

## ***Interactive comment on “A comparison of model simulations of Asian mega-droughts during the past millennium with proxy reconstructions” by B. Fallah and U. Cubasch***

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**Thank you so much for the positive and helpful suggestions. It would be our pleasure to do all the modifications and make the improvements you suggested in the next version. Following your advise, we have tried to cover all the inconsistencies within the manuscript as well as the typos and English inaccuracies. We added the new merged figures (3-7, 11+14 and 12+15) and a supplementary figure to this response.**

“General remarks:

This is a nice and detailed study about the occurrence and reasons of droughts in

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central and southern Asia over the 1300-1860 period. The comparison of different model ensembles with available proxy data sets is quite insightful and highlights the usefulness of paleo-climatological modeling. The physical explanation of drought conditions is also helpful and reasonable. Therefore, I basically recommend publication of this manuscript in *Climate of the Past* after minor revisions according to the following aspects: The bad point about this manuscript is that there are many inaccuracies in terms of the use of English, typos and inconsistencies with the reference list. I have made a large number of specific (mostly technical) remarks which should be addressed thoroughly. In addition, please check the entire document with respect to typos.

There are 15 figures assigned to 9 pages of text which is bit 'over-illustrated'. Maybe the authors can at least recombine the panels from Figs. 3-7 to one common figure. ”  
**We merged the figures 3-7.**

“One may also think of putting 11+14 and 12+15 together. ” **We merged the figures 11+14 and 12+15. The 850 hPa wind and OLR patterns for regime 1 and 2 of GISS-E2-R are also corrected. We also unified the color bars.**

“The remarkable differences between both model ensembles as seen in Figs. 10-15 is neither mentioned in subsection 4.2.2 nor discussed in section 4. In general, model uncertainty is barely addressed in the text. Some discussion is needed about how model uncertainty relates to uncertainty from proxies.”

**We acknowledge very much your legitimate comment about the differences between both model ensembles. In this regard, we have compared the ECHAM5/MPIOM model simulations with the proxies in our recently published paper (Polanski et al., 2014). In figure 1 of that manuscript we have compared the PC1 time-series of model derived PDSI for the five ensemble members of the “Millennium” experiment and for the PDSI from the MADA for the period 1300 to 2000 AD. Furthermore, we have illustrated the nonlinear trends of these time-series and included a discussion in the supplementary data of the above men-**

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tioned paper. Thus, we cite that study to cover to the ECHAM5/MPIOM model's uncertainties. For the GISS-E2-R model we will add an additional figure as the supplementary data (see the figures attached). The two ensemble members of GISS-E2-R which are used in our study differ only in the solar forcing. For r1i1p121 ensemble member the solar forcing according to the study of Steinhilber et al., 2009 and for r1i1p124 from the study of Vieira et al., 2011 are used (Schmidt et al., 2012). Figure S01 (Fig4 here) shows the PC1 of PDSI derived from the two ensemble members (dashed lines) along with their smoothed trends (solid lines). The Pearson correlation between the trends is 0.61 with p-value = 0.01.

Specific remarks: =====

Page 1, line 25: Insert: ... that 'are' lasting ... **We corrected it.**

Page 14, line 12: Shift Wang and Morrill 2010 to the right place in the reference list. **We corrected it.**

Page 2, line 18: Maybe to or into Asia instead of in Asia? **We corrected it.**

Page 3, first sentence: A verb is missing. Same for the next sentence in section 2. **We corrected it.**

Page 3, line 21: Schmidt et al. 2011 is missing in the reference list. **We added it.**

Page 3, last sentence: Is each model ensemble averaged to a model-specific ensemble mean, or is everything averaged to a multi-model ensemble mean? **Averaging is done on each specific model. We changed the sentence: ' we applied the arithmetic averaging on each of the two model experiments'**

Page 4, line 4: Monsoon or monsoons in Asia? **We corrected it.**

Page 4, line 12: What is a coupled EOF analysis? Do you mean SVD? Has SVD been used or entirely replaced by MCA? Please clarify. **We used the MCA for detecting**

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Discussion Paper



**coupled patterns. MCA uses the SVD to decompose the cross-covariance matrix of the two variables. Some authors have referred to MCA as the SVD (Björnsson and Venegas, 1997). We changed the sentences to clarify it.**

Page 4, line 16: The 1300-1860 period does not represent the past millennium, as promised in the title. Why is the anthropogenic component out of interest and why isn't the analysis starting before 1300?

