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Severity and exposure associated to tsunami actions in urban waterfronts. The case of Lisbon, Portugal.

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The Tagus estuary is recognized as an exposed location to tsunami occurrences, given its proximity to tsunamigenic faults such as the Marquês de Pombal and the Horseshoe fault system. Lisbon, bordered by the Tagus estuary, is a critical point of Portugal's tsunami hazard map, having been affected by several tsunamis (Baptista and Miranda, 2009) including the notorious event of November 1st 1755, the last major natural disaster known to have inflicted massive destruction in Portugal.
The main objective of this work, a joint initiative of CEHIDRO (IST – Universidade de Lisboa) and the Municipal Civil Protection Services of Lisbon, is to contribute to the quantification of severity and exposure of Lisbon waterfront to tsunami events.
For that purpose, the propagation of a tsunami similar to that of the 1st November of 1755 in the Tagus estuary was numerically simulated. Several scenarios were considered, articulating the influence of tidal (low and high tides), atmospheric (increase in water level due to storm surges) and hydrological (flow discharge in Tagus river) conditions. Different initial and boundary conditions were defined for each modelling scenario but the magnitude of the tsunami remained what is believed to be an exceptional event. The extent of the inundation and relevant hydrodynamic quantities were registered for all scenarios.
The employed simulation tool – STAV-2D – was developed at CEHIDRO (IST) and 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, Conde et al. 2013). STAV-2D features conservation equations for the finer solid phase of the flow and also a Lagrangian model for the advection of larger debris elements.
The urban meshwork was thoroughly discretized with a mesh finer than average street width. This fine discretization allows for resolving flow resistance associated to obstacles: no ad hoc formulations are needed to express drag on buildings, which is a key innovation in regard to previous studies. Additionally, vehicle-like particles were virtually placed over the major traffic nodes and routes, resulting in over 5000 lagrangian particles along the riverfront. This allows for an assessment of debris deposition patterns on the aftermath of the tsunami inundation.
Severity is herein assumed to depend on hydrodynamic features of the tsunami, namely its capacity to impart momentum. Exposure to tsunami actions depends on the extent of the inundation. Both severity and exposure thus vary with the tsunami scenario considered.
The obtained results, obtained with a high detail of hydrodynamic behavior, allow for a street-by-street quantification of severity, expressed in terms of the product of the depth-averaged velocity by the flow depth (Karvonen et al., 2000), herein the q-parameter. This parameter is shown to be larger during run-up, particularly in streets and narrow sections. It was observed that the scenario with greater exposure is a combination of a high-tide, a storm surge and a discharge equivalent to a 100 year flood on the Tagus River.
The work conducted allows for designing a methodology for exposure assessment due to tsunami propagating over urban meshes, where the influence of the existing infrastructures on the incoming inundation is highly relevant. Such methodology, here applied to Lisbon waterfront, is general since it is defined in terms of quantifiable hydrodynamic variables.

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