The November 1 st , 1755 Tsunami in Morocco - Uncertainties in Historical Reports and Consequences for Future TWS

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ABSTRACT

Coastal communities in the Atlantic marine limit of Morocco risk of inundation by regional and local tsunamis generated in the SW Iberia zone. Tsunami catalogs indicate that this area was the place of several tsunami events since historical time. Among them, the 1755 tsunami remains the largest eye witnessed historical event in the North East Atlantic area. Historical documents described, in some details, the generated waves along the coasts of Portugal, Spain and Morocco. They mentioned that the tsunami run-up has reached 15 m and the wave amplitude was as high as 24 m in some locations. However, these wave heights, run-up values and inundated areas may be (in some cases) overestimated as it was revealed in the recently published studies on historical documents focused on the Gulf of Cadiz area (Blanc, 2009) . One of the coastal segments where the reported historical data, related to the 1755 event, are uncertain is the city of Mazagão, actually El-Jadida, located at the SW of Moroccan Atlantic coast.

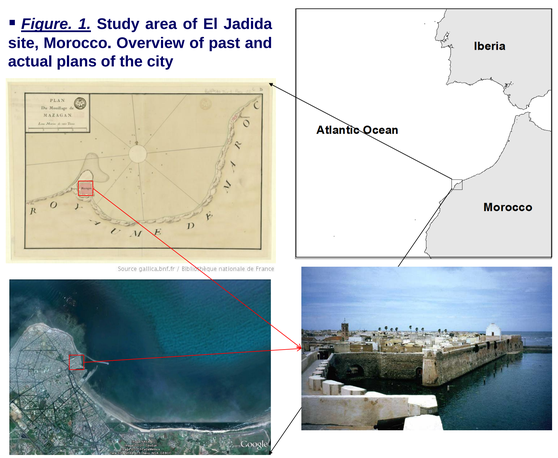
The present study seeks to numerically evaluate the tsunami impact along the El-Jadida coastal segment in order to clarify the uncertainties of the historical reports. A detailed numerical modeling of the tsunami waves evolution onshore and offshore El- Jadida site has been conducted. The digital terrain model (DTM) considered in this study is a reconstruction of the paleo-DTM of El-Jadida site in the 1750s, that we have computed from the paleo-bathymetric/topographic charts available before 1755. Earthquake scenario of magnitude ~8.5 has been considered to represent a 1755-like event. Results in term of wave heights, maximum run-ups, high resolution inundation maps and flow limits for the study area are presented for the considered tsunami scenario. Reliability and/or interpretation of historical reports is discussed in light of the comparison of these reports with the worst tsunami impact in El-Jadida obtained from numerical modeling. The results will be incorporated in the future tsunami warning system in the North East Atlantic area.

1. Study area :

El Jadida is a port city on the Atlantic coast of Morocco. This city was known as Mazagão under the Portuguese who held it from 1506 until 1769 and constructed the old Portuguese Medina. From the early 19th century the city has known a great development in terms of coastal infra-structures and occupation resulted in the construction of the harbor, various touristic projects and coastal infrastructures along the coast.

The ancient city of Mazagão, actually El Jadida, is one of the Moroccan Atlantic coastal sites where the impact of the 1755 tsunami event is described in some detail in several historical reports, which make this area a good candidate for conducting a numerical modeling study that aims to test the reliability of these historical information.

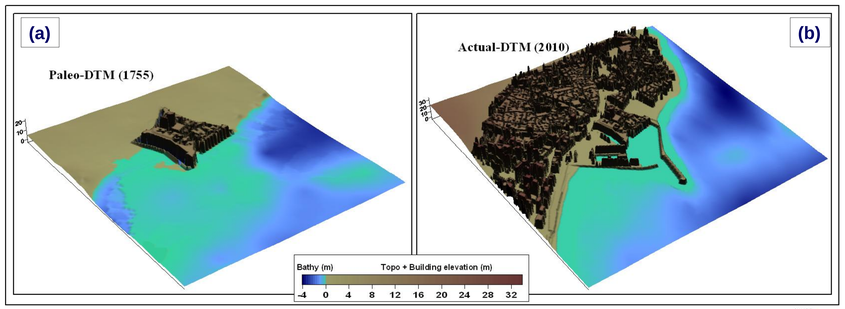
▪ ***Figure. 1.*** Study area of El Jadida site, Morocco. Overview of past and actual plans of the city



