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The effect of microstructure on static grain growth in ice

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Static grain growth, driven by grain boundary surface energy, is an important process in crystalline materials close to their melting temperature. In polar ice caps it is significant in the upper hundreds of meters where an increase in grain size with depth is usually observed. Grain growth is, however, important at all levels, as it modifies the microstructure in competition with other processes, such as dislocation creep-driven dynamic recrystallisation.

Grain growth is usually described by a growth law of the type $(r_t - r_0)^n = kt$, where r_t and r_0 are the mean grain radius at time t and time t=0, respectively, n the growth exponent and$k$ a material-dependent parameter. In case of ideal grain growth, the microstructures develops towards a foam texture and n=2. The values of k and n can be determined from experiments or measurements on natural ice, where it is commonly observed that $n > 2$. Deviations from ideal grain growth can be attributed to factors such as pinning particles (clathrates, air bubbles) or anisotropic surface energies. It is rarely taken into account that the microstructure is an important material property that also influences the growth rate. This has two consequences:

i) Experiments with evolving microstructures produce erroneous growth parameters (k and n). This is, for example, the case when the starting microstructure is not an ideal foam texture, but evolves towards one during the experiment. This typically leads to an overestimate of n.

ii) Values of k and n can only be applied to cases where the microstructure is identical to the one for which these values were determined. This means that values derived from static growth experiments cannot be used to model the effect of the competition of grain growth with other processes that act on the microstructure.

Numerical simulations with the software package Elle were used to study the effect of microstructure on the grain growth rate. These simulations showed, for example, that a change from a normal to a lognormal grain size distribution causes a threefold increase in the value of k.