A preliminary report on the Nov 17, 2015 M=6.4 South Lefkada earthquake, Ionian Sea, Greece

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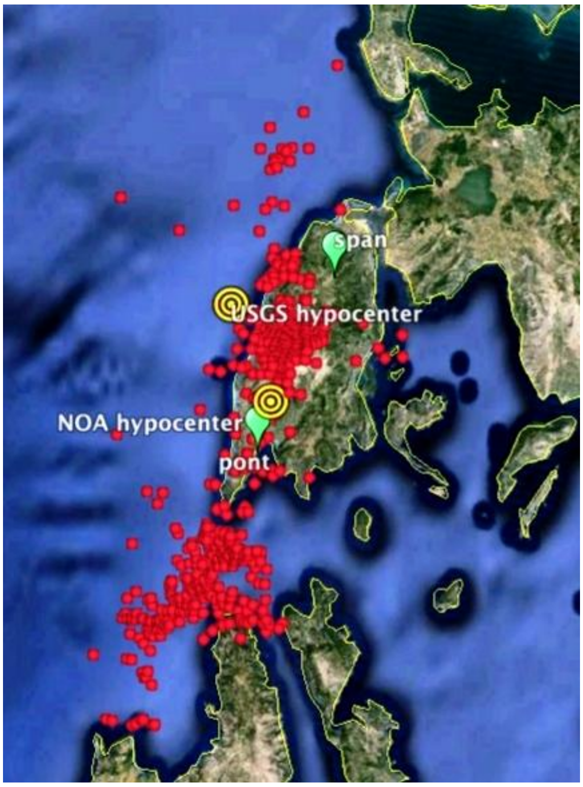

A preliminary report on the Nov 17, 2015 M=6.4 South Lefkada earthquake, Ionian Sea, Greece

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Abstract

The 17th November Mw=6.4 event occurred along a N20±5°E strike-slip fault with right-lateral sense of slip. Relocation of seismicity and preliminary inversion of geodetic data suggests the fault plane dips to east with an angle of about 70±5 degrees. The earthquake caused a lot of structural damage to the villages of Agios Petros, Athani, Dragano and Komilio. Environmental effects include liquefaction, extensive rock falls and landslides. No surface ruptures were found in the field. Road cracks are interpreted as secondary phenomena of gravitational nature induced by ground shaking. Preliminary inversion of geodetic data suggests that the upper part of the fault is offshore very close to the coast, and at very shallow depth (0.5±0.5 km), as constrained by the azimuth and amplitude of the motion at NOA GPS stations PONT (36 cm offset to the south) and SPAN. We have not observed significant vertical motion of the shoreline and this is consistent with the predictions of the model.

Date of report

This report was released to EPPO (www.oasp.gr) and to EMSC-CSEM on December 4, 2015, 9:30 pm Greek time.

1. Tectonic setting

Lefkada (Ionian Sea, Greece) is considered as among the most active tectonic areas in Europe and one of the most active zones in the eastern Mediterranean region. Lefkada has been repeatedly subjected to strong ground shaking due to the proximity of the island to 140-km long CTF (Cephalonia Transform Fault; Fig. 1, Louvari et al., 1999; Sachpazi et al., 2000). The most recent strong earthquake, with magnitude of Mw 6.2, occurred on August 14, 2003 offshore the western coast of Lefkada Island, causing severe damages around the whole island (Papadopoulos et al., 2003; Karakostas et al. 2004; Papathanassiou et al., 2005). Pavlides et al. (2004) assumed a division of 40-km long Lefkada segment of CTF into two smaller segments separated by Sesoula Islet – westward of Lefkada, striking at NNE-SSW to NE-SW and behaving rather independently in terms of seismic reactivation. The northern limit of Lefkada segment of CTF is constrained by a thrust solution of the November 4, 1973 earthquake with M = 5.8 (Baker et al. 1997), offshore the northwest coast of Lefkada island.

In terms of surface geology, Lefkada is built with sedimentary rocks (mainly carbonates) that belong to the so-called external Hellenides (Jacobshagen, 1979). In particular, the boundary between the two different geological zones – Ionian and Paxos, runs through this region and outcrops onshore Lefkada Island, forming the noteworthy Ionian Thrust. The main part of the island is consisted of a carbonate sequence of the Ionian zone, while the SW part of the island consists of limestone of Paxos geological zone (Bornovas, 1964). Detailed field observations on South Lefkada (Cushing M, 1985; Lekkas et al., 2001; Rondoyanni et al., 2012), showed several active and neotectonic faults striking N-S and NE-SW, of which the most important can be considered the Athani fault. This is a NNE-SSW-striking fault dipping north-west, very well expressed in the region’s morphology and marked on satellite images and aerial photos.

