Ocean wave research as an icebreaker to bridge polar science and engineering research

Takuji Waseda
Graduate School of Frontier Sciences, the University of Tokyo
Japan Agency for Marine-Earth Science and Technology

Japan has been engaged in coordinated government-sponsored Arctic research in the past 15 years, starting from the GRENE (Green Network of Excellence) project which was succeeded by the ArCS (Arctic Challenge for Sustainability), and ArCSII (Arctic Challenge for Sustainability II) projects. Each project is not independent of the other, and therefore over the past years, gradually the program has developed extending its scope from science to engineering, and social science. Japan, not being a part of the Arctic States, possesses a unique position in the Arctic research community. We hope that Japan continues its endeavor and takes a leadership role in bridging different disciplines.

This presentation aims to discuss how the new icebreaker can bridge between polar science and engineering. The Arctic Ocean is known to be the most sensitive to global warming. The sea ice in the summer Arctic Ocean is retracting and is the strongest signature of global warming on Earth. As the sea ice recedes, wind waves grow in the open waters, and the extreme wave events associated with polar cyclones increase[1)2)]. Those waves can propagate through the ice field, and eventually break the sea ice, possibly accelerating the melting of the sea ice[3)]. In October 2022, the strongest cyclone in the Western Arctic Ocean on record passed through the Canadian basin. The vast level ice field broke up after the passage of the cyclone, and resulted in a reduction of sea ice volume which was not explicable by atmospheric and oceanic heat transports[4)]. Waves inevitably play a significant role in the Arctic Ocean, and most likely will affect the local weather system and the coastal region. Coastal erosion, and the weakening of the land-fast ice in the Canadian Archipelago, will have a direct impact on the indigenous people in the Arctic region.

Growing waves are a threat to the ships in the Arctic Shipping Route (ASR) as well. Majority of the ship accidents in the Arctic Ocean are related to sea ice hitting the ships. As the open water area increases, drifting sea ice will be affected by the waves and become a threat to ships navigating through a rough sea state. Sea spray icing may be enhanced as well despite the air temperature increase, simply because the open water area is increasing. Prior knowledge of ocean waves is crucial for safe and efficient navigation of ships in the ASR.

It is apparent that for both scientific and engineering reasons, the advancement of the knowledge of ocean waves in the Arctic Ocean is essential. However, the accuracy of ocean wave forecasts needs to be improved. The forecast error is highly correlated with the uncertainty of the ice edge locations[5)] and is also affected by the uncertainty of the wind field[6)]. More observations are needed, and a coupled observation of waves, ice, and wind is needed. The use of a marine radar equipped on commercial vessels is a promising tool. RADAR by its definition, is used to detect and range the distance to the targets. The noise of the radar, called the sea clutter is known to relate to the wind waves and, therefore, can be analyzed to estimate the wave field. Sea ice is visible as the backscatter from the sea ice is much stronger than from the open water. Currently, the ice-wave radar is under development for the new Japanese Arctic R/V at JAMSTEC, to detect both sea ice and waves and eventually to detect sea-ice types and thickness.

Complementary to such remote sensing devices, deployments of expendable wave buoys will significantly improve the measurement accuracy[7)]. They can easily be deployed along the ship route, and remotely send data. Improvements in the data transmission bandwidth and the deployment method are necessary. For the latter, the use of drones (rotor and fixed wing) and helicopters is expected. During the 64th Japanese Antarctic Research Expedition, 21 wave buoys were deployed on the land-fast ice and drifting sea ice by a helicopter in the Lützow-Holm Bay within 60 km or so from the Syowa station. The buoys successfully observed the large drift of sea ice from April to May 2023, and the swells propagating through the ice triggering the breakups[8)]. Learning from the Antarctic expedition, buoy deployments along the trans-polar route and the surrounding ice fields will be desired. Those buoys should be the coupled instruments including wave sensors, atmospheric pressure sensors, wind anemometers, etc.

The Arctic Ocean is vulnerable to geopolitical perturbations. The possible ASR will depend on both climate variables and political constraints. Optimum routing inevitably requires archived as well as real-time data. The new Japanese Arctic R/V will be equipped with advanced sensing devices of the ship itself and the environmental variables. Those data will be archived on the ship. Those data should be assimilated into a hierarchy of coupled models and the assimilated models should be used to select the optimum locations of the measurements. A requirement for the deliverables should come from the users that will include, scientists, engineers, social scientists, and the local community. As the Chinese proverb says, whoever suggests should start. We propose to enhance ocean wave research in the Arctic Ocean to bridge science, engineering, and social science, and Arctic, and Antarctic research.

[References]

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