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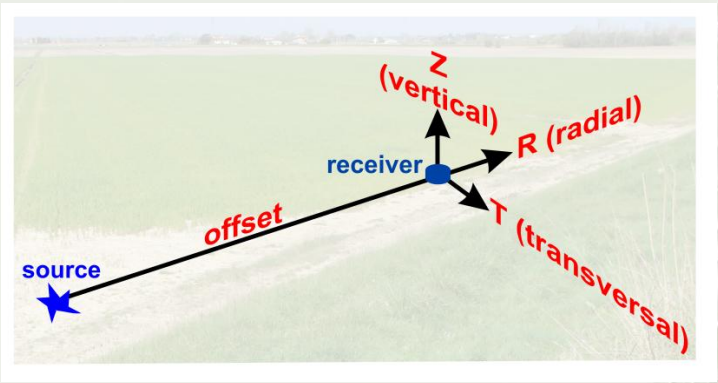
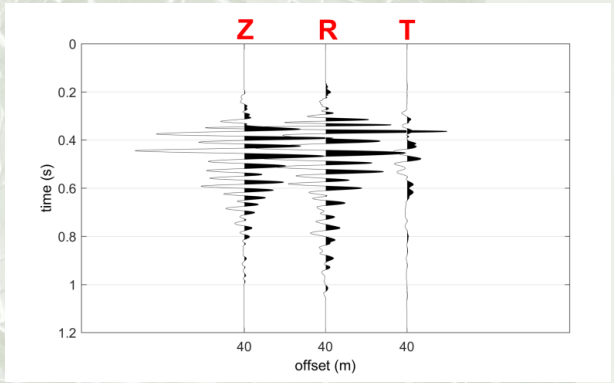
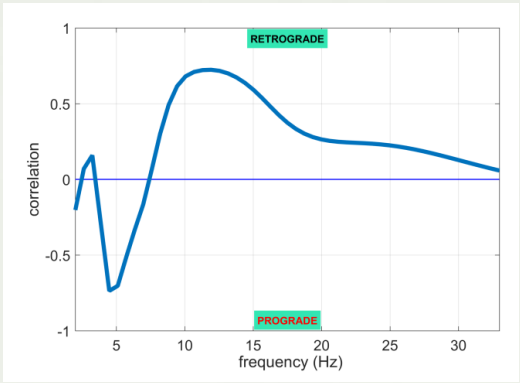
4-8 September 2016, Barcelona, Spain

Four Geophones for Seven Possible Objective Functions: Active and Passive Seismics in Tricky Areas







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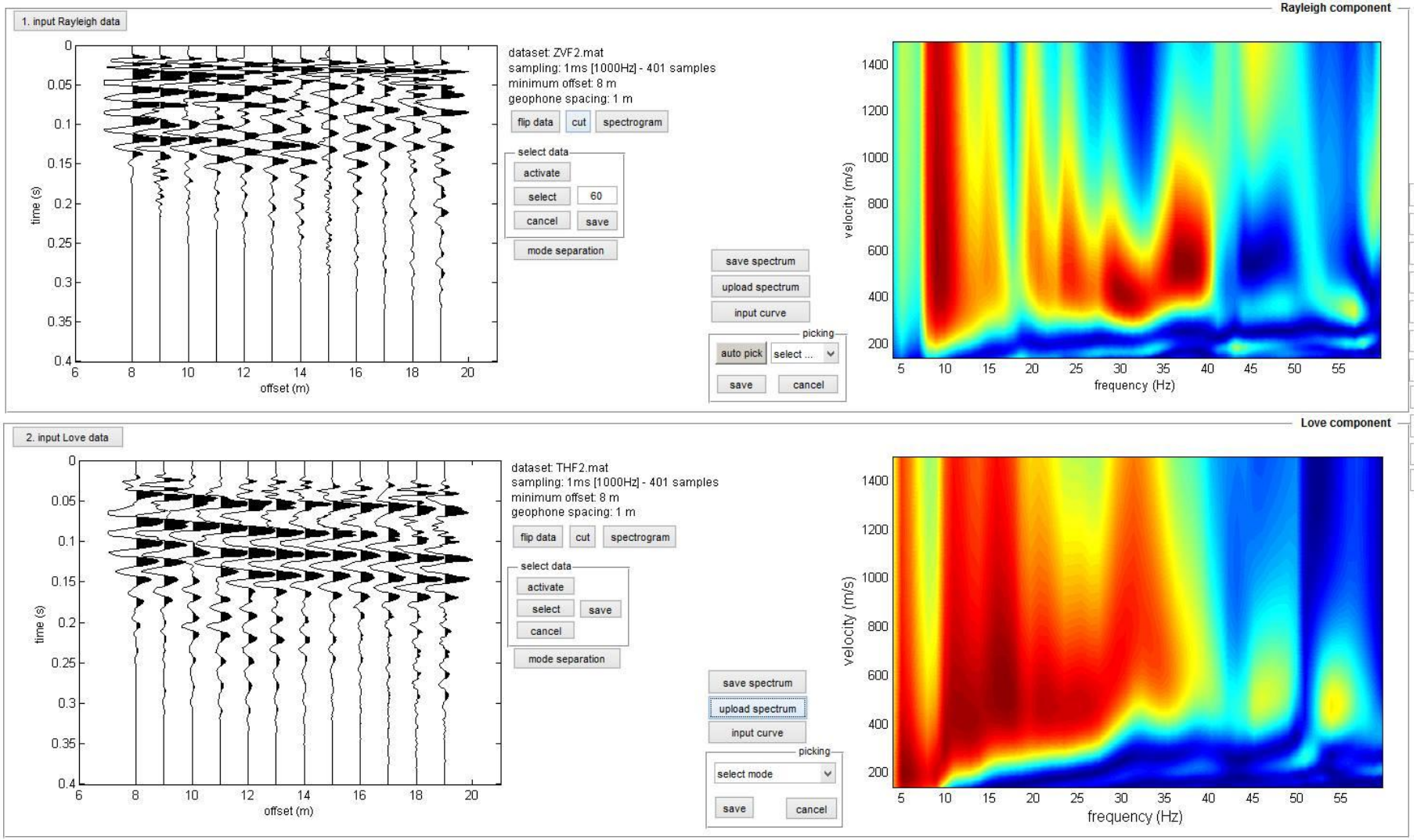
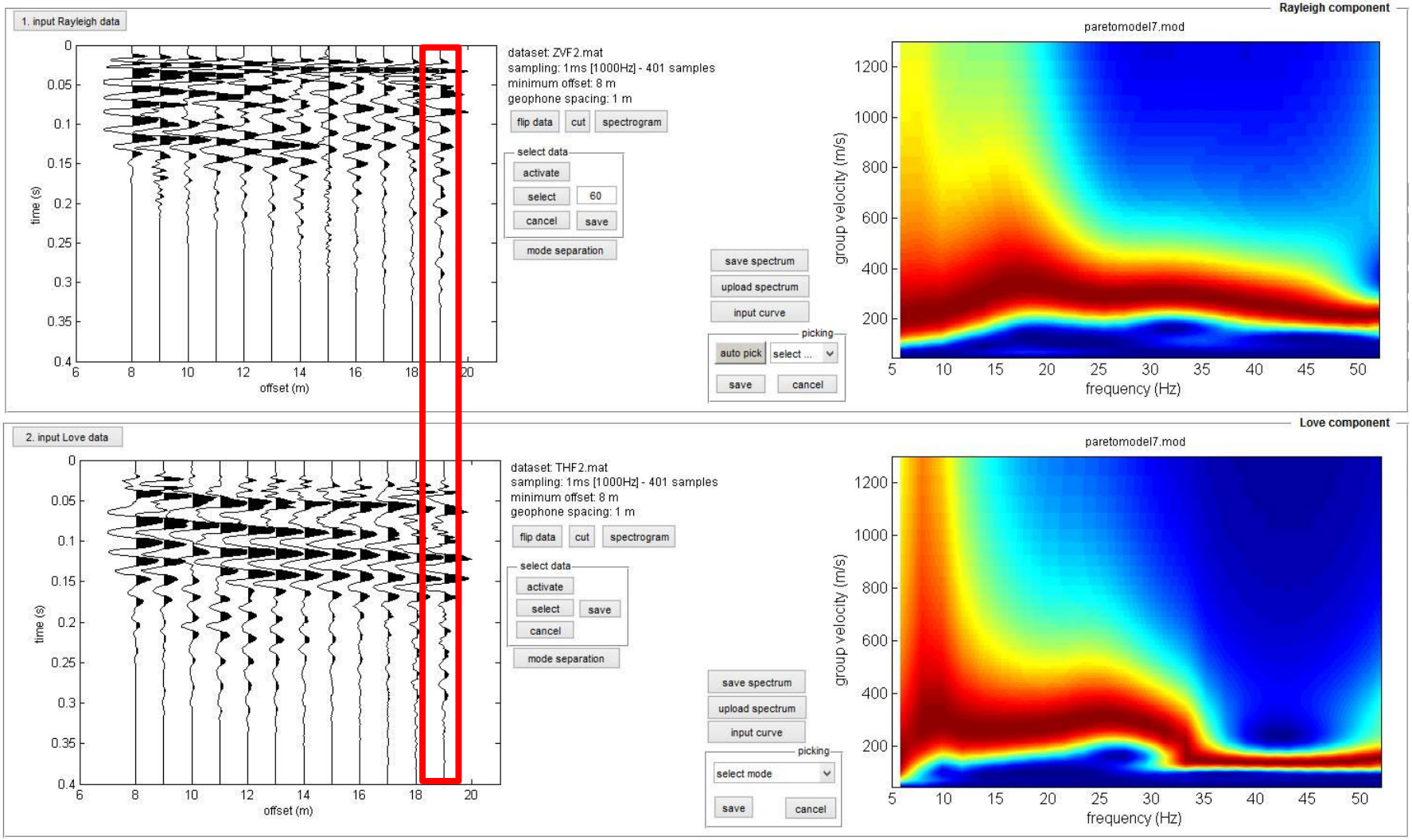
Questioning the multi-channel dogma:

is the analysis of *phase* velocity (analyzed via multi-channel data) better with respect to the single-channel data useful for the analysis of *group* velocities?



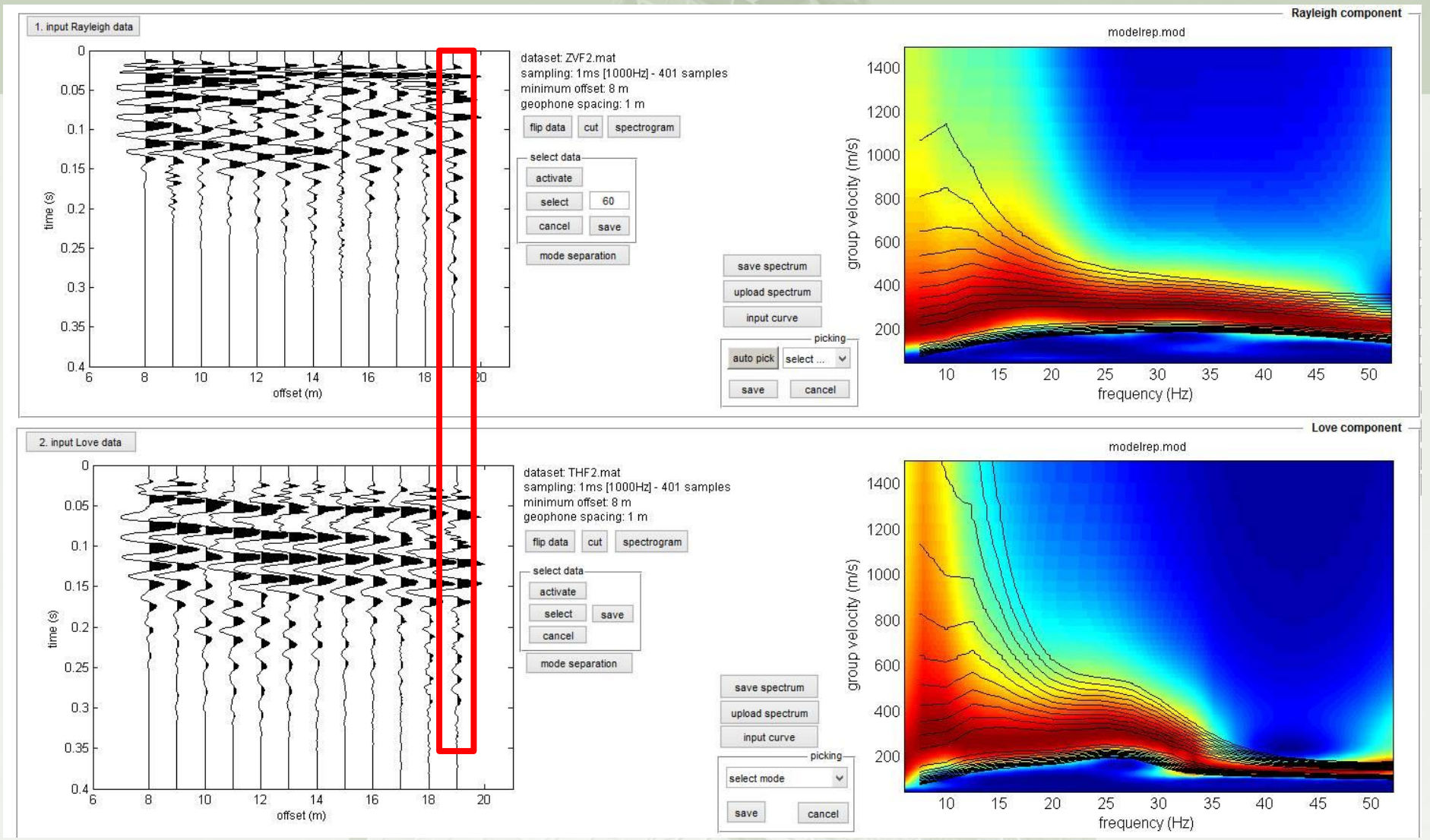
A recent dataset (ZVF + THF)

the multi-channel dogma:
here the *group* velocity spectra (Z and T components) for the most-distant trace



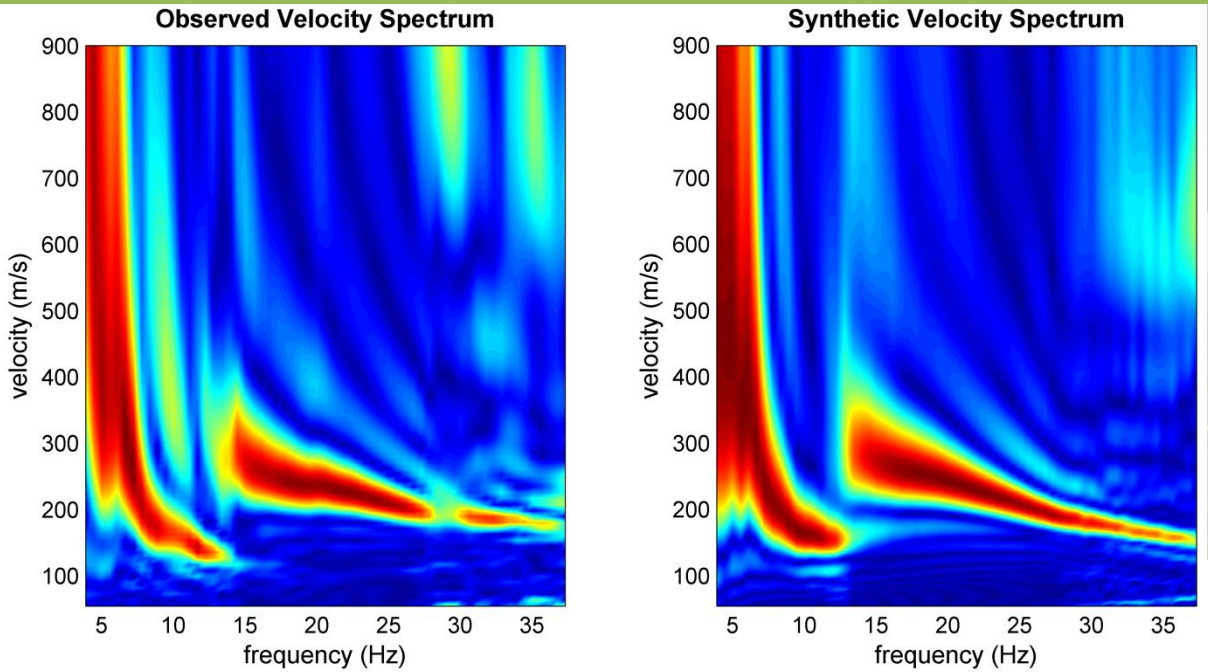
A recent dataset (ZVF + THF)

the multi-channel dogma:
here the FVS analysis of the *group* velocity spectra (Z and T components)

