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

Anonymous Referee #3

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Review The Cryosphere Manuscript # tc-2019-240.pdf Title: Scoring Antarctic surface mass balance in climate models to refine future projections Authors: Tessa Gorte, Jan T. M. Lenaerts, and Brooke Medley

Summary This submission presents a new method for the evaluation of Antarctic snow mass balance (SMB) in climate models. The method described is new at least in part as it compares the climate model output with the relatively new Antarctic Ice Sheet (AIS) SMB ice-core based reconstructions of Medley & Thomas (2019) rather than atmospheric reanalysis products. The models compared consist of CMIP5 and the few CMIP6 models available at the time of submission. AIS SMB from the climate models was compared with the reconstructed AIS SMB over 1850-2000 and in five categories: AIS integrated mean, trends, temporal variability, and two categories of

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spatial variability estimated via empirical orthogonal function (EOF) analysis (pattern and variance represented by the pattern). The best scoring models were NASA's GISS models and the Max Planck's MPI model.

The work described in this article represents an important scientific contribution to evaluating the ability of climate models to accurately simulate AIS SMB. I found, however, that the paper as written made it challenging for me to understand and retain the primary points. Much of the paper reports more details than necessary (burdening the reader) without adequately summarize the main point. Numerical results are presented as a string of numbers – and I get lost reading them. Many of the quantitative results could be better presented with an accompanying table and in the text a concise written summary. I also found that the section in the results discussing different sensitivities to different emission scenarios is unclear and needs more analysis/explanation (see below). As such I recommend consideration for publication with major revisions.

Here are some examples of unnecessary details/weak summary:

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.

Section 4 Results Lines 167-168: "The interquartile ranges for CMIP5 and CMIP6 are 1727 to 2282 Gt yr−1and1728 to 2229 Gt yr−1, respectively, with means of 1940 Gt yr−1and 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

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throughout this section.

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 GtâŮęC−1, 57±33 GtâŮęC−1, and 78±15 GtâŮęC 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 CO_2 remain same in all scenarios or do these change? (or do changes in CO_2 combine temperature and precipitation sensitivities into "one" proxy for these?)

Minor revisions and notes Line 71 "calculated spatial sampling uncertainty is based" should be "calculated spatial sampling uncertainty based"

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?).

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

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

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

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

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

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

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

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.

Figure 4. condense A-D onto one figure

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.

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

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