INGV-T3 Research Project 2015-2016

HYPSTHER

HYBRID GROUND MOTION PREDICTION EQUATIONS FOR PSHA PURPOSES: THE STUDY CASE OF SOUTHERN ITALY

Task 1 (WG-T1)

Empirical flat-file generation

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Abstract

The work of "Task 1" research unit is focused on three principal aspects: 1) the compilation of a qualified database of recorded waveforms, 2) the individuation of reference stations included into the data-set and, finally, 3) the flat-file generation.

Compilation of a qualified database of recorded waveforms

The selection criteria adopted for the data-set compilation are:

- latitude: min = 34, max = 40; longitude: min = 10, max = 18 (spatial limits valid for both stations and events);
- $M_W \geq 3.5$ (or, in case of missing value for $M_{W,}$ $M_L \geq 3.5$);
- epicentral distance $D_{EPI} \leq 200$ km.

Before the start of the project HYPSTHER, the above selection criteria results in a dataset of about 1000 three-component accelerometric waveforms which included mainly data from the "IT" (~700) and from the "IV" (~300) networks. It should be also noticed that IV data were mainly relevant to the Calabria region, since accelerometric stations from Sicilia region are still not available on the ORFEUS-EIDA platform (http://www.orfeus-eu.org/eida/).

First, Task 1 worked on the retrievement of available data (paying peculiar attention to the Sicilia region, since, as stated before, its lack of data): a) integrating the accelerometric data-set by velocimetric waveforms (in fact, velocimetric networks managed by INGV or other institutions are usually denser than accelerometric ones); b) adding off-line (i.e. not available on the ORFEUS-EIDA platform) accelerometric data of the IV network in cooperation with INGV-Catania.

After the inclusion of these data, the data-set enumerates about 3200 three-component waveforms (Figure 1, left panel), whose ~1200 accelerometric and ~2000 velocimetric, recorded by ~230 stations mainly belong to IT and IV networks (Figure 1, right panel).

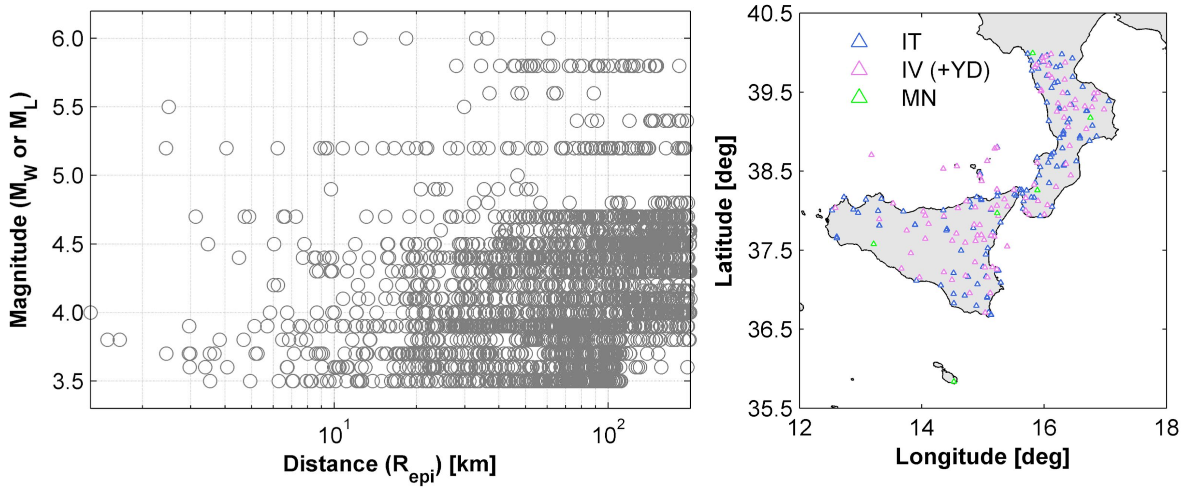

Figure 1. *Left panel: magnitude-distance distribution of the three components waveforms included in the data-set. Right panel: map of the recording stations (~230).*

Event metadata have been revised: in particular, the ISIDe catalogue (http://iside.rm.ingv.it) has been used to update locations and magnitudes (M_W and M_L) as well as moment tensor solutions and information on the geometries of the seismic source (strike, dip and rake). The data-set appears to be well sampled in terms of recordings for each bin of distances (Figure 2, left panel); on the other side, as expected, more than the 90% of the recordings belongs to the magnitude range 3.5 to 5 (Figure 2, right panel). The areal distribution of the events is denser in the central part and in the Tyrrhenian-sea at North-West of Calabria region, and in the oriental part of Sicily region, with a cluster of low magnitude events in proximity of Mt. Etna (Figure 3, left panel). Tyrrhenian-sea events are generally characterised by deep hypocenters (Figure 3, right panel).

