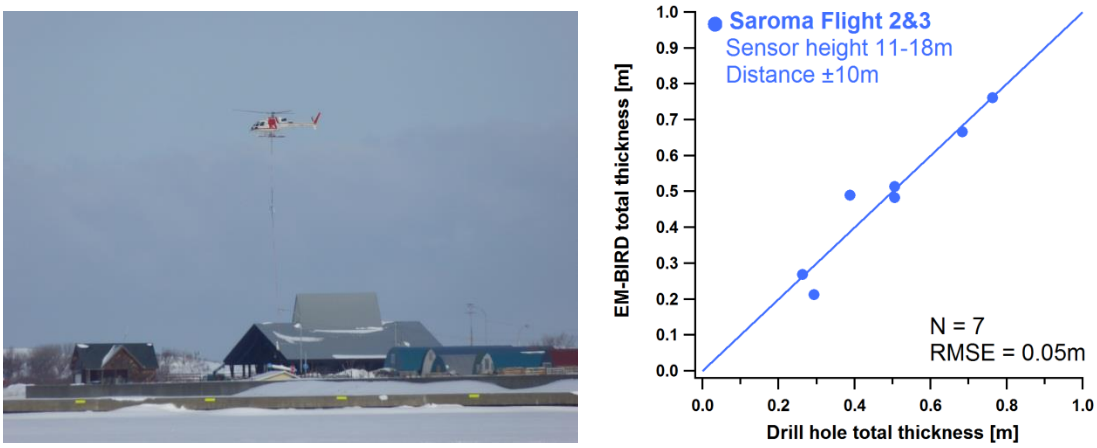


Figure 2. Field campaign at Saroma Lagoon

Helicopter flight (left), comparison of total thickness between EM-BIRD and in-situ measurement (right)

The field campaign was also conducted in Qaanaaq, northwest coast of Greenland from 21st to 26th April in 2016. Comparison with drill-hole measurements revealed that the RMSE of the total thickness was 0.07m for ice of 1.2 to 1.4m thick (Figure 3 left). Figure 3 right shows the comparison of snow depth between PMR and in-situ measurement indicating a fairly good agreement (RSME=0.06m). Advanced EM-BIRD has potential to measure ice thickness and snow depth separately.

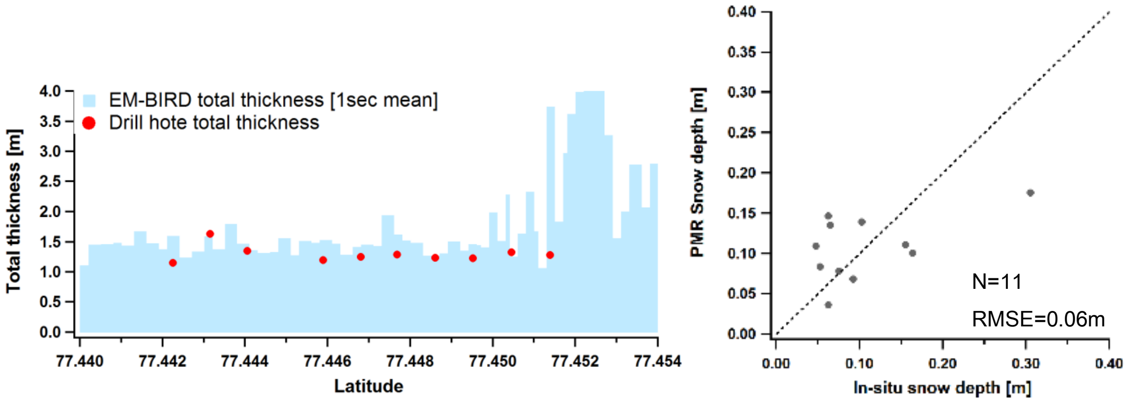


Figure 3. Field campaign at Qaanaaq, Greenland

Comparison of total thickness between EM-BIRD and in-situ measurement (left)

Comparison of snow depth between PMR and in-situ measurement (right)

Hybrid use of EM-BIRD and satellite SAR (Synthetic Aperture Radar) image is one of the key issues for obtaining high-resolution ice information around arctic oil and gas facilities. By comparing with the sea ice thickness by the EM-BIRD, the authors found a decreasing tendency of the back scatter coefficient of Synthetic Aperture Radar (SAR) against ice thickness. The authors proposed an algorithm for discrimination between un-deformed and deformed first year ice.

