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An intraglacial viscous mechanism for periodic glacial earthquakes

Christine McCarthy (1), Peter Kelemen (1), Rob Skarbek (1), and David Goldsby (2)

(1) Lamont Doherty Earth Observatory, Columbia University, United States (mccarthy.christine@gmail.com), (2) University of Pennsylvania, United States

Motion of glaciers and ice streams is analogous to fault slip. An equivalent variety of slip modes have been observed in each. We have developed a 1D numerical model of viscous flow on a pre-existing fine-grained ice shear zone that builds on observations of enhanced strain in dirty, fine-grained layers in the lowermost portions of glaciers. We incorporate grain-size sensitive flow laws determined from laboratory experiments, which we validate using direct measurements from borehole data containing layers of high dust particle concentrations. In the model, we monitor grain size evolution and shear heating as stress and strain rate evolve. In realistic parameter ranges, the model produces oscillatory flow behavior where no oscillatory external force is needed. Instead, periodicity comes from the increase in temperature due to shear heating, which eventually warms the shear zone to a temperature that allows it to accommodate all of the far field strain. Melting then releases stored elastic strain, and causes stress to plummet. The periodic shear-heating instabilities lead to “viscous earthquakes”. Such a mechanism may play a role in periodic strain rate variations observed for glaciers and ice streams worldwide.