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A lagrangian-eulerian description of debris transport by a tsunami in the Lisbon waterfront

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Several major tsunamis are known to have struck the Portuguese coast over the past millennia (Baptista and Miranda, 2009). The Tagus estuary has great exposure to tsunami occurrences and, being bordered by the largest metropolitan area in the country, is a particularly worrisome location in what concerns safety of populations and economic losses due to disruption of built infrastructures.

The last major earthquake and tsunami combination known to have critically affected the Tagus estuary dates back to November 1st 1755. This catastrophe critically damaged Lisbon's infrastructures, led to numerous casualties and priceless heritage losses. The urban tissue of the present city still bears visible the effects of the catastrophe and of the ensuing protection measures.

The objective of this work is to simulate the propagation of debris carried by a 1755-like tsunami along the present-day bathimetric and altimetric conditions of Lisbon waterfront. Particular emphasis was directed to the modeling of vehicles since the tsunami is likely to affect areas that are major traffic nodes such as Alcântara, with more than 1500 vehicles in road network of about 3 km.

The simulation tool employed is based on a 2DH spatial (eulerian) shallow-flow approach suited to complex and dynamic bottom boundaries. The discretization technique relies on a finite-volume scheme, based on a flux-splitting technique incorporating a reviewed version of the Roe Riemann solver (Canelas et al. 2013). Two formulations were employed to model the advection of debris: a fully coupled continuum approach, where solid bodies are described by the concentration only and an uncoupled material (lagrangian) formulation where solid bodies are tracked between two time-steps once the flow field is determined by the eulerian solver. In the latter case, concentrations are updated after tracking the solid bodies thus correcting the mass and momentum balance to be used for the next time-step.

The urban tissue was thoroughly discretized with a mesh finer than street width so that the buildings would act as obstacles and the streets would bind the incoming flow. To simplify the plan-view geometry, it was assumed that buildings would retain its original shape after the earthquake.

The results of the eulerian-continuum and of the lagrangian-discrete solutions are presented, compared and discussed. It was found that the patterns of deposition of the eulerian-continuum model can be considerably different to those obtained by the lagrangian-discrete solution if the latter assumes that vehicles have a small equivalent density and if momentum losses due to inter-particle collisions are neglected. Results become more similar if vehicles are considered much denser than water and that the mixture of water and solid bodies loses momentum due to particle collisions.

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References

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