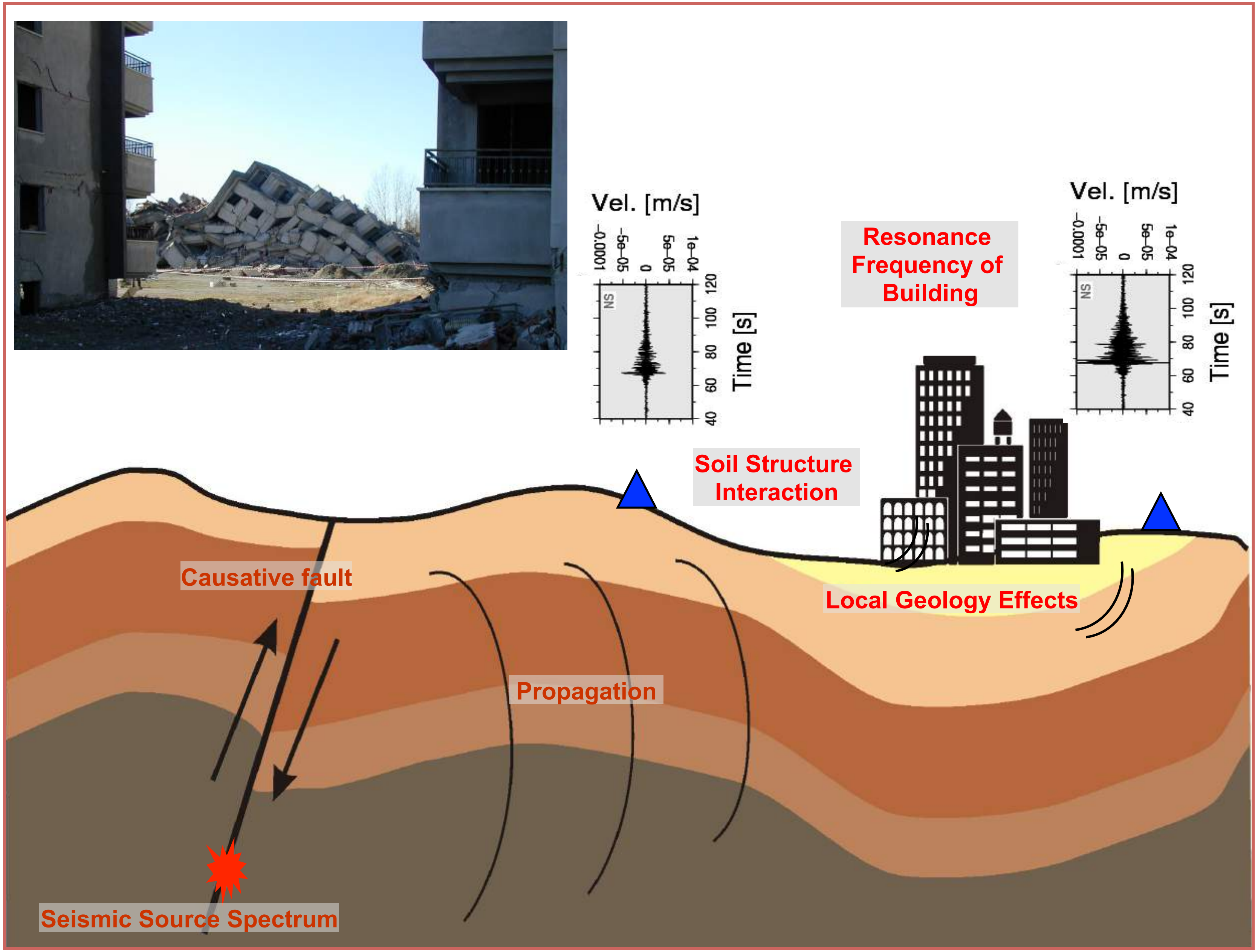
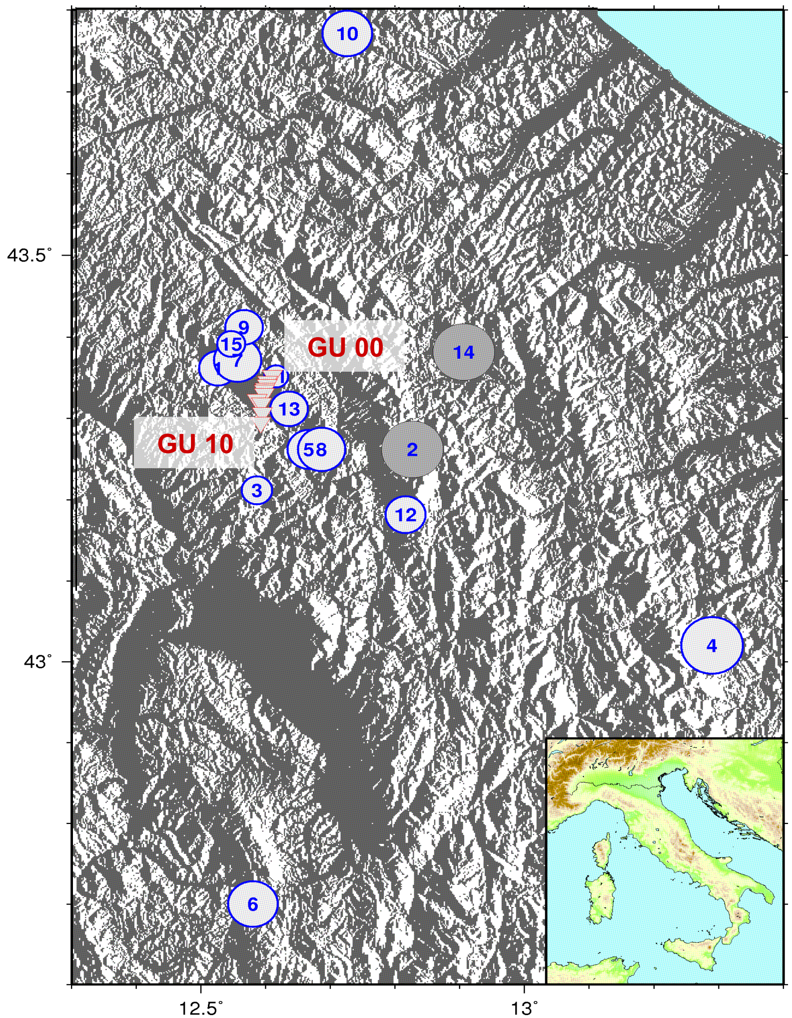
Effetti di sito ed interazione suolo struttura

