Review of: “Diverging runoff drives uncertainty in Antarctic surface mass balance projections under a high emission scenario”

Heurgue et al. 2026

This manuscript explores Antarctic ice sheet SMB and it’ components for future emission scenario SSP585 from the global climate model CESM2 and three different regional climate model runs, all forced with CESM2. The manuscript is generally well written, figures are clear, and I believe that the results are interesting and useful, especially considering current efforts in ISMIP7. I am selecting “major revisions” because I would like to see the revised version of this paper another time before acceptance, but I believe that most of my comments are relatively minor.

General comments:

I have questions about the reported water retention capacity values discussed throughout the manuscript. In L171, the authors say “… a fixed 2% in RACMO to a maximum set to 7% per layer in HIRHAM (Machguth et al., 2024).” However, I cannot find these values mentioned in the Machguth paper. If we look to the recently published version of this paper (which should be cited instead), the authors use the IMAU-FDM firn model (instead of RACMO’s firn model) in which the holding capacity depends on porosity. This study also does not use HIRHAM, so I don’t think it is an appropriate reference for the statement in L171. Where does the 2% maximum water capacity value in RACMO come from?

The reason I am questioning this is because I cannot wrap my head around RACMO runoff in relation to the reported maximum water capacity value. If we look at Table 2, the melt in RACMO and MAR are almost identical (with CESM2 forcing), but the runoff is 8x higher in MAR. If MAR has a higher maximum water capacity than RACMO, then each layer should hold more water and there should be less runoff. What then causes this discrepancy? Is it due to the thickness of the firn layer? I am sure that I am missing something important here, but perhaps this should be looked at closer and discussed in the manuscript. This is somewhat discussed in L482-500, but the discussion is a bit meandering and vague.

There are many places throughout the text that could use slight clarifications (small additions of words here and there). I have tried to point out several of these instances below, but I would suggest going through the whole manuscript and making sure that each sentence is clear what it is referring to.

- L7 – add “SMB” or “change in SMB”? before “spread”
- L16 – add “mass” after “Antarctic Ice Sheet”
- L27 – specify “air” before temperatures
- L266 – “This figure”. Which figure?
- L279 – add “SMB” before “anomalies”

- L285 – add “SMB” before “increase”
- L286 – add “SMB” before “means”
- L306 – add “grounded” before “SMB”
- L318 – add “over ice shelves” after “emergence”

Some parts of the Results section should be introduced in the Methods section instead. Examples include: AMSR2 and SSM/I and how these satellite products are used, metrics used for evaluation such as CMS, MMS, MMD, MOA

For Figures 6-8 (maybe also Fig. S3), I believe that this analysis would be more interesting if done with summer (DJF) near-surface temperatures, instead of annual temperatures. Most of these processes (melt, runoff, melt-albedo feedback) will be primarily relevant during the summer months and it is possible that this analysis will look different if just confined to the summer months (maybe the bias between RCMs for summer air temperatures is different than the annual air temperature bias).

Minor comments

Abstract – In general, I think the abstract could be a bit more extensive ,with more context as to why this work is important and relevant in the grander scheme. The last sentence of the abstract “Performance differences…” comes out of nowhere, especially because I don’t think this is actually mentioned again in the rest of the manuscript?

L17 – For consistency in sentence structure, change “-40 +/- 9 Gt yr-1 in 1979-1990 to -252 +/- 26 Gt yr-1 over 2009-2017” to “40 +/- 9 Gt yr-1 *over the* 1979-1990 *period* to -252 +/- 26 Gt yr-1 *over the* 2009-2017 *period*.”

Introduction – There is some really relevant work that would be worth introducing here and contextualizing with this study. Mottram et al 2021 could be discussed more, as this work is also an RCM intercomparison, although confined to the historical period. Machguth et al 2026 is also very relevant. While this paper focusses on Greenland, it discusses similar RCM differences in the representation of meltwater processes, particularly focusing on runoff divergence.

Mottram et al 2021: https://doi.org/10.5194/tc-15-3751-2021

Machguth et al 2026: https://doi.org/10.5194/tc-20-427-2026

L22-24 – can also mention here that more sophisticated firn models also predict that most meltwater refreezes in the snowpack on Antarctica (Medley et al., 2022)

Medley et al., 2022: https://doi.org/10.5194/tc-16-3971-2022

L26-29 – This sentence is quite convoluted and long. I suggest breaking this sentence up for clarity.

L46-48 – Can you elaborate on this last sentence of this paragraph? I'm not sure exactly what is meant here.

L75-78 – The sentence beginning with "Since runoff…" is also convoluted. I suggest moving the final part to the beginning of the sentence to make it more clear. Example: "The omission of wind-driven erosion and deposition is not expected to compromise our intercomparison since runoff rapidly becomes…"

L191 – What does "into-time series anomalies" mean?

L229 – Do you mean runoff instead of melt in "This refreezing partially suppresses melt"?

Random thought: Can you compare melt rates to QuikSCAT for each model? Has this already been done for all the RCMs?

L256 – The sentence beginning with "For HIRMAM, increasing…" is confusing. Consider re-wording this as I had to read several times and still don't fully understand what is being said.

L322 – Perhaps clarify with "(near-surface air temperature)" after "climate response" here.

L337 – Do you mean W m^{-2} K^{-1} here instead of mmWE yr^{-1}? Same thing in the caption for Figure 6.

L343 – Specify the starting temperature for HIRHAM over ice shelves. Also, in L345, it looks like from Figure 6b, that RACMO starts closer to 254 than 255.

L346 – "As shown in Figure 7, HIRHAM stands out throughout the entire simulation." Can you specify what is meant here? Looking at Figure 7, there are some panels where HIRHAM does not stand out (e,f). I would also say that it does not stand out in panel c as the difference between HIRHAM and CESM looks similar to that between CESM and RACMO.

Figure 8 – could you also add a plot showing the MOA as a function of near-surface temperature? It would also be helpful in the figure legend to indicate that the open dots are for accumulation and the closed dots for melt, instead of just putting this information in the caption.

L516 – I believe this should just be cited as: "The Firn Symposium team"

Figure S5 is missing in the document.

Technical corrections

L1 – Add "Global Climate Model" or "Earth System Model" before CESM and change "CESM" to "CESM2". I would suggest making the change from CESM to CESM2 throughout the manuscript.

L1 – Add "Regional Climate Models" before MAR, RACMO, and HIRHAM.

L84 – Danabasoglu reference should be in parenthesis.

L145 – missing period after SMB model.

L235 – Sentence “This is particularly important…” is repeated twice.

L263 – Remove “can” from “We can also”

L407 – Change “F. 8” to “Fig. 8”