From Substrate to Surface: The Impact of Aquatic Ecosystems on Exchange Processes at the Sediment-Water and Water-Air Interfaces

Abstract

The role of aquatic vegetation as “ecosystem engineers” is well recognized by the wide range of services it provides to its habitat. Flow modifications by aquatic vegetation affects processes at the sediment-water and water-air interfaces; impacting sediment transport, sediment oxygen demand and surface gas transfer. The detailed analysis of flow and scalar transport through aquatic vegetation has been a topic of constant investigation. Most of the studies have used an experimental approach, analyzing flow through patches of idealized vegetation to understand their effect on flow structure. Recently, the investigations have been extended to study the transport of sediment and dissolved oxygen through the vegetation canopies. Despite these advances, the detailed four-way interaction between air-water-vegetation-sediment is not fully understood, primarily due to lack of spatial and temporal resolution required to capture it. High-resolution numerical simulations have been found to address this gap in knowledge, as already observed in studies investigating the hydrodynamics within the vegetation canopies. The current work seeks integration of the various impacts of aquatic ecosystems on sediment and oxygen dynamics in natural waters. We focus on four fundamental processes: flow-vegetation interactions, sediment dynamics under flows altered by vegetation, turbulence modulation by suspended sediment, and sediment-oxygen dynamics as a driver of nutrients’ exchange from substrate to surface. In the current study, 3D high-resolution large eddy simulation (LES) of flow, suspended sediment, and gases, is being performed; with the goal to analyze the complex interaction between air-water-vegetation-sediment. Nek5000, an open-source spectral-element based higher-order incompressible Navier-Stokes solver has been used for the simulations. Transport of suspended sediment and dissolved oxygen have been modeled using the advection-diffusion equation. Simulations have been conducted for a range of Reynolds number, sediment sizes and initial scalar concentrations. The simulations are computationally intensive (more than100 million computational points), thus warranting the use of petascale supercomputer Blue Waters.

Speaker Biography

Pallav completed his undergraduate degree in Civil Engineering in 2015 from Indian Institute of Technology Roorkee, India. After graduation, he worked as a research assistant at Indian Institute of Technology Bombay, building computer models to assess inundation due to cyclonic and tidal surge in coastal areas. He joined the Department of Civil and Environmental Engineering, UIUC in 2016, where he completed his M.S. in Environmental Hydraulics and Hydrology in 2018, with a thesis titled “High-Resolution Numerical Investigation of Hydrodynamics and Sediment Transport within Emergent Vegetation Canopy”. Currently he is continuing as a graduate student in the department of Civil and Environmental Engineering, pursuing Ph.D. in the area of Environmental Fluid Mechanics. Due to the interdisciplinary nature of his work, he also works in close communion with researchers from the Department of Computer Science at UIUC.