Potsdam Institute for Climate Impact Research

Universität Potsdam

MODELING OF PINE ISLAND GLACIER AND THWAITES GLACIER WITH PISM-PIK

Pine Island Glacier (PIG) and Thwaites Glacier (TG), together draining about 40% of the volume of the West Antarctic Ice Sheet (WAIS), exhibit significant acceleration of ice flow, ice thinning and grounding line retreat. Resting on marine bedrock which is sloping inland, for both glaciers the preconditions for an instability mechanisms, potentially leading to self-amplified ice loss, are met. Here we present a regional model of their joint ice sheet-shelf system. Using the Potsdam Parallel Ice Sheet Model (PISM-PIK) and varying four relevant model parameters, a perturbed physics ensemble is generated.

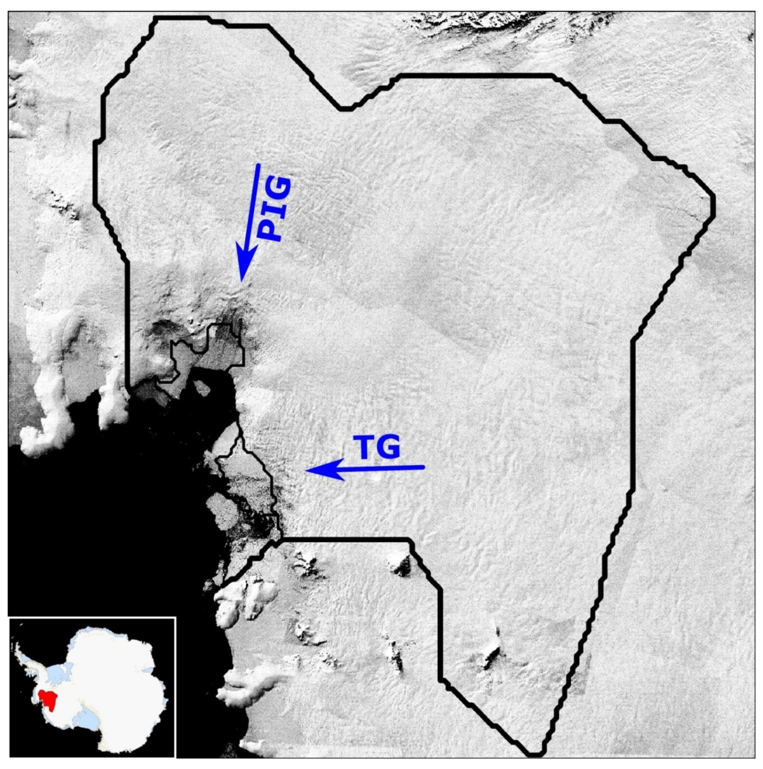

Fig. 1 Joint drainage basin of PIG and TG (thick black contour) and flow direction. The thin black contours denote grounding line and calving front as prescribed as initial condition in the model setup.

Authors Johannes Feldmann, Torsten Albrecht, Anders Levermann

PIK RD I Earth system analysis
University of Potsdam, Germany

THE MODEL: PISM-PIK

PISM is a thermomechanically coupled, three-dimensional, parallel, open source ice sheet model [1] . Based on version stable 02, it was improved at PIK for marine ice sheet modeling ➔ PISM-PIK [2], which uses a superposition of the shallow ice approximation (SIA) and the shallow shelf approximation (SSA) of the stress balance for calculating velocities. Meanwhile the improvements from PISM-PIK have been merged into PISM version stable 04.

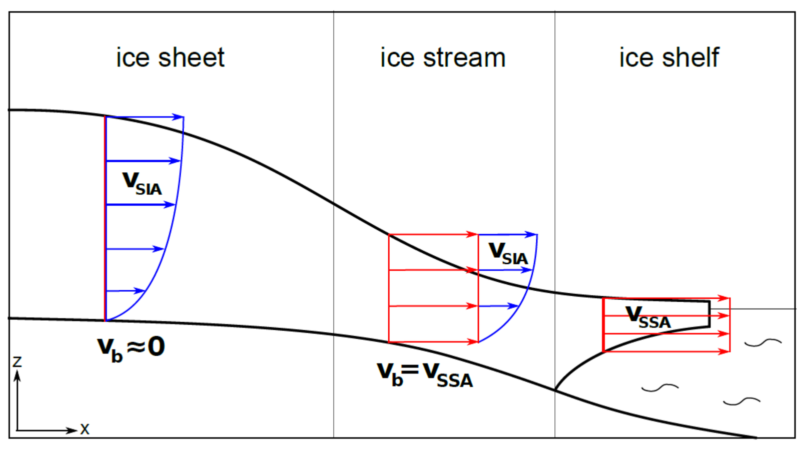

Fig. 2 Ice profile showing different regimes of glacier flow and the superposition of SIA and SSA velocities as used by the model.

