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A Dynamic Memory of Fracture Processes in Ice Shelves

a cumulative dissertation

Abstract

Future sea-level rise has the potential to affect a large fractions of the world's urbanized areas and many generations to come. In order to design suitable mitigation and adaptation measures, accurate sea-level projections are required. Ice dynamics within the Antarctic Ice Sheet constitutes the major uncertainty in state-of-the-art model approaches. Floating ice shelves around the Antarctic coastline play an indirect but essential role for ice-discharge estimates.

In order to gain a better understanding of the Antarctic ice-sheet-shelf system and to provide physically sound estimates for future seal-level rise we have developed the Potsdam Parallel Ice Sheet Model (PISM-PIK). Many numerical issues had to be solved in order to generate a realistic representation of ice shelf dynamics. In a dynamic equilibrium simulation of the entire Antarctic ice sheet under present day conditions, we could reproduce the characteristic pattern of ice flow, with a smooth transition between the different flow regime, in a way that is consistent with observations. PISM-PIK code was merged back into PISM and is now used by many groups around the world.

The position of the grounding line, which separates the grounded and floating ice, strongly influences the stress balance between ice shelves and ice sheet. In a model intercomparison I could show that, by the use of a combined shallow approximation of the stress balance, PISM features the same quality of steady-state grounding-line migration and reversibility as models using higher-order approximations. With the help of sub-grid techniques we improved PISM's performance for coarse resolutions as well.

Ice loss from the Antarctic ice shelves mainly occurs via calving of icebergs which is a highly complex process involving different spatial and temporal scales. I proposed a first-order kinematic calving parameterization which is based on the local spreading rates along the calving front which is associated with the propagation of preexisting fractures. In this simple formulation, in most cases modeled ice shelves remain within the basins where they are presently observed, mainly controlled by the confining boundary geometry via the non-local stress balances.

Fractures in ice shelves often form for certain conditions at the inlets or at shear margins when ice flows along prominent geographical features. Hence the calving at the ice front is connected with fracture formation far upstream. Therefore, I introduced a field state variable which remembers the damage history along the flow towards the calving front. It appears that active fracture zones strongly affect the flow dynamics especially in the small buttressing ice shelves. My *fracture density* approach nicely captures this interaction of fracturing and ice shelf dynamics and provides the tools for more sophisticated calving parameterizations in large-scale land-ice models.

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