

Interactive comment on “Robust increase of Indian monsoon rainfall and its variability under future warming in CMIP-6 models” by Anja Katzenberger et al.

Anonymous Referee #2

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Review of “Robust increase of Indian monsoon rainfall and its variability under future warming in CMIP-6 models” by Anja Katzenberger, Jacob Schewe, Julia Pongratz, and Anders Levermann

This study analyses change in Indian summer monsoon in a set of models from different CMIP6 scenarios. Authors found a long-term increase of Indian summer monsoon precipitation and an increased of its interannual variability. The paper is quite a description of Indian summer monsoon model results from newest generation of CMIP. The paper confirms the increased long term trend in Indian monsoon precipitation already found by previous CMIP models, as well its interannual variability (with some dif-

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ferences). Authors did not investigate what drives the large difference found at regional scale on monsoon response in the different models, which I think it is quite interesting. They just mentioned that the resolution matters (still). Overall, the paper addresses the questions within the ESD scope. It shows some new results based on new data available and conclusions are reached. Only Introduction needs substantial revision because it is a bit chaotic. I recommend to publish the paper after major revision.

Ln 35-39: “Multi-millennial paleorecords indicate strong changes both in the Indian and East Asian summer monsoon (Wang et al., 2005b, a, 2008; Zhang et al., 2008; Li et al., 2017; Wang et al., 2017; Zhang et al., 2019; Ming et al.; Wang et al., 2020). While it is speculated (Schewe et al., 2012; Herzschuh et al., 2014; Wang et al., 2020), that there might be abrupt monsoon changes due to a moisture-advection feedback at play (Levermann et al., 2009), these are generally associated with either aerosol forcing or changes in the sea surface temperatures of the surrounding ocean waters.”

This sentence is quite generic. What multi-millennial paleorecords are you referring to here? Are these changes related to orbital parameters during the Holocene? And in particular this sentence “... that there might be abrupt monsoon changes due to a moisture-advection feedback at play (Levermann et al., 2009), these are generally associated with either aerosol forcing or changes in the sea surface temperatures of the surrounding ocean waters.” is totally misleading. Aerosol forcing on multi-millennial time scales? No-way. I warmly suggest to rephrase here. Do not mix too much. If you really want to refer to both past and future Indian monsoon changes, you might find useful this paper for both contents and recent literature overview.

D’Agostino, R., Bader, J., Bordoni, S., Ferreira, D., & Jungclaus, J. (2019). Northern Hemisphere Monsoon Response to Mid-Holocene Orbital Forcing and Greenhouse Gas-Induced Global Warming. *Geophysical Research Letters*, 46(3), 1591-1601.

Ln 39-40: “Under future warming an overall strengthening of the monsoon rainfall is expected due to enhanced atmospheric moisture bearing capacity.” Please add a ref-

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erence here.

Ln 42-43: "The resulting decrease in the land-sea thermal gradient over South Asia and the consequently subdued Hadley circulation have lead to a reduction of the rainfall amount during the summer period since the 1950s (Roxy et al., 2015)." Try to expand a bit here.

Ln 45-82: These paragraphs are totally confusing. You are trying to summarise in a chaotic way three decades of studies about Hadley Circulation and monsoons, meridional and land/sea temperature contrasts influence on monsoon dynamics, oceanic warming, ENSO, aerosols, vegetation, energy budget... too much, not effective and not focussed. I strongly suggest to rewrite the section trying to put things in a clear way. You can list the different monsoon response sorting by the type of forcing for example. E.g. GHG vs aerosols or envisaging monsoon response in terms of moist static energy budget and energy framework.

Refer to:

Allan, R., Barlow, M., Byrne, M. P., Cherchi, A., Douville, H., Fowler, H. J., ... & Wilcox, L. (2020). Advances in understanding large-scale responses of the water cycle to climate change. *Annals of the New York Academy of Sciences*

Boos, W. R., & Korty, R. L. (2016). Regional energy budget control of the intertropical convergence zone and application to mid-Holocene rainfall. *Nature Geoscience*, 9(12), 892-897.

D'Agostino, R., Brown, J. R., Moise, A., Nguyen, H., Dias, P. L. S., & Jungclaus, J. (2020). Contrasting Southern Hemisphere Monsoon Response: MidHolocene Orbital Forcing versus Future Greenhouse Gas-Induced Global Warming. *Journal of Climate*, 33(22), 9595-9613.

Jalihal, C., Srinivasan, J., & Chakraborty, A. (2019). Modulation of Indian monsoon by water vapor and cloud feedback over the past 22,000 years. *Nature Communications*, 10(1), 1-8.

Seth, A., Giannini, A., Rojas, M., Rauscher, S. A., Bordoni, S., Singh, D., & Camargo, S. J. (2019). Monsoon responses to climate changes-connecting past, present and future. *Current Climate Change Reports*, 5(2), 63-79.

Ln 101: "...onle..." Typo. Ln 104-105: "Also under SSP5-8.5, the amount of rainfall over India is projected to increase by 18.7% by the end of the 21st century compared to 1961-1999 (Chaturvedi et al., 2012)." I thought that SSP5-8.5 is the newest experiment under CMIP6. How can be the ref so old? Maybe a typo?

Ln 107-108: about the thermodynamics vs dynamics add as ref D'Agostino et al., 2019 and 2020.

Ln 111: "The uncertain role of ..." Missing something here.

Ln 126: "67.5°0'0"E - 98°0'0"E and latitude 6°0'0"N-36°0'0"N". I do not think you need coordinates in minutes and seconds here.

Ln 250-253: refer to aforementioned studies about thermodynamics vs dynamics. Ln 253: linear -> linearly

Ln 213: Discussion... and Conclusions?

Ln 283: "In this study, we used 32 CMIP-6 models to analyse the Indian summer monsoon's response to climate change." I would not repeat "in this study...".

Interactive comment on Earth Syst. Dynam. Discuss., <https://doi.org/10.5194/esd-2020-80>, 2020.