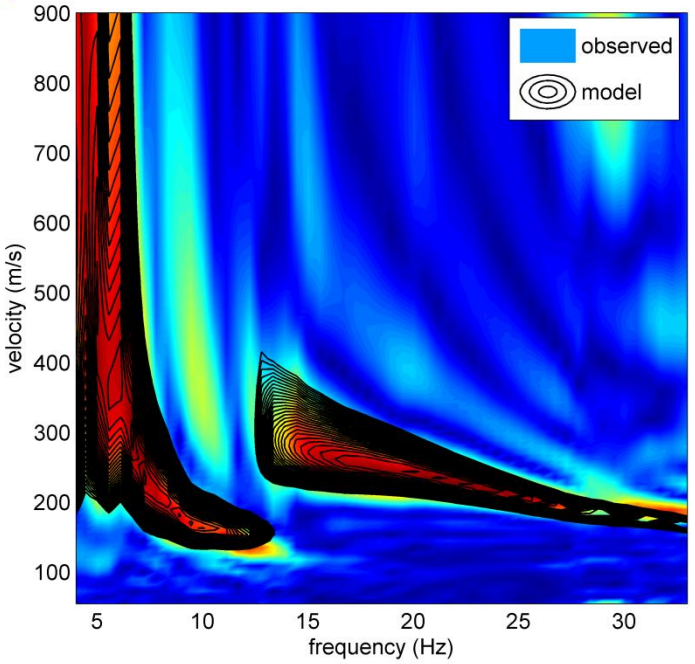


FVS joint inversion

The FVS (*Full Velocity Spectrum*) approach in short



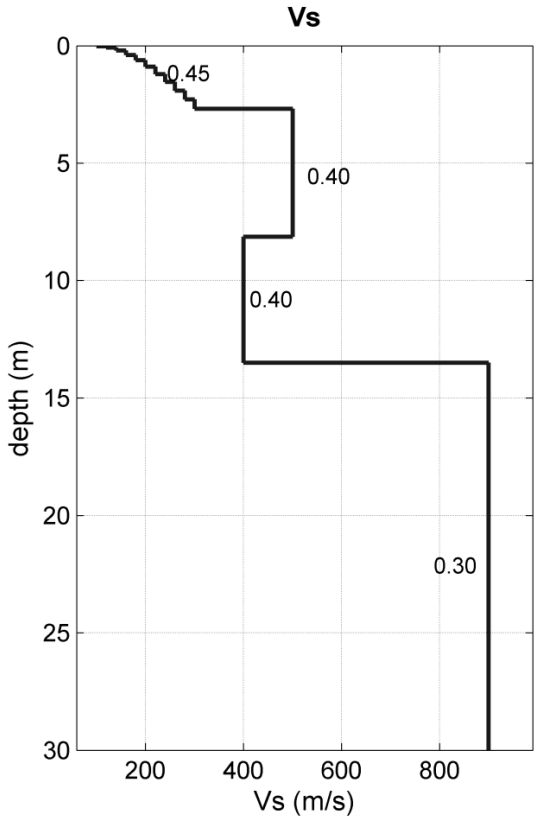
"comparing" the field and the synthetic velocity spectra [no interpretation in terms of dispersion curve(s)]

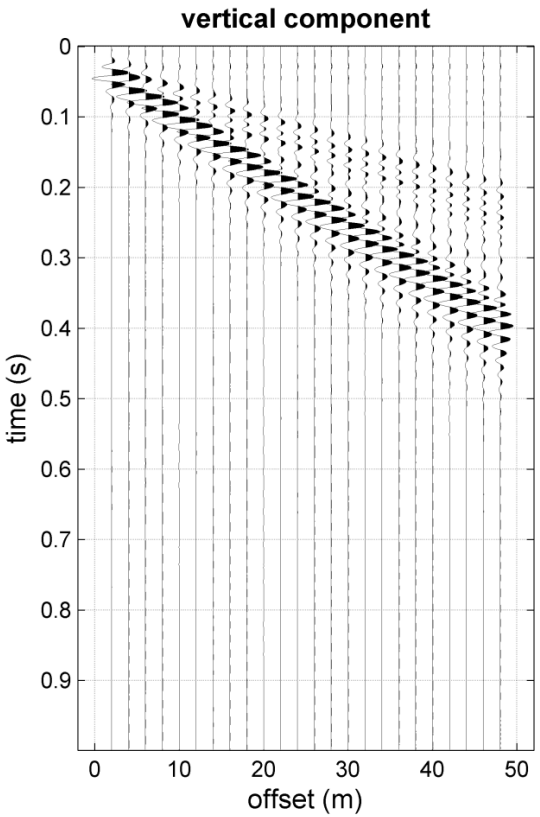


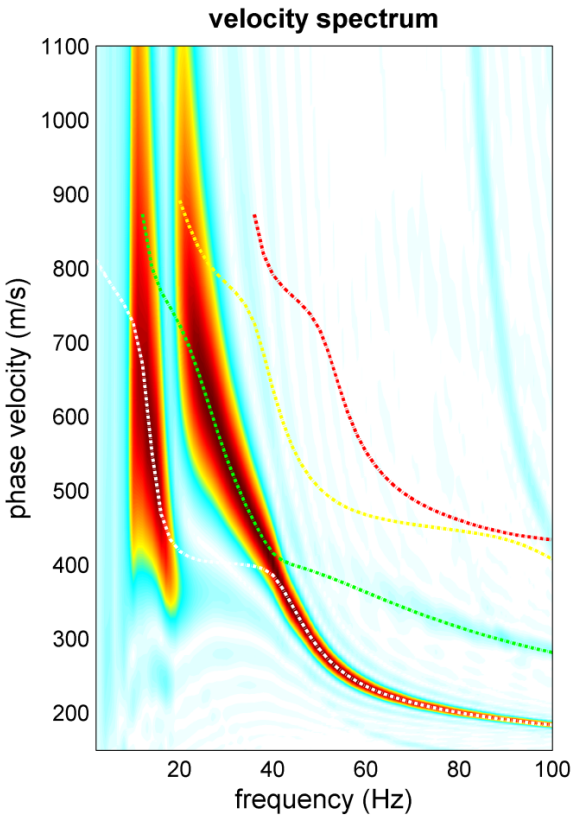
"compact" FVS representation: background colors refer to the field data, overlaying black contour lines to the synthetics

Retrieving the dispersive properties is something, but the way you understand/treat/process them something else:

- ***Modal*** **dispersion curves**
- ***Effective*** **dispersion curve**
- **FVS (*Full Velocity Spectrum*)**





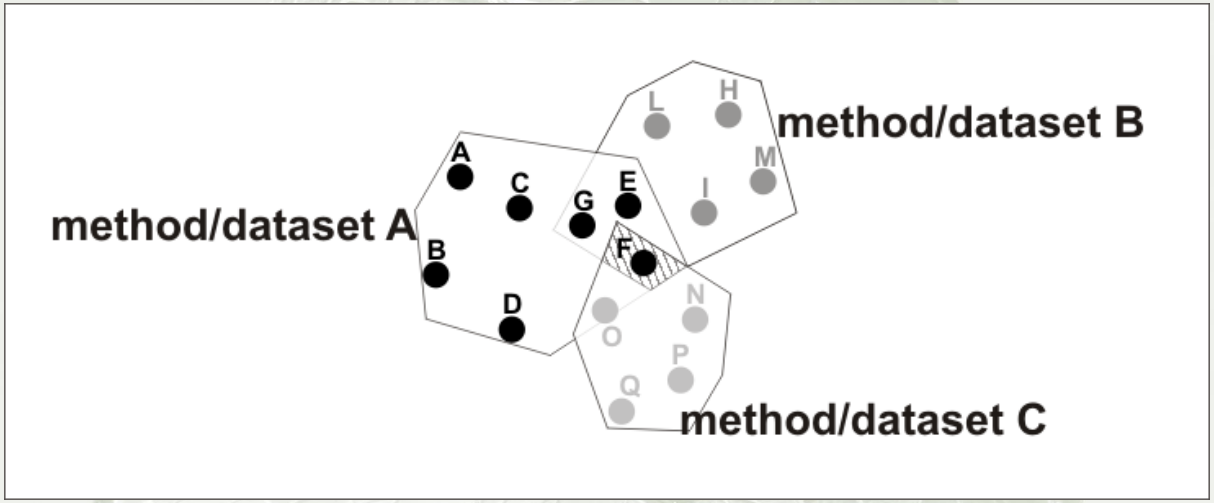


<u>The continuity of a signal does not mean that that signal pertains to a single mode.</u>

Tricky areas: the two (conflicting?) points

1. Logistical problems that prevent from using certain techniques

2. Need for various components/objective functions (to overcome ambiguities and non-uniqueness): joint analyses



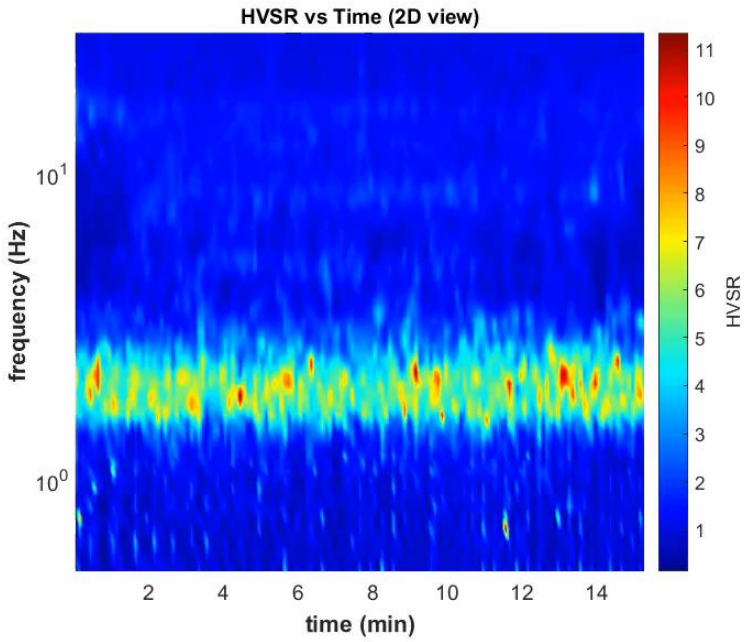
The Three Considered *Methodologies* (for 7 “objects”)

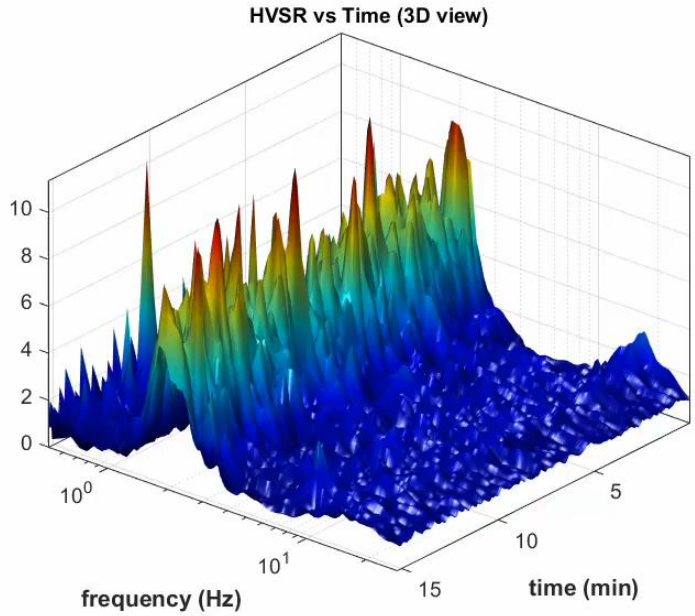
1. **HVSR (passive): *Horizontal-to-Vertical Spectral Ratio***
   [objective functions: 1]

2. **HS (active): *HoliSurface***
   [objective functions: 5]

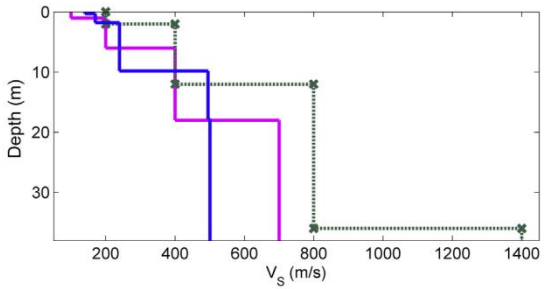
3. **MAAM (passive): *Miniature Array Analysis of Microtremors***
   [objective functions: 1]

1. HVSR (passive): *Horizontal-to-Vertical Spectral Ratio* [objective functions: 1]





HVSR: some problems
[Dal Moro, 2014]



Non-uniquness of the solution

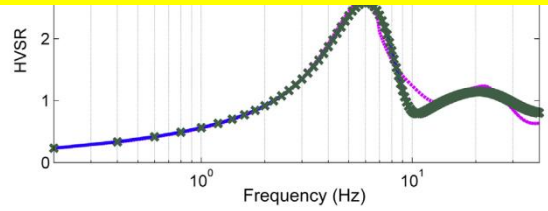
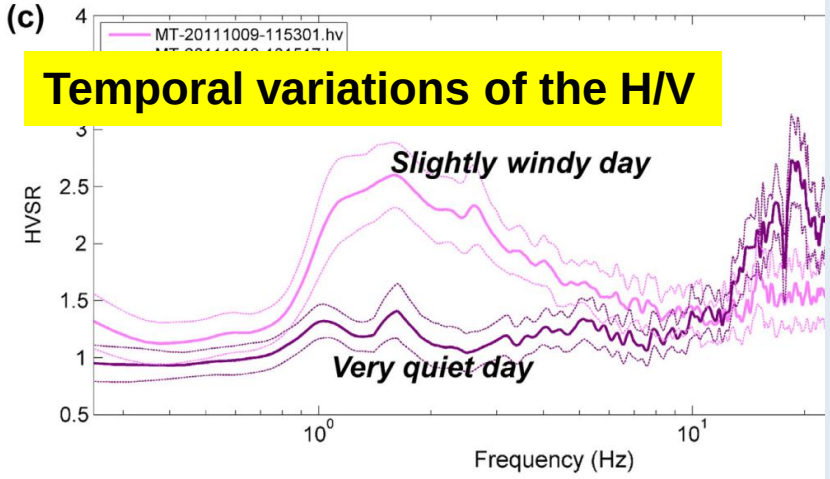


Figure 4.8 Nonuniqueness of the H/V spectral ratio (HVSR) in terms of reconstruction of the V_S profile

