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Using satellite observations to improve model estimates of CO2 and CH4 flux: a Metropolis Hastings Markov Chain Monte Carlo approach

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Peatlands are wetlands with an organic soil layer of >30cm (Limpens et al., 2008) that occur beneath a living plant layer as a result of the waterlogged nature of the soil restricting complete decay of the biomass (Charman, 2002). Peatlands are important ecosystems; boreal and subarctic peatlands are estimated to contain 455Pg of carbon (Gorham, 1991), about 15-30% of the world's soil carbon (Limpens et al., 2008), and yet constitute less than 3% of the world's total land area (Lai, 2009).
Peatlands not only sequester CO2 through photosynthesis and the partial decomposition of organic matter but they release methane (CH4) due to anaerobic microbial activity under waterlogged conditions. The balance is even more complex, as microbial consumption of CH4 can result in additional CO2 being emitted to the atmosphere.
Wetlands are the main source of natural CH4 (Le Mer and Roger, 2001). Northern wetlands contribute about 35Tgyr-1 (Bubier and Moore, 1994). The uncertainty on this estimate is large 1 mgm-2yr-1 to 2200 mgm-2yr-1. Given that CH4 is 20 to 30 times more efficient at absorbing infrared radiation than CO2 there is a need to better quantify CH4 emissions and their role in the net carbon balance of peatlands.
Two of the key variables in the calculation of CH4 production are water table depth and soil temperature. Water table depth is important as methanogenic bacteria are predominantly active in the anoxic zone. In order to accurately model the water table depth a correct representation of the whole soil moisture profile is important. Soil moisture and soil temperature are important variables in model calculations, as they affect the decomposition of carbon in the soil, as well as influencing the water and energy fluxes at the surface – atmosphere boundary. Microwave measurements of surface soil moisture and thermal measurements of land surface temperature from satellites can theoretically be used to improve the representation of the hydrology and soil temperature profile as a whole.
We present results from an Observing System Simulation Experiment (OSSE) designed to investigate the impact of management and climate change on peatland carbon fluxes, as well as how observations from satellites may be able to constrain modeled carbon fluxes. We use an adapted version of the Carnegie-Ames-Stanford Approach (CASA) model (Potter et al., 1993) that includes a representation of methane dynamics (Potter, 1997). The model formulation is further modified to allow for assimilation of satellite observations of surface soil moisture and land surface temperature. The observations are used to update model estimates using a Metropolis Hastings Markov Chain Monte Carlo (MCMC) approach. We examine the effect of temporal frequency and precision of satellite observations with a view to establishing how, and at what level, such observations would make a significant improvement in model uncertainty. We compare this with the system characteristics of existing and future satellites. We believe this is the first attempt to assimilate surface soil moisture and land surface temperature into an ecosystem model that includes a full representation of CH4 flux.

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