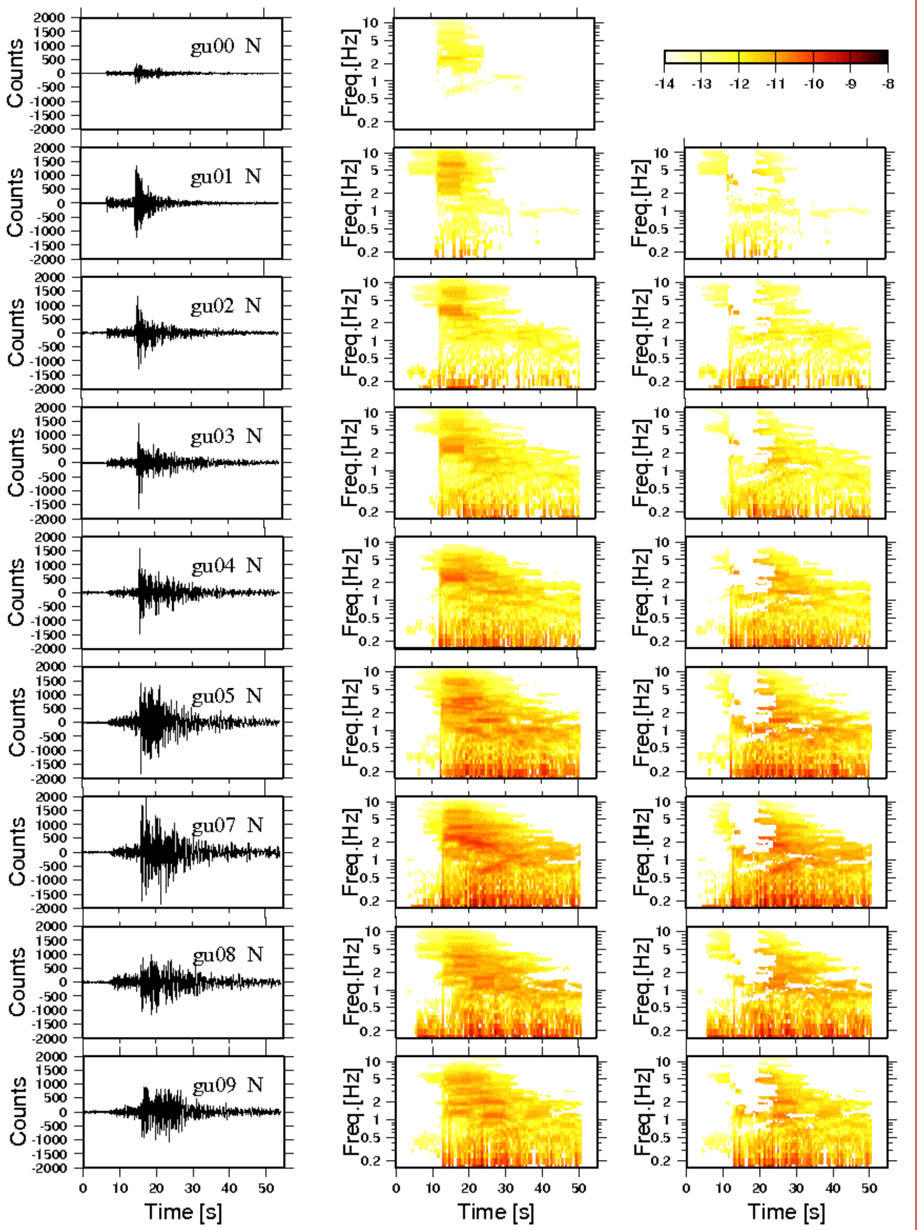
Prof. Dr. Stefano Parolai

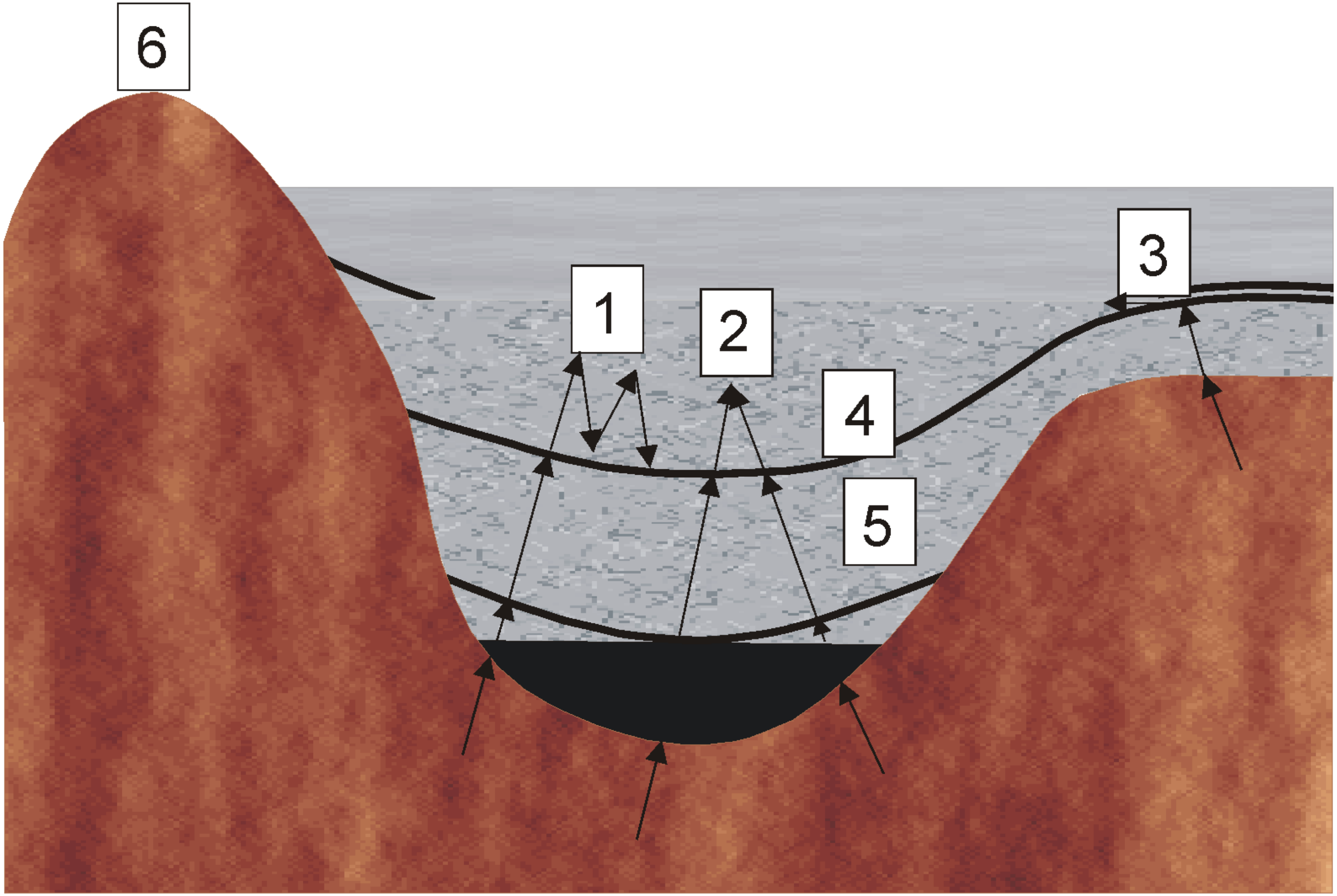

Vel. [m/s]
Time [s]
NS
Resonance Frequency of Building
Vel. [m/s]
Time [s]
NS
Soil Structure Interaction
Causative fault
Local Geology Effects
Propagation
Seismic Source Spectrum

Site effects: Gubbio Valley (Italy)

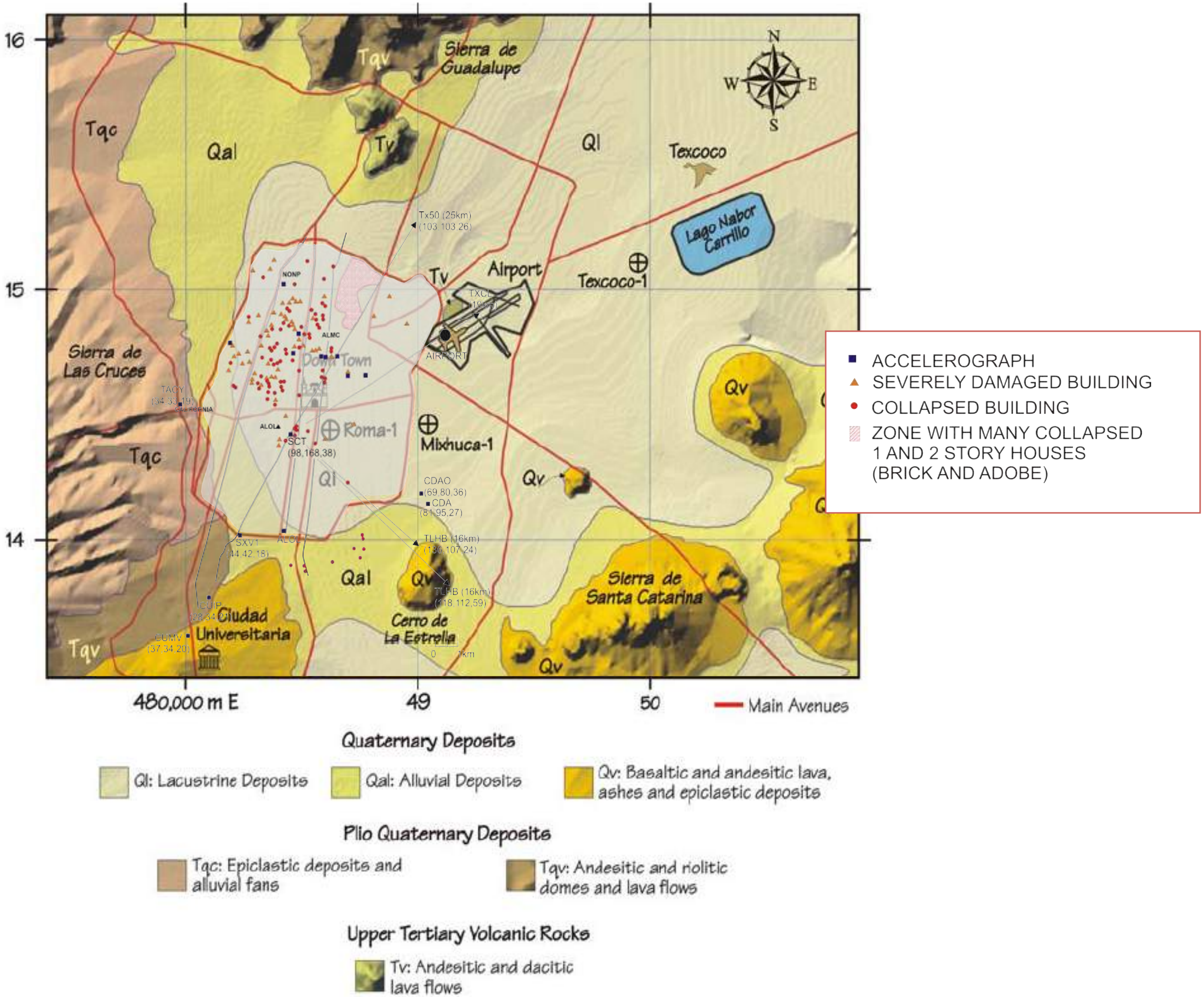
Ground motion increasing with increasing distance from the source! (within the valley)







1 - Resonance due to impedance contrasts, 2 - Focusing due to subsurface topography, 3 - Body waves converted to surface waves, 4 - Water content, 5 - Randomness of the medium and 6 - Surface topography



16
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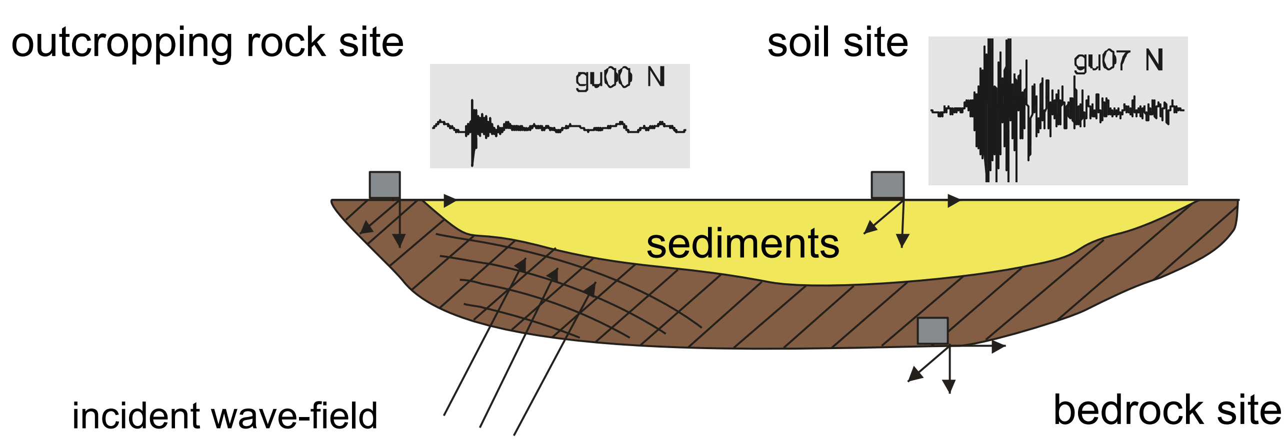
Tqv
Sierra de Guadalupe
Tqc
Qal
Tv
Ql
Texcoco
Lago Nabor Carrillo
Airport
Texcoco-1
Down Town
Roma-1
Mixhuca-1
SCT
(98,168,38)
Sierra de Las Cruces
Qv
Sierra de Santa Catarina
Cerro de La Estrella
Ciudad Universitaria
ACCELEROGRAPH
SEVERELY DAMAGED BUILDING
COLLAPSED BUILDING
ZONE WITH MANY COLLAPSED 1 AND 2 STORY HOUSES (BRICK AND ADOBE)
Main Avenues
Quaternary Deposits
Ql: Lacustrine Deposits
Qal: Alluvial Deposits
Qv: Basaltic and andesitic lava, ashes and epiclastic deposits
Plio Quaternary Deposits
Tqc: Epiclastic deposits and alluvial fans
Tqv: Andesitic and riolitic domes and lava flows
Upper Tertiary Volcanic Rocks
Tv: Andesitic and dacitic lava flows