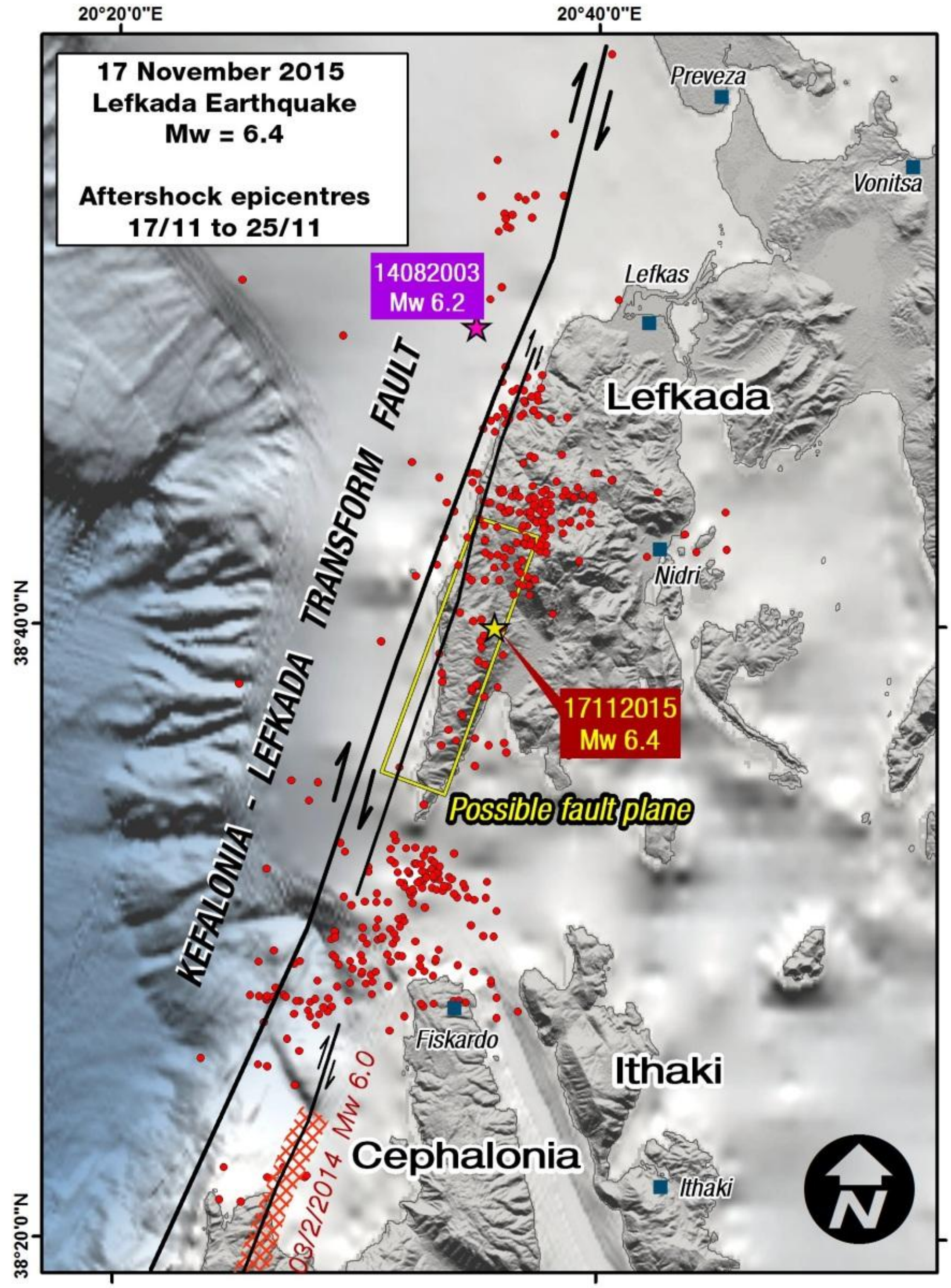

Figure 1. The 17th November 2015 Lefkada main earthquake (yellow star) and aftershock revised epicentres recorded by National Observatory of Athens (NOA). Dextral faults along the Cephalonia-Lefkada Transform boundary are shown as black lines.

2. Seismic data

On November 17, 2015, 07:10 GMT (09:10 local time) Lefkada was struck by a strong, shallow earthquake (NOA magnitudes ML6.0-Mw 6.4 respectively; depth 11 km). According to the National Observatory of Athens, Institute of Geodynamics (NOA; www.gein.noa.gr) the epicenter of the earthquake was located to the southwestern part of Lefkada island (see map). Based on published MT solutions the 2015 earthquake occurred on a near-vertical strike-slip fault with dextral sense of motion in response to ENE-WSW horizontal strain in central Ionian Sea (Ganas et al., 2013). The earthquake ruptured a coastal, strike-slip fault, in contrast to the 2014 events on shore Cephalonia (Valkaniotis et al., 2014; Boncori et al., 2015). According to EPPO-ITSAK (http://www.itsak.gr/uploads/news/earthquake_reports/Lefkas_M6.0_17-11-2015.pdf) the value of PGA recorded at the Vassiliki sensor was equal to a=0.36g. Revised NOA solutions from the period Nov. 17-30, 2015 are plotted in Figure 2. It is evident a general N-S arrangement of aftershocks possibly driven by Coulomb stress changes on either end of the rupture.

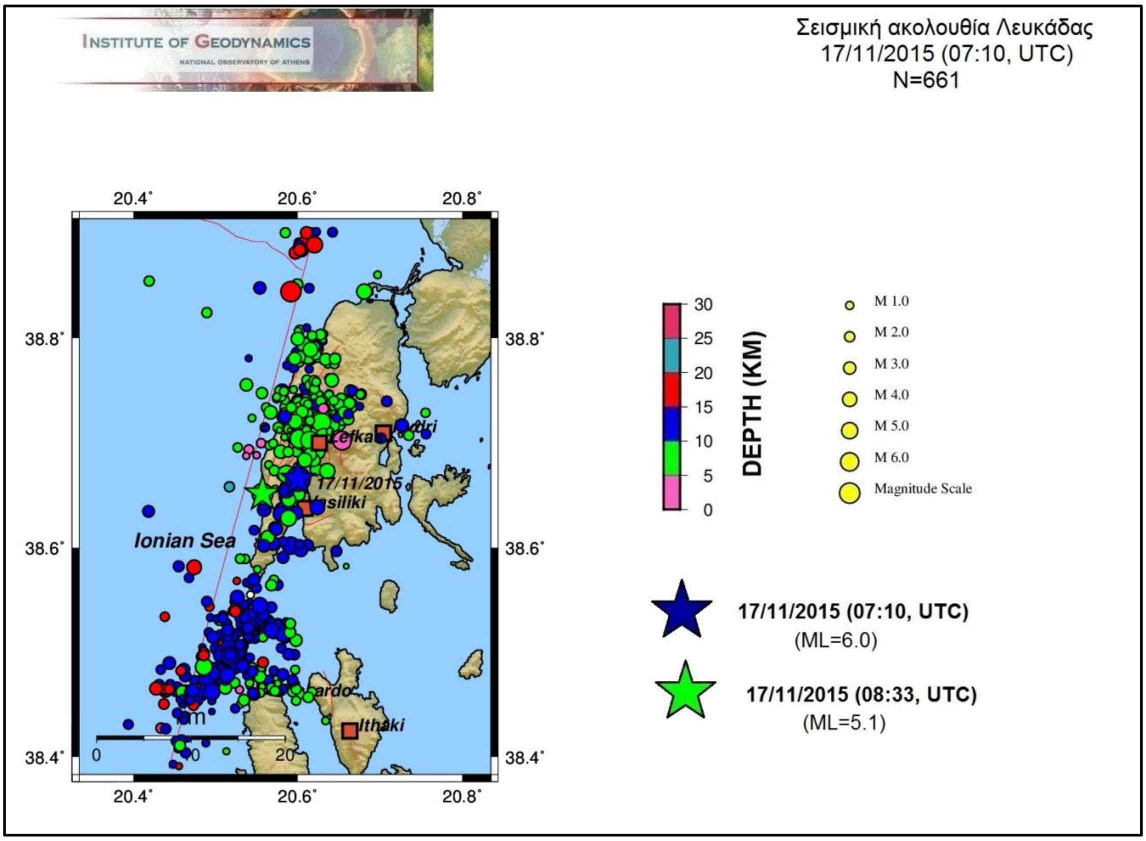

Figure 2 Seismicity map of the Lefkada sequence from NOA analysis (revised) data. Map contains 661 shallow events until Nov. 30th, 2015.

