Incorporation of grounding line parameterizations in the three-dimensional ice sheet model SICOPOLIS

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Flow of Antarctic ice sheet in a large-scale ice sheet modeling is commonly represented with Shallow Ice Approximation (SIA) and Shallow Shelf Approximation (SSA). However, under coarse horizontal resolution (O ~10km), which is necessary for simulations of paleoclimate and long-term future, a combined SIA/SSA model has limited utility in simulating the migration of grounding lines (Pattyn et al. 2012). In this study, a sub-grid grounding line parameterization is incorpolated to the 3-dimensional ice sheet model SICOPOLIS to improve the representation of grounding line dynamics.

We use the 3-dimensional ice sheet model SICOPOLIS, which has been used in future projection of Antarctic ice sheet (Greve et al. 2020). The Dynamics of the Antarctic ice sheet is represented by Shallow-ice approximation (SIA), hybrid SIA-Shelfy stream Approximation and Shallow Shelf approximation (Sato and Greve 2012). We employed the grounding line parameterization of Schoof (2007), which computes ice velocity based on sub-grid horizontal ice flux across the grounding line. We conduct (A) MISMIP2 experiments (Pattyn et al. 2012), which is a hysteresis experiments under idealized bedrock topography and parameters to check the fundamental performance of grounding line migrations, and (B) equilibrium experiments under present-day climate condition with free-evolving ice sheet topography to examine the performance of the present-day simulation.

(A): We set up a 3-dimensional bedrock topography which is orthogonal to flow-line to imitate the experimental design of MISMIP2. The horizontal resolution is set to 32 km, which will be used in realisitic Antarctic simulations later. The simulated grounding line positions were not exactly the same as full-stokes model, but exhibited hysteresis behavior to perturbations, which was largely in agreement with other ice sheet models.

(B): In the previous setting with different basal sliding formulation (that used in Sato and Greve 2012), the WAIS was not maintained under the present-day climate forcing at the equilibrium with horizontal resolution of 32 km. In the numerical simulations in this study, we find that WAIS was maintained under the chosen parameter of a spatially uniform basal sliding coefficients and the grounding line parameterization. In the results of the present study indicates the grounding line parameterization tends to increase the volume of Antarctic ice sheet in total, but the simulated advances/retreats in grounding line positions depend on regions. The greater basal sliding tends to retreat grounding line position, suggesting careful treatments on parameters related to flow of ice are needed. There was not large differences at least with the chosen parameters and experimental design, but it does not exclude that the grounding line parameterization significantly affects the transient evolution of ice sheets, which should be investigated further. We need more improvements on the choice of uncertain parameters (e.g. enhancement factors, basal sliding coefficients) and model evaluations using observational data.

References

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