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Basal motion beneath the Antarctic ice sheet: a comparison of linear and plastic till rheologies in a multi-modal flow model

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Our model of Antarctic ice sheet flow includes conservation of mass and energy (the latter couples the velocity and temperature fields), nonlinear ice rheology, and coupling to ice shelves. Ice streams are included because they couple ice shelf dynamics to the inland ice sheet far up-glacier via longitudinal stress gradients, and are thus integral to the flow dynamics of the ice sheet. Our model (like others) includes assumptions about basal motion, but there are few constraints on this aspect of the flow.

Flow of the inland ice sheet is simulated using the shallow ice approximation where the ice sheet is frozen to its bed and where basal sliding velocities are low. Ice stream flow is simulated using the "dragging ice shelf" equations of MacAyeal (1989), but we can use either a linear sliding law as suggested by MacAyeal or a bed model consisting of perfectly-plastic till as described recently by Schoof (2006). In the former case the locations of the ice streams must be specified before the depth-dependent (and depth–independent, within ice streams) velocity field can be calculated. We do this by specifying ice-stream flow wherever the balance velocities exceed an arbitrary maximum, using an automatic procedure. Measured surface velocities can also be used. (Surface velocity coverage, derived via satellite remote sensing [e.g., Joughin, 2002], is currently incomplete for Antarctica but it is generally good where there are ice streams.) In the case of the plastic till bed model of Schoof (2006), the locations of the ice streams are part of the solution. That is, for plastic till we solve a free boundary problem which determines the regions of ice-stream flow and the velocities simultaneously, given the ice geometry and temperatures.

We apply these ideas to modeling the current state of the Antarctic ice sheet. Based on a pre-computed velocity field and temperature state for the current sheet, we use the linear sliding law assumption to compute a map of the basal sliding friction coefficient that is consistent with the current mass balance (or alternatively, measured surface) velocities. From the same starting state we also compute the ice stream flow which results from a plastic till model. For this plastic till bed model, we will compare the results of several simplified assumptions about the spatial distribution of the yield stress. The results will be compared to the known locations and flow velocities of the ice streams.

References

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