A few hundred events were relocated by use of the software Nonlin-Loc (Lomax et al., 2000). The selection criteria used were a) azimuthal gap<180°, b) minimum number of phases per event 4 P-wave and 3 S-wave, c) solution rms <0.48s, d) error on the horizontal errx<1.6 km and e) error on the vertical errz<1.6 km. A crustal velocity model published by Hasslinger et al (1999) was used. The results (Figure 3) indicate a) post-seismic activity clusters at both ends of the rupture b) the fault plane is better seen (inferred from alignment of projected hypocentres) on the E-W cross section near the epicentre, dipping to the east (best fit at 68°).

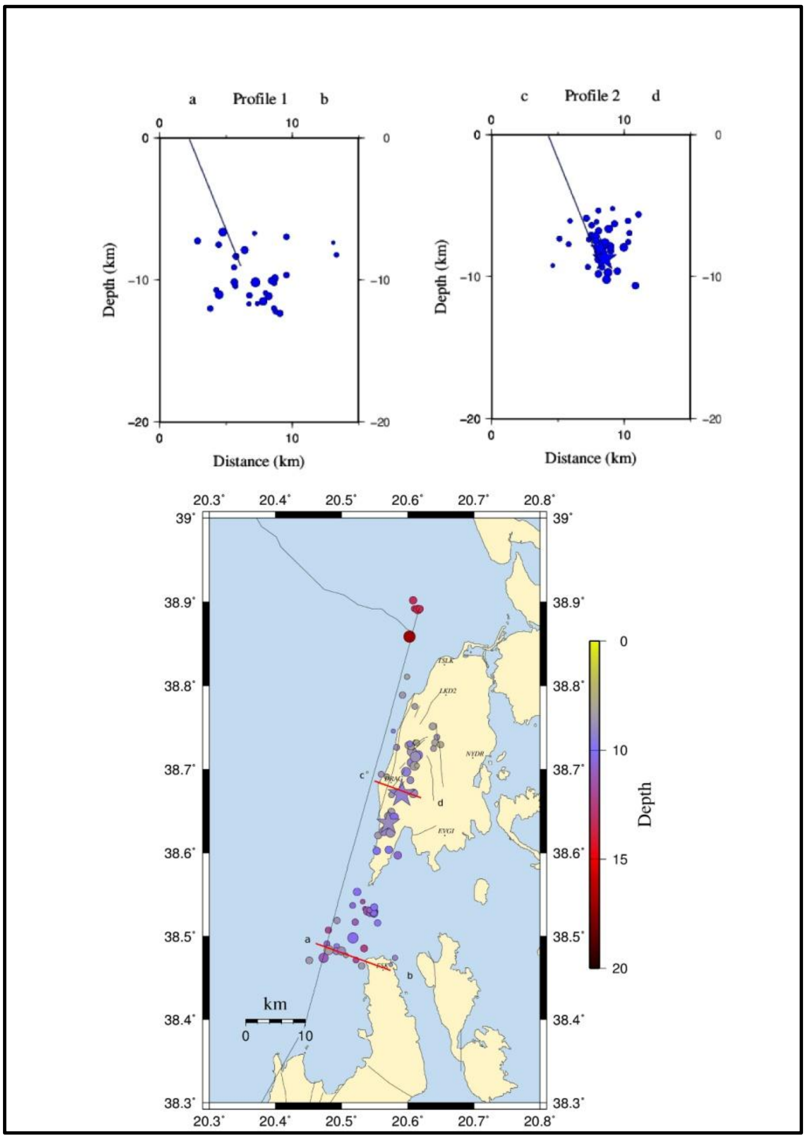

Figure 3. Map of relocated seismicity using NOA phase data (bottom) and E-W cross sections near the epicentre (top right; section c-d) and at the south end (top left; section a-b), respectively. Software used: NonLin-loc.

3. Satellite Geodesy Data

The National Observatory of Athens during the last 10 years has established several permanent GPS stations in central and western Greece in order to monitor the tectonic motion (Ganas et al., 2008, 2011). In western Greece there are six stations that operate since early 2006 – mid 2007 (VLSM, RLSO, PONT, SPAN, KASI, KIPO; see www.gein.noa.gr/gps.html for network map and site logs). Ganas et al. (2013) presented results showing N-S crustal shortening onshore Lefkada Island of the order of 2-3 mm/yr, which the authors evaluated as "*is probably related to increased locking on the offshore Lefkada fault*" implying pre-seismic deformation. This report presents results from data provided by two (2) permanent GPS stations onshore Lefkada (SPAN and PONT) [1] and one station in Cephalonia (VLSM). Our preliminary results include: time series of 1-s positions for stations SPAN, PONT (Figure 4) and static offset estimates (Table 1) due to seismic motion of Nov. 17. 2015 event. Figure 5 shows field photographs of station PONT in south Lefkada.

Table 1. List of NOANET stations with measured co-seismic offsets due to seismic motion. Station info can be seen at www.gein.noa.gr/gps.html . Further, comparable results of displacements observed at permanent GNSS stations after Lefkada's earthquake were published by NTUA[2] and other organizations such as AUTH, INGV etc.

Station	**dE (mm)**	**dN (mm)**	**dUP (mm)**
PONT	-201	-365	-65
SPAN	-59	-45	-3
VLSM	-4	-12	-4

[1] Following requests from groups and individuals the NOA geodetic data (30-s, 1-s) were released on Nov. 18, 2015 at 7:37 pm, local time.

