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Grain dissection as a grain size reducing mechanism during ice microdynamics

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Ice sheets are valuable paleo-climate archives, but can lose their integrity by ice flow. An understanding of the microdynamic mechanisms controlling the flow of ice is essential when assessing climatic and environmental developments related to ice sheets and glaciers. For instance, the development of a consistent mechanistic grain size law would support larger scale ice flow models. Recent research made significant progress in numerically modelling deformation and recrystallisation mechanisms in the polycrystalline ice and ice-air aggregate (Llorens et al., 2016a,b; Steinbach et al., 2016). The numerical setup assumed grain size reduction is achieved by the progressive transformation of subgrain boundaries into new high angle grain boundaries splitting an existing grain. This mechanism is usually termed polygonisation. Analogue experiments suggested, that strain induced grain boundary migration can cause bulges to migrate through the whole of a grain separating one region of the grain from another (Jessell, 1986; Urai, 1987). This mechanism of grain dissection could provide an alternative grain size reducing mechanism, but has not yet been observed during ice microdynamics.

In this contribution, we present results using an updated numerical approach allowing for grain dissection. The approach is based on coupling the full field theory crystal visco-plasticity code (VPFFT) of Lebensohn (2001) to the multi-process modelling platform Elle (Bons et al., 2008). VPFFT predicts the mechanical fields resulting from short strain increments, dynamic recrystallisation process are implemented in Elle. The novel approach includes improvements to allow for grain dissection, which was topologically impossible during earlier simulations. The simulations are supported by microstructural observations from NEEM (North Greenland Eemian Ice Drilling) ice core. Mappings of c-axis orientations using the automatic fabric analyser and full crystallographic orientations using electron backscatter diffraction (EBSD) are presented.

Numerical simulations predict and resolve the microstructural evolution over strain and time. The occurrence of processes such as grain dissection can only be proven using such time resolved movies of microstructure evolution. We will present movies that show grain dissection as a common process during the simulations. Microstructures obtained from NEEM ice core support the observations and we provide evidence for grain dissection in natural ice. Grain dissection is observed to be most efficient relative to polygonisation, when the microstructure approaches steady state grain sizes. This is consistent with analogue experiments observing grain dissection by Jessell (1986) and Urai (1987). Our research suggests a novel grain size reducing mechanisms in ice microdynamics that should be considered when developing a consistent grain size law.