Cite as: Iervolino, I., Baltzopoulos G., Chioccarelli E. (2017) *Preliminary engineering report on ground motion data of the Aug 21st 2017 Ischia earthquake V3.0. DOI: 10.13140/RG.2.2.31712.99842*, available at http://www.reluis.it.

PRELIMINARY ENGINEERING REPORT ON GROUND MOTION DATA OF THE AUG 21st 2017 ISCHIA EARTHQUAKE V3.1

Iunio Iervolino (iunio.iervolino@unina.it),[1] Georgios Baltzopoulos,[2] Eugenio Chioccarelli.[2,3]

Warning: This report was based on data available on Aug 27th 2017 and may be subjected to editing and revisions as new data become available, check www.reluis.it for updates.

Introduction

The earthquake occurred on August 21st 2017 at 18:57:51 UTC (20:57:51 local) near the island of Ischia in the bay of Naples (Figure 1). The sea-side settlement of Casamicciola Terme, on the northern part of the island, was the one mainly afflicted by the ground shaking that caused some structures to collapse (see http://www.reluis.it/images/stories/Ischia-21-agosto-2017-report-fotografico.pdf) and inflicted several casualties, including two fatalities (see DPC press release; in Italian).

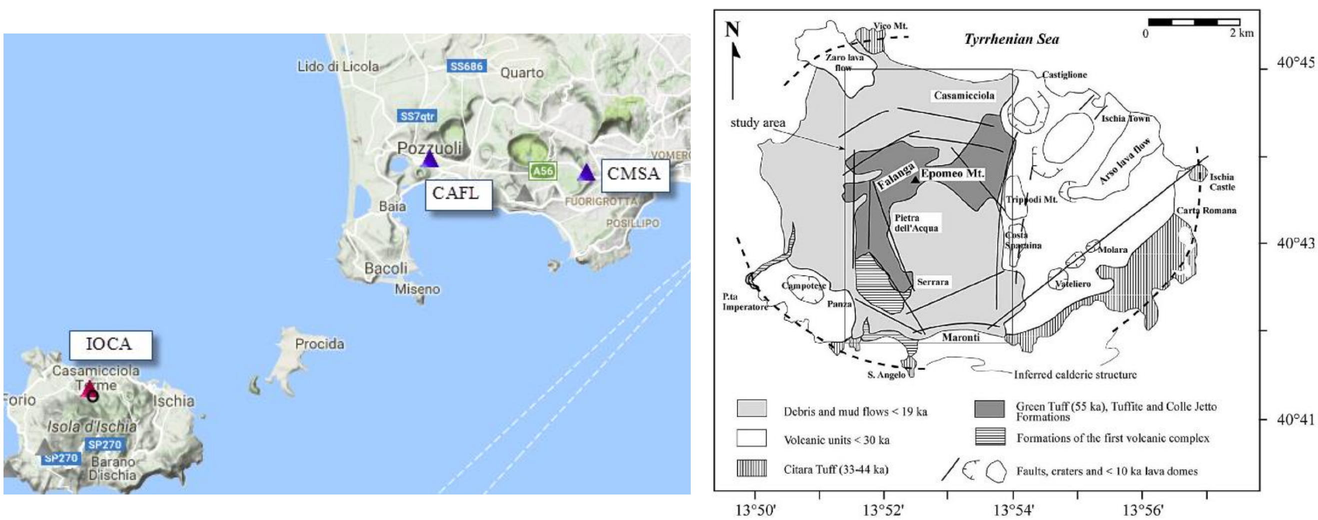

Figure 1. Map of Ischia and nearby coast indicating the position of recording stations (triangles) and 25/08/2017 INGV-OV estimate of the epicenter (black circle) on the left panel; geological map of the island taken from Molin et al. (2003) on the right panel.

Localization of the event given by the *Istituto Nazionale di Geofisica e Vulcanologia* (INGV) – *Osservatorio Vesuviano* – operations room (http://www.ov.ingv.it/ov/ - last accessed 26/08/2017) places the epicenter at a 40.74° latitude and 13.90° longitude and estimates a *duration magnitude* M_d equal to 4.0 and a hypocentral depth of around 1.7 km.[4] According to the time domain moment tensor solution (http://cnt.rm.ingv.it/event/16796811), the

[1] Dipartimento di Strutture per l'Ingegneria e l'Architettura, Università degli Studi di Napoli Federico II, Italy.

[2] Istituto per le Tecnologie della Costruzione ITC-CNR, URT Università degli Studi di Napoli Federico II, Italy.

[3] Università Telematica Pegaso, Italy.

[4] The *European-Mediterranean Seismological Centre* (EMSC-CSEM) provided an estimated epicenter location 40.68° latitude and 13.85° longitude, a *local magnitude* M_L 4.3 and hypocentral depth of 2 km (https://goo.gl/6L55o7; last accessed

focal mechanism appears to belong to a moderately steep dipping normal fault (dip angle 65°, rake -46°). These preliminary estimates appear consistent with what is already contained in the *Database of Individual Seismogenic Sources* (DISS – see Figure 2 and http://diss.rm.ingv.it/diss/) in terms of positioning and stress regime.

