THE 20th JULY 2017 (22:31 UTC) BODRUM/KOS EARTHQUAKE AND TSUNAMI; POST TSUNAMI FIELD SURVEY REPORT

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Update History

Version 0.0 as preliminary report (containing quick survey results (performed on July 22-24, 2017) has been publicized on July 28, 2017 which is available at
http://users.metu.edu.tr/yalciner/july-21-2017-tsunami-report/Report-Field-Survey-of-tsunami-effects-at-S-of-Bodrum-Peninsula.docx

Version 1.0 as complete report results (performed on July 28-August 03, 2017) has been publicized on August 10, 2017 which is available at

http://users.metu.edu.tr/yalciner/july-21-2017-tsunami-report/Report-Field-Survey-of-July-20-2017-Bodrum-Kos-Tsunami-ver-01.pdf

Version 2.0 as complete extended report (This report) has been publicized on August 17, 2017 which is available at

http://users.metu.edu.tr/yalciner/july-21-2017-tsunami-report/Report-Field-Survey-of-July-20-2017-Bodrum-Kos-Tsunami.pdf

In this version a new chapter (Chapter 8 prepared by Prof. Dr. Taro Arikava, Research Assistant Hasan Gokhan Guler and Prof. Dr. Ahmet Cevdet Yalciner) is added.

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ABSTRACT

A strong earthquake (Mw=6.6) of normal faulting striking about E-W occurred on July 20, 2017 (22:31 UTC) in between Bodrum town (Turkey) and Kos island (Greece). The earthquake caused a tsunami which affected the coast of Bodrum peninsula and the northeast coast of Kos island. Two post-event tsunami field surveys were performed. The first one was held on July 22 and 23, 2017 along the South of Bodrum Peninsula by METU and KOERI in collaboration with Turkish Chamber of Civil Engineers (TCCE). A. C. Yalciner, G. G. Dogan, H. G. Guler, T. E. Cakir, C. O. Sozdinler, L. Suzen participated at the first field survey. The other field survey was held in between July 28 and August 3, 2017 along the south coast of Bodrum Peninsula (A. C. Yalciner, G. G. Dogan, H. G. Guler, A. Annunziato, C. O. Sozdinler, T. Arikawa, T. E. Cakir, I. Guler, C. Synolakis, U. Kanoglu), Karaada-Black Island (A. C. Yalciner, G. G. Dogan), Akyaka town (A. Annunziato, C. O. Sozdinler, E. Ulutas), and Kos island (A. Annunziato, G. A. Papadopoulos, E. Ulutas).

The tsunami was recorded by a tide gauge, located in Bodrum, close to the earthquake epicenter. The main objectives of these surveys have been to document the variation of the tsunami effects along the coast, to obtain any available data on the wave height and inundation extent and to understand and explain the event in detail.

According to findings in field surveys and eyewitness reports, there was almost no significant water motion at the western face of Bodrum peninsula. The tsunami effects were observed at the south coast of Bodrum peninsula only from geographic latitude 27.255E to 27.528E as well as in the northeast coast of Kos Island. The maximum run-up of about 1.9 m was observed at the mouth of a small dry stream (27.407924E, 37.029879N) at Gumbet Bay, which is the most hit area by the tsunami at Bodrum Peninsula. There is an interesting observation that no damage happened in the next bay (Bitez bay at West and Bodrum marina at East of Gumbet bay) which indicates that main impacts of tsunami localized in Gumbet bay.

According to the analysis of the records of a security camera at easternmost end of Gumbet bay, sea receded 5 minutes after the earthquake and advanced up to 60m inundation at 13th minute. The run-up traces were found at 2 m elevation (not the inundation border) at Karaada-Black Island (27.461422E, 36.966323N) Kucuk Poyraz bay which is facing the tsunami source area at the epicenter. The tsunami has also been observed at Akyaka village at the eastern end of Gokova bay 80 km away from the epicenter. In Kos, the maximum amplitude of ~1.5 m was

observed in the old port of the town, as it comes out from eyewitness accounts, tsunami traces left behind and the analysis of security camera video. In the coast outside the Kos port the tsunami heights did not exceed ~1.0 m. This event occurred in a small area and showed unexpected run-up distribution in the near field area which indicates that the tsunami triggering mechanism is not homogeneous. The event also reminded that the tsunami potential in the eastern Mediterranean is considerable.

1. INTRODUCTION

A strong earthquake happened in Gokova Bay on July 20, 2017 (22:31 UTC) causing strong wave motions and damages at some small bays at South of Bodrum peninsula (SW of Turkey). The earthquake and wave motions have been felt in Kos island Greece; the port of Kos experienced extensive inundation and some damages to the infrastructures and some boats. Figure 1.1 shows the region where the tsunami was effective. A quick tsunami field survey along the south coast of Bodrum Peninsula was organized and performed by METU and KOERI in collaboration with Turkish Chamber of Civil Engineers (TCCE) on July 22 and 23, 2017. A second tsunami field survey was held on July 28-31, 2017 in collaboration with Costas Synolakis and Alessandro Annunziato, in order to obtain additional information and to fill the gaps in observations of the first field survey. Alessandro Annunziato, Gerassimos Papadopoulos and Ergin Ulutas also performed the Tsunami Field survey on the Greek island of Kos in order to report the situation and complete the picture of the Tsunami impact. Taro Arikawa, Lutfi Suzen, Costas Synolakis, Utku Kanoglu, Isikhan Guler and Philip England also participated to the post event survey. The UNESCO International Tsunami Survey Team (ITST) Post -Tsunami Survey Field Guide 2nd Edition, 2014 has been followed (http://itic.ioc-unesco.org/images/stories/itst_tsunami_survey/survey_documents/field_survey_guide/ITST_

FieldSurveyGuide_229456E.pdf).

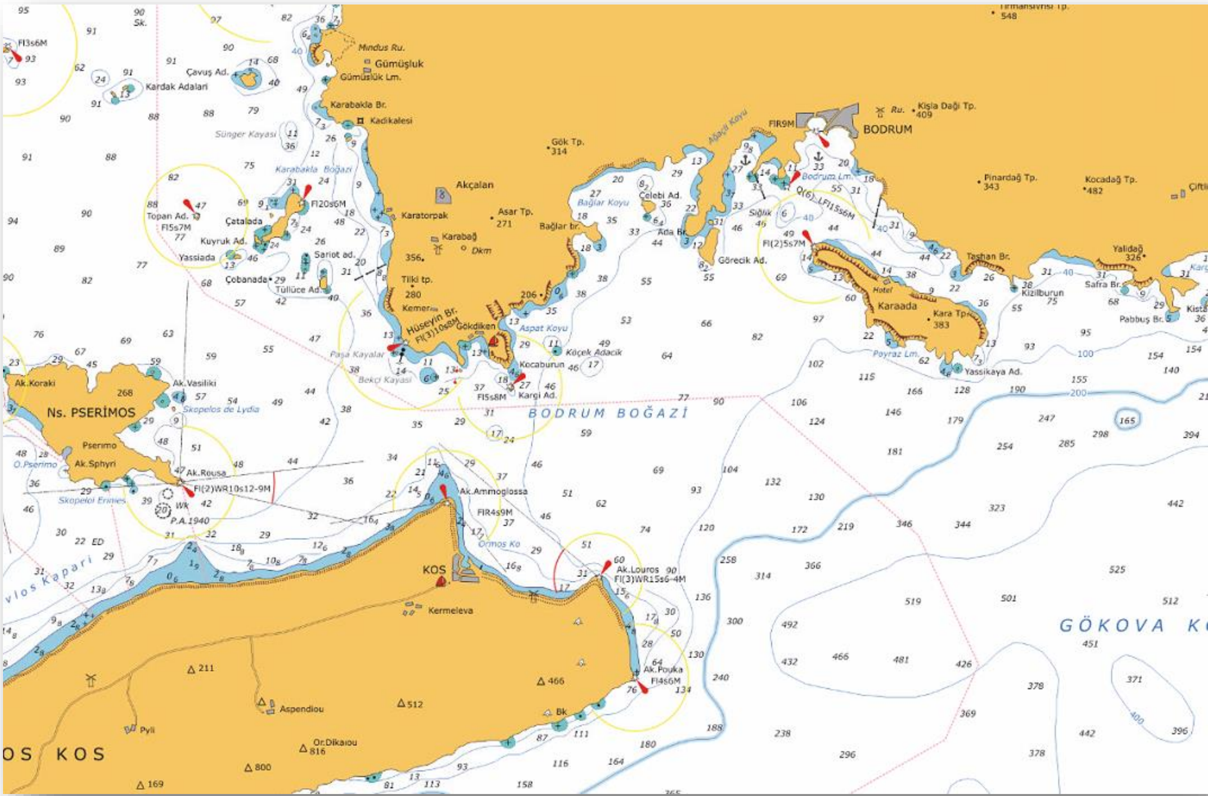


Figure 1.1: A bathymetric map around Kos and Bodrum

The main objectives of these surveys were to document the variation of the tsunami effects along the coast, to obtain any available data on the wave height and inundation extent and to understand the event in detail for the scientific studies of tsunamis. According to our field survey and eyewitness reports, there was almost no significant water motion at western face of Bodrum Peninsula. The tsunami effects are observed at south coast of Bodrum peninsula only from 27.255E to 27.528E and in the North-East coast of Kos island. The major run-up was about 1.9 meter observed at the mouth of small dry stream (27.407924E 37.029879N) at Gumbet Bay. This report briefly presents the observations, measurements and discussions/interpretations of eyewitness interviews. The report will be updated with further info when obtained.

The Tsunami has been measured by a very close tide gauge, located in Bodrum, thus very close to the Epicenter. Due to the importance of this measurement and to the fact that large difference appeared between this measurement (11 cm of oscillation) and the results of the first survey data (more than 1.5 m in Gumbet bay), it was decided to calibrate this instrument by performing a temporary installation of an IDSL[1] by JRC. Appendix B report the results of this calibration. Appendix D describe one of the tools that was used during the survey missions.

2. EARTHQUAKE INFORMATION

The earthquake happened in Gokova Bay on July 21, 2017 at 01:31 local time (22:31 UTC) at 36.9620N 27.4053E (KOERI), with the moment magnitude of M_w=6.6 (M_l= 6.2) at a depth of 5km. NOA estimations also give the earthquake at 36.9643N 27.4332E with a moment magnitude of M_w=6.4 (M_l= 6.2) at a depth of 10.2km. The epicenter is about 12km ENE of Kos, Greece and 8 km SSW of Bodrum, Turkey. The earthquake was highly felt in Southwestern Aegean Region, especially in Mugla Province. The fault mechanism calculations reveal that the earthquake occurred with a normal faulting and many aftershocks were recorded after the main shock having the maximum moment magnitude of M_w=4.8.

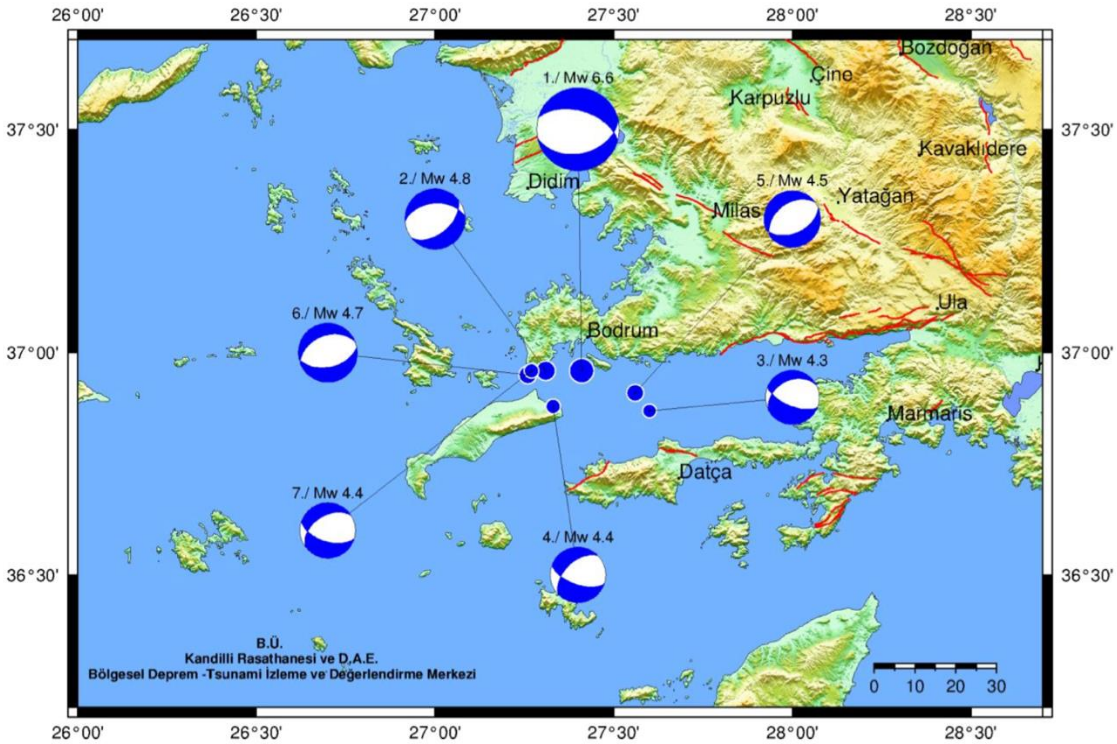


Figure 2.1: Fault mechanisms of main shock and aftershocks by KOERI

[1] Inexpensive Device for Sea Level measurements, it is a low-cost instrument, developed by JRC, that has been already installed in several locations in the Mediterranean Sea in the frame of UNESCO-IOC NEAMTWS activities.

According to the first intensity maps produced by ELER in KOERI, the earthquake intensity in Bodrum was VII which indicates that the perceived shaking was very strong while the potential damage was moderate. The earthquake intensity in Kos Island, Bodrum Peninsula and North of Datca Peninsula was VI representing strong perceived shaking and light potential damage.

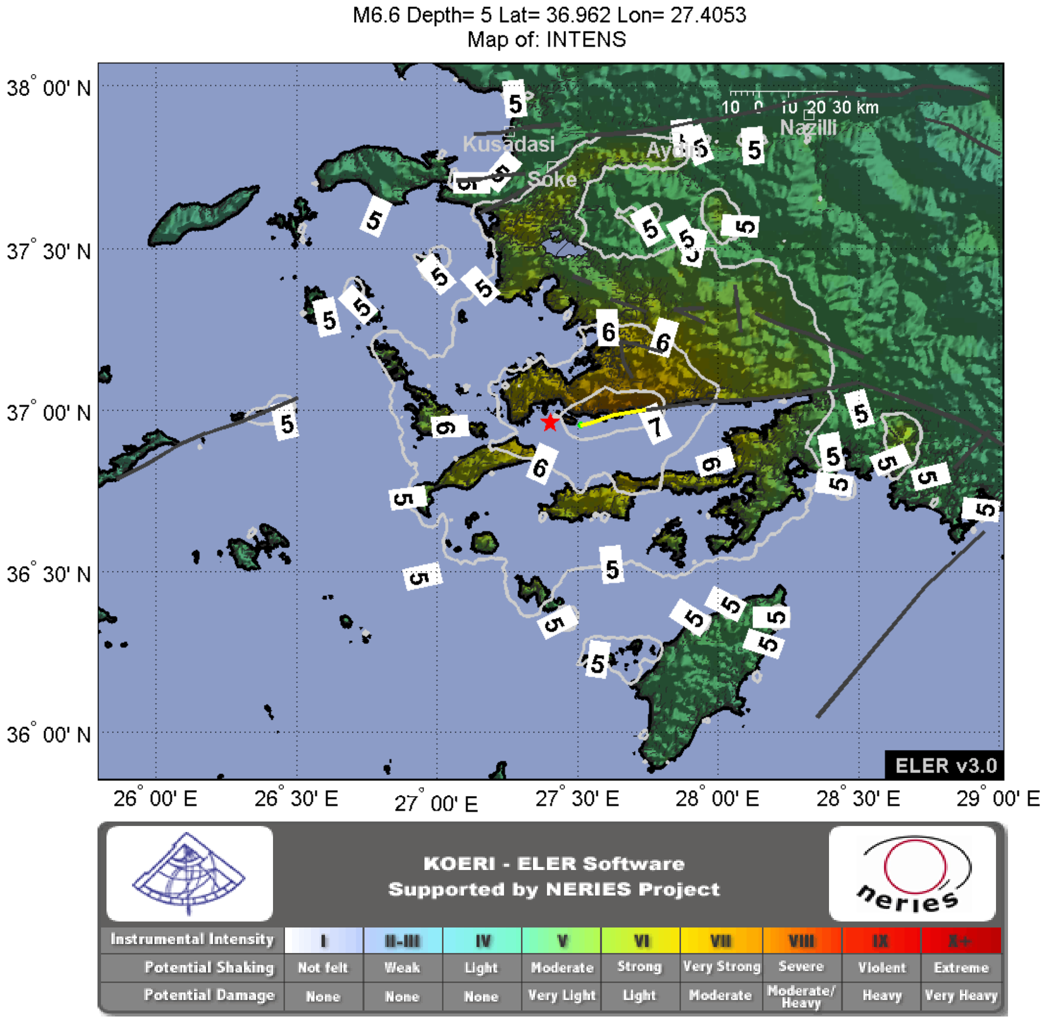


Figure 2.2: Earthquake Intensity Map produced by ELER (KOERI) (M6.6) (*Source:* ELER-v3.1: http://www.koeri.boun.edu.tr/Haberler/NERIES%20ELER%20V3.1_6_176.depmuh)

The Tsunami has been measured by a very close tide gauge, located in Bodrum very close to the Epicenter(http://www.iocsealevelmonitoring.org/station.php?code=bodr&period=1&endtime=2017-07-21%2020:00). Due to the importance of this measurement and to the fact that large difference appeared between this measurement (11 cm of oscillation) and the results of the first survey data (more than 1.5 m in Gumbet bay), it was decided to calibrate this instrument by performing a temporary installation of an IDSL[2] by JRC.

The calibration indicated that the tide gauge records can be considered reliable and therefore the different values measured at the tide gauge and in the various bays should be justified by modelling assumptions and bathymetry data.

Appendix B reports the results of this calibration activity.

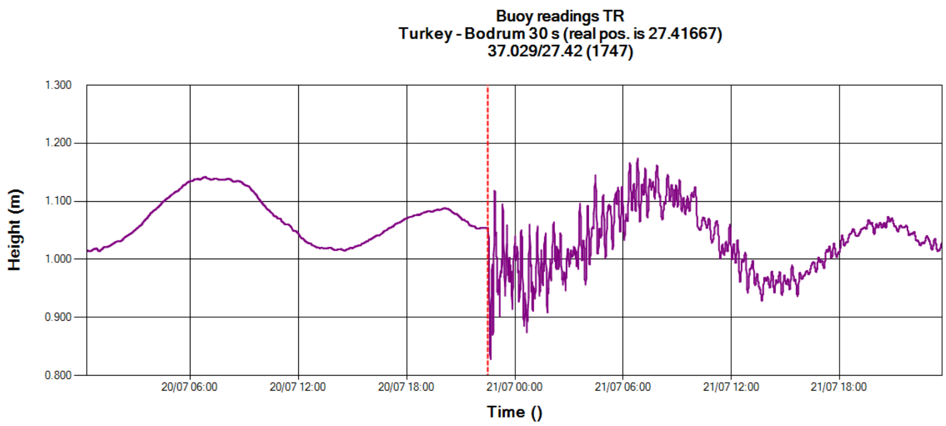


Figure 2.3: Sea Level in Bodrum

3. FIELD OBSERVATIONS ON TSUNAMI SUMMARY

The field survey is performed on July 22 and 23, 2017 along the southern coasts of Bodrum Peninsula in between 27.255E 37.000N (Turgutreis Marina) and 27.528E 36.992N (Yaliciftlik region). The second survey held on July 28-31, 2017 added more points to the survey area as well as the regions of Karaada (Black Island) and Akyaka. Another survey was performed from 1st to 3rd August on Kos Island. Figure 3.1 shows the survey locations on which the numbers indicate coastal sites where local authorities were contacted and observations on the tsunami waves are obtained. In Table 3.1, a complete list of these coastal sites is given. (The ID numbers in the figure are the same as in Table 3.1.).

