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CUT-CELL METHOD: APPLICATION TO WATER WAVES GENERATED BY A SUBMERGED OBSTACLE.

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This study addresses a problem of wave and current interactions. Experiments performed in a wave channel in which a flow is imposed over an obstacle have shown very interesting features such as wave blocking and the generation of blue shifted waves. These experiments can be used as analogue models of gravity in order to understand some phenomena such as the Hawking radiation of black holes.

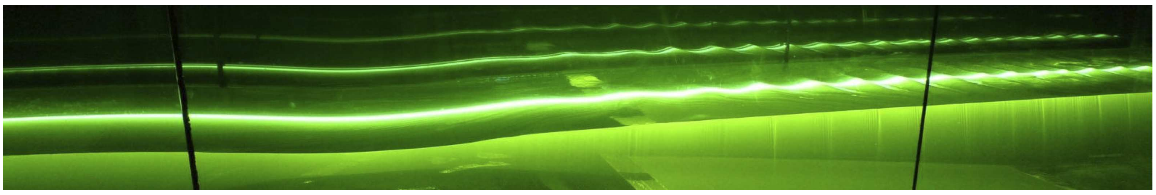

Figure 1: Image of an experiment performed in the wave channel at the Pprime institute

The linear theory of gravity waves, based on the assumption of an irrotational fluid can explain some aspects of the phenomenology. However, in order to fully understand the propagation of waves in such a context, it is necessary to use more complex models. We hence focused our research on the numerical simulation of the free-surface Navier-Stokes equations in the presence of obstacles.

The numerical method we used in order to solve the incompressible Navier-Stokes equations is a Chorin-type projection method. This leads to solve successively the prediction step:

$$\frac{\tilde{\mathbf{u}}^{k+1}-\mathbf{u}^k}{\delta t} - \frac{\mu}{\rho}\triangle\tilde{\mathbf{u}}^{k+1} = \mathbf{g} - \left(\mathbf{u}^k.\nabla\right)\mathbf{u}^k \quad , \quad \mathbf{g}=(0,-9.81) \tag{1}$$

and the projection step:

$$\frac{\mathbf{u}^{k+1} - \tilde{\mathbf{u}}^{k+1}}{\delta t} + \frac{\nabla p^{k+1}}{\rho} = 0 \tag{2}$$

$$\nabla.\mathbf{u}^{k+1} = 0 \tag{3}$$

where p, μ and ρ are respectively the pressure, the dynamic viscosity and the density. The variable coefficient Poisson problem

$$\nabla.\left(\frac{\nabla p^{k+1}}{\rho}\right) = \frac{\nabla.\tilde{\mathbf{u}}^{k+1}}{\delta t} \tag{4}$$

is obtained after tacking the divergence of (2). A standard MAC grid is used where p, ρ, μ and ϕ exist at the cell centers, while u and v are located at the appropriate cell edges. Away from both moving interface and obstacle, linear partial differential operators (divergence, gradient, Laplacian operator) and nonlinear terms are discretized on a fixed Cartesian grid by using standard second order Finite Differences approximations.

The main challenge here is to take into account the boundary conditions of the problem. On one hand, the Immersed Boundary Method [1] is used in order to enforce the no-slip boundary condition on the rigid obstacle. On the other hand, the moving interface will be tackled with the Level-Set technique. The jump conditions across the interface are solved by using the boundary condition capturing method [2].

Many direct and iterative approaches have been employed to find the solution of the linear systems (1) and (4). For large problems, the faster solver we have found is an algebraic multigrid method (HYPRE BoomerAMG). The resolution of the linear systems has been implemented in parallel using the PETSc Fortran library.

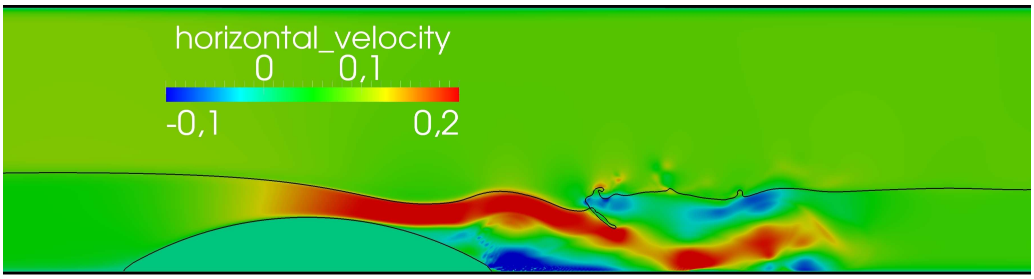

Figure 2: Numerical simulation of a moderate hydraulic jump between fresh and salt water.

REFERENCES

[1] F. Bouchon, T. Dubois and N. James, A second-order cut-cell method for the numerical simulation of 2D flows past obstacles, *Computers & Fluids*, 80–91, 2012.

[2] X.-D. Liu, R. Fedkiw and M. Kang, A Boundary Condition Capturing Method for Poisson's Equation on Irregular Domains, *Journal of Computational Physics*, **160**, 151–178, 2000.