Response to RC2: 'Comment on egusphere-2024-3140', Anonymous Referee #2, 22 Jan 2025

Brief Communication: annual large-scale atmospheric circulation reconstructed from a data assimilation framework cannot explain local East Antarctic ice rises' surface mass balance records By Cavitte, Goosse, Dalaiden, Ghilain

In this short communication, the authors use eight ice core surface mass balance (SMB) records from a previous study, annually resolved over the period 1987-2011, from ice rises located in coastal Dronning Maud Land, East Antarctica. They use a downscaling method that associate circulation patterns with surface fields (snowfall and surface wind) from the regional atmospheric model RACMO at 5.5km resolution. They apply this downscaling to the 10 ensemble members of the CESM2 Earth System Model. They use all years of this downscaled ensemble as prior for a data assimilation method, as well as a radar-based estimation of the representativeness error.

I think this article is interesting because the authors are honest with their results and with the limitations of the reconstructions. I would like to point out that it's not often that authors publish negative results, and I think this type of study is very useful for the scientific community.

We would like to thank the reviewer for their time in reviewing our manuscript, we really appreciate their reflections on its usefulness. And we apologize for the delay in our response.

However, I think the article would benefit from clarifying its objectives.

Major comments

In the introduction, the authors state that "To reconstruct SMB beyond direct instrumental measurements, which only cover the last decade or two (Wang et al., 2021), ice cores are the main in-situ observations (Lenaerts et al., 2019)." This sentence suggests that the article is about SMB reconstruction over a longer time period than the last decade or two. Then the time period of the ice rise records seems to be 1987-2011, which is covered by direct instrumental measurements.

We will clarify. The ice cores we use in this study indeed cover the recent instrumental period, but we meant to highlight that if it worked, it could then be extended to longer ice core records.

Then, the authors show that ice rises SMB records are not correlated to RACMO2 SMB, which means that either :

1. the ice rises SMB variability is not representative of a large-scale signal, or
2. RACMO2(ERA-Interim) SMB variability is wrong.

If I understood well, the authors have explored option (2), with the hypothesis that the link between large-scale circulation and SMB in RACMO2 is correct, but that it may be the large-scale circulation forcing RACMO2 that was wrong. Then they use the relationship between SMB and large-scale circulation to test whether they can obtain a SMB map more consistent with the ice rises SMB variability.

Can you tell me if I understood well or not? In any case, I think the article would need a clarification of the hypotheses that are being tested.

We actually test both hypotheses. As the other reviewer also found the setting up of the problem a little confusing, we will restructure the methods section to be as clear as possible. And we will detail the hypotheses being tested up front, as suggested.

I think the authors should also give there hypotheses on why RACMO2 SMB variability might be wrong. Are they suggesting that the ERA-Interim forcing reanalysis might have a biased atmospheric circulation?

The large-scale circulation is relatively well constrained in ERA reanalysis but the link between large-scale and local scale variability may be biased or may misrepresent some processes that can be corrected by data assimilation. This is what we want to test. This will be specified more clearly in the revised version.

Conversely, they use the relationship between large scale circulation and RACMO2 SMB to downscale a large ensemble CESM2, which means that they trust the downscaling but not the ERA-Interim large scale circulation. It would be good to clarify if this is based on previous studies or it is a working hypothesis.

This is a working hypothesis. We assume that in the whole downscaled CESM2 ensemble we have enough samples of the potential variability of the system to reproduce the observed variability. This will be mentioned more explicitly in the revised version.

Finally, I was troubled by the emphasis on "test(ing) if using the representativeness error derived from radar data improves the reconstruction of SMB" which at the end did not seem to be a center point of the article.

We will be more explicit as to what is used. We use the radar-derived representativeness error to assimilate the radar-derived SMB, which we compare to the assimilation of the ice core SMB, and featured in the Supplement.

Minor comments

Abstract

"To evaluate if large-scale atmospheric circulation explains contrasted SMB trends at eight East Antarctic ice rises"

- -> "contrasted SMB trends" with regard to what?
  We meant that the SMB trend of the various ice cores are very different from each other, we will clarify

1 Introduction

"Regional climate models with a high spatial resolution (~a few km2), such as the polar-oriented Regional Atmospheric Climate Model version 2.3 (RACMO) (Van Wessem et al., 2018), struggle to capture the mean SMB state in the ice sheet interior, while they have a reasonably good fit with coastal mean SMB (e.g. Agosta et al., 2019)"

- -> I don't see this information in Agosta et al., 2019, can you clarify where it comes from?
  This is from Fig2 of the Agosta et al., 2019 paper, the panel for Dronning Maud Land is a

good example.

