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The May 2, 2020, Crete tsunami: comparison between registered and modelled mareograms

Сравнение между регистрирани и моделирани сигнали на вълните цунами от 2 май 2020, о. Крит

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Abstract. The Eastern Mediterranean and Aegean Sea are susceptible to strong earthquakes and tsunami waves. On May 2, 2020 a strong shock with M_w6.6 induced tsunami that was registered in the mareographic network. The tsunami did not cause inundations, but it was the reason to enforce a tsunami alert from the Tsunami Service Providers. Our study is focused on the tsunami numerical simulations of this event and the results are compared to the registered signals in the stations NOA-03 and NOA-04 in Kasos and Ierapetra.

Keywords: tsunami, numerical modelling, Crete, mareograms.

Introduction

This paper is motivated by recent strong offshore earthquakes in the Aegean Sea area some of which generated local tsunamis (Dimova et al., 2020). Two of these events are located offshore southern Crete on May 2, 2020 and on October 12, 2021. The later one was located around ~30 km SE from Zakros village as reported by the Greek Institute of Geodynamics of NOA. Another recent earthquake in Aegean Sea occurred on October 30, 2020, where tsunami warnings were issued for several islands and Turkish localities.

This study presents results on the tsunami numerical simulations associated to the tsunami on May 2, 2020. The earthquake M_w6.6 ruptured the Hellenic Arc subduction zone southern of the Crete Island. The epicenter is located only ~90 km from the closest shore, where Ierapetra is located. The focal mechanism of this event shows reverse faulting striking ~W-NNW and dipping ~N-NNE (Papadopoulos et al., 2020a). Several datacenters defined the epicenter location and the focal mechanism solution for the event (Fig. 1a). The tsunami signals are registered in several tide-gauge stations depicted as black triangles in Fig. 1a.

After the initiation of the earthquake a tsunami alert was issued by the Tsunami Service Providers (TSPs) of the Istituto Nazionale di Geofisica e Vulcanologia (INGV), National Observatory of Athens (NOA) and Kandilli Observatory and Earthquake Research Institute (KOERI). Detailed information on the efficiency of tsunami warning in the Eastern Mediterranean can be found in Papadopoulos et al. (2020b).

Geodynamics and tectonic settings

Eastern Mediterranean and southern Aegean Sea are the most tsunamigenic zones in the whole Mediterranean area (Maramai et al., 2014). The area south of Crete is prone to large earthquakes due to the subduction zone called Hellenic Arc. Major tectonic plates collide in the region like the Africa Plate submerged beneath the Eurasia Plate. The total convergence plus the slab retreat in the mantle give around 1500 km of lithosphere subducted since 65 Ma according to the hypothesis and model pre-

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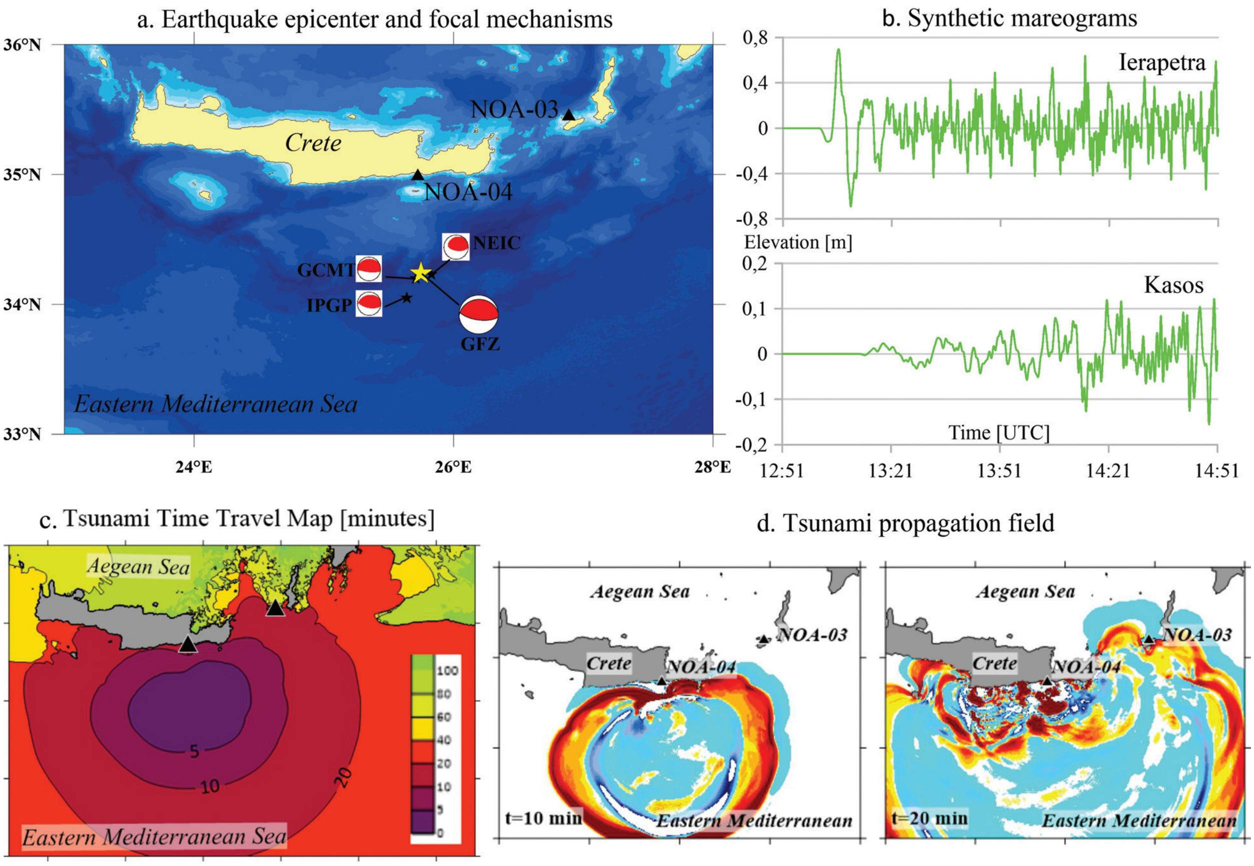

