СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО, год. 81, кн. 3, 2020, с. 244–246
REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY, vol. 81, part 3, 2020, p. 244–246

Национална конференция с международно участие „ГЕОНАУКИ 2020“
National Conference with international participation “GEOSCIENCES 2020”

# Strong offshore earthquakes in the past 10 years for the Southern Europe as an input for tsunami modelling

# Силни подводни земетресения през последните 10 години в Южна Европа като начални условия за моделиране на цунами

***Lyuba Dimova, Dragomir Dragomirov, Reneta Raykova***
***Люба Димова, Драгомир Драгомиров, Ренета Райкова***

Sofia University “St. Kliment Ohridski”, Department of Meteorology and Geophysics, Faculty of Physics, 5 James Bourchier Blvd., 1164 Sofia, Bulgaria; E-mails: lyuba_dimova@phys.uni-sofia.bg; dragomir.n.dragomirov@gmail.com; rraykova@phys.uni-sofia.bg

**Keywords:** offshore earthquakes, Southern Europe, tsunami modelling.

## Introduction

This study is focused on reviewing the strong offshore earthquakes in the region of Southern Europe, which could be used in tsunami modelling as initial conditions. The seismicity near the sea basins from Southern Europe in the last 10 years is revised. We take into account earthquakes with $M_w$ >6.0 situated between longitudes 15–42 °E and latitudes 20–46 °N. The region includes Adriatic Sea, Ionian Sea, Aegean Sea, Sea of Marmara, Sea of Crete, Levantine Sea and Black Sea. Figure 1 illustrates the position of the earthquakes and the relative plate motion.

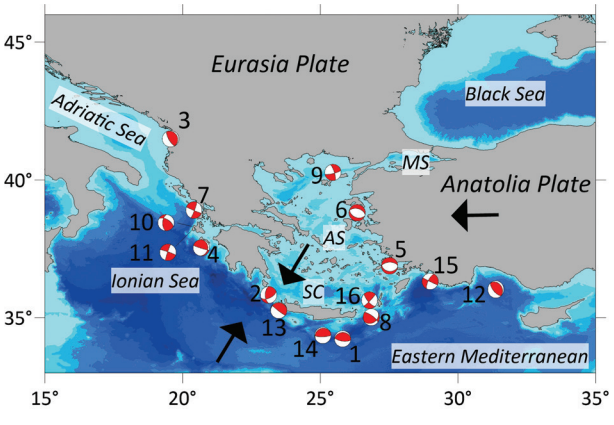


**Fig. 1.** Map of the study region. The black arrows indicate the plate’s motion (Yolsal-Çevikbilen, Taymaz, 2012). Beach balls denote the earthquakes focal mechanisms (data from GFZ). MS, Marmara Sea; AS, Aegean Sea; SC, Sea of Crete. Numbers correspond to the earthquakes in Table 1.

## Geodynamics and tectonic settings

The complexity of the tectonic settings in the Eastern Mediterranean and its connected seas originates from the plate convergence between the Eurasia and Africa and Arabia Plates. The main geological units where subduction is predominant are the Hellenic Arc (south of Crete) and Cyprus Arc. The collision on the border between the Adria and Eurasia Plates, where Ionian-Adriatic thrust faults exists, was observed during the sequence of strong earthquakes last year. The transform North Anatolian Fault and its three branches along Marmara and North Aegean Sea contributes to the higher seismic activity. The volcanic arc north of Crete supplements the variety of geodynamics in this region. The mentioned tectonic settings put the region as most tsunamigenic area in the Mediterranean (Maramai et al., 2014).

## Methods

In our previous study, the tsunamigenic zones in the region are identified (Dimova, Raykova, 2016). After reviewing the seismicity, we selected 16 events in the past 10 years capable to initiate tsunami waves. Table 1 presents the characteristics of the chosen earthquakes. One of the most important parameter for the generation procedure (suggested by Okada, 1985) is the focal mechanism. Meaning that if the vertical component of the rupture is dominant we expect higher initial tsunami elevations. Therefore strike-slip fault usually do not generates tsunamis. The relationships between moment magnitude and the geometry of the faults, proposed by May and

