Solid Earth Physics Seminar, Harvard University

Thursday, 29 August 2013, 1:30 pm
Faculty Lounge, 4th Floor, Hoffman Lab, 20 Oxford Street

Experimental Constraints on the Flow of Ice: From Greenland to Ganymede

David Goldsby

Department of Geological Sciences
Brown University

Abstract:

The rheological behavior of ice is classically described by the Glen law, an empirical power law expression between strain rate and stress, with a power (stress exponent) of 3. Glen-law behavior is usually attributed to, and is consistent with, a dislocation creep mechanism. Here I show that in fact the Glen law approximates an average of two creep mechanisms, dislocation creep proper (characterized by a stress exponent of 4) and a creep mechanism (characterized by a stress exponent of ~2) wherein dislocation slip on the basal slip system is accommodated by grain boundary sliding (GBS). The latter mechanism, for which the creep rate depends markedly on grain size, has been revealed by recent creep experiments on specimens of small (sub-0.2 mm) grain size. Extrapolation of the flow law for GBS creep to the grain sizes of glaciers and ice sheets strongly suggests that this mechanism controls flow within these bodies at stresses $< \sim 0.1$ MPa; at stresses of ~0.1 MPa or larger (for example, in ice stream margins and in rapidly deforming basal ice), ice deforms either at the field boundary between GBS creep and dislocation creep, or within the dislocation creep regime. Thus, modeling of flow in glaciers, ice sheets and icy planetoids is best accomplished using a composite flow law containing the contributions of GBS creep and dislocation creep. Diffusion creep is shown to contribute significantly to the flow of natural ice bodies at stresses no higher than $\sim 10^{-4}$ MPa.