Geophysical Research Abstracts
Vol. 15, EGU2013-9640, 2013
EGU General Assembly 2013

Using composite flow laws to extrapolate lab data on ice to nature

Hans de Bresser (1), Sabrina Diebold (1), and William Durham (2)

(1) Department of Earth Sciences, Faculty of Geosciences, Utrecht University, The Netherlands, (2) Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, USA

The progressive evolution of the grain size distribution of deforming and recrystallizing Earth materials directly affects their rheological behaviour in terms of composite grain-size-sensitive (GSS, diffusion/grain boundary sliding) and grain-size-insensitive (GSI, dislocation) creep. After time, such microstructural evolution might result in strain progressing at a steady-state balance of mechanisms of GSS and GSI creep. In order to come to a meaningful rheological description of materials deforming by combined GSS and GSI mechanisms, composite flow laws are required that bring together individual, laboratory derived GSS and GSI flow laws, and that include full grain size distributions rather than single mean values representing the grain size. A composite flow law approach including grain size distributions has proven to be very useful in solving discrepancies between microstructural observations in natural calcite mylonites and extrapolations of relatively simple laboratory flow laws (Herwegh et al., 2005, J. Struct Geol., 27, 503-521).
In the current study, we used previous and new laboratory data on the creep behavior of water ice to investigate if a composite flow law approach also results in better extrapolation of lab data to nature for ice. The new lab data resulted from static grain-growth experiments and from deformation experiments performed on samples with a starting grain size of either < 2 microns ("fine grained ice") or of 180-250 microns ("coarse grained ice"). The deformation experiments were performed in a special cryogenic Heard-type deformation apparatus at temperatures 180-240 K, at confining pressures 30-100 MPa, and strain rates between 1E-08/s and 1E-04/s. After the experiments, all samples were studied using cryogenic SEM and image analysis techniques. We also investigated natural microstructures in EPICA drilling ice core samples of Dronning Maud Land in Antartica. The temperature of the core ranges from 228 K at the surface to 272 K close to the bedrock. Grain size distributions (in 2D) were determined for all 41 samples studied.
Combining the experimental grain-growth results with the results of the fine-grained and coarse-grained samples allows us to describe the experimental deformation of ice in terms of composite flow and to speculate about the evolution towards a balance between GSS and GSI mechanisms. Flow stresses for the natural DML samples were calculated at realistic strain rates between 1E-10/s and 1E-12/s using i) pure GSS-creep, ii) pure GSI-creep, and iii) composite GSI+GSS creep taking the full grain size distribution into account. At a constant strain rate, the contribution of GSS mechanisms to the overall strain rate remains roughly the same along the ice core. Apparently, the change in temperature with depth goes hand in hand with a change in grain size such that there is an overall balance between GSI- and GSS-creep mechanisms. The results show that GSS-mechanisms might well be operative in ice at a range of conditions, but that GSI mechanisms will remain important except at very slow strain rates. In the presentation, new insights emerging from the composite flow law approach to ice as well as pitfalls of the method will be discussed.