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Climate of the Past Discussions

Interactive comment on "The Indian summer monsoon climate during the Last Millennium, as simulated by the PMIP3" *by* Charan Teja Tejavath et al.

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At the outset, we would like to thank the reviewer for the useful and encouraging comments, which have improved the standard of the manuscript.

Main concerns:

Question 1: First, you diagnose differences in correlation coefficients between two periods. However, Gershunov et al. (2001, http://dx.doi.org/10.1175/1520-442(2001)014<2486:LFMOTE>2.0.CO;2) and others discuss how correlation coefficients can change over time without a change in the underlying relation. My impression

is, that maybe one if any correlation-difference may be significant in your analyses.

Response:

Thank you for the comment. Gershunov et al., 2001 paper cautions about the sampling issues associated with a short (21-31year) running correlation within a 130-150 yrs period, which does not vary in terms of external forcings (i.e. change in solar signal, or significant volcanic eruptions etc.). In such a case (specifically, weakening of ENSO-Indian summer monsoon rainfall in the last 15-20years of the 20th century), it is very important to check if any such change in decadal variability may be subject to stochasticity.

However, in our case, we evaluate changes in a statistic (correlation) between two separate climatic (200 year) regimes, with different external forcings such as different frequencies of volcanic eruption, etc. Therefore, our results are not subject to the Gershunov et al., 2001 concern.

As we have shown in the manuscript, the difference between the ENSO-ISMR correlation from the MWP simulations and the LIA simulations are statistically significant at 0.05 level from a Student's two tailed t-test.

Having said this, we have anyway carried out a bootstrapping significance test for the above mentioned difference in correlation (1000 simulations). We find that the results from 4 out of 7 models are significant at 95% confidence level.

Question 2: Secondly, if I understand your analyses of the ENSO-frequencies correctly, you do not identify differences in La Nina and El Nino frequencies but just diagnose differences in the mean background state.

Response:

Thank you. Actually, we had shown the difference in the frequencies of El Niños and La Niñas to explain the relatively warm MWP and relatively cold LIA temperatures. Specifically, the MWP simulations exhibit more number of El Niños relative to the La

Niñas. It is well known that the El Niños (La Niñas) result in warmer (cooler) than normal global temperatures (e.g. Trenberth et al., 2002). Therefore, the simulated above normal global temperatures during the MWP are in conformation with the relatively more number of simulated El Niños. The simulated relatively cooler LIA is also easily explained by the simulated ENSO frequency skewed negatively, that is more simulated La Niñas as compared to El Niños during this period. Our results also clearly indicate (Figure R1) that the simulated global mean temperature is positively and significantly correlated with the Nino3.4 index during the LM and its sub-periods.

The differences in the simulated mean background state shown, on the other hand, explain why the simulated ISMR during the MWP is more than that during the LIA. For example, the 'anomalies' in large scale convergence and divergence patterns during the MWP relative to the LM averages explain that there is a relatively eastward shift in Walker circulation, with associated changes over India, which have resulted in more rainfall during this period as compared to the LM. To be clear, the correlations of the simulated Nino3.4 index with local summer monsoon temperatures over various places in India (Figure-A4 of the revised manuscript, attached below as Figure R1), and that with the ISMR (Figure-A5, attached below as Figure R2) are all negative, as is observed in general during the last 150years or so.

We must mention that, in the revision, we have refined the frequency distinction analysis for the sake of a better objectivity, notwithstanding that the result is qualitatively the same as compared to that from the earlier version of the manuscript. Specifically, the earlier version, we had identified a simulated ENSO event by fixing an amplitude-threshold of 0.5°C for the Nino3.4 index. Now, we identify a simulated ENSO event when the amplitude of the NINO3.4 index exceeds its standard deviation (If temperature is below one standard deviation considered as La Nina and if it is above one standard deviation, it is considered as strong El Niño or La Niña events). We still find that there are relatively more El Niños (La Niñas) during simulated MWP (LIA) as compared to LIA (MWP).

