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# Flow of pure water ice: Grain growth and deformation

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Water ice in outer space is a significant constituent, forming icy layers and ice bodies on moons and planets. Because of the extreme conditions on icy moons in the outer solar system, it is essential to acquire experimental data on the deformation behaviour of ice at a wider range of pressures and temperature than relevant for terrestrial ice. Only with a good understanding of ice at these conditions it is possible to include the microphysics of ice in meaningful numerical simulations. One important basis for ice flow modelling is a deformation mechanism map including both grain-size-sensitive (GSS) flow and grain-size-insensitive (GSI) flow. Due to dynamic recrystallization and/or grain growth, the grain size distribution of the deforming aggregate will be modified during deformation, resulting in a progressive change in the relative contribution of GSS and GSI mechanisms to the overall strain rate. A deformation mechanism map helps exploring such changes.

We studied grain size evolution both during static annealing and during deformation. Static anneals ran for up to two weeks at $213 \leq T \leq 268$ K and hydrostatic pressures 0.1 MPa and 100 MPa. Static grain growth observations allow us to calibrate values for the grain size exponent $m$ and the activation energy $Q$ as used in conventional grain growth laws. Axial deformation experiments were carried out for a variety of starting grain sizes, from smaller than 2 microns up to 250 microns, with both narrow and broad size distributions. Small grain sizes promote GSS creep; large sizes promote GSI creep and a mixture of large and small grains will result in mixed-mechanism deformation. All deformation runs were performed at temperatures $> 170$ K, pressures ranging between 30 MPa and 100 MPa and strain rates between 1E-08/s and 1E-04/s.

The new mechanical data of the deformation runs have been combined with data from various previous studies, allowing us to create an updated deformation mechanism map. Progressive changes in the microstructure appear to let the material evolve towards a steady state balance between GSS and GSI mechanism at high strain. With the application of such balance, modelling the flow of planetary ice would become easier than it is the case at present.