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A Novel Two-Way Coupled Model for Simulating the Interaction between Fluid flow and Floating Debris

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Extreme natural hazards such as tsunamis or storm surges have been frequently reported in recent years, posting serious threat to people and their properties. Numerical modelling has provided an indispensable tool to predict these hazardous events and assess their risks. However, most of the current models are based on the assumption of “clean” water and neglect the impact of floating debris as observed in reality. The interactive processes between the floating debris and the background fluid flow have not been well explored and understood. Few reliable modelling tool has been reported for simulating and predicting these complicated processes.

This work presents a two-way dynamic method to couple a 2D shallow flow hydrodynamic model with a discrete element method (DEM) model for simulating and analyzing the interactive process between fluid flow and floating debris under the extreme hydraulic conditions induced by tsunami or flash flooding. The proposed two-way coupling approach uses the high-resolution water depth and velocity predicted by the hydrodynamic model to quantify the hydrostatic and dynamic forces acting on the floating objects; the corresponding counter forces on the fluid are subsequently taken into account by including extra source terms in the governing shallow water equations (SWEs) of hydrodynamic model. This new approach lifts the limitation of traditional approaches that reply on calibrated empirical parameters to quantify the forces. In developing the resulting coupled model, a multi-sphere method (MSM) is adopted and implemented in the DEM model to simulate solid debris. This method ensures that the interaction of fluid and solid is realistically modelled and the application is not restricted by shapes and sizes of debris.

The new coupling model is validated against a dam-break flume experiment with three floating objects impacting two fixed obstacles. The predicted results in terms of water depth and floating object displacements in both horizontal and vertical directions compare well with the experimental observations. Furthermore, the new coupled model is computationally accelerated by implementation on modern GPUs to achieve high-performance computing. It provides a robust and innovative modelling tool for the simulation of large-scale flooding process including debris impact and assess the resulting risk.