Trenberth, K. E., J. M. Caron, D. P. Stepaniak, and S. Worley, Evolution of El Niño–Southern Oscillation and global atmospheric surface temperatures, J. Geophys. Res., 107(D8), doi:10.1029/2000JD000298, 2002.

Further concerns:

Concern:

I am not sure your use of the Multi-Model-mean is appropriate. I think for most of your analyses the spread and the differences between the models are of interest and the multi-model-mean analysis is not necessary. For example correlating the MMM-ISMR- and MMM-NINO3.4-indices seems not very meaningful. As another example, I am not sure, the premise of the paragraph on Page 6 Line 8 is valid.

Response:

Thank you for the comment. Accordingly, we have removed the relevant MMM correlations.

Concern:

You often refer to proxies but don't show any comparisons at all. For example on page 12 line 3, it would help to be able to make the comparison directly or at least in an appendix.

Response:

We had discussed related proxy records for comparisons in citations (e.g. Figure 8 of Ramesh et al., 2011; Box TS.5, Figure-1 of Technical Summary in the IPCC 2013; Stocker 2013), few more we will add in appendix part of revision.

Concern:

P7L14 and L16: I do not see the decreasing precipitation trend. If it is there, please quantify it more clearly.

Response:

Thank you. We have removed the statement.

Concern:

P12L7: I'd like to repeat, that I don't think these correlations mean much for the multi-model-ensemble-mean, as you don't identify the relation between ENSO and Indian climate by this, but just the common long term relation between the global mean and both the ENSO-region and India.

Additionally, the correlation coefficients are generally rather small, which to me also indicates that, at least for temperature, you just capture the concurrent relation between TG and TI and TG and NINO3.4.

Response:

As we had mentioned earlier, we have purged the discussion of the ISMR-NINO index analysis relevant to the MMM.

We have carried out the partial correlation between TG, TI and NINO3.4 to remove the concurrent TG signal on TI (not shown). This analysis demonstrates the significant impact of the ENSO on TI temperature at a 0.05 confidence level.

Concern:

Furthermore, you make some additional inferences which I would call wrong or at least your analyses do not warrant them, e.g.:

P11L25: "All this suggests a better agreement among the models in simulating the long term trend in rainfall over India relative to the variability during the MWP and that during the LIA."

I don't think your analyses allow to infer this.

Response:

Thank you for the comment. We removed the statement.

Concern:

P13L10: "we surmise that Indian Sub-continent was warmer (relatively cooler) during the CE 1000-1199 (CE 1550-1749) than the many other regions of the globe".

I don't understand how you come to this assumption, but I don't think you can infer this from comparing one regional series with the global mean.

Response:

We modify this sentence to "We surmise that Indian Sub-continent was warmer (relatively cooler) during the CE 1000-1199 (CE 1550-1749) than the concurrent global mean temperature"

Concern:

P14L3: "More importantly, these results suggest that any long term weakening between the ENSO-Indian summer monsoon (e.g. Kumar et al., 1999; Ashok et al., 2001) is not necessarily due to anthropogenic climate change." It's not that this isn't a possibility but from my point of view your data and your analyses do not give any indication of this, they in my opinion don't tell you anything at all about this.

Response:

We have re written the text for better clarity. Now it reads as "we can make a conjecture that any weakening between the ENSO-Indian summer monsoon (e.g. Kumar et al., 1999), associated with changed variability of either of them (Kriplani et al., 1999; Ashok et al., 2007), or for that matter associated with changed strength or frequency of another monsoon-driver such as the IOD (e.g. Ashok et al., 2001), may not be necessarily due to anthropogenic climate change."

Concern:

P14L21: “It is known that the El Niños (La Niñas) cause anomalous increase (decrease) in global temperature. Therefore, a predominant presence of higher number of simulated El Niños as compared to La Niñas in almost all the models is the reason why the simulated MWP is warmer as compared to the LIA. Given this agreement across the models, we can surmise that, in real world too, the MWP is likely due to the occurrence of a relatively higher frequency of El Niños as compared to the La Niñas”

a) Can you give references for “It is known . . .”