MODEL SETUP

➢ **Initial 5 km present-day data** of ice thickness, bed elevation, mean annual surface temp., surface mass balance, geothermal heat flux from the ALBMAP v1 dataset [3]

➢ **Boundary conditions** at the ice margins: **Landward** the ice thickness is held constant along the ice divide. **Seaward** the ice may not exceed the observed calving front.

➢ The **grounding line** is **free to evolve**

➢ **Basal resistance:** A plastic model is used. The input field for the yield stress comprises data from inverse modeling [4], available in the regions of fast ice flow, and a parameterization for the remaining region.

➢ **Sub-shelf melting** is determined by the difference between prescribed ocean temperature and calculated pressure melting temperature at the ice-shelf base [5].

PERTURBED PHYSICS ENSEMBLE

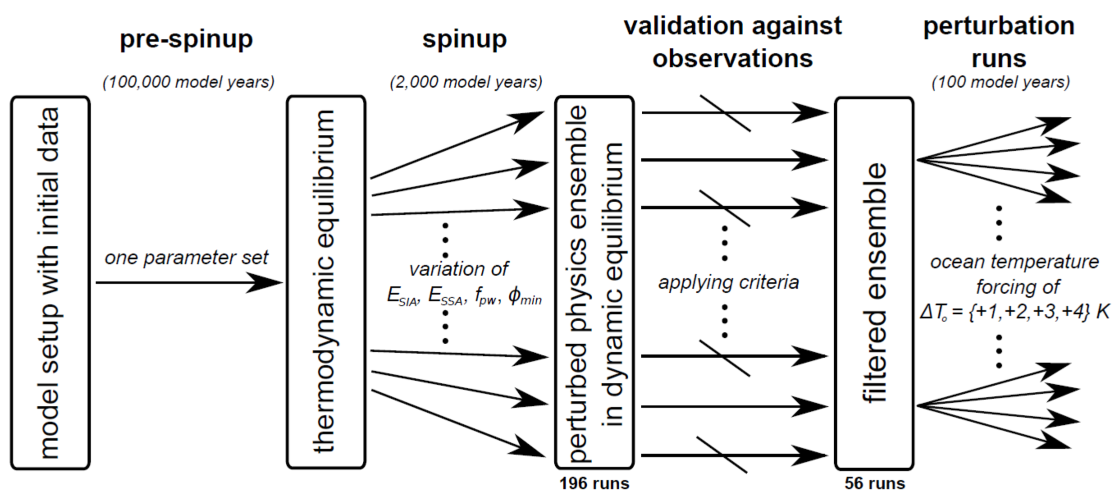

Fig. 3 Overview of the different stages for producing a filtered ensemble of equilibrium runs.

Four relevant model parameters, accounting for ice softness in different stress regimes and basal resistance, are varied to generate an ensemble of 196 simulations which are run into equilibrium. By applying criteria for ice velocity, volume and grounding line position 56 model runs remain. Their final output is used as initial state for perturbation experiments to analyze the model response to increased ocean temperatures.

