Geophysical Research Abstracts
Vol. 18, EGU2016-7469-2, 2016
EGU General Assembly 2016

Incorporating redox processes improves prediction of carbon and nutrient cycling and greenhouse gas emission

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Among the coupled thermal, hydrological, geochemical, and biological processes, redox processes play major roles in carbon and nutrient cycling and greenhouse gas (GHG) emission. Increasingly, mechanistic representation of redox processes is acknowledged as necessary for accurate prediction of GHG emission in the assessment of land-atmosphere interactions. Simple organic substrates, Fe reduction, microbial reactions, and the Windermere Humic Aqueous Model (WHAM) were added to a reaction network used in the land component of an Earth system model. In conjunction with this amended reaction network, various temperature response functions used in ecosystem models were assessed for their ability to describe experimental observations from incubation tests with arctic soils. Incorporation of Fe reduction reactions improves the prediction of the lag time between CO_2 and CH_4 accumulation. The inclusion of the WHAM model enables us to approximately simulate the initial pH drop due to organic acid accumulation and then a pH increase due to Fe reduction without parameter adjustment. The CLM4.0, CENTURY, and Ratkowsky temperature response functions better described the observations than the Q10 method, Arrhenius equation, and ROTH-C. As electron acceptors between O_2 and CO_2 (e.g., Fe(III), SO_4^{2-}) are often involved, our results support inclusion of these redox reactions for accurate prediction of CH_4 production and consumption. Ongoing work includes improving the parameterization of organic matter decomposition to produce simple organic substrates, examining the influence of redox potential on methanogenesis under thermodynamically favorable conditions, and refining temperature response representation near the freezing point by additional model-experiment iterations. We will use the model to describe observed GHG emission at arctic and tropical sites.