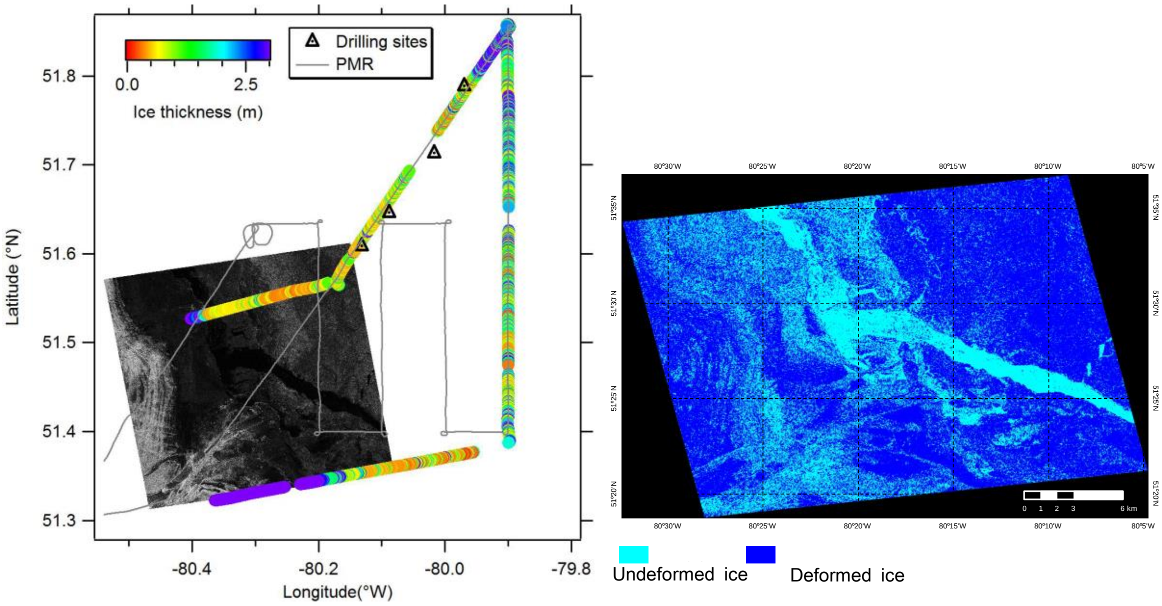


Figure 4. Flight path and total thickness by EM-BIRD and SAR image (left)

Discrimination of un-deformed and deformed ice (right)

Development of Onboard Pulse-doppler Radar

An X-band, pulse-doppler radar is one of the promising technologies for detecting motions of ice with higher accuracy than the existing marine radar. The University of Tokyo developed a prototype of a pulse-doppler radar and conducted a field campaign at the coast of the Sea of Okhotsk, Japan (Figure 5).

