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Local flow modelling of strain-induced anisotropic ice

F. Gillet-Chaulet (1), O. Gagliardini (1), J. Ruokolainen (2), T. Zwinger (2) and J. Meyssonnier (1)

(1) LGGE CNRS UJF-Grenoble I, France, (2) CSC-Scientific Computing Ltd., Finland
(Contact gagliar@lgge.obs.ujf-grenoble.fr/Fax: 33 4 76 8 42 01)

An efficient and *easy-to-use* method which allows to take into account strain induced fabric development in polar ice sheets has been implemented into the finite element (FE) code ELMER. Since the deformation mechanisms involved at very low strain rates, such as observed in polar ice sheets, cannot be reproduced under laboratory conditions, the mechanical behaviour of polycrystalline ice is currently obtained by using homogenization schemes that assume a known behaviour of the ice single crystal (grain). By construction, these models are too much time consuming to be easily implemented into a large scale ice sheet flow simulation code.
A way to remedy this is presented. The problem is twofold: first determine the mechanical behaviour of ice with a given anisotropy, second describe anisotropy evolution. Polycrystalline ice is considered as continuous medium whose behaviour is linearly orthotropic. On the other hand, fabric evolution is controlled by the rotation of the grains c-axes that results from their deformation. The ice fabric is described by using the second order orientation tensor for the c-axes. For a given fabric, the ice polycrystal behaviour is obtained by using a homogenization scheme. It is then tabulated as a function of the two independent coefficients of the second order orientation tensor. Analytical relations for the evolution of the second order orientation tensor are obtained by assuming either uniform stresses or strain rates in the polycrystal, and an intermediate relation is postulated by introducing a so called "interaction parameter". The main assumptions, i.e., orthotropy and fabric description by the second order orientation tensor, are discussed. Our results compare well to those obtained with the self-consistent model (VPSC) that considers the ice polycrystal as an aggregate of a finite number of grains.
While the VPSC model is difficult to implement into a large scale ice-sheet flow simulation code, our description of anisotropic ice as a continuous medium allows to do

this with smaller numerical efforts. The Stokes equation for anisotropic ice, as well as the convection dominated evolution equation for fabric strengthening, have been implemented into the finite element package ELMER. Preliminary results of a local flow simulation are presented.