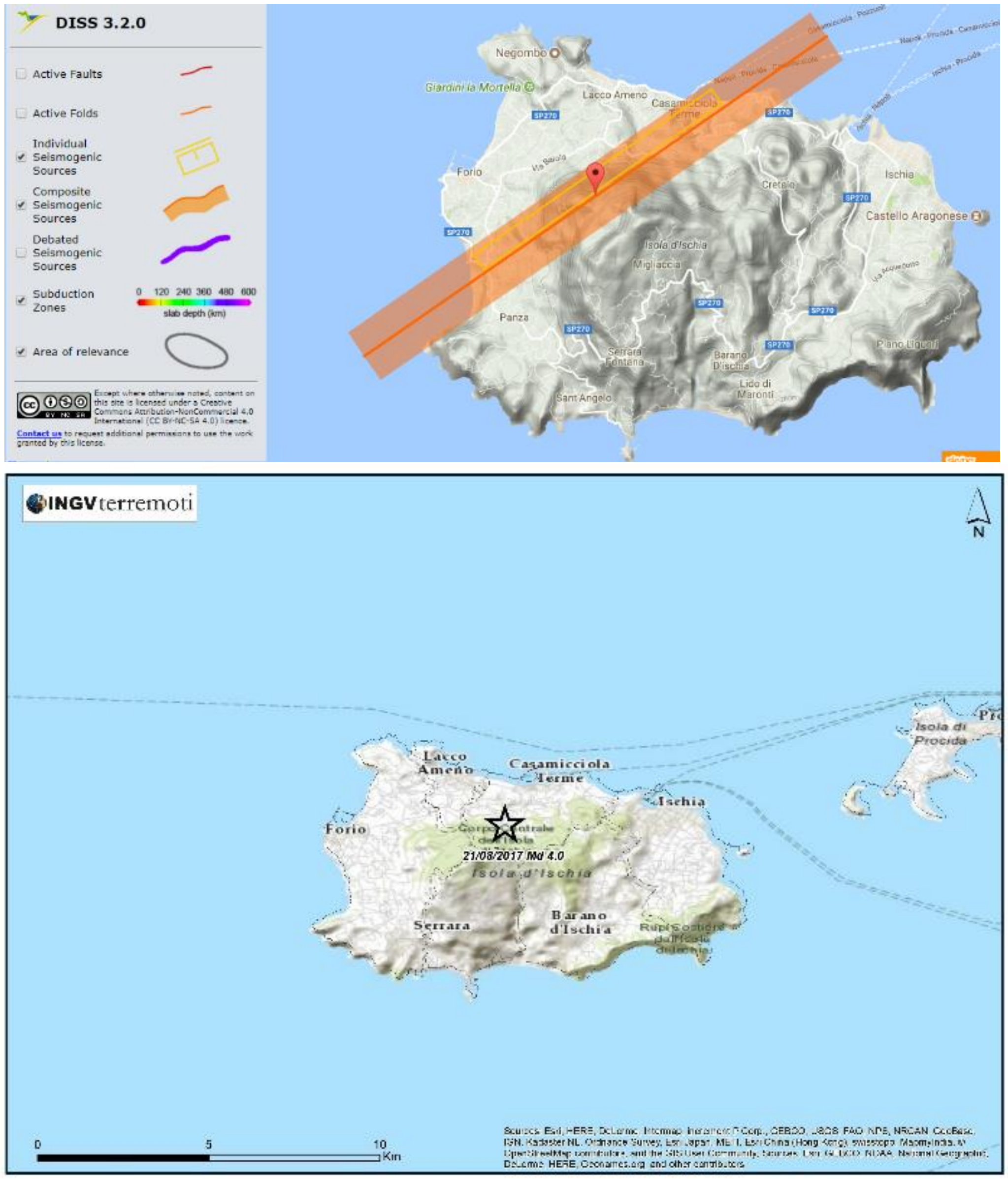

Figure 2. Ischia seismogenic source from the DISS (upper panel, image taken from http://diss.rm.ingv.it/diss/); INGV-OV epicenter localization according to the 25/08/2017 updated estimate (lower panel, image taken from http://terremoti.ingv.it/).

This event comes as an addition to the twelve historical earthquakes that hit Ischia in the past and are listed in the *Italian Parametric Earthquake Catalogue*– shown here in summary as Table 1 (see also https://goo.gl/XAoKGA for Casamicciola). The most notable among the past events in the catalogue is the 1883 earthquake that devastated

28/08/2017). The latter estimate places the epicenter a few kilometers offshore the island of Ischia while the former in the immediate vicinity of the village of Casamicciola Terme.

the same settlement of Casamicciola. One notes that the magnitude *estimates* for these past events are generally modest, as in the case at hand.

Table1. Estimated moment magnitude (M_w), MCS scale macroseismic intensity (I_{max}) and positioning of historical seismic events at Casamicciola Terme (taken from http://comunicazione.ingv.it/; in Italian).

