Effect of Hydrological Forcing on the Biogeochemical Transformation of Carbon and Greenhouse Gas Emissions in Riparian and Streambed Sediments

Martial Taillefert,[1,*] Chloe Arson,[1] Thomas J. DiChristina,[1] Kenneth M. Kemner,[2] Daniel I. Kaplan,[3] Christa Pennacchio,[4] Stephen J. Callister,[5]

[1]Georgia Institute of Technology, Atlanta, GA;
[2]Argonne National Laboratory, Argonne, IL;
[3]Savannah River National Laboratory, Aiken, SC;
[4]Joint Genome Institute, Berkeley, CA;
[5]Environmental Molecular Sciences Laboratory, Richland, WA

Contact: (mtaillef@eas.gatech.edu)

Project Lead Principal Investigator (PI): Martial Taillefert

BER Program: ESS

Project: University project

Project Abstract: Biogeochemical processes in riparian and hyporheic sediments regulate the transformation and exchange of carbon, nutrients, and greenhouse gases (GHGs) with surface waters. Riparian and hyporheic zones are terrestrial-aquatic interfaces (TAIs) where hydrological processes create strong biogeochemical gradients and redox microniches that are metabolically highly variable and influenced by temporal variations in precipitation, temperature, and stream discharge. The complex temporal and spatial variability of hydrological variations in riparian and hyporheic sediments create hot spots and moments that are difficult to quantify and account for in reactive transport models (RTMs). In addition, reactive transport in these systems is traditionally simulated on the continuum scale using upscaled empirical parameters that are not able to reproduce the effect of biogeochemical reactions on pore scale heterogeneities and their feedback on biogeochemical rates. These effects tend to overestimate rates at the Darcy scale and misrepresent GHG emissions from riparian and streambed sediments. In this new project, state-of-the-art in situ physical and geochemical measurements with high spatiotemporal resolution will be combined with meta-omic signals of the active microbial populations in riparian and hyporheic sediments of Steed Pond at the Savannah River National Laboratory to: 1) predict the role of hydrological forcing on the spatiotemporal transformation of carbon, nutrients, and redox processes along this gaining and losing wetland stream; and 2) determine the effect of these hydrobiogeochemical processes on GHG emissions. Gene-centric microbial metabolic rate laws developed during a previous exploratory project are currently integrated in pore-scale and continuum RTMs that will be combined with machine-learning algorithms to assess model sensitivity and calculate biogeochemical rates. Characterizing the distribution of the main redox species in wetland and stream sediments with high spatial and temporal resolution will provide unique insights into the processes that control GHG emissions from riparian and streambed sediments under varying hydrological conditions. The newly developed numerical models will predict how variations in hydrological forcing, competition between microbial metabolic processes, and porosity changes associated with biogeochemical feedback affect carbon and nutrient cycling as well as GHG emissions at TAIs. Ultimately, these efforts will capture the role of sediment heterogeneities in GHG emissions.