Review of "*Investigating the internal structure of the Antarctic Ice Sheet: the utility of isochrones for spatio-temporal ice sheet model calibration*" by Sutter, Fischer, and Eisen (2021)

From previous review: *The manuscript by Sutter et al. (2021) shows how the ice sheet internal layer structure can be exploited to understand and diagnose ice sheet model output. The authors present a clear case for the utility of comparing isochrones derived from observations and ice sheet model simulations to determine ice sheet model performance, particularly highlighting where we need:*

(1) Better constraints on boundary conditions (e.g. bed topography; geothermal heat flux);
(2) Better constraints on climate forcings (e.g. spatial variation in paleo accumulation rates);
(3) Better constraints on ice sheet model parameters (e.g. basal drag over marine sectors of the ice sheet);
(4) Long term simulations to adequately represent 3D flow fields and ice sheet geometries.

The diagnostic method presented in this manuscript (i.e. use of particle tracer method) is freely available and can be readily applied to any ice sheet model output, making this diagnostic tool accessible for ice sheet modellers.

The manuscript addresses a highly relevant scientific question, especially with the work of the AntArchitecture project. To the best of my knowledge the concept is novel, and the scope of the model simulations and comparison with observations is appropriate to support the interpretations and conclusions, and to demonstrate broad applicability of the method to the ice sheet modelling community. Overall, this is a worthwhile study that is certainly within the scope of TC.

The authors have addressed my concerns from the previous review. The structure of sections 3-5 has been greatly improved. The introduction of the RMSD analysis to benchmark the simulated isochrone elevations against the observed tightens the results/analysis nicely.

I have minor comments below that should be addressed before publication.

Minor comments

P1L9 (and throughout manuscript). Remove the comma before "that"

P1L9-11. Depending on word limits, you may want to consider adding to the abstract the fact that calibrating to present-day yields isochrone elevations that are often substantially more inaccurate, as per your point on L328-330.

P1L21. Add Edwards et al. (2021) to the citations

Edwards, T. L., Nowicki, S., Marzeion, B., Hock, R., Goelzer, H., Seroussi, H., ... & Zwinger, T. (2021). Projected land ice contributions to twenty-first-century sea level rise. Nature, 593(7857), 74-82.

P3L81. “...as detailed as possible” >> “...in as detailed a way as possible”

P3L85. “shortly” >> “briefly” (or delete)

P4L94 (and elsewhere in manuscript). “Ice-sheet model” >> “ISM”?

P7L161. “where” >> “were”

P9L213. “accurate enough” >> “within expected uncertainty tolerances”? I.e. from observations?

P9L222-224. “In regions where...” It’d be good to be more explicit in these sentences about which distances along the transect in figure 3 you’re referring to.

Also, is the divergence between 200 and 400 km of the 5 ka 10 k line in panel B related to spatial gradients in ice-flow and topography, as you suggest? If so, it’s hard to see why this happens here, but not later in the transect where there are significant gradients in topography (e.g. between 400 and 500 km).

Figure 3. Should “5 ka 10 k” in the figure legend be “5 ka 5 k”? The caption says that seeding was carried out with 200 000 and 5 000 tracers.

Figure 4 caption. “blow up” >> “magnification”

P12L276. Remove wayward parenthesis “)”

Figure 5. Topography color scale could be moved to left panel.

P13L280. “%3K^{-1}” >> “3 %K^{-1}”

P13L295. Check citation style with van Wessem reference

Figure 6. I didn’t understand where the 7 %K^{-1} scaling came from? Perhaps add a reason why in the caption, or add it to the list of experiments in section 2.2

P15L322. “relatively small”. Indicate % difference

P15L331-340. This is a really important point and it’d be good to see a follow-up on this point in the conclusion. E.g. how do we practically address the problems you’ve highlighted? Should long-term ice sheet model simulations all be starting from a paleo spin-up? Obviously this is

unfeasible in many cases, but it would be good to move towards a standard approach/methodology, or at least have a way forward to address some of these issues.

Figure 7 caption. Add % to the RMSD values in parentheses. Is it “root mean square error” or “root mean square difference”?

Figure 8. Can you modify the y-axis limits in panel B) so we can see all of the red line?

P18L389. “diversions” >> “divergence”

P18L400-401. “This could be due to the heuristics involved in determining the yield stress in subglacial basins.” This deserves elaboration here or in the conclusions.

P19L412-414. Given your conclusions about the issues with basal friction, can you recommend a more appropriate friction law to use?

P20L420. “underlines” >> “agrees with”?

P20L443. “...using the state of the art today” >> “...using the state of the art models today”

Figure 10. Add y-axis labels to the panels in C)

P24L484. “paloe” >> ”paleo”

P24L494-500. Mention that improved GHF estimates, as per Stål et al. (2020) may reduce uncertainty.

Stål, T., Reading, A. M., Halpin, J. A., & Whittaker, J. M. Antarctic geothermal heat flow model: Aq1. Geochemistry, Geophysics, Geosystems, e2020GC009428.