Preliminary Report

The April 16, 2015 Kasos Earthquake, SE Aegean, Greece

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On April 16, 2015, at 18:07 UTC, a strong earthquake of magnitude ML 6.1 (Mw 6.0), focal depth 38km, took place in the sea area 14km SW of Kasos Island, SE Aegean, Greece (Figure 1). The earthquake was felt in the South Aegean region (Crete, Dodecanese, South Cyclades) without any reported damages. The main event was followed by a rich aftershock activity, still on-going, with epicenter distribution shown in Figure 1. The largest aftershock took place on April, 17, 2015, at 02:05 UTC with magnitude ML 5.4 (Mw 5.4), focal depth 40km, in the sea area 25km SW Kasos Island, SE Aegean, Greece (Figure 1).

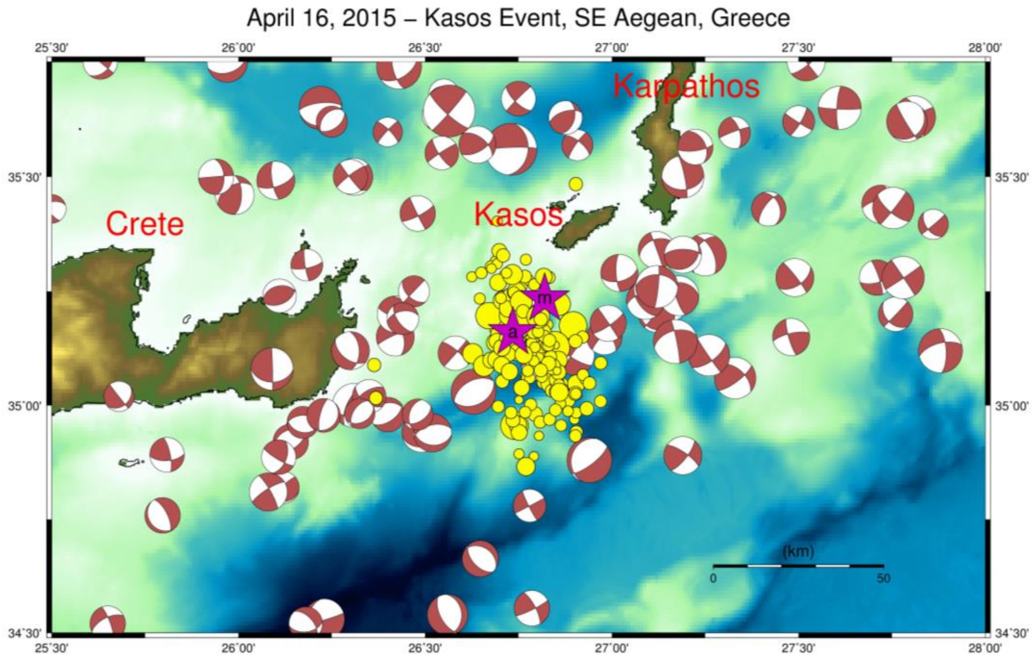
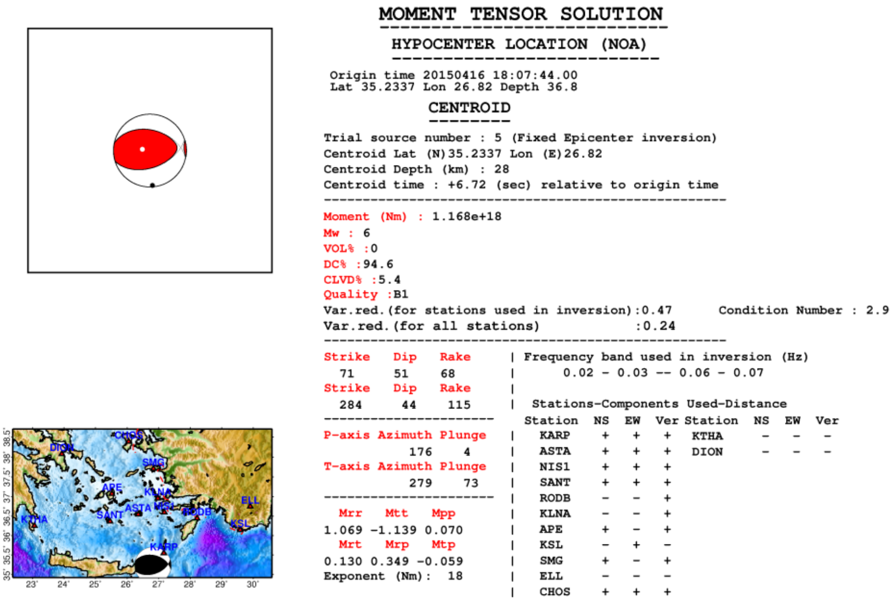
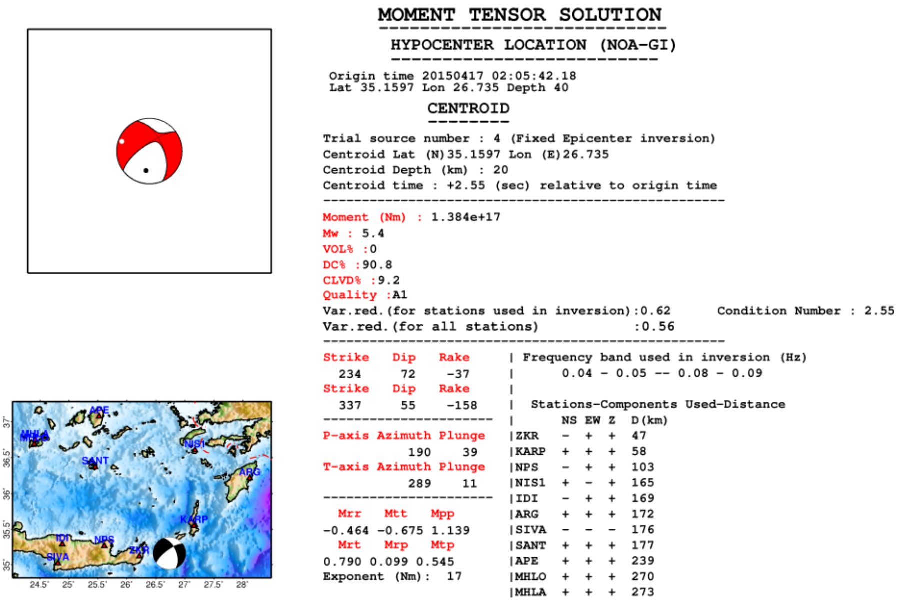