Response:

Trenberth et al., (2002)

Concern:

b) You do not identify a change in frequency of El Ninos but just describe the temperature change in the background state.

Response:

We have refined the frequency distinction analysis for the sake of a better objectivity, notwithstanding that the result is qualitatively the same as compared to that from the earlier version of the manuscript. Specifically, the earlier version, we had identified a simulated ENSO event by fixing an amplitude-threshold of 0.5°C for the Nino3.4 index. Now, we identify a simulated ENSO event when the amplitude of the NINO3.4 index exceeds its standard deviation (If temperature is below one standard deviation considered as El Niño (La Nina) and if it is above one standard deviation, it is considered as strong El Niño or strong La Niña events.

We still find that there are relatively more El Ninos (La Ninas) during simulated MWP (LIA) as compared to LIA (MWP), and conjecture that such a frequency distinction may have a role in with the relatively warmer (cooler) MWP (LIA). Having said that, this hypothesis needs some specialised sensitivity experiments with AGCMs, which we plan to, do in near future. Based on the statistically significant NINO3.4-ISMR correlations,

which are similar to those from current day observations, during both MWP & LIA, we believe that the interannual teleconnection impacts have been somewhat reduced by the long term changes. All these details also go into the revision.

Concern:

c) That is, the MWP in the models isn’t warmer and LIA isn’t colder because of ENSO. Rather your analysis just describes the warmer MWP and the colder LIA. d) Thus your inference is circular and in this context very likely wrong. Response:

For better clarity, we explain the limitations. Please see the above response.

Concern:

P19L2: “Our analysis of the PMIP3 datasets suggests that the Indian region was likely warmer than the global temperature during the MWP.”

I don’t think your analysis suggests this.

Response:

We have compared the global spatial anomaly of surface temperatures with Indian surface temperatures anomaly which clarifies this aspect. Spatial plots of global and Indian region anomalous temperatures have been attached. (Figures R3)

Minor points:

Concern:

Is the title appropriate? I would say, you discuss more the ISM-ENSO relation than the general state of the ISM.

Response:

Thanks for suggestion. We now modify the title slightly to “The Indian summer monsoon climate and its connection to ENSO through the Last Millennium, as simulated by the PMIP3”

Concern:

I would suggest to drop the MIROC-simulation completely from the paper. It is enough to mention from the start that you don't use it, because of the known problems with the simulation. There are a number of references available, I think.

Response:

We have accordingly dropped the MIROC from our analysis from both Historical and LM.

Concern:

I found the manuscript in parts hard to read, thus I would suggest to check where things could be rewritten to make the manuscript more clearly readable.

Response:

Thank you. We have revised the manuscript carefully to make it more clearly & better readable.

Concern:

Page 1 Line 24: The models can't confirm the proxy-data, they can only be consistent with them or, if you insist, can agree with the proxies.

Response:

We have modified the sentence accordingly, by replacing "in confirmation" to "consistent with"

Concern:

P2L11: What do you mean by "there is no apparently significant change in the external climate forcing from the first half of 20th century"?

Response:

It means, there is no apparent change in external forcing (solar forcing).

Concern:

P3L5: Is this full paragraph relevant for this paper?

Response:

We believe so, as this paragraph essentially, but just briefly, sum up the few proxy-based papers that discuss the Indian summer monsoon rainfall changes between the MWP & LIA.

Concern:

P3L33: Please give a reference for PMIP3.

Response:

Thank you. We cited it properly now with Schmidt et al. (2012).

Concern:

P4L19: I don't think you validate the models

Response:

We validate simulated features such as the temperature trends, ISMR-ENSO links, etc., in the historical simulations by the models by comparing these features with those from the available observed and reanalysis data sets. The actual paragraph reads as "It is indeed a challenging prospect to validate the simulated Indian summer monsoon features from the PMIP3 simulations for the LM period given the sparse and scanty observations. Fortunately, model simulations of the CMIP5 for the historical period (CE 1850-2005) can be validated using various observed/reanalysed gridded datasets, keeping in mind the uncertainties associated with such datasets during the pre-satellite period"

Concern:

P4L33: The correct references for the PMIP3-past1000 simulation-setup are Schmidt et al. (2011, doi:10.5194/gmd-4-33-2011) and Schmidt et al. (2012, doi:10.5194/gmd-5-185-2012)

Response:

Thank you for pointing out. We have cited these in the revised manuscript.