Year	MM	DD	Epicentral Area	Reference	Lat	Lon	I_{max}	M_w	$\pm ErrM_w$
1275	11	02	Island of Ischia	CFTI4med	40.743	13.942	8-9	4.01	0.5
1557			Island of Ischia	MOLAL008	40.721	13.953	D	3.5	0.5
1762	07	23	Island of Ischia	AMGNDT995	40.746	13.909	6-7	3.5	0.5
1767			Island of Ischia	AMGNDT995	40.735	13.919	D	3.5	0.5
1796	03	18	Island of Ischia	CFTI4med	40.746	13.909	8	3.88	0.5
1828	02	02	Island of Ischia	CFTI4med	40.745	13.899	9	4.01	0.5
1841	03	06	Island of Ischia	MOLAL008	40.749	13.899	6	3.25	0.5
1863	01	30	Island of Ischia	MOLAL008	40.746	13.909	5	2.87	0.5
1867	08	15	Island of Ischia	MOLAL008	40.746	13.909	5-6	2.99	0.5
1881	03	04	Island of Ischia	CFTI4med	40.747	13.895	9	4.14	0.5
1883	07	28	Island of Ischia	CFTI4med	40.744	13.885	10	4.26	0.5
1980	04	23	Island of Ischia	MOLAL008	40.718	13.89	5	4.37	0.2

Recorded ground motion at Casamicciola Terme

The strong ground motion recording of primary interest, provided by INGV – Osservatiorio Vesuviano, corrected data available at https://t.co/it4I2tZj68 (i.e., from the *Engineering Strong-Motion Database* or ESM; Luzi et al., 2016) correction according to Paolucci et al. (2011) was the only one that could be obtained on the island of Ischia at IOCA station (*Ischia Osservatorio Casamicciola* – see Figure 1), exhibiting a horizontal peak ground acceleration (PGA) of 0.28g in the east-west component. The station is situated at an elevation of 123 m from sea level and the soil classification according to Eurocode 8 is reported as B (inferred from geological maps, not measured - see https://t.co/uWrJ6mtEC9 for location and site classification). The epicentral distance of the station during the event was calculated at R=0.8 km according to the INGV-OV's 25/08/2017 estimate of the epicenter location (R=8.5 km according to the EMSC-CSEM estimate). The corrected acceleration and velocity time-history traces are shown in Figure 3. PGA, peak ground velocity (PGV) and displacement (PGD) per component are given in Table 2 below.

Table 2. PGA, PGV and PGD per recorded component of ground motion at IOCA station.

	PGA (g)	PGV (cm/s)	PGD (cm)
IOCA East-West	0.280	17.8	2.32
IOCA North-South	0.192	11.5	1.72
IOCA Vertical	0.275	11.8	1.45

Figure 4 shows the 5% damped pseudo-acceleration (Sa), pseudo-velocity (Sv) and displacement (Sd) spectra of all three ground motion components. It can be observed that the vertical component exhibits a PGA of 0.275g, almost identical to the EW components' 0.28g (with the NS component having 0.19g). Furthermore, the vertical spectral acceleration remains comparable with the horizontal components' up to a period of 0.40s but then drops off rapidly.

This short-period peak Sa spectrum has been observed previously even for such modest magnitude events at such short epicentral distances – see for example the case of the 1997 Mw 4.3 event record at the *Colfiorito Casermette* station (see the ITalian ACcelerometric Archive: https://goo.gl/1p5xzF; Luzi et al., 2008) with a horizontal PGA of 0.4g and a vertical of 0.7g (Suzuki and Iervolino, 2017). Maximum Arias intensity among the two components was calculated at 39.4 cm/s (EW) and significant duration $D_{5\text{-}95}$ at 3.61s (NS).

