Reply to comments by reviewer 1: Exploring Holocene temperature trends and a potential summer bias in simulations and reconstructions (egusphere-2023-86)

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Summary of Changes

We are grateful to the reviewer for evaluating our work, and the valuable and constructive comments that help substantially improve the manuscript. In response, we now

- implement text revisions throughout the manuscript, further detailed below in the response where appropriate
- expand the analysis by adding another simulation from HadCM3 of the Holocene
- expand on the role of the EBM in the analysis by providing and analysing sensitivity experiments; for analysing the role of volcanism we contrast them with an additional available simulation with HadCM3

We want to thank the reviewer again for the comments and suggested improvements of the manuscript. Below, we respond to the reviewer's individual comments in detail and describe the actions we will take to address them. We are convinced that our proposed actions will further improve the scientific value of our study.

Detailed response

(Original report cited in italics)

Reviewer's comment:

The manuscript compares the temperature trends simulated by climate models of various complexities with paleo data over the Holocene. Many explanations have been suggested to explain the disagreements between models and data, the authors addressing specifically the impact of potential seasonal biases. They describe in details the seasonal and spatial distribution of the trends in the selected models and in data. This description is very clear. The paper is well written and easy to follow. I thus have no minor comment or suggestion to improve the presentation of the manuscript. However, there are two major points to consider in a revised version of the text.

Authors' reply:

We thank the reviewer again for his constructive and helpful comments. We address the raised points below and propose actions to clarify the points and to further improve the manuscript.

Reviewer's comment:

1/ The added value of the study is not clearly explained and the authors should insist more on this in the conclusion, which is very short in the current version of the manuscript. The first paragraph of the conclusion summarizes the description of the trends presented in the previous sections. The second (and final) paragraph starts by a quite mild sentence: 'Regarding the Holocene conundrum, it follows that a simple seasonal proxy bias is unlikely as a full explanation' and then present some general suggestions for improvements or new studies. The fact that seasonal proxy biases might play a role but could not explain the full model-data disagreement is already around for some time (see the recent review of Kaufmann and Broadman, 2023) and the authors should explain more clearly the new contribution they bring to the debate.

Authors' reply:

We agree with the reviewer that in the current version of the manuscript and in the light of the recent review [Kaufmann and Broadman, 2023], which was not published at the time of submission, our conclusions can be sharpened to highlight the novelty of our study and how it further adds to the general discussion on Holocene temperature trends. We therefore plan to elaborate on our findings and contextualize them better in the revised version of the manuscript. Additionally, we will substantiate our conclusions further by broadening our simulation dataset and performing additional hypothesis testing as described below.

Action:

- We will implement text revisions throughout the manuscript to elaborate on the novelty of our study. In particular, this will be done in the discussion and conclusion.
- We will further support the analysis by providing and analysing sensitivity experiments, focussing on the role of volcanism in Holocene temperature development.

Reviewer's comment:

2/ The authors analyze relatively old simulations that have been discussed in several studies. The selected data base has also already been used in model-data comparisons. A new simulation is included (TransEBM) but it has in general a lower agreement than the other ones with observations (see for instance Figure 5). This new simulation might be helpful to understand some of the characteristics of the other models but this is not developed in the current version of the manuscript. Furthermore, the set of selected experiments is not designed to test hypotheses, such as the potential role of vegetation or of the volcanic forcing for instance, as done in some other studies. Several transient Holocene have been performed recently. Some only cover parts of the Holocene or might not be publicly available but a larger set of experiments would provide additional information for the discussion (see for instance Askjær et al. 2022, in particular Fig. 3).

Authors' reply:

We agree with the reviewer that in addition to the transient Holocene simulations used in our study there are more simulations on their way to publication or documented in publications. However, many of them cover only parts of the Holocene, which reduces their value for our study as we explicitly aim to compare models and reconstructions for the early, mid- and late Holocene. Simulations should, therefore, cover these time periods, which only few published simulations do and we consider almost all of those already. Aksjær et al. 2022 also includes simulations NNU12k and with HadCM3, which could extend the set of simulation we analyse. We therefore got in contact with the authors and have been granted access to the data from the HadCM3 simulations. Unfortunately, after several attempts with the involved authors, we have to conclude that the NNU12k simulations seems to be currently not available.