Figure 1. Map showing the epicentral distribution of the April 16th, 2015 Kasos earthquake sequence, as it was processed at NOA, Institute of Geodynamics. Purple stars denote the mainshock (m) and the strongest aftershock (a), respectively. The focal mechanisms shown for the broader area have been taken from the NOA-Institute of Geodynamics MT - database.



(a)



(b)

Figure 2. Moment tensor estimation for the main event (a) and the largest aftershock (b), as they were initially computed at NOA, Institute of Geodynamics.

The accelerographic network of NOA, Institute of Geodynamics (http://accelnet.gein.noa.gr) recorded the strong ground motion. The accelerographic data were used for the earthquake automatic location and magnitude estimation, the manual revised location and magnitude estimation, the Moment Tensor computation and the calculation of the strong ground motion values (i.e. PGA, PGV etc). Moment Tensor computation results are presented in Figure 2.

Latest upgrades and extension of the accelerographic network show improvements in the recording-monitoring of strong events in Greece and the adjacent region, with ability towards updating attenuation studies for Greece, as well as in the accuracy and the immediacy to inform the State and the general public.

The current preliminary analysis includes recordings from accelerographs situated up to 400km epicentral distance and deployed on a variety of site conditions. PGA extracted values are shown in Table 1. It has to be noted that this report presents initial information that currently has been analyzed. Indicative values from this analysis are presented in this preliminary report.

Table 1. Accelerographic stations information and the Peak Ground Acceleration values extracted from the processed strong motion records of the main shock.

Station Code	Location / Building	Surface geology	Epicentral Distance km	PGA (cm/s^2)		
				Z	X	Y
KRPA	Karpathos, Town Hall	Alluvium	47	25.60	83.25	98.54
ZKR	Zakros, Municipal Building	Rock	56	20.00	49.75	55.95
AGNA	Ag. Nikolaos, O.T.E.	Rock	100	5.90	11.84	19.27
IERA	Ierapetra, O.T.E.	Alluvium	101	11.26	15.96	17.67
ASTA	Astypalaia, Town Hall	Alluvium	152	0.74	1.60	1.27
THRA	Santorini, Town Hall	Alluvium	181	4.65	5.54	6.10
SIVA	Sivas, free-field	Rock	184	3.13	4.67	3.93
RODB	Rhodes, Hotel Thermes	Alluvium	185	1.33	2.00	2.62
KLNA	Kalymnos, Hospital	Alluvium	192	1.79	1.66	1.07
RTHF	Rethymno, Municipal Building	Alluvium	213	2.00	2.96	3.47
CHNB	Souda, Town Hall	Alluvium	251	1.66	5.02	4.17
GVD	Gavdos, free-field	Soft rock	253	0.54	1.09	1.12
IKRA	Ikaria, Town Hall	Alluvium	268	0.40	0.64	0.64
KSL	Kastelorizo, free-field	Rock	270	0.17	0.25	0.22
TNSA	Tinos, Town Hall	Alluvium	296	0.21	0.27	0.36
ANKY	Antikithira, free-field	Soft rock	326	0.31	0.53	0.43
LVRA	Lavrio, Town Hall	Alluvium	370	0.10	0.14	0.20
KARA	Karystos, Town Hall	Alluvium	376	0.09	0.14	0.14
MNVA	Monemvasia, Town Hall	Alluvium	377	0.23	0.22	0.23
YDRA	Ydra, Town Hall	Alluvium	381	0.22	0.28	0.18
PSRA	Psara, Town Hall	Alluvium	384	0.22	0.30	0.46
ATHA	N. Psychiko, private house	Soft rock	410	0.23	0.13	0.15
NOAC	Thissio, NOA premises	Rock	411	0.12	0.13	0.11
DRPA	Drapetsona, Town Hall	Alluvium	415	0.12	0.16	0.18
ACHA	Acharnes, Town Hall	Alluvium	418	0.20	0.26	0.29
ELFA	Elefsina, Town Hall	Alluvium	428	0.15	0.20	0.16