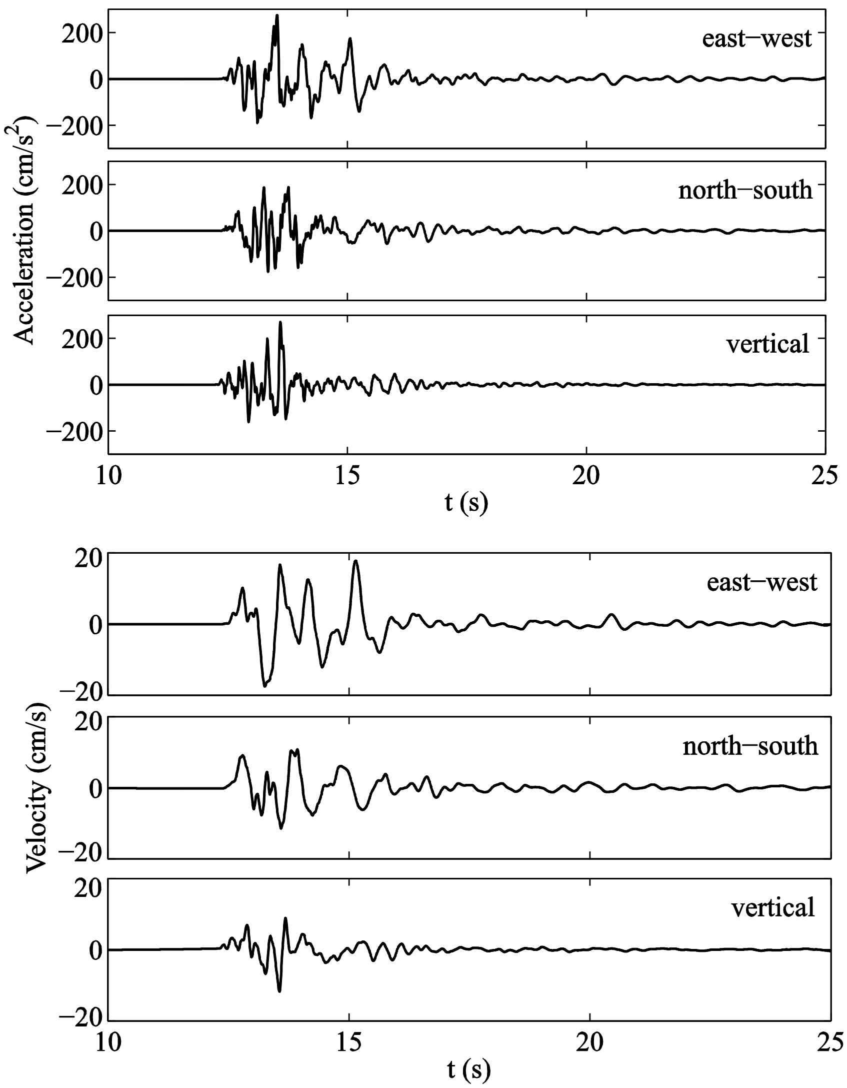

Figure 3. Acceleration (above) and velocity (below) corrected time history traces recorded at the IOCA station in Casamicciola Terme.

An interesting feature that can be seen on the horizontal component spectra is the existence of local amplification peaks at a vibration period of around 0.60s in the velocity and acceleration spectrum of both components simultaneously. Such isotropic amplification could hint at a local stratigraphic effect and this appears to be corroborated by the horizontal to vertical (H/V) ratios calculated for the IOCA site and two more locations on the island by the INGV's EMERSITO workgroup (EMERSITO Working Group, 2017; https://ingvterremoti.files.wordpress.com/2017/08/rapporto_1_emersito_ischia2017.pdf and shown in Figure 5.

These H/V ratios were derived from the Fourier spectra of ambient seismic noise velocimetric signals and reveal significant amplification exhibited by the IOCA site between frequencies of 1.5 Hz and 2.0 Hz (i.e., periods of 0.5s to 0.67s). Such pronounced amplification effects are not encountered in the other two stations, which is a testament to the heterogeneity of local site response in the island's volcanic subsoil (for further details see EMERSITO Working Group, 2017).

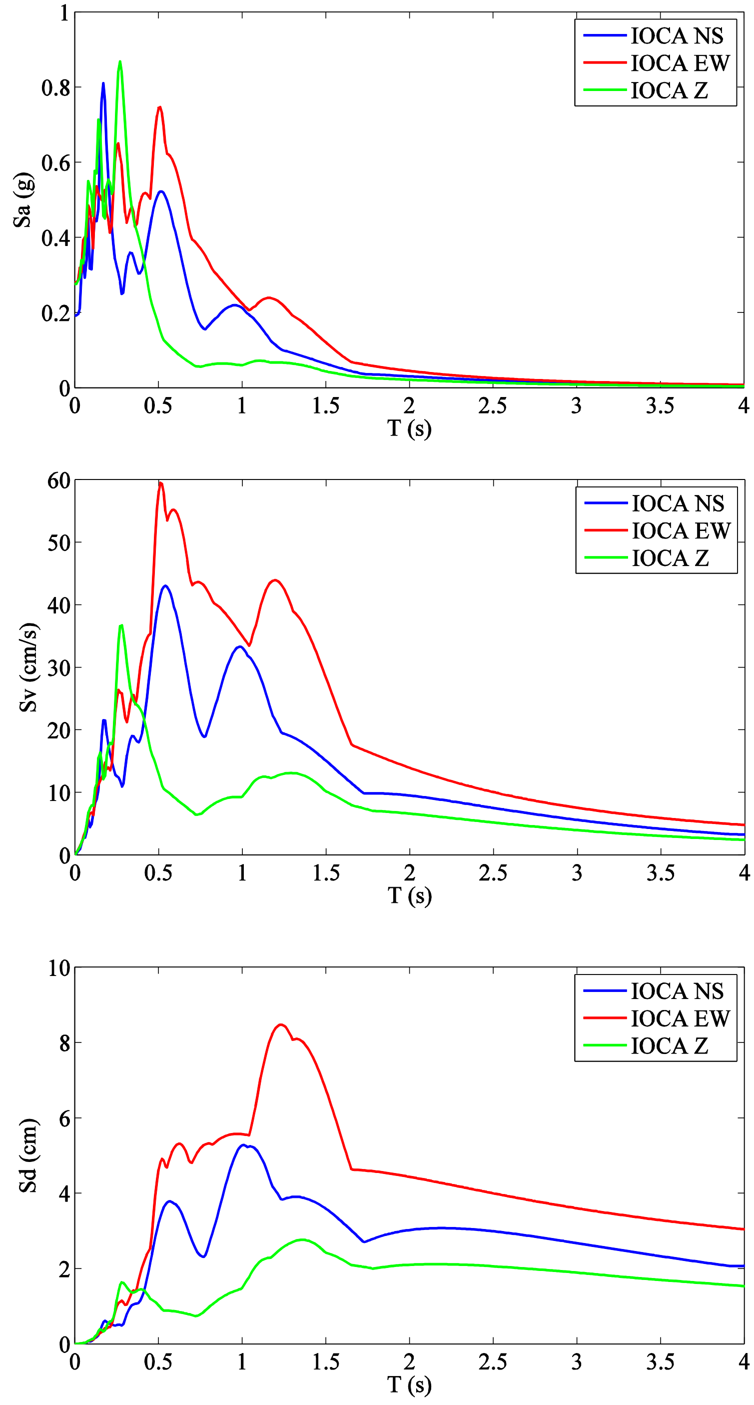

Figure 4. Five percent damped pseudo-acceleration (above), pseudo-velocity (middle) and displacement (below) spectra of all three ground motion components recorded at the Ischia – Osservatorio Casamicciola station.

