Institute of Atmospheric Physics

Chinese Academy of Sciences

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Dear editor:

The manuscript (bg-2015-154) entitled "**Impacts of climate and reclamation on temporal variations in CH_4 emissions from different wetlands in China: From 1950 to 2010**" by Tingting Li *et al*. has been revised according to the comments from the reviewers. We are very grateful for their helpful comments.

In the revised manuscript, we added a detailed description of $CH4MOD_{wetland}$ in section 2.1. In addition, we added section 4.5 to compare our model with currently used process-based models and discuss the present current knowledge gap in modeling CH_4 processes and quantifying large-scale CH_4 emissions. For your guidance, the itemized responses to the reviewer's comments are appended to the end of this letter.

Thank you for your suggestions and detailed instructions for the revision of the MS. Correspondence regarding the MS should be directed to W. Zhang using the following address, phone number, or e-mail address:

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Yours sincerely,

Wen Zhang

Anonymous Referee #1

1) Section 2.1: It may be better to move the brief description of $CH4MOD_{wetland}$ in Supplement to section 2.1. In addition, I think a more detailed description of the model, including basic model assumptions and structures, is needed. It seems to me that current description of the model only covers model inputs, outputs, etc.

Response: The description of $CH4MOD_{wetland}$ in Supplementary S2.1 was moved to section 2.1 in the revised MS, and additional details were added (page 4, lines 3-24). Additional details regarding the model can be found in Li et al. (2009, 2012).

2) Section 2.2: The author should justify why only two parameters are calibrated. Are these two most important in the model? What about other parameters?

Response: Five parameters (listed in Table S3 in Supplementary S2) are used in $CH4MOD_{wetland}$. These parameters are mainly related to the plant species (Table S3) and include the proportion of root to total production (f_{root}), the vegetation index (*VI*), the fraction of CH_4 oxidized during plant-mediated transport (P_{ox}) and the fraction of available plant mediated transport (T_{veg}). The values of f_{root} and T_{veg} were obtained from the literature (shown in Table S3). We defined T_{veg} as 1 for grass and 0 for shrubs and trees to indicate that CH_4 can be transported only by ebullition and diffusion in wetlands with trees and shrubs, respectively (Walter et al., 2000). *VI* and P_{ox} signify the differences in the CH_4 production and oxidation capacities among plant species. We added a description of the parameters in section 2.2 (page 5, lines 19-29) and Table S3 (in the supplementary material).

In our previous studies (Li et al., 2009, 2012), *VI* and P_{ox} were calibrated using measurements in the Sanjiang Plain in region I (Fig. 1), where the wetlands are dominated by *Carex*. However, in other regions, the dominant plant species in wetlands is *Phragmites*, and *VI* and P_{ox} must be recalibrated to reflect the differences between plant species. We added a detailed explanation of why *VI* and P_{ox} should be recalibrated in section 2.2 (page 5, lines 29-33 and page 6, lines 1-10).

3) Section 3: I think "temporal variations" also include seasonal dynamics. I would suggest the authors add some results on seasonal dynamics (or intra-annual variations) of CH_4 emissions in this section. This should be a part of a "comprehensive" study of CH_4 dynamics.

Response: We agree with the comment that "temporal variations" should include seasonal dynamics. In the original manuscript, the seasonal variations of the fluxes at sites were shown in the supplementary material (Fig. S1). Please see S2.3 "model validation" in the supplementary material. In the revised MS, we added a figure (Fig. 3 in page 41) to show the seasonal dynamics of the modeled CH_4 fluxes of the five regions from the 1950s to 2000s. In addition, we added a paragraph to discuss the seasonal variations of the CH_4 fluxes and the differences among the five regions in section 3.1 (page 10, lines 7-19).

4) Section 4: Some additional discussion is needed to present current knowledge gap in modeling CH_4 processes and large-scale CH_4 emission quantification. How is your CH_4 model different from other CH_4 models? Such as those used in recent CH_4 model inter-comparison studies (e.g., Bohn et al. 2015, Melton et al. 2013). What are present research state and largest challenges in large-scale CH_4 emission simulations? In addition, it is also helpful to compare temporal dynamics of CH_4 (inter-annual, intraannual, trends) in your simulations with other studies.

