The Cryosphere Discussions

The Cryosphere Discuss., author comment AC1
https://doi.org/10.5194/tc-2022-53-AC1, 2022

Reply on RC1

Elise Kazmierczak et al.

Author comment on "Subglacial hydrology modulates basal sliding response of the Antarctic ice sheet to climate forcing" by Elise Kazmierczak et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2022-53-AC1, 2022

General comments

The paper is a well-written investigation into the the respective effects of exponents in the sliding law versus those of coupling with (simple) subglacial hydrological models on the evolution of the Antarctic Ice Sheet up until 2100. It tests four sliding-law exponents (m=1,2,3,5) and four different subglacial hydrology approaches, as well as a no-hydrology approach, across two extreme forcing scenarios and three realistic forcing scenarios. The authors conclude that, at the ice-sheet-wide scale, the exponent in the sliding law has a larger impact than the choice of subglacial hydrology model; this choice only modulates the eventual mass loss value up and down slightly. At a basin level, however, this finding is less evident.

Overall, I think the paper is well-written and logically structured, as well as being sound science. The figures are well-presented and clear. I do, however, have a couple of reservations that I would like to see addressed before recommending the paper for publication, which I detail below. Specifically, I question the values of some parameters, and the relationship between the presented results and conclusions.

We thank the referee for the effort in reviewing our manuscript and for the positive comments. Below we answer the specific comments in more detail (in bold italic).

Specific comments

I have two areas of specific concern with the paper that I feel may need some improvement before publication:

- **The choice of the maximum saturated till layer thickness parameter**. This parameter is shown in the results section to be of considerable importance in the behaviour of the ice sheet in the TIL scenario (and this is discussed towards the end of the discussion section), yet the choice of 2 m as the value used is never justified or referenced. If it is a value that has been taken from the literature, please include appropriate references; if not, please justify why this value was chosen (sensitivity tests, model stability, …). I suspect that, ultimately, it will not make a huge difference

to the conclusions of the paper, but I feel this aspect needs to be better explained.

This value is taken from Bueler and Brown (2009) and Bueler and Van Pelt (2015) and is used in the standard PISM model. In Bueler and Van Pelt (2015) the same limits have been applied to the Greenland ice sheet and the results (conform ours) are shown in their Figure 7. Areas at the pressure melting point have a W_til value of 2 m (saturated). Other values of W_til (max) would lead to a similar result, if the water fill up in the till is larger than the till drainage. Since subglacial conditions in Antarctica are relatively stable over the time periods we considered, there is not much we expect to change, like the Greenland experiment in Bueler and Van Pelt (2015). Nevertheless, we realize that this approximation is rather crude, but the overall idea of our paper was to test existing and relatively simple hydrological models to be applied to the Antarctic ice sheet. We are currently developing more exhaustive treatments.

- **The link between the presented results and conclusions**. The authors conclude that the choice of the sliding law exponent is of much greater importance at the ice-sheet scale than the choice of the subglacial hydrology model in determining the evolution of the ice sheet. I agree that this is strongly supported by the results from the extreme-forcing scenarios (ABUK and ABUM), but this does not seem to be the case for the ISMIP6 experiments (compare, for example, Figure 5 with Figures 6-8), where the subglacial hydrology seems to be at least as important, if not more so, than the sliding law exponent (the range, for a given exponent, between the mass-loss values for the different subglacial hydrology models looks to be equal to or greater than the range for different exponent values for a given subglacial hydrology model). The lack of a clear relationship at the basin scale is noted and discussed, but not at the ice-sheet-wide scale. I feel therefore that the discussion could benefit from an additional paragraph addressing this contrast between the extreme- and realistic-forcing scenarios, along with a modification of the abstract and conclusion to acknowledge this.

We thank the referee for this observation. ABUMIP gives dominant mass loss, so the sensitivity to overall mass loss is easier to gauge. However, the ISMIP6 experiments lead to a variety of responses on the pan-Antarctic scale, for which it is not obvious to derive what makes the difference in response for the different basal hydrologies. These responses are not only reflecting differences in hydrology, but also other interactions with forcings, such as increased accumulation rate across vast areas of the East Antarctic ice sheet. This is the reason why we put the emphasis on the basin approach. However, we comply with the referee that more could be said on the difference between both forcing scenarios in terms of response and will acknowledge this in both abstract and conclusion.

Technical comments

We will correct these in the revised manuscript.

p.1,l.3: ‘classic’ for ‘classical’

- 1,l.5: ‘the above’ for ‘above’
- 1,l.5: remove ‘i.e.’ and replace with a colon
- 1,l.8: the sensitivity of the ice sheet in what sense? You make it clear at the end of the

sentence, but it might be worth adding 'to climatic forcing' or something similar here to clarify things a little.

- 1,l.10 'modulate' not 'modulates'
- 1,l.11: an increased sensitivity of what to what? Again, it's fairly obvious you mean of the ice sheet to climatic forcing, but it bears restating, especially here in the abstract, just so it's really clear.
- 1,l.14: 'store' for 'storage'
- 1,l.15: 'from', not 'of'
- 1,l.23: 'laws'
- 1,l.24: delete the second occurrence of 'conditions'
- 2,l.25: the sensitivity of ice-sheet flow to what?
- 2,l.29-30: replace the 'either...or...' phrasing with a 'both...and…' one
- 2,l.36: 'the spatial and temporal scale'
- 2,l.40-41: replace 'and to gauge' with 'nor the gauging of'
- Table 1: You refer to Cd here for the till drainage rate, but then talk about Ct later in Section 2.1.4. Pick one and make it consistent across the table and the text.
- 8,l.164-165: Is the historical run sufficient as a relaxation run? I think it would be good to include a sentence here justifying why you don't need to do an actual relaxation run (or to change the phrasing, because it sounds very casual at the moment – something like 'and thus also serves as a relaxation run' would sound better)
- 8,l.165: replace 'i.e' with a colon
- 13,l.223-224: This description of Fig. 6 is a little confusing. The NON model run (i.e. no subglacial hydrology coupling) shows zero mass loss or a slight gain, but most of the model runs with some form of subglacial hydrology show near-zero or a slight mass loss, contrary to what the text says. I think you may have meant 'without' rather than 'with' in l.223, but, even then, the text would give the impression that mass gain is the rule, rather than the exception. I'd suggest re-wording this description slightly to make things clearer.
- 15,l.254: I'd replace 'is more uncertain in altering' with 'has a more uncertain effect on'. I would also add, at the end, 'than is seen at an ice-sheet level'
- Figure 10 caption: 'Line colors' for 'Lines color'
- Figure 10: what are the red lines on the two left-most panels (are they GL position, but, if so, why are there none on the two middle panels?)
- Figure 10: make it clear that the Schoof runs are the runs presented in the results section earlier. I was a little confused and it took me a while to work out what was going on.