

[www.winmasw.com](http://www.winmasw.com)

# HoliSurface<sup>®</sup>

Holistic Tool for  
Surface Wave Analysis

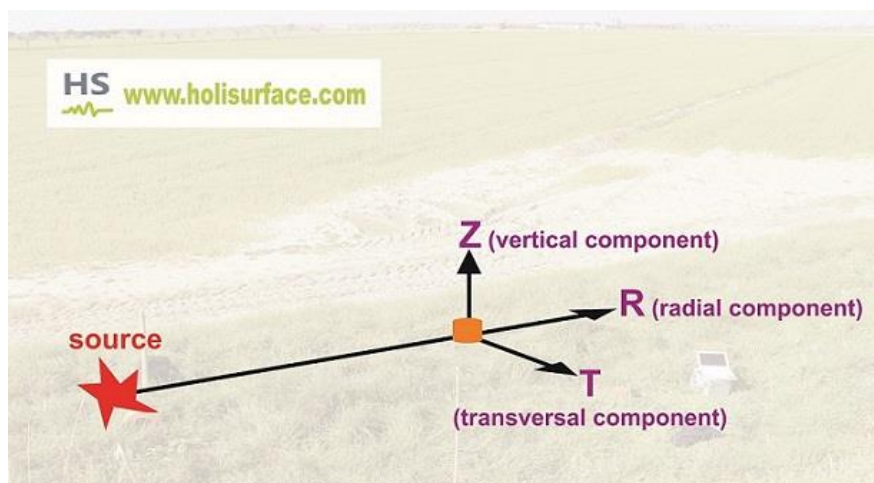
December 2019

file name	<i>HoliSurface_Z_R_HVSR_case_study_tutorial.pdf</i>
contact	<a href="http://www.winmasw.com">www.winmasw.com</a> e-mail: <a href="mailto:gdm@winmasw.com">gdm@winmasw.com</a>

In Italiano & English

Simple tutorial about the joint analysis of the Z and R components of Rayleigh waves and the HVSR in **HoliSurface<sup>®</sup> 2019**

Tutorial riguardo l'analisi congiunta delle component Z e R e dell'HVSR in **HoliSurface<sup>®</sup> 2019**



Tutti i diritti sono riservati ©

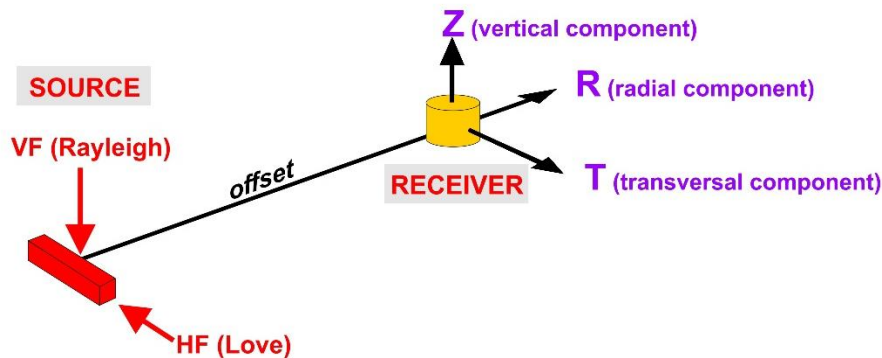
All rights reserved ©

### Cos'è HoliSurface?

Un modo molto avanzato (con solide radici nella basi della sismologia) di analizzare la propagazione delle onde di superficie in modo congiunto grazie all'analisi dei dati (attivi e passivi) raccolti da un unico geofono triassiale posto ad una distanza fissa dalla sorgente.

### What is HoliSurface?

An advanced way to analyse the propagation of surface waves thanks to the active and passive data obtained from a single 3-component (3C) geophone deployed at a fixed distance from the source (see picture).



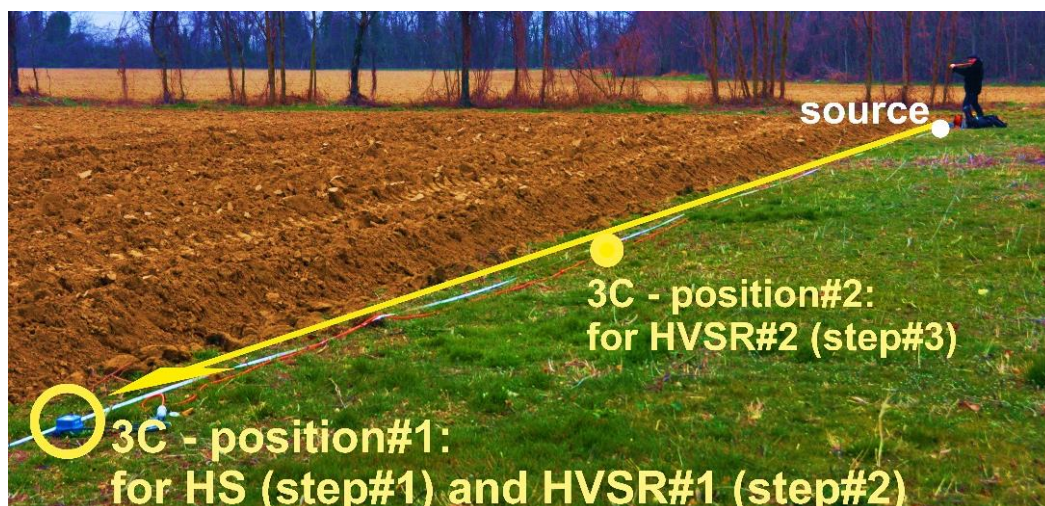
Nel presente piccolo caso studio (*tutorial*) considereremo i dati raccolti secondo la procedura più semplice consigliata e illustrata anche nel libro *Efficient Joint Acquisition and Analysis of Surface Waves and Introduction to Vibration Analysis: Beyond the Clichés* (in uscita ad inizio 2020 per la Springer) e possibile a chi possiede un unico geofono triassiale. In pratica:

- 1) Sismica attiva (approccio HS): distanza tra sorgente e ricevitore pari a 50 m;
- 2) Primo HVSR acquisito lasciando il triassiale nello stesso punto in cui era stato posto per l'acquisizione attiva (position#1 della seguente figura);
- 3) Secondo HVSR ottenuto spostando il geofono alla position#2 e usato sia per verificare non sussistano significative variazioni laterali sia perché acquisire un solo HVSR è a volte rischioso (nella sismica passiva qualcosa può sempre andare storto).

