Circumpolar mapping of the Antarctic coastal polynyas with discrimination of ice type

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In Antarctic coastal polynyas, high production of sea ice occurs due to huge heat loss to atmosphere, resulting in the formation of dense water, precursor of Antarctic Bottom Water. Sea-ice production within polynyas is directly related to polynya extent and thin-ice thickness within the polynya. Thus, it is important for the calculation of sea-ice production to estimate thin ice thickness accurately. Several studies have developed algorithms for estimation of the thin ice thickness from brightness temperature (TB) of satellite passive microwave sensor [e.g., Martin et al., 2004; Nihashi and Ohshima, 2015]. In these algorithms, ice thickness of less than 20 cm is empirically estimated by utilizing negative correlation between the ice thickness and a ratio of the horizontally to vertically polarized TBs (PR). Several studies have also extended these algorithms to mapping of sea-ice production for Antarctic coastal polynyas. However, ice type, which has an influence on microwave characteristic of thin-ice, has not been considered in these algorithms.

Thin ice (polynya) areas are classified roughly into two ice types. One is active frazil type: a mixture of open water and frazil/grease ice areas. The other is thin solid ice type: nearly uniform thin ice covered area. Nakata et al. [in prep.] indicated that PR-thickness relationships are different clearly between these two ice types: active frazil type has much smaller thickness than solid ice for the same PR value. Based on the result, Nakata et al. [in prep.] also developed a thin ice algorithm in which ice thickness for each ice type is estimated from the corresponding empirical equation after discrimination of ice type. This improved algorithm provides more accurate estimation of sea-ice production. In addition, the algorithm can specify a predominant ice type for each Antarctic coastal polynya, which is useful for examination of the polynya dynamics. In this study, we apply the new algorithm to the entire Southern Ocean and carry out mapping of the Antarctic coastal polynya and its ice production.

We used AMSR-E/Aqua Level 2A (L2A) global swath spatially resampled TBs at 36 and 89GHz. We first mapped all AMSR-E L2A data obtained within a day onto the NSIDC polar stereographic grid (the spatial resolution of 6.25 km), with the land and fast ice mask by Nihashi and Ohshima [2015]. Then, we use the algorithm to obtain ice-type and thin ice thickness. Sea-ice production is calculated from heat flux calculation using the obtained thin ice thickness and ERA-Interim atmospheric data. From the above procedure, we create a data set of ice type, thin ice thickness and ice production for the entire Southern Ocean on a daily basis, during winter (April-October) for the period 2003-2010.

The climatological mapping shows that the active frazil type is more predominant in polynyas in the East Antarctica, where the strong offshore wind is prevailing. Thin solid ice type is predominant in polynyas with relative weak wind, such as in the Ross Ice Shelf polynya. These suggest that the difference in predominant ice type is mainly caused by the difference in strength of offshore wind.

In the previous algorithms, ice thickness was overestimated because the PR-thickness relationship is similar to that of the thin solid ice type. In the new algorithm, sea-ice production in the polynyas along the East Antarctica is corrected. Especially, sea ice production in the Cape Darnley polynya with the highest occurrence frequency of active frazil type is calculated to be about 1.5 times as that of the previous studies.

Keywords: coastal polynya, ice type, sea-ice production, AMSR-E

