**Reply on Referee #1 Comments**

Review: "Optimizing Precipitation Parameterizations in Regional Climate Model (RegCM5): A Case Study of the Upper Blue Nile Basin (UBNB)"

A set of 7 numerical experiments using Regional Climate Model version 5 (RegCM5) was conducted to understand the better precipitation parametrization to reproduce the monthly and daily precipitation over the upper blue Nile basin (UBNB). The numerical experiments combine different cumulus convection schemes (over the land the Kain-Fritsch, or Grell, or Emanuel, or Tiedke, or Emanuel are used, combined with Emanuel over the sea) and large-scale precipitation schemes (SUBEX and NoTo). Simulations were driven by ERA5 reanalysis and PP7 precipitation data was used as observational reference. For the comparison between simulated and observed precipitation it is used some statistical indices. The main conclusion is that predominates a general overestimation of the simulated rainfall in most seasons of the year, with an acceptable performance being obtained by the combination of Emanuel for cumulus convection and NoTo for large-scale precipitation schemes. The analysis of simulation performance in the region is a relevant topic with large potential to add new knowledge related to models' physical parameterizations behavior in the tropics. However, as highlighted in the major points, there are some statements/interpretations that need to be clarified/better founded before the acceptance of the manuscript.

Major points

1. The title does not correspond to the analysis presented in the manuscript. The authors did not conduct any “optimization” in the model since they used the default code and parameters. The manuscript only presents a comparison of different schemes to represent the moist deep convection and large scale precipitation. One suggestion of title is:

“Comparison of precipitation parametrizations in Regional Climate Model (RegCM5): A case study for Upper Blue Nile Basin (UBNB)”

Done. Thanks.

2. In L226-240 (L287-289 of conclusions) the authors attributed the simulated precipitation errors to the difficulty of the simulations to reproduce important features of large scale circulation in the region. However, no figures/tables and their interpretations are presented to justify the claims which are only based on the previous literature. Th e authors need to improve this part of the manuscript

by presenting/analyzing how the experiments simulate the mentioned circulation features.

We appreciate the reviewer's valuable comment. In the revised manuscript, we have added a new analysis of the large-scale circulation to support our discussion. Figures 6 and 7 now present the mean wind at 200 hPa and 850 hPa from both ERA5 and RegCM5 for the FMAM and JJAS seasons. The discussion part in section 4.2 (L275-312) interprets how discrepancies in upper- and lower-level circulation patterns, such as the over-intensified easterly inflow from the Indian Ocean during FMAM and the weakened southwesterly monsoon flow during JJAS, affect the simulated rainfall distribution and bias over the UBNB. Correspondingly, the conclusion has been updated to reflect these findings in L339-347

3. (L264-271) After identifying a considerable overestimation of rainfall by the simulations, the authors present several arguments that could have provided more realistic simulations. My question is: Why didn't the authors use these recommendations in their numerical experiments? In particular, the use of a hydrostatic dynamics at 10 km resolution, which is considered the interface (or limit) of validity for this approximation, is highly questionable. Why did not the authors use the MOLOCH that is non-hydrostatic and makes the RegCM5 code very fast? The authors need to clearly justify their decision to use the hydrostatic approximation core.

We thank the reviewer for this important point. We selected the hydrostatic dynamical core for the experiments for the following reasons:

1. In earlier studies that relied on ERA-Interim reanalysis, achieving such high resolution using the hydrostatic dynamical core typically required double nesting (e.g., downscaling from around 50 km to 12–10 km) (Prein et al., 2016; Torma et al., 2015). Therefore, the current higher spatial and temporal resolution of ERA5 encourages us to use it for direct simulations at 10 km (the interface) at once.
2. In (Giorgi et al., 2023), that describes the release and development of the fifth RegCM, simulations using the new non-hydrostatic core have been tested, exhibiting better performance than the hydrostatic core, however; they stated that further optimization work in under way to fully test the model in different climate settings and reduce current biases.

These reasons made us decide to use the hydrostatic core first. In addition, despite identifying the considerable bias, the model successfully captures the dominant pattern of the precipitation variability over the basin. This is more important than the

absolute values for certain applications, since it is recommended to do a bias correction for the climate variables simulated from the RCMs before it is used in applications such as hydrological applications. For example, (Osman et al., 2021) tested the WRF model sensitivity towards different microphysics and Planetary Boundary Layer (PBL) parameterization schemes over the Eastern Nile. The precipitation was highly underestimated over the UBNB; therefore, they corrected the simulation using a bias correction method before applying it to the hydrological model.

