Estimation of ice thickness and volume in the Sea of Okhotsk using ICESat and CryoSat-2 data

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Sea-ice thickness in the Sea of Okhotsk is estimated from freeboard derived from satellite altimeter data. Ice thickness is estimated by assuming densities of sea ice, snow, and seawater based on in-situ observations (Toyota et al., 2007; Ohshima et al., 2001). Snow depth is assumed 10% of ice thickness by referring to in-situ observation (Toyota et al., 2007). Ice freeboard (thickness) derived from a laser altimeter GLAS on ICESat is used for 2004-08 (Nihashi et al., 2018). After 2011 to 2018, data from radar altimeter SIRAL-2 on CryoSat-2 is used. CryoSat-2 freeboard is obtained by a method of Kurtz et al. (2014). Comparison with ice thickness observed hourly aboard icebreaker Soya by visual observation suggests that ice thickness derived from ICESat and CryoSat-2 are almost consistent. Total ice thickness (ice thickness including snow depth) in February and March, when the sea-ice area is maximum, averaged over the entire sea-ice zone ranges from 77.5 cm (2008) to 123.0 cm (2017). The mode of total ice thickness ranges from 50-60 cm (2007; 2008; 2017) to 90-100 cm (2013). Ice volume in the Sea of Okhotsk is estimated from the total ice thickness and ice concentration derived from AMSR-E (2004-11), SSMI (2012), and AMSR2 (2013-18). Ice volume is estimated by interpolating these sea-ice datasets onto an NSIDC polar stereographic grid at a spatial resolution of about 12 km. The maximum ice volume is 8.3×10^{11} m^3 (2016), while the minimum is 5.4×10^{11} m^3 (2015). The interannual variability is shown to be mainly determined by the sea-ice area, although ice thickness seemed to be effective in 2008. It has been shown that the maximum sea-ice area and ice production in the Sea of Okhotsk can be explained from atmospheric and oceanographic conditions (e.g., Ohshima et al., 2006; Nakanowatari et al., 2010; Kashiwase et al., 2014). Based on these studies, we compare the ice volume with the atmospheric and oceanographic data. And then we find that the ice volume can be explained to some extent by the air temperature in the northwest and north of the sea just before the freezing season (November-December), the air temperature in the northwest of the sea during active freezing period (February-March), and the wind toward the offshore during the ice advance season (January-March). Multiple regression analysis is performed on the ice volume using these atmospheric conditions. And we try to reproduce the ice volume in the Sea of Okhotsk since the 1950s when the satellite data does not exist from the atmospheric data by using the regression line.

Keywords: Sea of Okhotsk, sea-ice thickness, satellite altimeter