2. Paleo and Present Digital Terrain Model:

As the objective of this study is to investigate the reliability of historical reports using tsunami numerical simulations, we propose to reconstruct the bathymetric/ topographic situation close to the 1755 case. The reconstructed paleo-DTM (Digital Terrain Model) includes also information on the buildings geometry and elevation existed at that time. The actual-DTM is also generated with the present day buildings and coastal infrastructures data.

Figures 2.a and 2.b show , respectively, the elaborated 5m resolution paleo- and actual -DTM grids for El Jadida site including the existing coastal infrastructures.

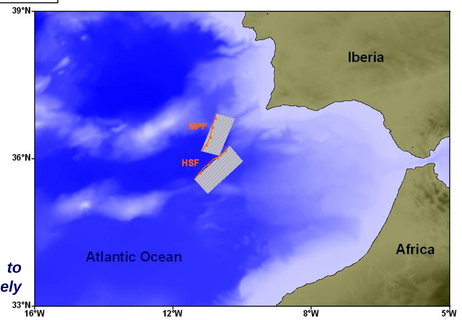


▪ ***Figure. 2.*** Digital Terrain Model of 5m resolution for El Jadida site, incorporating buildings and coastal infrastructures: (a) Paleo-DTM for the 1750s period and (b) Actual-DTM.

3. 1755-like Tsunamigenic Scenario

The 8.5 parent earthquake is simulated using a composite rupture structure of Horseshoe and Marques de Pombal, with 11m and 8 m slip respectively. Both are thrust faults (Matias L., pers. Comm.) This rupture model is able to account for an 8.5 magnitude event, corresponding to the magnitude estimation for the 1755 event (Solares and Arroyo,2004).

MPF and HSF are the most important thrust faults identified in MCSS surveys in the Gulf of Cadiz. Both faults were clearly identified in the multi-channel reflection seismic (MCS) survey performed in 1992 in the Gulf of Cadiz area (Zitellini et al 2001, 2009) and both present neotectonic activity.

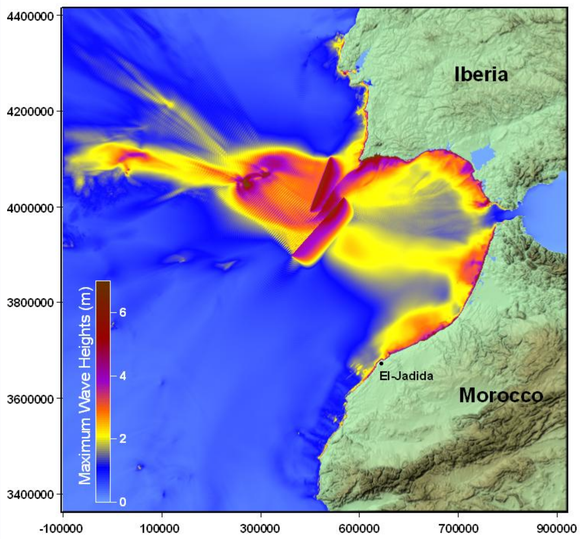


▪ ***Figure. 3***. *Tsunamigenic scenario (~8.5 Mw) considered in this study to represent a 1755-like tsunami event. It is a composite of two thrust faults, namely the Marques de Pombal fault (MPF) and the Horseshoe Fault (HSF).*

4.Tsunami Numerical Modelling:

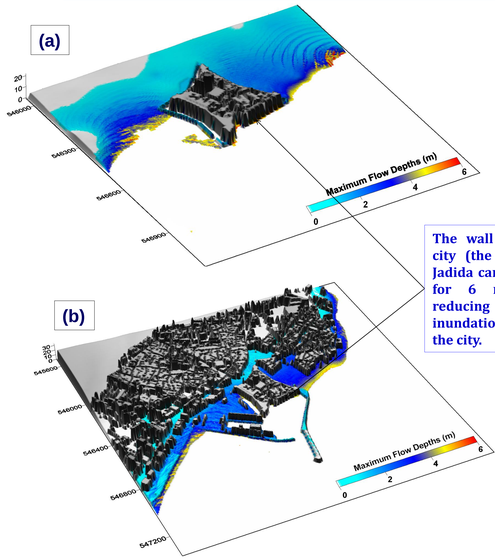
Non-linear approximations of shallow water equations (SWEs) are adopted to simulate tsunami propagation in both open-ocean and near-shore areas, respectively. The adapted version COMCOT-Lx of the Cornell of the COMCOT code is used to solve numerically these equations. This code employs a dynamically coupled system of nested grids and solves SWEs using an explicit leap-frog finite differences numerical scheme. Here, four nested grid layers, that have different resolutions extending from 800m for the parent grid to 5m for the finer one, are considered. The high-resolution or finer grid layer that represents the near-shore bathymetry/topography of the study site contains also data on buildings and coastal structures. During the inundation process we suppose that the both natural and man-made coastal infrastructure play the role of obstacles and no damage on those structures is considered.

4.1. Maximum Wave heights



▪ ***Figure. 4.*** Computed Tsunami Maximum Wave heights distribution in the Gulf of Cadiz area due to the occurrence of the MPF/HSF submarine earthquake scenario

4.2. Mximum Flow depths and inland inundations

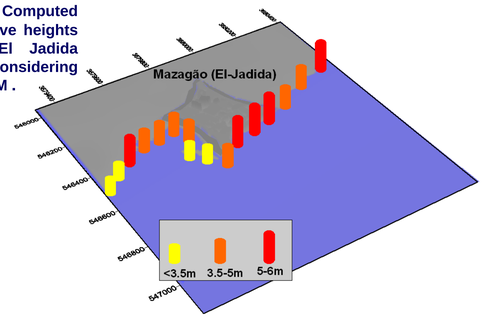


The wall of the Portuguese city (the old Medina) of El Jadida can act as a protection for 6 m tsunami wave, reducing the tsunami inundation risk in this part of the city.

▪ ***Figure. 5.*** Computed inland inundation depths for the El Jadida-Morocco site considering both: (a) the paleo-DTM and (b) the actual-DTM. Both natural and man-made coastal infrastructures are supposed to play the role of obstacles and no damage on those structures is considered.

5.Comparaison of simulated waves heights with Historical reports:

▪ ***Figure. 6.*** Computed Maximum wave heights along the El Jadida shoreline considering the Paleo-DTM .



Large disagreement is found between the numerical simulation results (Fig. 6) and the quoted values of wave heights in the historical reports for El Jadida. Soyris's letter (1755) repported that a wave of 70 feet (~ 24.36m) had struck Mazagao during the 1755 tsunami event; however the simulations indicate that only a maximum of 6m wave height could be reached at El Jadida site.

6 .Conclusions:

1. Tsunami simulation results (Fig. 6) indicate that the tsunami scenario used is compatible to the historical tsunami observations along the Gulf Cadiz. This scenario generates large waves along the Atlantic coasts of Morocco, Portugal and Spain. This is in good agreement with tsunami historical reports and also with paleo-tsunami studies indicating significant wave heights and the presence of tsunamites in some coastal locations in the area.
2. The computed maximum wave heights along the El Jadida shoreline (6m as maximum value) show a large disagreement with the wave height values quoted in historical documents (~24.6m), when using a mean slip value of 10 meters. Even if we thrust some reports that indicate overtopping of the walls in the old city this value should be discarded as the height of the wall is circa 11m.
3. In view of a future tsunami event we believe that the wall around the old Medina of El Jadida will increase the protection against a 6 meters tsunami wave (or less than 6m) in this specific part of the city. However the present day city extends far away from the old medina area being more prone to tsunami flows due to the absence of sea-defense infrastructure.
4. Established results are useful for emergency planners and should be are useful for emergency planners to trace tsunami evacuation maps.

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