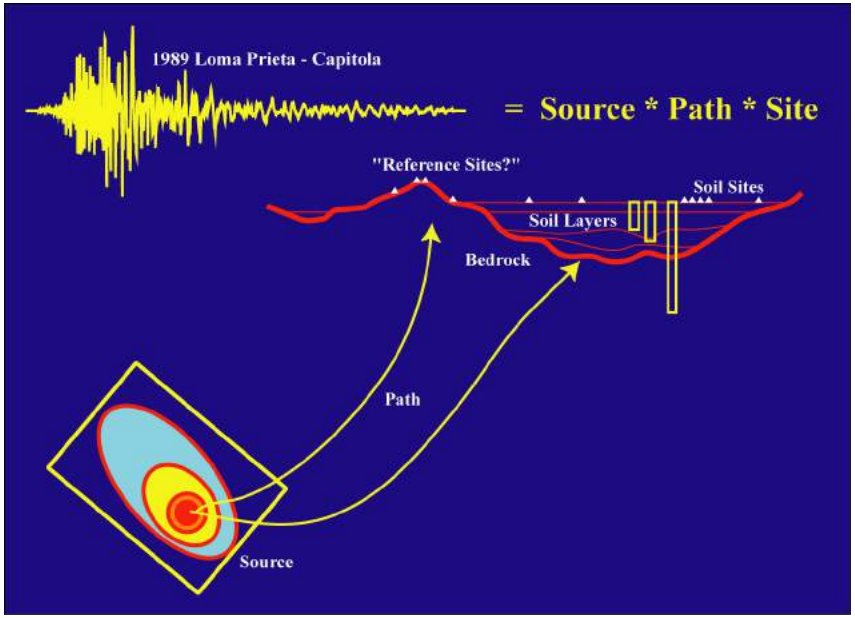
Earthquake based Reference Site methods

1) *Standard spectral ratio*: spectral ratio between the same ground motion components of 2 close stations

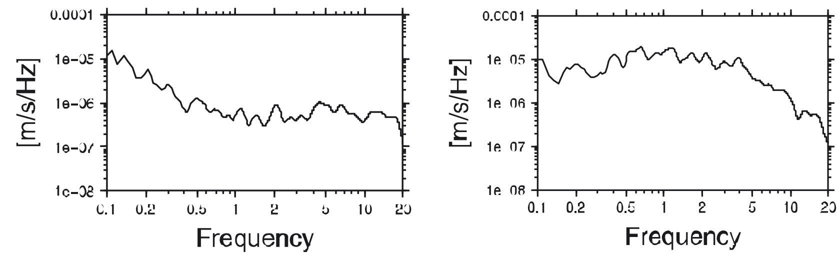
2) *Generalized inversion techniques*: a spectral inversion is performed in order to correct for the path effects if the reference station is faraway from the actual one.



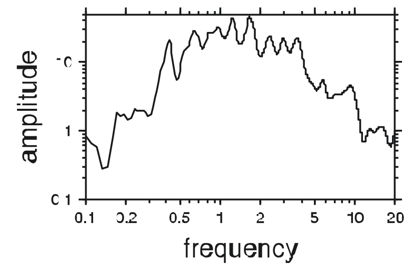
Fourier Amplitude Spectra A(f)



Amplitude



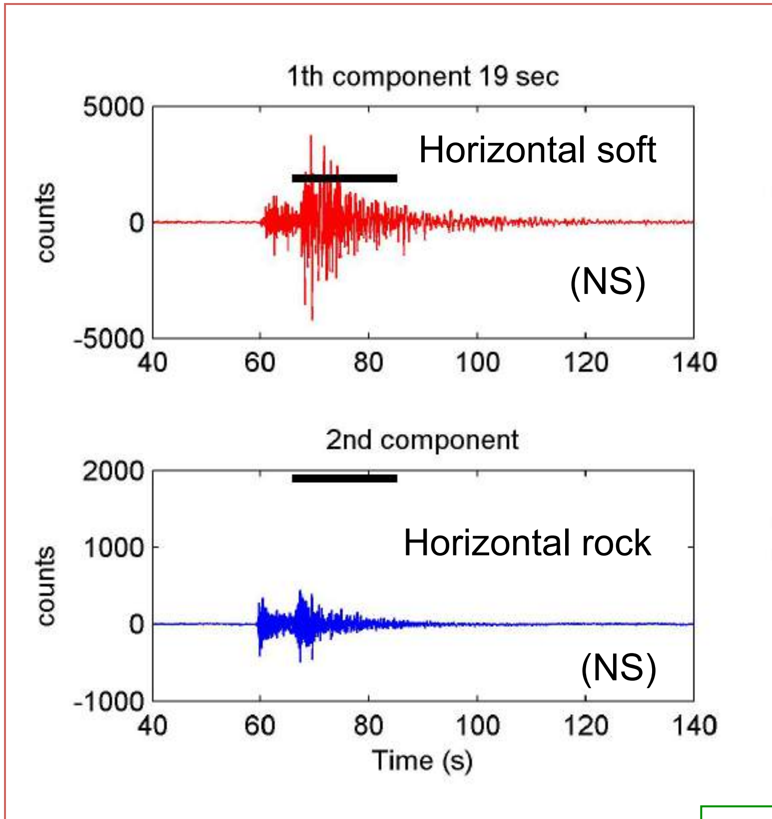
Amplification function

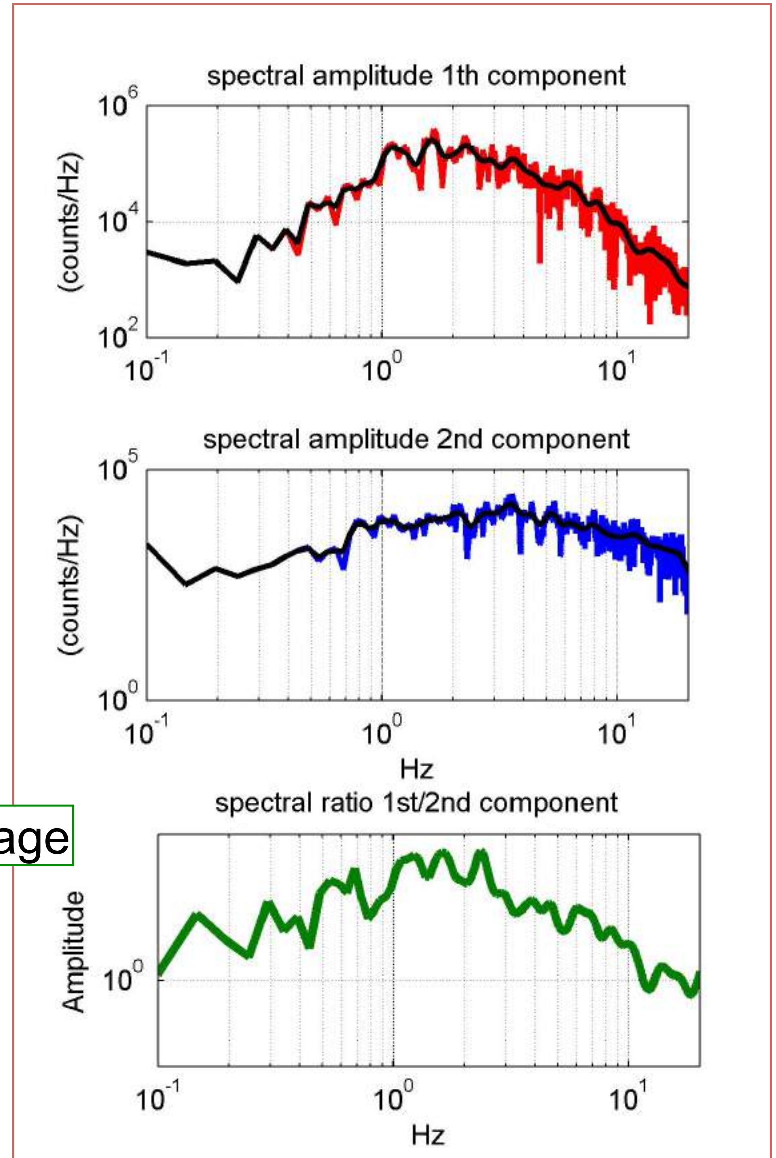


$$\frac{A_{soil}(f)}{A_{rock}(f)} = \frac{\cancel{Source_{soil}}\, Path_{soil}\, Site_{soil}}{\cancel{Source_{rock}}\, Path_{rock}\, Site_{rock}} = \frac{\cancel{Path_{soil}}\, Site_{soil}}{\cancel{Path_{rock}}} = Site_{soil}$$

