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Response to the comments on "Methane emissions associated with the conversion of marshland to cropland and climate change on the Sanjiang Plain of Northeast China from 1950 to 2100"

Anonymous Referee #1

Received and published: 20 July 2012

The authors intend to estimate methane emissions associated with marshland conversion to cropland and climate change in Sanjiang Plain of northeast China for the period from 1950 to 2100 by using two biogeophysical models. The CH4MOD model was used for simulating methane emission in paddy soils and $CH4MOD_{wetland}$ was used for natural wetland. The main conclusions include that 1) marshland conversion and climate variation resulted in a significant reduction of 1.1 Tg yr^{-1} during 1950s-2000s, and 2) future climate warming and wetting would lead to large increases in CH_4 emission in this area. Such a research topic is clearly of interest to scientific community and policy makers, but I have a number of significant concerns regarding the models, data and hence the conclusions:

Below are some major concerns:

1) The modeling approach used in this manuscript is unable to simulate how marshland conversion processes affect methane emission, which could largely influence direct methane emission during the conversion process as well as indirect methane emission after marshland conversion.

Reply: We agree with the referee that the conversion process could directly and indirectly influence methane emission. The reclamation of wetlands to croplands involves mainly the drainage of the water and tillage of the soil. Drainage aerates the soil and mitigates activities of methanogenesis. Tillage of the soil accelerates decomposition of the soil organic matter and reduces methanogenic substrates gradually. The changes after wetland reclamation therefore have the results of reducing methane production and emission (Jiang et al., 2009; Liu et al., 2010; Roulet & Moore, 1995; Smith & Conen, 2004).

In the present study, we simulate processes concerning methane emission from wetland and rice paddies by $CH4MOD_{wetland}$ and CH4MOD model, respectively. Both models had been validated to have reliable performances in their subject domains (Huang et al., 2004; Li et al., 2010). During the development of the model, we have considered the direct influence of marshland conversion on CH_4 emissions. The key factors in the models that directly influence CH_4 emission during the conversion of marshland to rice paddies involve changes in plant growth, the nutrient level (from non-fertilizing to fertilizing), methanogenic substrate, the water level (from non-irrigation to irrigation) and the agriculture practice (from no-tillage to tillage). Firstly, marshland plants are not harvested, but rice will be harvested at the end of the season. So plant litter is a main source of methanogenic substrate in marshland. In $CH4MOD_{wetland}$, we pay more attention on this process. Secondly, after marshland conversion to cropland, fertilizing will be inevitable. In CH4MOD, we divided the organic matter that added into the rice fields into crop roots and stubble, as well as straw and farm manure. Then we calculated the methanogenic substrate derived from this organic matter. Thirdly, when marshland converted to cropland, tillage of the soil accelerates decomposition of the soil organic matter and reduces the soil organic matter. So in $CH4MOD_{wetland}$, the soil organic matter supplies part of the methanogenic substrate, but in rice paddies, this can be negligible compared with root exudates. Fourthly, the fluctuation of water level is a natural process in marshland, which is dependent on the precipitation, the evaporation and the terrain. In $CH4MOD_{wetland}$ the water level is simulated by a water table model. However, when marshland converted to rice paddies, irrigation happened. So in CH4MOD, we cataloged five patterns of water management for rice cultivation in China. The flood-drainage-re-flood-moist with intermittent irrigation was used to control the water level for single rice in northern China. Finally, when marshland converted to rice paddies, the soil properties which can affect CH_4 emissions were also changed. This change was embodied in the soil input parameters.

In the Sanjiang Plain, the wetland was cultivated to plant rice or upland crops, e.g. maize, soybean and wheat etc. In case of upland crops, no obvious methane emission had been observed and therefore assumed zero emission in the present study. Data of land use change involving wetland reclamation were distinguished between rice cultivation and upland crop cultivation (Section 3.2.1 of the paper). In the present study, we simulate methane emission in wetland by the $CH4MOD_{wetland}$ model before reclamation and by the CH4MOD model after the wetland were cultivated into rice paddies (Figure 4 and Section 2.2 of the paper).

References:

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2) Marshland may be converted to different types of cropland such as rice, corn, soybean, etc. The magnitude of methane emission is largely dependent on the fate of marshland conversion. For example, methane emission may decrease while marshland converts to corn or soybean. The conversion from marshland to dryland such as corn and soybean cropland needs to be considered for assessing methane emission associated with marshland conversion.

Reply: We agree with the referee in that the magnitude of methane emission is largely dependent on the fate of marshland conversion. Methane production in soils occurs only when organic matter is degraded anaerobically (Oremland 1988; Svensson & Sundh 1992; Conrad 1989). Dryland produce little CH_4 or consume CH_4 according to Jiang et al. (2009) and Chan & Parkin (2001), which is negligible compared to emissions from rice paddies and marshland (20-65 g CH_4 m^{-2} $year^{-1}$) (Fig. 3). In this study, when marshland converts to upland crop cultivations, e.g. corn or soybean, we assumed the CH_4 emission decreased to zero. The area of wetland cultivated into rice paddies and dryland were also compiled respectively to account for the differences of methane emission owing to the wetland conversion fate (Figure 4).

