PhD Open Days

Effect of suspended sediment load on vegetation

PHD PROGRAM CIVIL ENGINEERING

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Introduction

The flow past emergent cylinders is a fluid mechanics problem of fundamental interest in environmental fluid mechanics and it is a proxy of vegetation in open channel flows. The presence of vegetation strongly modifies the flow and sediment transport in waterways hence the morphological and ecological dynamics of river and coastal areas. The increased form drag associated to the plants reduces the mean flow velocity promoting sedimentation and retention of nutrient and pollutants thus improving water quality and playing an crucial role in the water cycle at organism and ecosystem levels. Engineering tools are needed for estimating both the mean flow and turbulence structure as well as the suspended sediment transport capacity of vegetated waterways.

Aim

In this work open channel flows past an array of randomly placed vertical cylinders mounted on a flat and rough bed are analyzed including suspended sediments with different grain size and concentration (C) profiles. The objective is to observe how the buoyancy effect due to the presence of suspended sediment load influences the flow field within the array.

Methods

Large-eddy simulation (LES) tool including a suspended sediment model has been adopted to provide a complete description of the instantaneous 3D turbulent flow field and to study flow-vegetation-sediment interactions. The methodology addresses the effect of the suspended sediment solely through buoyancy effect. As next step, the simulations will be validated with laboratory experiments carried out through PIV measurements.

Results

The LES-COAST code [1] is an Euler-Euler single-phase approach involving LES with sub-grid-scale model to solve the 3D Navier-Stokes equations coupled with an advection-diffusion equation to solve the suspended sediment concentration. The LES model has been firstly validated against laboratory data [2] for open channel flow through an isolated cylinder. Good agreement with experiments have been found (Figure 1). Numerical simulations have been performed for one value of the grain size (100 μm) and two values of the suspend sediment concentration (C=0.0 and C0.01) for both isolated cylinder and array of cylinders cases. The numerical results for both geometries show strong buoyancy

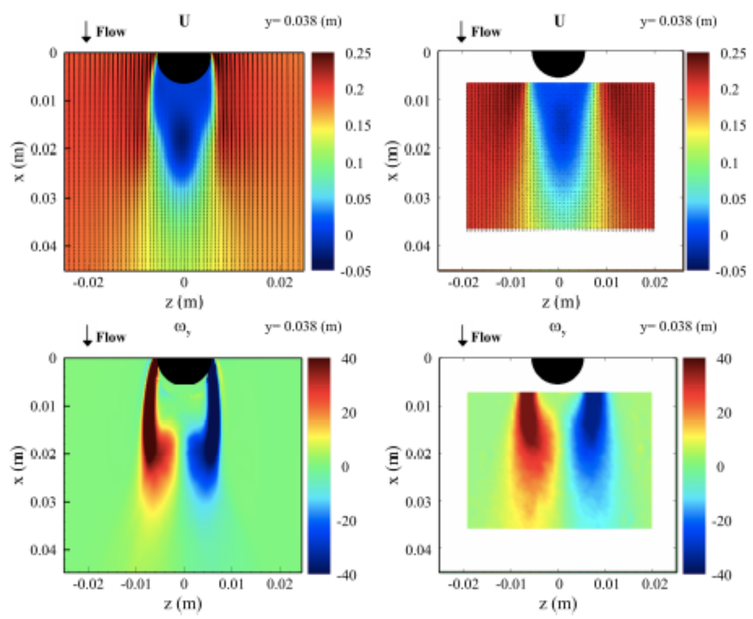

Figure 1: Validation of flow past an isolated cylinder. LES (left) vs experimental (right) data.

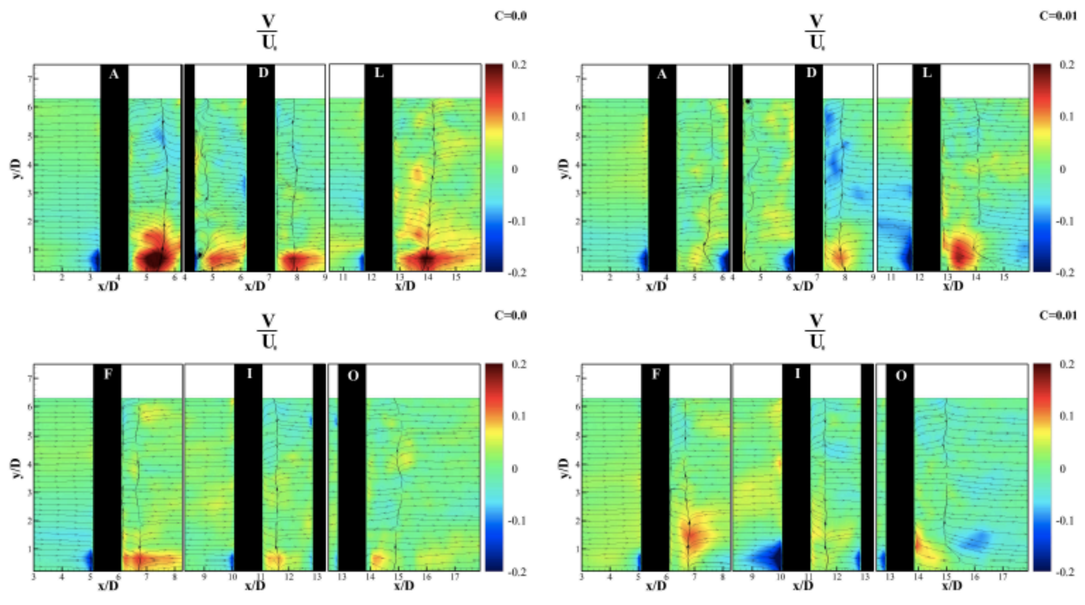

Figure 2: Time-averaged vertical velocity in vertical planes within array of cylinders with and without suspended sediment.

effects close to the bottom due to high values of the concentration imposed at the inlet. In the case of the array of the cylinders was found that: at very low flow height i) the time and double-averaged flow field show reduction of drag, velocity and turbulence; ii) the up-flow regions are weaker while the down-flow and recirculation regions are enhanced (Figure 2); iii) the wake interference effect and the flow lateral deflections of the neighbouring elements are damped; iv) the vortex formation lengths increase. At higher flow heights, where the sediment concentration was approximately zero, weaker effects can be observed (e.g. the reduction of the formation lengths).

Conclusions

The stratification effects due to the presence of suspended sediment load are clearly observed in the regions close to the bed. A better understanding and deeper investigation of the buoyancy influence within the array of cylinders will be obtained through the validation against laboratory experiments and performing new experiments with different grains sizes and concentration profiles.

Acknowledgments

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References

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[2] Ricardo, A.M., Koll, K.; Franca, M.J., Schleiss, A.J. & Ferreira, R.M.L. 2014 (b) The terms of turbulent kinetic energy budget within random arrays of emergent cylinders. Water Resour. Res., 50(5):4131-4148.