EXECUTIVE SUMMARY

Aquatic vegetation provides a wide range of services to the ecosystem: improving water quality through nutrient uptake and oxygen production, providing flood buffering and coastal protection services, and regulating erosion and deposition patterns, thus playing a paramount role in habitat creation and promotion of biodiversity. While vegetation–flow interactions have been studied extensively for unidirectional flows, much less is known about oscillatory conditions. The current study is geared toward increasing our understanding of the interactions among vegetation, flow, and sediment under oscillatory flows. Direct Numerical Simulations (DNS) and Large-Eddy Simulations (LES) through large arrays of cylinders to understand the effect of spatial heterogeneity of the vegetation on the flow. The study focuses primarily on the scale of the experimental setup to be modeled is a challenge. The number of computation points required to model the whole domain is near 1.2 billion. While such simulations are still tractable on a petascale platform like Blue Waters, the computational cost is high, resulting in a reduction of the number of cases one can run, thus constraining the insights a broader range of parameters could yield. To increase variable space, a wide range of conditions are first calculated it, and a few LES studies, which had to settle for a relatively small number of vegetation elements. Our study is geared at bridging this gap by conducting numerical simulations at unprecedented scales, based on previous and ongoing experiments at the Ven Te Chow Hydrodynamics Laboratory at the University of Illinois at Urbana-Champaign. We investigated flow through random and staggered arrays of cylinders to understand the effect of spatial heterogeneity of the vegetation on the flow. The study focuses primarily on oscillatory flow, through a few cases of unidirectional flow will be conducted for comparison purposes. Coupling the experimental and numerical study will yield further understanding of sediment dynamics under the influence of vegetation [4].

METHODS & CODES

High-resolution LES and DNS of the flow at different configurations of the idealized vegetation were conducted using the open-source, spectral element-based higher-order incompressible Navier–Stokes solver Nek5000 [5]. The Spectral Element Method combines the accuracy of spectral methods and the flexibility of Finite Elements Method [7]. In the planned simulations with sediment transport, sediment would be modeled as Lagrangian particles using a novel semi-implicit time-stepping scheme developed to simulate polydisperse sediment accurately.

RESULTS & IMPACT

2D simulations have been conducted for the full domain on different configurations. Two cases having the same vegetation density and Reynolds number, but different array configurations, are presented here. The velocity magnitude, along with the pressure field, is shown in Fig. 1. For the staggered case, in contrast with the random array, a vortex being shed from a cylinder is impeded by the one behind it, which is not the case for the random case. 3D simulations have been conducted for the full domain on different elevations. Planes at (a) 0.5 %, (b) 5 %, (c) 10 %, (d) 50 %, (e) 75 %, and (f) 95 % water depth.