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The Cryosphere Discussions

Interactive comment on "Balance between driving stress and basal drag results in linearity between driving stress and basal yield stress in Antarctica's Siple Coast Ice Streams" *by* Jan Wohland et al.

Anonymous Referee #1

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The paper entitled "Balance between driving stress and basal drag results in linearity between driving stress and basal yield stress in Antarctica's Siple Coast Ice Streams" by J. Wohland, T. Albrecht, and A. Levermann presents an analysis of the relationship between driving stress and basal yield stress along five flow lines in the Siple Coast Region. The authors find that membrane stresses are negligible and that there is a linear dependence between driving stress and basal yield stress.

1 General Comments

The paper is well written, and is easy to follow. I was a bit surprised by the abstract because it seemed to be a bit contradictory to our current understanding of ice stream dynamics. While it is now broadly accepted that membrane stresses are negligible near the divides and in slow moving regions, it has been shown in different studies that membrane stresses are key in order to explain ice acceleration and thinning when the grounding line (or ice front) retreats (e.g., Fürst et al., 2013; Seroussi et al., 2014). If membrane stresses were negligible, grounding line retreat would have no impact on ice velocity several kilometers upstream (just like with the Shallow Ice Approximation), which is not what we observe (e.g., Howat et al., 2008; Rignot et al., 2014).

Joughin et al. 2002 looked at velocity changes over the Siple coast region and, using a simple approach, found that basal friction was about half the driving stress. So, I wondered why the conclusions of this study were so different. In fact, the authors of this paper mention that they are using "inverse modeling" to infer basal stress, but if I understand correctly, InSAR derived velocities are not used here, except at the upstream boundary. The velocity is calculated using a simple, one dimensional equation that only relies on snow accumulation and the distance along the flow line:

$$u = \frac{Q_0 + ax}{H} \tag{1}$$

where Q_0 is the input flux, a is the surface mass balance (SMB), x is the coordinate along the flow line and H the ice thickness. First, saying that $a = 0.5$ m/a is chosen because it is similar to MISMIP experiments is not a very convincing argument. Several model outputs from regional climate models are available online (MAR, RACMO) and show that the SMB in this region is more around 0.1 m/a. But, as the authors mention, this does not make a big difference in the calculation because Q_0 is much larger than ax, so we can assume that the flux is almost constant.

Now, what I am more worried about is that the authors use this very simple description of ice velocity to determine longitudinal drag and basal drag, instead of measured ice velocities. The problem with this approach is that the conclusions of the papers are entirely dependent on ice velocity since the ice velocity determines the stress regime. So I tried to do the same experiment and compared the velocity predicted by this simple model to measured surface velocities from Rignot et al. 2011. Figure 1 shows my 4 flow lines and figure 2 shows the difference between the "modeled" velocities (according to equation 1) and InSAR derived velocities along these flow lines, and the misfit is very large.

This difference is probably explained by the hypothesis of 1-dimensional flow, where ice coming from the sides is ignored. That is my second criticism. I don't believe that lateral drag can be neglected in these ice streams. Flow line models are good for process studies, but they are too simplistic to investigate real-life scenarios, as too many important factors are missing (lateral drag, and how it changes through time, flow convergence divergence, bump shapes, etc).

2 Minor comments

- l.10: the driving stress is linear in the basal yield stress → there is a linear relationship between the driving stress and the basal yield stress
- l.10: the ice "surface" topography ...
- l.14: remove "grounded" (ice sheets are grounded by definition)
- l.23: paradoxon → paradox
- l.36: summary

- l.73: membrane stresses include both longitudinal stress and lateral drag. You are assuming that lateral drag is negligible here.
- l.86: is represented here by the SSA
- l.146: include space between number and its unit
- l.227: the often used value in ice sheet modeling
- Conclusions: model limitations should be at the end of the discussion rather than in the conclusions

