Project N. 037110

Project Acronym: **NEAREST**

Project title: Integrated observations from NEAR shore sourcES of Tsunamis: towards an early warning system

Instrument: STREP

Thematic priority: 1.1.6.3 GOCE (GlObal Change and Ecosystems)

Deliverable n 27
"Inundation Maps for Lagos and Sagres"

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Final release

Project Co founded By the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination level		
PU	Public	
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to a gruop specified by the Consortium (including Commission Services	
CO	Confidential, only for members of the Consortium (including Commission Services)	**CO**

1 NEAREST

NEAREST is addressed to the identification and characterization of large potential tsunami sources located near shore in the Gulf of Cadiz; the improvement of near real-time detection of signals by a multiparameter seafloor observatory for the characterization of potential tsunamigenic sources to be used in the development of an Early Warning System (EWS) Prototype; the improvement of integrated numerical models enabling more accurate scenarios of tsunami impact and the production of accurate inundation maps in selected areas of the Algarve (SW Portugal), highly hit by the 1755 tsunamis. In this area, highly populated and prone to devastating earthquakes and tsunamis, excellent geological/geophysical knowledge has already been acquired in the last decade.

2 DESCRIPTION OF OBJECTIVES

To prepare the first inundation maps covering a portion of Algarve coast based on potential off-shore tsunami sources and a new collation of high resolution bathymetric, topographic and construction areas close to the coast. Mapped inundation line will be based on run-up computations for the worst case scenario. In the framework of the cooperation between NEAREST and TRANSFER, model validation will be made to support risk assessment and emergency planning in south Portugal.

3. Tsunami Scenarios

To investigate the impact of tsunami events in the Gulf of Cadiz it is necessary to define the seismic scenarios able to generate tsunamis in the coastal areas. In this study we employ the concept of typical fault to infer the Maximum Credible Earthquake Scenarios (MCE) (Miranda et al., 2008; Omira et al., 2009a).

Two recent papers published in the framework of NEAREST and TRANSFER projects: Omira et al., 2009 and Lima et al., 2010, respectively focused in tsunami impact on selected areas in the Gulf of Cadiz: Casablanca in Morocco (Omira et al., 2009b) and Huelva in Spain (Lima et al., in press); these papers considered a set of five different typical faults. In this study we focus on two typical faults, both thrusts, that we consider the most relevant candidate sources: the Marques de Pombal fault (MPF) and Horseshoe Fault (HSF) (cf. Fig. 2 and discussion in Omira et al., 2009a and Lima et al., 2010). The fault characteristics are specified in Table 1.

Table 1

Scenarios name	*L (km)*	*W (km)*	*Epicenter coordinates Lon*	*Lat*	*D (km)*	*slip (m)*	*Strike (º)*	*Dip (º)*	*Rake (º)*	*μ (Pa)*	*M_w*
MPF	129	70	-9.890	36.574	4.0	8.0	20.0	35	90	3.0×10^{10}	8.1
HSF	165	70	-9.913	35.796	4.0	10.7	42.1	35	90	3.0×10^{10}	8.3