Fig. 1. *a*, map of the study area. Yellow star denotes the epicenter used in the simulations. Beach balls denote the earthquakes focal mechanisms (data from GFZ, IPGP, GCMT and NEIC). Black triangles point out the tide-gauge stations NOA-03 (Kasos) and NOA-04 (Ierapetra); *b*, synthetic mareograms calculated for Kasos and Ierapetra; *c*, tsunami time travel map; *d*, tsunami propagation field for 10 and 20 min. after the initiation of the tsunami.

sented in Jolivet and Brun (2010). In addition, the Aegean province is an extensional back-arc basin. The movements of the Anatolian block toward the Aegean microplate originates the variety of earthquake mechanisms. To the north of Crete there is a volcanic arc, including the volcano of Santorini (Thera), which ~1600 BC eruption created massive tsunami, devastating the Minoan civilization.

Methods

Nowadays the numerical models are involved in the operational work of the scientist. The simulations are useful for both reconstructing past events and future forecasts of potential tsunami-prone areas. In order to build reliable initial conditions for tsunami generation we collected data on seismicity, tsunami sources, tectonic structures and focal mechanism of the event. We compute the initial tsunami elevations using the model proposed by Okada (1985). The resolution data of a topography and bathymetry is essential in the computation as the fine the resolution, the better the results, especially near the shore, where the model compute the maximum water column on the coastline. In this study, the bathymetry and topography data are taken from GEBCO 30 s and the built domain consists of 500 m spatial resolution and 1 s temporal resolution. The model UBO-TSUFD is used for computing the tsunami propagation, the maximum elevation field, the synthetic mareograms and the tsunami time travel map (Tinti, Tonini, 2013). The calculated length, width and displacement over the faults are 40 km, 20 km and 2 m, respectively. The selected focal mechanism of the May 2, 2020 event is estimated by GFZ[1] (see details in Dimova et al., 2020).

Results

The May 2, 2020 earthquake initiates local tsunami recorded by two near-field mareographs located in Ierapetra (~90 km epicentral distance) and Kasos (~180 km). Tide-gauge station placed in Alexan-

[1] GFZ, Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences; https://geofon.gfz-potsdam.de/

dria, Egypt at about 500 km also recorded the tsunami but due to the noise in this station it is difficult to distinguish the tsunami signal clearly. The registered tsunami data shows maximum amplitudes of 0.16 m in NOA-04 (Ierapetra) and 0.05 m in NOA-03 (Kasos). Figure 1b presents two synthetic signals of tsunami registered in virtual tide-gauges in Kasos and Ierapetra. The mareograms show the first 2 hours of the simulations as the X axis indicate the time in UTC, starting with the time of the origin of the earthquake. It is clearly seen that the wave reaches Ierapetra between 10 to 15 min, while the waves travel more to Kassos, around 20 min. In Ierapetra, the signal indicates short-period oscillations but constantly in time, while in Kasos firstly the negative wave appears followed by longer periods of oscillations. In NOA-04, the simulated waves indicate larger values than the registered one, whereas in NOA-03 the tsunami heights are quite similar around ~0.5 m. On Fig. 1c and Fig. 1d are illustrated the tsunami time travel and the tsunami propagation field respectively. This type of maps could be used for predicting locations, where future inundations or tsunami prone-areas are expected. Both figures (Figs. 1c, d) confirm that Ierapetra is hit by the tsunami around ~10 min after the earthquake and the Kasos Island in less than 20 min.

Conclusions

The aim of this study was to compare the results from tsunami modelling and registered tsunami signals during the earthquake and tsunami on May 2, 2020 near the Crete Island. The model reproduces quite well the observed tsunami heights especially for Kasos mareogram. The computed time arrival is in good accordance with the registered one in the mareographic network. The tsunami alert system in the Mediterranean should be improved and the computing time needed for the earthquake and tsunami parameters estimation must be reduced. This study could be supplemented if more detailed bathymetry resolution is applied or including nested grids for specific locations which are of interest like: populated areas, exposed touristic places, important infrastructures like power plants or other factories. The recent strong offshore earthquakes induced tsunami near the Crete Island and Aegean Sea once more reminded us about the strength of such events and the high tsunamigenic potential in the area.

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