We thank reviewer 1for the thorough review of our work. Below I will split the reviewer's comments into pieces and provide our responses. (Our responses are in red).

The sensitivity calculations are informative at the site level, and not at the model gridcell level. This immediately raises the question how the site-level model can be scaled to the gridcell and to the globe. The authors could have and should have confronted the scaling issue and carried out additional sensitivity calculations to assess the global and regional emission estimates - the ms gives me no reason to have confidence in the estimates reported here.

Response: We agree with the reviewer that there is much more work to do in examining global sensitivities and through the use of model-measurement comparisons. Scaling global model results where only a few sites are available is always a tricky proposition, however, there is really no other way to build a bottom up model. In this paper we emphasized site level comparisons. As we show in the paper, evaluating at the site level gives a much different result than evaluating on the grid cell level. However, we did extend our sensitivity results globally in section 4.9 (see Figure 13) and discuss the global budget in section 5. Many additional global sensitivity studies are conducted in Riley et al., using a similar model. In section 5.1 we discuss our results in more detail in the revised paper, and discuss some of the fundamental underlying reasons why our results are different from those obtained in previous studies.

Specific Comments:

The land model CLM4CN does not include plant function types (pft's) associated with wetland vegetation (Section 2.4). Instead of adding pft's for wetland vegetation (which the authors acknowledged to be a better solution), the authors assumed that methane production from the inundated portion of a gridcell scales with the heterotrophic respiration (R_H) in the entire grid cell (Equation 1). Such an assumption ignores the fact that wetland vegetation is structurally and functionally different from non-wetland vegetation, and that methane production is associated with anaerobic decomposition, while R_H is associated with aerobic processes. Granted, Walter et al. (JGR 2000), Spahni et al (BGD 2011) and others similarly assumed that the modeled NPP or R_H of a gridbox is indicative of substrate availability for methane production in the inundated portion of the gridbox. Walter et al.'s comparison with the observations shows however that the production is too large: they discussed this discrepancy at length and emphasized that the model must account for subgrid scale heterogeneity of R_H and perhaps of precipitation as well. In Spahni et al., the CH4:CO2 ratio (f_CH4 here) is not a global constant (as assumed here), but is used as a tuning parameter for each wetland ecosystem. For quantifying global methane emissions, the most important sensitivity calculations to perform are those related to the scaling of R_H and f_CH4. These are not included in this study.

Response: We agree that wetland speciation is important as well as the possible importance of subgrid scale heterogeneity of heterotrophic respiration (HR). These are both beyond our modeling capabilities at the present time. Most global models do not include these capabilities. These and other shortcomings of CLM4 are highlighted in the revised manuscript on Page 6. We acknowledge that these shortcomings impact the methane emissions; however, the incorporation of methane emissions into the current generation of Earth System Models, despite their deficiencies, is an important first step towards understanding the response of methane emissions to changes in climate.

We have shown in our paper that f_ch4 is a very important parameter in our model. Indeed, our sensitivity analysis at several sites suggests that f_ch4 plays a very important role in controlling global methane budget. On page 24 in the revised text we emphasize the importance of this parameter. As mentioned in Spahni et al. (2011) and Wania et al. (2010) papers, there exists a large uncertainty for f_ch4 value and it ranges from 0.0001 to above 1. Ideally, spatial distribution of f_ch4 value would be used in a global methane model. Unfortunately, the data is not available. However, since Pch4(methane production rate) = HR*f_ch4, the sensitivity test on f_ch4 (which we have included) does allow the assessment of some of other uncertainties due to our simple assumptions.

Our model derived methane production from CLM4CN simulated heterotrophic respiration (HR) is not a scalable parameter. Errors in methane emissions are due not only to the methane process model but the model on which it is based. As stated on page 6 in the revised manuscript it is outside the scope of this study to correct the deficiencies in the base model.

The second most important set of sensitivity calculations to perform is the dependence of methane production on the modeled hydrology in CLM4CN. These calculations are also not included in this study. The comparison with the site measurements avoids the water table issue entirely by choosing the flux from the saturated or the unsaturated portion of the gridcell according to observed state of the water table. The authors should at minimum comment on the realism of CLM4CN simulation of hydrology, and how the simulation impacts the emission estimates. Does CLM4CN have a wet or dry bias?

