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Interactive comment

Interactive comment on "Mid-Holocene climate change over China: model-data discrepancy" *by* Yating Lin et al.

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We greatly appreciate the constructive comments and suggestions on the previous version of the manuscript from Reviewer #2. We have attempted to address every point raised. The following is the outline of the changes we have made, with reference to the order of the comments made by the referee.

Comments from Reviewer #2: Data-model comparison is often problematic especially at regional scale, for which there are many reasons. This paper presents an interesting analysis to investigate the possible impact of poor representation of vegetation in climate models on the model-data discrepancy over China. The authors compare the PMIP3 results with their "reconstruction" and propose that lack of vegetation dynamics is the main reason of model-data discrepancy in seasonal climate over China. The results are clearly explained and the paper is well written. Especially, a large amount of data are presented and would be a remarkable contribution to the Holocene study. I would recommend its publication after the following comments are considered: 1. At least to my knowledge, regional diversity exists inside China regarding the timing of the mid-Holocene thermal maximum. However, the insolation of 6 ka BP is used in the PMIP3 simulations. In which degree might the model-data discrepancy be related to the forcing used in the climate models? Have the authors compared their reconstructions to simulations of other periods like 9 ka and 12 ka or to transient simulations to see whether the data-model comparison can be improved if different forcing is considered?

RE: Yes, there is a regional diversity exists over China regarding the timing of mid-Holocene thermal maximum (from ∼8 ka to 4 ka). But our paper is focused on mid-Holocene time (defined as 6 ka in PMIP), not MH thermal maximum, and we also selected the pollen data at 6±0.5 ka. So for us, in term of the consistency in time, it's better to do a model-data comparison with the 6 ka isolation forcing used in PMIP3, rather than 9 ka or 12 ka. For the transient simulation, Liu et al.(2014) analyzed the model results from 22 ka in three coupled ocean-atmosphere models: CCSM3, FAMOUS and LOVECLIM. It turns out that all three models reproduced a colder than present annual mean temperature during Holocene, no matter at 12 ka, 9 ka or 6 ka, which is consistent with our results. And we agree with the reviewer that 9 ka and 12 ka are also very important periods to understand the mechanism of climate change during MH, we plan to do these comparison in the future work.

Comment: One way to test the proposal of the authors would be prescribing the reconstructed vegetation in a climate model to see how the model results would be altered and whether the model would reproduce more realistic results when compare to other proxy data.

RE: We agree with the reviewer, it's a very efficient way to test our proposal if we can run the simulation with the reconstructed vegetation in GCM. However, as far as we know, prescribing the vegetation in a coupled GCM is not easy. Moreover, the GCM models in PMIP3 have their own vegetation module, it definitely takes much time to do such test, that's why in this paper we choose BIOME4 to evaluate MH vegetation simulation against the reconstructed result. Although we can't prescribe the MH vegetation with our reconstructed results in all PMIP3 models, we succeeded to conduct such test in CESM version 1.0.5. This version, developed at the National Center for Atmospheric Research, is a widely used coupled model with dynamic atmosphere (CAM4), land (CLM4), ocean (POP2), and sea-ice (CICE4) components (Gent et al., 2011). Here, we use $\sim 2^{\circ}$ resolution for the CAM4, configured by $\sim 1.9^{\circ}$ (latitude) $\times$ 2.5° (longitude) in the horizontal direction and 26 layers in the vertical direction. The POP2 adopts a finer grid, with a nominal 1° horizontal resolutions and 60 layers in the vertical direction. The land and sea-ice components have the same horizontal grids as the atmosphere and ocean components, respectively. Two experiments were conducted, including a mid-Holocene (MH) experiment (6 ka) with original vegetation setting (prescribed as PI vegetation for MH) and a MH experiment with reconstructed vegetation (6 ka_VEG). In detail, experiment 6 ka used the MH orbital parameters (Eccentricity=0.018682; Obliquity=24.105°; Angular precession=0.87°) and modern vegetation (Salzmann et al., 2008). Compared to experiment 6 ka, experiment 6 ka_VEG used our reconstructed vegetation in China. Except for the changed vegetation, all other boundary conditions were kept unchanged in these two experiments, including the solar constant (1365 W m$-$2), modern topography and ice sheet, and pre-industrial greenhouse gases (CO_2 = 280 ppmv; CH_4 = 760 ppbv; N_2O = 270 ppbv). Experiment 6 ka was initiated from the default pre-industrial simulation and run for 500 model years. Experiment 6 ka_VEG was initiated from model year 301 of experiment 6 ka and run for another 200 model years. We analyzed the computed climatological means of the last 50 model years from each experiment here. Fig. 1 (enclosed below, labeled as Fig. 8 in the new manuscript) shows the climate anomalies between two simulations (6 ka_VEG minus 6 ka), for both annual and seasonal scale. For temperature, it's clear that the 6 ka_VEG simulation reproduces the warmer annual (~0.3 K for grid mean) and winter temperature (~0.6 K for grid mean), especially the winter temperature. For precipitation, the reconstructed vegetation leads to higher annual and seasonal precipitation, which can also reconcile the discrepancy of increase amplitude for precipitation during MH between model-data (data reproduced larger amplitude than model, revealed by our study). So it's true that the mismatch between model-data in MH vegetation has significant influence on the discrepancy of climate, this is consistent with our proposal in this study. Each model has different sensitivity to the boundary change, further work should be carried out in more models to test the influence of vegetation on climate, this is an ongoing work. This response is on pages 16-17, lines 382-400 in the revised version.