[2] http://dionysos.survey.ntua.gr/dsoportal/_projects/supersites/lefkada/

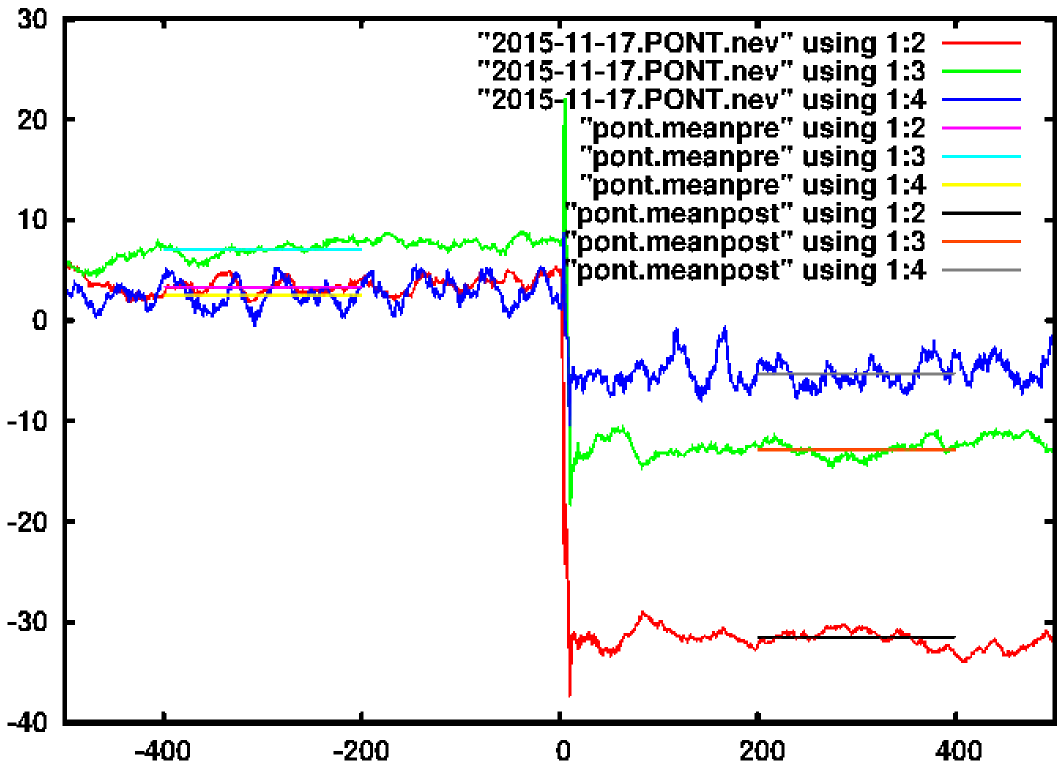

Figure 4. Graph showing static offsets of NOA station PONT (South Lefkada). Each time series shows the time window in which the average position (and the relative standard deviation) before and after the event have been computed. X-axis is time (s), Y-axis is displacement (cm).

Figure 5. Picture mosaic of field photos + location of NOANET station PONT in Vassiliki area, south Lefkada.

The PGD magnitude of this event (as defined in Melgar et al., 2015; Figure 6) equals to Mw=6.5 and it works exceedingly well in this case thanks to the proximity of the permanent GPS stations to the epicentre. First estimate is at only 5s after origin time. The measurement stabilizes after 20-s. Neglecting data from the vertical components provides a more stable solution, however both solutions are quite good.

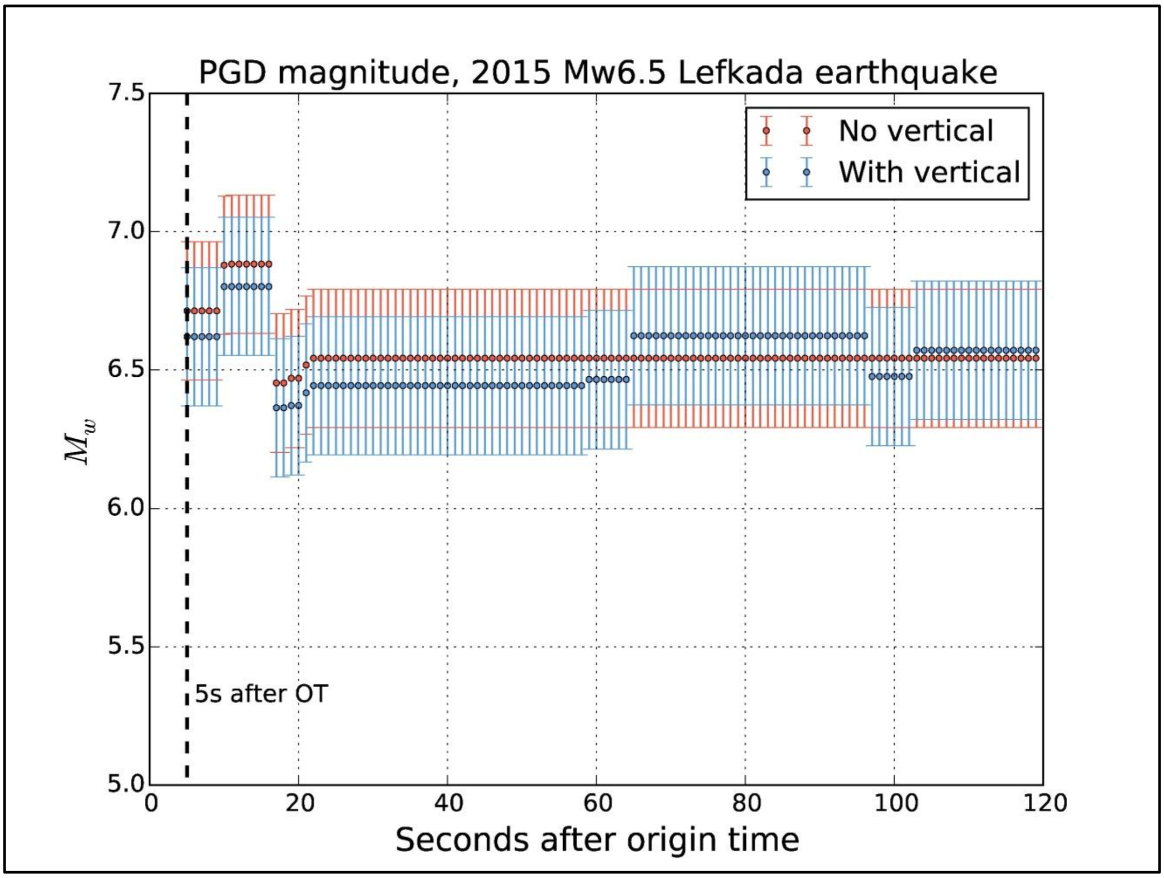

Figure 6. Plot showing the estimated moment magnitude (Mw=6.5) from the high-rate GPS as a function of time with uncertainties. First estimate is at only 5s after origin time.

A preliminary modellling (version 1) of the co-seismic displacements at the NOA stations VLSM (Cephalonia), PONT and SPAN (Lefkada) together with LOS displacements from SAR interferometry (version 2) gives the following parameters for the fault (figure 7 shows version 1, determined on Nov. 19, 2015). Fault parameters: Fault length: **21**km instead of 22, Fault width **10**km instead of 11.5, Fault Dip angle **73°** instead of 70°, Azimuth **N18°E** instead of N25°E, Fault Slip: **1.44 m** instead of 1.2 m, Centre of upper edge of the fault: E_458.0 N_4271.6 (UTM34) instead of E_458.4 N_4272.0 (i.e. almost identical), Top of the fault **150 m** instead of 700 m (this means that the fault almost reaches the surface). The main differences/improvements (constrained by InSAR) are: a) azimuth N18°E instead of N25°E, and thus more consistent with the Aug. 14, 2003 M=6.2 event b) this was very shallow event, this is a consequence of the high value of the GPS at PONT (further confirmed by the large number of fringes).

