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The Cryosphere Discussions
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Interactive comment on "Scoring Antarctic surface mass balance in climate models to refine future projections" *by* Tessa Gorte et al.

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Reviewer #3

We thanks the reviewer for providing a lot of thoughtful insight and asking a lot of very good questions. To address the predominant remarks, here, we will make the necessary adjustments to the wording to make the paper more accurate and comprehensible. We have also added Fig. **??** and eq. (1) to help with this process. Additionally, we would like to thank the reviewer for their helpful comments on figure adjustments. We appreciate how important for overall comprehension good figures are and we will strive to make ours as palatable as possible.

Section 2.1 SMB reconstructions:
This section summarizes the methods used by Medley & Thomas in creating their ice-core derived SMB reconstructions. I found that I was confused by how these were created, as if all the details might be correct but without the "big picture" context. Once I read the abstract for Medley & Thomas, however, I understood. This section can be re-written (and shortened) to better summarize the reconstructions. If the reader wants all the details of the SMB reconstruction, he/she can refer to Medley & Thomas for that.

We will trim down the details of this section and add in more "big picture information" to the effect of: the reconstructions, generated by Medley & Thomas, provide a 200-year record of AIS SMB. The authors synthesize SMB time series from an extensive ice-core database with reanalysis-derived spatial coherence patterns to generate a continent-wide AIS SMB data set. We will move the details about the actual hybridization process of the ice-cores with reanalysis spatial fields to supplementary material.

Section 4 Results Lines 167-168: "The interquartile ranges for CMIP5 and CMIP6 are 1727 to 2282 Gt yr−1 and 1728 to 2229 Gt yr−1, respectively, with means of 1940 Gt yr−1 and 2115 Gt yr−1, respectively."
What is the take away? For example, something like "CMIP5 models tend to have a slightly smaller mean AIS SMB with a larger range than the CMIP6 models (Table XXX)". The figure shows this, and a table could present the quantitative results for any readers that want them. Similarly for the other results throughout this section.

We will add more context for the each result throughout the section including how the different CMIP ensembles compare to one another and where the reconstruction falls in relation to each. We will also add more information, where relevant, about how these values compare to other recent studies within the CMIP5/CMIP6 framework.

Section 4 results: AIS SMB sensitivities to changes in temperature: Lines 294-297: "Comparing the projected change in SMB per degree warming between the emission scenarios gives median sensitivities of 64±80 Gt C−1, 57±33 Gt C−1, and 78±15 Gt C for RCPs 2.6, 4.5, and 8.5, respectively, for the best scoring models. Combined, these data tell us that for stronger emission scenarios, the AIS SMB response will be stronger in both magnitude and trend."
The results do not back up this claim. The mean sensitivity for RCP4.5 is lower than that for the RCP2.6! Furthermore, there is no indication here if the differences in the means are statistically significant or not. If model sensitivities of AIS SMB-Temp change with different scenarios – this is a very interesting result (and needs to be backed up better if it is your result – with some explanation to the apparent contradiction of the RCP4.5 having the lowest sensitivity – or maybe there's a typo?). If so, some discussion about what mechanism might explain this. For example, AIS SMB is driven by precipitation and evaporation/sublimation. Are there processes in changing climate that might drive changes in precipitation in addition to changes in temperature? Changes in synoptic weather patterns? Or? Do sensitivities of AIS-SMB to changes in CO2 remain same in all scenarios or do these change? (or do changes in CO2 combine temperature and precipitation sensitivities into "one" proxy for these?)

We would like to apologize here. The reviewer is correct in that the results are not statistically different between the three forcing scenarios. This text is based off an early result that had since been updated in the figure. We failed to update the text as a result and will do so to make sure it accurately reflects this newer result to the effect of: these results indicate that there is no difference in the sensitivity response to changes in temperature between the three forcing scenarios. We will also make sure that this result is changed throughout the document to accurately portray the result presented here.

Line 71 "calculated spatial sampling uncertainty is based"

should be "calculated spatial sampling uncertainty based"

We will correct this typo.

lines 84-87
How many CMIP6 models? Later it is claimed that there were so few CMIP6 models available that statistics are not robust for that set...yet the numbers here (53 models, 28 independent and of these 30/19 are CMIP5 which leaves at least 20 CMIP6?).

Because we were performing the analysis as CMIP6 was being released, we only had access to 12 models at the time. We are continuing to add in more CMIP6 models as they are released and we will add them into our analysis and discussion.

Line 114
4 Repeat 1850-2000...think you mean 1950-2000 in second instance

Will will correct this typo.

Language is a bit cumbersome and over the top in 3.1 (AIS-integrated SMB criteria)

We recognize that the language here is difficult to parse and we appreciate the reviewer's comment. We are adding Fig. **??** and will use it when referring to our scoring process. With this, we aim to clarify our scoring method in a concise way.

Got lost again in 3.2 Maybe a couple equations and a map (example) would help. I have the sense it's pretty straightforward but description overcomplicates

Again, we agree with the reviewer here that the language lends itself to being

difficult to understand. We are adding eq. (1) to further inform the reader of the process we used to parse the spatial criteria.

Figure 2
Can't see dots in Figure 2B (they overlap too much?)

