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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Atmospheric methane source and sink sensitivity analysis using Gaussian process emulation" *by* Angharad C. Stell et al.

Anonymous Referee #1

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This paper uses Gaussian process emulation to explore the sensitivity of simulated methane to the uncertainties in multiple parameters. The greater computational speed of the emulator compared to the 3-dimensional model it emulates allows a more thorough exploration of parameter space than would be possible with the original model. This is a state-of-the art method and the study brings some interesting insights to the long-standing challenge of constraining the methane budget, such as the importance of freshwater emissions. Consequently, it would be a useful addition to the literature. However, some clarifications and greater use of observations would strengthen the paper, as noted in the comments below.

General comments

1. While the focus of this study is understanding model sensitivities, it would be useful to include more comparisons to observations to demonstrate whether the model sensitivities are reasonably realistic. In other words, if the model shows high sensitivity to a particular source or sink, are we confident that methane observations are really that sensitive to that source or sink? This information is difficult to determine from Fig. 3. Perhaps showing the model has reasonable skill in capturing interannual variability at a site heavily influenced by biomass burning or by wetland emissions would help demonstrate a realistic level of sensitivity to those sources.

2. The large number of 3D model simulations used to train and test the emulator is itself a substantial effort and potentially a valuable resource. Could these simulations provide additional information to support the analysis? For example, this study focuses on just hemisphere or global averaged measures of methane, but the 3D model fields could potentially take greater advantage of geographic differences.

3. Section 2.5: Please justify why the uncertainty in the invariant parameters is a good estimate of the CTM error, and compare to the error you would get from the model-data mismatch.

4. Since the initial conditions for the isotopic composition are listed as one of the important quantities to constrain, more detail is needed regarding how the initial conditions are specified in the model simulations. Are observations used in any way to constrain the initial state?

Specific Comments

1. Line 30: Please rephrase without parentheses

2. Lines 58-62: Another reference relevant to this work is: Wild, O., Voulgarakis, A., O'Connor, F., Lamarque, J.-F., Ryan, E. M., and Lee, L.: Global sensitivity analysis of chemistry–climate model budgets of tropospheric ozone and OH: exploring model

diversity, Atmos. Chem. Phys., 20, 4047–4058, https://doi.org/10.5194/acp-20-4047-2020, 2020

3. Line 134: Does this spin-up lead to a reasonable reproduction of surface observations in the early portion of the time period?

4. How was the number of simulations chosen? It might help to refer to the Supplemental Figure S8 here.

5. Line 202: Please explain the difference between x and x*

6. Line 277: What is the meaning of “arbitrary initial condition range”?

7. Line 341: What is the “initial condition source del-13C”? Do you mean the initial conditions for the del13C values of atmospheric methane? Or are you talking about an emission source?

8. Lines 340-355: Isn’t the initial condition at least partially constrained by surface observations?

9. Line 360: It would be nice to know the sensitivity to the assumption of hemispheric parity in OH

10. Line 373: Do you mean the magnitude of the agricultural source or its trend?

11. Line 414: Is this because the trends and hemispheric differences are themselves small compared to the mean?

12. Fig. S8: Why does the plot have only 3 points?

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