**Thanks for pointing this out. The past millennium simulations of the “GISS-E2-R” are until the year 1860 AD. The continuations of these simulations are not similar to the other “historical” simulations. The control run will not be the same and aerosol and ozone forcings are slightly different (<http://data.giss.nasa.gov/modelE/ar5/>). Another reason for the selection of this time slice is that, there is a clear rising trend in PC1 time-series of PDSI for the period 1800 to 2000 (ref. Supplementary material in Polanski et al., 2014). This would affect the MCA and EOF calculations and produce spurious correlations.**

Fig. 2: The different scales of y-axes are misleading and, in my opinion, not necessary. **We changed the Figure.**

Page 5, line 8: Remove 'dipole' once. **We corrected it.**

Page 5, lines 10+13: It must be mid-14th century. **We corrected it.**

Figs. 3-7: Dots indicate that models and proxies agree by sign? **Yes, we changed the caption to clarify that.**

Page 5, line 15: Refer to Fig. 4. **We referred to the new figure in the text.**

Page 5, line 25: What means the 'broad drought patterns of the linear trends between reconstructions and simulations ...'? Please clarify. **We changed the sentence: 'The broad drought patterns captured by reconstructions and simulations are comparable during the “Strange Parallels” drought (Fig.3.d).'**

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Page 5, line 29: Is Kazakhstan already Siberian Plains? **We changed this sentence to 'The GISS-E2-R model did not simulate the drought pattern over Kazakhstan and north of the Lake Balkhash.'**

Page 5, bottom: If the dryness is not related to the monsoon because the latter is hardly (= almost not) weakened, what has been the cause for the drought in India? **As mentioned by Cook et al., 2010, the weak dryness captured by MADA could be a result of "limited tree-ring coverage" in India. In contrast to MADA, both models show dry conditions north of India which are in consistent with historical data from that region (Walsh et al, 1999). Cook et al., 2010, suggested that this drought may have non-climatic factors that led to its "societal consequences".**

Page 6, line 7: Really the observed ocean influence - over the period 1300-1860? **We removed "observed".**

Page 6, line 12: El Nino-like instead of ENSO-like. **We made the correction.**

Page 6, line 13: Krishna Kumar et al. 2006 is missing in the reference list. **We added the reference.**

Table 1: A measure of statistical significance should be indicated for the correlation coefficients. **We added the statistical significance to the correlation coefficients. There was an error in Table 1 that we corrected. The corrcoef. between Temp. and the GISS-E2-R PDSI is 0.52 instead of 0.19.**

Page 6, last line: Grove 2007 is missing in the reference list. **We added the reference.**

Page 8, line 9: Define LIA - Little Ice Age - when first used. **We made the correction.**

Page 8, line 31: Given the results in Fig. 2, I suggest to use a more constraining statement like, e.g., ... mostly agree ... **We changed it to 'Our analysis showed that, the mega-droughts are mostly linked to El Niño-like patterns in central equatorial Pacific'.**

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Page 9, line 7: Mann et al. 2005 is missing in the reference list. **We added the reference.**

Reference list: Some of the references have not been cited in the text. Please check D'Arrigo 2006, Raftery et al. 2005, Taylor et al. 2012. **We made the correction.**

References:

1- Polanski, S.; Fallah, B.; Befort, D. J.; Prasad, S. Cubasch, U.: Regional moisture change over India during the past Millennium: A comparison of multi-proxy reconstructions and climate model simulations, *Global and Planetary Change*, 122, 176-185, 2014.

