TSUNAMI ANALYSIS OF THE 1722 EARTHQUAKE

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ABSTRACT

From the analysis of historical sismicity, it can be seen that several earthquakes were originated in the frontier between the African and Eurasian plates. One example is the 1722 earthquake that generated a tsunami, which was analyzed by a numerical model. The main problem related to these events is the lack of tide gauge stations.

INTRODUCTION

According to historical data, at 5 pm on 27th December 1722 an earthquake occurred in the South region of Portugal. It was estimated a maximum intensity of X (see figure 1) and magnitude of 7.5. Faro and Tavern were the cities with more destruction and casualties [1], however there are some records about incidents in other cities.

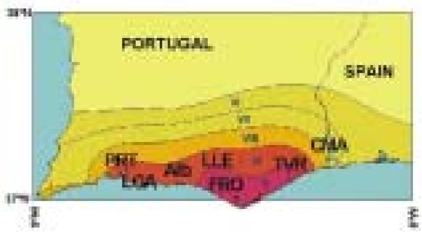

Fig. 1: Ground shake intensity from the 1722 earthquake.

The earthquake generated a tsunami that reached the southern coast of Portugal, specially noticed in the cities of Faro and Tavira. In this paper is shown a numerical simulation for the tsunami: propagation in deep ocean and inundation, including run up in Tavira city.

THE TSUNAMI SOURCE

The epicenter was located at 37.17°N and 7.58°E. However, because of accuracy of the numerical models, it was used the UTM coordinate system. In this case, the coordinates of the epicenter are 608 km and 4071 km. This is shown in figure 2, represented by the cross, along the bathymetric line of 500 m.

The source parameters are the length L and width W of the fault, the focal depth HH, dip angle δ, rake angle θ, slip angle λ and dislocation d. Their values are shown in table 1.

Table 1: Values of the fault parameters of the 1722 earthquake.

Parameter	Value
L	40 km
W	15 km
HH	500 m
δ	45°
θ	90°
λ	90°
d	5 m

Using the Mansinha and Smylie theory (1971) it was possible to calculate de tsunami source, represented in figure 2. It was calculated an uplift of 40 cm (dark) and a subsidence of 2.7 m (white).

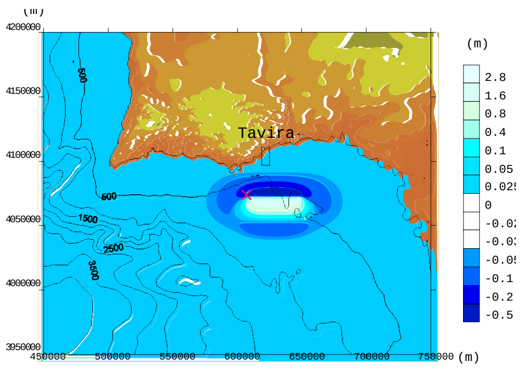

Fig. 2: Tsunami source area. The cross indicates the location of the epicentre.

THE HYDRODYNAMICAL MODEL

A tsunami is considered to be a long wave, so we can use the shallow water theory as the fundamental equations. This is a system of three equations: 2 for the momentum x and y direction (equations (1) and (2)) and the continuity equation, shown in equation (3) below.

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}\left(\frac{M^2}{D}\right)+\frac{\partial}{\partial y}\left(\frac{MN}{D}\right)+ gD\frac{\partial\eta}{\partial x}+\frac{gn^2M}{D^{7/3}}\sqrt{M^2+N^2}=0 \qquad (1)$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}\left(\frac{MN}{D}\right)+\frac{\partial}{\partial y}\left(\frac{N^2}{D}\right)+ gD\frac{\partial\eta}{\partial y}+\frac{gn^2N}{D^{7/3}}\sqrt{M^2+N^2}=0 \qquad (2)$$

$$\frac{\partial\eta}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0 \qquad (3)$$

Where M and N are the discharges fluxes in the x and y directions, respectively. D is the total ocean depth and η is the ocean free surface displacement. The gravitational acceleration is g and n is the manning roughness coefficient.
It was applied a numerical scheme, the leapfrog scheme, to equations (1) to (3).
For the other hand, taking in consideration the relationship between D and η, it s possible to make some approximations.

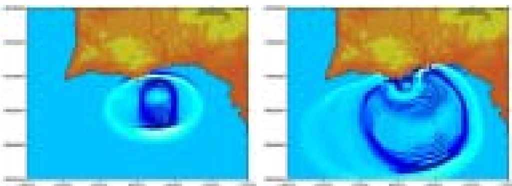

Fig. 3: Tsunamis propagation at 600 s and 1200 s after the generation.

So, in deep ocean (D > 100 m), without losing accuracy, it was used the linear approximation which includes the first and forth terms of equations (1) and (2) and equation (3). This was used to calculate the tsunami path, shown in figure 3.
Consider the small rectangle represented in figure 2, near Tavira s coast. In this area was carried out a second numerical simulation. But in this case it was used the full equations (1) to (3), called the non-linear approximation. This approach allows calculating the tsunami path with more accuracy, the inundations areas and run up. In Tavira, it was calculated a maximum inundation extension of 600 m with a run up of 6 m.

$$c\frac{\Delta t}{\Delta x}\leq 1 \qquad (4)$$

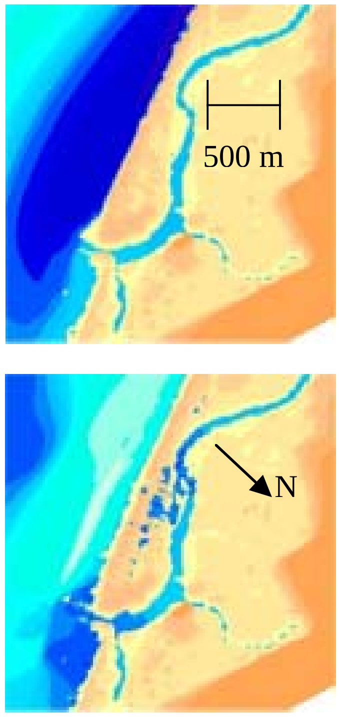

Fig. 4: Snapshots for inundation in Tavira for 8 min (up) and 10 min (down) after the earthquake.

It s important to ensure the stability of the model. So, it was taking in consideration the Courant-Friedrichs-Levy (CFL) conditions. This establishes that the phase velocity c, space grid Δx and time step Δt are related as shown in equation (4). So, in the case of linear approximation, figure 3, it was used Δx = 1 km and Δt = 1 s; in the case of non-linear approximation, figure 4, it was used Δx = 50 m and Δt = 1 s.

CONCLUSION

The main purpose of work was reached since it was possible to carry out a numerical simulation of the tsunami, from the source to Tavira s coast, including run up.
The existence of detailed topography and bathymetry are relevant for accurate results. This is crucial especially near the coast.
The CFL conditions can be crucial in the program s stability, mainly in deep ocean.
In the case of historical events the available information is scarce. In most cases, the only way to get a quantitative estimation is to use numerical simulation of the event.

REFERENCES

[1] Santos, A. Modelling the tsunami run up generated by the 27th December 1722, in Tavira city, Portugal, Graduate thesis, 2001.