Geo-INQUIRE Transnational Access Project Report:

Geo-INQUIRE installation: PTHA - Probabilistic Tsunami Hazard Assessment (TA2-541-3/TA2-541-4/TA2-541-5) - Geo-INQUIRE

Project title: PTHA-Tide in Cádiz (Spain): Incorporating tidal variability into probabilistic tsunami hazard assessment at local scale.

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Project acronym: GeoIn_placs

Project report ID: C1-TA2-541-3-1

Transnational access team: INGV (Manuela Volpe and Dr. Stefano Lorito), UMA (Dr. Jorge Macías Sánchez), NGI (Dr. Steven Gibbons and Dr. Finn Lovholt)**.**

Date of visit: 17 - 22 November 2024 and 27-31 January 2025

Geo-INQUIRE Virtual Access:

Data/Products: The data will be stored in the Simulation Data Lake (SDL) (*In process*).

- **DOI:** https://doi.org/10.82554/sdl-324.335

Project report:

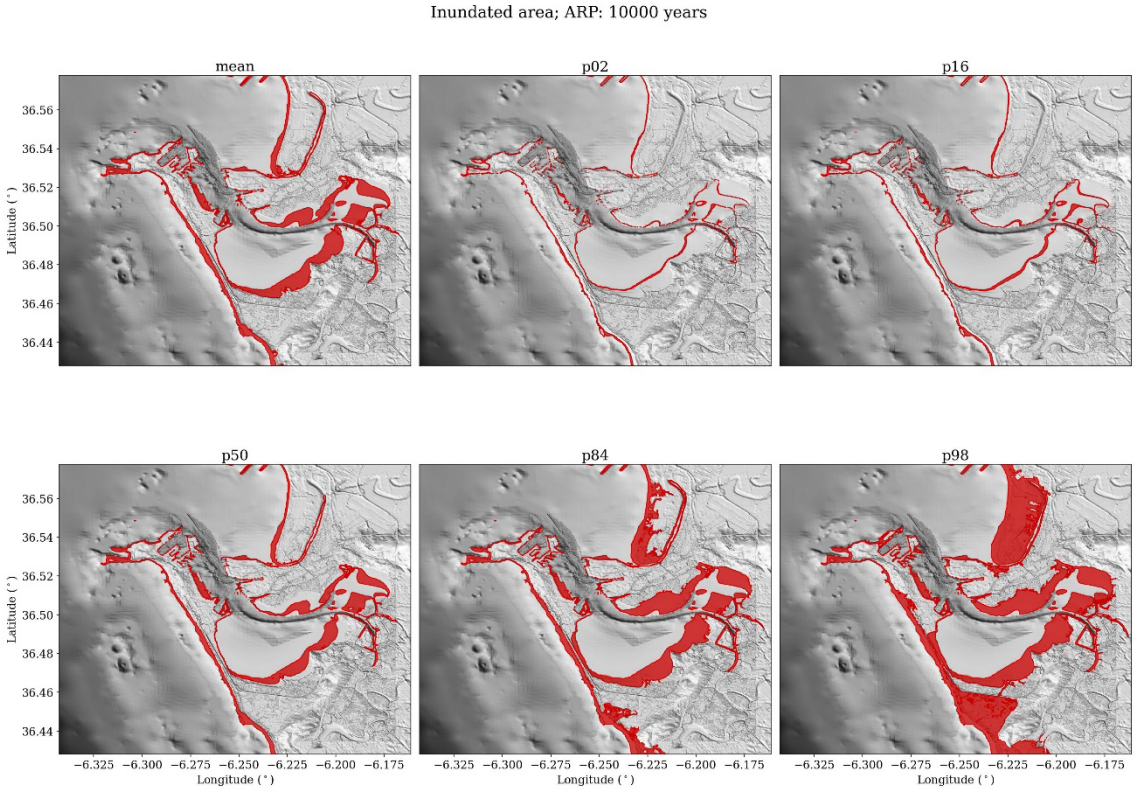
The seismic structures in the Gulf of Cádiz have produced one of the most emblematic tsunami events in European history: the 1755 Lisbon earthquake and tsunami. Despite recent advances in probabilistic tsunami hazard assessment and the availability of tools such as the NEAMTHM18 model and GPU-based codes like Tsunami-HySEA, these frameworks have not yet been systematically applied in Spain. Furthermore, they have not explicitly accounted for the meso-tidal range in the Gulf of Cádiz (up to about 4 m), which shifts the sea-level baseline and can significantly enhance local tsunami inundation in coastal communities such as Cádiz.

