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Numerical simualtions and implications of air inclusions on the microdynamics of ice and firn

Florian Steinbach (1), Ilka Weikusat (1,2), Paul Bons (1), Albert Griera (3), Johanna Kerch (4), Ernst-Jan Kuiper (5), and Maria-Gema Llorens-Verde (1)

(1) Eberhard Karls Universität Tübingen, Dept. of Geosciences, Tübingen, Germany (florian.steinbach@uni-tuebingen.de), (2) Alfred-Wegener-Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, (3) Departament de Geologia, Universitat Autònoma de Barcelona, Spain, (4) Institute of Environmental Physics, Ruprecht Karls University of Heidelberg, Germany, (5) Department of Earth Sciences, Utrecht University, Netherlands

Although ice sheets are valuable paleo-climate archives, they can loose their integrity by ice flow (Faria et al. 2010). Consequently, understanding the dynamic processes that control the flow of ice is essential when investigating the past and future climate. While recent research successfully modelled the microdynamics of pure ice (e.g. Montagnat et al., 2014; Llorens et al., 2015), work taking into account second phases is scarce. Only a few studies also show the microstructural influence of air inclusions (Azuma et al., 2012, Roessiger et al., 2014). Therefore, modelling was performed focussing on the implications of the presence of bubbles on the microdynamical mechanisms and microstructure evolution.

The full-field theory crystal plasticity code (FFT) of Lebensohn (2001), was coupled to the 2D multi-process modelling platform Elle (Bons et al., 2008), following the approach by Griera et al. (2013). FFT calculates the viscoplastic response of polycrystalline materials deforming by dislocation glide, taking into account mechanical anisotropy. The models further incorporate surface- and stored strain energy driven grain boundary migration (GBM) and intracrystalline recovery simulating annihilation and rearrangement of dislocations by reduction of internal misorientations. GBM was refined for polyphase materials following Becker et al. (2008) and Roessiger et al. (2014). Additionally, the formation of new high angle grain boundaries by nucleation and polygonisation based on critical internal misorientations has been implemented. Successively running the codes for different processes in very short numerical timesteps effectively enables multi-process modelling of deformation and concurrent recrystallisation.

Results show how air inclusions control and increase strain localisation, leading to locally enhanced dynamic recrystallisation. This is in compliance with Faria et al. (2014), who theoretically predicted these localizations based on firn data from EPICA Dronning Maud Land (EDML) ice core. We propose that strain localisation has a strong control on the dominating recrystallisation mechanisms and can account for microstructural observations from alpine and polar ice cores. Our results confirm dynamic recrystallisation occurring in the uppermost levels of ice sheets as observed by Kipfstuhl et al. (2009) and Weikusat et al. (2009) in EDML core.

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