Ice-sheet flow transitions: for how long can crystallographic preferred orientations be preserved?

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Abstract

Creep due to ice flow is generally thought to be the main cause for the formation of crystallographic preferred orientations (CPOs) in polycrystalline anisotropic ice. However, linking the development of CPOs to the ice flow history requires a proper understanding of the ice aggregate's microstructural response to flow transitions.

In this contribution the influence of ice deformation history on the CPO development is investigated by means of full-field numerical simulations at the microscale. We simulate the CPO evolution of polycrystalline ice under combinations of two consecutive deformation events up to high strain. Ice polycrystalline viscoplastic deformation was simulated using the Fast Fourier Transform algorithm (VPFFT), within the numerical open-source platform ELLE (http://www.elle.ws).

A volume of ice is first deformed under co-axial boundary conditions, which results in a CPO. The sample is then subjected to different boundary conditions (co-axial or non-coaxial) in order to observe how the deformation regime switch impacts on the CPO.

The model results indicate that the second flow event tends to destroy the first, inherited fabric, with a range of transitional fabrics. However, the transition is slow when crystallographic axes are critically oriented with respect to the second imposed regime. Therefore, interpretations of past deformation events from observed CPOs must be carried out with caution, particularly, in areas with complex deformation histories.

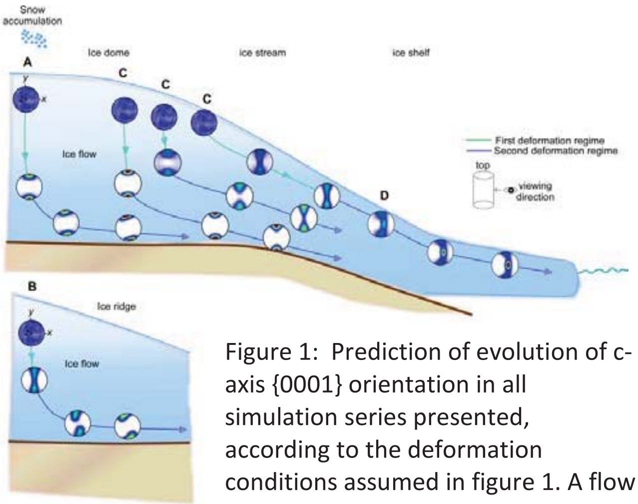

Figure 1: Prediction of evolution of c-axis {0001} orientation in all simulation series presented, according to the deformation conditions assumed in figure 1. A flow change produces an overprint of the previous CPO, with a range of transition fabrics.

References

Bons, P.D., Koehn, D., Jessell, M.W., 2008. Microdynamic Simulation. Lecture Notes in Earth Sciences 106, Springer, Berlin. 405 pp.

Lebensohn, R.A., Rollett, A.D. 2020. Spectral methods for full-field micromechanical modelling of polycrystalline materials. Computational Materials Science, 173, p.109336.

Llorens, M.G., Gomez-Rivas, E., Ganzhorn, A.C., Griera, A., Steinbach, F., Roessiger, J., Labrousse, L., Walte, N.P., Weikusat, I., Bons, P.D. 2019. The effect of dynamic recrystallisation on the rheology and microstructures of partially molten rocks. Journal of Structural Geology, 118, pp.224-235.