Estimation of the Arctic sea ice thickness based on the backward tracking analysis

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Since 1972, observations using satellite microwave sensors have provided continuous images of sea ice. It improved our knowledge of sea-ice cover and its temporal and spatial variability. This study aims to derive the ice thickness by a new way based on the backward tracking of sea ice. Thickness is the most important information about sea ice. However, monitoring of the ice thickness is not easy. There have been several attempts to derive the ice thickness from satellite data analysis or numerical models, but these have not yet produced satisfactorily accurate sea ice thickness data. We first analyze the ice trajectory traced back to the ice formation. Based on the derived trajectory, we examine the sea ice age and other parameters such as ice divergence/convergence or heat budget history.

This analysis uses the daily sea-ice velocity derived from satellite microwave sensor AMSR-E and AMSR2 data. The calculation of the ice drifting speed was based on a pattern matching method, the maximum cross correlation technique. This method determined the spatial offset that maximized the cross-correlation coefficient between two brightness temperature arrays in consecutive images separated by 24 hr. After applying filtering and interpolation processes, we constructed a daily ice-velocity dataset without missing data over the sea-ice area on a 60 × 60 km grid for 2003–2022. Backward trajectory is calculated using this daily ice motion. First, particles are arranged at an interval of 10 km over the ice area on a certain day. Daily displacement of particles is calculated from the ice velocity on one-day time steps. When the particle reaches open ocean (no-ice) area, we assume it to be ice production. In this way, birth place, birth day, and trajectory of sea ice were determined. In addition, heat budget was calculated assuming an open water at freezing temperature at the location of the daily particle, and the resulting daily growth was added up to derive the accumulated ice-thickness.

Generally, old thick sea-ice exists the Greenland-Canadian side of the Arctic. The area expands toward the Atlantic side along the north and west coasts of Greenland via the Transpolar Drift Stream and the East Greenland Current, and toward the North American side, moving across the Beaufort Sea to the East Siberian Sea. Sea ice thickness is estimated by developing an empirical formula that relates the sea ice thickness observed in the field to the estimated ice-history parameters such as the accumulated ice-thickness. Comparison of the accumulated ice-thickness with the observed values shows that a constant value multiplied by the accumulated ice-thickness agrees well with the observed ice-thickness. We aim to increase the number of observed values used and derive more versatile formulas for the derivation of the ice thickness by using other ice-history parameters.

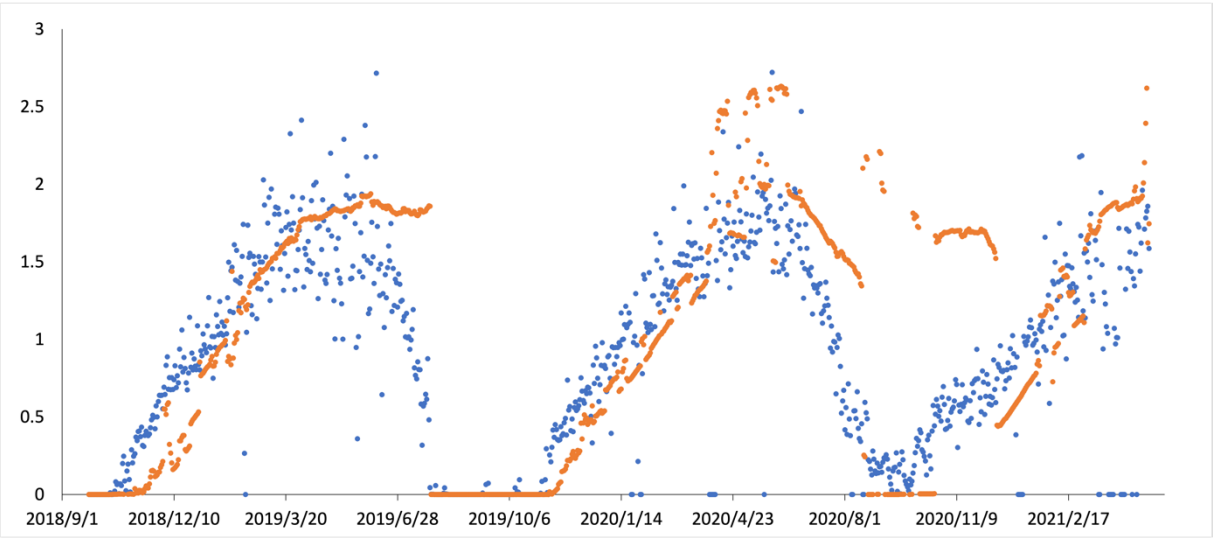

Fig 1. Time-series of the ice thickness observed by moored Upward Looking Sonar (blue dots) and accumulated ice-thickness (orange dots) in the Beaufort Sea