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Evaluation of tsunami scenarios for western Peloponnese, Greece

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ABSTRACT Tsunami hazard assessment of the eastern part of the Mediterranean Sea is the current interest of the countries having a coastline in this region. Considering today's increasing population on the coasts and historical tsunamis, it is essential to estimate the probable tsunami risk, which might occur, to be able to mitigate the risk before the actual tsunami event happens. For this purpose, European Union funded project, SEAHELLARC is formed to develop a methodology and tools for seismic and tsunami safety and enhance the protection of coastal areas in the western part of Peloponnese in Greece by simultaneous observations and evaluation of onshore and offshore data. In this paper, we present the tsunami simulations of characteristics of possible tsunami source scenarios for the Pylos-Zakynthos-Filiatra and Kyparissia regions, located at western part of Greece. We use NAMIDANCE tsunami simulation and visualization tool to estimate extreme but possible tsunami wave effects in these regions. In the simulations the tsunami arrival times, maximum positive and negative amplitudes are computed, plotted, compared and discussed for the coastal areas of Zakynthos, Filiatra, Kyparissia and Pylos. Furthermore, a detailed mapping of the bathymetric features is performed to define possible landslides and lithological variations at the marine bottom. The uppermost sediments are mapped by sub-bottom profiling, while possible faults are identified by multi-channel reflection mapping at the western Peloponnese. This paper also builds upon the background of a seismic hazard assessment for the region to draw several credible tsunami occurrence scenarios that have been numerically simulated.

Key words: tsunami, Peloponnese, SEAHELLARC.

1. Introduction

The Earth's lithosphere beneath the eastern Mediterranean constitutes a broad boundary region at three major tectonic plates, the Eurasian, African, and Arabian plates. The motions of the major plates drive smaller plates, and it is the shapes and motions of these smaller plates that determine the locations and focal mechanisms of earthquakes in the region. Greece is the most seismically active country in Europe, accounting for more than half of the continent's seismic energy release and exhibits the highest seismic activity at the Mediterranean basin (SEAHELLARC Working Group, 2010). Most shallow earthquakes in central and northern Greece (depths less than 50 km) result from interaction between the Eurasia plate and the small Aegean Sea plate. The boundary between the Aegean plate and the Eurasian plate in central and northern Greece is diffuse. The east-trending zones that are most prominent in mainland Greece, are characterized by predominantly normal faulting, and have produced earthquakes with magnitudes close to 7. Strike-slip fault earthquakes characterize the NE-trending belts predominantly. One of these zones is off the west coasts of Cephalonia and Lefkas, western Greece, and other NE-trending zones occurring beneath the Aegean Sea east of the Greek mainland (Papadopoulos, 2001; Papadopoulos and Fokaefs, 2005; Papadopoulos *et al.*, 2007, 2010; USGS, 2008; Zaytsev *et al.*, 2008).

The western part of the Hellenic Arc between Pirgos and Pylos, western Peloponnese, is one of the most seismically active areas in the entire Mediterranean region. Severe destructions and human losses were caused by the 1886 Filiatra *M*7.3, 1893 Zante-Keri *M*6.5, 1899 Kyparissia *M*6.5, 1947 Pylos *M*7.0, and 1997 Gargaliani *M*6.6 earthquakes. Some of the largest regional tsunamis in the Mediterranean Sea have also been observed in association with large earthquakes, affecting near-field as well as remote coastal segments in western Peloponnese, Crete, and as far as Alexandria, the Adriatic Sea and east Sicily.

The aim of this study is to determine the characteristics of possible tsunami sources in the western part of Greece, especially for the Pylos-Zakynthos, including Filiatra, by using the results of probabilistic seismic assessment (PSHA) obtained by Slejko *et al.* (2014) in the framework of the EU SEAHELLARC project (Papoulia *et al.*, 2014) and estimate the possible tsunami effects in the region using tsunami modelling.

The method covers collecting and enhancing reliable data, applying numerical tools and models to this data to estimate the characteristics of probable tsunamis selected from the region and evaluating tsunami effects to the Pylos-Zakynthos region. The available results of modelling are analyzed and displayed with GIS-based applications in order to contribute to develop preparedness and mitigation strategies for the region.

2. Bathymetry, shoreline and topographical data

The available bathymetric and topographic data for the western part of Greece specifically for Zakynthos, Kyparissia, Filiatra and Pylos regions have been obtained and analysed to get a highly accurate bathymetry/topography needed for the tsunami simulations. As a first step, 1 minute (1800 m grid size) resolution from GEBCO (General Bathymetric Chart of the Oceans) of the British Oceanographic Data Centre was used to get bathymetry data for the offshore. ASTER 3A 60 km by 60 km, 14 band orthorectified satellite image with a radiometric resolution of 8 bit in 3 different pieces involving different regions was the source for the onshore. The spatial resolution of the ASTER data is 30 m. The data was analyzed to form a database of bathymetry, topography and shoreline data of the region in coordinates by i) setting

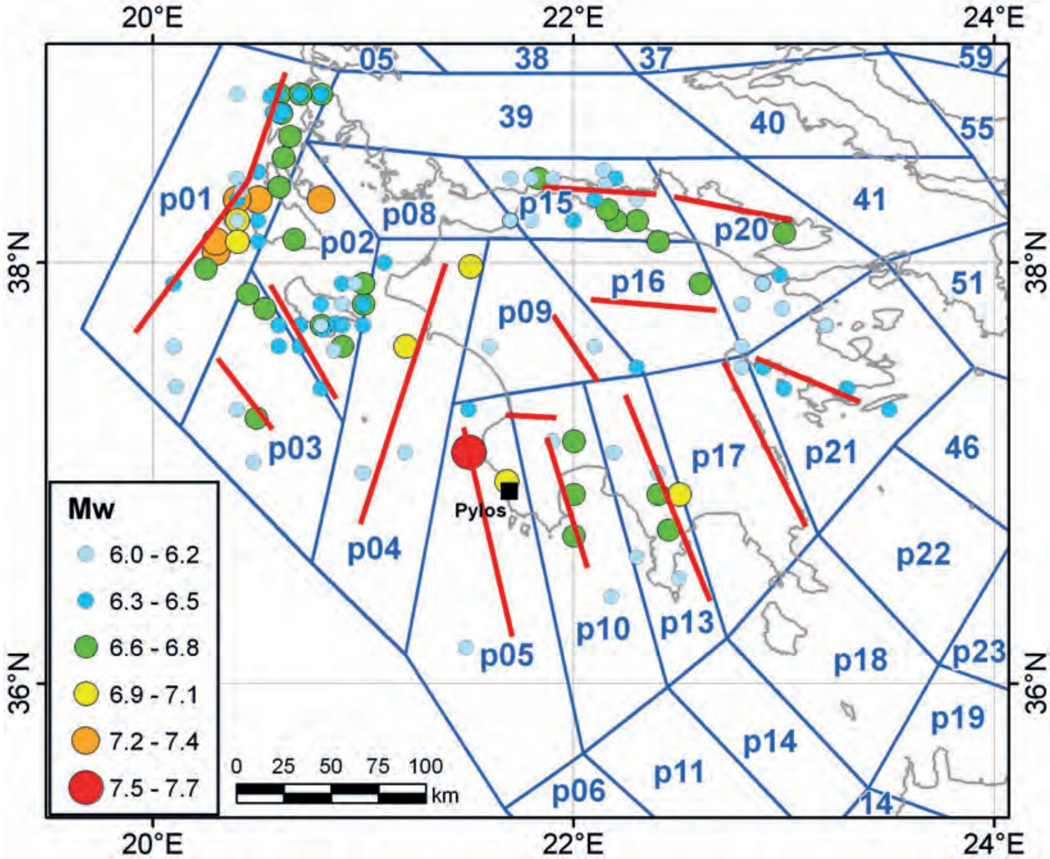


Fig. 1 - Seismogenic zones, main faults (red lines), and earthquake epicentres (M_W≥6) in the region (SEAHELLARC Working Group, 2014).

