Geophysical-based Approaches for Quantifying the Spatiotemporal Distribution of Physicochemical and Hydraulic Properties that Influence the Biogeochemical Functioning of the Rifle CO Floodplain

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Gaining a predictive understanding of terrestrial environmental functioning requires information about the key controls on system behaviors and their variations over space and time. As part of the Genomes-to-Watershed LBNL SFA, advanced geophysical acquisition, inversion, and integration approaches are being developed to meet this objective. Here, we describe two recent advances – one associated with using geophysical and stochastic approaches to delineate the 3D distribution of hydrostratigraphic units having distinct physicochemical properties that control reactive transport, and the other focused on developing novel inversion schemes using autonomously collected, streaming datasets to jointly quantify hydraulic and thermal behaviors of the shallow floodplain subsurface. The developed characterization and monitoring strategies are being used to parameterize the genome enabled reactive transport watershed simulation capability (GEWASC) at the Rifle CO biogeochemical field study site. The approaches are also being extended based on conceptual models of hot spots and hot moments in the East River Watershed in the Upper Colorado River Basin, a developing LBNL SFA field study site.

A Bayesian approach was used with surface electrical resistivity tomography and time-domain induced polarization datasets to identify the presence and distribution of naturally reduced zones in the Rifle floodplain and their associated uncertainties. These zones are characterized by increased organic matter and reduced mineral concentrations, as well as unique microbial signatures and are considered as biogeochemical hotspots due to their importance in carbon and other nutrients cycling. The Bayesian estimation approach also took advantage of well log stratigraphy and a surface elevation model inferred from a kite-based aerial imaging platform. Results revealed that the developed approach enable a reliable mapping and uncertainty quantification of each major hydrostratigraphic units and hotspot locations.

A joint hydrogeophysical inversion framework was developed and implemented using autonomous, streaming electrical, thermal, capillary pressure and meteorological data to quantify in high resolution hydrological-thermal interactions as a function of weather conditions, snowmelt, and a variety of other forcings. Gaining an understanding of these interactions is critical due to their control in microbial mediation of key biogeochemical dynamics at the site, which have documented periodic infiltration pulses as a key hot moment controlling biogeochemical functioning of the floodplain. The developed approach used the iTOUGH2 platform, and effectively accounts for the multiphase and nonisothermal flow in porous media and for petrophysical relationships and uncertainty to link soil moisture and temperature with the electrical resistivity. Results revealed that the developed framework is adapted to quantify hydraulic and thermal parameters and understand spatiotemporal variability in water and heat fluxes. Overall, results of these efforts demonstrate the value of using various datasets collected in a minimally invasive manner and at high spatial resolution, and advanced data inversion and integration framework.