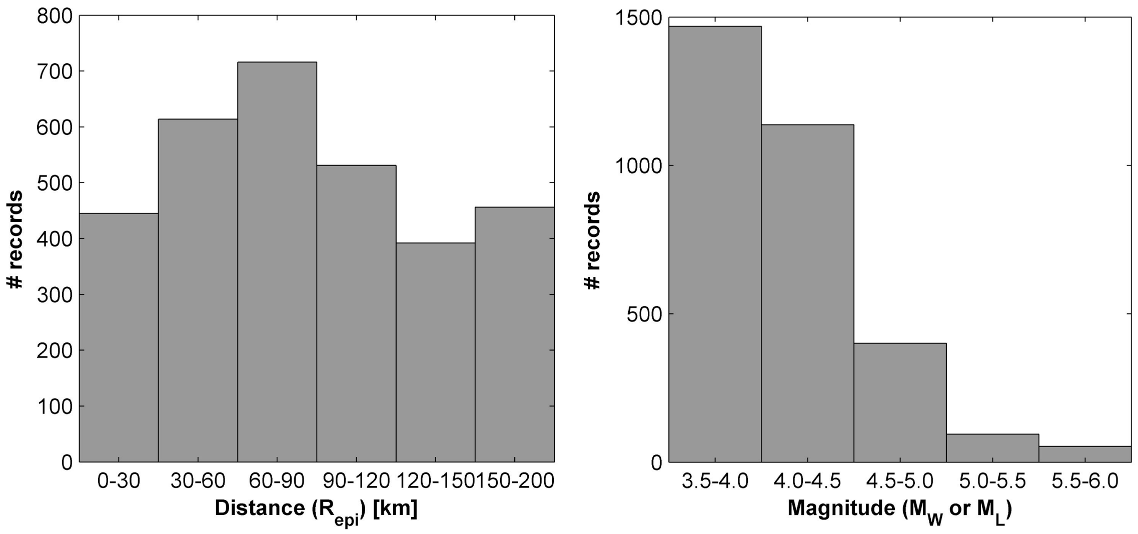

Figure 2. *Left panel: number of records in function of epicentral distances. Right panel: number of records in function of magnitude ranges.*

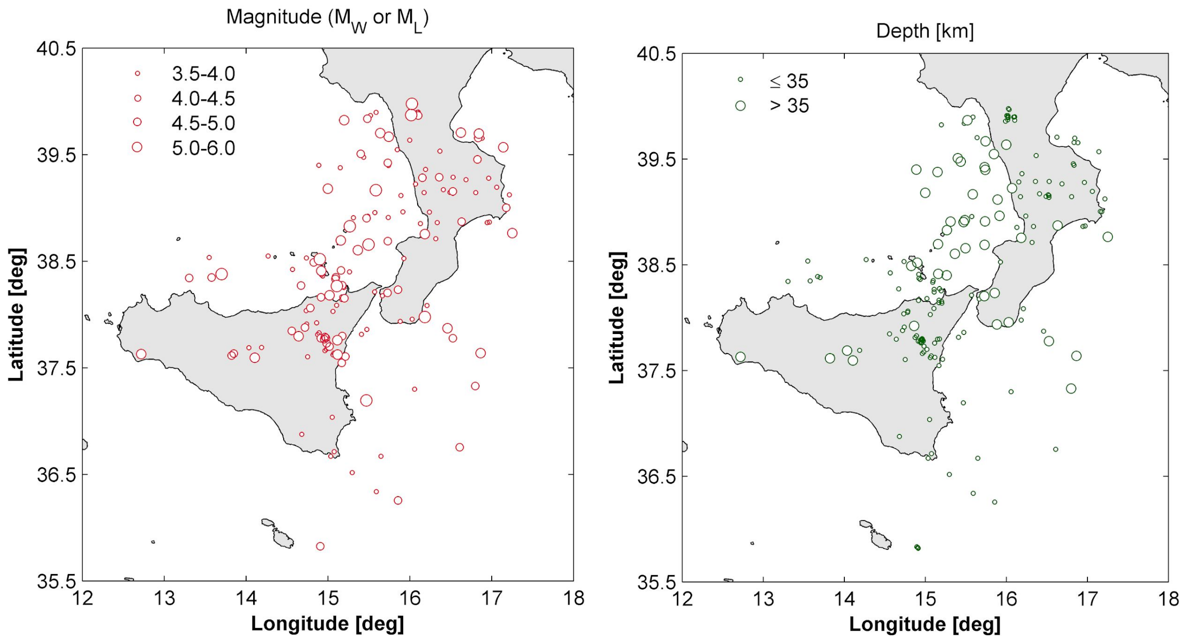

Figure 3. *Left panel: map of epicenter locations grouped by magnitude ranges. Right panel: map of epicenter locations grouped by hypocentral depth.*

The left panel of Figure 4 shows focal mechanisms estimated from the rake of the fault as suggested by Aki and Richards (2009): the prevalent style of faulting within the data-set is normal (NF, ~30%), however a significant number of records are associated to unknown mechanism (UN, ~30%) since information on the geometries of the seismic source are not available for such low-magnitude events.
As well as events, station metadata has been revised too: in particular, sites are classified according to EC8 (CEN., 2004). The right panel of Figure 4 shows the site classification associated to each recording. Site classes marked by an asterisk (i.e. A*, B* and C*) indicates that no $V_{S,30}$ (average shear wave velocities in the shallow 30m) is available at the site. Therefore, the site class attribution is performed on the basis of geological information alone, following the Di Capua et al. (2011) approach. The list of stations classified in EC8-A on the base of measured $V_{S,30}$ is reported in Table 1.

