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Microtremor measurements in the area of Camerino

Chiara Felicetta, Maria D'Amico, Lucia Luzi

INGV (Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Milano)

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Acquisizione di registrazioni di microtremore nel territorio di Camerino

In questo lavoro si riportano i risultati di una campagna di acquisizione di microtremore ambientale nel territorio comunale di Camerino. Le indagini sono state condotte a seguito della sequenza sismica dell'Italia Centrale del 2016-2017 che ha causato crolli e danni ingenti all'edificato e, in particolare, al patrimonio storico-artistico. Lo scopo principale di questo studio consiste nel fornire elementi utili per migliorare le conoscenze sulla risposta sismica locale dell'area, propedeutiche a studi di microzonazione sismica di livello II o III.
Sono state eseguite 25 misure in 6 aree contraddistinte da diversi livelli di danneggiamento e tipologie costruttive. In generale, le curve del rapporto spettrale tra la componente orizzontale e verticale non mostrano una rilevante variazione spaziale del valore della frequenza fondamentale che, nella maggior parte dei casi, si assesta intorno a 1 Hz.

In this work we present the results of a microtremor survey conducted in the area of Camerino following the 2016-2017 seismic sequence of the Cental Italy. Such sequence caused a heavy damaging level in Camerino, and especially in the historical center. The present study aims to provide useful information to increase the knowledge on the local seismic response of the study area, which is preparatory for future seismic microzonation of higher level.
Twenty-five ambient noise recordings have been carried out in six zones characterized by different damaging levels and type of buildings. In general, the Horizontal to Vertical Spectral Ratio (HVSR) curves show similar trends, whit a fundamental frequency around 1 Hz.

Introduzione

Dall'evento del 24 agosto 2016 (01:36:32 UTC, Mw6.0) l'Appennino Centrale italiano è stato interessato da una sequenza sismica caratterizzata da 9 terremoti di magnitudo momento superiore a 5.0 (Figura 1a). La scossa più forte si è verificata il 30 ottobre 2016 (06:40:18 UTC, Mw6.5) nell'area di Norcia causando, in alcuni casi, picchi di accelerazione del moto del suolo superiori a 300 gal (http://esm.mi.ingv.it).
Tra i numerosi comuni che hanno risentito di un elevato grado di danneggiamento, si annovera Camerino. Il comune di Camerino ricade in un'area a moderata pericolosità sismica (Figura 1b), essendo caratterizzato da un valore di base di accelerazione massima del suolo pari a 0,217 g, ed è stato interessato in passato da eventi sismici distruttivi (http://emidius.mi.ingv.it/CPTI15-DBMI15/).
Nonostante gli interventi sugli edifici lesionati in seguito alla sequenza sismica umbro-marchigiana del 1997, numerose costruzioni (prevalentemente edifici ecclesiastici e fabbricati in muratura all'interno della cerchia muraria) sono state severamente danneggiate o parzialmente crollate a seguito degli eventi del 26 e del 30 ottobre 2016 (Figura 2).
Al fine di contribuire ad una definizione più accurata della risposta sismica locale di Camerino, è stata pertanto condotta una campagna di misure di rumore ambientale in diverse aree del centro storico, delle zone di espansione e in corrispondenza della frazione di S. Erasmo. Tali aree sono caratterizzate da diversi livelli di danneggiamento e tipologie costruttive. Complessivamente sono state eseguite 25 misure nelle 6 aree riportate in Figura 3.

1. Assetto geologico e geomorfologico

Il territorio comunale di Camerino occupa la zona centrale della cosiddetta sinclinale di Camerino, delimitata a ovest dalla dorsale calcarea Umbro-Marchigiana, interessata dal fronte del sovrascorrimento Monte Cavallo-Monte Primo a vergenza orientale, e a est dalla dorsale calcarea Marchigiana interna.
I litotipi più diffusi nella zona in studio (Figura 3) sono rappresentati dalla successione di sedimenti torbiditici silicoclastici di età Miocenica, appartenenti alla Formazione delle Arenarie di Camerino, che si sovrappongono in conformità ai calcarei, calcarei marnosi e marnosi della serie carbonatica Umbro-Marchigiana.
L'azione tettonica compressiva ha determinato il sollevamento dell'Appenino occidentale e la deformazione del baci-

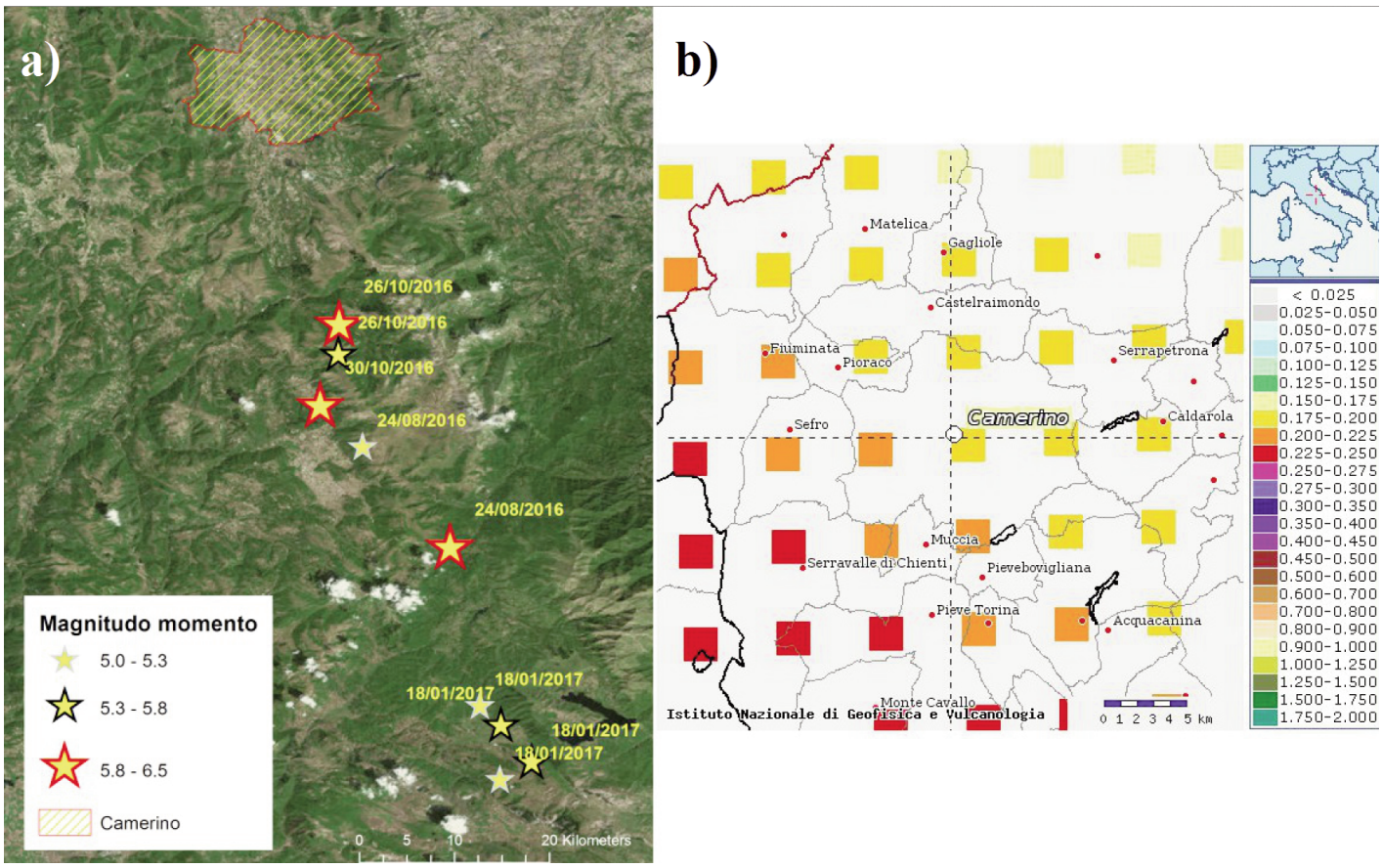


Figura 1 a) Localizzazione degli eventi della sequenza sismica dell'Italia Centrale del 2016-2017 caratterizzati da magnitudo momento superiore a 5 e distanza massima epicentrale inferiore a 80 km; b) pericolosità di base del Comune di Camerino in termini di probabilità di superamento del valore di picco dell'accelerazione (periodo di ritorno 475 anni) riferita a suoli rigidi (Vs30 > 800 m/s) (http://esse1-gis.mi.ingv.it/).
Figure 1 a) Localization of the events of the 2016-2017 Central Italy seismic sequence characterized by moment magnitude larger than 5; b) seismic hazard of the Camerino municipality in terms of probability of exceedance of the peak ground acceleration (return period of 475 years) for rock soils (Vs30 > 800 m/s) (http://esse1-gis.mi.ingv.it/).

no marchigiano in dorsali e depressioni, allungate in direzione nord sud, con la suddivisione in bacini più piccoli dove la tipologia di sedimentazione passa da emipelagica a torbiditica conseguente ad apporti fluviali che hanno dato luogo alla deposizione della Formazione delle Arenarie di Camerino.
Questa è costituita da alternanze di strati pelitici (argille e argille siltose) ed arenacei ricoperti da depositi quaternari di spessore variabile in base alla morfologia. La coltre detritica è costituita in prevalenza da depositi eluvio-colluviali e di frana in corrispondenza dei versanti collinari, costituiti da limi sabbiosi e limi argillosi con elementi clastici arenacei sparsi. Sono inoltre presenti depositi alluvionali e di versante. I depositi alluvionali sono costituiti da ghiaie a prevalente litologia calcarea immerse in matrice sabbioso-limosa cui s'intercalano livelli e lenti di limi sabbiosi di differente spessore e continuità laterale. I detriti di versante occupano generalmente la base dei rilievi calcarei e sono formati principalmente da clasti calcarei e calcareo-marnosi immersi in matrice sabbiosa.
Dal punto di vista geomorfologico il territorio camerte è costituito da: i) rilievi montuosi calcarei ai margini occidentali ed orientali caratterizzati da morfologia aspra e acclive; ii) un sistema collinare di modesta quota ai piedi dei rilievi montuosi segnato da incisioni fluviali; iii) pianure alluvionali di modeste dimensioni.
L'azione gravitativa esercita la maggiore influenza sull'evoluzione morfologia del territorio poiché motore di fenomeni di caduta e di movimenti di masse rocciose e di frane. Quest'ultime sono largamente distribuite sul territorio, ricadendo, in alcuni casi, all'interno o in prossimità di aree urbanizzate (es. area compresa tra il cimitero e la località Montagnano).

2. Sismicità Storica

La sismicità storica dell'area dal XII secolo ad oggi [DBMI15, Locati et al., 2016], è caratterizzata da un centinaio di eventi che in alcuni casi hanno prodotto a Camerino un grado di risentimento macrosismico superiore alla soglia del danno ($I_F \geq 7$ MCS in Tabella 1 e Figura 4). L'evento del 30 Aprile

1279 (I_F = 8-9 MCS; Mw6.20), che ricade approssimativamente nella stessa area epicentrale del terremoto di Colfiorito del 1997 (Io = 8-5 MCS; Mw5.97), causò numerose vittime e il crollo di buona parte degli edifici. A tal proposito Baratta [1901] riporta che

> *"…in Camerino rimase diroccato l'altissimo campanile di S. Maria, la torre di S. Giacomo … caddero pure due terzi dei tetti con mortalità di persone".*

Nei quattro secoli successivi non si hanno fonti storiche sull'evidenza di terremoti.
Nel XVIII secolo una serie di eventi ha prodotto gravi danni a Camerino. Il 24 Aprile 1741 un forte terremoto (I_F = 7-8 MCS, Mw6.17) ha interessato le Marche meridionali causando il crollo della maggior parte delle abitazioni di Camerino, danni rilevanti al Duomo e alla chiesa di S. Venanzio (Baratta, 1901). La sequenza del Luglio-Agosto 1799 ne rase al suolo ancora una volta la quasi totalità degli edifici, incidendo negativamente anche sul contesto socio-economico della città [Guidoboni et al., 2007]. Fra gli edifici pubblici, le fonti storiche riportano notizie di notevoli lesioni alla torre pubblica, sita sopra la chiesa dei padri Conventuali di S. Francesco, il crollo del tetto del Duomo, di parte della volta e del catino della chiesa di S. Venanzio. Cadde inoltre la cupola di S. Maria in Via e si lesionarono il tetto, la volta e le pareti. Le chiese e i monasteri del Carmine e di S. Chiara subirono gravi danni che li resero inagibili mentre la chiesa di S. Maria del Carmine fu completamente distrutta.
In tempi più recenti, la sequenza sismica umbro-marchigiana del 1997 ha causato danni ingenti ad infrastrutture e l'inagibilità di numerosi edifici.



Figura 2 Immagini rappresentative dei danni riscontrati a Camerino a seguito della sequenza sismica dell'Italia Centrale del 2016-2017; a) crollo del campanile della chiesa di S. Maria in Via; b) lesioni della facciata della chiesa di S. Maria in Via; c) crollo parziale e lesioni ad un fabbricato sito in S. Erasmo.
Figure 2 Pictures of the damages observed in Camerino following the 2016-2017 Central Italy seimic sequence; a) collapse of the S. Maria in Via church bell tower; b) S. Maria in Via church injuries; c) partial collapse and injuries of mansory in S. Erasmo.

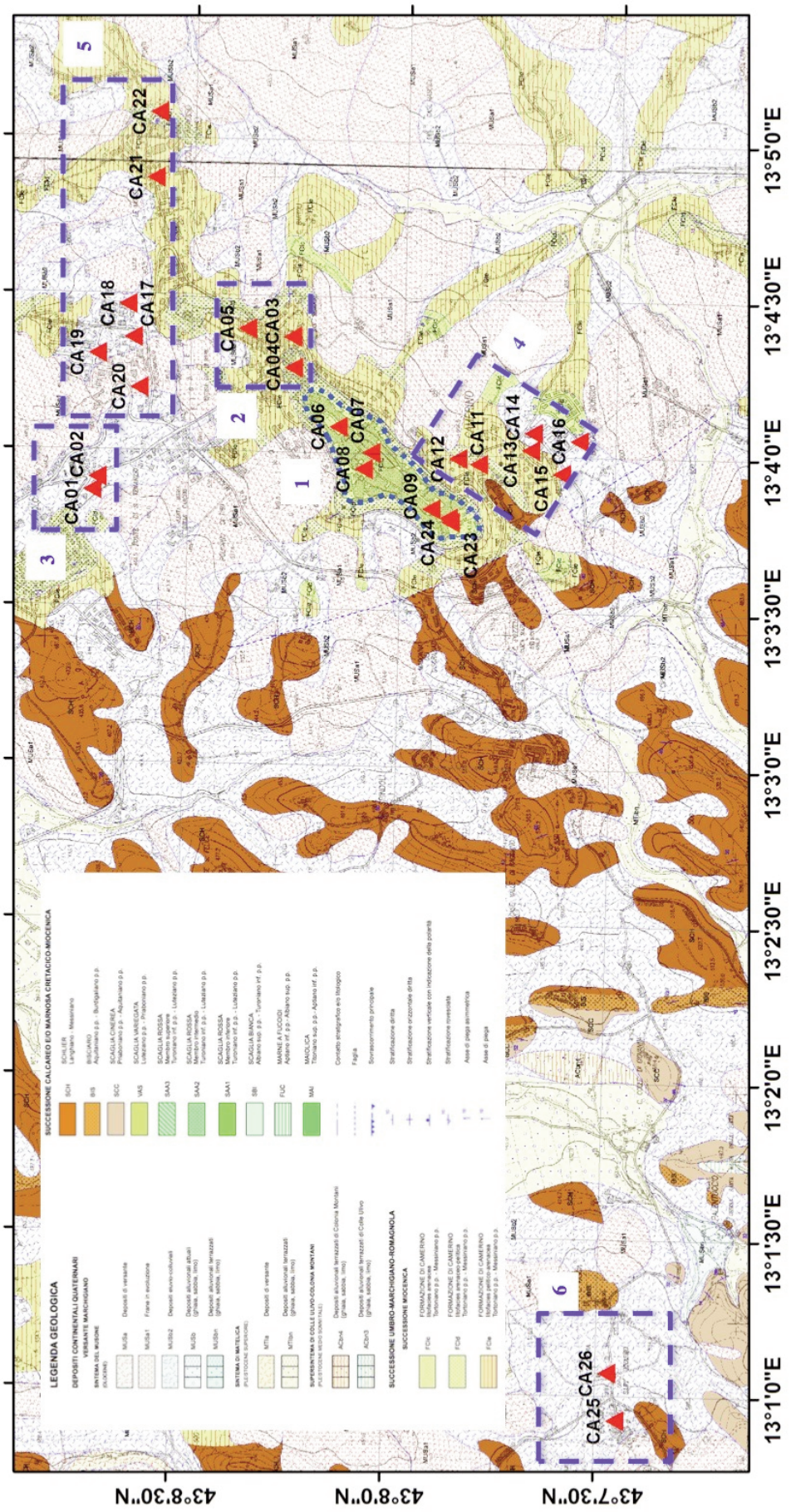


Figura 3 Mappa geologica del territorio di Camerino (estratta dalla carta geologica regionale in scala 1:10.000) e ubicazione dei punti di acquisizione di microtremore ambientale; i poligoni tratteggiati in blu indicano le zone indagate. 1) Centro Storico dentro la cerchia muraria; 2) Centro Storico fuori dalla cerchia muraria; 3) Viale Ottaviani; 4) quartiere Le Vallicelle; 5) quartieri Montagnano e Le Mosse; 6) frazione S. Erasmo.