Finally, we would like to clarify our decision to stop at this situation and publish our results as such experiments using the hydrostatic core, despite the high resolution of ERA5 reanalysis as an input to RCMs, there will be a considerable bias at the interface resolution of 10km, and it is recommended to test the new non-hydrostatic option. We have already conducted this recommendation to be published as a new work.

4. Figure 4 and 5 are redundant since both are showing the same information of the biases (underestimation or overestimation) of the simulations in relation to the observed precipitation. In addition, Figure 4 has different scales in each season and it is not easy to compare them. In this way, it should be better to combine the top panels of Figure 4 with the relative biases in Figure 5 to have only one Figure showing the biases.

Done, Thanks. They have been combined in Figure 3, and the discussion has been updated in L218-224

5. The statements in L19-20 do not correspond to what is presented in the manuscript. In the actual form, no sensitivity numerical tests (by changing the core from hydrostatic to non-hydrostatic or increasing/reducing the number of vertical levels) or the circulation pattern were presented in the manuscript. I am suggesting: 1) to remove "Sensitivity analysis ... precipitation outputs"; 2) to include in the manuscript an analysis of the circulation patterns (point 2) to justify the affirmation in the end of phrase.

1) Done, Thanks.
2) Done in L19, Thanks.

6. To improve understanding, the authors could reorganize the introduction. Suggestion:

Starting with L24-27 and following with L37-45. After that, L27-37 would be followed by L46-58.

Done. Thanks.

7. I noted that the main objective of the text is not clearly established at the end of the introduction. There are some indications of the objectives in L64-67. I suggest that the authors reorganize the objectives clearly at the end of introduction.

We appreciate the reviewer's helpful observation. The end of the introduction has been revised to explicitly present the main objective and motivation of the study in L92-97.

Minor points

In many parts of the text (L31; L46; L142-150; L195; L265), the citations are not correct. For example: L108 - in (Giorgi et al, 2023b) should be in Giorgi et al. (2023b); L148 should be "by Holslag et al. (1990)"; L149 should be "by Zeng et al. (1998)" and many others in the text. Please, check all the text.

We thank the referee for the careful reading and for pointing this out. We would like to clarify that the in-text citations in our manuscript follow the Copernicus Publications reference style. For example, the journal specifies "(Smith et al., 2021)" rather than "Smith et al. (2021)".

L30-31 - should be "... interannual) controlled by the Global .... Abtew et al. (2019) found ... "

Done in L39, Thanks.

L37 - should be " ... rainfall since it is the main rain ..."L39;

I think this was in L36. I want to clarify that "... as a main rain producing system ..." belongs to the ITCZ. It appears that it is not clear, so the sentence is paraphrased in L47.

L109-111 - should be "are driven by atmospheric variables and SST from ERA5 reanalysis data from ECMWF (Hersbach et al., 2020) with 0.25o x 0.25o of horizontal resolution for the period 2000-2009. For evaluation, observed ... for the period 2001-2009" since SST was already defined in L31.

Done in L109. Thanks,

L118 - should be "The domain has a 10 km horizontal ... longitude (Fig.2 ), involving ...""

Done in L18, Thanks,

L121 - The 18 vertical levels is a very small number for a 10km horizontal resolution. Why only 18 vertical levels?

We thank the reviewer for this important point. RegCMs have a long history of applications using 18 sigma vertical levels as the default configuration and with a model top of 50 hPa. This configuration has been used across a range of horizontal resolutions, including high-resolution of 10 km, because it represents a compromise between vertical resolution and the substantial computational cost of multi-year/high-resolution runs. For example, previous RegCMs applications have used 18 sigma levels at 10 km and comparable resolutions (e.g., (Torma et al., 2011)). We fully agree that for very high-resolution or convection-permitting simulations (grid spacing less than 10 km up to ≤ 4 km), it is recommended and necessary for accuracy. This is because the sigma-coordinate system compresses in meters as moving up, meaning more levels are needed to provide sufficient vertical resolution near the surface. However, for the current hydrostatic 10 km configuration, the 18-level setup remains within the standard and widely validated range used in many RegCM studies.