Temporal variations of the H/V



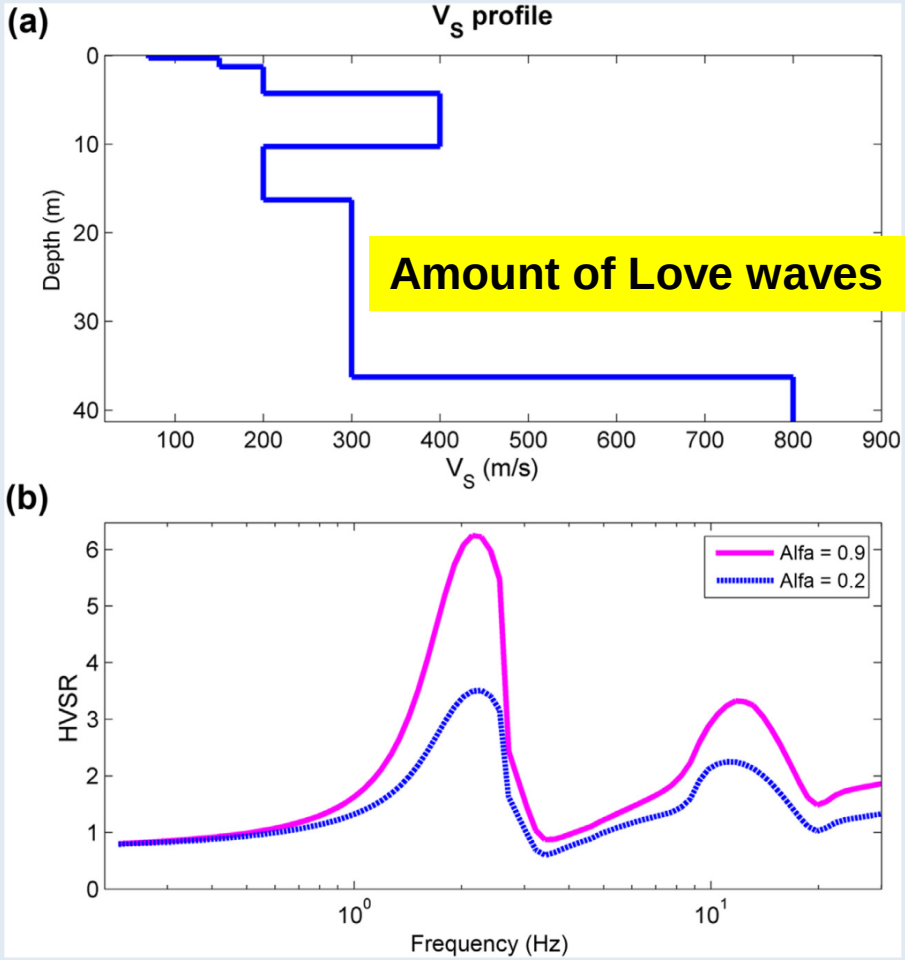
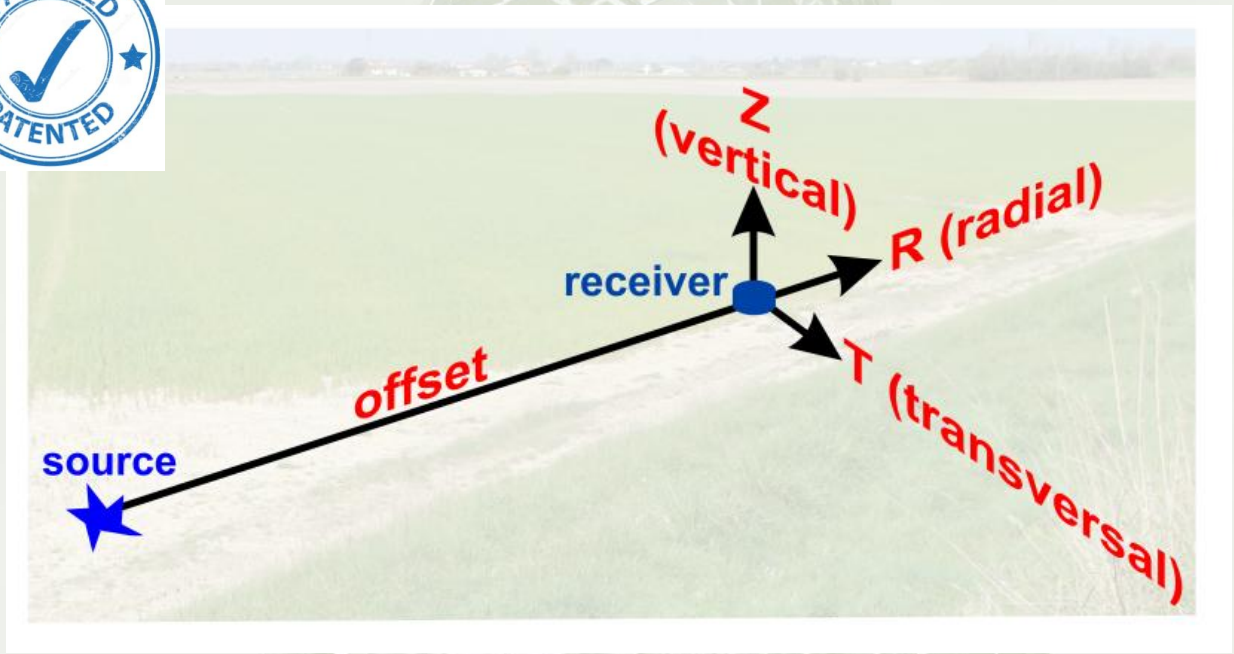


Figure 4.14 Effects of Love waves on the HVSR: (a) considered V_S profile; (b) the HVSR curves obtained while considering a different amount of Love waves (the α factor) in the microtremor field. In both cases Q_S values are fixed according to a simple rule of thumb ($Q_S = V_S/8$).

Two consequences are straightforward:

1. The amount of Love waves (synthetically expressed by the α factor) should be considered as a further variable in the inversion process aimed at determining the V_S profile (experience teaches that its value typically ranges from 0.3 to 0.6).
2. The HVSR curve alone is insufficient to properly and precisely define a V_S profile even when geological/stratigraphical information are available and, consequently, the only viable approach is represented by the joint inversion with further geophysical data (typically the dispersion curves of Rayleigh or Love waves).

2. HS (active): *HoliSurface* [objective functions: 5]



Active seismics (HS approach): the *components* acquired in case a single 3C geophone is used to record the signal(s) produced by both a Vertical and Horizontal Force (VF and HF).

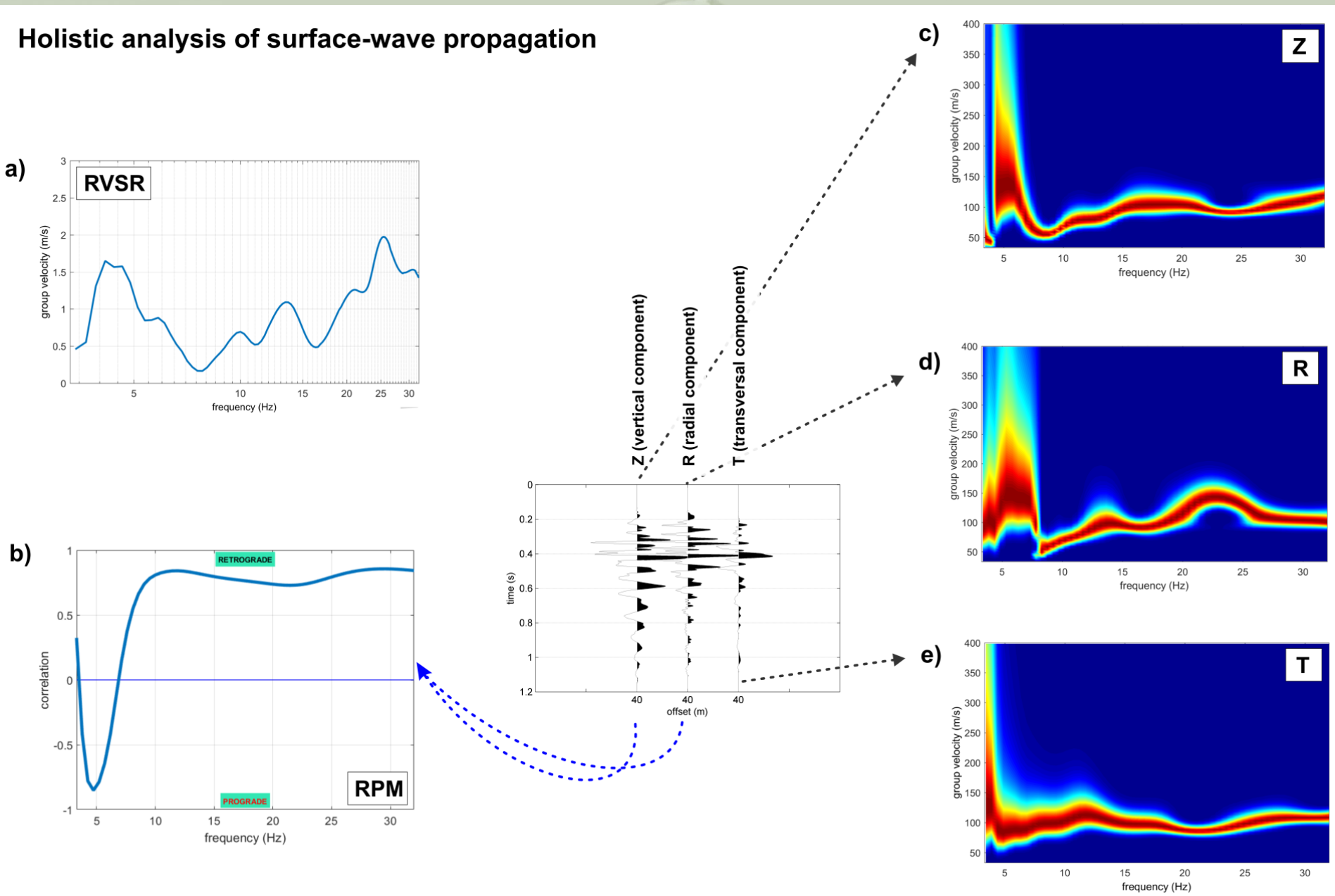
2. HS (active): *HoliSurface* [objective functions: 5]

One source

Just one receiver

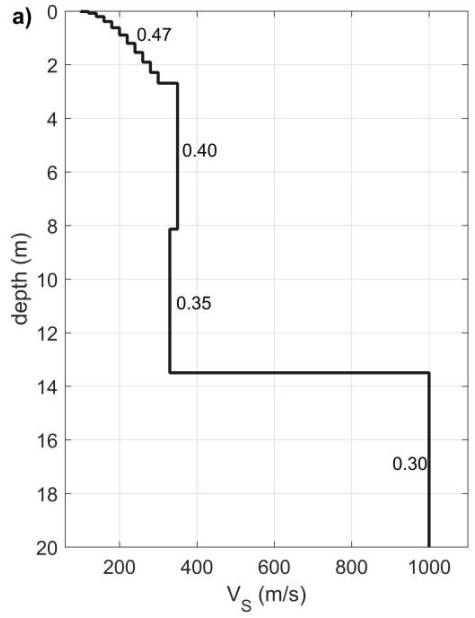
(a 3-component geophone)

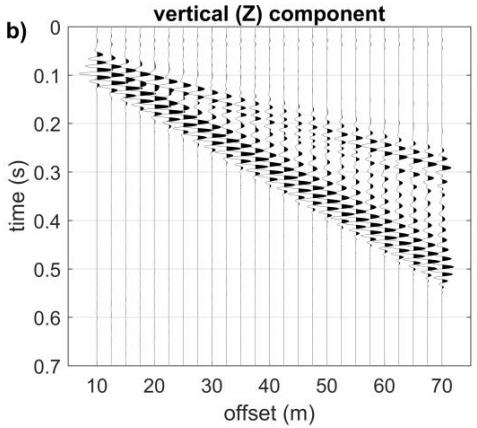
2. HS (active): *HoliSurface* [objective functions: 5]

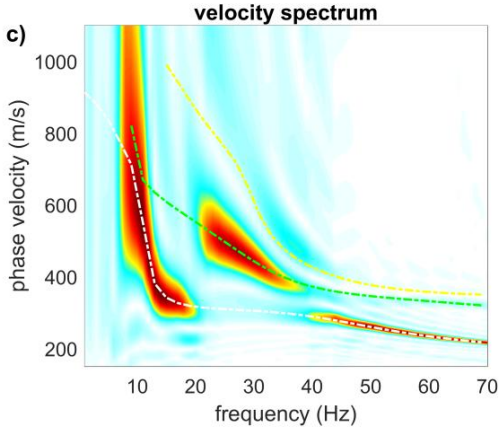


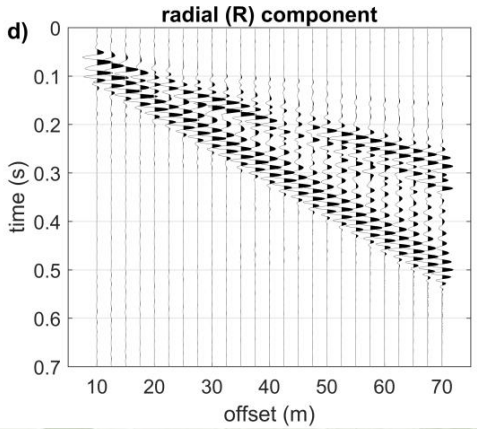
2. HS (active): *HoliSurface* [objective functions: 5]

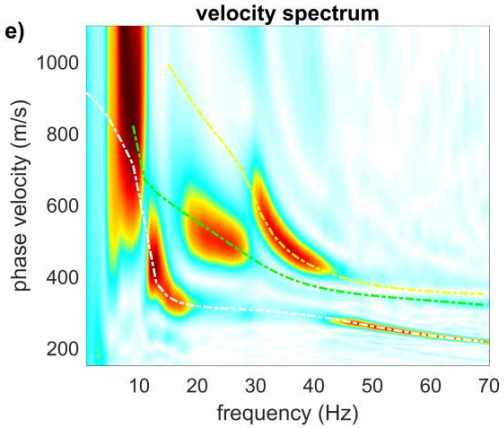
Rayleigh waves: the radial (R) and vertical (Z) components are different



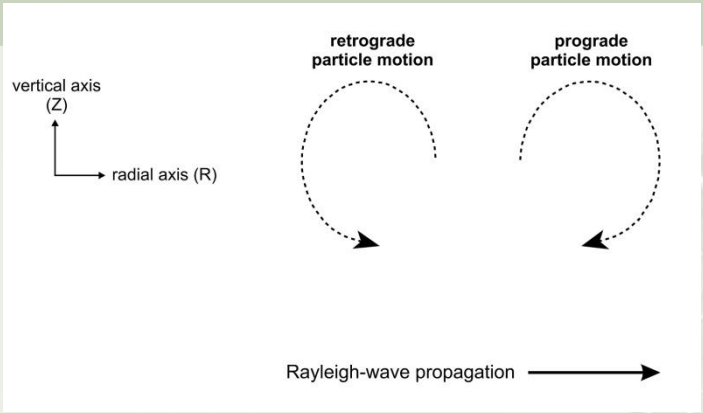




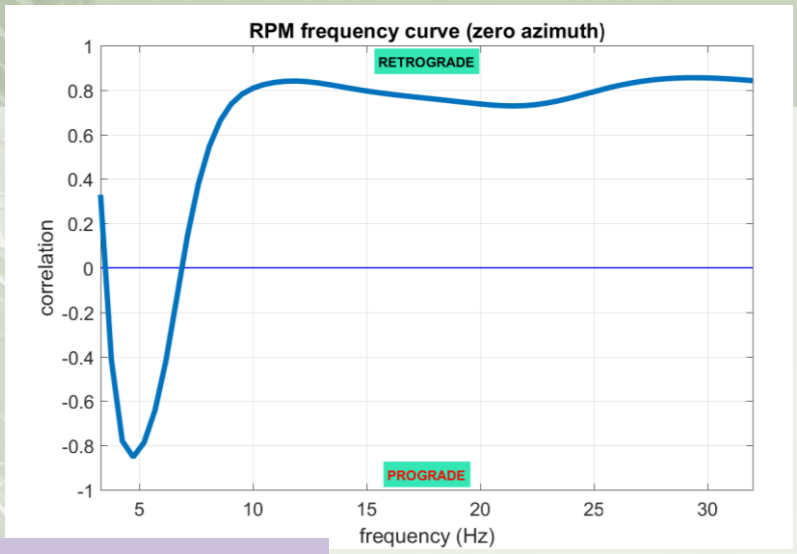




2. HS (active): *HoliSurface* [objective functions: 5]



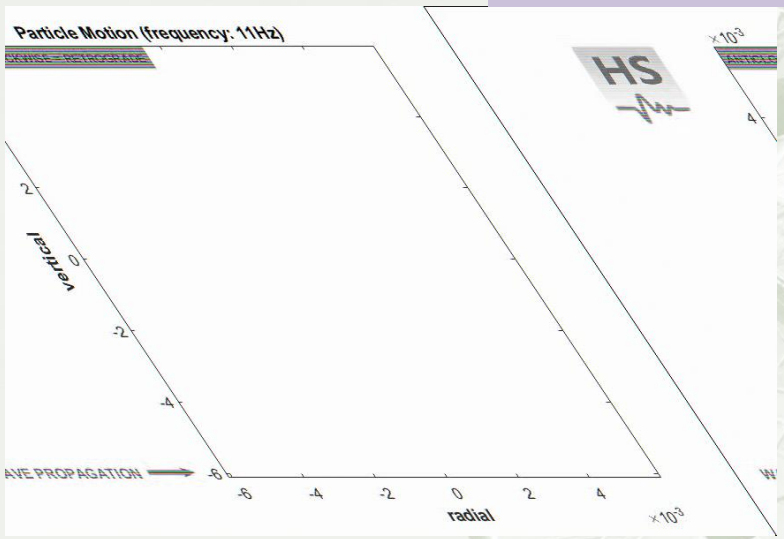
RPM frequency curve (Dal Moro et al., BSSA - 2016)

