Peer review of 'Holocene Stabilization of Conway Ice Ridge' by Andrew O. Hoffman et al.

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General comment

In this manuscript, the authors combine ground-based radar data and ice-flow modeling to infer the dynamics of shear margins in the Siple Coast region during the Holocene. Specifically, they investigate the stabilization of the Conway Ice Ridge, which divides the van der Veen and Mercer Ice Streams. Their approach includes interpreting internal features such as disrupted layering and buried crevasses, which imply faster flow and higher past stress conditions.
Through the interpretation of englacial features, they suggest that the ice streams were wider and flowed faster in the recent past before they slowed down and readvanced to their present configuration. Using a 1D model for dating these features, they estimate that these changes occurred between 3000 and 1000 years ago. This readvance of the ice sheet in the Ross region aligns with other evidence, such as carbon dating, indicating this readvance during the Holocene. Additionally, by employing a thermomechanical ice-flow model, they estimate the sensitivity of the ridge to different scenarios of thinning, velocity changes, and past basal strength. Their model successfully produces sufficiently fast flow and stress conditions on the promontory at the confluence of the van der Veen and Mercer Ice Streams when all three conditions are included. This approach is undoubtedly a step forward in understanding the dynamics of the ice sheet during the Holocene.
I therefore recommend its publication after some minor revisions which I detail below.

Specific comments

The methodology employed in this work is appropriate and sound. The direct interpretation of internal features is convincing and the supporting ice flow model is a significant strength. The paper is well-written and structured, making it a valuable contribution to the field. However, I suggest some clarifications with regards to the limitations of the ice-flow models employed, as well as refinements of the visualization of the results.

Firstly, you performed a large set of model experiments to investigate the sensitivity of the ridge to three prescribed perturbations. You included very few visualizations of the results in the text, but a large amount of plots in the appendix. What I am missing is a synthesis plot of the ensemble, which quantifies the sensitivity of the ridge to these perturbations in your model. For example a scatter plot that explicitly shows the required conditions to reach the crevassing von Mises stress in your model. From my understanding of the text, you need all three perturbations simultaneously to reach these conditions, so it would be great to see it in one single plot.

Secondly, I was wondering how your steady-state model results would transfer to transient simulations. In the text, you do not clearly specify that this is all in steady-state, while you are studying 'the least stable of the Ross inter-ice stream ridges', which can be a bit confusing. In case you ran non-steady-steate simulations this would be very interesting to include , otherwise I understand that this would be a lot more work, maybe outside the scope of this paper or reserved of another paper. This is just a suggestion, feel free to ignore it if you think that it would not support your findings here. But I think it would be worthwile to discuss the limitations of using a steady-state model in a region experiencing 'rapid reorganization'? Furthermore, could transient simulations help you with the evaluation of the timing of the readvance? Have you planned this in the future?

Finally, you employed steady-state 1D models to date the layers. Previous studies have shown that accumulation rates fluctuated significantly during the Holocene, influencing the timing of the Ross Sea readvance [1, 2, 3, 4, 5]. Furthermore, your results indicate that the region thickened during the readvance, yet your model does not account for these thickness changes. I have read reviewer 1's comments and concur with their recommendations and suggest documenting the model's limitations more thoroughly in the manuscript.

Other comments

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- Figure 2: This figure is hard to read. Are you plotting the data as semi transparent on top of the SAR imagery? The colors appear grayish with little contrast, making it hard to read the data. The hardest to read is panel c, where the colorbar has dark shades for small speed changes, making the overall plot very dark and difficult to distinguish between green and pink. Can you use a more diverging colormap, usually brighter around 0 and darker for increasing values? In general, you can also use extended colorbars with a min and max limit, to better distinguish small changes. The colorbar for the bed elevation is confusing, it goes from blue to green to blue to green to yellow to green to yellow... On x and y axes, you put both the lon/lat and polar-projected Cartesian coordinates (I guess?). I don't mind, but you need to legend the units of the Cartesian coordinates.

In addition you add a scale on the maps, which is not necessary then if you have the Cartesian coordinates in km. Maybe remove one of the two. One cannot see the radar lines well.

- Figure 3: This figure does not bring much information. Panel a: we have already seen the model domain in Figure 2, and you can describe the boundary conditions in the text. It can eventually go in the appendix, maybe merged with Fig. D1. The units and fonts between panel a and b are different. Panel b: the bounds of the colorbar are to large compared to the displayed values. If you want to keep figure 3 for illustrating the experiment, it would be nice to see as well one plot of the velocity perturbation. Instead of the gray and black contours (which I guess are already results for this experiment), replace with the velocity perturbation contour.

- Figure 4, 5, 6: Panel a) is a repetition of a plot we have already seen, it does not bring more information except the bed roughness, which is not easily interpretable anyways. But you show the bed roughness along the transect on panel b) (and Appendix) so you could get rid of panel a). I understand that you still need to show the location of the transects. I don't know if this can be combined with figure 2. Or a smaller map not labeled in the corner of the figure, showing only the region contours, surface speed and the radar line location. This will give more space for the radargrams.

