The Cryosphere Discussions

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Reply on RC2

Anna Derkacheva et al.

Author comment on "Seasonal evolution of basal environment conditions of Russell sector, West Greenland, inverted from satellite observation of surface flow" by Anna Derkacheva et al., The Cryosphere Discuss., https://doi.org/10.5194/tc-2021-170-AC2, 2021

Dear reviewer,

We thank you for the positive general assessment and given comments. Please find below the answers to all your questions and comments on our manuscript.

- Line 1: I found this opening sentence a little unclear on first reading, I think because modelling is implied by "better constraints" but never explicitly mentioned. I'd suggest something structured more like "Due to increasing surface melting …, better constraints on … are required by models".

Agreed.

- Line 5: I'd expand this to say "using the ice-flow model Elmer/Ice", as it's possible some readers may not have come across it before.

Agreed.

- Line 23-4: Is this the authors' own assumption, or are there other studies to cite?

Indeed, there are many other studies that have linked water pressure and glacier acceleration during the melt season. The overviews cited in the previous line (Davison et al, 2019; Nienow et al., 2017) widely cover this topic. We will rewrite the sentence to avoid ambiguity.

- Line 122-3: It would be useful to add a brief explanation of the "master and slave" terminology.

These terms will be changed to "primary" and "secondary" as requested by reviewer #1.

- Line 123: It would be good to specify what x and y are, since this is the first mention of them (presumably polar stereographic north as in fig. 1?)

Agreed.

- Line 126: State what LOWESS stands for.

LOWESS stands for LOcally Weighted Scatterplot Smoothing (Cleveland, 1979; Cleveland and Devlen, 1988) and is also known as locally weighted polynomial regression.The acronym and source references will be given in the revised text.

Cleveland, W. S. (1979) 'Robust locally weighted regression and smoothing scatterplots', Journal of the American Statistical Association, 74(368), pp. 829–836.

Cleveland, W. S. and Devlin, S. J. (1988) 'Locally weighted regression: An approach to regression analysis by local fitting', Journal of the American Statistical Association, 83(403), pp. 596–610.

- Line 162: Assumed by who? Should be made clear if this is the authors' own assumption, or citing another reference.

This is assumed by us. We will clarify this point. Note that except a short remark made by Berthier et al. (2005), to the best of our knowledge, no previous description of the impact of changing shadows length on ice speed measurements have been published.

Berthier, E. et al. (2005) 'Surface motion of mountain glaciers derived from satellite optical imagery', Remote Sensing of Environment, 95(1), pp. 14–28.

- Line 163: vy is a velocity vector, not speed.

Agreed.

- Line 204: A brief explanation/sentence on kriging could be useful.

Kriging is a widely used technique of thickness interpolation in ice sheet mapping. To stay consistent in our text, we will add a very short note on the consequences of kriging usage for the topography data quality, but without explanations on the method. We will simply refer to Morlighem et al. (2017) who describes how kriging is applied in BedMachine Greenland.

Morlighem, M. et al. (2017) 'BedMachine v3: Complete Bed Topography and Ocean Bathymetry Mapping of Greenland From Multibeam Echo Sounding Combined With Mass Conservation', Geophysical Research Letters, 44(21), pp. 11,051-11,061.

- Line 210-11: There are several acronyms here which could be fully introduced. I'd certainly specify Digital Elevation Model and Advanced Very-High-Resolution Radiometer. Perhaps expanding the names of specific models isn't necessary, but ASTER and SPOT-5 should probably be given relevant citations.

Agreed.

- Line 267-8: It doesn't make sense to justify the initial condition using the results it produces, which is how this reads to me. This sentence should be reworded to make the meaning clear.

This point has already been raised by the first reviewer. As explained in our reply, this is not totally circular as in diagnostic the results in the interior of the domain are insensitive to the details of the boundary condition. We will improve this discussion in the revised version of the manuscript.

- Line 273: What is the reason for this choice of friction law? Given the later focus on interpreting results using an effective pressure-based law, I think an explanation is needed for why that law wasn't used in the inversions to begin with.

Good point. We will better explain this in a revised version of the manuscript. We preferred to invert the effective friction coefficient (\beta in Eq. 8) and then interpret the temporal variations of \beta in terms of effective pressure in a second step. There are several reasons for this. First, it should be numerically more stable to use a linear relation, and, in winter, the effective pressure-based law is close to the Weertman regime and thus weakly sensitive to N, so the results would be much more sensitive to the regularisation terms. Second, as we show in the manuscript, this two-step approach allows us to discuss the choices that are made to calibrate the parameters (As and C) of the effective pressure-based law.

- Fig 3: I think a fourth panel is needed here, showing the difference from observed velocities. The mismatch is currently discussed without a visual aid.

Agreed, we will add a subpanel in Figure 3 showing the mismatch between observed and modelled surface speed. As this figure shows the results obtained for the winter mean state (January/February/March), the mismatch is very similar to that of the individual months of January, February or March. Thus, we initially expected that the Figure A1 in appendix would be sufficient.

- Line 332-3: State this more clearly: ud=us-ub.

Agreed.

- Line 380-1: What is the reason for choosing only the early halves? Wouldn't it be useful to see the later halves as well, especially for the months where conditions change quickly?