Concern:

P5L6: I don't think ERA-Interim goes from 1900 to 2010?

Response:

Sorry for the mistake. It should read as ERA-20CM (Monthly means of daily means). We have now revised it.

Concern:

P5L8: Can you please provide a reference for the IMD-data? And is this data publically available? If yes, please provide a URL, if not please provide contact details where the data can be obtained. [Dear editor, please crosscheck this with the data availability requirements.]

Response:

We did mention the reference citation. It is Rajeevan et al., (2006).

Concern:

P6L33: Is this relevant? What does this imply?

Response:

In the manuscript, Figures 1c and 1d show anomalous global and Indian surface temperatures with 11-year running mean. We had shown this to show that all the models are able to capture the current warming trend.

Concern:

P7L11: You do not plot events but just the 11-running means which possibly masks the higher frequent ENSO-variability.

Response:

We have corrected it (removed the relevant smoothed time series of the Nino3.4 index with the unsmoothed time series). The Nino3.4 frequency tables also clearly show the higher (lower) number of simulated warm (cold) ENSO events, represented by the positive Nino3.4 index, during the MWP (LIA)"

Concern:

P8L18: You shortly write about standard deviations here and elsewhere. From my point of view, it does not become clear, what's the point of these discussions.

Response:

This analysis has been carried out to show the spread of any parameter mentioned across the models.

Concern:

P10L16: Which models are these outliers, what is the bias because of which you call them outliers, where do you show this?

Response:

The models whose anomalous TG is above or below 1σ are outliers. In general, that the spread in various statistics across the models is within the limits defined by 1σ except the model S2.

Concern:

P11L2: Much of what you describe here for the global temperature is in the IPCC and other publications.

Response:

We agree. We had actually mentioned so in the manuscript.

Concern:

P11L18: I do not see these decreasing ISMR-trends, please clarify.

Response:

For better clarity we have mentioned a trend line diagram of simulated ISMR during LM (Figure R4) below with the trend line equations. We have modified the sentence for clarity.

Concern:

P11L20: I cannot really follow the premise of this sentence.

Response:

We have modified the sentence for better clarity.

Concern:

P11L22: Why would we “expect” this?

Response:

In general, slowly increasing temperatures in the tropical regions are associated with a decreasing rainfall. This is based on the Tetens formula which suggests that every 1C rise in temperature leads to the moisture holding capacity of the atmosphere by 7%.

Concern:

P12L11: I think you mean “1000-year”.

Response:

Corrected the typo.

Concern:

P13L1: Maybe I miss something why are these statistics of interest/relevant?

Response:

Standard deviation analysis has been carried out to show that the spread of any parameter mentioned across the models.

Concern:

P13L17: What do you mean by “realistic”?

Response:

Thank you. We revise the sentence to “All these correlations are comparable to the corresponding correlations from observations during the historical period, as well as .....”

Concern:

P13L19: GOALS should read FGOALS.

Response:

Corrected it.

Concern:

Your Figure 7 does not show the ensemble but only one model, as far as I can see.
Response:

Thank you. Corrected the typo.

Concern:

P15L4: What do you mean by this “discrepancy”.

Response:

We revised this sentence for better clarity as “Further, there is relatively more discrepancy in the simulated El Niño & La Niña frequencies, i.e. the skewness of ENSO, across the models in the LIA simulations as compared to those for the MWP.

Concern:

P15L5: What kind of “factor” is this “discrepancy” meant to be?

Response:

We realise that this sentence is ambiguous. We remove it.

Concern:

P17L7: Maybe you should discuss the different models first before writing about the composite.

Response:

In the revision, we have briefly listed out the details of the models in a table.

Concern:

P19L29: Can you provide a reference for this cautionary note.

Response:

We have already provided some references. The sentence (“A plausible. . .”) is basically speculative one.

