

Interactive comment on “Holocene biome changes in Asia – an analysis of different transient Earth system model simulations” by Anne Dallmeyer et al.

Anne Dallmeyer et al.

anne.dallmeyer@mpimet.mpg.de

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Referee #2 (R2)

Major comments:

R2: "A clearer explanation of the rationale of the methods is needed: What's the resolution of BIOME4? Although we could speculate the resolution of BIOME4 in this study is 0.5x0.5 degree according to the resolution of CRU TS3.1, it should be better if the author could state this clearly and explain why 0.5x0.5 degree is sufficient? Would higher resolution of BIOME4 be beneficial? "

A: We agree, this is poorly explained in the manuscript. The resolution of BIOME4

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depends on the resolution of the input data. The resolution of CRU TS3.10 is $0.5 \times 0.5^\circ$. This is the best and highest resolved dataset that is available. We now write in Ch.2.2: "Furthermore, the CRU TS3.10 data is provided in relatively high spatial resolution of $0.5^\circ \times 0.5^\circ$, resolving the climate gradients along the complex Asian orography better than the Global climate model simulations."

R2: "It is said that "The differences between the monthly mean climatologies (long-term averages of 120 years) simulated for each time-slice and the simulated pre-industrial climate have been added to the reference dataset. " How do authors calculate the difference? Is it absolute difference or relative difference? Do the author use the same methods for all the climate variables ? "

A: It is the absolute difference between the climate of each time-slice and the pre-industrial climate (e.g.6k-0k). We use the same method for all simulations and for all climate variabilities. We added 'absolute' to this cited sentence.

R2: "Some of the ESMs used in the study also include dynamic vegetation (e.g., COSMOS, COSMOSacc, and PLASIM). Have the authors checked how the vegetation changes in these fully couple runs? Are they consistent with the offline simulations using BIOME4? "

A: We tested the consistency for the COSMOS simulation and it appears that in principle, the tendencies of less desert and more grassland and forested area in the desert-steppe-forest transition zone during 6k and more forest in the northern latitudes are the same. However, the vegetation in COSMOS (and also in the other vegetation models) is described in form of few plant functional type fractions whose distribution is not directly comparable with the different biomes. Changes in vegetation are given in changes in cover fraction, only, and not from one vegetation type to another. Construction of a matrix for direct comparison between different vegetation types and biomes used in different models is subject of an ongoing project which, however, is not yet finished.

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R2: "BIOME4 simulations using output from COSMOS and COSMOSacc seem to exhibit the largest difference between mid-Holocene and present day. Is this partially related to the fact that vegetation feedbacks have been included in COSMOS and COSMOSacc runs? "

A: This is a very interesting question, but to assess the role of vegetation feedbacks in the mid-Holocene to pre-industrial climate change, sensitivity experiments have to be undertaken. For the COSMOS model, we have analysed this on the basis of simulations with similar setup as in this study (the 6k simulation is the same) for the Asian monsoon region (cf. Dallmeyer et al., 2010: Contribution of oceanic and vegetation feedbacks to Holocene climate change in monsoonal Asia, *Clim. Past*, 6, 195–218, doi:10.5194/cp-6-195-2010.) Interactive vegetation in the COSMOS model has a negligible effect on the precipitation change in the desert-steppe-forest-transition zone, but contributes to the warmer mid-Holocene climate in the high northern latitudes, but for the high northern latitudes interactive ocean has a much stronger impact. We add this information in the Discussion (ll. 428-435; see also comment to Referee #1).

R2: "I suggest more discussion on the temporal variation of Asian vegetation in the proxy and in the model, which is one of the key aspects in this study. The decline of forest biome from 6k to 0k in Daihai record can be related human activity. The author should separate possible human induced changes from climate driven changes so as to better compare with the model results which is purely climate driven changes. For instance, based on Figure 11, the proxy record implies a strong decline of forest biome from 3500 to 2500 BP in Daihai. Can this be caused by human activity? "

A: Human interference cannot be excluded at this site, but archaeological investigation rather show cultural remains from mid-Holocene warm and humid period, disappearing from Daihai Lake region when the climate has become worse (4300 cal years ago, see Xiao et al., 2004 and references therein). Thus, the forest decline at Lake Daihai may probably results from climate change. Though human impact may have affected local vegetation change since the mid-Holocene in Eastern and Central Asia, overall climate

