Antarctic Ice-shelf basal melting as a possible tipping element

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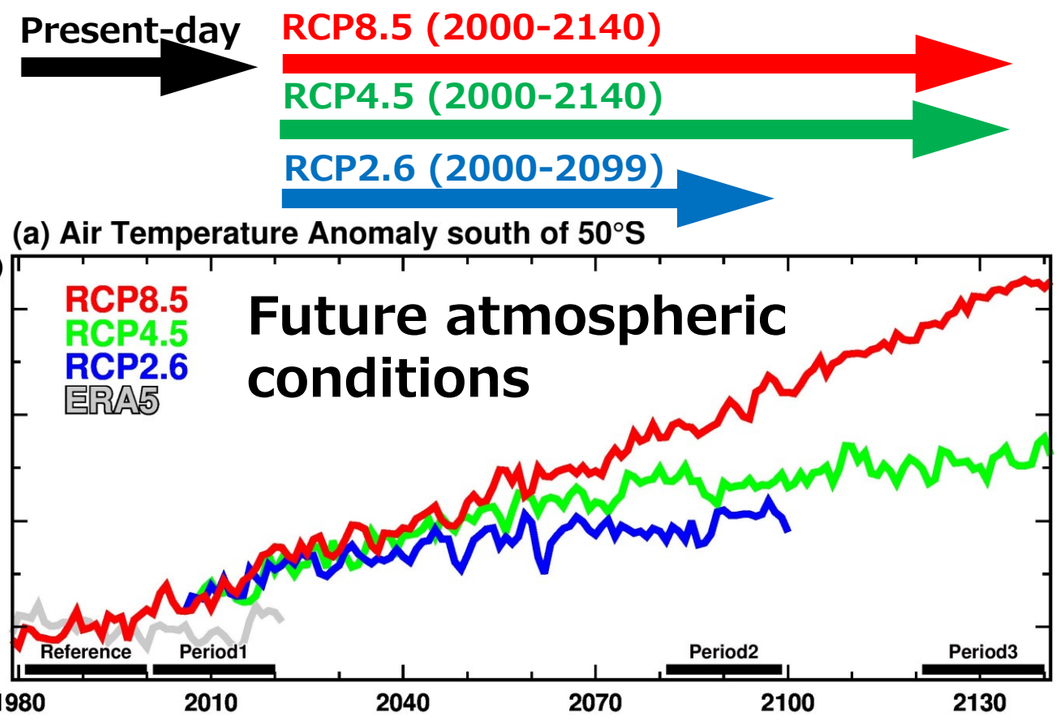
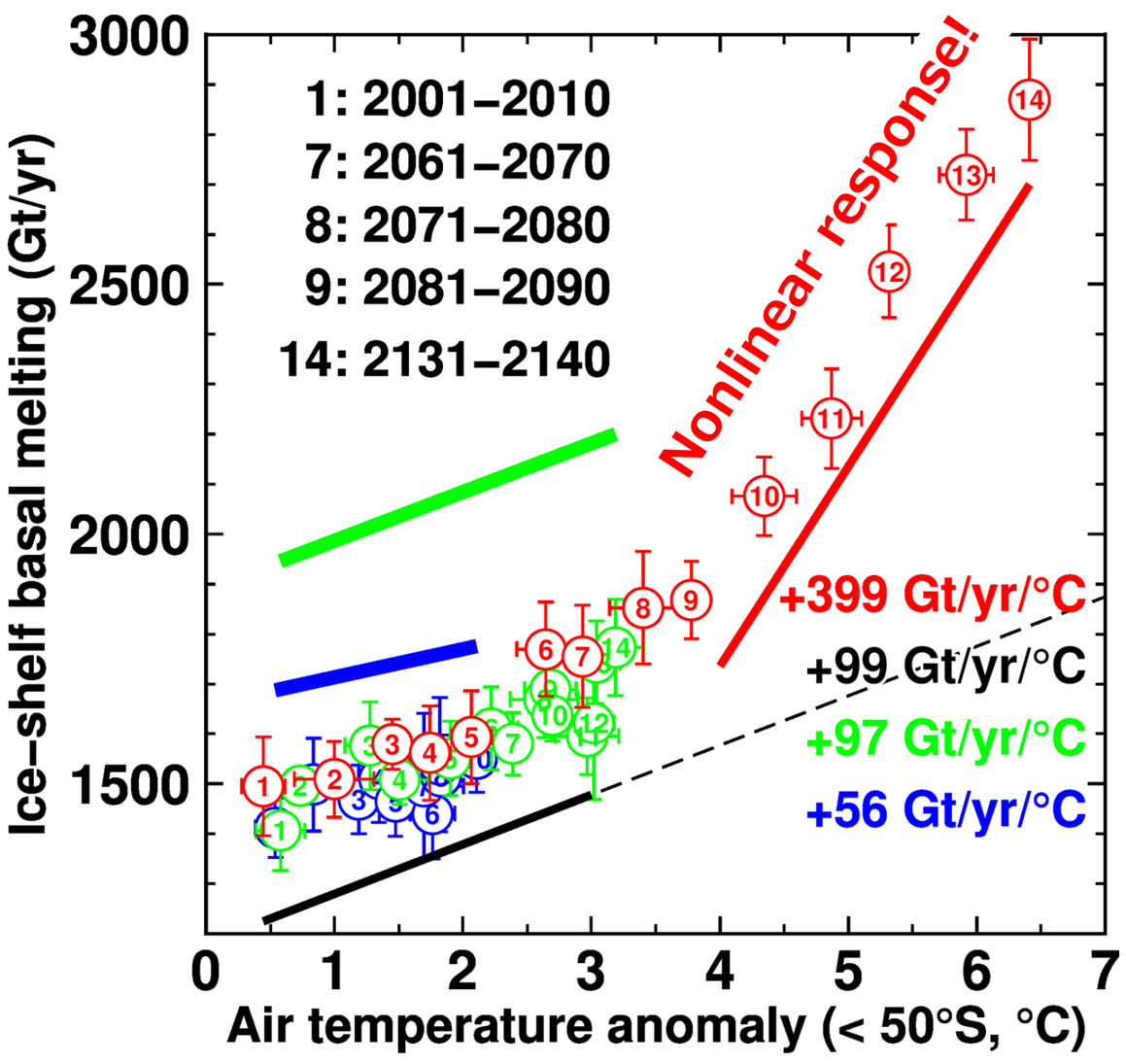
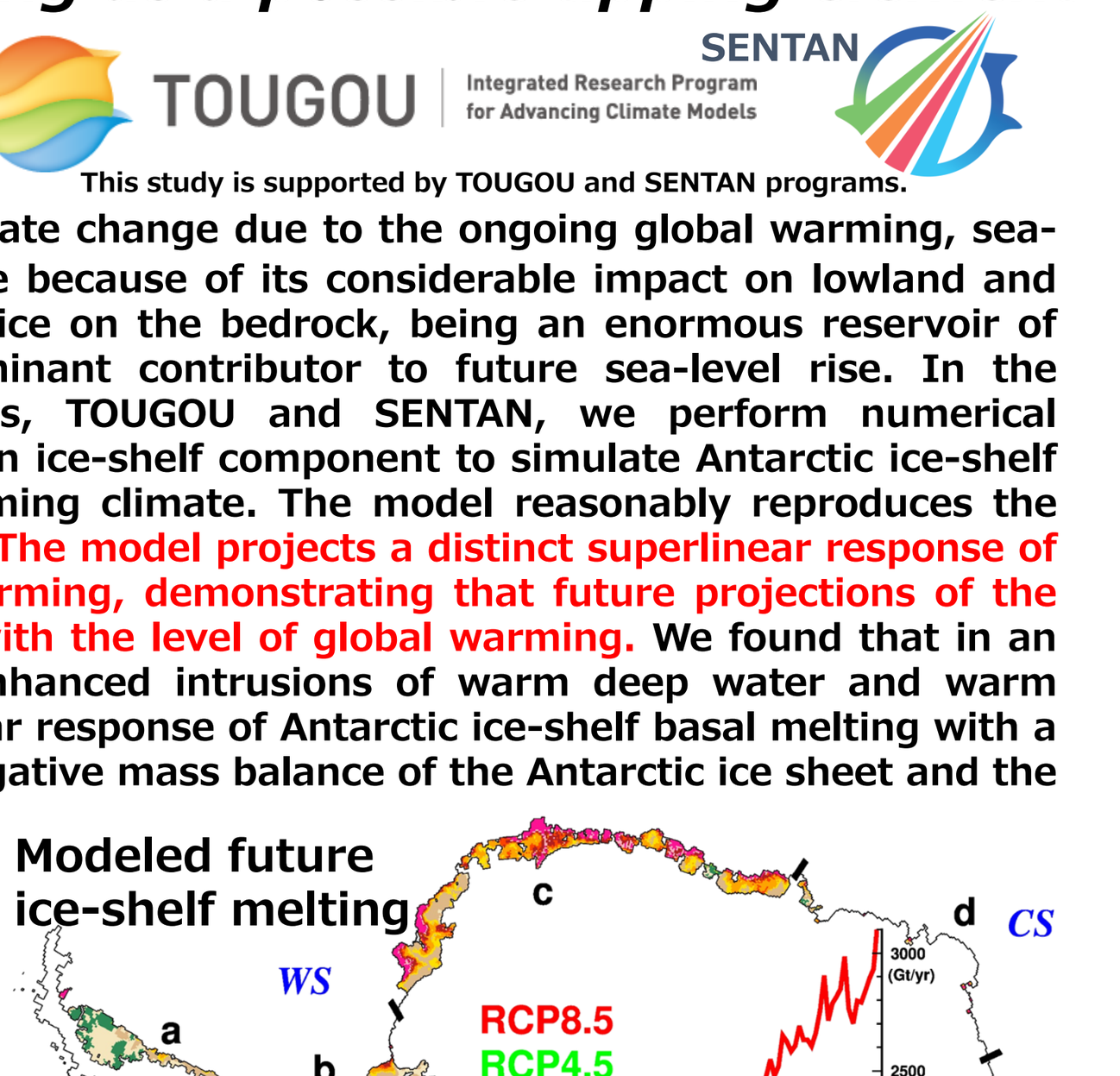
Abstract: Among the negative impacts of climate change due to the ongoing global warming, sea-level rise is a social, political, and economic issue because of its considerable impact on lowland and coastal environments. Antarctica stores massive ice on the bedrock, being an enormous reservoir of earth-surface freshwater and a potentially dominant contributor to future sea-level rise. In the Japanese climate model development programs, TOUGOU and SENTAN, we perform numerical experiments using an ocean-sea ice model with an ice-shelf component to simulate Antarctic ice-shelf basal melting from the present to a future warming climate. The model reasonably reproduces the observed total amount of ice-shelf basal melting. The model projects a distinct superlinear response of ice-shelf basal melting to future atmospheric warming, demonstrating that future projections of the Antarctic and Southern Ocean climate bifurcate with the level of global warming. We found that in an extreme warming scenario, a combination of enhanced intrusions of warm deep water and warm summertime surface water can cause the nonlinear response of Antarctic ice-shelf basal melting with a tipping nature, presumably contributing to the negative mass balance of the Antarctic ice sheet and the sea-level rise.

