Replies to Reviewer 2

May 7, 2020

Scope and format of this Brief Communication

- Reviewer comment: *While this is relevant work and a potentially interesting work, I am not sure why the authors chose to turn it into a 'brief communication' paper, given that I think many results are somewhat unsubstantiated and/or incomplete, and important details are missing.*

- Reply: This Brief Communication should be considered as an undate to the article "Evaluation of current and projected Antarctic precipitation in CMIP5 models" by Palerme et al. (*Climate Dynamics*, 2017, doi:10.1007/s00382-016-3071-1), which provides an in-depth evaluation of CMIP5 model output against CloudSat and ERA-Interim data. With CMIP6 (and ERA5) output now available and the IPCC AR6 in preparation, this update is timely. This is why we chose the Brief Communication format: We build heavily on previously published and well-recognized work (56 citations in peer-reviewed literature, according to the Web of Science on April 30, 2020), which provides the in-depth background discussion the reviewer seems to be calling for. We clarified this at the end of the introduction in the following sentence:

  > Using new reanalyses and output of the most recent CMIP exercise, this work provides a brief update of the analysis by Palerme et al. (2017), which focused on CMIP5 and ERA-Interim.

Uncertainties of the CloudSat dataset over some regions

- Reviewer comment: *While the authors present CloudSat as a benchmark data set, its performance over the Antarctic interior is highly doubtful.*
- Reply: To assess the statistical significance of the difference between the observations from CloudSat and the reanalyses and the models,

we performed a Welch t-test that has been added in Appendix D. As it was mentionned, it attests that the difference between the snowfall means of the CloudSat dataset and ERA5 and the CMIP (5 & 6) ones are significantly different in some regions. In particular, comparisons have to be taken with caution on the Plateau and the Low West regions where there may be a significant underestimation of the surface snowfall means by CloudSat - due to various microphysical processes occuring at lower levels. We choose to keep the results of the CloudSat climatology as it is the only source of observations covering most of the Antarctic continent but we highlighed that there is a low confidence in these areas.

Link between temperature and precipitation

- Reviewer comment: *As the authors surely can confirm, there are many levels of complexity involved with precipitation formation, and only focusing on near-surface temperature definitely understates these complexities.*
- Reply: Of course, as the reviewer rightly presumes, we did not intend to imply that near-surface temperature was the only parameter or process that determines Antarctic precipitation rates, even though there is a strong link between temperature and precipitation changes over the Antarctic Ice Sheet on long time scales and larger spatial scales, as ample literature on this issue shows. But of course we agree that this is at best a very first order effect, with many much more subtle physical processes involved in precipitation formation. These processes complicate the detailed picture as soon as one goes beyond the very first order. To reduce the risk of such misunderstandings among our readers, we decided to 1) remove the description of the temperature station data from the main text and to move it into the supplementary material) and, more importantly, to 2) rewrite the short paragraph mentioning the reduced temperature errors:

  > We note that although there is no progress in the representation of large-scale mean precipitation and of its seasonality from CMIP5 to CMIP6, there is a concomitant measurable progress in the representation of surface air temperature. Regional-scale multi-model median root-mean square errors are reduced by typically 5 to 10% between these successive CMIP generations (see Figure D1 in the annex). This indicates that in spite of a clear physical link between temperature and precipitation changes on long time scales (e.g., Krinner et al., 2008;

Frieler et al., 2015), precipitation errors in current-generation AGCMs are not dominated by the first-order physical link between temperature and water vapour saturation pressure, but by errors in the representation of other processes such as atmospheric circulation and cloud microphysics.

Temperature analysis

- Reviewer comment: *The statistical analysis of near-surface temperature needs to be expanded. Only the RMSE is currently shown, but that fails to represent the mean bias ... Moreover, there is no analysis of statistical significance whatsoever ...*
- Reply: The mean bias has no sense in this analysis because of the risk or error compensation. We compute the error statistics using monthly means over the entire mean annual cycle. Therefore, one could, for example, obtain a zero annual mean bias in spite of a strong positive summer bias, compensated for by an equally strong, but opposite, winter bias. The RMSE (or, alternatively, the mean absolute bias) is therefore much more meaningful. To allow for a visual assessment of the reality of the improvement, we added error bars indicating the regional mean inter-model standard deviation of the simulated temperature errors, which shows reduced spread in CMIP6 compared to CMIP5 and, depending on the regions, substantial improvement of the mean root mean square errors. As this short analysis of temperature errors is not the focus of the paper and only very riefly mentioned in the main text, we do not think that a more detailed analysis of this aspect is warranted.

Map of the regions

- Reviewer comment: *One smaller issue is that Figure 1 should mask out regions south of 82 South. What are the white areas.*
- Reply: The map of the studied regions (Figure 1) has been modified to mask out regions south of 82° South where there is no data from CloudSat.