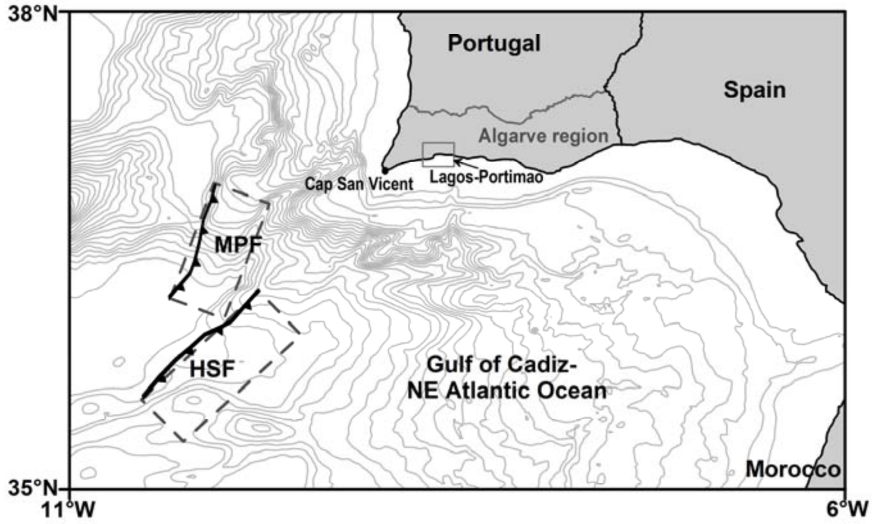

Figure 1: Typical faults used in the study. MPF: Marques de Pombal Fault; HSF: Horsehoe Fault. As a background the bathymetric data are plotted every 200 m. (in Omira et al, submitted to PAGEOPH)

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4.1 Modelling Inundation

Tsunami hydrodynamic modeling was made with a slightly modified version of Liu et al. (1998) COMCOT code (Omira et al., 2009a; 2009b) that uses an explicit leap frog finite difference scheme to solve linear and non linear shallow water equations on a dynamically coupled system of nested grids. Nested grids have resolutions of 800 m, 200 m and 50 m respectively, in order to assure a good description of bathymetric and topographic features in the area.

The finer grids are focused along the Sagres and Lagos-Portimao south Portuguese coast.

The digital terrain models (DTM) (bathymetry/topography) were generated from a compilation of multisource height/depth data from multibeam surveys digitalized bathymetric charts and digital cartographic data.

All grids are in Cartesian coordinates (UTM 29), which does not correspond to any limitation, seen the size of the study area. The coupling between a sub-grid and their parent grid follows the requirements of Wang and Liu (2007) and Liu et al. (1998). In the outer grid an open radiation boundary condition is used.

The static vertical displacement of the ocean floor due to the submarine earthquake scenario is modelled using Mansinha and Smylie (1971) homogenous elastic half space approach, as implemented in Mirone suite (Luis, 2007). Slip in the source is considered non-homogeneous, following the smooth closure condition of Geist and Dmowska (1999).

For run-up and inundation computation, a moving boundary scheme to track the moving shoreline (Liu et al. 1995) is adopted.

To parameterize the effect of the bottom friction in both shallow water and flooded area, the Manning coefficient, which varies with the bottom roughness, is integrated in the numerical model. The results presented in this study do not take into account the tide.

4. 2. Inundation Maps

The inundation maps were produced for Lagos and Sagres area for the Marquês de Pombal scenario.
The influence of bottom friction in the inundation parameters: run up, maximum inundation distance and current velocity was investigated only for Lagos area, using three different values of the Manning coefficient in the range (0.0; 0.015; 0.030).

4.2.1 Inundation Maps – Marques de Pombal scenario

The influence of bottom friction in the spatial distribution of inundation and flow depths overland in Lagos, for the two proposed earthquake scenarios, is presented in figures 2,3 and 4. As expected, the changing of the bottom condition affects considerably the maximum flow depth.