a projection system; ii) creating digital elevation model (DEM) and adding coordinates, iii) doing overlay operations. Then, the satellite image in the file format of "ASTER.3A.dat" was orthorectified by using ground control points of the region and exported to ".tiff" file format. Hence the data set in XYZ (longitude, latitude and elevation) format representing bathymetry (from GEBCO) and topography (ASTER image) are produced. Furthermore the coordinates of the shoreline are obtained from Google Earth images and added to the data set. The coordinate system of all the layers used in the project was "WGS_1984_UTM_Zone_35N Projection: Transverse Mercator". All layers have been converted to the same projection system as ASTER Satellite Image. The data set was transferred to ArcGIS. DEM of the regions was obtained. Points with 20 m interval were settled at the center of each cell of DEM. Thus, the values of coordinates of these points were extracted from DEM in ".dbf" file format.

The visible band coordinate system given in ASTER image was changed, and the coastal zones of Zakynthos, Filiatra and Pylos were digitized. Polyline and polygon types of shape files were formed with the same coordinates as the ASTER image for coastal strip of mainland and islands, respectively and a buffer zone of 20 m distance was used in the landward of the coastal strip in order to analyze the coordinate values at these coastal areas. For the final step of the data analysis procedure, the buffer zones created with 20 m horizontal distance and polygon and polyline shape files were overlaid in ArcMAP to extract the points on coastal strip. After collecting and combining the data, the bathymetry and topography database was obtained that was used as the input to tsunami numerical modelling.

The collected and analyzed data set was processed to create regularly spaced bathymetry and topography database in study domains (METU, 2008).

3. Shallow seismic zones, probable tsunami sources and estimated rupture characteristics

The final seismic hazard estimates (Slejko *et al.*, 2014) were used as a reference for the estimation of rupture characteristics in western Greece. The surficial seismogenic zones (SZs) and their names are given in Fig. 1.

The tsunami sources, which might be creating a tsunami risk on Zakynthos-Filiatra-Pylos region were selected from Slejko *et al.* (2014) and computed by using Okada (1985) fault model. The rupture parameters of selected six tsunami source scenarios were estimated (Fig. 2).

Table 1 summarizes the scenario earthquakes from Slejko *et al.* (2014), which collects all previous considerations. It formulates a hypothesis of scenario earthquakes for tsunami generation. The hypothesis considers the locations obtained by the disaggregation analysis, the geometry of the major fault identified in each SZ, and the mechanisms of the main earthquakes, which occurred in the past.

Table 1 - Scenario earthquakes for tsunami generation (Slejko *et al.*, 2014).

Source	Mw	Length	Lon.	Lat.	Depth	Nodal Plane A			Nodal Plane B		
		(km)			(km)	Strike	Dip	Rake	Strike	Dip	Rake
p01	7.4	180	20.14	37.96	12	18	59	-168	285	85	-31
p02	6.8	90	20.86	37.45	10	330	57	83	330	57	83
p03	6.7	120	20.54	37.33	32	354	20	159	113	81	60
p04	6.8	55	21.08	37.04	11	26	89	-152	210	82	175
p05	6.9	15	21.57	36.82	25	318	84	-87	112	7	244
p10	6.5	25	21.97	36.86	32	123	72	84	322	19	108

Table 2 - The tsunami sources of the scenario earthquakes and their parameters.

Sources	Epicenter Location		Length of Fault (km)	Strike Angle (°)	Width of Fault (km)	Focal Depth (km)	Dip Angle (°)	Rake Angle (°)	Fault displacement (m)	Max (+) Amp.	Min (-) Amp
	Lon (E°)	Lat (N°)								(m)	(m)
p01	20.14	37.96	180	18	25	12	60	-168	5	0.38	-0.62
p02	20.86	37.45	90	330	25	10	57	83	5	1.93	-0.22
p03	20.54	37.33	120	354	20	32	20	159	5	0.49	-0.28
p04	21.08	37.04	55	26	25	11	89	-152	5	0.36	-0.27
p05	21.57	36.82	15	310	20	25	84	-87	5	0.44	-0.61
p10	21.97	36.86	25	322	15	32	19	108	5	0.47	-0.17