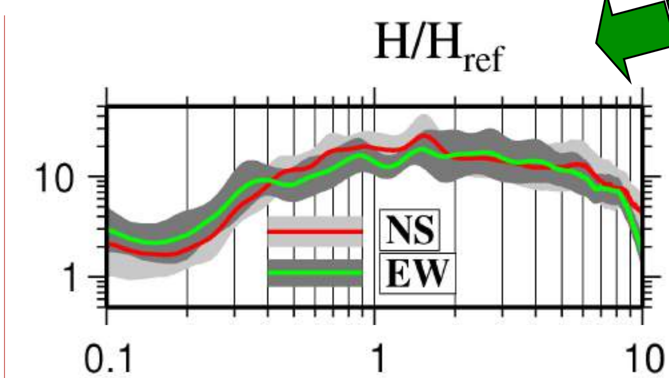
=1 (reference)

Window selection in time domain → Fourier amplitude and smoothing





Average



$$\frac{H(f)}{H(f)} = |SSR(f)|$$

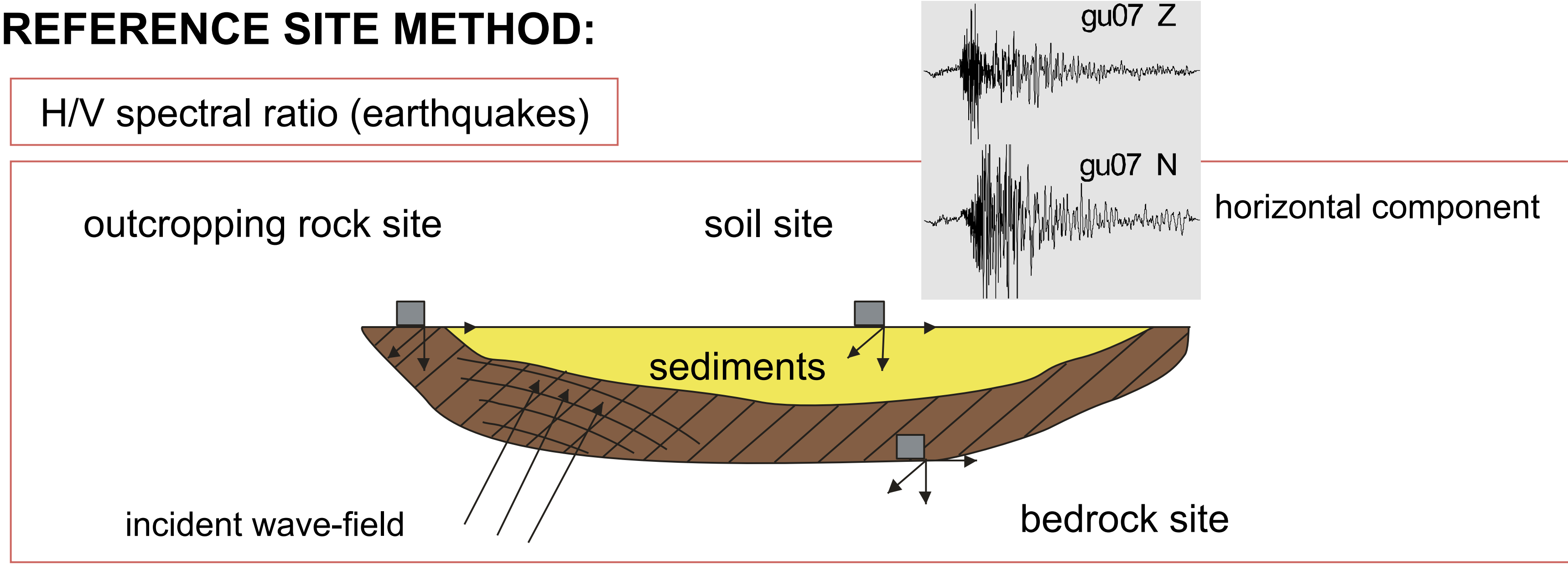
For standard spectral ratio, the distance between the 2 stations should be at least 5 time smaller than the hypocentral distance in order to assume that the path is the same.

A close good reference site might not be available.

Also rock site may have their own site response

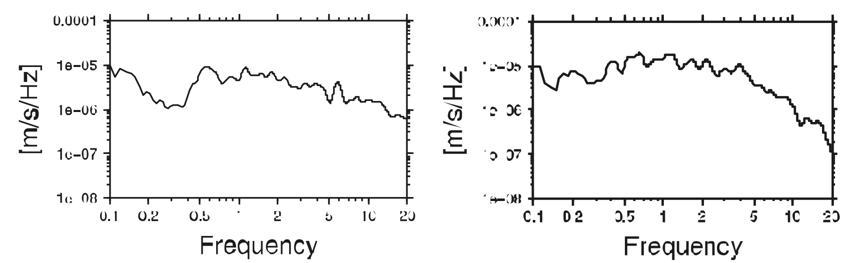
EARTHQUAKE BASED NON-REFERENCE SITE METHOD:

H/V spectral ratio (earthquakes)



Fourier Amplitude Spectra A(f)