The seismic moment from this geodetic model is 9.5×10^{18} Nm (intermediate between CMT and GEOSCOPE) but double that of NOA (4.4×10^{18} Nm). The Sentinel-1A fringe pattern provided by ESA (Michael Foumelis), HUA (I. Parcharidis) and BEYOND (H. Kontoes; http://beyond-eocenter.eu/) teams is, at the first order, compatible with this V.2 model. The fault might be very close to the west shore of Lefkada.

According to the model obtained with the GPS vectors, the maximum land subsidence is 60 mm in the Vassiliki harbor (see Figure 4, blue line). Along the west coast of Lefkada the expected vertical displacement ranges between -30 and +16 mm, and the northern coast of Cephalonia, near the southern end of the fault might have been uplifted by 10 cm according to the model (constrained by the InSAR fringes observed in Cephalonia).

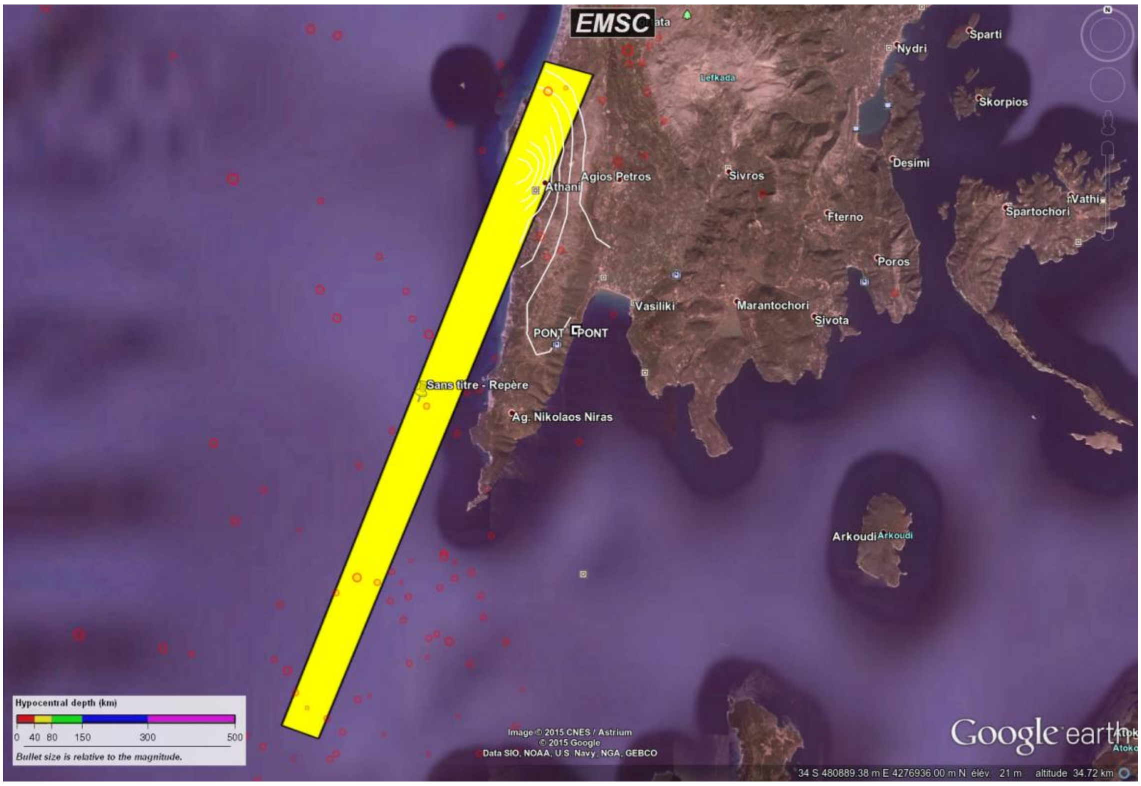

Figure 7. Preliminary fault model (yellow rectangle) of the Nov. 17 2015 event.

3.1 Local GPS network

Following the mainshock NOA installed a local GPS network in south Lefkada (Figure 8). This network was established during Nov. 20-22, 2015 by A. Ganas and E. Mendonidis. The monument type is 70 mm thick nail inside rock, to be observed in pillar mode using a steel adapter (115 mm long). Five (5) points were occupied on Nov. 21 and Nov, 22 with LEICA receivers (15-s mode, 6-9 hours of observations). Point LE06 near Dragano was measured by P. Elias during Nov. 24-25, 2015 using Topcon equipment.

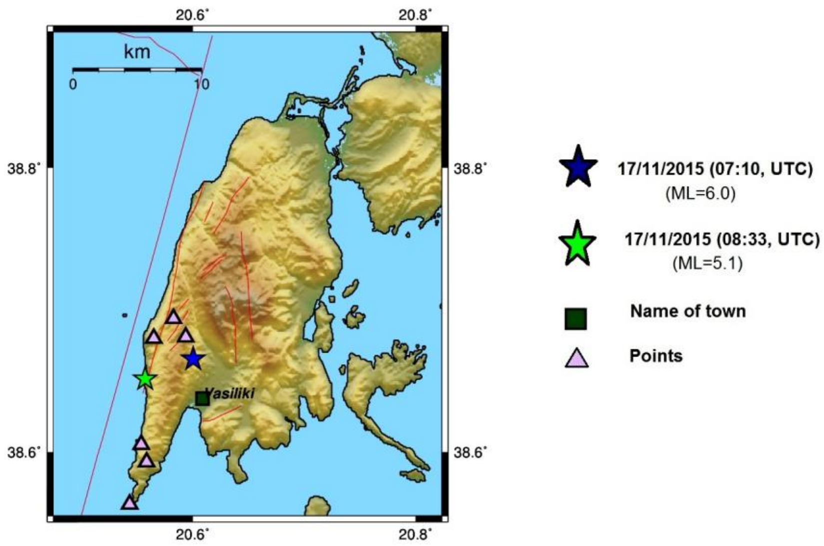

Figure 8. Map of Lefkada showing location of campaign GPS stations.

The GPS signal quality was evaluated by Panagiotis Argyrakis by use of TEQC software (Estey, and Meertens, 1999; Figure 9). It was found that the overall quality was improved as much as 50% after removal of specific space vehicles with limited number of observations and increased multipath. The improvement is visible in the following graph for GPS frequency L1.