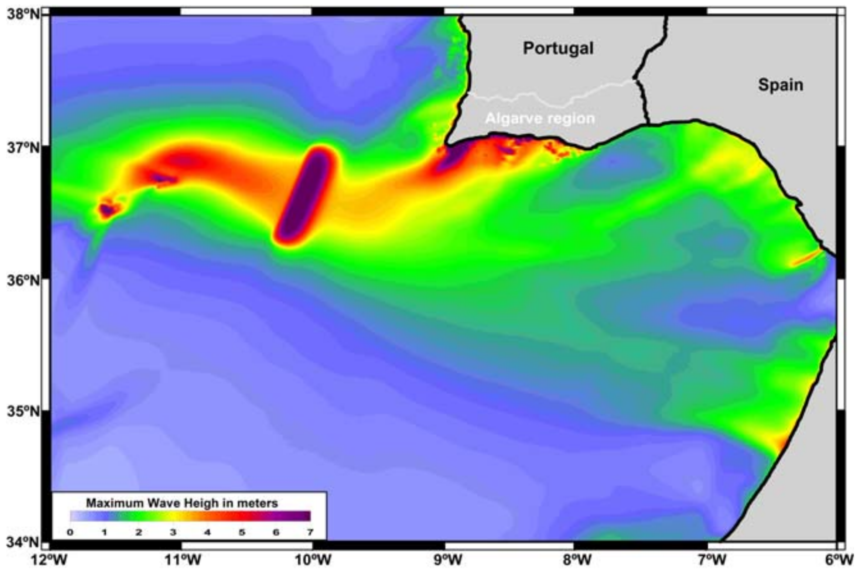

Figure 2: Results of the propagation modeling for the Marques de Pombal scenario.

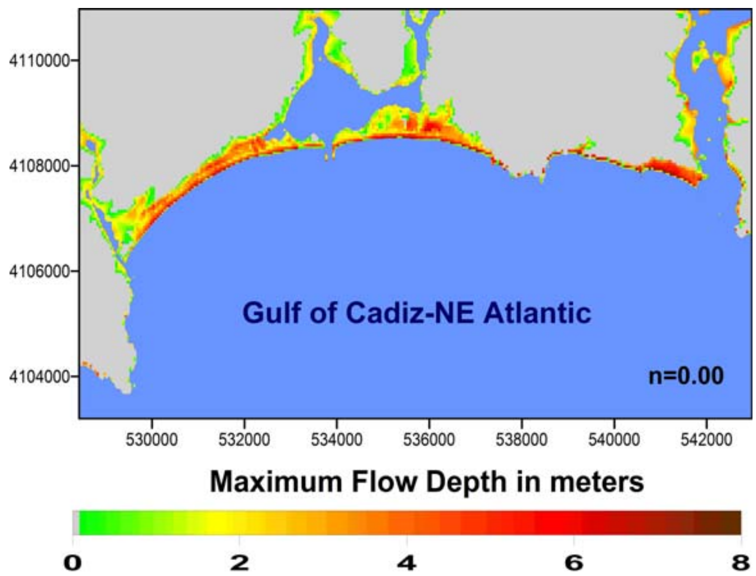

Figure 3: Inundation Map – Lagos –Portimão area; Marques de Pombal scenario; Manning Coefficient 0.00

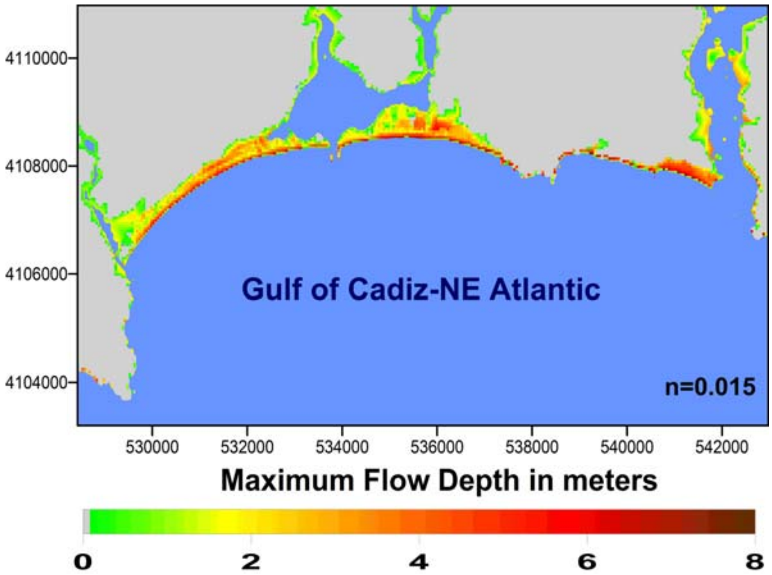

Figure 4: Inundation Map – Lagos –Portimão area; Marques de Pombal scenario; Manning Coefficient 0.15