Experiments of an ocean-sea ice-ice shelf model under three future scenarios (RCP8.5, RCP4.5, and RCP2.6 from a climate model, MIROC) were performed after 50-year present-day spinup.





The ratio of ice-shelf basal melting against the air temperature rise can highlight the different response among the warming scenarios.



Summary: Scaling the total Antarctic ice-shelf melting with the degree of air temperature rise over the Southern Ocean reveals a nonlinear response of ice-shelf basal melting to future atmospheric changes with a threshold of warming level lying between RCP4.5 and RCP8.5 scenarios. We found that differences in the sea-ice fields and coastal water masses significantly impact future changes in Antarctic ice-shelf basal melting. Detailed examinations of sea ice and water masses show that in an extreme warming scenario, a combination of enhanced intrusions of warm deep water and warm summertime surface water can cause the nonlinear response of Antarctic ice-shelf basal melting. A large reduction in Antarctic coastal sea ice and the associated ocean freshening by decreasing coastal sea-ice production in winter provide favorable conditions for summertime warm surface water formation and warm deep-water intrusions onto some continental shelves. The model results demonstrate that disappearing summertime sea ice along the Antarctic coastal margins in a warming climate heralds the nonlinear increase in Antarctic ice-shelf basal melting, presumably contributing to the negative mass balance of the Antarctic ice sheet and the sea-level rise.

Details are found in our paper.
Kusahara, Tatebe, Hajima, Saito & Kawamiya: Antarctic sea ice holds the fate of Antarctic ice-shelf basal melting in a warming climate, *Journal of Climate* (in press)