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Hydrology and Earth System Sciences
Discussions

Interactive comment on "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.

Anonymous Referee #2

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SUMMARY In this study, a 3-step bias correction method is introduced to address, in a simultaneous way, three global climate model (GCM) deficiencies including underestimation of extremes, poor seasonal simulation, and high-frequency wet day error relative to observations. The introduced method depends on determining a regional pattern of climate variability through multi-model selection. The performance of the method is assessed for various climatic zones based on four catchments from Sri Lanka, Philippines, Japan, and Tunisia. One of the limitations of the proposed method is its reduced accuracy for low spatio-temporal scale of data.

The potential contribution of the study is interesting and relevant for climate change studies. However, because the authors need to first implement and/or address a num-

ber of issues to enhance the scientific quality of the contribution, I recommend major revision.

COMMENT No. 1 With respect to the text in lines 5-19 (page 2), this part of the Introduction Section is not adequately informative. For instance, what are the gaps in the existing bias correction methods such as the Delta method, distribution mapping, etc? How do the authors wish to close the identified gaps from other bias correction methods using the method they are proposing? The authors were somewhat jumpy instead of maintaining the required logical connections between the ideas. This made the Introduction Section not so well organized and needs an improvement.

COMMENT No. 2 In line 6 (page 3), each of the two periods 1981-2000 and 2046-2065 is 20 years in record length. However, according to the Intergovernmental Panel on Climate Change IPCC (2001), a 30-year period is sufficient and required to represent an effective GCM simulation. Can the authors justify that the projections and/or performance of the GCMs with respect to the meteorological variables considered based on the 20-year periods are not significantly different from that of the 30-year time frame recommended for climate change analyses?

COMMENT No. 3 In lines 2-3 (page 3), the authors stated they used the GCMs from previous generation i.e. phase 3 of the Coupled Model Inter-comparison Project (CMIP). The latest generation GCMs from phase 5 (CMIP5) are expectedly more improved than those of the CMIP3 especially with respect to bias in the extreme meteorological events. Recent climate change studies also seem to have tacitly adopted the use of rather the CMIP5 than CMIP3. In this same vein, can the authors clarify the rationale for the selection of the GCMs from rather the CMIP3 than CMIP5? On what basis did the authors select the few GCMs and their simulation runs?

COMMENT No. 4 Whereas the authors claim to have proposed an efficient bias correction approach for climate change impact investigation, in lines 30-31 (page 2), it is stated that the accuracy of the proposed method is contravened by spatio-temporal

scale of data.

i) Does it mean the proposed method cannot be usefully applied for data scarce regions? what options do the authors recommend to deal with this influence of data limitation on the accuracy of the proposed method?

ii) if validity of high resolution gridded freely available data (FAD) e.g. reanalysis or interpolated series can be verified, can the augmentation of the observed or historical datasets by such FAD enhance the applicability of the proposed method?

iii) In combination with the suggestion from (ii), could the downscaling procedure applied by Zhao et al. (2016) be useful to supplement bias correction procedures proposed by the authors?

Finally, I suggest that the authors acknowledge and also have the readers informed of the emphasis on the use of a number of bias correction techniques to even out the uncertainty due to the difference in the downscaling methods. In doing so, the authors may find the next three sentences constructive to include in their discussion as they acknowledge the limitation of their proposed method.

The differences between the downscaling methods and the performance of the bias correction approaches tend to vary from one catchment to another Sunyer et al. (2015). According to Sunyer et al. (2012) it is better to test the performance of different downscaling methods while importantly acknowledging their limitations, advantages as well as the downscaling uncertainties. Furthermore, statistical bias correction procedures should be applied on a case by case basis in line with the objectives of the climate change study (Onyutha et al., 2016), e.g. when dealing with moderate or extreme hydro-meteorological events.

COMMENT No. 5 Lines 17-18 (page 5): The main GCM deficiencies that the authors attempt to address include i) underestimation of extremes, ii) poor seasonal simulation, and iii) high-frequency wet day error relative to the observations. Although the

authors claim their proposed method attempts to solve the above GCM deficiencies in a simultaneous way not like by other bias correction techniques (as they state in lines 22-24 of page 2), I expect bias due to (i)-(iii) to be adequately addressed by the advanced quantile-perturbation-based (AQP) downscaling approach e.g. that presented by Willems and Vrac (2011). What advantages (if any) does the proposed method therefore have compared with, e.g. the AQP downscaling technique?

