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Interactive comment

Interactive comment on "Bias correction schemes for CMORPH satellite rainfall estimates in the Zambezi River Basin" *by* W. Gumindoga et al.

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Interactive comment on "Bias correction schemes for CMORPH satellite rainfall estimates in the Zambezi River Basin" By W. Gumindoga et al.

Anonymous Referee #2 Received and published: 12 June 2016

GENERAL COMMENTS

Comment: General comments: This study evaluate the performance of five bias correction techniques for CMORPH rainfall dataset in Zambezi River basin. The topic is certainly attractive and suits well within the scope of the journal. However, many descriptions in the manuscript is not clear enough, and some methods and results do not make sense.

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Discussion paper

Response: We thank the reviewer for this observation. The authors have greatly improved the descriptions in the revised manuscript to make it more attractive to the readers. Reasons for certain aspects included in the methodology and results section are now more explicitly described and justified. For example: why topographic zones are developed for bias correction, how and why different rainfall rates are selected for assessment of different bias correction effectiveness. The methods section has been revisited and tools/techniques applied have been justified. We have also made sure the use of symbols in the methods section is harmonized as this improves readability of the revised manuscript.

SPECIFIC FLAWS:

Comment: Lines 104, I am interested which technique(s) consider the spatial patterns in bias, how about their performance?

Response: The authors have revisited the paragraph as below. We hope this response captures the aspects of spatial patterns in bias and their performance.

"Besides that bias may change over time, some correction schemes can consider the spatial patterns in bias, commonly known in literature as space variant/invariant. Studies by Habib et al. (2014) in Ethiopia, Tefsagiorgis et al. (2011) in Oklahoma (USA) and Müller and Thompson (2013) in Nepal evaluated different forms of the space bias correction schemes. The above studies concluded that the space variant technique is effective in reducing SRE bias. Contrary, the approach of using the average bias for all stations (space fixed) to correct SRE has its roots in radar rainfall (Seo et al., 1999) and is unsuitable in large basins (> 10,000 km2) where bias is known to vary spatially and over time (see Habib et al., 2014). In fact Habib (2014) in the Upper Blue Nile basin in Ethiopia, noted that additional bias correction improvements (> 50%) are realized when both the spatial and temporal variability in the bias are accounted for. The above assessments are however linked to the respective field sites and as such do not allow generalization for the Zambezi Basin"

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Comment: Introduction, add simply some description about the CMORPH.

Response: A relatively small description on CMORPH has been added in the introduction section. The description is adapted from the developers of the product:

"CMORPH is a gridded precipitation product that estimates rainfall with information derived from IR data and MW data (Joyce et al., 2004). CMORPH combines the retrieval accuracy of passive MW estimates with IR measurements which are available at high temporal resolution but with lower accuracy. The important distinction between CMORPH and other merging methods is that the IR data are not used to produce any rainfall estimates. Rather, the IR data are used only to propagate rainfall features that have been derived from microwave data. The flexible 'morphing' technique is applied to modify the shape and intensity of rainfall patterns. CMORPH is operational since 2002 for which data is available at the CPC of the National Centers for Environmental Prediction (NCEP) (http://www.ncep.noaa.gov/)."

Comment: Figure 1, I recommend to re-plot the figure, remove the noisy line, and only show the information about the elevation, station location, lakes in the basin, and the boundary of three hydrological region. Moreover, please check the station number, I don't think there are 54 rain gauging station in Figure 1.

Response: Figure 1 has been revised as suggested by the reviewer. We also added contours for distance from large scale water bodies. To create an additional map for that would make the paper unnecessarily long. We modified the map to include the correct number of rain gauges (60). Initially we had 54 raingauges but we obtained data for 6 additional raingauges to make them 60 (see Figure 1). Note that because of the font we selected, some label of stations do not exist even though their location symbols are visible.

Comment: Table 1 and 2, I suggest to show them as the Supplemental Information

Response: Table 1 and 2 now exist as supplementary information. In fact the paper

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now only has one table.

Comment: Section 3.2 Bias correction schemes, I strongly suggest to unify the variable among 5 kinds of bias correction techniques (P* in equation 4 means CMORPH precipitation after bias correction, however, it was changed to SDT in equation 7 and PQME in equation 8.).

Response: The authors have unified different variables amongst the 5 kinds of bias correction techniques. Equations 1-10 now have unified symbols.

