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Microstructure-based simulations of the viscous densification of snow and firn.

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In this paper, the authors present significant contributions to the homogenization of the viscous behavior of snow and firn. They perform finite element simulations of the mechanical behavior of snow and firn in oedometer conditions based on X-ray micro-tomography images. They compare the homogenized viscous behavior to experimental results to back analyze the micro origin of the viscous behavior. In particular, they discuss in details the modeling of the ice matrix as a poly-crystal in case of firn (isotropic behavior) and as a mono-crystal in case of snow (anisotropic behavior). This is done by considering a sensitivity analysis on different ice rheologies.
The paper is well written, easy to follow with a rather clear three dimensional formulation of the viscous behavior of ice and snow. I recommend publication subjected to the minor following comments.

1. In the simulations of the mechanical response of snow and firn samples, did the authors model the transient elasto-visco-plastic regime? How did they isolate the visous response?

2. Does the local anisotropy of the ice behavior reflect on the macroscopic behavior, or does the local fluctuations in the directions of ice anisotropy cancel out at the macroscale?

3. Complementary to the given reference (Tsuda et al. 2010), I would like to underline a few theoretical references showing that the exponent n of the viscous behavior of a porous material is preserved in the up-scaling process. The authors could also refer to Auriault et al., 1992; Suquet, 1993; Orgéas et al., 2007.
Auriault, J.-L., Bouvard, D., Dellis, C., and Lafer, M.: Modeling of hot compaction of metal powder by homogenization, Mech. Mater., 13, 247–275, 1992.
Suquet, P.: Overall potentials and extremal surfaces of power law orideally plastic composites, J. Mech. Phys. Solids, 41, 981–1002, 1993.
Orgéas, L., Geindreau, C., Auriault, J.-L., and Bloch, J.-F.: Upscaling the flow of generalised Newtonian fluids through anisotropic porous media, J. Non-Newton. Fluid, 145, 15–29, 2007.

4. As a curiosity, the authors could include some explanations on how the ice matrix switches from mono to poly-crystals when snow transforms into firn.

5. In addition to the given references, the anisotropic formulation of the viscous behavior of the ice behavior (which relies on the form of the fourth order tensor a) could be included explicitly in the text to have a self-supporting paper. In the mono-crystal model, what are the conditions applied on the interfaces between two crystals?

6. When referring to the segmentation of the ice matrix into mono-crystals (l.215), the authors could refer more explicitly to the images obtained using diffraction X-ray micro-tomography.

7. Maybe the authors could consider moving Section 3.3 "testing the finite element setup" in an appendix.