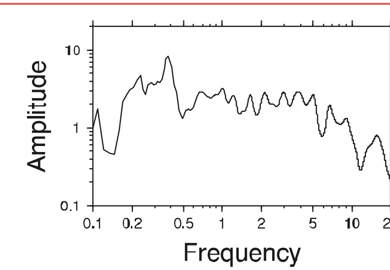
Amplitude



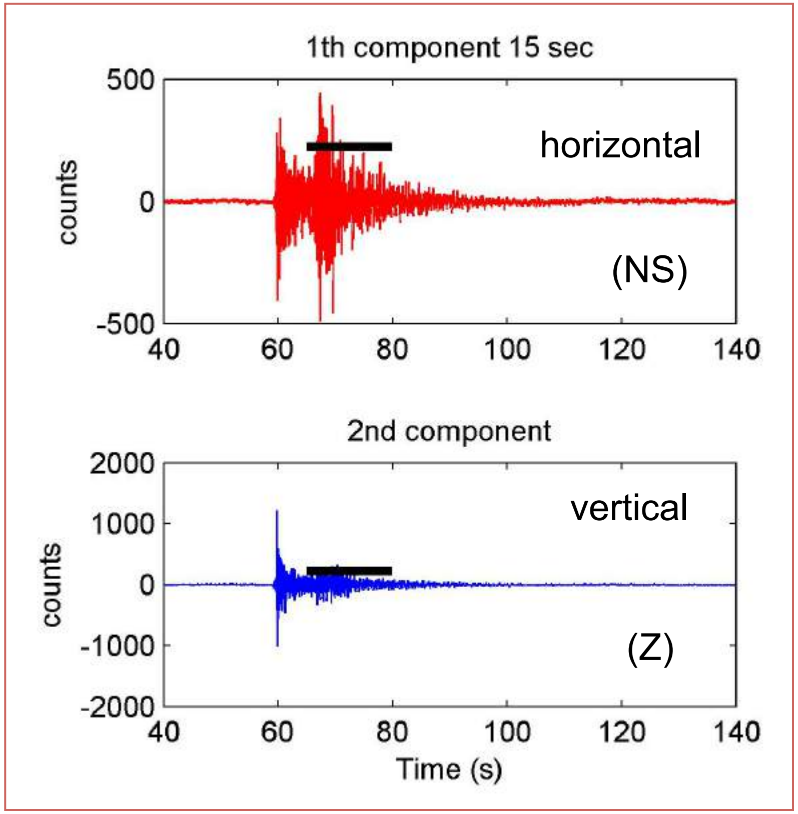
Site response or Spectral ratio

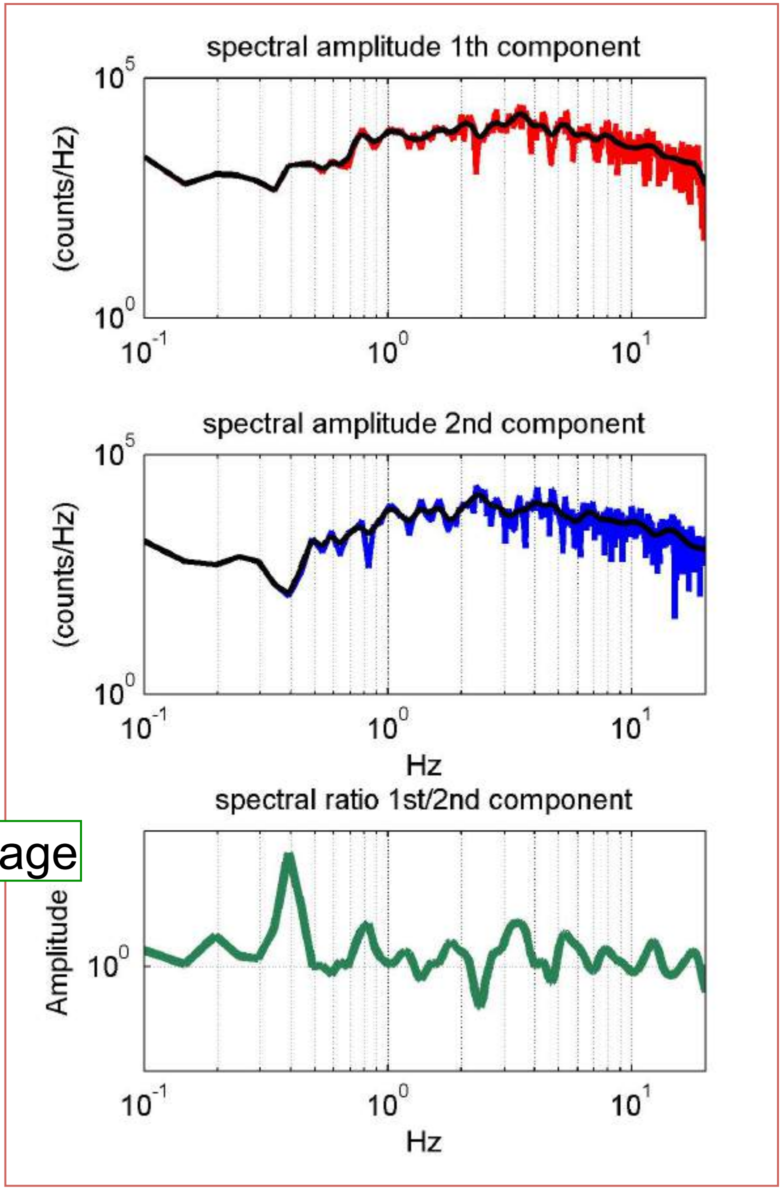
$$S(f) = \frac{H(f)soil}{V(f)soil}$$

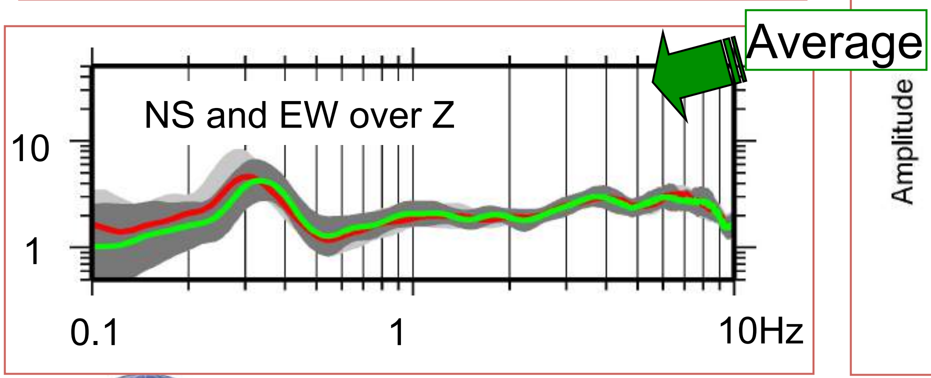
Amplification function



Window selection in time domain → Fourier amplitude and smoothing







H(f) / Z(f) = |H/V(f)|

Reference site versus no-reference site methods

The H/V does not represent the seismic transfer function of the site.

In the case of site amplifications dominated by the vertical resonance, many studies in literature found that:

-the fundamental frequency of resonance estimated by the H/V is in good agreement with the one estimated by the SSR method

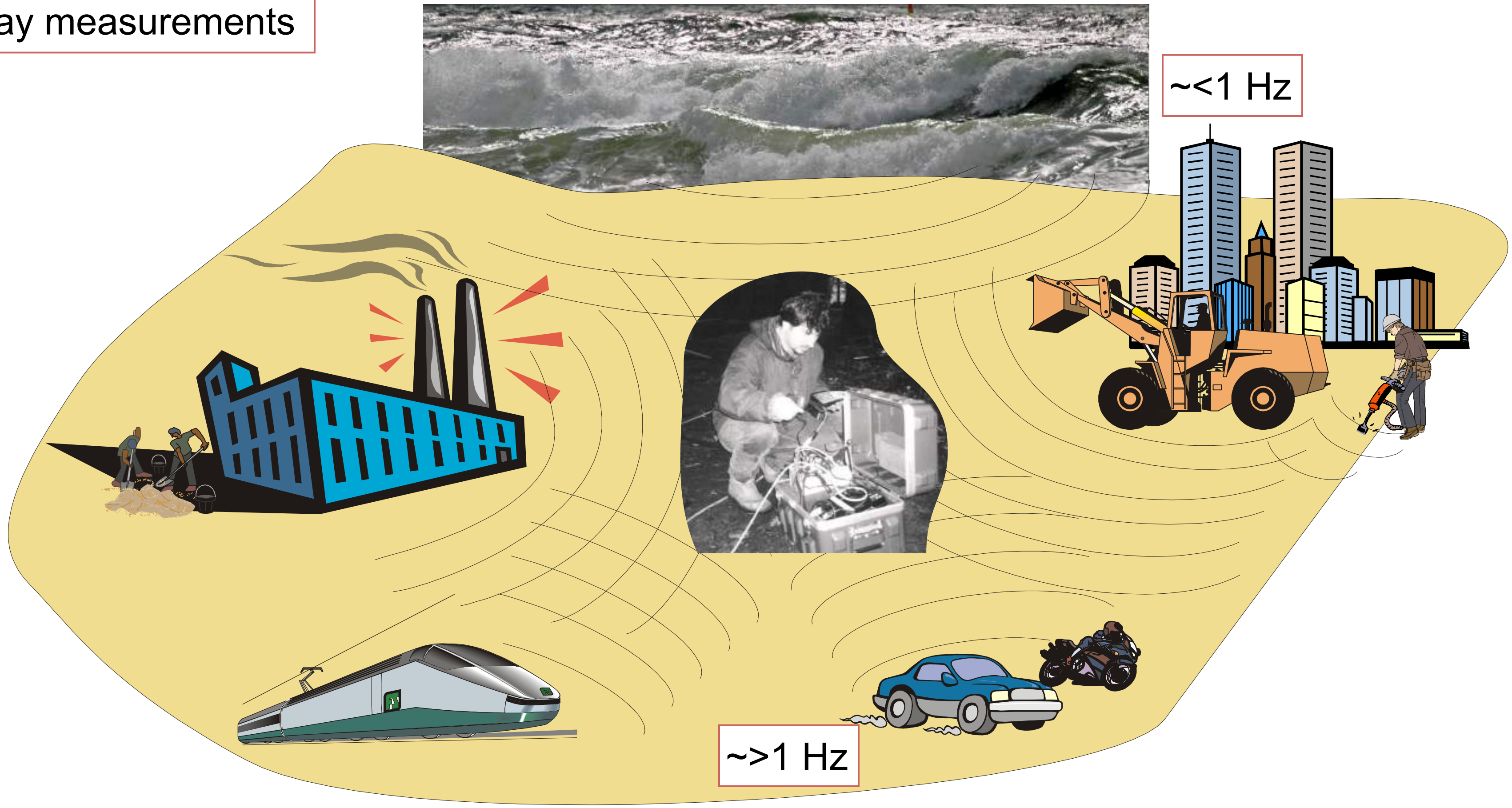
-the amplification of the H/V peak is generally a lower bound for the amplification obtained by applying the SSR method

The H/V can fails in determining the amplification at frequencies larger than the fundamental one, due to amplification of the vertical component. In particular, for complex site effects (e.g. 2D-3D site effects), can fail in estimating the site amplification.