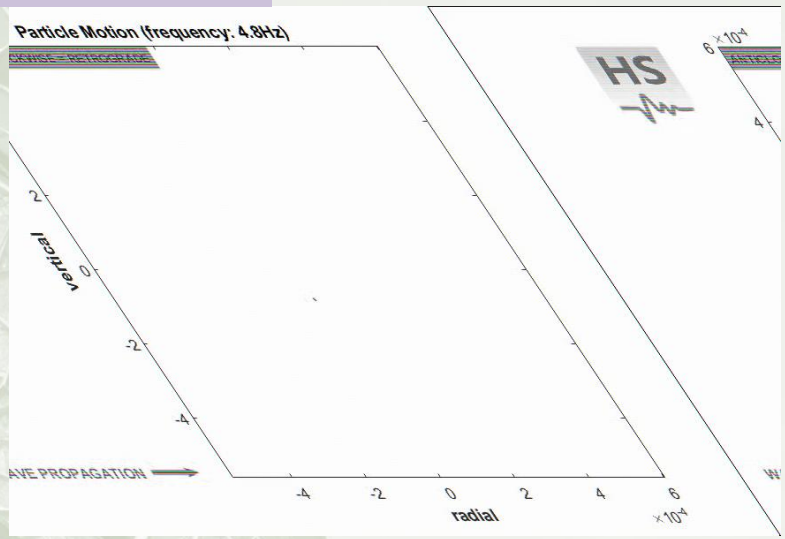


11Hz (retrograde)

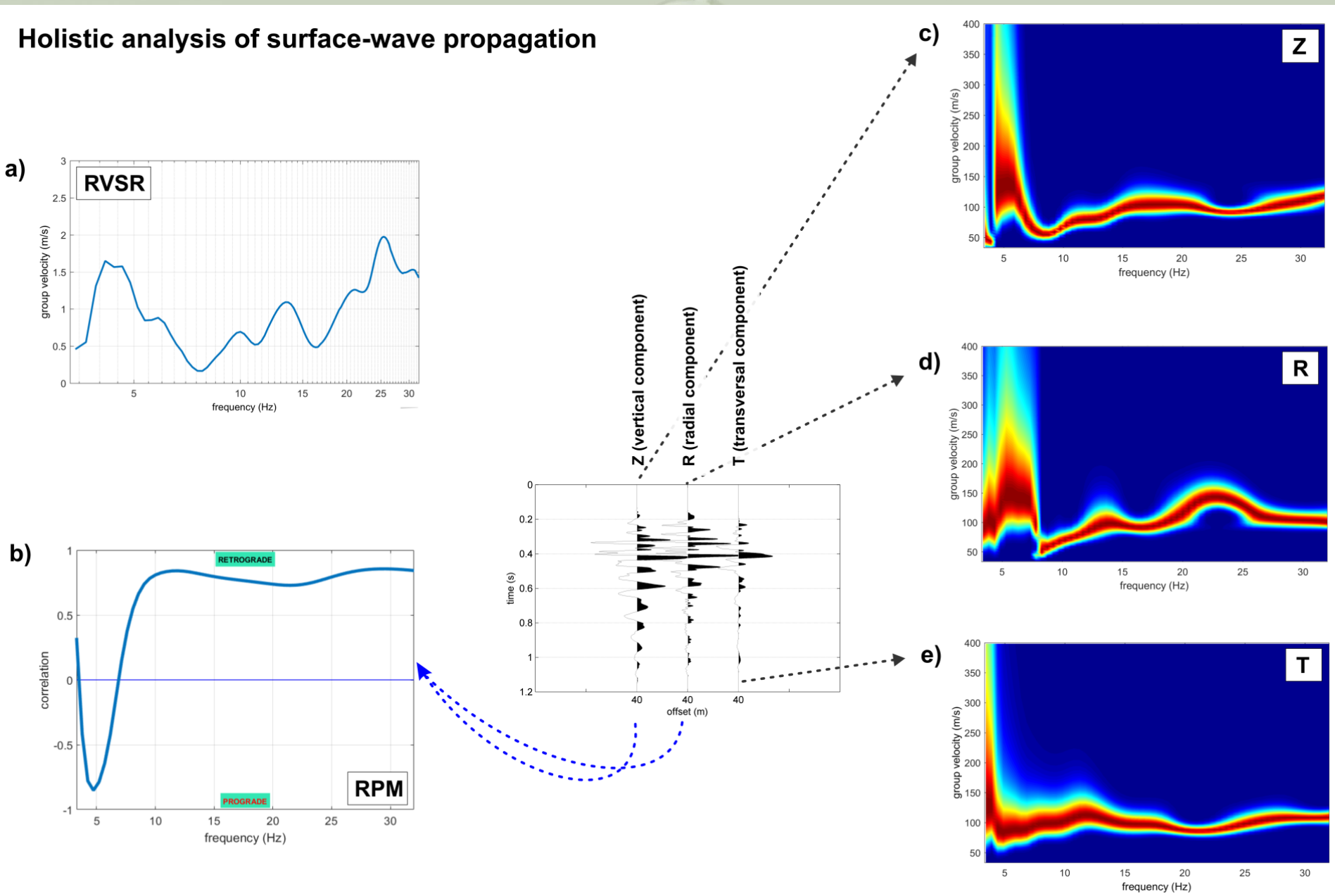
video animations (field dataset)
[available on request or see the BSSA paper]

4.8Hz (prograde)

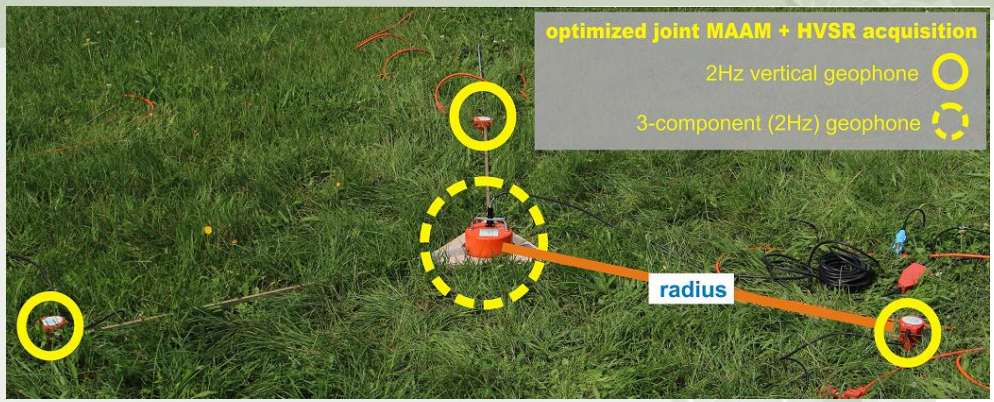


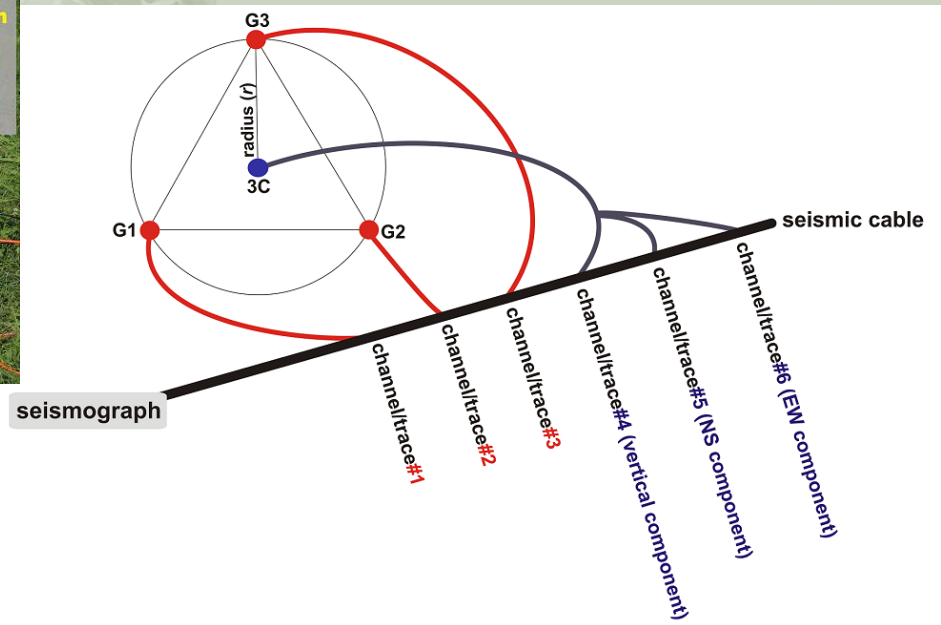


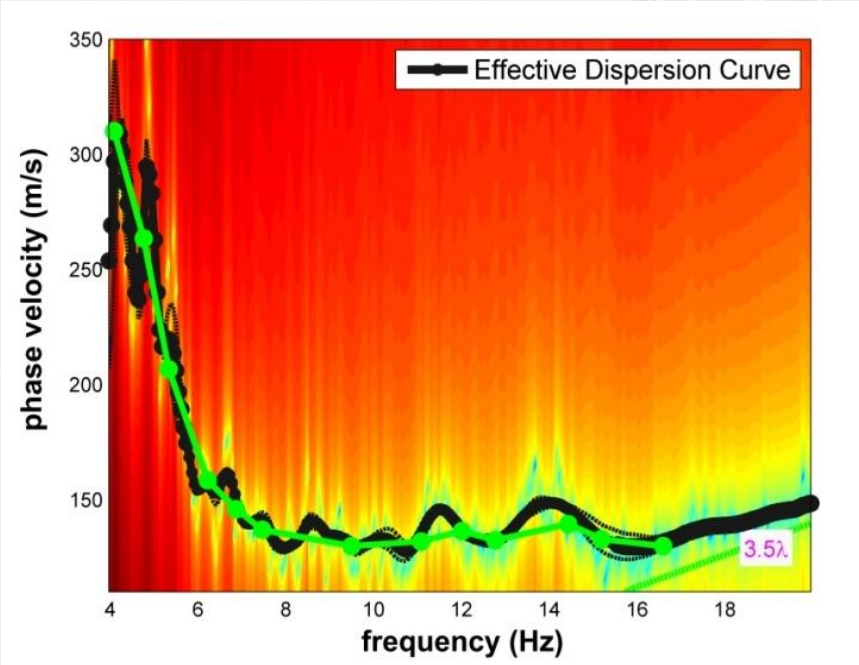
2. HS (active): *HoliSurface* [objective functions: 5]

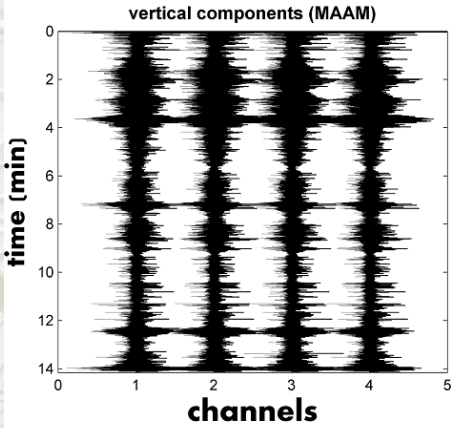


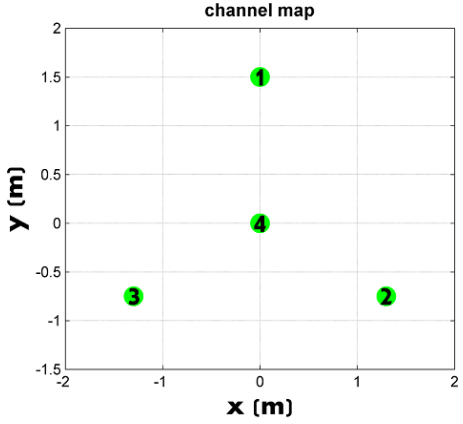
3. MAAM (passive): *Miniature Array Analysis of Microtremors* [objective functions: 1]











Noise and Joint Analysis: two quick notes

1. What is *noise*?

Noise **is everything that is in our data (and that influences your analyses) while we would like not be there.**

Does the expression “ambient noise” make thus really sense?

2. Joint inversion is necessarily a *compromise.*

Case study#1

The acquisition parameters

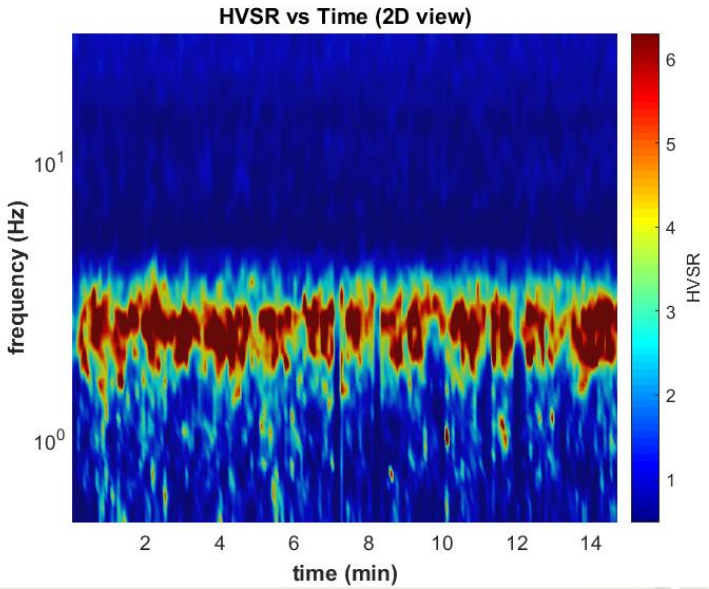
sampling rate	4 ms (Nyquist frequency 125 Hz)
acquisition length	30 min
radius	2 + 5 m
sensors	four vertical 4.5Hz geophones

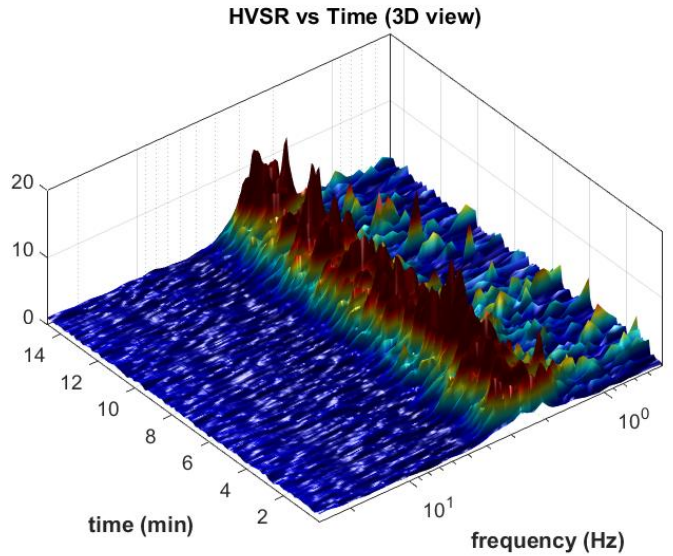
MAAM acquisition parameters

sampling rate	1 ms (1000 Hz)
acquisition length	1 s
offset (m)	40
sensor	one 3-component 2Hz geophone
stack	4