[2] Inexpensive Device for Sea Level measurements, it is a low-cost instrument, developed by JRC, that has been already installed in several locations in the Mediterranean Sea in the frame of UNESCO-IOC NEAMTWS activities.

Figure 3.1: Location map showing the distribution of the observations of the tsunami waves, obtained from locals, from debris or traces identified

Table 3.1: List of the surveyed places local people inquired to describe the effects of the tsunami

	Place	Region	Lon. E	Lat. N	Locals inquired	Tsunami Measurement	Wave Receding
1	Turgutreis D-Marin	Turgutreis	27.257491	37.001613	Chief of the marina	No major wave oscillation	
2	Olivia Restaurant	Fener Beach, Akyarlar	27.264562	36.964772	Restaurant manager	No major wave oscillation	
3	Kilavuz Motel Beach	Akyarlar Bay	27.29093	36.967359	Fishermen and summerhouse residents	1.2m	
4	Balmahmut's Place	Karaincir	27.300496	36.972961	Restaurant manager	1.4m	≈-1.2m
5	Aspat Beach	Aspat Bay	27.312356	36.979592	Beach workers	1.0m	
6	Camel Beach	Kargi Bay	27.330562	37.013582	Beach and restaurant workers	0.5m	≈-1.2m
7	Bitez Beach	Bitez Bay	27.383582	37.025615	Beach and restaurant workers	0.5m	
8	Municipality Café (MC) and River Stream (RS)	Gumbet Bay	27.405322	37.030868	Fishermen, visitors and other locals	0.56m (MC) 1.9m (RS)	
9	Bodrum Marina	Bodrum Center	27.424827	37.035808	Marina workers and visitors	1.0-1.2m	≈-1.7m
10	Yali Café	Yaliciftlik	27.527908	36.992786	Café workers	No major wave oscillation	
11	Turgut Reis Fishery Harbor	Turgut Reis	27.256357	37.005985	Fisherman	0.6m	≈-1.0m
12	Small Beach Hotel	Turgut Reis	27.256784	36.982089	Beach bar workers	No major wave oscillation	
13	Meteor Beach	Dogu Beach	27.278796	36.966191	Beach workers	0.9m	

14	Xanadu Island Hotel	Akyarlar Peninsula Tip	27.286211	36.960685	Hotel manager and several beach workers	0.5m	
15	La Brezza Beach	Western Karaincir Bay	27.300179	36.969923	Beach Café manager	1.2m	
16	Meteor – 2 Beach	Eastern Karaincir Bay	27.300932	36.973495	Beach Café manager and workers	1.4m	
17	Tek Sitesi	Eastern Karaincir Bay	27.304098	36.975839	Summerhouse residents	0.8m-1.0m	≈-1.5m
18	Bitez Mor Beach	Western Bitez Bay	27.372414	37.023757	Beach Café workers	-	
19	Western Bitez Beach	Western Bitez Bay	27.372940	37.026947	Beach Café workers	0.9m	≈-1.5m
20	Eastern Bitez Beach	Eastern Bitez Bay	27.384460	37.024770	Beach Café workers	0.5m	≈-1.5m
21	Nagi Beach	Gumbet Bay	27.403552	37.031463	Beach workers	1.15m	
22	Cesar Beach Hotel	Gumbet Bay			Hotel general manager	-	≈-1.3m
23	Voyage Hotel Bodrum	Bodrum Marina Region	27.416967	37.027506	Hotel manager and workers	1.0m	≈-1.7m
24	Kucukpoyraz	Karaada (Black Island)	27.461422	36.966323	Visual observation	1.5m-2.0m	
25	Akyaka Beach and River Branch	Akyaka	28.324425	37.050832	Workers of cafes and fisheries cooperative	0.6m	≈-1.0m

Figure 3.2: Results of Bodrum Tsunami Survey

The description of post tsunami field observations is split into areas as follows:

- Bodrum area and surroundings
- Karaada Island
- Akyaka
- Kos

4. FIELD OBSERVATIONS IN BODRUM AND SURROUNDINGS

The observations of the post event started on 22th of July 2017 on Saturday at Gumbet Bay **(8)** which seems the most hit area by the tsunami waves in Bodrum Peninsula. Waves first receded 5min after the earthquake and then the first wave arrived 12-13 minutes after the earthquake. Figure 4.1 describes the motion of the wave according to the observations.

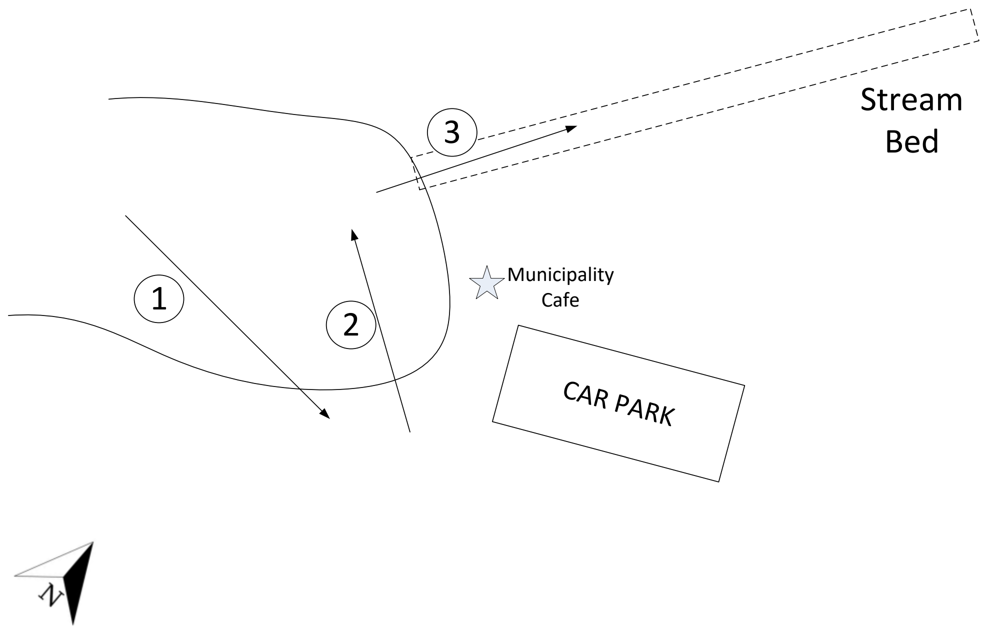


Figure 4.1: The motion of tsunami at eastern end of Gumbet Bay (Municipality café is at 27.408503E 37.029732N).

It is stated by the workers that approximately 20m of inundation is observed near the municipality café. The flow depth in front of the municipality café is measured as 0.56m in the second survey. Waves dragged the parked cars near the shoreline on the concrete bed of dry stream. Totally 12 cars have been dragged and all were collected in the same location (37.031137N 27.406882E) away from the shore at the stream and concrete planters in front of these car parking area. Eyewitnesses from the sea front restaurant staff reported successive waves (sea withdrawal and advancing) until the sun rise (about three hours after the earthquake). In the next morning after the earthquake, water level was decreased about 2m in vertical (Figure 4.2). People have found dead fish mostly near and around the stream bed, and all along the coastline of the bay. Besides, they observed remarkable increase in the number of rare insects in last couple of days on the ground.

Figure 4.2: View of sea withdrawal in Gumbet Bay about three hours after the earthquake

The waves mostly penetrated through the dried stream bed (used as a road and parking place) near Ayaz Hotel (Figure 4.3). The width of the road is 3.3 meters (5.7 meters with side walls). The waves penetrated through this stream bed, accelerated as flowing in a channel and reached up to 100m away from the shoreline. The maximum flow depth in the stream bed was around 0.85 m (Figure 4.4). According to the security camera records of a hotel, waves reached to the entrance door of hotel about 13min after the earthquake. The tsunami inundation distance is about 60 meters and flow depth reached up to 0.5-0.6m. Waves flew in strong current in hotel front.

Figure 4.3: Penetration of the waves through the dried stream bed near Ayaz Hotel

Figure 4.4: Observer showing the flow depth by his foot (37.031412N 27.406703E**)**

Figure 4.5: View of the stream bed that the tsunami inundated (27.407821E 37.029761N**)**

In the second survey, the run-up height is measured as 1.15m at Nagi Beach (**21**) which is located at the western part of Gumbet Bay with an inundation distance of 35m. In the last 15 days before the earthquake, there were anomalies in the sea (eyewitnesses reported that at some time the water temperature dramatically increased in some locations of Gumbet bay (Nagi beach club, 27.403552E 37.031463N) in the last 2 weeks before the earthquake. Some eyewitnesses reported the sea bottom topography was changed in two weeks before the tremor. Abnormal currents have been felt by some people when they were swimming in Gumbet Bay. An amateur fisherman (an Australian tourist) reported that about two weeks before the earthquake while he was fishing in his boat at a location (40m water depth) between Kara Ada-Black Island (27.423E, 36.9958N) and Aquarium bay at Adabogazi (27.3875E, 37.0003N), he observed that water uplifted like a pumping up. The waves dispersed away. The coordinate measurements and related observations along Gumbet Bay are given in Table A.1 in Appendix A.

In the second survey, the general manager of Cesar Beach Hotel in Gumbet Bay (**22**) reported an inundation distance of 100m. The sea withdrawal was measured as 30m up to a depth of 1.3m.

At the most eastern part of Gumbet bay (27.407621E, 37.037478N), the small boats berthed at shallow region. Tsunami dragged all boats together and moved them away from the shore to the location (27.405029E, 37.0281.33N) in the bay. More than 30 boats were damaged and more than 10 boats sunk in this location. The boat captains reported that there was very strong swirling water motion at three locations in the bay. Approximate locations are i) 27.405029E, 37.0281.33N, ii) 27.400399E, 32.029001N, iii) 27.403934E, 37.030043N. In the second survey, the run-up height is measured as 1.72m in this berthing region.

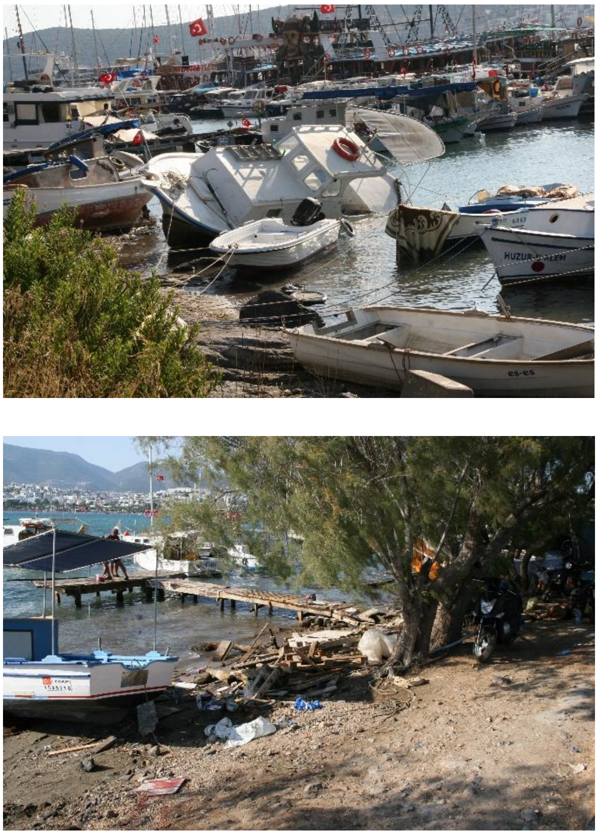


Figure 4.6: View of damaged boats and coastline of Gumbet Bay

Figure 4.7: Damaged minibus and advertisement board

In the second survey, the team also gathered information from Voyage Hotel Bodrum Beach (**23**) which is located at southwest of Bodrum Marina entrance. According to the observer statements, the sea receded 30m up to a depth of 1.7m. The inundation distance at this location is 20m and the run-up height is reported as 1m. An observer who was on his boat at Bodrum Marina (**9)** at the time of earthquake occurrence also stated a run-up height of 1.2m. He said that he observed swirling water and 4-5 times of water withdrawal and water level increase.

On July 23, 2017, the survey team started to collect information from Yaliciftlik Bay **(10)** which seems the most probable boundary for significant inundation at the eastern end of Southern coastline of Bodrum Peninsula. Any major damage is not reported in the bay and the boats in the dockyard were toppled due to the earthquake effect). Limited inundation was observed along the coast and it is noted by the locals that the sea is not shallow along this coast and the sea slope is steep). No inundation was also observed along the stream. Big holes which can be seen in Figure 4.8 might have appeared due to liquefaction and/or collapse of the sand material placed on the rubble material. The coordinate measurements and related observations along Yaliciftlik Bay is given in Table A.2 in Appendix A.

Figure 4.8: Big hole appeared at Yaliciftlik Bay after the earthquake (27.527908E 36.992786N)

The survey continued at D-Marin **(1)** at Turgut Reis area which is located at western coast of Bodrum Peninsula. According to the chief of the marina, strong currents were observed along the circulation channels on the breakwater. On the other hand, no run-up is observed or reported. The marina chief states that ±50cm is the normal tide and they did not observe any additional sea level change. The chief also got information from the captains of the yachts moored at Kalimnos Port and Vathi bay. According to indirect information, the water level decreased first just after the earthquake and the boats sat on sea bed at Kalimnos. Currents occurred at Vathi bay 4 hours after the earthquake. Kalimnos Port had major damage due to the earthquake effect.

In the second survey, additional information is obtained at Turgutreis Fishery harbor (**11**). In this location, the water level increased 60cm in front of the vertical wall. The subsidence is observed about -1m. The beach bar workers at Small Beach Hotel (**12**), however, stated that they observed no water level anomalies at sea during the night of the earthquake occurrence.

Fener Beach **(2)** which is located at the corner of western and southern coasts of Bodrum Peninsula is the most probable boundary for significant inundation at the western end of Southern coastline of Bodrum Peninsula according to the information obtained from Olivia Restaurant workers (Figure 4.9). However, information on Meteor Beach which is at the western nearby of Fener Beach shows approximately 40cm water level change. Locals state 2-2.5 m water drawdown at first and then 1-2m inundation. The coordinate measurements and related observations at Fener Beach is given in Table A.3 in Appendix A. In the second survey, the inundation distance is measured as 8.6m and the run-up height is measured as 0.9m at Meteor Beach (**13**) according to the statements of the beach workers (Figure 4.10).

Figure 4.9: Boundary of the tsunami observation at the western end of the Southern Coastline of Bodrum Peninsula according to eyewitnesses (27.264562E 36.964772N**)**

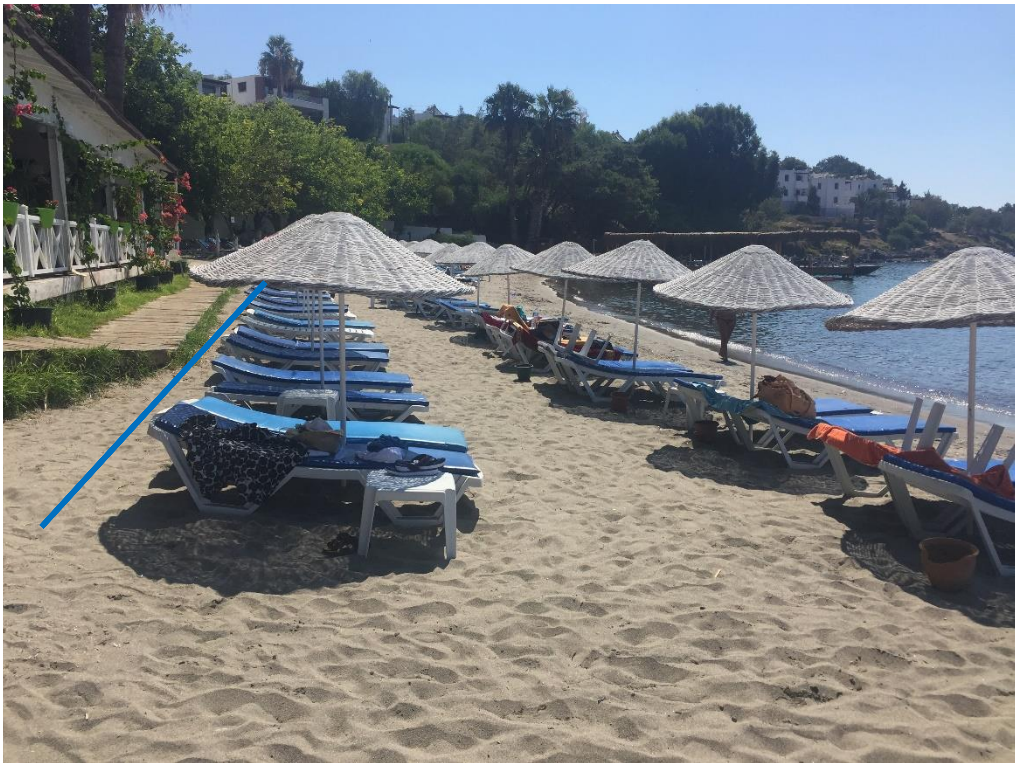


Figure 4.10: View of inundation line at Meteor Beach (27.278796E 36.966191N**)**

Approximately 10 meters of inundation distance is observed along the coast of Akyarlar Bay **(3).** One of the summerhouse residents observed that the small hole at 10-15m distance from the coast was all washed up by the waves. He stated that the flow depth was about 50cm. The port in this bay is at a safe location by the natural conditions, therefore no damage observed by the waves in the port. According to the fisherman observations in the port, the sea level first decreased and then rising was observed. Also, strong currents were observed at the nose of the breakwater, one of the fishermen said *''it was flowing like stream water at the entrance of the port''.* The dock height was measured as 80cm. The water level rise at the harbor was 120 cm according to the eyewitnesses. (Figure 4.11). Waves affected the part up to Akyarlar Motel (27.294602E, 36.967830N) if one considers a perpendicular line to the coastline from the head of the breakwater. The water level increased 40cm in front of the vertical wall of this motel. The coordinate measurements and related observations along Akyarlar Bay is given in Table A.4 in Appendix A.

There is a small peninsula oriented to south on the western part of Akyarlar Bay on which Xanadu Island Hotel (**14**) is located at the tip. There are no observed water level changes at the beach of this hotel according to the hotel manager and several beach workers. However, in the survey, there was some seaweed residuals 3m onshore of the beach at a level of 50cm which may be washed by the tsunami waves.

Figure 4.11: Schematic view of wave motion in Akyarlar Bay (27.290930E 36.967359N**)**

The field survey continued at Karaincir, Balmahmut's Place **(4)**. Inundation is reported approximately 60m near Atakan Beach, water drawdown is approximately 20m and the motion was like tidal wave according to the observers. The observers state that water level was first decreased and then rised up resulting in a total wave oscillation of +1.4m -1.2m. Also, in the second survey, the maximum run-up height is observed and measured in the stream bed (width: 2.5m) as 1.4m (0.8m flow depth + 0.6m elevation) at 100m away from the shore. Then the inundation was observed up to 150m along the stream bed. Furthermore, the traces on the walls of the stream bed shows that more than one wave (at least three waves) has reached (Figure 4.12) the Karaincir locality. The run-up height is also measured as 1.5m (0.5m flow depth + 1m elevation) on the road (width: 6m) just near the stream (Figure 4.13). The incoming wave washed away cars along the road. The visualization of the inundation can be described in Figure 4.14.

