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Sliding conditions beneath the Antarctic Ice Sheet

Rupert Gladstone[1], John Moore[1,2], Michael Wolovick[2], and Thomas Zwinger[3]
[1]Arctic Centre, University of Lapland, Rovaniemi, Finland (RupertGladstone1972@gmail.com)
[2]College of Global Change and Earth System Science, Beijing Normal University, Beijing, China
[3]CSC IT Center for Science, Espoo, Finland

Computer models for ice sheet dynamics are the primary tools for making future predictions of ice sheet behaviour, the marine ice sheet instability, and ice sheet contributions to sea level rise. However, the dominant mode of flow for ice streams is sliding at the bed, and the physical processes that control sliding are not well understood. Ice sheet models often use hard-bed (often Weertman-type) sliding rules for computational efficiency. However, soft beds with deformable sediments, which are known from laboratory experiments and direct glacier observations to exhibit Coulomb plastic behaviour, are ubiquitous beneath fast flowing ice streams. Using hard-bed sliding rules leads to actively misleading rates of inland surface diffusion and grounding line migration as compared to plastic beds, leading to incorrect forecasts of future sea level rise. Here, we use a 3D Stokes-flow ice sheet model along with observations of the Antarctic Ice Sheet to infer, through inversions and steady temperature simulations, key basal properties, most important of which are sliding speed, basal resistance, friction heat and grounded ice basal melt rate. In addition to simulations of the whole Antarctic Ice Sheet we implement fine resolution simulations of the Pine Island Glacier and its catchment. Contrary to the predictions of most hard-bed sliding relations, we find no correlation between basal resistance and sliding speed for fast moving ice streams. These results emphasize the importance of Coulomb plastic sliding, and strongly suggest that ice sheet modelers should devote greater efforts to developing models that can incorporate Coulomb plastic sliding relations without generating numerical instabilities. We use our model results, along with some assumptions, to infer properties of the sub-glacial hydrologic system. Assumptions about connectivity of the sub-glacial hydrologic system to the ocean limit our capacity to assess sliding relations that incorporate a dependence on effective pressure, and likely cause underestimates of ice sheet mass loss in model-based predictions utilising such sliding relations. Hydrology modelling is likely essential both to further assess sliding relations and to use sliding relations in future predictions. We estimate that the dominant source of basal meltwater for Pine Island Glacier is due to friction heat caused by basal sliding, despite recent estimates of high heating due to volcanic activity.