

Interactive comment on “The evolution of sub-monsoon systems in the Afro-Asian monsoon region during the Holocene – comparison of different transient climate model simulations” by A. Dallmeyer et al.

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R2: “Monsoon precipitation has strong seasonality and usually it is the summer precipitation that is used to discuss the monsoon variations and to indicate the monsoon intensity. In this paper, the annual mean precipitation over different monsoon regions is used to make several conclusions (for example sections 3.2.1 and 3.4). Using annual mean would smooth out the seasonal signal and might lead to totally different conclusion especially for the region where the seasonal contrast is large like East Asia.

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“Moreover, Fig6 shows that contrary to the pollen data reconstructions, most of the models simulate less annual mean precipitation at 6k over East Asia. The model-data comparison would be better if summer precipitation is used. “

“The same remains for the correlation between different monsoon regions. I would recommend the authors to revisit at least their conclusions which were drawn from sections 3.2.1, 3.4, 4.2 and 4.3.1 by doing the same analysis but with summer precipitation to see if the same conclusions are still obtained.”

A: We agree to all these points. The rainfall in monsoon regions has a strong seasonality. In most monsoon regions, annual precipitation is dominated by summer monsoon precipitation (e.g up to 80% in the Indian monsoon). The only exception is Eastern Asia, where approx. 30% of the annual rainfall already falls during spring. Spring precipitation is decreased during mid-Holocene balancing the increase in summer monsoon precipitation at 6k. Therefore, annual precipitation is decreased at mid-Holocene in most models. Since most reconstructions (e.g. based on pollen data) are rather indicative of precipitation accumulated over the year, we decided to use annual precipitation (the synthesis of reconstruction by Bartlein et al. also shows annual precipitation). Nevertheless, we performed the trend and correlation analysis also for ‘summer precipitation’ (May-September). With the exception of the East Asian monsoon region (EASM), the results are not very different (see attached Table 1).

We now write in the method section:

“Precipitation in monsoon regions has a strong seasonality and usually the summer (i.e. June-September) precipitation is taken to analyse changes in the monsoon intensity and to discuss rainfall variations in the monsoon regions. We decided to use annual precipitation because we also include the East Asian monsoon region in which precipitation is not solely related to the summer season. Here, more than 30% of annual rainfall already falls during the months February-May (c.f. Yihui and Zunja, 2008). Since reconstructions rather indicate annual accumulated rainfall, we do not want to

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exclude the pre-monsoon precipitation in East Asia from our analysis. In all other here considered regions, annual precipitation is highly correlated with summer precipitation. Therefore taking annual rainfall instead of summer rainfall does only slightly affect the results in these regions. Furthermore defining a meaningful time period (in form of months) as summer monsoon season is difficult in palaeo-studies because the summer monsoon season may be variable over the time.”

And in the result section (3.3):

“The seasonal precipitation change indicates that the annual rainfall signals in the African and Indian monsoon region are mostly related to the increased summer monsoon precipitation at 6k. In contrast, the decreased mid-Holocene rainfall in parts of the East Asian monsoon area (c.f. Fig. 6) can not be explained by summer monsoon changes. With the exception of PLASIM, precipitation is increased in most parts of the East Asian monsoon domain during the mid-Holocene summer monsoon season (not shown) revealing that the decrease in precipitation is related to changes in the pre-monsoon season as previously pointed out in Dallmeyer et al. (2013). In this region, the Holocene summer monsoon signal is overcompensated by the pre-monsoon signal. In comparison to the reconstructions of Bartlein et al. (2010) showing increased precipitation in East Asia, COSMOS and ECHO-G may overestimate the decreased pre-monsoon precipitation at 6k.”

R2: “Page2315, Lines 13-16: Averaging over a large area is probably not the only reason for the lack of abrupt changes in the model results. Other reasons might include: only change in insolation has been considered in the model, other factors like ice sheet and vegetation related processes being not active; the proxy-based reconstructions might not reflect only the precipitation change; or the model resolution is not high enough.”

A: We fully agree and add this information to the text: “Abrupt changes such as those recorded in the North African monsoon region can not be seen in the model results,

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but the simulations were performed in a coarse resolution and we chose a relatively large area representing the North African monsoon eventually smoothing out drastic changes. On local scale, abrupt changes might be possible (e.g. Bathiany et al., 2012). Furthermore, important processes such as ice-sheet dynamics or vegetation related processes are not or only partly represented in the models. The proxy-based reconstructions might not reflect only the precipitation change.”

R2: “The seasonal precipitation change over North Africa has been found to follow the insolation gradient between 30N and 30S. Any explanation of why it is so is welcome.”

