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Modeling assessment of microbial kinetics in controlling methane production in wetlands

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Methane bioproduction in wetlands is a key process of carbon cycling, accounting for 20–39 % to the global methane emissions (IPCC, 2007). The large range of the estimation reflects the complexity of methane bioproduction: the degrdation of soil organic matter includes both extracellular enzyme reactions and a series of microbial metabolisms. As a result, methane fluxes are regulated by both environmental and biological factors, from pH and temperature to carbon quality, and to microbial activties. Here we constucted a biogeochemical reaction model and evaluated how methane bioprdocution in wetlands is modulated by environmental and microbiological factors.

Our biogeochemical reaction model considers the enzymatic hydrolysis of soil organic matter (SOM) to dissolved organic carbon (DOC), DOC degradation to acetate and H_2, and acetoclastic and hydrogenotrophic methanogenesis. The model accounts for the temperature dependence of SOM hydrolysis by using the Arrhenius equation. It computes the rates of microbial metabolisms using the Monod equation, and considers the temperature effect using the triangle function.

We applied the model to a series of laboratory incubation experiments of peatland samples from upper peninsula of Michigan, USA. These experiments incubated the soil samples at 7, 15, and 25°C, and tracked methane production, and monitored the concentraion dynamics of DOC, acetate, H_2, and CO_2. Our model reproduced the experimental observations, including the concentration dynamics at the different temperatures. We then carried out a sensitivty analysis to evaluate how the different biogeochemical processes affect the fluxes of methane production at different temperatures. The results confirmed carbon quality as a key controlling parameter. Moreover, among the three microbial groups in the model, only fermentative microbes showed a significant control, which is consistent with the hypothesis that fermentation is a rate-controlling step of organic matter degrdation. These results suggest that in addition to carbon quality, the metabolisms of microbial groups should also be included in predicting the fluxes of methane production in wetlands.