In the present small case study (*tutorial*) we consider the data collected according to the simplest procedure illustrated also in the book *Efficient Joint Acquisition and Analysis of Surface Waves and Introduction to Vibration Analysis: Beyond the Clichés* (to be published at the beginning of 2020 for Springer) and possible for those who own a single 3C geophone.

From the practical point of view:

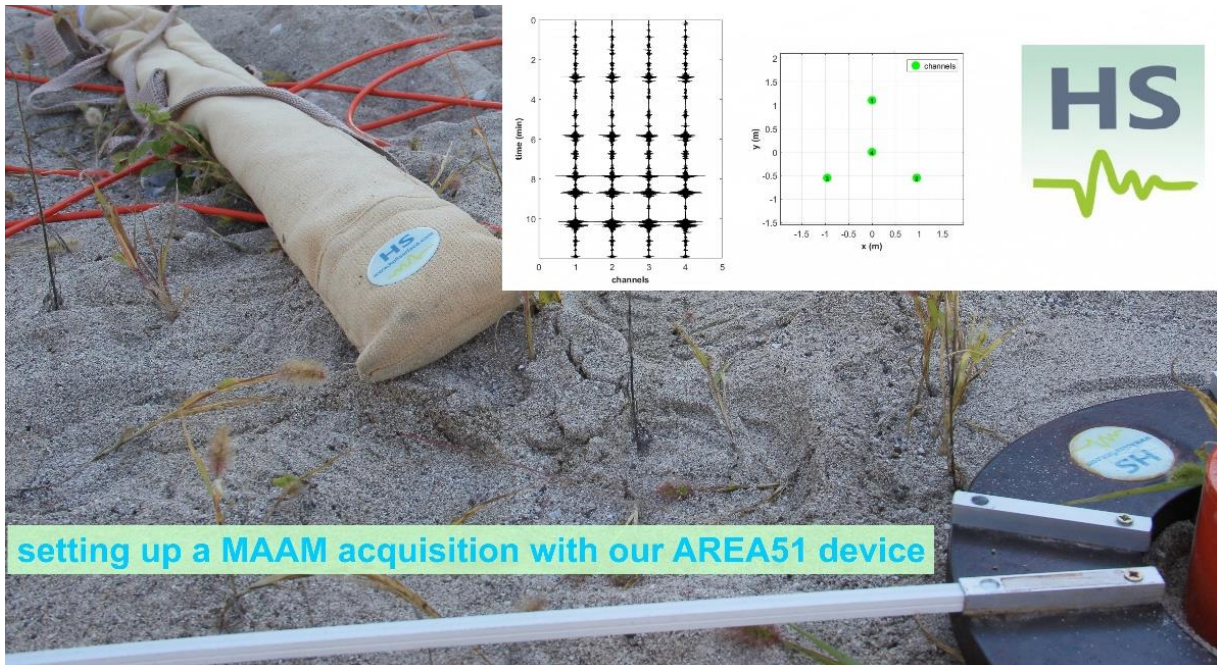
- 1) Active seismic (HS approach – see e.g. Dal Moro et al. 2019): distance between source and receiver equal to 50 m;
- 2) First HVSR acquired while the 3C is at the same point where it was placed for the active acquisition (position#1 in the following figure);
- 3) Second HVSR obtained by moving the geophone to the position#2 and used to verify that there are no significant lateral variations and because it is not recommended to rely on just a single HVSR since, sometimes, something can always go wrong while recording passive data.



## Dati / Data

I dati mostrati in questo breve caso studio non sono particolarmente “belli” e l’intera analisi non rappresenta un “caso eccezionale” (come raramente si incontrano nella vita professionale di tutti i giorni). Intendono invece rappresentare un caso molto comune di dati non ideali ma certamente sufficienti ad ottenere un buon profilo delle  $V_S$ .

The data shown in this brief case study are not particularly "beautiful" and the entire analysis does not represent an "exceptional case". Current data and analyses intend to represent a very common case: data are not “ideal/perfect” but are surely sufficient to obtain a reliable  $V_S$  profile.





## Le due curve HVSR in breve / The two HVSR curves (main facts)

### HVSR#1 (from the data of the geophone at the position#1)

show current data    reset

step#1 (optional) - decimate  
 54 Hz    new frequency    resample

step#2 - HV computation  
 remove events    top flat & tr.    clean axes  
 25    window length (s)  
 0    tapering (%)    Min. freq.: 0.385 Hz  
 4.4    amplitude threshold    last removal  
 240    HVSR threshold  
 15%    spectra smoothing (triangular window)  
 6    detrending order    H01HSC 2 Hz  
 full output  
 particle motion all HVSRs, from top to bottom  
 close windows  
 save videos    quad: all mean    compute

continuity    show 3D motion

directivity analysis  
 frequencies to highlight: 1 5 10 20    Hz    composite

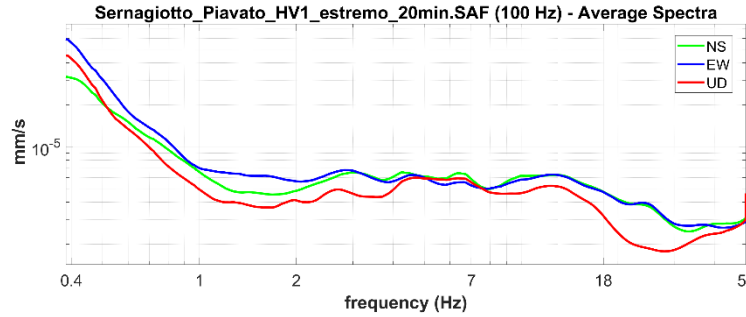
save - options#1: save HVSR as it is  
 save HV from 0.385 to 60 Hz  
 save HV curve (as it is)

picking HV or amplitude spectra  
 -HVSR    pick data  
 save picked HV    compute

quick analysis (F-Vs/4H)  
 200    average Vs (m/s)  
 20    depth of the bedrock (m)  
 0.00    Vs of the bedrock  
 data    compute

highlight a frequency  
 draw/highlight    10    Hz    Upload HVSR curve

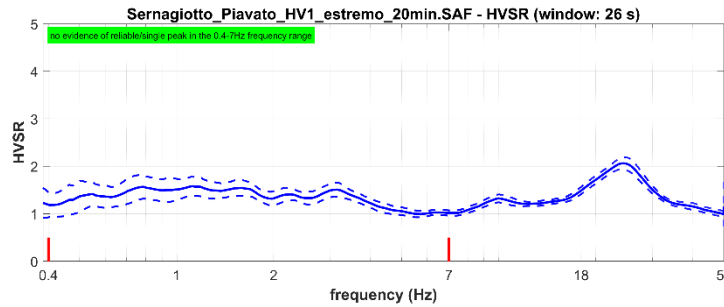
directivity over time  
 directivity in time    time    30    s