Response: In fact we did not **use modeled hydrology** to calculate methane production within this paper. Indeed there are large differences between CLM4CN inundated fraction and satellite inundated fraction. We have also stated this reason in the revised manuscript on page 16. We have modified the text to emphasize our methodology in both the abstract and page 16. The use of satellite inundated fraction is described in details in section 3.1 on page 16. At the site-level, in order to minimize the impact of errors in CLM4CN hydrology on methane production, we prescribed the water table depth based on observational data. Our goal is to have a better understanding of methane emissions without considering errors in the CLM4CN hydrology.

In CLM4CN, NPP is overestimated in the tropics and underestimated at high latitudes (Section 2.5; Fig 6). Maybe this is why close to 80% of the global methane flux comes from the tropics and so little comes from the high latitudes. However, the modeled annual mean NPP has been adjusted (equation 11) at every gridcell to match that derived from MODIS.

Response: We did not apply NPP adjusted factor at every gridcell. We applied this factor only at several sites to test the impact of substrate production uncertainty on methane emissions and not to modify our global emission estimates. Our finding suggests that adjusted NPP does not improve model bias at individual sites and the methane emission model biases are not just because of errors in the NPP. However, it might be true that the overestimation of NPP in the tropics and underestimation at high latitudes might change the distribution of the global estimates. We added a few sentences to address this issue on Page 23. The relatively high tropical emissions and low high latitude emissions are now discussed in much greater detail in section 5.1.

Yet Section 6 attributes the low high-latitude flux to the low high latitude productivity in CLM4CN. It is not clear what's going on.
Response: At a regional level, adjusting NPP might change the regional methane emissions. On a site level, it is clear there are many other sources of error besides just biases in NPP. See discussion on Page 21.

The authors should explore what parameters give high tropical methane emissions in the model. Also, as far as I can tell, there are no peatlands or permafrost in the model. Is this a reason for the low emissions from high-latitudes?
Response: In our paper, we mentioned that higher tropical production may be partially attributed to the fact that CLM4CN overestimates gross primary production over the tropical regions (Bonan et al., 2011). Because methane production is derived from NPP, the overestimation of NPP will have direct impacts on tropical methane emissions. We do have permafrost in the model. Since we used satellite inundated fraction in our model, the permafrost in the CLM4CN does not have an impact on our global methane emissions. We devote more extensive discussion to these issues in the revised section 5.1.

For the low emission from high latitudes, this underestimate could be partially due to the underestimation of inundated area (as suggested in Prigent et al. (2010) paper) and it could be due to an underestimate in NPP.

However, while our high latitude emissions are low compared to previous estimates, there is considerable evidence that many previous results may be somewhat biased high. In fact, the recent inverse study of Spahni et al. (2011) found the posteriori emissions in the northern peatlands (north of 45^o) decreased by approximately 25% from their apriori values (from 38.6 to 28.2 Tg CH_4 y^{-1}). Another inverse study of Kim et al. (2011) estimated a methane emission of 3.0 Tg CH_4 y^{-1} from West Siberian wetlands which is much lower than the GISS inventory estimation (6.3 Tg CH_4 y^{-1}). Methane emissions from Canadian wetlands are estimated to be 3.5 Tg CH_4 y-1(Bachand et al.,1996). Canada and West Siberia have approximately 40% and 30% of the northern wetlands(Rydin and Jeglum,2006). So 70% of the northern wetlands account for ~7 Tg CH4 y-1. Assuming that other northern wetlands have similar methane emissions as Canadian and West Siberian wetlands would add another 3 Tg CH4 y-1. Walter et al. (2006) estimated an emission of 3.8 Tg CH4 y-1 from melt lakes in Siberia that might also appear as inundated land. Therefore, total methane emission from northern wetlands is about ~14 Tg CH4 y-1 which is close to our estimate.

