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Controls of Hydrological Connectivity on Dissolved Organic Carbon Export in a Seasonally Snow-Covered Watershed

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Biogeochemical reactions at the watershed scale release dissolved organic carbon (DOC), a key solute affecting nutrient cycling and surface water quality. Flushing behaviors have been mostly observed for DOC across different watersheds under diverse conditions. However, underlying mechanisms for such flushing behaviors are poorly understood. Our overall goal is to: 1) develop a watershed-scale hydro-biogeochemical model to enable the simulation of DOC and other microbially-mediated processes; 2) use data-model integration to understand key controls of the DOC behavior at the Coal Creek, which is a seasonally snow-covered watershed (53 km^2) located in the west central Colorado.

In this work, a physically-based bio module, bioRT-Flux-PIHM, has been developed on the basis of RT-Flux-PIHM. This new bio module adds a Monod-type subroutine to solve for microbially-mediated processes and thus enables us to simulate DOC and DOC-relevant species (e.g. nutrients, and organic-metal complexes) at the watershed scale. This bio module has been verified against the widely used subsurface reactive transport code CrunchTope on soil carbon and nitrogen processes.

The application of bioRT-FLUX-PIHM in the Coal Creek watershed show that hydrologic connectivity largely determines stream DOC dynamics by shifting the dominant flow pathways and the major DOC sources connected to the stream. Under dry and low connectivity conditions, stream DOC is mainly from groundwater with low DOC concentration; under snow-melting season with high connectivity, stream DOC is predominantly composed of soil water with high DOC concentrations. Responsive SOC reaction rate to hydrologic conditions is a key mechanism to maintain a flushing DOC pattern. Groundwater is an indispensable component to reproduce stream DOC dynamics under baseflow conditions. In summary, stream DOC dynamic is controlled by groundwater influx when the watershed is under low hydrologic connectivity (transport-limited); however, it is largely controlled by soil water reaction when the watershed is under high hydrologic connectivity (supply-limited). These results have important implications for understanding and predicting watershed response to changing hydrological conditions and solute export from land to water.