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Source Parameters for tsunami prone cities in Aegean Sea coastal areas of Turkey

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Abstract – This study was focused on earthquake induced tsunamis to prepare source parameters for accurate estimations of what would be the maximum heights and the shortest time of the arrival of the tsunami waves in Aegean Sea coastal areas of Turkey. Since the earthquake parameters available right after an earthquake are preliminary and not enough, calculations using preliminary parameters can lead to misleading results in tsunami wave modelling. For that reason, the geometries of the tsunamigenic sources in Aegean Sea have been examined to put in the effect of fault geometry and depths of earthquakes into the tsunami simulations. The accuracy of the fault geometry is directly dependent on the source parameters for the initial conditions of the tsunamis. In order to calculate the possible initial heights of tsunamis for the gridded areas in Aegean Sea, it was consider the source zones which are defined in accordance with the tectonic regime and where a single fault model can be credible. Each of the seismic sources is characterized by a representative focal mechanism examined and compiled from the previously published scientific literature. The results from the focal mechanism solutions show that the larger tsunamis would be much more effective in the southwestern coastal areas of Turkey such as Datça, Bodrum, Marmaris, Aksaz, Fethiye in the cases of low-angle thrust faults along the Hellenic arc system and South of Rhodes.

Keywords –Earthquake, Source parameters, focal mechanism, tsunami simulation, Aegen Sea.

I. Introduction

The Mediterrenean region is bordered by some of the active subduction systems, notably Gibraltar, Calabrian and Hellenic Arc, that occurs next to back-arc extensional basins in the Calabrian-Tyrrhenian and Hellenic-Aegean systems (Fig. 1). The complex morphology of the Mediterranean region, characterized by deep basins and arcuate fault-and-thrust belts, has originated from the long-lasting plate convergence between Africa/Arabia and Eurasia [1]-[3]. In western and central Mediterrenean, most of the earthquakes are confided to narrow belts along the Gibraltar and Calabrian Arcs. However, the earthquakes are confined to broad belt in the eastern Mediterrenean Region along the Hellenic Arc. Seismicity of the region reported by USGS–NEIC during 1973–2012 for M> 3.0 and for M>6.0 are shown in by small black circles in Fig.1 and Fig. 2 respectively.

In south of Aegean Sea, the oceanic crust is being actively subducted along the Hellenic and Cyprus trenches, and presumably within the complexly deformed region connecting these trenches [4],[5] . Hellenic and Cyprus arcs, deep Rhodes and Finike basins, Anaximander and Erasthothenes Sea Mountains, Pliny and Strabo trenches, and the Dead Sea Transform Fault are the best examples reflecting the tectonic complexity of the region [6]. Within this tectonic complexity of the region, south of Aegean Sea is one of the regions where many historical and pre-historical tsunamis have been recorded [7]. Numerous events indicate that the most devastating earthquakes which spawn tsunamis took place, such as southern and eastern Creete, southern Cyprus and southern Rhodes. They caused loss of life and property in the residential areas [8].

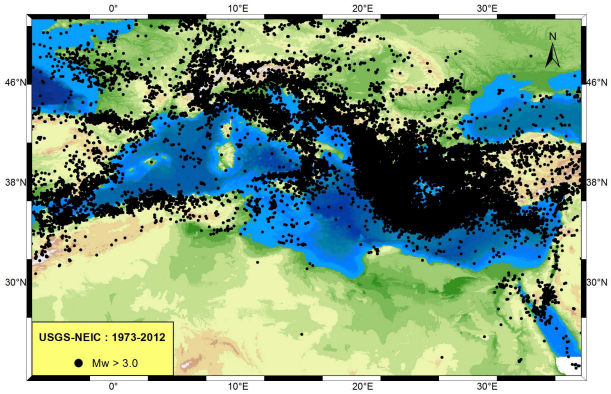


Fig. 2. Distribution of epicenters at the Mediterrenean Region for magnitude greater than 3.0 (Data from [9])

II. Materials and Method

It was firstly defined the geometrical parameters of seismogenetic regions based on the previously published studies related to the focal mechanism solutions). [10] have applied the moment tensor summation technique proposed by [11] to characterize seismogenetic areas at different spatial scales in Mediterranean region. Their results give a synoptic view of the large-scale seismic deformation pattern and seismotectonically homogeneous boxes, on the basis of the observed seismicity. However their results are constructed a set of two possible orthogonal fault planes and slip vectors. For that reason, it is not possible to determine solely from a

focal mechanism which of the orthogonal fault planes is in fact the fault plane. For that reason, principal stress orientations and relative magnitudes from these mechanisms were determined in order to decide which fault plane is the main plane. The chosen main fault planes could be used for possible tsunami waves if there are earthquakes in that gridded regions mentioned also sourse zone in this study.

