Modelling Amery Ice-Shelf/Ocean Interaction

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The effect of climate change on the mass balance of ice shelves and bottom water formation is investigated using a terrain-following three-dimensional numerical ocean model. The Regional Ocean Modeling System was modified to simulate the thermodynamic processes beneath ice shelves, including direct basal processes and frazil ice dynamics. The Amery Ice Shelf/ocean model is forced with tides, seasonal winds and relaxation to seasonal lateral boundary climatologies. The open ocean surface fluxes are modified by an imposed climatological sea-ice cover that includes the seasonal effect of polynyas.

The circulation and basal melting and freezing show good agreement with glaciological and oceanographic observations. Strong horizontal and thermohaline ("ice-pump") circulation is primarily driven by melting and refreezing of the ice shelf interacting with High Salinity Shelf Water. The net basal melt rate is ~45 Gt year-1 (~0.7 m ice year-1), which represents 67 % of the total mass loss of the Amery Ice Shelf. The total amount of refreezing is ~5.3 Gt year-1, of which 70 % is due to frazil accretion. The seasonal variability of the basal melt/freeze (up to +-1 m ice year-1) within 100 km of the open ocean is the same magnitude as the area-averaged melt rates. The annual averaged bottom water formation rates are ~1 Sv to the west of the Amery, in the vicinity of Cape Darnley.

The Amery Ice Shelf/ocean model is used to investigate the sensitivity of the basal melt/freeze and bottom water formation to the inclusion of various physical mechanisms and changes in forcing. Direct comparison with glaciological observations shows that ice-shelf models that include frazil processes improve the simulated pattern of marine ice accretion. Simulations without ice-shelf/ocean thermodynamic processes overestimate bottom water formation by up to 2.8 times as much as simulations with ice-shelf/ocean thermodynamic processes, due to the missing buoyant freshwater from the melting ice shelf. Climate change sensitivity studies suggest that an ocean warming of 1 degree C above present day temperatures can potentially remove the Amery Ice Shelf in ~700 years, solely due to increased basal melting, and can also lead to a significant decrease in the formation of bottom water. This research contributes to understanding how interaction between ice shelves and various forcing mechanisms can lead to changes in basal melt/freeze and dense water formation, which has major implications for the stability of ice shelves, sea level rise, and the salt budget of the global oceans.