Figure 4.12: Wave traces in the stream bed, Karaincir Bay (27.300718E 36.973574N**)**

Figure 4.13: Wave trace on the sidewalls of the road, Karaincir Bay (27.300718E 36.973574N**)**

Figure 4.14: Debris material accumulated, Karaincir Bay (27.30041E, 36.97433N)

Figure 4.15: Maximum inundation distance in Karaincir Bay along the streambed

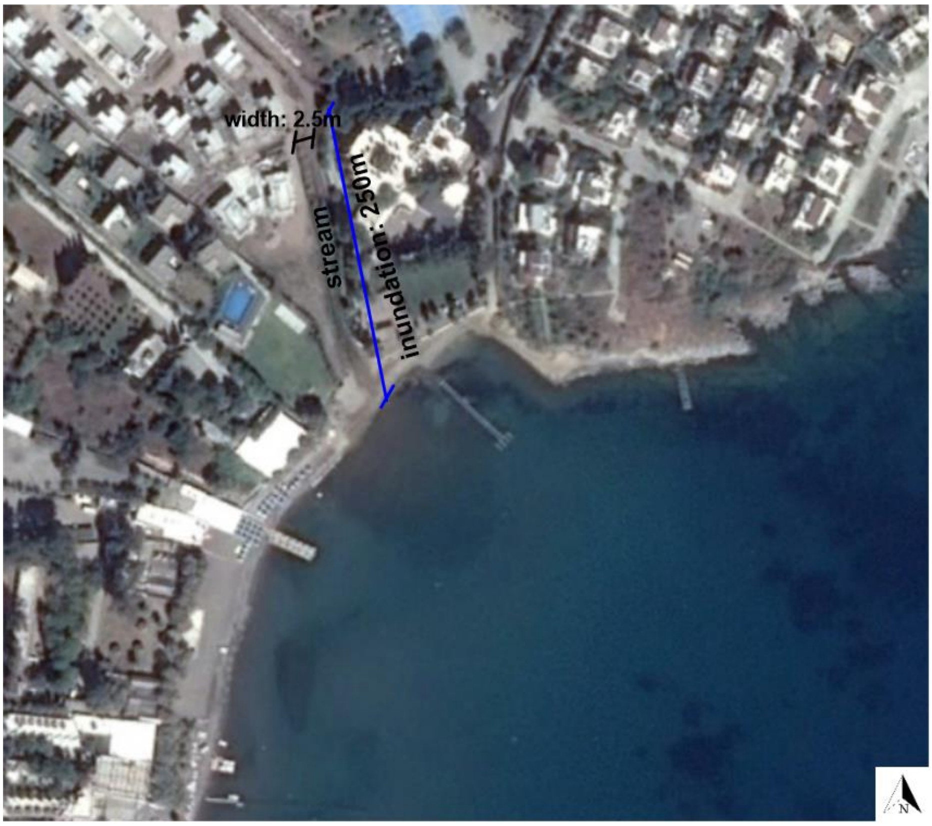


Figure 4.16: Schematic view of the inundation at Karaincir Bay (27.300496E 36.972961N**)**

In the second survey, more points in Karaincir Bay were investigated. One of them is La Brezza Beach (15) which is located at western part of the bay. 125 m inundation distance is reported at this beach and 40cm of water level is measured at an elevation of 1.2m with respect to the sea level, for a total of 1.6 m (Figure 4.17).

Figure 4.17: Water level sign observed at La Brezza Beach, western part of Karaincir Bay

(27.300179E, 36.969923N**)**

Another survey point which is added in the second survey to Karaincir Bay is the beach called Meteor – 2 (**16**) which is located at the eastern part of the bay. At this beach, the sea is receded about 70m from the shoreline and inundated 30m as measured. The run-up height is measured as 1.4m with a flow depth of 0.6m.

As going more towards east in Karaincir Bay, in TEK Sitesi bay (27.304098E, 36.975839N) sea receded 60m in horizontal direction up to 1.5 water depth. Maximum water elevation at this location is 0.8-1m. Similar wave motion is also observed at 27.294602E, 36.967830N as 80cm maximum water elevation in front of the vertical wall and no inundation.

In Aspat Bay **(5),** the run-up height is reported as 100cm (75cm elevation of stream wall + 25cm overtop) and the inundation distance is observed as approximately 60m. Azmak stream rised up and flooded according to the observers. The pier in the coast is also damaged due to the earthquake effect (Figure 4.18). The coordinate measurements and related observations at Aspat Bay is given in Table A.5 in Appendix A.

Figure 4.18: Damaged Pier in Aspat Bay (27.312356E 36.979592N**)**

Camel Beach in Kargi Bay **(6)** is another affected area after the earthquake and the tsunami. According to the inquired beach and restaurant workers, the first wave came after approximately 10 minutes later than the earthquake and the second wave came at 02:48 (77 minutes after the earthquake). The first motion of the sea was drawdown and then rising. The run-up height is reported as approximately 40-50cm whereas water level decrease is 120cm. The inundation distance is also reported as 7-8 meters.

The field survey ended at Bitez Bay **(7)** of Bodrum where the first motion of the sea is reported as drawdown of 3m, 10-15 minutes after the earthquake. The inundation distance is stated as approximately 10m in the middle of the bay but the eastern part of the bay is more affected by the waves (inundation distance is approximately 30m in this part) due to the location (Figure 4.19). Flow depth is reported as nearly 50cm and no strong current was observed in the bay.

Figure 4.19: Schematic view of wave inundation at Bitez Bay (27.383582E 37.025615N**)**

In the second survey, more places on the western and eastern sides of Bitez Bay are investigated. In Mor Beach (**18**) which is located at the westest part of Bitez Bay, the sea first receded about 7-8m, 15 minutes after the earthquake. In the western part of Bitez Bay (**19**), there exists a stream bed and observations show that the sea inundated around 250m along the stream. The run-up height at this location is reported as 0.9m. In Bitez Beach (**7**), the inundation distance is measured as 20m (Figure 4.20). The sea withdrawal is also observed to the depth of 1.5m. On the other hand, in the eastern part of the bay (**20**), there is no observed/reported boat damage and the observers reported small wave oscillations with an inundation distance of 11m.

Figure 4.20: Inundation at Aktur Beach (27.366069E 37.02439N**)**

4.1. Tsunami Information from Datça Peninsula

Turkish Chamber of Civil Engineers, Datça Branch (President, Mr. Levent Ozberk), has been contacted by Dr. Yalciner on phone and got preliminary information about the wave motions at Karakoy Kormen Marina (27.617741E 36.771399N) which is located at North of Datça Peninsula. It was reported from the captains whose boats parked in the marina that the water elevation was maximum about 1.2m (at the elevation of fixed berthing platform). The time of sea drawdown and uplift have not been confirmed. The drawdown of water level was observed about 1m at the marina.

Another important information has been obtained from the fisherman, Mr. Ozhan Yigiterhan who has a boat in the fishery harbor at Palamutbuku (27.503260E 36.669318N). He informed that probably 1 minute after the earthquake, the water level subsided up to 1m and very strong currents were observed outside the harbor. 10 minutes later, strong currents towards the harbor started. The inward and outward water motion continued until the morning, he reported. All boats in the harbor were moved towards outside of the harbor by abnormal strong currents, he reported. He also reported that he rescued his boat and tried to rescue other boats. However, unfortunately, one of the boats sank. He also informed that one of the fisherman (his friend) found mud blocks in his nets taken from 40m water depth 2 hours before the earthquake around Palamutbuku locality.

5. FIELD OBSERVATIONS ON TSUNAMI AT SOUTH OF KARAADA (BLACK ISLAND)

Karaada in English Black island, is located in between Bodrum town and Kos island with a size 7km along NW-SE direction and in average 1.2km along SW-NE direction. A special field survey has been performed to Karaada by boat on July 31, 2017 by Yalciner and Dogan). At south coast of island (facing to epicenter) there are two small gravel beaches. The view of small gravel beach at Kucuk Poyraz bay (27.461422E 36.966323N) is given in Figure 5.1 a and b from different perspectives.

Figure 5.1: Kucukpoyraz Gravel Beach at Karaada (Black Island) a) view from the shore b) view from the beach

The team visited Kucuk Poyraz beach at Karaada and found small gravels in the spaces on the rocks of the beach which are thought to be washed by the tsunami waves. The elevation that the gravels reached is approximately 2m (Figure 5.2).

Figure 5.2: Small gravels found in the gaps between the rock surfaces at Kucukpoyraz Beach, Karaada (Black Island)

6. FIELD OBSERVATIONS ON TSUNAMI AT GOKOVA BAY (AKYAKA VILLAGE)

Akyaka village (28.324425E, 37.050832N) is located at the eastern tip of Gokova Bay, which is about 80km from the earthquake epicenter. A field survey has been performed by Annunziato, Sozdinler and Ulutas at Akyaka Village and near Azmak stream mouth.

Figure 6.1: The location of Akyaka village in Gokova Bay (28.324425E 37.050832N)

The survey team has been contacted with the workers of cafes in Akyaka beach and fisheries cooperative. The eyewitnesses informed that in Akyaka beach wave receding was first observed around 35 minutes (not confirmed yet) after the earthquake with about 50m distance. Then tsunami inundation was observed up to the first trees in the beach, which is about 18m from the shoreline.

The workers of fisheries cooperative informed that wave receding was first observed in the Azmak stream and then waves penetrated through the river up to the first bridge (about 160m inundation distance) with a height of about 60cm. No flooding was observed on the banks of Azmak stream.

Figure 6.2: Schematic view of wave inundation at Akyaka Beach


Maximum inundation distance~ 18m
Inundated beach

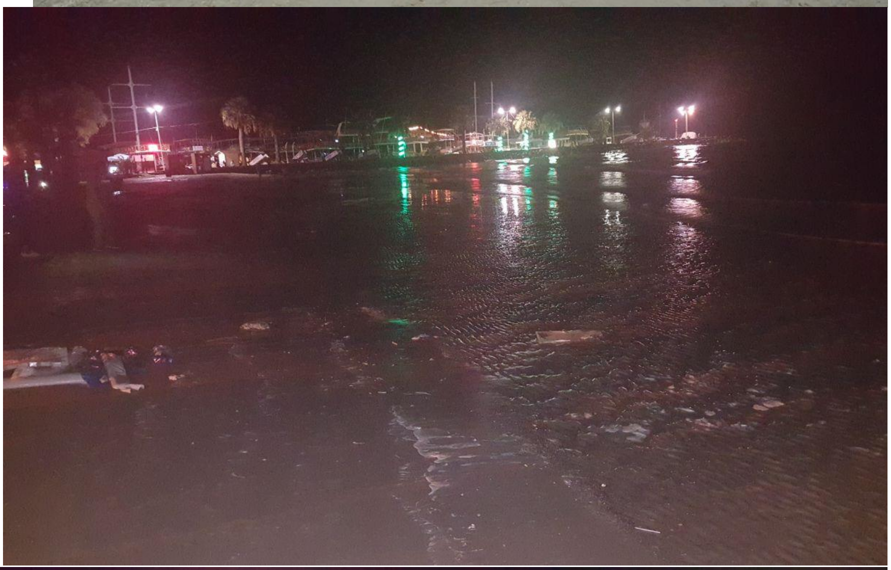


Figure 6.3: Akyaka Beach; original beach condition (above) and the picture shot by an eyewitness after wave inundation (two photos below)

Figure 6.4: Akyaka Stream Branch; waves penetrated through the river up to the first bridge and sea level increased about 60cm

7. FIELD OBSERVATIONS ON TSUNAMI AT KOS ISLAND

The Greek island of Kos was surveyed by Alessandro Annunziato, Gerassimos Papadoupulos and Ergin Ulutas on 1st, 2nd and 3rd August 2017. The analysis was driven by the preliminary estimation of the major impact and those limits were almost confirmed. The survey was performed, in clock rotation, from 27.20733 E/36.89026 N to 27.34983 E /36.85770 N.

Figure 7.1: Results of Kos Tsunami Survey

The height distribution along the coast of Kos was quite regular and not as in the case of Bodrum area where bays with high wave height were followed by bays with negligible height. One exception is the Kos port in which, probably due to the special form of the port with a small converging entrance, some resonance could have occurred and cause a marked higher water level respect to the surrounding locations.

Most of the locations have been identified by looking for tsunami traces, mainly in algae or other form of debris that was possible to identify. In some cases, eyewitness observations could confirm the water extent locations or, when debris was absent due to early cleaning, were the only available information.

About eyewitnesses, in particular of the owners of properties, a strong fear appeared of the word **Tsunami**, probably scared by the fact that a Tsunami could cause abandon of several tourists from the area. Indeed, we found several beaches without any tourist. Asking them about their experiences many answered: *which Tsunami? No no, here there was no Tsunami. The water* *receded several meters and then advancing arrived up to middle of the beach but this is not a Tsunami; Tsunami is a large wave that we have not seen!*

In the case of Kos port, thanks to the local municipality Mayor George Kiritsis, we could obtain the security videos of a travel agency (Blue Star Ferries) that identified perfectly the time of the earthquake and the moments of the tsunami inundation of the port. From those images, it was also possible to reconstruct the timeline of the wave action at this location, after a careful measuring of the structures present in the video[3].

Table 7.1: The list of measured points, grouped by similar area, is indicated in the table below.

ID	Lon(1)	Lat(1)	Height (min/max, m)	Note
North Coast (between 27.20733 / 36.89026 and 27.27983 / 36.91567)				
1	27.20733	36.89026	0.05	End of impact
2	27.23833	36.8965	0.1	La Branda Acqua Marine Resort, Coastal Erosion
3	27.25805	36.90433	0.5	North Kos
4	27.27254	36.91216	1.3 - 1.5	North Kos
5	27.27521	36.91367	1 - 1.4	North Kos
6	27.27574	36.91433	0.7	North Kos
7	27.27983	36.91567	0.6	Ammoglossa Cape
North Coast (between 27.27983 / 36.91567 and the port)				
8	27.28111	36.91493	0.5 - 0.6	East Kos before Port
9	27.28283	36.91059	0.3 - 0.6	Atlantis Hotel
10	27.28507	36.90557	0.3	East Kos before Port
11	27.28572	36.9008	0.5 - 1.2	East Kos before Port
The Port of Kos				
12	27.28745	36.89592	1.35 - 1.5	Port
Between Kos port and Louros Cape				
13	27.29408	36.89324	0.70	Hotel Aktis Kos
14	27.30099	36.89277	0.80	Kos Marina
15	27.30517	36.88766	0.5 - 0.7	East Kos after Port
16	27.3192	36.88519	0.5 - 0.8	East Kos after Port
17	27.32562	36.88459	0.7 - 0.8	East Kos after Port
18	27.33243	36.88718	0.6	East Kos after Port
19	27.33874	36.88978	0.1 - 0.5	Louros Cape

[3] The video shows a time stamp, anticipated of about 6 minutes. This was confirmed by requesting to view the security screen which indeed showed an anticipation of time of exactly 6 minutes. In the video frames, the earthquake appears at 01:25 instead of 01:31.

Between Louros Cape and Agiou Foca				
20	27.3464	36.88202	0.7 - 0.8	South-East Kos
21	27.35215	36.87097	0.7	South-East Kos
22	27.34983	36.8577	0	Agiou Foka

(1) The coordinates indicated are the average of the various points (3-5) that compose the 'location'. In the text below, instead, the real coordinates of each image are indicated. For this reason, they may not be identical. When only one point was used, they coincide.

7.1. North Coast (between 27.20733 / 36.89026 and 27.27983 / 36.91567)

Starting from the left part of the North section of Kos island, 4 points have been identified ranging from 0.1 to 1.4 m.

The North coast of Kos shows an increasing intensity starting from the southern locations towards the top cape of the island.

The largest impact has been noticed at about 900 m from the cape with a maximum height of 1.5 m. The maximum height then decreases at the cape to about 0.4 m.

Figure 7.2: Image taken at 36.89991/27.24879, showing debris at elevation 0.1 m, point (2) in table 7.1; the sharp change is not clear if is due to the Tsunami (subsidence) or just to coastal

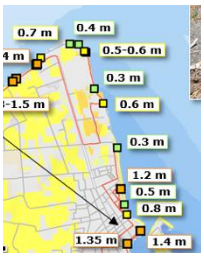
erosion.

Figure 7.3: Image taken at 36.90433/27.25805. One witness, point (3), reported that the beach was inundated by 16 m and corresponding to 0.5 m water height.

Figure 7.4: The image above was taken at 36.91370/27.27521 (5) and shows several sea deposits up to 1 m. The beach is very small, the distance from the sea is less than 5 m.

Figure 7.5: Image taken at 36.91358 / 27.27503, showing the presence of sea debris below the trees but also on the other side of the bicycle street.

7.2. North Coast (between 27.27983 / 36.91567 and the port)



In this section, most of the estimated heights are in the order of 0.5-0.6 m with only one exception where a more intense height has been reported, 1.2 m. No trace has been found but only the witness reporting who indicated a quite intense water withdrawal and then water return.

Figure 7.6: The image above, taken at 36.91564 / 27.28037, shows debris close to the shore but an eyewitness reported that the water arrived up to the stones (red arrow). The height measured was 0.6 m, point (7).

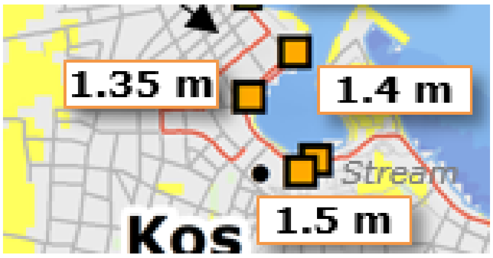
Figure 7.7: The image above, done at 36.91130 / 27.28229, point (9) shows multiple series of deposits which could indicate the presence of various waves. The maximum height here is estimated 0.3 m.

Figure 7.8: The image was done at 36.90156 / 27.28551, point (11). The height is between 0.5 and 1.2 m.

The largest height in this area before the port has been reported here by Dimitri Giagoglu, the owner of the beach, who also indicated that water receded several tents of meters (yellow buoy indicated by the yellow arrow) before advancing. He mentioned that, according to him, the magnitude was much larger, 7.5 or 8.0 as it was very very strong, cut umbrellas. He showed movement of a large anchor fixed on a wall, left and right. He recorded about 10 min of audio.

By chance he is the father of another eye witness that we had interviewed the day before at the port (see later). Also, his son was speaking a lot with several details about his experience.

7.3. The Kos Port



Four points have been collected from the Port area **(12)**.

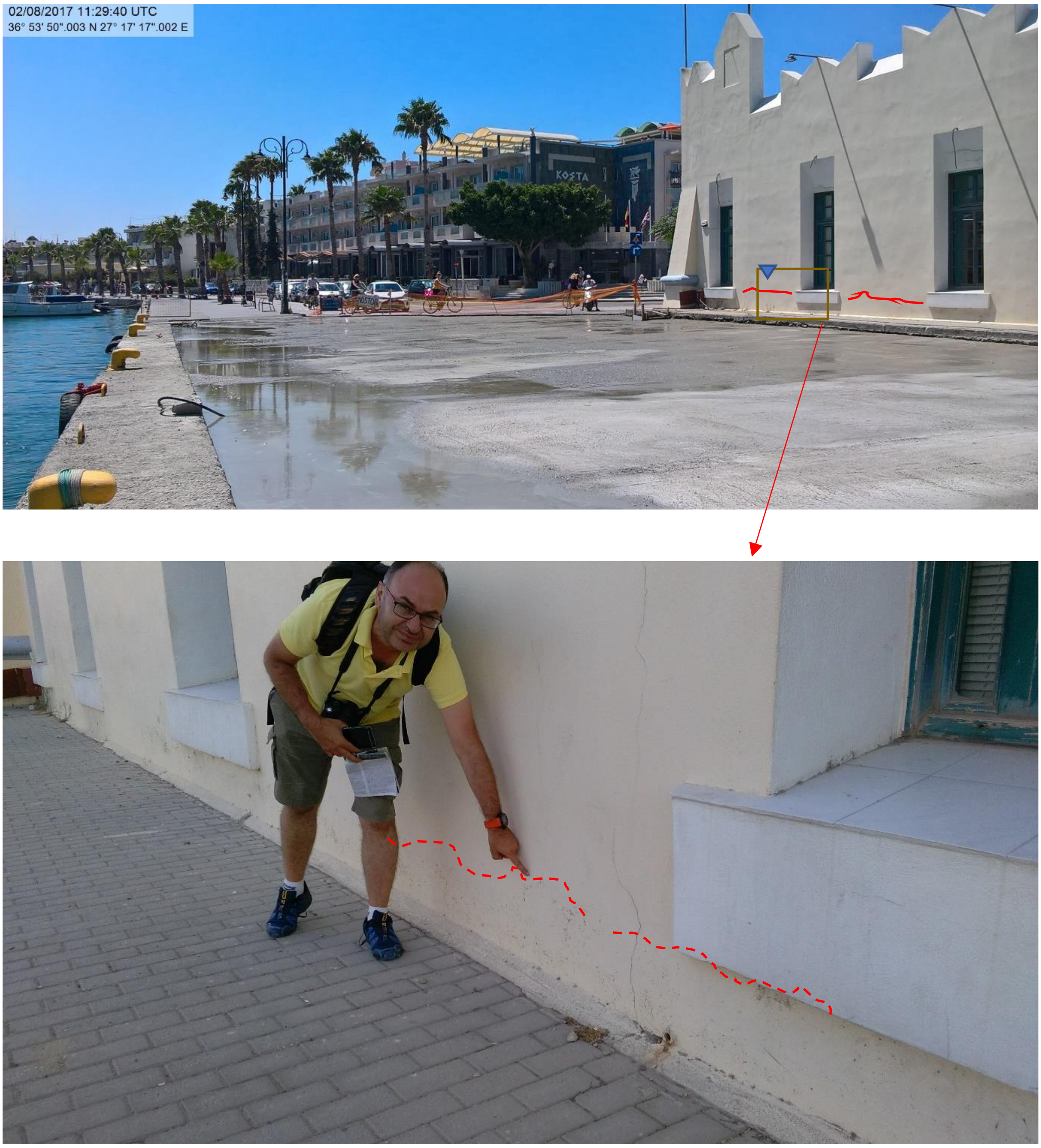


Figure 7.9: Image above was taken at point 36.89745 / 27.28791 and the estimated height is 1.4 m.

