

Response to reviewers' comments

We would like to thank the Editor and both reviewers for their constructive and thoughtful feedback on the first version of our manuscript. The manuscript has been significantly improved based on the reviewers' comments. As a result of the revision, we now have two additional coauthors, Dr. Zhangcai Qin and Ms. Hailing Li, who contributed new observed datasets for model validation and helped with revisions. Below we offer a point-by-point response to each comment. Our responses are shown in blue text starting with *RE*. The relevant modifications are highlighted in the revised manuscript.

Anonymous Referee #1

1. The authors should add the background and implications of this work in the abstract.
RE: According to the reviewer's suggestion, we added the background at the beginning of the abstract (lines 26-28 in the revised manuscript) and also added the implications at the end of the abstract (lines 49-51 in the revised manuscript).

2. There are several process-based models for simulating CH₄ emissions from natural wetlands. Why do the authors choose CH₄MOD_{wetland} and TEM? In the methods and materials, the authors should clearly state the reasons of choosing CH₄MOD_{wetland} and TEM.

RE: We agreed with the reviewer's comment that several process-based models have been developed in recent decades. Among these models, some are simple semi-empirical models that focus on the biochemical processes of CH₄ production, oxidation and emission, e.g., Walter's model (Walter et al., 1996; Walter and Heimann, 2000), CASA (Potter, 1997) and CH₄MOD_{wetland} (Li et al., 2010). This kind of model requires simple inputs and parameters and is easily extrapolated to a regional scale. Other models are based on more complex land ecosystem models coupled to the CH₄ processes module, such as CLM4Me (Riley et al., 2011), ORCHIDEE (Ringeval et al., 2010; 2011), SDGVM (Hopcroft et al., 2011) and TEM (Zhuang et al., 2004; Melillo et al., 1993). These models describe complex ecosystem processes and require more inputs and parameters. In this study, we aimed to compare the model performance of a simple easy-to-run model, e.g. CH₄MOD_{wetland} and a sophisticated land ecosystem model, e.g., TEM. Moreover, both models have been validated at the site scale, but no comprehensive accuracy analysis in different continents or for various wetland types has been done before. We state these reasons in the revised manuscript (lines 120-130 in the revised manuscript).

3. The authors collected 30 wetland sites across the world, including 6 marsh sites, 14 peatland sites, 6 swamp sites and 4 coastal wetland sites. More information about the environmental conditions of the sites, e.g., climate, soil and hydrological conditions should be introduced in the data description. Also, it is better to add observed CH₄ flux data for each site.

RE: According to the reviewer's comment, we added Table S1 to introduce the climate,

water table, salinity conditions as well as the observed CH₄ flux data for each site. We didn't add the soil conditions because most of sites didn't report the information of soil conditions.

4. There are too many details presented in the results section. Please refine your results and remove unnecessary details.

RE: According to the reviewer's comment, we refined section 3.1 and 3.2. We also moved "Spatial pattern of annual mean CH₄ fluxes" to supplementary material S4.

5. L54: "stratospheric water vapor and CO₂", lead to an increase or decrease?

RE: This estimate considers that the emission of CH₄ leads to an increase of ozone production, stratospheric water vapor and CO₂, which can affect its own lifetime. We modified this sentence in the revised manuscript (lines 58-60 in the revised manuscript).

6. L62: typo: CH₄emitted. And wetlands should be the largest natural source of CH₄ emitted to the atmosphere.

RE: Modified.

7. L74: It might be better to remove this sentence, since it is unreasonable to say top-down or bottom-up is better.

RE: We have removed this sentence.

8. L78: the unit should be Tg CH₄ yr⁻¹.

RE: Modified.

9. L87: remove "and" from " : : because the processes of and controls on: : :"

RE: Modified.

10. L200: change "PH" to "pH".

RE: Modified.

11. L214: seasonal CH₄ fluxes refer to monthly or daily fluxes?

RE: We modified seasonal CH₄ fluxes to seasonal/annual CH₄ emissions in the revised manuscript (line 230 in the revised manuscript). The observation periods last for the growing season or a whole year. We calculated the total amount of CH₄ emissions during the growing season or a whole year as the observed seasonal/annual CH₄ emissions. For most of the wetland sites, the total amount of seasonal/annual CH₄ emissions during the observation period was calculated by summing the daily observations. We added this explanation in the revised manuscript (lines 176-178 in the revised manuscript).

12. L217: remove "and" from " : : the coefficient of determination (CD) and were used to: : :"

RE: Modified.

