Local processes determine global sea level rise

Ice sheet–ice shelf–ocean interaction in the marginal seas of the Southern Ocean

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Kurzgefasst

- coupled ocean–sea ice–ice shelf–ice sheet modelling
- marginal seas in the center of our research

Melting of glaciers, ice caps, and ice sheets contributes to changes in the global sea level. Most of the Antarctic Ice Sheet drains into floating ice shelves which serve as buttresses to the ice flow. Ice shelf basal melting has been shown to be an important component in the southern hemisphere's ice mass budget and its variability. In order to explore mechanisms of ice-ocean interaction and the potential of substantial changes in ice-shelf basal mass loss in a warmer climate, we use the global Finite Element Sea ice–ice shelf–Ocean Model FESOM (Timmermann et al., 2012) with a high resolution in the Antarctic marginal seas. Simulations are performed with prescribed cavity geometries and with a dynamic ice shelf as part of a coupled ocean–ice shelf–ice sheet model. Next to the implications for the Antarctic ice sheet mass budget (which is relevant to global sea level), we are interested in the effects of an increased melt water input for Southern Ocean hydrography and the formation and properties of Antarctic Bottom Water (AABW), one of the driving components of the ocean's global thermohaline circulation.

In close collaboration with the Potsdam Institut for Climate Impact Research (PIK), and supported by funding from the DFG SPP “Antarktisforschung”, a new coupled ice sheet–ice shelf–ocean model with an explicit representation of ice-shelf cavities has been developed. Similar to the Regional Antarctic and Global Ocean (RAnGO) model (Timmermann and Goeller, 2017), the coupled system is based on a global FESOM implementation with a mesh that uses hybrid vertical coordinates and is substantially refined in the marginal seas of the Southern Ocean. The Antarctic cryosphere is now represented by a regional setup of the Parallel Ice Sheet Model (PISM), comprising the Filchner-Ronne Ice Shelf (FRIS) and the grounded ice in its catchment area up to the ice divides. At the base of the FRIS, melt rates and ocean temperatures from FESOM are applied. PISM returns ice thickness and the position of the grounding line. Dynamic FESOM mesh modification and several other aspects of the RAnGO coupler have been adopted to the new system. The ice sheet model is run on a horizontal grid with 1 km resolution to ensure an appropriate representation of grounding line processes. Enhancement factors for the approximation of the stress balance, as often used in coarse-resolution ice sheet models, become obsolete at such high resolution.

The goal of this project is to implement an interactively coupled ice–ocean model system capable of resolving dynamic processes in and around Antarctica. The Antarctic ice sheet responds on timescales that are longer than those of climate variability. As it is thus never in equilibrium, the ice-sheet component requires a high-resolution spin-up procedure that provides a realistic configuration of the present-day Antarctic Ice Sheet and at the same time accounts for the long-term drift as a delayed response to the climate conditions during the last glacial cycles. The distributed architecture of the RAnGO coupling interface allows us to perform spin-up and coupled integration of the ice model on the same server (not at HLRN), thus avoiding unnecessary porting of the PISM code, and at the same time benefit from the very robust and computationally efficient FESOM installation at HLRN.

At the time of writing this text, the coupled model is being run in a stable integration with present-day forcing, with 40 years already completed and giving good results. Compared to the 10-km resolution used in the ice sheet component of the original RAnGO, year-to-year fluctuations of the grounding-line position are smaller, but a trend towards advancing grounding lines in shallow parts of the cavity, i.e. areas with a small cavity water column thickness, still needs to be understood and addressed (Fig. 1).

In order to provide projections of the future sea level contribution from the Antarctic Ice Sheet on multi-decadal to centennial time scales, we plan to perform coupled simulations with future climate forcing. The coupled FESOM-PISM model will also allow us to assess whether the warm water inflow projected in earlier simulations is a robust feature in a coupled model with an eddy-permitting ocean component.

Another workpackage in this project contributes to the EU-funded project Tipping Points in Antarctic Climate Components (TiPACCs). The goal of this effort is to study two closely-related tipping points of the Southern Ocean and the Antarctic Ice Sheet and the physical processes that link them. The first tipping point involves an irreversible switch from “cold”
to “warm” oceanic conditions within the ice shelf cavities, similar to the mechanism discussed by Timmermann and Hellmer (2013) and Hellmer et al. (2017). Such a shift will result in a greatly enhanced basal melting of the Antarctic ice shelves and a decrease in ice shelf buttressing provided to the ice sheet. The second tipping point involves a switch from stable to unstable grounding-line configurations due to the loss of ice-shelf buttressing. Such an unstable grounding-line retreat may lead to an abrupt and large-scale disintegration of the ice sheet. The project will determine the loss in ice-shelf buttressing caused by transition from cold to warm oceanic conditions, assess if such a loss is sufficient to cause an unstable grounding-line retreat, and determine the resulting implications for global sea level. While the relevant processes have so far mostly been investigated for the Weddell Sea, TiPACCs aims at assessing sensitivities and potential tipping points for other cold- and warm-water ice shelves.

Weitere Informationen


Projektpartner
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