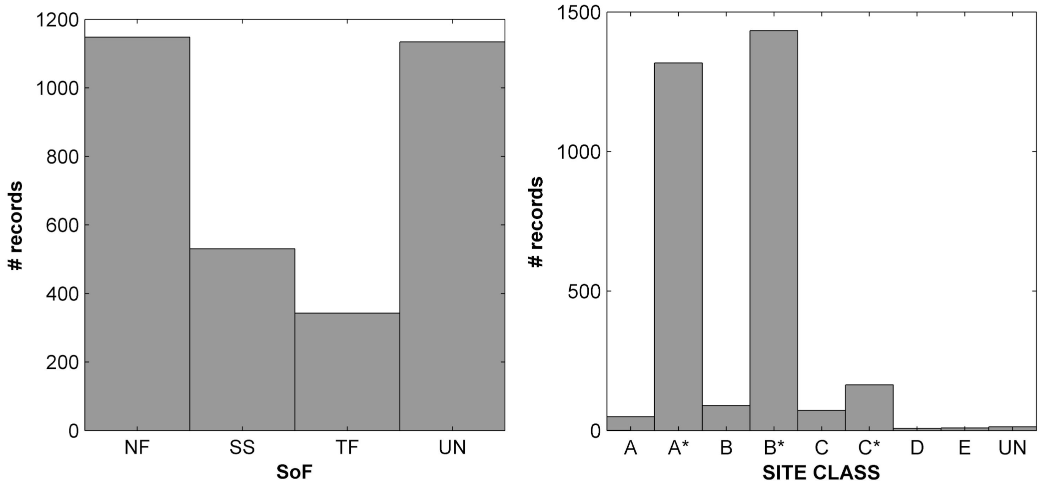

Figure 4. *Left panel: number of records grouped by focal mechanisms (NF: normal fault; SS: strike-slip fault; TF: thrust fault; UN: unknown mechanism). Right panel: distribution of site categories.*

Table 1. *Stations classified as EC8-A from measured $V_{S,30}$ present within the data-set.*

IT.CFL	IT.LNT	IT.RGS	IT.SRC
IT.ISI	IT.MRM	IT.SCR	IT.SRT

The whole data-set has been manually processed using the web interface of the ESM database available at http://esm.mi.ingv.it/processing/ which adopts the Paolucci et al. (2011) processing scheme. Figure 5 shows Peak Ground Velocities (PGV) recorded year by year.

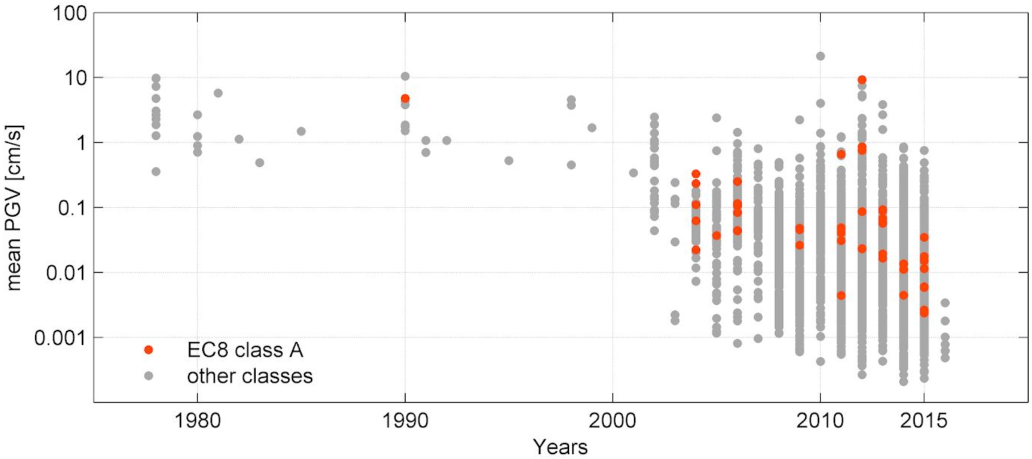

Figure 5. *Annual distributions of the peak ground velocities (geometric mean of the horizontal components). Data relevant to EC8 site category "A" are evidenced in red.*

Individuation of reference stations

The objective of this section is the individuation of the reference rock sites within the data-set. As reported in Figure 5, very few waveforms have been recorded at EC8 class A sites - i.e. reference rock within current European and Italian seismic codes -, due to the lack of geological and geotechnical information at the station. Therefore, another approach can be followed: which is not based on a priori subdivision, but it relies on the natural aggregation of empirical amplification function of the sites. Those are obtained by normalizing the spectra of the recorded motion by a reference (rock) spectrum from a ground motion Model (GMM). The adopted GMM is that developed by Bindi et al. (2011). The normalised spectra of sites are finally aggregated by means of cluster analysis, in order to individuate the cluster characterised by the lowest amplification. Stations belonging to this cluster are considered reference rock.

The analysis has been preceded by data selection into ESM database. To be analysed, each station - out of the starting list of stations (~230) - needs at least 3 recordings with the following characteristics:

- waveform normally triggered, i.e. both P and S phases should be present in the record; S-wave triggered waveforms - quite common in old data - have been rejected;
- the epicentral distance has to be lower than 200 km and the event depth < 35 km, to fulfil the principles of the GMM by Bindi et al. (2011);

- Mt. Etna events - i.e. events within latitude range 37.60-37.85 and longitude range 14.88-15.14 - have been excluded;
- moment magnitude of the event has to be > 3.5 (M_L is used if M_W is missing).

The selection reduced the initial dataset to about 120 stations.

For each station the acceleration response spectra of single records were normalised to the expected response spectra predicted for an average rock site (for the same style of faulting, magnitude and distance). The analysis was performed for 5% damped response spectral acceleration in the period range, T, 0.04-4s. The geometric mean of the normalised spectra was evaluated (Figure 6). At this point, another restriction was settled: if the standard deviation (std) within the normalised spectra at the site is higher than 1.5, the station has been excluded from the following cluster analysis ('std' is reported on top of each graph in Figure 6). This restriction results in about 80 station taken into account hereafter.

