Statistical bias correction for climate change impact on the basin scale precipitation in Sri Lanka, Philippines, Japan and Tunisia

by C.T. Nyunt et al.

Thanks for reviewing this manuscript and for your valuable comments which make our manuscript more constructive and informative. We mark our response as "AC: Author comment" and please see our responses as below:

Anonymous Refree#1

Nyunt et al. introduced a new approach of correcting biases from GCM outputs, mainly precipitation, to study basin-scale climate change impact. While their 3-step bias correction approach accounting for biases in extreme events and wet-day frequency is interesting, there are a few scopes for improvement which should be addressed.

Specific comments:

1. **The method of selecting GCM adopted in this study is not convincing. Addressing the uncertainties as reflected by the disagreements among the model simulations is a topic of extensive research. The authors tend to oversimplify this issue by selecting GCMs based on their "scores" used in this study. I understand that some criteria might be needed to narrow down the list of data sets to be analyzed. However, those criteria should not appear as the main focus of this study. The way the approach of selecting GCMs was emphasized in abstract and in the first paragraph of introduction (from line 23 on page 1 to line 4 on page 2), readers might find it as one of the main objectives of this study.**

AC: The method of selecting GCM adopted in this study is based on their performance scores of the synoptic scale simulation. It is a kind of standardized method or an adequate criterion to be generalized the way of selection (in line 2 from the abstract) under the conventional strategies of impact analysis. In other words, this method is the exclusion of improper GCMs which cannot express the significant regional climate characteristics in the reasonable spatial pattern and errors because the local seasonal precipitation is mainly governed by the synoptic scale features. Without prior poor GCMs rejection, the considerable bias of GCM may be unfeasible and it is hard to believe the promising range of future quantitative outcomes. Hence, the proposed method convinces to disregard the undesirable GCMs.

The authors modified in “Abstract” and summarized (from line 1-6 on page 1) as follows: “A three-step statistical bias correction method is introduced to solve global climate model (GCM) bias after excluding the improper GCMs through the decisive scoring scheme. It is determined according to spatial correlation and root mean square error (RMSE) of regional and mesoscale climate variation in a comparison with global references.”

In “Introduction”, the paragraph (from line 23 on page 1 to line 4 on page 2) is deleted and modified as: “To ascertain feasible ranges of projected change, most studies recommend multi-GCM bias correction and simulations (Wilby et al., 2004; Paeth et al., 2008). Therefore, the present study introduces the three step statistical bias correction and the typical benchmark for discarding undesirable GCMs which cannot express the representative regional climate pattern to reduce specific contingencies in basin-scale impact assessment.”

The title of Section 3.1 “Decrement of GCM uncertainty” is changed to “Exclusion of GCMs with poor regional climate characteristics”.

2. **The method of selecting GCMs prior to bias correction is, I think, contradictory to the core idea of this study. Since authors introduce a new approach to correct the model biases, to examine its efficiency, the best approach would be selecting a pool of GCMs with worse performance or larger uncertainties. Selecting only the better models somehow undermine the efficiency of the bias correction method.**

AC: The proposed strategy is a standard way to access the climate change impact on the basin scale precipitation effectively and to save the heavy computation load. This kind of strategy is indispensable to provide the trustworthy uncertainty range for national and local infrastructures planning and IWRM. It is important to realize that GCMs simulation over the target basin showing a similar pattern with the feasible biases can be corrected by the proposed method and not for the GCMs with disparate pattern together with the enormous biases. Therefore, we proposed to discard some GCMs which are very poor in the region or / and the local scale performance. The selection method is a guide to exclude the undesirable GCMs for impact assessment and not the way to choose the best GCMs (line 6-7 page 5). The multi GCM analysis can achieve the final goal to convince the reasonable range of impact analysis results for feasible implementation plan.

3. **Figs. 16-19 are useful, since spatial plots are often more telling in climate study. However, in addition to presenting the observation and bias-corrected model simulation, another plot representing the raw GCM mean precipitation before bias correction would be interesting. Also I am not sure why authors used different color scale for each of those spatial plots. A uniform color scale would be more informative. Figs. 16-19 can be combined into one single spatial plot where first, second and third column represent observation, raw GCM mean and bias-corrected GCM mean respectively, with each row representing a different river basin.**

AC: Fig 16 - 19 are combined into one single plot as a Fig. 17 (Fig. 1 in the interactive comment) where first, second and third column represent observation, raw GCM mean and bias-corrected GCM mean respectively, with each row representing a different river basin. A uniform color scheme is used in the first, second and third row of spatial plots but semi-arid basin from Tunisia, the last one, cannot be in the same scale because of its low intensity per month.