Furthermore, we agree with the reviewer that discussing the added value of TransEBM as a low complexity model should be expanded and improved in the manuscript. A major strength of low complexity models is their low computational cost such that they can be used for single forcing experiments and hypothesis testing, as mentioned by the reviewer. Especially the role of volcanism during the Holocene and its impact on Holocene climate is relatively unknown [Bader et. al. 2020]. Therefore, we will add analyses of additional sensitivity experiments we performed using TransEBM (cmp. Fig. 1) and those available for HadCM3 simulations to test the impact of volcanic forcing. By comparing TransEBM with HadCM3 simulations, we investigate the impacts of non-linear processes and feedbacks of the volcanic forcings on the Holocene climate.

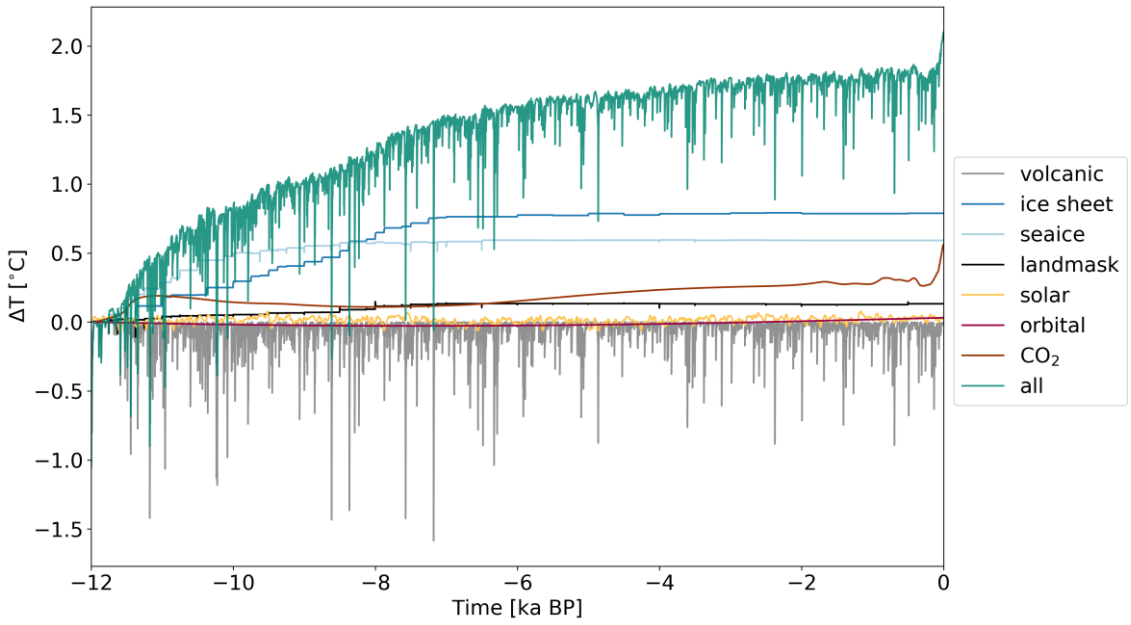

Fig. 1: Temperature anomalies with respect to 12k BP for different sensitivity simulations of TransEBM. *Volcanic, ice sheet, sea ice, landmask, solar, orbital* and *CO2* are simulations in which only one forcing

component changes transiently while the other forcings are kept constant. All forcings change transiently in the *all* simulation.

Action:

- We will improve the discussion of TransEBM and its added value for our study throughout the text.
- We will include sensitivity experiments using TransEBM and HadCM3 to discuss the impact of volcanic forcing, in particular.

References:

Askjær et al., 2022. Multi-centennial Holocene climate variability in proxy records and transient model simulations. Quat. Sci. Rev. https://doi.org/10.1016/j.quascirev.2022.107801

Bader, J. et al. Global temperature modes shed light on the Holocene temperature conundrum. Nat. Commun. 11, 4726 (2020).

Kaufman D.S. and E. Broadman, 2023. Revisiting the Holocene global temperature conundrum. Nature 614, 425-435 . https://doi.org/10.1038/s41586-022-05536-w