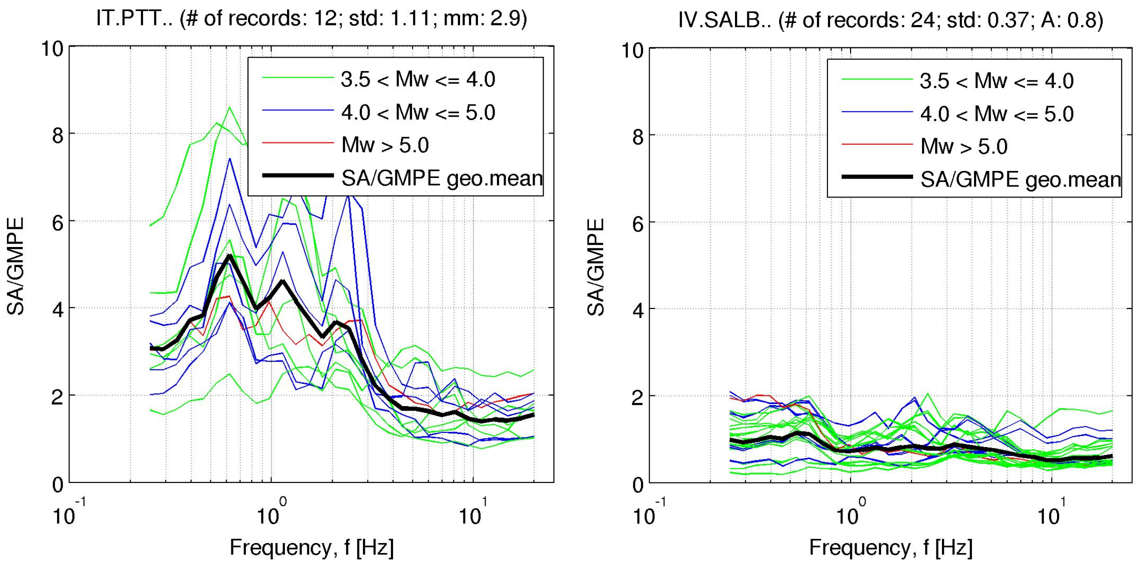

Figure 6. *Mean (black lines) and single (coloured lines) normalized spectra. Left panel: station "IT.PTT". Right panel: station "IV.SALB".*

The distance between the mean of normalized spectra (black line in Figure 6), relative to station i and j, is evaluated as the mean Euclidean distance, over m periods, between spectral ordinates, as:

$$d_{ij} = \sqrt{\frac{\sum_{k=1}^{m} \left(X_{ik} - X_{jk}\right)^2}{m}}.$$

The rank of the matrix containing the distances between couple of stations has been progressively reduced adopting a hierarchical clustering algorithm (Davis, 1986).

The cluster analysis converged on the aggregation of the normalized spectra characterized by the lowest amplification (Figure 7). Table 2 reports the lists of selected reference stations aggregated by cluster analysis. The geometric means and single normalised spectra for reference stations are reported in the *Appendix A.*

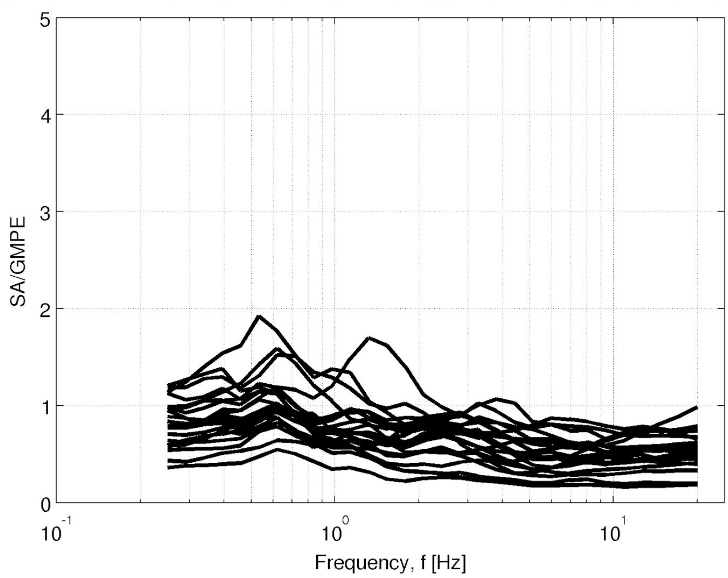

Figure 7. *Single-station mean normalised spectra relevant to the lowest cluster in terms of amplitude.*

Table 2. *Stations corresponding to each normalised spectrum reported in Figure 7.*

IT.CON	IV.GALF	IV.ME10	IV.PLAC	IV.SOLUN	MN.CUC
IT.GSM	IV.GRI	IV.MMME	IV.SALB	IV.T0702	MN.TIP
IT.RCU	IV.LADO	IV.MSFR	IV.SERS	IV.TDS	
IV.CELI	IV.MCPD	IV.PIPA	IV.SOI	MN.CEL	

Flat-file

The metadata collected are stored into a flat-file in which each row corresponds to three-component (east, west and vertical) waveform. The metadata are grouped into three main categories related to stations, events and ground-motion parameters.

Recording site metadata regard station code, geographic coordinates, instrument code to discriminate accelerometers from velocimeters and sensor depth.

Information related to the soil characterization in terms of soil category, value of $V_{S,30}$, resonance frequencies from microtremor and earthquakes and a proxy to $V_{S,30}$, calculated from topographic slope (Wald and Allen, 2007) are also available.