L127 - should be "... in the different numerical experiments ..." since the authors used the code as it is, i.e., they do not change any parameter or physical parametrization.

Done in L129-130. Thanks.

L139-140 - should be "Hence, a new set of simulations was conducted by using Nogherotto-Tompkins (NoTo; Nogherotto et al., 2016) microphysic scheme, which treats the mixed .... Over East Africa, Godoshava and Semazzi (2019) revealed .... In addition, Kalmár et al. (2021) ..."

Done in L140-141. Thanks.

L150 - In many parts of the text, the authors used Emanuel_NoTo, Tiedke_Noto and Kain-Fritsch_NoTo. This information should be in Table 2.

We thank the referee for the suggestion. As recommended, we have revised Table 2 Iin L155 and added a new column specifying the scenario names.

L157 - remove "calibration"; it is more common to use "relative bias" instead "percent bias".

Done in L158. Thanks.

L158 - What is the interpretation of the RSR index? What is the range of acceptance of RSR? It was calculated considering a time series or for the mean spatial pattern in UBNB? Please, clarify it in the text and also include a reference for the index.

We thank the reviewer for this valuable comment. The RSR (RMSE–observations standard deviation ratio) index was calculated following (Moriasi et al., 2007). The RSR is defined as the ratio of the root mean square error (RMSE) to the standard deviation of the observed data, and it provides a standardized measure of model performance where lower values indicate better agreement between simulated and observed values. The RSR values range from 0 to ∞, with 0 indicating a perfect match between simulation and observation. According to (Moriasi et al., 2007), model performance is considered satisfactory when RSR ≤ 0.70.

In our study, we first computed the monthly mean spatial precipitation over the UBNB, then used this basin-averaged monthly time series to calculate the RSR between simulated and observed precipitation. The requested clarification and the reference have been added to the revised manuscript in L160-162.

L163 - remove “estimated”

If the word is deleted, the meaning of the sentence is not complete.

L165 - remove “to check spatiotemporal distribution” since this information is already in the beginning of the phrase.

Done. Thanks.

L180 - should be “ ... for the period 2001-2009 since the year 2000 was considered as ...”

Done in L186. Thanks.

L190 - What is the meaning of “reduces the significance between CCs”? Please, clarify in the text.

It is modified to be clear in L196.

L194 - should be “ are presented in Fig. 3b”.

Done in L200. Thanks.

L183 - should be “ ... UBNB the Fig. 3 and Table 3 show the evaluation of the simulated precipitation for the seven numerical experiments””

Done in L190. Thanks.

L202 - Suggestion “The performance of the experiments S5, S6 and S7, which use the NoTo microphysics scheme, is evaluated by analyzing the spatial pattern …”

Thanks a lot for the suggestion. It is done in L216.

L206 - should be “The model also overestimated rainfall in eastern …”

Done in L218. Thanks.

L218 - should be “need an improvement”

Done in L234. Thanks.

L221 - should be “exhibit a low correlation”

Done in L238. Thanks.

L242-243 - should be “ characteristics simulated in the experiments S5, S6 and S7 and observed by PP7 during the FMAM, JJAS and ONDJ (Fig. 7). “

Done in L244. Thanks.

L245 - should be “… (S6) slightly better represents the observed distribution of the daily precipitation during the FMAM (Fig. 7a)”

Done in L246. Thanks.

L278 - I think that should be better “non-convective precipitation and reduces the biases in the simulated total precipitation.”

Done in L331. Thanks.

L296 - What is the meaning of “refine the physical parametrizations”?

We mean to investigate and test more physical parametrizations that affect the precipitation simulation. It is modified in the revised manuscript in L353. Thanks.

Figures:

1) The labels in most of the figures need to be improved since they are very small, which makes it difficult for readers to interpret the figures.

The figures have been improved. Thanks.

2) Please, highlight the UBNB basin (shown in Fig. 1) in panel (a) of Figure 2.

Done in L124. Thanks.

## References


Giorgi, F., Coppola, E., Giuliani, G., Ciarlo`, J. M., Pichelli, E., Nogherotto, R., Raffaele, F., Malguzzi, P., Davolio, S., Stocchi, P., and Drofa, O.: The Fifth Generation Regional Climate Modeling System, RegCM5: Description and Illustrative Examples at Parameterized Convection and Convection-Permitting Resolutions, Journal of Geophysical Research: Atmospheres, 128, e2022JD038199, 2023.

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