Response: We appreciate the reviewer's suggestions and have added a discussion of this issue in section 4.5. In the discussion, we compare our model with models recently used in inter-comparison studies focused on methanogenic substrate processes, environmental factors and CH_4 oxidation (please see page 19, lines 30-34, page 20, lines 1-23 in the revised MS). By sharing the common knowledge of methane emissions from flooded soils, the primary processes regarding methane emissions are similar between $CH4MOD_{wetland}$ and other process-based models, such as CLM4Me (Rieley et al., 2011), LPJ-WhyMe (Wania et al., 2010), DLEM (Tian et al., 2010; Xu et al., 2010), Wetland-DNDC (Zhang et al., 2002) etc. However, the $CH4MOD_{wetland}$ model also has its own characteristic. Regarding the modeling mechanism, most of those models were based on land ecosystem models (e.g. LPJ and CLM), which describe comprehensive ecological processes beyond the need of simulating methane emissions. $CH4MOD_{wetland}$ only includes equations that are necessary for modeling methane production, oxidation and emissions and is significantly less complicated than other models. For comparable modeling performances, the simplicity of the model mechanism requires fewer calibrated parameters and simpler variable inputs, which makes the model more applicable for large regions. For example, CLM4Me requires 16 parameters

(Table 1 in Rieley et al., 2011) while $CH4MOD_{wetland}$ only requires 5 parameters (Table S3 in Supplementary material). To reduce the estimation uncertainty in the present study, we validated the model using more field measurements at Chinese wetland sites than used in previous studies (Bohn et al. 2015, Melton et al. 2013, see section 4.3 of the revised MS for a detailed discussion of the estimates from different studies). Among the models, only $CH4MOD_{wetland}$ considers the effect of salinity on CH_4 production, which improved the model performance in coastal regions (S2.1 in Supplementary material).

Change in wetland area is the most important factor for estimating methane emissions from wetlands at regional scales. Compared with previous studies, e.g. Xu & Tian (2012), we used remote sensing data of wetland changes in China (Niu et al., 2012), which provided more reliable information regarding the effects of environmental and anthropogenic activities on wetland changes in China.

In the revised MS, we added a paragraph to address the present research state and largest challenges in large-scale CH_4 emission simulations (page 21, lines 9-32 in the revised MS). In summary, we think the inaccuracies in model mechanisms and model parameters, rough characterization of vegetation conditions and poor availability of information regarding the spatial distribution and temporal variations of wetlands are the largest challenges.

According to the referee's suggestions, we also compared the temporal dynamics of CH_4 (inter-annual, intra-annual, trends) with observations and the results of other simulations (please see page 20, lines 24-33, page 21, lines 1-8 in the revised MS).

Others:

1) P7057 L2: you may update radiative efficiency of CH_4 from IPCC 2013.

Response: We have updated the radiative forcing of CH_4.

2) P7057 L11: delete "e.g.,"

Response: We have deleted "e.g.,"

3) P7057 L13: change "sinks" to "sources"?

Response: We have modified the sentence to "While the majority of CH_4 sinks remain relatively stable, variations in atmospheric CH_4 have been attributed to CH_4 sources." Thus, this statement indicates that the CH_4 sinks remain relatively stable and the variations in atmospheric CH_4 are induced by sources.

4) P7059 L5: delete "and"

Response: This paragraph has been modified. We moved the description of $CH4MOD_{wetland}$ to this section and deleted the original sentence.

5) P7060 L8: what does "vegetation index" mean?

Response: VI is a vegetation index identifying differences in methane production among vegetation types. We added a description of this parameter in section 2.2 (page 5, lines 30-31).

6) P7062 L6: change "assigned to" to "assigned based on".

Response: We have changed "assigned to" to "assigned based on".

7) Figure 4: add (a),(b), : : : (e); delete "at a significantly"

Response: We thank the reviewer for this comment. We have added (a),(b), : : : (e), and deleted "at a significantly" in Fig. 5 in page 43 (original Fig. 4).

Anonymous Referee #2

1) I noticed that the authors used the wetland maps, but it seems that all of them are the "snapshot" of a specific year. The model requires the annual wetland distribution maps; the question here is how did you generate the time series of the wetland maps?

Response: In the present study, we used the $CH4MOD_{wetland}$ model to simulate CH_4 fluxes at each of the grids. Then, we multiplied the modeled CH_4 fluxes by the wetland area in each grid to calculate the CH_4 emissions (page 4, lines 24-28).

