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Scenario-Based Tsunami Hazard Assessment for Karpathos Island, Southeastern Aegean Sea

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ABSTRACT

Karpathos is the second largest of the Greek Dodecanese islands. Historical data such as the event of 9 February 1948, indicate that this area is prone to earthquakes and tsunamis. In this study we evaluate the tsunami hazard for the Karpathos Island (Karpathos, Arkasa and the Airport) by means of a scenario-based technique. We take into account tsunamis generated by three main seismic sources in agreement with local tectonics and historical records: one placed near Crete in the Eastern Hellenic Arc (EHA), with reference to the 1303 A.D., Mw=8.0 event), another near Rhodes (hypothetical scenario earthquake, Mw=7.3), and one near the coast of Karpathos, based on the 1948, Mw=7.3 earthquake. The code UBO-TSUFD, developed by the Tsunami Research Team from University of Bologna, Italy, is used for all numerical simulations (Tinti and Tonini, 2013). Tsunamis are computed in several domains with different resolution for a better calculation of the maximum coastal wave height and tsunami inundation. Tsunami parameters for each individual scenario are used to construct a unique aggregated scenario, which help us to evaluate the buildings in the inundation zone. The contribution of all scenarios along the coast of Karpathos is studied via synthetic mareograms. It is found that seismic source EHA dominates and that the southern part of Karpathos is more exposed to tsunamis.

TSUNAMI INITIAL CONDITIONS

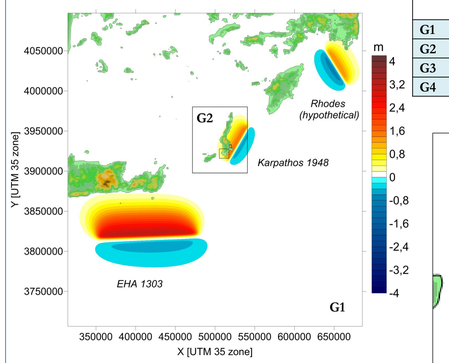


Table 1. Characteristics of the used grids

	Easting [m] (UTM 35 zone)	Northing [m] (UTM 35 zone)	Spatial resolution [m]	Time step [s]	Nodes in X direction	Nodes in Y direction	Total number of nodes
G1	314500-685500	3706500-4097000	500	1.0	743	782	581026
G2	470200-539700	3900200-3979700	100	0.2/0.25	696	796	554016
G3	505340-517340	3916240-3927840	20	0.1	601	581	349181
G4	517540-520740	3928940-3932840	20	0.125	161	196	31556

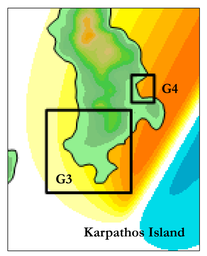
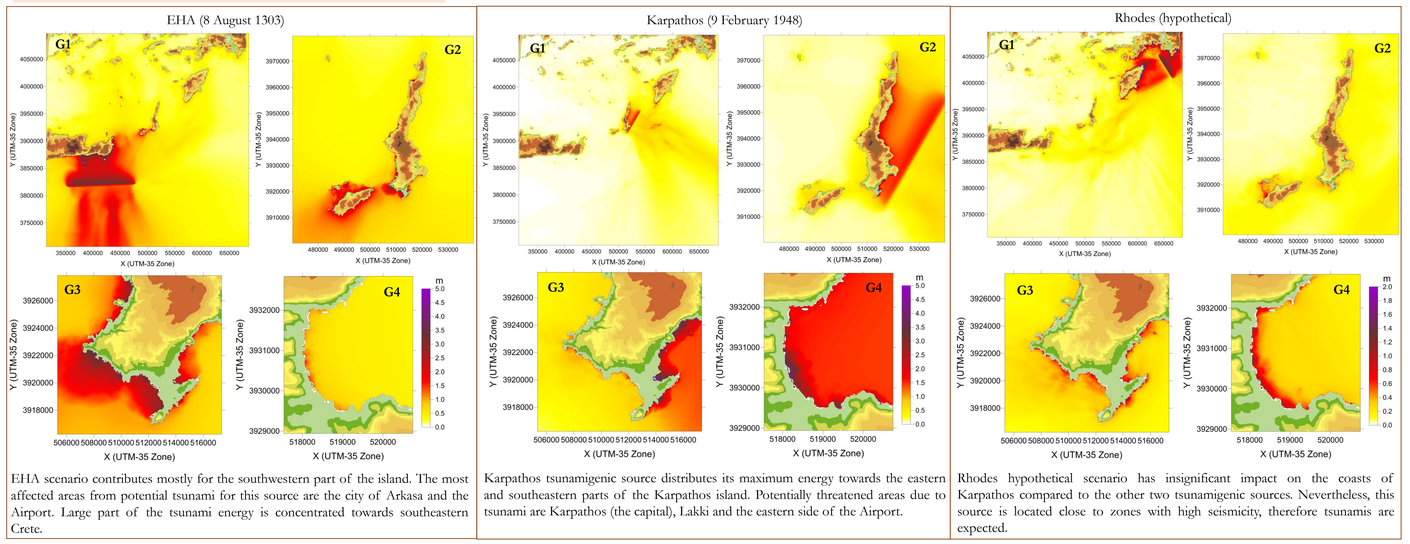