The maximum extracted values (PGA, cm/s^2) range from $98cm/s^2$ in the city of Karpathos Island (epicentral distance 45km) and $56cm/s^2$ at Zakros, Lasithi, Crete (epicentral distance 55km) to 0.1 – 0.2 cm/s^2 at locations in Attika (epicentral distance 410-420 km).

Figure 3 presents a comparison of strong motion records available at the shortest epicentral distances for the main event at Karpathos and Zakros.

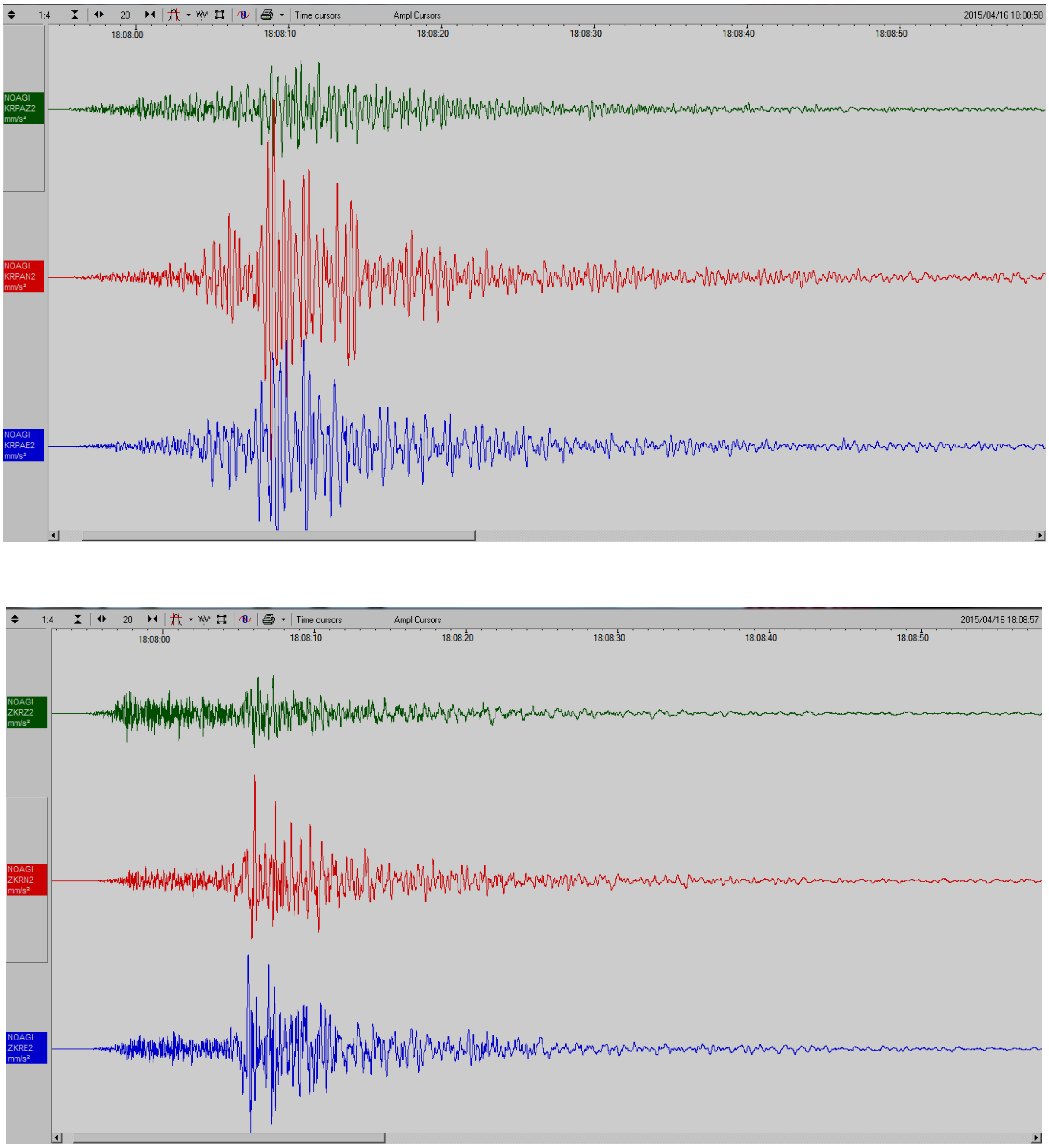


Figure 3. Indicative strong motion records of the main shock from the accelerographs deployed at Karpathos (up) and Zakros (bottom) presented in the same amplitude and time scale. The 3 components are presented (Z – green, Y – red, X – blue). The accelerograph in Karpathos is installed at the Town Hall, a 2-storey R/C building on alluvium, while the accelerograph in Zakros is installed in a small one-storey R/C building on limestone.

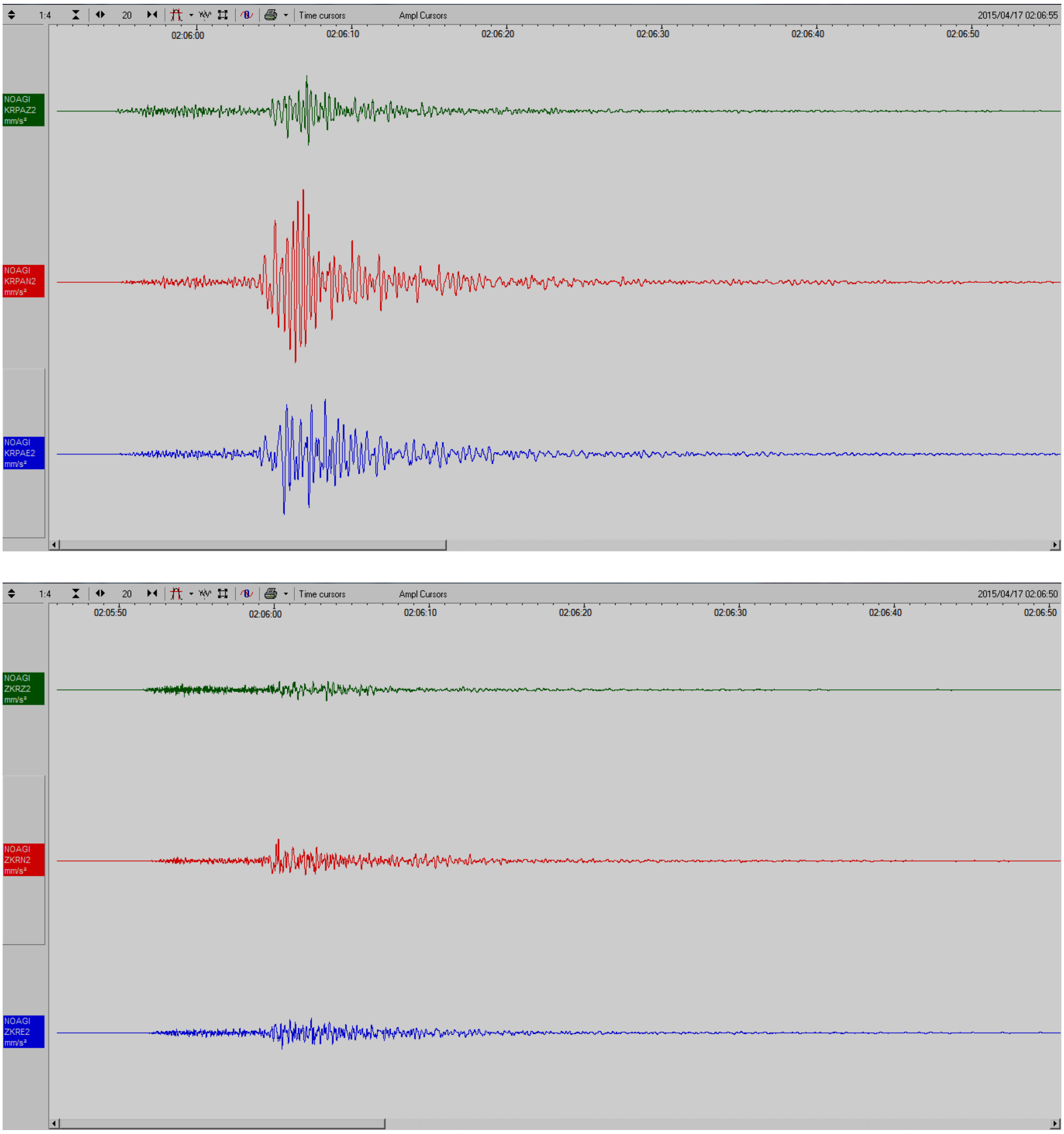


Figure 4. Indicative strong motion records of the largest aftershock at the accelerographs installed in Karpathos (up) and Zakros (bottom), with the same amplitude and time scales as in Figure 3. The 3 components are presented (Z – green, Y – red, X – blue). Although the hypocentre location indicates that the instrument in Zakros is closer to the epicenter, the recording in Karpathos shows again higher peak ground acceleration values.