HS acquisition parameters

HVSR data





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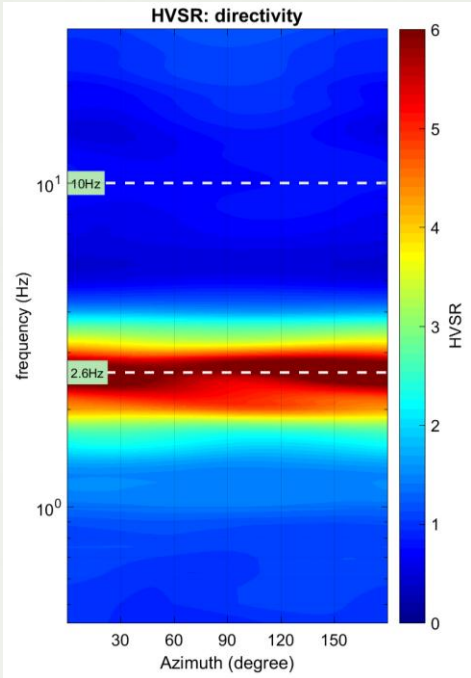
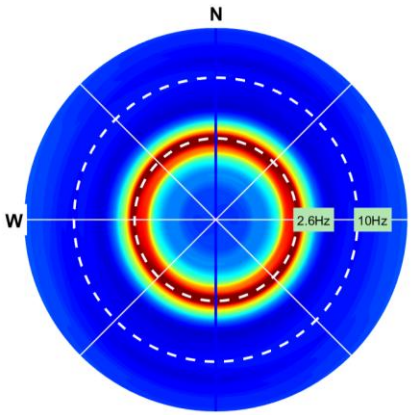
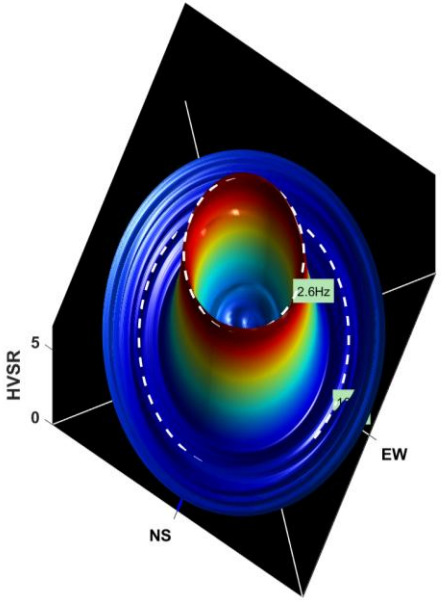
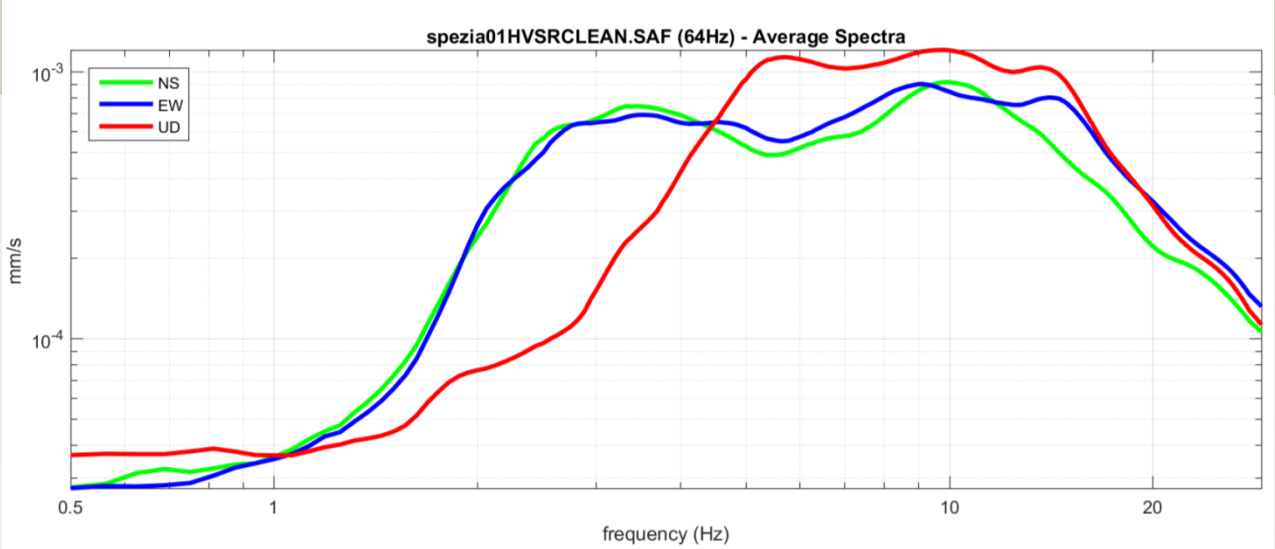






no directivity

HVSR


spezia01HVSRCLEAN.SAF (64Hz) - Average Spectra
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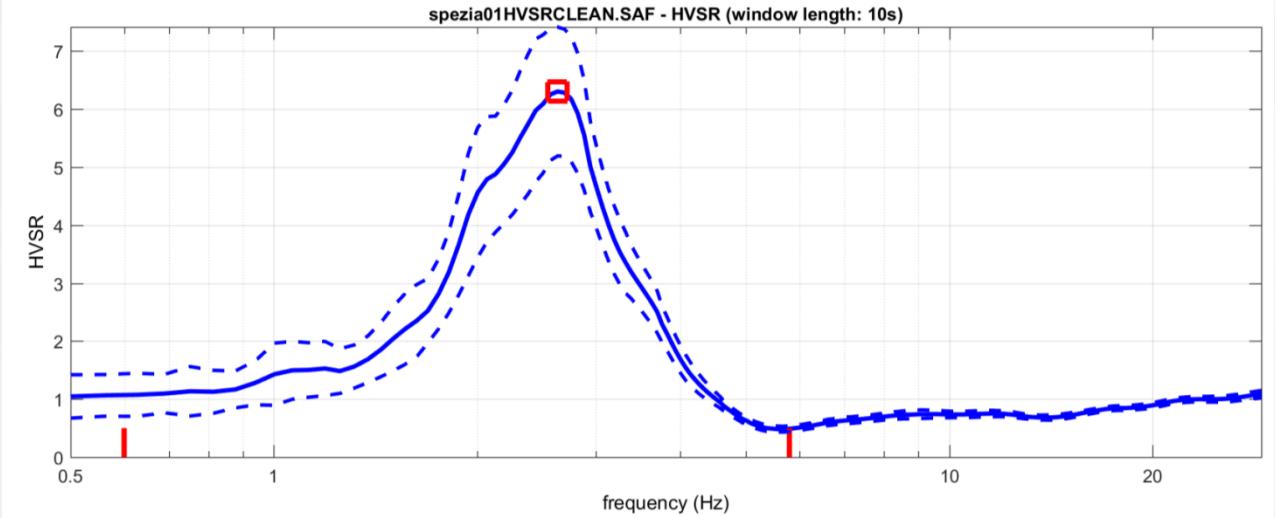
frequency (Hz)


spezia01HVSRCLEAN.SAF - HVSR (window length: 10s)
HVSR
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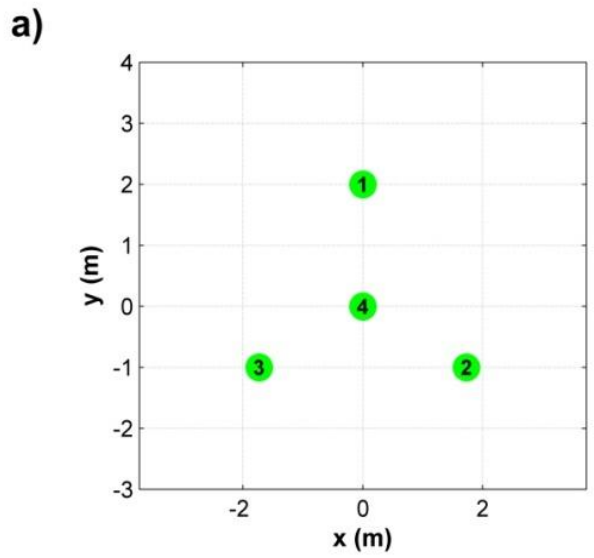
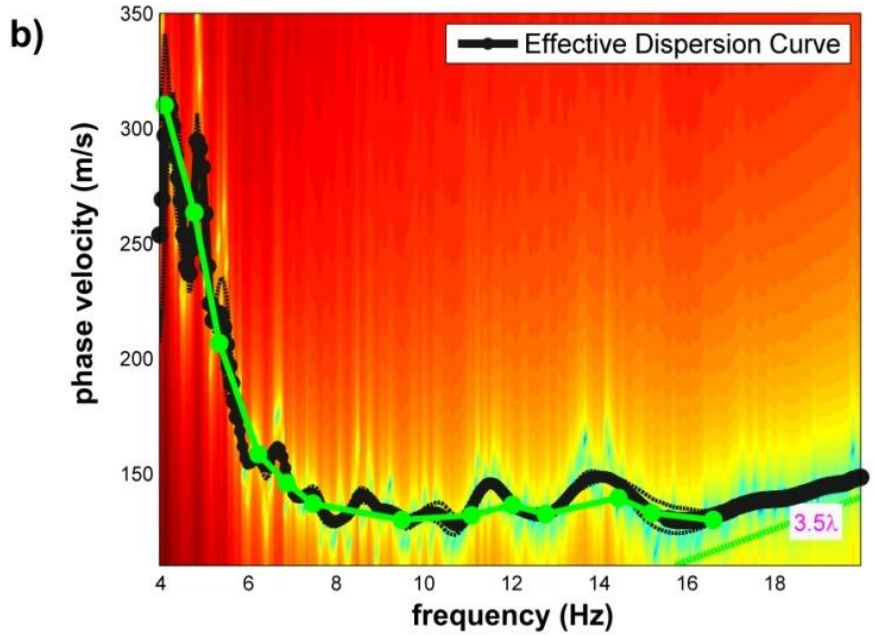
frequency (Hz)

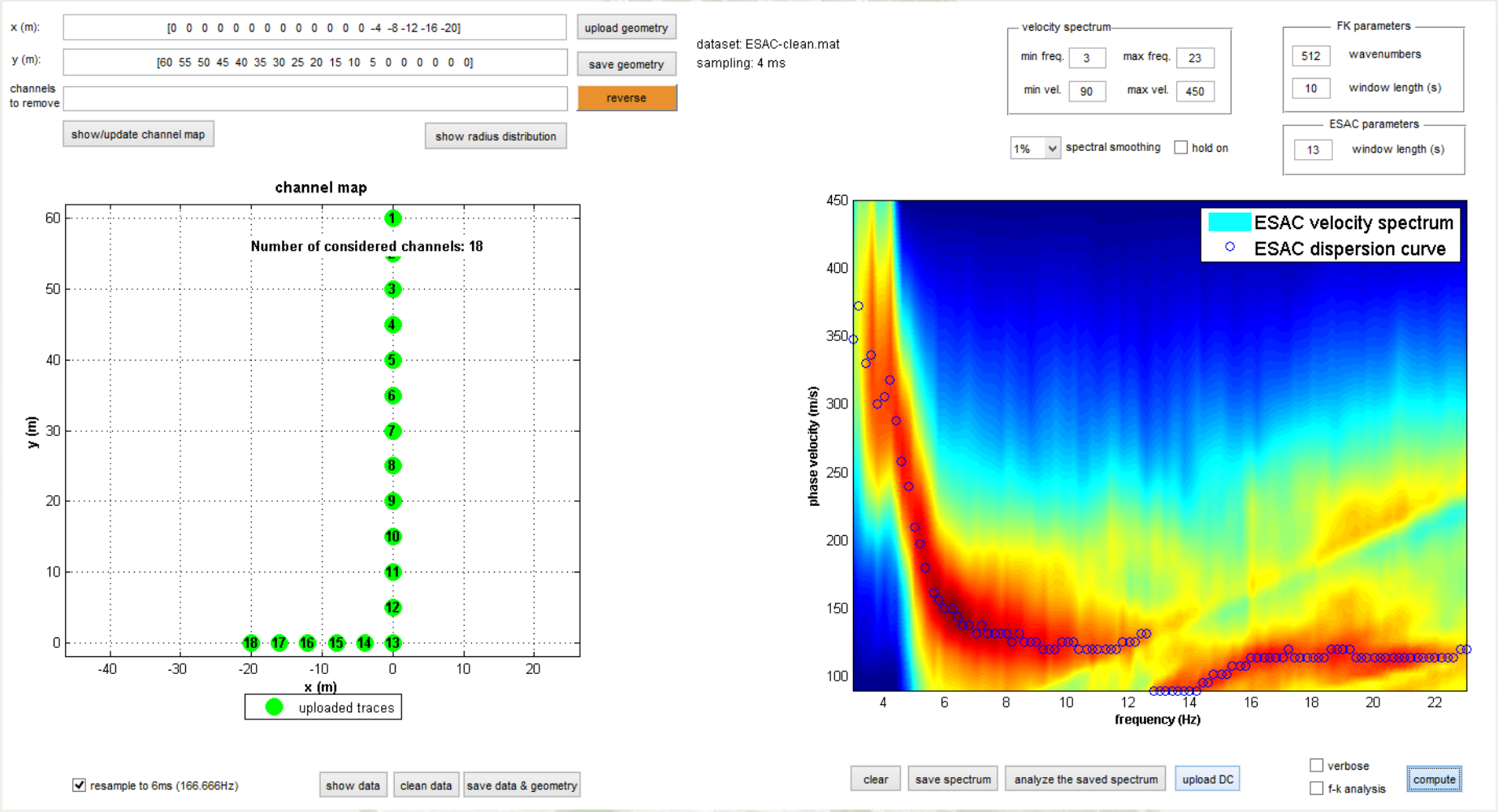
MAAM





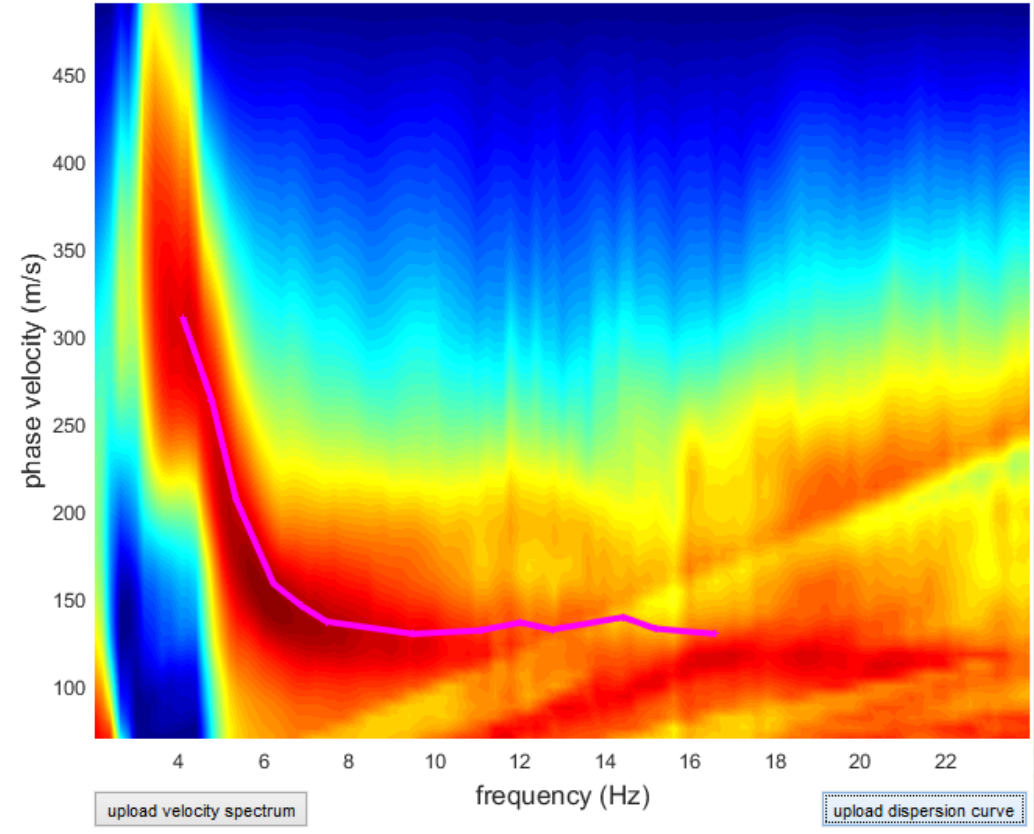
MAAM (passive seismics): a) acquisition setting (in this case the four vertical-component geophones are along a 2m-radius circle); b) Rayleigh-wave effective (Tokimatsu et al., 1992) dispersion curve (vertical component) determined while considered the data acquired for the present case study.

Validation: comparing MAAM and ESAC



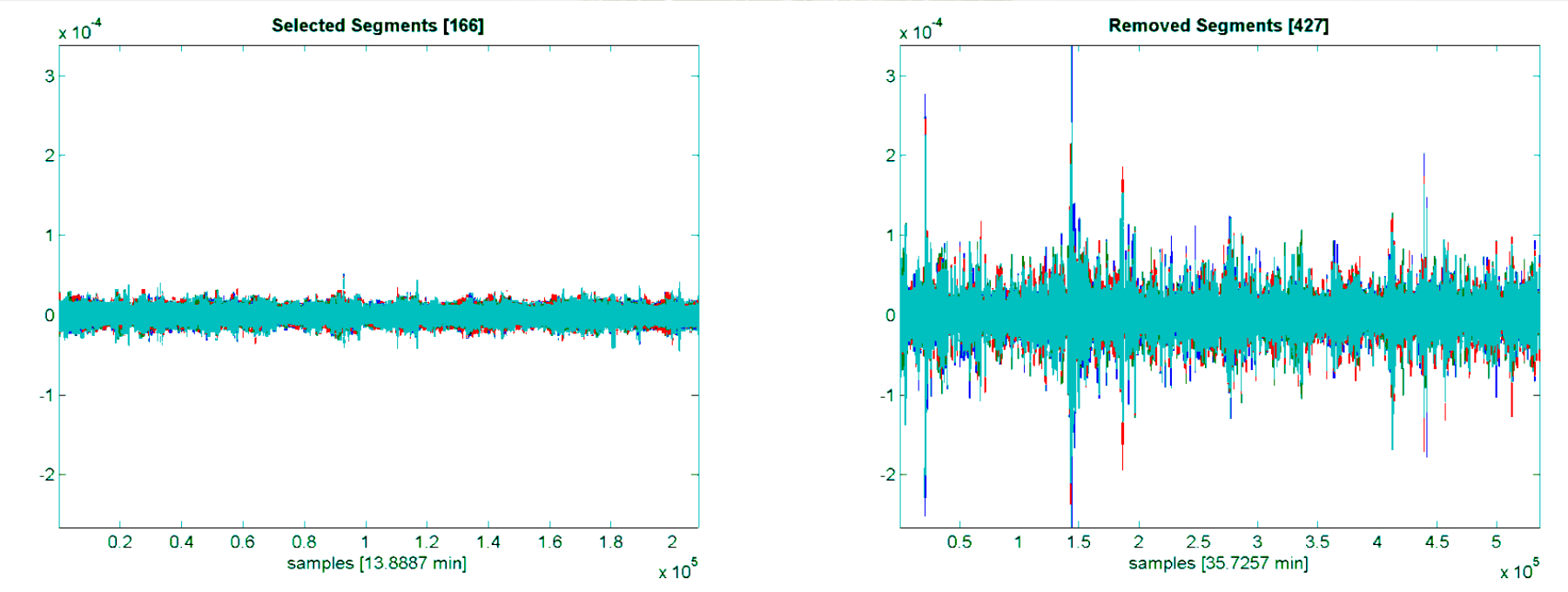
Validation: comparing MAAM and ESAC

In the background the ESAC velocity spectrum and, overlaying, the MAAM (effective) dispersion curve.



