Replies to the Editor's and John Scinocca's suggestions and comments

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The Editor's suggestions

- The zenodo repo was last updated in July 23 (version 1). Please check if any updates are needed and provide an update to the code availability if relevant.

  Reply : We updated the Zenodo repository by adding a modified tarball containing all the analysis and figure production scripts. This is now V2 of the repository.

- I noticed one sentence that caught my attention on L245 which reads: "We are therefore rather certain that main our results and conclusions remain valid at a higher horizontal resolution". The paragraph preceding this is well justified but I think perhaps it is too strong to say "rather certain". Could you consider rephrasing this please?

  Reply : Yes, sure we can. This sentence apparently sounds much stronger to a native speaker's ears than what we meant. We are sorry for this. We rephrased it as follows:

  > We are therefore fairly confident that our main results and conclusions remain valid at a higher horizontal resolution.

  We also took the opportunity to invert (and correct) the order of the words "results" and "main".

Comment by John Scinocca

Minor Point #1 (related to Main Point #3 of my original review)

The authors' revisions usefully clarifies the role of parameterization tuning. However, the manuscript does not provide sufficient support for a general conclusion that temperature ERBC is dynamically problematic. The behaviour described appears specific to LMDZ v6.3, which exhibits a substantial cold bias and a tuning strategy closely tied to TOA radiative balance. In contrast, earlier work (e.g., Krinner et al., 2020) using LMDZ6A(-LR) (CMIP6 version), which is a closely related configuration within the same model family, did not report comparable degradation when temperature was corrected. This indicates that the response to temperature nudging is not intrinsic to the method itself, but depends on the particular model configuration.

Also, the reference to Maraun et al. (2017) does not seem to support the argument for a general distinction between "dynamical" and "physical" variables in bias correction. That paper emphasizes that the usefulness of bias correction depends on how well the model represents the underlying processes, and that structural errors (such as misplaced circulation features) reflect deficiencies in those processes and therefore cannot be corrected after the fact. This is regardless of whether the variable is dynamical or physical. As written, the authors statement appears to overinterpret the reference and so does not support a general argument for limiting corrections to dynamical variables.

A more consistent explanation, as outlined in my original comment, is that the impact of temperature ERBC is more appropriately interpreted in the context of how parameterizations have been tuned in the presence of biases. In the case of LMDZ v6.3, correcting a pronounced cold bias likely perturbs a tuning balance that was compensating for that bias, leading to degraded performance. Framing the result in this way would better align the discussion with the evidence presented and avoid implying a broader limitation of temperature ERBC that is not supported by the contrasting behaviour seen in LMDZ6A(-LR) and other models. I leave it to the authors to decide how they would like to handle this.

Reply : We agree with the reviewer that the problem we face with temperature bias corrections is model-dependent, and we had stated this fairly clearly already. Concerning the reference to Maraun et al. (2017), we

also agree with the reviewer that this paper does not argue for conceptually separating "dynamical" and "physical" variables in bias correction. However, the example given in that paper does very clearly show what can go wrong with bias corrections of "physical" variables (in that case, precipitation rates) when circulation features are misplaced, and that was the point we wanted to make. To clarify this, we slightly rewrite the sentence :

> The effect of misplaced circulation features (for example, a misplaced storm track) often cannot be corrected a posteriori (see an example by Maraun et al. (2017)), ...

We think that the reviewer was irritated by the last sentence, which could be seen as arguing for a general practice of not correcting temperature in GCMs. That was not our intent. We therefore delete this sentence:

> ~~In short, we think that it can be seen as conceptually consistent to limit the empirical run-time bias correction to errors primarily linked to the model dynamics, and to avoid strong interference with the model physics which primarily determines the model response to external forcings, notably in climate change experiments.~~

With these changes, and given the fact that throughout this section we use many cautious formulations such as "One can argue that..." or 'It can therefore make sense...", we are confident that we prevent possible over-interpretation of our discussion. Fundamentally, we basically agree with the reviewer on his point of view.

References

Maraun, D., Shepherd, T. G., Widmann, M., Zappa, G., Walton, D., Gutiérrez, J. M., Hagemann, S., Richter, I., Soares, P. M., Hall, A., et al.: Towards process-informed bias correction of climate change simulations, Nature Climate Change, 7, 764–773, 2017.