High-performance modelling of tsunami impacts on built environments

Summary

Tsunamis have an enormous devastating potential and are known to be a recurring threat in the Portuguese coast. In a broader European context, recent reviews have raised the concerns regarding the continent's resiliency against such threat. Over 130 million inhabitants and critical infrastructures along the European coastlines pose a very significant exposure, leading to several governmental measures from the EU and United Nations, similarly to the US Congress actions.

The results from highly-resolved tsunami simulations provide detailed mappings of the exposed areas, with corresponding severity and associated risks, comprising a fundamental layer of information for emergency relief mechanisms. Presently, very few studies have recognized the relevance of high-resolution tsunami modelling for urban environments, since the respective calculations often require a computation time that is incompatible with conventional models.

The present work aims at the development and complete implementation of a high-performance mathematical model for tsunami overland propagation (HiSTAV), based on emerging technologies such as parallel, distributed and graphics-based computing. The proposed design introduced relevant advantages in terms of code performance and maintainability.

Different code structures and data-layouts were tested and benchmarked, with their advantages and disadvantages quantified in terms of performance. Supported by an object-oriented approach, the final model obtained good scalability and speedup on modern processors. On a distributed setting, the model is able to scale supra-linearly and obtain speedups of two orders of magnitude.

The developed mathematical model was validated with specific tests for tsunami modelling, showing excellent agreements between numerical solutions and experimental or analytical data.

A case study on the Tagus estuary highlights the relevance of high-resolution modelling for a correct definition of the severity and exposure of urban waterfronts to tsunami actions. The obtained data represents a relevant component for risk analysis, by objectively quantifying the hydrodynamic forces and their associated risks for assets and population.

Keywords

Mathematical modelling, tsunamis, urban inundation, high-resolution, high-performance computing.

Inundation of present day Lisbon waterfront (Belém reach) due to a tsunami arising from an earthquake with the same magnitude as that of the Lisbon earthqueake of 1755.

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