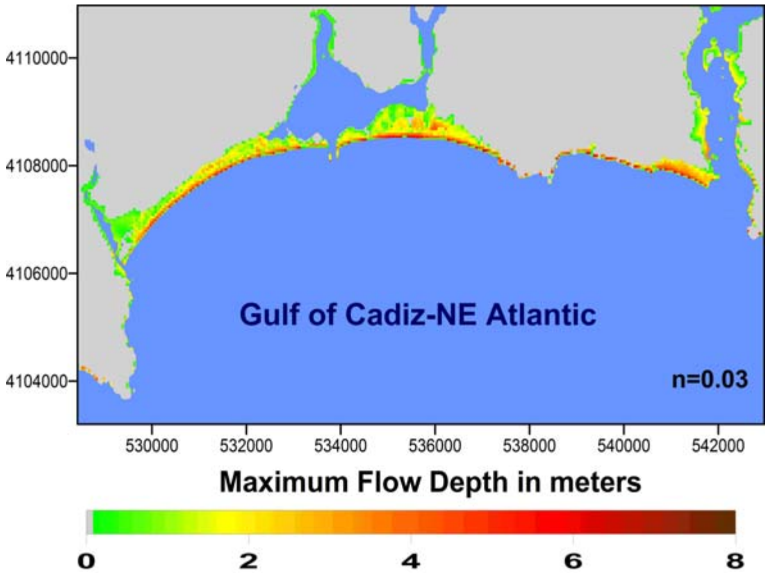

Figure 5: Inundation Map – Lagos –Portimão area; Marques de Pombal scenario; Manning Coefficient 0.03

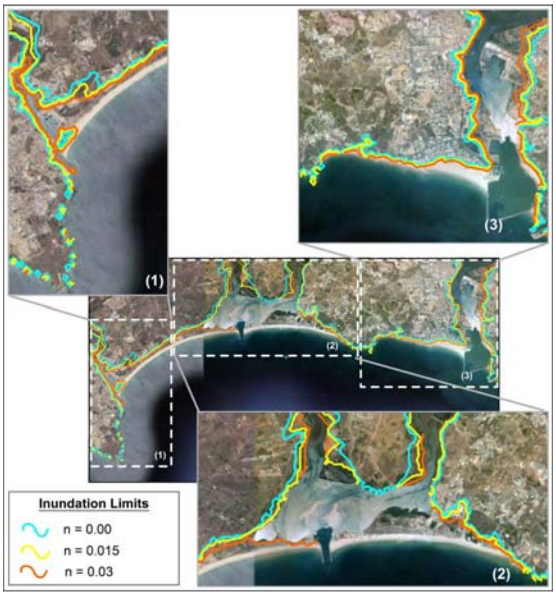

Figure 6: Influence of bottom friction in maximum inundation distance/maximum inundation area, with (using MPF scenario).

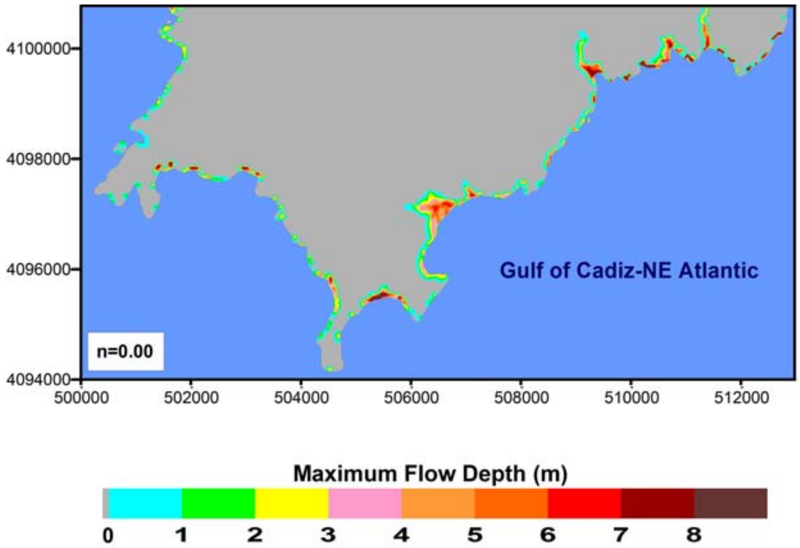

Figure 7: Inundation Map Sagres; Marques de Pombal scenario; Manning Coefficient 0.00