COMMENT No. 6 Lines 15-17 (page 6): "The heavy-tailed distributions are the most common in hydrology". Such naive generalizations are potentially misleading with respect to frequentist inference. According to Cai et al. (2013), the variables in meteorology and the environmental science generally exhibit the generalized Pareto distribution (GPD) shape parameter (k) around zero i.e. the normal tailed GPD. Even based on the data shown by the authors in Figure 6 (a) on page 23, it is noticeable that as the threshold becomes sufficiently large, indeed, the k tends towards zero. The necessitation of the estimators of the GPD parameter k to allow its estimation without having prior knowledge of its sign commonly tends to eliminate the need to make assumptions or fix the distribution class as heavy, normal or light-tailed (Onyutha and Willems, 2015). This generality leads to systematic bias (i.e. under/over-estimation) of quantiles in the tail of the GPD for some of the common parameter estimation methods such as the method of moments (which the authors applied), L-moment and maximum likelihood as demonstrated in Figure 8 of Onyutha and Willems (2015). Based on the above text and references, the authors are required to make it clear on the need to assess the class of the GPD before applying the proposed bias correction technique they are introducing. If possible, they should also ensure they incorporate the aspect of the discrimination between GPD classes as part of their proposed scheme for bias correction of extremes.

COMMENT No. 7 As proposed by Onyutha and Willems (2015), one way to minimize the bias in the quantiles from the tail of the GPD is to select the scale parameter (ξ) in an optimal way using graphical approach to identify the key event above which the

mean squared error on the GPD calibrated to the extreme events is minimal. The implementation of this proposal adequately by the authors based on Figure 6 a-b was a very good step in their proposed bias correction approach. However, some key parameter seems to be missing in equations (4) and (5).

It is well-known that: a) if the GPD parameter ξ (threshold) is known, using the method of moment approach (as adopted by the authors), the shape (k) and scale (α) parameters can be computed using:

k=0.5([(μ-ξ)/σ)]ˆ2-1) A1

α=(1+k)(μ-ξ) A2

where μ and σ denote the sample mean and standard deviation respectively.

b) if ξ is unknown, method of moment estimates of k and α can be obtained using an iteration scheme (e.g. Newton-Raphson) from:

Ψ=2(1-k)(1+2k)ˆ0.5/(1+3k) A3

ξ=μ-α/(1+k) A4

k=σ(1+k)(1+2k)ˆ0.5 .....A5

where Ψ is the sample skewness.

Can the authors check the correctness of the their equations (4) and (5) on page 6 in comparison with those provided above i.e. A1 to A5?.

TECHNICAL CORRECTIONS (TC)

TC 1 Line 5 (page 1): delete "(Scorr)" since it was never used again within the abstract.

TC 2 Lines 15 (page 3): change "A total of .....Sri Lanka" to "Rainfall data from a total of 26 stations were obtained from the Meteorology Department of Sri Lanka".

TC 3 Throughout the manuscript, the authors should be consistent with the use of

comma to separate thousands in figures (e.g. see, on page 3, lines 15, 19, 20, 22- 24, 28, etc).

TC 4 Instead of only mentioning the number of stations considered, the author should clearly specify the resolution of the data (e.g. daily, monthly etc) obtained from the different catchments. In the same vein, the data temporal domain for each hydro-meteorological variables used should also be included in Table 1.

TC 5 Line 4 (page4): replace "comparison to" with "in comparison with"

TC 6 Equation 2: is the RMSE the same as ERMS? Be consistent with one of the two for both text and equation(s).

TC 7 Line 28-29 (page4): What is i in xi or yi? "....and N the total time series". Do you want to mean N is the sample size of the series at each station? or is N the total number of time series? If N used in equation 2 is different in meaning from that of equation 7, the authors should not use the same notation.

TC 8 Lines 1-2 (page 5): For clarity, rephrase the sentence "By comparing all analysis months.....was implemented" to "To implement the scoring scheme, a particular GCM's average of the Scorr and RMSE obtained by considering the analyses from all the months were compared to the mean values of the 'goodness-of-fit' metrics (Scorr and RMSE) of all the GCMs."

TC 9 Line 6 (page 5): what is "ceratain"?

TC 10 Line 10 (page 5): "....we excluded GCMs that did not have a precipitation score of 1.....". It is possible that a particular GCM can have two or more simulation runs e.g. gfdl_cm2_1 and gfdl_cm2_0. I find it confusing whether the authors excluded the whole of such GCM or specifically the simulation runs with unsatisfactory scores. In case the entire GCM but not the simulation runs were excluded, which GCMs were those discarded? If the main purpose of the proposed method was bias correction, why should the GCMs with large bias be discarded? How can the authors verify the

efficacy of their proposed method if they ideally want to use the GCMs with minimum bias? The answers to these questions should be presented clearly.