Table 2 presents PGA values for the largest aftershock extracted from strong motion records at epicentral distances up to 200km and Figure 4 the corresponding recordings at Karpathos and Zakros, respectively.

Table 2. Accelerographic stations information and corresponding peak ground acceleration values from strong motion records processing for the strongest aftershock.

Station Code	Location / Building	Surface geology	Epicentral Distance km	PGA (cm/s^2)		
				Z	X	Y
ZKR	Zakros, Municipal Building	Rock	47	5.52	8.21	11.25
KRPA	Karpathos, Town Hall	Alluvium	58	18.41	31.36	48.06
AGNA	Ag. Nikolaos, O.T.E.	Rock	92	1.12	2.50	3.12
ASTA	Astypalaia, Town Hall	Alluvium	158	1.12	0.48	0.34
SIVA	Sivas, free-field	Rock	176	0.41	0.66	0.64
THRA	Santorini, Town Hall	Alluvium	182	0.99	1.86	1.65
RODB	Rhodes, Hotel Thermes	Alluvium	196	0.42	0.82	1.08
KLNA	Kalymnos, Hospital	Alluvium	201	0.30	0.37	0.28

Figure 5 presents response spectra acceleration values for the main event of April 16, at the locations of Karpathos and Zakros. It is indicated clearly that the largest values were observed in Karpathos at larger periods (0.5s) in comparison to Zakros (0.15s).

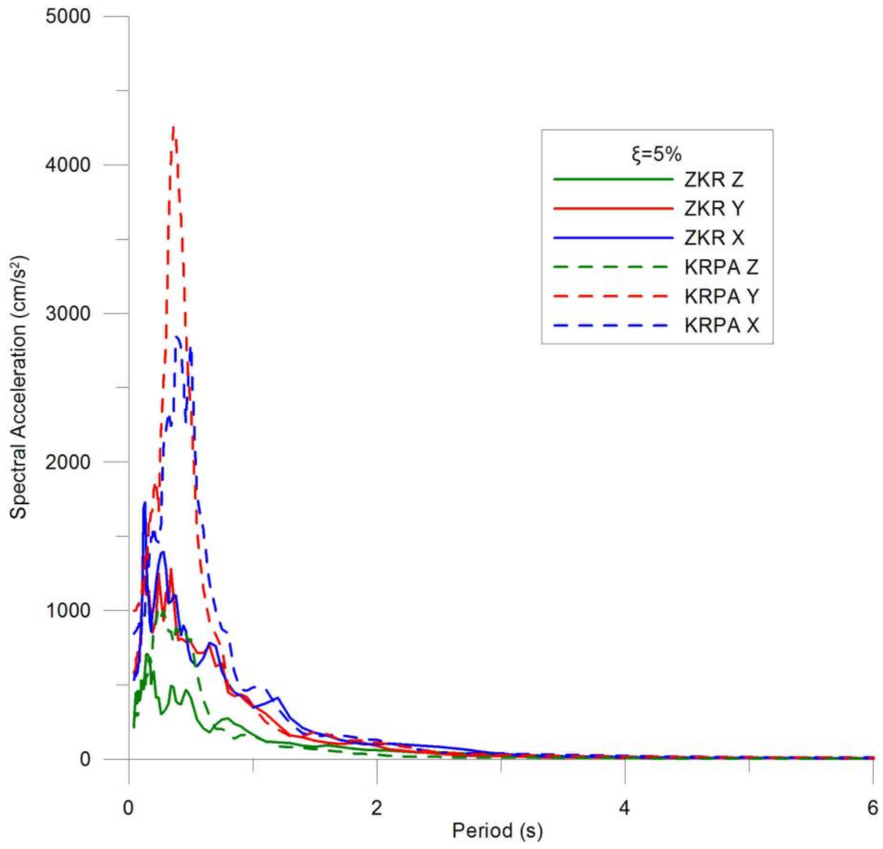


Figure 5. Response spectra for the main shock as they were calculated from KRPA (dotted line) and ZKR (continuous line) strong motion records and for damping factor ξ=5%.

NOA, Institute of Geodynamics operates a pilot application of the module ShakeMap® (Wald et al., 1999a, 1999b), based on real time seismic recordings (broad band and strong motion) and produces maps indicative of the expected - felt shaking of strong events in Greece. Figure 6 presents an example of shake map for the main event of April 16, which shows the low degree of shaking felt in the greater region of the epicenter (Crete and Dodecanese).

