

Review of Mottram et al: “What is the Surface Mass Balance of Antarctica? An Intercomparison of Regional Climate Model Estimates”

By Tessa Gorte and Jan Lenaerts, University of Colorado Boulder.

Mottram and co-authors present an intercomparison of different regional climate models regarding their performance in simulating Antarctic Ice Sheet surface mass balance. They show that the RCMs, all forced by ERA-Interim at their boundaries, show overall satisfying (but to a varying degree) correspondence with available weather and SMB observations, and that many remaining biases are common between the different models. The integrated ice sheet SMB varies widely from model to model, but interannual variability is very similar. Overall, we think that this is an interesting paper, containing relevant and important results for the climate, SMB, and ice sheet modeling communities, and very fitting for potential publication in *The Cryosphere*. However, this paper lacks a bit of context and broader impacts in its current form, and it suffers from some internal inconsistencies, ambiguities, and poor figure and language quality in places. We would invite the authors to consider our general and more specific comments, highlighted below.

General comments

First of all, in many places it is not clear to what the ice sheet integrated SMB numbers refer to, i.e. grounded ice sheet or full ice sheet (including ice shelves)? That’s an important issue to improve, not only to enhance clarity, but also since the former is directly translatable to sea level equivalent, the latter is not. An obvious place to start is the abstract (e.g. page 1, line 7 and 11). Using appropriate labels and explanations, and clearly separating grounded and full ice sheet throughout the paper would be essential.

Second, although we understand that the authors want to refrain from ‘ranking’ the models, we would argue that, based on the input-output method of determining mass balance (in e.g. the IMBIE assessments), one could qualify the new RACMO2 and MARv3 models more realistic than other models. Using other models would draw a completely different picture of AIS mass balance; based on Table 3, using e.g. COSMO-CLM would more than double current AIS mass loss, and HIRHAM would suggest AIS mass gain, both of which cannot be reconciled with other methods that determine AIS mass balance (GRACE, altimetry, etc.). A discussion on this would strengthen the impact of this paper beyond a straightforward intercomparison, and inform the community on strengths and weaknesses of the different models.

Thirdly, many of the figures are very difficult to read, and colors showing different models are difficult to separate. Moreover, the figures could use a bit more explanation in the text as well as in the caption. A lot is left to the reader to decipher these figures (which potentially convey very interesting information).

Lastly, language needs to be improved throughout. A few places are consistently lacking commas: after/around thus, therefore, moreover, etc. Several sentences were a bit long and could be broken up to make them easier to read. The authors switch between active and passive voice quite often throughout the text (i.e. “parameterizations are included” instead of “the models

include parameterizations), suggesting that various authors have contributed to the writing and the end result is somewhat heterogeneous. We have pointed out a few locations below, but there are many more in the paper. Try to avoid phrases like ‘clearly’ throughout the paper. This is a subjective statement, and findings may not be so clear to the reader as it is to the authors.

Specific Comments

P1: Why are SMB and Gt given as abbreviations but not AIS which is abbreviated later?

P1L1-2: Technically, Antarctica loses mass through enhanced ice discharge across the grounding line into ice shelves (not compensated by an increase in SMB), and ice shelves lose mass by *enhanced* calving and basal melt (not compensated by an increase in ice shelf SMB and/or solid ice influx). Separating these various processes can help to separate the grounded and full ice sheet (see General Comment 1).

P1L3-4: “... of crucial importance...” → “crucially important”

P2L1: “compar” → “compare”

P2L12: “... a significant part of the climate system” is a bit vague and could be expanded upon

P2L15: Is “submarine melting” a common phrase for basal melting?

P2L20-21: Scambos and Shuman maybe shouldn’t be in all caps.

P2L27-28: “In the future... climate change” → this sentence requires a change in punctuation for readability for me. For instance, consider changing to “In the future, a “greenlandification” of the ice sheet climate (increased melt and refreezing within the snowpack) is projected due ...”

P3L12-16: “Souverijns et al... peer review literature” → this is quite a long sentence. Perhaps consider breaking it up for readability.

P3L27: It might be good to list all 5 RCMs at the beginning of the Methods section

P7L4: “Parameterizations are included...” → “The models include parameterizations...”

P8L2: “... nudging whether spectral or with simpler techniques keeps...” → “nudging, whether spectral or with simpler techniques, keeps...”

P9L6: “Weather observations are used...” → change to active voice

P9L22-27: Change paragraph to active voice

P10L10-11: “Observations between... 5 years” → consider rephrasing for readability

P10L15-20: Authors say SMB was computed in 3 steps but only two seem to be explicitly mentioned.

P11L10: So you’re saying that the higher resolution the model, the poorer skill it will show due to increased internal variability? Please clarify, since this is essentially contradicting many other studies that are suggesting enhanced performance with resolution.

P11L17: What causes you to suspect “...biases in cloud cover and long-wave radiation...” are the leading factors in divergence from observation? How would you expect a model bias that overestimates cloud cover to effect observations, for example?

P12L7-8: “The models can be divided into two groups...” → how are you dividing these groups? Not sure we understand the origin or the purpose of having two groups here.

P12L22: Extra parenthesis.

P12L23: “...in the colder, and therefore higher elevation locations, while...” → is this supposed

to be “...in the colder, and therefore higher elevation, locations while...”? Also, perhaps consider changing the order to “in the higher elevation, and therefore colder, ...” such that it seems like temperature is a function of elevation and not the other way around.

P14L14: What do you mean by “good results” exactly?

P16L2: “...we here show...” → “...here we show...”

P17, Table 2: Arguable showing an RMSE with absolute SMB numbers that decrease rapidly from the coast to the interior is not justified, since the RMSE will tend to decrease along with the SMB itself. Adding relative RMSE (i.e. as a ratio to the mean) is required to compare apples to apples across the elevation bins.

P20: When looking at the ensemble mean, have you considered how your results may change if you calculate the mean on different grids? What grid did you use for this (i.e. how does this common grid resolution compare to that of any of the given models)?

P24L9: “bring” → “brings”

P25L9-11: “The HIRHam5 ... below the mean respectively” → This sentence is long and difficult to read due to the lack of commas.

P25L17-20: The authors address the period of the “1990s and 2000s” for SMB trend, but since SMB is so highly variable, can you really say that this is significant/important?

P26L16: “west Antarctica” and “Antarctic peninsula” → “West Antarctica” and “Antarctic Peninsula”

P27L29: “bee” → “been”

Figure Comments:

Figure 1: These Taylor diagrams are very interesting way to convey information, but many readers will have never seen something like this before. It will be important to better clarify the metrics conveyed by the figure. For instance, we are unsure what the curved lines (i.e. ranging 1.60 to 13.50 in the left panel) are supposed to represent.

Figure 2: Could you perhaps also include a table of correlation and/or bias for each model?

Figure 4: The same comment as figure 3, but with the color bars

Figure 5: Is this meant to be rotated? Also, increase the font size again.

Figure 6: Increase label size