The events parameters are related to: instrumental hypocenter (event latitude, longitude, depth); earthquake magnitude (moment, M_W, local, M_L, surface-wave, M_S); focal mechanism; event time and various source-to-site distances as summarized in Table 3.
In addition, for some events, fault model is available from literature or national/worldwide databases. The corresponding parameters (length, width, top depth, strike, dip, rake) are specified in the flat-file. Several ground motion parameters are available for each waveform component: Peak Ground Acceleration, Peak Ground Velocity, Peak Ground Displacement, duration Arias and Housner intensity, 31 spectral ordinates in the period range (T) 0.01-10 s.
All waveforms have been corrected to ensure reliable values of displacement after double-integration of acceleration according to Paolucci et al. (2011); processing parameters such as cut-off frequencies are indeed included in the flat-file.

Table 3. Different source-to-site distances including in the flat-file.

R_{EPI}	Epicentral distance
R_{JB}	Distance measured perpendicular to the fault strike from the surface projection of the up-dip edge of the fault plane
R_{RUP}	Shortest distance to rupture plane
R_X	Distance measured perpendicular to the fault strike from the surface projection of the up-dip edge of the fault plane
R_Y	Distance measured parallel to the fault strike from the midpoint of the surface projection of the fault plane

The data-set described in this report includes, to date, about 3000 three-component waveforms generated by 174 earthquakes with magnitude between 3.5 and 6.0 and recorded by about 230 accelerometric and/or velocimetric stations in the frame time 1978-2016. This dataset represents the most complete and finest collection of both weak and strong motion data for the Southern Italy (Calabria and Sicily).
During the project, the data-set will be integrated with other accelerometric records and updated metadata, therefore the final version of the HYPSTHER flat-file will be published at the end of the project (December 2016).

Data and resources

Raw data considered within this study have been recorded by the National Accelerometric Network (IT), operated by the Italian Civil Protection Department - Presidency of the Council of Ministers (DPC) and the National Seismic Network (IV), operated by Istituto Nazionale di Geofisica e Vulcanologia (INGV). Data from IT network were taken from the institutional download service available at http://ran.protezionecivile.it. While data from IV network are mainly available through the EIDA web-services at http://www.orfeus-eu.org/eida/. The IV accelerometric data recorded in Sicily have been provided by Giuseppina Tusa and Antonio Scaltrito under the supervision of Raffaele Azzaro (INGV, Sezione di Catania).

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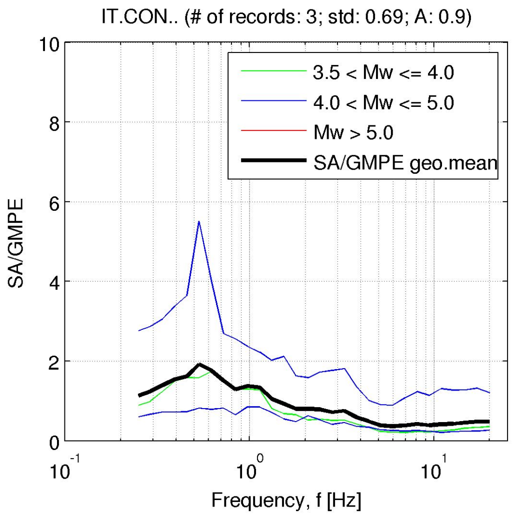
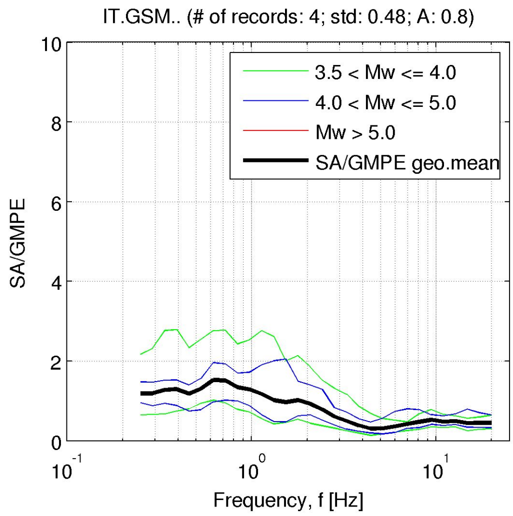
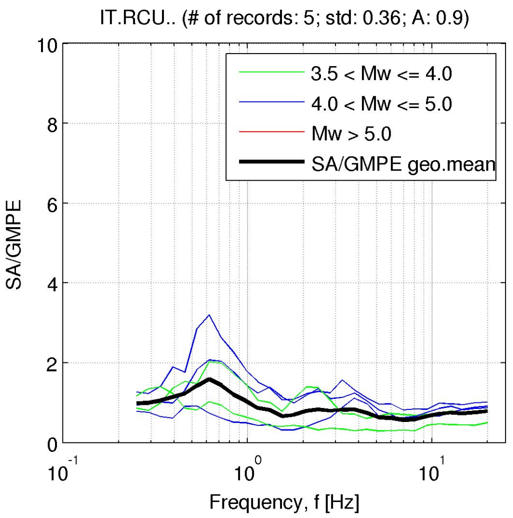
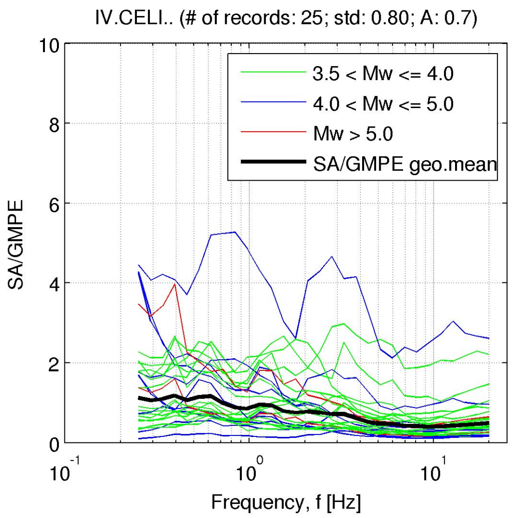
Appendix A

