The Global Methane Budget: 2000-2017

Saunois et al., ESSDD, 2019

Detailed Response to Tonatiuh Guillermo Nuñez Ramirez

The authors thank Tonatiuh Guillermo Nunez Ramirez for his comments on some specifics part of the text that needed some clarification.

Below are the responses to his comments (in italics, blue). Changes in the text follow each response in bold font.

The emission estimates for the decade of 2000-2009 in Saunois 2016 have larger ranges than in Saunois 2019. I think, if the GCP condenses all information that exists, there should be at least a table explaining which studies were left out and why as supplementary information.

We thank Dr Nunez Ramirez for the suggestion. We will probably consider to do this for the next release to highlight the methodology changes between the different budget releases.

A major problem with the bottom-up budget is that it is so much larger than the top-down estimate. The border between wetlands and other fresh water systems is very fuzzy and more discussion is required. Historically wetlands have been classified as bogs, fens, swamps, floodplains, and shallow lakes (Bartlett 1993). For example lake Chapala, Mexico's largest lake, has a maximum depth of 2 m, is it a wetland or a lake? Is a floodplain to be considered a wetland or a freshwater system? For example, in the Amazon inundation can vary for several meters.

The definition of wetland as well as the boundaries between the different non-wetland inland water systems (lakes, reservoirs, ponds, …) is critical. The different definitions used within the scientific community make difficult the budget assessment and favors double counting issues. The issues raised by Dr Ramirez are emphasized in the wetland subsection as well as in the inland water subsection. Section 6 presents some recommendations to overcome these issues.

Furthermore, in the Eastern Amazon, emissions tend to be larger at as river flow starts to decrease in August and September (Devol 1988, Beck 2012, Ringeval 2014, Basso 2016). This seasonal maximum is not capture by any of the WETCHIMP models, which instead show a maximum between January and April (Ringeval 2014). Ringeval (2014) were able to reproduce a seasonal cycle of CH4 emissions from the Amazon mainstream that was more similar to observations by using output from a hydrology model to identify floodplains.

Specific behaviors of surface land models are not investigated in this budget and none of the models used included a hydrology model for floodplains, as they used satellite-based wetland (flooded area) data which may not capture inundated areas covered by trees such as the Amazon floodplains (see Hastie et al. 2019). However, further details will be provided in a side paper led by Ben Poulter.

Furthermore, from your description it seems you classify as wetlands as saturated soils and fresh water systems can be lakes, rivers, reservoirs. Early studies, e.g. Devol (1988, 1990), Bartlett (1988, 1990), Tathy 1992, Keller 1994 and Melack (2004) made measurements both over saturated soils, emergent plants and open water. These early studies were used to calibrate many models, for example, in Spahni (2011), the LPJ-Bern model was calibrated to match the seasonal cycle from an inverse modeling estimate.

The calibration (and evaluation) of wetland models remains difficult due the lack of appropriate observation data sets. As stated by Melton et al. (2013), model comparison to observations requires observations compatible with the spatial scale of the models (usually 0.5 degree). Some models use flux measurements to adjust their flux density, and others use atmospheric top-down estimate to calibrate their model –for example by latitudinal band in Sphani et al. (2011).

Furthermore, DelSontro et al. (2018) has very high emissions but is stratification and transport within a lake were not taken in consideration. For example, lakes in East Africa are highly stratified and anoxic below the mixed layer but the amount of emissions estimated by DelSontro (2018) is difficult to bring in agreement with satellite CH_4 cartographies (e.g. Frankenberg, 2011). they do not emit high quantities of methane continuously due to the same stratification of the water column. Is the future of CH4 emission modeling the merging of dynamic vegetation models with hydrology models?

The DelSontro et al. (2018) study does not consider seasonal variations in stratification and transport, rather they use sample from the warm season and satellite-based product for Chl-a based on the growing season for phytoplankton apparently (see Sayers et al., 2015).

Yes, future developments need to integrate both wetlands and other inland waters systems together. This would avoid double counting and integrate flux transfer between systems. Recommendations for future development are suggested in Section 6, newly reformatted.