2- Steinhilber, F., J. Beer, and C. Fröhlich: Total solar irradiance during the Holocene, *Geophys. Res. Lett.*, 36, L19704, doi:10.1029/2009GL040142, 2009.

3- L. E. A. Vieira, S. K. Solanki, N. A. Krivova and I. Usoskin: Evolution of the solar irradiance during the Holocene, *AA 531 A6* (2011), DOI: <http://dx.doi.org/10.1051/0004-6361/201015843>, 2011.

4- Schmidt, G. A.; Jungclaus, J. H.; Ammann, C. M.; Bard, E.; Braconnot, P.; Crowley, T. J.; Delaygue, G.; Joos, F.; Krivova, N. A.; Muscheler, R.; Otto-Bliesner, B. L.; Pongratz, J.; Shindell, D. T.; Solanki, S. K.; Steinhilber, F. Vieira, L. E. A.: Climate forcing reconstructions for use in PMIP simulations of the Last Millennium (v1.1) *Geosci. Model Dev.*, Copernicus Publications, 5, 185-191, 2012.

5- Björnsson, H. and Venegas S.A.: *A Manual of EOF and SVD Analysis of Climatic Data*, McGill University , 1997.

6- Walsh, R.; Glaser, R. and Miltzer, S.: The climate of Madras during the eighteenth century, *Int. J. Climatol.*, John Wiley Sons, Ltd., 1999, 19, 1025-1047.

### Figures' Caption:

Fig.1: Drought patterns during (a) the demise of Khmer empire (1351–1368) (Buckley

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et al., 2010), (b) the late 16th century drought (1560–1587), (c) the late 17th century drought (1682–1699), (d) the “Strange Parallels” Drought (1756–1768) and (e) the East India Drought (1790–1796). Left panels are for MADA, middle panels for the GISS-E2-R model and right panels for the ECHAM5/MPIOM simulations. Dots indicate that models and proxies agree by sign.

Fig.2: Model simulations’ composite anomalies of 850 hPa wind (m/s) and OLR (W/m<sup>2</sup>) for the first ((a) and (b)) the second regime ((c) and (d)) for the ECHAM5/MPIOM (left panels) and the GISS-E2-R (right panels). Largest wind vector in left panels is 0.6 m/s. and in right panels is 0.1 m/s.

Fig.3: Model simulations’ composite anomalies of 850 hPa wind (m/s) and OLR (W/m<sup>2</sup>) for the five mega-droughts (totally 84 years) of the past millennium from (a) the ECHAM5/MPIOM and (b) the GISS-E2-R model. Largest wind vector in (a) is 0.33 m/s and in (b) is 1.02 m/s.

Fig.4: PC1 of PDSI derived from the two ensemble members of the GISS-E2-R (dashed lines) along with their smoothed trends (solid lines). The Pearson correlation between the trends is 0.61 with p-value = 0.01.