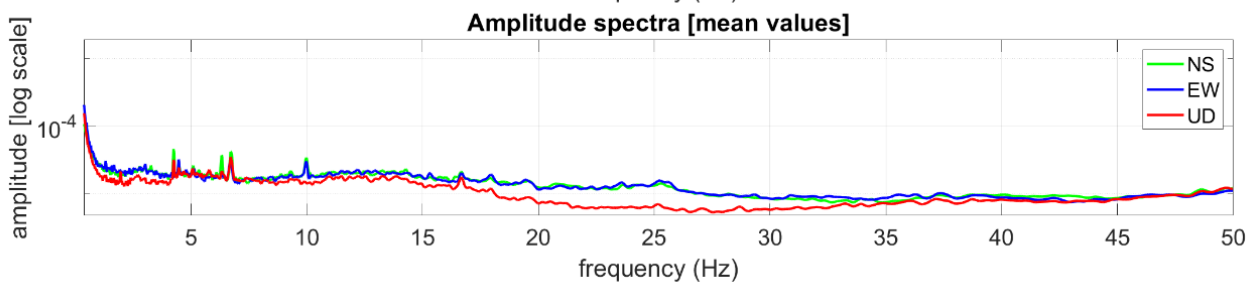
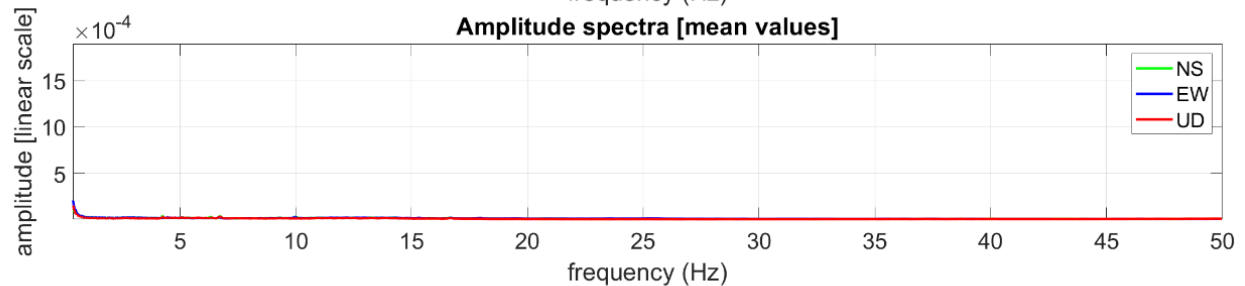
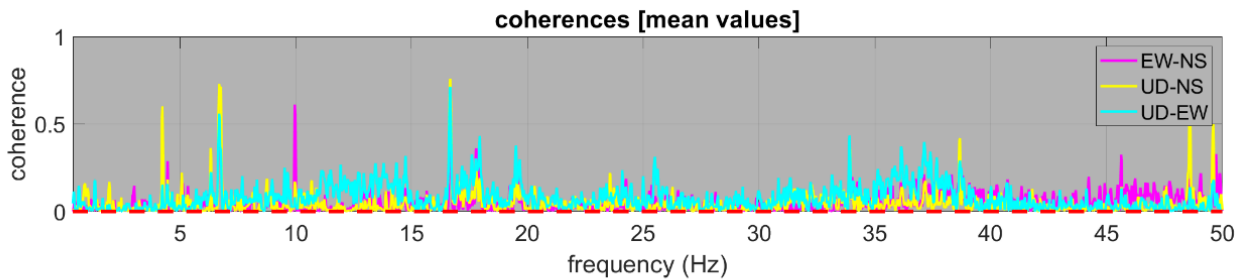
open working folder  
 show location  
 field notes

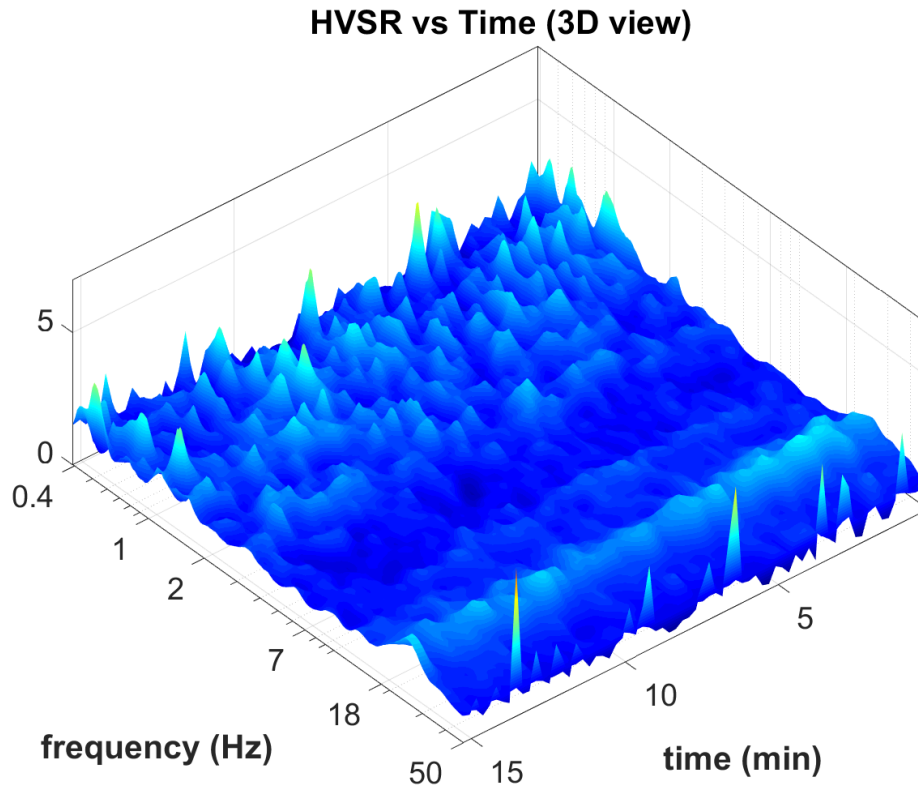
your comments

default axes



To model the HVSR (also jointly with MASW or ReMi/ESAC data), go to the "Velocity Spectrum/a, Modeling & Picking" panels and upload the saved HV curve





Per dettagli riguardo il significato e l'uso delle funzioni di coerenza e degli spettri poco smussati vedi manuale di *winMASW*® o *HoliSurface*® (o il libro *Acquisizione e analisi di dati sismici e vibrazionali per studi di caratterizzazione sismica e geotecnica* – Flaccovio 2019).

