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Multi-scale characterization of strain heterogeneities and associated misorientations in laboratory deformed polycrystalline ice: Image Correlation techniques, EBSD observations and full-field modeling

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During transient creep in polycrystalline ice, strong stress and strain-rate intragranular heterogeneities develop as the result of the very large viscoplastic anisotropy of the ice crystal. In order to characterize these heterogeneities, creep tests were performed on "2D" columnar ice samples with in-plane grain size of the order of 10 mm. Strain heterogeneity development was measured during the tests with a Digital Image Correlation technique at the (sub)millimeter scale. Lattice orientations were evaluated at a spatial resolution of about 43 microns over the whole specimen surface (10*10 cm2) with an Automatic Ice Texture Analyzer, which only provides the orientation of crystal c-axes. For a few selected grains further analyses by EBSD allow obtaining the full local lattice orientation (c- and a- axes) with spatial resolution lower than one micron.
Complex strain paths are evidenced at the sample scale with strain highly concentrated close to grain boundaries and triple junctions No direct correlation between local grain orientation and strain field can be observed, as a result of the complex stress redistribution within the sample. Recrystallization is observed locally in areas where the local strain level is approximately one order of magnitude larger than the applied macroscopic strain. At the local scale, misorientation maps provided by the EBSD data evidence the initiation of sub-structures at the grain boundaries, with propagation inside the grains. Variations of dominant rotation axes and orientation of planes of maximum misorientation changes within the same grain point to local change of the activated slip systems i.e. the nature of the involved dislocations. To investigate the causes for these variations results are analyzed in view of full-field modelling of analyzed grain areas allowing us to evaluate a possible link between main stress axis orientation variations and slip system activation.
This study provides a step towards the understanding of strain heterogeneities developing during transient creep in ice (and more generally highly anisotropic materials) by means of multi-scale approaches.