Reply to Anonymous Referee #2

by Thomas Kleinen

We very much thank the reviewer for taking the time to review our manuscript. I have included the reviewer's comments in blue colour, while our reply is in black.

Summary:

This paper by Kleinen et al. makes use of a CMIP6-generation Earth System Model, MPI- ESM, with an interactive methane cycle to investigate changes in the methane budget between the last glacial maximum and the pre-industrial period. The model includes interactive emission schemes for many of the natural emission sources relevant for the time period of interest and includes a parametrised approach for the atmospheric methane sink. Using novel, and for the first time, transient simulations, they focus particularly on the rapid changes in the methane cycle occurring during deglaciation.

The paper is well organised, with clear and sufficient detail for the reader to understand the model set up and the results. It is well written and made for an enjoyable and interesting read. More importantly, this study represents a significant step change in model capability, model setup, and an advancement in the state-of-the-art, particularly in relation to running transient simulations from the last glacial maximum to the present day. To date, other studies addressing changes in the methane cycle over this time period have either used simple models or timeslice simulations.

We very much thank the reviewer for her or his praise of our manuscript.

Below, I have some minor general and/or specific comments. However, I would unreservedly recommend that the manuscript be published.

General comments:

You say that the tropical wetland extent is overestimated in the model. Can you comment on how much that overestimate influences your conclusions regarding the role of tropical wetlands in driving the changes?

In Kleinen et al (2020), we compare the modelled inundation to remote sensing data by Prigent et al. (2012), with areas by Prigent about 30% smaller than the model estimate. However, this remote sensing estimate very likely is an underestimate, as it relies on optical sensing, combined with radar estimates in a band that cannot penetrate the tree canopy. As a significant part of the tropical wetland area is located in rainforests, the likelihood that the true extent is larger than in this data set is rather high. Thus the model estimate may be an overestimate, but as the uncertainty in the remote-sensing data is higher than we would like, it the model might also be closer to the true extent than this comparison would suggest.

Having said that, the modelled latitudinal distribution of present-day wetland emissions, as well as the total emissions, is similar to data-based estimates. We thus assume that we are "close enough" to the true extent, but we cannot prove it.

The emissions from tropical wetlands are the largest single factor in the methane balance, making up at least 50% of emissions at all times. Also, the absolute increase in emissions is largest for tropical wetlands. However, the increase in emissions from NH extratropical wetlands is not much smaller than the increase in tropical emissions in absolute terms, implying that the ranking would change if our estimated wetland extent proves to be significantly too large.

We will discuss this in the revised version of our manuscript and word it more carefully.

As a scientist with an interest in the more contemporary period and future projections, I'd be keen for the manuscript to include some discussion on the implications of this study for future projections of methane and the role of tropical wetland sources. You say that for the purpose of

accounting for the soil uptake, you prescribe the atmospheric concentration of methane. Can you comment on the potential impact on model performance that would arise if soil uptake was coupled to the modelled concentration?
In Kleinen et al. (2021) we have already published an assessment of future methane concentrations under a number of the SSP scenarios. We would very much prefer not to duplicate our previous publication and therefore refrained from including any results for beyond preindustrial.
With regard to the soil uptake of methane, the difference between using prescribed or modelled methane concentrations is relatively small, as long as the difference between modelled and reconstructed concentration is small. The impact would thus be most significant at mid-Holocene when the difference between reconstructed and modelled concentration is largest. The modelled methane uptake at that time would have been slightly higher, thus decreasing atmospheric methane, if we had used the model methane concentration.
We will discuss this in the revised manuscript.

Specific comments:

Page 3, line 89: Change “is produces” to “is produced”
Thanks for pointing this out, will be corrected.

Line 161: For use of “CI” in the first instance, please write out in full with abbreviation. Thereafter, CI is okay to use.
Thanks, will be included.

Line 195: On first use, please write out “AMOC” in full with abbreviation
We will correct this oversight.

Lines 196 and 199: As a reviewer whose main expertise is more in the contemporary period, it would be useful to explain what is meant by “1a” and “1b” when referring to the meltwater pulse. If they are simply referring to the different transitions in the AMOC which occur, perhaps these could either be labelled in the figure (and with addition to figure caption) or made more explicit in the text.
Thank you very much for pointing this out, we neglected to explain this properly in our manuscript. The meltwater pulses 1a and 1b were (to our knowledge) first identified by Fairbanks in reconstructions of deglaciual sea level rise from Barbados corals (R.G. Fairbanks (1989), A 17,000-year glacio-eustatic sea level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation, Nature, 342, 637-642, doi:10.1038/342637a0) and occurred at 12000 and 9500 radiocarbon years BP.
As the sea level history is not actually part of the model forcing, we cannot easily label these in the Figure. We will, however, discuss it more carefully in the text, referring the reader to Fairbanks.

Caption for Table 1: Suggest that you change “timeslices” to “time periods”
Thanks. Will be changed in revised manuscript.