

Interactive comment on “Risks of seasonal extreme rainfall events in Bangladesh under 1.5 and 2.0 degrees’ warmer worlds – How anthropogenic aerosols change the story” by Ruksana H. Rimi et al.

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Received and published: 2 July 2019

This study focuses on the investigation of changes in total and extreme precipitation in Bangladesh due to changes in greenhouse gas and aerosol concentrations. Large ensembles of regional climate simulations are used to represent regional dynamics and aerosol effects with sufficient detail and at the same time obtain statistical robust results also for extreme events with long return periods. In my opinion, the research represented in this manuscript is generally sound and provides novel insights (although not outstandingly new/innovative) into future rainfall changes in a highly impact-relevant

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region. However, I think the presentation and discussion of the research needs a substantial revision before the manuscript could be published. In my view, the interpretation of the results is too superficial at several places throughout the manuscript. Furthermore, the language and wording are not always adequate. With respect to the second point, I list a few issues below, but this list is not complete, and actually the native speakers among the co-authors should be able to fix this in a better way than I am.

We thank for the constructive comments from the anonymous Reviewer 3. We have carefully revised the manuscript to incorporate necessary amendments as per suggestions. Responses to the Referee Comments 3 (RC3) are presented in the following Author's Comments 3 (AC3):

RC3 Specific Comments

RC3: Page 1 Line 22: As this is a model study, I'd avoid the term "impacts were observed"

AC3: Rewritten the line as "Climate change impacts on the probabilities of extreme rainfall events are found during both pre-monsoon and monsoon seasons, but the level of impacts are spatially variable across the country."

RC3: P 1 L 28: "specifically with respect to...": I was confused when reading this as I though the whole study would focus on extreme events. It is not clear from the abstract that also seasonal mean rainfall is analyzed.

AC3: To make it clear that we have also looked at climate change impacts on seasonal mean rainfall, we have now added the following line in abstract: "Analysis of percent change, standardized precipitation index and absolute change in seasonal mean rainfall revealed that there both GHGs and anthropogenic aerosols play important roles in determining the overall climate change impact over this region."

RC3: P 2 L 16: Nirapad (2017) is not in the list of references

AC3: The reference for Nirapad (2017) is now added to the Bibliography.

RC3: P 2 L 23: “help to provide...”: wording issue

AC3: Deleted ‘to provide’

RC3: P 3 L 12-14: I think these detailed information regarding the sub-regions would fit better in the methods section.

AC3: Agreed and moved to method section.

RC3: P 3 L27: “observational” appears too often in this sentence

AC3: Rewritten as “The daily observational data sets that are used as a comparison against model results include: (i) Asian Precipitation Highly Resolved Observational Data Integration Towards Evaluation of Water Resources (APHRODITE) (Yatagai et al., 2012) and (ii) NOAA’s Climate Prediction Center (CPC) global 0.5° analysis (Chen et al., 2008a).”

RC3: P 3 L 35: This is my only purely methodological comment: I am a bit sceptical with respect to the usage of bi-linear interpolation, as this does not conserve the area-average rainfall amount and also biases the extremes compared to the original grid point values. I would ask the authors to at least test the sensitivity of their approach using a more appropriate conservative interpolation method (see, e.g., Chen and Knutson, 2008, doi:10.1175/2007JCLI1494.1).

AC3: Thank you for the comment. We have checked our ACT precipitation data over Bangladesh in this regard. As per figure AC3.a, we can argue that changing the method from bilinear interpolation to conservative have no effect on the high intensity precipitation events.

RC3: P 4: The fact that some experiments are mentioned twice (in the first paragraph and further below) leads to some repetitions.

AC3: We have now aimed at avoiding repetitions in the manuscript as good as possible.

RC3: P 4 L 16: I'd mention already here in which way the ensemble members differ from each other.

AC3: The model ensemble members differ in their initial conditions. They are either slightly perturbed, or the atmospheric field to restart the next model run is slightly different (i.e. it originates from a different member that has been run earlier). In contrast to the scenarios, all forcing parameters are the same. As far as NAT, GHG-only and the HAPPI scenarios are concerned, we use 11 different delta SST pattern (prescribed SSTs to define the lower boundary conditions). Those 11 patterns correspond to the same forcing scenario in CMIP5 (where the delta SSTs are derived from), but they do show slightly different spatial SST anomalies and add therefore additional variability to the weather@home ensemble of the counterfactual and future model scenarios.