Throughout the manuscript, we showed the results of the annual CH_4 fluxes (CH_4 emissions per area) simulated by the model (Fig. 4). When we analyzed the national or regional CH_4 emission results in section 3.2, only the regional or national CH_4 emissions of the specific year were listed (please see Table 1).

We only used wetland maps from 1950, 1978, 1990, 2000 and 2008 (please see section 2.6, page 8, lines 24-33, page 9, lines 1-11). It is difficult to obtain a time series of wetland maps. When calculating the CH_4 emissions for a specific year, the available wetland map obtained nearest the considered year was used (footnote of Table 1).

2) I noticed the soil temperature is from the TEM results. If soil is frozen, how did you handle this situation in the methane simulation?

Response: There are two major sources of CH_4 in frozen soils: (1) CH_4 produced de novo in winter by psychrophilic microorganism and (2) the stored CH_4 formed by mesophilic microbes during the warm period. In our model, CH_4 was transported from the frozen soil to the atmosphere by the standing litter of macrophyte aerenchymatous plants and by diffusion. We compared the simulated CH_4 fluxes with the observations at the Sanjiang site, which has a long freezing winter (Fig. S1 in supplementary material, Fig. 3a in section 4.5, page 20, lines 32-33, page 21, lines 1-5). Although the simulated CH_4 fluxes matched the observed fluxes well, large biases in the modeled winter CH_4 fluxes occurred because the model lacks a process for simulating thawing, freezing and snowmelt. However, because the methane emission fluxes during the winter are very low, the modeling biases of the winter fluxes have trivial contributions to the annual fluxes. We discuss this knowledge gap in section 4.5 (page 21, lines 24-27 in the revise MS).

3) The TEM also has the soil moisture as one output. Is there special reason to select other soil moisture as the input rather than using the TEM output?

Response: To simulate methane production and emissions, soil moisture to the depth of 160 cm is needed for the model used in the present study. However, TEM only provides the soil moisture to a depth of 20 cm.

4) For the wetland pixels indicated by your wetland maps, what if their water tables (from TOPMODEL) are quite low? In other words, TOPMODEL and the wetland maps yield the different wetland extent. How to process it?

Response: TOPMODEL has been extensively used to predict wetland distribution dynamics (Kleinen et al., 2012; Stocker et al., 2014; Melton et al., 2013). However, the simulated wetland change is not sensitive to the impacts of anthropogenic activities that lead to biased estimates of the wetland area (Wania et al., 2013). In China, the dynamics of wetland area are mainly attributed to anthropogenic activities, which cannot be accounted for by the mechanisms in TOPMODEL. In this study, we used wetland change data (Table 1) estimated using the remote sensing approach (Niu et al., 2012) to reflect the wetland changes that occurred in China from 1950 to 2010 (Please see section 2.6, page 8, lines 24-33). We added a discussion of the uncertainty induced by the wetland extents in section 4.2 (page 16, lines 4-20).

5) What is the time step for your TEM simulation? I remember the TEM is monthly model rather than daily?

Response: TEM is a monthly model that provides monthly soil temperatures. We used temporally linear interpolation to produce the daily soil temperatures as inputs for $CH4MOD_{wetland}$. The interpolation may result in the loss of the temporal variation in the daily soil temperatures; however, in our sensitivity analysis (not show in the MS), adding random variations to the interpolated daily soil temperature data did not result in significant differences (approximate 1%) in the modeled annual methane fluxes.

6) How do you select the decay parameter in the TOPMODEL?

Response: In this study, the decay parameter (*m* in equation S2.2) of TOPMODEL was calibrated using the observed daily water tables at SJ and REG (Table S2). At WLS and LRD (Table S2), only the average annual mean water table depth was available; thus, we could only use the average annual mean water table depth to perform the calibration. By setting a step increment of 0.1, the model ran for every step value of *m* within 0.1—3.0 until the root-mean-square error (RMSE) between the simulated and observed water table depth was minimized. The values of "*m*" at each site were shown in Table S3. We extrapolated the calibrated value of "*m*" at a site to the region in which it is located. Additional details regarding how we obtained and extrapolated the decay parameter "*m*" are presented in S2.2 in the supplementary material.

7) I also agreed with the suggestion that the authors should provide the brief introduction to their CH4MOD_wetland model in the Supplemental material.

Response: According to the reviewers' wish, we added a detailed introduction of the $CH4MOD_{wetland}$ model in the manuscript. Please see section 2.1, page 4, lines 3-24.

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