RESULTS

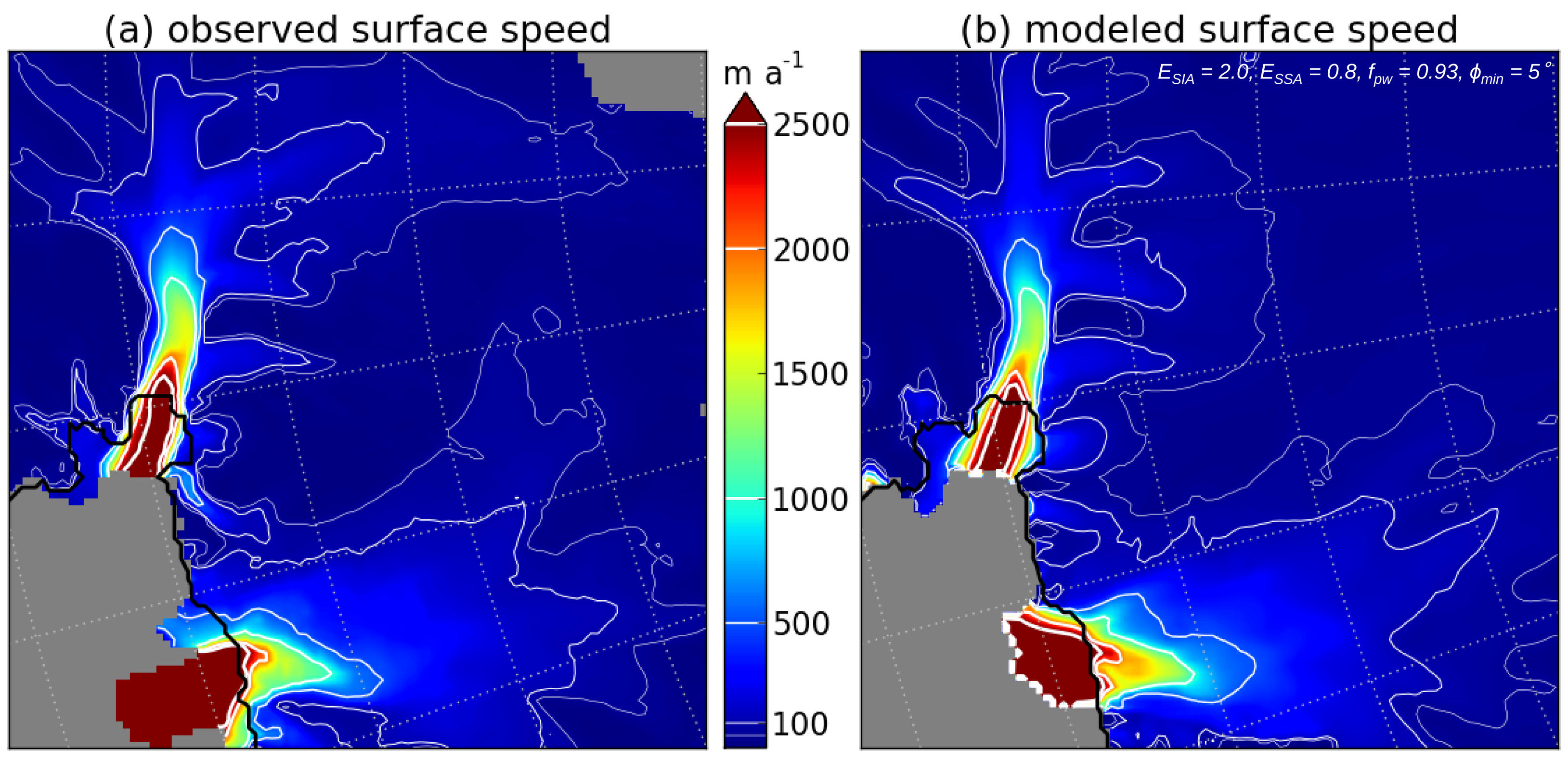

Fig. 4 Comparison of observed (provided by Ian Joughin) and modeled ice surface speed in the region of fast ice flow, i.e., the main trunks and tributaries of PIG and TG. The black contour denotes the grounding line.

