APPLYING PROBABILISTIC DATABASES TO DEFINE INPUTS FOR INUNDATION NUMERICAL SIMULATIONS: THE MESSINA STRAIT CASE

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INTRODUCTION

Tsunamis in recent history have caused large destruction on coastal communities and ecosystems (Mori et al., 2011). To mitigate the impact of these events, recent studies focused on hazard assessment of tsunami-prone areas. Studies based on probabilistic frameworks defined a methodology known as Probabilistic Tsunami Hazard Assessment, or PTHA (Grezio et al., 2017), are increasingly common and becoming essential for planning risk reduction, which significantly helps in saving lives and reducing economic losses. Focusing on earthquake-generated tsunamis, the seismic-PTHA database NEAMTHM18 was recently developed as part of the European project TSUMAPS-NEAM (Basili et al., 2018) covering the coasts of the North-Eastern Atlantic, the Mediterranean Sea, and connected seas, a basin referred as NEAM.

PTHAs usually provide to the final user a single or a set of tsunami parameters, e.g., wave amplitude *a*, wave height *H*, Maximum Inundation Height *MIH*, defined at a prescribed distance from the coast, to assess the hazard to a certain coastal stretch. The propagation inshore of these parameters is usually simplified and does not consider specific local bathymetry features. Due to this, directly using simplified propagation tools might not be cautelative when developing projects for high relevance areas or critical infrastructure, where high resolution results are needed (Tonini et al., 2021). A specific methodology to consider the variability of the coast with high resolution numerical simulations starting from a PTHA database is therefore needed for reliable hazard assessment. Here, this new methodology is developed starting from the hazard curves provided by the NEAMTHM18 to obtain tsunami input time series for propagation and inundation numerical modelling, which is then used for high resolution hazard assessment of an area of interest.

METHODOLOGY

The developed methodology takes advantage of the results from NEAMTHM18 hazard curves to define inputs for inundation numerical simulations carried out by using the non-hydrostatic, non-linear shallow water equation model SWASH (Zijlema et al., 2011). The methodology is illustrated here for the case study of the Messina Strait (Figure 1). However, it can be easily generalized to other coasts and applied to different probabilistic databases. The available synthetic parameter that quantifies the tsunami hazard, in this specific case, is the *MIH* and it is given in the form of hazard curves at fixed points of interest (POIs) along the NEAM region coast. These POIs are defined at an interval of 20 km, and they are positioned at a depth of -50 m.

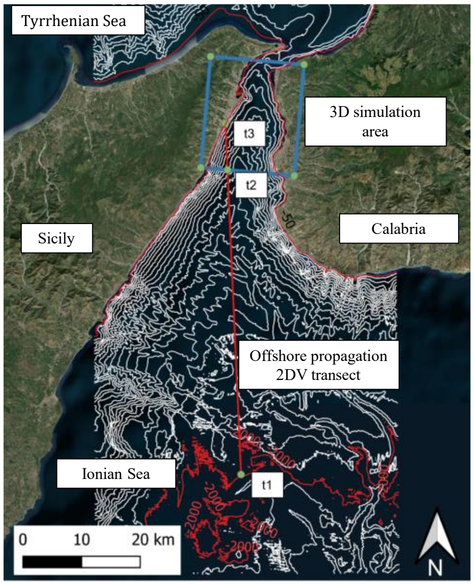

Figure 1 - Sketch of the methodology applied for the analysis of the Messina Strait.

The new methodology can be summarised in the following steps:

1) MIHs are first defined by evaluating a probability of exceedance, exposure time for the specific project, and percentile of the hazard curve at each POIs close to the area of interest. The design MIH is then selected as the highest value of all POIs in a 40km radius circumference around the interest area following Tonini et al. (2021) recommendations.

2) We conservatively assume that the design *MIH* =*a* of the incident tsunami at the position of the resulting POI (in this study this is t3, in Figure 1).

3) Due to the infinite possible signals that could be generated during real events and to reduce the simulations to a reasonable number for engineering purposes the field of considered wave periods *T* is reduced between 120s and 3600s, following NEAMTHM18 (Basili et al., 2021) in which it is considered a reasonable range for this phenomenon.