Figure 7.10: Interview with eyewitness at Kos Port

The eyewitness reported that he came to the port just after the earthquake and no anomaly was present. When he returned a second time the situation in the port was degraded. Due to the strong currents (about 10 knots) it was very difficult to manage the boats. All boats were going outside the port and people tried to push the boats back. On the question when the wave arrived about 15-20 min (times consistent with the timing estimated from the images of the video security, see later. He provided many details of the problems in the port, explaining that few boats escaped before the problems appeared, other boats detached themselves from the fixing ropes due to the high currents and low level in the water. One boat travelled alone for long distance out to the port and was finally blocked by the anchor that grasped the sea bottom and stopped.

He spoke for more than 10 min and by chance he is the son of the “Dimitri” that was mentioned in the previous chapter, who spoke exactly the same! The witnesses of those two individuals have been extremely helpful for the understanding.

Figure 7.11: Corn panicles seller (36.89626 / 27.28635)

Figure 7.11 is done at 36.89626 / 27.28635, has been reported by the corn panicles seller, who mentioned that his chariot was flooded for about 45 cm. Considering the height of the plane on the water the resulting height was **1.35 m**.

Figure 7.12: Boats damaged due to crashes among the boats, agitated by the tsunami waves or against the trees on the docks

Figure 7.13 (36.89445 / 27.28840) represents Ioanidi Road. The road was flooded with sea water up to the Pharmacy sign. According to eyewitnesses the wave arrived 30 min after the event.

Measurements indicate about **1.5 m** from sea level. It should be noted that this road is in front of the port mouth and therefore some larger wave height should be expected.

Figure 7.13: Ioanidi road flooded with sea water up to the pharmacy sign

Figure 7.14: Boat resting on the pavement after its removal inland near the observation point 36.89478/ 27.28959, east side of Kos Port locally called "Bridge" (*photo credit Reuters*).

The Marina Officer Mr Kostas Liakovassilis arrived near the "Bridge" point ~ 1-1.5h after the earthquake. The area was wet apparently due to previous tsunami inundation. Bikes and motorbikes had fallen down and drifted. Cars crashed and drifted (see next pictures). At that time, the sea level was ~1.5-2.0 below its usual place. In about 1-2 m the sea level increased quickly by ~0.5m above the dock level, inundated by ~25-30 m and removed away motorbikes. After that the water retreat and the sea remained at its normal place. As the dock is at about 1m from the sea level the estimated height is **1.5 m**.

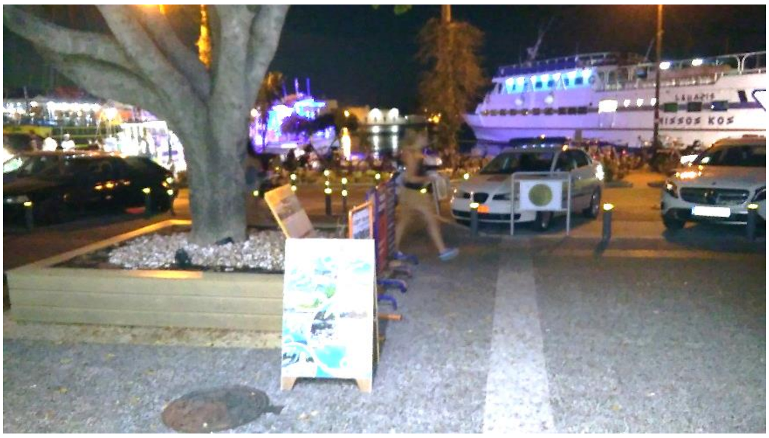
Figure 7.15: Bikes, motorbikes and other objects overthrown and drifted by the tsunami in Port of Kos, near the "Bridge" point (photo credit ANA-MPE).

Figure 7.16: Cars drifted by the tsunami in Port of Kos, near the “Bridge” point (photo credit ANA-MPE).

Figure 7.17: Bikes, motorbikes and other objects overthrown and drifted by the tsunami in Port of Kos, near the "Bridge" point (photo credit ANA-MPE).

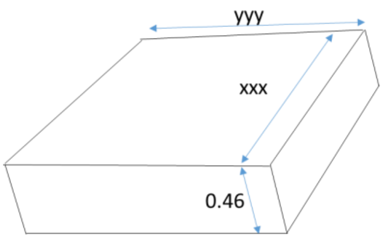
Figure 7.18: People trying to take away cars crashed due to tsunami attack in Port of Kos (photo credit ANA-MPE).

Kos port image analysis:



In the case of Kos port, thanks to the local municipality Mayor George Kiritsis, we could obtain the security videos of a travel agency (Blue Star Ferries) that identified perfectly the time of the earthquake and the moments of the tsunami inundation of the port. From those images, it was also possible to reconstruct the timeline of the wave action at this location, after a careful measuring of the structures present in the video[4]. The dimensions of the box above, which is extremely important for the identification of the Tsunami timeline, are indicated below.

[4] The video shows a time stamp, anticipated of about 6 minutes. This was confirmed by requesting the travel agency staff to view the security image which indeed showed an anticipation of time of exactly 6 minutes. So, in the video frames the earthquake appears at 01:24:41 instead of 01:31



xxx and yyy are about 2.8 m.

1 second before the earthquake strucks. Look at the position of the fenders of the boat in yellow and the light in the city, very bright. The yellow line indicates the bottom of the plant box that is very important to establish the water height.

	The earthquake hits: timestamp is wrong as it should be 1:31, so it is 6 min back. Look at the position of the advertisement that is oscillating.
	People in panic runs around. Please note that now all lights are off and the area is much darker due to blackouts

This is the time of minimum of the Boat on the right of the image

FIRST WAVE

The road is full of water but the water in this first wave do not overpass the sidewalks elevation. We attribute the maximum height as 5 cm above the sidewalks, to be sure that the wave height is not larger than this.

	The road is still web but almost empty
	This is the time of minimum height of the water in the port and the boat is down. No fender is visible.

	**SECOND WAVE:** Water is out of banks and has reached the limit of the sidewalk
	At this time, the water reaches the bottom of the plant box

	In few seconds, the water reaches half of the plant box The white part in the bottom of the image is reflected wave from the wall of the municipality that breaks and creates some foam
	This is the time of maximum. So in about 28 s the water rises and the start receding. At this time, the white car in the image starts floating and changing position Look at the vortex created

	Water recedes. The car is moved floating. Pieces of floating material appears
	Water disappears and people start passing

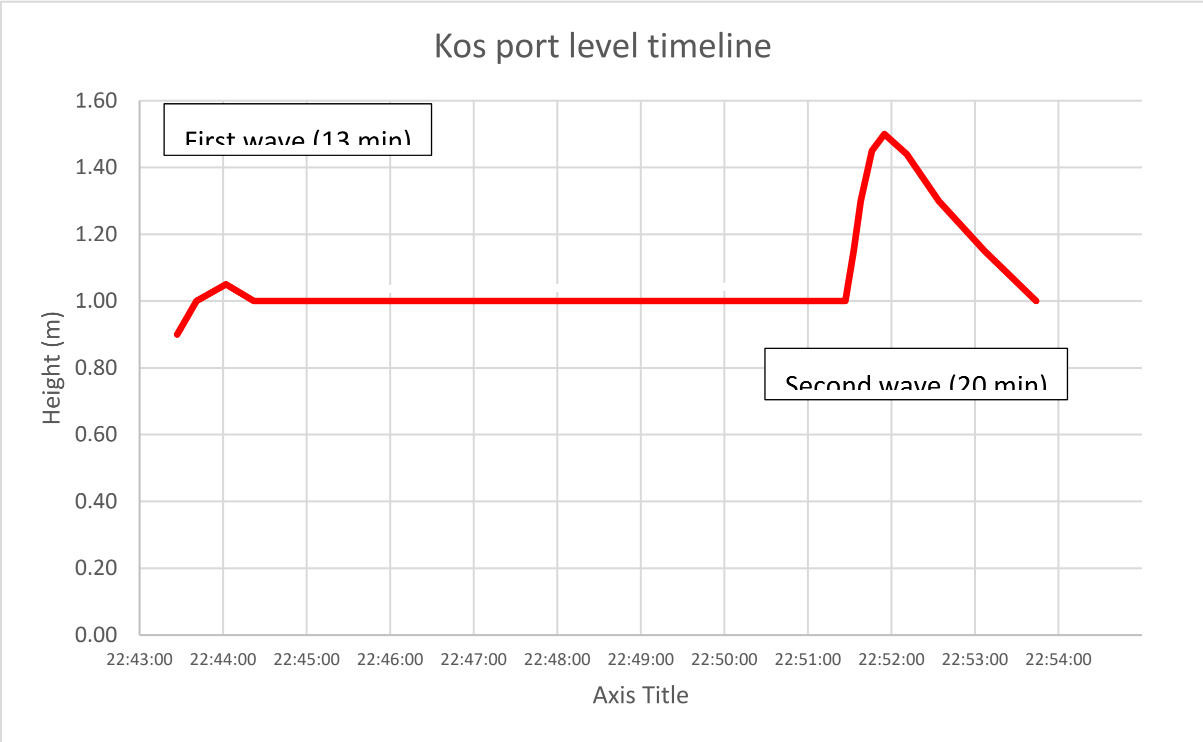


Figure 7.19: The analysis of the images and once corrected for the time delay, the plot represents the absolute height of the water, considering the location of the plant box (1 m from sea level) and the height of the plant box (46 cm). Then, the maximum 1.5 m, at the location of the plant box, occurs at 22:51 UTC but two distinct waves are present, 13 and 20 min after the earthquake.

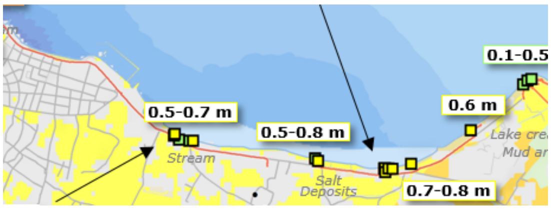
Table 7.2: Timeline obtained from the image analysis

Time in video (local time)	Water Level[5] (cm)	Corrected Time (UTC)[6]	Corrected level (m)	Time difference from EQ	Notes
21/07/2017 01:24:40		20/07/2017 22:30:02		00:00:00	EQ
21/07/2017 01:38:05	-10	20/07/2017 22:43:27	0.90	00:13:25	First wave
21/07/2017 01:38:19	0	20/07/2017 22:43:41	1.00	00:13:39	
21/07/2017 01:38:40	5	20/07/2017 22:44:02	1.05	00:14:00	
21/07/2017 01:39:00	0	20/07/2017 22:44:22	1.00	00:14:20	
21/07/2017 01:46:05	0	20/07/2017 22:51:27	1.00	00:21:25	
21/07/2017 01:46:11	15	20/07/2017 22:51:33	1.15	00:21:31	Arrival Second Wave
21/07/2017 01:46:16	30	20/07/2017 22:51:38	1.30	00:21:36	
21/07/2017 01:46:24	45	20/07/2017 22:51:46	1.45	00:21:44	
21/07/2017 01:46:33	50	20/07/2017 22:51:55	1.50	00:21:53	Maximum
21/07/2017 01:46:49	44	20/07/2017 22:52:11	1.44	00:22:09	
21/07/2017 01:47:12	30	20/07/2017 22:52:34	1.30	00:22:32	
21/07/2017 01:47:45	15	20/07/2017 22:53:07	1.15	00:23:05	
21/07/2017 01:48:22	0	20/07/2017 22:53:44	1.00	00:23:42	

[5] This level is referred to the base of the plant box, that is positioned 1 m above the sea water level.

[6] Time is corrected by adding 6 min to compensate the time error and removing 3 h to have UTC.

7.4. Between Kos port and Louros Cape



The impact along the north coast of Kos, between the port and Louros Cape is rather uniform with a decreasing trend towards Louros Cape, also justified by the position of the fault and its orientation.

We found several interesting locations, characterized by dried-up streams in which tsunami traces were found for long distances along the stream. Also, eyewitness accounts proved very useful.

The manager of the Hotel Akti Kos (location 13 in Table 7.1) reported to Prof. E. Lekkas, Earthquake Planning and Protection Organization, that the tsunami height was ~0.7 m.

Further, in Kos Marina (location 14 in Table 7.1), the Port Authority Mrs Christina Bourboula was on duty there at the earthquake time. She reported to us that initially the water level decreased by ~1m about ~15 min. after the earthquake. Then it increased about 0.8 m above the dock level and inundated 8-10 m inland. A second wave arrived ~25-30 min after the earthquake and inundated ~10m. The sea level oscillation happened about 3 times in ~1h time interval.

The image below, shot at 36.88694/27.30707 – position **(14)**, nicely provided by an eyewitness, identifying himself as *Mike*, shows the water receding during one of the multiple waves arrivals (he mentioned that this was not the first one but he could not indicate the right time of the image). The shoreline is advanced to from its normal position (following figure). Counting the white sand bags, it seems that approximately **7-8 m** is visible.

Figure 7.20: The water receding during one of the multiple waves arrivals (at 27.30707E 36.88694N, position 14)

Figure 7.21: Water penetration along Leoforus Papandreu Georgiou (location 14)

At this location, again **(14)**, along Leoforus Papandreu Georgiou, the water penetrated for about **33 m** inside the stream and the maximum height is between **0.5 and 0.7 m**.

Another nice stream, located at 36.88435 / 27.32517 **(15)**, shows the presence of several deposits for about **39 m**; at that location, the estimated run-up is **0.7 m**. The couple shown in the next photo along with two of us (Annunziato and Ulutas) verified the tsunami inundation by **~15 m** in their house location which is situated exactly next to the stream at location **(15).**

Figure 7.22: The stream at location (15) where the presence of several possibly tsunami deposits were observed.

Figure 7.23: Salt remnants at the floor of the stream at location (15).

Figure 7.24: A couple (left hand side) at location (15) verified the tsunami inundation by ~15 m in their household place.

The stream at location (15) where the presence of several possibly tsunami deposits were observed.

Figure 7.25: The line of deposits quite close to the shore, with about 0.5 m of height above the water.

The image in Figure 7.24 is shot at 36.88489 / 27.32734 at location **(17)** and shows the line of deposits quite close to the shore, with about **0.5 m** of height above the water.

Louros Cape was very interesting because many features were present. At the cape, a tall antenna is present with a large basement. Looking at Google Earth position and few images from the users, it is clear that the basement is on shore for about 10 m.

Figure 7.26: ***Image by Sofia Karagianni, uploaded December 2011***

(http://www.panoramio.com/user/6522978?with_photo_id=63318452)

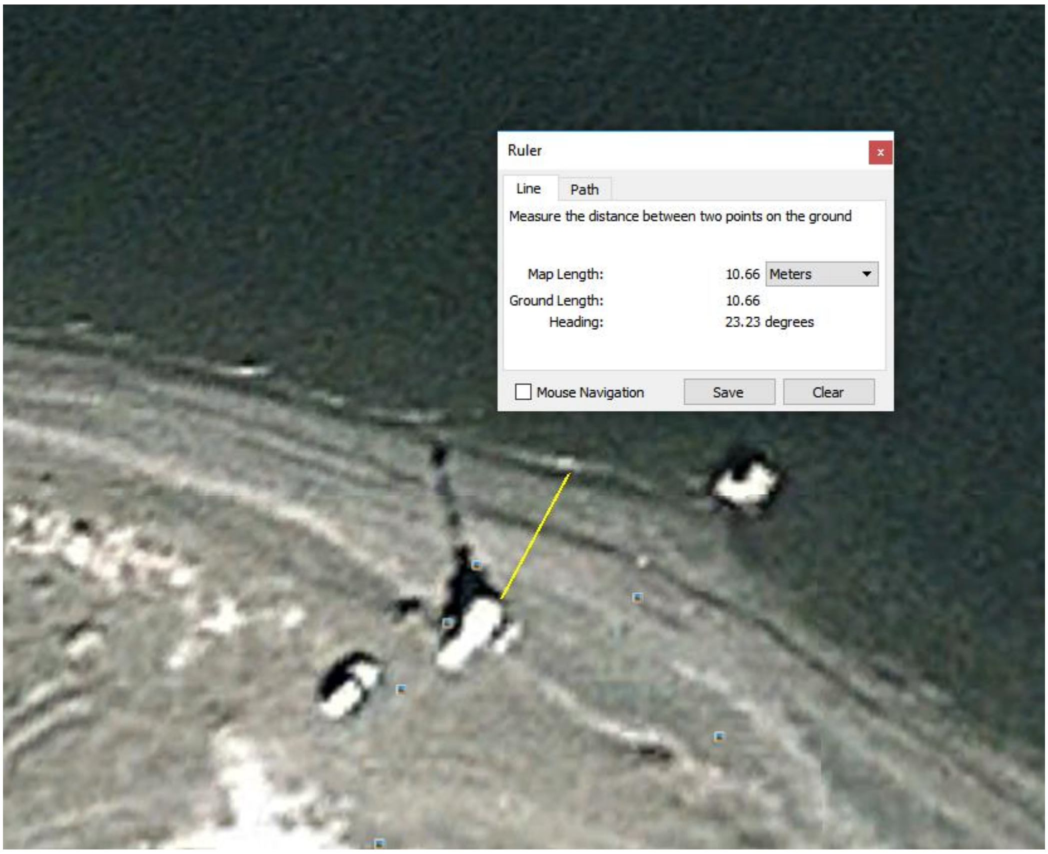
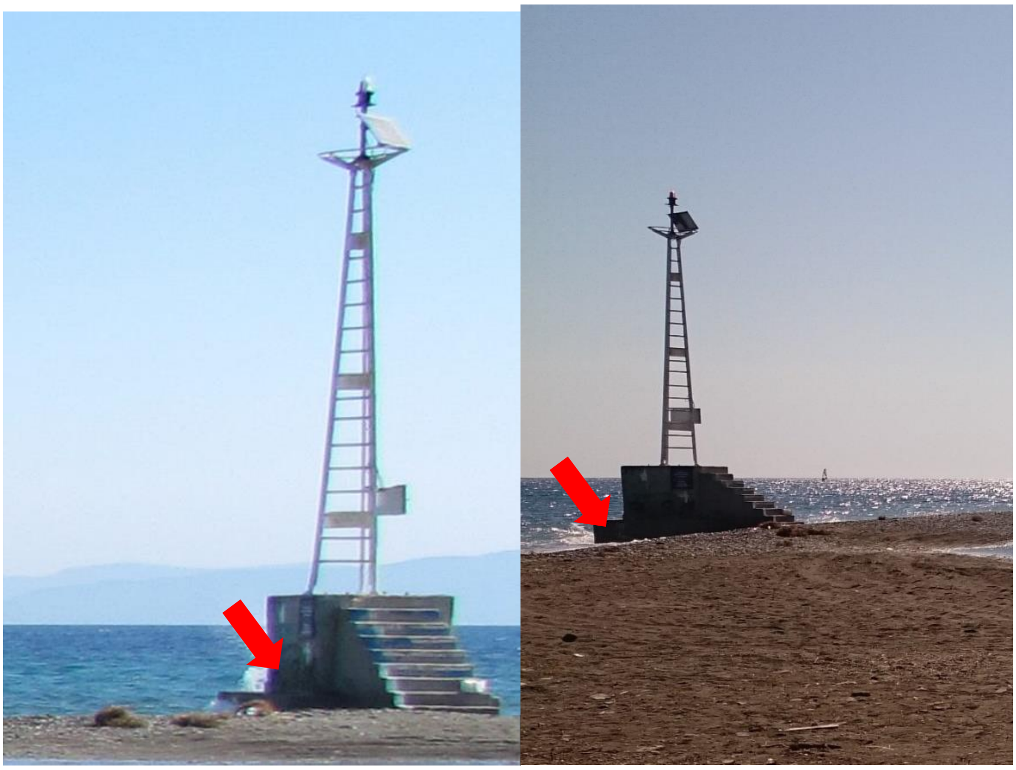


Figure 7.27: Basement of the antenna at the shoreline

Now the basement of the antenna is practically at the shoreline (Figure 7.27). Either a strong beach erosion or some subsidence occurred.