Table 2. Source parameters

	EHA (8 August 1303)	Karpathos (9 February 1948)	Rhodes (hypothetical)
L (km)	125	50	50
W (km)	50	23	23
Strike (°)	268	210	328
Dip (°)	48	60	73
Rake (°)	71	115	71
Slip (m)	6	3.2	3.2
Upper border depth (km)	4	2	3
UBMP (UTM35)	(415550, 3819090)	(529004, 3934086)	(652446, 4029658)
Mw	8.0	7.3	7.3

Tsunami simulations are carried out in four grids with different resolution in order to evaluate the maximum wave elevation and the inundation zone. Characteristics of the computational grids are presented in Table 1. The outer grid (G1) includes the eastern part of Crete, the islands of Karpathos and Rhodes and the southeastern Aegean Sea. The smaller grid G2 covers the area of Karpathos Island. Grid 3 and Grid 4 are located in the southern part of Karpathos with focus on the city of Arkasa, the Airport and the city of Karpathos. The initial sea surface elevations (plotted above), caused by the assumed seismic sources, are calculated by the analytical formulas of Okada (1985). The minimum and maximum values are in the range between -0.5 and 3.3 m. The geometry and the focal mechanisms of the modelled events are given in Table 2. The fault models are taken to be in accordance with the results obtained in Dimova 2018, Ebeling et al., 2012 and Yolsal and Taymaz, 2012. The strike angle for Karpathos scenario is oriented to maximize the effects towards the island of Karpathos.

MAXIMUM WATER ELEVATION FIELDS

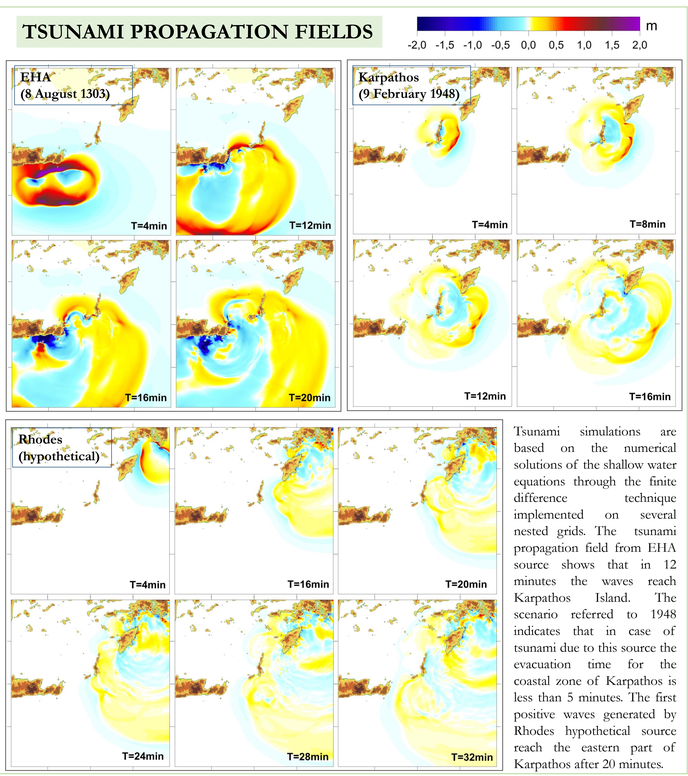


EHA scenario contributes mostly for the southwestern part of the island. The most affected areas from potential tsunami for this source are the city of Arkasa and the Airport. Large part of the tsunami energy is concentrated towards southeastern Crete.

Karpathos tsunamigenic source distributes its maximum energy towards the eastern and southeastern parts of the Karpathos island. Potentially threatened areas due to tsunami are Karpathos (the capital), Lakki and the eastern side of the Airport.