2. The spatial resolution of all the GCMS is very coarse when regional diversity within China is considered. The regional details of topography are not necessarily well represented. I wonder in which degree the model-data mismatch is related to rough topography used in the climate models.

RE: Thanks for the important comment, yes, we should consider the possible influence of rough topography on the model-data discrepancy, especially the Tibetan Plateau (TP). Numerical simulations had been widely utilized to investigate the climate response of the uplift of TP, and it is also indicated by previous studies that most of the experiments use coarse resolution GCMs have deficiency in describing the small-scale topography and hence climate (Wang et al., 2005; Gao et al., 2008; Jiang et al., 2016). In PMIP3, the topography for mid-Holocene is same as CMIP5 PI, and thus, each model has the same topography boundary for both MH and PI, the difference between them concerning the topography is the interpolation due to their different resolutions. Among the 13 models used in this paper, MRI-CGCM3 has the highest resolution (Atmosphere: 320*160*L48; Ocean: 364*368*L51), while IPSL-CM5A-LR has the lowest one (Atmosphere: 96*96*L39; Ocean: 182*149*L31). The possible influence of topography on the model-data mismatch captured in our study could be tested from two points: Firstly, for the model with high resolution. In Fig. 2 (enclosed below), we give the actual modern orography and the interpolated orography used in MRI-CGCM3 and IPSL-CM5A-LR. For MRI-CGCM3, the topography is very close to the observation, so for this model, the model-data discrepancy during MH over China is not related to rough topography.

Secondly, for the model with course resolution. When we compare the topography of observation and that used in IPSL-CM5A-LR, it's true that the course version of model will lead to biases in topography when the regional diversity is discussed. To quantify such influence, we compare the results of IPSL-CM5A-LR and IPSL-CM5A-MR (Fig. 3). The difference in topography caused by model resolution has influence on some small regional climate, but no significant change for general pattern.

3. Line 372: the authors consider the poor capacity of vegetation modelling in climate models to be the major reason for model-data discrepancy. Before the author test for other reasons like those related to topography, soil types, selected climate forcing, I am not very convinced that vegetation is the major reason.

RE: For the selected climate forcing and topography, we have already gave the answer above (in question 1 and question 3). For soil type, to our knowledge, there is no relative research to quantify the soil type effect on climate over China during MH. But it's certainly true that soil type change could lead to climate anomaly through surface albedo variation and hydrology processes. For instance, if the bare soil transferred into vegetated soil, the regional climate could be warmer due to the decreased surface albedo. But for the further quantification of this contribution, it will be done in the future work. In this paper, we only focus on the vegetation influence on the model-data discrepancy, and we do present and prove the mismatch between model-data in MH vegetation could partly account for the discrepancy of climate. We don't emphasis that the vegetation influence is the main reason. And according to your suggestion, we add the sentence: "Moreover, besides the vegetation influence, to which extent this model-data discrepancy is related to rough topography, soil type and other possible factors should be investigated in the future work." (on page 17, line 398-400).

