学　位　論　文　内　容　の　要　旨

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学　位　論　文　題　名

Modeling studies of ocean heat transport toward ice shelves in West and East Antarctica
（西南極および東南極の棚氷に向かう海洋による熱輸送に関するモデル研究）

Antarctica is losing ice, contributing to global sea-level rise at an estimated rate of approximately 0.41 mm yr^{-1} from 2002 to 2020. The primary driver of this ice loss is intrusions of warm ocean water onto the continental shelf, specifically modified Circumpolar Deep Water (mCDW). This leads to ice shelf thinning, reduced buttressing, accelerated ice flow, and, ultimately, the loss of grounded ice. This dissertation presents numerical modeling studies of ocean heat intrusions toward ice shelves in the Bellingshausen Sea in West Antarctica and off Totten Glacier in East Antarctica.

Since the discovery in the early 2000s of rapid ice loss in the West Antarctic region, the Amundsen Sea, a neighboring sea west of the BS, has attracted many research campaigns; over the past few decades, it has become one of the most extensively observed Antarctic continental shelf regions. One of the key oceanographic discoveries from these observations is that ice shelf melting is highly sensitive to the thermocline depth, a sharp temperature rise at the interface between cold Winter Water and warm mCDW near the ice shelf front, which varies significantly on interannual timescales. However, much of the Antarctic continental shelf extends for several hundred kilometers, and significant knowledge gaps remain in understanding the cross-shelf break and on-shelf processes that transport ocean heat from the vast mid-depth CDW reservoir of the Southern Ocean, across the continental shelf slope and wide shelf, and into ice shelf cavities—ultimately linking the hydrography at the ice shelf front with that of the open ocean and how this process changes to other Antarctic continental shelf regions.

The Bellingshausen Sea is a critical sector of the Antarctic continental shelf represented by rapid ice shelf melting and thinning. The thermocline depths there located are at about 200m-300m similar to the Amundsen Sea. Here, using a regional ocean circulation model and ship-based hydrographic observations, I show that the simulated water mass distributions in several troughs guiding mCDW inflow are in good agreement with observations. This suggests that the model has the skills to simulate hydrographic structures as well as on-shelf ocean circulations. Simulated mCDW reaches the George VI Ice Shelf cavities through the Belgica and Marguerite troughs within one year. Ice shelf melting is primarily driven by mCDW intrusions along these troughs. The mCDW inflow toward the George VI Ice Shelf shows little seasonal variability. In contrast, the inflow toward the Venable Ice Shelf exhibits marked seasonality, with higher velocities in summer likely due to coastal trapped waves.

Additionally, we conduct particle-tracking experiments to trace glacial meltwater and reveal the connectivity between the Bellingshausen and Amundsen Seas.

East Antarctica's Totten Glacier holds enough ice to raise global sea levels by more than 4 m, and it has recently been melting been melting at an alarming rate. The thermocline depth off Totten Glacier persistently stays about 500-600 m and these features characterize the unique hydrographic structures of this region. However, all existing models fail to reproduce such water mass structures: most ocean models show simulated thermocline depth to be at least a few hundred meters shallower than observations. In the second chapter, I investigate the mechanisms behind this model-observation mismatch by using a regional ocean model for East Antarctica. I find that realistic thermocline depths can be reproduced when both the Antarctic Slope Current (ASC)—which has been identified as a barrier to warm water intrusions—and iceberg melt fluxes are present. The inclusion of iceberg meltwater leads to a thicker, colder, and fresher Winter Water layer, which helps maintain a deeper thermocline in the presence of the ASC. In contrast, when the ASC is absent, the same iceberg melt flux results in substantial warming of the continental shelf region, highlighting the contrasting role of iceberg melt in regulating on-shelf hydrography. Given that most coarse-resolution global models (e.g., CMIP6 simulations) significantly underestimate the strength of the ASC, our results suggest that they likely overestimate the inflow of warm ocean water onto the Antarctic continental shelves. This is especially concerning as these models typically impose iceberg and ice shelf melt as a constant freshwater flux from the Antarctic continent, potentially misrepresenting key regional processes.