

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

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Referee #3 (R3)

R3: "In order to simulate biomes in Asia, the authors use a slightly modified BIOME4 equilibrium vegetation model. As a result, most of the results depend on the BIOME4 model.

A: We fully agree, the results depend on the BIOME4 model, but many processes that are included in BIOME4 are implemented in a similar, albeit more complex way, in other vegetation models (e.g. the bioclimatic limits). The variance in the results is received by using (very) different climate input data.

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R3: "Although the authors slightly modified and recalibrated the BIOME4 model for pre-industrial CO<sub>2</sub> concentration (280 ppm), readers may not understand how to validate the model. Therefore, the authors need to validate the modified BIOME4 model performance quantitatively. I think this is a key process for this study because your study really depends on the vegetation model. "

A: We fully agree, and add a figure in the Appendix showing the 0k reference simulation performed in the modified BIOME4 model and the original BIOME4 model (Fig. A2). Furthermore, we add to the end of Ch2.1 (BIOME4 model description): "The difference between the modified and original BIOME4 model can be seen in the Appendix (Fig. A2) based on the 0k reference simulation and the ensemble mean 6k simulation (including comparison with reconstructions)."

R3: "Moreover, if possible, the authors should use more than one model in order to reduce the dependence of the results on the choice of vegetation model."

A: We agree, that our results are model depending, but unfortunately the variety of vegetation models that are suitable for calculating the mid-Holocene to pre-industrial biome change is small. Other biome models are less complex, and results of vegetations models calculating PFT fractions only would have had to be translated into Biomes, a process that could be an additional source of errors. Therefore, we decided to use BIOME4. Furthermore, BIOME4 has the advantage of needing only few climate variables as forcing.

R3: "The authors select one pollen-based biome reconstruction for each target transition zone, but the data does not represent sufficiently the feature of the large regions. Therefore, if possible, the authors should use more than one data for the target regions. You might download more pollen data from Neotoma database (<http://www.neotomadb.org>)."

A: High quality data is quite few. For the desert-steppe-transition zone no record is available in the Neotoma database at all. Therefore, we decided to select from all

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(for us) available records in the target-regions the record, that shows the best quality with respect to dating and data and that is additionally representative for the regional vegetation changes, as inferred from comparison to literature results. The general vegetation trend indicated by the Dahai record is in line with other records in North central China (cf. Zhao et al, 2009) and the 13-CH-12 record agrees with the other records from the northern Siberian tree line area. We also mention this in the main text, and add the information to the methods section (2.5): "For comparison, representative, high quality (with respect to dating and the data) pollen records covering the last 6000 years have been chosen. For the taiga-tundra-transition zone, a record from a small lake located on the southern Taymyr Peninsula (technical name: 13-CH-12; Klemm et al., 2016) is used, that is in line with the vegetation trend seen at other records located at the Siberian treeline (Pisaric et al., 2000, McDonald et al., 2000, Bigelow et al., 2003). The biome change in the forest-steppe-transition zone is reflected by the record from Daihai Lake in Inner Mongolia (China, 40.5°N; 112.5°E, 1225 m a.s.l.; Xu et al., 2010) that is in line with other records in north central China (Zhao et al., 2009 and references therein)."

#### Specific comments

R3: "L 1. The title might be a little vague for me because your target period is during the last 6000 years, not the entire Holocene."

A: We agree, and changed the title to: Biome changes in Asia since the mid-Holocene – an analysis of different transient Earth system model simulations

R3: "L 31. "since the mid-Holocene"? for "during the Holocene". Your study focuses on the changes in climate and vegetation over the last 6000 years, not the entire Holocene."

A: We changed this.

R3: "L 41. "during the Holocene", As mentioned before, do you check the entire

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Holocene? “

A: done. No, unfortunately most of the simulation do not capture the entire Holocene. Therefore, we decided to start at 6k.