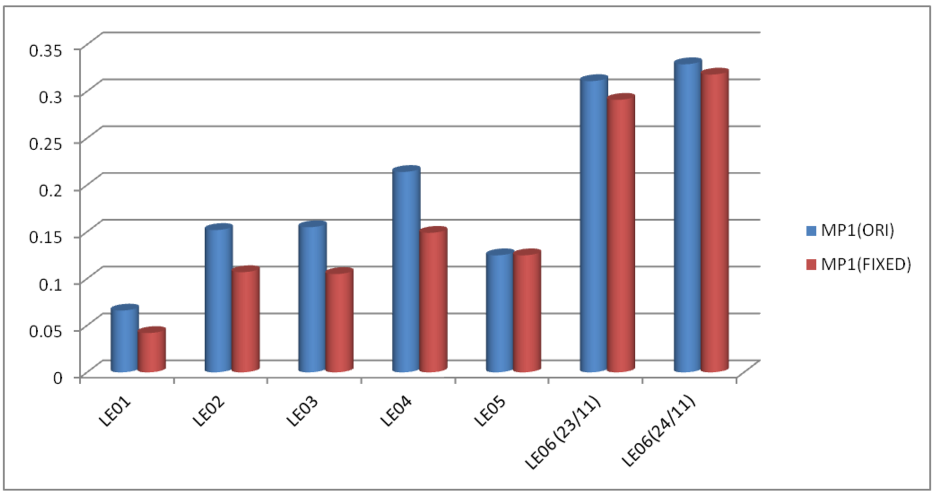

Figure 9. Excel chart showing L1 multipath suppression of six campaign stations in south Lefkada (November 2015 campaign).

4. Geo-environmental Effects

In this section we report the outcome of a post-earthquake field survey organized by NOA (A. Ganas) in collaboration with the Department of Geology of AUTh (G. Papathanassiou). The field survey took place immediately after the occurrence of the earthquake (Nov 19-22, 2015), and thus we were able to report the triggered geo-environmental effects. In the following pages, a brief description of the earthquake-induced failures is presented while more information will be published after data processing. No primary fault surface ruptures were observed in the field. The majority of earthquake-related phenomena were rock falls (e.g. Figure A5), landslides (e.g. Figures A1, A7 & A9), road-fill failures (e.g. Figure A2 & A6) and small-size liquefaction. The area that was widely affected by these phenomena is the one delineated by the villages of Komilio, Dragano and Athani on the east and to the west by the coastal zone from Porto Katsiki (Figure A3) to Ag. Nikitas (Figure A9). This zone is characterized as very likely to slope failures due to the combination of geomorphological parameters (high elevation and steep slope) with the highly fracture rock mass due to tectonic activity (Papathanassiou et al. 2005). Regarding the eastern part of the island, the earthquake triggered only sparse and small size rock falls on very prone to slope failures sites e.g. road cuts while at the northern part of the island, where the city of Lefkada is located, no geoenvironmental effects have been reported. The documentation of the earthquake-induced environmental effects was realized using the Earthquake Geo Survey App. (for Android OS). Several field photos are shown in the Appendix of this report.

4.1 Slope Failures

The dominant geoenvironmental effects triggered by the 2015 Lefkada earthquake were related to slope failures. Rock falls and shallow landslides were widespread on the western part of the island and at the central area, on both natural and cut slopes. The most densely concentration of these type of earthquake-induced ground deformations was reported on the coastal zone from Porto Katsiki to Egremnoi beach and along the 6 km long road of Tsoukalades- Ag. Nikitas, and are accompanied by small and large-size rock falls, rock mass slides and shallow landslides. In most cases, rock falls are directly associated with pre-existing tectonic discontinuities and steep slopes within sedimentary rocks. The shallow landslides were mainly generated in areas where the clastic material covered the bedrock and particularly in places where the rock mass was heavily jointed. It should be pointed out that this zone has been classified as very susceptible to slope failures by Papathanassiou et al (2013). Furthermore, cracks on paved roads were observed along the road network at the central and western part of the island, mainly within the zone that has been previously mentioned. One of the most representative cases of this type of failure has been observed at the entrance of village Athani, resulted to the closure of this road.

4.2 Liquefaction

Although the fact that event is characterized as one of the strongest shocks that occurred in the island of Lefkada, generation of liquefaction-induced ground failures were mainly concentrated along the coastal zone between the villages of Vassiliki and Ponti. In particular, spots of small-scale liquefaction features e.g. sand craters and a ground crack of approximately 5 m length and 10 cm opening through which grey fine-grained material was ejected were reported. In Nydri, a place where liquefaction phenomena have been induced by the 2003 event (Papathanassiou et al. 2005), only one small-size sand crater has been observed.

However, the 2015 earthquake induced severe damages to the waterfront area of Vassiliki and particularly to the recently constructed pier and quay (e.g. Figure A4). It should be pointed out that no evidence of liquefaction, like ejecta through the cracks, was observed.

4.3 Environmental Seismic Intensity scale ESI-07

One of the goals of the post-earthquake field survey was to quantitatively report the earthquake-induced ground failures in order to proceed to the assessment of the macroseismic intensity. In order to achieve this, we applied the Environmental Seismic Intensity scale **ESI-07** (Michetti et al., 2007). As a preliminary outcome, it can be concluded that the highest intensity was observed within the area delineated by the villages of Dragano – Athani – Porto Katsiki and Egremnoi beach. The value of the macroseismic intensity ESI-07 within this zone was assessed as **VIII-IX**.

5. Acknowledgments

We thank the NOA seismic data analysis team for phase data and the BEYOND / HUA / INGV / JPL satellite data analysis teams for Sentinel 1A interferograms. We thank the ESA Seismic Pilot Lead Philippe Bally and the GEO Supersite Coordinator Stefano Salvi, for activating satellite acquisition imagery. We are indebted to local residents Gerassimos Katopodis and Panagiotos Zogos for their help in the field. We also thank Efthimios Lekkas, Iannis Koukouvelas, Efthimios Sokos, Yiannis Kassaras, Vassilis Karakostas, Panagiotis Paschos, Fillippos Doukatas and Spiros Pavlides for discussions. Fieldwork was funded by the GSRT project INDES-MUSA http://www.indes-musa.gr/ . The establishment of NOANET in the Ionian Islands was funded by EU projects PREVIEW (FP6 contract 516172; scientific responsible A. Ganas) and the GSRT project ODISSEUS (scientific responsible G. Drakatos).