Close to the cape other interesting phenomena of ground failures occurred. Note that the ground in this area is soft consisting by sea sand mixed up with gravels of various sizes. People managing the local wind surf stand reported that the day after the earthquake their stand was found within a local lake formed apparently due to the earthquake. The lake was still existing on 2nd August 2017 during our visit, while the area around the lake “bank” was wet. The people removed their stand further but one small kiosk remained at the edge of the lake. The lake is roughly of elliptical shape with its major axis being of ~20-25m in length and the minor of ~10m in length. It was also reported that in about the center of the lake a ground hole of ~1m deep opened, while similar holes opened in the nearby area but they closed by the wind surf people. The lake side facing the lighthouse-antenna stand lies at distance of ~ 10m from the seashore. At the perpendicular direction, the distance of the lake from the seashore is at ~50-60 m. Then, tsunami inundation does not account for the lake creation.

An alternative is the local subsidence that may have occurred in the Cape Louros due to the earth shaking with the large earthquake. Subsidence evidence comes from the observations at the lighthouse-antenna place, as reported above. In addition, the Mayor of Kos Mr George Kyritsis told us that two scuba divers reported to him that the sea floor around Cape Louros had deepen significantly after the earthquake. Local subsidence may have caused the very shallow water table to expose above the surface thus creating the local lake.

Subsidence evidence comes also from the marshy field situated next to the lake. In this field, we observed ground failures typical for soil liquefaction due to earthquake shaking. Namely, in the soft ground we observed fissures and local depressions, while an extensive area of the marshy field was covered by an extensive mantle of soft sand that came out from ground fissures and depressions. The sand mantle covers an area of ~30m in length and ~ 12-15m in width. A global dataset was used by de Magistris et al. (2014) to identify, on the basis of simple statistical analysis, a PGA threshold on the free ground surface below which liquefaction is unlikely to occur, regardless of the geological site conditions. The calculated value is on the order of 0.07–0.1 g[7].

Figure 7.28: The lake as seen from the lighthouse-antenna stand. The liquefied area is at the left side. The distance to the right side is ~50-60 m. A small kiosk of the wind surf stand remained at the left edge of the lake.

[7] F. Santucci de Magistris, G. Lanzano, G. Forte, G. Fabbrocino, 2014. A peak acceleration threshold for soil liquefaction: lessons learned from the 2012 Emilia earthquake (Italy). Natural Hazards, DOI 10.1007/s11069-014-1229-x.

Figure 7.29: G. Papadopoulos and A. Annunziato (with the official T-shirt of a past Symposium) discussing about the formation of the lake at Cape Louros

Local ground depression in the liquefied area. Sand mantle is shown at the background.

7.5. Between Louros Cape and Agiou Foca

As the height at Louros Cape varied between **0.1 and 0.5 m** the estimated height, by the deposits, restarted to increase up to **0.7 m**.

Figure 7.30: At this location 36.87120/27.35213, point (19), the estimated height is about 0.7 m.

The last point that showed no sign of Tsunami, also by witnesses is 36.85770/27.34983, point **(21)**, which also does not present any sign of algae deposits. The end of the impact is therefore before this location.

Figure 7.31: Point (21) that showed no sign of tsunami

7.6. Damages due to the Earthquake in Kos

Although the main aim of the field survey is to find tsunami traces along the coastal regions of North Kos, it is considered useful to report few observations to visible damages to buildings, focused mainly on downtown and old city of Kos.

The building damage in Kos Island was restricted in the easternmost side of the island which is occupied by the capital city of Kos with permanent population of about 20,000. Because of the earthquake, two persons were killed hit by the debris from the surrounding building and 115 injured. From official post-event building inspections performed by civil engineers of the Natural Disasters Rehabilitation Directorate, Ministry of Infrastructure, until the 31st of July 2017, it comes out that 523 house buildings were inspected but only 141 were found temporary uninhabitable (the overall number of buildings in Kos is much larger, of course). The respective figures for commercial buildings are: 33 temporaries uninhabitable out of 146 inspected buildings. Additional 76 inspections were performed in public buildings, churches and monuments. Several of these buildings suffered damage. The commercial port of Kos rendered temporarily useless due to damage in the dock. Less damage was present in the tourist (old) port of Kos (Fig.7.33-7.34). Remarkable damage was caused in several monuments of the Kos city.

Figure 7.32: Damaged building at Kos in the old part of Kos City

The collapse of the upper floor of this old building (Figure 7.32) in the old part of the Kos city caused the death of 2 persons being there at the earthquake time and having fun in a local bar. Several others injured.

Figure 7.33: A) Damage line at the dock of port B) Damage at the dock of port C) Damage at the dock of port D) Distancing of the materials of the dock

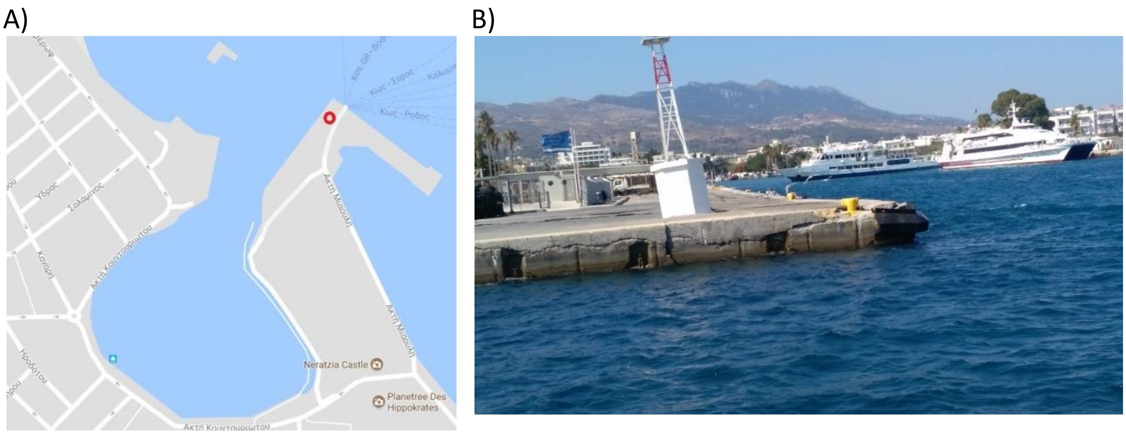


Figure 7.34: Failure on the ground of the lighthouse were occurred by the strong shaking of the earthquake and structural problems of the dock. A) Location of the light house B) Port structure deformation due to the earthquake

Figure 7.35: The church of Agia (St.) Paraskevi (old part of the Kos city) damaged and rendered temporarily unusable.

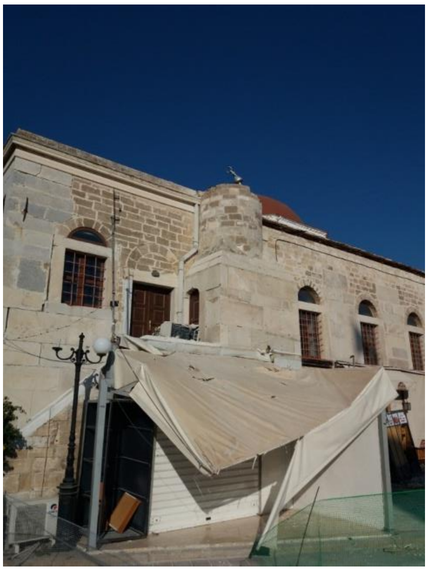


Figure 7.36: The minaret of the Mosque of Defterdar, built in Eleftherias Square at the end of 18th century (old part of the Kos city) collapsed due to the earthquake, only its base remained.

Figure 7.37: One fountain of Mauritanian style, situated next to the Defterdar Mosque (old part of the Kos city) damaged due to the strong earth shaking but also because the Mosque minaret fell on it. Please note the change of the relative position between the column and the roof structure (red lines).

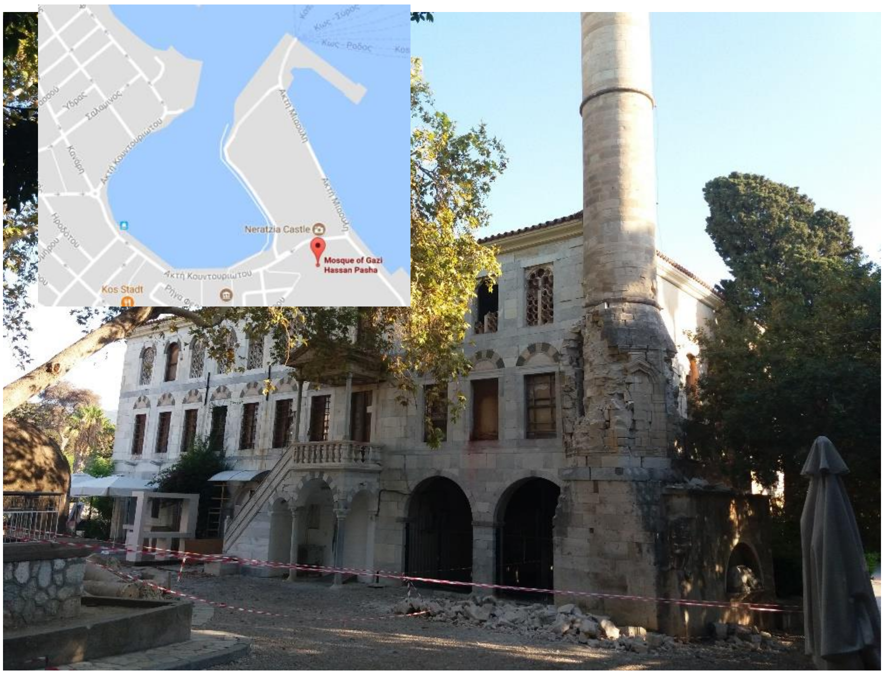


Figure 7.38: The minaret of the Gazi Hasan Pasha Mosque (old part of the Kos city) was damaged at its base. The Mosque building also damaged.

Figure 7.39: One fountain of Mauritanian style, situated next to the Gazi Hasan Pasha Mosque (old part of the Kos city) was completely collapsed.

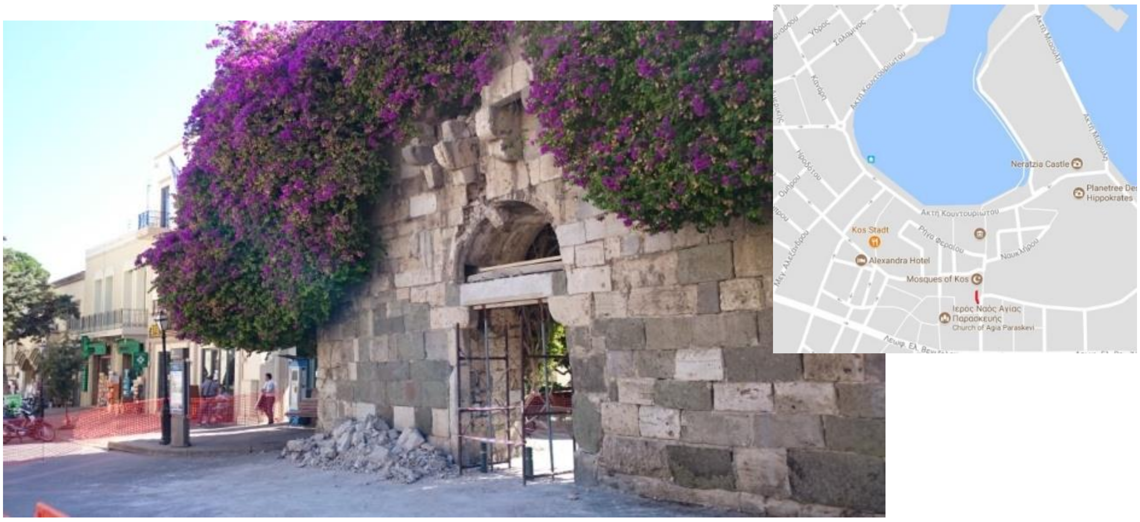


Figure 7.40: Damages occurred to a number of historical building from Roman time in various parts of the city

A sliding ship from the holder attachments at the marina was seen because of the strong shaking from the earthquake**.**

Figure 7.39: **A) Location of the marina B) Sliding the ship from attachments to the walking road**

8. EVACUATION INVESTIGATION AGAINST KOS-BODRUM EARTHQUAKE AND TSUNAMI İN TURKEY · BODRUM

An earthquake of magnitude 6.6 occurred off the coast of Turkey, Bodrum at 22:31 on July 20, 2017 (UTC, local time July 21, 25:31). Figure 8.1 shows the seismic intensity at that time. In the Bodrum region targeted this investigation, the intensity was about 6 to 7.

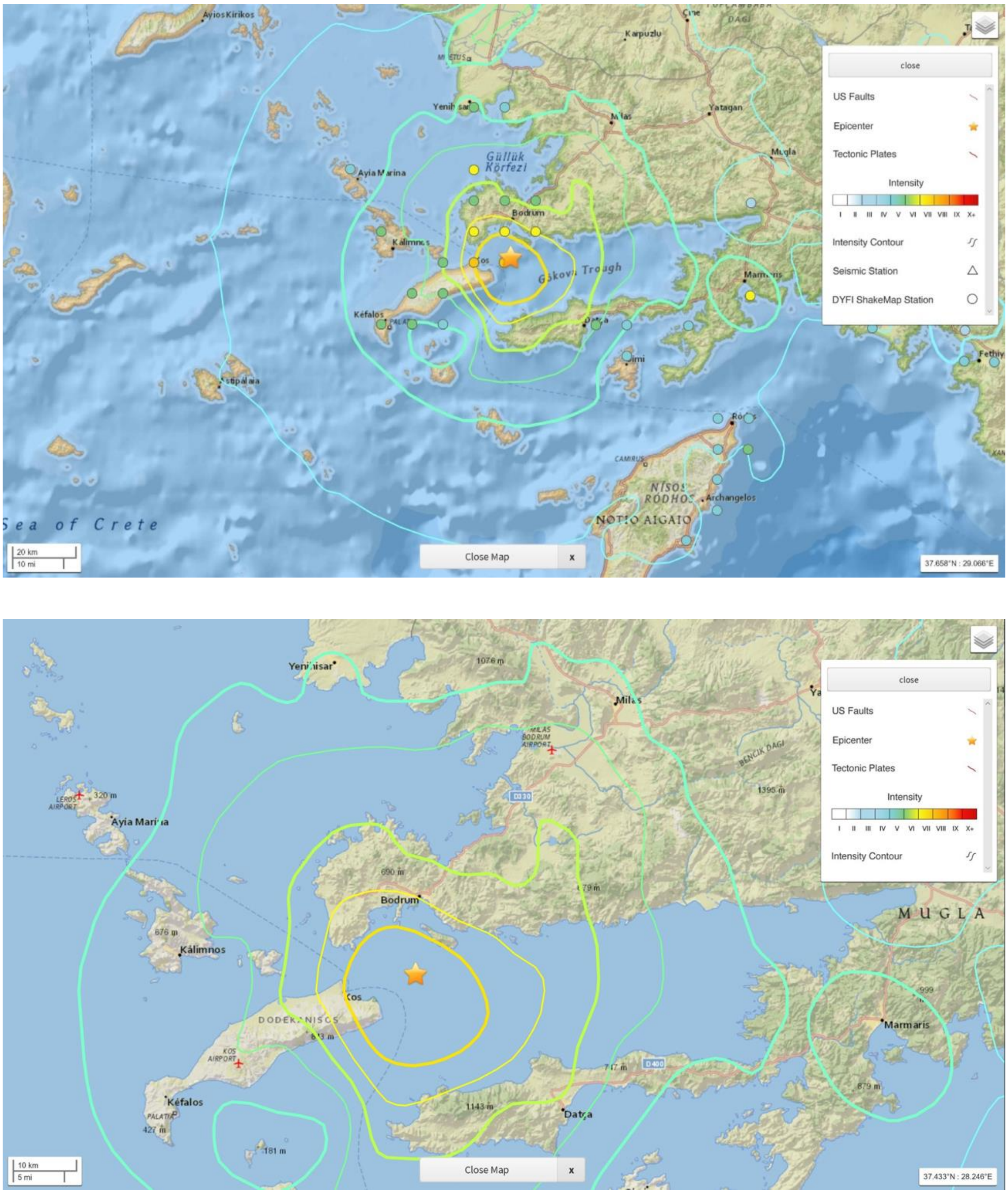


Figure 8.1 Seismic intensity in the earthquake on July 20, 2017 (USGS: lower enlarged view)

8.2. Outline of questionnaire survey

Itinerary: 28th - 30th July

Investigator: H. Gokhan Guler (METU), Taro Arikawa (Chuo University), Ahmet C Yalciner (METU)

Survey target location · Number of people: 10 locations shown in Figure 8.2, according to the interviews by 22 people

Content of the questionnaire:

1. Where were you when the earthquake occurred? (July, 21, 2017 – 01:31 local time- July 20, 2017-22:31 UTC)

2. When the shaking was occurring, was it difficult to keep standing?

3. Did you evacuate from tsunami?

4. What made you decide to evacuate? (If they evacuate)

5. What was the main reason why you did not evacuate? (If they did not evacuate)

6. Do you know what a tsunami before the disaster is?

7. Have your family (parents, grandparents, etc.) ever taught you to evacuate from a tsunami?

8. Did you experience or know 1956 Bodrum Tsunami and Earthquake?

The actual questionnaire form is shown as a reference material in Appendix E.

Figure 8.2. Location of questionnaire survey (Main shock is approximate)

Result of the questionnaire

The results of interview questionnaire are shown in the following. In this case, It is surprising that nearly all of the respondents were replied similar responses.

1) The earthquake is so strong that they cannot stand, since they felt that the house is not safe, they went out immediately after the earthquake motion

2) They understood that places without buildings are safer. Therefore, depending on the location, they evacuate to an open space like a beach. So that, there were many people gathering at the beach from a house at a high position and spending the night there.

3) No tsunami was recalled by the earthquake. Someone thought the tsunami was coming, when they watched the sea receding abnormally and they began to evacuate towards the upper elevations.

4) Looking at the video of the 2011 Japan tsunami's disaster, people understand that the tsunami inundated further the inland and it is dangerous.

There was also one respondent who experienced the effects of 1956 Southern Aegean earthquakes and tsunami in Bodrum. He remarked, "I remembered the strength of the earthquake but I forgot the tsunami, because I was a hotel manager, I guided the guests from the building to the open space and let them wait. From the roof, we monitored the sea, I did not induce evacuation to the hill. "

Comparisons of Evacuation Responses in Japan, Chile and Turkey

The responses of the evacuation against the tsunami in Japan (2011), Chile (2015), Turkey (2017) are compared. Figure 8.3 shows the seismic intensity of the earthquake that occurred off Illapel on September 16, 2015 in Chile. In the coastal area near the epicenter, the strength is about 7 to 8, but the intensity is getting smaller at place far from the epicenter. According of the questionnaire survey, it was found that evacuation was almost completed within 10 minutes, where the seismic intensity were strong, and the evacuation rate depended on the strength of the shake.

Comparing the idea of tsunami education, alarms, and protection facilities in Japan, Chile and Turkey,

Japan; Protective facilities and warning system are developed, tsunami education enhanced

Chile; Protective facilities are underdeveloped, warning system is recently developed, tsunami education is enriched

Turkey · Protective facilities, warning system are underdeveloped, tsunami education is inadequate, tsunami knowledge is not enough but the video kowledge. Earthquake education has been active since the earthquake in 1999.

A comparison of evacuation rates within 10 minutes among countries is shown in Figure 4. From the results, it is assumed that the behavior of the evacuation against the tsunami during the earthquake is as follows.

Japan; Waiting for information and do not depend on alert only. As a result, they do not evacuate until the limitation of their feeling or risk perception.

Chile; If the earthquake shakes, the people run away quickly from the shoreline regardless of warning.

