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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.

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

Anonymous Referee 1 Received and published: 2 March 2016

GENERAL COMMENTS

Comment: The authors have included so many aspects in this paper and a reader tends to get lost in all the several techniques used and the results presented. May be, instead of including all possible methods for bias correction, they could have investigated those methods that remove the bias for specific uses of satellite derived rainfall.

Response: We thank the reviewer for the comment and removed part of our analysis

as suggested. We note that 5 schemes are selected. For this study linear and non-linear and time-space variant/invariant bias correction schemes were selected since only limited efforts on bias correction has been reported for the Zambezi.

Our literature review (lines 84-115) gives the merits and demerits for the bias schemes.

Comment: There are several instances when the reasons for undertaking some of the analysis is not clear, e.g. what were the reasons for plotting rainfall for a selected station against that of several other stations?

Response: We thank the reviewer for this observation. Our preliminary analyses show that time series of some stations are not directly reliable. Following the remark we removed the double mass-curve analysis given that there is little novelty.

Comment: The purpose of undertaking quality assessment is not clear, and how the outcomes are used in the paper.

Response: Quality assessments are needed since daily time series from 66 stations (located in 4 countries) across the Zambezi basin serve as base data (i.e., the true rainfall data) for any bias assessment. After initial screening, and rigorous quality control we remained with 60 stations. In the procedure preliminary checks were performed on the gauge data and missing rainfall values were filled in. A number of stations are affected by data gaps but time series of the 60 stations covers sufficiently long observation period that ranges from 1998 to 2013.

Comment: Some of the results presented in the form of a Table are best illustrated say using bar graphs, e.g. Table 4.

Response: The authors have improved representation of the results. Some of the tables have been converted into graphs. We are left with only 1 table (Table 1) in the main text as other tables are now appearing as figures and some synthesized into Appendix 1.

Comment: The authors frequently present rainfall values without including the units of measurement.

Response: We have made sure all variables that requires units have got relevant units. For example, Mean annual precipitation (MAP) calculated in mm/yr and bias calculated as a percentage.

Comment: The authors tend to over-emphasize the influence of elevation on rainfall at a location, yet other important factors are not considered. For example, orography or aspect has not been considered when this is very important in the Zambezi Basin. Distance to lake water bodies such the equatorial regions, Indian Ocean has a major influence on rainfall in the Zambezi Basin.

Response: We thank the reviewers for this important comment. We have made sure that in addition to elevation, we included distance from the large water bodies in the Zambezi basin. Therefore a distance map of all the 60 stations from the major water bodies (> 700 km2) in and around the Zambezi was developed. Based on rain gauge Euclidian distance from large scale water bodies the basin was divided into 4 arbitrary distance zones. These are zone 1: < 10 km (mean distance = 5 km), zone 2: 10 - 50 km (mean distance = 35 km), zone 3: 50 -100 km (mean distance = 80 km) and zone 4: > 100 km (mean distance = 275 km).

A Taylor diagram was then employed to assess whether the relationship between CMORPH satellite rainfall performance is dependent on elevation and distance to large water bodies. Some of the water sources include the Indian Ocean, Lakes: Kariba, Cahorra Bassa and Malawi and other perennial water bodies scattered in the basin.

Comment: It is also difficult to ascertain how the conclusions are supported by the results obtained. This is mainly due to so many results having been presented, and the reader has difficulties linking these to conclusions.

Response: The authors have improved on the presentation and interpretation of the results. They have also now made a great effort to link the conclusions to the results.

This has been made possible by revisiting the objectives of the study. We have revised specific objectives as follows: to 1) establish if performance of CMORPH estimates is affected by elevation and distance from large scale water bodies 2) evaluate the effectiveness of linear/non-linear and time-space variant/invariant bias correction schemes in the basin 3) assess the performance of bias correction schemes under different seasons and rainfall rates.

There are so many results we have removed so that focus is on bias correction schemes. This includes double mass-curve analysis, results on performance of uncorrected CMORPH is now summarized using the bias (

SPECIFIC COMMENTS

Comment: Line 48-51 and elsewhere, I suggest that you avoid using the abbreviation SREs for satellite-derived rainfall estimates. If you do an electronic search, SREs is commonly understood to represent Special Report on Emission Scenarios in the climate and hydrology community. Why do you not use RFE which is widely understood to represent satellite rainfall estimates?