13. L258-259: the sentence "The result indicated that the variations in the CH₄ emissions between sites and in different years could be delineated by both process based models" should be moved to the end of this paragraph, and changed to "These results indicated that: : :"

RE: Modified.

14. L270: change unit "g m-2" to "g m-2 month-1"?

RE: As explained in question 11, this is the seasonal/annual CH₄ emissions.

15. L303-305: please remove the sentence "Marsh, swamp, peatland and : : : of natural

wetlands. Although the process-based models showed : : : for each wetland type”.

RE: Modified.

16. Figure 2: (a) and (b) are missing in the sub-figures. Add explanation for red lines

RE: Modified.

17. Figure 3 and 4: figure with higher resolution or vector figure is better

RE: We modified both figures to 600 dpi resolution.

Anonymous Referee #2

The paper deals with a topic which is of great importance to climate change studies, and requires attention by terms of model development despite of multi-year efforts. Novel studies comparing performance of models in representing wetland methane emissions are highly welcomed. Especially efforts toward evaluating the models at swamps, marshes and coastal wetlands and selecting sites equally from all important emission regions of the world is a benefit. It is also a weakness of the paper, as the number of sites is not large when comparing to existing literature (e.g. Turetsky et al., GCB2014, Treat et al., GBC2018), and when the sites are divided into different categories, the number per category becomes even smaller. Also analysis of the seasonality of the fluxes is missing, and would be best studied by using eddy covariance flux measurements, as noted by the authors. However, the paper brings a welcomed contribution to the field and can be accepted after making the text more consistent and explaining more details.

RE: We highly appreciate the reviewer’s positive comments and constructive suggestions. According to the reviewer’s comment, we managed to find more data of observed wetland CH₄ emissions. The site must locate in the global wetland distribution map so that we can make comparison between the observed and simulated CH₄ emissions. Now there are 43 sites in this study. The observations were made by chamber method and eddy covariance method. We also analyzed the seasonal variations of simulated CH₄ fluxes by CH₄MOD_{wetland} and TEM in the modified manuscript (lines 347-350 and Fig. S1 in the revised manuscript). The addition of data did not change the conclusion of the study but did improve the overall robust of modeling vs. observation comparison. A point-by-point response to the comment is given below.

Detailed comments:

*The manuscript needs a language check

RE: The modified manuscript has been edited by “American Journal Experts” for proper English language, grammar, punctuation, and spelling. We attached the editing certificate by the “American Journal Experts”.

*The global emissions are in the lower end of the range given in literature (see e.g. Saunio et al., ESSD 2019, and other references in introduction of this manuscript). What could be the reasons behind this?

RE: We discussed this difference in section 4.2: “The global estimations of wetland area ranged from 4.3 M ha to 12.9 M ha during the period of 1990 to 2005 (Melton et al., 2013). The wetland extent of 9.2 M ha from the GLWD excluded water bodies. In this study, the global wetland area (excluding rivers) was estimated by the “Global Review

of Wetland Resources and Priorities for Wetland Inventory (GRoWI)” as 530-570 M ha (Spiers, 1999). The GLWD value was ~40% higher than the wetland area used in this study. That is, this difference was the main reason for the lower global estimations determined in this study than those reported in previous works (Zhu et al., 2015; Melton et al., 2013; Poulter et al., 2017; Saunois et al., 2016).”

144-46: You should here shortly clarify what the ‘more accurate model’ means

RE: We clarified ‘more accurate model’ in the revised manuscript (lines 47-48 in the revised manuscript).

1130: What does soil Eh mean?

RE: It’s the soil redox potential. We modified it in the revised manuscript (line 143 in the revised manuscript).

1214-215: What does seasonal flux mean in this context? Is it the season of annual maximum emissions? How long does it last for the different sites?

RE: As described in Fig. 1, the observation periods last for the growing season or a whole year at different sites. We modified “the seasonal flux” to “seasonal/annual CH₄ emissions”, which means total CH₄ emissions during the growing season (seasonal CH₄ emissions) or a whole year (annual CH₄ emissions) (line 230 in the revised manuscript). We clarified the “seasonal/annual CH₄ emissions” in section 2.2.1 (lines 176-179 in the revised manuscript). We also modified seasonal CH₄ emissions to seasonal/annual CH₄ emissions in other places of the manuscript.

1402: Here, annual fluxes are mentioned, but in the Fig 2 (and Fig 3 and Fig 4) caption you mention seasonal fluxes. Which is correct? Furthermore, which methods did you apply for gap-filling to obtain annual totals?

