We are grateful to the reviewer for taking the time to re-review our manuscript and the positive final assessment. We refer to the marked up manuscript for the changes based on the review.

We are grateful to the reviewer for taking the time to re-review our manuscript and the positive final assessment. In the following we provide a point-by-point response (reviewer comments in black, replies in blue, changes to the text in non-serif) and refer to the attached track-changes document for the changes made to the manuscript (new text in blue, modified text in red).

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.

Again, we thank the reviewer for the positive final assessment!

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

done

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

done

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.

We thank the reviewer for this suggestion. We tried this, but we already maxed out the abstract word count for TC-manuscripts unfortunately.

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.

Done. We were not sure where best to place this reference as Edwards et al. use statistical emulators of existing models. We added a general reference on page 2 l24.

P3L81. "...as detailed as possible" >> "...in as detailed a way as possible"

done

P3L85. "shortly" >> "briefly" (or delete)

deleted

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

done

P7L161. "where" >> "were"

Thanks for spotting this! Done.

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

Done. We modified the sentence "[…] accurate enough (small deviations compared to the model uncertainties with respect to observations) for the mostly relatively slow ice flow in East Antarctica.

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).

Thanks for spotting this. We amended the manuscript by the sentence This is shown along kms 400-200 in Figure 3 B where elevated surface velocities closer to the coast lead to more pronounced deviations for a coarse seeding strategy.

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.

Yes. Thanks for spotting this!

Figure 4 caption. "blow up" >> "magnification"

done

P12L276. Remove wayward parenthesis ")"

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

We decided to leave the color scale in panel B as panel A would otherwise be too crowded.

P13L280. "%3K^{-1}" >> "3 $\%K^{-1}$"

Thanks for spotting this, done.

P13L295. Check citation style with van Wessem reference

done

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

Yes this is confusing. We use 7% here as it best matches the reconstruction of Cavitte et al 2018 after bias correction. We did not carry out a paleo simulation with 7% however.

P15L322. "relatively small". Indicate % difference

done

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.

We thank the reviewer for this comment, as we also think that this touches on a key issue in current modelling efforts: a more structured approach to ice sheet spin-ups. As the Reviewer stated, every research hypothesis and model setup will lead to a specialised model spin-up. However, for a general "species" of model studies such as paleo-simulations or long term projections common spin-up standards should be formulated. A more detailed assessment of the status quo and the way forward is a little beyond the scope of this manuscript which is already lengthy. But we will keep this in mind for the planned model intercomparison project. Thanks again for pointing this out!

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

Done and corrected, we mean RMSD

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

Done. We thank the reviewer for commenting on this, as during re-plotting of the data we realised that we used an experiment with a coarse seeding strategy to plot the data for this figure

P18L389. “diversions” >> “divergence”

done

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.

done

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

This is something we want to investigate in a planned research project ☺

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

done

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

done

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

done

P24L484. “paloe” >> ”paleo”

Thanks for spotting this! Done.

P24L494-500. Mention that improved GHF estimates, as per St l et al. (2020) may reduce uncertainty.
St l, T., Reading, A. M., Halpin, J. A., & Whittaker, J. M. Antarctic geothermal heat flow model: Aq1. Geochemistry, Geophysics, Geosystems, e2020GC009428.

Done.