References:

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Oremland, R.S.: Biogeochemistry of methanogenic bacteria. In: Zehnder, A.J.B. (Eds.) Anaerobic Microbiol, Wiley, New York, 641-705, 1988.

Svensson, B.H. and Sundh, I.: Factors affecting methane production in peat soils, Suo, 43: 183-190, 1992.

3) The spatial extrapolation method used by the authors is county-level simulations, which could lead to large uncertainty. Spatially-explicit process modeling and spatial data with fine resolution are needed to estimate methane emission in this area. I suggest using gridded environmental data as model input.

Reply: Uncertainties in estimating methane emission from wetland and rice paddies may come from a lot of imperfections, inaccuracy of the model structure and coefficients, representative errors in data and the data processing etc. In the present study, our attention was on the temporal changes of methane emission along with the wetland conversion. The spatial variation of methane emission in the Sanjiang Plain might not be comprehensively represented by the model results due to the spatial resolution adopted. But because of the limited data in anthropogenic activities, detailed environmental data may contribute little to reduce the uncertainty of the regional estimation. The uncertainty in spatialization method of the environmental data was discussed in 3.2.2 (page 5903, lines 5-14).

4) The authors did not provide detail description of how their simulations generated the baseline methane emission in the 1950s. Additional details on simulation initialization are needed in order to evaluate model performance.

Reply: Climatic data were ready for all of the years from 1950s to 2000s (page 5898, lines 7-10). The average values obtained through measurements performed from 2002-2005 for *C. lasiocarpa* and from 2002-2004 for *D. angustifolia* were used as input data of 1950 for the maximum above-ground biomass (3.2.2, page 5903 lines 15-17) which is one of the model input variables. We set the initial above ground biomass (W_0) to be 2 g m^{-2} the same as in the model validation (Li et al., 2010). The soil input parameters of 1950 were from SSSSC (1994, 1996). The description of the marshland area in 1950 was described in 2.3.1 (page 5897, line 20-25).

We used the water table states to be the initial water table value of the year of 1950. The water table states were obtained by a 10-year spin-up simulation by the water table empirical model, the forcings for which were climate data of 1950-1959.

We add specific description about model initialization in the paper (page 5898, line11 and line 19).

References:

Li, T. T., Huang, Y., Zhang, W., and Song, C. C.: $CH4MOD_{wetland}$: A biogeophysical model for simulating CH_4 emissions from natural wetland, Ecol. Model., 221, 666-680, 2010.

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State Soil Survey Service of China (SSSSC) (Eds.): China Soil Series, vol. 6, China Agriculture Press, Beijing, 512-513 pp, 1996 (in Chinese).

5) Estimates on methane emission with CH_4 model are more uncertain than those of the basic carbon cycle. For example, what are uncertainties associated with major parameters, marshland area, and spatial resolution, etc. I strongly suggest performing uncertainty analysis associated with marshland conversion and key parameters.

Reply: We are aware of the huge uncertainties in estimating methane emission from wetlands and rice paddies by models. As pointed out by the referee and in many other studies (King, 1991; van Bodegom et al., 2000), the uncertainties may associate with many factors, the inaccuracy in model structure, error in data measurements, limited abundance of the model input data and spatial resolution etc. Comprehensive uncertainty analysis is the major concern in modeling studies (Ogle *et al.*, 2003, 2010). In this study, we made a primary discussion on the uncertainty of the modeling results concerning methane emission associated with marshland conversion in Section 3.1 (page 5900, lines 5-20) and Section 3.2.2 (page 5903, lines 4-25). We agree in that there may be uncertainties in estimating the conversion area from marshland to cropland. And it might induce uncertainties in the simulated regional CH_4 emissions. However, it is difficult to carry out comprehensive uncertainties analysis of CH_4 emissions associated with marshland conversion, because the sufficient data of marshland conversion is unavailable in annual sequence from 1950 to 2009 at a higher spatial resolution. At present, the obtained data of marshland conversion can only support a baseline simulation of the annual methane emission changes at a lower spatial resolution. Our future study will pay more attention on the uncertainty analysis when more data are available.

References:

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Ogle, S., Breidt, F., Eve, M. and Paustian, K: Uncertainty in estimating land use and management impacts on soil organic carbon storage for US agricultural lands between 1982 and 1997, Global Change Biol., 9(11), 1521-1542, 2003.

Ogle, S., Breidt, F., Easter, M., Williams, S., Killian, K. and Paustian, K.: Scale and uncertainty in modeled soil organic carbon stock changes for US croplands using a process-based model, Global Change Biol., 16 (2), 810-822, 2010.

6) For the future projection, I would clearly state the assumptions and caveats of the study. The manuscript leads you to believe that climate change will be the biggest driver of methane, where in many instances other anthropogenic drivers such as landuse change and agricultural management could have a far bigger effect.

Reply: In future, not only the climate, but also the anthropogenic activities will change significantly along with the possible environmental, economic and social changes, in and out the subject region. But in this study, we only discuss impacts of the projected climate change on CH_4 fluxes, with other factors of methane emission remain as in the present (**page 5896, line 12**). It is probable that other factors such as landuse change and agricultural management may play a major role in methane emission in future, depending on how much they will change. But we didn't compare the contribution of climate change against other factors to methane emission in the future. **We made a few descriptions to avoid possible mis-understanding of the present result (page 5896, line 12).**