

Reply to Reviewer 1's comments

General

This is an interesting application that remaps coarse-resolution Antarctic accumulation fields from a GCM to high (5.5 km) resolution using two intermediate products, a coarse resolution re-analysis product (ERA-Interim/ERA5) and a high-resolution regional climate model (RACMO). There are three problems that I identified while reading the paper: the introductory sections are poorly written, the goal is not well-motivated, and most of the figures are of mediocre quality.

Authors:

The authors thank reviewer 1 for careful reading of the manuscript and the comments.

Major comments

Unfortunately, the introductory parts of the paper are not well written. Many formulations could be clearer and more concise. Sometimes not even the meaning of a sentence is clear, for example, the sentence starting at l. 19: “While the Greenland Ice sheet is eroding at an increasing speed both from the base and the surface, the Antarctic Ice Sheet is sometimes viewed as subject to a mitigation mechanism to the observed melting of the ice shelf through an increased coastal precipitation due to a higher atmospheric humidity.” is really unclear. It is true that in a warmer atmosphere, snowfall over ice sheets is expected to increase, mitigating future mass loss. This is true for both Greenland and Antarctica, so why make the distinction? Solving this requires a thorough and critical re-reading of the manuscript, maybe the co-authors can be of assistance here?

Authors:

The introduction will be re-phrased and carefully reviewed by all the co-authors to ensure that all the text is clear and concise.

Please better motivate the goal of the study. The title suggests that ‘real’ snowfall amounts are reproduced, but these are merely time series with improved statistics that do not represent ‘real’ events, rather ‘real’ variability. So please clarify: what are these data derived for?

Authors:

The authors thank reviewer 1 for bringing to our attention the ambiguous meaning of the title. As said by reviewer 1, this reconstruction is not a “reanalysis” of daily snowfall (“real daily snowfall”), but a reconstruction of daily rates of snowfall over a long period with spatio-temporal characteristics similar to the ones of the highest resolution products currently available. As such, it presents an improvement with respect to available information given by reanalyses & RCMs (short time period, max 40 yrs) and climate GCMs (coarse resolution, 1 degree). The reason for producing this dataset is to provide an improved representation of detailed spatial patterns of snowfall over Dronning Maud Land. Firstly, this dataset allows for a more accurate comparison of trends and long-term temporal variability with local measurements (here, SMB deduced from ice cores). Secondly, it enables a better understanding of the potential differences between estimates at small scale (such as the ones derived from ice cores) and the ones at the scale of the grid of a GCM. Finally, it makes it easier to associate synoptic meteorological conditions to snowfall events that determine the annual totals.

We therefore suggest to modify the title as follows, to emphasize that the primary source of information is a climate model: Large ensemble of downscaled historical daily snowfall from an Earth System Model to 5.5km resolution over Dronning Maud Land, Antarctica.

The motivations will be made clearer in the different parts (abstract, introduction and conclusion), especially at the end of the introduction by re-stating explicitly the purpose and assets of the dataset as detailed in the response above.

Reviewer 1: Please improve figure quality, below are some suggestions.

Fig. 1: what do the colours of the text boxes represent?

Fig. 2: add elevation contours to map, what are axis units? To see the improvement, time series should also show the non-downscaled ERA-Interim time series. Increase font size, add units to colour bar, 'nbr months' is not really a clear axis label etc.

Fig. 5: increase the font size, add a unit to the colour scale.

Fig. 7b: unclear which colour represents which principal component

Fig. 9: increase the font size, add a unit to the colour scale.

Fig. 10: add colour scale.

Fig. 11, 12, 13: consider removing.

Authors:

Thank you for the suggestions to improve the readability of the figures.

Fig 1: Each uniform colour corresponds to a model (GCM, reanalysis, RCM), we mix colours with a gradient when an operation including more than one source has been done. This will be made clearer in the caption.

Fig 2: We will increase the font size, the units will be added to the colour bar, and we will add the axis units of top-left sub-figure. The non-downscaled ERA-Interim data will also be added.

Fig 5, 9, 10: the font size will be increased and will add units to colorscale.

Fig 7b: we propose to label the first principal components.

Fig 11, 12, 13: we consider the figures are illustrative of the variability of the estimations considering the different sources of uncertainties.

Reviewer 1: Minor and textual comments

ERA-Interim is known to have a serious dry bias in the interior ice sheet (doi.org/10.1175/2011JCLI4074.1).

Authors:

The authors thank reviewer 1 for pointing this out. To see the effect of the reanalysis, we had chosen to repeat the exercise with another reanalysis (ERA5), and included this the dataset (see section 3.1). Similar performances were obtained, even though some regional differences are present, driving at some places slightly different trends when applying to CESM2 runs (eg figure 12, bottom time series - DIR). This will be made clearer in the new version of the manuscript.

Reviewer 1: 850 hPa values for humidity, temperature are used, but this pressure level intersects with the surface of the ice sheet. How was this dealt with?

Authors:

As we have tested several levels (500, 700, 850 hPa) and different domain sizes, fields have been interpolated or extrapolated whenever necessary. Finally, 700 hPa level for relative humidity was chosen, as the scores were better than 500 hPa, and similar to scores at 850 hPa, but without requiring interpolation. The choice was already mentioned in the method section (section 2.2), but it will be formulated more clearly in the revised manuscript.

Reviewer 1: Abstract: the first few sentences do not really belong in an abstract, but rather in the introduction.

Authors:

Thank you very much for the suggestion. We have modified the abstract as follows.

We explore a methodology to statistically downscale snowfall – the primary driver of surface mass balance in Antarctica – from an ensemble of historical (1850-present day) simulations performed with an Earth System Model over the coastal region of Dronning Maud Land (East Antarctica). This approach consists in associating daily snowfall simulations from a polar-oriented Regional Atmospheric Climate Model at 5.5 km spatial resolution with specific weather patterns observed over 1979-2010 AD with the atmospheric reanalyses ERA-Interim and ERA5. This association is then used to generate the spatial distribution of snowfall for the period from 1850 to present day for an ensemble of ten members from the Earth System Model CESM2. The new dataset of daily and yearly snowfall accumulation based on this methodology is presented in this paper (MASS2ANT dataset, <http://doi.org:10.5281/zenodo.4287517>, Ghilain et al. (2021)). Based on a comparison with available ice cores and spatial reconstructions, our results show that the spatial-temporal distribution of snowfall is improved in the downscaled dataset compared with the CESM2 simulations. This dataset thus provides information that may be useful in identifying the large-scale patterns associated with the local precipitation conditions and their changes over the past century.

Reviewer 1:

l. 1: over -> of

l. 9: Dronning Maud -> Dronning Maud Land

l. 18: the global -> global,

l. 31: reconstitutions?

l. 114: lead -> led

Table 1: please adjust the number of decimals of the coordinates

Authors:

Thank you for noticing these errors, the text will be changed accordingly.