Critical points in the MAAM analysis:

- Acquisition: necesary a very low amount of “electronic” noise
- Choosing the maximum amplitude of the considered segments



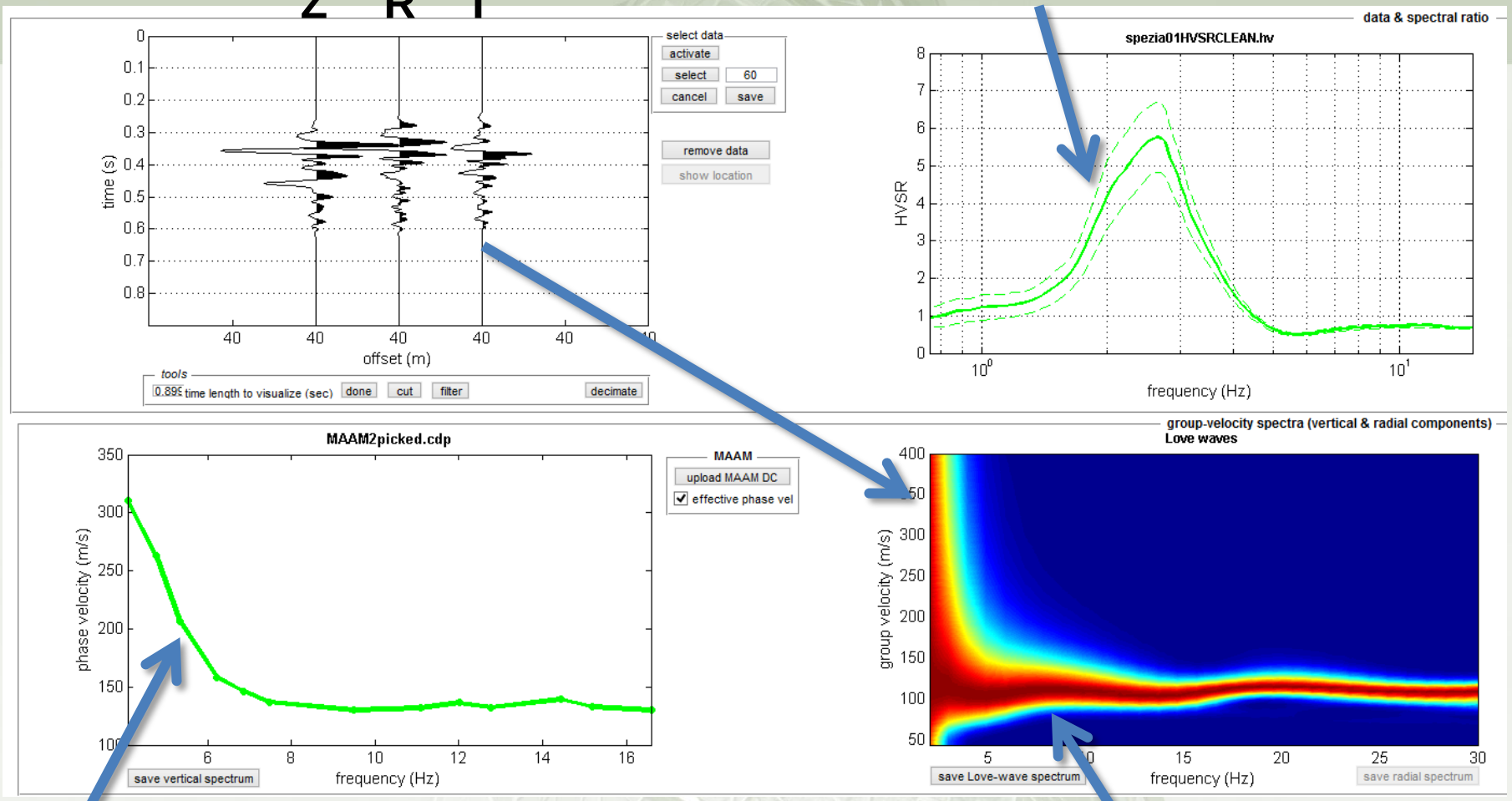
Joint (Multi-Objective) Analysis:

HVSR: alfa (α) parameters as variable

Active data (Rayleigh- and Love-wave group velocity spectra): FVS approach

Effective dispersion from MAAM: effective Z-component (Tokimatsu et al., 1992)

A joint analysis: the DATA

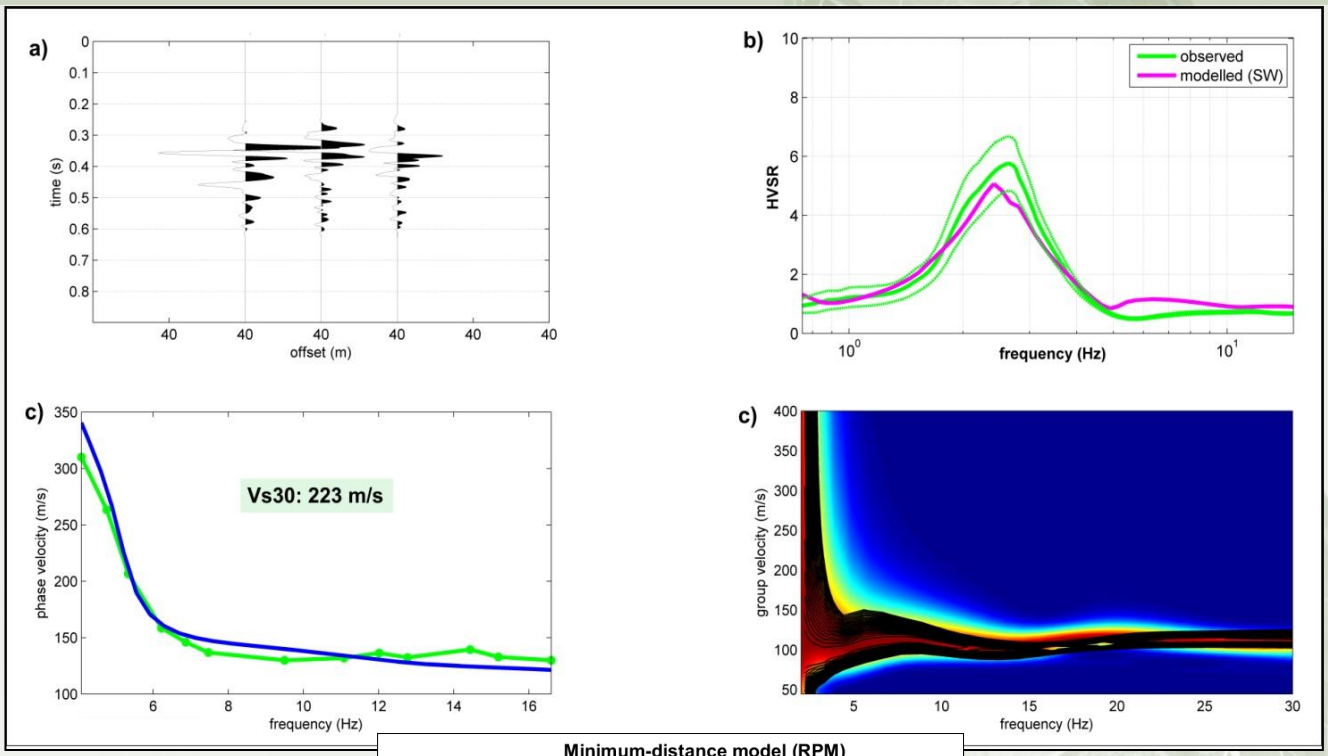


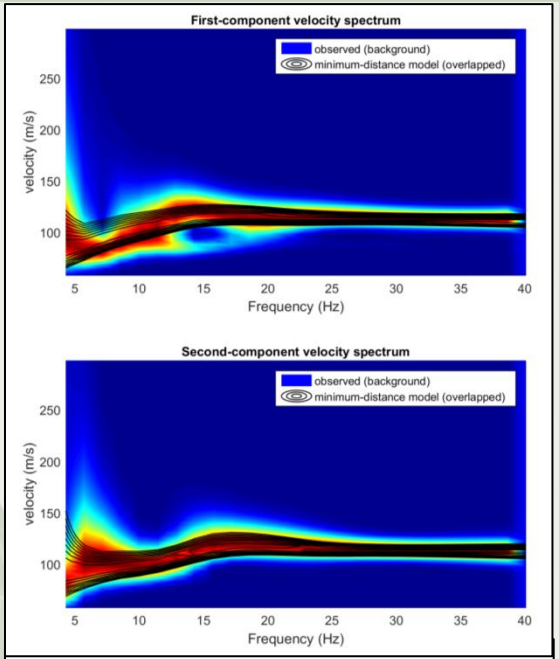
Rayleigh-wave effective dispersion curve (Z component) from MAAM

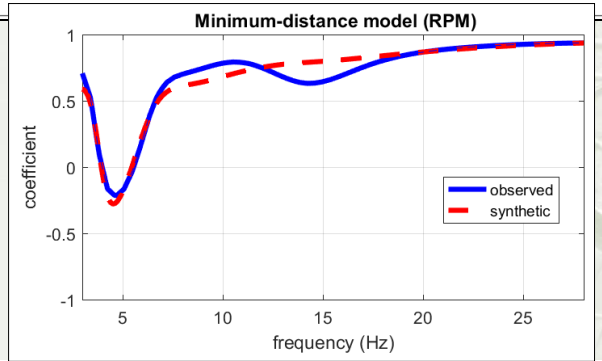
THF – Love waves (group velocity spectrum)

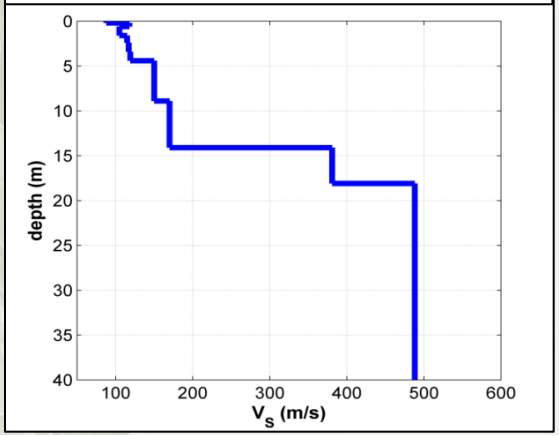
A joint analysis: the results

Joint analysis of the five here-considered components: a) acquired active traces (vertical, radial and transversal components); b) field and synthetic HVSR curves; c) field (from MAAM) and synthetic Rayleigh-wave (vertical component) effective dispersion curves; d) field (background colors) and synthetic (overlain black contour lines) Love-wave group velocity spectra from the active acquisition (FVS analysis). Also shown the ZVF and RVF velocity spectra.



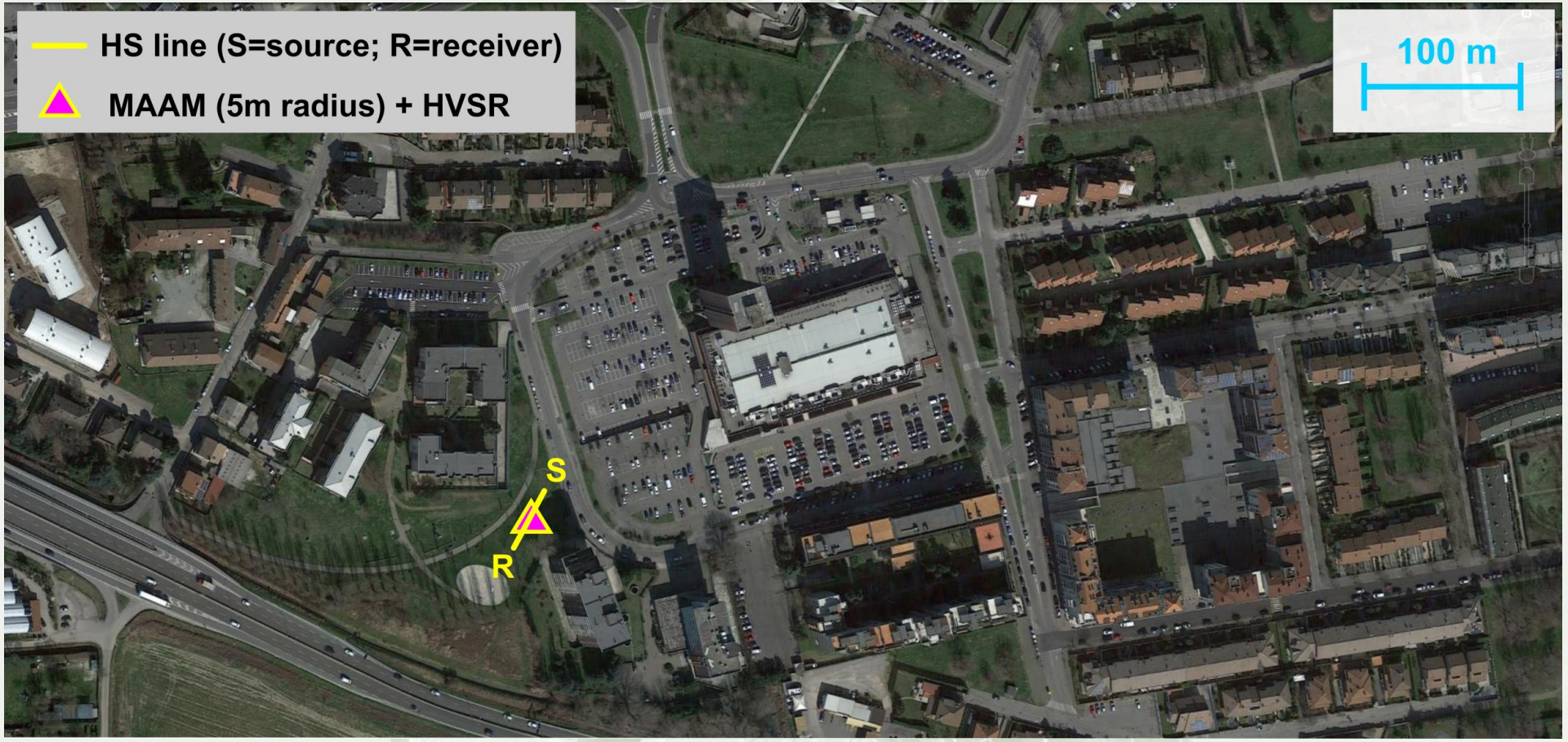






Case study#2 (a bit dirtier data)