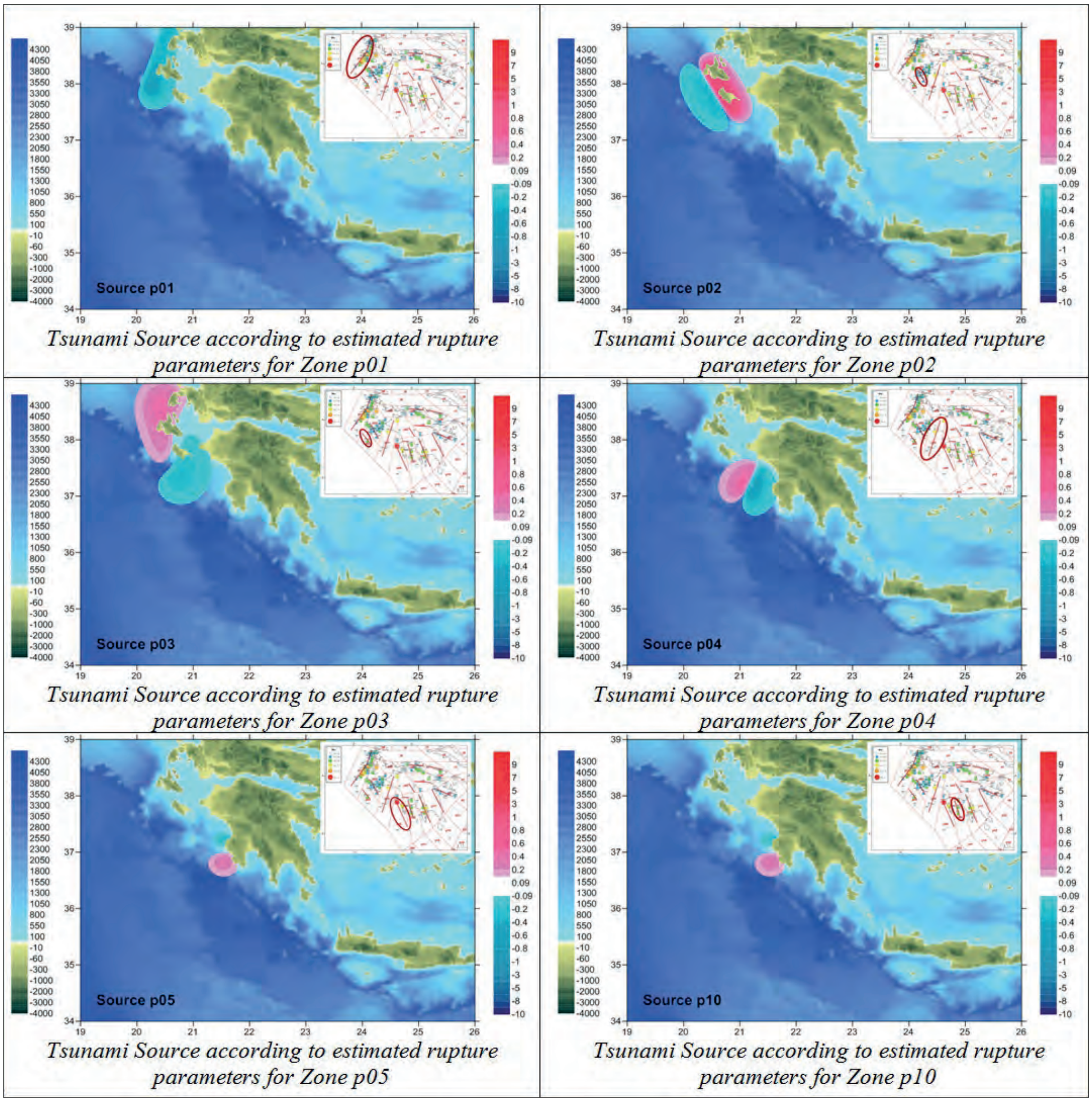
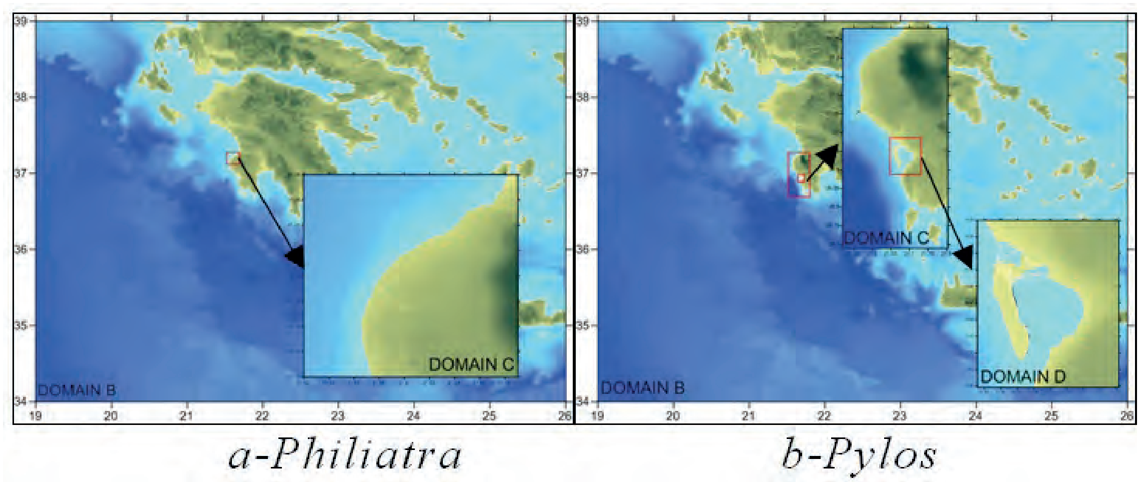


Fig. 2 - Selected tsunami sources for the scenario earthquakes at tsunami zones.

4. Tsunami modelling and hazard assessment

NAMI DANCE tsunami simulation tool was used to perform tsunami modelling[1]. The tool provides direct simulation and efficient visualization of tsunamis to the user and for assessment, understanding and investigation of tsunami generation and propagation mechanisms. The model

1 The tool was developed by profs. Andrey Zaytsev, Ahmet Yalçiner, Anton Chernov, Efim Pelinovsky and Andrey Kurkin in collaboration between Ocean Engineering Research Center, Department of Civil Engineering, METU, Turkey and Special Research Bureau for Automation of Marine Researches, Far Eastern Branch of Russian Academy of Sciences and Department of Nonlinear Geophysical Institute of Applied Physics, Russian Academy of Science, Russia specifically for tsunami modelling



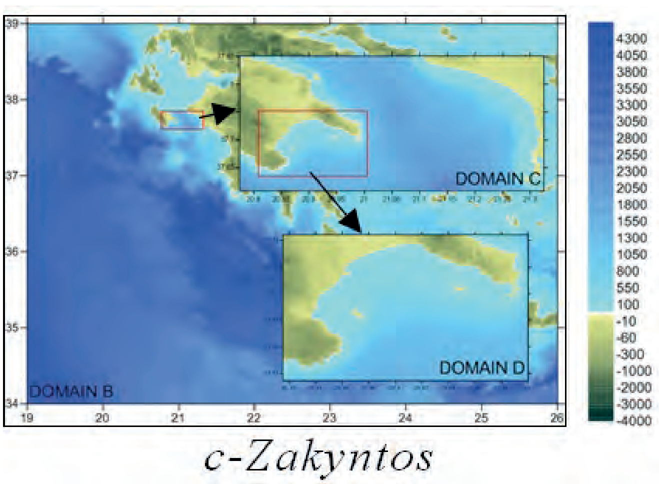


Fig 3 - The structure of nested domains (Domain B and Domain C) for the simulation of Filiatra (a) region and (Domain B, Domain C and Domain D) for the simulation of Pylos (b) and Zakynthos (c) regions.

is tested and verified for research and operational purposes. (Zahibo *et al.*, 2003). The model computes tsunami wave propagation, run-up and depth-averaged velocities with non-linear shallow water equations numerically by discretisizing them with finite difference technique and leap-frog scheme for basins of irregular shape and bathymetry in nested domains (Yalçiner *et al.*, 2006, 2007, 2010; Onat and Yalçiner, 2013).

The sources p02, p04, p05, and p10 were selected for simulations due to their close proximity to Pylos, Zakynthos and Filiatra and their higher initial wave amplitudes compared to the other sources.

The simulations were performed in three nested B, C, and D grids extracted from the DEM to understand the coastal amplifications of tsunami at selected locations. The simulation duration is selected as 90 minutes with the time step of 0.05 s. The location (Fig. 3) of the selected tsunami sources and the study areas were used to determine the boundaries of each nested domain for each simulation. The largest domain is the Domain B, which covers western coast of Greece with 180 m grid size. Smaller domains (C) are formed near i) Zakynthos, ii) Filiatra, iii) Pylos and their neighbouring areas with 60 m grid size. The smallest domains (D) cover Zakynthos and Pylos harbours and towns separately with 20 m grid size. The boundaries and their latitude and longitude coordinates of each domain are shown in Table 3. In order to be able to view the water surface fluctuations and the maximum positive and maximum negative wave amplitudes, artificial gauges were placed at specific locations in Domains D near the towns.

