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A Multiscale Approach to Modeling Carbon Cycling Within a High Elevation Watershed

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The rates of soil carbon accumulation, transformation and release to the atmosphere and surface waters remain a key uncertainty in global-scale models. 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 complex soil reaction networks may obscure critical processes; whereas individual soil profiles provide a limited view of the ensemble of pathways that ultimately determines carbon fluxes. 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 at molecular-level all the way to the watershed-scale within the LBNL SFA East River, CO watershed study site.

To date, we have characterized landscape-scale carbon fluxes within the upper catchment using concentration-discharge relationships and through distributed soil sampling and flux measurements. To understand the biogeochemical and hydrologic dynamics driving these fluxes, we developed two microcatchment study sites at different elevations and life zones (2950 and 3500 m; upper montane and upper subalpine) where we have depth-resolved soil moisture and temperature sensors, soil gas wells and lysimeters paired with measurements of soil surface CO_2 fluxes. Newly developed spectroscopic methods for characterizing molecular-level soil carbon speciation are coupled to field measurements. The depth-resolved CO_2 concentrations suggest that the depth of maximum respiration rates increases throughout the growing season, likely reflecting seasonal drying and the downward movement of optimal soil moisture conditions. An inverse-model of respiration rates suggests two local maxima at shallow (~25 cm) and deep (100-150 cm) depths. This is supported by differences between the observed pCO_2 and model simulations of the microbial dynamics constrained by incubation experiments, indicating that root respiration is vertically offset from the maximum microbial respiration. Collectively, our combined modeling and data collection suggest that vertical movement of water and seasonal shifts in soil moisture distribution are a critical control on subsurface respiration rates that will need to be accounted for in large-scale models.