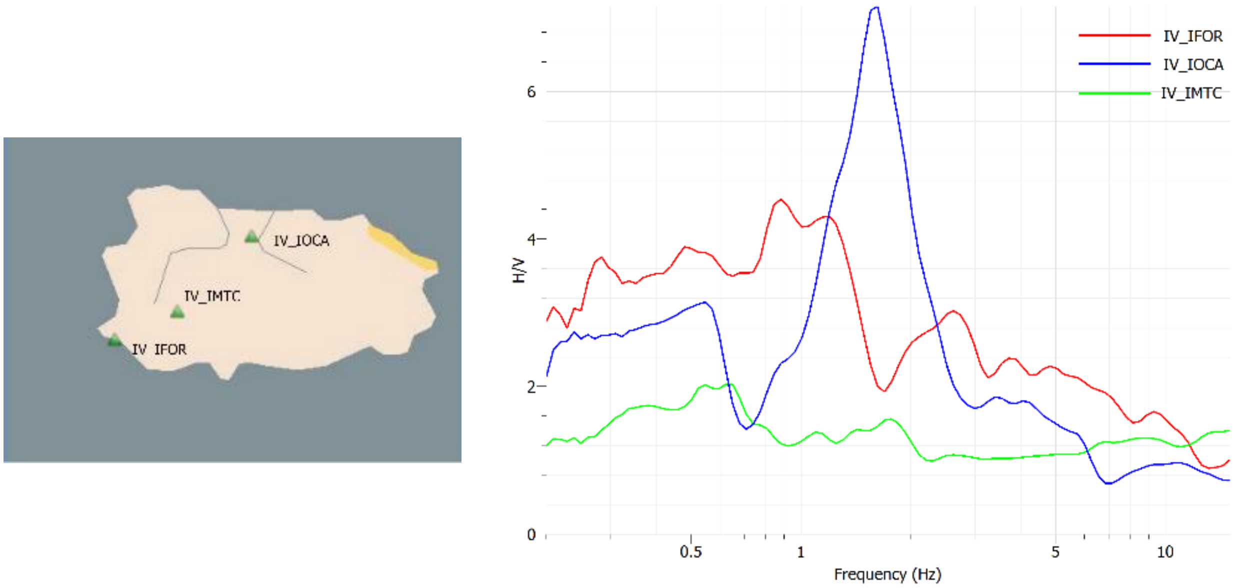

Figure 5. H/V ratios for three recording stations on the Island of Ischia (EMERSITO Working Group, 2017).

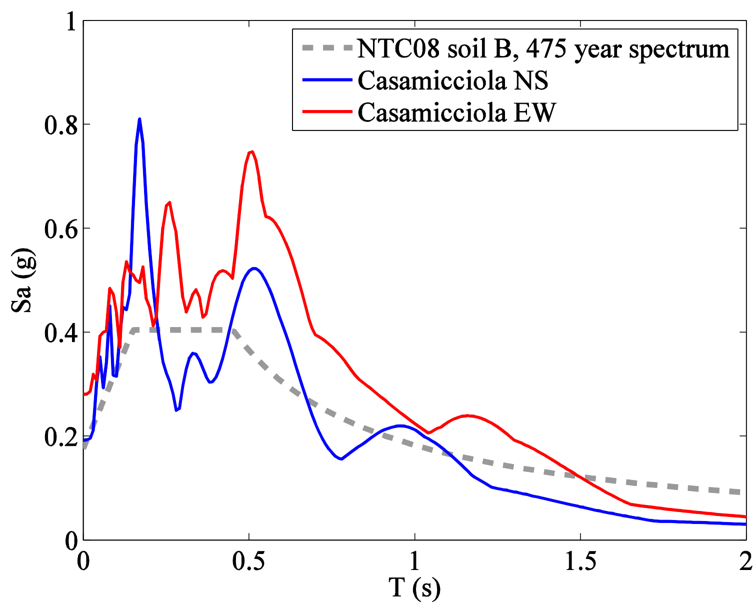

Figure 6. Horizontal pseudo-acceleration spectra recorded at Casamicciola Terme and corresponding NTC08 475 year return period spectrum. (Data to build the code spectrum for the site taken from ESM database, https://t.co/uWrJ6mtEC9, last accessed 26/08/2017)

Another interesting observation is the fact that, despite the modest estimated magnitude, both horizontal components' acceleration spectra are comparable with those for new construction according to the Italian code (*Norme Techniche per le Costruzioni* 2008 – NTC08). In fact, according to Figure 6, the EW component's spectrum appears to exceed the code spectrum, for 475 year return period elastic spectrum at various vibration periods. Such exceedances are not totally unexpected and can be due to a combination of proximity to the source, shallow hypocentral depth and local site conditions; some relevant discussion can be found in Iervolino and Giorgio (2017).