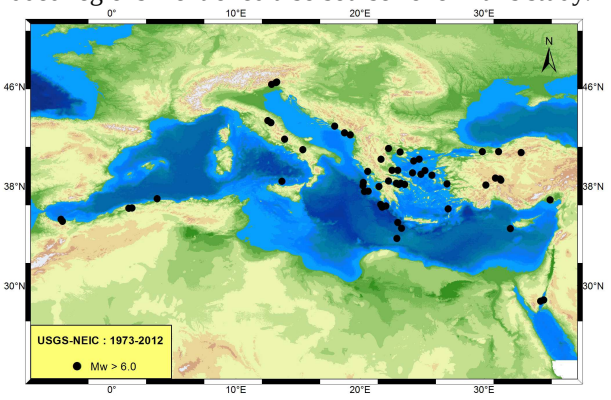


Fig. 2. Distribution of epicenters at the Mediterrenean Region for magnitude greater than 6.0 (USGS-NEIC, 2012).

The source zones for all the Aegean Sea region consist of totally 110 sources that are chosen to be small enough to represent regions of relatively homogeneous earthquake activity rates and faulting regimes. The methodology used for the calculation of tsunami wave heights from the gridded sources are the determination of earthquake parameters such as magnitude, depth, fault length, fault width, average slip, strike, dip and slip angles. Then, the initial tsunami surface is applied the same displacement as the vertical deformation of the ocean bottom due to the above mentioned earthquake parameters for every gridded sources. The ocean bottom displacement, assumed to be responsible for the initial water surface deformation giving rise to the tsunami, was computed using the dislocation algorithm provided by [12]. The assumed magnitude for every gridded source is M_w:7.5. This is not credible for every source zone, however it is assumed for a worst case value. Non-linear shallow water equations [13] for tsunami propagations are solved with a finite difference scheme, using a computational grid with different cell sizes over GEBCO30 (General Bathymetric Chart of the Ocean) bathymetry data.

III. Results

The representative focal mechanisms assigned to every source zones were uploaded on a GIS using the ArcGIS platform of ESRI ([13]). The color coded parameters of refresentative focal mechanisms such as strike, dip and rake according to various interval ranges are shown in Fig 3, 4 ,5 according to various intervals.

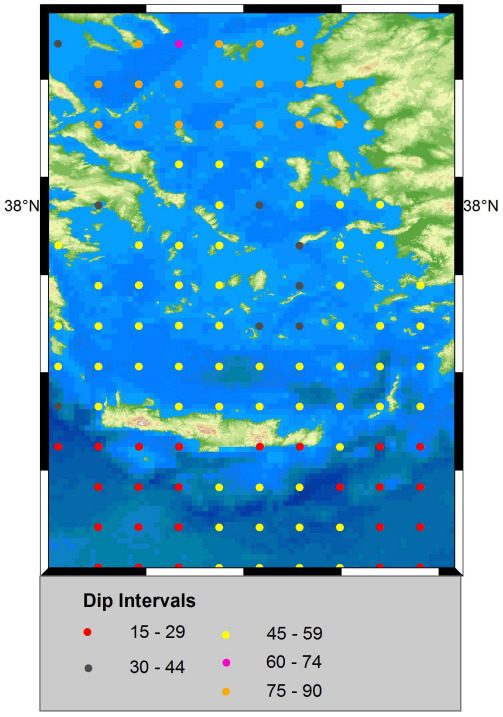


Fig. 3. The color coded strike intervals from North for every reprasantative grid points.

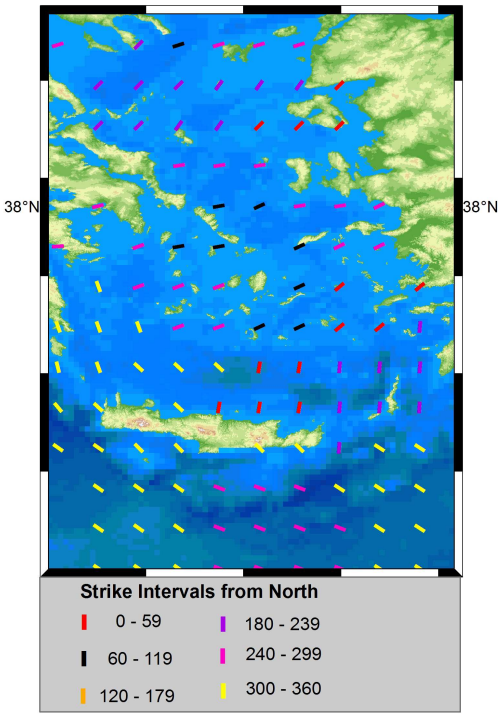


Fig. 4. The color coded dip angle intervals for every reprasantative grid points.

