Reply to the review

by Thomas Kleinen

We thank the reviewer – again – for her or his helpful comments on the revised version of our manuscript. For the (hopefully) final revision of our manuscript, we have taken up most of the suggestions.
In the following, we discuss point-by-point our response to the reviewer's comments. The reviewer's comment will be in blue, and our response will be in black. All line numbers refer to the track-changes document.

Reply to Anonymous Referee #2

Kleinen et al. have done a great job addressing my previous comments in a satisfactory manner. They also done a great job in elaborating and adding several important discussion points to their paper. This study provides a novel first attempt to model the transient evolution of methane during the last deglaciation. From modeling approach, it brought forward many important results and ideas, mainly the importance of tropical wetlands in driving the bulk of deglacial methane rise, the role of methane emissions from shelf areas, the evolution of atmospheric methane lifetime during the deglacial transition. As such I would highly recommend this manuscript for publications.

We thank the reviewer for their appreciation of our manuscript.

Here are some minor notes I have that might be useful in polishing up the paper:

Page 1 line 13: "Between the last glacial [...] doubling in concentration during those 11000 yrs." I would cite Figure 2 here just to orient readers who are not extremely familiar with deglacial methane evolution.
Added reference to Fig. 2 on line 13.

Page 2 line 27: "Or they used a more detailed [...]." Here 'they' refer to non-box model (so non transient) time slice studies but it is not immediately clear. To clarify and draw the contrast against the box model studies I would just say something like "An alternative approach to box models would be ... "
We reformulated the text along the lines the reviewer suggested, though using a slightly different wording, Lines 25 – 27: Many of these studies were performed with strongly simplified... The alternative to very simplified models were studies using models with more detailed...

Page 3 line 60-65: This opening paragraph is quite redundant as every aspect is elaborated further in details below. I would consider removing it entirely.
We thank the reviewer for the suggestion but take the liberty to deviate from this suggestion: This paragraph serves to set the stage for the following more detailed description, we believe it makes the text more accessible. We therefore opted to keep it.

Page 4 line 103: "assuming no human population before 12 ka BP". I'm sure with regards to methane emissions, the effect of no human population vs. small human population at the time is fairly negligible, but this statement jumps out as obviously untrue as humans were clearly around in the LGM. Maybe just explicitly say something like "we assume no human population because the effect of ~2 million stone age people on fire emissions is small" to avoid confusion. I'm not an expert in human population during the LGM, just happen to stumble across the 2 million number from Gautney and Holliday (2015).
Thank you, that is obviously correct. We reformulated (line 104): ... (assuming no human impact on

fires before 12 ka BP due to small population size and using Klein Goldewijk et al. (2017) afterwards)…

Page 6 line 178-181: This part I think fit better with the previous section, maybe just add it to section 2.1 and add "geological emissions" to the title of section 2.1
We did exactly that, moving the paragraph to lines 109-113. This passage now reads: Finally, methane emissions from geological sources are prescribed using a spatial distribution from Etiope (2015), but scaled down to give total geological methane emissions of 5 T gCH 4 yr−1 , as Petrenko et al. (2017) and Hmiel et al. (2020) show from ice-core data that geological emissions larger than this value are not possible for either the Younger Dryas or the preindustrial period.

Page 11 line 247: "when dust accumulation". I think the word 'concentration' fits better here than 'accumulation.'
Thanks, corrected.

Page 11 line 255: "Finally, the tropical methane concentration [...] throughout the experiment." Might be worth mentioning that this result is in contrast to some earlier time slice studies like for example very clearly shown in figure 2b of Valdes et al. (2005) where methane concentration during the LGM is highest in the tropics.
Lines 260 - 262 now read: Finally, the tropical methane concentration (Fig. A1a) stays in between the values for Antarctica and Greenland throughout the experiment, in contrast to previous studies showing LGM concentrations highest in the tropics (Valdes et al., 2005).

Page 11 line 257-274. This is arguably the crux of the paper. Methane is driven by wetlands, which is driven by AMOC. Here the authors have a very nice description of the model results where methane emissions from wetlands respond to AMOC. What is a bit lacking (I understand this is later elaborated in section 3.3) is maybe a brief explanation of why (process- wise) wetland emissions are coupled so strongly to AMOC.
We have added a brief sentence here (lines 272 – 274): Here, the AMOC collapse leads to a significant decrease in NH temperatures around the Atlantic ocean, in turn leading to decreased evaporation and thus decreased precipitation, thereby decreasing wetland areas and methane production in the NH tropics.

Page 19 line 355 to page 21 line 370. This section again pertains mostly to AMOC, Bolling-Allerod and YD transitions. I personally think this should be on Section 3.3 rather than a section about Holocene.
Here, we once again beg to differ, as we believe that this text should really be in this location. However, the reviewer drew our attention to the fact that the title of this section may have been less than ideal – we therefore renamed the section to "Regional distribution of methane fluxes over time" (Section 3.5, line 352), as it is really less about the Holocene and more about the regional flux distribution.

As you can see, we addressed most of the reviewer's comments, hopefully in a satisfactory fashion. We hope that the manuscript can now be accepted for publication.