Ground motion recorded on the mainland

Ground motion resulting from this modest-magnitude event was characterized by rapid attenuation with distance, probably due to the shallow hypocentral depth and volcanic nature of the propagation medium. The two nearest-to-the-source recording stations on the mainland (see Figure 1), Arco Felice (CAFL) found at an epicentral distance of R=19.9 km and Monte Sant'Angelo (CMSN) at R=26 km recorded PGAs in the order of 0.005g and 0.002g, respectively, which are two orders of magnitude inferior to the those recorded on the island of Ischia. The corresponding pseudo-acceleration spectra can be seen in Figure 7, where the richness in long-period frequency content typically acquired during propagation far from the source is evident. Significant duration $D_{5\text{-}95}$ for these stations (maximum between horizontal components) was 45.0s at CAFL and 79.7s at CMSN.

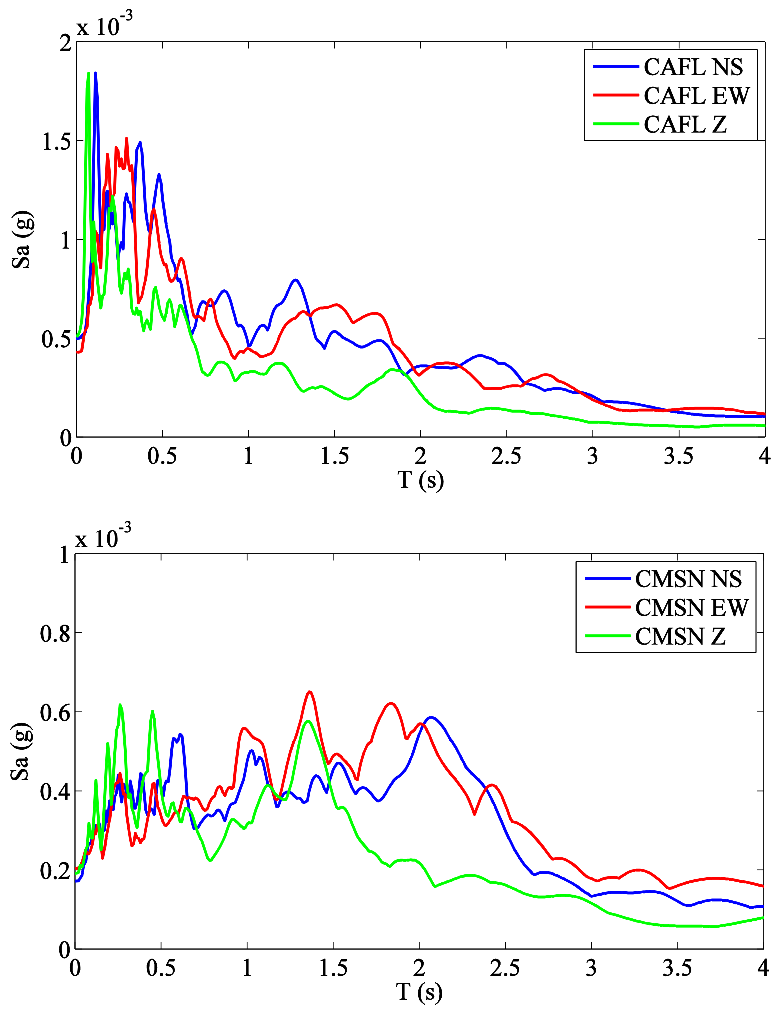

Figure 7. Five percent damped Pseudo-acceleration spectra of all three ground motion components recorded at the Arco Felice (top) and Monte Sant'Angelo (bottom) stations.

Comparison with ground motion propagation models

The 5% damped pseudo-acceleration spectra of the horizontal recorded ground motions are compared with the results of two ground motion propagation models (GMPMs) in the range of 0s (PGA) - 2.0s vibration periods. The considered GMPMs are: Tusa and Langer (2015) and Ambraseys et al. (1996). The former (hereafter named Tusa2015) was specifically developed for the volcanic area of Mt. Etna (Sicily, Italy) fitting data from 91 earthquakes with epicentral distances between 0.5 km and 100 km. In fact, in volcanic areas, the shallow earthquakes sources and the highly-fractured rocks tend to decrease the capability of transmitting high-frequency ground motion (e.g., Montaldo et al., 2005). The range of magnitudes covered by Tusa2015 for shallow events (focal depth lower than 5 km) is $3.0 \le M_L \le 4.3$ while the metric of source-to-site distance is the epicentral distance. This model refers to the geometric mean of horizontal components. The second considered GMPM, here identified as Amb.1996, is fitted on European data of tectonic earthquakes in the range of magnitude $4.0 \le M_S \le 7.5$ and for a source-distance, measured in terms of closest distance to the surface source projection (R_{jb}), up to 200 km. It provides the larger pseudo-acceleration response ordinate between the two horizontal components. Although not strictly appropriate for volcanic areas, this GMPM is considered here by virtue of being consolidated in the context of Italian hazard studies.

