Public justification (visible to the public if the article is accepted and published):
Dear Dr. Bernard,

I have read your response letter and the two rounds of comments by the reviewers. As you can see in the second round, both reviewers remain concerned about the ~50% underestimation of wetland emissions at high-emission sites and on a global scale. While I recognize that your model provides a new, independent estimate of wetland emissions, this issue requires further discussion. For example, how well does the fitting perform? Would it be possible to show a scatter plot of the observed versus modelled points and assess deviations from the 1:1 line? Additionally, if you are able to tune the parameters to match the global budget, would it bias the site-level estimates?

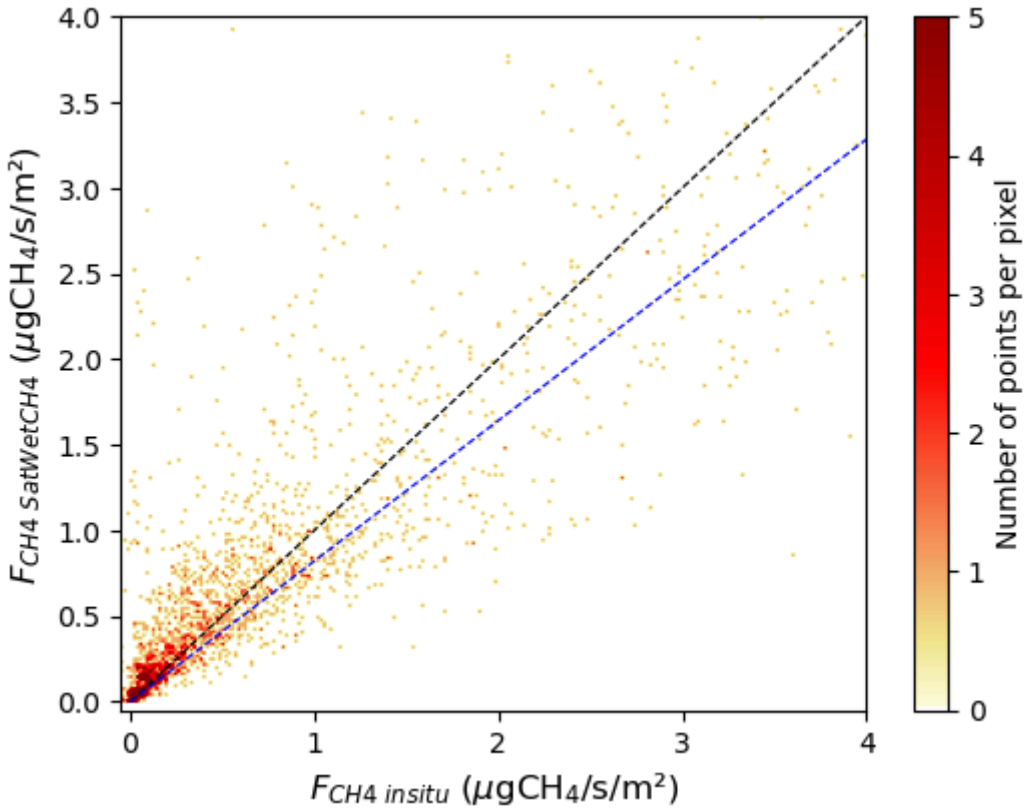
I would appreciate it if you could provide further details on these points.

Best regards,
Yilong

Dear Yilong,

Thank you very much for reading the exchanges of the review process and for your suggestions.

To address the issue raised by the reviewers and following your advice, we have made a scatter plot of the observed and modeled fluxes at site levels, where the colorbar represents the density of the measurements, as it is most commonly done, with a 1:1 line (dashed dark line) and the linear regression through the origin (0,0) (dashed blue line). This Figure shows that the model is slightly biased toward lower values when comparing to monthly site data. We have included this Figure in the Supplementary as Figure S1. Regarding the tuning of k and Q10 to match other global budget estimates (e.g. GMB), 2 parameters (k and Q10) are sufficient to achieve both a constraint on the monthly site data and a constraint on the global estimates, with similarly low biases on the monthly estimate scatter plot. However, this estimate would then lose its independence from the others estimates.



Indeed, the total output of SatWetCH4 in this manuscript (86TgCH4/yr) is below the bottom-up estimates, e.g., estimates of the Land Surface Models (102-182TgCH4/yr) or McNicol et al. 2023 (103-189 TgCH4/yr). SatWetCH4 certainly underestimates global methane emissions. Though, we would like to remind here that the LSMs have been generally calibrated against top-down estimates or other historical values and that such calibrations lack independence across LSMs.

SatWetCH4 is a simplified model, with the aim of running it on a global scale, using satellite observations as input data to provide independent estimates from top-down or LSMs

estimates. While the model's emissions estimate is lower than the GMB LSMs estimates, it remains within a comparable range and captures similar spatio-temporal variations, making it suitable for further studies. We also show in the manuscript that adding more variables at 0.25° resolution (such as WTD or SWC) with currently available datasets does not improve model accuracy. This issue of the local scale to large scale representativity is never challenged in the global models' design, which extrapolate relationships observed at the site level.

This manuscript, submitted to Global Model Development, aims to describe the approach of SatWetCH4. **We believe that the value and strength of this method does not lie in providing a precise total global wetland methane budget, but in offering a straightforward and efficient tool for investigating large-scale spatio-temporal changes in wetland emissions.** We are currently carrying out two studies based on the development presented in this manuscript.

1. The first study is to **run SatWetCH4 using satellite data to examine large changes** in terms of inter-annual variations, long-term trends, and spatial patterns that could be explained by changes in temperature and wetland extent. The aim is to determine if such a simple approach can explain the spatial pattern of wetland methane emissions and the recent atmospheric methane changes over the last decades in terms of concentration and isotopic signature. This was not possible due to the limitations of WAD2M, but we have recently derived a new dataset of wetland extent (in review in ESSD https://doi.org/10.5194/essd-2024-466) that allows us to model and study wetland methane emissions over 30 years.
2. Another study aims also to **calibrate SatWetCH4 using an inversion model.** Here, we calibrated the two parameters k and Q10 in using in situ measurements, which are limited (58 sites), and really sparse over the Tropics. The use of an atmospheric inversion framework will allow optimizing the k and Q10 with global satellite data of methane concentration (e.g., GOSAT data). This approach will also provide observational constraints on total methane emissions and sinks. As more data with a global coverage will be available, the optimization of Q10 (and k) could be refined and performed per latitudinal band or wetland types (provided by a prescribed map such as GLWDv2).

We have revised the manuscript, particularly in the conclusion, to better clarify our objectives, which we believe are now more apparent. While we feel the manuscript clearly conveys its goals, we remain open to further revisions if the editors or reviewers suggest alternative wording.

Best regards,