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Pore- to Core- Controls on Ecosystem CO_2 fluxes: Soil Microscale Hydrology Drives Thermodynamic Controls on Carbon Decomposition

Jianqiu Zheng[1*], Ben Bond-Lamberty[2], Vanessa L. Bailey[1]

[1] Pacific Northwest National Laboratory, Richland, WA
[2] Joint Global Change Research Institute-Pacific Northwest National Laboratory, College Park, MD

Contact: jianqiu.zheng@pnnl.gov

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Developing models that accurately simulate soil processes is an important challenge in predicting soil organic carbon decomposition and projecting atmospheric carbon dioxide concentration in response to environmental changes. Microbial-explicit biogeochemical models are rapidly developing and significant efforts have been put into microscale characterization of microbial functions, and harmonization of microbial models with observations. Yet the incorporation of microscale soil physical structure and hydrology has lagged behind the numerical representation of soil microbial dynamics. Soil water influences the physicochemical habitat for microbes that drive soil carbon cycling by regulating the availability and transport of carbon and other nutrients, but microbially-explicit responses to soil moisture changes and associated physicochemical changes are largely missing. Here we leverage our previous observations on how soil moisture regulates carbon decomposition in different soil types to represent the relationship between soil hydro-geochemistry and carbon decomposition in a microbially- explicit model. In particular, we attempt to incorporate the influences of soil physical structure and pore networks on organo-mineral interactions, microbial growth kinetics and enzymatic functions. To account for these controls, we built a microbially-explicit carbon decomposition model into a geochemical framework PHREEQC, which allows aqueous chemistry and thermodynamic calculations. Through modeling carbon decomposition under varying soil moistures within distinct soil types, we demonstrate that parameterization with one pre-selected moisture response function generates significant uncertainties. We further employ a new moisture function that considers variations in soil properties by introducing competitive diffusion of organic carbon and oxygen, and the collocation of organic carbon and microbes. This new moisture function addresses part of model uncertainties by providing more flexibility in representing moisture responses. Investigation of microbial explicit responses to soil moisture changes and associated physicochemical environmental changes is needed to further resolve model uncertainties in predicting carbon cycling in response to soil moisture.