Capturing Transient Climate-Driven Contributions of Surface to Subsurface Processes at Watershed Scales

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The response of humid mid-latitude forests to changes in precipitation, temperature, nutrient cycling, and disturbance is critical to improving our predictive understanding of ecosystem-climate feedbacks to greenhouse gas fluxes and changes in the surface-subsurface energy balance. Predictive understanding of terrestrial systems will require an integrated modeling/experimental approach applied across multiple scales. Recent scientific advances in computing, spectroscopy, and “omics” enable unprecedented process-level studies to address critical knowledge gaps. Mechanistic understanding of the effects of long-term and transient moisture conditions are needed to quantify linkages between changing redox conditions, microbial activity, and soil mineral and nutrient interactions on C cycling and greenhouse gas release in surface to subsurface transition zones. To study these concepts we established transects across hydraulic and topographic gradients in a small watershed with transient moisture conditions. Valley bottoms tend to be more frequently saturated then ridge tops and side slopes which generally are only saturated when shallow storm flow zones are active. Fifty shallow soil cores were collected during timeframes representative of low CO₂ winter conditions and high CO₂ summer conditions. Cores were subdivided into 240 samples based on pedology and analyses of the geochemical (moisture content, metals, pH, Fe species, N, C, CEC, AEC) and microbial (16S rRNA gene amplification with Illumina MiSeq sequencing) characteristics are being conducted. To associate microbial metabolic activity with greenhouse gas emissions we installed 17 soil gas probes, collected gas samples for 16 months and analyzed them for CO₂ and other fixed and greenhouse gasses. Surface water and groundwater data are also available. Parallel to the experimental efforts our data is being used to support hydrobiogeochemical process modeling by coupling CLM with PFLOTRAN to simulate processes and interactions from the molecular to watershed scales. Including above ground processes (biogeophysics, hydrology, and vegetation dynamics), CLM provides mechanistic water, energy, and organic matter inputs to the surface/subsurface models, in which coupled biogeochemical reaction networks are used to improve the representation of below-ground processes. Preliminary results suggest that inclusion of above ground processes from CLM greatly improves the prediction of moisture response and water cycle at the watershed scale. We are investigating the coupled biogeochemical C, N, P, and Fe cycles in the surface and subsurface with improved biogeochemical models that incorporate geochemical and microbial reactions for process-based representation. The results will improve our understanding of the coupled hydrobiogeochemical processes at multiple scales and the representation of these processes in earth system models.