For details about the meaning and use of the coherence functions and the slightly rounded spectra, see *winMASW*® or *HoliSurface*® manual or the book *Efficient Joint Acquisition and Analysis of Surface Waves and Introduction to Vibration Analysis: Beyond the Clichés*.

## HVSR#2 (from the data of the geophone at the position#2)

show current data

step#1 (optional) - decimate  
 54 Hz

step#2 - HV computation

28 window length (s)  
 5 tapering (%)  
 4.4 amplitude threshold   
 240 HVSR threshold  
 15% spectra smoothing (triangular window)  
 6 detrending order

full output  
 particle motion all HVSRs, time aperture  
 close windows  
 save videos

directivity analysis  
 frequency to highlight: 1 5 10 100 Hz

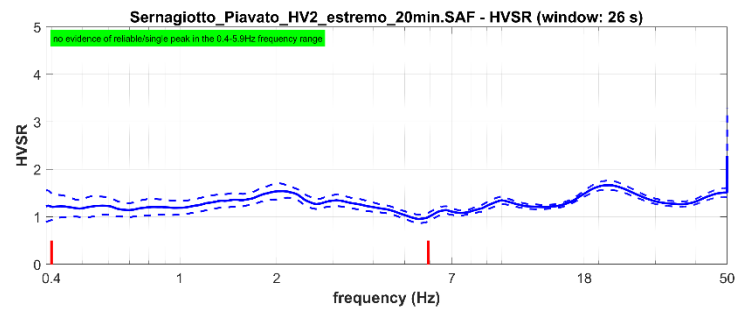
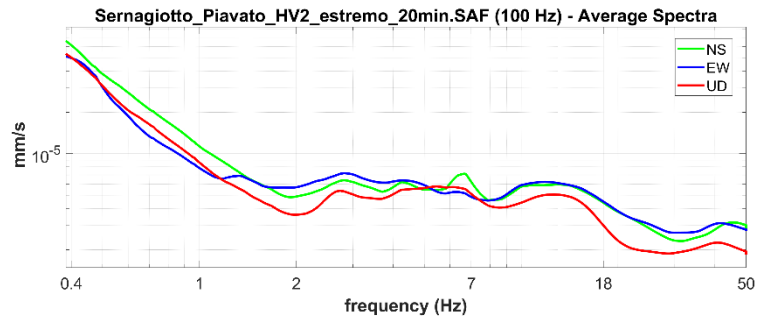
save-option#1: save HVSR as it is  
 save HV from 0.385 to 60 Hz

picking HV or amplitude spectra

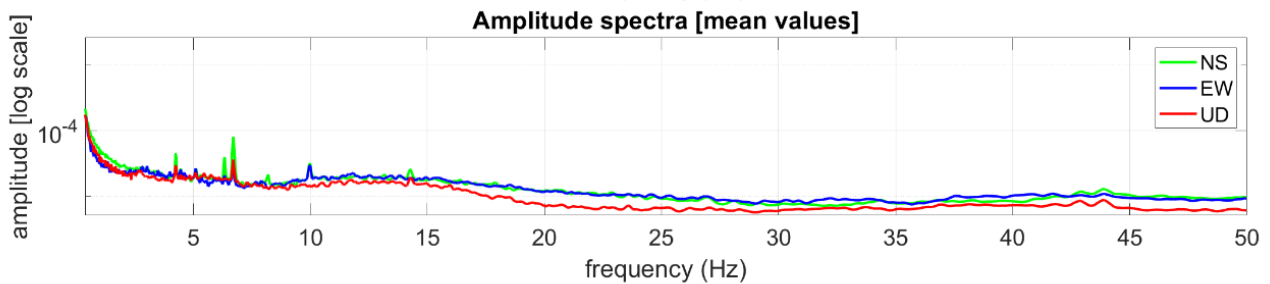
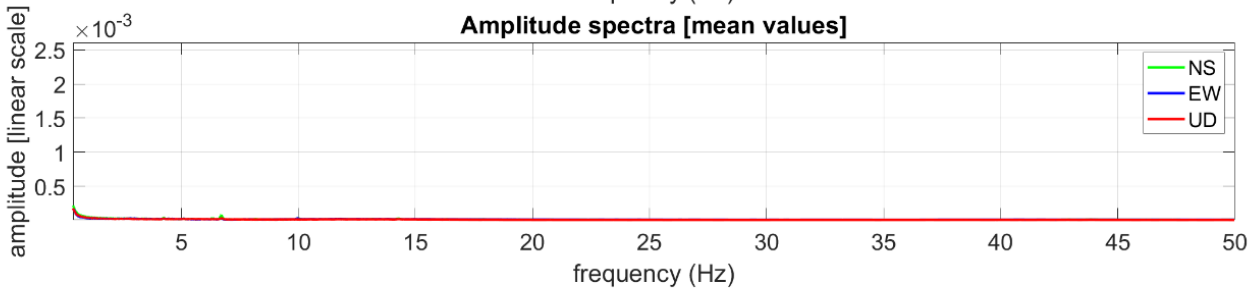
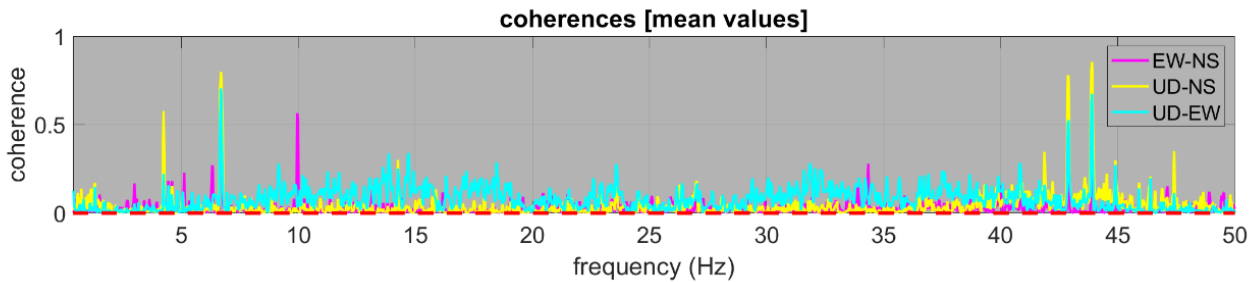
quick analysis (H-Vs/H)  
 200 average Vs (m/s)  
 from surface to bedrock  
 20 depth of the bedrock (m)