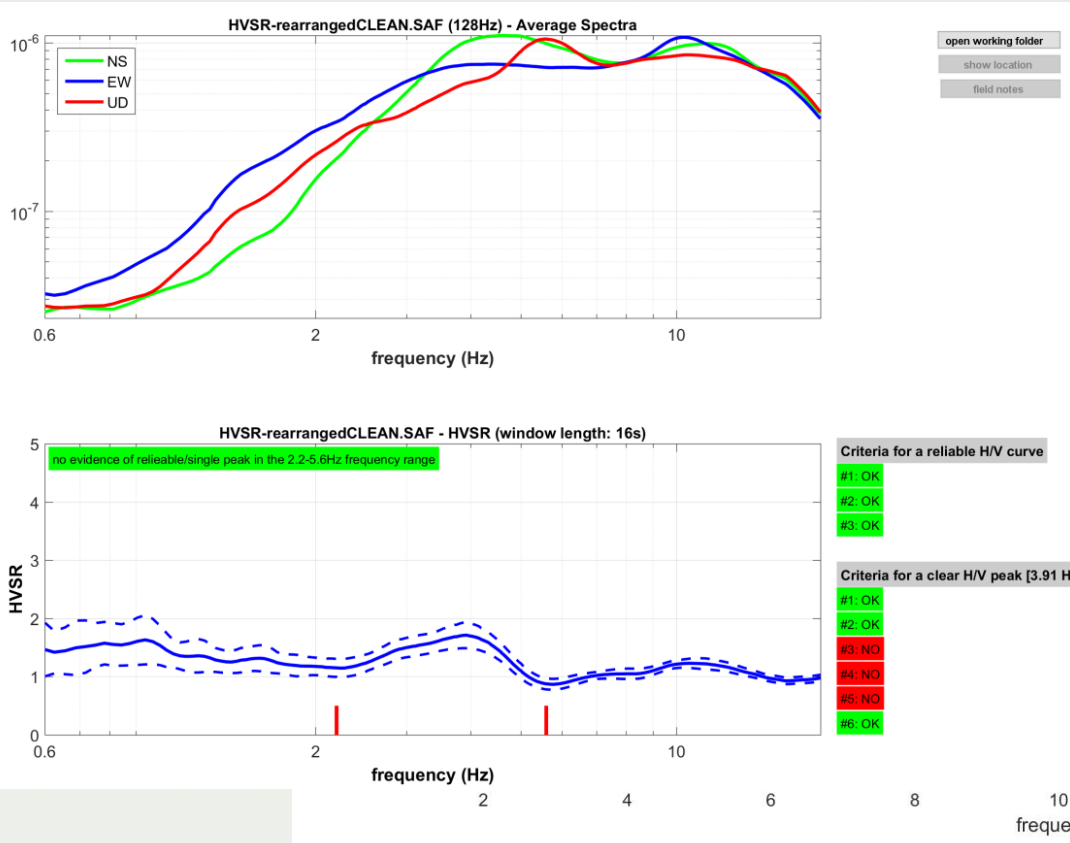
Location

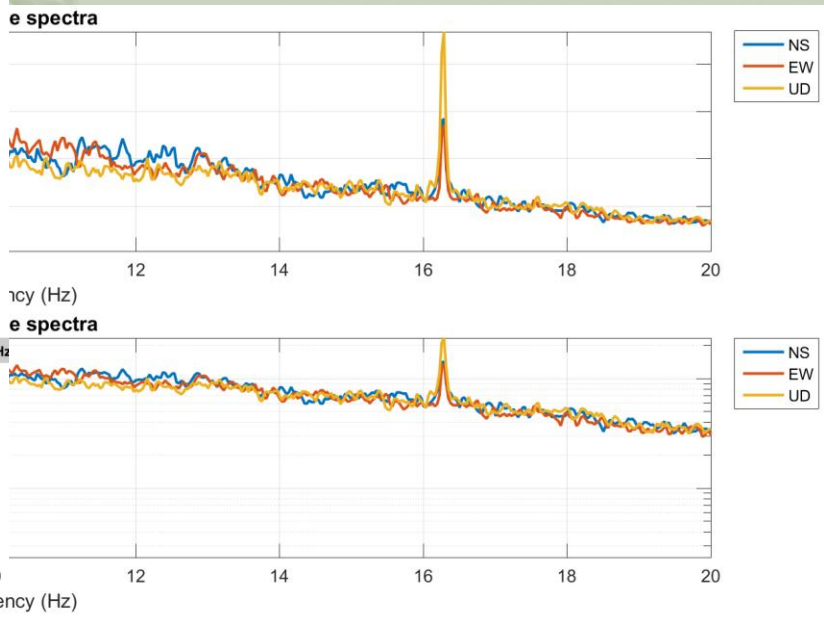


Location

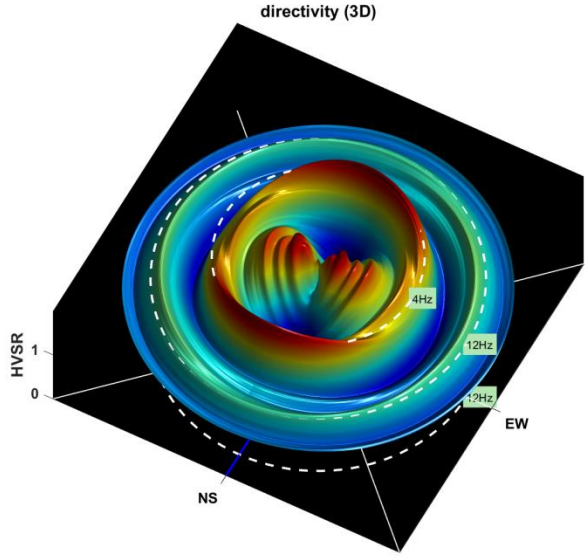

Fai clic per passare da Street View alla visualizzazione del livello suolo e viceversa
Esci da Street View
© 2016 Google
Google earth
Segnala un problema
Data di acquisizione delle immagini: 10/2015 45°18'02.74"N 9°29'29.37"E elev 119 m alt 78 m

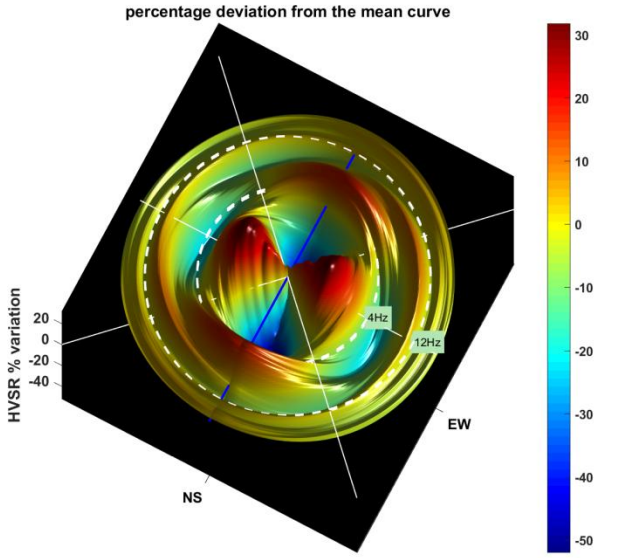
HVSR

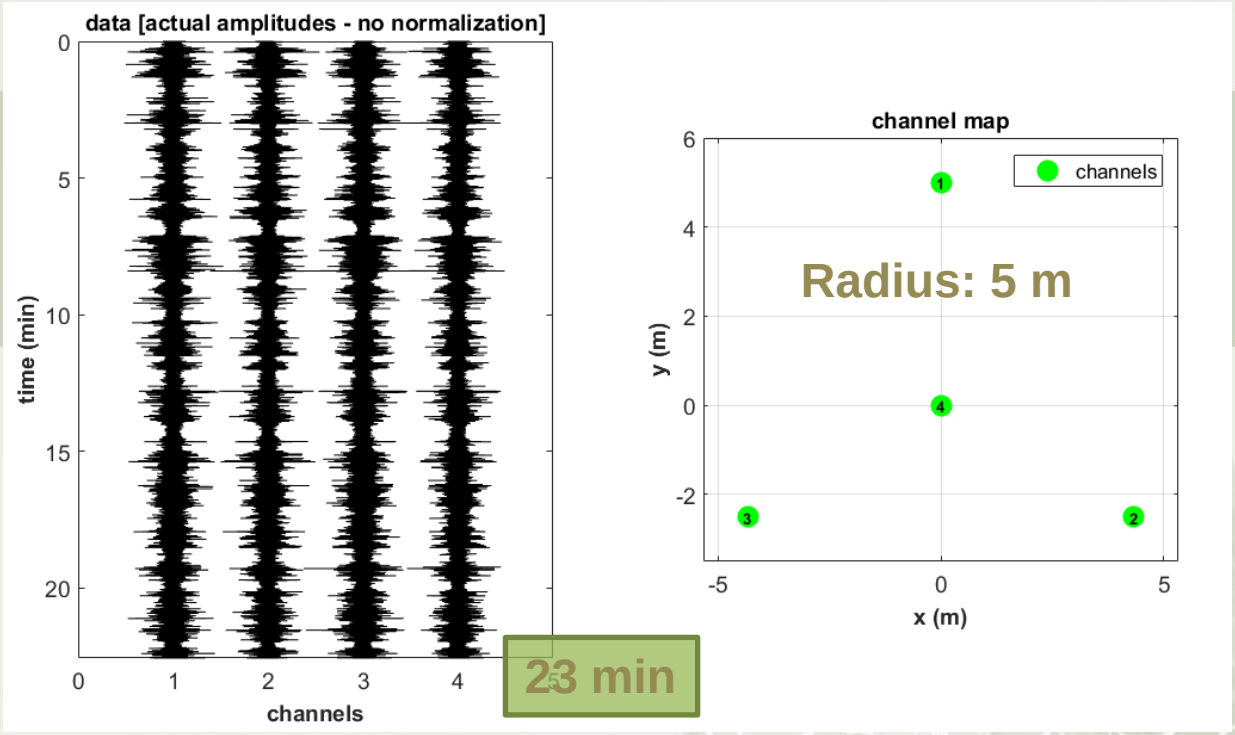




The 4Hz "peak" is azimuthally quite homogeneous, while the lower frequencies…

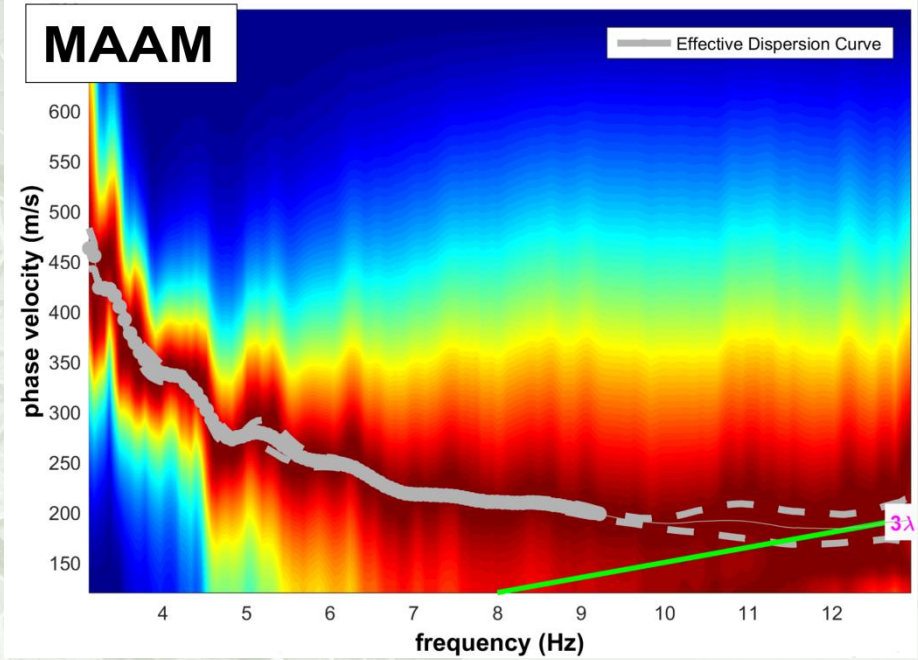






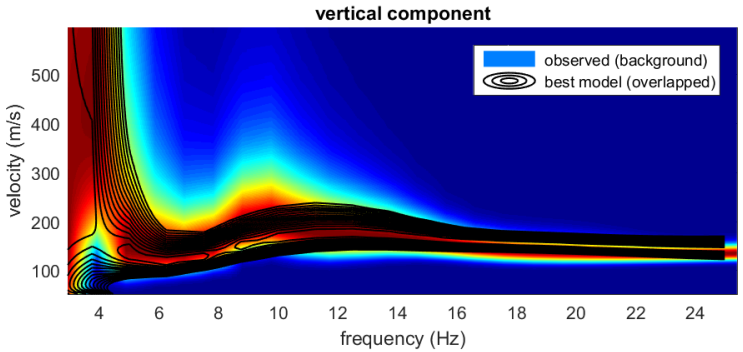
MAAM

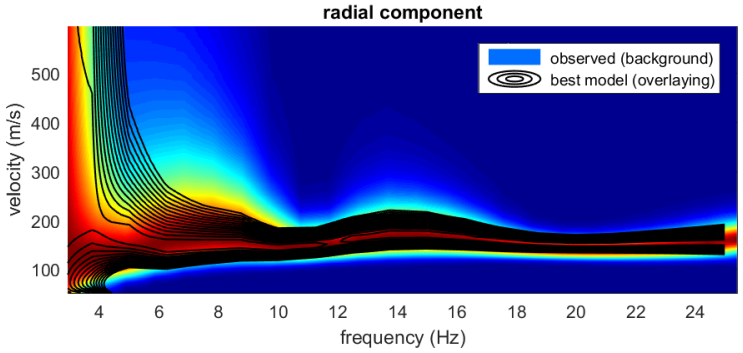
Please, notice the consistency of the trace amplitudes

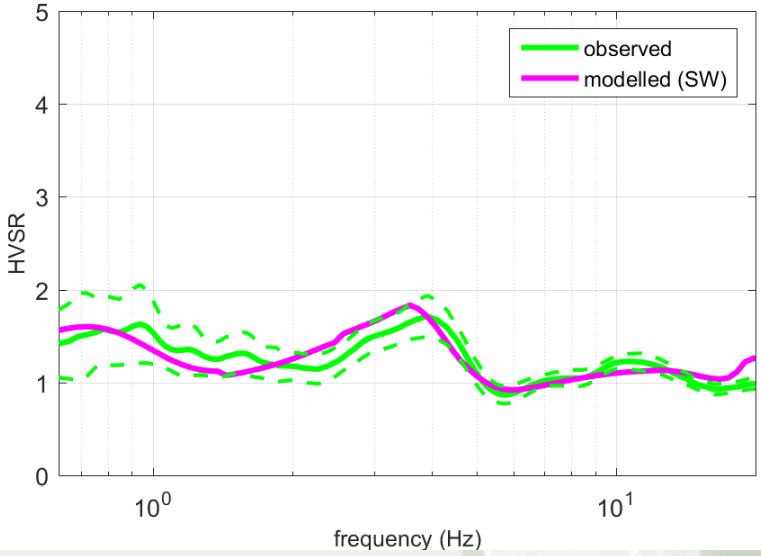


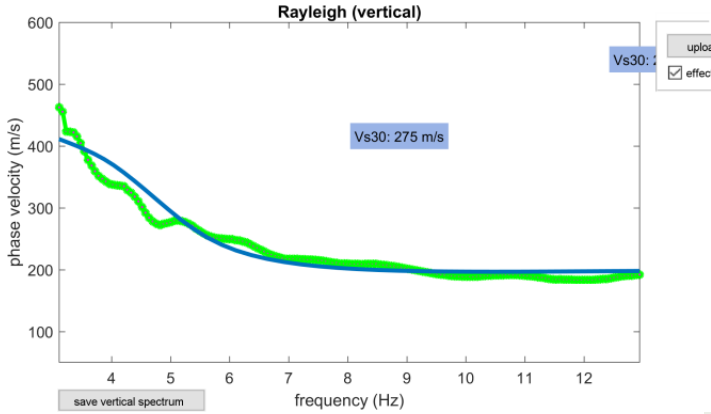
Rayleigh-wave (vertical component) effective dispersion curve

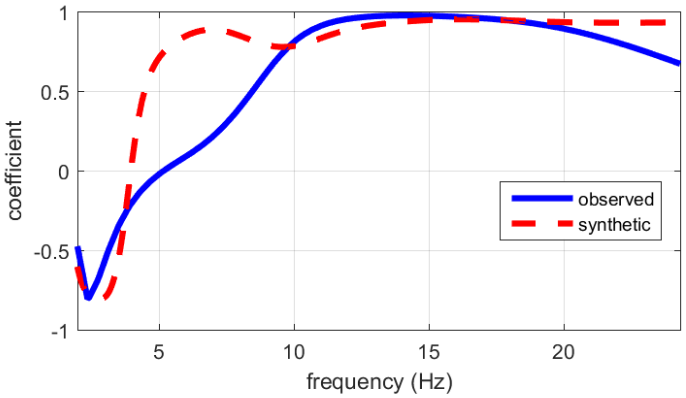
Joint Analysis

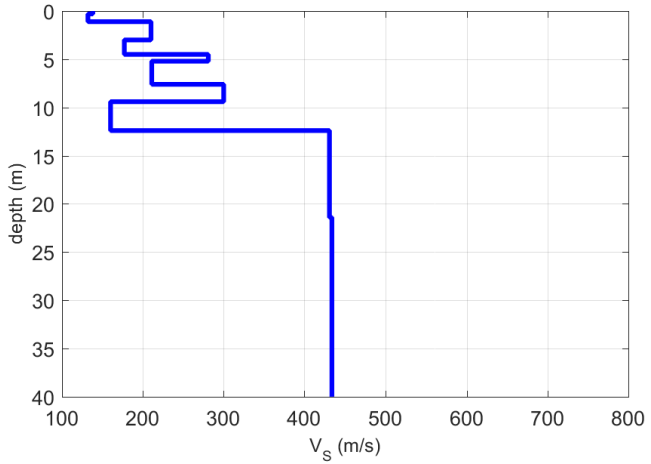












Some conclusive points [1/3]

