Characterizing Biogeochemical Hot Spots and Hot Moments in a Floodplain System

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Although spatially discrete biogeochemical hotspots and temporally restricted hot moments are known to account for a high percentage of nutrient cycling within terrestrial and aquatic ecosystems, the ability to effectively identify and incorporate them into reactive transport models remains a significant challenge. Using a combination of geophysical, solid and aqueous geochemical, hydrological, geological and microbiological datasets, and statistical techniques, we seek to identify relevant biogeochemical zonation and to quantify spatial and temporal variability of hydrological-biogeochemical properties across the Rifle floodplain. The zonation approach exploits the suppositions that: (1) many subsurface properties are likely to be correlated with each other; (2) some properties may exert a dominant control on biogeochemical cycling; and (3) some spatially extensive measurements (such as geophysical and remote sensing) may provide reasonable proxies for controlling variables, thus offering an approach to characterize zonation and key properties over large regions and in a minimally invasive manner. Once such zonation is identified, it can be used to parameterize the modeling domain as well as to guide characterization campaigns in a cost effective manner.

We develop and test our methods at the Rifle CO biogeochemical field study site as part of the LBNL Sustainable Systems SFA. Cluster analysis of all the datasets revealed the presence of several spatial zones across the site, which had unique distributions of geomorphic, hydrological, microbial, and geochemical properties. Using this method, we also identified and distributed biogeochemical hot spots, called naturally reduced zones, which are important regions for subsurface biogeochemical cycling. Furthermore, wavelet analysis was used to quantify the key controls on temporal variations in the geochemical data. Wavelet analysis results revealed that seasonal perturbations (~4 months) constitute hot moments that drive biogeochemical cycling at Rifle, with such activity confined to hot spots corresponding to the anthropogenically-contaminated zone. Interestingly, wavelets revealed a different dominant frequency (~3 months) for the naturally reduced zone at the Rifle site. The correspondence between biogeochemical zonation, seasonal variability, and other site-specific interactions from this study provide the characterization necessary for quantifying key controls at the Rifle site. Importantly, this zonation-based work is providing a framework for tractable yet sufficient parameterization of the LBNL SFA genome enabled reactive transport watershed simulator, GEWaSC.