Seismic noise analysis

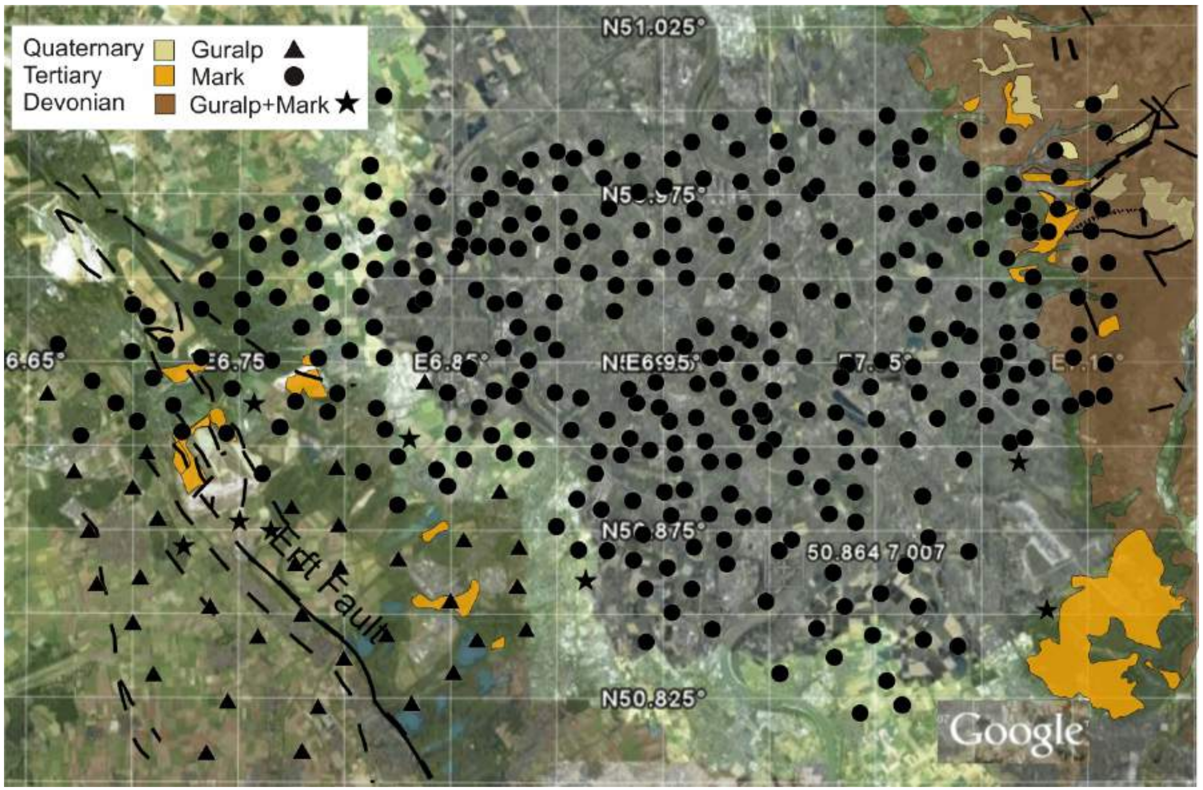
Single station noise measurements: H/V

Array measurements

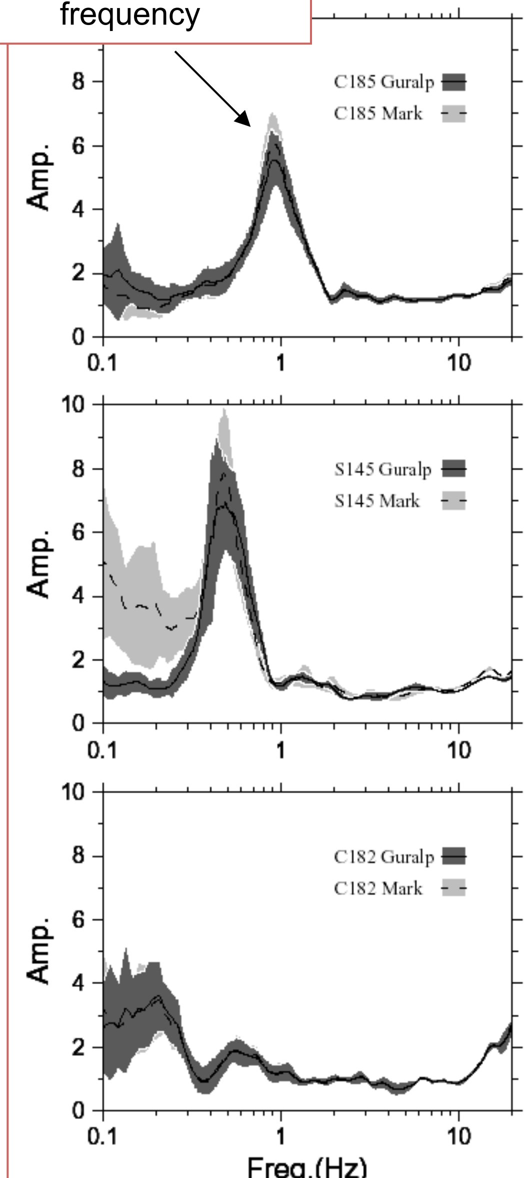


H/V spectral ratios

Ambient Seismic Noise



fundamental resonance frequency



<u>Different instruments have different self-noise. Furthermore different sensors act as different filter! If the seismic noise is lower than the self noise it cannot be recovered!</u>

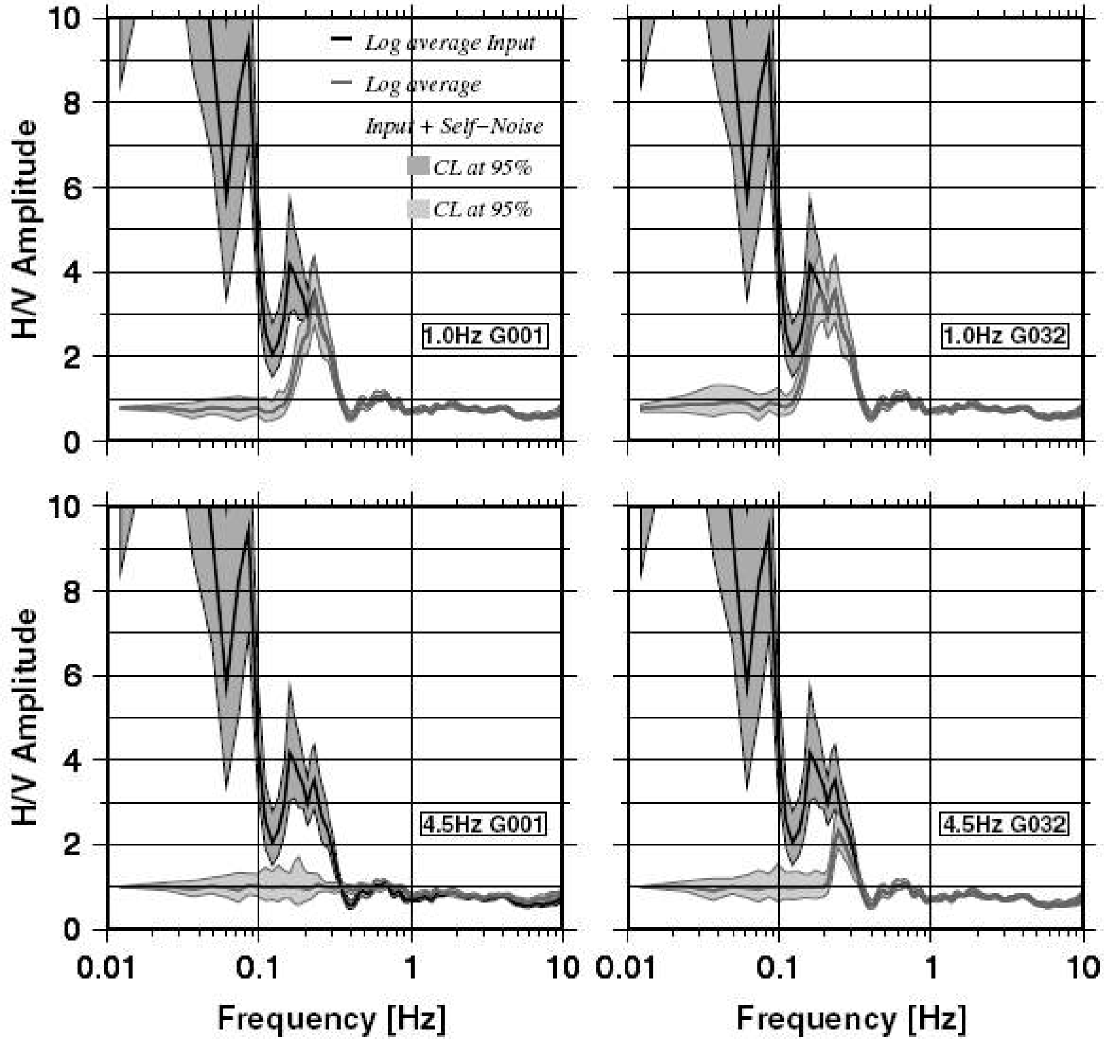
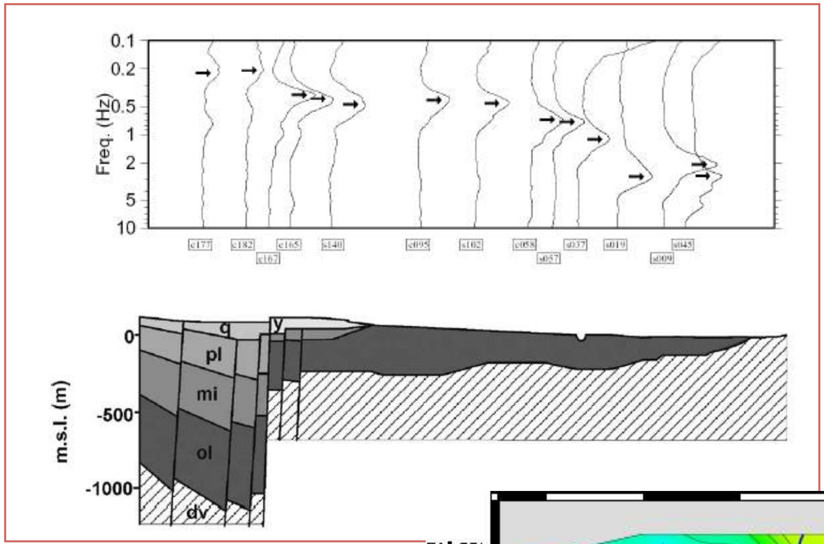
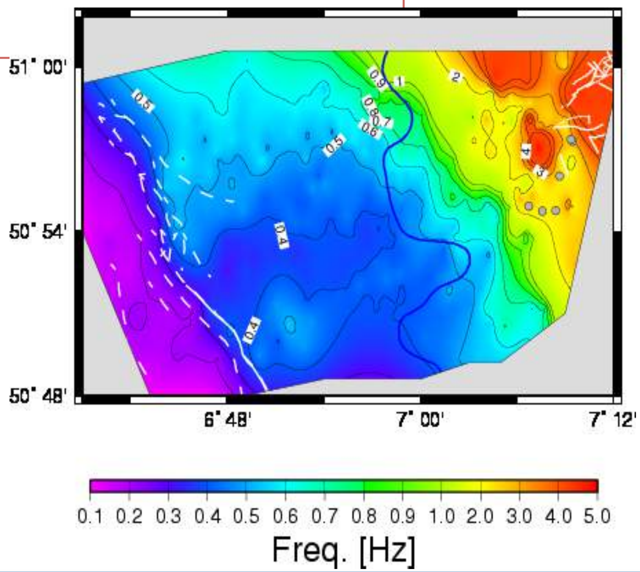


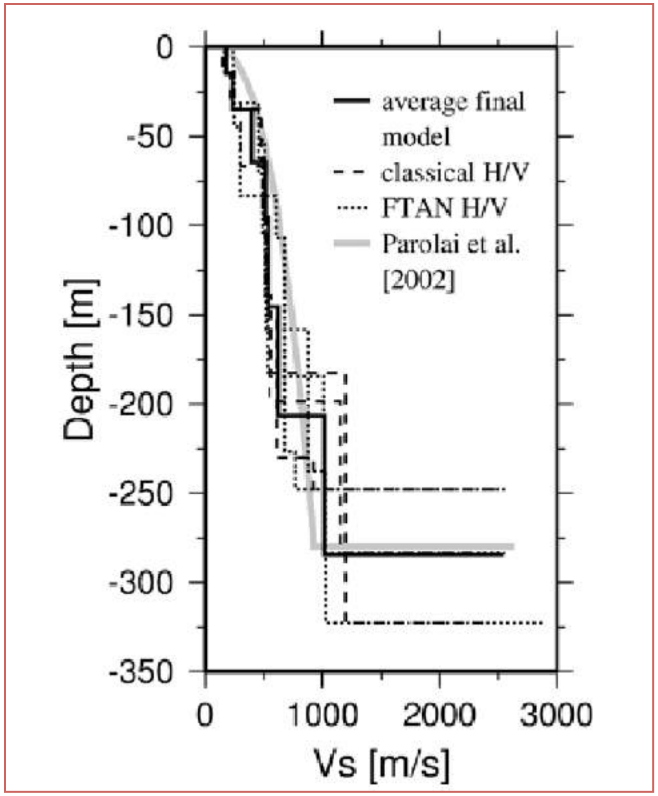
Figure 5. H/V spectral ratio results for the REFTEK 72 A and different SPESs. Left: Results for gain = 1. Right: Results for gain = 32. Top: Results for 1-Hz SPESs. Bottom: Results for 4.5-Hz SPESs.