3 References

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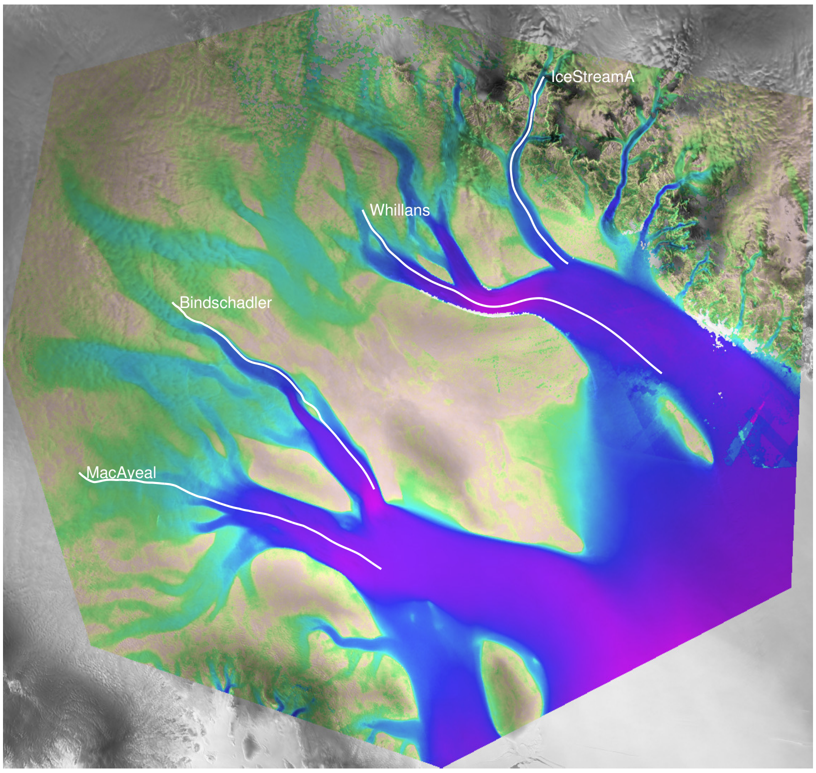

Fig. 1. Flow line locations

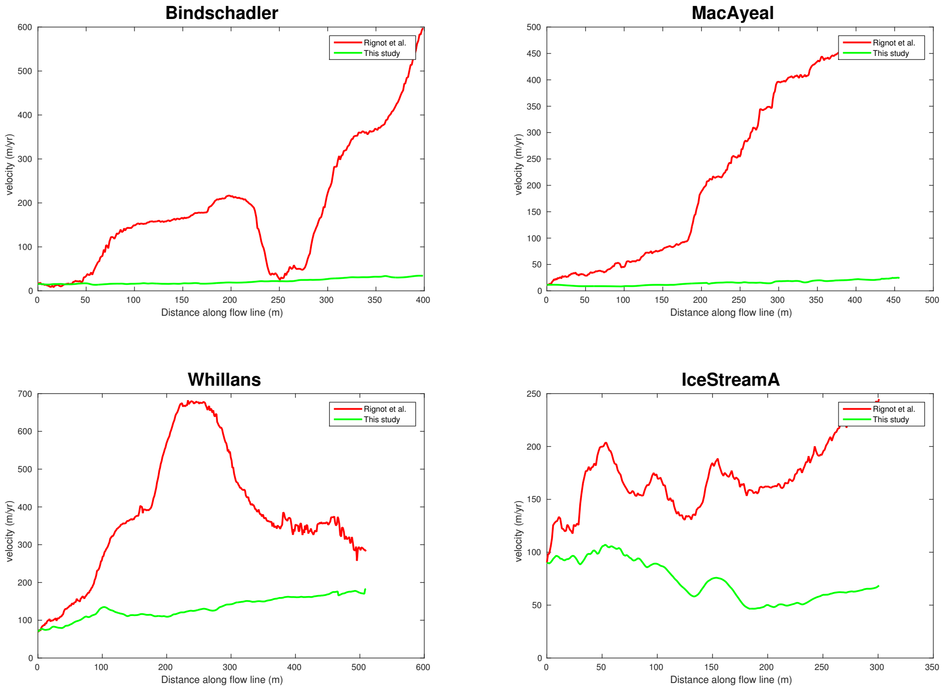

Fig. 2. Calculated vs InSAR derived velocities