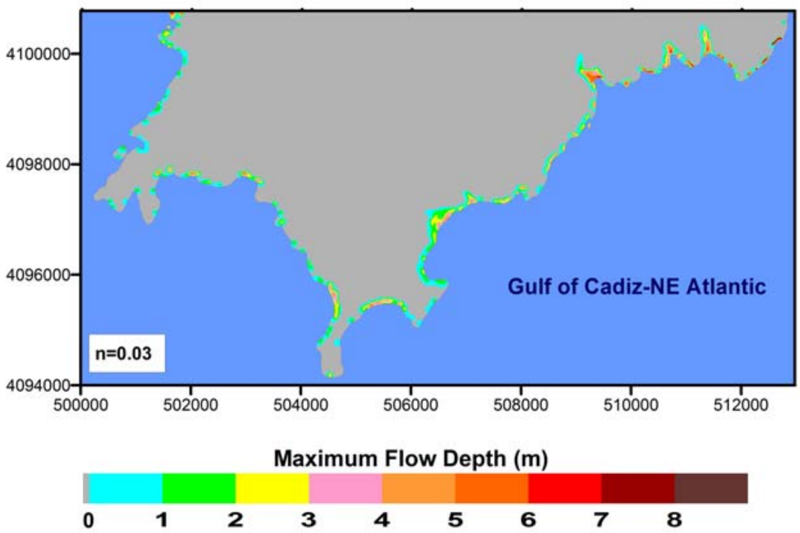

Figure 8: Inundation Map – Sagres area; Marques de Pombal scenario; Manning Coefficient 0.03

4.2.2 Inundation Maps – Horseshoe scenario – only Lagos

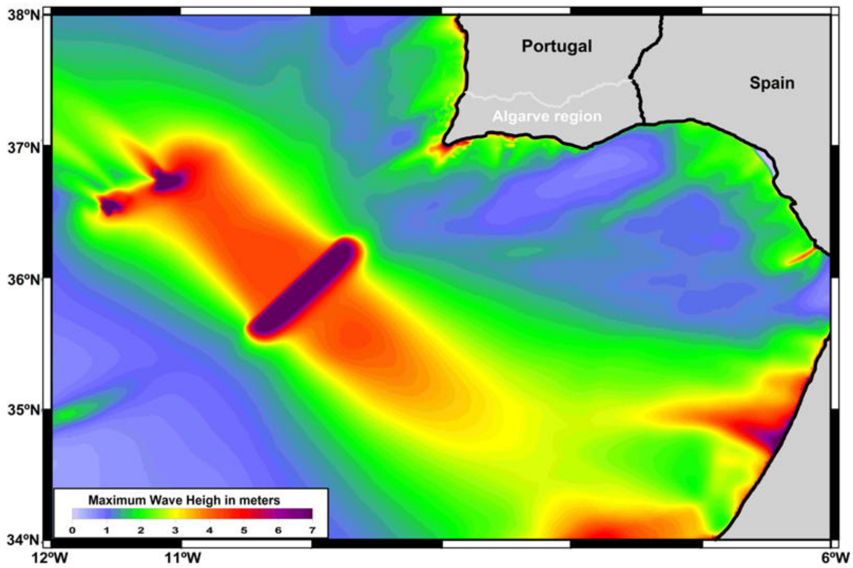

Figure 9: Results of the propagation modeling for the Horseshoe scenario.