The H/V can provide important information but <u>does not</u> represent the seismic transfer function of the site.





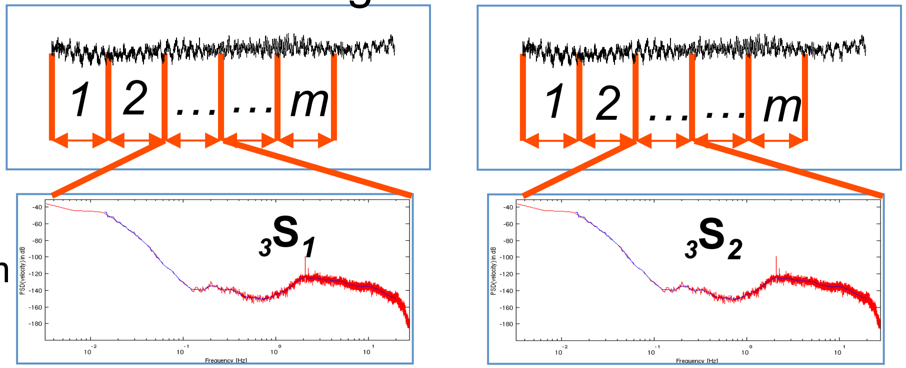
S-wave velocity profile



Using seismic noise to estimate the characteristics of a site: standard SPAC method

For every couple of stations (fixed the distance r) the function $\phi(\omega)$ can be calculated in the frequency domain by means of (Malagnini et al., 1993; Ohori et al., 2002; Okada, 2003):

Recordings of seismic noise



Fourier spektrum

$$\phi(\omega) = \frac{\frac{1}{M}\sum_{m=1}^{M} \mathrm{Re}\left({}_m S_{jn}(\omega)\right)}{\sqrt{\frac{1}{M}\sum_{m=1}^{M} {}_m S_{jj}(\omega) \sum_{m=1}^{M} {}_m S_{nn}(\omega)}}$$

where *mSjn* is the cross-spectrum for the *m*th segment of data, between the *j*th and the *n*th station, and *M* is the total number of used segments. The power spectra of the *m*th segment at station *j* and station *n* are *mSjj* and *mSnn*, respectively.

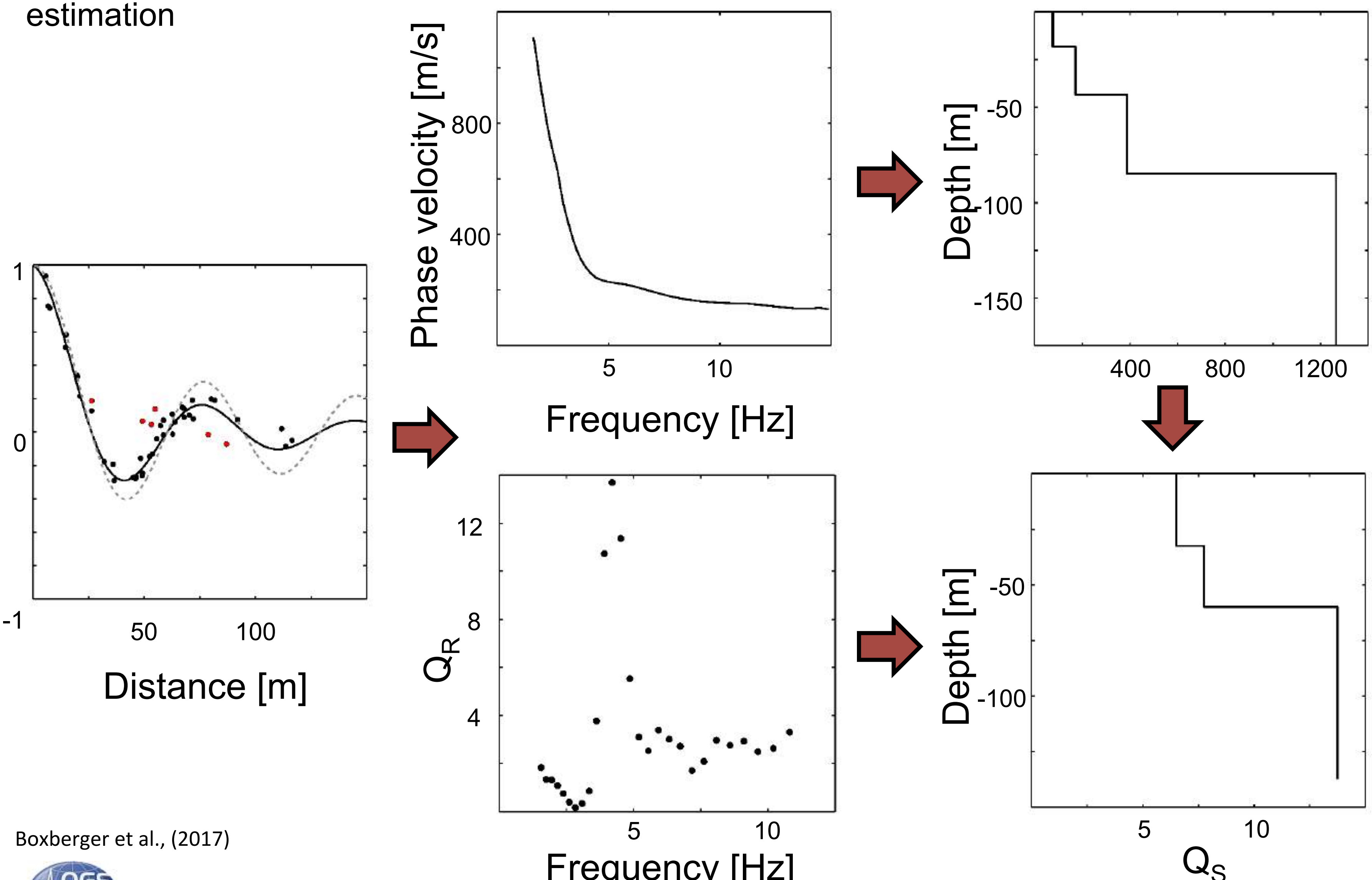
$${}_3S_{12} = {}_3S_1 \cdot {}_3^{*}S_2$$

Estimation of the quality factor

Phase velocity and alpha estimation

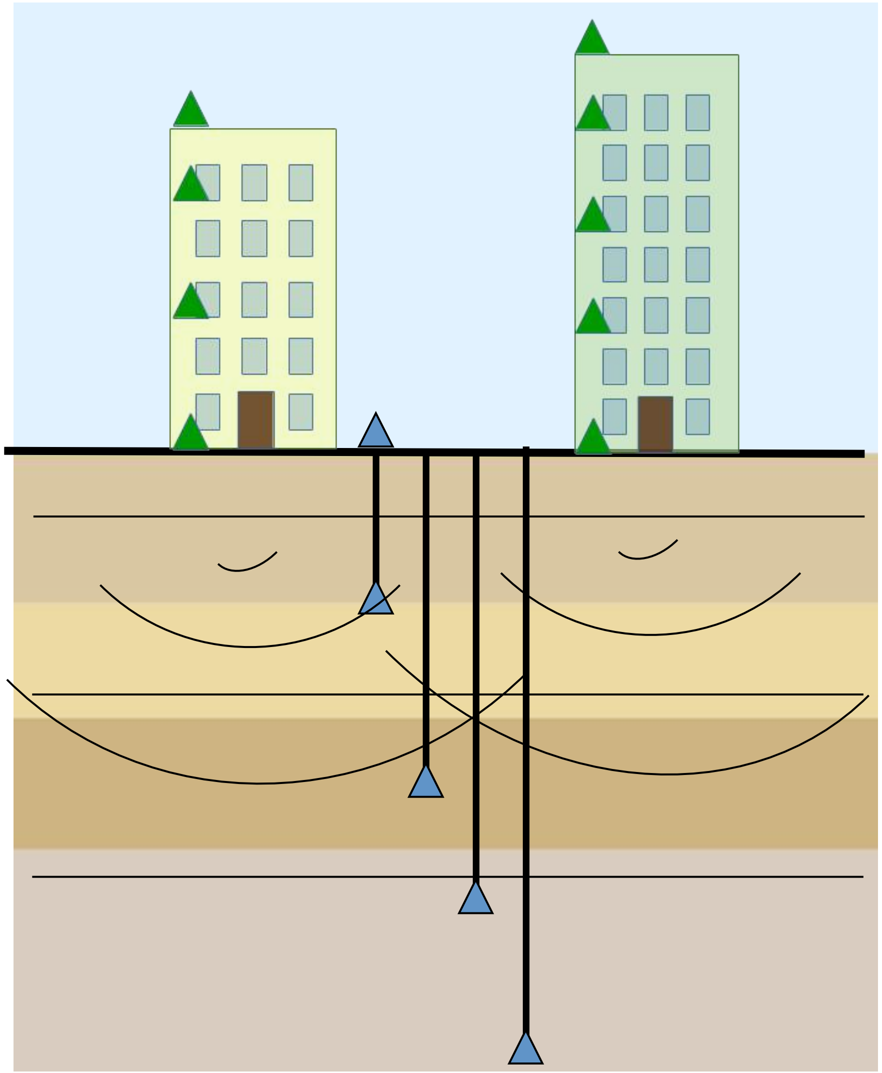
Dispersion and Q_R curve

Inversion: V_S, Q_S

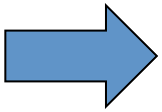


Boxberger et al., (2017)

Studying and understanding soil-structure and site-city interactions using real data sets