Figure 3 Geological map of Camerino (from regional geologial map with scale 1:10,000) and location of acquisition points; poligons in blue indicate the investigated zones. 1) Historical Centre inside the fortification wall; 2) Historical Centre outside the fortification wall; 3) Viale Ottaviani; 4) Le Vallicelle; 5) Montagnano e Le Mosse; 6) S. Erasmo.

I_F	Anno Me Gi Or Mi Se	Area Epicentrale	Io	M_w
8-9	1279 04 30 18	Appennino umbro-marchigiano	9	6.2
7-8	1741 04 24 09 20	Fabrianese	9	6.17
9	1799 07 28 22 05	Appennino marchigiano	9	6.18
6-7	1997 09 26 00 33 12.88	Appennino umbro-marchigiano	7-8	5.66
6-7	1997 09 26 09 40 26.60	Appennino umbro-marchigiano	8-9	5.97

Tabella 1 Terremoti sopra la soglia del danno citati nel testo [CPTI15, Rovida et al., 2016]. I_F = Intensità risentita a Camerino; Io = Intensità epicentrale; M_w = magnitudo momento.
Table 1 Earthquakes with Intensity felt in Camerino greater than 7 mentioned in the text [CPTI15, Rovida et al., 2016]. I_F = Intensity felt in Camerino; Io = Epicentral Intensity; M_w = moment magnitude.

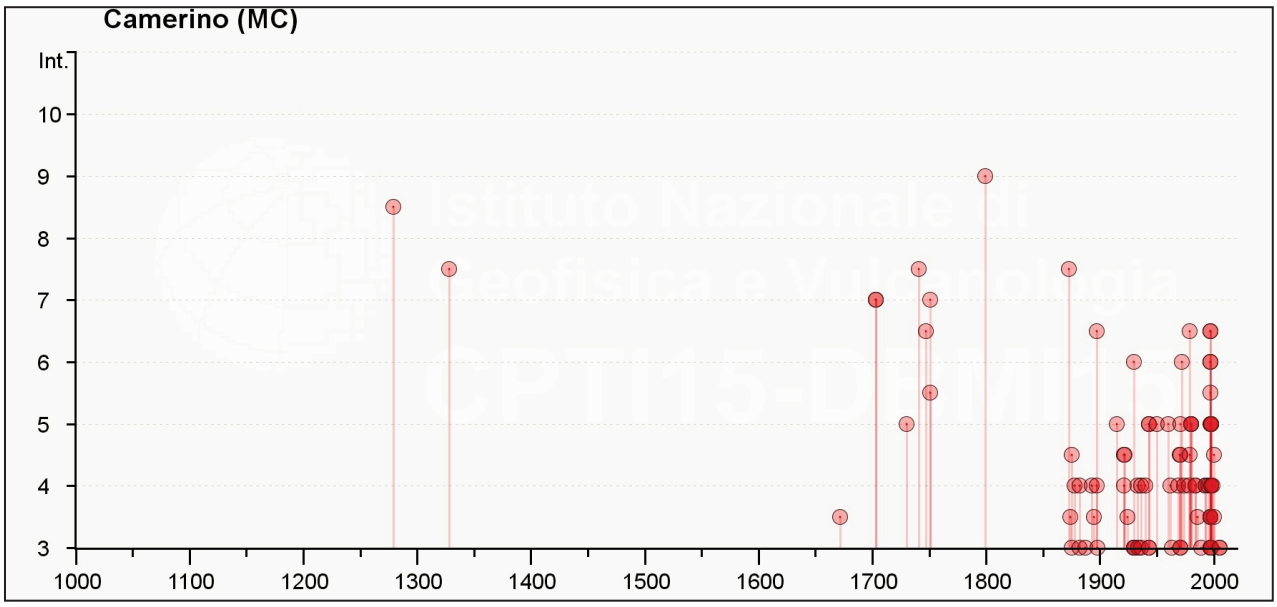


Figura 4 Sismicità storica di Camerino [DBMI, Locati et al., 2016; http://emidius.mi.ingv.it/CPTI15-DBMI15/description_DBMI15.htm].
Figure 4 Camerino seismic history [DBMI, Locati et al., 2016; http://emidius.mi.ingv.it/CPTI15-DBMI15/description_DBMI15.htm].

3. Sismica Passiva

In seguito alla sequenza del centro Italia del 2016-2017, sono state eseguite misure a singola-stazione di microtremore ambientale, al fine di contribuire allo studio di microzonazione sismica, come da Legge n. 8 del 9 Febbraio 2017. Sono state eseguite 25 misure in 6 aree distinte (Figura 3): 3 nel Centro Storico al di fuori della cerchia muraria (CA03, CA04, CA05); 6 nel Centro Storico dentro la cerchia muraria (CA06, CA07, CA08, CA09, CA23, CA24); 2 nel piazzale antistate le scuole elementari site temporaneamente in Viale V. Ottaviani (CA01, CA02); 6 nel quartiere Le Vallicelle (CA11, CA12, CA13, CA14, CA15, CA16); 6 nei quartieri Montagnano (CA17, CA18, CA19, CA20) e Le Mosse (CA21, CA22), 2 nella frazione di Sant'Erasmo (CA25, CA26).
La scelta dei siti è stata dettata dalla distribuzione del danneggiamento che le diverse zone hanno subito durante la sequenza sismica che ha interessato il Centro Italia a partire dal 24 Agosto 2016.
Le zone maggiormente danneggiate in seguito alla sequenza

sono: il Centro Storico, il quartiere Le Vallicelle e alcune frazioni ubicate ad ovest di Camerino, in corrispondenza del sovrascorrimento Monte Cavallo – Monte Primo, di cui S. Erasmo è stata selezionata come località rappresentativa.
Attualmente il centro Storico e il quartiere Le Vallicelle sono classificati come zona rossa, avendo subito ingenti danni sia agli edifici commerciali che a quelli abitativi. Nel Centro Storico le costruzioni maggiormente danneggiate sono gli edifici religiosi e d'interesse storico-artistico.
Altre zone sono state selezionate poiché, a parità di tipologia costruttiva, non hanno subito danni o sono state debolmente danneggiate, come ad esempio i quartieri Le Mosse e Montagnano.
Infine, Viale V. Ottaviani è stato scelto poiché zona in cui si prevede la ricostruzione delle scuole situate, prima degli eventi sismici, all'interno della cerchia muraria.

3.1 Strumentazione

La strumentazione utilizzata per effettuare le misure di microtremore ambientale è mostrata in Figura 5 e consiste in un sensore sismometrico Lennartz LE-3D/5s (www.lennartz-electronic.de) accoppiato ad un acquisitore Reftek-130 (www.reftek.com) che consente di immagazzinare i dati in locale direttamente su Compact Flash disk. L'acquisitore incorpora un convertitore analogico-digitale a 24 bit, con una dinamica maggiore di 138 dB. Il Lennartz LE-3D/5 è in grado di registrare il segnale su tre componenti (verticale, Nord-Sud, Est-Ovest) con una risposta piatta in un intervallo di frequenze tra 0.2 – 40 Hz. L'alimentazione, durante le misure, è stata garantita da batterie 12V e le coordinate geografiche sono state acquisite con un sistema GPS. I dati sono stati registrati per un tempo non inferiore ai 40 minuti e utilizzando un passo di campionamento pari a 100 campioni al secondo (100 Hz). Il gain dell'acquisitore è stato impostato ad un valore pari a 32, in modo da sfruttare a pieno la dinamica in relazione alle ridotte ampiezze da registrare.

3.2 Analisi Dati

Le 25 misure di microtremore ambientale sono state effettuate per stimare i picchi in frequenza dalla curva del rapporto spettrale orizzontale su verticale (HVSR) e, al fine di rendere i risultati comparabili, è stato usato sempre lo stesso metodo di analisi [Puglia et al., 2011] sviluppato nell'ambito del progetto sismologico Italian Strong Motion Database (DPC-INGV S4 2007–2009; http://esse4.mi.ingv.it).
Ad ogni serie temporale è stato applicato un filtro Butterworth passa-banda tra 0.1 e 20 Hz; le frequenze d'angolo sono state fissate alla metà della minima frequenza registrabile dallo strumento (LE-3D/5s) e a 20 Hz per coprire la fascia di frequenze di interesse ingegneristico (0.5 – 10 Hz).
Successivamente, ogni segnale è stato suddiviso in finestre temporali di lunghezza variabile a seconda della durata del segnale come suggerito dai criteri SESAME [2005]: in particolare, sono state utilizzate finestre di 50s per le registrazioni di lunghezza compresa tra 40 e 80 minuti e di 100s per le registrazioni più lunghe di 100 minuti (CA23 e CA24). Ogni finestra temporale è stata, poi, corretta per la linea base di primo ordine, è stato applicato un taper del 5% e, quindi, sono stati calcolati gli spettri di Fourier per ciascuna componente (Est-Ovest, Nord-Sud, verticale) in frequenze equi-spaziate in scala logaritmica tra 0.01 e 20 Hz. Agli spettri è stato applicato lo smoothing proposto da Konno e Ohmachi [2006] fissando il coefficiente di larghezza di banda (b) pari a 40. Il rapporto tra lo spettro di Fourier delle componenti orizzontale e verticale [HVSR, Nakamura et al., 1989; Nakamura, 2000] è stato calcolato per ogni finestra temporale. La curva media è stata ottenuta considerando una distribuzione log-normale delle ampiezze. Le componenti orizzontali sono state combinate tramite composizione vettoriale, per cui l'ampiezza minima, affinché si possa parlare di picco di amplificazione, è pari a $2\sqrt{2}$.
L'ampiezza della curva HVSR non può essere considerata una stima della reale amplificazione del moto sismico, in quanto il suo valore può variare a seconda delle frequenze maggiormente eccitate dall'input e dalla direzione di propagazione delle onde [Haghshenas et al., 2008].
In Allegato si riportano le schede riassuntive per ogni punto di misura che raccolgono le informazioni relative all'acquisizione, ai parametri adottati nell'analisi e ai risultati finali in termini di: (i) spettri di Fourier non filtrati per ciascuna delle tre componenti (*Single component spectra*); (ii) HVSR nel tempo relativi alle due componenti orizzontali (*HVSR time*

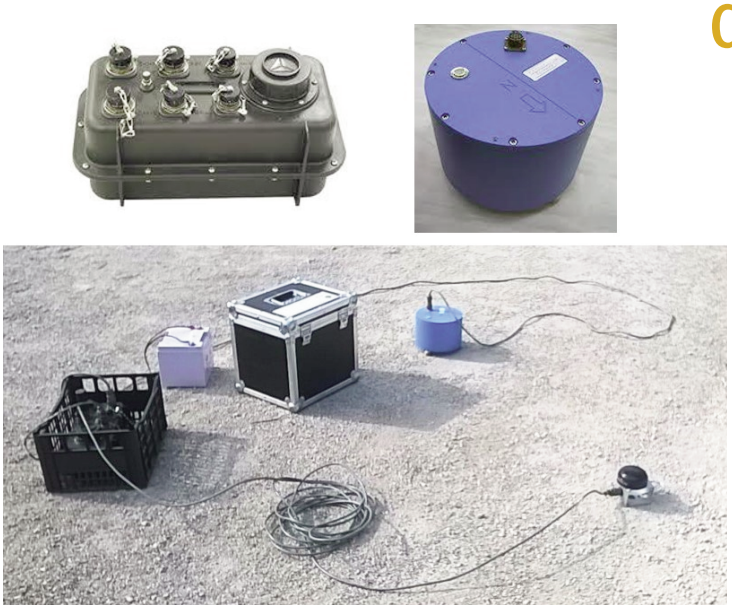


Figura 5 Acquisitore Reftek-130 (in alto sinistra); sensore sismometrico LE-3D/5s (in alto a destra); configurazione della strumentazione durante una misura di microtremore ambientale (in basso).
Figure 5 Top left: Reftek-130 digitizer; top right: LE-3D/5s seismometric sensor; bottom: instrument configuration.

histories); (iii) HVSR in funzione dell'azimuth (*Directional HVSR*); (iv) curva media HVSR e deviazione standard associata (*Horizontal to vertical spectral ratio*) e (v) criteri definiti dal progetto SESAME per indicare l'attendibilità dei picchi delle curve HVSR (*SESAME criteria*). Sono inoltre riportate le frequenze fondamentali di risonanza del sito (f_{01}, f_{02}).

I *Single component spectra* si riferiscono agli spettri di Fourier delle singole componenti processate senza l'applicazione del filtro passa-banda per identificare eventuali derive del segnale in bassa frequenza.

Per ottenere i *Directional HVSR* che danno indicazioni sulla stazionarietà e sulla direzionalità del rapporto HV, gli spettri di Fourier vengono calcolati tra 0° e 180° con un passo di 5° ruotando la composizione vettoriale delle componenti orizzontali.

3.3 Risultati

I risultati delle misure vengono di seguito discussi per le 6 zone indagate, mostrate in Figura 3. In Figura 6 si riportano le curve HVSR raggruppate per ciascuna zona.

In corrispondenza della cerchia muraria (Zona 1) sono state eseguite 6 misure da Piazza Cavour al Piazzale della Vittoria, con spaziatura media di 300 m (CA06, CA07, CA08, CA09, CA23 e CA24). Le curve HVSR (Figura 6a) mostrano un evidente picco intorno a 1 Hz caratterizzato da ampiezze comprese tra 4 e 5. La curva corrispondente alla misura CA08, pur mostrando comunque il picco a 0.95 Hz in accordo con le altre acquisizioni in Zona 1, è di scarsa qualità e, pertanto, si è scelto di non rappresentarla in Figura 6a. Le misure CA23 e CA24 oltre al picco con frequenza 1 Hz, evidenziano ampiezze non trascurabili a frequenze comprese tra a 0.2 e 0.4 Hz. L'evidenza di tali ampiezze potrebbe dipendere da aspetti peculiari del sito che dovrebbero essere investigati in dettaglio.

All'esterno della cerchia muraria del Centro Storico (Zona 2), le misure effettuate, rispettivamente, nel piazzale antistante alla chiesa di S. Venanzio, presso l'ex convento di S. Domenico, e alle spalle del Monastero di Santa Chiara (CA03, CA04 e CA05), mostrano un'amplificazione di tipo *broad-band* nell'intervallo di frequenze 1 – 4 Hz con ampiezze comprese tra 3 e 4 (Figura 6b).

Le misure effettuate in Zona 3 (Figura 6c) nel piazzale antistante alle scuole temporanee (CA01 e CA02), mostrano un

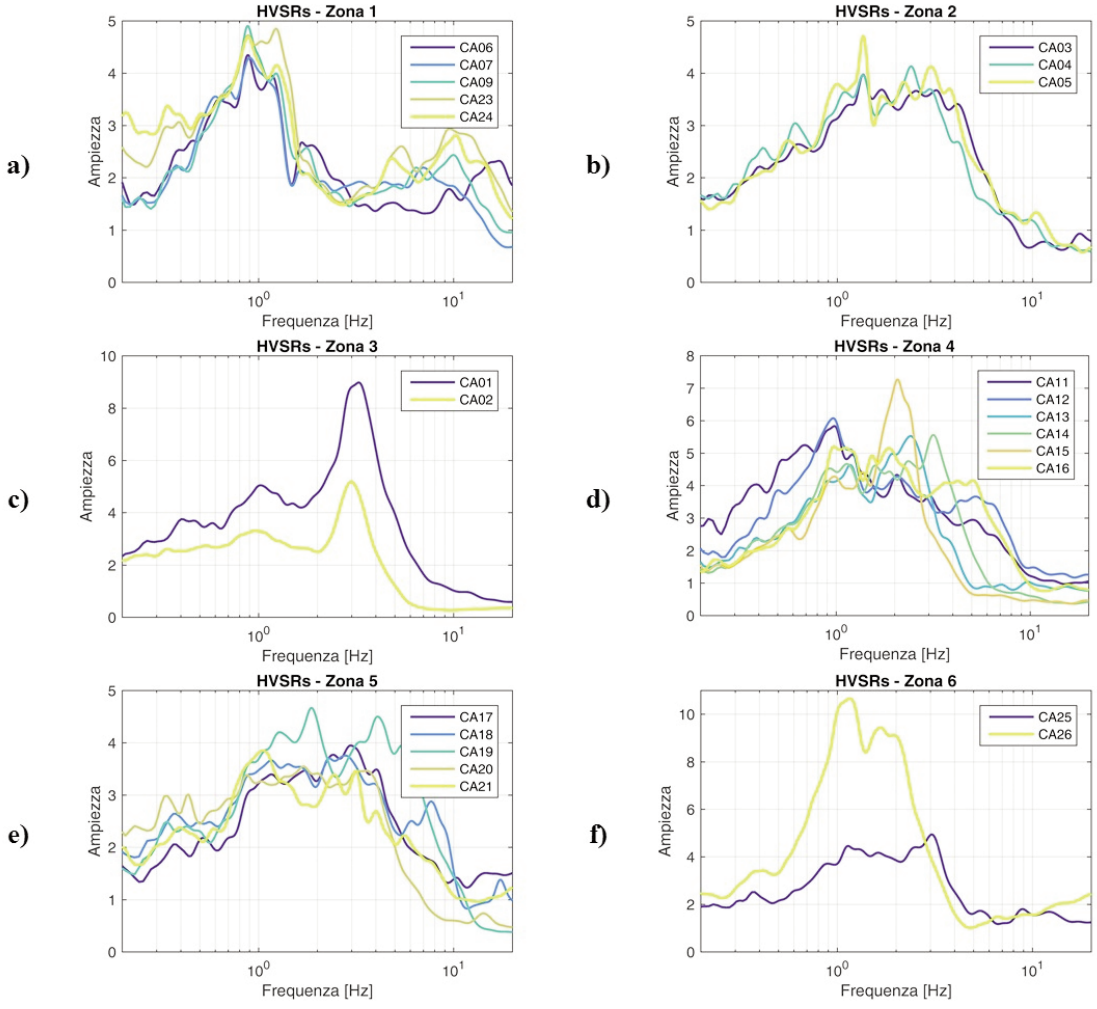


Figura 6 Curve HVSR per le 6 zone indagate.
Figure 6 HVSR curves for the 6 investigated zones.