4. Two models of 13 use dynamical vegetation model. According to your analyses, is there obvious advantage of using AOV instead of AO?

RE: As we mentioned in the manuscript, only 2 models (HadGEM2-ES and HadGEM2-CC) in PMIP3 has the dynamic vegetation simulation for mid-Holocene. However, the main vegetation changes during MH demonstrated by these two models are very different. HadGEM2-ES simulated increased tree coverage (~15%) and a decreased bare soil fraction (~6%), while HadGEM2-CC depicts a ~3% decrease in tree fraction and a ~1% increase in bare soil (Fig. S9 in supplementary information). We made a rough calculation of albedo variance caused solely by vegetation change for both two models and for our reconstruction, based on the area fraction and albedo value of each vegetation type (Betts, 2000; Bonfils et al., 2001; Oguntunde et al., 2006; Bonan, 2008). Reconstruction showed vegetation changes during MH leading to a ~1.8% decrease in albedo when snow-free, with a much larger impact (~4.2% decrease) when snow-covered. The results from HadGEM2-ES are highly consistent with the albedo changes from the reconstruction, featuring a ~1.4% (~6.5%) decrease without (with) snow, while HadGEM2-CC produces an increased albedo value during MH (~0.22% for snow-free, ~1.9% with snow-cover), depending on its vegetation simulation. The difference in simulating MH vegetation distribution between these two AOVGCM will influence their ability in capturing the climate change during MH. From Fig. 3 in the manuscript, we can see that HadGEM2-ES succeeded to capture the increased annual temperature anomaly (~0.42 K), with relatively higher MTWA and MTCO among models, while HadGEM2-CC showed similar results with other models. In conclusion, according to our analysis, there is an obvious advantage of using AOVGCM instead of AOGCM when we discussing about the MH climate, but the premise is that the AOVGCM can simulate accurate vegetation distribution.

5. Line 36: do you mean "an increase in the seasonal cycle of insolation"?

RE: Thanks for the correction, we mean "an increase in the seasonal cycle of insolation" in Line 36, and that has been modified in the new version of manuscript on page 2 line 40 in revised version.

6. I wonder how the pollen data of PI was collected. Were they collected from the surface? Is there any influence from human activities?

RE: Yes, the pollen data of PI are collected from the surface, but we only choose the sites without or with little influence of human activity. Moreover, our study is focused on the climate reconstruction based on pollen data, so the key point here is that weather can we trust the climate reconstruction if the pollen records are influenced by human activities during PI. To clarify this issue, we have examined the statistical correlations between observed meteorological values and reconstructed climates by inverse vegetation model at the sample sites for PI (Table 6 in manuscript). The regression coefficients are very high (from 0.75 to 0.95), which means that IVM is able to reconstruct the PI climates over China based on the pollen data. In other words, the PI pollen data are reliable to obtain the climate parameters, and the human activity has no significant effect on it.

7. In Figure 3: is the anomaly relative to PI? How was the grid mean value calculated?

RE: Yes, it's the anomaly relative to PI. About the grid mean value, we firstly extract the simulated values at each pollen site, and then calculate the grid mean value in ncl.

8. Line 320: PMIP3

RE: Thanks, we have modified it.

The revised version of manuscript and supplementary information are enclosed below as supplement.zip.

Reference: Wang, B., Ding, Q., Fu, X., Kang, I., Jin, K., Shukla, J., Francisco, D.: Fundamental challenge in simulation and prediction of summer monsoon rainfall, Geophys. Res. Lett, 32, L15711, 2005. Gao, X., Shi, Y., Song, R., Giorgi, F., Wang, Y., Zhang, D.: Reduction of future monsoon precipitation over China: comparison between a high resolution RCM simulation and the driving GCM. Meteorog, Atmos. Phys, 100, 73–86, 2008. Jiang, D., Tian, Z., Liang, X.: Reliability of climate models for China through the IPCC Third to Fifth Assessment Reports, Int. J. Climatol, 36, 1114–1133, 2016. Betts, R. A.: Offset of the potential carbon sink from boreal forestation by decreases in surface albedo, Nature, 408, doi: 10.1038/nature. 35041545, 2000. Bonfils, C., de Noblet-Ducoudré, N, Braconnot, P., and Joussaume, S.: Hot Desert Albedo and Climate Change: Mid-Holocene Monsoon in North Africa, Journal of Climate, 14, 3724–3737, 2001. Bonan, G. B.: Forests and Climate Change: Forcings, Feedbacks, and the Climate Benefits of Forests, Science, 320, 1444-1449, 2008. Oguntunde, P. G., Ajayi, A. E., and Giesen, N.: Tillage and surface moisture effects on bare-soil albedo of a tropical loamy sand, Soil and Tillage Research, 85, 107-114, 2006.