6. References

Baker, C., Hatzfeld, D., Lyon-Caen, H., Papadimitriou, E. and Rigo, A. 1997. Earthquake mechanisms of the Adriatic Sea and Western Greece: implications for the oceanic subduction-continental collision transition. Geophysical Journal International, 131: 559–594.

Boncori, Merryman John Peter, Ioannis Papoutsis, Giuseppe Pezzo, Cristiano Tolomei, Simone Atzori, Athanassios Ganas, Vassilios Karastathis, Stefano Salvi, Charalampos Kontoes, and A. Antonioli, 2015, The February 2014 Cephalonia Earthquake (Greece): 3D Deformation Field and Source Modeling from Multiple SAR Techniques, Seismological Research Letters, January/February 2015, v. 86 no. 1 p. 124-137, http://dx.doi.org/10.1785/0220140126.

Bornovas, J. 1964. Géologie de l'île de Lefkade. Geol. Geophys. Res. (Special Publication by Greek Geological Survey), V.10 (1) (Athens).

Cushing M, 1985. Evolution structurale de la marge nord ouest helle´nique dans l'ı^le de Levkas et ses environs (Gre`ce nord occidentale). The`se 3me cycle, Univ. de Paris-Sud.

Estey, L.H. and C.M. Meertens, 1999. TEQC: The Multi-Purpose Toolkit for GPS/GLONASS Data, GPS Solutions (pub. by John Wiley & Sons), Vol. 3, No. 1, pp. 42-49, doi:10.1007/PL00012778, 1999.

Ganas, A., G. Drakatos, S. Rontogianni, C. Tsimi, P. Petrou, M. Papanikolaou, P. Argyrakis, K. Boukouras, N. Melis and G. Stavrakakis, 2008. NOANET: the new permanent GPS network for Geodynamics in Greece. Geophysical Research Abstracts, Vol. 10, EGU2008-A-04380.

Ganas, Athanassios, Kostas Chousianitis, George Drakatos, Marios Papanikolaou, Panagiotis Argyrakis, Maria Kolligri, Panagiota Petrou, Evagelia Batsi, and Christina Tsimi, 2011. NOANET: High-rate GPS Network for Seismology and Geodynamics in Greece. Geophysical Research Abstracts, Vol. 13, EGU2011-4840, 2011, EGU General Assembly 2011.

Ganas, A., Marinou A, Anastasiou D., Paradissis D., Papazissi K., Tzavaras P., Drakatos G. 2013. GPS-derived estimates of crustal deformation in the central and north Ionian Sea, Greece: 3-yr results from NOANET continuous network data. Journal of Geodynamics, 67, 62– 71.

Haslinger, F., Kissling, E., Ansorge, J., Hatzfeld, D., Papadimitriou, E., Karakostas, V., Makropoulos, K., Kahle, H. G., and Peter, Y, 1999. 3D crustal structure from local earthquake tomography around the Gulf of Arta (Ionian region, NW Greece), Tectonophysics, 304, 201–218, 1999.

Jacobshagen, V. (1979) Structure and geotectonic evolution of the Hellenides. Proc. VI Colloq Aegean Region Athens 1977, IGMR, Athens, pp 1355-1367.

Karakostas V, Papadimitriou E, Papazachos C. 2004. Properties of the 2003 Lefkada, Ionian islands, Greece, Earthquake seismic sequence and seismicity triggering. BSSA 94/5:1976-1981

Lekkas, E, Danamos G, Lozios S, 2001. Neotectonic structure and neotectonic evolution of Lefkada Island. Bull Geol Soc Greece XXXIV(1):157–163.

Lomax, A., Virieux, J., Volant, P., and Berge-Thierry, C., 2000. Probabilistic earthquake location in 3-D and layered models, in: Advances in Seismic Event Location, edited by: Thurber, C. H. and Rabinowitz, N., Kluwer Academic Publishers, Dordrecht/ Boston/London, 101–134.

Louvari, E., Kiratzi, A.A. and Papazachos, B.C., 1999. The CTF and its extension to western Lefkada Island. Tectonophysics, 308, 223-236.

Melgar, D., B. W. Crowell, J. Geng, R. M. Allen, Y. Bock, S. Riquelme, E. M. Hill, M. Protti, and A. Ganas 2015. Earthquake magnitude calculation without saturation from the scaling of peak ground displacement, Geophys. Res. Lett., 42, doi:10.1002/2015GL064278.

Michetti, A. M., Esposito, E., Guerrieri, L., Porfido, S., Serva, L., Tatevossian, R., Vittori, E., Audemard, F., Azuma, T., Clague, J., Comerci, V., Gurpinar, A., McCalpin, J., Mohammadioun, B., Morner, N.A., Ota, Y., Roghozin, E. 2007. Intensity Scale ESI (2007). In Memorie Descrittive Carta Geologica d'Italia L. Guerrieri and E. Vittori

(Editors), APAT, Servizio Geologico d'Italia— Dipartimento Difesa del Suolo, Roma, Italy, 74, 53 pp.

Papadopoulos, G. A., Karastathis, V. K., Ganas, A., Pavlides, S., Fokaefs, A., and Orfanogiannaki, K. 2003. The Lefkada, Ionian Sea (Greece), shock (Mw 6.2) of 14 August 2003: Evidence for the characteristic earthquake from seismicity and ground failures, Earth Planet. Space, 55, 713–718.

Papathanassiou, G., Pavlides, Sp., Ganas, A., 2005. The 2003 Lefkada earthquake: Field observations and preliminary microzonation map based on liquefaction potential index for the town of Lefkada, Engineering Geology, Volume 82, Issue 1, Pages 12-31.

Papathanassiou G, Valkaniotis S, Ganas A., Pavlides Sp. 2013. GIS-based statistical analysis of the spatial distribution of earthquake-induced landslides in the island of Lefkada, Ionian Islands, Greece, Landslides, Volume 10, Issue 6, pp 771-783.

Pavlides, S. B., Papadopoulos, G. A., Ganas, A., Papathanassiou, G., Karastathis, V., Keramydas, D. & Fokaefs, A., 2004. The 14 August 2003 Lefkada (Ionian Sea) Earthquake. 5th International Symposium on Eastern Mediterranean Geology, Thessaloniki, Greece, 14-20 April 2004, Reference T5-34.

Rondoyanni, Th., M. Sakellariou, J. Baskoutas, N. Christodoulou, 2012. Evaluation of active faulting and earthquake secondary effects in Lefkada Island, Ionian Sea, Greece: an overview. Nat Hazards 61:843–860, DOI 10.1007/s11069-011-0080-6

Sachpazi, M. et al., 2000. Western Hellenic subduction and Cephalonia Transform: local earthquakes and plate transport and strain. Tectonophysics, 319, 301-319.