RC3: P 4 L 33-34: This notation is awkward. I'd either write this in text form or as a "real" equation, but not mix these things up.

AC3: Agreed, we have now removed the equations and only kept text to describe this model ensemble.

RC3: P L 12-15: This description of the aerosol affect is too short and not very clear. The term "omitted aerosol induced rainfall" should be explained. I am also confused by the sign of the signal and the figure caption: The caption of Fig. 2 says that the figure shows present-day relative to GHG only; positive values would thus mean that the present-day rainfall including the aerosol effect is larger than the rainfall due to GHG only, which is not consistent. Finally, before directly linking this result to potential future decreases in the aerosol effect already in the second sentence, the actual content of the figures should be described and explained.

AC3: The positive values for percent change in MAM mean rainfall shown in Fig. 2d in present-day ACT relative to GHG-only indicates the additional rainfall that could happen in the present-day if only GHGs were the dominant forcing and if anthropogenic aerosols (reduced to pre-industrial levels) were not effecting rainfall. But, instead of

such additional rainfall, we see a drying effect in present-day ACT relative to NAT because existing aerosols over-compensate the GHG warming effects over this region.

RC3: P 6 L 19-28: I think this whole discussion is too superficial. There are many speculations on how thermodynamic and dynamic effects could influence the precipitation changes which, in my view, are speculative and should be based on a more quantitative and solid analysis. For instance, I am not sure how an “approximately linear” scaling is deduced from the data presented in this study. If this just refers to the differences between the 1.5 and 2.0 simulations, I could well imagine a case in which precipitation increases due to both increase in the atmospheric moisture content and in the monsoon circulation, and this increase is amplified in the 2.0 case, which may also produce a linear change over these simulations. Moreover, is a linear scaling really what we expect thermodynamically? The Clausius-Clapeyron relation is non-linear.

AC3: We are indeed speculating based on work by others (e.g. Bollasina et al. 2011). It is beyond the scope of this paper to investigate the dynamic response in detail. We are planning on doing that in a more advanced study with additional model simulations from HAPPI, but for now all we do is to “indicate” or “suggest” that a combination of mechanisms might be at play. None of what we say is conclusive, but it provides a potential explanation as to which factors could be at play. We can simply delete this paragraph, yet we believe that this would severely affect the integrity/content of this section. We would therefore pledge to keep the gist of the paragraph. We have added a sentence clarifying that our statements are rather speculative.

RC3: The conclusion that dynamic changes play a secondary role should be manifested in a quantitative way. Also the statement that the thermodynamic response “usually scales with 20-40% of Clausius Clapeyron” is vague and, as such, not comprehensible.

AC3: We did reformulate in order to make a less strong conjecture as to what could be going on. We deleted the last statement (although we are not sure why it is not

comprehensible).

RC3: P 7 L 1-2: I cannot follow here: In the region with the strongest decrease in Fig. 3a, the aerosol effect is small.

AC3: This sentence is now deleted to avoid confusion.

RC3: P 7 L6: The abbreviation “SPI” has not been introduced.

AC3: Added now.

RC3: P 7 L 11-3: Again I cannot follow. For instance, the changes in 5b,d are similar to those in 4b,d

AC3: This is rewritten as: “Changes in mean absolute rainfall are much more pronounced over sub-regions 1 and 2, where both MAM and JJAS rainfall exhibit clear shifts from one forcing to another forcing scenario (Fig. 4). On the other hand, over sub-regions 3 and 4, only JJAS rainfall exhibited a robust shift (Fig. 5 b & d).”

RC3: P 7 L 14: It is difficult to assess the relative change at this point, as the figures show absolute values

AC3: Not sure we can exactly follow their point. Fig. 2 and 3 (as well as S1 and S2 for SPI) show relative percent changes. We now discuss absolute changes. Can the referee elaborate on what is meant with that comment? We would highly appreciate that.

