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Watershed Function Simulation and Aggregation

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Watershed hydrological processes mediate a wide range of biogeochemical interactions, ranging from vegetation growth to elemental and nutrient cycling to contaminant fate and transport. However, there are huge uncertainties associated with predicting how watersheds will respond to such perturbations (e.g., droughts or floods) at space and time scales relevant to the management of environmental and energy strategies. In particular, we lack capabilities to predict (1) how watersheds function - that is, how the different parts of a watershed work together to cycle water, nutrients, carbon and other elements - from bedrock to canopy, from across terrestrial and aquatic interfaces, and along environmental gradients; (2) how watersheds respond to atmospheric perturbations, particularly episodic changes in temperature and precipitation; and (3) what watershed properties and processes are critical to include in mechanistic watershed models that feed larger-scale models, such as E3SM or the National Water Model (NWM).

Complementing modeling activities focused on intensive study sites in other components of the Watershed Function SFA, the Watershed Reactor effort aims to understand and predict the aggregated behavior of the system affected by coupled hydrological, energy, and biogeochemical processes. One important challenge is the resolution of hot spots (spatially focused zones of intense hydrological or biogeochemical activity) and hot moments (transient events with potentially outsized impact on system function). As an example, hydrological flow and biogeochemical processes may generate meter scale gradients in concentration in reactive floodplains, and these may need to be captured in models to accurately represent fluxes. Since the overall size of the floodplain system can be quite large, however, efforts are underway to develop scaling motifs based on stream sinuosity, in parallel with similar efforts on hillslopes and deep bedrock that feed water and nutrients to the river system. These upscaling analyses will serve as the basis of a new reactive transport model developed for the Lower Triangle (between the Copper Creek and the PumpHouse). In addition, we use high resolution hydrological modeling based on the ParFlow-CLM software, we have developed an approach to calculating travel time distributions for water within the East River watershed. We will use this in conjunction with a newly developed watershed reactive transport capability combining ParFlow-CLM and CrunchFlow. These residence time distributions, in addition to providing a quantification of the overall water budget within the East River watershed, provide input for distributed, residence time-based models for nitrogen fate and transport.