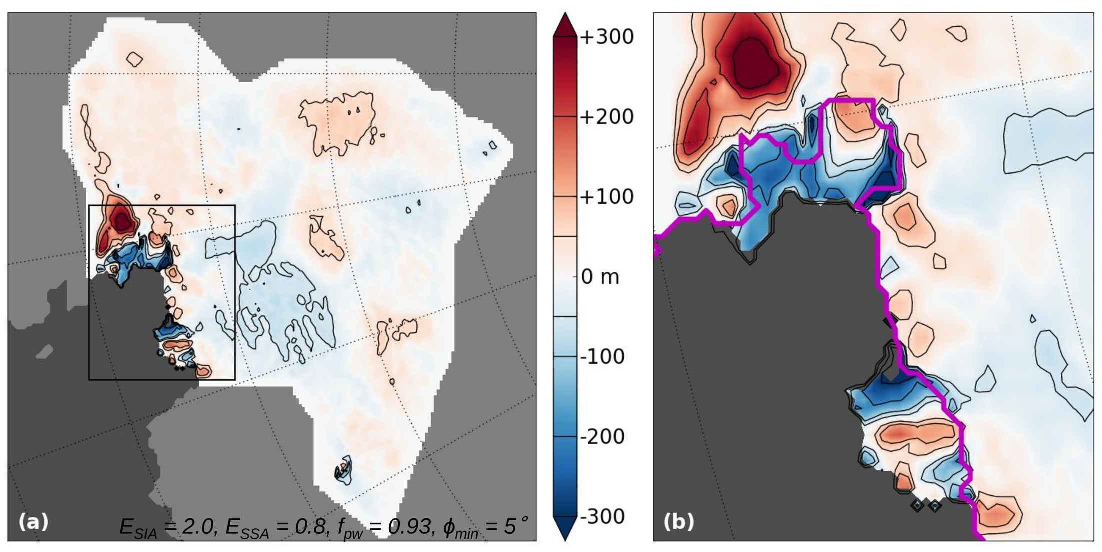

Fig. 5 (a) Ice thickness anomaly [modeled – observed], (b) close up of grounding line region. Grounding line highlighted in magenta.

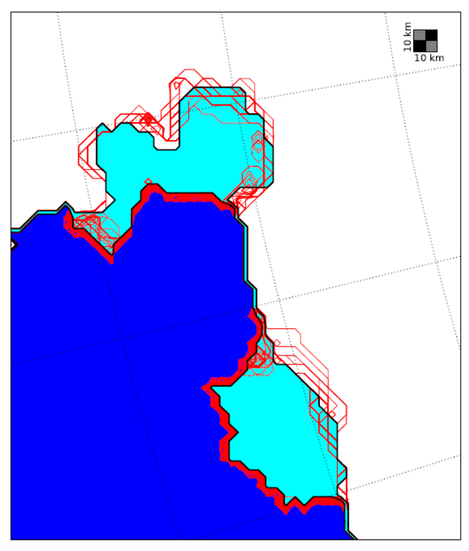

Fig. 6 Comparison of the 56 modeled grounding line and calving front positions (red contours) to the observed position (black contours). Observed areas of ice sheet and ice shelf are in white and light blue, respectively.

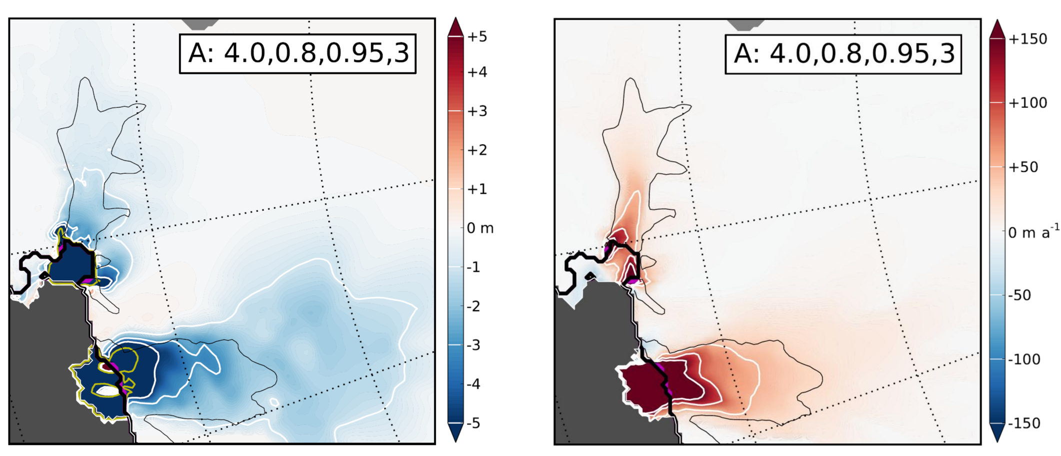

Fig. 7 Ice thickness change (left) and surface speed change (right) after ten model years of forcing (increase of 1K of ocean temperature). The thick black contour denotes the initial grounding line position. Deviations from this position in the perturbation run are colored magenta. Yellow contours confine areas of more than 1 m/a thinning on average.

CONCLUSIONS

The **ensemble reproduces** the **detailed structure of fast ice flow.** The **grounding line position** is in **good agreement with observations.** The **ice thickness distribution** is **reproduced for major parts** of the computational domain.

The **transient model response** to a realistic forcing of increased ocean temperatures shows observed features like **grounding line retreat**, as well as **significant ice thinning** and **speed up**, both propagating inland.

Contact Johannes Feldmann
Telegraphenberg A62 | 14473 Potsdam
johannes.feldmann@pik-potsdam.de

References

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