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Exploring climate controls on hyporheic zone dynamics and feedbacks between sediment distribution, riverbed bioclogging, infiltration, and microbial CO_2 production

Michelle E. Newcomer[1], Susan S. Hubbard[2], Craig Ulrich[2], Baptiste Dafflon[2], John Peterson[2], Yoram Rubin[1]
[1]University of California, Berkeley
[2]Lawrence Berkeley National Laboratory

In regions worldwide, losing rivers are common and can introduce feedbacks affecting total transport of infiltration and nutrients. Permeability decline from hyporheic zone bioclogging is one feedback that is thought to depend on climatic events that control riverbed parameters, primary productivity, and subsurface gas production. River life-cycles are an important component of this cycle as they typically represent a sink of CO_2 gas from the atmosphere. When benthic organisms decay, however, this provides a source of dissolved organic carbon (DOC) to subsurface microbes for transformation back to CO_2. Net CO_2 and other greenhouse gas (GHG) fluxes from the surface-subsurface interface are highly dependent on hyporheic flows, infiltration rates, and groundwater-surface water interactions to facilitate their transformations. Both surface and subsurface metabolism, leading to bioclogging of subsurface sediments are linked to GHG fluxes and are not well quantified in river-aquifer zones. Nor are their interactions and dependencies understood in rivers that have variable surface-water flow and infiltration regimes from climate perturbations such as from the El Niño Southern Oscillation (ENSO).

To address the effect of large scale climate-controls on biogeochemical fluxes, we simulated riverbed biological growth and hyporheic zone carbon dynamics using 1D/2D numerical models, allowing a range of initial grain size distributions (GSD) to represent ENSO control of riverbed scour. GHG fluxes from subsurface microbes were quantified as a function of surface ecological DOC production and river discharge. We modeled primary productivity and DOC production using surface water quality data and samples of phytoplankton from a floodplain located in the upper East River watershed in Colorado (Field site of the LBNL-SBR Subsurface Biogeochemistry Watershed Function SFA). Two model types were considered: 1) river scale river-aquifer flow model, and 2) hyporheic flow model. Within the numerical model, simulated hyporheic flow paths, transformation of DOC to GHGs, and redox conditions allowed precipitation of metals (Fe II and Fe III), and redox-stratified microbial communities that feedback into surface ecological growth.

Our work links climatic perturbations of surface water discharge as a major control on riverbed sediment GSD, bioclogging, and subsurface transformations. Results show that GHG production is not only a function of surface ecology, but linked to the statistics of extreme climatic events that control riverbed initial conditions. These results provide a new understanding of nutrient cycling and hotspot bioclogging in losing rivers where climatic extremes occur.