

## **Response to Interactive comment on “A multi-scale comparison of modeled and observed seasonal methane cycles in northern wetlands”**

**We thank the two reviewers for carefully reviewing this manuscript and providing constructive suggestions that will significantly strengthen this study. The following document (in blue) details the authors’ responses to reviewers’ comments.**

### **Response to Referee #1:**

#### **Anonymous Referee #1**

Received and published: 4 July 2016

The paper is devoted to calibration and validation of the CLM4Me model, that is the methane module embedded in the Community Land Model, version 4.5. It presents an important step towards further model development, i.e. the identification of the major drawbacks of the model performance in the area of northern wetlands. The methane model output is compared to different sources of data, covering spatial scales from particular sites (towers, chambers), through regional (WRF-based footprint analysis) to global (inverse modeling estimates). The parameter, characterizing the aerenchyma area, was tuned to get better agreement with empirical data on surface CH<sub>4</sub> emissions. Two methods of inundation parameterization were applied, and compared in the model output. The special focus is made on the Alaskan methane emissions, however a number of chamber and eddy covariance measurements from Swedish and Finnish sites are involved in the model validation as well. One of the main results of the study is that CLM4Me significantly underestimates wintertime CH<sub>4</sub> fluxes calling for deeper understanding of snow-period methane release to the atmosphere from terrestrial ecosystems.

I don't have principal concerns on the results of this study. There are some suggestions, however, which I hope could improve the paper:

- The title of the paper presumes a wider scope that has been actually taken place in the study: "cycles" mean much more than "emissions". I suggest to change the title as: "A multiscale comparison of modeled and observed seasonal methane emissions in northern wetlands"

*Authors:* We replaced “cycles” by “emissions”.

- The structure of the paper could be bettered. For instance, in the model description section 2.1.1 some of the model results are discussed. I recommend to move the latter to the appropriate sections.

*Authors:* We moved the results from section 2.1.1 to section 3.1.

- I could not understand why aerenchyma-related parameter S was the only one that was calibrated, whereas there are a lot of others in any methane model. Moreover, I didn't see any significant impact of changing S on the zonally-averaged methane emission annual cycle in the northern latitudes, depicted at Fig.1, whereas such an impact had been anticipated as one of the main points of the paper.

*Authors:* In this study, we did not intend to make a full parametric uncertainty quantification, but rather to fix the issue that was responsible for the unrealistic CH<sub>4</sub> emission seasonal pattern (very high CH<sub>4</sub> emissions in the thaw period followed by relatively low CH<sub>4</sub> emissions through the growing season in inundated areas). We only calibrated the aerenchyma-related parameter S because we found the original assumption related to aerenchyma area caused the unrealistic high latitude seasonal pattern of CH<sub>4</sub> emissions. We also performed sensitivity analyses of other parameters, including those for CH<sub>4</sub> production, oxidation, and transport pathways (e.g.,  $f_N$  in aerenchyma transport) and found that other parameters have minimum impact on the unrealistic seasonal pattern. To clarify these points, we added to section 3.1 the sentence “We performed sensitivity analyses of all the parameters affecting seasonal CH<sub>4</sub> production, oxidation, and emission pathways and found that the parameterization of aerenchyma transport

had the greatest impact on the seasonal CH<sub>4</sub> emissions in saturated areas.”  
Compared with CarbonTracker predictions, our changes resulted in several CLM CH<sub>4</sub> emission prediction biases being reduced (e.g., overestimation between 30 and 60 °N in May and June, underestimated growing-season CH<sub>4</sub> emissions north of 56°N, and overestimated CH<sub>4</sub> emissions in 2-53°N and 34-56°S; Fig. 1d and f).

- I have a number of more specific remarks, that are given as **sticky notes** in the manuscript pdf. I propose to accept the paper for publication after corresponding revision.

*Authors:* All the responses and revisions to sticky notes are incorporated into the new drafts of this manuscript.

## **Response to Referee #2:**

### **Anonymous Referee #2**

Received and published: 5 July 2016

General Comments: I liked to read this paper as they used an improved CLM-BGC model to estimate the methane fluxes from northern wetland and compared the model- estimated methane fluxes with static chamber measurements, eddy covariance and aircraft measurements. However, I see some major shortcomes which need to be addressed in a revision. Specific comments:

- 1. In this study, the major improvement of the CLM4.5-BGC is related to the methane transport through aerenchyma. In the Equation 2 (Line 210), several parameters were used to calculate the aerenchyma area. However, the author only analyzed and discussed the variation of “S”. Why? I missed to see the discussion at this point. How about fN (belowground fraction of current NPP)? Is this a fixed parameter or it will change during different growing stages? If it is a fixed parameter, you should also discuss the related uncertainties.

*Authors:* We addressed this same point above in our response to Reviewer #1.

- 2. In the Section 3.1 (Line 350-362), the author compared the model-estimated results with TD and BU estimation from Kirschke et al., 2013, which was unexpected. It seems that the whole manuscript was talking about the methane fluxes from northern high latitude (mostly in Alaska). And the wetland types in the tropical regions are very different from the ones in high latitude region. I suggested to remove this part or only focus on the northern wetland, and make the whole manuscript more consistent.

*Authors:* Since CLM is a global model, changes to a parameter will have effects globally. We compared the results with TD and BU estimation from Kirschke et al., 2013 to clarify that the improved model predictions extended globally.

- 3. In the Section 3.2.1, there should be further discussion about the overestimation, underestimation and misrepresentation of seasonal emission from CLM compared with site-level observation, especially for Figure 2a, b, d, h and k. Otherwise, it was hard to say CLM has the capability to reproduce the methane fluxes.

*Authors:* A detailed site-level comparison was not a goal of this paper, since the model was not initialized at each site, nor were parameters chosen specifically for sites. Instead, we describe in the text the potential reasons for the misrepresentation of seasonal emissions from CLM, and note that the reasons vary by site and year.

- 4. It is good to make the unit consistent throughout the manuscript, especially in Section 3.2.2. It made readers very confusing to have different units even within the same paragraph.

*Authors:* We revised to use the same unit of CH<sub>4</sub> emissions (mg CH<sub>4</sub> m<sup>-2</sup> day<sup>-1</sup>). Accordingly, we updated Fig.1 to use the same unit.

- 5. In Section 3.3, I was just curious about the analysis of temperature and precipitation. Did the author analyze the temperature and precipitation over Northern wetland (only inundated area)? Line 525-527, it is hard to read the bias from the Fig. 6.

*Authors:* The temperature and precipitation anomalies are calculated over all of Alaska. In Fig. 6, the modeled wintertime CH<sub>4</sub> emissions (blue and green lines) are much smaller than the CarbonTracker CH<sub>4</sub> emissions (brown line).