Geophysical Research Abstracts
Vol. 14, EGU2012-7500, 2012
EGU General Assembly 2012

Predictions of nearshore hydrodynamics based on free-surface lattice Boltzmann approximations

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The focus of the present free-surface model developments is to utilize gas dynamics theory to predict and investigate underlying mechanisms of the dynamics of nonlinear water waves. Since water wave mechanics is a topic not concerned with the notions from thermodynamics, the basics of the physics of incompressible gas dynamics provides a relatively simple means for describing the theory and predictions of nonlinear wave propagation through advanced random and nonlinear particle collision processes [1].

Nonlinear free-surface physics are investigated using the Lattice Boltzmann Method (LBM) at intermediate to shallow water depth. The LBM simulates fluid flow by tracking particle distributions in a Lagrangian manner. The particles are constrained to move on regular or octree lattices depending on wave steepness and/or wave-structure interaction details sought. The Boltzmann equation relates the time evolution and spatial variation of a collection of molecules to a collision operator that describes the interaction of the molecules. Mathematically, the collision integral of the LB equation poses difficulties when solution of the equation is sought. Investigators overcome this through descriptions of models with different levels of accuracy in the approximations of the integral. We consider a model in which the collision assumption is approximated by a multiple relaxation time form. The free-surface algorithm involves an interface tracking scheme based on the volume fraction of the fluid combined with the LBM for the advection equation in which the solver reconstructs the missing probability distribution functions taking into account the distance to the interface [2, 3].

The approximate forms of the LBM describe comparisons of the nonlinear shallow water equations and the Navier Stokes equations. Test cases involving predictions of run-up/run-down on cylinders and beaches are shown. The wet-dry interface conditions, viscosity treatment, surface break-up amongst others are discussed. Furthermore, many offshore wind farms and future wave energy farms consist of arrays of surface piercing structures. From a renewable energy perspective, the physics of wave structure interactions are also discussed and the corresponding expected wave energy output reported.

References

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