The local magnitude used for the comparisons is $M_L = 4.3$ according to the EMSC-CSEM estimate (https://t.co/it4I2tZj68 - last accessed 28/08/2017). The same value is also used for M_S (Hanks and Kanamori, 1979). Finally, according to Montaldo et al. (2005), R_{jb} is assumed equal to the epicentral distance (R), the magnitude event being lower than 6.

Figure 8 shows the comparisons between the median response spectra provided the GMPMs and the recorded ground motion at the IOCA station. In the same plot, the median plus/minus two standard deviations (σ) of the corresponding GMPM are also reported. Referring to Tusa2015, the recorded ground motion is above the median plus two standard deviations only for vibration periods around 0.60s, which falls within the range of periods for which local stratigraphic amplification effects were discussed above.

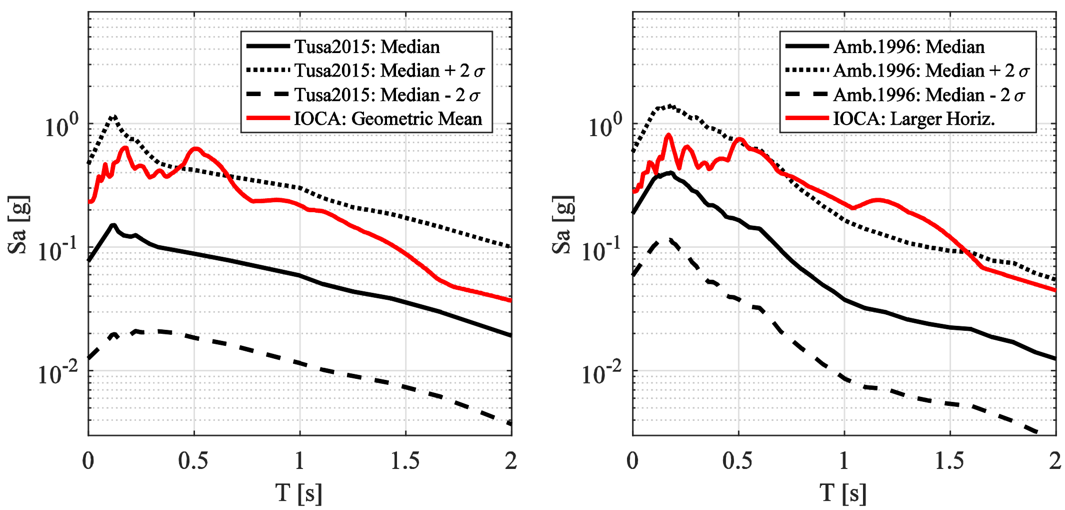

Figure 8. Comparison between the five percent damped pseudo-acceleration spectra recorded and predicted by the Tusa2015 (left) and Amb.1996 (right) GMPMs: IOCA station.

The same comparisons are reported in Figures 9 and 10 at the CAFL and CMSN stations, respectively.[5] Recorded ground motion are generally comprised within the median plus/minus two standard deviations interval when Tusa2015 is considered. On the other hand, as expected, the fast attenuation with distance of volcanic earthquakes cannot be accounted for by Amb.1996 and this model seems to overestimate the observed response spectra.

[5] Soil B is assumed for CAFL and CMSN stations in lack of further information.

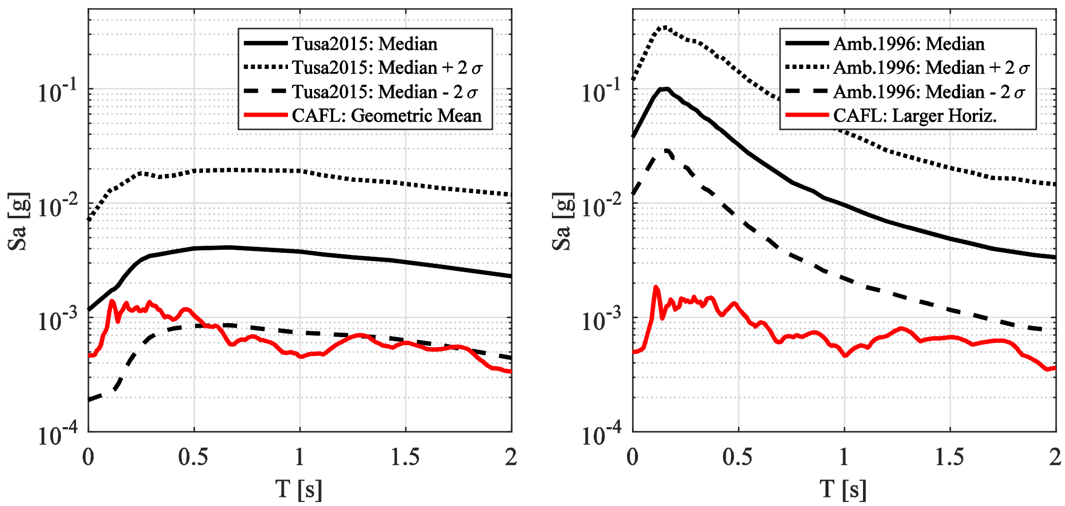

Figure 9. Comparison between the five percent damped pseudo-acceleration spectra recorded and predicted by the Tusa2015 (left) and Amb.1996 (right) GMPMs: CAFL station.