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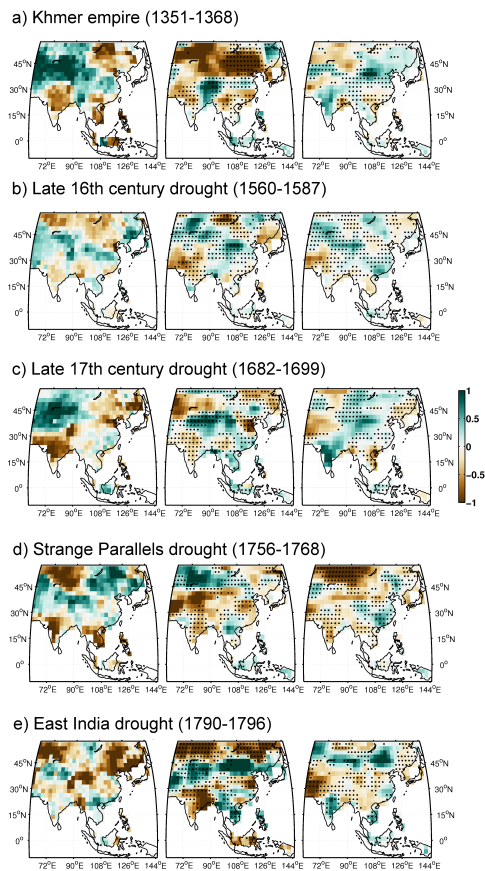
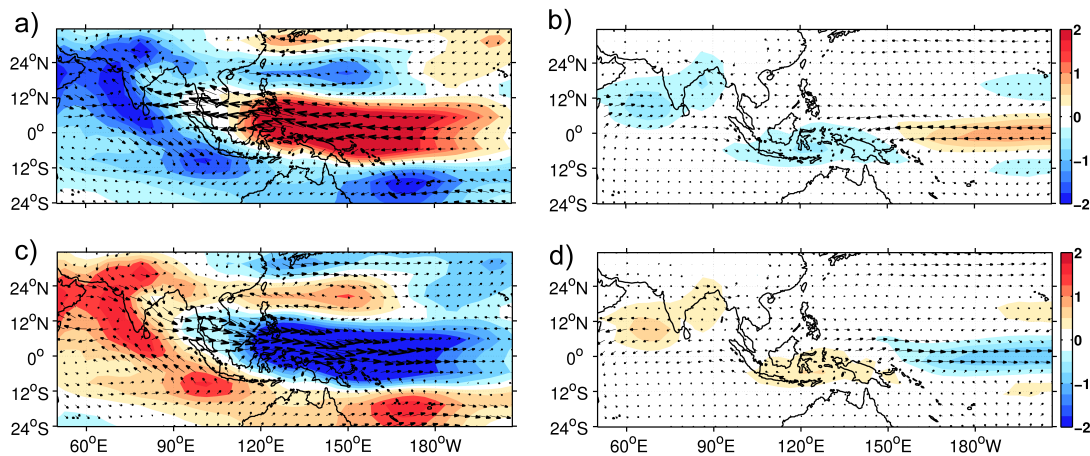