Valkaniotis, S., Ganas, A., Papathanassiou, G., Papanikolaou, M., 2014. Field observations of geological effects triggered by the January–February 2014 Cephalonia (Ionian Sea, Greece) earthquakes. Tectonophysics 630, 150–157.

7. PHOTOGRAPHIC APPENDIX

Figure A1. Field photo of landslide to the west of Dragano village. View to the south. Date photo was taken 22 Nov. 2015.

Figure A2 . Field photo of asphalt cracks along the road between Dragano and Athani villages. View to the south. Date photo was taken 20 Nov. 2015.

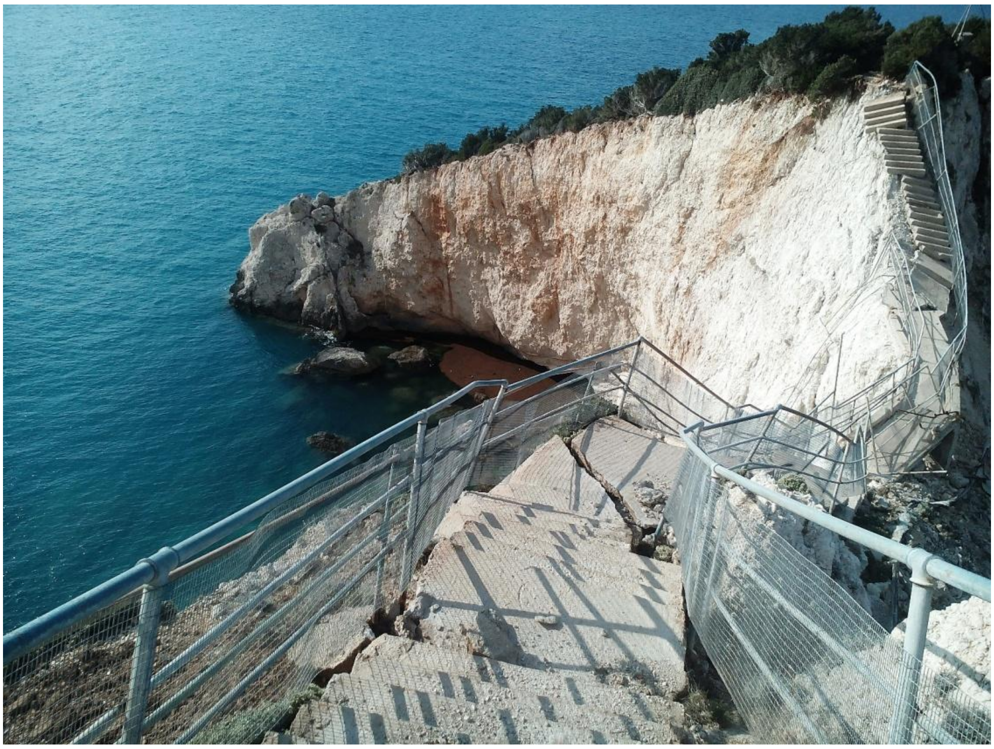

Figure A3 Field photo of damaged path to Porto Katsiki cape. View to the west. Date photo was taken 20 Nov. 2015.

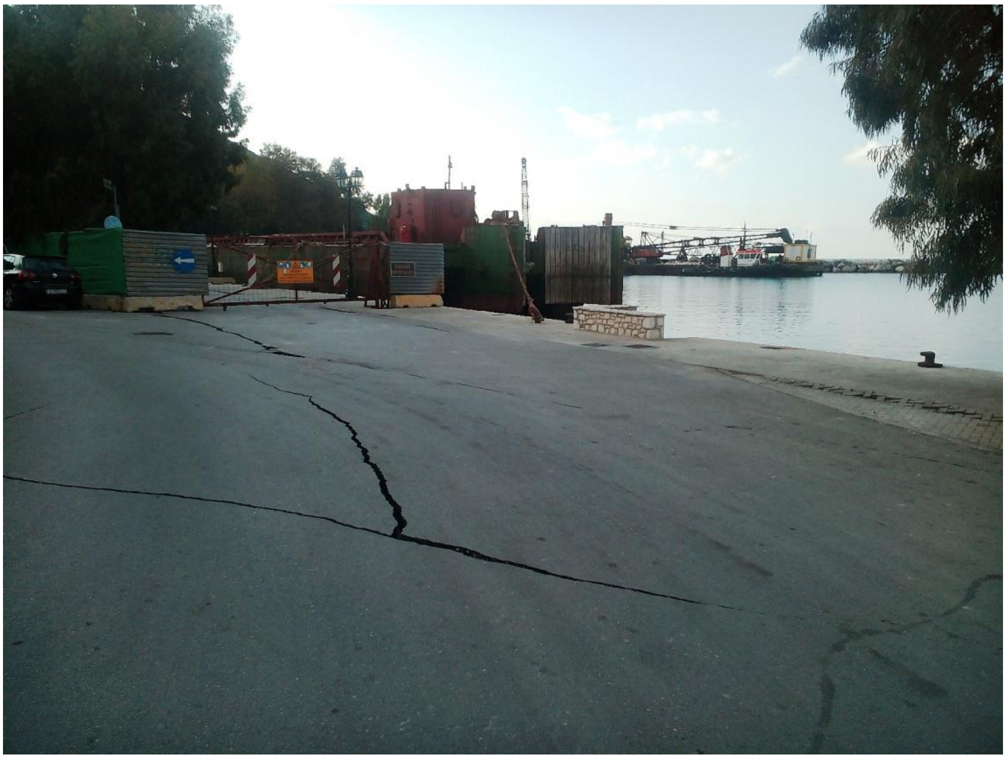

Figure A4 Field photo of asphalt cracks at Vassiliki port. View to the south. Date photo was taken 20 Nov. 2015.

Figure A5 Field photo of rock falls at the south-east end of Vassiliki village. View to the north. Date photo was taken 20 Nov. 2015.

Figure A6 Field photo of damaged road at the entrance of Athani village. View to the south. Date photo was taken 21 Nov. 2015.

Figure A7 Field photo of damaged road due to landslide at Platys Gialos beach. View to the south. Date photo was taken 21 Nov. 2015.

Figure A8 Field photo of damaged cemetery at Ypapanti church, to the west of Dragano village. View to the north. Date photo was taken 21 Nov. 2015.

Figure A9 Field photo of landslide at Agios Nikitas village. View to the north. Date photo was taken 22 Nov. 2015.

Figure A10 Field photo of 7cm wide tensional crack at Dragano village. Extension azimuth is N130°E. Nadir view. Date photo was taken 22 Nov. 2015.