Geophysical Research Abstracts
Vol. 19, EGU2017-17365, 2017
EGU General Assembly 2017

Coupling a 2D Eulerian shallow-flow solver with a 3D Lagrangian rigid-body solver: application to debris transport by tsunamis

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The destructive potential of tsunami impacts is significantly due to the capacity of the overland flow to incorporate large quantities of solid debris, as depicted in the widespread footage of the 2004 and 2011 events in Sumatra and Japan, respectively. The transported debris increase the imparted momentum of the resulting solid-fluid flow to existing structures, causing massive and extensive destruction to the affected built environments and resulting in severe casualties. Understanding the role of the transported debris in the combined solid-fluid flow dynamics is of vital importance for the development of reliable tools for tsunami impact forecast.

The STAV-2D model has been under development at CEris – Instituto Superior Técnico, Universidade de Lisboa – and successfully applied and validated for tsunami overland propagation (Conde et al., 2013 & Conde et al., 2015). The model has been recently re-designed to take advantage of parallel and heterogeneous CPU-GPU architectures, allowing for highly resolved simulations of shallow-flows. The increased resolutions now achievable with the parallel model justify the integration of STAV-2D with a rigid-body solver capable of greater physical detail than the one proposed in Conde et al. (2015). Namely, the PhysX physics engine from NVIDIA, featuring full 3D dynamics (6 degrees of freedom) for rigid or soft bodies and collision detection, is integrated into STAV-2D.

Specific laboratory work was carried out at the University of Ottawa in order to validate the coupled 2D Eulerian - 3D Lagrangian solid-fluid flow solver. A non-intrusive tracking system (Goseberg et al., 2016 & Stolle et al., 2016) was used to obtain the trajectories of a set of scaled-down shipping containers impacted by a tsunami-like wave. A set of different experiments, with varying configurations regarding the position and number of static obstacles and containers, was performed with point measurements obtained for the fluid flow. The performance of different alternatives for the coupling of STAV-2D's mesh-based fluid solver with the PhysX's 3D Lagrangian solver are discussed and analyzed in comparison with the obtained experimental data for individual debris.

This new validation effort further enhances STAV-2D's capability to forecast tsunami impacts over built environments, namely in what concerns debris transport and accumulation, providing a valuable output for emergency response planning.

Acknowledgements

This research as partially supported by Portuguese and European funds, within programs COMPETE2020 and PORL-FEDER, through project PTDC/ECM-HID/6387/2014 and Doctoral Grant SFRH/BD/97933/2013 granted by the National Foundation for Science and Technology (FCT).

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