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Transient Anoxic Micro-zone Development in an Alpine Stream

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Biogeochemical processes in the hyporheic zone occur over a broad range of temporal and spatial scales. The experimental challenge lies in how to obtain in-situ and time-resolved data at these different scales from a remote field site. We present spatially resolved profiles of dissolved oxygen (DO) concentration and temperature at a resolution of one data point every five minutes over an entire hydrological year from the hyporheic zone of a snow-dominated sub-alpine stream in the East River watershed in southwestern Colorado, USA (the primary site of the Watershed Function Scientific Focus Area of Berkeley Lab). We obtained these datasets from an array of novel DO sensors developed by OptiO2, LLC. The probes were located in the stream as well as buried within the streambed sediment, data being telemetered in real-time from the remote study site over a 15 month-long period. A time-lapse analysis of the oxygen profiles reveals the appearance and disappearance of anoxic micro-zones at the centimeter scale within the stream bed. Results suggest that the anoxic micro-zones move vertically over periods of days driven by processes such as snow melt and precipitation. These coupled hydrological processes lead to lateral flow in the hyporheic zone, representing a time-varying respiration contribution to the river.

We geocoded and analyzed these in-situ measurements of oxygen and temperature using spectral frequency analysis. The data were then used in a flow and reactive transport model with a Bayesian inversion procedure to predict coupled stream and hyporheic zone respiration. Specifically, we constructed a fully-coupled saturated/unsaturated flow and reactive transport model for the 2D riverbed hyporheic zone using the code MIN3P. An interesting finding from the oxygen data with depth is the observation of declining then increasing oxygen concentrations with depth. We hypothesized this was due to turbulence pressure conditions and the inclusion of sediment heterogeneity. We incorporated the role of turbulence by simulating the pressure head boundary condition as a function of Reynolds number for the river. Additionally, we included stochastic geostatistical representations of sediment parameters. Results indicate turbulence is an important metric to consider for correctly simulating subsurface redox conditions.

The data from the novel OptiO2 sensors highlight the transient behavior of anoxic micro- zones in the context of an unusual snow drought hydrological cycle. Efforts are underway to use these high-resolution oxygen and temperature data in mechanistic models to enhance process understanding in stream beds and hyporheic zones.