Punti di misura	Longitudine [°]	Latitudine [°]	f_{01} [Hz]	f_{02} [Hz]	Codice zona	Posizione
CA01	13.06456	43.14543	1.04	3.16	3	Asfalto
CA02	13.06524	43.14522	0.95	2.94	3	Asfalto
CA03	13.07289	43.13771	broad-band		2	Asfalto
CA04	13.07123	43.13764	broad-band		2	Pavé
CA05	13.07326	43.13947	broad-band		2	Pavé
CA06	13.06814	43.13586	0.93		1	Pavé
CA07	13.06677	43.13453	0.94		1	Pavé
CA08	13.06591	43.13483	0.95		1	Pavé
CA09	13.06385	43.13215	0.9		1	Pavé
CA11	13.06627	43.13033	0.88		4	Asfalto
CA12	13.06656	43.13114	0.94	1.94	4	Asfalto
CA13	13.06707	43.12831	1.08	2.26	4	Asfalto
CA14	13.06799	43.12821	1.03	2.98	4	Asfalto
CA15	13.06583	43.12708	2.06		4	Asfalto
CA16	13.06759	43.12641	1.1	4.16	4	Asfalto
CA17	13.07274	43.14393	broad-band		5	Asfalto
CA18	13.07449	43.14418	broad-band		5	Asfalto
CA19	13.07184	43.14532	broad-band		5	Asfalto
CA20	13.07005	43.14367	broad-band		5	Asfalto
CA21	13.08127	43.14319	1.01		5	Asfalto
CA22	13.08474	43.14311	0.9		5	Terreno
CA23	13.06316	43.13138	1.04		1	Pavé
CA24	13.06336	43.13147	0.92		1	Pavé
CA25	13.01541	43.12417	1.28	2.81	6	Terreno
CA26	13.01795	43.12454	1.13		6	Asfalto

Tabella 2 Coordinate punti di acquisizione, frequenze del picco di amplificazione e posizione dei sensori in corrispondenza delle 6 zone considerate; f_{01}= frequenza di risonanza f_{02}= prima armonica.
Table 2 Coordinates of the acquisition points, frequencies of the amplification peaks and sensors installation for the 6 considered zones; f_{01}= resonance frequency f_{02}= first harmonic.

chiaro picco a circa 3 Hz con ampiezze variabili tra 4 e 8 (Figura 6c). La misura CA01 è molto disturbata anche se si può comunque considerare attendibile sulla base del confronto con la CA02.

In Zona 4, in corrispondenza del quartiere Le Vallicelle (CA11, CA12, CA13, CA14, CA15, CA16), si osserva nuovamente la presenza di una prima frequenza fondamentale di risonanza a circa 1 Hz, come riscontrato per la Zona 1, maggiormente evidente per la CA11 e la CA12. Si evidenzia una seconda frequenza di circa 2.5 Hz più evidente nelle curve CA13, CA14 e CA15 (Figura 6d).

In corrispondenza della zona di espansione urbana dei quartieri Montagnano e Le Mosse (Zona 5) sono state effettuate 6 misure (CA17, CA18, CA19, CA20, CA21 e CA22). Le curve HVSR mostrano un andamento simile a quello riscontrato in Zona 2, essendo caratterizzate da un'amplificazione di tipo *broad-band* tra 1 e 4 Hz (figura 6e). La misura CA22 è disturbata e non è da considerarsi rappresentativa della zona in esame.

In Zona 6 (figura 6f), le misure effettuate alla frazione S. Erasmo (CA25 e CA26) indicano un'amplificazione tra 1 e 3 Hz, con una massima ampiezza di circa 10 per il sito CA26.

In generale si osserva, un'amplificazione di tipo broad-band (1 – 4 Hz) per le zone 2, 4 e 5, in corrispondenza del membro pelitico-arenaceo della formazione di Camerino (Figura 3). La Zona 1, circoscritta dalla cerchia muraria, evidenzia una frequenza dominante di 1 Hz, in corrispondenza del membro arenaceo della formazione di Camerino. Per le rimanenti zone la risposta dei siti è variabile, in dipendenza dalla natura e dallo spessore dei terreni di copertura.

Per un maggiore dettaglio dei risultati ottenuti dall'analisi spettrale si rimanda all'Allegato.

Ringraziamenti

Si ringrazia il Sig. Gianluca Pasqui, Sindaco del Comune di Camerino, per la disponibilità e l'interesse dimostrato.

Si ringraziano l'Unità di Crisi Locale ed in particolar modo il Corpo Nazionale dei Vigili del Fuoco e gli Alpini che hanno garantito sulle condizioni di sicurezza all'interno delle zone rosse.

Si ringrazia il geologo Marcello Maccari per avere cortesemente fornito indicazioni sulla geologia di base dell'area di Camerino.

Infine, ringraziamo Rodolfo Puglia per il suo prezioso aiuto nell'analisi dei risultati e il gruppo strumentale della sezione INGV di Milano per il supporto tecnico.

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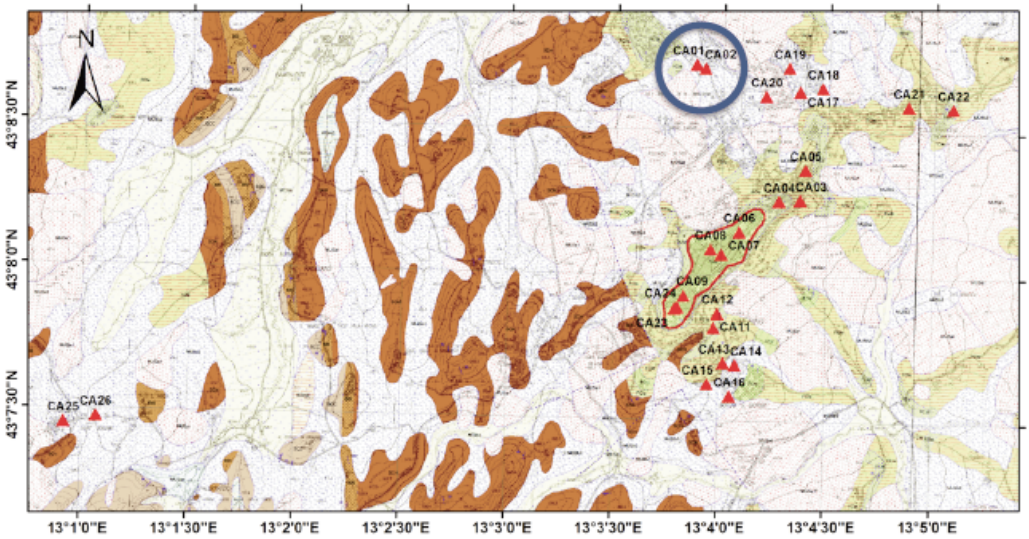
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Anno **2017**_Numero **145**

Allegato



Comune: CAMERINO
Località: S. Paolo (Scuola elementare temporanea)

Stazione: CA01
Longitudine: 13.0645616°
Latitudine: 43.14543°
Quota [m]: 501

Stazione: CA02
Longitudine: 13.0652483°
Latitudine: 43.14522°
Quota [m]: 512

Station: CA01

Recording duration: 65:12 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 63 windows (52:30 [min:sec])

Window length (l_w) = 50 [s]

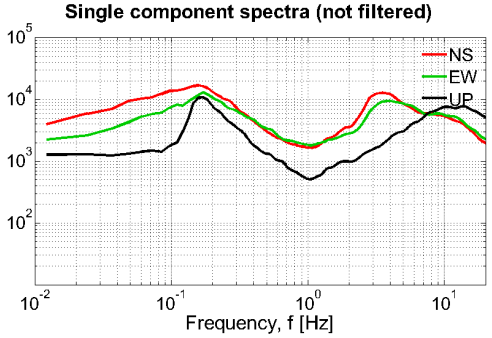
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

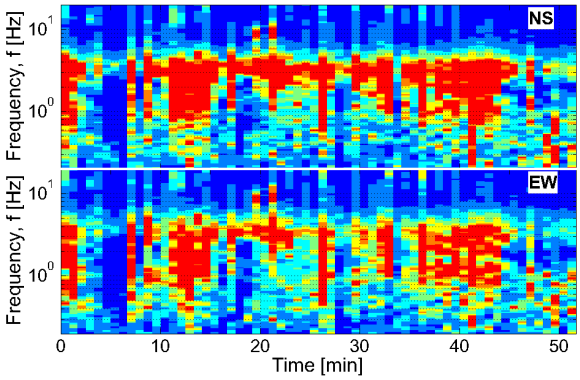
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

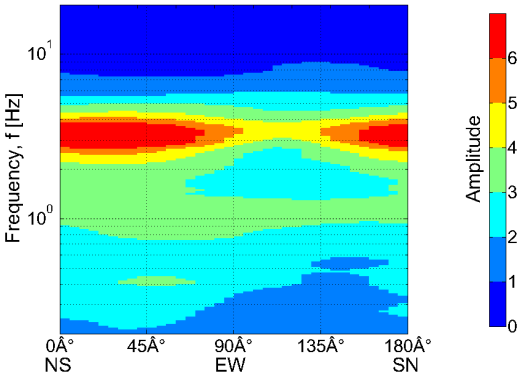
Single component spectra (not filtered)



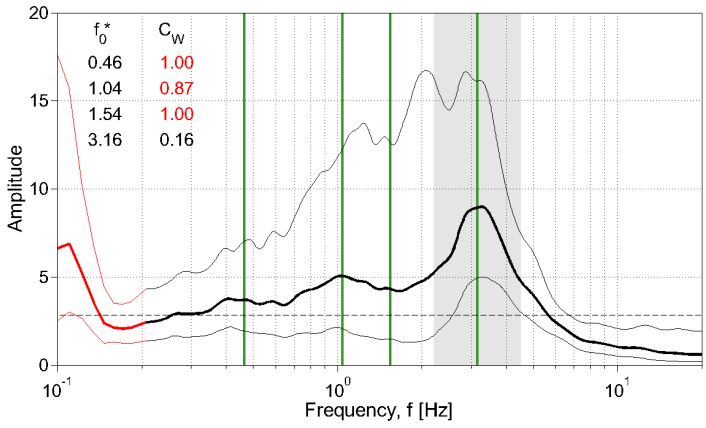
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists\, f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists\, f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 0.46 - Fulfilled crit.: 3/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists\, f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists\, f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> No

f^*_{02} = 1.04 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA02

Recording duration: 76:20 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 85 windows (70:50 [min:sec])

Window length (l_w) = 50 [s]

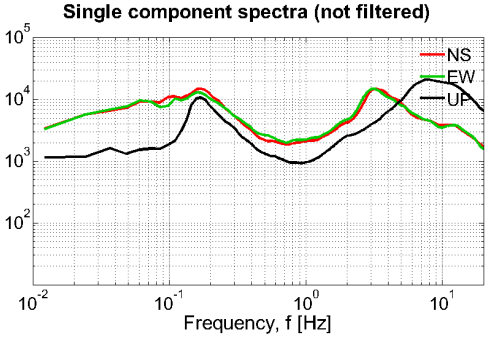
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

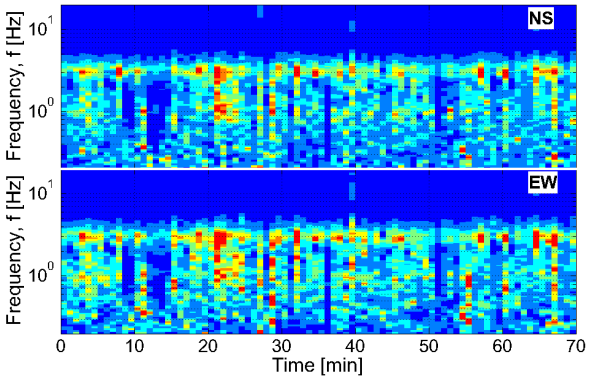
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Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

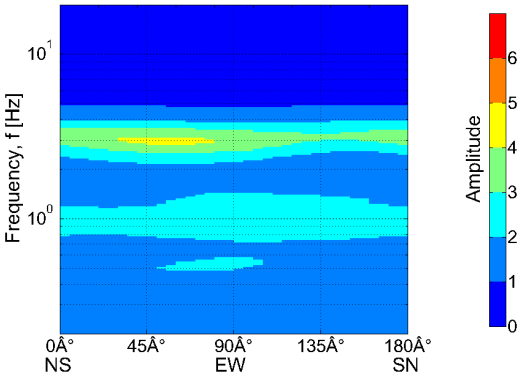
Single component spectra (not filtered)



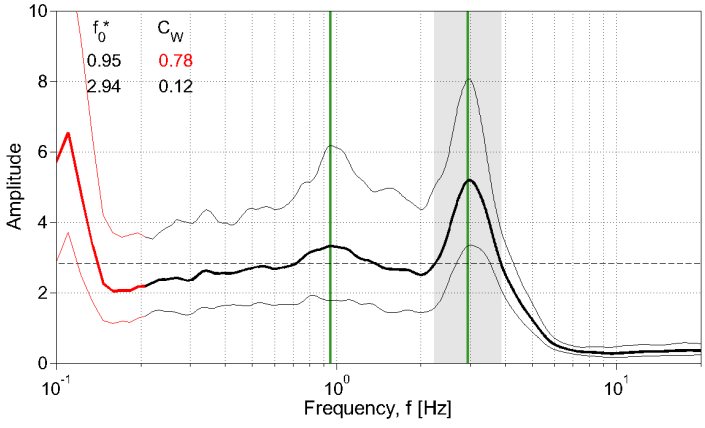
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

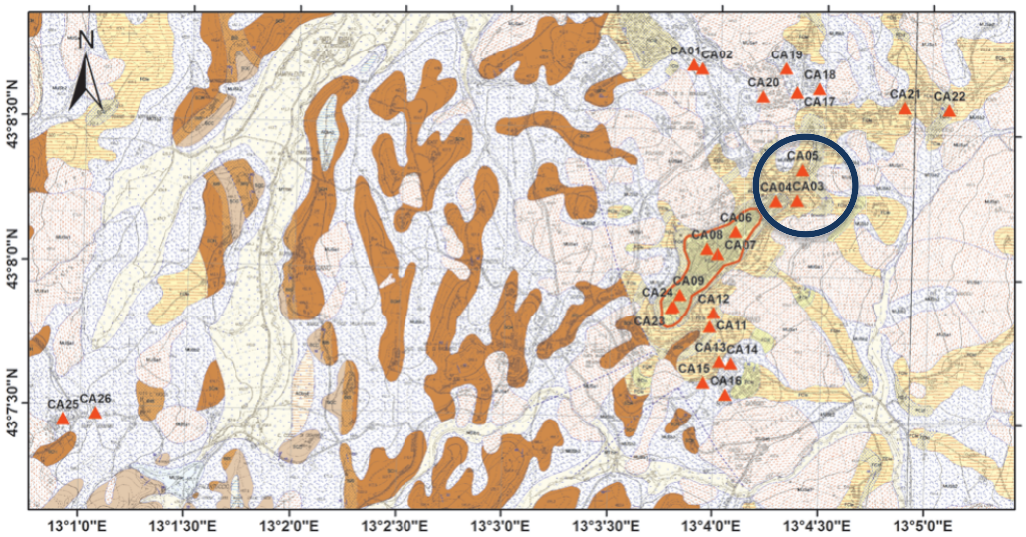
Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 0.95 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 2.94 - Fulfilled crit.: 5/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean



Comune: CAMERINO
Località: Basilica S. Venanzio
Stazione: CA03
Longitudine: 13.0728916°
Latitudine: 43.13771833°
Quota [m]: 624





Comune: CAMERINO
Località: S. Domenico
Stazione: CA04
Longitudine: 13.07123°
Latitudine: 43.1376483°
Quota [m]: 638



Comune: CAMERINO
Località: S. Chiara (Scuola in Costruzione)
Stazione: CA05
Longitudine: 13.07123°
Latitudine: 43.1376483°
Quota [m]: 638

Station: CA03

Recording duration: 64:29 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 58 windows (48:20 [min:sec])

Window length (l_w) = 50 [s]

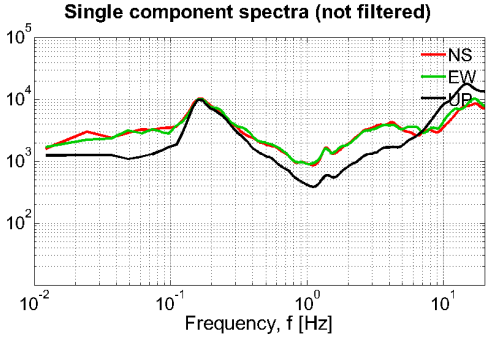
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

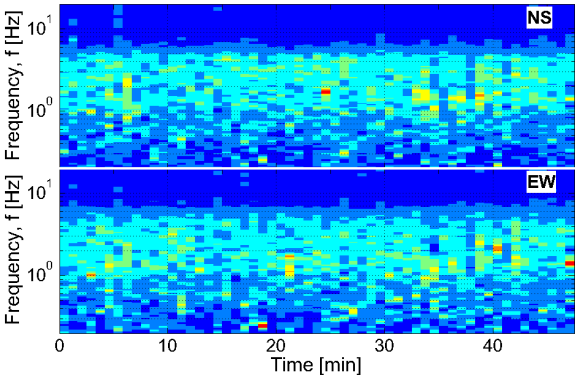
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