TC 11 Lines 18 (page 5), 33 (page 2), 1 and 20 (page 3), 6 (page 4), 1 (page 1) ....etc, : "We did this and that...." such colloquial words do not have spaces for their accommodation in papers to be published by a top journal like HESS.

TC 12 Line 23 (page 5): replace "it just considers the top as extremes in a year basic, in other words" with "by considering the maximum event in each year, the"

TC 13 Line 24 (page 5): replace "year?s" with " year's"

TC 14 Line 25-26 (page 5): ".....20 maxima (1981-2000) by defining extremes that were larger than the smallest one." This sentence is unclear. Do you mean the Annual Maxima Series (AMS) extracted from 20-year (1981-2000) data? "... larger than the smallest one." which smallest one? Still if you refer to AMS, it is well-known that for the AMS extraction, the largest event in each hydro-meteorological year is selected.

TC 15 Line 27 (page 5): in using Partial Duration Series (PDS), the authors should clearly present the criteria they used to ensure that the key requirement of frequency analysis (viz the extreme events to be independent and identically distributed) was fulfilled.

TC 16 Line 28 (page 5): replace "of maxima" with " the extreme events"

TC 17 Line 28 (page 5): change "occurred" to " occur"

TC 18 Line 29 (page 5): insert "quantile" between "improve" and "estimation"

TC 19 Line 30 (page 5): change "rain" to "rainfall intensity"

TC 20 Lines 1-3 (page 6): delete the sentences "This is because all rain.....bias correction efficiency". Replace "Therefore, the" with "The"

TC 21 Line 4 (page 6): replace "desirable" with "applied" and put a full stop after

"correction" not a comma

TC 22 Line 4 (page 6): replace "and" with "The GPD was used because"

TC 23 Line 5 (page 6): delete "variables using"

TC 24 Line 5 (page 6): replace "annual maximum flood" with "peak high flows"

TC 25 Equation 3 (page 6): define the symbol ξ as it appears the first time (not as you did later in line 7 of page 7). What about x? is it similar to that used and defined in equations 1 and 2? The authors should make this clear.

TC 26 Line 17 (page 7): replace "tuned for the best fit" with "taken to be indicative of the best performance by the GCM".

TC 27 Line 24 (page 7): replace "We solved this problem" with "Attempt to apply bias correction for the frequency of wet days was made by".

TC 28 Line 26 (page 7): change "rain days" to "wet days". Implement this correction throughout the manuscript.

TC 29 Line 27 (page 7): Is the word "beyond" the same as "above"? If so, change it accordingly.

TC 30 Line 22 (page 8): replace "just get rid of" with "minimize"

TC 31 Line 9 (page 8): replace perfect"" with "reasonable"

TC 32 Line 29 (page 9): what is "?a?" ?

TC 33 Line 25 (page 11): what is basin?level?

TC 34 Figure 5 (page 22): these plots are neither so informative nor scientifically convincing with respect to the extreme value analysis which the authors claim to be considering. Since comparison of the quantiles from extremes extracted based on the AMS and PDS are being compared, why can't the quantile plots be made instead of showing the number of days and rainfall intensity? I recommend better plots than those in Fig-

ure 5 be made e.g. extreme rainfall intensity versus log-transformed return periods for better quantile-based assessment of bias. For an example of such plots, the authors can see Figure 3 of Sunyer et al. (2012), Figure 2 of Willems and Vrac (2011), Figure 4 of Onyutha et al. (2016), etc.

TC 35 Line 29 (page 13): replace "eliminates" with "reduces"

TC 36 The maps in Figures 1, and 16-19 should be presented with clearly marked grids and graticules to show locations (degrees of latitude and longitude) in geographic coordinates.

TC 37 For Figures 9 and 10 it cannot be understood that the letters a, b, ...and g in the horizontal axis represent the IDs of the GCMs as presented in Table 3 though stated in lines 28-29 of page 9. Make this clear in the Figure caption as well. No any difference seems noticeable by comparing the plot for the GCM 'a' before and after the application of the bias correction. How can the authors explain this realization? This should be clarified within the text of second paragraph in section of 3.4.

TC 38 Figure 14: compute the exceedance probability of each extreme rainfall event and use it to replace the ranking order plotted on the horizontal axis. I also recommend that throughout the manuscript, the expression "ranking order statistics" be replaced with "exceedance probability".

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