Advancing Numerical Capabilities for Microbial and Biogeochemical Processes in Hyporheic Zones

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Introduction

Application of numerical methods to hyporheic zones provides a perfect testbed for cross-scale, coupled surface water and subsurface system investigations. Not only do hyporheic zones serve as control points for watershed scale solute and nutrient processing, but at the small scale they balance residence and reaction timescales to effectively sustain flow, biogeochemical cycling, and localized microbial populations. In our current research, we develop a predictive understanding of the subsurface and surface controls on hyporheic biogeochemical behavior through data-model integration. We investigate a loose-coupling strategy for hyporheic systems that allows river gross primary productivity (GPP) and hillslope runoff contributions to augment hyporheic zone function. Additionally, we showcase a novel microbial capability in reactive transport codes[1,2] whereby Monod kinetics and biological permeability functions[3] are used to allow feedbacks between flow and microbial growth—as microbes grow, they fill the pore-spaces and limit the flow that initially supported their growth. We apply this model to the hyporheic zone along the East River, Colorado which is the main research site of the Department of Energy's Watershed Function Scientific Focus Area. Across the hyporheic zone and floodplain, we measured surface and subsurface gases, geochemistry, isotopes, and used this data to constrain our model in the presence of transient hydrological flow conditions. A Bayesian approach was used for the river model that allows GPP, respiration, and diffusion parameters to vary with season, constrained by radiation, barometric pressure, water depth, temperature, pH, DIC, and atmospheric CO_2. These river simulations were used as boundary conditions to test the dynamic nature of the hyporheic zone in response to future temperature and atmospheric CO_2 representing carbon emission futures, and to compare future and current hyporheic zone processing. Our data coupled with the predictive power of our numerical model reveal that hyporheic zones can serve many roles throughout the year and indicate the importance of hyporheic cycling as a critical control point on watershed scale exports.

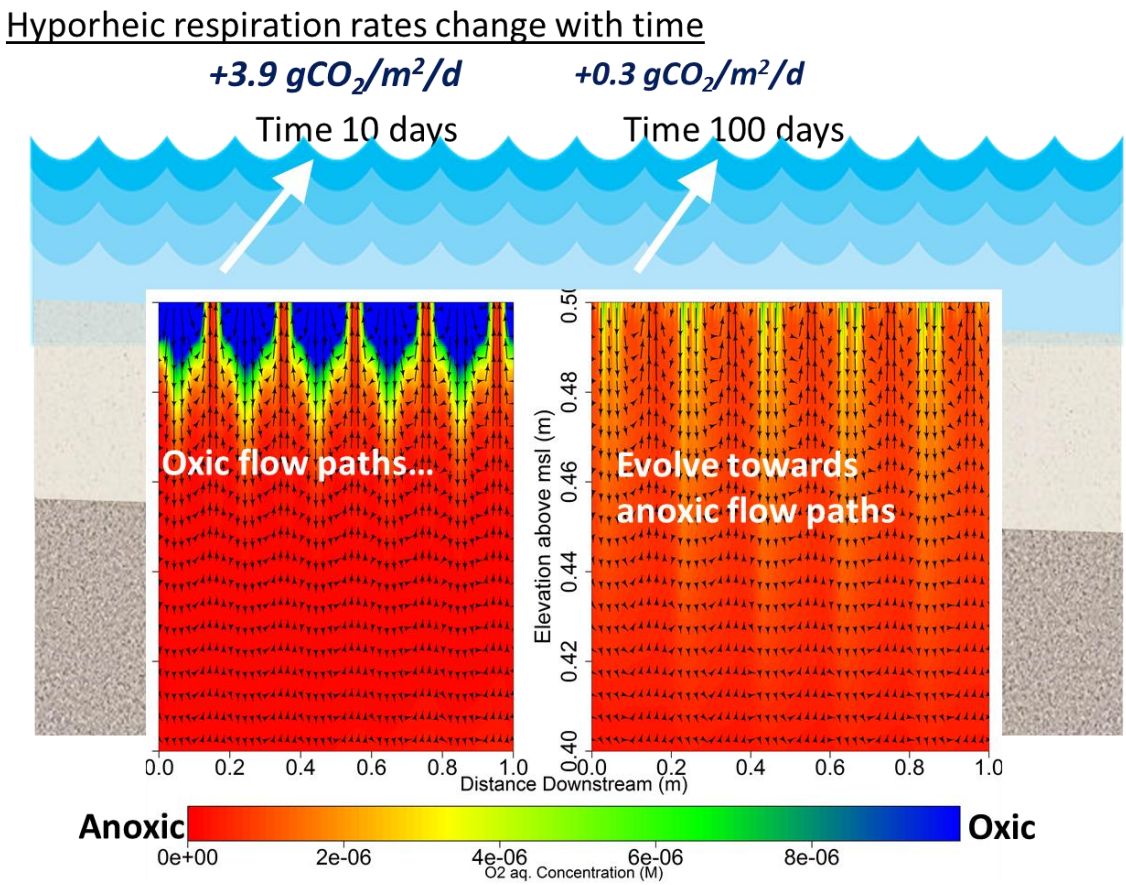

Figure 1: Subsurface model of the hyporheic zone showing evolution of reaction rates over time.

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