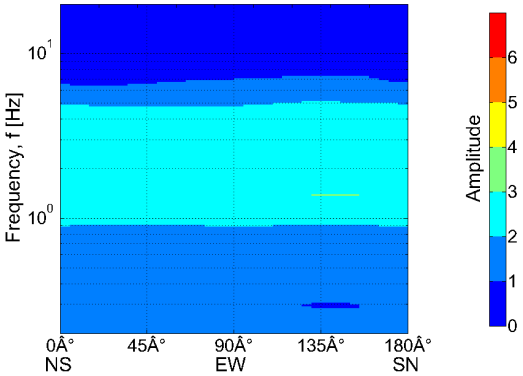
Single component spectra (not filtered)



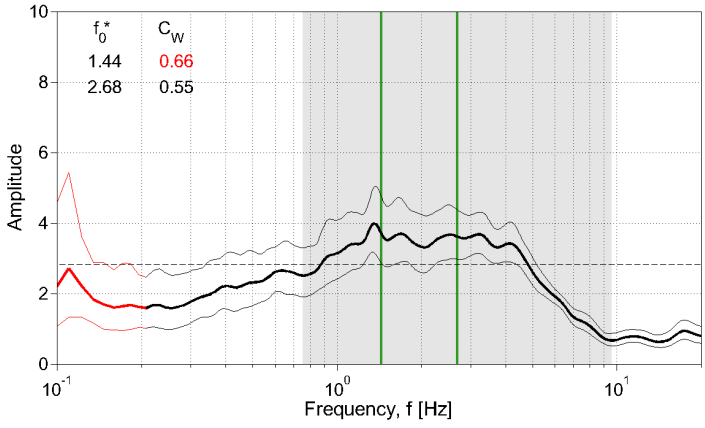
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.44 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 2.68 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA04

Recording duration: 56:26 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 38 windows (31:40 [min:sec])

Window length (l_w) = 50 [s]

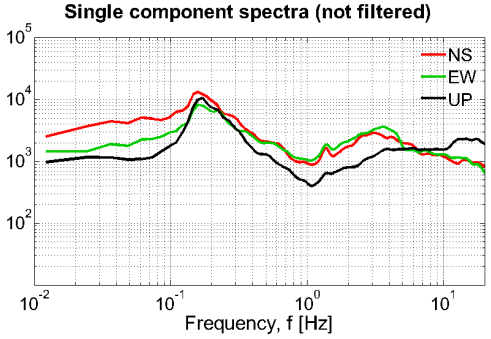
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

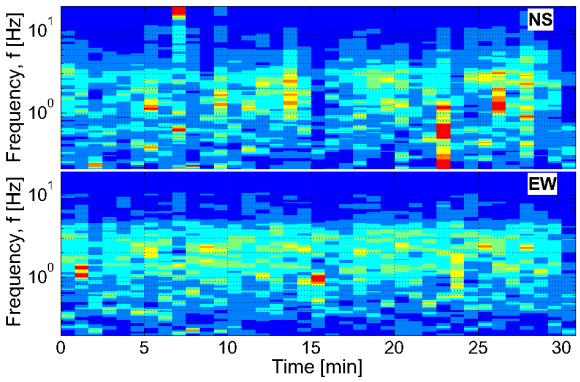
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

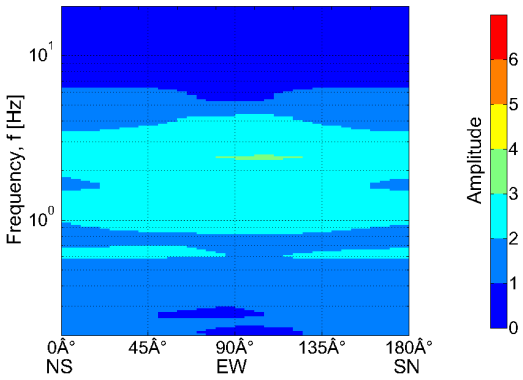
Single component spectra (not filtered)



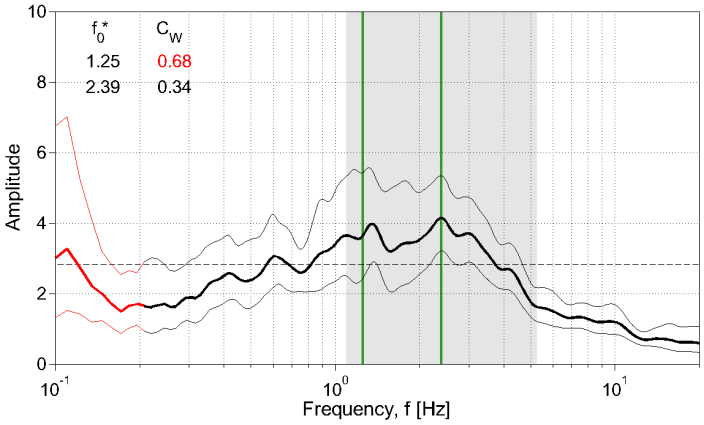
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.25 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 2.39 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA05

Recording duration: 42:43 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 45 windows (37:30 [min:sec])

Window length (l_w) = 50 [s]

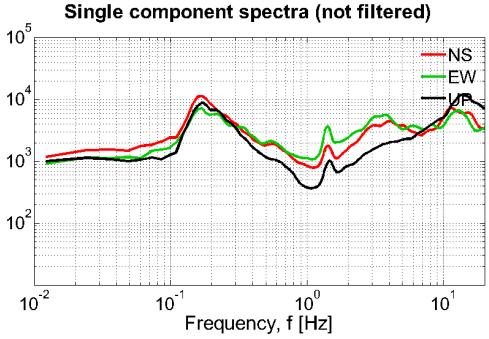
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

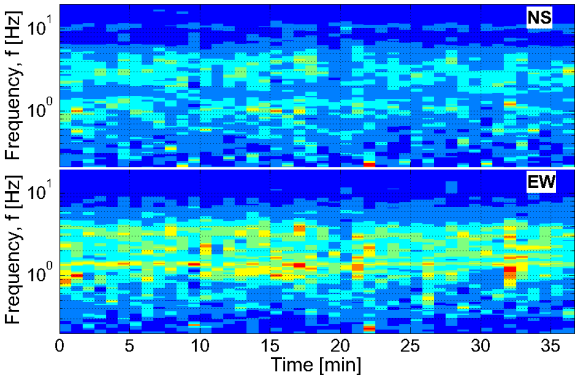
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

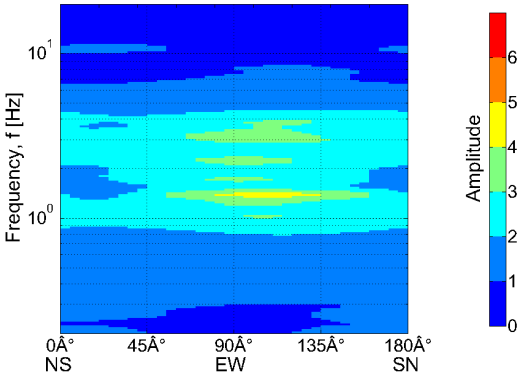
Single component spectra (not filtered)



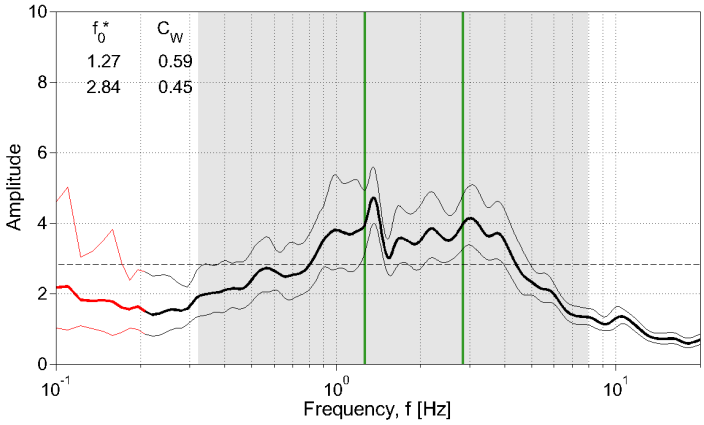
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

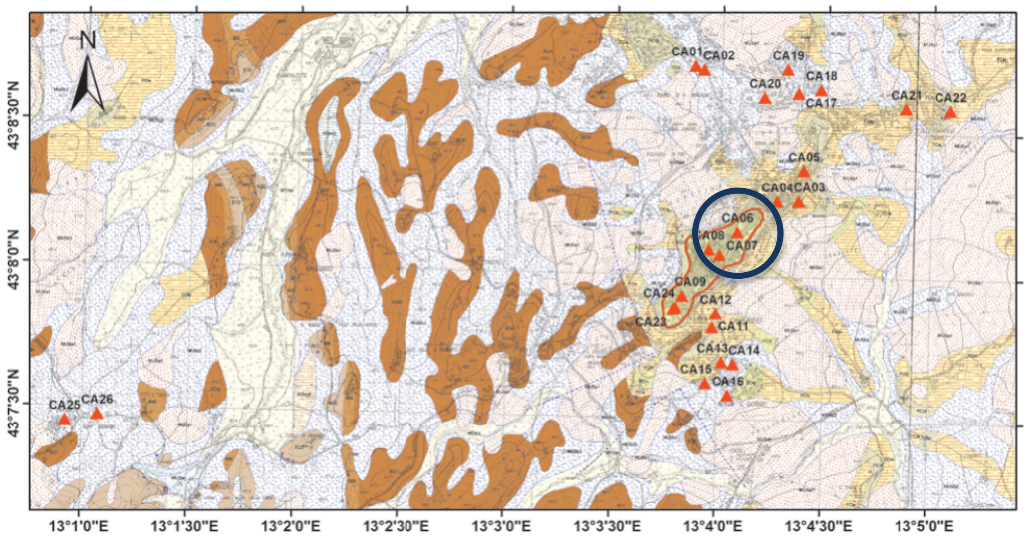
Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists\, f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists\, f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.27 - Fulfilled crit.: 3/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists\, f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists\, f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 2.84 - Fulfilled crit.: 4/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean



Comune: CAMERINO
Località: P.zza Duomo
Stazione: CA06
Longitudine: 13.0681416°
Latitudine: 43.13586°
Quota [m]: 693





Comune: CAMERINO
Località: P.zza Garibaldi
Stazione: CA07
Longitudine: 13.0667783°
Latitudine: 43.1345483°
Quota [m]: 679





Comune: CAMERINO
Località: P.zza Mazzini (Ex Tribunale)
Stazione: CA08
Longitudine: 13.0659083°
Latitudine: 43.134833°
Quota [m]: 676





Station: CA06

Recording duration: 44:45 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 34 windows (28:20 [min:sec])

Window length (l_w) = 50 [s]

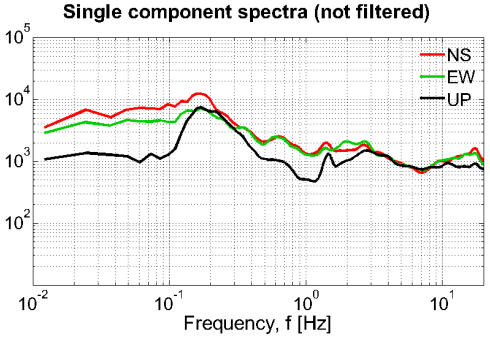
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

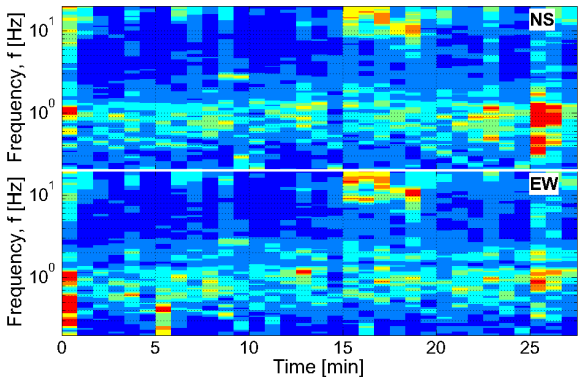
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

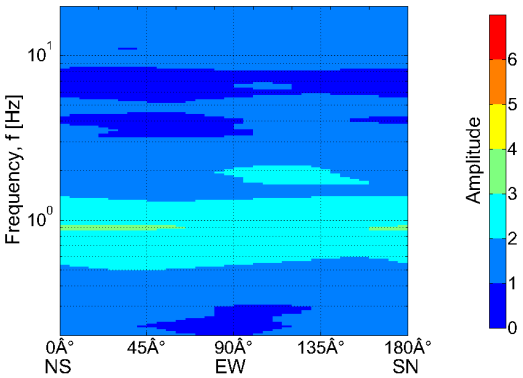
Single component spectra (not filtered)



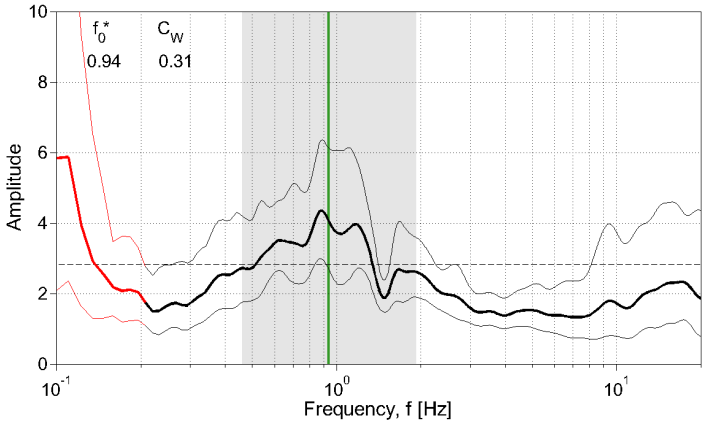
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak *(at least 5 out of 6 criteria fulfilled)*	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

$f_0^* = 0.94$ - Fulfilled crit.: 5/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA07

Recording duration: 47:30 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 27 windows (22:30 [min:sec])

Window length (l_w) = 50 [s]

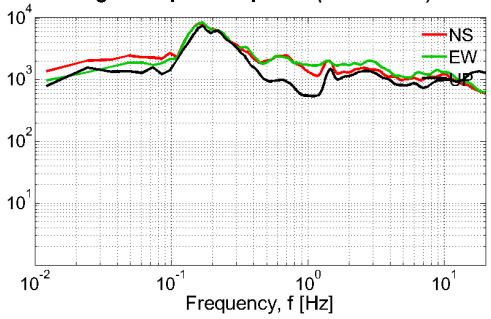
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

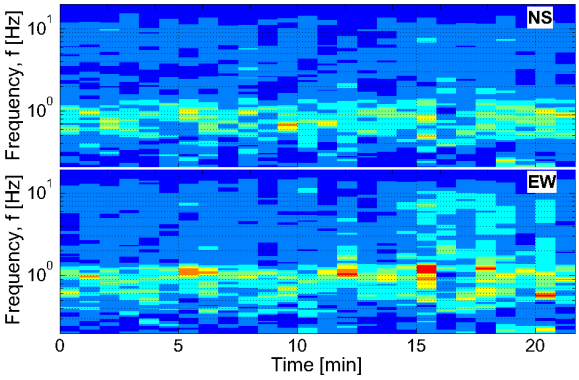
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

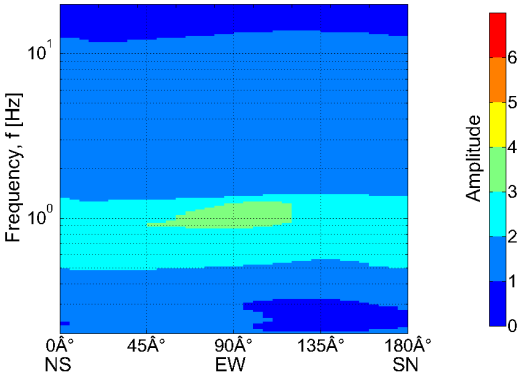
Single component spectra (not filtered)



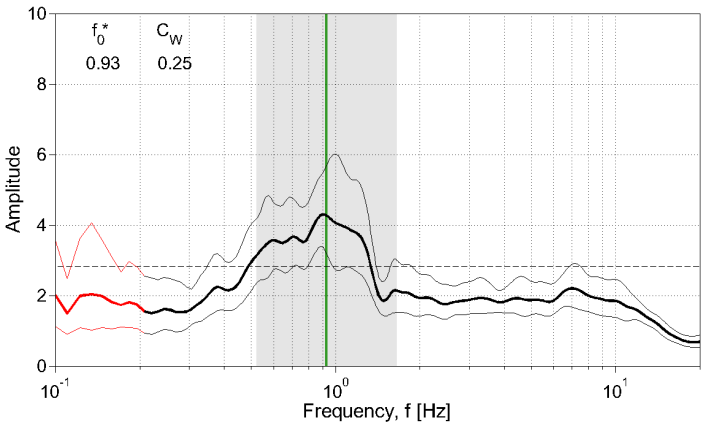
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_0^* = 0.93 - Fulfilled crit.: 4/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA08

Recording duration: 42:55 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 39 windows (32:30 [min:sec])

Window length (l_w) = 50 [s]

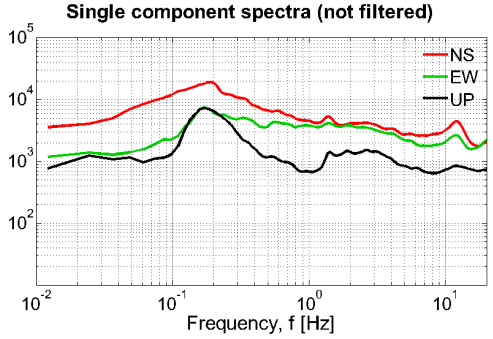
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

