

Interactive comment on “Terrestrial methane emissions from Last Glacial Maximum to preindustrial” by Thomas Kleinen et al.

Anonymous Referee #1

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Summary

The authors present a comprehensive suite of ESM simulations including methane emissions. They focus in 5 ka intervals from the LGM to the present day. They show that emissions are reduced by around 50% at the LGM relative to the PI, meaning that no atmospheric lifetime change is required to explain the observed low concentration at the LGM, consistent with 3 recent studies of the atmospheric chemistry of the LGM. This is the first study to reconcile the emissions required by the observed CH₄ drop without requiring to a large change in lifetime. Hence, these results will be important for understanding CH₄ during ice-ages. I recommend minor revisions as explained below.

Main comments

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To me, the main results of the paper require more explanation. If the model is able to correctly resolve a 50% emissions reduction at the LGM relative to the PI, there may be different reasons for this, e.g.: (i) the simulated LGM climate is less favourable for emissions than in older studies; (ii) the CH₄ model is more sensitive to LGM conditions than in older studies, either through a different tuning, or because of increased model realism/complexity. (iii) the coupling of the methane model to the ESM increases the sensitivity to LGM conditions. In my opinion these options need to be clearly evaluated, otherwise we only know that it is possible to get this 50% reduction but not why or how.

Moreover, these results don't show increasing southern hemisphere emissions over the past 6ka that would explain the observed recovery of atmospheric CH₄, thus meaning that a human influence is not required. It would be good to understand how and why your results don't replicate this result from Singarayer et al., 2011. You discuss this a bit in lines 397-402, but I believe this could benefit from more detail, without needing further simulations.

Technical comments

Line 1: Sorry to be picky, but past tense would make more sense: "Underwent", "nearly doubled" etc.

Line 50: "However, Levine et al. (2011) found very small changes in CH₄ lifetime between LGM and PI"

You could mention here that this has also been found by Murray et al 2014, and Hopcroft et al 2017, using different atmosphere-chemistry models.

It would also be worth pointing out here why the lifetime didn't change. i.e. because of balance of competing influences from changes in reactive compounds like isoprene and reduced reaction rates due to lower temperatures, and lower generation of OH from lower water vapour levels.

Line 54: Here you can set up the main finding of you paper, by pointing out here that

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none of these earlier studies have managed to get the right change in emissions and lifetime together.

Line 177: insured -> ensured

Line 313: delete 'in'

Line 397: This is really interesting, but why/how does your model manage this and previous studies did not? I realise this is complex, but are there any obvious difference in your simulated LGM state? Is it drier in critical areas? Or is it due to the added complexity of your wetland module?

Line 399: This is an interesting finding. What is the explanation though? Do you see the same reduction in precipitation and hence wetland flux in Southern hemisphere as found by Singarayer et al 2011?

Line 433: I think I understand the meaning of this sentence: "In total the wetland emissions account for 93–96% of the net CH₄ flux, and all other methane sources are of minor importance." , but perhaps you could reword it.

Figures: It is slightly surprising to see Termite CH₄ emissions in Europe.

References L. Murray, L.J. Mickley, J.O. Kaplan, E.D. Sofen, M. Pfeiffer and B. Alexander (2014). Factors controlling variability in the oxidative capacity of the troposphere since the Last Glacial Maximum, *Atmos. Chem. Phys.* 14, 3589-3622.

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