We show only one half of each month to keep the figure at a reasonable size. As the differences between the early and late halves are not large for the majority of months, we feel only showing the early halves is enough to demonstrate the variability. This statement will be more clearly articulated in the text.

- 417-19: Isn't the limited effect of deformation at least partly a result of the choice mentioned previously to neglect deformation profiles when setting up the model? This could be a misunderstanding on my part based on what was said in lines 267-9.

It is possible that there is a misunderstanding coming from lines 267-9 of how the ice deformation is taken into account in our model inversions. We will better explain this point in the revised manuscript.

In lines 267-9, we state that the deformation profile is not prescribed in the starting conditions of an initializing inversion (using the winter mean speed (WMS) data. With a full-Stokes model, the 3D velocity field will quickly adapt to the boundary conditions, first of all to the basal friction, thereby the deformation will appear progressively for the areas at a distance of few ice thicknesses from the lateral boundaries. In the interior of the domain, e.g. where we compare our deformation profiles with those measured by Maier et al. (2019) in Fig.5, we assume that 200 iterations is enough for the WMS-based inversion to converge and reproduce entirely the deformation which the ice column would have for the given conditions.

As the 24 seasonal inversions start from this WMS-produced solution, their initial conditions already contain the vertical deformation. Here, as we don't change the surface topography over time, only model-inferred basal friction can influence the deformation profile, making it variable from one inversion to another. Here we discuss that this effect is small but still visible.

- Fig 6: In the top row, it would be good to use the same scale on the y-axis in each case, and to include horizontal grid lines like in the bottom row.

We will add the horizontal grid lines for the bottom row. Considering the y-axis in the top row, during the manuscript preparation we tested many options and found that the same scale is less optimal. While it makes the plots more easily comparable, the individual nuances of friction and pressure behavior are lost for points A and C.

- Line 470-4: Can this behaviour be explained? The other two points behave as I'd expect (ie. an inverse relationship between speed and friction), but this stands out as more of an anomaly.

Yes, this behaviour can be explained and is what is predicted by the Weertman friction law, i.e. friction in absence of cavitation. As described in lines 631-639, point B follows a power friction law (friction increases with sliding) most likely due to longitudinal stress-gradient coupling with regions being much more actively forced by meltwater (like point A). Simply put, the friction rise here is a consequence of acceleration imposed from outside.

In detail, we interpret annual friction and ice speed changes at Point B as follows: from January to May, the gradual recharge of the subglacial water system locally reduces the friction and the velocity slowly increases (van der Wal et al. 2015, Harper et al. 2021). In May, when surface melting begins, local topography and/or organisation of the hydrological system does not lead to an increase in water pressure and consequent facilitation of sliding. However, via longitudinal coupling to other accelerating areas such as point A, point B is forced to accelerate as well. Higher sliding speed for a relatively unchanging set of bed properties leads to a higher local friction.

This type of "passive" melt season response has been inferred in numerous previous studies in Greenland (Ryser et al., 2014b, Price et al. 2008, Maier et al. 2021, Young et al. 2019)

Ryser, C. et al. (2014) 'Caterpillar-like ice motion in the ablation zone of the Greenland ice sheet', Journal of Geophysical Research : Earth Surface, 119, pp. 2258–2271.

Maier, N. et al. (2021) 'Basal traction mainly dictated by hard-bed physics over grounded regions of Greenland', The Cryosphere Discussions, pp. 1–31.

Young, T. J. et al. (2019) 'Physical Conditions of Fast Glacier Flow: 3. Seasonally-Evolving Ice Deformation on Store Glacier, West Greenland', Journal of Geophysical Research: Earth Surface, 124(1), pp. 245–267.

Van De Wal, R. S. W. et al. (2015) 'Self-regulation of ice flow varies across the ablation area in south-west Greenland', Cryosphere, 9(2), pp. 603–611.

Harper, J., Meierbachtol, T., Humphrey, N., Saito, J., & Stansberry, A. (2021). Variability of Basal Meltwater Generation During Winter, Western Greenland Ice Sheet (preprint). Ice sheets/Greenland.

Price, S. F., Payne, A. J., Catania, G. A., & Neumann, T. A. (2008). Seasonal acceleration of inland ice via longitudinal coupling to marginal ice. Journal of Glaciology, 54(185), 213–219.

- Line 621: Is there a reason for not showing a profile through point B? Since it displayed different behaviour from the other points, it could be interesting to see that here as well.

The initial reason was to keep the number of figures reasonable. We will consider adding it to the Appendix.

- Line 634-6: It’s not clear to me what is being said in this sentence. It needs rewording.

Agreed. We are trying to explain that the total force balance during summer is still sufficient to prevent the glacier from collapsing. Therefore, when friction locally becomes very small and the ice accelerates, the local change in stress is transmitted by longitudinal stress coupling to other places that will thereby offer enhanced flow resistance (larger friction). We will rephrase accordingly.

- Line 645-6: I think I understand the meaning here, but this sentence is unclear. Is it that conditions are the same/similar down the whole length of profile C’?

The sentence will be rewritten as: "The whole 30km of profile C' mainly exhibits the same conditions as were described for point C. "

- Fig A5(b): What are the dotted lines? Mention them in the caption.

Caption will be updated.

- Technical corrections

Thank you for the technical corrections, we will correct all of them.