Table 3 - Study domains of tsunami simulations.

Name	Domains			Coordinates (°)	Grid Size (m)	Simulation Duration (min)
Greece	B			19.00E-26.00E 34.00N-39.00N	180	90
Filiatra		C		21.52 E-21.69E 37.12N-37.28N	60	90
Pylos		C		21.52E-21.80E 36.88N-36.99N	60	90
Zakynthos		C		20.77E-21.32E 37.60N-37.85N	60	90
Filiatra			D	21.225E-21.58E 37.12N-37.28N	20	90
Pylos			D	21.64E-21.73E 37.25N-37.26N	20	90
Zakynthos			D	20.81E-21.00E 37.63N-37.74N	20	90

The tsunami source parameters were computed using Okada (1985) fault model according to the estimated rupture characteristics in order to understand the possible effects of tsunamis in the region affecting Zakynthos, Filiatra and Pylos (Table 2). The tsunami simulations were performed using NAMIDANCE in nested domains for all tsunami cases. In the simulations tsunami parameters such as tsunami wave amplitudes, wave currents and flow depths in the near shore area of the selected towns were computed. The results of the simulations related to tsunami sources p02, p04, p05, p10 are given in the following sections.

4.1. Simulations

4.1.1. Tsunami source p02

The distribution of the maximum positive wave amplitudes of tsunami waves in Domain B, Domain C of Filiatra region and Domain D of Pylos and Zakynthos regions are shown in Fig. 4 as a result of the simulations for the tsunami source p02. As seen from the Fig. 4, the tsunami has higher wave amplitudes near Zakynthos. Maximum tsunami amplitude at the shallow regions in SW coast of Zakynthos is reaching to 5 m (Fig. 4a). In eastern bay, maximum wave amplitude is around 4 m (Fig. 4d). They exceed 2.2 m near Filiatra and Pylos.

The computed time histories of water surface elevations near the selected towns were investigated and the arrival time of the first and of the maximum wave, the computed maximum positive and negative tsunami amplitudes at selected coordinates near the towns for the simulation of p02 are given in Table 4. The arrival time of the first wave is detected when

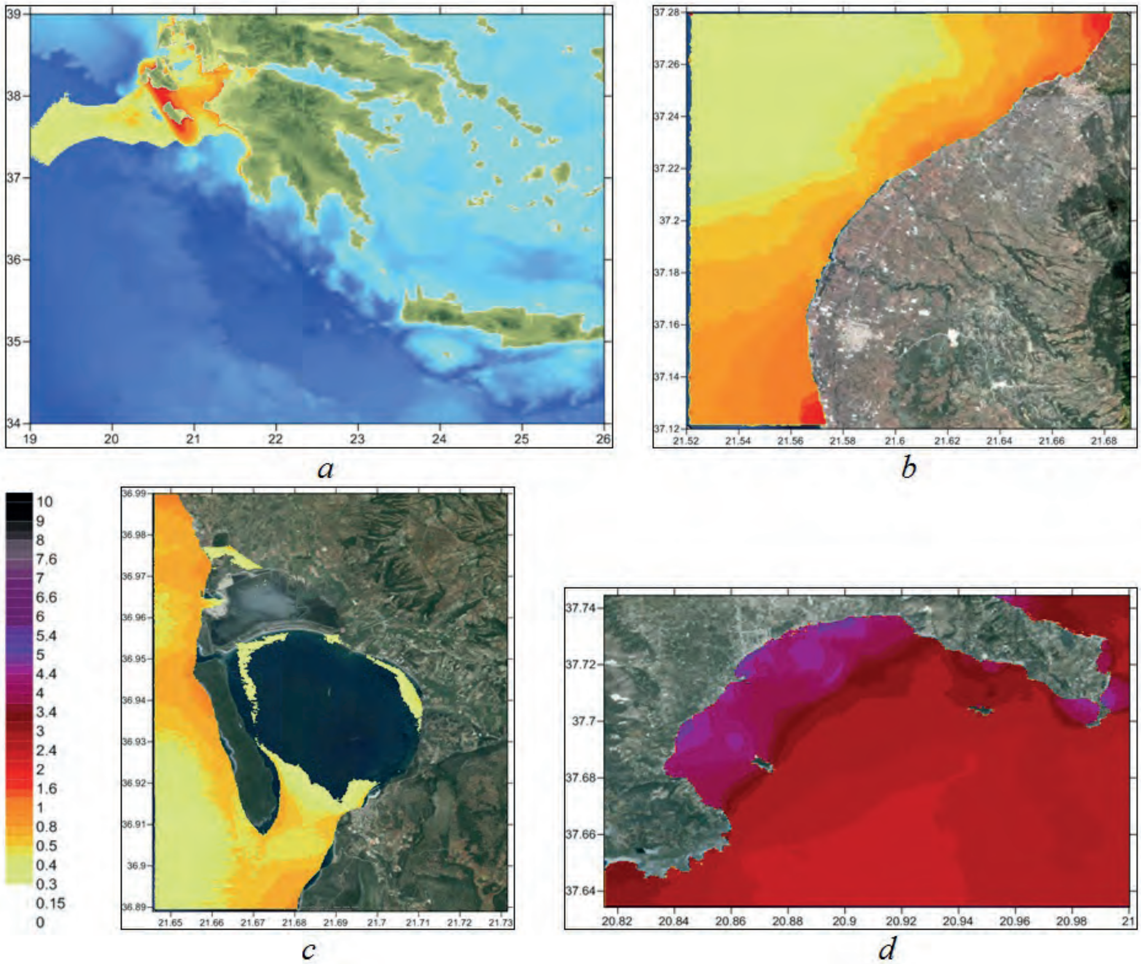


Fig. 4 - Maximum positive wave amplitudes for Domain B (a), Domain C in Filiatra region (b) and, Domain D in Pylos (c) and Zakynthos (d) regions.

the sea level change exceeds +/- 0.15 m. The arrival time of the maximum wave was taken as the time, which maximum tsunami amplitude occurs at the location. As seen from Table 4, tsunami waves from the source p02 arrive at Zakynthos, Filiatra at around 7 minutes, and Pylos between 0-20 minutes. The maximum positive and negative amplitudes are in the range of 0.3-4.7 m at those regions.

4.1.2. Tsunami source p04

The distribution of the maximum positive amplitudes of tsunami waves in Domain B, Domain C of Filiatra region and Domain D of Pylos and Zakynthos regions are shown in Fig. 5. According to the simulation for the tsunami source p04, the tsunami related to the source p04 is heavily affecting near Pylos and Filiatra. Maximum tsunami amplitudes at the shallow regions in Pylos and Filiatra are close to 2 m (Figs. 5b and 5d). They are about 1.2 m at Zakynthos region.

