MODELLING THE METHANE EMISSIONS FROM NORTHERN PEATLAND WITH THE JSBACH MODEL

M. TOMASIC\(^1\), S. SMOLANDER, \(^1\) T. VESALA\(^1\), M. RAIVONEN\(^1\),
T. MARKKANEN\(^2\), L. BACKMAN\(^2\), A. LAAKSONEN\(^2\)

\(^1\) Division of Atmospheric Sciences, Department of Physics, University of Helsinki, Finland
\(^2\) Finish Meteorological Institute (FMI), Helsinki, Finland

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GLOBAL IMPORTANCE OF THE METHANE CYCLE

Understanding the methane cycle is considered as one of the crucial questions for a more precise climate prediction. This is confirmed by the fact that the radiative forcing caused by methane is considered as 21 to 24 times higher than the one for CO\(_2\) (US EPA 2007). Northern peatlands play an important role in the global storage for carbon as well as a significant source of global methane emissions. They represent around one third of the overall wetland resources (Bartlett and Harriss:1993). Although the overall global surface of is less than 5% of the total Earth surface (Matthews and Fung:1987; Aselman and Crutzen:1989), they contribute to more than 20% of the annual methane atmospheric emission and thus have to be considered the largest natural resource of atmospheric methane (Wuebbles and Hayhoe:2002; Kapoor:1985; Prather et al.:1995 ). Future climate change will have a severe impact especially on northern peatlands (Kattenberg et. al.:1996,). Apart from the shift of peatland behaviour, the expected rise of temperature will also be the cause for a thawing of permafrost (Anisimov et. al.:1997) which could change the landscape towards more peatland. Changing climate is assumed to be crucial for northern peatlands. The hydrological aspects of peatland are very difficult to model (Frolking et al.:2002), and thus although peatlands are a very significant landscape in terms of global biogeochemistry and ecosystems, they have not been represented in models to an adequate level yet. Every model dealing with the emission of methane from wetland has to consider water table changes and its consequence for the production of methane. Changes in peatland hydrology are among the largest uncertainties for the calculation of the circumpolar carbon budget calculation (Frolking et al.:2002).

METHANOCENESIS AND EMISSION PATTERNS

Northern peatlands are a very slow carbon decomposition pool and thus the storage is seen as a sink for the CO\(_2\) cycle (Frolking et al.:2001). They are characterized by the limited amount of oxygen available leading into anaerobic conditions (Clymo:1992). The land carbon cycle is basically represented by the carbon storage from the growth and death of plants and the remineralization of carbon in soils. Methanogenesis happens especially under anaerobic conditions of a wetland while organic matter is decomposing. This fermentation process can be either the final step of the decomposition of cyclic litterfall or caused by the accumulating carbon in wetlands. Lower temperatures and the isolating characteristics of peatland vegetation (especially moss) also are the reason for a less dynamic carbon transfer (Roulet et al.:1997). Roots are critical for the methane production (Chanton et al.:1995) as well as for the overall terrestrial carbon cycle. Especially the microorganisms around plant roots have a very important role in the methanogenesis as well as for the overall carbon cycle. Assumptions for the fraction of the overall exudation of photosynthesized
carbon by plant roots range between 15-20 percent. Ferric iron reduction seems to be a limiting factor for the methane activity of bacteria, however a lot of uncertainties remain for this topic. Diffusion of methane through the peat layer, mediated transport through the aerenchyma (hollow body of wetland vascular plants) and bubble formation (ebullition) are identified as the main methane release mechanisms from peatlands (Wania et al.:2010). However, not all the produced methane reaches the atmosphere. Aerobic decomposition via methanotrophic bacteria in the peat-layers (Hanson et al.:1996) are a limiting factor for the further release towards the atmosphere. Most of this oxygen needed to decompose the produced methane is transported either via the same pathway of the vascular plants or diffuses through the top layer of water and into the peat (Wania et al.:2010). Modelling the emission of methane on a global scale however is a more complex approach due to the large variability of soil types, productivity, tissue decomposability and water-level in wetlands (Frolking et al.:2002). Hence carbon fluxes from different sites can have a large variability due to the specific hydraulic properties.

MODELLING APPROACH

Several modelling approaches have been taken before to study the carbon cycle balance in wetlands either statistical-stochastical (Alm et al.:1999) and/or monitoring methods (Carroll et al.:1997). Most of these approaches were monitoring the effects of methane emission on local or regional scale. The vegetation model JSBACH will implement a large part of the parameterizations which have been used by Wania (e.g.(Wania et al.:2009)). They are a recent addition to the LPJ model (Lund-Potsdam-Jena). JSBACH is the land component of the ECHAM5 general circulation model and is used to calculate the global climate predictions with a high resolution. The land carbon tool of JSBACH, CBALANCE will be the main coupling interface of the new global methane emission modelling tool. The interaction between ECHAM and JSBACH is multilateral and encompasses many parameters. Several different compartments will be necessary to represent the processes of methane emission. The position of the water table has consequences for the methane production, its consumption by aerobic bacteria and finally also its emission. The acrotelm represent the level above water level and the catotelm the one bellow it. The carbon cycle comprises the decomposition of litter and organic
matter at different speed. Hence, the methane emission tool must also consider that organic matter can be part of the slow and fast pool decomposition cycles. Implementation of a root size distribution will be crucial to locate the amount of methane produced. Other important factors that need to be incorporated are e.g.: leaf area indexes (LAI) of the plant functional types, decomposition and dry and flooded conditions, soil carbon storage potential, amount of litter accumulated, oxygen or the exudation rate of plants.

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