Turkey; the people evacuate properly against the earthquake. On the other hand, they do not recall the tsunami even strong earthquake occurs. As a result, after they see the tsunami, they would run away. One of the reasons of this reaction may be there was not a significant tsunami the residents and tourists have experienced.

In Japan and Turkey, as a measure to make evacuation against the tsunami appropriate, it is taught as follows. In Japan, it is not realistic to eliminate protective facilities and alarms, so it seems better to raise the accuracy of warnings or increase the reliability of protective facilities from now on. In Turkey, while strengthening the education for the tsunami, it is thought that it is important to enhance tsunami warnings, secure escape places on the higher grounds and establish evacuation signs for the immediate effect and awareness.

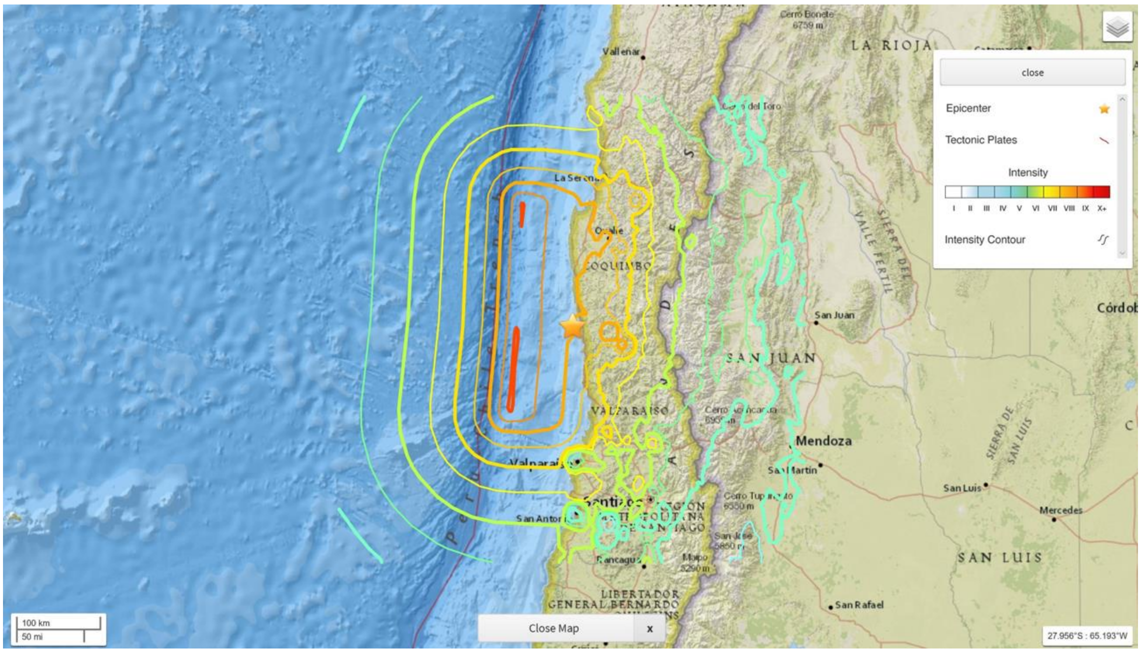


Figure 8.3. Seismic intensity of the off the coast of Illapel earthquake (Chile) on September 16, 2015 (USGS)

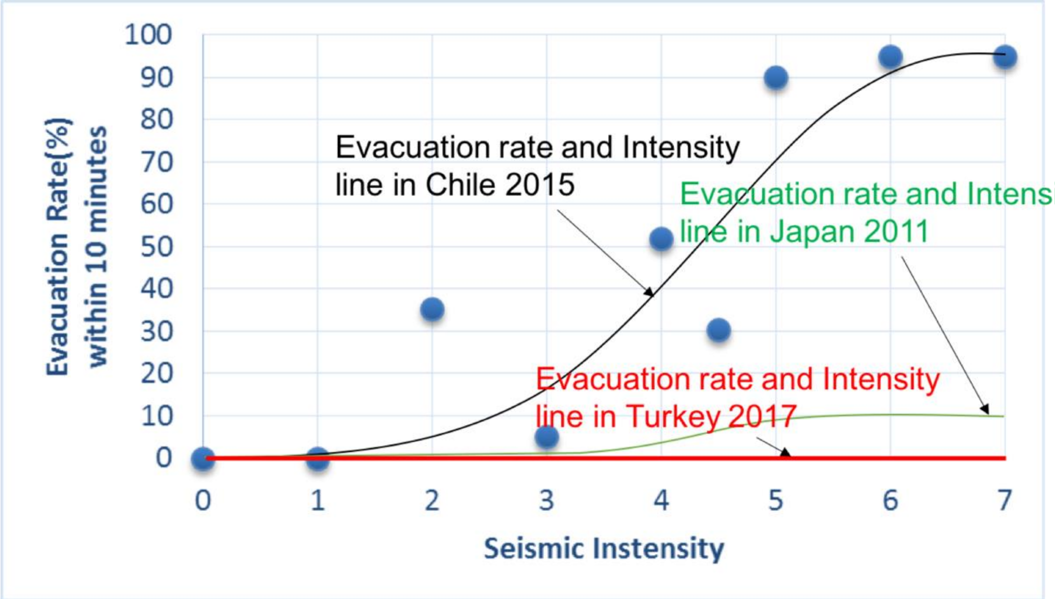


Figure 8.4. Relation between seismic intensity and evacuation rate within 10 minutes in Turkey, Japan and Chile

9. DISCUSSIONS AND CONCLUSIONS

The 21 July 2017 Bodrum/Kos earthquake and tsunami was quite a strong event that caused damage to southern coast of Bodrum Peninsula. Considering the importance of collecting tsunami data in the affected coastal areas, it is necessary to perform surveys as soon as possible in order to observe the tsunami traces and deposits before they are altered or removed. A day after the event, two field surveys were organized. In the first survey, the team surveyed the southern coasts of Bodrum Peninsula, took the measurements and interviewed people obtaining a picture of the phenomenon. Regarding the measurements, the team focused on an estimate of the height reached by the seawater as well as its horizontal inundation. As to the second work, the team tried to understand the time evolution of the event through eyewitnesses. There was a lack of data along some portions of the coast, such as the small peninsula of Bitez Bay and some places on the eastern part of the southern coast of Bodrum Peninsula due to the fact that there is no settlement in these areas.

Regarding the collected information from measurements and eyewitness reports, Gumbet Bay is the most hit and damaged region of Southern Bodrum Peninsula by the tsunami with more than 1m of flow depth at a certain location and the inundation distance reached up to 60m at some places. Tsunami penetration is much higher wherever any streambeds exist in the bays such as in Karaincir, Bitez and Gumbet Bays. The observations and eyewitness reports reveal that in Gumbet bay the maximum inundation distance reaches up to 280m along the stream. According to the preliminary elevation measurements performed by topographical engineering division of Bodrum Municipality, the maximum runup was determined as 1.9m in Gumbet Bay.

There are similarities between the layout and boat parking locations of Bitez bay and Gumbet bay. The boat parking locations of both bays are at the easternmost points of the bays. While significant inundation, strong whirlpools, currents and consecutive damaging motions occur, dragged all small crafts, damaged about 30 boats, and caused sinking 10 boats in Gumbet bay, there was no dragging and damaging of the boats in Bitez bay.

Furthermore, Fener Beach seems the most probable boundary of significant inundation at the western end of Southern coast of Bodrum Peninsula whereas Yaliciftlik Bay is the most probable boundary at the eastern end.

Karaada islet located in between Bodrum and Kos acted as a tsunami breakwater and protected Bodrum town. The runup at Kucukpoyraz bay at south of Karaada is measured 2m. There may be higher runup at some other small narrow bays at South of Karaada where the survey could not be performed at those critical bays facing to Epicenter location.

Also, the island of Kos was hit by Tsunami and Earthquake. Most of the damage from the Tsunami have occurred in the port where a wave height of about 1.5 m has been detected. Several boats have been relocated or damaged by hitting each other or against the port infrastructures. A video sequence allows also to estimate the timeline of the first two waves that arrived 13 and 20 min after the event, with the second one much larger than the first. In many other locations along the island signs of Tsunami were identified and measured with heights ranging between 0.5 and 0.8 m. Liquefaction and holes formation have been detected in the Lourus Cape, where a small lake was also formed. The earthquake also damaged several sections of the port, old and historical buildings and some private buildings: detailed inspections are under way.

10. ACKNOWLEDGEMENTS

Bodrum and Datca branches of Turkish Chamber of Civil Engineers (TCCE) and Bodrum Municipality are acknowledged for their close cooperation, logistics, collaboration, support and data collection. This study was partly supported by EC project Assessment, Strategy And Risk Reduction for Tsunamis in Europe - FP7-ENV2013 6.4-3, Grant 603839 (ASTARTE), EC DG ECHO funded ECHO/SUB/2015/718568/PREV26-"Probabilistic Tsunami hazard maps for the NEAM Region" (TSUMAPS-NEAM), Japan–Turkey Joint Research Project by JICA on earthquakes and tsunamis in Marmara Region by MarDim SATREPS, and in Erasmus+ program EC Turkish National Agency funded Contract number 2015-3-TR01-KA205-024506, Training Of Youth for Preparedness Against Marine Induced Hazards, (TROYO), TUBITAK 113M556, TUBITAK 108Y227 Projects and UDAP-Ç-12-14 project granted by Disaster Emergency Management Presidency of Turkey (AFAD) which provided invaluable support to gain experience and develop knowledge for investigating tsunamis not only for Europe but also for humanity. Satellite images are taken from Google Earth 7.1.8.3036, image on 1/17/2017, at 12:38:00am, server kh.google.com. METU Faculty of Engineering, DOLFEN Engineering, Consultancy Company, Oya Butik Hotel in Bodrum, KOERI-Regional Earthquake-Tsunami Monitoring Center (RETMC), Department of Earthquake Engineering from KOERI, Underwater Research Society Turkey, Philip England, Chiara Projetti, Ocal Necmioglu, Naeimeh Sharghivand, Emrecan Isik, Duygu Tufekci, Ghazal Khodkar, Can Goztepe, Bora Yalciner, Andrey Zaytsev, Marinos Charalampakis, Şükrü Ersoy, and Tuncay Taymaz are also acknowledged.

APPENDIX A: List of Measurements at Bodrum

Table A.1: Coordinate Measurements at Gumbet Bay:

#	Coordinates	Accuracy of the GPS Signal (m)	Note
1	37.030487N 27.406725E	5	Cars drifted in the stream bed. Coordinate of the car park.
2	37.031137N 27.406882E	5	Cars drifted from Point 1 to this location.
3	37.031412N 27.406703E	5	Flow depth reached 85 cm at this point.
4	37.032087N 27.406866E	10	Flow depth 85 cm in front of the car (Brand: Fiat – Kartal in the photos)
5	37.032310N 27.406834E	5	Flow depth reached 98 cm in front of the headwall.
6	37.032802N 27.406801E	5	Maximum inundation distance (mandarin in the photo taken at the taxi station)
7	37.032466N 27.406865E	5	- Flow depth reached 1.1 m near the sides of the headwall. - For scaling, height of the side of the headwall: 1.05m (at the right-hand side, concrete wall in the photo)
8	37.031579N 27.404888E	5	Maximum inundation distance along the road near Sami Hotel (White BMW)
9	37.027047N 27.407369E	5	Damaged yachts in the Gumbet Bay
10	37.031424N 27.399539E	5	Maximum inundation distance is about 25 m.

Table A.2: Coordinate Measurements at Yaliciftlik Bay:

#	Coordinates	Accuracy of the GPS Signal (m)	Note
1	36.992786N 27.527908E	5	Location of one of the holes in Yalıçiftlik
2	36.991411N 27.532678E	5	Most probably boundary for significant inundation at the eastern end of Southern coastline of Bodrum Peninsula.

Table A.3: Coordinate Measurements at Fener Beach:

#	Coordinates	Accuracy of the GPS Signal (m)	Note

1	36.964772N 27.264562E	5	Most probably boundary for significant inundation at the western end of Southern coastline of Bodrum Peninsula.

Table A.4: Coordinate Measurements at Akyarlar Bay:

#	Coordinates	Accuracy of the GPS Signal (m)	Note
1	36.967359N 27.290930E	5	Maximum inundation along the bay is near here.

Table A.5: Coordinate Measurements at Aspat Bay:

#	Coordinates	Accuracy of the GPS Signal (m)	Note
1	36.979592N 27.312356E	5	- Maximum inundation from the stream in Aspat Bay. - Maximum inundation from the sea is at 50 m South of this point

APPENDIX B: IDSL Test in Bodrum

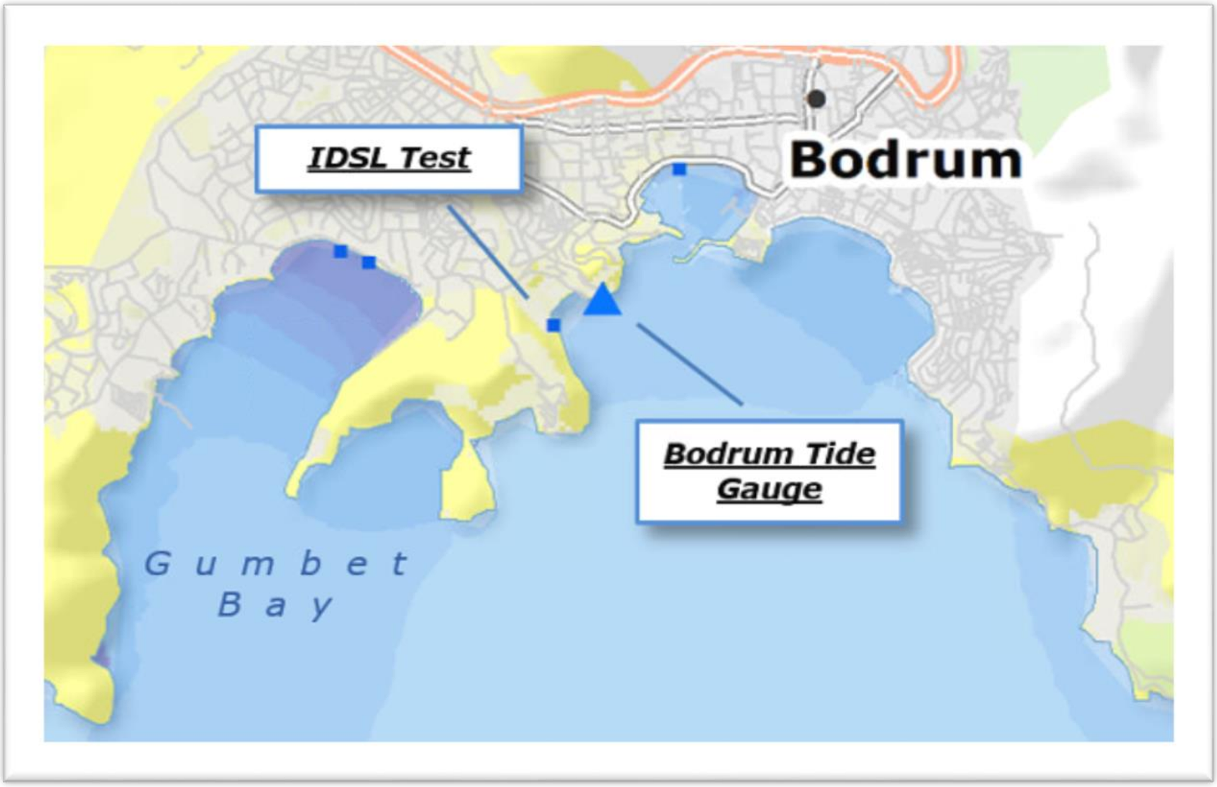


Figure B.0.1: Image showing the location of Bodrum Tide Gauge

The Bodrum tide gauge is located in a restricted area located about 500 m from the exit of the Bodrum port. A portable version of an IDSL (Inexpensive Device for Sea Level measurements) has been installed by Annunziato and Sozdinler on 29th July at a structure of the Voyage Hotel, 37.027506/27.416967. The objective was to verify for at least 1 full day, that the readings of the Bodrum tide gauge were consistent with the measurements of the IDSL.

Figure B.0.2: The IDSL installed at the Voyage Hotel

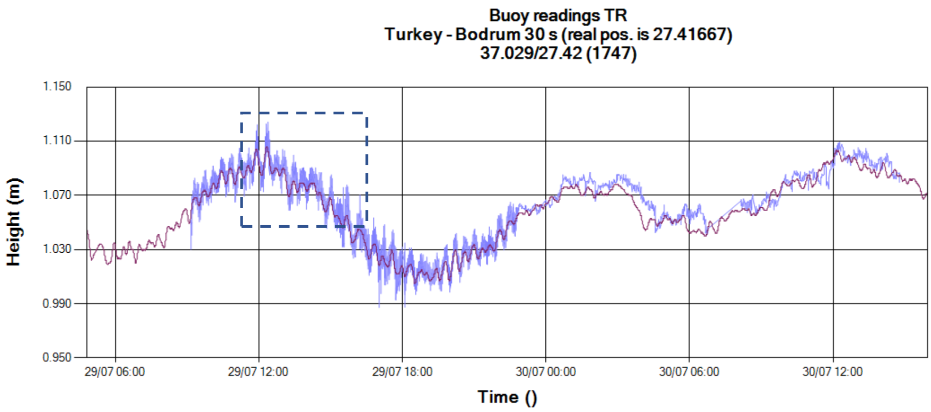


Figure B.0.3: Bodrum Tide Gauge and IDSL Buoy Readings

The dark red curve is the Bodrum tide gauge while the blue curve is the IDSL; the IDSL has been left measuring since 9:11 UTC of 29th July until 14:47 UTC of 39 July, thus for more than 29 hours. However, starting from 22:50 of 29th July the acquisition frequency of the device was degraded, probably having reached a limit of band width (Italian Vodafone SIM card provided by JRC). This is the reason why in the curve after half of the period the oscillations are less strong.

In the period of high frequency acquisition however, the comparison between the two instruments is excellent (Figure B.0.3). The IDSL has an acquisition frequency higher than the Bodrum tide gauge (5 s interval vs 30 s interval) and has also been installed in a location with very low water below. That is why the IDSL has a larger oscillation amplitude around the Bodrum signal.

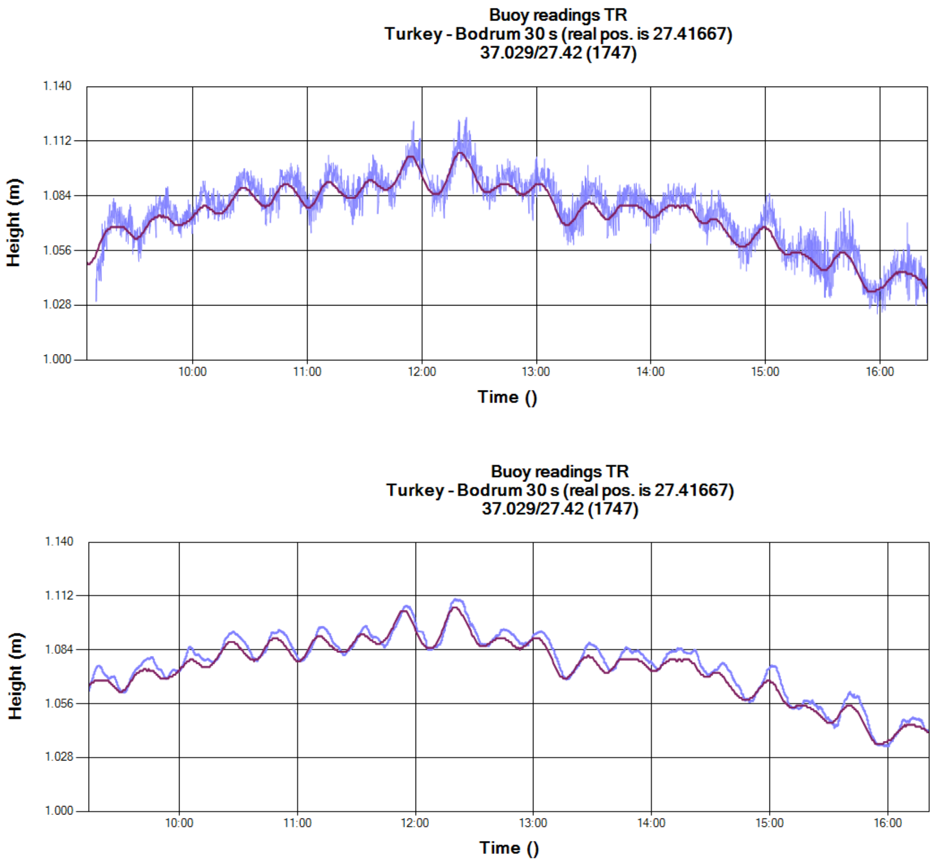


Figure B.0.4: Comparison of Bodrum Tide Gauge and IDSL Buoy Readings

It is sufficient to apply a low pass filter (moving average with 30 points that the two signals appear almost identical. The remaining small difference may be due to the different installation location. On the other hand, a closer installation was found impossible in the time frame of the mission.