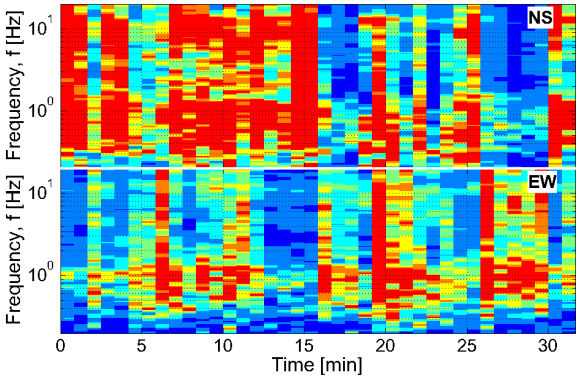
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

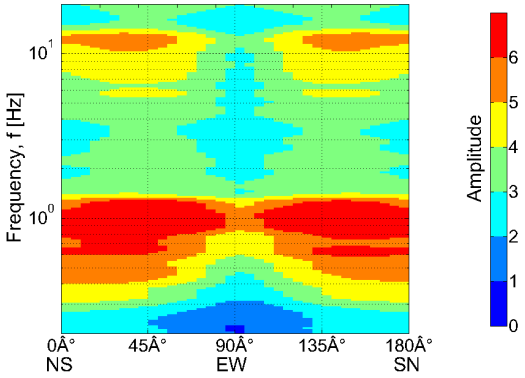
Single component spectra (not filtered)



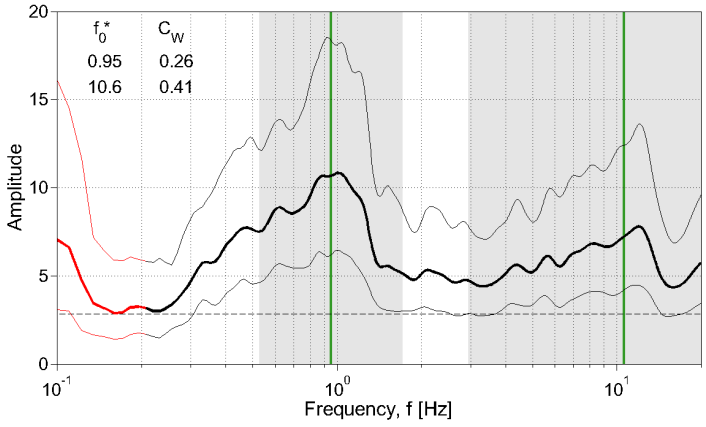
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

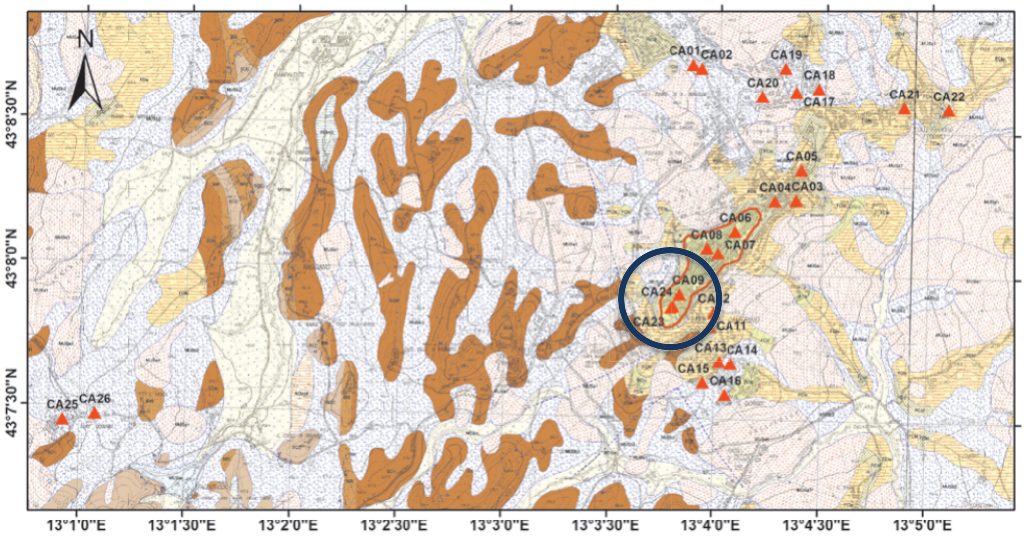
Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 0.95 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 10.60 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean



Comune: CAMERINO
Località: P.zza Umberto I°
Stazione: CA09
Longitudine: 13.063846°
Latitudine: 43.132153°
Quota [m]: 642





Comune: CAMERINO
Località: P.zza Vittoria
Stazione: CA23
Longitudine: 13.063163°
Latitudine: 43.131386°
Quota [m]: 648





Comune: CAMERINO
Località: P.zza Vittoria
Stazione: CA24
Longitudine: 13.0633616°
Latitudine: 43.1314716°
Quota [m]: 645





Station: CA09

Recording duration: 45:44 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 44 windows (36:40 [min:sec])

Window length (l_w) = 50 [s]

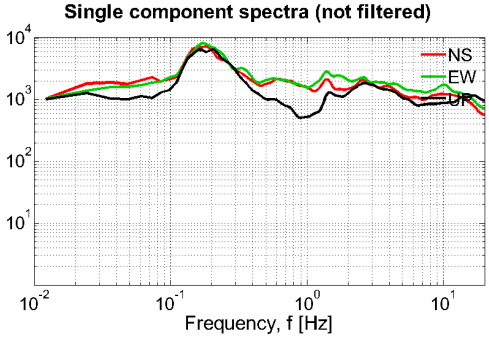
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

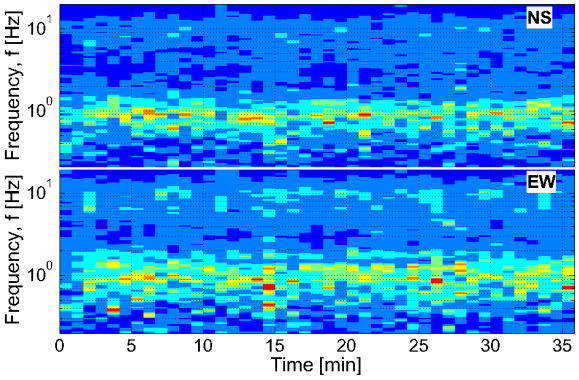
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

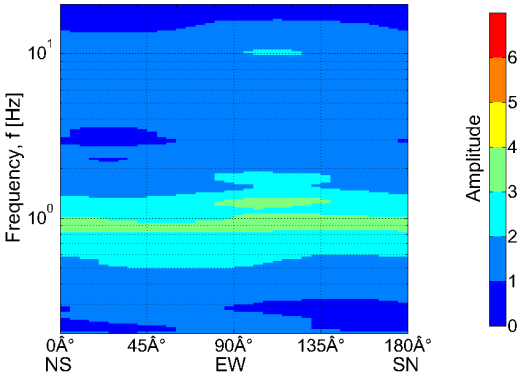
Single component spectra (not filtered)



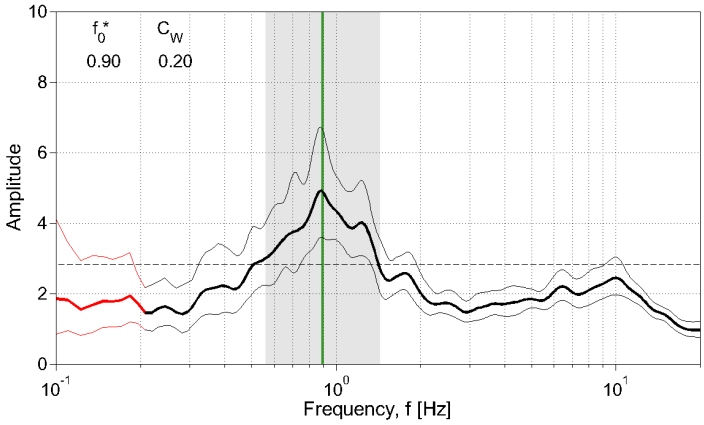
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> Yes
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_0^* = 0.90 - Fulfilled crit.: 6/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA23

Recording duration: 145:37 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 64 windows (106:40 [min:sec])

Window length (l_w) = 100 [s]

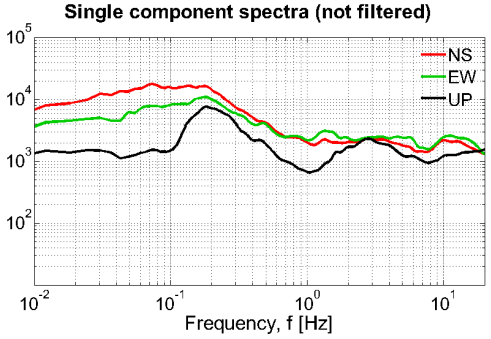
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

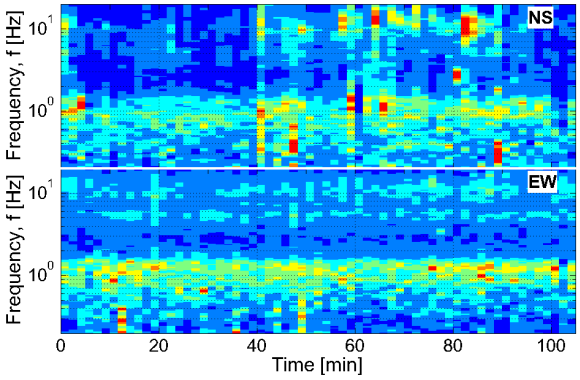
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

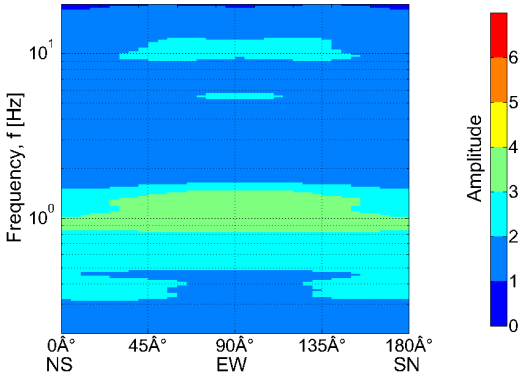
Single component spectra (not filtered)



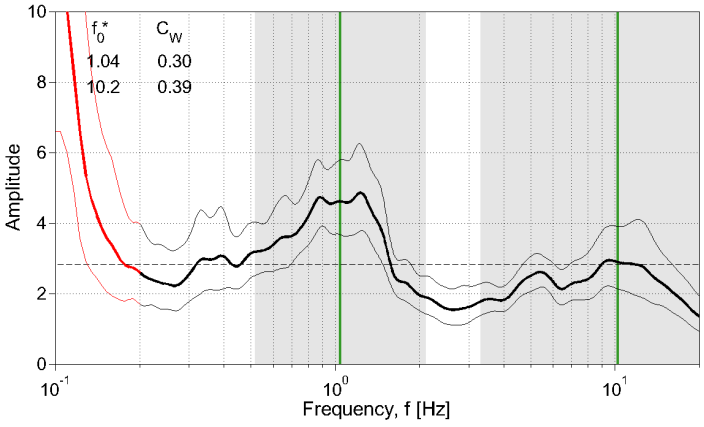
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.04 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> No
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 10.24 - Fulfilled crit.: 2/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA24

Recording duration: 134:44 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 54 windows (90:00 [min:sec])

Window length (l_w) = 100 [s]

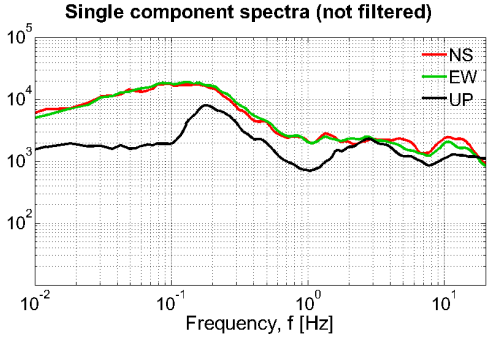
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

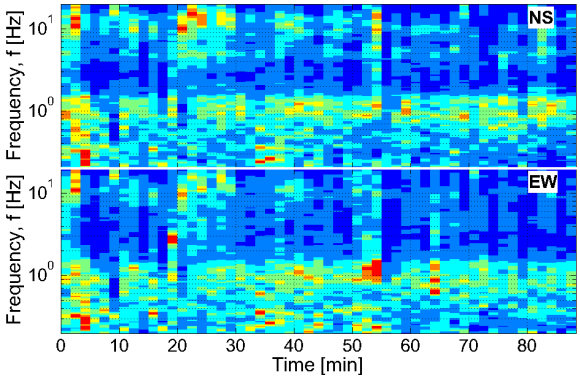
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

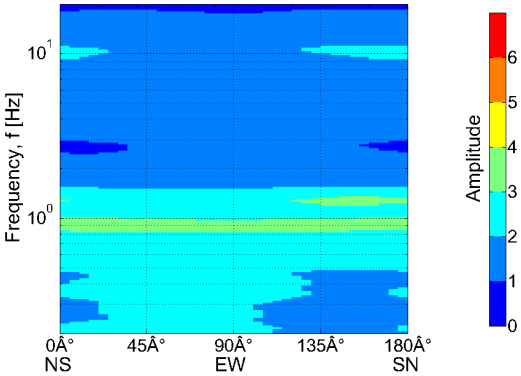
Single component spectra (not filtered)



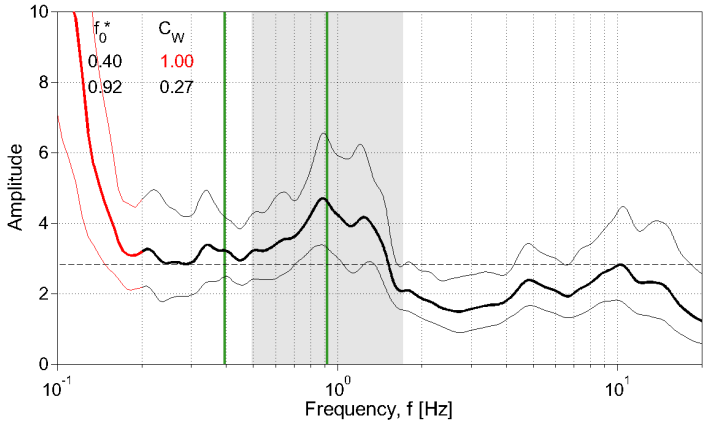
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

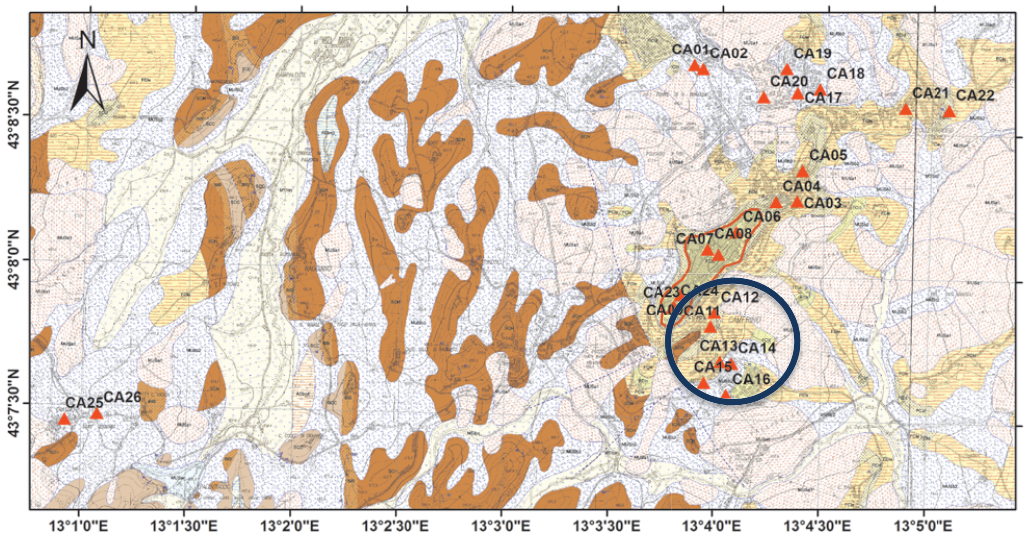
Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 0.40 - Fulfilled crit.: 2/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 0.92 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean



Comune: CAMERINO
Località: Vallicelle
Stazione: CA11
Longitudine: 13.06627°
Latitudine: 43.13033°
Quota [m]: 590





Comune: CAMERINO
Località: Vallicelle (Via Orazi)
Stazione: CA12
Longitudine: 13.0665583°
Latitudine: 43.131143°
Quota [m]: 590





Comune: CAMERINO
Località: Vallicelle (Via Conti di S. Maroto)
Stazione: CA13
Longitudine: 13.0670716°
Latitudine: 43.12831°
Quota [m]: 559



Comune: CAMERINO
Località: Vallicelle (Area Accoglienza "Vallicelle A")
Stazione: CA14
Longitudine: 13.067986°
Latitudine: 43.128216°
Quota [**m**]: 550

Comune: CAMERINO
Località: Vallicelle (Via Varano)
Stazione: CA15
Longitudine: 13.06583°
Latitudine: 43.127086°
Quota [**m**]: 550

Comune: CAMERINO
Località: Vallicelle (Area Accoglienza "Vallicelle B")
Stazione: CA16
Longitudine: 13.067596°
Latitudine: 43.126413°
Quota [**m**]: 532

Station: CA11

Recording duration: 38:49 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 37 windows (30:50 [min:sec])

Window length (l_w) = 50 [s]

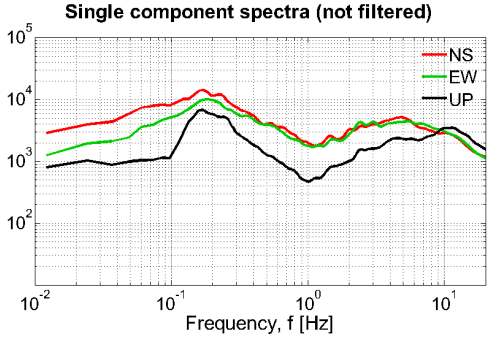
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