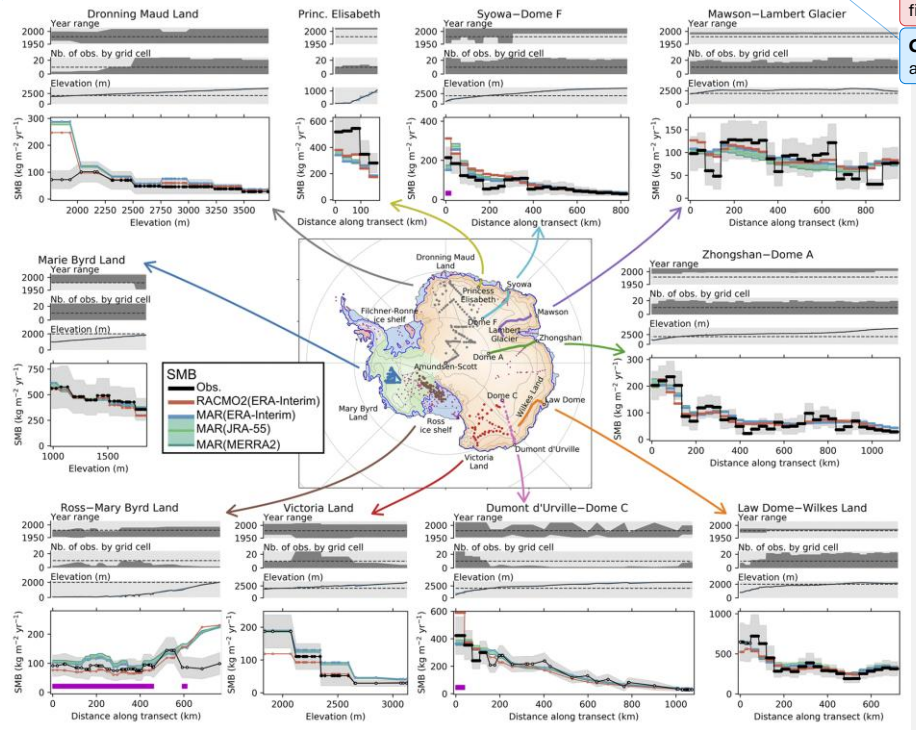

Figure 1. Figure reproduced from Agosta et al., 2019, The Cryosphere

Commented [HG1]: Are you allowed to reproduce the figure here (it will be online) ?

Commented [MC2R1]: It's open access so I think so, and I've added a ref

- "Fig. 1" Nice figure. Thank you!

- "Fig. 1: Background is the RAMP RADARSAT mosaic (Jezek et al., 2013) with superimposed the Reference Elevation Model of Antarctica (REMA) v2 elevation for each site (units are meters and referenced to the WGS84 ellipsoid)." Will be added.

  - -> the colorbar is missing for REMA elevation maps , and I recommend to use a continuous colormap instead of the rainbow colormap.
    Will be done.

- "Fig. 1: (b) Mean 10-m winds over Dronning Maud Land for 1987-2011."

  - -> from which dataset? RACMO2.3p. Will be added.

2. Method

2.1 Data assimilation

"Particle weights are assigned based on the agreement between model results and observations, with closer matches receiving higher weights. "

- -> provide the exact metric : extract the model at the nearest grid cell? And RMSE across model-obs? Yes, this will be added explicitly.

- -> Then can you provide the exact formula of weighted mean using this weigth?
  We will provide a reference for this

Commented [HG3]: Not sure it is useful (it is given in plenty of other papers). Can we just day that we will give a reference for that ? Otherwise, we can just add it ...

- "Our observation error is the root-mean-square combination of the instrumental error and the representativeness error (Supplementary Table S1)."

- -> I don't see in the short method description where the observation error is taken into account. We will make sure to clarify this in the method description.

2.2 SMB observations

- -> add more details about SMB observations, notably the time period, time resolution and associated uncertainties with regard e.g. on ice core dating.
  Will be added.

2.3 Downscaled model ensemble

"This downscaled product has an improved spatio-temporal distribution of snowfall compared to global climate models, such as the CESM2 simulations on which it is based, and can thus provide information on large-scale atmospheric circulation patterns associated with local snowfall changes."

- -> Is the improvement quantified in this study or in a previous study? In both case, can you give the reference to this quantification?
  This is shown in the Ghilain et al., 2022 paper in ESSD, which presents the downscaled SMB product. Based on a comparison with available ice cores and spatial reconstructions, they show that the spatio-temporal distribution of snowfall is improved in the downscaled dataset compared with the CESM2 simulations. We will add this reference in the paragraph.

3 Results

- "We highlight that the number of particles retained by the filter is quite low (about 7% on average). Retaining too few particles implies that the reconstruction may be based on too few samples and the estimate may become less accurate (filter degeneracy)."

- -> The final number of particles retained should be added in the Method section.
  We will add a few words on this in the methods.

  - Figure 3:

- -> I suggest that you add the difference in SMB field between the reconstruction and RACMO for the full period, and the same for winds, to assess the difference between the reconstruction and RACMO2 SMB (on top of the difference in changes in SMB).
  We will add this to the figure, to show the difference in mean state.

"Because the ice core records are rarely sub-annually resolved, due to the nature of the measurements (if we want to go back further than 10 years), we would need to turn to other types of SMB records such as automatic weather stations. The issue in that case is that such records are currently not long enough to retrieve meaningful SMB trends"

- -> Many automatic weather stations are already assimilated in reanalyses, though not for SMB. Can you clarify what you want to reconstruct or constrain with ice cores? Do you want to reconstruct circulation patterns beyond the reanalyses era? Do you want to

use SMB to better constrain reanalyses?
What we meant here is that we would like to reconstruct circulation patterns beyond the reanalysis era, beyond AWS measurements. This paper was the first step: testing it over a short recent timescale, to see if then we can extend further back in time. We will clarify the objective in the paper.

"ML and AI emulators"

- -> replace abbreviations by full words. Done

" downscaled annual wind simulations are available at xxxx."

- -> typo. The online portal will be added upon publication.