Evaluating an Antarctic flow model (PISM) using InSAR surface velocities

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We present a thermomechanically coupled hybrid model [2] of the current state of the whole Antarctic ice sheet, it uses both the nonsliding shallow ice approximation (SIA) [3] and the shallow-shelf approximation (SSA) with plastic till [9].

The model is fully parallel, using the PETSc library for parallel scientific computation (www-unix.mcs.anl.gov/petsc/petsc-as/). The source code is publicly-available and well-documented (`www.pism-docs.org`).

Inputs

The model uses publicly-available data to describe the current climate, and it assumes steady climate as the interest is in dynamical features. We use thickness and bed elevation from BEDMAP [7], with smoothing of the bed elevations where the ice is thick. Accumulation and surface temperature were provided by D. Vaughan at BAS from [11,4]. Geothermal flux varies according to the Shapiro-Ritzwoller map [10].

Ice dynamics and basal models

Both vertical shear stress balance (SIA) and membrane stress balance (SSA) control the flow. The velocities are combined by averaging, with greater SSA contribution where the sliding is fast. Simplified geometry experiments, similar to EISMINT but using SSA-controlled sliding, show that ice stream flow is stable for long (100ka) runs and produces consistent and physically reasonable flow speeds under grid refinement [2].

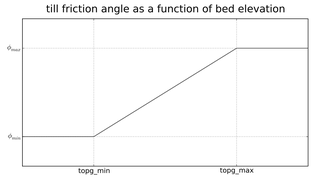
The model has few tunable parameters, and inverse modeling is not used to compute bed strength. Instead, a standard model for till yield stress is used, $\tau_c = (\tan\phi)(\rho g H - p_w)$, where the till friction angle ϕ is determined by bed topography, with weakest till where the bed is significantly below sea level. The modeled pore water pressure p_w is proportional to the time-integrated basal melt rate.

Evaluation methods

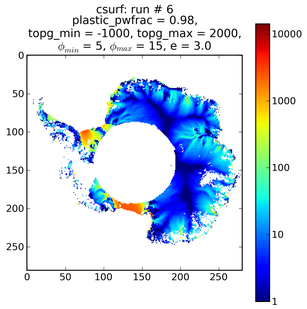
- Modeled surface velocity versus MAMM observations where available (http://bprc.osu.edu/rsl/; [6]).
- Histogram of modeled surface velocity versus MAMM.
- Modeled ice volume rate of change versus GRACE rate [12].

Future work

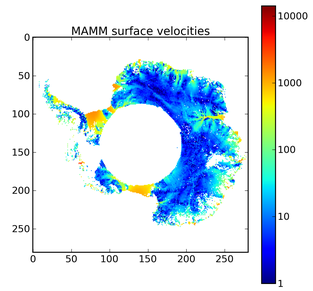
- Perform parameter studies on 10km grid. We have identified three major parameters for study: (i) viscosity normalization for the SSA balance in sliding parts, (ii) grain size for the Goldsby-Kohlstedt flow law used in SIA, and (iii) maximum fraction of overburden which pore water pressure is allowed to reach (controls average sliding resistance).
- More observational data to compare to: IceSat surface elevation rate, Vostok age-versus-depth relation, RIGGS data for the Ross ice shelf.



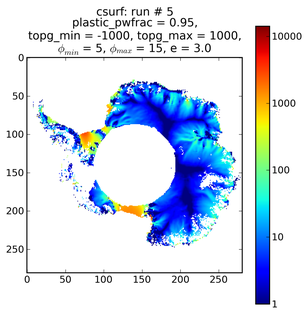
Surface velocities



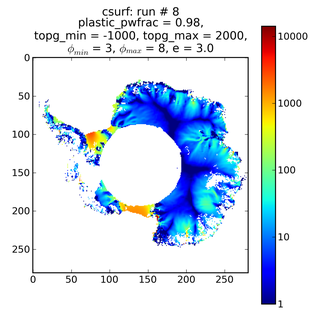
model output, $\frac{m}{a}$



MAMM data, $\frac{m}{a}$

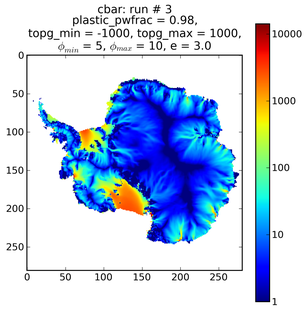


model output, $\frac{m}{a}$

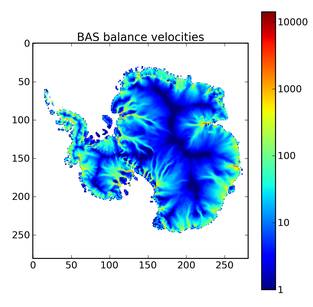


model output, $\frac{m}{a}$

Vertically-averaged velocities

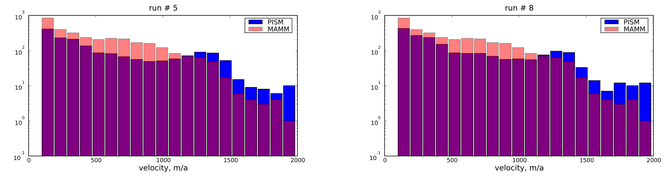


model output, $\frac{m}{a}$

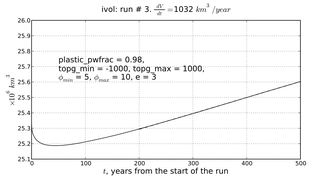


BAS (assumes steady geometry), $\frac{m}{a}$

Histogram of modeled surface velocity versus MAMM



Model ice volume rate of change



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