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Effect of vorticity on polycrystalline ice deformation

Maria-Gema Llorens (1,2), Albert Griera (3), Florian Steinbach (1,2), Paul D. Bons (1), Enrique Gomez-Rivas (4), Daniela Jansen (2), Ricardo A. Lebensohn (5), Ilka Weikusat (1,2)

(1) Department of Geosciences, Eberhard Karls University of Tübingen, Germany (maria-gema.llorens-verde@uni-tuebingen.de), (2) Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany, (3) Departament de Geologia, Universitat Autònoma de Barcelona, Spain, (4) School of Geosciences, University of Aberdeen, United Kingdom, (5) Material Science and Technology Division. Los Alamos National Laboratory, USA

Understanding ice sheet dynamics requires a good knowledge of how dynamic recrystallisation controls ice microstructures and rheology at different boundary conditions. In polar ice sheets, pure shear flattening typically occurs at the top of the sheets, while simple shearing dominates near their base. We present a series of two-dimensional microdynamic numerical simulations that couple ice deformation with dynamic recrystallisation of various intensities, paying special attention to the effect of boundary conditions. The viscoplastic full-field numerical modelling approach (VPFFT) (Lebensohn, 2001) is used to calculate the response of a polycrystalline aggregate that deforms purely by dislocation glide. This code is coupled with the ELLE microstructural modelling platform that includes recrystallisation in the aggregate by intracrystalline recovery, nucleation by polygonisation, as well as grain boundary migration driven by the reduction of surface and strain energies (Llorens et al., 2016a, 2016b, 2017). The results reveal that regardless the amount of DRX and ice flow a single c-axes maximum develops all simulations. This maximum is oriented approximately parallel to the maximum finite shortening direction and rotates in simple shear towards the normal to the shear plane. This leads to a distinctly different behaviour in pure and simple shear. In pure shear, the lattice preferred orientation (LPO) and shape-preferred orientation (SPO) are increasingly unfavourable for deformation, leading to hardening and an increased activity of non-basal slip. The opposite happens in simple shear, where the imposed vorticity causes rotation of the LPO and SPO to a favourable orientation, leading to strain softening. An increase of recrystallisation enhances the activity of the non-basal slip, due to the reduction of deformation localisation. In pure shear conditions, the pyramidal slip activity is thus even more enhanced and can become higher than the basal-slip activity. Our results further show that subgrain boundaries can be developed by the activity of the non-basal slip systems. The implementation of the polygonisation routine reduces grain size and SPO, but does not significantly change the final LPO, because newly nucleated grains approximately keep the c-axis orientations of their parental grains. However, it enables the establishment of an equilibrium grain size, and therefore the differential stress reaches a steady-state.

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