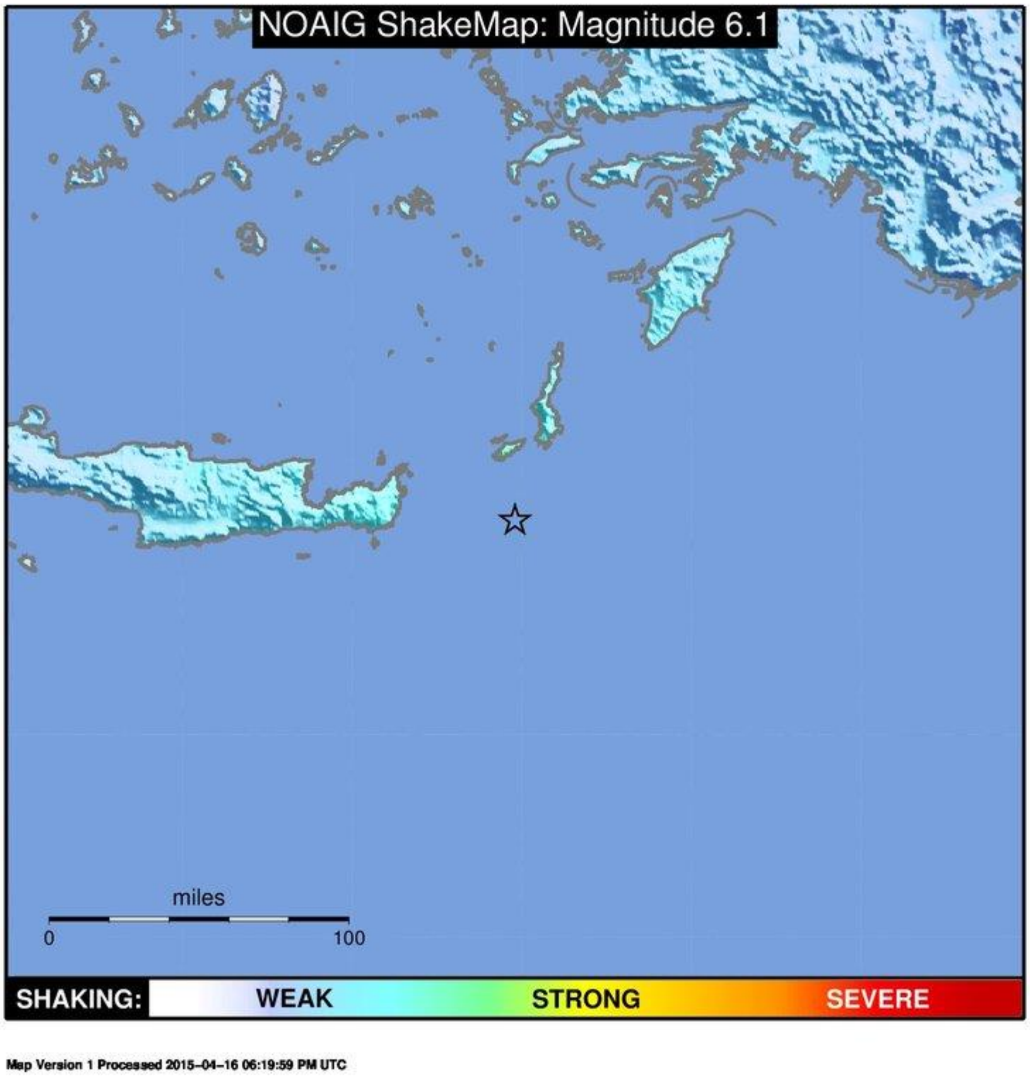


Figure 6. Shake map produced automatically from the available seismic data at NOA, Institute of Geodynamics, for the April 16, 2015 main shock. Note the low grade of shaking which became apparent in the region around the epicenter.

A similar application is operated at the Earthquake Planning and Protection Organization (EPPO, http://shakemaps.ingeoclouds.eu/auth2015hlcm/intensity.html, seen on 21/4/2015). Figure 7 presents a map with indication of the epicenter (purple star) and the location of stations that reported PGA values for the main shock. Green and blue triangles indicate the location of stations used in the automatic processing procedure of ShakeMap for NOA, Institute of Geodynamics and EPPO, respectively. NOA, Institute of Geodynamics station locations used in the present report and Table 1 are shown with red filled circles.

All resulted PGA values are combined and shown in a diagram in Figure 8, for comparison with the attenuation relationship derived from Skarlatoudis et al. (2003) for surface earthquakes with thrust focal mechanism and magnitude Mw 6.0. Thus, the curve which corresponds to soil is marked with dark red (Soil) and with light red its deviation ±σ on either side (+S, -S). In a similar manner, with green the curve that corresponds to rock is represented (Rock), with its deviation ±σ on either side marked with light green (+R, -R). The dark blue diamond symbol denotes the automatically resulted PGA values (in %g) from the available ShakeMap products at NOA, Institute of Geodynamics and EPPO. The orange filled circles correspond to maximum PGA values estimated manually from processing records of the accelerographs given in Table 1. A comparison of all values shows:

- Agreement between the values derived from the automatic for ShakeMap and the manual processing procedures for the records at Karpathos. However, they do not correspond to the presented attenuation curves.
- Small difference for the corresponding values derived similarly for Zakros. This is a comparison using the broadband and strong motion records respectively, and hence this small difference. However again, there is also a disagreement to the corresponding presented attenuation curves.
- Agreement in general for PGA values in epicentral distance ranging greater than 100km and up to 200km.