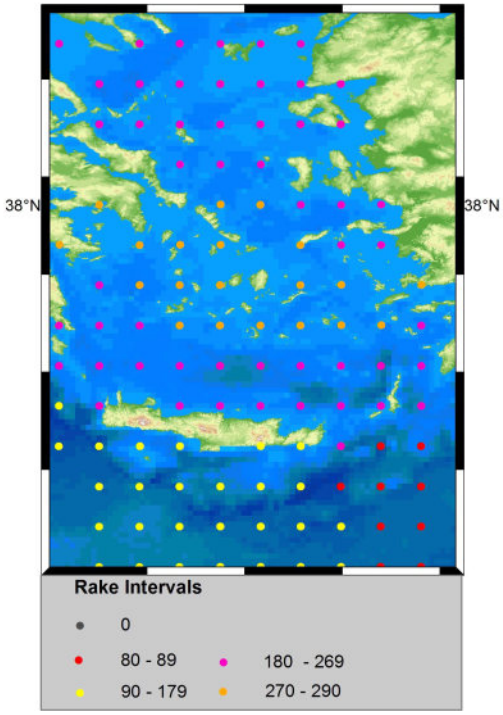


Fig. 5. The color coded rake angle intervals for every representative grid points.

The earthquake scenarios for only the south of Rhodes and South-West of Crete was considered in this study for only the M_w:7.5 and M_w:8.0 respectively. The physical model of the earthquakes considered herein could be a similar repetition of the 1481 Rhodes and 1303 Crete earthquakes. The focal mechanism parameters of the earthquakes used for the tsunami simulations are feasible based on the proposed parameters in gridded source zones that coincide with the earthquake locations. The estimated maximum heights due to a scenario earthquakes were given in Table 1 and Table 2. It is calculated that the maximum heights could be 1.4, 1.2, 1.1 and 0.9 in the coasts of Marmaris, Fethiye, Dalaman, Aksaz according to a scenario earthquake around Rhodes with a magnitude of M_w:7.5, respectively. As for other earthquake scenario around southeast of Crete with a magnitude of M_w:8.0, it is calculated that the maximum heights could be 0.7, 0.8, 0.7 and 1.0 m in the coasts of Marmaris, Fethiye, Dalaman, Aksaz respectively. It is also calculated the arrival times of tsunami waves as 5-10 minutes and 40-50 minutes according to the possible large earthquakes around Rhodes and southeast of Crete.

Table 1. The estimated maximum heights due to a scenario earthquake Mw: 7.5 with epicenter located at south of Rhodes.

Country	**Location**	**Max Height (m)**
Greece	Rodos	2.8
Turkey	Dalaman	1.1
Greece	Megisti	0.7
Turkey	Fethiye	1.2
Turkey	Aksaz	0.9
Turkey	Marmaris	1.4
Greece	Simi	0.3
Greece	Mesochori	0.1
Turkey	Antalya	0.1
Greece	Kos	0.1
Turkey	Bodrum	0.2

Table 1. The estimated maximum heights due to a scenario earthquake Mw: 8.0 with epicenter located at southeast of Crete.

Country	Location	Max Height (m)
Greece	Ayia Marina	2.5
Greece	Siteia	2.3
Greece	Agios Nikolaos	1.1
Greece	Karpathos Mesochori	0.4
Greece	Heraklion	1.1
Greece	Rhodos	1.3
Greece	Kastelorizo Megisti	0.4
Turkey	Dalaman	0.7
Greece	Santorini Ormos Firon	0.3
Greece	Simi	0.4
Turkey	Fethiye	0.8
Turkey	Aksaz	1
Turkey	Marmaris	0.7
Greece	Amorgos Katapola	0.4
Greece	Kos	0.3
Turkey	Antalya (m)	0.2
Turkey	Antalya	0.2
Turkey	Mugla Bodrum (m)	1.1
Greece	Ikaria Agios Kirikos	0.3
Greece	Marathokambos	0.5
Greece	Mikonos Chora	0.3
Turkey	Aydin Didim	0.1
Turkey	Yenihisar	0.3
Greece	Samos karlovasi	0.1
Greece	Samos	0.1

IV. DISCUSSION

The sources parameters proposed for tsunamigenic earthquakes in Aegean Sea have indicated that the importance of focal mechanism on local tsunami heights and possible largee run-up heights according to the shape of bays in the region. The decision makers for preparing tsunami evacuation zones in the region should undertake the results of the study to reduce the possible effect of tsunamis in the future. The worst scenarios could be done further for the evacuation procedures by using the proposed parameters calculated in this study.

V. CONCLUSION

The main conclusions of the study is to define the possible tsunami hazards around the coastal areas of south-western Aegean Sea in Turkey. While offshore Greek islands in Aegean Sea usually protect some of the coasts of Turkey, simulations suggests they may amplify tsunami waves reaching the mainland for some of the coastal areas. Unfortunately, it is still a challenge to determine the finite fault models immediately after occurrence of the earthquake providing multiple fault segments of variable depth, slip, rake

angle, rupture time and seismic moment. For that reason, it could be used the proposed source parameters for tsunami early warnings in Aegean Sea.

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