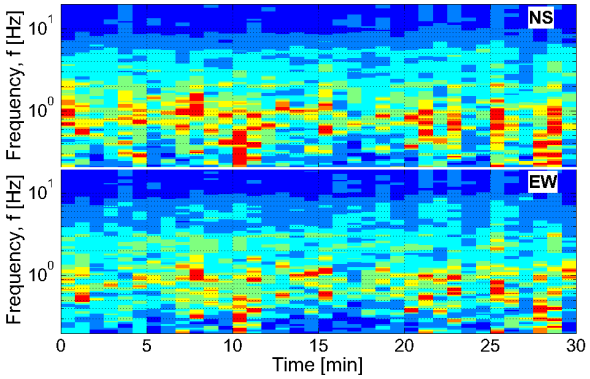
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

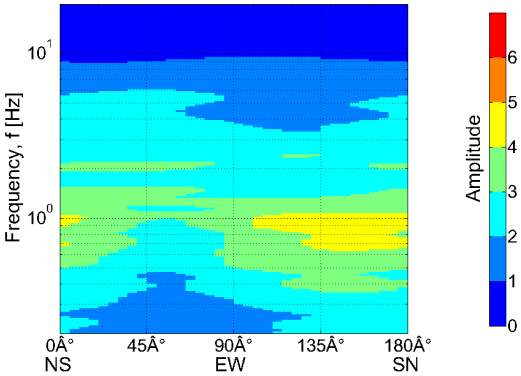
Single component spectra (not filtered)



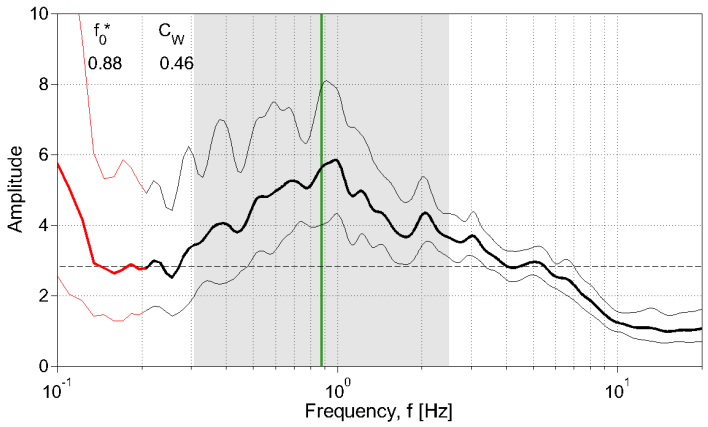
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak *(at least 5 out of 6 criteria fulfilled)*	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_0^* = 0.88 - Fulfilled crit.: 4/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA12

Recording duration: 42:38 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 35 windows (29:010 [min:sec])

Window length (l_w) = 50 [s]

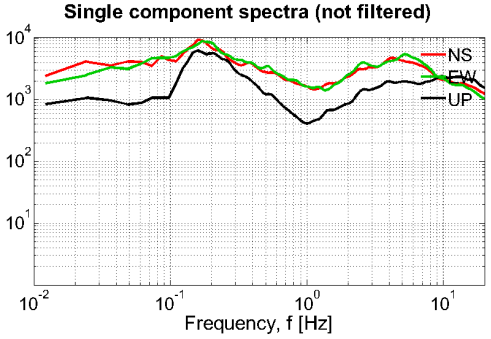
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

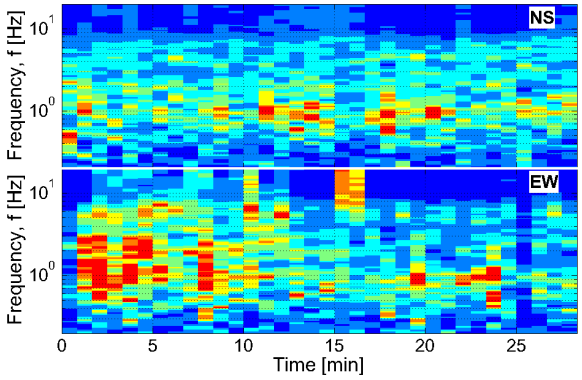
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

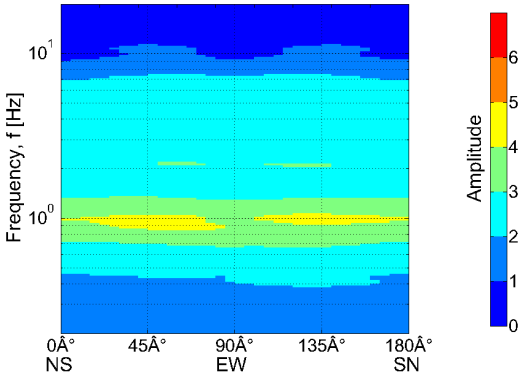
Single component spectra (not filtered)



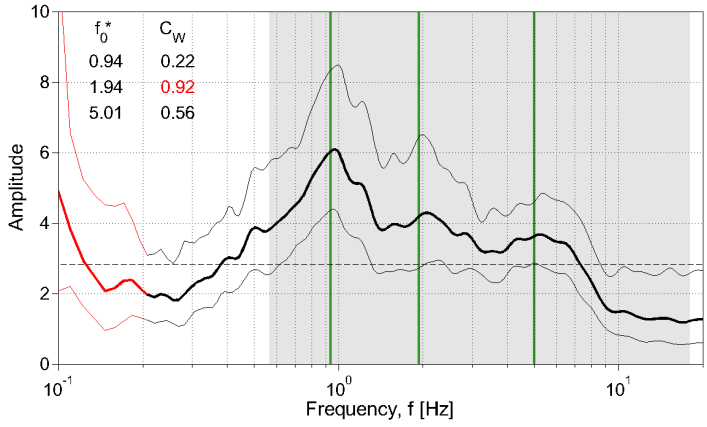
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 0.94 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 1.94 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA13

Recording duration: 42:17 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 31 windows (25:50 [min:sec])

Window length (l_w) = 50 [s]

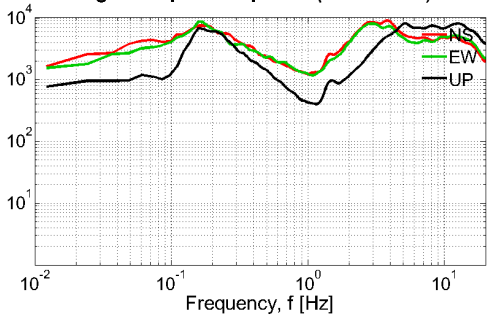
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

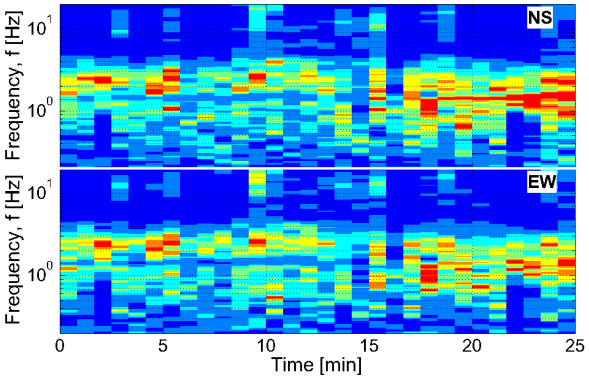
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

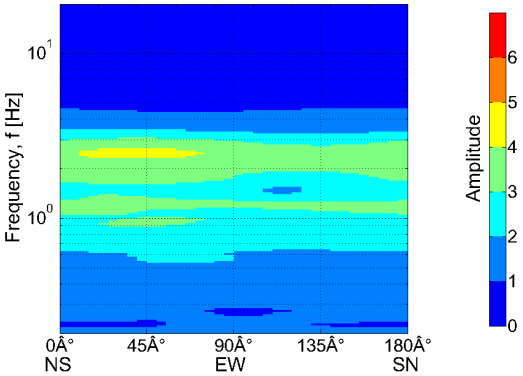
Single component spectra (not filtered)



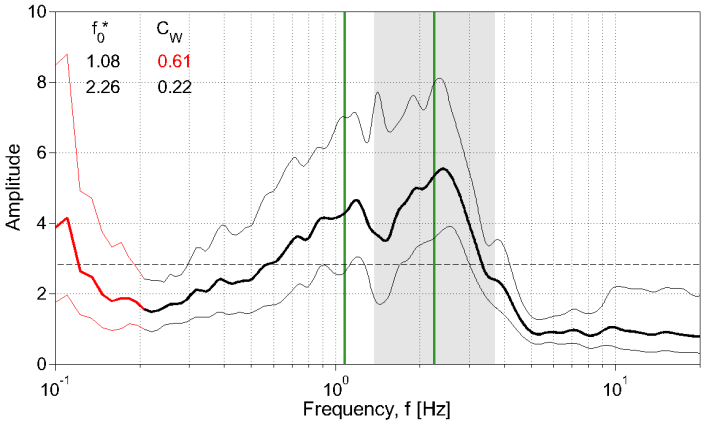
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.08 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 2.26 - Fulfilled crit.: 5/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA14

Recording duration: 48:33 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 48 windows (40:00 [min:sec])

Window length (l_w) = 50 [s]

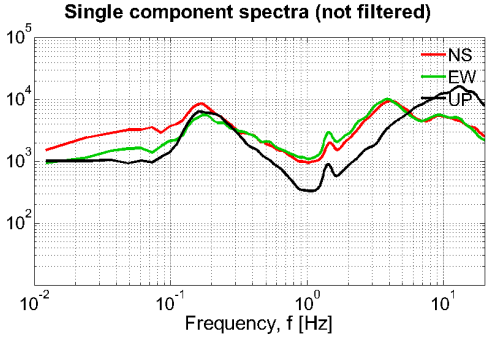
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

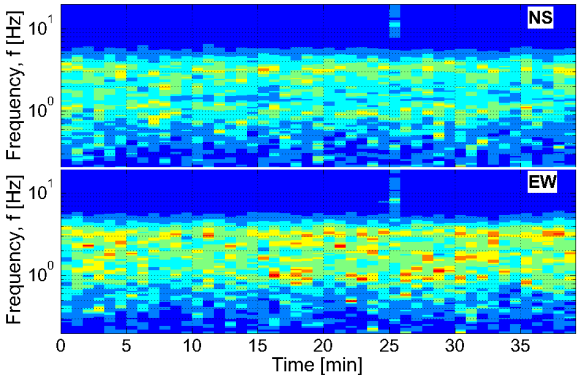
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

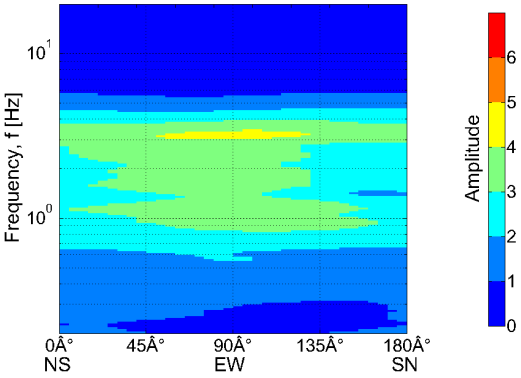
Single component spectra (not filtered)



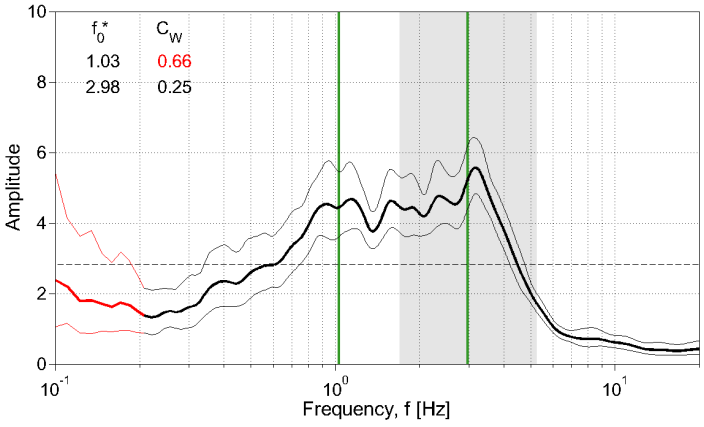
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_{01}^* = 1.03 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_{02}^* = 2.98 - Fulfilled crit.: 4/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA15

Recording duration: 55:12 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 50 windows (41:40 [min:sec])

Window length (l_w) = 50 [s]

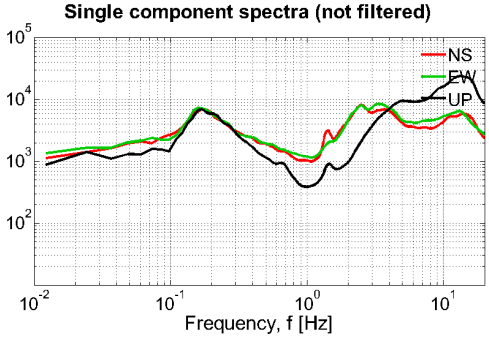
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

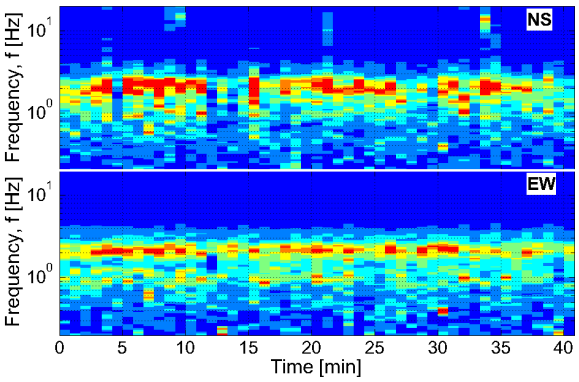
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

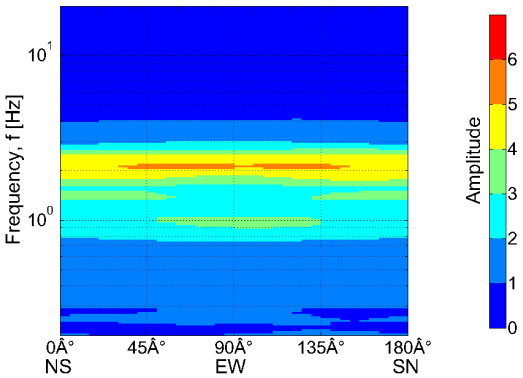
Single component spectra (not filtered)



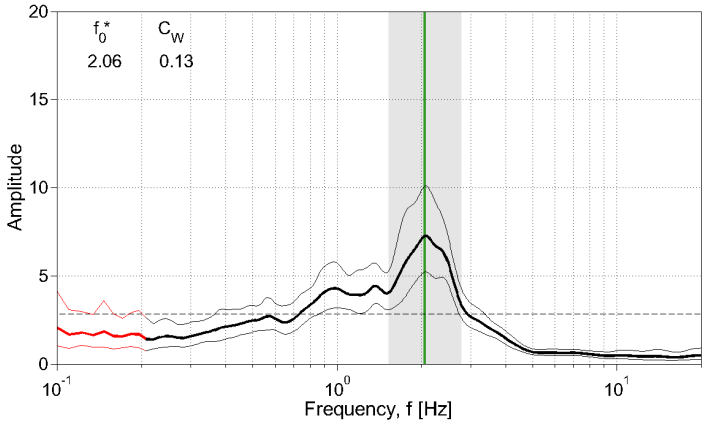
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_0^* = 2.06 - Fulfilled crit.: 5/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA16

Recording duration: 48:27 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 35 windows (29:010 [min:sec])

Window length (l_w) = 50 [s]

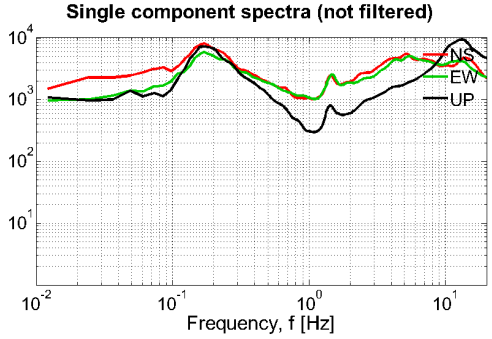
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

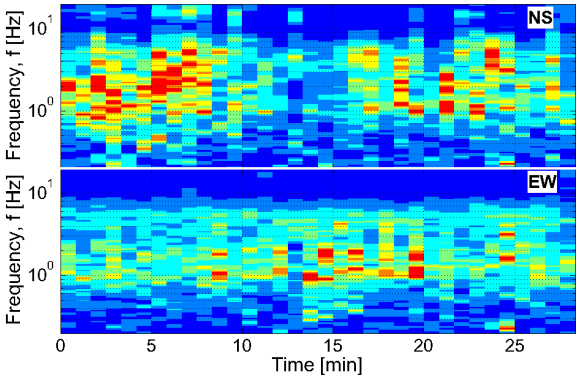
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

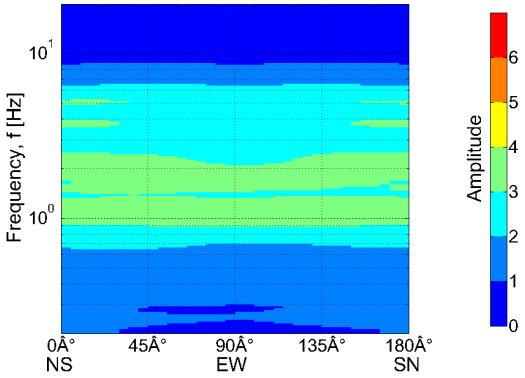
Single component spectra (not filtered)



