EGU2020-13927
https://doi.org/10.5194/egusphere-egu2020-13927
EGU General Assembly 2020

Evolution of crystallographic preferred orientations in flowing polycrystalline ice: A continuum modelling approach validated against laboratory experiments

Daniel Richards[1], Sam Pegler[2], Sandra Piazolo[3], and Oliver Harlen[2]
[1]University of Leeds, School of Computing, Fluid Dynamics CDT, United Kingdom of Great Britain and Northern Ireland (d.h.m.richards@gmail.com)
[2]University of Leeds, School of Mathematics, United Kingdom of Great Britain and Northern Ireland
[3]University of Leeds, School of Earth and Environment, United Kingdom of Great Britain and Northern Ireland

Understanding the anisotropic flow of ice is likely a key factor for the reliable prediction of the evolution of certain regions of the Earth's ice sheets. Anisotropy of the crystal lattice alignment of ice grains is typically neglected in the large majority of ice-sheet models, however the viscosity of ice can vary by a factor of at least 9 in different directions, indicating the potential to provide a dominant control. Even though anisotropy can have a large regional influence, its effects are currently poorly understood. For example, it is an open question as to how different varieties of crystal fabrics are produced by different forms of deformation, and how these dynamics vary with temperature.

To address these questions, we use a continuum-mesoscopic approach, proposed by Faria (2006a) and Placidi (2010) to model the evolution of the ice crystallographic preferred orientations (CPOs). The model assumes strain induced crystal lattice rotation i.e. crystal plasticity with rigid body rotation where parameters representing the following processes are incorporated: the relative importance of basal slip, the magnitude of grain-boundary migration and the magnitude of rotation recrystallization. We solve the system using a new spectral method, which is computationally highly efficient, and able to fully resolve the multiple dimensions of the problem (time, space and the two dimensions of orientation angle). By considering the predictions of the model in the cases of deformation representing shear and compression, the model is determined to reproduce all the detail features observed in ice CPOs evolution such as secondary clusters or cone shapes. The results show excellent agreement with experiments of ice deformation in both shear and compression. The experimental comparison is used to determine the first constraints on three temperature-dependent dimensionless numbers defining the relative important of the recrystallization and slip processes. With these dependencies constrained using shear experiments, the application of the model results is able to reproduce the observations of crystal structure in compressive experiments with no further fitting parameters. The model is thus found to provide good agreement with laboratory experiments across a range of temperatures, strain rates and flow fields. Moreover, the predicted patterns correspond qualitatively to those observed in natural ice from cores, with our results providing the first theoretical demonstration of the

characteristics of the fabric structure.