Atmos. Chem. Phys. Discuss., 10, C13653–C13661, 2011
www.atmos-chem-phys-discuss.net/10/C13653/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Annual variation of methane emissions from forested bogs in West Siberia (2005–2009): a case of high CH_4 and precipitation rate in the summer of 2007" *by* M. Sasakawa et al.

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Received and published: 15 February 2011

Comment; My question to Sasakawa et al. is: why did you choose similar/same products and why there is no reference to that paper? I do not say it is wrong using same products but I would like to know if it was just a coincidence or were strong scientific reasons to choose them.

Reply; This is just a coincidence. We agree that our methodology adopts data and schemes similar to those used in Petrescu et al. (2010) published on October 29

half month after our submission of the first manuscript (October 13), simply because these data and schemes are most up-to-date and reliable. For example, the CH4 emission scheme by Walter and Heimann (2000) is intermediately mechanistic and therefore most effective for process-based evaluation at regional scale, compared with other empirical schemes (e.g., Cao et al. 1996, JGR 101:14399-14414) and complicated schemes (e.g., Zhuang et al. 2004, doi: 10.1029/2004GB002239). Also, the global wetland dataset by Lehner and Döll (2004) is clearly up-dated and high-resolution data. Actually, these data and schemes are increasingly used in recent studies focusing on terrestrial CH4 exchange (e.g., Ringeval et al. 2010, GBC, doi: 10.1029/2008GB003354).

Comment; Please be consistent with using CH4 / methane.

Reply; We use "CH4", but "Methane" should be used at the top of a sentence.

Comment; Abstract A last paragraph is needed to conclude the main findings and draw a line to this scientific attempt.

Reply; We have added the following sentence at the end of the abstract; "Although the emission in 2007 was 2∼3 times higher those in other years, the anomalous CH4 emission from the targeted area around KRS by itself does not appear to explain all the recently observed variability in the global CH4 concentration growth."

Comment; Introduction It is well written but a little poor in references. There are a lot of studies published on CH4 emissions from northern wetlands and their variability and patterns. Also the link to precipitation/water table and temperature should be more discussed. There are at least 3 other sites with active measurements over Siberian area which can be mentioned in the introduction and the results can be compared when interpreting the current work.

Reply; Concerning the variation in CH4 concentration at Siberia after 2007, there are only few manuscripts. Kozlova et al. (2008) showed CH4 concentration in the boreal

forest of central Siberia only for the period November and December 2006. Recently, Winderlich et al. (2010) showed CH4 concentration from May 2009 to April 2010 at the same place studied by Kozlova et al. (2008). We have added these references. We already referred to the manuscript by Bohn et al. (2007) which evaluated the sensitivity of CH4 emission from western Siberian wetlands to increases in temperature and precipitation.

Comment; Method Site description I think a separate figure for site description is needed. Now it is included in Figure 1. If another figure cannot be added please add to Figure 1 caption the tower coordinates.

Reply; We have added the tower coordinates in the figure caption as follows; "KRS and DEM denote the tower position at Karasevoe (58°15N, 82°25E) and Demyanskoe (59°47N, 70°52E), respectively."

Comment; The Figure needs an explanation about the wetland fraction: e.g. the pixels with 100% wetland fraction (red) are the same for all five years or this map shows the mean for 2005-2009? Which months/years are represented in this figure? If you say you used Prigent climatology why didn't you compute such a map for each study year? Please explain!

Reply; Wetland fraction is the same for all five years. We have modified the section 2.3 as follows; "2.3 Ecosystem model Monthly CH4 fluxes of wetlands were estimated with a process-based ecosystem model, VISIT (Inatomi et al., 2010; Ito, 2010), to evaluate the variation of gas fluxes responding to weather and biological conditions. Fig. 1 shows a schematic diagram of the CH4 exchange scheme employed in VISIT. The model consists of carbon, nitrogen, and water cycle sub-schemes, each of which is composed of several functional compartments such as leaves, stems, roots, dead biomass, and organic soil. Plant photosynthetic CO2 uptake, allocation, biomass growth, and mortality are simulated in the carbon cycle scheme in an ecophysiological manner (Ito and Oikawa, 2002). Wetland CH4 flux is simulated using a