4) Using the chosen T range and the shallow water theory the mild slope condition is checked on the bathymetry offshore of the POI defined in 2). This condition needs to be verified in order to be able to generate a wave form appropriate to the local conditions and to apply the correct wave theory. If this condition is not verified at the POI position the tsunami needs to be generated at suitable depth where this condition is met. In this study the mild slope was generally verified for depths *h* larger than 2000 m where the point t1 (Figure 1) lies. Additionally, t1

position was chosen due to its vicinity to already active seismic faults and to guarantee the most direct path to the Messina Strait and to point t3,

5) By using the chosen T, local h and initially considering *H* at the generation point as $H = 0.001h$ (Tadepalli and Synolakis, 1996) the most appropriate wave theory to be applied (e.g. cnoidal, solitary or N-Waves) is determined.

6) For each fixed T and/or wave theory, different input free water surface time series are propagated with 2DV simulations (red line in Figure 1) from t1 (h=2000 m) up to t3 (h=50m) until the condition $M/H = a$ is verified at t3 (following 2). Simulations need to be carried out so that reflection is avoided on the onshore end of the numerical domain.

7) After finding the different input tsunami time series for which $M/H = a$ is verified, the incident tsunami waves from the 2DV simulations are extracted at point t2 (Figure 1).

8) These incident time series are used as inputs in the offshore boundary of the 3D inundation simulations that in this specific case are carried out in the area outlined with a blue line in Figure 1.

9) Simulations are carried out for each chosen boundary condition and the results are merged to evaluate the cumulative hazards of all simulations by applying a conservative approach.

RESULTS

Figure 2 shows example results for asynchronous maximum inundation depths in a single scenario. The figure shows that all areas of interest in this study were subject to inundation with the most severe outcome on Villa San Giovanni and Messina Marittima harbours, which will require particular attention during the development of new coastal structures. This contribution will additionally better highlight the effect of the inundation in the entirety of the Messina Strait with particular focus on the areas of Villa San Giovanni, Messina e Reggio Calabria. Results will also be qualitatively compared to the historical database (Guidoboni et al., 2018) of the 1908 tsunami event occurred in the same area.

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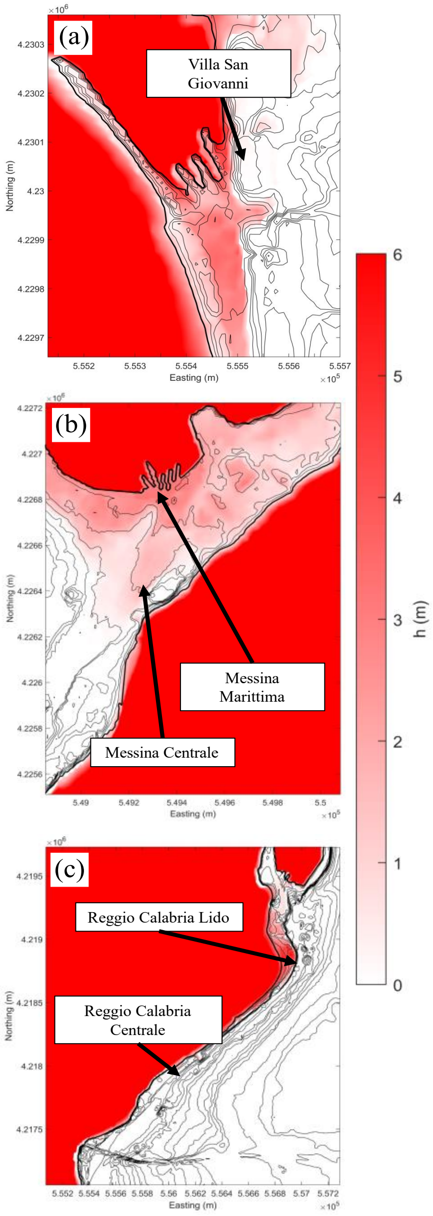

Figure 2 – Maximum asynchronous inundation depths reached in (a) Villa San Giovanni, (b) Messina, and (c) Reggio Calabria areas for a single tsunami scenario.