SEA ICE PRODUCTION IN THE POLYNYA AND THE ASSOCIATED BOTTOM WATER FORMATION OFF THE CAPE DARNLEY, EAST ANTARCTICA

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1. INTRODUCTION

It is widely recognized that dense water formation caused by brine rejection due to high ice production in Antarctic coastal polynyas is responsible for the formation of Antarctic Bottom Water (AABW), which is the densest water mass in the world ocean. Antarctic coastal polynyas are formed by divergent ice motion due to prevailing winds and/or oceanic currents, and most of the area is covered with thin ice. During winter, heat loss over thin ice is one or two orders of magnitude larger than that over thick ice, and thus coastal polynyas are regarded as the ice production factories. Active and passive satellite microwave data are very strong tools to detect polynya areas as thin ice regions (Markus and Burns, 1995; Martin et al., 2004; Wakabayashi et al., 2004; Kwok et al., 2007).

Tamura et al. (2008) provided the first mapping of sea ice production in the Southern Ocean, based on heat-flux calculation with thin ice thickness algorithm of passive microwave (SSM/I) developed by Tamura et al. (2007). Their mapping (Fig. 1) shows that the highest ice production occurs in the Ross Ice Shelf Polynya region. According to this mapping, the Cape Darnley Polynya, which is located west of the Amery Ice Shelf, is found to be the second highest production area, suggesting a possible AABW formation area. Actually, downslope flow of newly formed dense water was suggested from the hydrographic observation in the self-slope region downstream of the Cape Darnley Polynya (Jacobs and Georgi, 1977).

In this study, we first examine the formation process and variability of this polynya using the active and passive satellite microwave data. Then we will investigate sea ice production in the polynya and the associated dense water formation based on the mooring and hydrographic observations along with the satellite microwave data.

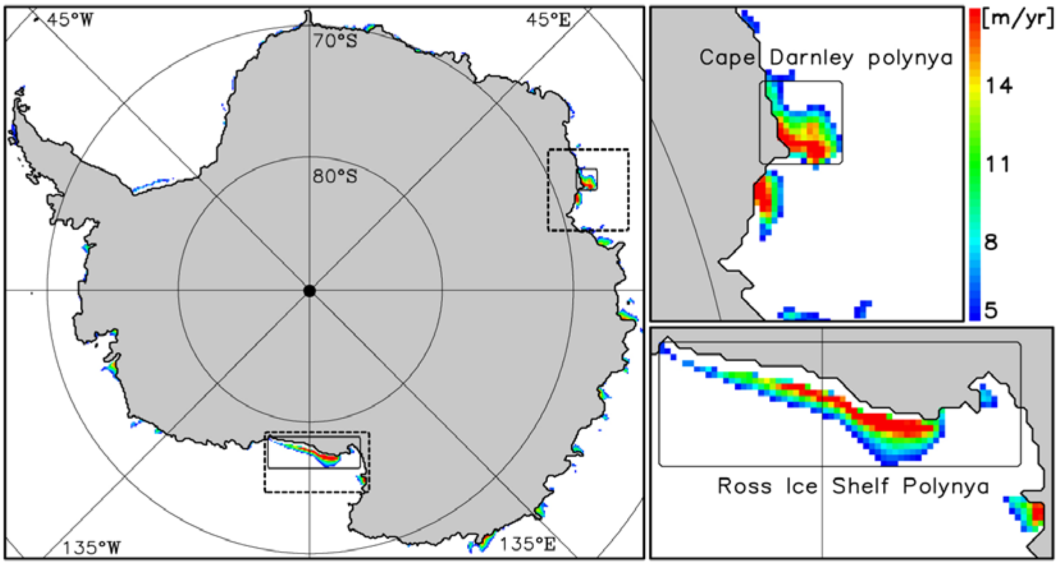

Figure 1: Spatial distribution of annual cumulative sea-ice production (in meter) averaged over 1992-2001 with enlargements along the coasts of the Cape Darnley and Ross Sea (modified from Tamura et al., 2008).