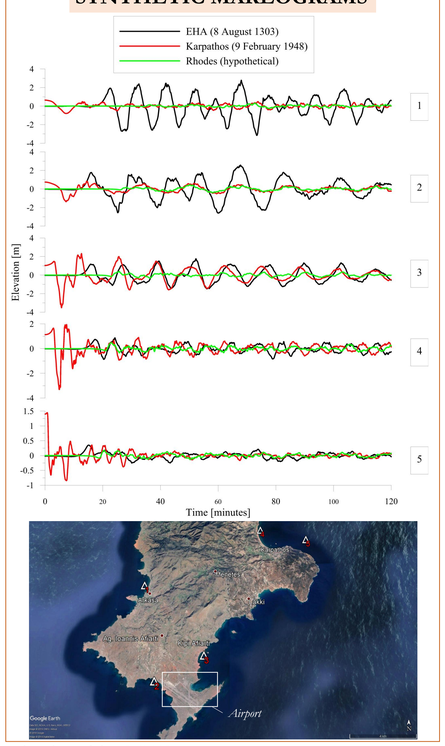
Rhodes hypothetical scenario has insignificant impact on the coasts of Karpathos compared to the other two tsunamigenic sources. Nevertheless, this source is located close to zones with high seismicity, therefore tsunamis are expected.

TSUNAMI PROPAGATION FIELDS



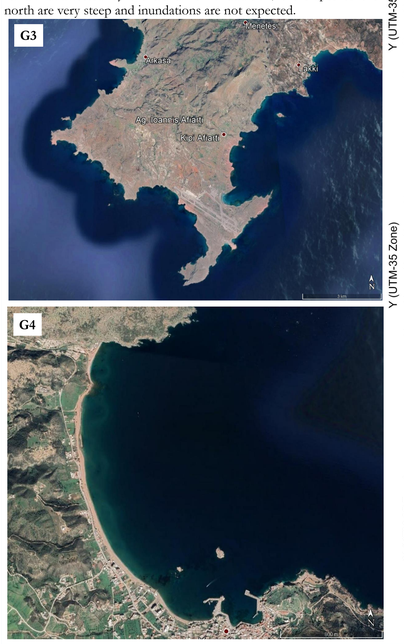
Tsunami simulations are based on the numerical solutions of the shallow water equations through the finite difference technique implemented on several nested grids. The tsunami propagation field from EHA source shows that in 12 minutes the waves reach Karpathos Island. The scenario referred to 1948 indicates that in case of tsunami due to this source the evacuation time for the coastal zone of Karpathos is less than 5 minutes. The first positive waves generated by Rhodes hypothetical source reach the eastern part of Karpathos after 20 minutes.

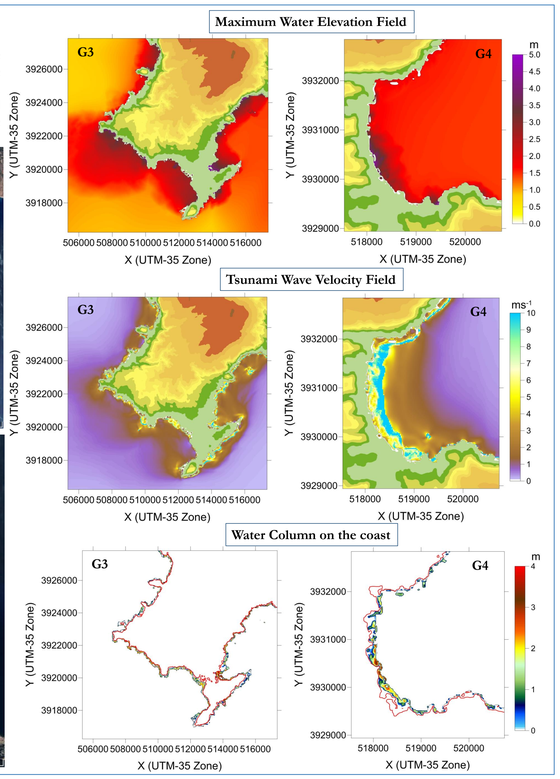
SYNTHETIC MAREOGRAMS



AGGREGATED SCENARIO

The aggregated scenario is the maximum value reached in each node for the three tsunami scenarios. Zooming on the southern part of the island it is seen that the bay of Karpathos, Arkasa and the Airport are flooded while the northern and northwestern parts of the island remain unaffected by the tsunamis. In addition, the slopes to the north are very steep and inundations are not expected.





CONCLUSIONS

Historically documented tsunamis in the region of the southern Aegean Sea and Karpathos Island are reviewed in Dimova and Raykova, 2016 and in Papadopoulos et al., 2014. Destructive tsunamis in this area are not so frequent events, but their tsunamigenic potential is high, since the region lies between a subduction zone to the south and a volcanic arc to the north. Therefore, numerical simulations of tsunamis are extremely important to evaluate tsunami hazard, especially in areas where the historical information is insufficient. In this work we assess the tsunami hazard on the coasts of Karpathos by means of an aggregated scenario. The results show that the EHA source, referred to the 1303 AD event has a maximum tsunami impact on the southern part of the island, whereas the Karpathos source (reference event 1948) affects mostly the eastern coastline. Nevertheless secondary effects like underwater landslides must not be excluded in the generation of tsunamis. Indeed such complex events could increase significantly the expected maximum tsunami heights.

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