Development of a molecularly informed biogeochemical framework for reactive transport modeling of subsurface carbon inventories, transformations and fluxes

Kate Maher[1*], Matthew J. Winnick[1,2], Dana K. Chadwick[1], Hsiao-Tieh Hsu[1], Yuchen Liu[3], Jennifer L. Druhan[3], Corey R. Lawrence[4]

[1] Department of Earth System Science, Stanford University, Stanford, California 94305, USA
[2] Department of Geosciences, University of Massachusetts Amherst, Amherst, MA 01003
[3] Department of Geology, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, USA
[4] U.S. Geological Survey, Denver, Colorado 80225, USA

Contact: kmaher@stanford.edu

Project Lead Principal Investigator (PI): Kate Maher

BER Program: SBR

Project: University Project

Project Abstract: Soils moderate the two largest fluxes in the carbon cycle: plant uptake of atmospheric CO_2 through photosynthesis and the resulting heterotrophic and autotrophic respiration that returns CO_2 to the atmosphere. Imbalances in these fluxes can thus substantially alter global carbon budgets and promote positive feedbacks in the climate system that are not well resolved in large scale climate models. The flux of carbon between the vegetation and the atmosphere is moderated by the soil organic carbon (SOC) reservoir, which is highly sensitive to shifts in (1) water availability and (2) vegetation dynamics. To address the potential for moisture-driven feedbacks, the overarching goal of our project is to develop new techniques to quantify soil organic carbon transformations that support development of new models of carbon (and nutrient) transfers to and from the soil reservoir.

To quantify the controls on depth-resolved net CO_2 production rates and the spatial variability in SOC inventories and guide model development, we are using field measurements of soil respiration, soil pCO_2 and SOC content in tandem with remote sensing data across the unique field laboratory of the East River, CO watershed, in collaboration with the Lawrence Berkeley Lab SFA. An inverse 1-D diffusion-reaction model constrained by soil pCO_2 and surface efflux rates was developed to calculate net CO_2 production rates (R_{CO2}) over time. Field measurements are accompanied by laboratory incubation experiments and a meta-analysis of literature studies to assess theoretical constructs needed to accurately capture the response of microbial respiration to variable soil moisture. In both field and laboratory studies, East River soil profiles demonstrate unique responses to precipitation events, and accurate prediction of the associated respiration of carbon requires a sophisticated modeling approach. To capture this behavior, we have built a 'dormancy model' which allows the native soil microbial population to respond transiently to the presence or absence of water. However, field measured R_{CO2} show a dampened respiration response to moisture delivery when plants are senesced, suggesting that vegetation status is also important control on soil respiration. Collectively, our results suggest that plant phenology regulates the response of soil respiration rates to pulse wetting events. In particular, these results emphasize the importance of the timing of snowmelt and the summer monsoon relative to phenology on soil CO_2 fluxes and their sensitivity to projected changes in climate.