highlight a frequency  
 10 Hz

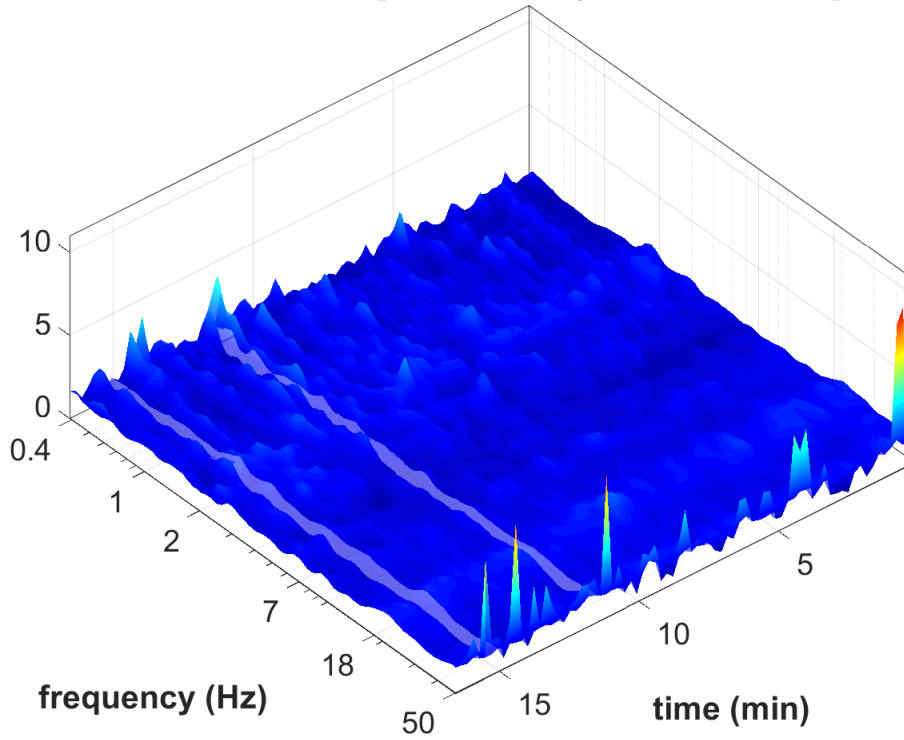
directivity over time  
 time 10 s



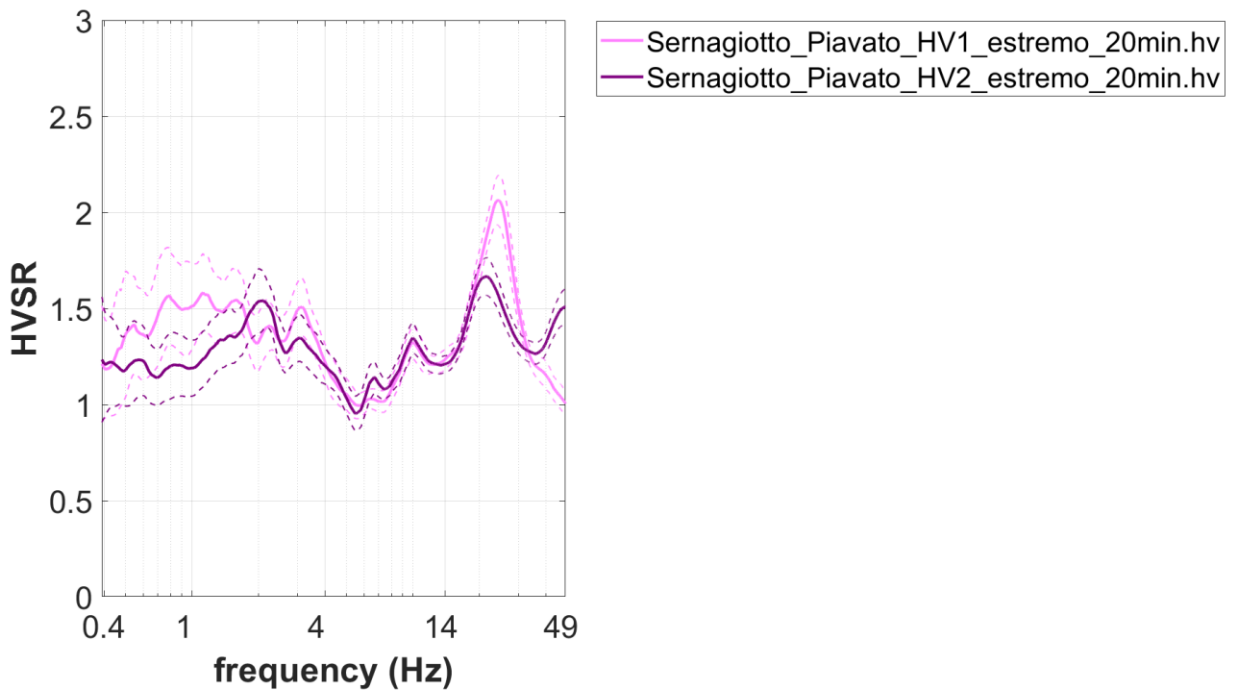
To model the HVSR (also jointly with MASW or ReMi/ESAC data), go to the "Velocity Spectrum/s, Modeling & Picking" panels and upload the saved HV curve

