The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2018-213-AC3, 2019

The Cryosphere
Discussions

Interactive comment on "Microstructure and texture evolution in polycrystalline ice during hot torsion. Impact of intragranular strain and recrystallization processes" *by* Baptiste Journaux et al.

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Received and published: 27 February 2019

This response is similar to the one given for reviewer 2 Scientific Discussion 4. We would like to thank M.G. Llorens, P. Bons and A. Griera for their useful comments on our work that helped us to greatly enhance the quality of the discussion on models in our manuscript. We provide here a detailed response and the details on the edits made in the revised version of the manuscript.

We made use of the Etchecopar model just to highlight the likely role of subgrain bound-

aries in the process of accommodating basal glide of dislocations during simple shear of ice. To our point of view, this model can only explain that strain incompatibility accommodation processes are required to obtain the strong single maximum observed in the laboratory and in the field (Hudleston et al. 1977). We will be clearer about that in the text. Considering FFT homogenization schemes as the one used by Llorens et al. (2017) and the one that we used in Grennerat et al. (2012) or self-consistent viscoplastic models (Castelnau et al. 1996), they stand on strain being produced by the activity of slip systems only. For ice, the only slip system for which there is experimental evidence of easy activation is the basal system. However, the basal slip system cannot, alone, produce a general type of deformation. Thus for maintaining strain compatibility, these homogenization approaches require the activation of the non-basal systems, namely, prismatic and pyramidal systems. Activation of these systems induces specific rotations of the crystals. This is the main reason why, unless extra mechanisms (which mimic the role of dynamic recrystallization in helping to enforce strain compatibility) are added to these models, such as in Wenk et al. (1999) or Signorelli and Tommasi (2015), the crystals never reach the stable position observed experimentally or in naturally deformed samples, in which the main slip system is parallel with the imposed macroscopic.. Models, which do not include any strain compatibility relaxation process, as Llorens et al. (2017) produce a strong clustering of c-axes, similar in intensity to the one observed experimentally or in the field, but offset from the normal to the shear plane. We do not pretend that polycrystal plasticity models are not useful. We just discuss that, by construction, the vertical single maximum cannot be reproduced in a model where deformation is fully accommodated by dislocation glide. In the experiments, other mechanisms do come into play. By consequence, yes, the comparison is very helpful to quantify the role of these mechanisms. The text has been modified to be more clear about this point. We also noticed a mistake. The reference about simple shear modeling of ice in simple shear is Castelnau et al; 1996, JGR. It has been modified in the text.

Added text: (pp.18 L15): Pioneering work on 2D modeling of polycrystalline aggregates under simple shear by Etchecopar (1977) was able to repro- duce the sub-maxima M1 and M2. This was simply done by considering a single slip system (basal slip system for ice) and adding an accommodation process by allowing cells to subdivide (polygonization) and undergo rigid body rotation. The very good agreement of this simplistic model with evolution of textures observed experimentally for ice under shear was empha- sized by Bouchez and Duval (1982), who hypothesized that the polygonization processes in ice would be formation of GNDs and kink-bands. In our results few kink bands were observed, but the prevalence of GNDs at most finite shear strains suggests that Bouchez and Duval (1982) supposition is reasonable. Although Etchecopar (1977) is too simplistic to pretend reproduc- ing every shear-induced textures in ice, it was useful to raise the likely role of polygonization as an efficient accommodation mechanism for solving strain incompatibility problems. Modeling of shear in ice has been done by mean-field approaches as in (Castelnau et al., 1996) or more recently by full-field modeling as in (Llorens et al., 2016). Both works reproduced the formation of a strong single maximum texture from shear strain of about 0.4 and above. Nevertheless, neither orientation of this single maximum normal to the shear plane, nor the existence of two submaxima observed at lower strains in the field or experimentally are correctly reproduced. The fact that the single submaxima prescribed is inclined from the tangent to the shear plane is significant, and stands from the fact that these homogenization techniques require the activation of non-basal slip systems. The activation of secondary slip systems, whose contribution to strain has never been proven experimentally, induces a geometrical rotation of the crystal, that is responsible for the modeled inclination of the clustered CPO compared to the vertical. The activity of these secondary slip systems relative to the basal ones is controlled by a parameter that is arbitrarily defined (it has been defined in comparison to experimental observations in Castelnau et al. (1997), using the mean-field VPSC approach, and values different than the one chosen is the previously cited studies were obtained). The higher is non-basal activity, the softer is the mechanical response of the crystal to accommodate the imposed conditions. The geometrical constraint of crystal rotation under shear,

owing to the activity of non-basal slip systems, can be artificially relaxed, such as in Wenk and TomeÌĄ (1999), by forcing the growth of selected grains, or as in Signorelli and Tommasi (2015), by an association of polygonization and local (within a grain) relaxation of the strain compatibility constraints. By comparing these various modeling approaches, and their inclusion of recrystallization mechanisms, it appears that accommodation mechanisms, other than non-basal slip systems, must come into play to explain recrystallization induced shear textures in ice. Although we consider that fast grain boundary migration might be an efficient strain accommodation mechanisms, we suggest here that an efficient additional contribution to the texture reorientation, at the high homologous temperatures of our experimental studies (and the ones of Bouchez and Duval (1982) or Qi et al. (2017, 2019)), might well be nucleation assisted by polygonisation (or sub-grain boundary rotation).

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