Goldschmidt 2022 Abstract
https://doi.org/10.46427/gold2022.12594

Developing insights into river corridor and watershed hydro-biogeochemistry across scales

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Improving the predictive capabilities of the river corridor and watershed hydro-biogeochemistry across the watershed scale requires overcoming several underlying challenges, such as implementing an appropriate model structure as well as applying adequate parameters and meeting significant computational demands. To address these challenges, we developed a scale-adaptive framework: a cascade of process integration from a meander to the floodplain to the sub-watershed and watershed scales to compute geochemical exports and river water quality as a function of the characteristic watershed features, such as topography, wetness index, meanders, sinuosity, and amplitudes. To demonstrate our approach, we conducted this study at the East River Watershed, the study site of Berkeley Lab's Watershed Function Scientific Focus Area. We modeled a floodplain with 10-meander and 2-meander systems using PFLOTRAN—an open-source, high-resolution, three-dimensional, reactive flow, and transport code—and then developed scaling relationships in the East River Watershed. We developed the RiverFlotran Module and integrated it with PFLOTRAN to account for the bi-directional exchange of geochemical species and quantify river water quality changes. The RiverFlotran module uses the fully dynamic 1D shallow-water equations. We integrated a complex biotic and abiotic reaction network, representing heterotrophic and chemolithoautotrophic pathways and precipitation and dissolution of various minerals, into PFLOTRAN. The model results indicated that the East River floodplain is dynamic; it experiences a highly variable saturation profile in space at different water conditions, both low and high. Flow velocities demonstrated upwelling at times and significant temporal variability. Dissolved iron and nitrogen profiles showed strong redox gradients in the subsurface. We found that hot spots and hot moments of nitrogen were produced due to river stage, bathymetry, and meander geometry (e.g., sinuosity). We noted that meander amplitudes and river stages influence denitrification in the river and subsurface. Denitrification potential is favored by amplitude augmentation whereas the rising limb promotes denitrification potential, followed by the baseflow and recession limb. These results indicate that biogeochemical processes and their responses to low- and high-water conditions are complex and require more study.