Because there are relatively small differences between the top scoring models compared to the entire ensemble, it is difficult to differentiate the dots, yes. However, we do believe that better color choices could be made to accentuate any differences and we will make a note in the caption that some dots may be overlapping.

Line 190
Just because there are fewer models does not necessarily imply that the spread in trends will be less! For example, one could pick CMIP5 models and only use a subsampling and still get same spread if the models selected have large range in trends.

This is a very good point. We will change our wording to reflect words to the effect of: the spread in trend in the CMIP6 models is significantly lower than for CMIP5 models which is likely due to a smaller sample that isn't capturing the extreme ends of the distribution seen in CMIP5.

Line 200
Not only melt and discharge distributed unequally, but also accumulation (precipitation)!

We thank the reviewer for catching this. We will change the wording to: ... spatial variations in SMB are also important in AIS SMB representation in models as precipitation, melt, and discharge are not distributed equally.

Lines 213-216
If using place names, have a map showing where these are

We will add a map to the supplementary material with all place names referenced in the work located with labels.

Lines 235-236
already defined RCP earlier, no need to do so again here...

We will remove this redundancy.

Conclusions
The recent and similar work of Barthel et al (2019) is mentioned (lines 45-49). Bartel et al was addressing a related albeit slightly different question (than this submission), namely "which climate models would best be used to force a stand-alone ice sheet model?" and compared climate model output to atmospheric reanalysis products. Did their suggestions (best models for stand alone Antarctic Ice Sheet forcing) differ than yours (best models for AIS SMB in the coupled system) or were they similar? Why do you think that is? (perhaps in conclusions – and only need a couple of sentences). Essentially tie in the results of this submission to other current related results.

We agree that further discussion of this paper is relevant for our conclusions. Barthel et al. were addressing a slightly different question, as the reviewer points out, and their methodology is different as well. One of their first steps was to exclude models whose output was not 6-hourly and models that didn't include both RCP2.6 and RCP8.5 output (as this was a stipulation of the ISMIP6 experiment). With that first step, Barthel et al. already excluded the GISS and MPI model groups which we found to have the best results for CMIP5. As such, making a one-to-one comparison with the

final results of this paper is difficult, but we will address some of the similarities and differences in other model results while stressing the differences in methodology and purpose of the work.

Figure 4
condense A-D onto one figure

We have tried to combine panels A-D for this figure but have found that the distributions are too similar in width and height that they are largely indistinguishable.

Figure 5
Reconstruction EOFs are low enough that on scale plotted hard to see patterns. Recommend a different scale for reconstruction (and point out in figure caption). Also to help clarify, only need one legend for reconstruction (if you re-scale) and one for 6 panels of model (do not need 9 identical legend bars - extraneous). This will simplify.

We will update the scale on the reconstruction EOF figure to make the patterns more apparent and make note of the scale change in the figure caption. We will also remove duplicate color bars to simplify the plot and enhance overall readability of the figure.

Figure 6
Yellow x's very difficult to see. Make more visible.

We will change these x's to make them more visible.

Figure 7
Hard to see differences from different scenarios (and until 2006 they are identical). Find a way to combine these three panels into one – this will give same information

and also new, comparative information

We agree that it is a bit difficult to see accurately the differences between the scenarios in this figure. We have tried multiple ways to convey this information succinctly in a single frame to alleviate this issue but have repeatedly found that our attempts to do so only reduce the readability of the figure. For instance, combining the figure as is into one frame makes it such that the larger model spread (for all models) are difficult – if not impossible – to differentiate due simply to the fact that there is significant spread amongst all the models in every forcing scenario. We can, however, try to add a frame that just looks at the four best models in each of the forcing scenarios to be able to make direct comparison among a smaller subset of models.

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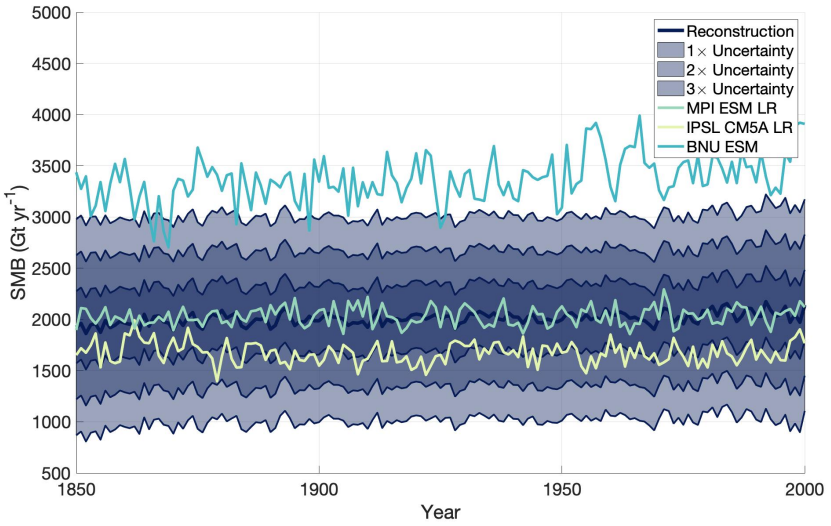
Reconstruction
1× Uncertainty
2× Uncertainty
3× Uncertainty
MPI ESM LR
IPSL CM5A LR
BNU ESM
SMB (Gt yr^{-1})
Year
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
1850
1900
1950
2000

Fig. 1.