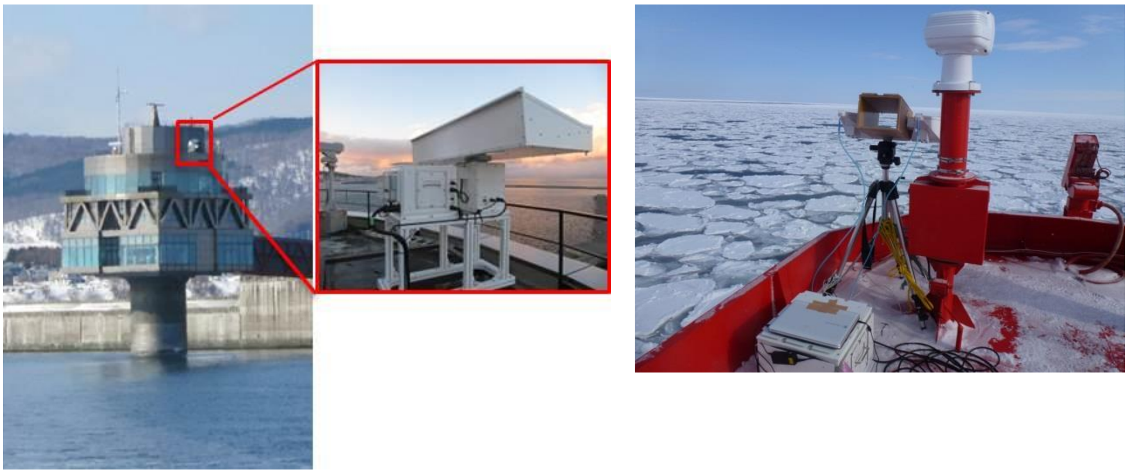


Figure 5. Ice radar at Okhotsk tower (left) and icebreaker Garinko (right)

A new algorithm was developed to detect presence and types of thin ice such as nilas and young ice in the range of 4 km (Figure 6). It is estimated that the ice radar system is capable of detecting massive ice feature 10km away from the radar.

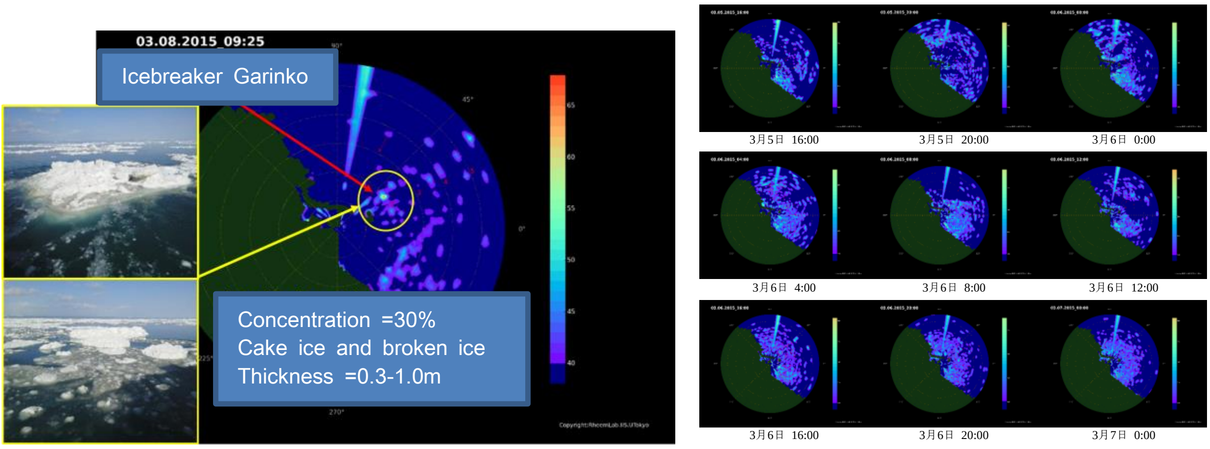


Figure 6. Matching radar image and ice observations (left) and four-hour interval images from 5th to 6th March, 2015 (right)

Development of Parametric Sub-bottom Profiler

Accurate measurement of gouge depth is important to protecting subsea equipment and pipelines from massive ice features such as icebergs. However, it is difficult to estimate its true depth if gouge is infilled by seabed sediment transport (ex. Palmer and Croasdale, 2012). The University of Tokyo developed a parametric sub-bottom profiler (PSBP) for detecting ice gouging depth including sub-bottom structure of sediment layers.

Figure 7. Sensor probe of PSBP (left) and experimental setup (right)

Field campaigns were conducted at Lake Aoki, Nagano and Saroma Lagoon, Hokkaido, Japan. The PSBP was able to have a finer view of sediment structure which was identified as a single layer by the boring survey. The PSBP has a potential to detect the original gouge depth infilled by sediment layers.