To conclude, we have to note that the attenuation relationship in use, which is based on a particular set of Greek surface earthquake data, provides information only for epicentral distances to 200km, as a result of the data availability up to year 2000 and due to the configuration of the National Strong Motion Network in Greece at those times. Since then, the upgrade and expansion of the national network will lead at the present state, towards an update of this information, using the newly recorded data, at short (near field) and long distances, as it is demonstrated in this preliminary presentation. Figure 8 makes clear that such an upgrade is needed and it is expected under the frame work of the updated National Strong Motion Network.

References

EPPO Shake Map application website: http://shakemaps.ingeoclouds.eu/auth2015hlcm/intensity.html

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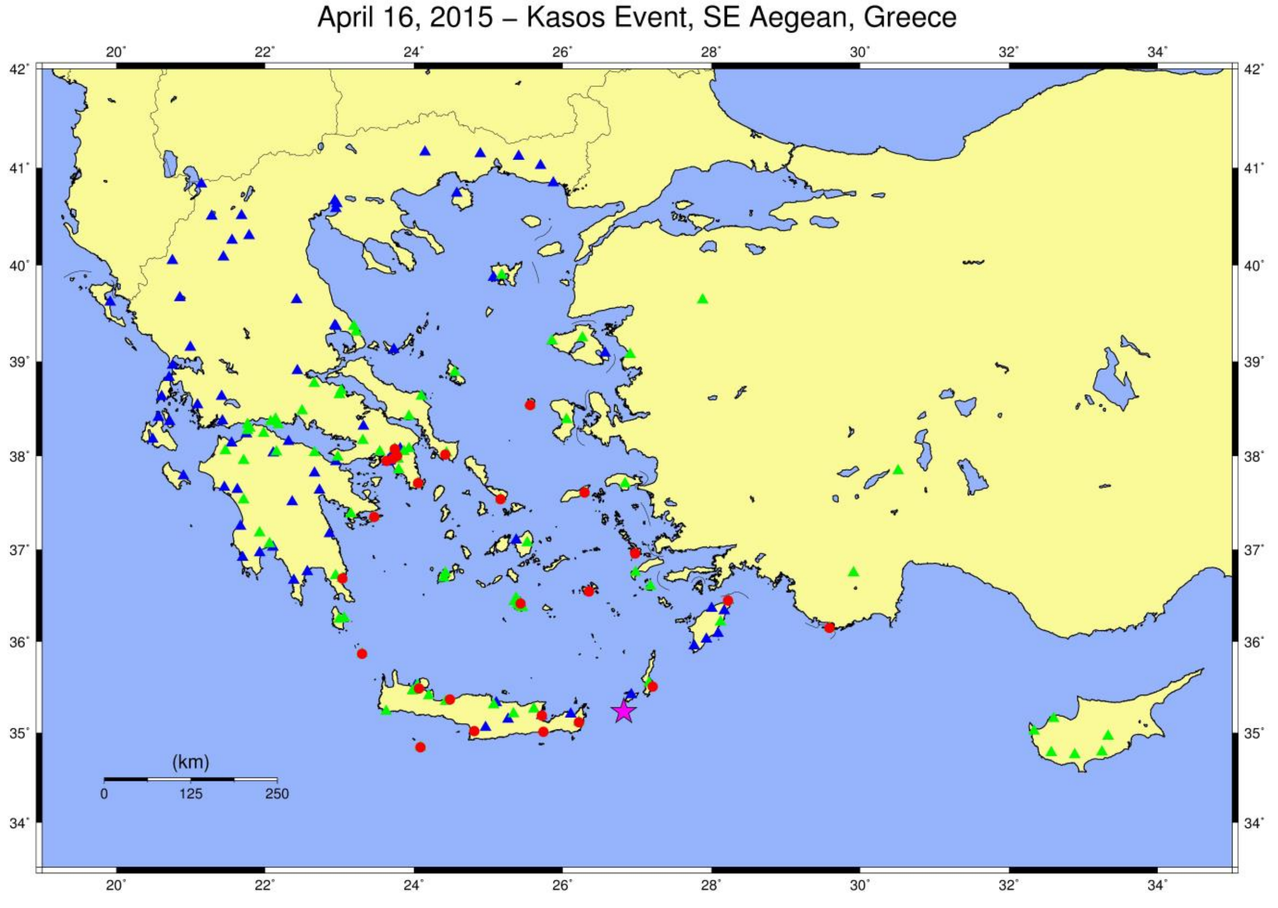

Figure 7. Map showing the epicenter of the main shock (violet star) and the locations of seismic stations used in this report. The green and blue filled triangles denote the locations of the stations used for the automatic ShakeMap application by NOA, Institute of Geodynamics and EPPO, respectively. Red circles indicate NOA, Institute of Geodynamics accelerographs used in Table 1.