Response: They abbreviation SRE is most commonly used in the work field of satellite rainfall estimation so we prefer to maintain SRE in the revised manuscript. Also, SRE is well defined in the revised manuscript.

Comment: Line 65, replace “have challenges” by “has problems or has weaknesses”.

Response: This change has been implemented.

Comment: Line 160-161 rainfall is a flux and therefore the units must clearly show the period over which the measurement was made, “1400 mm/yr” not “1400 mm”. All major hydrology journals including HESS decided last year that they will insist that units of fluxes such as rainfall, evaporation, runoff should be clearly written. We do not normally use MAR for rainfall rather MAP. Annual rainfall should be stated as "mm/yr"

Response: The authors are now using Mean Annual Precipitation (MAP) with units mm/yr. A major overhaul on the use of appropriate units has been done on all the sections of the revised manuscript

Comment: Lines 244 – 251 defining symbols used in Equation (2) should immediately follow this equation.

Response: The definition of all symbols have been done as per recommendation of the reviewer.

Comment: Line 226, why did you decide to use a minimum of five rainy days?. Line 227, why did you decide to use a ten-day window? Line 228, why did you decide to use a threshold of 5 mm?

Response: Based on literature (Bhatti et al., 2016; Habib et al, 2014) and understanding of rainfall patterns and intensity in the Zambezi basin the authors decided to use a minimum of 5 rainy days and a threshold of 5mm/day. Preliminary test based these thresholds were promising so there was no reason to deviate.

Comment: Line 238, letter "d" used in Equation (2) has not been defined what this represents.

Response: Letter 'd' has been defined and there is now detailed description of the superscripts and subscripts in all the equations

Comment: Line 249, simply state what "n" represents. By defining this as the number of gauges in the domain of the study, this may imply that this was changing depending on whether you were considering the upper, middle, and lower Zambezi Basin.

Response: 'n' is now removed. It was a mistake to include it. 'n' actually belongs to equation 3

Comment: Line 250, is T representing the number of years in the sample rather than duration of the study period. Do you mean the time it took you to do the study?, e.g. 6 months

Response: T is removed from the equation. It was existing in the document by mistake.

Comment: Line 255, justify the use of 3 elevation zones, and the elevations used to separate these zones.

Response: The elevation zones are based on the hierarchical clustering technique in SPSS that groups the raingauge locations into several clusters. Based on more than 20 iterations by the clustering technique, and also based on our knowledge of the study area, we decided on 3 zones that we think are representative of topographic and landsurface characteristics in the basin. The 3 zones are presented in Appendix 1: These are zone 1: elevation of < 250 m (mean elevation = 90m), zone 2: elevation range of 250- 950 m (mean elevation = 510 m) and zone 3: elevation > 950 m (mean elevation = 1 140m).

Comment: Line 256, how valid is the assumption that stations within the same elevation zone will have the same bias when it is a fact that within the Zambezi Basin, orography and distance from moisture sources are very important?

Response: We thank the reviewer for the thoughtful comment. In revising our manuscript and analyses we have put more attention on assessing these aspects by considering analysis at subbasin scale instead of distance and elevation zone. We also look at more detail at distance aspects to large water bodies as requested by the reviewer.

Comment: Line 303, What do Gt and St represent in view of the fact that these letters had a different meaning in Equation (2)?

Response: We thank the reviewer for this important observation. However, we have clarified it like below. G and S are mean 7-day gauge and CMORPH rainfall estimates for all stations, respectively. Gt and St, are also 7-day standard deviations for gauge and CMORPH respectively. As such the above symbols are different from G and S that are used to represent gauged and CMORPH based estimates respectively in equation

[2]

Comment: Line 322, what is the meaning of CDF and ecdf? Line 328, you are now using Praw to represent CMORPH rainfall, but earlier on this was represented by S(I,t). Line 356 to 359, you are again using different symbols/letters to represent rain gauge and satellite derived rainfall.

Response: The line on ecdf now reads as follows: 'The bias corrected rainfall (SQME) using quantile mapping can be expressed in terms of the empirical cumulative distribution function (ecdf) and its inverse (ecdf-1)' Line 255-396, we have made a revamp of the symbols we used. We have adopted similar and unified symbols for variables representing the same variables.

Comment: Line 364 no need to give a definition of the correlation coefficient. Trivial.