semi-mechanistic scheme (Walter and Heimann, 2000), in which three processes of CH4 emission flux are considered: physical diffusion, plant-mediated transportation, and ebullition. The physical diffusion rate depends on the CH4 concentration gradient between the surface and soil air, which is affected by CH4 production and oxidation within the soil. In the soil, the CH4 production rate is determined by microbial activity and substrate supply from plants, producing sensitivity to temperature variability that leads clearly to seasonal cycle in the CH4 emission. Spatial heterogeneity in diffusivity through soil pore spaces is considered on the basis of sand/clay composition data (Hall et al., 2006) and water table depth. The plant-mediated transport of CH4 is dependent on the plant growing stage determined by the cumulative temperature and biome-specific rooting depth (typically, 20 cm for wetlands). The ebullition flux occurs only when the CH4 concentration exceeds 500 μmol liter–1 (Walter and Heimann, 2000). Wetland distribution is determined on a 0.5° × 0.5° grid based on Global Lakes and Wetland Database (GLWD, Lehner and Döll, 2004) (Fig. 2), and a distribution of natural vegetation type including both uplands and wetlands is derived from the global data set (Olson et al., 1983; Ramankutty and Foley, 1999). For performing broad-scale simulations, wetland soils are stratified into 20 layers of 5 cm thickness each. To include the spatial heterogeneity of wetlands, CH4 fluxes are separately estimated for flooded (i.e., inundation) and non-flooded (i.e., drainage) fractions of the ground surface, each of which has different water table depths. Thus, the total CH4 emission (E) for each grid cell is obtained as: E = w × (finund × Einund + fdrain × Edrain) (2) where w represents the wetland fraction in each grid cell, and f and E denote the land fraction and CH4 exchange flux of inundation and drainage parts (subscripts), respectively. Monthly average inundation fraction (finund) is derived from the SSM/I observation for 1993–2000 (e.g., Prigent et al., 2007). Because we estimate the inundation fraction on the basis of seasonal variation for each grid cell, in some cases, snow cover and extensive floods after snow melting could affect the base line. To avoid these apparent variations (e.g., too much severe drying after a spring flood) during the growing-period (May–August), we have decided to use the average inundation fraction derived from

the SSM/I observation during the period. The baseline water table depths of the inundation and drainage wetland surfaces are assumed as 0 and −25 cm, respectively, on the basis of an observation at West Siberian wetlands (Bohn et al., 2007). At layers lower than the water table, CH4 production is estimated as a function of temperature and plant carbon supply, which is obtained from the vegetation production scheme of the model. We also evaluated the influence of precipitation rate on the CH4 emission from wetlands. Inter-annual variability in the water table depth was estimated from the cumulative precipitation anomaly at each model grid as deviation from the 2001–2009 mean obtained from the reanalysis data of the NCEP/NCAR (Kalnay et al., 1996). To assess the possible range of estimation, a high (+1mm water table depth/+1mm precipitation anomaly) and a low (similarly, +0.2 mm/+1 mm) response cases are conventionally examined. To validate the CH4 flux estimated by VISIT with widely used CH4 flux distribution map from the wetlands (bogs, swamps, and tundra), we used the climatological data published by the NASA Goddard Institute for Space Studies (GISS) (Fung et al., 1991)."

Comment; Ecosystem model Perhaps the authors can be more detailed in explaining how this VISIT model works. Which are the water cycle components (how is hydrology represented/simulated by the model) and how the split between flooded non-flooded cells was done?

Reply; We modified the description of the VISIT model. See the detail in the modified section 2.3 and newly made Figure 1.

Comment; Please add the reference for VISIT model first time when it appears in the text, page 27762 line 9.

Reply; We have added the reference.

Comment; I read the description of VISIT model by Inatomi et al., 2010 and I did not find anywhere the Walter and Heimann reference for CH4 flux calculations.

Reply; The paper (Inatomi et al. 2010) focused on greenhouse gas exchange of a forest ecosystem, and then description was provided only on aerobic CH4 oxidation. Because the model was firstly applied to a specific study on wetland CH4 emission, a more detailed description on CH4 emission based on the scheme by Walter and Heimann (2000) has been provided in the section 2.3.

Comment; You also mention the soil stratification in 20 layers each 5 cm thick. Please explain how this was made or where did you took it from.

Reply; We agree that a model with finer resolution is, in general, expected to work more accurately. However, it depends on compromise with computational cost, especially at regional scale, and then we decided to reduce vertical resolution of the CH4 emission scheme. In a preliminary study at Japanese paddy field, we examined different thicknesses of the parallel layers and found that the moderately reduced-resolution model (i.e., 5cm for each layer) works reasonably in terms of CH4 emission flux.

Comment; In order to provide a better picture for the VISIT model I suggest adding a brief diagram of the processes used in your study.

Reply; We added a simple diagram of the processes used in this study for Figure 1.

Comment; Please provide a more detailed explanation on how you used the Prigent et al., 2007 climatology and GLWD to calculate the flooded non-flooded fractions.

Reply; We revised the section 2.3 and showed a more detailed explanation.

Comment; What assumption are you using when you state in the last sentence of the abstract that: "the area flooded (corr.: the flooded area) with water (self explanatory) is proportional to the cumulative anomaly in monthly precipitation rate" what is the anomaly? Also, what is the base line inundation fraction? Page 27764 lines 1-15: please rephrase!