Comment: Section 3.2.4 I understand the process from equation 5-7, however, I don't think it belongs to the category of 'DT'.

Response: We borrowed and modified the concept from the additive approach to bias correction whose origin is in statistical downscaling of climate model data (Bouwer et al., 2004). In this study the method determines the statistical distribution function at daily base of all raingauge station estimates as well as CMORPH values at the respective stations. The CMORPH statistical distribution function is matched from the raingauge data distribution following steps described in equations [4-6]. Both the difference in mean value and the difference in variation are corrected.

Comment: The authors tried to bias-correct the daily rainfall by use of STB, EZB, QME, and bias-correct the monthly rainfall by use of PT, and then compare the performances of different bias-correction technique. In my opinion, it is unfair to compare them since that the methods were adopted to corrected the rainfall in different temporal scales (The author had not mentioned the temporal scale for DT).

Response: We have now clarified the unclear statements relating to the temporal aspects of the bias correction schemes by the following statements:

'For equation 4 (Power transform (PT)), the optimized values of a and b are obtained through the generalized reduced gradient algorithm (Fylstra et al., 1998) within a 7-day time window but the bias correction applied to CMORPH daily time step. The advantage of this bias scheme is that rainfall variability of the daily time series is preserved by adjusting both the 7-day mean and standard deviation of the CMORPH estimates. The bias scheme also adjusts extreme precipitation values in CMORPH estimates (Vernimmen et al., 2012).'

NB: The bias-correction for PT is daily timestep and not monthly.

The temporal scale of DT is also daily. But the bias correction factors for mean and standard deviation are established at a 7-day time window, and applied to correct all daily CMORPH based estimates (S) through equation [6].

The bias corrected rainfall (QME) using quantile mapping is expressed in terms of the empirical cumulative distributed function (ecdf) and its inverse (ecdf-1) that are developed on a 7-day time window but application of the ecdfs will be on a daily basis (Equation 7):

So it means we are still dealing with daily estimates for all the bias correction schemes and hence rendering all of them comparable.

NB. EZB is now abbreviated as just EZ

Comment: Section 3.2.5, how to deal with the situation that no rainfall in CMORPH but rainfall in gauge? How to calculate the ecdf for the days without precipitation.

Response: We thank the reviewer for this important observation. The empirical cumulative distribution function (ecdf) and its inverse (ecdf-1) are developed on a 7-day time window but applied on a daily basis and still has to satisfy the condition described in section 3.2 in the revised manuscript. The bias correction factor is calculated for a certain day only when a minimum of five rainy days were recorded within the preceding 7-day window with a minimum rainfall accumulation depth of 5 mm, otherwise no bias is estimated (i.e. a value of 1 is assigned). In other words the situation that no rainfall in CMORPH but rainfall in gauge (missed bias) and for days without precipitation really depends on the conditions (number of rainy days and cumulative rainfall) in the 7-day time window.

Comment: This research focused on the period 1998-2013, I have not found any statement about the calibration and validation period. Did the authors regard the period 1998-2013 as a whole? It doesn't make sense.

Response: We thank the reviewers for this important observation. We did not split the data since a large data size is required to reliably estimate systematic errors (i.e., bias) in the SRE.

Comment: The title of this manuscript is 'Bias correction schemes for CMORPH satellite rainfall estimates in :::', however, the most of the statements in section 4.1- section 4.3 has not related with the topic (bias correction).

Response: We thank the reviewer for this important observation. The authors have synthesized the revised manuscript and have reformulated various paragraphs to more explicitly address aspects of bias correction. The revised manuscript also has been shortened by removing sections and results that are not at the core of the study such as e.g. double mass curve analysis.

Comment: Figure 9 – Figure 10, most of the bias-correction techniques showed the poor performances, with larger bias than that in R-CMORPH. It is opposite to our normal expectation, is it true? Please check the raw data carefully?

Response: The authors have checked the raw data and realized that there was a mix-up in the figures. Our new results show bias corrected rainfall having lower biases than the uncorrected CMORPH in all the performance indicators (Figures 3-6). The multiplicative bias correction schemes (STB and EZ) outperform the exponential form (PT), quantile mapping (QME) and the additive (DT) based bias correction schemes. Our results however suggest that a single best bias correction scheme for the entire Zambezi basin cannot be selected.

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