Anonymous Referee #2
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General Comments:

This paper describes the performance of Relaxed Arakawa -Schubert Scheme with aerosol cloud microphysics (McRAS-AC) in simulating global cloud cover, radiation budget and precipitation in the GEOS-5 GCM. The work is very relevant to current modeling studies and the authors have vast experience in this field. The manuscript is well written; describe the methodology and results clearly. Therefore, I recommend publishing this paper. However, I have a few relatively minor comments, which the authors might like to address during the revision.

REPLY: Thank you for the encouraging comments about our past model development work.

Specific comments:

1. *It is not clear, from the Experimental details section, for what period the model was run. Although it is mentioned that run length is 10 years, but was it with climatological SST or interannually varying SST? In case the later is true, what were the start and end years. These are required for further comparison with observations/analysis. For example, climatology of the model with climatological SST could be very different that the climatology of the model with interannually varying SST.*

Reply:

The model run started from analyzed initial conditions for early May 1993 with SST of the following ten years prescribed for every simulated month from the SST analysis of the available observations (Reynolds et al., 2002). A primary goal was to obtain a reasonable climatological response to aerosol loading on the simulated clouds and circulation; besides, the current paper, many other aspects of the model performance are available in references of the previous works in which the parameterizations used in McRAS-AC were extensively discussed and/or evaluated. We have included some more details about the model in response to R-1.

2. *In case, SST was interannually varying, it will be nice to see if interannual variation of precipitation over the Indian region has got improved using this new model of clouds.*

Reply:

Yes, the SSTs were prescribed from SST analyses (Reynolds et al., 2002) and that includes interannual variations of observed SSTs. Both MAC and CTL runs show similar rainfall climatology with large regional biases as compared to GPCP rainfall data (Adler et al., 2003); in other words, neither CTL nor MAC runs show much skill in simulating the observed spatial

variation of JJA rainfall over India (see panels a and b; Figure 1). The grid-point by grid-point correlations between simulated and observed rainfall in the same 10-year period is also quite low. In fact, skillful response of the Indian summer (JJA) rainfall to SSTs in GCMs remains a difficult problem and presumably that is the basis of R-2's question. Its major cause is large biases in the JJA rainfall climatology over and around India and nearby Asian land masses. It is largely caused by the model's inability to simulate realistic circulation and rainfall in response to Himalayas, so called "orographic-rainfall problem". This leads to large rainfall biases (see top panels, Figure 1) that in turn are the root cause of large biases in the soil moisture and its dependant evapotranspiration. Since evapotraspiration is key modulator of moist convection, its biases lead to correspondingly large biases in the precipitation. Even though, mean large-scale circulation over the Indian subcontinent is comparatively more realistic (top left panel), the interannual variability of simulated rainfall by both CTL and MAC simulations remains unskillful. This has been a generic problem and for this reason, scientists designed Monsoon Indices based on low-level circulation to achieve better skill (e.g., Wang and Fan, 1999). On the positive note, however, the west coast of India representing rolling hills called Ghats show more discernible skill (Figure 1) because the incoming low level winds, produced by the large-scale monsoon circulation, are reasonable and both models seem to handle orographic response to rolling hills somewhat better with the MAC showing a slight edge over the CTL. We plan to revisit model's monsoon prediction skill after the implementation of an improved parameterization of orographically influenced precipitation and more realistic monsoon rainfall climatology.

We thank the reviewer for pointing out the need to capture the influence of the observed SST variability on the Indian monsoon season rainfall. Both MAC and CTL fail, but with upcoming upgrades that better formulate the orographic effects on the moist physics, we expect to overcome this deficiency in the next model version.