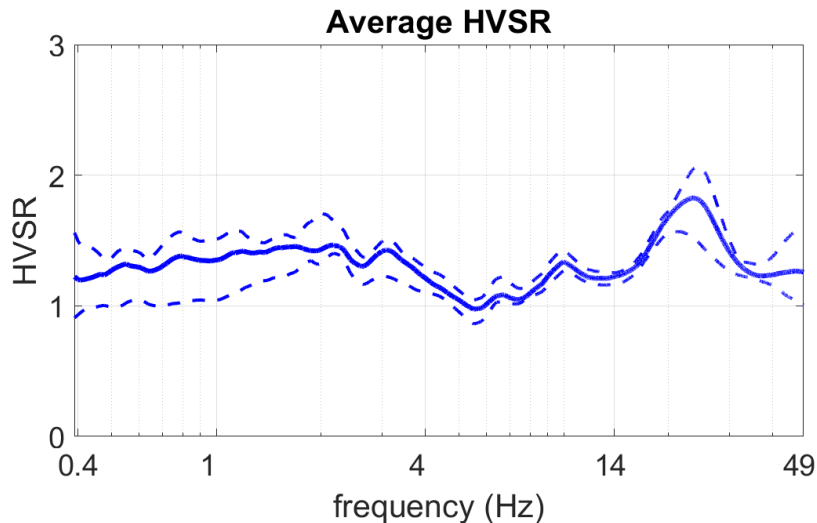
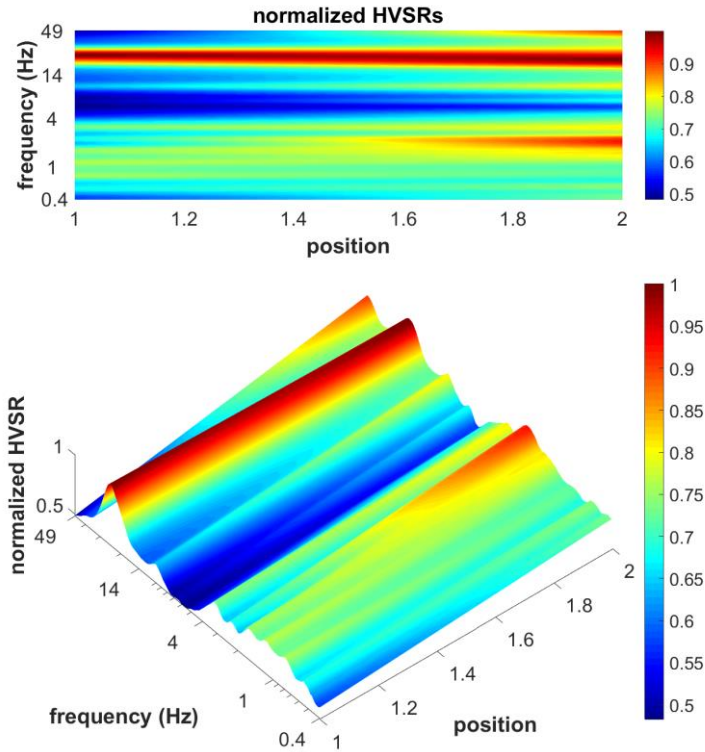


HVSR vs Time [transparency: outlier curves]



Computo della curva HVSR media / Computation of the mean HVSR curve





Le due curve HVSr sono leggermente diverse. Mentre la (piccola) differenza alle alte frequenze (> 15 Hz) può essere facilmente dovuta a variazioni laterali negli strati superficiali, le differenze alle frequenze basse (<3 Hz) possono essere correlate a diversi fatti, probabilmente anche un non perfetto accoppiamento del sensore con il terreno. In ogni caso, le differenze sono piccole e, nell'analisi congiunta con i dati attivi, possiamo tranquillamente considerare la curva media (vedi prossimo paragrafo).

The two HVSr curves are just slightly different. While the (small) difference at the very high frequencies (> 15 Hz) can be easily due to lateral variations in the shallow layers, the differences in the low frequencies (<3 Hz) can be related to several facts also possibly a non-perfect coupling of the sensor with the ground. In any case, the differences are small and, for the joint analysis with the active data, we can soundly consider the average curve (see next section).