Results for p04 are given in Table 4. Tsunami waves from the source p04 arrive at Filiatra, Pylos, and Zakynthos around 0-10 minutes. The maximum positive and negative amplitudes are in the range of 0.35-2.8 m.

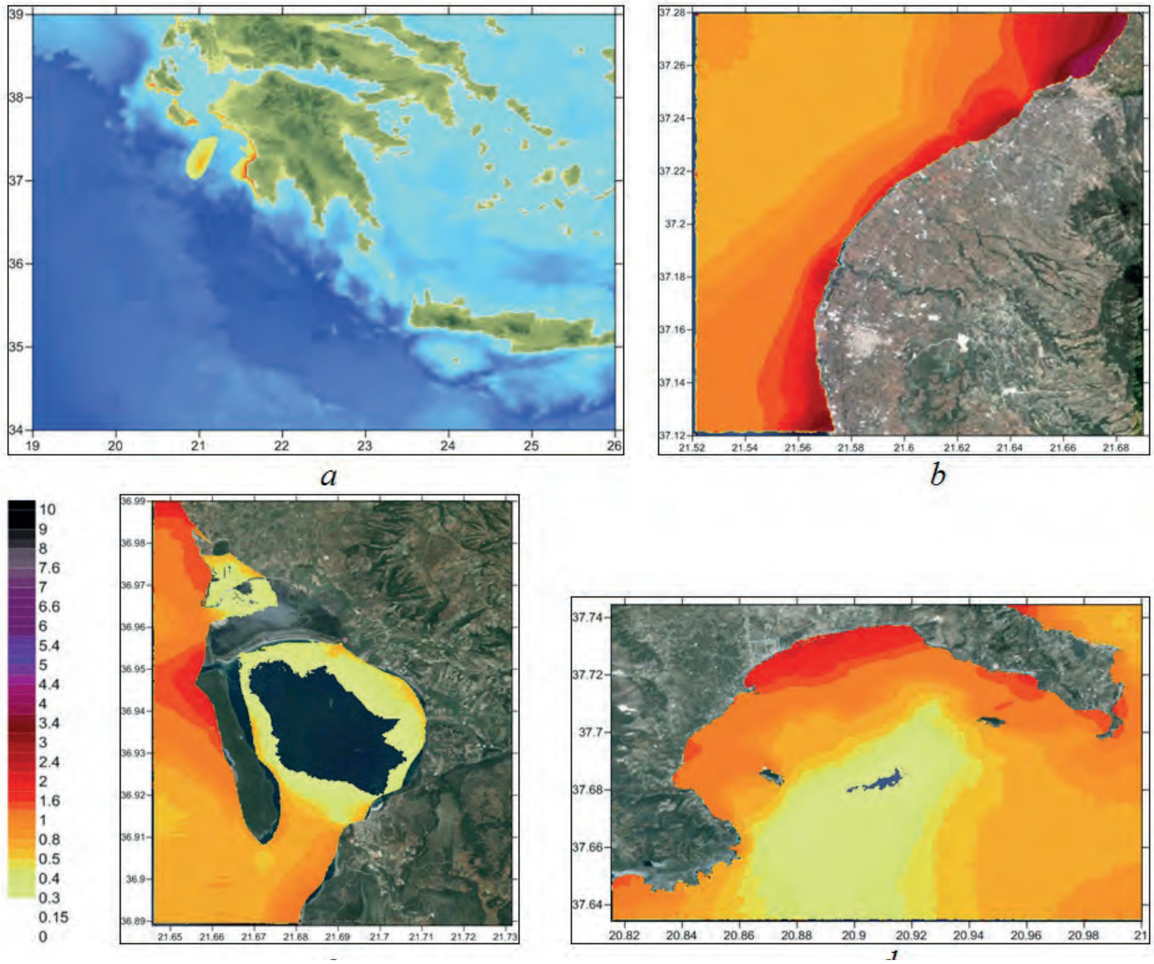


Fig. 5 - Maximum positive amplitudes for Domain B (a), Domain C in Filiatra region (b) and, Domain D in Pylos (c) and Zakynthos (d) regions.

Table 4 - Results of simulations of sources p02 and p04.

Source			p02				p04			
Name	Coordinates (°)	Depth (m)	Arr.time of first wave (m)	Arr.time of max. wave (m)	Max(+) wave amp. (m)	Max(-) wave amp. (m)	Arr.time of first wave (min)	Arr.time of max. wave (min)	Max(+) wave amp. (m)	Max(-) wave amp (m)
Zakynthos	20.899E 37.732N	5.7	0	15	4.68	-4.32	5	19	2.07	-1.61
Zakynthos	20.848E 37.701N	5.8	0	45	4.62	-3.76	4	52	1.30	-1.51
Filiatra	21.575E 37.188N	3.2	7	33	1.52	-0.88	1	8	1.87	-1.23
Filiatra	21.569E 37.133N	5.9	8	34	2.68	-2.22	1	9	2.72	-2.51
Pylos	21.694E 36.917N	3.1	17	68	0.40	-0.44	7	29	0.49	-0.58
Pylos	21.679E 36.923N	3.8	0	71	0.31	-0.29	0	29	0.35	-0.39

Table 5 - Results of simulations of sources p05 and p10.

Source			p05				p10			
Name	Coordinates (°)	Depth (m)	Arr.time of first wave (m)	Arr.time of max. wave (m)	Max(+) wave amp. (m)	Max(-) wave amp. (m)	Arr.time of first wave (min)	Arr.time of max. wave (min)	Max(+) wave amp. (m)	Max(-) wave amp (m)
Zakynthos	20.899E 37.732N	5.7	8	29	0.44	-0.42	13	49	0.19	-0.19
Zakynthos	20.848E 37.701N	5.8	9	80	0.40	-0.41	13	49	0.19	-0.16
Filiatra	21.575E 37.188N	3.2	0	19	0.35	-0.45	0	58	0.19	-0.22
Filiatra	21.569E 37.133N	5.9	1	31	0.59	-0.68	1	57	0.26	-0.21
Pylos	21.694E 36.917N	3.1	3	13	0.40	-0.19	2	4	0.27	-0.04
Pylos	21.679E 36.923N	3.8	0	13	0.31	-0.11	0	16	0.20	-0.01