With respect to the soil sink, your estimates are based on published model estimates. However, in these models, the sink strength depends on atmospheric mixing ratio (of-ten a global constant value). For example, in the Curry (2007) model, the flux j is

$j = C_0 * g_0 * r_w * r_c * \quad D * k$

where C_0 [ppm] is the CH_4 mixing ratio and g_0 is a conversion factor from ppm to mass units. Taking this into account, the sink becomes much larger may become much larger and changes in time in proportion to the atmospheric abundance. Furthermore, both Ridgwell (1999) and Curry (2007) had use the ideal gas law to set the g0 parameter to 610 and 578 assuming a pressure of 100 kPa and temperatures of 0°C and 15°C respectively. By determine the g0 per gridcell based on monthly temperatures and pressure, the g0 ranges between 320 and 750.

Indeed, the soil sink depends on atmospheric methane concentration. Changes in the soil sink needs to be further investigated and in particular, included in the priors of top-down simulations, which is not systematically the case presently.

Regarding the conversion factor g0, this factor is inversely proportional to T (expressed in K), so that even for a temperature range of -10 C to 30 C (typical of a continental mid-latitude location), g0 changes by only 16%. g0 does not depend on pressure. Reviewer SC1 may be confounding the temperature dependence of g0 with the T and P dependence of CH_4 diffusivity in air (D_{air}); but this too is only weakly dependent on T, and in the opposite sense to g0—see, e.g., CRC Handbook of Chemistry & Physics, 20th Ed. (2016), p 6-259. More importantly, the error involved in assuming a global constant value of g0 and D_{air} in this parameterization is dwarfed by the uncertainty in the oxidation coefficient k0 which, as emphasized by Curry (2007), could change the derived uptake by a factor ~3 or more in either direction.

Additionally, there are important contribution from Hackstein (1994, 1996, 2006) concerning potentially large emissions from wild terrestrial vertebrates and three arthropod taxa apart from termites.

We thank Dr Nunez Ramirez for pointing this to us. We understand from this literature that the uncertainty is quite large.

In the future, it would be useful to also have estimates of the year-to-year variability for wetlands and OH in order to understand what drove the observed year-to-year variability of the growth rate.

Further study on the year to year variability from wetlands emissions or OH will be conducted in another paper as in Saunois et al. (2017). For the future budgets, we will consider if and how the IAV and changes in emissions and atmospheric methane can be discussed in the same paper without lengthening to much the manuscript.

References:

Hastie, A, Lauerwald, R, Ciais, P, Regnier, P. Aquatic carbon fluxes dampen the overall variation of net ecosystem productivity in the Amazon basin: An analysis of the interannual variability in the boundless carbon cycle. Glob Change Biol., 25, 2094– 2111, https://doi.org/10.1111/gcb.14620, 2019

Melton, J. R., Wania, R., Hodson, E. L., Poulter, B., Ringeval, B., Spahni, R., Bohn, T., Avis, C. A., Beerling, D. J., Chen, G., Eliseev, A. V., Denisov, S. N., Hopcroft, P. O., Lettenmaier, D. P., Riley, W. J., Singarayer, J. S., Subin, Z. M., Tian, H., Zürcher, S., Brovkin, V., van Bodegom, P. M., Kleinen, T., Yu, Z. C., and Kaplan, J. O.: Present state of global wetland extent and wetland methane modelling: conclusions from a model inter-comparison project (WETCHIMP), Biogeosciences, 10, 753–788, https://doi.org/10.5194/bg-10-753-2013, 2013.

Sayers, M.J., Amanda G. Grimm, Robert A. Shuchman, Andrew M. Deines, David B. Bunnell, Zachary B. Raymer, Mark W. Rogers, Whitney Woelmer, David H. Bennion, Colin N. Brooks, Matthew A. Whitley, David M. Warner & Justin Mychek-Londer: A new method to generate a high-resolution global distribution map of lake chlorophyll, International Journal of Remote Sensing, 36:7, 1942-1964, DOI: 10.1080/01431161.2015.1029099, 2015.