References

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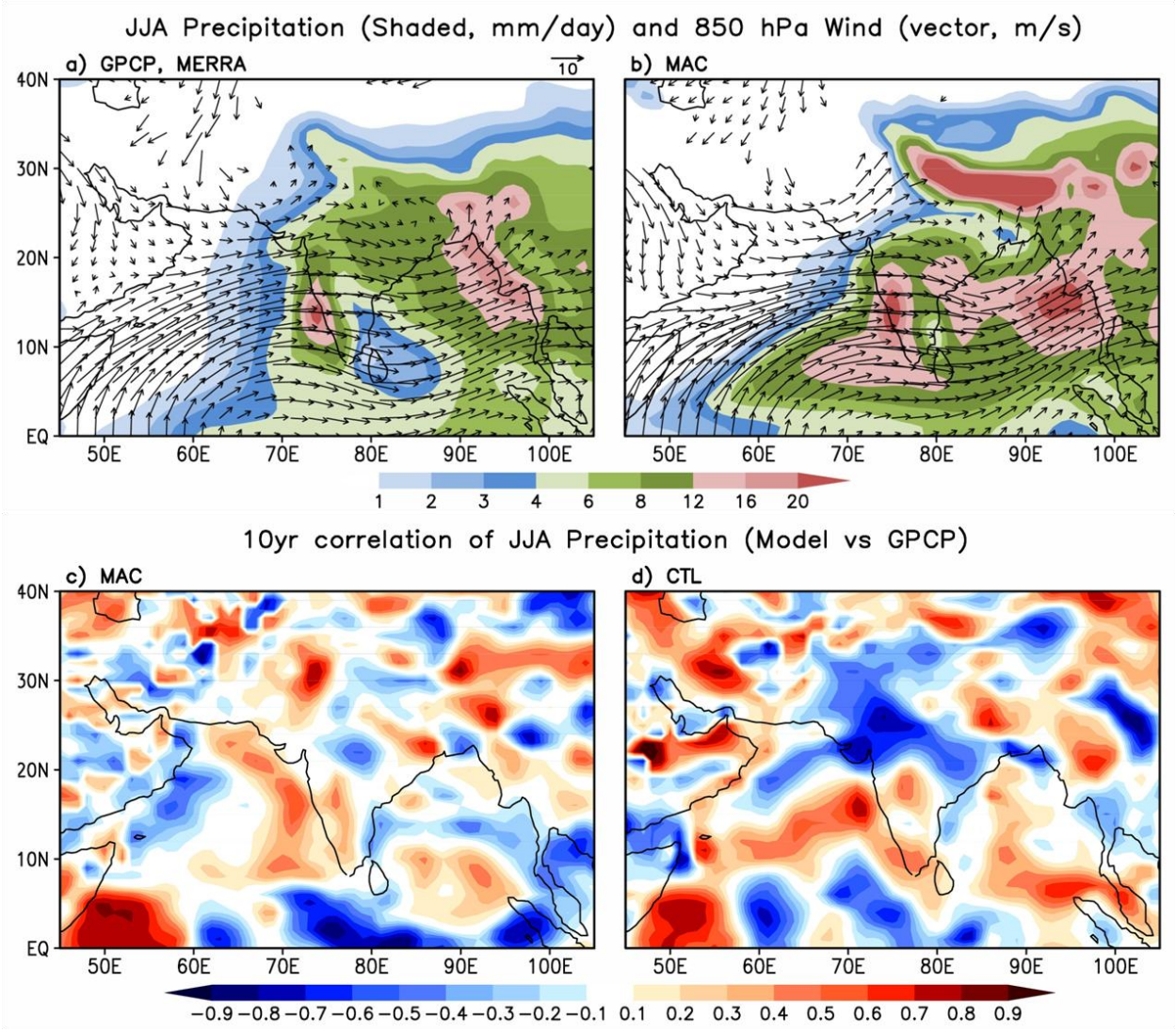

Figure 1: Top Panels (a and b) show 10 year mean JJA precipitation [mm/day] and 850hPa wind vectors [m/s] for JJA for a) OBS (GPCP and NCEP reanalysis) and b) MAC simulation. Bottom panels (c and d) show 10 year anomaly correlation of simulated versus GPCP precipitation in JJA for c) MAC and, d) CTL simulations.