The Watershed Function SFA: Mountainous System Hydrobiogeochemical Response to Disturbance across Genome to Watershed Scales

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Project Abstract:
Uncertainty associated with predicting watershed hydrobiogeochemical behavior remains high as climate change, extreme weather, wildfire, land-use change, and other disturbances significantly reshape interactions within the world's watersheds. The Watershed Function SFA is reducing this uncertainty through answering the grand challenge question: "how do mountainous watersheds retain and release water, nutrients, carbon, and metals?". The current phase focuses on how variability in snow accumulation and snowmelt timing and distribution influence mountainous watershed hydrobiogeochemical dynamics over sub-seasonal, seasonal and multi-annual timescales, with a focus on predicting aggregated water and nitrogen exports. The project is based within the East River Watershed, an emblematic mountainous headwater of the Upper Colorado River Basin, a region critical to U.S. water, energy and agricultural needs and one increasingly vulnerable to changing snow dynamics.

Given that mountainous watersheds embody significant gradients in vegetation, elevation, climate, and geology, their responses to disturbance are particularly complex, involving multi-physics, multi-scale processes occurring from bedrock through canopy, across land-water interfaces, and from genome-to-watershed scales. To confront this complexity, the Watershed Function SFA is developing new ways of conceptualizing, characterizing and predicting aggregated watershed system behavior. For example, the Watershed SFA takes a "system-of-systems" approach, where remotely sensed and ground-based information is used to develop a digital '4D East River Watershed', and machine learning approaches are used to identify key subsystems or "functional zones" within the watershed, which are hypothesized to have unique properties that influence the response to disturbance in that zone. Working within representative functional zones across the East River, process-based investigations paired with models are advancing predictive understanding of distributed hillslope ecohydrogeologic and river corridor responses to snow dynamics, the latter including processes occurring in the river, hyporheic zone, and across terrestrial-aquatic interfaces. A Scale-Adaptive Watershed Simulation Capability (SAWaSC) is being developed to enable 'telescoping' into regions that may have an outsized impact on larger watershed response to snow dynamics. SAWaSC will be compared with a functional zone approach for simulating aggregated watershed functional zone behavior using machine learning and hybrid modeling approaches. The functional zone approach to characterizing and modeling watershed system function is expected to provide a novel, site agnostic, and computationally efficient means for predicting aggregated system exports in response to perturbations that is scalable from catchment to drainage to basin scales.