Achievements of Research of Ocean-ice BOundary InTeraction and Change around Antarctica (ROBOTICA)

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The Antarctic and surrounding Southern Ocean are changing. Acceleration of ice mass loss and warming of the coastal ocean in West Antarctica are the problems of substantial impacts on the global climate system. In East Antarctica, which has been considered to be stable and attracted relatively less attention, regional characteristics of interactions among climate subsystems have been recently revealed and potential evidences of variations on various time scales from decades to millennium have been accumulating. Off Sabrina Coast, Wilks Land, underneath the Totten Glacier Ice Shelf, whose drainage system as a whole has a potential of 3.5m rise of global sea level and ice discharge is accelerating, a potential pathway of warm water access has been discovered (Greenbaum et al., 2015). Along the East Antarctic coast, sea ice formation and subsequent brine rejection in polynyas, including Cape Darnley Polynya as the head of the list, result in production of Dense Shelf Water and lead to the export of bottom water (Ohshima et al., 2013; Kitade et al., 2014). In the Lützow-holm Bay off Enderby Land, decadal or longer-term variabilities of sea ice condition have been observed (Ushio, 2006). Despite the global impact of these coastal variabilities, investigations of the mechanisms and variabilities in East Antarctica are insufficient.

Under the project called ROBOTICA for the 9th six-year plan (2016-2023), we planned to utilize state-of-the-art unmanned observations such as under-ice oceanographic, seafloor and cryospheric observations using ROV/AUVs, geodetic network observations of ice/ocean motion and deformation using GPS/ GNSS, and oceanographic observations using tethered and moored profiling observation systems to acquire the detailed environmental information both in time and space. With these implementations, we made intensive, interdisciplinary observations for the three typical regions of importance (Fig. 1).

In Lützow-holm Bay the warm water heat supply and ice-ocean interaction has been clarified. In front of Shirase Glacier, our shipboard hydrography has detected the warm water inflow through the deep glacial canyon and subsequent meltwater outflow in the upper layer (Hirano et al., 2020). Direct measurements through the ice shelf of the Langhovde Glacier provided the evidence of the under-ice ocean circulation melting the ice from the below (Minowa et al., 2021). Weddell seals captured the access of deep near-surface warm water even in autumn (Kokubun et al., 2021). For the ice system, satellite measurements clarified the interannual changes in motion of landfast sea ice and Shirase Glacier Tongue, indicating the mutual interactions (Nakamura et al., 2022) and in-situ measurements revealed the interannual variability in sea ice properties (Sahashi et al., 2022).

For the region off Cape Darnley Polynya significant progress have been made for the understanding in the sea ice and dense water formation processes. The minimum of sea ice cover in 2017 has provided the excessive heat in melting the Amery Ice Shelf to anomalously freshen the Cape Darnley Polynya (Aoki et al., 2022). These changes in summer environment can change the relatively stable sea ice production in winter so far (Tamura et al., 2016) for the coming decades. The findings are possible with the technical deployment of a state-of-the-art tethered profilers (Aoki et al., 2020).

Off Sabrina Coast, we conducted intensive oceanographic and geophysical observations during Dec. 2019 and Feb.-Mar. 2020 as a program of 61st Japanese Antarctic Research Expedition (JARE61) for the first time. Bathymetric survey with multi-narrow beam were effective and describes new and detailed topographic features. Hydrographic measurements, including

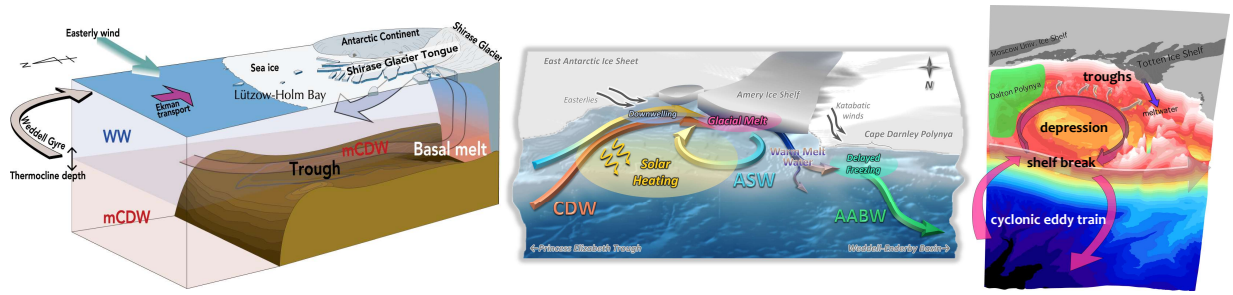

Fig. 1 Schematic diagrams for the ice-ocean environment and interactions. (left) Lützow-holm Bay, (middle) Prydz Bay/off Cape Darnley, and (right) off Sabrina Coast.

CTD/MS and XCTD, revealed the ubiquitous presence of deep warm water in this region. Air-borne XCTD and XBT helped enhance the spatial sampling in difficult access area, and largely expand the distribution of water mass property (Nakayama et al., in press). Warm water was found near the bottom throughout the study area, with its temporal change from days to years scales (Hirano et al., in revision) and shapes the nutrient and other chemical water compositions (Tamura et al., in press).

Analysis of samples obtained by ROBOTICA is on-going for the chemical, biological, and ecological studies. A new species of "mud dragon" was identified from the sediments (Yamasaki et al., 2022). Sediments and their cores were taken for the first time in this region were conducted at the marginal ice zone off Dolton Polynya, which will shed new light on the quaternary environmental change. Chemical composition of sea water will provide insight on the carbon cycle in the Southern Ocean. Our interdisciplinary achievements have promoted an acceleration in understanding of the sector and provided a big step forward for realization of sustained observation system around Antarctica.

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