Project: **1347**

Project title: **RESCUE: Ice sheet simulations representing Greenland and Antarctica**
Principal investigator: **Christian Rodehacke**
Report period: **2024-11-01 to 2025-10-31**

In the project "RESCUE: Ice sheet simulations representing Greenland and Antarctica," we performed simulations with the Parallel Ice Sheet Model (PISM) representing the Antarctic Ice Sheet. The balance between ice mass gain (snowfall) and loss (basal melting of ice shelves and iceberg discharge) controls the ice sheet's evolution.

Despite various difficulties described in previous reports, we have finally obtained a set of initial states that will be used in the next phase of this DKRZ project 1347, entering a different stage. During the reporting period, we analyzed how the ice sheet responds to interannually varying atmospheric and oceanic forcing. It is critical because ice sheet simulations commonly neglect interannual variability and its impact on the ice sheets' temporal evolution, whereas we aim to consider the variability effect in our ice sheet projections.

To further test the resilience of our approach, we selected one of the several spin-up states obtained. As our project partners in the European RESCUE project have been affected by massive delays, they have not yet provided the necessary data. Hence, we adjusted our working plan and integrated our initial state into an Earth System Model (ESM) that is coupled to PISM, collaborating closely with activities outside this DKRZ project 1347.

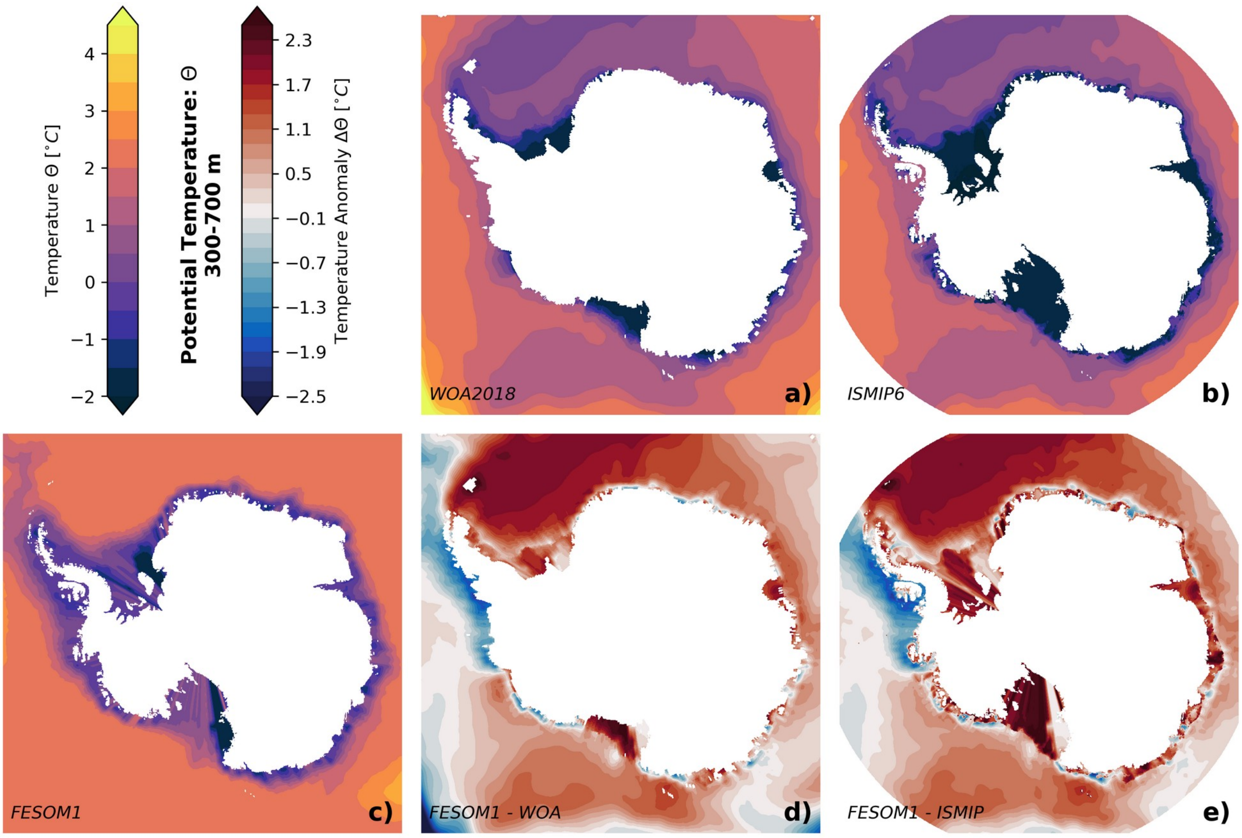

Figure 1: Ocean temperature around Antarctica for the depth range between 300 and 700 m. The top row depict the climatological distributions of the World Ocean Atlas 2018 (WOA2018, a) and the Ice Model Intercomparision Project (ISMIP6, b). The corresponding distribution of the ocean models FESOM1 is shown in the lower left subfigure (c). The difference between the FESOM distribution and the two climatologices is depicted in the subfigures d) and e) under the corresponding climatologies. Note that we use the updated version FESOM2 in our setup.