R3: "L 80. How many plant functional types (PFTs) do we need to describe the vegetation in Asia? How many PFTs are used in the current Earth System models; Does BIOME4 vegetation model have enough PFTs for the aim? "

A: This is indeed a good question. The current Earth System models uses 2-10 natural PFTs (in the interactive mode), it depends on the model. BIOME4 uses 13 different PFTs. The description of tree-PFTs is similar to other vegetation models, but the advantage of BIOME4 is, that it includes several PFTs representing arctic vegetation (e.g. tundra shrubs, cold herbaceous, lichen/forb) that are only partly considered in the dynamic vegetation models.

R3: "L 91. Why do you choose BIOME4 vegetation model? Can you choose other vegetation model(s) in this study?

A: "Since reconstructions are often presented on taxa or biome level, a biome model is most appropriate for the aim of our study. Other biome models are less complex, so we decided to use BIOME4.

R3: "L 115. “280 ppm” for “280ppm” “

A: done.

R3: "L 115-129. How do you calibrate and validate the BIOME4 model for pre-industrial CO2 concentration (280 ppm)? You should show the modified BIOME4 model performance quantitatively using the any data/observations. I do not know whether the model works better or not in the Figure 2, map-map comparison.

A: We agree, and add a figure in the Appendix showing the 0k reference simulation performed in the modified BIOME4 model and the original BIOME4 model (see comment

above).

R3: "L 123. "1200 C" for "1200C" "

A: done.

R3: "L 125. "280 ppm" for "280ppm" "

A: done.

R3: "L 126. "CRU TS3.10" for "CRU TS3.1"; why don't you use a newer reference climate data (e.g., CRU TS3.21 or TS3.22)?"

A: done. Since we only use the years 1960-2000, it does not matter, which CRU dataset we choose. The data for these years is supposed to be the same in all CRU-datasets.

R3: "L 132. "0 ka" or "0 ka BP" for "0k" because of the consistent abbreviation between model and data(?) "

A: '0k' in the model and '0 cal ka BP' is not the same, so we keep the abbreviation, but added a notice on this in the method section: Please notice, that the pollen reconstructions are dated in calibrated years before present, i.e. before the year 1950 AD (cal. ka BP), thus the time-step 0 cal. ka BP is not identical with the time-slice '0k' used in the modelling result (i.e. a mean of 120 years).

R3: "L 135-139. As mention before, you have to show your modified BIOME4 model performance quantitatively. Compared to the original BIOME4 model, does your BIOME4 model simulate a better biome distribution in Asia? Why don't you use BIOME 6000 data for your model validation? "

A: We agree, and add a figure in the Appendix showing the 0k reference simulation performed in the modified BIOME4 model and the original BIOME4 model (see comment above). We are currently preparing a new synthesis of Palaeovegetation change in Asia, which will also be biomised (for China cf. Ni et al., 2014: Biome distribution over the last 22,000 yr in China, doi:10.1016/j.palaeo.2014.04.023). We will compare

updated versions of these proxy datasets with vegetation model results in a follow-up manuscript. Since we agree, that a spatial comparison of our model results and the BIOME6000 data will improve the reliability of our results, we add a figure, showing the ensemble mean 6k simulation in the original and the modified model in the Appendix (Figure A2).

R3: "L 165. "6000 years ago, 6 ka" for "6000 years before present (henceforth referred to as 6k)" or "6 ka BP" for "6k" because of the consistent abbreviation between model and data (?)"

A: We kept the term '6000 years before present', because this is commonly used in climate modelling studies.

R3: "L 226. "The simulated biomes"? for "the model-based biome reconstructions"

A: done.

R3: "L 241. You should evaluate the mid-Holocene biome distribution using BIOME 6000 data in Asia because we do not know your model results are consistent with observed data or not."

A: Please, see above.

R3: "L 243-261. How do you choose the target regions (95-125E, 32-52N) and (60-180E, 15-80N)? I mean Figure 3 also show large vegetation changes occur at eastern Siberia (tundra vs. taiga) and west-central Asia (60-80E, 50-60N; grassland vs. cool/cold forest)."

A: We agree, this is not explained in the text. We now write in Ch.2.5: "The simulated biomes were evaluated for key biome transition areas showing the strongest biome change in the model ensemble, i.e. the taiga-tundra transition zone in the high northern latitudes and the forest-steppe-desert-transition zone in north-central China. Since the model fails to appropriately represent modern biome distribution in eastern Siberia (cf. Fig.2), the taiga-tundra key transition zone was confined to the north-central Siberian

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region. For comparison, representative pollen records covering the last 6000 years have been chosen...“ In the west-central Asian region, the biome model results also deviate strongly from the reference.