- **A careful use of a limited number of geophones (three vertical + one 3-component) and appropriate acquisition procedures (that require a limited field effort) can provide data suitable for the characterization of urban or remote/complex regions.**

- **The analysis performed according to the considered techniques (HS, MAAM and HVSR) impose a clear and deep understanding of a number of issues related to the malicious role of possible noise components**

- **In some cases, in order to avoid exceedingly pervasive noise related to the human and industrial activities, data acquisition could be accomplished during night time and/or in the weekends.**

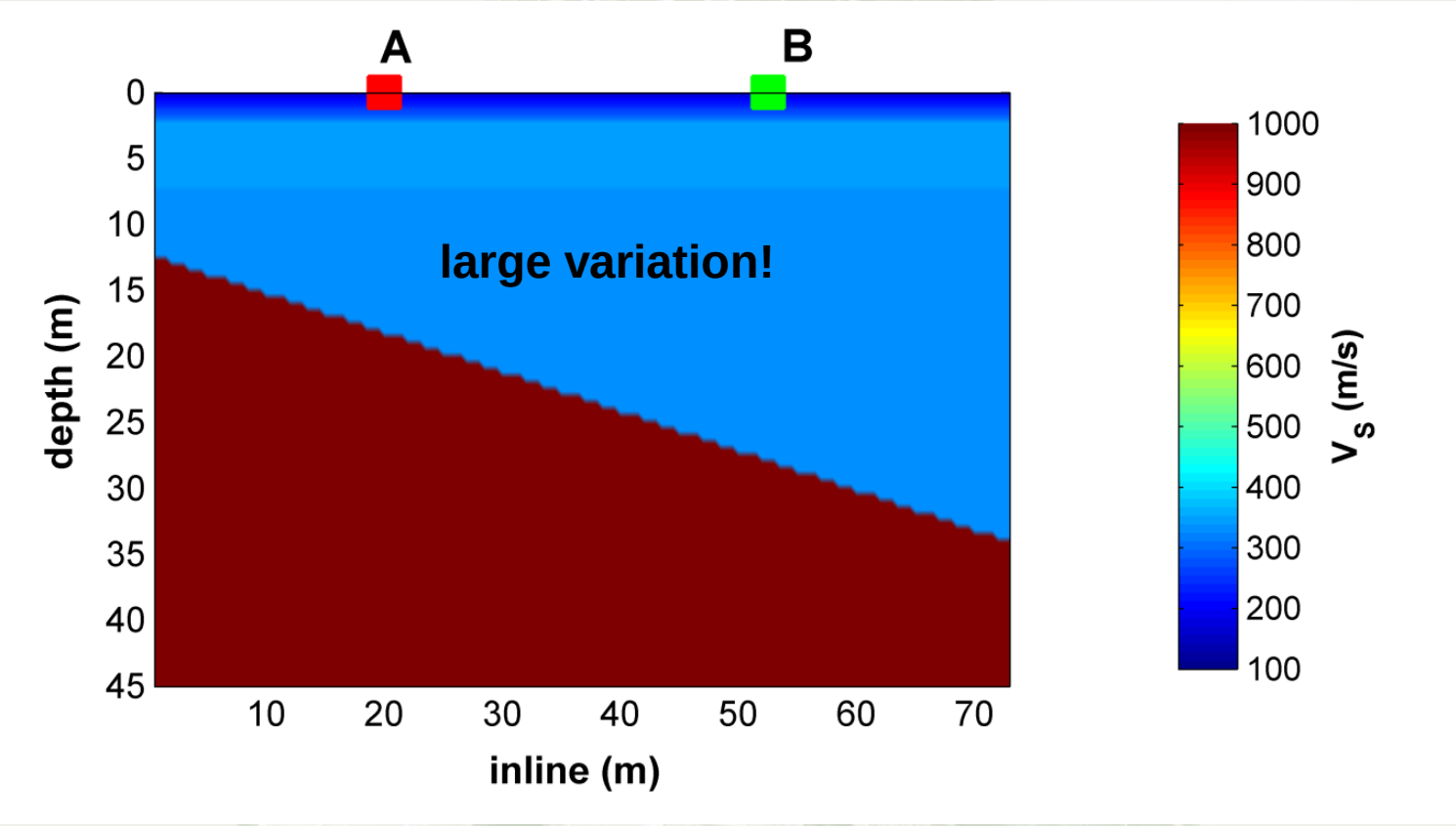
- **HS (as MASW, ESAC etc) relates to the average conditions between the *Source* and the *Receivers***

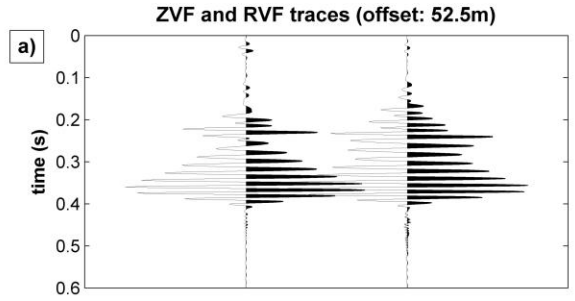
- **RVSR or RPM frequency curve?**

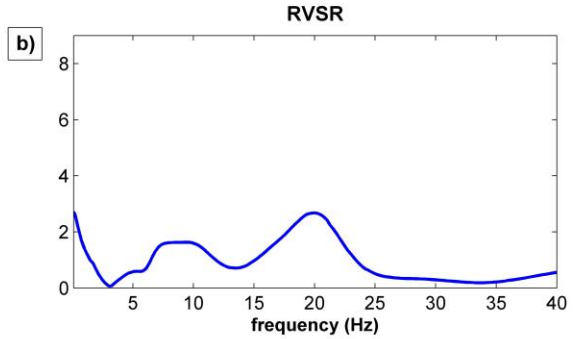
RVSR: extremely (too?) sensitive;
RPM: less sensitive but more stable

Some conclusive points [2/3]

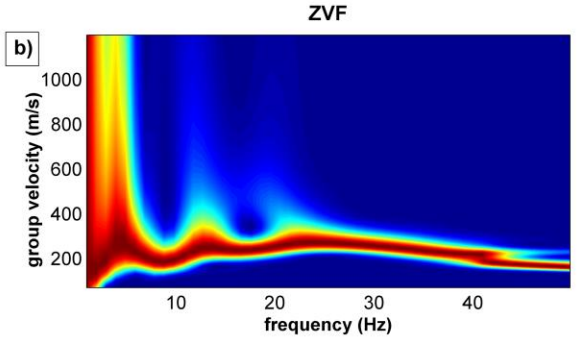
➢ **Verifying lateral variations via HS by swapping the Source & Receiver positions**

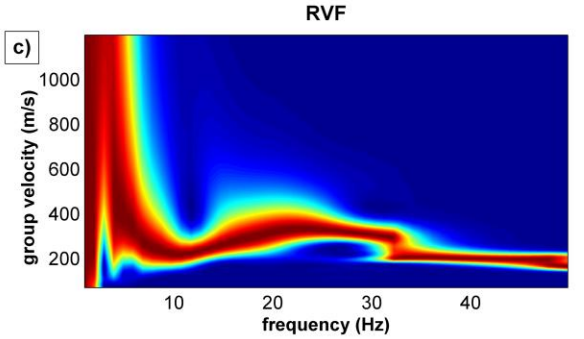




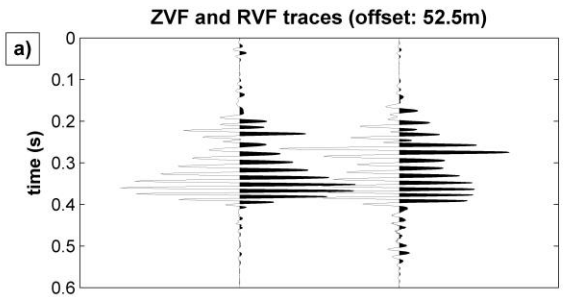


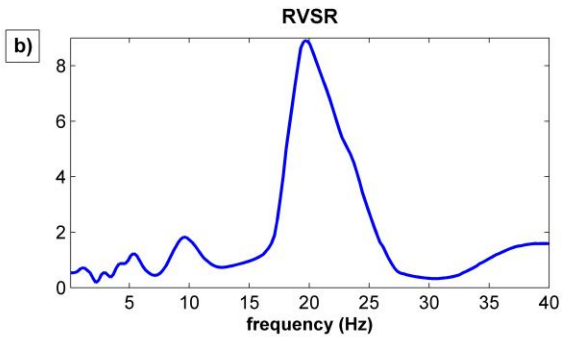
large lateral variations



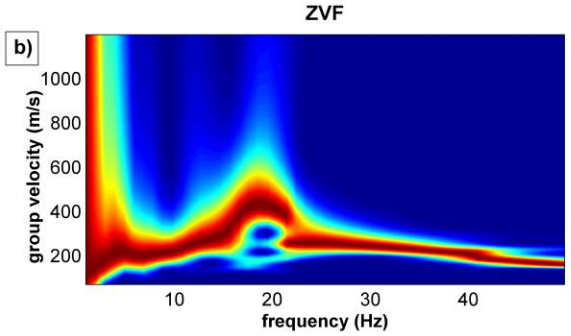


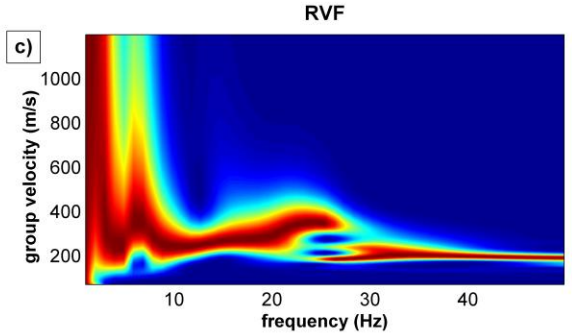
direct





reverse

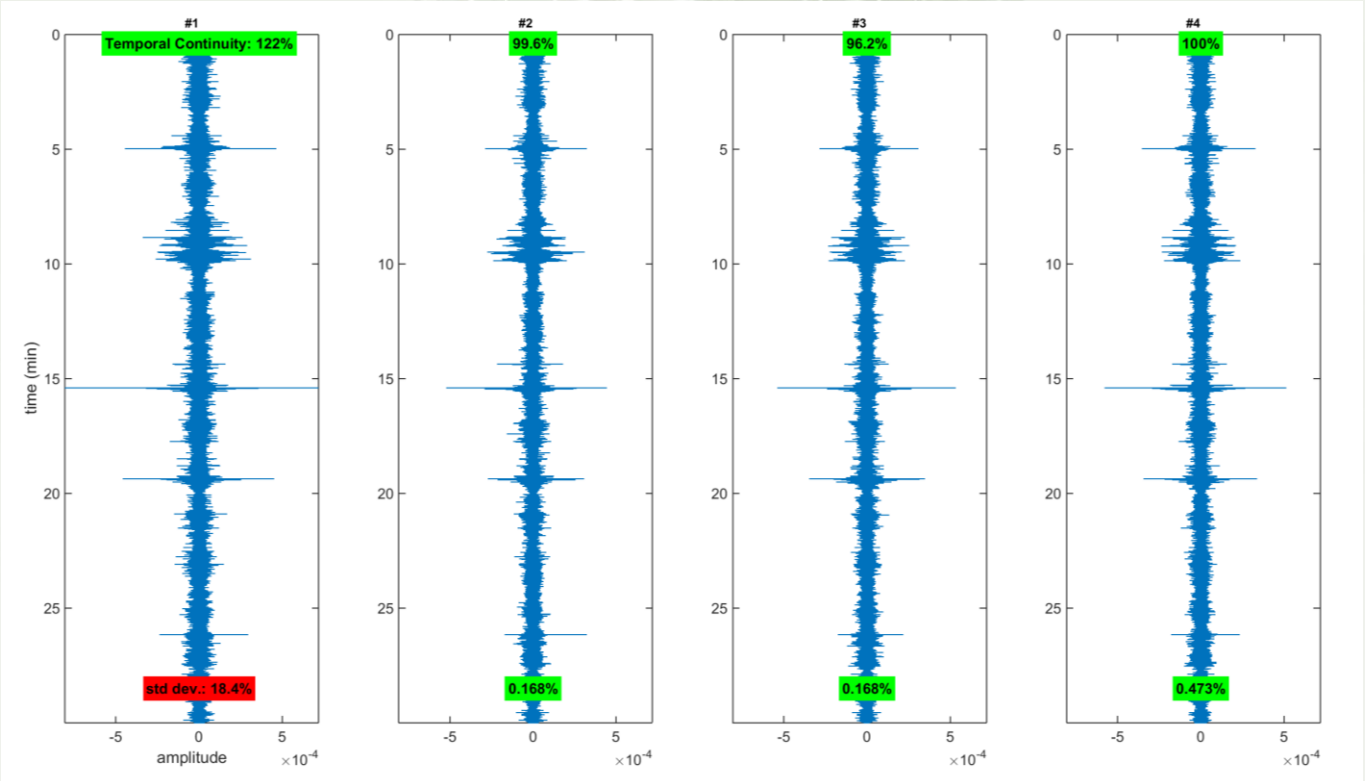




Some conclusive points [3/3]

- **MAAM and HVSR relate to very local conditions (HS, MASW, ESAC etc to larger areas)**

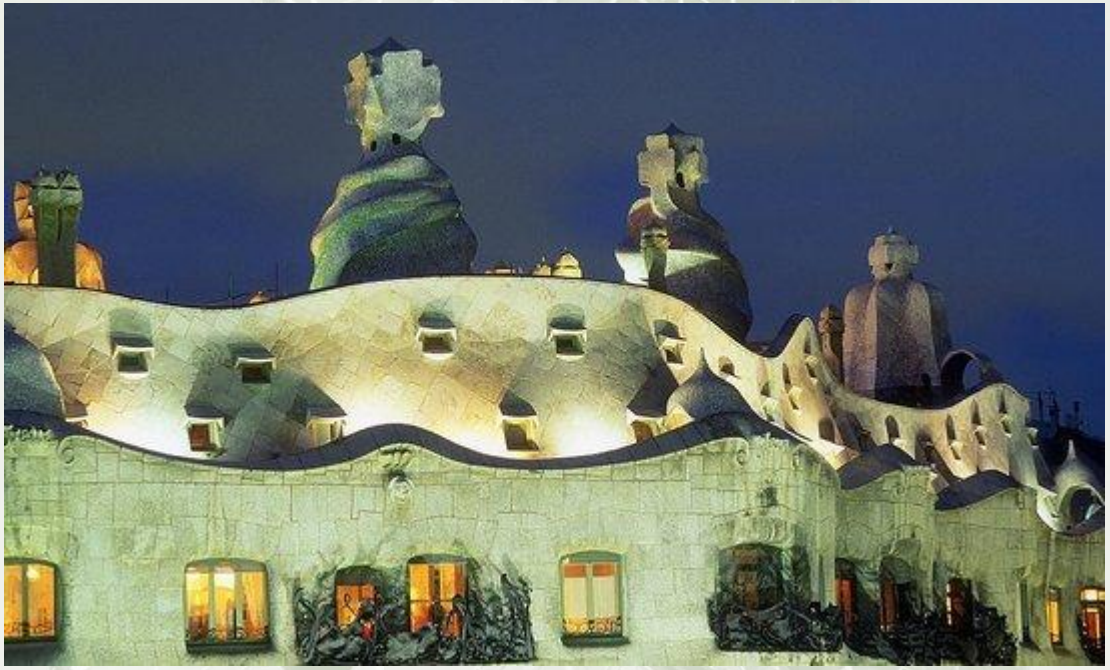
- **MAAM acquisitions require a very careful acquisition (Quality Check on the field) and high-quality (specifically designed) equipment**



THANKS

22nd European Meeting of Environmental and Engineering Geophysics Near Surface Geoscience 2016
4 - 8 September 2016 - Barcelona, Spain

***Urban Geophysics* workshop**
Sunday 4 September 2016, 09:00 - 17:00



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