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Sea ice production and bottom water formation in the Southern Ocean from a global view

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Global overturning circulation is driven by density differences: water sinks in dense water formation areas and then gradually upwells in other areas. Densest water is produced in the Southern Ocean and named as Antarctic Bottom Water (AABW). AABW extends to the abyssal layer of the global ocean, accounting for 30-40% of the global ocean mass. AABW production is a major contributor to the global overturning circulation and represents an important sink for heat and possibly CO_2. AABW originates as dense shelf water, which forms on the continental shelf by regionally varying combinations of brine rejection from sea ice growth and ocean/ice-shelf interactions. By contrast, such dense/bottom water cannot be produced in the Arctic Ocean. Densest water in the North Pacific is produced in the Okhotsk Sea, which causes the North Pacific overturning extending to the intermediate layer. Saline water rejected during sea ice formation is the main source of such dense water, and thus sea ice production is a key factor in the overturning circulation. We have developed an algorithm to estimate sea ice production globally from satellite data with heat flux calculation. Global mapping of sea ice production demonstrates that the production rate is particularly high in the Antarctic coastal polynyas, in contrast to the Arctic ones. This is consistent with the formation of Antarctic Bottom Water (AABW). High sea ice production around the Antarctica is caused by two factors. One is divergent ice field there, resulting in active polynya formation, which is in contrast to the Arctic Ocean. The other factor is the presence of fast ice (landfast ice and glacier tongue). Most of the Antarctic polynyas are formed on the western side of fast ice. Winds diverging from a boundary comprising both coastline and fast ice are the primary determinant of polynya formation. The blocking effect of fast ice on westward sea ice advection by the coastal current would be another key factor. The Cape Darnley polynya (65-69E) is found to be the second highest ice production area in the Southern Ocean, suggesting a source of AABW. Recent Japanese IPY observations revealed that this is the missing (fourth) source of AABW. In the region off the Mertz Glacier Tongue (MGT), the third source of AABW, sea ice production decreased by as much as 40%, due to the MGT calving in early 2010. Recent observations suggested a significant reduction in AABW there, likely caused by the decrease in sea ice production. These demonstrate the strong linkage between variabilities of sea ice production and bottom water.

Keywords: Antarctic Bottom Water, sea ice production, coastal polynya, overturning, landfast ice