

## Response to Comments for “Development of Fully Interactive Hydrogen with Methane in UKESM1.0”

Reviewer comments are in *italics* and our responses are in blue. We have used the line numbers for the 1<sup>st</sup> revised version of the manuscript.

General comments:

*The revised manuscript reads much more smoothly than before, in my opinion, and I highly appreciate the additional experiments. Almost all comments have been addressed, and I can recommend publication of the revised version in GMD after consideration of a few more, but minor, issues.*

*(Line numbers in the following refer to the revised version without tracked changes.)*

We'd thank the reviewer for taking the time to go through the paper a second time and offer further suggestions. We have incorporated all the comments into the manuscript

Specific comments:

1. l. 107: *Why would you scale 48 Tg yr<sup>-1</sup> (l. 103) by 3.5 to make up for a (wetland) source reduction from 190 Tg yr<sup>-1</sup> to 135 Tg yr<sup>-1</sup>? Wouldn't that require 55 additional Tg yr<sup>-1</sup>?*

The scaling up of the additional methane is partly due to changes in the interactive wetland fluxes between different simulations (which we have outlined in the text). However, the scaling is also due to the differences in methane lifetime between the present day timeslice and the nudged historical simulation which leads to different total emissions required to balance the budget. We ran the model with just a 55 Tg yr<sup>-1</sup> increase initially, but the surface methane concentration was very low (dropping to 800 ppbv). We had to increase it further to balance the methane budget. The explanation for the different lifetimes would require further investigation and breakdown of the methane budget (which is beyond the scope of this study). To make it clear that this increase is not purely due to the reduced wetlands, we have added the following to line 107: “To compensate for the reduced wetland source, as well as for differences in the chemical methane lifetime, the flux adjustment from the PD simulation...”

2. - Appendix A1: Besides the  $T$  vs.  $T_s$  and the Celsius typo, my comments from the initial review remain. Even if the authors prefer to use "total volume" instead of "soil", the units of  $\theta_a$  have to be revised ( $m^3$  air /  $m^3$  total volume, l. 385).

We have corrected the units in line 385 for the air fraction from  $m^3$  air /  $m^3$  total volume.

3. Furthermore, if they prefer to maintain  $\theta_a$  as the argument of function "f", it would be easier to follow the math if the argument also appeared in the function definitions, i.e., if  $\theta_w$  was then replaced by  $\theta_p - \theta_a$  in Eqs. (A7) and (A10). Still,  $\theta_a$  in l. 402 needs to be replaced by  $f(\theta_a)$  in this case. The redefinition of  $\theta_a$  as  $\theta_w / \theta_p$  in l. 398 must be avoided, as Eq. (A4) would then use the same symbol for different quantities on both sides of the equals sign.

We have replaced the  $\theta_w / \theta_p$  with  $(\theta_p - \theta_a) / \theta_p$  for clarity as suggested, so  $f(\theta_a)$  is now easier to follow. We also corrected the typo in 398 to  $\theta_a = \theta_p - \theta_a$ . We have renamed  $k_s \theta_a$  (in A1, A4, and line 388) to avoid confusion with  $f(\theta_a)$ . We have changed line 401 to: "For loam:"

4. Finally, I do not see a correction of the applicability limits for the "f" functions. To make the limits consistent with the code that I received for review, inequalities (A8) and (A11) have to be reversed. Since checking  $\theta_w$  and  $\theta_p$  against individual limits instead of checking their ratio deviates significantly from the original publication by Ehhalt & Rohrer, 2013, <https://doi.org/10.3402/tellusb.v65i0.19904>, I suggest to also add a note about this to the main text.

We've switched the signs around for A8 and A11. We have also added the following to line 407 as suggested: "Further limits applied to the ratio of  $\theta_w$  and  $\theta_p$  are described in Section 2.4."

5. Furthermore, I would ask the authors to add the functions they apply outside the validity ranges to the Appendix. Before future applications of this model version, the authors may want to consider computation and use of the limits as originally intended, and running a sensitivity simulation to check the effect of their modifications.

We have added in further functions to describe the changes to the model . We thank the author for this suggestion - we have run a series of sensitivity tests for Brown et al. (2024) when originally developing this scheme, which is how we calculated these limits.

6. - Fig. A2: Please double-check if the dip in 1986 in *\_all\_* quantities might be due to a processing error rather than contained in the actual data.

During the post-processing of the data, two months of 1986 were corrupted when transferring from the HPC system (ARCHER2) to the data analysis system (JASMIN). Unfortunately it would require re-running of the model to regenerate these files. However, as this was a post-processing issue, this did not impact the model results. We have replotted the sources and sinks as monthly averages and interpolated across the two missing months (as done in the surface average concentrations plots).

Technical corrections:

- l. 32: delete parentheses around "~30%" Done
- l. 53f: include the two scaled-H<sub>2</sub>-emissions simulations in sentence Done
- l. 99: FFolberth -> Folberth Done
- l. 118: burden to -> burden of Done
- l. 122: uptake -> deposition velocity Done
- l. 155: deposition -> deposition velocity Done
- l. 189f ("These sites were chosen ..."): Move 3 sentences up (l. 186) Done
- ll. 240ff: I think these two sentences are now obsolete. Removed
- l. 270: decrease to 25% is a 75% reduction Done
- l. 271: increase to 400% is a 300% increase Done
- l. 294: global methane -> global surface methane Done
- Fig. A2, y axis label: abundance -> rate Done
- Fig. A2, caption: 'emissions' -> 'emission' Done