1. Reviewer 1 Comments

General

This paper on Intercomparison of wetland methane emissions models, using the West Siberian Lowlands as a test area. It is a very useful evaluation of the performance of models and wetland data sets used for modeling, and it clarifies the sources of the strong variability of wetland methane emission estimates produced by models. It shows the large effects of input data, in particular wetland or soil moisture/inundation mapping products, and of model structure. The choice of the West Siberian Lowland as a model test area is a very appropriate one because of the availability of test data sets and the large contribution of this area to northern wetland methane emissions. To simulate northern wetlands accurately, it is crucial to determine model features that are required, and to which parameters and input data these models are most sensitive. The conclusions which are drawn in this paper, can be considered as guidelines for improvement of methane emission models for northern wetlands.

A minor drawback of the paper is, that there is hardly discussion on what actually defines a wetland, although the word 'wetland' is used throughout the paper. This is not just a matter of theory. Each of the wetland data sets used as model input, and each of the models, implicitly contain a certain definition of wetland. To understand the differences between the model outputs properly, it is important to know what these implicit definitions of wetlands look like. For instance, do the "Sheng2004" and "Peregon2008" include smaller lakes, and if so, to which size limit, and what determines the delineation of wetlands from non-wetland areas? Likewise, from the description of the models it is clear, that some models define wetlands based on hydrological modeling (e.g. TOPMODEL), and some require input of external wetland data sets. Some of these data sets (e.g. GIEMS) appear to map only inundation, while methane emission is not necessarily restricted to inundated soils (as also concluded in the paper). Again, 'inundation' is an implicit definition of wetlands. Elsewhere (p 16) it is suggested that wetlands always imply the presence of peat soils, which is not always the case. I suggest the authors to pay some attention to definition of wetlands, and their relation to methane emission, soil type and the delineation of wetlands. It would be useful to list these implicit wetland definitions in the input data sets.

Specific remarks (numbering added by author)

1. Page 6, line 16-18: "The vast majority of these wetlands are peatlands, with peat depths ranging from a few cm to over 5 m, comprising a total soil carbon pool of 70 Pg C (Sheng et al., 2004)." Note that in most soil classification systems, soils with less than a few decimeters of peat would not classify as peat soil but as mineral soil.
2. Page 7, line 15-23: Please provide some more information on the remote sensing inundation products. Do they contain information on the seasonal variation of inundation, if so, what is the temporal resolution?
3. Page 8, line 26-27: "In both cases, monthly coefficients (uniform in space over a region) were derived for each of 11 large regions of the globe." It is difficult to understand immediately what is meant here. Try to reformulate.
4. Page 16, line 27-32: This is not very clear. Are wetland soils taken as synonymous to peat soils, and if a wetland data set indicates the absence of wetlands, the soil is automatically assumed to be a mineral soil? Please explain.

5. Page 21, 13-27. This demonstrates my point about wetland definition, explained above. Again, could there be overlap between the inundation data sets and lakes, of which the carbon cycling and methane emission processes may indeed differ from those in terrestrial wetlands?
6. Page 23 1-2: You could add here also, realistic soil freezing and thawing, for proper simulation of permafrost wetlands.
7. Page 23 5-12: This effectively means that realistic soil hydrology is necessary, calculating water table depth independent of wetland delineation.
8. Tables 2 and 3: These tables suffer from too short and non-informative captions. For instance the 'code' should not be described in the text only, but also at least an indication of what it means should be given in the caption

2. Author Response

General

We agree with the reviewer that wetlands, and other terms that we use, need to be clearly defined. Therefore, we have created a new section (2.2) to define this and other terms used throughout the manuscript. To be consistent with these definitions, we have changed the terms we use in referring to various components throughout the paper. As requested, in section 2.3 (previously section 2.2), we have added descriptions of which components (e.g., surface water, or wetlands excluding large lakes) are included in each observational dataset. In section 2.4 (previously section 2.3), we have added descriptions of which components are handled in the various models. We also moved the text in section 2.5 (previously section 2.4) dealing with different models' definitions of wetland area (now CH4-producing area) into the parts of section 2.4 describing those models' hydrologic schemes, since these two discussions were so closely related. Hopefully this reorganization makes it clearer which wetland components are handled in each model, which components produce CH4, and how accurately the CH4-producing areas reported by the models reflect their true CH4-producing areas. For details, please see the "Author's Changes in Manuscript" section.