We summarize, not exhaustively, the required steps to have Antarctica actively coupled to AWI-ESM. As part of the coupling between AWI-ESM and PISM, representing Antarctica, we applied a bias correction to successfully handle existing biases (e.g., ocean temperature, Figure 1) in the forcing from the ESM. Here, we not only correct biases of the ocean temperature and salinity fields, although the ocean temperature correction is critical. Atmospheric fields are corrected too, such as a positive atmospheric temperature bias, which is accompanied by an enhanced hydrological cycle due to the Clausius-Clapeyron relation, among other effects. Since current atmospheric temperatures across Antarctica are well below the freezing temperature, we use the positive degree day (PDD) method to determine the surface mass across Antarctica in the coupled setup, which simplifies the correction of atmospheric fields. After a combined spin-up of the coupled system, we started simulations that include an interactive Antarctica. Besides Antarctica, we also integrated Greenland into the system in a slightly different way. However, we restrict the report predominantly to Antarctica.

In the following, we inspect the sea level contribution from Antarctica and Greenland under an idealized warming scenario, which is similar to the likely scenario used in future Ice Sheet Modeling Intercomparison Project (ISMIP) activities. In the warming scenario, the atmospheric carbon dioxide concentration increases by 1% per year starting in 1850 until it reaches four times the pre-industrial value. Afterward, the carbon dioxide concentration stabilizes. In addition to this warming scenario, control climate simulations are performed under pre-industrial conditions.

Under both scenarios, we run four different configurations (Figure 2), where the ice sheets interact differently with the climate system: both ice sheets (red line), only Greenland (green) or Antarctica (orange), or no ice sheet (blue) interacts with the climate system. Uncoupled (standalone) ice sheet simulations utilize the forcing from the related ESM simulations. Although the drift in the sea level contribution under the control climate is negligible, we subtract the corresponding evolution from the warming scenario.

In our simulations, we see a positive sea level contribution towards the end of the simulations, while at the beginning, sea level drops slightly (Figure 2). The initial sea level drop is related to an enhanced hydrological cycle as the warming atmosphere delivers more precipitation across Antarctica. Approximately after 1975, the combined sea level contribution from the annual ice sheets becomes positive.
For Antarctica, the balance between amplified snowfall and the onset of grounding line retreat determines the evolution of global sea level.

The obtained coupled simulations will be included in a forthcoming publication that highlights the current state of coupled ESM-ice sheet model systems and the related protocol. Therefore, we are in close contact with the ISMIP working group that drafts the protocol within the framework of the upcoming CMIP activities.

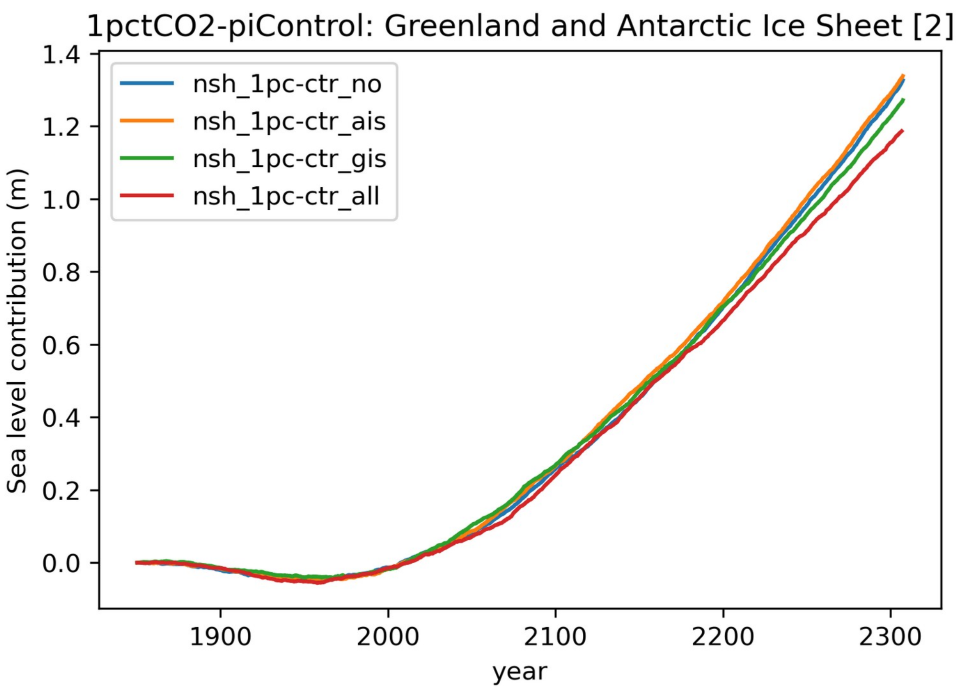

Figure 2: Combined sea level contribution of Greenland and Antarctica in our coupled ESM-ice sheet model for four configurations, where both ice sheets (red line), only Greenland (green) or Antarctica (orange), or none ice sheet (blue) interact with the climate system. Shown are the resulting sea level contributions of the 1pct4CO2 minus the control climate simulations (details see text).