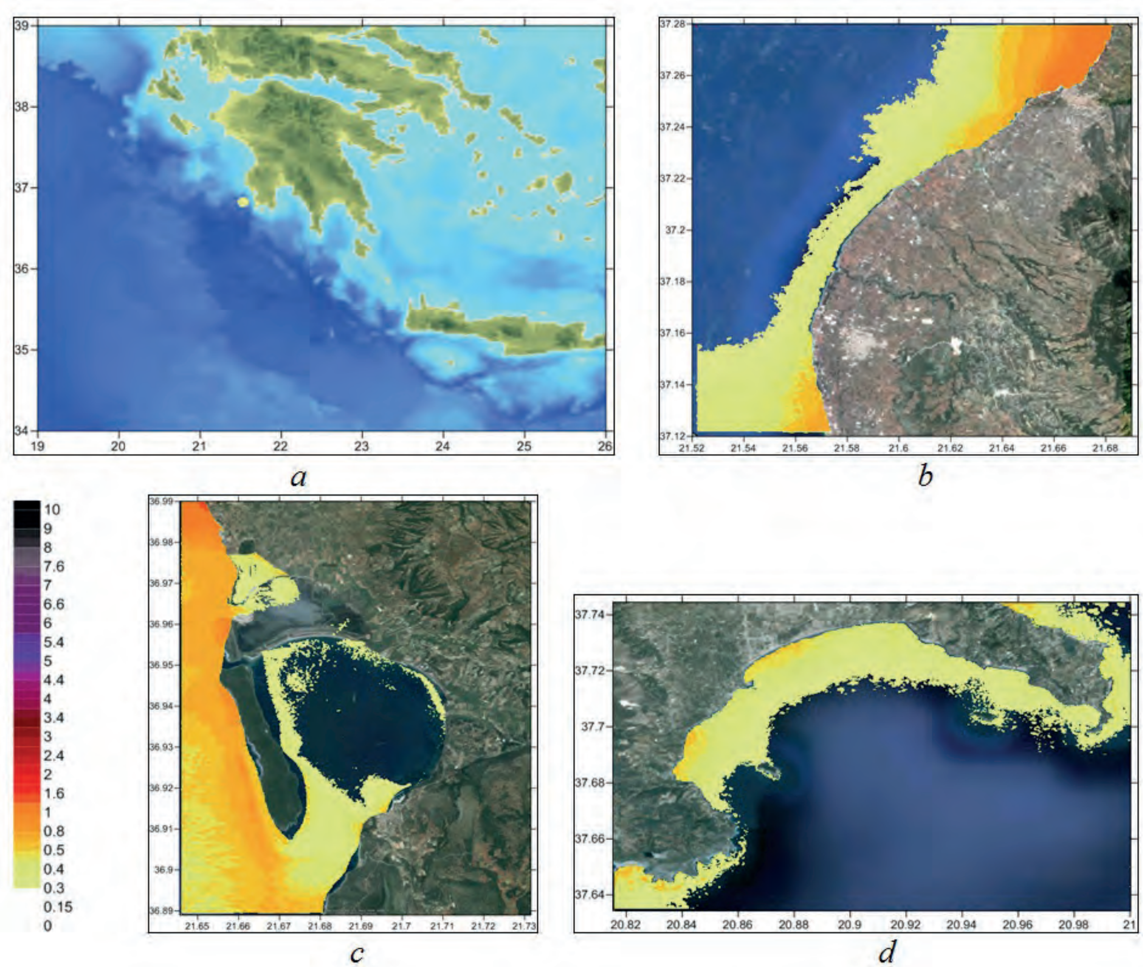


Fig. 6 - Maximum positive amplitudes for Domain B (a), Domain C in Filiatra region (b) and, Domain D in Pylos (c) and Zakynthos (d) regions.

4.1.3. Tsunami source p05

The distribution of the maximum positive amplitudes of tsunami waves in Domain B, Domain C of Filiatra region and Domain D of Pylos and Zakynthos regions are shown in Fig. 6 according to the simulation for the tsunami source p05. As seen from Fig. 6 that the tsunami related to the source p05 is more effective near Pylos comparing to other locations. Maximum tsunami amplitude at the shallow regions in Pylos is 0.5 m (Fig. 6d). They exceed 0.4 m near Filiatra and also Zakynthos regions.

The computed values time histories of water surface elevations near the selected towns are investigated and the arrival time of first and maximum wave, computed maximum positive and negative tsunami amplitudes at selected coordinates near the towns for the simulation of p05 are given in Table 5. The arrival time of first wave is said to be detected when the sea level changes exceeds +/-0.15 m. The arrival time of maximum wave is determined at the time of maximum tsunami amplitude at the location. As seen from Table 5, tsunami waves from the source p05 arrives in Pylos and Filiatra at around 0-5 minutes, and Zakynthos around 5-10 minutes. The maximum positive and negative amplitudes are in the range of 0.1-0.7 m.

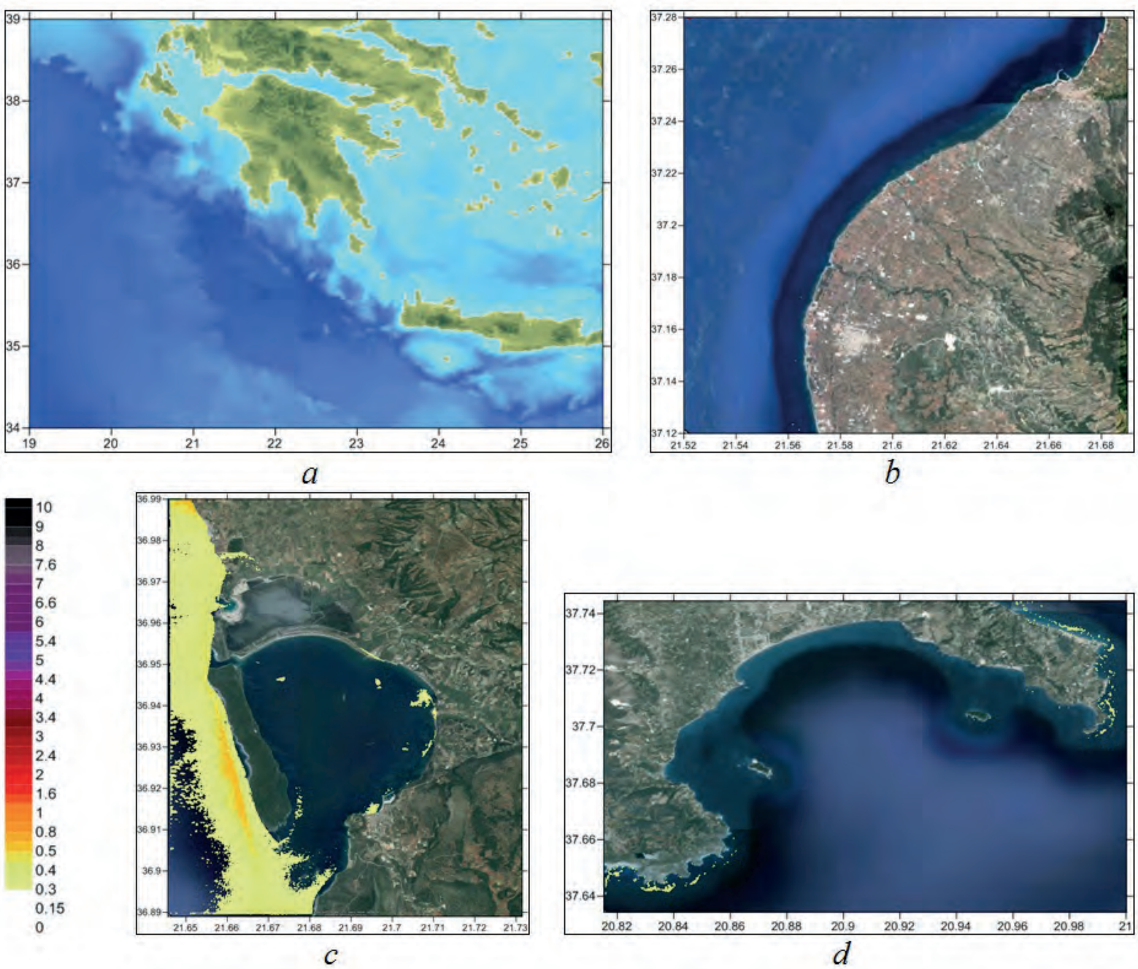


Fig. 7 - Maximum positive amplitudes for Domain B (a), Domain C in Filiatra region (b) and, Domain D in Pylos and Zakynthos (d) regions.