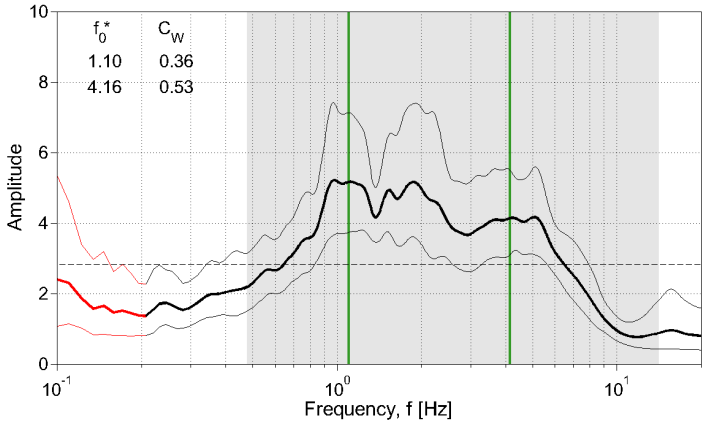
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

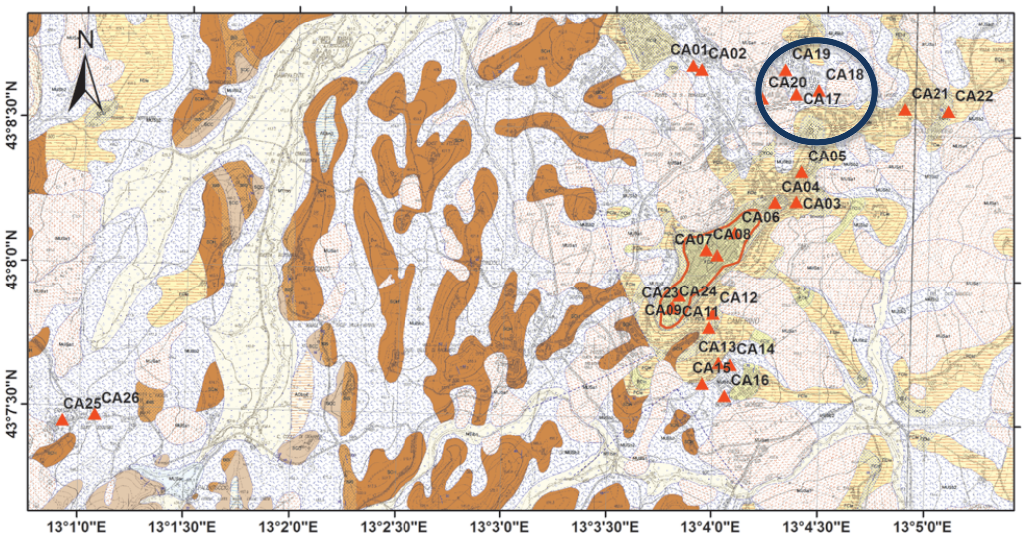
Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_{01}^* = 1.10 - Fulfilled crit.: 3/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_{02}^* = 4.16 - Fulfilled crit.: 4/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean



Comune: CAMERINO
Località: Montagnano (Via Pallotta)
Stazione: CA17
Longitudine: 13.0727416°
Latitudine: 43.1439383°
Quota [m]: 532

Comune: CAMERINO
Località: Montagnano (Via Allevi)
Stazione: CA19
Longitudine: 13.071845°
Latitudine: 43.14532°
Quota [m]: 508

Comune: CAMERINO
Località: Montagnano (Via F. Savini)
Stazione: CA18
Longitudine: 13.0744983°
Latitudine: 43.1441833°
Quota [m]: 539

Comune: CAMERINO
Località: Montagnano
Stazione: CA20
Longitudine: 13.070055°
Latitudine: 43.14367°
Quota [m]: 530

Station: CA17

Recording duration: 42:56 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 46 windows (38:20 [min:sec])

Window length (l_w) = 50 [s]

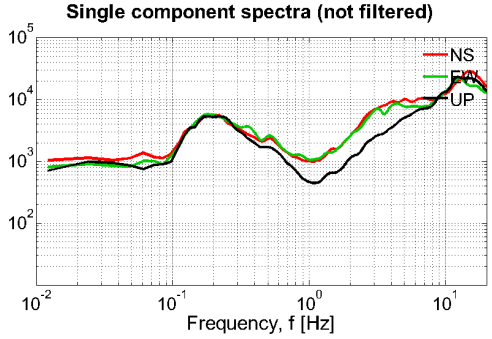
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

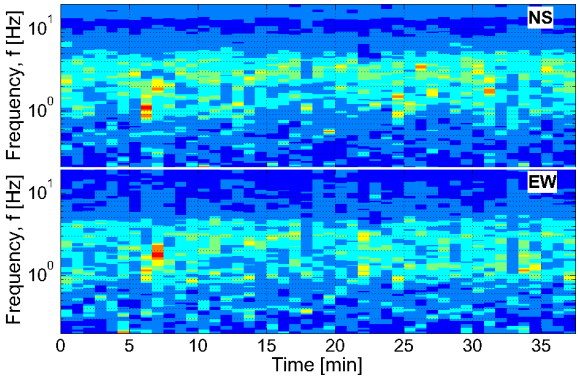
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

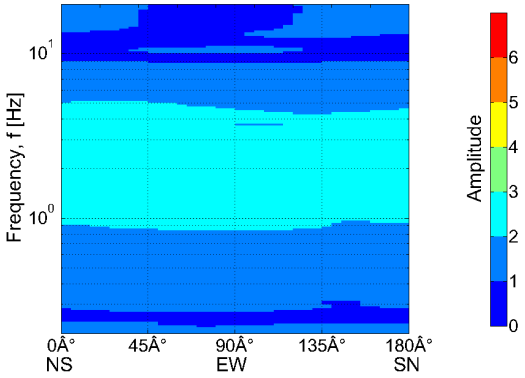
Single component spectra (not filtered)



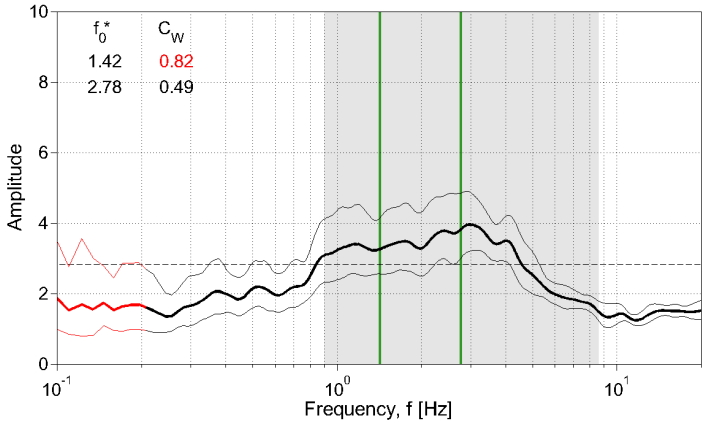
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.42 - Fulfilled crit.: 3/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 2.78 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA18

Recording duration: 54:47 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 43 windows (35:50 [min:sec])

Window length (l_w) = 50 [s]

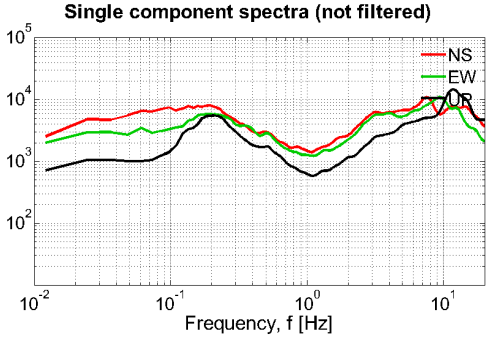
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

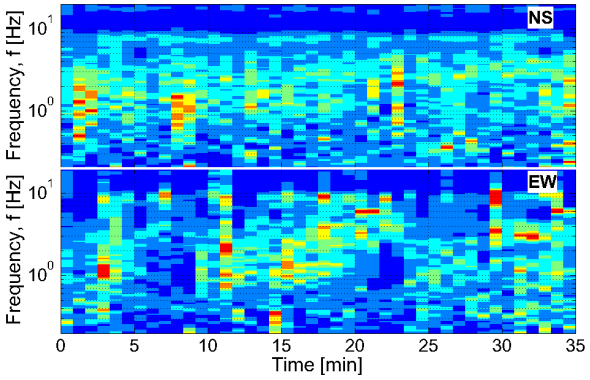
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

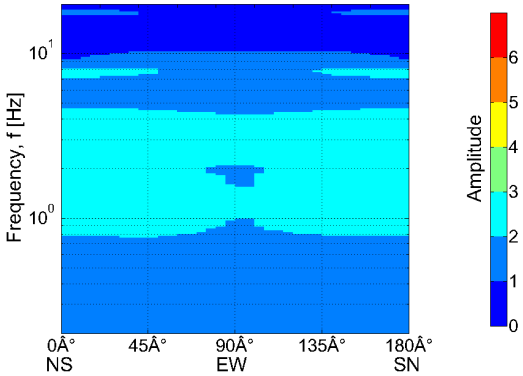
Single component spectra (not filtered)



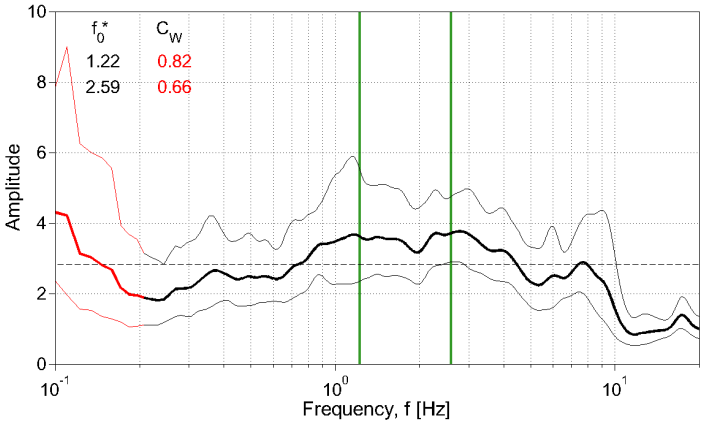
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.22 - Fulfilled crit.: 2/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 2.59 - Fulfilled crit.: 4/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA19

Recording duration: 52:02 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 42 windows (35:00 [min:sec])

Window length (l_w) = 50 [s]

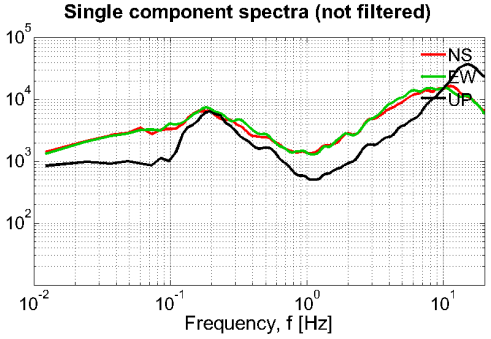
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

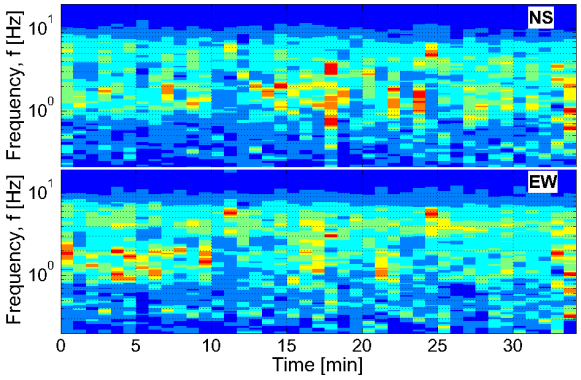
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

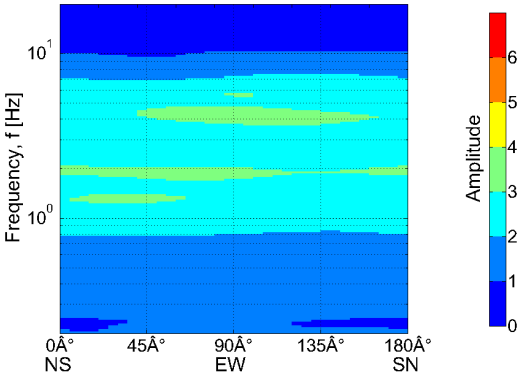
Single component spectra (not filtered)



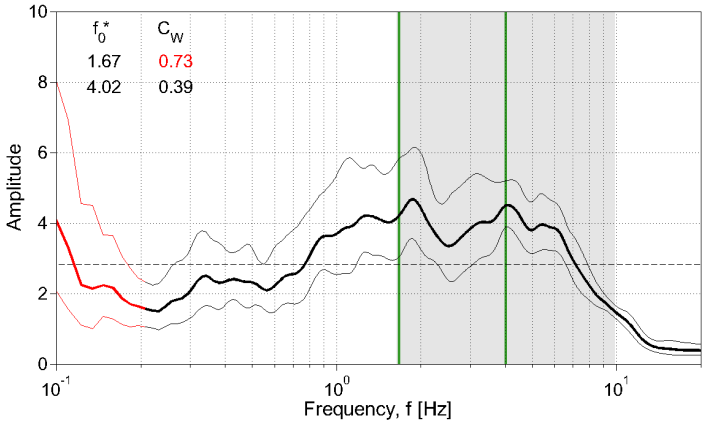
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.67 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 4.02 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA20

Recording duration: 46:31 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 39 windows (32:30 [min:sec])

Window length (l_w) = 50 [s]

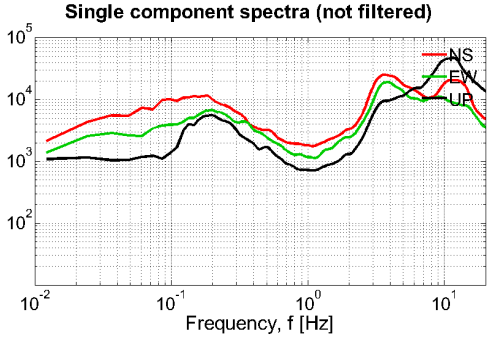
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

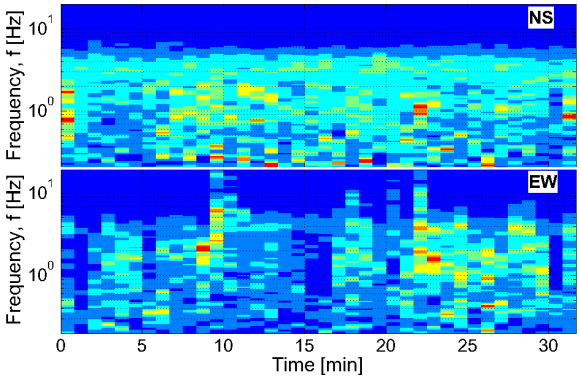
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

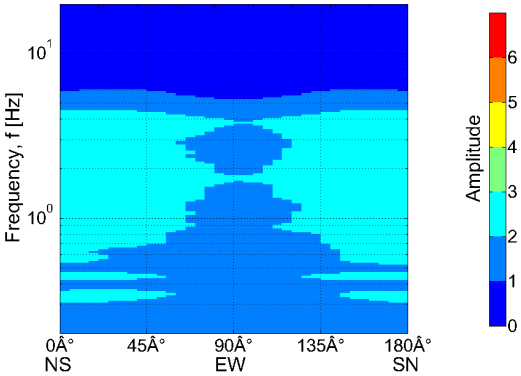
Single component spectra (not filtered)



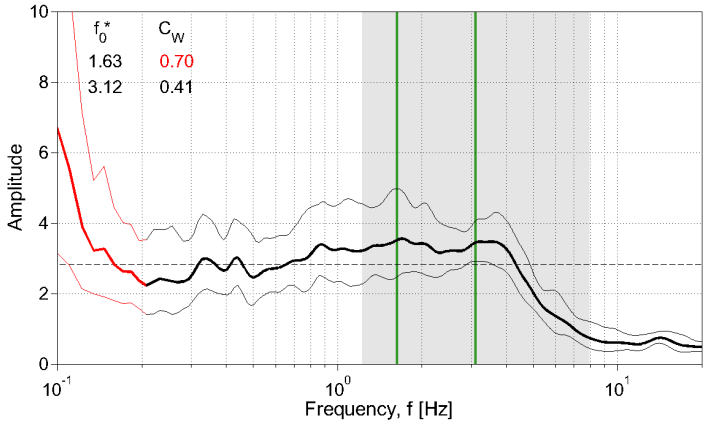
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

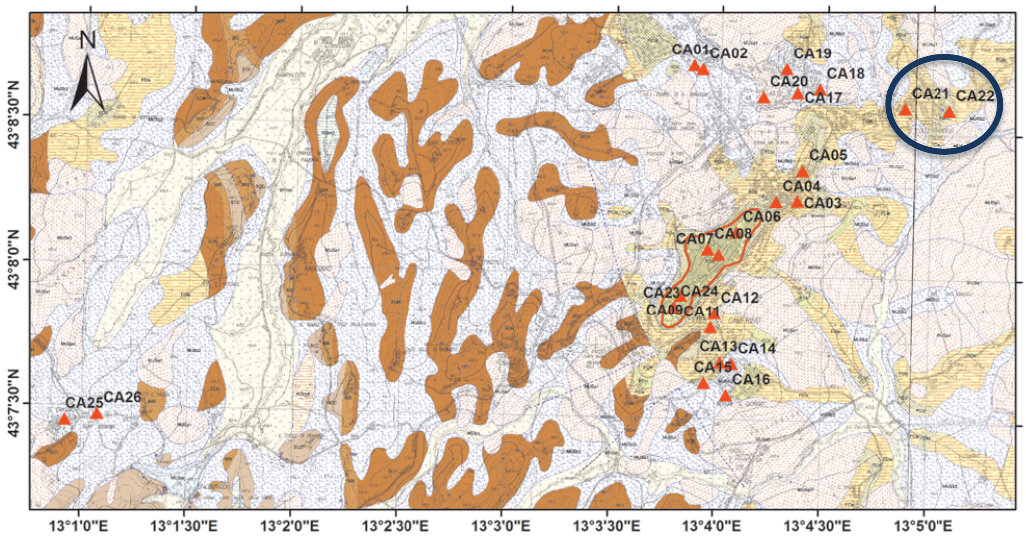
Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.63 - Fulfilled crit.: 3/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 3.12 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean