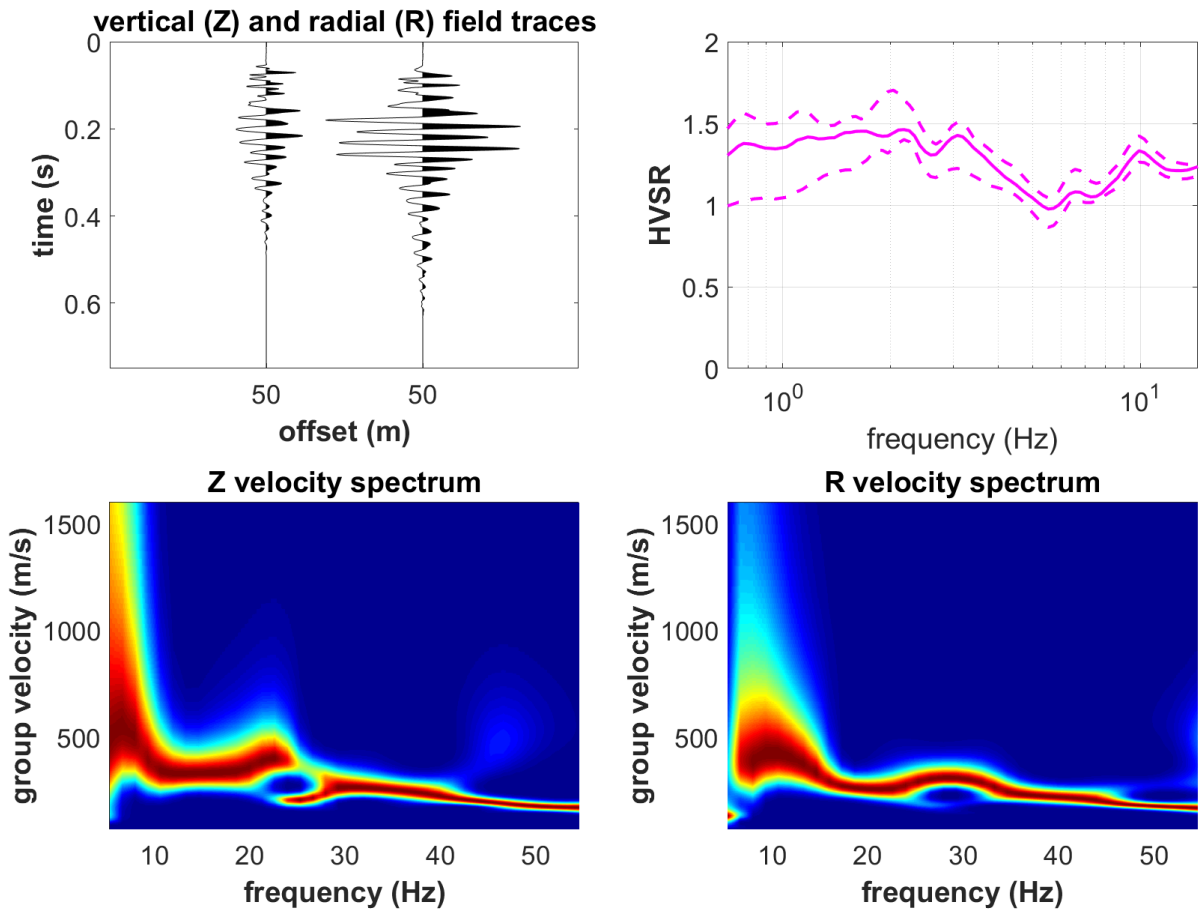
### Sintesi dei dati / Data in brief

Nella seguente figura sono riportate:

- a) le tracce Z (verticale) e R (radiale) acquisite dal triassiale (posto a 50 m dalla sorgente);
- b) la curva HVSr media (ottenuta dalle due curve HVSr acquisite in due diversi punti dello stendimento);
- c) spettro di velocità di gruppo della componente Z;
- d) spettro di velocità di gruppo della componente R.

The following figure shows:

- a) the active Z (vertical) and R (radial) traces acquired from the 3C (located 50 m from the source);
- b) the average HVSr curve (obtained from the two HVSr curves acquired at two different points of the array);
- c) group velocity spectrum of Z component;
- d) group velocity spectrum of the R component



## Inversione automatica / Automatic inversion

Dopo un po' di *modelling* preliminare (per avvicinarci ad un accettabile modello di partenza), si lancia il *tool* di inversione congiunta dei tre "oggetti" qui considerati (i due spettri delle velocità di gruppo e la curva HVSr).

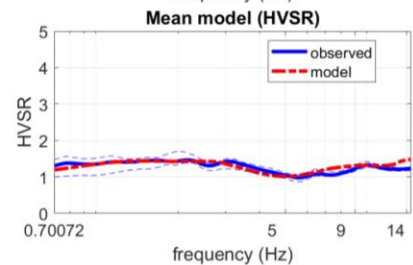
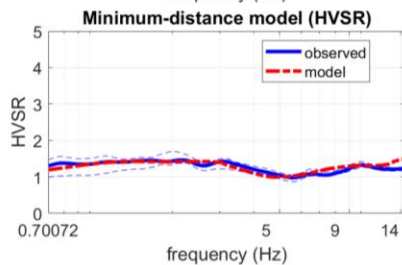
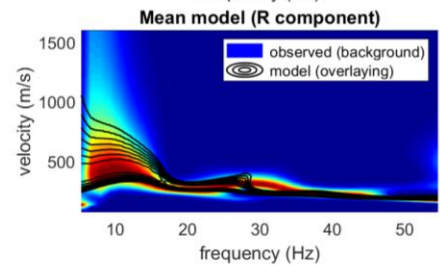
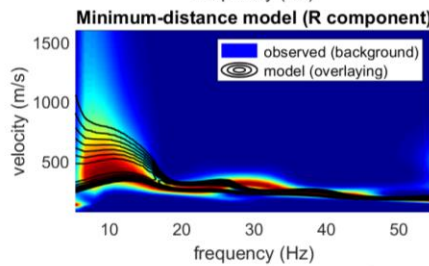
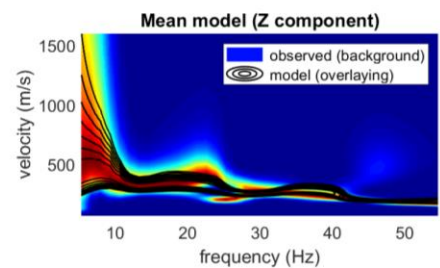
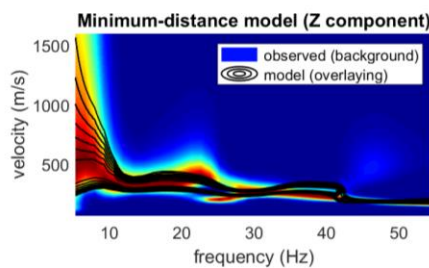
I risultati sono riportati nelle seguenti immagini. Si noti come i dati dei modelli finali (medio e *minimum-distance model*) si sovrappongono molto bene ai dati di campagna.

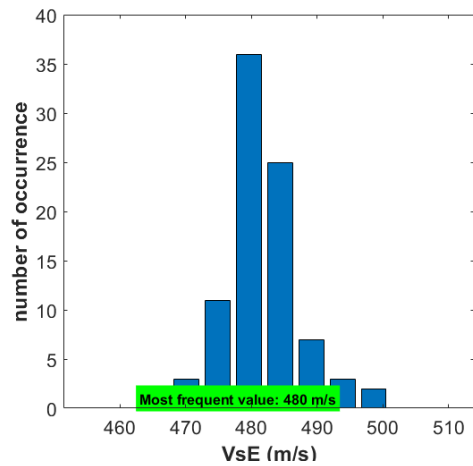
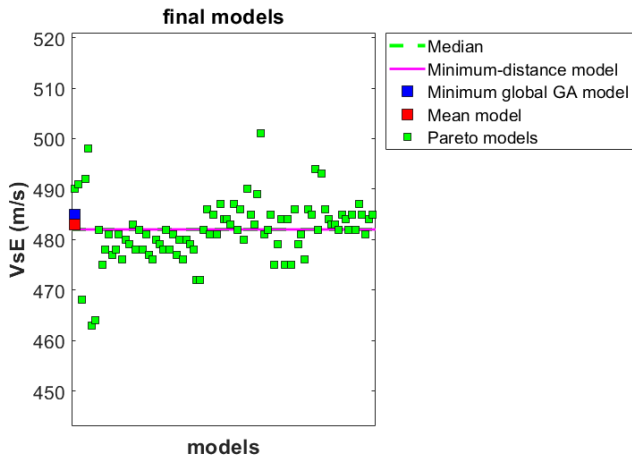
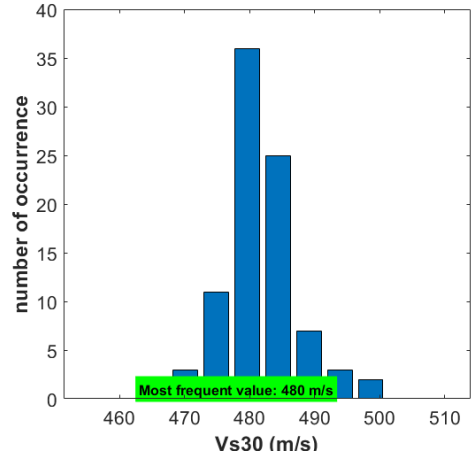
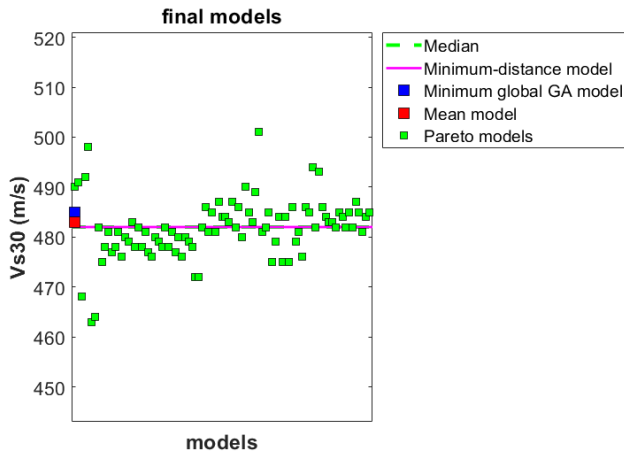
Per dettagli sul come funzionano un'*inversione congiunta* vedi Riferimenti bibliografici e il menzionato libro pubblicato per la Flaccovio.