RC3: P 7 L 16-17: This doesn't fit with the interpretation in the figure caption. In general, I find it difficult to shift parts of the discussion to the figure captions.

AC3: Figure caption reformulated as “..... aerosol impacts over both sub-regions 1 and 2 are larger in MAM dry season than that in JJAS wet season.” Part of the figure caption is now also discussed here (as opposed to the figure caption).

RC3: P 7 L 18: lapse rate and stability changes are not different feedbacks

AC3: We agree. Instead we have clarified the point and added effects on boundary layer turbulence. Rewritten as: “Consequently, direct and indirect aerosol effects, accompanied by feedbacks such as reduced lapse rate, reduced boundary layer turbulence, or a modified land-sea circulation, remain to be a potent driver for changing monsoonal rainfall amounts.”

RC3: P 7 L 21: Again I don’t understand what “linear” increase means here.

AC3: By linear response, we meant steady and gradual increase in the climate change impact on rainfall from one forcing scenario to another due the warming effects, for example, from ACT to HAPPI 1.5 and HAPPI 1.5 to HAPPI 2.0. In other words, a ‘linear’ response is when we impacts (e.g. drying, wettening, warming, cooling) continue as a function of increased warming, i.e. scaling with global mean surface temperature.

RC3: Section 3.3, first paragraph: There is an imbalance between the amount of text/discussion and the number of figures. The reader is left alone with much of the material shown in Figs. 6-9. Either expand this discussion, or, if you think that the results are not that important, move parts of the figures to the supplement.

AC3: This section is expanded to discuss results from figures 6-9.

RC3: P 8 L 4: “appear to counter”: I cannot see how you come to this conclusion.

AC3: Rephrased: “Might partially” instead of “appear”

RC3: P 8 L 24: “to a lesser extent”: Really? Aren’t the relative changes larger for the extremes?

AC3: Revised to: [are projected to increase seasonal mean and extreme rainfall probabilities during] “probabilities”.

RC3: P 8 L 31: “we conclude that the drier subregions ...”: I don’t think this has been demonstrated. To show this, the masking effect has to be quantified. Furthermore, it is not clear to me which region and season you’re referring to.

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AC3: This part was indeed very confusing. Please accept our apologies. We have revised this paragraph including a more quantitative statement.

RC3 Comments on Figures

RC3: Fig. 1: I think this figure is too busy. I cannot distinguish the different shadings and also the lines of the observations are hard to see.

AC3: Figure 1 is redone with higher resolution and better visual clarity (see Fig. AC3 b).

RC3: Fig. 3: shorten caption (as Fig. 2, but for the monsoon season)

AC3: All figure captions are now reasonably shortened.

RC3: Fig. 4: I cannot follow the interpretation in the caption. For instance, I don't see such large differences in the masking effect between the regions. More in general, it is hard for me to understand how the masking effect is quantified here.

AC3: You are right; the masking effects vary only with wet and dry seasons. The figure interpretation is rewritten as: "The figure shows that aerosol impacts over both sub-regions 1 and 2 are larger in MAM dry season than that in JJAS wet season." We compare the NAT, ACT and GHG-only (green, gray and orange boxplots) results to quantify the aerosol masking effects for both sub-regions (see Figure AC3.c).

RC3: Fig. 10: Again, the interpretation in the caption is unclear (e.g., which region and season are you referring to?)

AC3: Rewritten the figure caption as follows (see Figure AC3.d): Same as Figure AC3.c but for sub-region 3 and 4. During MAM over both sub-regions 3 and 4, aerosol effects suppress the mean rainfall change between NAT and ACT (i.e., ACT rainfall is lower than NAT). On the other hand, during JJAS over both sub-regions 3 and 4, with lesser aerosol masking effects, ACT has higher mean rainfall than NAT and GHG-only would have noticeably much higher mean rainfall.

References:

Bollasina, M.A., Ming, Y. and Ramaswamy, V.: Anthropogenic Aerosols and the Weakening of the South Asian Summer Monsoon, *Science* 334 (6055), 502-505, doi: 10.1126/science.1204994, 2011.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., <https://doi.org/10.5194/hess-2018-400>, 2018.

