A multiscale approach to modeling carbon cycling within a high-elevation watershed

Kate Maher[1], Matthew J. Winnick[1],Yuchen Liu[2], Jennifer L. Druhan[2], Corey R. Lawrence[3], Reed Maxwell[4], Carl. I. Steefel[5], Kenneth H. Williams[5], Rosemary Carroll[6]

1. Department of Geological Sciences, Stanford University, Stanford, California 94305, USA
2. Department of Geology, University of Illinois at Urbana-Champaign, Urbana, Illinois 61801, USA
3. U.S. Geological Survey, Denver, Colorado 80225, USA
4. Geology and Geological Engineering, Colorado School of Mines, Golden, Colorado 80401, USA
5. Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA
6. Division of Hydrologic Sciences, Desert Research Institute, Reno, Nevada 89512, USA

Although soils are the largest repository of carbon at the Earth's surface, the rates of soil carbon accumulation, transformation and release to the atmosphere and surface waters remain a key uncertainty in forecasts of global change. Within the soil environment, residual plant material is transformed into a continuum of organic products of variable accessibility and reactivity. At the watershed scale, averaging over a variety of these soil reaction networks may obscure critical processes; whereas individual soil profiles provide a limited window into the ensemble of pathways that ultimately determines carbon fluxes to the atmosphere and surface waters. To address how collections of spatially and temporally linked reaction networks are manifest at larger scales and the consequences of scale for process-based models, we are studying C fluxes from the soil profile (0.3 to 2 m^2) to the watershed (85 km^2) scale (0.005 to 0.1 m^2) within the LBNL SFA East River, CO watershed study site.

At the watershed scale, concentration-discharge relationships show considerable hysteresis, with dissolved organic carbon (DOC) fluxes dominated by the seasonal peak in discharge associated with snowmelt. The hysteresis behavior remains remarkably similar for DOC across multiple years. Evaluation of sub-watershed solute dynamics indicates that hillslope aggregation controls solute delivery and increasing discharge is thus flushing DOC that accumulated in the shallow soil during the previous season. Soil profiles generally show decreasing total organic carbon with depth; however, the depth gradients and distributions of organic carbon functional groups vary markedly between different vegetation types (*e.g.*, conifer forest to meadow) and landscape position within one vegetation type (*e.g.*, crest to hillslope). Variability in the carbon distribution with landscape position suggests the importance of soil moisture relative to litter inputs. Soil incubations at variable moisture contents also demonstrate the dependence of CO_2 fluxes on moisture content, with respiration rates increasing with increasing soil moisture from 0 to 66% saturation, followed by a decrease as soils approach saturation. On-going work includes the development of reactive transport descriptions of carbon transformations and how they are mediated by water availability and soil mineralogy.

Collectively, our data suggest that seasonal hydrologic variations create a pulse of DOC to surface waters that temporarily starve the soil environment of labile DOC and provide sub-optimal conditions for heterotrophic respiration, creating a lag time between the hydrologic forcing and the metabolic response. As a result, modeling carbon transformations at the watershed scale will require coupling the temporal dynamics of vertical and lateral water transport with those of soil biogeochemical reaction networks.