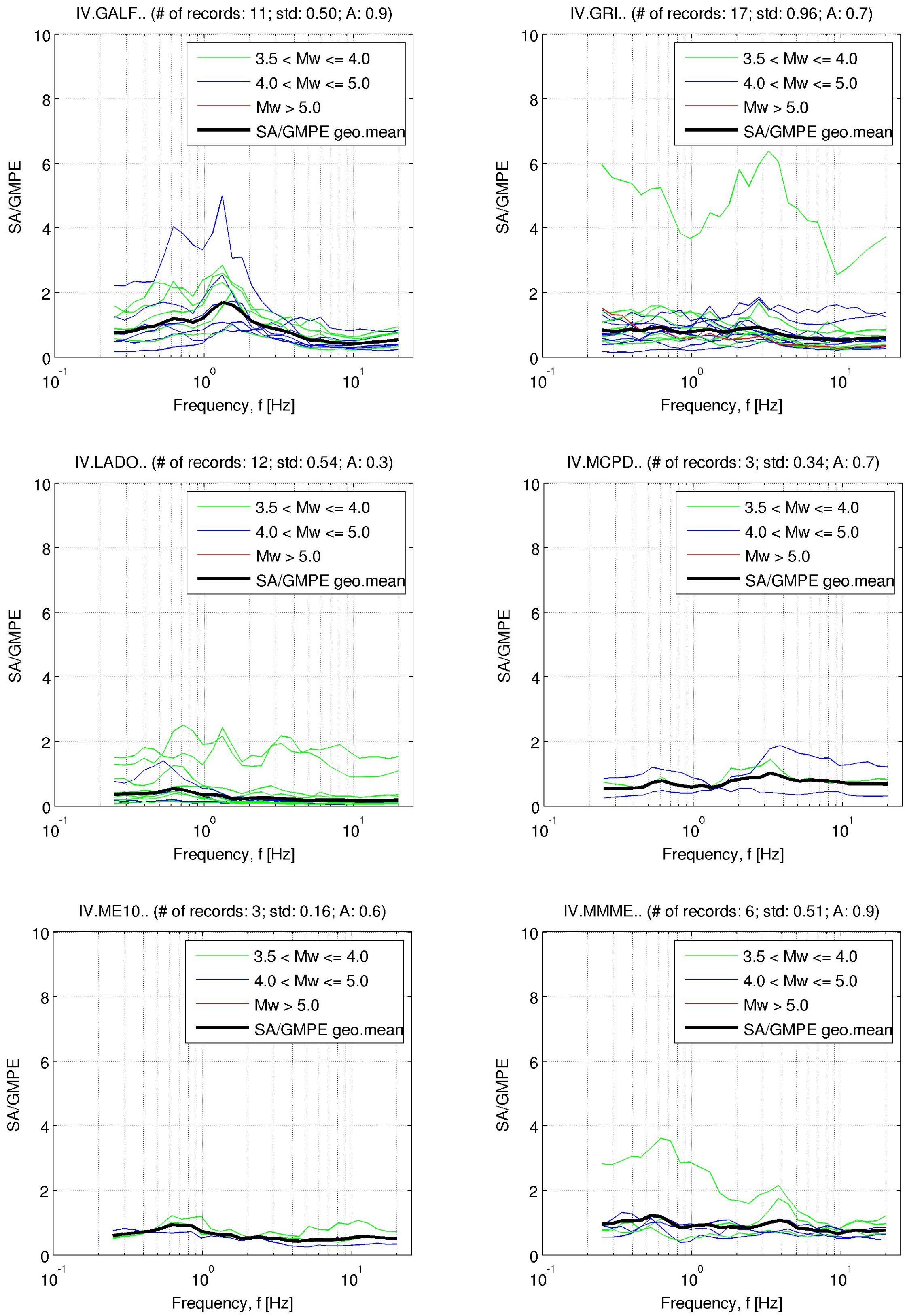
Mean (black lines) and single (coloured lines) normalised spectra for each station in Table 2 are reported in the following.