A: We agree that not presenting an explanation for this relationship is not satisfying. The monsoon systems are very complex and depend on very different processes. We can not infer the reasons for this connection from our simulations. We now add: “The precipitation signal over northern Africa in the model KCM follows the change in interhemispheric insolation gradient (e.g. 30°N-30°S) with a lag time of about one month, probably reflecting the dependence of the monsoon system on the South Atlantic Ocean and the interhemispheric energy gradient.”

R2: “Moreover, this relationship has been found by using the results of three time slices (9k, 6k, 0k). As the authors have the results of several transient simulations, a confirmation of this relationship by using these transient results would also be welcome.”

A: Unfortunately, KCM is the only simulation performed in a comprehensive global climate model that also includes the Early Holocene. The major differences are between 9k and 6k, therefore we predominantly discuss these periods. We do not claim that this relationship is valid for all simulations or for reconstructions. Nevertheless, we analysed the time-slices 6k and 3k of the COSMOS simulation for the precipitation changes in North Africa and the results are not contradictory to the conclusions drawn in this section. In the revised manuscript, we emphasize that these results are only based on one model.

R2: “Page 2320, Lines 28-29: I would be careful to say “The simulated East

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Asian monsoon rainfall signal reveals no clear relationship to the change in insolation ...". First, fig.13 shows clearly that the intensity of the summer precipitation of the northern EASM region is strongly depending on the intensity of summer insolation (9 k is the strongest followed by 6 k and 3k). This result has also been found in other model studies. For example, Yin et al (2014, <http://www.clim-past-discuss.net/10/1025/2014/cpd-10-1025-2014.pdf>) found that the change in insolation has strong impact on summer precipitation in northern China but little in southern China. Second, proxy records in both northern (eg. Sun et al 2006 <http://www.sciencedirect.com/science/article/pii/S0277379105002039>) and southern (Wang et al 2005 cited in this paper) China have shown strong astronomical periodicities, which indicates the impact of insolation on the East Asian monsoon."

A: We fully agree, this sentence is misleading. The strength of the rainfall signal in the East Asian monsoon region is of course controlled by the insolation change. We here mean the change in seasonal rainfall cycle.

We changed the text to: "Besides the strength of the rainfall change and the decreasing precipitation during spring reflecting the Holocene insolation change on the Northern Hemisphere, the simulated change in annual rainfall cycle in the East Asian monsoon region reveals no clear relationship to the seasonal insolation change. This indicates that other factors might also be relevant."

R2: "6 ka simulation has been done by many modelling studies especially by PMIP. The response of different sub-monsoon systems to insolation has also been discussed in some papers. It would be important to compare the results and even conclusions of this paper to these PMIP papers to see if different analytical methods lead to different conclusions. For example, the analysis of Wang et al (2010, <http://www.sciencedirect.com/science/article/pii/S0031018210000465>) shows a warmer and wetter summer in East Asian at 6k."

A: We agree. Since we performed the analysis based on annual precipitation, we can

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not compare the results directly with the PMIP studies, which usually use summer precipitation for comparison with reconstructions. With the exception of PLASIM, the models considered in this study as show wetter mid-Holocene summer climate in East Asia, but the spring precipitation is strongly decreased. Therefore the annual mean precipitation is decreased during mid-Holocene in these simulations.

We add this point in section 4.1 (Performance of the model): “The simulated mid-Holocene climate agrees well with results from other global climate modelling studies, e.g. the analyses undertaken within the Paleoclimate Modelling Intercomparison Project (PMIP, e.g. Zhao and Harrison, 2011, Wang et al, 2010) showing generally a wetter mid-Holocene summer climate in the boreal monsoon regions. With the exception of PLASIM all here considered models simulate an increase in summer precipitation within the Afro-Asian monsoon domain (not shown) leading to an increased annual precipitation in most monsoon sub-regions. This is also in line with reconstructions. Only in eastern Asia, annual rainfall is decreased during mid-Holocene in nearly all simulations, disagreeing to the reconstructed precipitation from cave records in this domain (c.f section 4.2). In all regions the amplitude of precipitation change is too weak compared to reconstructions. This result is also shown in other model intercomparison studies (e.g. PMIP, Zhao and Harrison). It is possible, that reconstructions may overestimate the Holocene precipitation change as there is some degree of uncertainty in the reconstructions. “

R2: “Conclusion section should be more concise.”

A: We restructured the Summary and Conclusion section and hope that this form highlights our conclusion more.

Please also note the supplement to this comment:

<http://www.clim-past-discuss.net/10/C1619/2014/cpd-10-C1619-2014-supplement.pdf>

Interactive comment on Clim. Past Discuss., 10, 2293, 2014.

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