Please also note the supplement to this comment:
https://www.clim-past-discuss.net/cp-2018-145/cp-2018-145-AC3-supplement.zip

Interactive comment on Clim. Past Discuss., https://doi.org/10.5194/cp-2018-145, 2018.

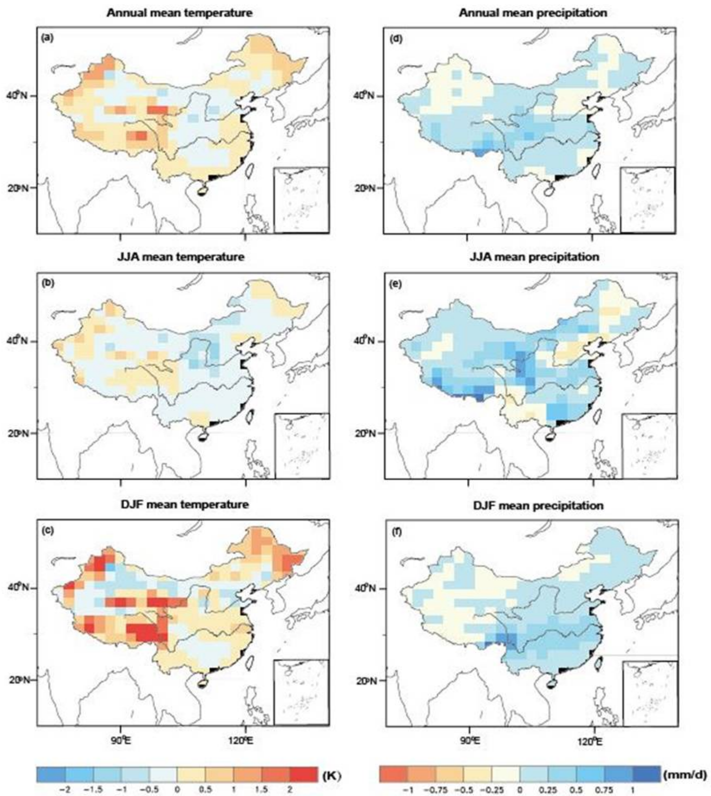

Figure 1. Climate anomalies between the two experiments (6 ka and 6 ka_VEG) conducted in CESM version 1.0.5. The anomalies (6 ka_VEG-6 ka) of temperature and precipitation at both annual and seasonal scale are presented, and all these climate variables are calculated as the last 50-year means from two simulations.

Fig. 1.