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2. DETAILED STRUCTURE OF THE CAPE DARNLEY POLYNYA DERIVED FROM PALSAR DATA

Figure 2 is an example of a Synthetic Aperture Radar image (ALOS PALSAR ScanSAR mode) in winter off Cape Darnley. White (black) indicates high (low) backscatter. The PALSAR backscatter images can discriminate between icebergs, fast ice, first-year ice, and new ice around this area and clearly visualize the series of streamers of new ice (Langmuir-like circulation), represented by white in the image, within the polynya. The streamers of new ice are directed offshore-ward in the area close to the coast, while shifted westward in the offshore area, which is probably due to the effect of westward Antarctic Coastal Current. The image demonstrates that the polynya is a huge one whose size is more than 100 km x 100 km.

Since a shallow bank with 50-200 m depths exists east of this polynya, icebergs drifting from the Amery Ice Shelf via the Antarctic Coastal Current are apt to be grounded on this bank, indicated by small white patches in Fig. 2. The image suggests that the first-year ice is accumulated around the grounded icebergs and then the iceberg tongue (fast ice) is formed from the coast (south) to offshore (north) for about 100 km length, indicated by thick contours in Fig. 2.

Figure 3 shows time series of PALSAR ScanSAR mode images throughout the year. It is

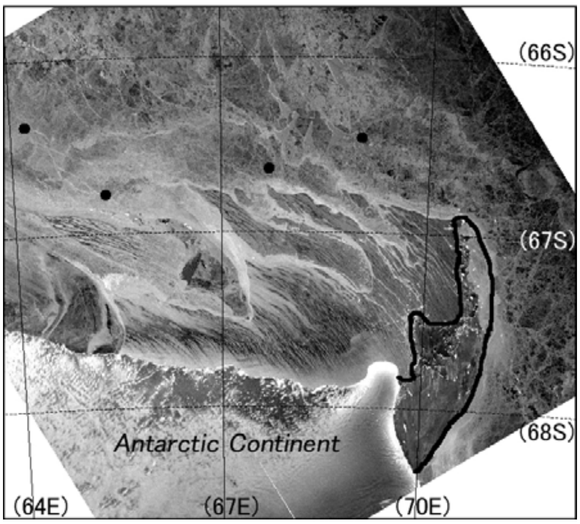

Figure 2: ALOS PALSAR ScanSAR mode image off Cape Darnley, East Antarctica on 31 July 2007. Solid circles indicate mooring sites.

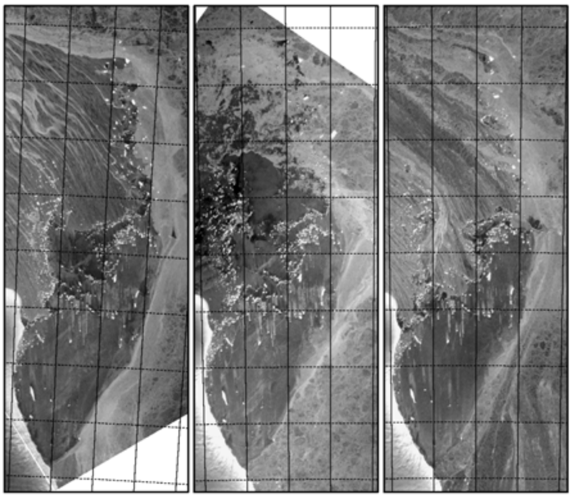

Figure 3: Time series of PALSAR ScanSAR mode images off Cape Darnley (left: 31 July 2007; center: 26 December 2007; right: 10 May 2008).

found that positions of most of the icebergs and the shape and location of the grounded iceberg tongue have not been changed at least for our analysis period of one year.