R3: "L 254. If possible I would like to see the Figure 4 information using the 0 ka simulated biomes and reference data. Which is a larger differences of biomes between 6 ka/ vs. 0 ka and 0 ka vs. reference data? “

A: Comparing 6ka vs 0ka with 0ka vs reference data is possible, but one can not draw any conclusion from this exercise. The Asian orography is very complex and is only poorly resolved in Earth System models ( $3.75^\circ$  on a Gaussian grid). For instance, the Tibetan Plateau is a small 'hill' reaching 4000m in a few grid-boxes, only. The approach of using climate anomalies has the advantage of preserving regional climate pattern that are an imprint of the orography. With this approach, we can use a much finer resolution ( $0.5^\circ$ ), the resolution of the reference dataset. The difference between 0ka and the reference data might be of similar magnitude as the 6ka-0ka difference, but this is to a large part related to the differences in resolution.

R3: "L 271-272. The results from the sensitivity experiments show the real vegetation response or just BIOME4 response? If we use different vegetation models, do we get different results, for example cloud cover is a key factor of vegetation changes (it is opposite to L 275)? Nemani et al. (2003, Science) also shows the similar results about geographic distribution of potential climatic constraints to plant growth.“

A: This is an interesting question. Our results show the response of the BIOME4 model, but the temperature limitation of vegetation in the high northern latitudes and moisture limitation in steppe-desert transition zones are in line with observations and other studies, so, we think that the main results will not change when using other vegetation models.

R3: "L 357. About Figure 11, less/more what? What does the x-axis shows, fractional changes in biome or ...? “

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A: As mentioned in the Figure caption, the reconstructions are given in arbitrary units. We now write: "The reconstructions are given in arbitrary units and show the dominant biome at a certain time and the trend qualitatively (i.e. less or more dominant than other biomes)"

R3: "L 357. Why do you use only two reconstructions? Can you use more pollen data from Neotoma database (<http://www.neotomadb.org>)? "

A: Comparing the simulated biome distributions with (spatial) reconstructions is not the main aim of this study. We are currently preparing a new synthesis of Palaeovegetation change in Asia, which will also be biomised (for China cf. Ni et al., 2014: Biome distribution over the last 22,000 yr in China, doi:10.1016/j.palaeo.2014.04.023). We will compare these datasets with vegetation model results in a follow-up manuscript. We further specify the main aims of this study in the introduction: "The main aims of this study are: a) to get a consistent ensemble of possible changes in biome distribution since the mid-Holocene, b) to test the robustness of the simulated vegetation changes and quantify the differences among the models, i.e. to assess how large the vegetation variability is that results from different climate forcings, and c) to compare simulated vegetation changes in selected key regions with pollen-based reconstructions."

R3: "L371. "The overall change in biome composition since the mid-Holocene"? for "The overall change in the Holocene biome composition" "

A: done.

R3: "L 380-383. You should consider the vegetation model deficits too. Your results really depend on BIOME4 vegetation model."

A: We fully agree, that the results depend on the BIOME4 model. The discussion of the Biome4 model deficits are included in the discussion of the reference simulation (Ch. 2.2).

R3: "L 398. "Local"? for "regional" "

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A: done.

R3: "L 405-412. Even if vegetation reconstructions for Asia are sparse, you should use available data (i.e. BIOME 6000 data) for your simulated biomes at the pre-industrial and mid-Holocene first."

A: See comments above, done for mid-Holocene in the Appendix.

R3: "L 410-412. Please put any references."

A: done.

R3: "L 431. Your simulations focus on the last 6000 years, not "during the Holocene" "

A: done.

R3: "L 439. "500 years" for "500years" "

A: done.

R3: "L 496. "More pollen records are needed to evaluate the simulated results." I understand your argument, but please use available dataset and show us the results first."

A: We see the point. We further specify this statement to: "More pollen records are needed to evaluate the simulated results, particularly in the desert-steppe transition zone."

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