The conclusion is that the Bodrum tide gauge provide perfectly valid measurements.

APPENDIX C: List of Measurements done at Kos

Table C.1: List of all the measurements done at Kos

ID	Lon	Lat	Height (m)	Notes
1	27.207330	36.890260	0.1	End of impact
2	27.227870	36.893080	0.1	La Branda Acqua Marine Resort
2	27.248790	36.899910	-	Coastal Erosion or subsidence
3	27.258050	36.904330	0.5	
4	27.272320	36.912010	1.5	
4	27.272760	36.912300	1.3	
5	27.275030	36.913580	1.0	
5	27.275220	36.913650	1.4	
5	27.275250	36.913720	1.0	
5	27.275320	36.913740	1.2	
6	27.275740	36.914330	0.7	
7	27.279290	36.915690	0.4	Edge of Kos
7	27.280370	36.915640	0.4	
8	27.281050	36.914970	0.6	
8	27.281170	36.914890	0.5	
9	27.282290	36.911300	0.3	Atlantis Hotel
9	27.283360	36.909880	0.6	
10	27.285070	36.905570	0.3	
11	27.285510	36.901560	1.2	
11	27.285930	36.900030	0.5	
12	27.288136	36.894100	1.5	Port
12	27.286312	36.896210	1.4	Port
12	27.287914	36.897453	1.4	Port
12	27.28959	36.89478	1.5	Port, close to the old Bridge
13	27.29408	36.89324	0.70	Hotel Aktis Kos
14	27.30099	36.89277	0.80	Kos Marina
15	27.288404	36.894493	-	Stream
15	27.307016	36.886818	0.7	
15	27.307072	36.886951	0.7	
15	27.307074	36.886940	0.7	
15	27.307404	36.886543	-	Stream
15	27.307444	36.886562	0.5	
15	27.308334	36.886475	0.5	
15	27.308651	36.886471	0.7	
16	27.319109	36.885265	0.5	
16	27.319126	36.885201	-	Salt Deposit
16	27.319351	36.885090	0.8	
17	27.325029	36.884586	0.8	East Kos after Port

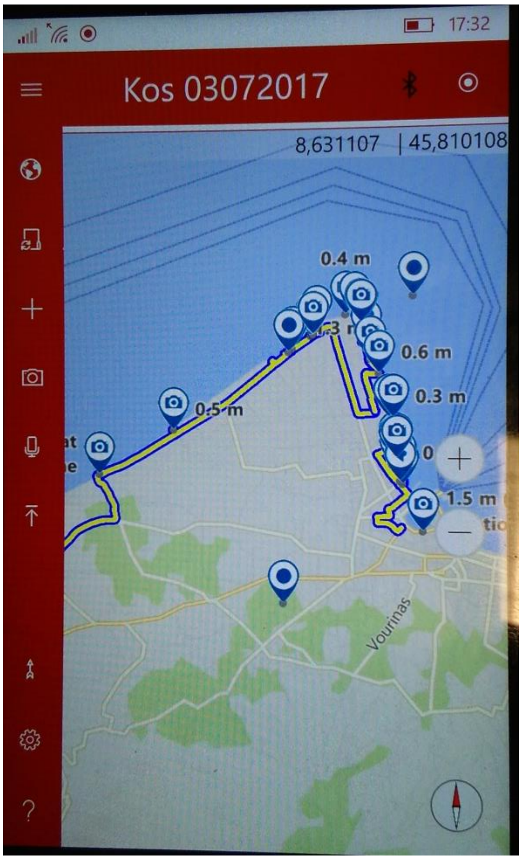
17	27.325085	36.884602	0.8	
17	27.325106	36.884331	0.7	
17	27.325403	36.884586	0.7	
17	27.325729	36.884548	0.8	
17	27.327345	36.884888	0.8	
18	27.332430	36.887180	0.6	
19	27.336952	36.890324	0.5	Lourus Cape
19	27.337317	36.890587	0.4	
19	27.337637	36.890690	0.1	
19	27.340555	36.888866	0.4	
19	27.341215	36.888420	0.5	
20	27.344984	36.883469	0.7	
20	27.346458	36.882256	0.7	
20	27.346926	36.881554	0.7	
20	27.347225	36.880806	0.8	
21	27.352135	36.871197	0.7	
21	27.352173	36.870750	0.7	
22	27.349827	36.857700	0.0	Agiou Foka

APPENDIX D: Field Reporting Tools

The mission conducted by A. Annunziato was performed making use of the Field Reporting Tool (FRT). This is an application, developed specifically in order to allow to report in the server of a crisis room the data from the Field. The original development was done in occasion of the Chile Tsunami in 2010; the new application, developed in collaboration with the Italian Fire Brigade, allows a number of features

- Geolocation: all activities performed by the operator, therefore all data shared with the Crisis Managers, needed to be provided with a geographic reference
- Multimedia: in order to help the Crisis Managers creating a Common Operational Picture, pictures, video and audio are needed to get a better understanding of the situation
- Ease of use: the application must provide a fast and easy approach to the main functionality. Advanced and more complex features will then be available by navigation, menus and other common means
- Low profile: the application must not require specific, expensive or fragile devices to be operated
- Interoperability: the platform must adhere at commonly adopted protocols and formats to improve the capability to share information with other systems
- Identity: the application needed to be recognizable by the user as owned; therefore, the visual identity of the users should be easy to implement and the platform must be translated in many EU languages

Once the data are acquired (text, pictures, videos, voice messages or telemeter measurements (for Tsunami height), they are immediately available in the web portal. And in fact, JRC staff could prepare the overall maps while the mission was still being conducted.



All the data acquired during the Tsunami Survey in Bodrum and Kos, acquired with FRT, are available at this address.

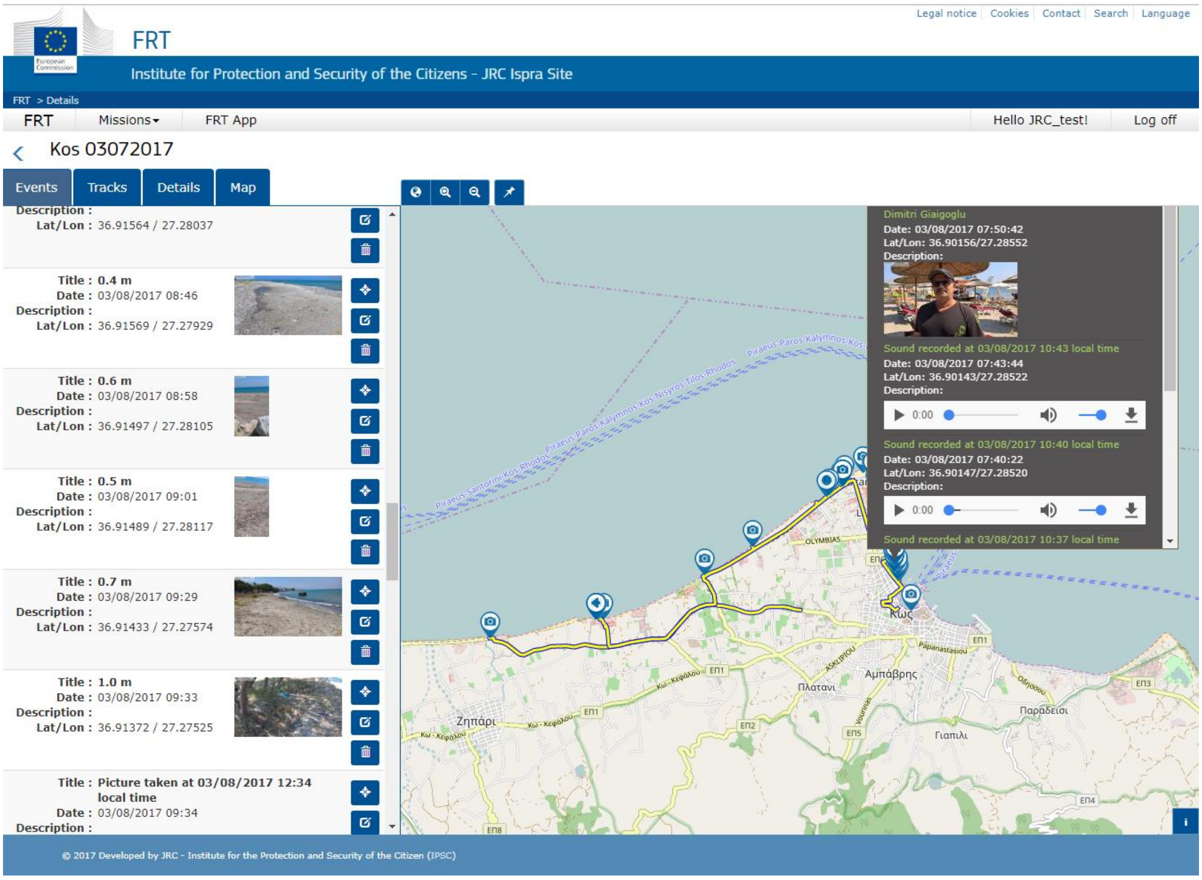
JRC FRT url: http://critechportal1.jrc.it/FRT_JRC

JRC test credentials:

- user: JRC_test
- pwd: Jrc@2017

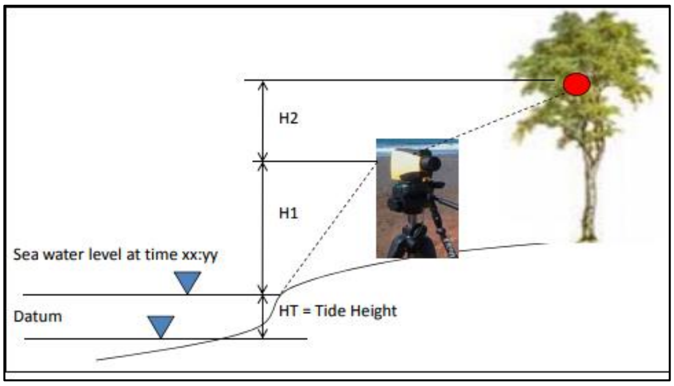
First login (top right) and then you will see my missions.

On the right, the screen on the device for the Kos mission and the same mission as published online. It is possible to see all the tracks of the movements done, the points collected, the images, the videos, geolocalized and download data in KMZ, Word report and other formats.



For the measurement of the tsunami water level-or height of wave above sea level- two pieces of information were needed at each point of measurement: the current sea level that needed to be set in advance of each measurement (H1) and the height measurement (H2). The Trimble device was used for this purpose using a point where specific tsunami marks could be found such as algae deposited on trees, dirty marks found on the walls of houses, or debris on the field transported by the waves. The Trimble device was transmitting the height values directly to the device, via Bluetooth connection.


Laser Trimble


H2
H1
Sea water level at time xx:yy
Datum
HT = Tide Height

APPENDIX E: Reference Material Questionnaire

Style of questionnaire survey

SURVEY DATE	____/_____ / 2015	**START HOUR**		**FINISH HOUR**	
QUANTITY OF REJECTIONS BEFORE ACHIEVINGTHE SURVEY					
SURVEY TAKER				**CODE**	

Good morning/afternoon/evening. I am survey taker of Consultants. We are conducting a survey for the Japan International Cooperation Agency (JICA), regarding the evacuation Tsunami Alert in the Illapel earthquake in September 2015 and we would like to know your opinion. This study aims to identify relevant elements to help improve the behavior of the population in evacuations required in emergency situations. I would appreciate answer some questions that will be kept in discretion and anonymity.

SURVEY RESPONDENT INFORMATION			
Sex		**Name**	**Age (last birthday)**
Woman	**1**		
Man	**2**		

1. Where were you when the earthquake occurred? (July, 21, 2017 – 01:31) (ONE ANSWER)

At my home	1	In an open space	5
At work	2	Inside a vehicle	6
In an Educational Establishment	3	Other:	7
In other closed space	4	Don't know (DON'T READ)	99

2. When the shaking was occurring, was it difficult to keep standing?

I was able to stand without any problems	1	I was easily fell by the movement	4
It was difficult to stand	2	Don't know/remember (DON'T READ)	99
Although I tried, I was not able to stay standing	3		

3. Did you evacuate from tsunami?

Yes, I evacuated to a height area	1
Yes, I went to high floors, buildings of medium or high height	2
No, I could not evacuate	3
No, I did not evacuate	4
Other:	5
Don't know/remember (DON'T READ)	99

If the person evacuated, go to No. 4, if not , No. 5

4. What made you decide to evacuate?

The quake was strong, and I thought tsunami would come	1	I saw all escape	4
My family and/or friends recommended me to evacuate	2	I was forced to evacuate (by a third)	5
I saw tsunami	3	Don't know/remember (DON'T READ)	99

4_B. Which travel means did you use to evacuate mainly? (ONE ANSWER)

Your own car or pickup truck	1
Other person car or pickup truck	2
Walk	3
Bicycle	4
Motorbike	6
Other:	7
Don't know/remember (DON'T READ)	99

4_C. Please comment freely what are the reasons why you evacuated

In text:

5. (IF NOT EVACUATED, OR COULD NOT EVACUATE) **What was the main reason why you did not evacuate?**

I thought the tsunami would not reach my house (or place where I was)	1	I looked after my house to avoid thieves	6
I am handicapped (NOT READ IF OBVIOUS)	2	I did not want leave my pet(s)	7
I had a handicapped family member	3	Other:	8
I was sick	4	Don’t know/remember (DON’T READ)	99
I had a sick family member	5		

5_B Please comment freely what are the reasons why you did not evacuate, your idea about tsunami risk, and your past experience of tsunami evacuation.

In text:

6. Do you know what is a tsunami before the disaster?

YES	1
NO	2
DN/DA (DON’T READ)	99

7. Have your family (parents, grandparents, etc.) ever taught you to evacuate from a tsunami?

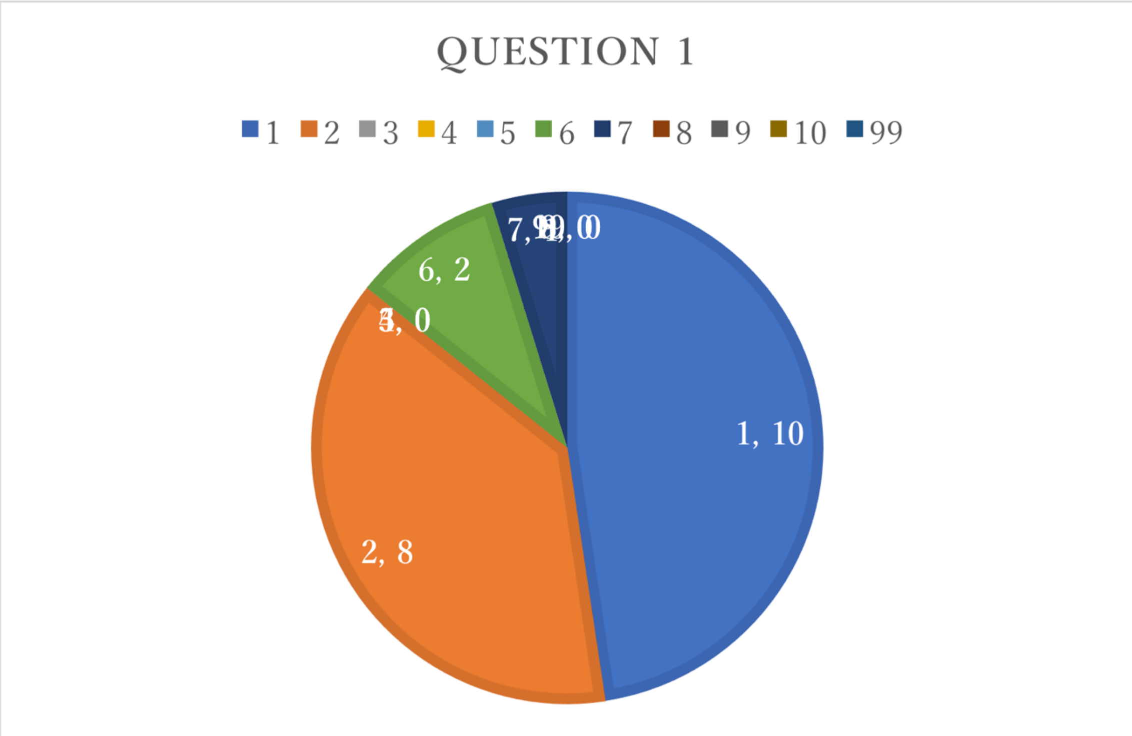
YES	1
NO	2
DN/DA (DON’T READ)	99

8. Did you experience or know 1956 Bodrum Tsunami and Earthquake?

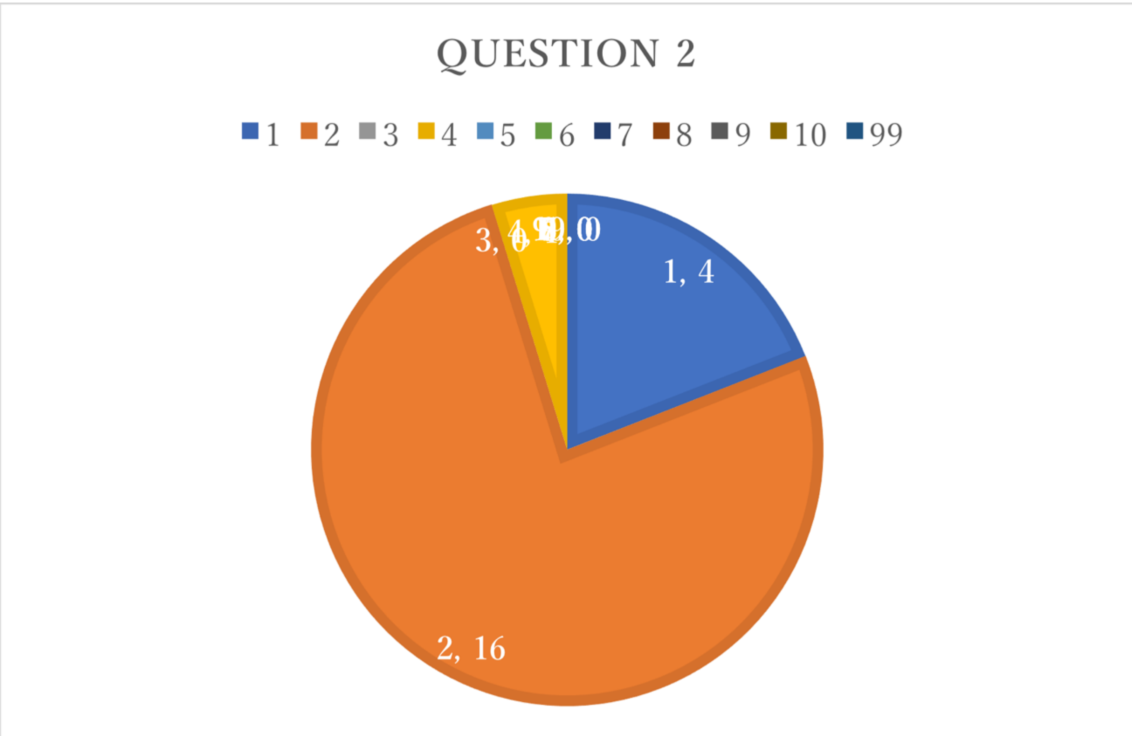
Yes, I experienced	**Yes, very much**	**Yes, some how**	**No**	**DN/DA**
1	**2**	**3**	**4**	**99**

