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The influence of sliding velocity and effective stress on the distribution of strain in subglacial till

Dougal Hansen[1], Anders Daamsgard[2], and Lucas Zoet[1]
[1]University of Wisconsin-Madison, Department of Geoscience, United States of America (ddhansen3@wisc.edu)
[2]Stanford University, Department of Geophysics, United States of America (anders@adamsgaard.dk)

The distribution of strain in actively deforming subglacial till is an important control on the sliding velocity and sediment transport of soft-bedded glaciers. In situ field observations, laboratory experiments, and numerical simulations have demonstrated that strain accumulation within subglacial till is often greatest at the ice-bed interface and decreases monotonically with depth, forming a convex-upward profile. However, the mechanisms that set the form of the profile and depth of deformation remain unconstrained. Here we systematically test the influence of two independent variables, effective stress and sliding velocity, on the distribution of strain in a fine-grained, sandy till emplaced beneath a layer of moving ice. Laboratory sliding experiments, conducted with a brand-new ring-shear device with a transparent sample chamber, are coupled with two suites of state-of-the-art numerical experiments using 1) a discrete element model and 2) a non-local granular fluidity continuum model designed to emulate till deformation. Five effective stresses and five sliding velocities are tested with the other parameter held constant (velocity and effective stress, respectively). For the ring shear experiments, images of the till bed are acquired at regular intervals, and we quantify the displacement of sediment grains that occurs between image captures using digital image correlation. These experiments represent the first instance where the deformation of till during glacier slip can be observed in real-time and linked directly to its controlling processes. Furthermore, they provide an opportunity to juxtapose the predictions of two new granular dynamic models against empirical observations in a controlled setting, providing an invaluable ground truth for future, larger-scale implementations simulating bedform genesis and soft-bedded glacier dynamics.