RE: Both “annual fluxes” and “seasonal fluxes” mean seasonal/annual emissions, as described in the above response. We modified “annual fluxes” and “seasonal fluxes” to seasonal/annual emissions both in the text and the captions in Fig. 2, Fig. 3 and Fig. 4.

For most of the observations by chamber method, we used the “GetData Graph Digitizer version 2.22” (<http://getdata-graph-digitizer.com/>) to get the daily fluxes from the figures published in the literatures. The absence of CH₄ emission measurements between two adjacent days of observation was linearly interpolated. The total amount of seasonal/annual CH₄ emissions during the observation period was calculated by summing the daily observations. For a few wetland sites without publish the seasonal variations of CH₄ fluxes, the observed seasonal/annual CH₄ emissions were directly obtained from the literature (We pointed these sites out in Table 1). For all of the observations by eddy covariance method, we used the reported seasonal/annual CH₄ emissions in the literature, since it’s difficult to get daily CH₄ flux from the EC observations. The gap-filling method for the EC observations at each site was described in the literature. We described the method in section 2.2.1 (lines 176-179 in the revised manuscript).

Supplementary *Not much is told about calibration data. You tell only in 4.2 that you used chamber measurements. It would be useful to add information here, or in Table 1, introducing the measurement method. How did you process the data and how many data points did you use in the calibration? * What does VI (vegetation index) mean in

this context? Does have a seasonal cycle? From where is it obtained? Did you calibrate it? *Table S2: Where did you get tundra and peatland values? Which sites were used in calibration?

RE: We greatly appreciate the reviewer's comments. The manuscript has been significantly improved to clarify details regarding site specific information. The revisions were made to both Table 1 and Table S1 in the new version of our manuscript. The site measurements method was also added in Table S1. We marked the sites used for calibration were in Table 1. The observed data used in the modeling were directly from the published observation datasets. We just calculated the seasonal/annual CH₄ emissions as we explained in previous questions.

For CH₄MOD_{wetland} calibration, we used four cases from four wetland sites. We described the calibration process in Supplementary material S1 (lines 13-18): "CH₄ measurements from the Sanjiang plain, China (Table 1) in year 2002 (Hao, 2006; Song et al., 2009; Yang et al., 2006) and from the Wuliangsu lake, China (Table 1) in year 2003 (Duan et al., 2005) were used to make calibration for the wetland dominated by the herbaceous plants. CH₄ measurements from Sarawak, Malaysia (Table 1) (Melling et al., 2005) in year 2002 were used to make calibration for the wetland dominated by the woody plants. The empirical constant of the salinity influence (*a*) is calibrated as -0.025 by minimizing the RMSE between observed fluxes and simulated fluxes at the coastal wetland in Chongming island, China (Table 1) in year 1997."

"*VI*" is the parameter in CH₄MOD_{wetland}. It is vegetation index, which was used to quantify the different capacities for producing root exudates of the various plant species. It is a dimensionless value with no seasonal variations. We added the description of *VI* in the modified manuscript (lines 152-153 in the revised manuscript). We described the calibration of *VI* in supplementary material S1 (lines 20-24): "By setting the increment of 0.1 for *VI* and P_{ox}, the model was run for all combinations of *VI* within the range of 0.5-3.0 and P_{ox} within the range of 0.1-1 until the root-mean-square error (RMSE) between the daily simulated and observed CH₄ fluxes was minimized."

For TEM model, we recalibrated the parameters for tundra, peatland, marsh, swamp, and coastal wetland (in Table S3), following the same "Monte-Carlo" approach from previous studies (Zhuang et al., 2004). The calibration cases were not clearly presented in the first version, it is now revised to clarify specific cases used for calibration in Table 1. In addition, we clearly described the sites used for calibration TEM's parameters in the modified supplementary material (lines 35-41): "CH₄ measurements from Toolik Lake, USA in year of 1992 and 1993 (Schimel et al., 1995), from Saskatchewan, Canada, in year of 1995 (Sellers et al., 1997), from the Sanjiang Plain, China in year 2002 (Hao, 2006; Song et al., 2009; Yang et al., 2006), from Sarawak, Malaysia (Melling et al., 2005) in year 2002, from the coastal wetland in Chongming island, China in year 1997 (Li et al., 2016) were used to calibrate parameters for tundra, peatland, marsh, swamp and coastal wetland. We used the Monte-carlo approach to calibrate parameters for each wetland type (Zhuang et al., 2004)..."

References

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