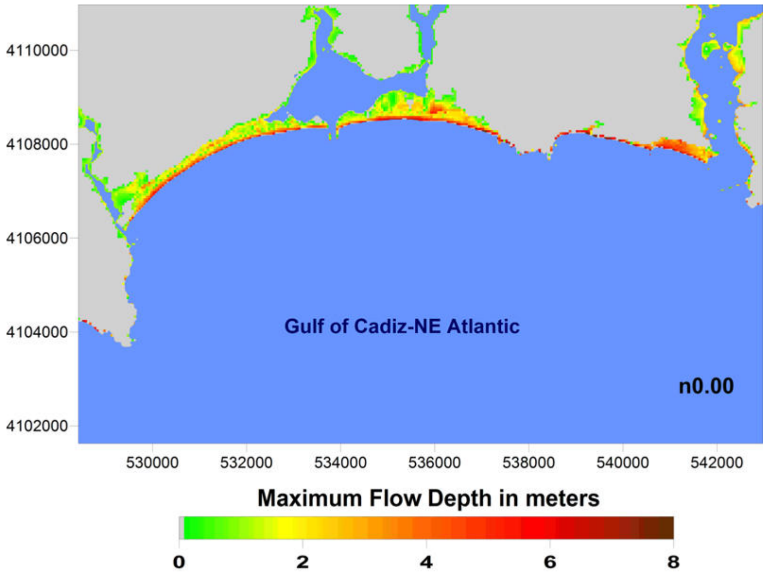

Figure 10: Inundation Map – Lagos –Portimão area; Marques de Pombal scenario; Manning Coefficient 0.00

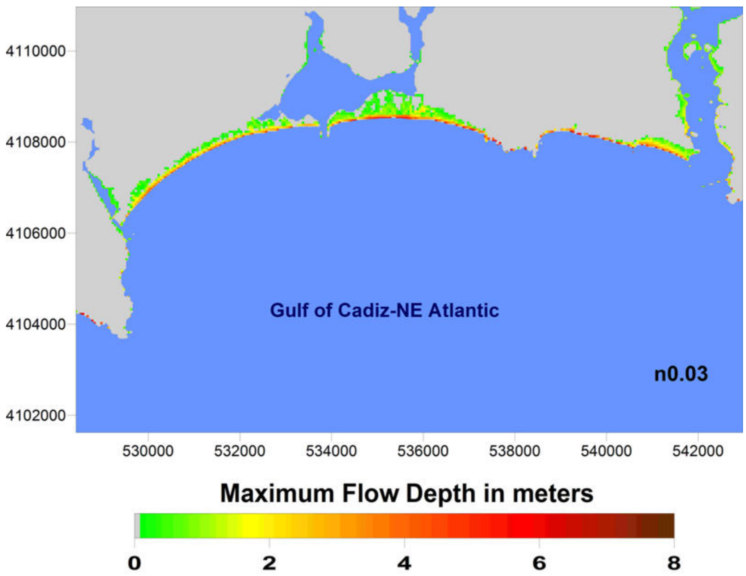

Figure 11: Inundation Map – Lagos –Portimão area; Horseshoe scenario 0.03

4.3 Conclusions

The results presented in figures 2 and 9 shows that both scenarios steer tsunami energy toward the coastal areas of the Algarve region. The Marques de Pombal scenario generates large waves of 2 to 7 m of amplitude along the south of Portuguese coast; the impact of the Horseshoe scenario in this area generates maximum wave heights of 4 m;

It is clear that the fault strike plays an important role in the near field propagation and the tsunami amplitude is maximal in the direction perpendicular to the fault strike. Near the coast the effect of bottom topography becomes more important than the fault strike;

As expected, the variation of the bottom condition, through variation of Manning coefficient, strongly affects inundation parameters: maximum flow depth and maximum inundation distance (cf. figure 6)

According to Takahashi (2005), at locations where the flow depth exceeds 0.5m, generally, people cannot remain standing if the current velocity exceeds 1.5m/s. Current velocity computation results obtained for different bottom friction show values much larger than 1.5 m/s at the most locations of the studied area.

The case with no bottom friction (n=0.000) represents the worst case of flooding and current velocity and should be used for warning purposes.