IV.GALF.. (# of records: 11; std: 0.50; A: 0.9)
IV.GRI.. (# of records: 17; std: 0.96; A: 0.7)
IV.LADO.. (# of records: 12; std: 0.54; A: 0.3)
IV.MCPD.. (# of records: 3; std: 0.34; A: 0.7)
IV.ME10.. (# of records: 3; std: 0.16; A: 0.6)
IV.MMME.. (# of records: 6; std: 0.51; A: 0.9)
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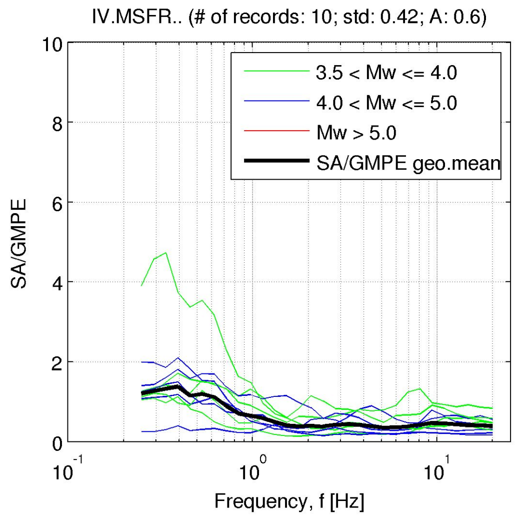
4.0 < Mw <= 5.0
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]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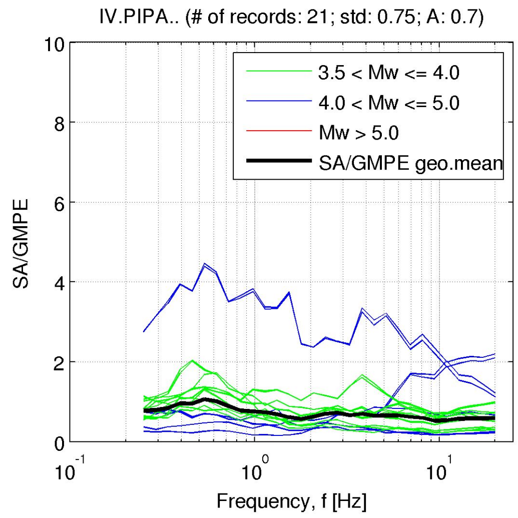
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]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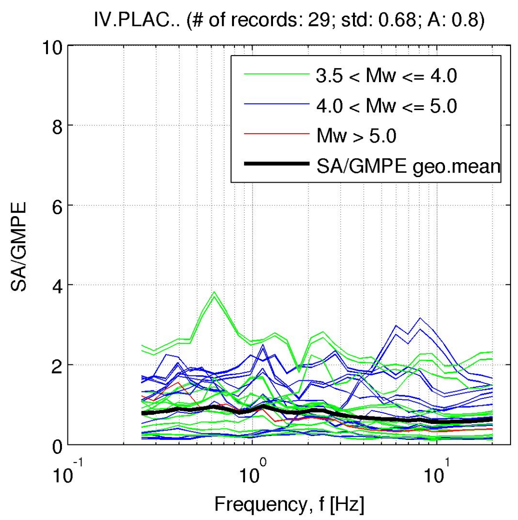
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]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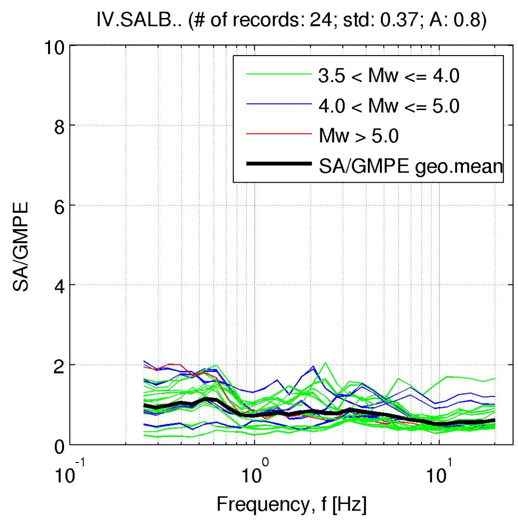
4.0 < Mw <= 5.0
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]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Mw > 5.0
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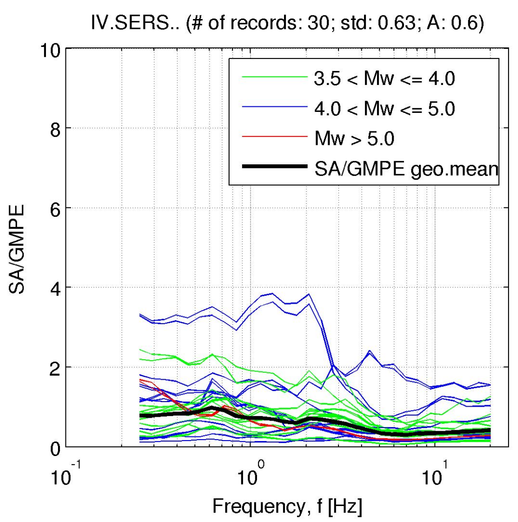
SA/GMPE
Frequency, f [Hz]


IV.SERS.. (# of records: 30; std: 0.63; A: 0.6)
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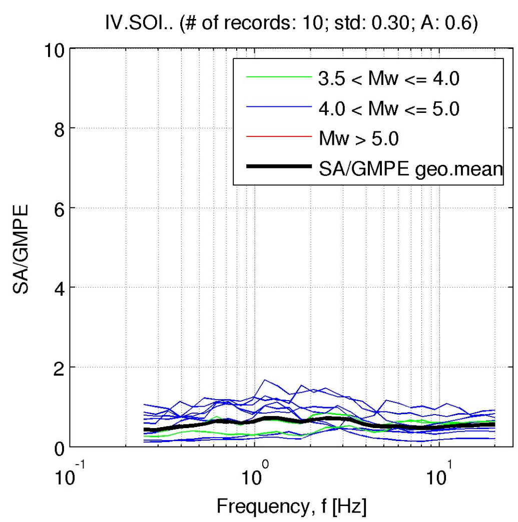
Frequency, f [Hz]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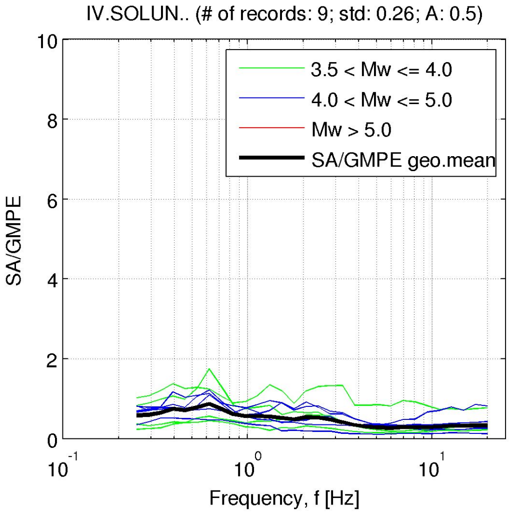
SA/GMPE
Frequency, f [Hz]