Specific

1. We apologize; this was a mistake. The peat depths from Sheng et al. 2004 ranged from 50 cm to over 5 m. We have corrected this statement.
2. The final sentence of the paragraph states that we aggregated these products from daily to monthly temporal resolution. We thought it would be clear from that statement that the original temporal resolution of these products was daily. Table 1 (referred to in the first sentence of this section) also describes all of these datasets, including their spatial and temporal resolution. However, to make this clearer and more convenient for the reader, we have also inserted the adjective "time-varying" in our description of the 2 global inundation products.
3. We have reformulated the text to make this clearer.
4. We apologize; we should have worded this entire section more clearly. We have edited it to make it clearer.

5. Again, we apologize for our poor wording. In fact, we were trying to make the same point you make here, that lakes are erroneously included in remote sensing datasets. We have edited the passage to make it clearer.
6. We have added "including freeze-thaw dynamics" to that bullet.
7. We have changed the first sentence to read: "Realistic representations of unsaturated (non-inundated) peatlands, including the dependence of CH_4 emissions on water table depth."
8. We agree, these tables were poorly documented. We have added footnotes explaining the meanings of the column headings and values. If the editor prefers, we can move the information into the captions.

3. Author's Changes in Manuscript

General

We have added section 2.2, "Terminology" as follows:

> Estimating wetland CH_4 emissions over large scales requires accurately delineating the wetland area over which CH_4 emissions can occur. Unfortunately, "wetland" definitions vary within the scientific community (Mitsch and Gosselink, 2000). For the purposes of estimating CH_4 emissions, the key characteristics include anoxia and available labile carbon substrate; therefore we will adopt the definition proposed by Canada's National Wetlands Working Group (Tarnocai et al., 1988): land that is saturated with water long enough to promote wetland or aquatic processes as indicated by poorly drained soils, hydrophytic vegetation, and various kinds of biological activity which are adapted to a wet environment. Because permanent, deep (> 2m) open water bodies are subject to additional processes (e.g., allocthonous carbon inputs, wind-driven mixing of the water column; Pace et al., 2004), we will exclude them from our definition. Unfortunately, explicit observations of lake depths are lacking for all but the deepest lakes; therefore we will instead use an area threshold (1 km^2) to identify permanent lakes. This definition of wetlands therefore includes all peatlands (inundated or not), seasonally-inundated non-peatland soils (e.g., river floodplains), and small ponds or lakes; but excludes rivers and large lakes.
>
> We define "surface water" as all fresh water above the soil surface; i.e., the superset of inundation, lakes, and rivers. We define "inundation" as temporary (present for less than 1 year) standing water above the soil surface; "lakes" as permanent water bodies (present for more than 1 year) exceeding 1 km^2 in area; and "rivers" as channels that carry turbulent water. Surface water therefore includes areas that do not emit large amounts of CH_4, such as rivers, and also excludes some CH_4-emitting areas such as non-inundated peatlands.

> For models, we will use the term "CH_4-producing area" to refer to the area over which CH_4 production is simulated, which might not coincide exactly with the areas of actual or simulated wetlands.

To be consistent with these definitions, we have therefore replaced instances of "inundation" with "surface water" or "Fw" when referring to the remote sensing products GIEMS and SWAMPS. Similarly, we have replaced instances of "wetland area" with "CH4-producing area" when referring to the areas over which models simulate CH4 dynamics. The "I" code in table 2 and Figures 5 and 12 has been changed to "S" to denote the use of "surface water" products instead of "inundation" products. These changes occur in too many places to list them here. However, this did require new versions of Figures 3, 7, and 10, in order to update the axis labels to use the correct terms.

