

***Interactive comment on* “Consistent increase in Indian monsoon rainfall and its variability across CMIP-5 models” by A. Menon et al.**

Anonymous Referee #2

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Summary: This study analyzes GCMs data from CMIP5 ensemble simulations to investigate the response of South Asian summer monsoon to future increase in greenhouse forcing under different Representative Concentration Pathways. Author’s show that majority of the GCMs in CMIP5 ensemble predominantly simulate an increase in South Asian summer monsoon rainfall in the 21st century period. Authors note that precipitation response in CMIP3 models was anything but robust. In contrast, they show that South Asian summer monsoon response is robust across the CMIP5 ensemble that should build some confidence in this regard.

Major Comments: Overall, this manuscript provides good summary of the area averaged simulated summer monsoon rainfall changes in the CMIP5 GCMs over South Asia. However, it stops short of providing any details regarding the mechanisms driving

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those changes. It should be noted that there are a number of manuscripts that have already been published or accepted (e.g. Levine et al, Climate Dynamics) that describe the overwhelmingly positive precipitation response in CMIP5 GCMs over South Asia, therefore, while this manuscript provides some additional details that have not been provided in recent studies, it does not add anything new to what now is already known. More importantly, authors' opinion that confidence is a function of how many models agree on the sign of precipitation change is naive. Confidence should be a function of how accurately models are able to simulate South Asian summer monsoon dynamics and the spatial and temporal distribution of summer monsoon rainfall. If most of the models are not able to simulate critical aspects of the South Asian summer monsoon dynamics then a qualitative presentation of their projections is not sufficient to prove the reliable of their future projections regardless of their agreement on the sign of the rainfall changes. This issue of future projections reliability is particularly more critical over South Asia because of the controversy surrounding the mismatch between simulated and observed summer monsoon trends over South Asia, as noted by the authors.

Apart from that, I am amazed to see authors' generosity that they accept a GCM as reasonable if it falls within "two standard deviation" of the observed area averaged summer rainfall. First, error of two standard deviations or more is quite significant when it is based on area average. Second, just a mere litmus test of an area-averaged rainfall is not sufficient to determine the skill of a GCM. Further, this study just focuses on the mean or seasonal climate response whereas everyone knows that it is the extreme and intra-seasonal climate variability that defines the socioeconomic impacts of monsoon variations in South Asia. Overall, a substantial quantitative strengthening of analysis is required in this study before it can be considered useful and meaningful contribution to the monsoon research. Following are the few suggestions that can substantially improve this study:

1) A case regarding the more reliability of the simulated South Asian summer monsoon response in CMIP5 GCMs than that in CMIP3 GCMs cannot be made unless authors

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quantify that CMIP5 GCMs have more skill in the simulation of South Asian summer monsoon dynamics compared to the skill exhibited by CMIP3 GCMs.

2) CMIP3 GCMs showed a weakening of monsoon circulations, it is important to know the similarities/dissimilarities in the simulated circulations response in CMIP5 GCMs.

3) Most of the GCMs in CMIP5 ensemble are significantly drier than observations; it is imperative to quantify whether this dry bias has any influence on their simulated response in the 21st century period.

4) Authors must provide details of the driving mechanisms that are responsible for increase in rainfall in future under all RCPs and that whether the cause of positive precipitation response is consistent across the CMIP5 ensemble.

5) Authors should also show grid based model results in addition to the area averaged time series. Time-series analysis cannot be helpful if reader wants to know whether or not a spatial robustness in rainfall response also exists across the models.

6) This study didn't discuss a single high-resolution regional model based study over South Asia. There is more than one high-resolution study from recent past that simulates suppression in South Asian summer monsoon in response to increase in greenhouse forcing (e.g. Ashfaq et al, GRL).

7) It will be useful to know that how many of these models simulate rainfall response that is outside of the envelope of the baseline variability and that when this happens during the 21st century period. Perhaps, one can also look across the models to see how consistent models are in the simulation of the climate state where monsoon rainfall is permanently beyond the natural climate variability if that at all happens in CMIP5 GCMs in their 21st century rainfall projections.

8) In addition to the analysis of mean and inter-annual variability, authors should also add analysis of extremes and intra-seasonal variability. It is important to know that how fine- and intra-seasonal time-scale climate variations shape the mean simulated

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response in the GCMs and that how consistent the fine-temporal scale variations are across the CMIP5 ensemble.

Collectively, these analysis will help to address the issue of reliability given that a “robust” bias exists in CMIP5 ensemble in the representation of process that control intra-seasonal to inter-annual variability of the South Asian summer monsoon in their historical simulations.

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