4.1.4 Tsunami source p10

The results of tsunami simulation for p10 at Domain B, Domain C of Filiatra region and Domain D of Filiatra, Pylos and Zakynthos regions are shown in Fig. 7. Maximum tsunami amplitude at the shallow regions in east bay of Zakynthos is around 1 m (Fig. 7e). They are about 0.7 m near Filiatra and also Pylos regions.

The computed values time histories of water surface elevations near the selected towns are investigated and the arrival time of first and maximum wave, computed maximum positive and negative tsunami amplitudes at selected coordinates near the towns for the simulation of p10 are given in Table 5. The arrival time of first wave is when the sea level changes exceed +/-0.15 m. The arrival time of maximum wave is determined at the time of maximum tsunami amplitude at the location. As seen from Table 5 that, tsunami waves from the source p10 arrives in Filiatra and Pylos at around 0-5 minutes, and Zakynthos around 15 minutes. The maximum positive and negative amplitudes are in the range of 0.01-0.3 m.

4.1.5. Landslide simulations for Kyparissiakos Gulf

Tsunamis can also occur as a result of submarine landslides. Heidarzadeh *et al.* (2014) presented the state of the art and numerical tools for modelling of landslide tsunamis. Papadopoulos *et al.* (2014) presented the historical seismicity of the Kyparissiakos Gulf. A detailed mapping of the bathymetric features was performed and the possible landslides and lithological variations at the marine bottom are determined in marine surveys of SEAHELLARC Project (Camera *et al.*, 2014). The uppermost sediments were mapped by sub-bottom profiling, while possible faults were identified by multi-channel reflection mapping. The possible landslide and associated tsunami in the Kyparissiakos Gulf is investigated by modelling in this section.

In the selected underwater landslide case 50 m maximum thickness is assumed to occur at the west coast of the study domain. Coordinates of landslide are taken between 21.48 E - 21.59 E and 37.42 N - 37.52 N. The area and volume of the landslide is estimated as 75 km^2 and 15 km^3, respectively using Camera *et al.* (2014). The location of the landslide and its thickness distribution is shown in Fig. 8.

The landslide case is simulated by using TWO LAYER model for 5 minutes duration. TWO LAYER model (Imamura and Imteaz, 1995) computes landslide motion by solving nonlinear shallow water equations in two layers (lower layer is mud and upper layer is water). After simulating landslide with TWO LAYER model for 5 minutes, the simulation is continued with NAMI DANCE for 1 hour. The maximum water surface elevation is computed as 26.7 m at landslide location. The distribution of the maximum water surface elevation is shown in Fig. 9a.

The distribution of arrival time of first wave is shown in Fig. 9b. The wave arrives Kyparissia and Filiatra nearly in 8 minutes and Pylos and Zakynthos in 15 minutes.

The time histories of the water surface fluctuations at selected gauge locations are also computed. The locations of the selected four points (near Zakynthos, Filiatra, Kyparissia, Pylos) and the water surface fluctuations at these locations are shown in Fig. 10.

The results are summarized in Table 6. The table shows gauge point locations, depths, arrival time of first and maximum waves and maximum positive and negative wave amplitudes. According to the results, the most affected area is Filiatra with maximum wave amplitude nearly 10 m and arrival time less than 5 minutes. The other areas investigated are

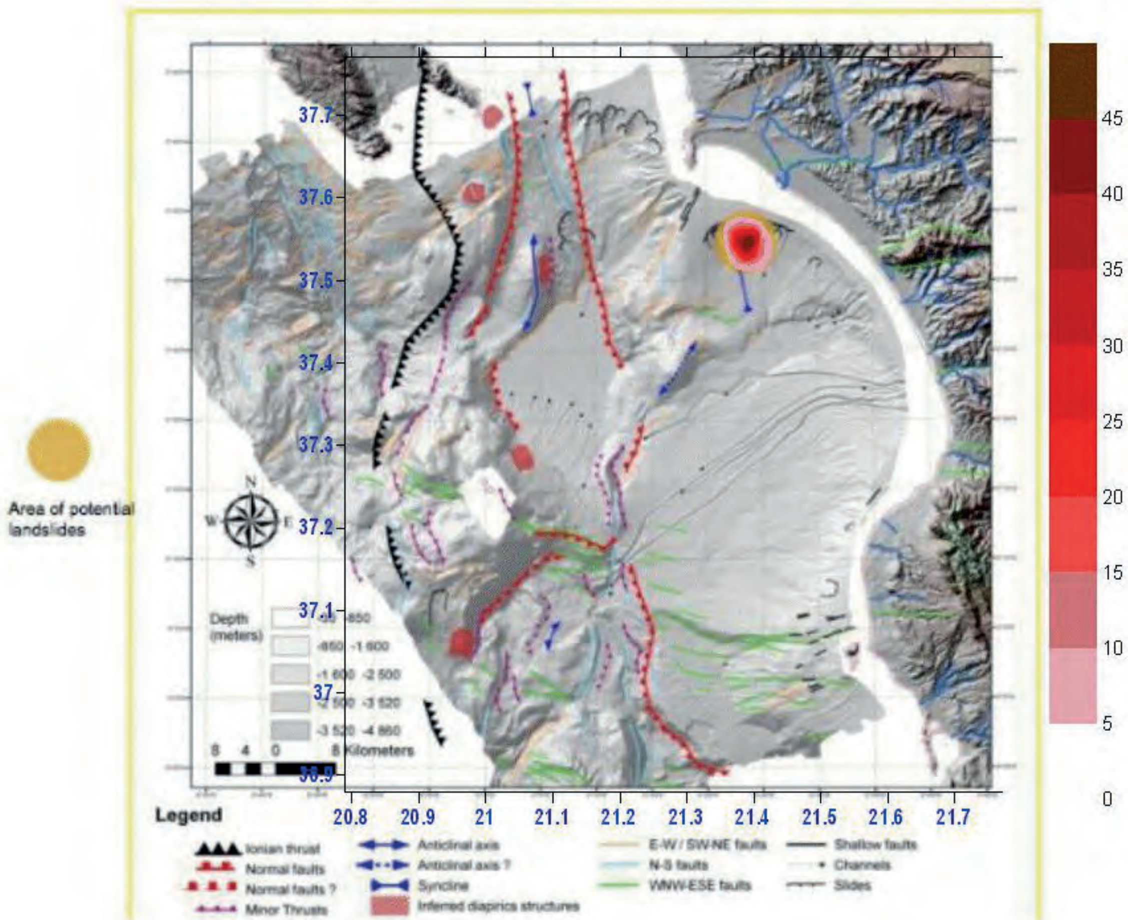


Fig. 8 - Landslide location and selected thickness distribution of the landslide (modified from Wardell *et al.*, 2014).