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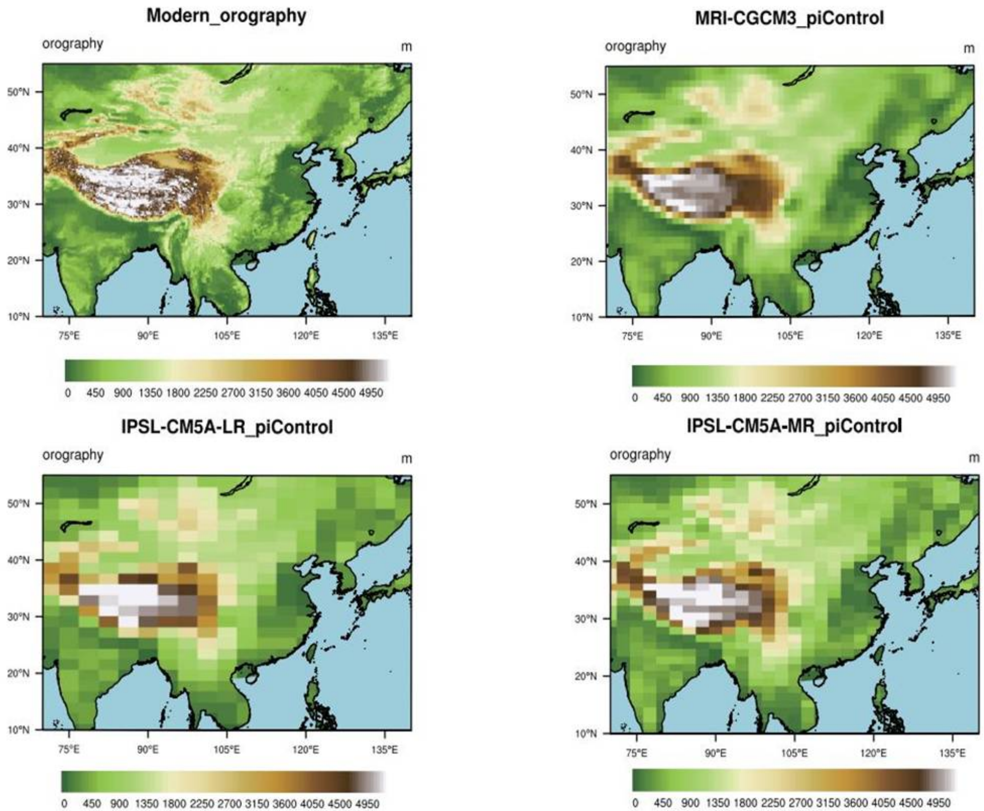

Figure 2. The topography comparison between models and observation

Fig. 2.

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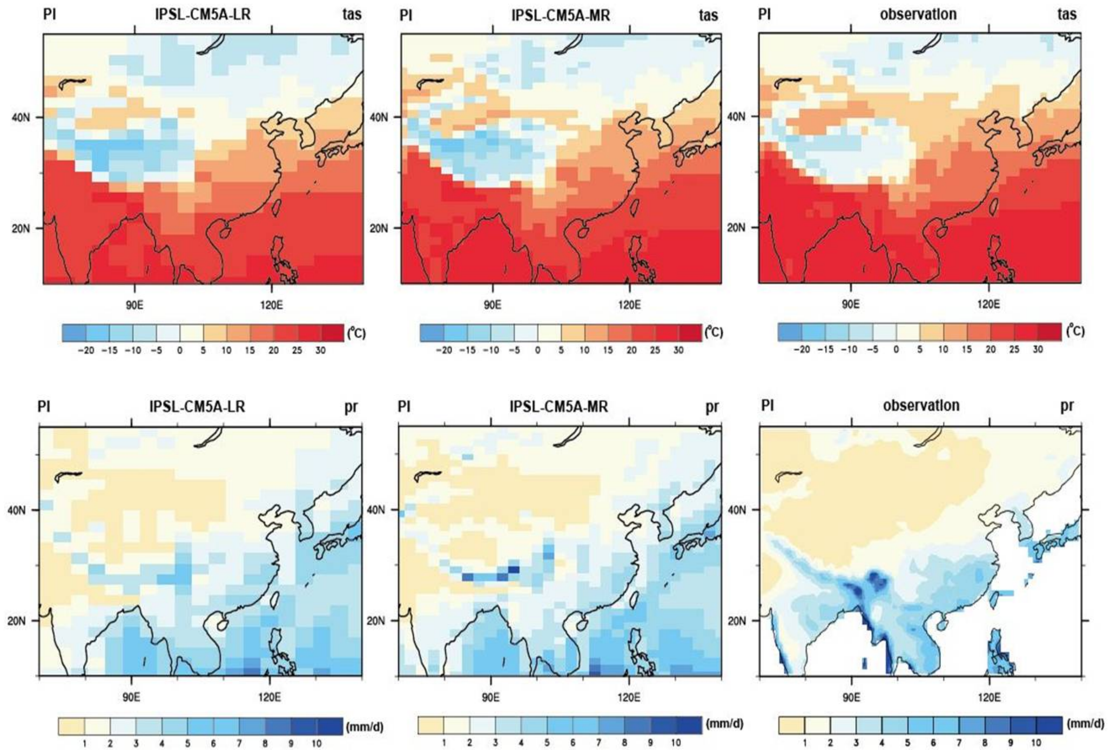

Figure 3. The preindustrial climate comparison between simulation and observation. Tas means temperature above 2m surface, pr means precipitation.

Fig. 3.