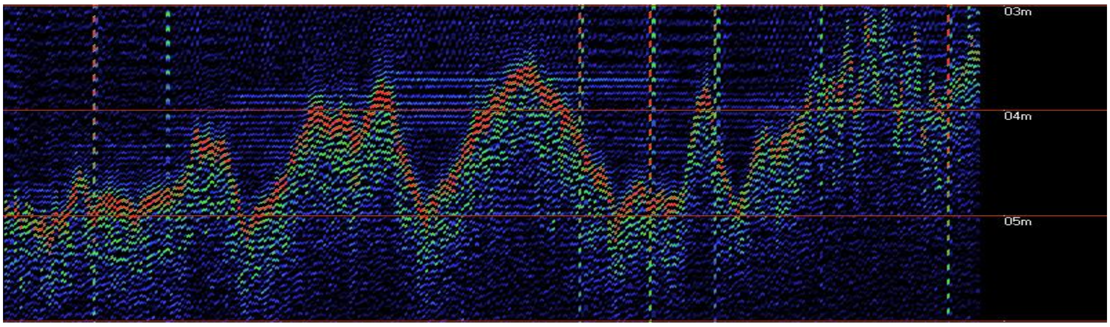
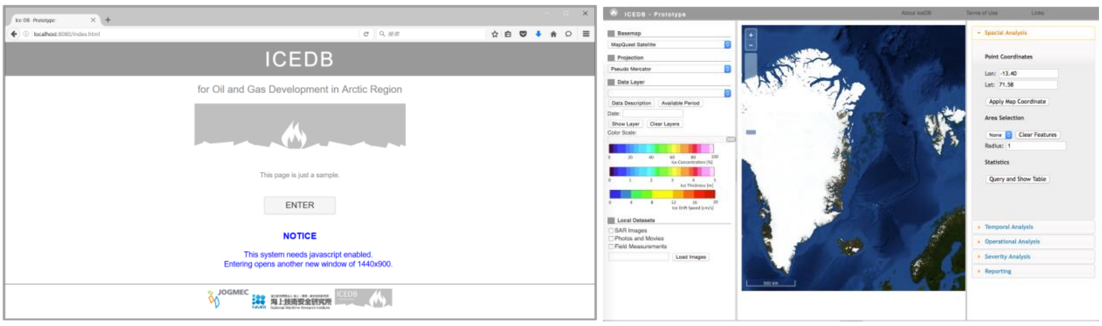