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is assumed to be the major driver of forest decline (e.g. Wang et al., 2010, Cao et al. 2015, Tian et al. 2016) We added to the manuscript: "Human interference cannot be excluded at this site (cf. Xiao et al., 2004), but may have affected vegetation change since the mid-Holocene rather locally. In Eastern and Central Asia, overall climate is assumed to be the major driver of forest decline (e.g. Wang et al., 2010, Cao et al., 2015, Tian et al. 2016)"

R2: "The potential linkage of vegetation changes between the monsoon region and the Arctic region. From mid-Holocene to present, a southward shift of forest-tundra boundary in the Arctic (colder Arctic) corresponds to a eastward shift of desert-steppe-forest boundary in the transitional monsoon region (weaker East Asian summer monsoon). Does this relation between Arctic and monsoon vegetation change also exist in a shorter time scale in both proxy and the model results? "

A: The temporal resolution of the model simulation is not high enough to appropriately analyse this link. Further simulations have to be done to investigate this, but this is not part of this study.

R2: "Why the temporal changes of vegetation from 6k to 0k is non-linear in both proxy and model results? Does this related to orbital forcing or internal feedbacks? "

A: To disentangle the climate response to the orbital forcing and to internal feedbacks further sensitivity simulations have to be undertaken, which is beyond the scope of our study.

R2: "The shift of desert-steppe-forest boundary in the transitional monsoon region is shown to be linked to precipitation changes in this region, but is it also linked to East Asian summer monsoon strength? It would be interesting to see if the shift of desert-steppe-forest boundary is in line with the changes of the East Asian summer monsoon strength from 6k to 0k."

A: We studied the evolution of different monsoon sub-system in another paper using

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the same set of climate model simulations (cf.:Dallmeyer et al., 2015).

Specific comments:

R2: "Introduction: An introduction of existing vegetation simulations for the mid-Holocene in Asia may be useful."

A: We agree, an overview of other vegetation simulations for mid-Holocene is interesting, but it is not necessary for the understanding of our manuscript. Therefore, we decided to leave it out and keep the Introduction 'short'.

R2: "Line 200: "medium" should be "intermediate" "

A: In principle, the reviewer is right. PLASIM is considered an Earth system model of intermediate complexity (EMIC), as the authors put their model in the Table of EMICs. We kept "medium", however, as this is the term the authors of PLASIM used in the paper cited.

R2: "Line 277-278: Why cold season temperature decrease in the tropical region in mid-Holocene? "

A: This is probably related to the orbital forcing revealing less winter insolation during mid-Holocene compared to present day.

R2: "Line 327-329: rephrase the sentence to be clearer: Should "westward of 118" be "eastward of 118"? "

A: Yes, it should be eastward. We changed it.

R2: "Line 342, Line770: "Fig.D" does not exist? "

A: Thank you, it is Fig. B3.

R2: "Line 418-419: references need to be added for the statement"

A: We fully agree, and added references to both statements (ll 452-453).

R2: "Summary and Conclusion: can be shortened."

A: We split up the Summary and Conclusion into 2 Chapter.

R2: "Table 3: Please add information on whether the models use dynamic vegetation"

A: done.

R2: "Figure1: Please explain the rational for the lightblue line in the figure? How do you define the extent of the Asian monsoon region? Please specify which climate dataset or reference the summer circulation at 850 hPa in the figure is based on? The sketch of the summer circulation may be oversimplified and thus misleading to the reader.

A: "We use the summer (JJA) mean precipitation isohyet of 2mm/day as definition of the Asian (summer) monsoon region. The sketch is based on observations and reanalysis data (GPCP: for precipitation, ERA40 for wind vectors)." We added this information to the caption.

R2: "Figure2: Why there is no vegetation cover over India and South East Asia in the reference map? Please explain."

A: We translated the dataset that where available for us, unfortunately, a dataset for India and South East Asia was not available.

R2: "Figure6,7,8,9,10: Please use different color or line type to represent each individual simulations."

A: It was not the aim of our study to find the "best" model with respect to the Holocene climate or biome change in Asia. We wanted to present a range of possible changes. Therefore we decided not to represent the individual models separately in the climate discussion.

R2: "Figure9: While the caption says (a) is absolute difference in annual mean temperature, the figure title of (a) have unit "% " suggesting relative difference? Which one is

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true? “

A: Thank you very much for this hint, it is indeed the absolute difference in temperature, we corrected it in the Figure.

R2: "Figure11: The label of time axis is better to be consistent with previous figures (using minus values for year?). It would be better if each individual simulation can be shown in the figure to see which simulation is in the best agreement with the proxy data."

A: We changed the label of the time axis. It was not the aim of our study to find the "best" model. Therefore we decided not to present the individual models separately.

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