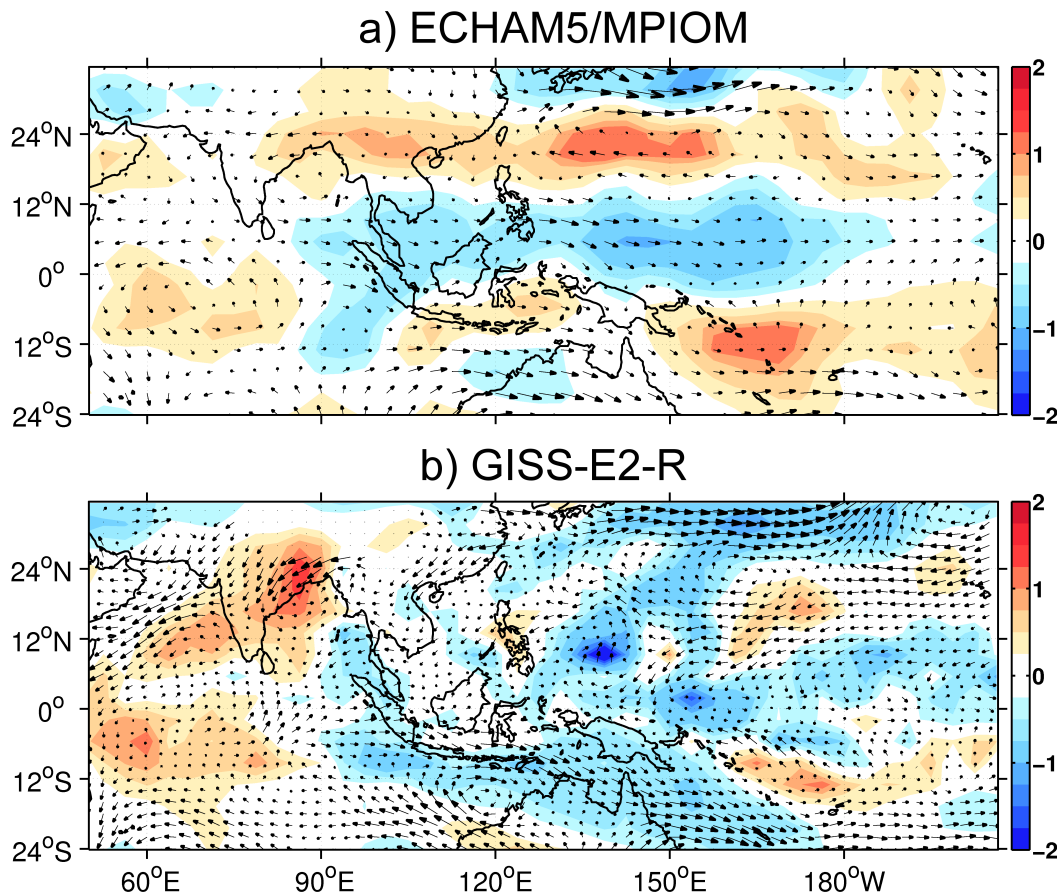
Fig. 1. Drought patterns





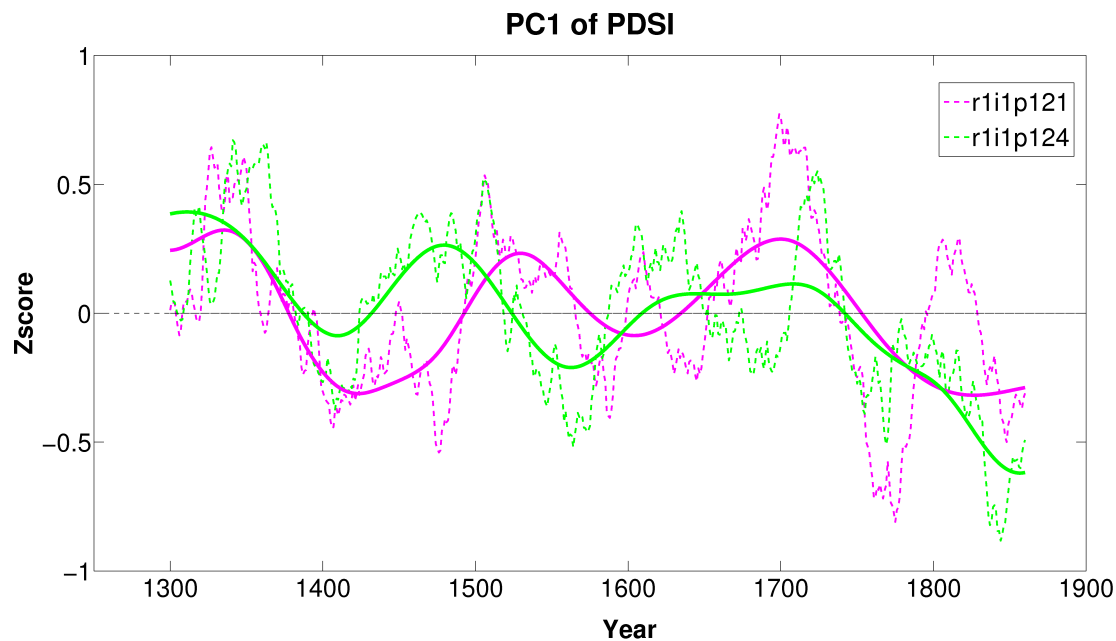
**Fig. 2.** Model simulations' composite anomalies of 850 hPa wind (m/s) and OLR (W/m<sup>2</sup>)

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**Fig. 3.** Model simulations' composite anomalies of 850 hPa wind (m/s) and OLR (W/m<sup>2</sup>) for the five mega-droughts

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**Fig. 4.** PC1 of PDSI derived from the two ensemble members of the GISS-E2-R

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