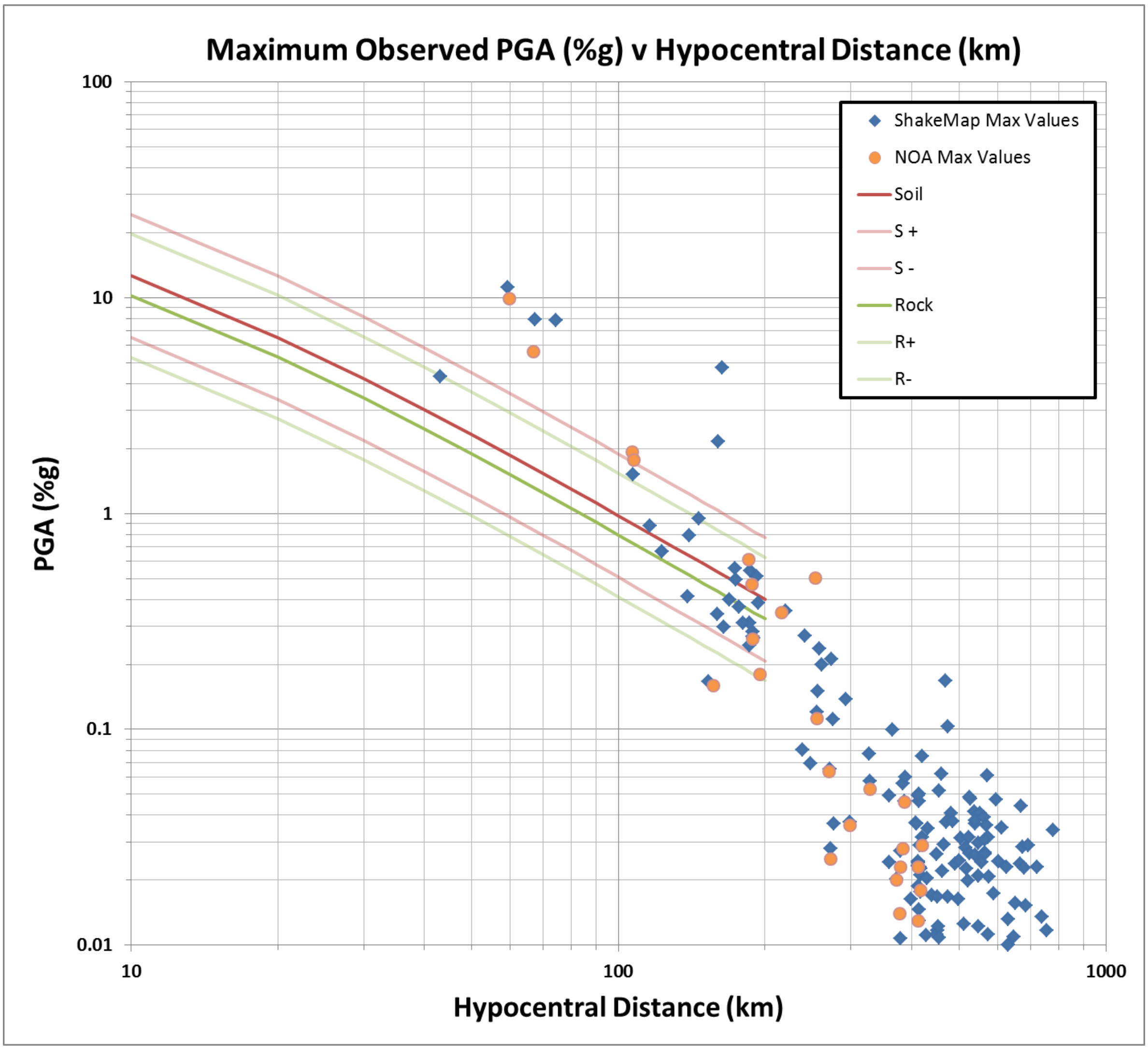

Figure 8. Plot for the comparison of Skarlatoudis et al. (2003) attenuation relationship (lines in different colours explained in the legend), with the peak ground acceleration values: (a) calculated automatically (in blue) for ShakeMap in near real time at NOA, Institute of Geodynamics and EPPO, and (b) manually processed and presented in Table 1 (in orange). For more details see text. The attenuation curves were calculated for the Kasos main shock (surface focal depth, thrust faulting, Mw 6.0).