

Answer to Editor decision, 24 Jul 2021

Dear Ms Keagan, dear Referees,

We again like to thank you for your very helpful contribution in improving our manuscript. Below you can find our point-to-point answers to your latest comments.

We have included another example firm profile in the manuscript to show and discuss the influence of seasonal variations on the optimisation. We also added another section to discuss how the optimisation approach is affected by assumptions we make regarding the boundary conditions of our model. As these additions increased the length of the manuscript further, we decided to move most of the former third section describing the model to an appendix, as suggested by the referees and the editor, to improve the readability of the manuscript. This led to an adjustment of the manuscript's structure. To cite all of the firm profiles used within the study correctly and to give an overview of the optimisation results, we added a table to the supplementary material which features all references and optimisation results.

Again, many thanks for your input and your effort to improve this manuscript.

Sincerely,

Timm Schultz on behalf of the co-authors

On the Contribution of Grain Boundary Sliding to Firn Densification

Referee #1's second comment: I appreciate that the authors do not have a background in regional climate modeling. Please include a statement in your revised manuscript addressing that local data is found by interpolation and introduces systematic errors into the RACMO data, which may introduce error into your results.

As proposed by the editor, we added a remark pointing out that the spatial interpolation of the forcing data from the different grids used by RACMO2.3 to the locations of the analysed firn profiles introduces errors to the data. It can be found within the Section 3.2 of the revised manuscript.

Spatial interpolation of the fields obtained from RACMO2.3 output leads to forcing data for the locations of the investigated firn profiles. It has to be mentioned that such an interpolation may introduce systematic errors.

Referee #1's third comment: Be sure to include information about how 'tests have shown that a seasonal temperature signal has very limited influence on the resulting firn density profile compared to the same model setup using the mean annual temperature', whether it be your own work included or appropriate citations to others' work.

In the revised manuscript we added a second example showing the influence of monthly averaged forcing data on our model and optimisation approach in Section 3.2. This example features a firn core retrieved at site 3 of the iSTAR Traverse conducted in 2013/14 on Pine Island Glacier in West Antarctica (Morris et al., 2017). To force the simulation we used "ERA5-Land monthly averaged data from 1981 to present" (Muñoz Sabater, 2019; Hersbach et al., 2020) as it is freely available. We compare this simulation result with another one using yearly averaged forcing data computed from the monthly averaged data to point out that our optimisation result is very little affected by the higher resolution forcing. Although the detail of the simulated firn density profile improves, we decide to use yearly averaged data from RACMO2.3 because a longer time period is covered and less overhead is produced.

Referee #2's general comment about uncertainty: as both referees highlighted a need for a discussion of the uncertainty analyses in your study, please make sure to thoroughly address this in your revised manuscript.

We added another section to the manuscript titled "Distribution and Influence of Input Data" in which we evaluate different concerns expressed by the referees regarding uncertainties. This new section features discussion on the layering of firn profiles and the use of a Neumann boundary condition.

On the Contribution of Grain Boundary Sliding to Firm Densification

Referee #2's general comment about Section 3: I respect your wishes to want to retain Section 3 within the paper, instead of moving it to an appendix. I agree with Referee #2's concern about the readability of this section, though, so I strongly encourage you to implement their suggestions to improve Section 3 in your revised manuscript.

Due to the additions we made in the revised version of the manuscript and its growing length, we finally decided to move most of the former Section 3 describing the model to an appendix, as suggested by Referee #2. Only the part on the constitutive relation for grain boundary sliding by Alley (1987) remains within the body of the manuscript because it is important for understanding the optimisation approach. It is now part of the "Methods" section. Nevertheless, we implemented all suggestions made by the referees and the editor.

Referee #2's general comment about Section 5: I respect your wishes to retain the order of your sections. Please consider editing the previous sections so that Section 5 begins earlier in the manuscript.

Due to the rearrangement of the manuscript including the addition of an appendix, the former Section 5 begins earlier in the manuscript now while maintaining the general structure of the sections.

References

- Alley, R. B.: Firn Densification by Grain-Boundary-Sliding: A First Model, *Journal de Physique*, 48, C1–249 – C1–256, <https://doi.org/https://doi.org/10.1051/jphyscol:1987135>, 1987.
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