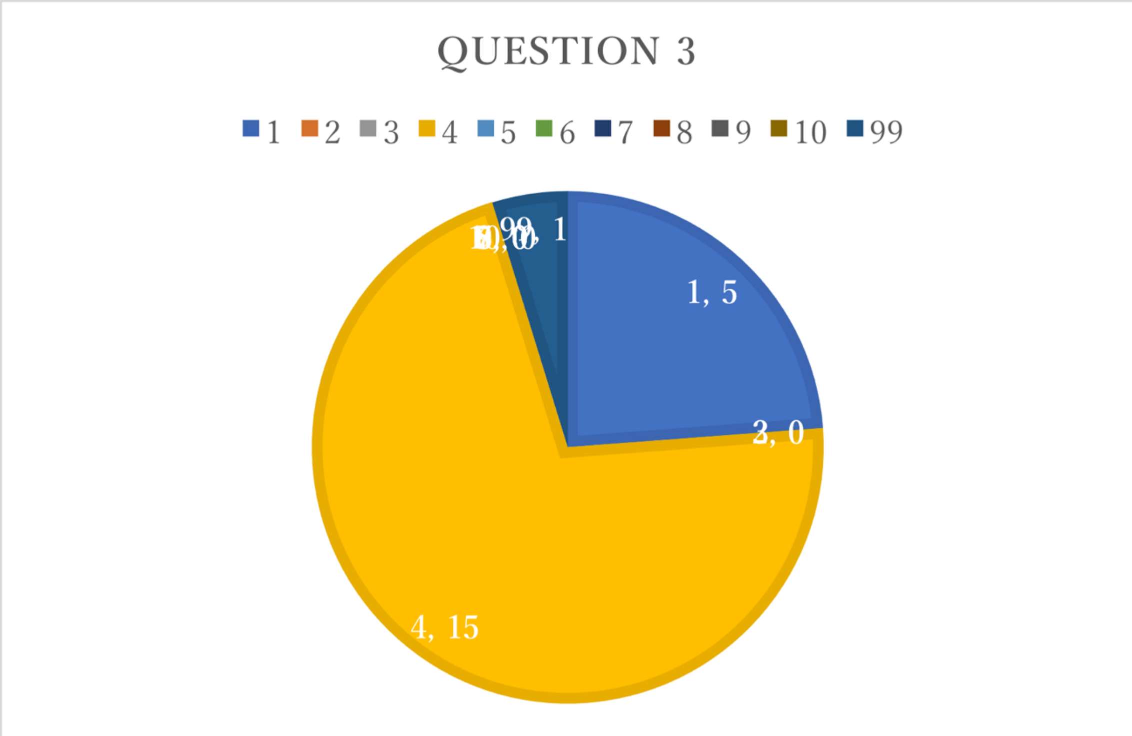
<table>
<tr><th colspan="5">INTERVIEWED INFORMATION</th></tr>
<tr><td colspan="2">REGION:</td><td colspan="3">PHONE:</td></tr>
<tr><td>ADDRESS</td><td colspan="4"></td></tr>
<tr><td>What is the OCCUPATION of household head? (WRITE TEXTUAL) (ONE ANSWER)</td><td colspan="4">______________________________</td></tr>
<tr><td rowspan="5">Could you indicate me EDUCATIONAL LEVEL of the household head?</td><td>Did not study</td><td>1</td><td>incomplete Technical</td><td>6</td></tr>
<tr><td>Incomplete basic education</td><td>2</td><td>Complete Technical</td><td>7</td></tr>
<tr><td>Complete basic education</td><td>3</td><td>incomplete University</td><td>8</td></tr>
<tr><td>Incomplete secondary education</td><td>4</td><td>complete University</td><td>9</td></tr>
<tr><td>Complete secondary education</td><td>5</td><td>Post grade studies</td><td>10</td></tr>
</table>

Questionnaire results

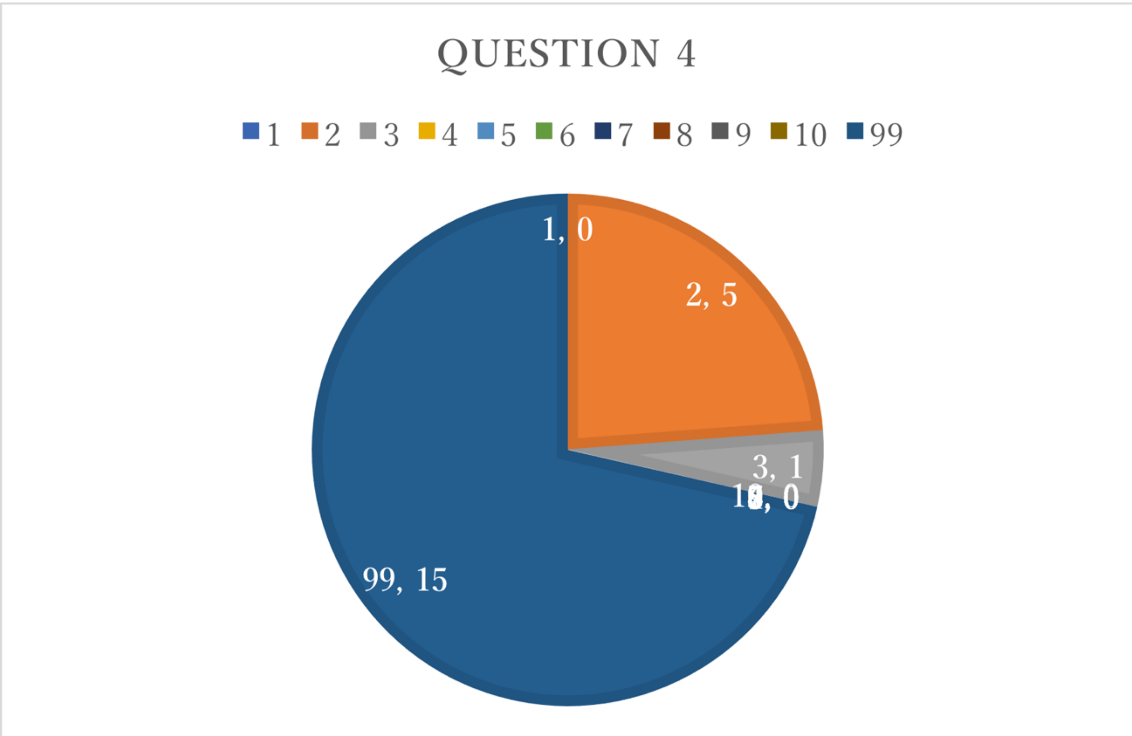


Numbers indicate the answer number on the left side and the number of people who answered on the right side (the same below)

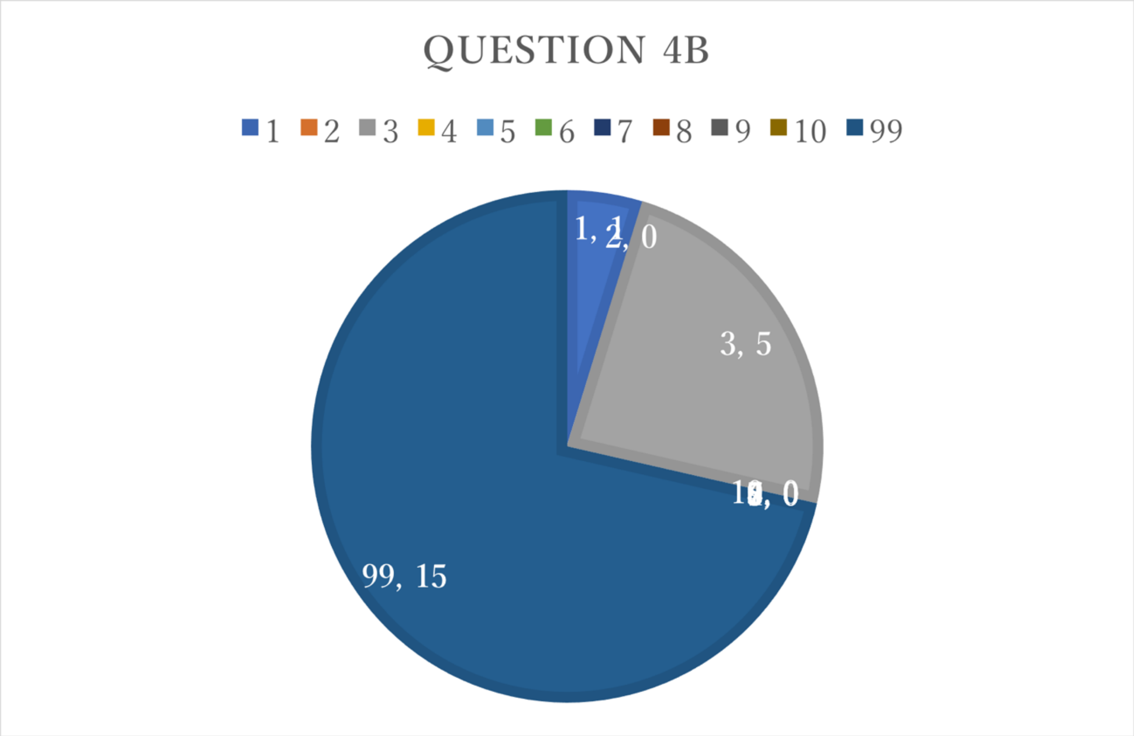




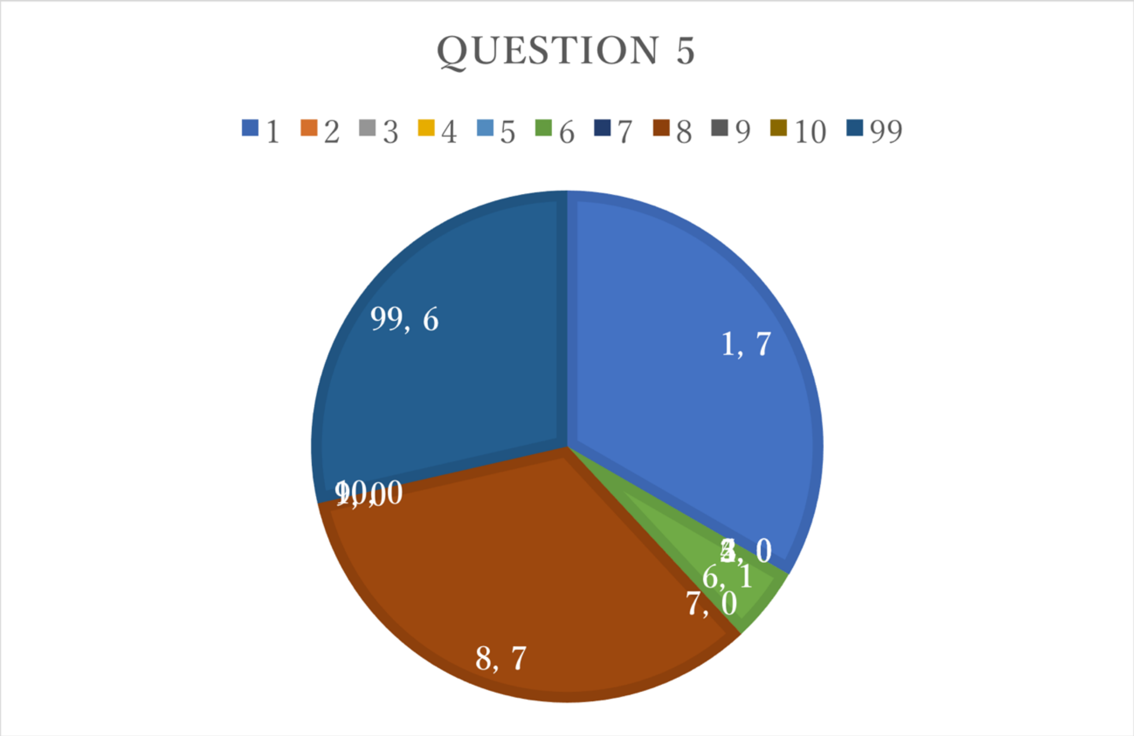
There are five people who ran away, but as shown in Question 4, they heard that a tsunami would come or they were running away by looking at the state of the sea



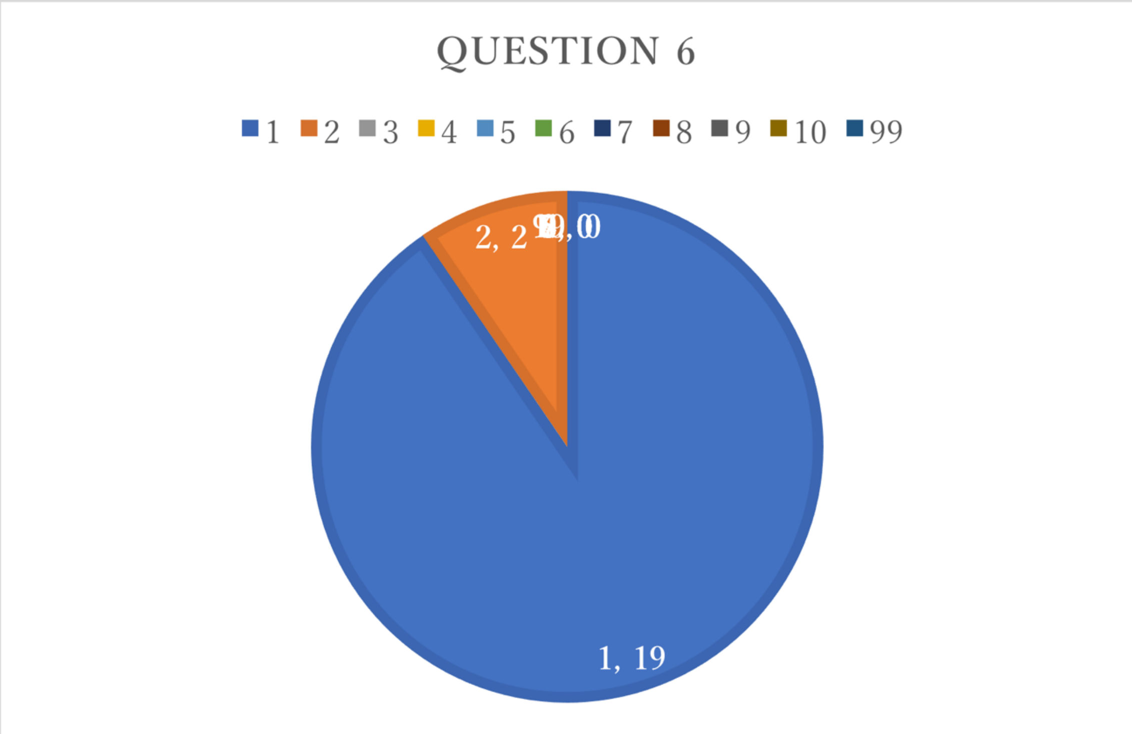
Five people who said they ran away in Question 3 pick No. 2.



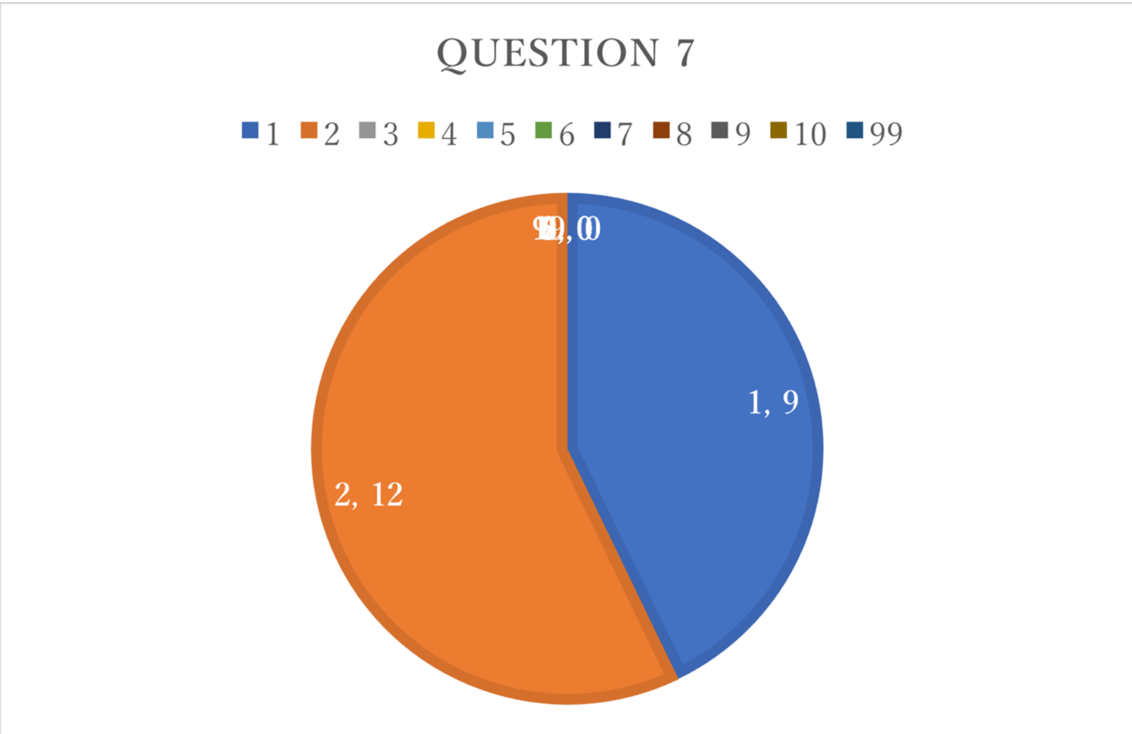
The number of walking evacuees seems to be large. It is thought that it was affected to being in the middle of the night and narrow roads.

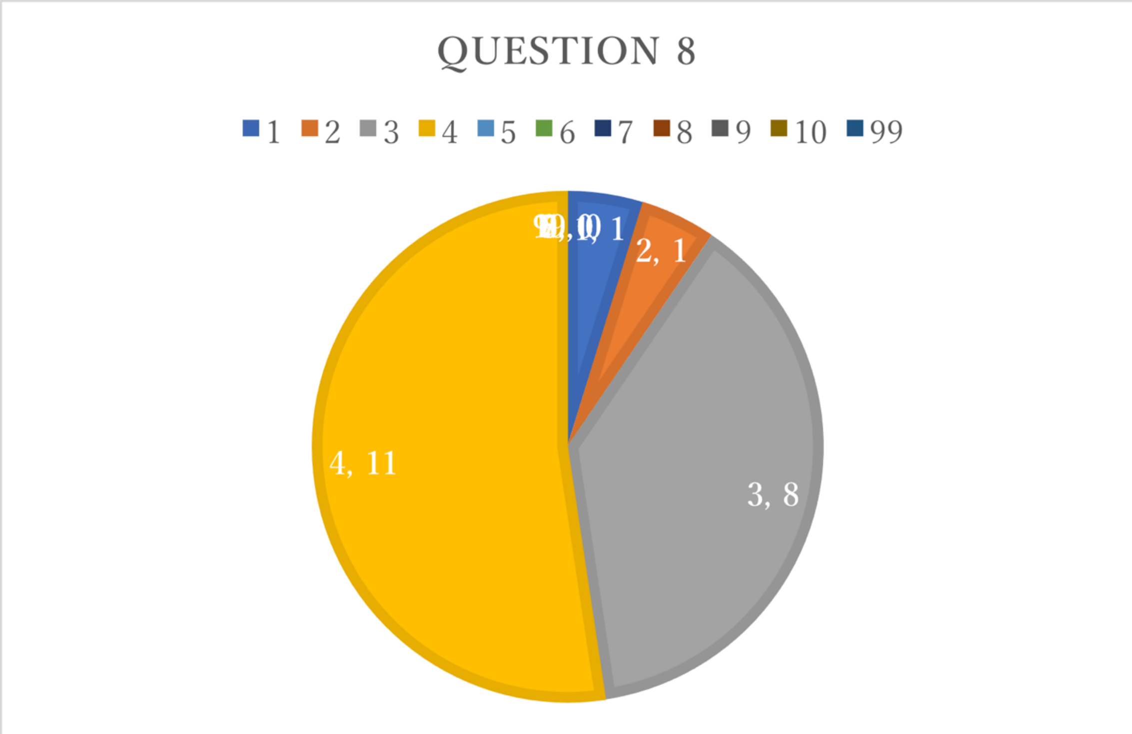


Other answers included responses from religious things such as not being afraid of death, and from lack of education that the tsunami does not occur in Turkey.



Many people said they learned about the tsunami in the 2011 picture of Japan. I knew the word itself, the tsunami itself.





Although there are several people who know the earthquake tsunami in 1956, I feel the necessity of education for the tsunami.