3. VARIABILITY AND FORMATION MECHANISM OF THE CAPE DARNLEY POLYNYA

Figure 4 shows time series of the polynya areal extent (bar) derived from SSM/I, offshore-ward wind component (blue lines), and alongshore/west-ward wind component (red lines) from NCEP2 data. It is found that the polynya area is significantly correlated with the offshore wind with 0.5-1 day lag, suggesting that the polynya is formed by the offshore-ward wind. It is noted that the polynya area is also correlated with the alongshore/westward wind with 1-3 day lag. The coastal current is considered to

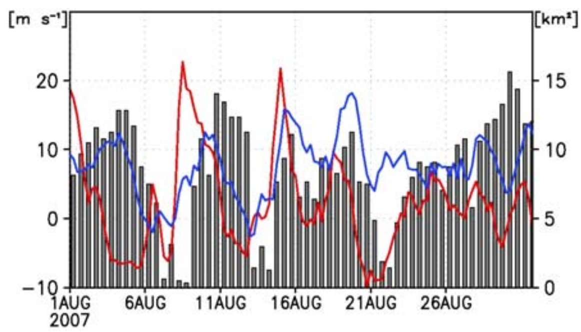

Figure 4: Time series of the areal extent of the Cape Darnley Polynya (bar) derived from SSM/I data, offshore-ward wind component (blue lines), and alongshore/westward wind component (red lines) from NCEP2 data.

be driven partly by the alongshore wind. This result, along with the westward-shift of the streamers in Fig. 2, suggests the importance of the westward coastal current on the polynya formation.

Figure 5 shows the schematics of the proposed formation mechanism of the Cape Darnley Polynya. Because a part of the westward coastal current can pass through the iceberg tongue, sea ice is carried away in the west side of the tongue while accumulated in the east side of the tongue. This filtering effect of the tongue is considered to be responsible for the polynya formation and thus cause the high productivity of sea ice. Similar mechanism can be also applied to other coastal polynyas in East Antarctica (Massom et al., 1998).

4. MOORING OBSERVATION

To clarify the formation process of the polynya and the associated dense water formation, ADCP (Acoustic Doppler Current Profiler), current meters and CT (conductivity-temperature recorders) have been moored at four stations (solid circles in Fig.2) off the Cape Darnley by the Japanese IPY project. They are planned to be recovered in January 2009. These moorings will further clarify the formation process of the polynya and the associated dense water formation. In our presentation, we plan to present the preliminary results of the mooring observation and hydrographic survey planned during the recovery cruise. We further plan to deploy a couple of sets of IPS (Ice Profiling Sonar)/ADCP/CT mooring for continuous monitoring of ice and ocean inside the polynya area in 2010. This will provide ice thickness data with high temporal resolution. These data will serve as the great data set for truth and validation of ice thickness and production algorithm of the satellite microwave data.

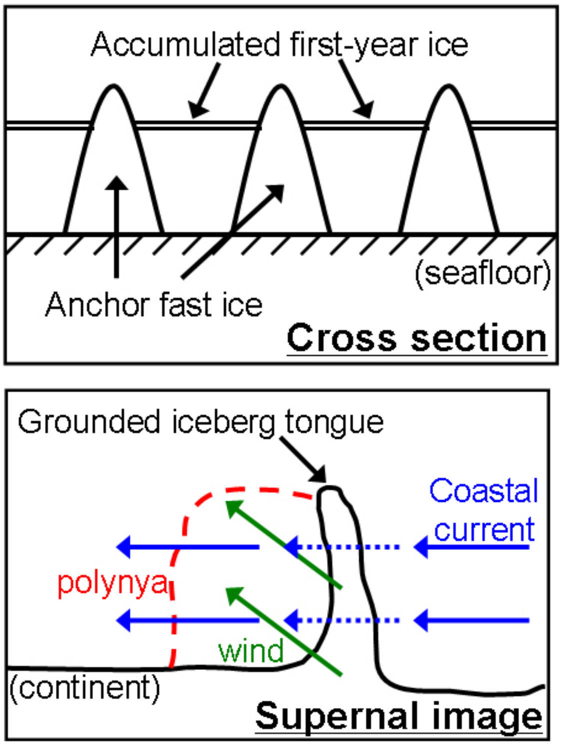

Figure 5: Schematics of the formation mechanism of the Cape Darnley Polynya.

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