Text S1

Ice sheet model and inversion technique

In this work we use the higher-order Community Ice Sheet Model (CISM) to simulate ice flow on the Siple Coast of Antarctica. The model solves the conservation of momentum, mass, and thermal energy, as described in Bougamont et al. [2011], and is applied with a 5 km spatial resolution. To obtain realistic simulations of ice streams, we use an inversion technique (as described by *Price et al.* [2011]) through which surface velocities in the model are iterated towards target values. In our case the target values are surface velocities observed in A) 1997 [*Joughin et al.*, 2002] and B) 2009 [*Rignot et al.*, 2011]. With constant model geometry prescribed from Bedmap2 [*Fretwell et al.*, 2013], mean annual surface air temperatures prescribed from AVHRR infrared data [*Comiso*, 2000], accumulation rates derived from interpolation of in-situ point measurements [*Arthern et al.*, 2006], and geothermal heat flux [*Maule et al.*, 2005; *Shapiro and Ritzwoller*, 2004], we converge temperature, effective viscosity, and velocity fields to equilibrium.

In the first step of this inversion technique, we prescribe a no-slip basal boundary condition. The speed obtained in this first step represents internal ice deformation, and we subtract this value from the target surface velocity, to determine the sliding velocity, U_b, needed to fully converge model and observation. We then use the sliding law $|\tau_b| = \beta |U_b|$ to obtain the basal traction, τ_b, and traction parameter, β, required to enforce sliding at the desired speed, U_b. The model is, in this way, iteratively run to a new and complete equilibrium. The average misfit between the final, modelled surface-velocity and the observational target, for the regions included in this study, is 6 m yr^{-1}, which is satisfactory given that the measurement error in the target velocity datasets are of a similar magnitude (about 10 m yr^{-1}).

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