Figure 8. Sediment layer structure obtained by PSBP

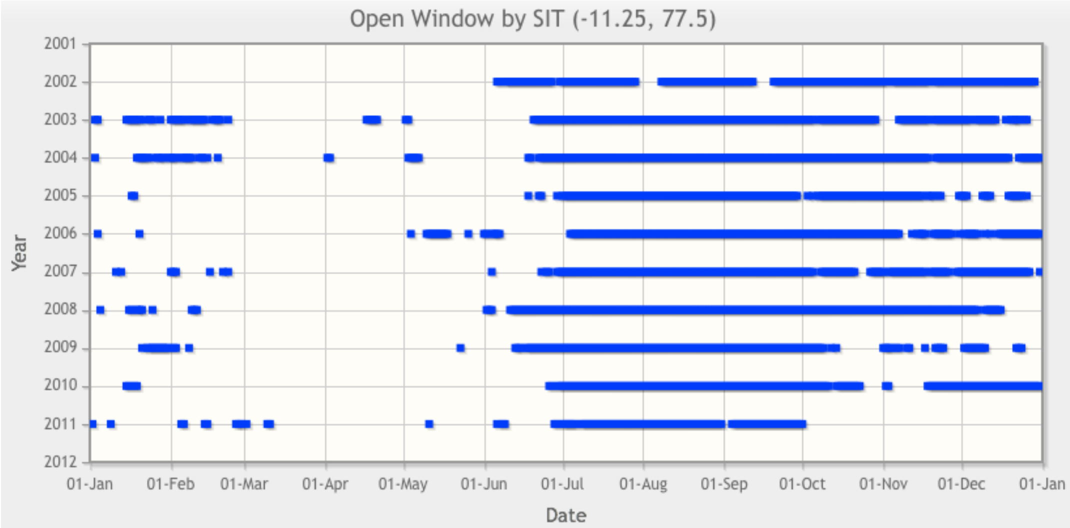
ICE DATABASE SYSTEM

An ice database system was developed for supporting designs and operations of Arctic oil and gas developments. It consists of ice data covering sea ice regions in the Northern Hemisphere and the interface enabling for users to browse and analyze data through the network as a web application (Figure 9). It has functions of spatial, temporal and operability analyses of ice conditions for design purposes, and those of displaying in-situ data measured by sensors such as the Advanced EM-BIRD, the on-board pulse doppler radar and the PSBP for the operation support. Figure 10 shows the result of operability analyses. Based on the limiting ice thickness derived from the experiences of operations in Beaufort Sea and using ice thickness information, it is capable of analyzing the operation window, a time window in which ice condition allows a given operation, from 2002 to 2011 for the drilling operation in North East Greenland (NEG).

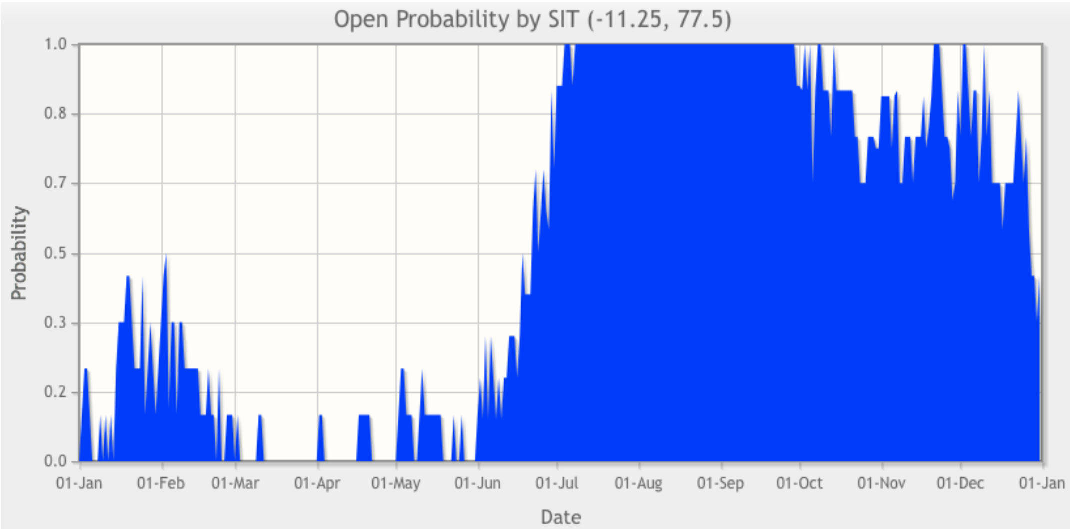


(a) Top page **(b) Interface**

Figure 9. Example views of the ice database system



(a) Operation window for drilling in NEG based on the limiting ice thickness condition



(b) Probability of operation windows

Figure 10. Operation window for the drilling operation in NEG

CONCLUSIONS

Arctic is one of the most important areas for the future oil and gas development. However presence of ice is a serious hazard for safe, efficient and sustainable developments. From the engineering point of view, sea ice information with high resolution and accuracy is required for the rational design and safe operation of arctic facilities. JOGMEC conducted the R&D project on accurate ice observation technologies and ice database for oil & gas development. Three Japanese universities, one research Institute and one company joined this project and developed the Advanced EM-BIRD, pulse doppler ice radar and sub-bottom profiler for observing ice and snow thickness, ice motion and ice-type discrimination, and gouging depth with layered sub-bottom sediment structure, respectively. Extensive field campaigns were conducted in Japan and northwest Greenland to verify their functionality and measurement accuracy. Ice database system was also developed containing satellite remote-sensing and field data measured by the developed sensors for the operability analysis of arctic facilities.

REFERENCES

Haas, C., Lobach, J., Hendricks, S., Rabenstein, L. and Pfaffling, A.,”Helicopter-borne measurements of sea ice thickness, using a small and lightweight, digital EM system” Journal of Applied Geophysics, 67, 234-241, 2009.

Palmer, A. and Croasdale, K., “Arctic Offshore Engineering”, World Scientific, 2012