The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2017-54-RC2, 2017

The Cryosphere Discussions

Interactive comment on "Implementing an empirical scalar tertiary anisotropic rheology (ESTAR) into large-scale ice sheet models" *by* Felicity S. Graham et al.

Anonymous Referee #2

Received and published: 4 July 2017

The paper presents the implementation of an isotropic rheology that accounts for the effects of ice fabric (ESTAR) and it is easy to implement in large-scale ice sheets models. The method, based on Budd 2013, estimates the local effect of ice fabric directly from the instantaneous flow field and incorporates it in a Glen flow law relation. The authors apply this method to three idealized scenarios and compare the results with those from an identical Glen flow relation where the enhancement factor has been keep uniform. They conclude that the results are different.

I find the paper clear and well written but I believe that the method presented is wrongly described and the discussion is lacking some interesting points. I give bellow a few

general comments that, I have just realized, incorporate all the specific comments I have pencilled in the manuscript.

General Comments I have had a chance to look at the other reviewer comments and I have to say that I fully agree with him/her in the main two points of his/her review. First, the authors always refer to the method as "anisotropic", it is the "A" in the acronym. That is not simply misleading, it is wrong. In an isotropic rheology the relation between stress and strain-rate is a scalar number, twice the viscosity, in a more general anisotropic rheology it is a tensor. The method presented in the paper is simply not anisotropic. Also in this point, the authors refer to Glen flow relation vs ESTAR throughout the manuscript. ESTAR as far as I can see is a Glen flow relation with a pre-exponential factor that varies spatially to account for ice fabric. A in Equation 1 is known to depend on ice fabric and a myriad of other things (not only on temperature as stated in the manuscript), the whole point of ESTAR is that it is giving a method to estimate the effect of ice fabric on A. And second, the empirical relation to extract the enhancement factor is based on laboratory experiments of tertiary flow, and it may well be that it can not reproduce the widespread observations of strain-induced anisotropy in polar ice. There is no discussion in the paper about how the proposed method explain observations or even expectations of the effect of ice fabric in polar flow. Do the vertical or horizontal variations of enhancement factor make sense according to observations of fabric or strain-rate fields?

I also miss an important point in the paper, what is the point of using ESTAR in a large-scale ice sheet model? I may be missing something here but large-scale models are capable to initialize the local depth-averaged hardness parameter in the Glen flow law using satellite observations. What is ESTAR adding? Could ESTAR inform the initialization of a large-scale model somehow? It could be applied to simulations were there is no satellite observations but then, as I suggested in my previous point, shouldn't we check how well does it do in a case where we have observations? Also, are there any significant vertical variations on enhancement factors that are captured by ESTAR but can't be inverted by a large-scale model? In any case, the paper needs be clearer about what is ESTAR and what can it do.

Finally, I find really intriguing that the authors state that results are very similar with different aspect ratios in the experiments presented in Sections 5.1 (P9-L31) and 5.2 (P11-L25). What do they mean? In the embayed ice-shelf, I would expect the ice fabric induced by extension and shear at the margins to be different. The narrower the ice-shelf is I would expect that the overall effect of lateral shearing should be more important. In the ice flow over a bumpy bed, L is the wavelength of the bedrock undulations. I would expect the increase in basal roughness to have a strong control over the orientation of the fabric. What does it mean that aspect ratios don't affect ESTAR results? I would like to see some discussion about the results presented.

Interactive comment on The Cryosphere Discuss., https://doi.org/10.5194/tc-2017-54, 2017.