Poster #21-9

From universal scaling for flow resistance in vegetated channels to predicting algal bloom and the evolution of benthic algae in riverine systems at the reach scale

Ilenia Battiato[1*]

[1]Stanford University, Stanford, CA

Contact: ibattiat@stanford.edu

BER Program: SBR
Project: University Award

The impact of submerged vegetation on nutrients and contaminants distribution in rivers and streams has been generally overlooked in recent multiscale modeling efforts. Yet, submerged aquatic vegetation (SAV), that consists of rooted macrophytes and attached algae, acts as the regulatory layer between many hydrological and ecological functions. SAV plays a pivotal role in fluvial systems by (1) mediating and regulating the transport between surface waters and the hyporheic zone and (2) promoting biodiversity through the creation of spatial heterogeneity in the flow field. One common challenge in modeling flow and transport in vegetated rivers and streams is the lack of predictive models linking vegetation type and morphology with effective transport properties of the vegetative layer itself and its dynamic linkages to its surroundings (i.e. groundwater and surface waters). Furthermore, the impact of environmental conditions such as water temperature, nutrient availability, light, local hydrodynamics and near-bed fluxes on SAV biomass dynamics (e.g., growth, uptake and removal) has been hard to disentangle. While the availability of LiDAR and unmanned aerial vehicle (UAV) data has opened new opportunities to spatially characterize vegetated environments over large scales, it also has demonstrated the startling limitations of existing models in establishing a mechanistic connection between vegetation morphology, its function and coupled response to variable river and environmental inputs. Here we use a combination of analytical and numerical methods to understand the impact of morphologically complex canopies on friction factor and the dynamic coupling between momentum, mass and SAV biomass evolution in the Khors rover bent in Montana. First, we discover a universal scaling law that relates friction factor with canopy permeability and a rescaled bulk Reynolds number; this provides a valuable tool to assess habitats sustainability associated with hydro-dynamical conditions [1]. Second, we develop a 3D code, CladoFOAM, in the OpenFOAM framework, to model Cladophora biomass distribution at the 1.5 km long Khors bent of the Clark Fork river in Montana, where extensive measurements of spatiotemporal evolution of Cladophora coverage at the reach scale, as well as seasonal variations of river discharge, nitrogen input, river temperature, light penetration, and daily/nightly variations of respiration rates, are available. The code, which solves a system of 18 coupled PDEs and ODEs, is able to accurately model the yearly vegetation coverage evolution at the reach scale [2].

[1] S. Rubol, B. Ling and I. Battiato, “Universal scaling-law for flow resistance over canopies with complex morphology”, Scientific Reports, Accepted, (2018).

[2] Ling, B., S. Rubol, I. Battiato, ‘Predicting algal bloom: the evolution of benthic algae in riverine systems’, In preparation for Submission to PNAS, (2018).