During his stay at INGV, Iñigo learned to apply the ChEESE-CoE physics-based HPC workflows for PTHA at a local scale in Cádiz, Spain, using UMA's HySEA code and CINECA's HPC resources. He conducted numerous simulations under different tidal stages to assess how tsunami impact varies with tidal conditions. The expected outcome is the first NEAMTHM18-based PTHA in Spain, aiming to establish a new national standard upon which other regions can base their own PTHAs. A particular emphasis has been placed on incorporating astronomical tide as a new variable in the PTHA workflow.

We find that tidal sea-level variability in meso- and macro-tidal regions plays a critical role in tsunami risk management. For the same earthquake-generated tsunami, inundation extent and flow depths are significantly larger when the event coincides with high tide compared to mean or low-tide conditions. This leads to a substantial increase in the exposure of buildings, infrastructure, and evacuation routes in coastal areas such as Cádiz. These results highlight that neglecting tidal stage can lead to a systematic underestimation

of local tsunami hazard and underscore the need to explicitly account for tidal conditions in future PTHA exercises, as well as in the design of coastal risk reduction and emergency planning measures. An example of hazard maps comparing mean sea level and +1.5 m of high tide for a chosen Average Return Period (ARP) is shown in Figure 1.

Moreover, a paper is currently in preparation, which will explain the incorporation of astronomical tides into the PTHA workflow.



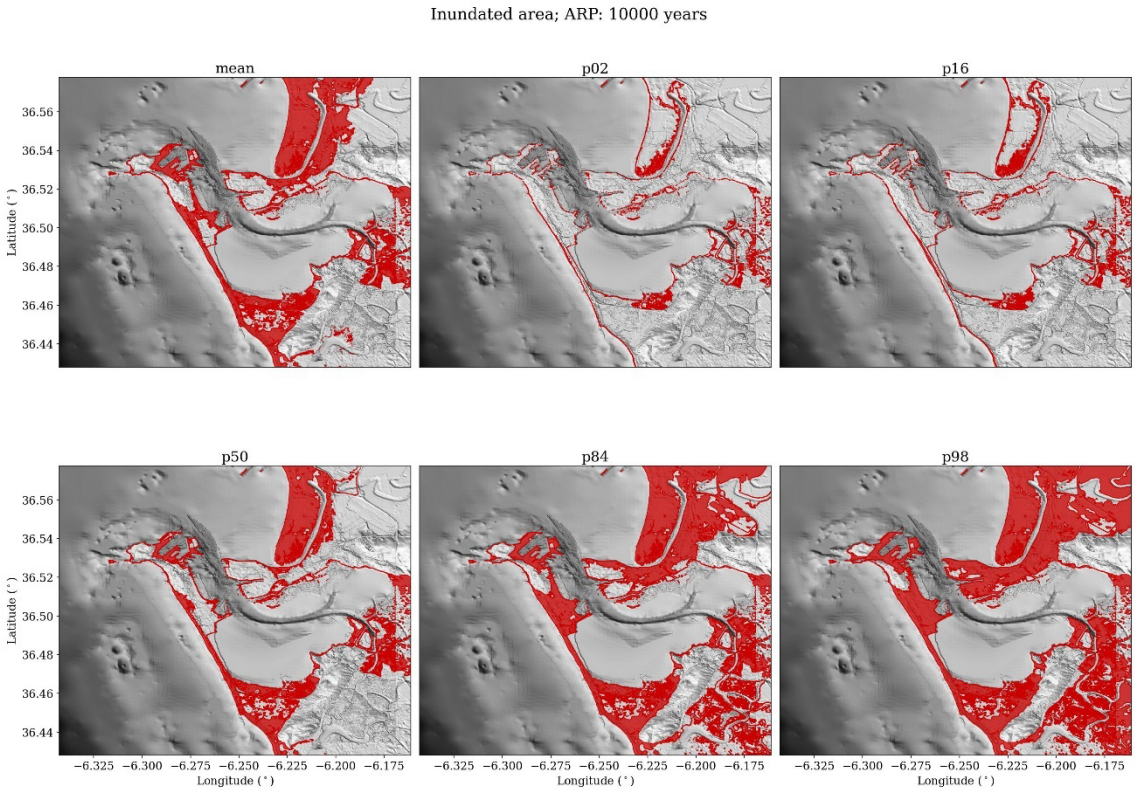


Figure 1. Example of tsunami inundation hazard maps for Cádiz for an annual rate of exceedance corresponding to an ARP of 10 000 years. Panels show, from left to right, the mean and selected percentiles (p02, p16, p50, p84, p98) of inundated area. The upper set of maps corresponds to low tide (−1.5 m), whereas the lower set corresponds to high tide (+1.5 m).