Comune: CAMERINO
Località: Le Mosse (Case Popolari)
Stazione: CA21
Longitudine: 13.081273°
Latitudine: 43.143185°
Quota [m]: 596





Comune: CAMERINO
Località: Colle Paradiso (Residenza UNI-Mattei)
Stazione: CA22
Longitudine: 13.0847483°
Latitudine: 43.143106°
Quota [m]: 606





Station: CA21

Recording duration: 63:52 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 57 windows (47:30 [min:sec])

Window length (l_w) = 50 [s]

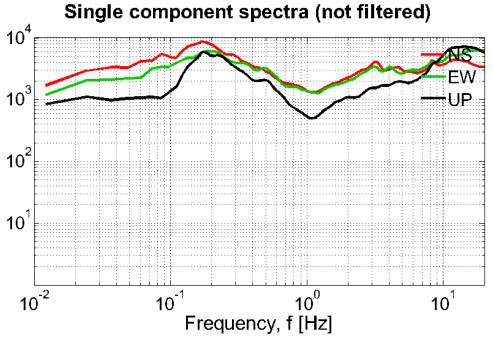
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

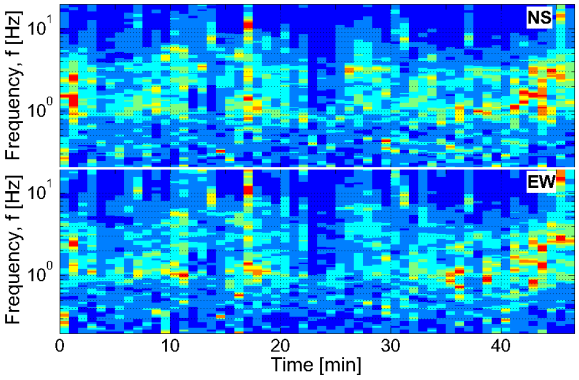
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

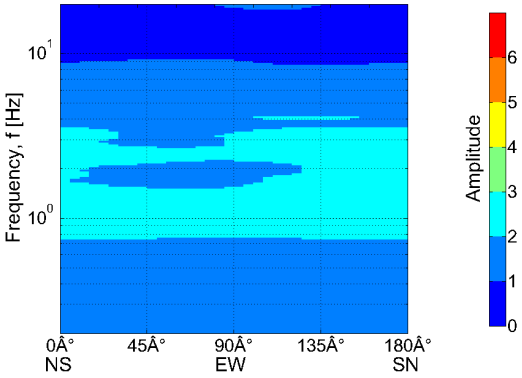
Single component spectra (not filtered)



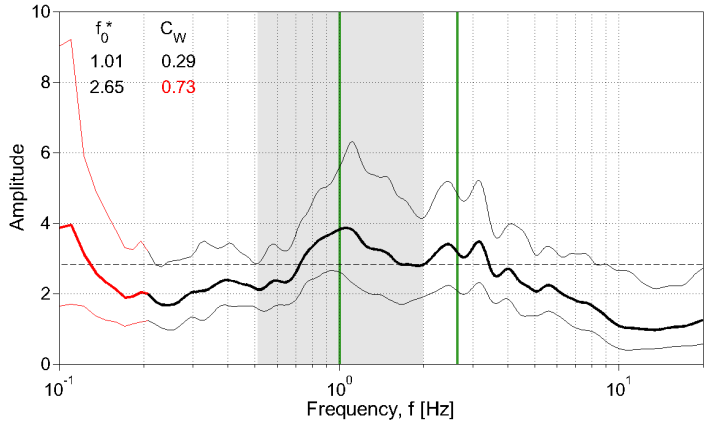
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 1.01 - Fulfilled crit.: 3/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> No

f^*_{02} = 2.65 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA22

Recording duration: 41:01 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 41 windows (34:010 [min:sec])

Window length (l_w) = 50 [s]

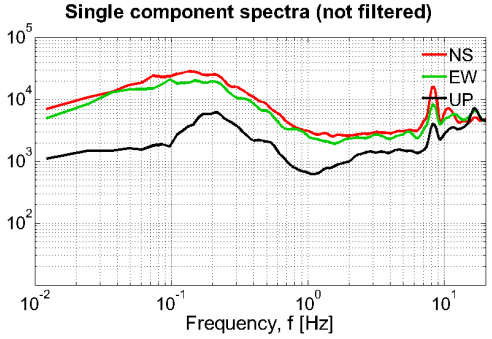
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

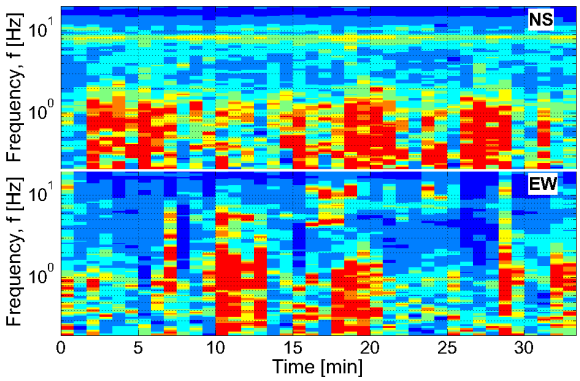
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

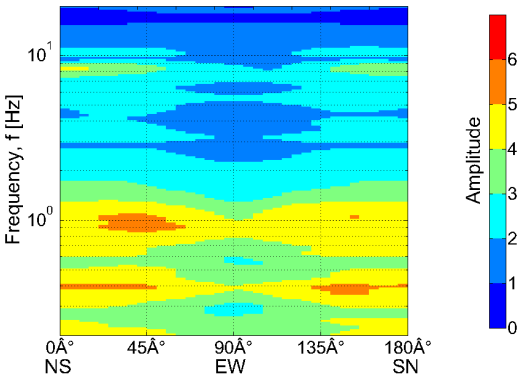
Single component spectra (not filtered)



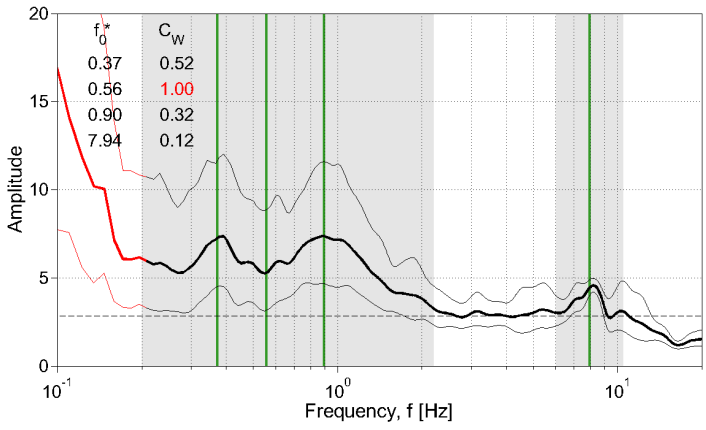
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

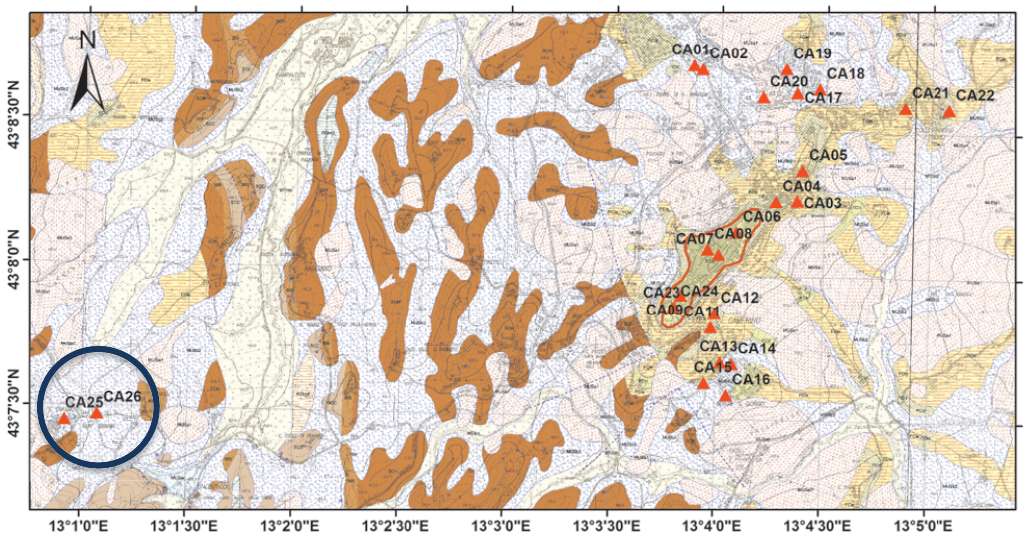
Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> No
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> Yes
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{01} = 0.37 - Fulfilled crit.: 3/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f^*_{02} = 0.56 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean



Comune: CAMERINO
Località: S. Erasmo
Stazione: CA25
Longitudine: 13.0154116°
Latitudine: 43.124175°
Quota [m]: 568



Comune: CAMERINO
Località: S. Erasmo
Stazione: CA26
Longitudine: 13.017956°
Latitudine: 43.124543°
Quota [m]: 549

Station: CA25

Recording duration: 56:010 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 45 windows (37:30 [min:sec])

Window length (l_w) = 50 [s]

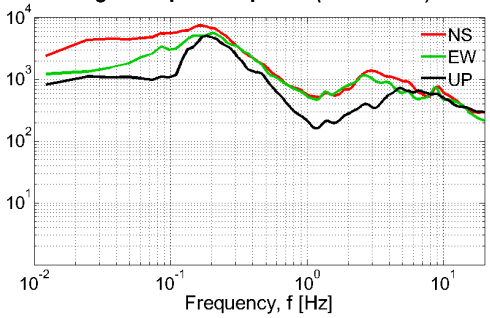
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

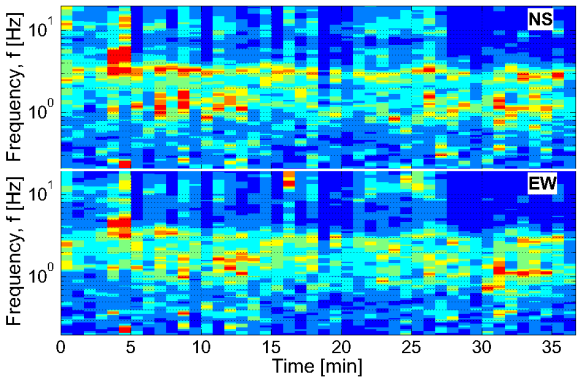
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

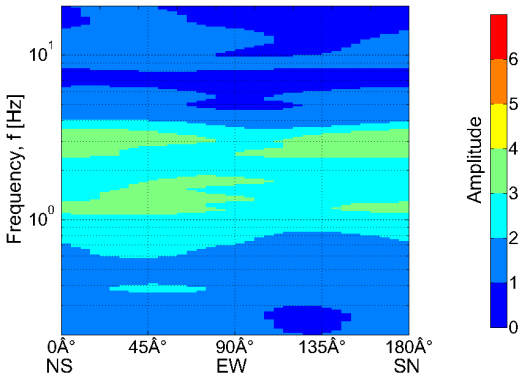
Single component spectra (not filtered)



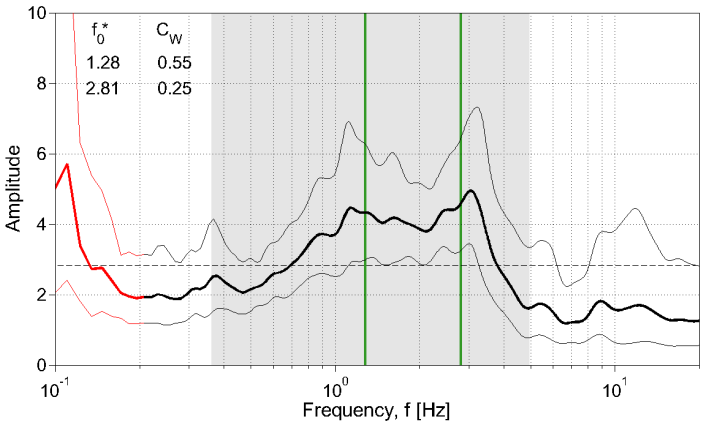
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists\, f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists\, f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta\ (f_0)$	==> Yes

f^*_{01} = 1.28 - Fulfilled crit.: 4/6

Criteria for a clear H/V peak (at least 5 out of 6 criteria fulfilled)	
i) $\exists\, f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> No
ii) $\exists\, f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta\ (f_0)$	==> Yes

f^*_{02} = 2.81 - Fulfilled crit.: 3/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

Station: CA26

Recording duration: 58:31 [min:sec] (dt = 0.01 [s])

Measurement by: INGV-MI

Instrument: Lennartz LE-3D/5s

Analysis performed on 63 windows (52:30 [min:sec])

Window length (l_w) = 50 [s]

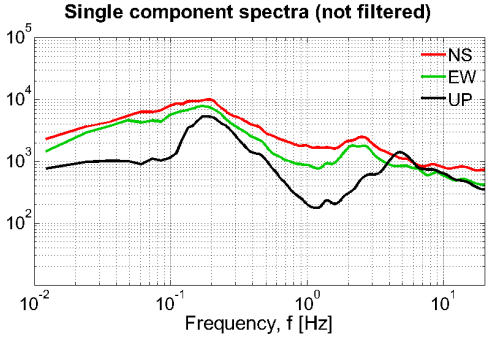
Minimum expexted f_0 = 0.2 [Hz]

Deconvolution: no

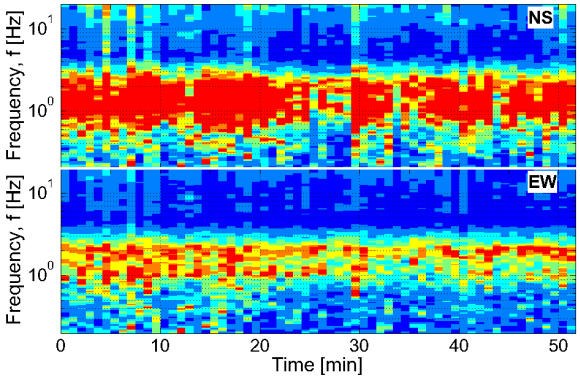
Butterworth filter: LP = 0.1 [Hz] - HP = 20 [Hz] - ord. = 4

Taper: 5 [%] - Konno & Ohmachi smoothing: b = 40

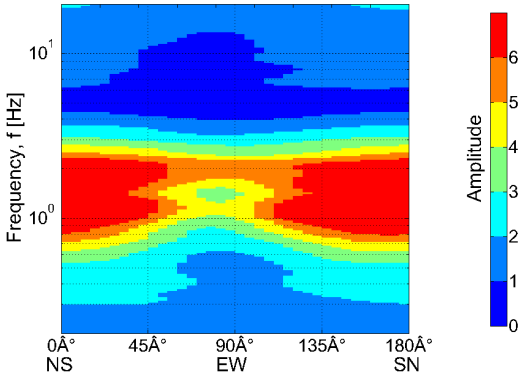
Single component spectra (not filtered)



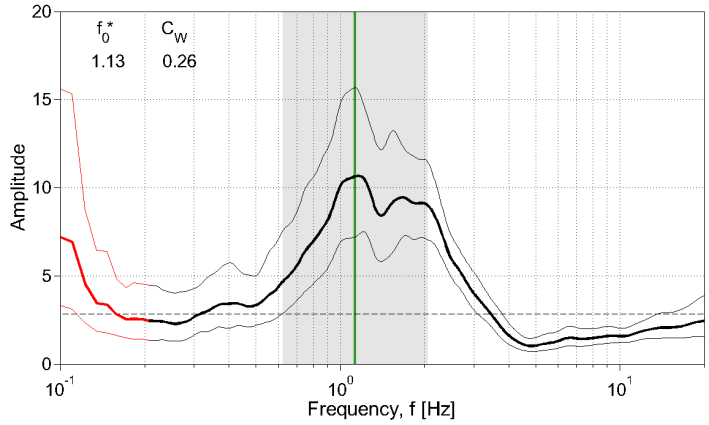
HVSR time histories



Directional HVSR



Horizontal to Vertical Spectral Ratio (1)



SESAME (2004) criteria (2)

Criteria for a clear H/V peak *(at least 5 out of 6 criteria fulfilled)*	
i) $\exists f^- \in [f_0/4, f_0] \mid A_{H/V}(f^-) < A_0/2$	==> Yes
ii) $\exists f^+ \in [f_0, 4f_0] \mid A_{H/V}(f^+) < A_0/2$	==> Yes
iii) $A_0 > 2$	==> Yes
iv) $f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	==> No
v) $\sigma_f < \varepsilon(f_0)$	==> No
vi) $\sigma_A(f_0) < \theta(f_0)$	==> Yes

f_0^* = 1.13 - Fulfilled crit.: 4/6

(1) based on horizontal components merged through vectorial sum
(2) based on horizontal components merged through geometric mean

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© 2017 INGV Istituto Nazionale di Geofisica e Vulcanologia
Via di Vigna Murata, 605
00143 Roma
Tel. +39 06518601 Fax +39 065041181

http://www.ingv.it



Istituto Nazionale di Geofisica e Vulcanologia