4. **Since correcting biases of extreme precipitation is one of the major highlights of this study, a similar spatial plot comparing raw and bias-corrected GCM simulations with observed extreme precipitation over different river basins would be an interesting addition.**

AC: The authors really appreciate the valuable comments about correcting biases of extreme precipitation and prepared Fig. 15 (Fig. 2 in the interactive comment) as a similar spatial distribution plot for 95 percentile precipitation of total rain days in all of the river basins. Similarly, first, second and third column represents observation, raw GCM mean and bias-corrected GCM mean respectively. Same color scheme for top three rows of figures with different maximum limit and smaller scale for the last basin in Tunisia.
The explanation of Figure 15 is added in Section 4.2 from line 26 on page 11 to line 2 on page 12 as below:
"To confirm the basin-scale performance, we choose 95 percentile rainfall (95Ex) from the total wet days during the control period at every point in the pilot basins. For the

spatial pattern checking, the spline interpolation is used to delineate in each basin. The summary of all river basins is shown in Fig.15 and panel a, b and c represent observation, raw GCM mean and bias corrected GCM mean respectively. In general, all of raw GCM mean 95Ex (panel (b)) undervalue compared to the observation (panel (a)). Distributions of bias corrected rainfall (panel (c)) from each river basin are noticeable matching with ground data except the top row where corrected one shows slightly low intensity in the middle of a sparse rain gauges. This difference occurs due to the balance of GPD fitting between the most extreme and lower intensity rainfall. As a result, imperfect fitting may happen in somewhere of the basin. Moreover, bias corrected results show around ± 5~20 mm day^{-1} compared to the ground and the performance looks good enough for outlier rainfall bias-correction in all of the basins. In fact, it is important to realize both the station and basin level extreme bias-correction is successfully worked out."

Technical Comment:

The introduction part should be more organized. Especially, in the third paragraph of introduction (line 19-35 on page 2), authors tend to go back and forth among three distinct points – 1) main focus/features of this study, 2) brief descriptions of methods, and 3) limitations of the approach. This seems to interrupt the flow of the manuscript.

AC: Authors reorganize "Introduction" as the following. First paragraph explains why multi-GCM simulation is necessary for local scale studies, the procedures and goal of the proposed method. Second one briefly outlines the various bias correction techniques and the last one summarize the scope, how to treat GCM selection process, the specialty, strategy, successes of the proposed method, an assumption theory, a limitation and then a summary.

The third paragraph from "Introduction" is modified as below:

"The scope of the present study is to access the impact of climate change on the basin scale precipitation through multi-GCM bias correction. Defective GCMs are judged by the convectional scoring scheme based on the pattern and error analysis of the distinguished features of synoptic scale seasonal characteristics. The major outstanding factor of the proposed bias correction method is its simultaneous action in addressing all GCM deficiencies, such as underestimation of extremes, poor simulation of inter-seasonal rain sequences, and wet day errors whereas most correction approaches treat only either one of them. The major achievement is excluding biases in both amplitudes and frequencies of GCM precipitation time series on an inter-annual and yearly basis, which contributes to the projection of basin-scale flood and drought analysis. Furthermore, the transferability of the application is confirmed by its implementation in three river basins in Asia and one in the Mediterranean region under diverse climates and local spatial variation as the benchmark of choice. The assumption of time-invariant GCM bias during control and projection periods is verified by two decadal simulations, 1981–2000 as the calibration period and 1961–1980 as the evaluation period, at a few ground locations where long-term data are available. A limitation of the approach is that reasonable numbers of well-scattered stations with a few decades of data are prerequisite. In this way, a comprehensive and integrated statistical bias correction and spatial downscaling method together with tackling poor GCMs concern was developed. Particularly, analysis of potential impacts on basin-scale precipitation is successfully achieved with low computation and high efficacy."

References

Wilby, R., Charles, S., Zorita, E., Timbal, B., Whetton, P., and Mearns, L.: Guidelines for use of climate scenarios developed from statistical downscaling methods, IPCC task group on data and scenario support for impacts and climate analysis, 2004.

Paeth, H., Scholten, A., Friederichs, P., and Hense, A.: Uncertainties in climate change prediction: El Niño-Southern Oscillation and monsoons, Global and Planetary Change, 60, 265–288, 2008.