

# The Earth system in the distant future

## Climate-ice sheet simulations for the next 5000 years

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### In Short

- We seek to investigate long-term climate-ice sheet interactions
- We use the coupled model CESM-PISM
- We study the likelihood of abrupt climate events
- The project is part of the German climate modeling initiative PalMod

PalMod is a modeling project aiming at understanding the spectrum of climate variability from the last interglacial, through the last glacial to the present and at projecting the climate of the next millennia with several Earth system models under different scenarios. The motivation of PalMod relies on the following assumption: if we could successfully simulate the spectrum of climate variability during the last glacial cycle, such a simulation might enable us to more reliably assess the future climate and to assess whether, for example, a regime shift in the variability or abrupt events could occur during the next centuries and millennia in response to global warming. Will the future climate be more or less variable, and what is the probability of rapid climate transitions? Could polar ice sheets collapse catastrophically? How quickly can sea level rise under present and future climate conditions? To this end, PalMod aims at filling knowledge gaps about climate processes and climate modeling, in particular with respect to non-linear behavior and long-term feedbacks that may become important as the Earth's surface temperature continues to warm due to increasing atmospheric greenhouse gas concentrations.

This project seeks to investigate the long-term interactions between climate and ice sheets over the next 5,000 years using the coupled Earth system model CESM-PISM. This research aims to address critical questions about future climate stability, potential tipping points, and the role of ice sheet dynamics in long-term projections. The study will conduct simulations under different emission scenarios and orbital forcings, comparing experiments with fixed versus interactive Greenland ice sheets. Key objectives include assessing the likelihood of abrupt climate events, such as Atlantic Meridional Overturning Circulation (AMOC) slowdowns or ice sheet collapse,

and evaluating the feedback mechanisms between ice sheets, oceans, and the atmosphere. By extending simulations beyond the typical 21st-century horizon, the project will explore irreversible changes and uncertainties in sea-level rise projections. The technical approach employs the Community Earth System Model (CESM1.2.2), coupled with the Parallel Ice Sheet Model (PISM). CESM1.2.2 consists of the atmosphere model CAM5, the land model CLM4, the ocean model POP2, and the sea-ice model CICE4 (Hurrell et al., 2013). POP2 and CICE4 share the same horizontal grid with a nominal resolution of 1 degree, where the North Pole is placed in the middle of Greenland. A horizontal grid of 1.9 x 2.5 degree is used for CAM5 and CLM4. CAM5 runs with 30 vertical layers and POP2 with 60 depth levels. PISM (Parallel Ice Sheet Model), a high-performance computational model designed to simulate the dynamics of ice sheets, ice shelves, and glaciers, emphasizing scalability and hybrid dynamics, runs on a 20 km grid. In this phase of the project, only the Greenland ice sheet is simulated. The simulations will start from pre-industrial conditions and run transient experiments to analyze climate-ice sheet interactions under varying forcings. The greenhouse gas concentrations for the next millennia are derived from emission-driven simulations with the Earth system model of intermediate complexity CLIMBER-X (PIK, Potsdam), where atmospheric CO<sub>2</sub> and CH<sub>4</sub> concentrations were interactively simulated.

### WWW

<http://www.marum.de>

### More Information

[1] J. W. Hurrell et al., The Community Earth System Model – A framework for collaborative research. *Bull. Amer. Met. Soc.*, **94**, 1339-1360 (2013).

[2] <http://www.palmod.de>

### Funding

BMBF

### DFG Subject Area

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