Unlike Walter et al., the seasonality of methane fluxes are not well simulated at the few measurement sites (Fig 7, 8), despite claims in the text. While the modeled spring peak is discussed in Appendix B, there is no discussion of the poor simulation of the phasing of the methane flux. The observed methane emission in Alberta is later in the season than that modeled, while the Rhizospheric oxidation fraction appears to have the opposite seasonal trend from that observed. The model fails to capture the seasonal dynamics in Florida as well. This could be related to the poor simulation of the seasonal cycle of NPP, which may in turn depend on the modeled seasonal cycle of hydrology. The authors should figure out why the seasonal cycles are so poorly simulated here when they are well simulated in other studies (e.g Walter and Heimann, 2000), and how the uncertainties in seasonal cycles propagate to annual emission estimates.

Response: We agree that the seasonality of methane fluxes is relatively well simulated in Walter and Heimann (2000) paper. However, note that in Walter and Heimann (2000) the methane fluxes are calculated at four of their five wetland sites with measured water table positions and measured soil temperature (except Panama site). In addition, several important model parameters are modified in order to get a better match with observed methane fluxes. At our site simulation, we only used observed monthly water table position at the site level. All other variables (such as soil temperature) are from CLM4CN model and are calculated on the scale of the global model resolution. As described on page 6 we want to simulated methane emissions within an Earth-System Model.

In order to address the issue raised here, we have examined closely the seasonal cycle of model estimated heterotrophic respiration (HR). We find that the poor match in seasonal variation of methane fluxes between model and observation is likely to be at least partially due to the fact that CLM4CN derived HR peaks in early spring and not in summer when measured methane fluxes were highest. We have added a few sentences in our revised manuscript to specifically mention the disagreement in terms of seasonal variation the seasonal variation in HR on Page 20. This is one of the many difficulties in building a methane model in a global Earth System Model: the methane model is subject to the biases in the global model. In this case, our predicted methane fluxes are obviously subject to the biases in CLM4CN predicted HR.

Reference

Bachand, R., Moore, T. R., and Roulet, N. T.: A map of methane emissions from wetlands in Canada. Report 96-7, Centre for Climate and Global Change Research, McGill University, Montreal, 1996.

Bonan, G. B., Lawrence, P. J., Oleson, K. W., Levis, S., Jung, M., Reichstain, M., Lawrence, D. M., and Swenson, S. C.: Improving canopy processes in the Community Land Model (CLM4) using global flux fields empirically inferred from FLUXNET data, J. Geophys. Res., 116,G02014,doi:10.1029/2010JG001593, 2011.

Kim, H.-S., Maksyutov, S., Glagolev, M. V., Machida, T., Patra, P. K., Sudo, K., and Inoue, G.: Evaluation of methane emissions from West Siberian wetlands based on inverse modeling, Environmental Research Letters, 6, doi:10.1088/1748-9326/1086/1083/035201, 2011.

Prigent, C., Papa, F., Aires, F., Rossow, W. B., and Matthews, E.: Global inundation dynamics inferred from multiple satellite observations, 1993-2000, Journal of Geophysical Research-Atmospheres, 112, doi:10.1029/2006JD007847, Artn D12107
Doi 10.1029/2006jd007847, 2007.

Rydin, H., and Jeglum, J.: The Biology of Peatlands, Oxford University Press., 2006.

Spahni, R., Wania, R., Neef, L., van Weele, M., Pison, I., Bousquet, P., Frankenberg, C., Joos, F., Prentice, I. C., and van Velthoven, P.: Constraining global methane emissions and uptake by ecosystems, Biogeosciences, 8, 1643-1665,doi:1610.5194/bgd-1648-1643-1665, 2011.

Walter, B. P., and Heimann, M.: A process-based, climate-sensitive model to derive methane emissions from natural wetlands: Application to five wetland sites, sensitivity to model parameters, and climate, Global Biogeochemical Cycles, 14, 745-765, 2000.

Walter, K. M., Zimov, S. A., Chanton, J. P., Verbyla, D., and Chapin, F. S.: Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming, Nature, 443, 71-75, doi:10.1038/nature05040, 2006.

Wania, R., Ross, I., and Prentice, I. C.: Implementation and evaluation of a new methane model within a dynamic global vegetation model: LPJ-WHyMe v1.3, Geosci. Model Dev., 3, 565-584,doi:10.5194/gmd-3-565-2010, 2010.