Reply; We revised the section 2.3 and explained them.

Comment; Results and discussions It is a bit confusing for me when reading this paper what model was used and when and compared with what. In results section the GISS model appears and I would suggest presenting it in the methodology section as a tool used for comparison; same for GPCP.

Reply; We have added the explanation for GISS in the section 2.3. GPCP dataset consists of monthly means of precipitation derived from satellite and gauge measurements (Adler et al., 2003). We believe the description is proper as it is.

Comment; Page 27766-27767: you mention that CH4 fluxes are high in July and you relate this to hot summers. Please explain why is this happening, why small water bodies act as significant source of CH4 and are higher in July than other months: : :.which are the processes behind, reference this, there's plenty of material available on this topic.

Reply; The calculated CH4 fluxes around KRS were higher than the regional mean flux estimates for the wetlands by the GISS in June, July, and August instead of only in July. We have modified the expression. Methane production in lakes occurs in anoxic sediment during summer (e.g. Bastviken et al., 2008). We have added the reference and reported emission rate for CH4 from some lakes as follows; "Bastviken et al. (2008) reported that mean diffusive emission of CH4 from three lakes ranged from 3.5 to 14 mg m-2 day-1 during summer stratification, which can contribute to the difference."

Comment; Why elevated water table levels lead to increased CH4 fluxes?

Reply; As shown in the new Figure 1, the area of oxidation zone decreases and production zone increases when water table elevates. This results in increase for CH4 flux from wetland surface.

Comment; Conclusions You present total numbers for the CH4 emissions in Tg yr-1. Please explain if these are mean annual or totals and how these were calculated.

Reply; As written as "Integrated CH4 emission", it is total values for each year (2005

to 2009). The emission was calculated from the same area for the estimation of CASA CO2 flux ($\pm$ 3° lat., $\pm$1° long.). This area size is approximately 7.8 $\times$ 104 km2. We have added the lat/long expression.

Comment; Figures: I agree with Referee #2 that the unit for presenting the results should be only mg CH4 m-2 d-1.

Reply; We have shown only "mg/m2/day".

Comment; Concluding remarks Please check the English, I am not a native speaker but improvements can be made!

Reply; As shown in acknowledgment, an English native scientist rechecked English.

Interactive comment on Atmos. Chem. Phys. Discuss., 10, 27759, 2010.

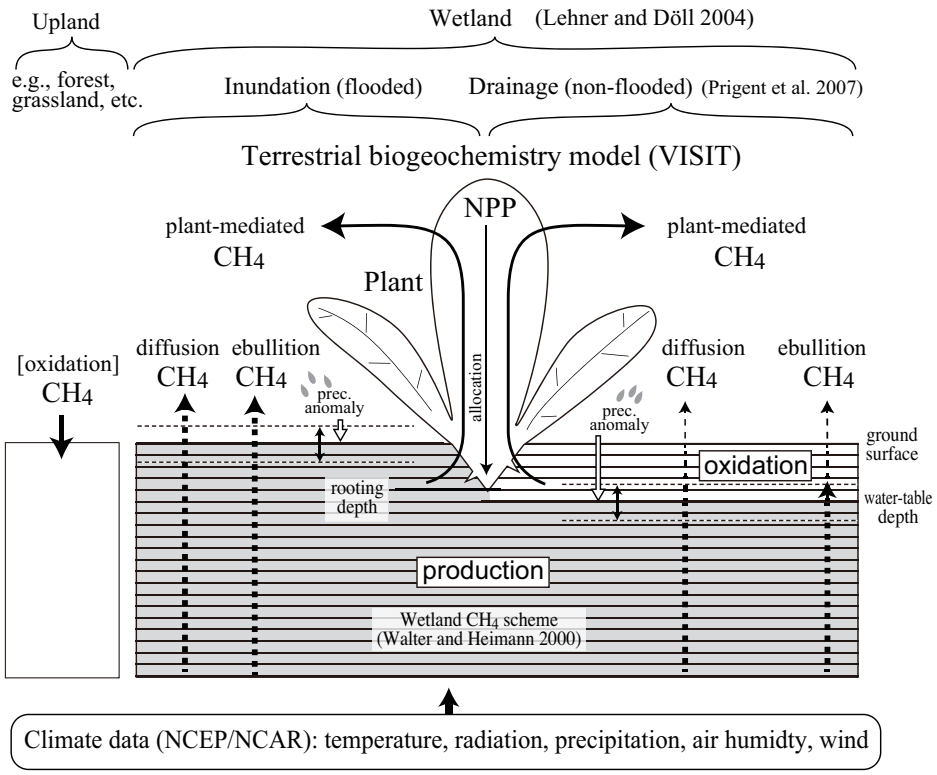

Fig. 1. new Fig.1 A schematic diagram of the CH4 exchange scheme used in this study.