- Section 3.3, paragraph 2: You only describe the figures here which should be in the legends and the captions of the figures. For example [344-345], you could add a legend box on figure 8 with '- - : 30m.yr-1 contour'. This would make the text more concise, and you could provide a more quantitative analysis of the sensitivity in this section.

- [356-360]: Those results are interesting, but only shown in the appendix. Also it's not so evident to see the difference in Figure D5, supporting the idea of a quantitative plot in this model result section as I mentioned in major comments.

- Figure 8: There are figures that we have already seen (a) and h)). Furthermore, we do not see much the differences between b), c) and d). Maybe a single bigger plot with color coded/labeled dashed line, showing the retreat of the promontory against thinning (potentially including more scenarios). I like e), f) and g), it zooms on the region and use a clear color threshold. However it looks much smoother than your model resolution in Fig D1?

- [368-370]: if I understand correctly, you need both velocity perturbation and the HAF basal strength to exceed the von Mises stress? It would be worth adding a conclusion paragraph to this section, synthesizing the required conditions to reach the crevasse proxy threshold in the model.

- Figure 9: It is a good idea to include such a schematic. However, we do not really see that the ice streams were larger 3kyr ago as mention in the caption.

- Conclusion: Here you conclude that your model was able to produce sufficient past conditions to create surface crevasses at the ridge promontory, through a phase of faster flow and thinner ice streams. However, if I understand correctly, your model reaches those conditions only when using an HAF dependent basal strength. Maybe this should be mentioned?

Technical corrections

- [109] & [113]: repeated citation for the Reference Elevation Model of Antarctica, use the acronym?
- [130]: traced traced
- [159]: use active citation
- [253]: 'and van der Veen Ice Stream'. Should it be Whillians Ice Stream? Maybe I am just confused about where van der Veen and Whillians merge. Reading the following text it sounds like it should be Whillians to me.
- [269]: should it be 'southeastern ridge (region IV)'?
- [271]: Fig. 2b is refered as ice thickness but it is bed elevation.
- [295]: 'in Figure 4c km 50-72'. Should it be Figure 6c?
- [325]: Should it be Appendix C?
- [456] repetition of 'northern half of the ridge (region II)'
- [552]: 'features'
- Figure D2: 2x 'to' in caption
- Figure D4,5,6, 9: are the green and blue dotted lines necessary? There are difficult to see on the computer and invisible on print. - Figure D6: there is a tool bar on panel Q
- Figure C1: the units of the axes are missing, colorscales are confusing

References

[1] J. A. Bodart, R. G. Bingham, D. A. Young, J. A. MacGregor, D. W. Ashmore, E. Quartini, A. S. Hein, D. G. Vaughan, and D. D. Blankenship. High mid-holocene accumulation rates over west antarctica inferred from a pervasive ice-penetrating radar reflector. *The Cryosphere*, 17(4):1497–1512, 2023. doi: 10.5194/tc-17-1497-2023. URL `https://tc.copernicus.org/articles/17/1497/2023/`.

[2] M. R. Koutnik, T. J. Fudge, H. Conway, E. D. Waddington, T. A. Neumann, K. M. Cuffey, C. Buizert, and K. C. Taylor. Holocene accumulation and ice flow near the west antarctic ice sheet divide ice core site. *Journal of Geophysical Research: Earth Surface*, 121(5):

907–924, May 2016. ISSN 2169-9011. doi: 10.1002/2015jf003668. URL http://dx.doi.org/10.1002/2015JF003668.

[3] D. P. Lowry, N. R. Golledge, N. A. N. Bertler, R. S. Jones, and R. McKay. Deglacial grounding-line retreat in the ross embayment, antarctica, controlled by ocean and atmosphere forcing. *Science Advances*, 5 (8), Aug. 2019. ISSN 2375-2548. doi: 10.1126/sciadv.aav8754. URL http://dx.doi.org/10.1126/sciadv.aav8754.

[4] E. J. Steig, C. P. Hart, J. W. C. White, W. L. Cunningham, M. D. Davis, and E. S. Saltzman. Changes in climate, ocean and ice-sheet conditions in the ross embayment, antarctica, at 6 ka. *Annals of Glaciology*, 27: 305–310, 1998. ISSN 1727-5644. doi: 10.3189/1998aog27-1-305-310. URL http://dx.doi.org/10.3189/1998AoG27-1-305-310.

[5] Y. Yokoyama, J. B. Anderson, M. Yamane, L. M. Simkins, Y. Miyairi, T. Yamazaki, M. Koizumi, H. Suga, K. Kusahara, L. Prothro, H. Hasumi, J. R. Southon, and N. Ohkouchi. Widespread collapse of the ross ice shelf during the late holocene. *Proceedings of the National Academy of Sciences*, 113(9): 2354–2359, Feb. 2016. ISSN 1091-6490. doi: 10.1073/pnas.1516908113. URL http://dx.doi.org/10.1073/pnas.1516908113.