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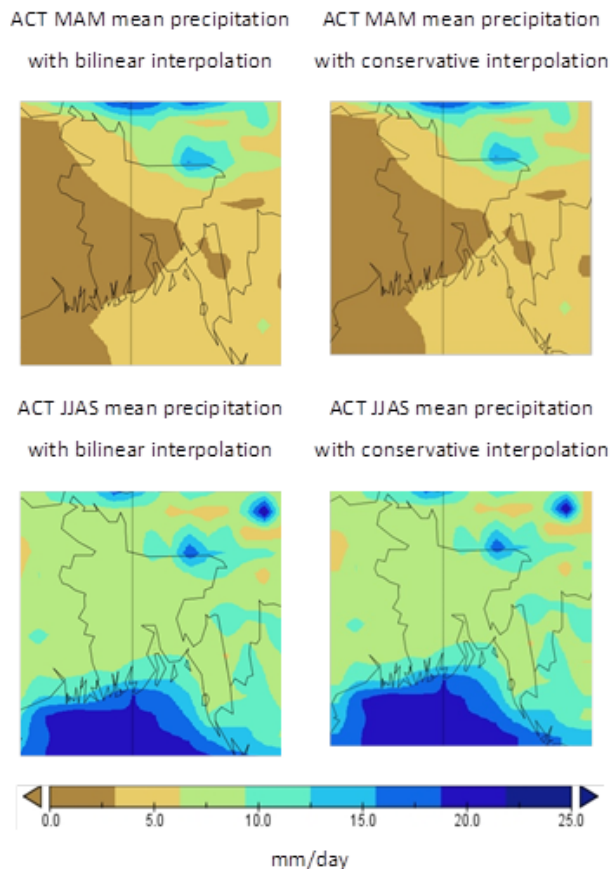


Fig. 1. AC3 a: Comparison between two interpolation methods applied for seasonal mean precipitation during JJAS and MAM over Bangladesh.

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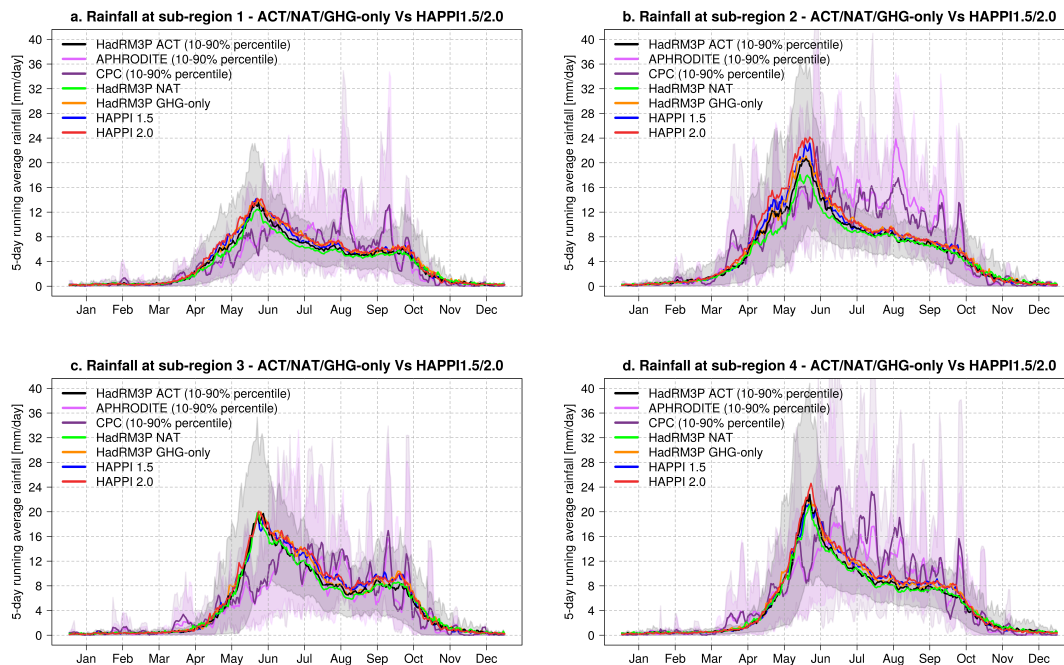


Fig. 2. AC3 b: Seasonal cycles of five day mean rainfall under different forcing scenarios over the four sub-regions of Bangladesh.