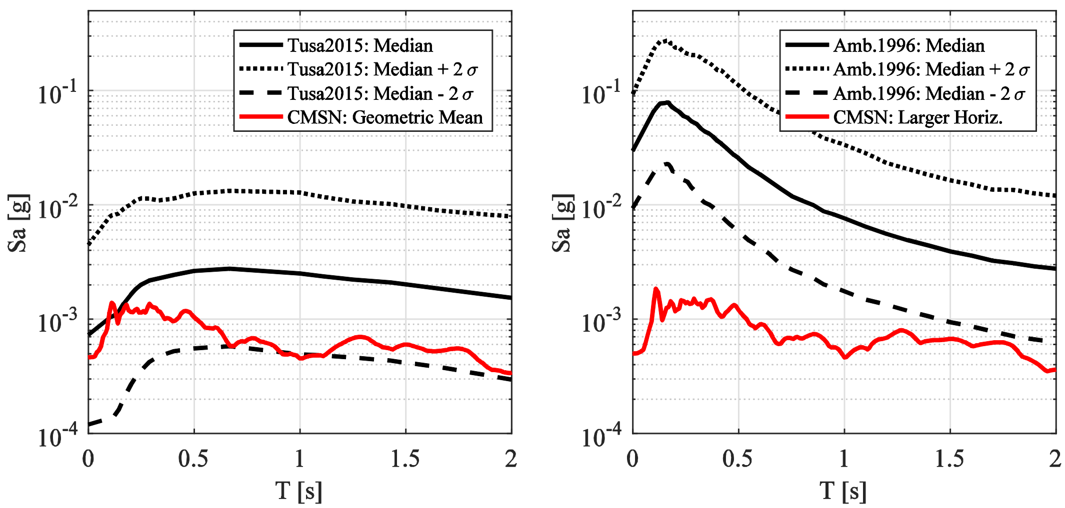

Figure 10. Comparison between the five percent damped pseudo-acceleration spectra recorded and predicted by the Tusa2015 (left) and Amb.1996 (right) GMPMs: CMSN station.

Acknowledgements

For data and the valuable insights, we would like to thank Giovanna Cultrera, Lucia Luzi, Alberto Michelini Giuliano Milana and Rodolfo Puglia, all of the INGV, as well as Dino Bindi of the German Research Centre for Geosciences (GFZ) and Mauro Dolce of the Italian Civil Protection.

References

Ambraseys, N.N., K.A. Simpson and J.J. Bommer. (1996). Prediction of horizontal response spectra in Europe. Earthq. Eng. Struct. D. 25, 371–400.

D'Ambra, C., A. Prota, M. Di Ludovico and G. Manfredi (2017). Rapporto fotografico relativo ai danni subiti da alcuni edifici a seguito dell'evento sismico del 21 Agosto 2017 presso isola d'Ischia - M=4.0. (in Italian) Available at www.reluis.it

EMERSITO Working Group (2017). Gruppo operativo EMERSITO evento sismico Ischia 2017 Rapporto n.1. Istituto Nazionale di Geofisica e Vulcanologia 23/08/2017.

Hanks C.T. and H. Kanamori (1979). A moment magnitude scale. J. Geoph. Res. 84(B5), 2348-2350.

Iervolino, I. and M. Giorgio (2017). È possibile evitare il superamento delle azioni di progetto nell'area epicentrale di terremoti forti? Progettazione Sismica, 8(1) (in Italian, in press).

Luzi, L., S. Hailemikael, D. Bindi D, F. Pacor, F. Mele, F. Sabetta (2008), ITACA (ITalian ACcelerometric Archive): A Web Portal for the Dissemination of Italian Strong-motion Data. Seismol. Res. Lett., 79(5), 716-722.

Luzi, L., R. Puglia, E. Russo and ORFEUS WG5 (2016). Engineering Strong Motion Database, version 1.0. Istituto Nazionale di Geofisica e Vulcanologia, Observatories & Research Facilities for European Seismology. doi: 10.13127/ESM

Molin, P., V. Acocella and R. Funiciello (2003). Structural, seismic and hydrothermal features at the border of an active intermittent resurgent block: Ischia Island (Italy). J. Volcanol. Geoth. Res., 121, 65-81.

Montaldo, V., Faccioli E., Zonno G., Akinci A. and Malagniniv L. (2005). Treatment of ground-motion predictive relationships for the reference seismic hazard map of Italy, J. Seismol. 9(3), 295-316.

Paolucci, R., F. Pacor, R. Puglia, G. Ameri, C. Cauzzi and M. Massa (2011). Record processing in ITACA, the new Italian strong motion database, in Earthquake Data in Engineering Seismology, Geotechnical, Geological and Earthquake Engineering Series, S. Akkar, P. Gulkan, and T. Van Eck (Editors), Vol. 14(8), 99-113.

Suzuki, A. and I. Iervolino (2017). Italian vs worldwide history of largest PGA and PGV. Ann. Geoph. Italy, 60(5), S0551.

Tusa, G. and H. Langer (2015). Prediction of ground motion parameters for the volcanic area of Mount Etna. J. Seismol., 20(1), 1-42.