After some preliminary *modelling* (to get closer to an acceptable starting model), the joint inversion tool of the three considered observables (the two group-velocity spectra and the HVSr curve) is launched. The results are shown in the following images. Please, notice the good match between the obtained models (mean model and minimum-distance model) and the field data.

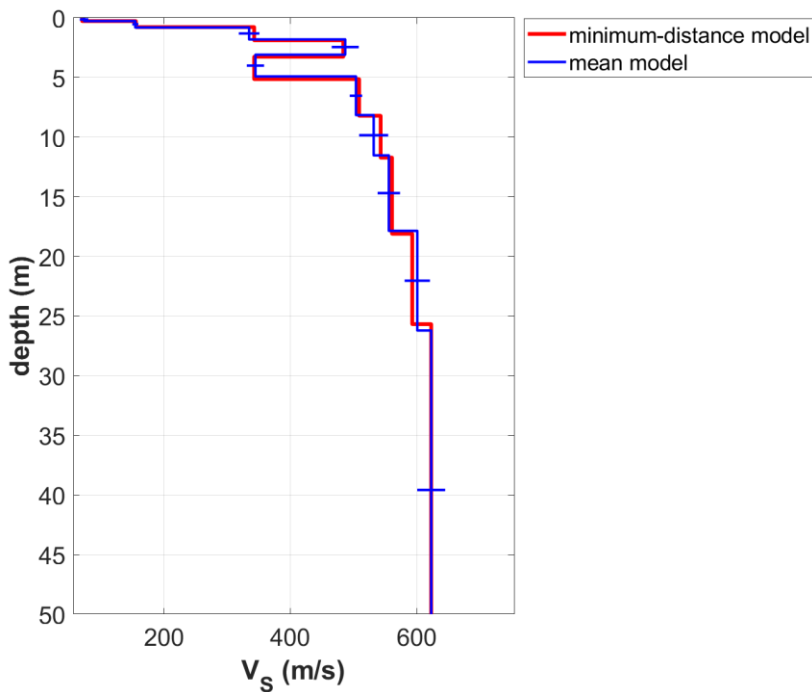
For details about how a *joint inversion* works, please see References.

**HoliSurface®**





Statistics for the Pareto-front models (Vs30 and equivalent Vs)



## Ringraziamneti / Acknowledgements

Dati gentilmente concessi dal Dott. Geologo Roberto Callegari (Nervesa della Battaglia - TV).

Data kindly provided by Dr. Geologist Roberto Callegari (Nervesa della Battaglia – Treviso - Italy).

## Alcuni riferimenti / Some references

**Efficient Joint Acquisition and Analysis of Surface Waves and Introduction to Vibration Analysis: Beyond the Clichés** (Dal Moro G., 2020) Springer (in press)



**Acquisizione e analisi di dati sismici e vibrazionali per studi di caratterizzazione sismica e geotecnica** (Dal Moro G., 2019). Dario Flaccovio Editore, ISBN 9788857908786, 280pp [in italiano]

**On the efficient holistic approach to Rayleigh-wave acquisition and analysis** (Dal Moro G., Al-Arifi N., Moustafa S.R., 2019), Soil Dynamics and Earthquake Engineering, 125, 105742, <https://doi.org/10.1016/j.soildyn.2019.105742>

**Effective Active and Passive Seismics for the Characterization of Urban and Remote Areas: Four Channels for Seven Objective Functions** (Dal Moro G., 2018). Pure and Applied Geophysics, <https://rdcu.be/bbT04>

**Improved Holistic Analysis of Rayleigh Waves for Single- and Multi-Offset Data: Joint Inversion of Rayleigh-wave Particle Motion and Vertical- and Radial-Component Velocity Spectra** (Dal Moro G., Al-Arifi N., Moustafa S.R., 2017), Pure and Applied Geophysics, 175, 67–88

**Four Geophones for seven objective functions: active and passive seismics for tricky areas** (Dal Moro G.), Invited presentation and Extended Abstract for the Urban Geophysics workshop at the 22<sup>nd</sup> EAGE Near Surface Geoscience conference (Barcelona - Spain, 4-8 September 2016)

**Shear-wave velocity profiling according to three alternative approaches: a comparative case study** (Dal Moro G., Keller L., Moustafa S.R., Al-Arifi N., 2016). Journal of Applied Geophysics, 134, 112–124

**Less is more: from van der Rohe to the 4-channel system for the efficient and holistic analysis of surface waves. A urban case study** (Dal Moro G., Moustafa S.R., Al-Arifi N., 2015). Proceedings of the GNGTS ([gngts.ogs.trieste.it](http://gngts.ogs.trieste.it)) congress (17-19 November 2015 - Trieste, Italy).