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Snowpack Dynamics and Coupled Plant-Soil-Microbial Processes in a Mountainous Watershed

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In mountainous systems with seasonal snow-cover, interactions between vegetation, microorganisms and regolith properties are key to the retention or loss of water, nutrients and other elements. Snowpack dynamics, including snow depth and timing of snowmelt, shape these interactions. Vegetation phenology, regulated by environmental cues such as photoperiod, soil and air temperature, is tightly coupled to snowmelt date. The timing of snowmelt is changing, occurring earlier, shifting vegetation phenology with consequent impacts on the hydrology and biogeochemistry of mountainous watersheds. As part of the Watershed Function SFA at East River, CO, our goal is to build a mechanistic understanding of how coupled plant-soil-microbial processes respond to perturbations such as early snowmelt and project changes in exports from watershed subsystems to the river.

Over the last three years we have observed record high and low snowpacks and have manipulated snowmelt date at select locations. Early snowmelt (natural or manipulated) advances vegetation greening, shifting peak evapotranspiration (ET) earlier which in some watershed subsystems results in an ET-induced foresummer drought and compressed growing seasons. Across the watershed elevation gradient, greater synchrony in greening and flowering was observed in low snow years and early snowmelt, shifting typical ET distributions with implications for water and nutrient exports.

River nitrogen discharge peaks during snowmelt and isotopic studies have demonstrated that river nitrate is primarily derived from nitrification of terrestrial ammonia rather than atmospheric deposition. Under the insulation of a deeper snowpack, microbial activity is at its highest and microbial biomass blooms, retaining N until snowmelt when a crash in biomass is observed. Using metagenomic, transcriptomic and metabolic approaches we have documented the importance of volatile organic compounds that support microbial growth, increases in phage abundance associated with the microbial biomass crash, and significant archaeal nitrification associated with the observed nitrate pulse at snowmelt. These processes are muted under low snowpack conditions demonstrating that snowpack dynamics effect both vegetation and microbial phenology and the timing of nutrient availability.

To scale beyond intensively studied locations, we have developed simultaneous above and belowground sensing platforms to relate surface observables to subsurface physical, chemical and biological properties. A strong relationship between canopy phenology and subsurface electrical conductivity (EC, a proxy for soil physical properties and water availability) was observed and related to hillslope factors that are also strong predictors of vegetation distributions. Efforts to evaluate such surface-subsurface covariance are ongoing at the watershed scale using LiDAR and hyperspectral data.