*Table 1. Earthquakes characteristics*

| | Origin Time UTC | $M_w$ | Lat (°N) | Lon (°E) | Depth (km) | | Strike (ϕ, °) | Dip (δ, °) | Rake (λ, °) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | GFZ | ISC/**NEIC*** | | | |
| 1 | 2020-05-02 12:51:06 | 6.6 | 34.24 | 25.75 | 15 | **11.5** | 98<br>264 | 67<br>22 | 95<br>76 |
| 2 | 2019-11-27 07:23:40 | 6.0 | 35.71 | 23.22 | 52 | **69** | 180<br>67 | 56<br>59 | 38<br>140 |
| 3 | 2019-11-26 02:54:12 | 6.4 | 41.46 | 19.58 | 26 | **17** | 151<br>335 | 72<br>18 | 89<br>94 |
| 4 | 2018-10-25 22:54:50 | 6.8 | 37.52 | 20.66 | 18 | **15** | 107<br>5 | 85<br>23 | 68<br>167 |
| 5 | 2017-07-20 22:31:12 | 6.6 | 36.93 | 27.47 | 11 | 10.2 | 98<br>270 | 35<br>56 | –82<br>–94 |
| 6 | 2017-06-12 12:28:39 | 6.4 | 38.83 | 26.34 | 10 | 9.7 | 112<br>285 | 42<br>48 | –84<br>–94 |
| 7 | 2015-11-17 07:10:09 | 6.4 | 38.79 | 20.47 | 13 | 11.4 | 112<br>22 | 87<br>84 | 6<br>177 |
| 8 | 2015-04-16 18:07:43 | 6.1 | 35.18 | 26.87 | 29 | 22.6 | 60<br>305 | 33<br>74 | 29<br>120 |
| 9 | 2014-05-24 09:25:03 | 6.8 | 40.28 | 25.38 | 20 | 8.2 | 343<br>76 | 76<br>77 | –12<br>–164 |
| 10 | 2014-02-03 03:08:47 | 6.0 | 38.23 | 20.39 | 14 | 14.5 | 183<br>300 | 56<br>56 | 138<br>43 |
| 11 | 2014-01-26 13:55:44 | 6.1 | 38.25 | 20.45 | 17 | 13.8 | 289<br>198 | 85<br>86 | 4<br>175 |
| 12 | 2013-12-28 15:21:05 | 6.0 | 36.06 | 31.38 | 47 | 59.5 | 138<br>318 | 65<br>25 | 90<br>90 |
| 13 | 2013-10-12 13:11:54 | 6.5 | 35.57 | 23.31 | 25 | 46.9 | 128<br>262 | 84<br>8 | 96<br>44 |
| 14 | 2013-06-15 16:11:02 | 6.0 | 34.41 | 25.04 | 20 | 21.5 | 88<br>244 | 76<br>16 | 96<br>66 |
| 15 | 2012-06-10 12:44:14 | 6.1 | 36.35 | 28.94 | 29 | 32 | 116<br>207 | 88<br>70 | 160<br>2 |
| 16 | 2011-04-01 13:29:12 | 6.0 | 35.54 | 26.72 | 62 | 75.5 | 138<br>45 | 72<br>83 | 7<br>162 |

* National Earthquake Information Center (NEIC) author is used when ISC data is missing.

Beroza (2000) and Wells and Coppersmith (1994) are used to evaluate the length, width and displacement.

## Discussion

Some of the selected events from the past 10 years generated local tsunami waves. The earthquake from 2nd of May 2020 near the Island of Crete initiates local tsunami recorded by several tide-gauge stations located in Ierapetra (~90 km from the epicenter), Kasos (~180 km) and Alexandria (~485). The tsunami signal varies from 0.02 m in Alexandria to 0.16 m in Ierapetra (Papadopoulos et al., 2020). The strong shock near Durres, Albania on 26th November 2019 did not generate any tsunami. Several seismological centers determined the epicenter offshore the coastline, the area is populated and tsunami simulations could be very useful. The earthquake of July 20, 2017 ($M_w$ 6.6) in Bodrum-Kos, Aegean Sea generated tsunami waves recorded in station located in Bodrum Bay (~1.9 m). In our previous study, we tested several focal mechanisms and run tsunami numerical simulations and the results are in good accordance with the observed amplitudes in Kos, Akyarlar and Bodrum (Dimova, Raykova, 2018).

## Conclusions

The purpose of this study was to evaluate the seismicity in the Southern Europe region and collect strong offshore earthquakes. Among the selected events, there are those generated tsunamis in the past 10 years. The earthquakes characteristics in the table will be used as an input for tsunami simula-

tions. Such waves in the Eastern Mediterranean are not gigantic as the tsunamis in the Pacific, but they possess a lot of energy, in addition, the location of all earthquakes is very close to the shores as seen from Figure 1. The size of the tsunamis in the South European sea basins should not be neglected and many damages, building collapse and even injured or dead people are expected.

*Acknowledgements*: This study if funded by the BNSF project No. CP-06-COST-7/24.09.2020.

## References

Dimova, L., R. Raykova. 2016. Observations and modeling of tsunamis in the Eastern Mediterranean (Review). – *Ann. Sofia Univ. „St. Kliment Ohridski", Faculty of Physics*, *109*, 24–41.

Dimova, L., R. Raykova. 2018. Numerical simulations of the earthquake-induced tsunami of July 20, 2017 (Mw=6.6) in Bodrum-Kos, Aegean Sea. – *Rev. Bulg. Geol. Soc.*, *79*, 1–2, 5–12.

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

Mai, P., G. Beroza. 2000. Source scaling properties from finite-fault-rupture models. – *Bull. Seismol. Soc. Am.*, *90*, 3, 604–615.

Maramai, A., B. Brizuela, L. Graziani. 2014. The Euro-Mediterranean tsunami catalogue. – *Annals Geophys., 57*, 4, doi:10.4401/ag-6437.

Okada, Y. 1985. Surface deformation due to shear and tensile faults in a half-space. – *Bull. Seismol. Soc. Am.*, *75*, 4, 1135–1154.

Papadopoulos, G., E. Lekkas, K. Katsetsiadou, E. Rovythakis, A. Yahav. 2020. Tsunami alert efficiency in the Eastern Mediterranean Sea: The 2 May 2020 earthquake (Mw6. 6) and near-field tsunami south of Crete (Greece). – *GeoHazards*, *1*, 1, 44–60.

Wells, D., K. Coppersmith. 1994. New empirical relationships among mragnitude, rupture length, rupture width, rupture area, and surface displacement. – *Bull. Seismol. Soc. Am., 84*, 4, 974–1002.

Yolsal-Çevikbilen, S., T. Taymaz. 2012. Earthquake source parameters along the Hellenic subduction zone and numerical simulations of historical tsunamis in the Eastern Mediterranean. – *Tectonophys.*, *536*, 61–100.