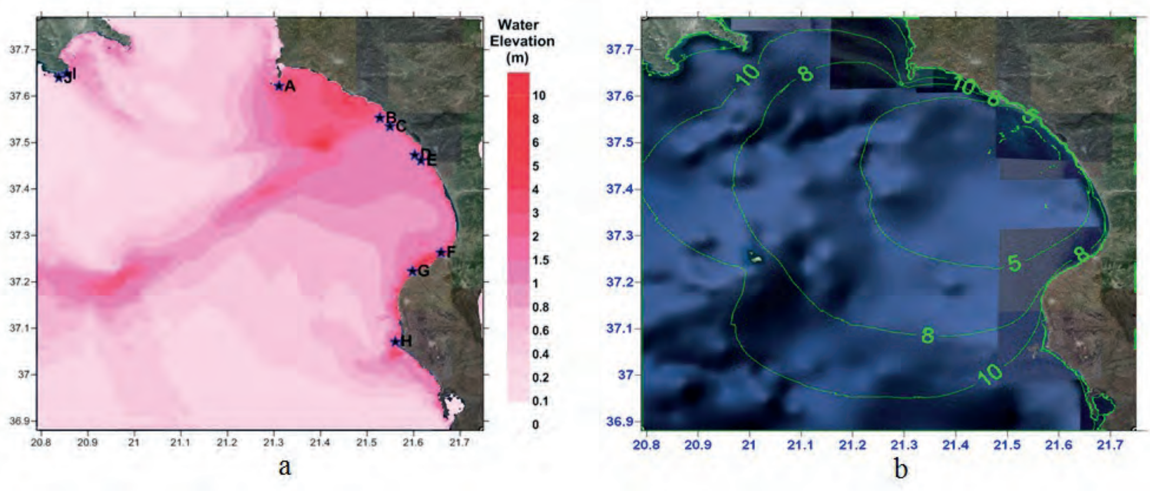


Fig. 9 - Distribution of maximum water surface elevation (a) and arrival time of first wave in minutes (b).

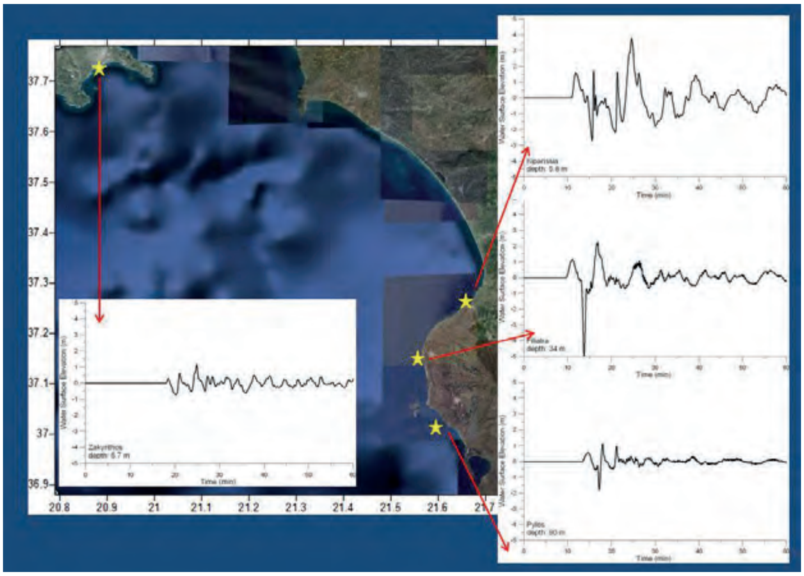


Fig. 10 - Time histories of water level change at some numerical gauge points according to simulated landslide generated tsunami.

expected to be affected less severly. The amplitude at north of Pylos is maximum 4 m while the maximum at Kyparissia and Zakynthos is nearly 5 m.

Table 6 - Summary results of landslide simulation.

Name		Depth (m)	Long. (°E)	Lat. (°N)	Arr.time of first wave	Arr.time of max.wave	Max.(+) wave amp. (m)	Max.(-) wave amp (m)
Pylos	**A**	6.4	21.311	37.62	8	9	2.2	-3.6
Pylos	**B**	32.9	21.528	37.553	<5	9	3.8	-1.2
Filiatra	**C**	35	21.549	37.535	<5	9	**7.1**	-1.1
Filiatra	**D**	55.2	21.603	37.473	<5	9	**9.8**	-2.0
Filiatra	**E**	35.3	21.616	37.461	<5	9	**9.4**	-3.0
Kyparissia	**F**	5.8	21.659	37.263	9	22	4.6	-4.2
Kyparissia	**G**	13	21.597	37.223	8	11	4.6	-9.2
Kyparissia	**H**	10.7	21.561	37.072	12	20	3.2	-4.9
Zakynthos	**I**	25.2	20.855	37.645	13	17	4.6	-5.5
Zakynthos	**J**	41	20.837	37.639	13	17	5.1	-3.6

5. Discussion and conclusion

In this study, we evaluated the tsunami generation mechanisms and estimated the tsunami sources related to surficial SZs given in Slejko *et al*. (2014) for western Greece region. These sources are considered to be the possible tsunami sources, which might occur in the region.

They are also considered to be effective for the Pylos area and the other additionally selected areas such as Kyparissia, Filiatra and Zakynthos.

The rupture characteristics of historical earthquakes triggered tsunamis cannot be determined accurately by using only available instrumental seismic data. In order to perform tsunami modelling as accurate as possible, the bathymetry/topography data with high resolution were used in the simulations.

The estimated values of the rupture parameters of the selected surficial zones (p01, p02, p04, p05, p10) were used and complete simulations were performed. We assumed a range of fault parameters that are compatible with the seismicity of the region. We also calculated the tsunami wave heights and arrival times to the towns in the region. Our calculations appear to be in broad agreement with the accounts of paleo-tsunamis that have been reported for these towns, and indicate that the tsunami may constitute a realistic threat for the regional tourist and fishing industry. In Tables 4 to 6 we listed the calculated wave heights that might be used in the preliminary safety assessment of critical sea front facilities.

According to simulation results of selected tsunami cases, it is seen that the tsunami generated i) at the source p02 is more effective near Zakynthos, ii) at the source p04 is more badly effective near Pylos and Filiatra, iii) Filiatra, comparing to other study locations, has higher risk of getting damaged as a result of tsunamis of the sources p05 and p10. The landslide tsunami simulated in this study cause much higher wave amplitudes in Filiatra than Pylos, Kyparissia, and Zakynthos, which means higher probability of human and property loss in the case of a landslide generated tsunami comparing to seismic tsunami sources.

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