Concern:

P20L8: Maybe I missed it in your results-section but I think you should discuss these contrasts between the LM-relations and the modern relations in more detail and possibly show them in Figures or at least supplementary materials.

Response:

We will discuss more about individual in revised version.

Concern:

The Figures produced with GrADS are sometimes of suboptimal quality. Furthermore I recommend to change the color scale which is rather easy in GrADS if I recall correctly. The reason for this is, e.g., https://www.climate-lab-book.ac.uk/2014/end-of-the-rainbow/.

Response:

Our sincere apologies. We have changed the colour scale.

Concern:

It is often unclear whether MMM refers to the multi-model-mean or to the multi-model-ensemble, its members, or its spread. One example is on page 8 in line 11.

Response:

MMM refers to multi-model mean not multi model ensemble.

Concern:

Please do not insert tables as pictures into the manuscript.

Response:

Thank you, we corrected it.

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2017-24/cp-2017-24-AC1-supplement.pdf

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2017-24, 2017.

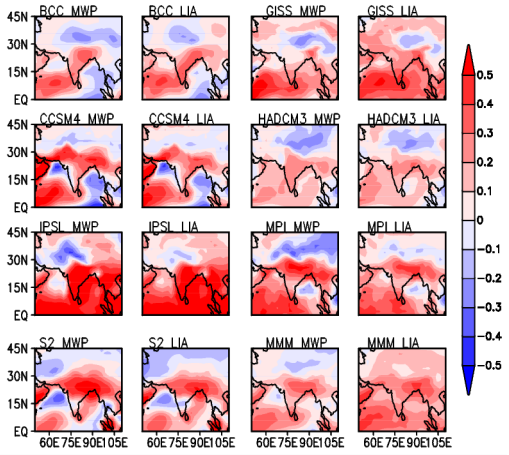

Figure R1: Correlation between simulated JJAS NINO3.4 and simulated JJAS surface temperatures zoomed over Indian region during MWP and LIA.

Fig. 1.

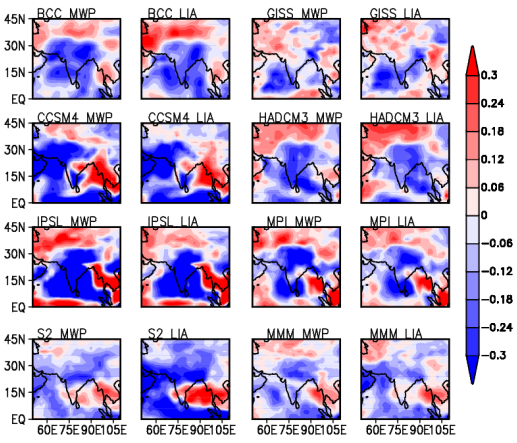

Figure R2: Correlation between simulated JJAS NINO3.4 and simulated ISMR during MWP and LIA.

Fig. 2.

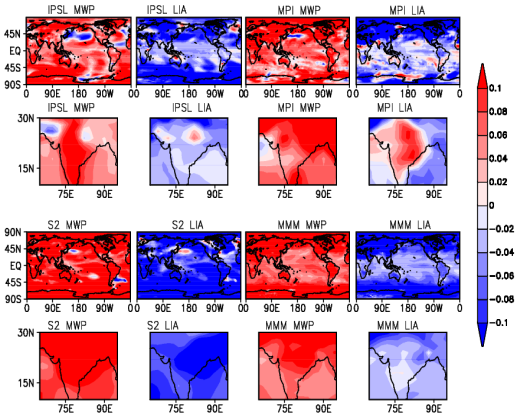

Figure R3: Spatial distribution of anomalous surface temperatures during MWP and LIA.

Fig. 3.

Figure R4: Linear trend plot of ISMR during LM.

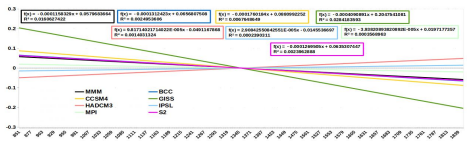

Fig. 4.