In section 2.3 (previously section 2.2), we have added descriptions of which components (e.g., surface water, or wetlands excluding large lakes) are included in each observational dataset (page 8, lines 3-12).

In section 2.4 (previously section 2.3), we have added descriptions of which components are handled in the various models (page 11, lines 16-30; page 12, lines 6-13 and lines 21-26). The new text on page 11, lines 16-30 was moved there from section 2.5 (previously section 2.4), page 14, lines 9-22. Hopefully this reorganization makes it clearer which wetland components are handled in each model, which components produce CH4, and how accurately the CH4-producing areas reported by the models reflect their true CH4-producing areas.

We also added a citation of Mitsch and Gosselink (2000) on page 41, lines 19-20, and of Tarnocai et al. (1988) on page 46, lines 23-28.

Specific

(page and line numbers refer to the Word document *with markup shown*)

1. Page 6, line 17: replaced "a few cm" with "50 cm".
2. Page 8, line 15: inserted "time-varying".
3. Page 9, lines 27-32: we have modified the text as follows:

   "In both cases, a single, spatially uniform set of monthly coefficients was derived for each of 11 large regions of the globe. The region containing the WSL was Boreal Asia (in which the WSL makes up the majority of the wetlands). Consequently, spatial patterns in estimated emissions at the scale of 1×1° were identical to those of the prior emissions; only the regional total emissions were constrained by the inversions."

4. Page 18, line 28 – page 19, line 8: here is the new wording:

   "Similarly, the low emissions of LPJ-WHyMe and LPJ-Bern in the South can be explained by their use of the NCSCD map, which only considered peatlands (histels and histosols) within the circumpolar permafrost zones (which only occur north of 60° N). For LPJ-WHyMe, these permafrost peatlands were the only type of wetland modeled (i.e., the model domain only included the circumpolar permafrost zones), so LPJ-WHyMe's emissions were almost nonexistent in the South. LPJ-Bern also used the

NCSCD's histels and histosols to delineate peatlands, but additionally simulated methane dynamics in wet or inundated mineral soils outside the permafrost zone. While this allowed LPJ-Bern to make emissions estimates in the South, the much lower porosities of mineral soils resulted in larger drops in water table levels than would occur in peat soils for a given evaporative loss. These drier soils led to net methane oxidation in much of the South."

5. Page 24, lines 14-27: The new wording of this section is (note that we have replaced "inundation" with "surface water" when referring to satellite products):

   "The most striking finding, in terms of long-term means and spatial distributions, was the substantial bias in CH_4 emissions that resulted from using satellite surface water products or inaccurate wetland maps to delineate wetlands. Surface water is an important component of wetland models, but it clearly is a poor proxy for wetland extent at high latitudes, because it both excludes the large expanses of strongly-emitting non-inundated peatlands that exist there (Section 2.1) that were missed by GIEMS and underrepresented by SWAMPS; and erroneously includes the high concentrations of large lakes there (e.g., Lehner and Döll, 2004), which do not necessarily emit methane at the same rates or via the same carbon cycling processes as wetlands (e.g., Walter et al., 2006; Pace et al., 2004). The practical difficulties in detecting inundation under forest canopies with visible or high-frequency microwave sensors (e.g., Sippel and Hamilton, 1994) compound these problems. In the case of the WSL, equating wetlands with surface water not only caused underestimation of total CH_4 emissions, but also led to attribution of the majority of the region's emissions to the permafrost zone in the North."

6. Page 26, line 3: We have inserted ", including freeze-thaw dynamics".
7. Page 26, line 9: We have changed the first sentence to read: "Realistic representations of unsaturated (non-inundated) peatlands, including the dependence of CH_4 emissions on water table depth."
8. Pages 52-58, tables 2-3: We have added footnotes underneath the tables to explain the column headings (in addition to changing the wording of the column headings to be more consistent with our terminology).