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Understanding Influences of Hydrologic Exchange Flows on River Corridor Function in a Managed Watershed through Integrated Modeling and Observations

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This element of the PNNL SFA is monitoring key components that modulate carbon and nitrogen dynamics along the river corridor of a managed watershed and employing results in a novel watershed modeling framework with explicit representations of river corridor processes. Hydrologic exchange increases contact time with reactive environments within river corridors (RCs), facilitating biogeochemical reactions and controlling the fate and transport of solutes along the river corridor, and therefore impacting ecosystem health and responses to changing hydro-dynamic conditions.

Our watershed modeling framework features the coupling among PFLOTRAN, a massively parallel subsurface reactive transport model, the Community Land Model (CLM), and the river routing model from the Soil and Water Assessment Tool (SWATR). As a proof-of-concept, we apply the modeling framework in the Upper Columbia-Priest Rapids (UCPR) watershed to investigate the influence of RC on watershed function. Long-term observations from three eddy covariance stations as part of the AmeriFlux network, groundwater monitoring well, and discharge from USGS streamflow gages were used to inform and validate the model. Our results show that the upland and riparian ecosystems exhibit drastically different water and carbon dynamics. The upland sagebrush-steppe ecosystem relies heavily on rainfall for water supply, and ET and NEE peak in late spring when both precipitation and energy inputs are relatively high. In contrast, the riparian sagebrush-steppe and grassland ecosystems are dominated by exchanges between river water and groundwater, and ET and NEE peak in the summer when plants are physiologically active and less water-stressed.

To investigate the effect of hydrological exchange and biogeochemical processes on the fate of nutrients, SWATR has been enhanced with a multi-rate mass transfer (MRMT) module, created to model the coupled nonlinear multicomponent reactive transport in the channel water and its surrounding RCs. RCs are conceptualized as transient storage zones where two-step denitrification and aerobic respiration reaction are represented. By applying the SWATR-MRMT model to the UCPR watershed with estimated transfer rates with the basin-scale Networks with EXchange and Subsurface Storage (NEXSS) model, our simulation results suggest that (1) only biogeochemically active vertical RCs can contribute to significant nitrate removal in surface water due to the short residence times; and (2) mass transfer using a single exchange rate rather than a spectrum of exchange rates may overestimate the attenuation role of RCs.

Future work in improving the coupling among model components and collecting additional observations to inform and validate the model will be discussed.