Response: Definition removed

Comment: Line 386, the sentence is not clear Line 405 – 422 is rather confusing. What were you attempting to achieve?. How did you select stations that you considered to be the dependent which are plotted on the Y-axis, and those you considered to be the independent on the X axis? It is not clear to the reader what you are trying to convey.

Response: Results for double mass curve have been removed so that we give more focus on performance of uncorrected and bias corrected CMORPH

Comment: Line 427, what are you referring to as the "daily average time series (1998-2013) CMORPH? Do you mean average over the whole basin or for specific locations?

Response: This refers to average for specific stations. The sentence has been revised

Comment: Line 432 – 439, it seems in Line 432 to 436 you are describing the values of the standard deviation for rain gauge data. However, in subsequent sentences, it seems you are highlighting that there is no matching. I am not sure of what.

Response: The paragraph is meant to compare performance (std dev, RMSD and CC)

of gauge based estimates versus CMORPH. Corrections in the text have been made accordingly.

Comment: Line 473 – 475, I do not think it is informative to compare absolute differences among stations receiving possibly very different amounts of rainfall. A 2 mm/day difference on a station receiving an average of 20 mm/day is considerable but not for a station receiving 200 mm/day.

Response: This is now corrected and we acknowledge the advice of the reviewer on this matter. We are no longer comparing absolute values by the individual stations. Bias in CMORPH is now expressed as

Comment: Line 520, what do you mean by "rainfall types"? Take note that in climatology, "rainfall type" has a specific meaning.

Response: We have now replaced rainfall type by 'rainfall rates' as used to define longer rainfall intensities accumulated for more than a day.

Comment: Line 544, it seems information presented in Table 4 could have been simplified like in Figure 9. By the way, is Figure 9 not presenting information contained in Table 4? If that is the case, one of them has to be removed.

Response: We have summarized our figure and tables appropriately to remain with only 8 figures and 1 table.

Comment: Line 576, what do you mean by "bias correction schemes averaged"?

Response: The paragraph has been revisited and such a sentence no longer exists.

Comment: Line 583 not clear Line 607, how did you select the rainfall intensity classes? Line 625, how did you define a wet season and a dry season?

Response: Rainfall rates and seasonality commonly affect the performance of SRE. Performance of SRE for varying rainfall rates and in different seasons is still unclear. To explore aspects of bias corrected CMORPH rainfall for rainfall rates, five arbitrary classes are defined that are 0.0-2.5, 2.5-5.0, 5.0-10.0, 10.0-20.0 and >20.0 mm/day. Classes indicate light (<5 mm/day), moderate (5-20 mm/day) and heavy rainfall (> 20mm/day) respectively.

Furthermore, CMORPH rainfall was divided into wet and dry periods to assess the influence of seasonal variation on performance of bias correction schemes. A wet season for Southern Africa normally starts from October-March and Dry season from April-September

Comment: Line 641 – 642, Mushumbi, Zumbo, and Kanyemba are not on the Zambezi Escarpment. Line 643, Mvurwi, Guruve, Karoi do not have elevations below 400 m. See the elevation information you gave in Table 1.

Response: There was a mix up on which stations are on the escarpment and which ones are on the valley. The however has been emerge with previous paragraphs on gauge based analyses.

Comment: Line 648 – 656 are unclear and confusing because of the incorrect elevations you are assigned to the stations are stated in the previous sentence.

Response: In line with the synthesis of research findings and shortening of the paper, this paragraph no longer exists

Comment: Line 663, it is incorrect to refer to the Zambezi basin as being semi-arid. Yes some parts are semi-arid, but most of the Upper Zambezi, Upper Kafue, Upper Luangwa, parts of the Shire basin are sub-humid to humid.

Response: We are no longer using an umbrella term to refer to the Zambezi basin climate. We have provided a detailed description of the climatic zones of Zambezi in the study area section.

Comment: Line 674 – 675, did you prove this?

Response: Sentences have been corrected to justify all statements.

Comment: Change of paper title to: ‘An assessment of the performance of bias correction schemes of satellite-derived rainfall estimates in the Zambezi River Basin’

Response: The title of paper is now: ‘Performance of bias correction schemes for CMORPH rainfall estimates in the Zambezi River Basin’. We have maintained the term ‘SRE’ since we are dealing with one SRE.

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