IV.SOLUN.. (# of records: 9; std: 0.26; A: 0.5)
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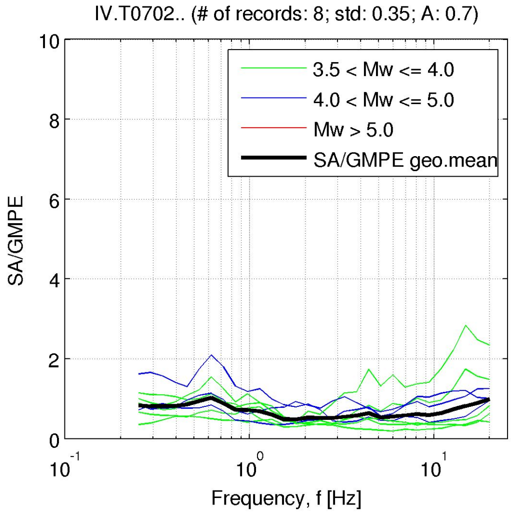
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]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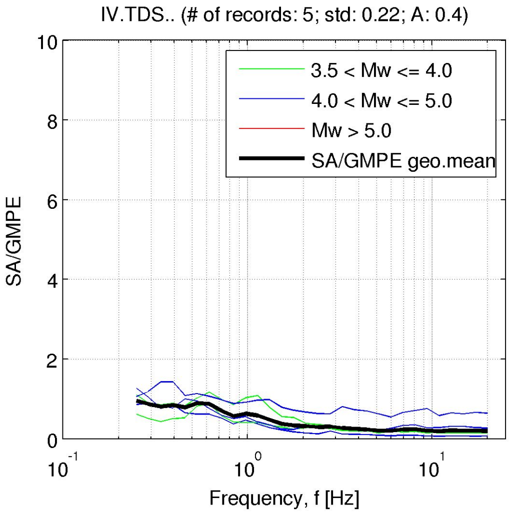
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]


IV.TDS.. (# of records: 5; std: 0.22; A: 0.4)
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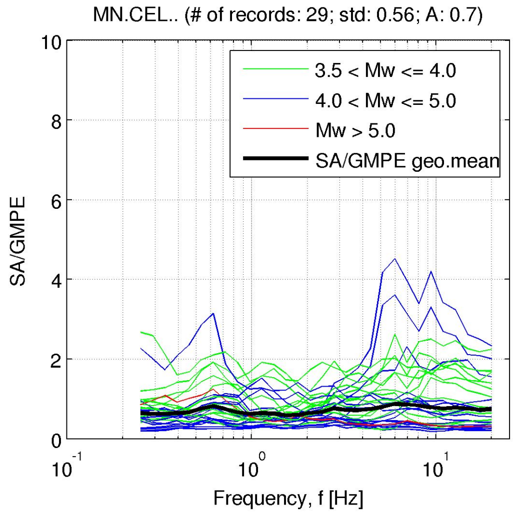
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]


MN.CEL.. (# of records: 29; std: 0.56; A: 0.7)
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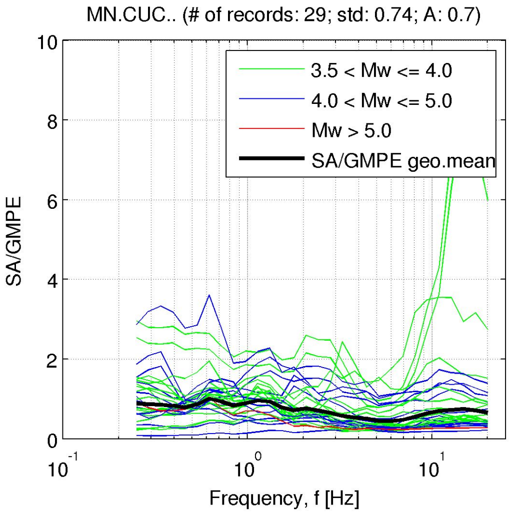
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]


MN.CUC.. (# of records: 29; std: 0.74; A: 0.7)
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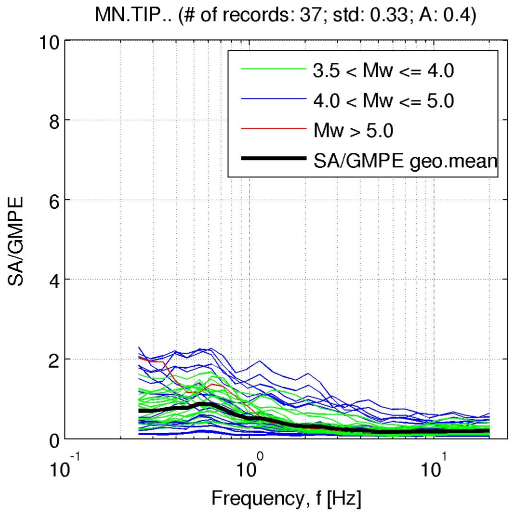
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]


MN.TIP.. (# of records: 37; std: 0.33; A: 0.4)
3.5 < Mw <= 4.0
4.0 < Mw <= 5.0
Mw > 5.0
SA/GMPE geo.mean
SA/GMPE
Frequency, f [Hz]

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