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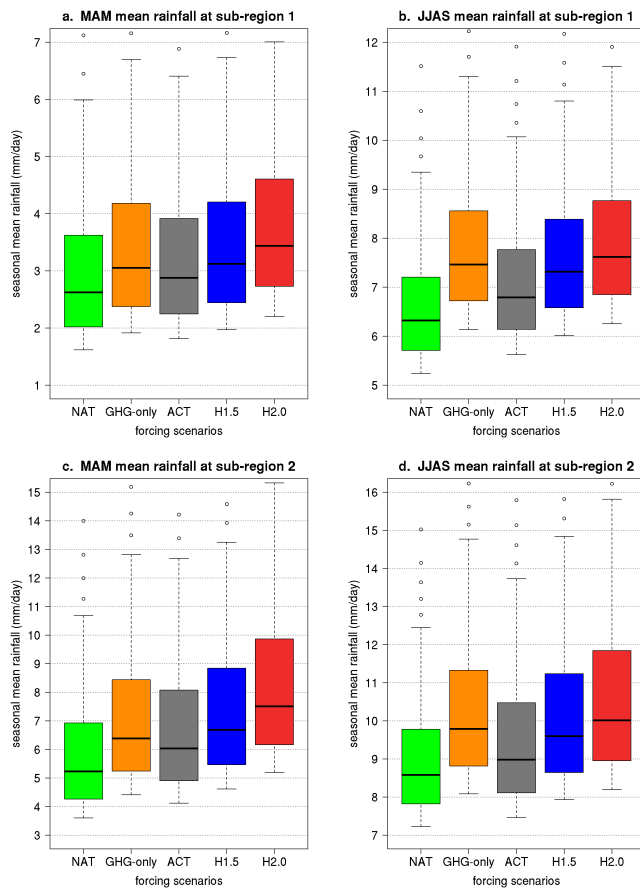


Fig. 3. AC3 c: Seasonal mean rainfall in MAM (left column) and JJAS (right column) over the sub-regions 1 and 2 (top and bottom row) of Bangladesh.

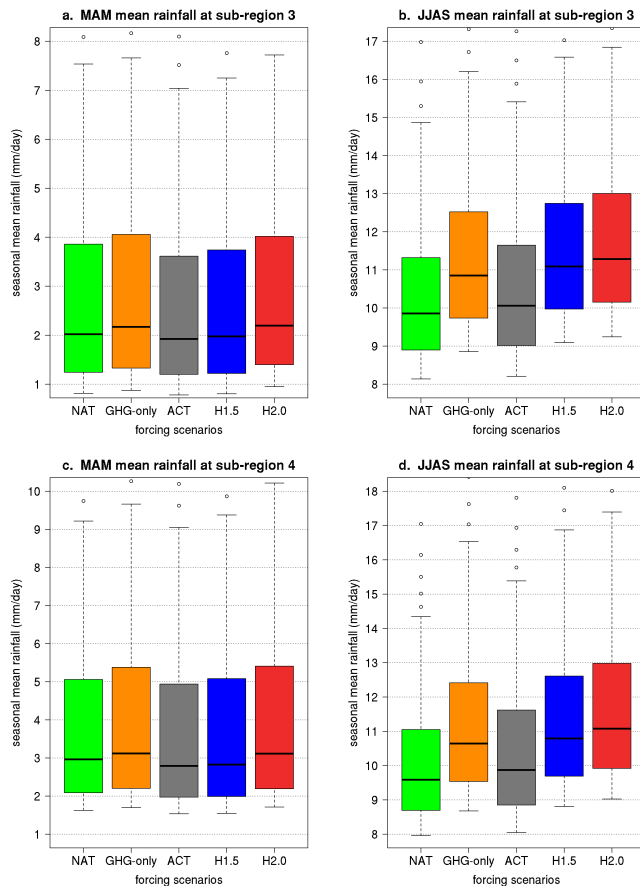


Fig. 4. AC3 d: Same as Figure AC3.c but for sub-region 3 and 4.