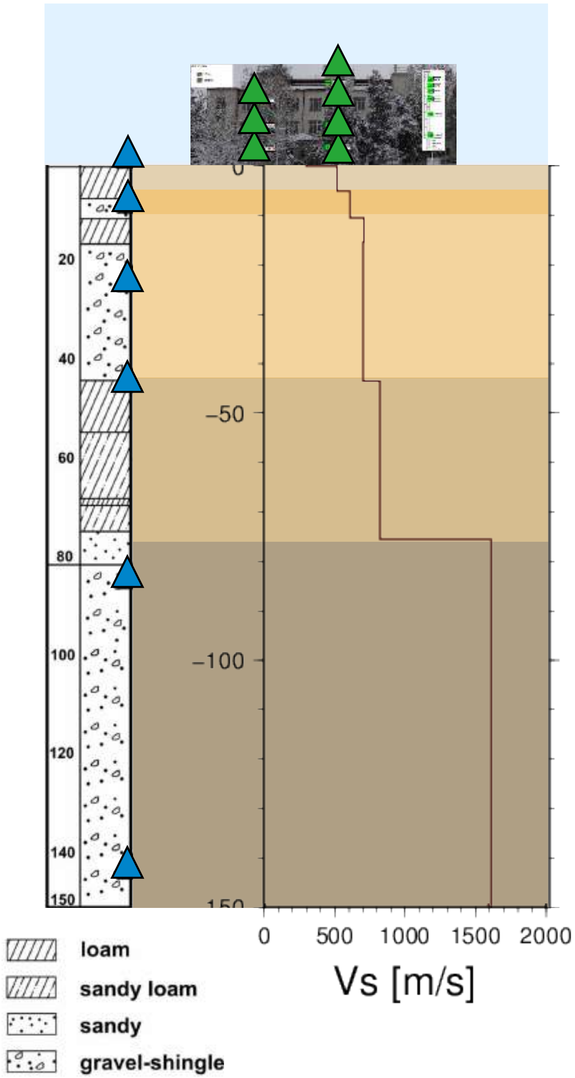
- Do built structures modify the ground motion?
- Is energy being radiated back from the building to the soil and if so, down to which depths?
- Do interactions between built structures take place through the soil?

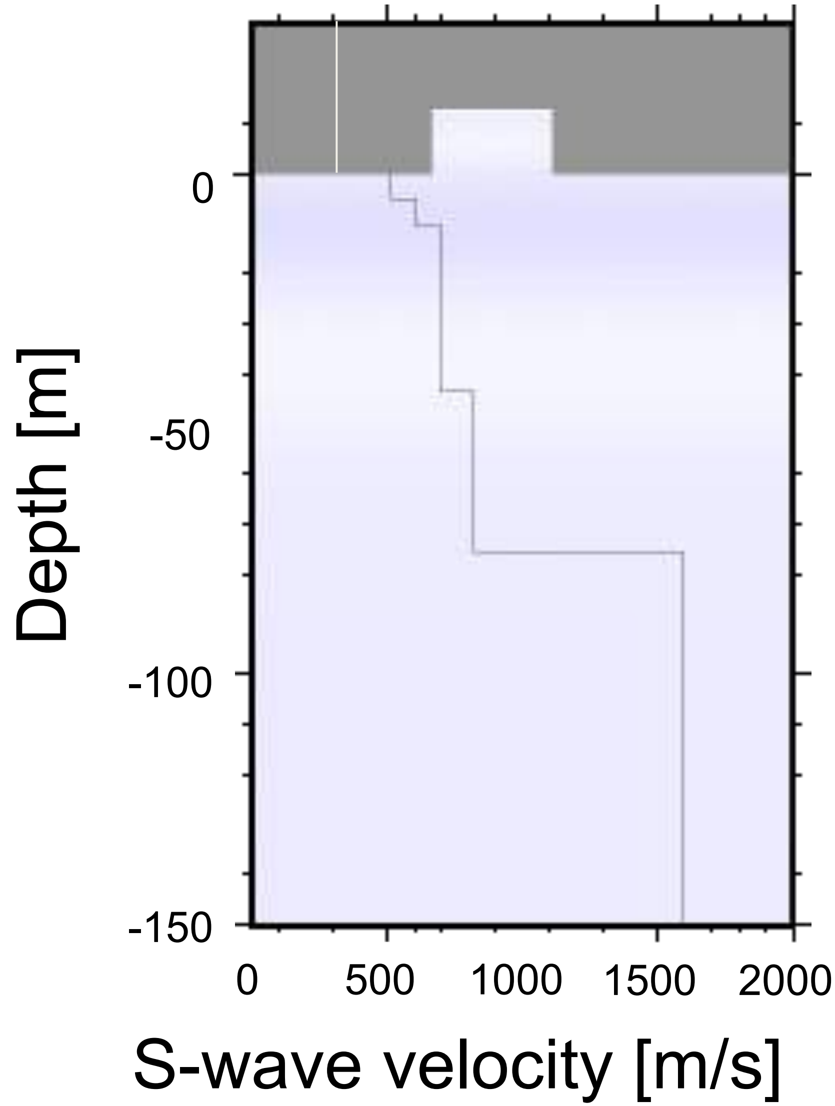


Long term aim: Improvements in seismic risk assessment and mitigation.

Petrovic and Parolai, (2017)

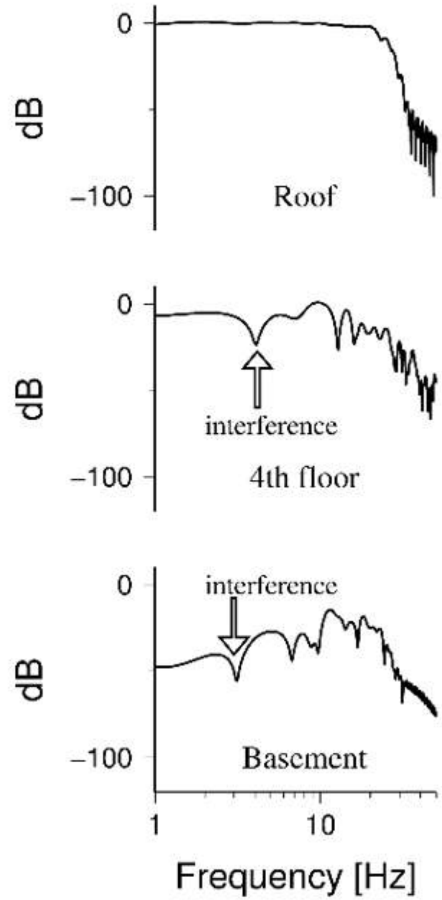
Wave propagation through building-soil-layers





Petrovic and Parolai, (2017)

Deconvolution approach



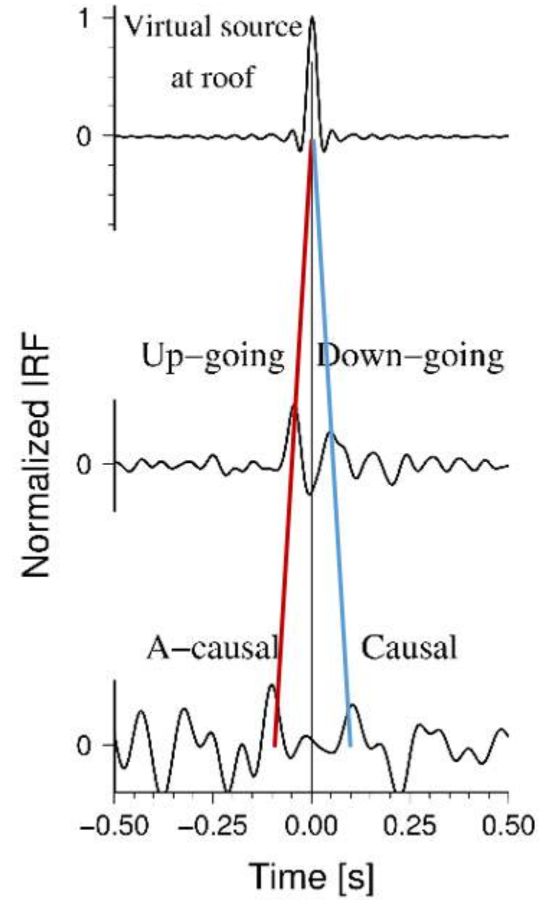
Deconvolution

$$D(\omega) = \frac{\hat{u}(\omega)}{\hat{u}_{ref}(\omega)}$$

Regularized deconvolution

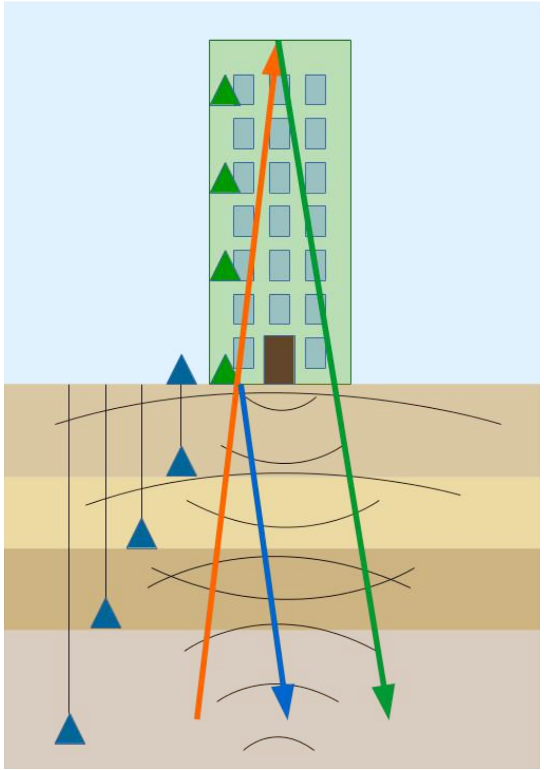
$$D(\omega) = F(\omega)\hat{u}(\omega)$$

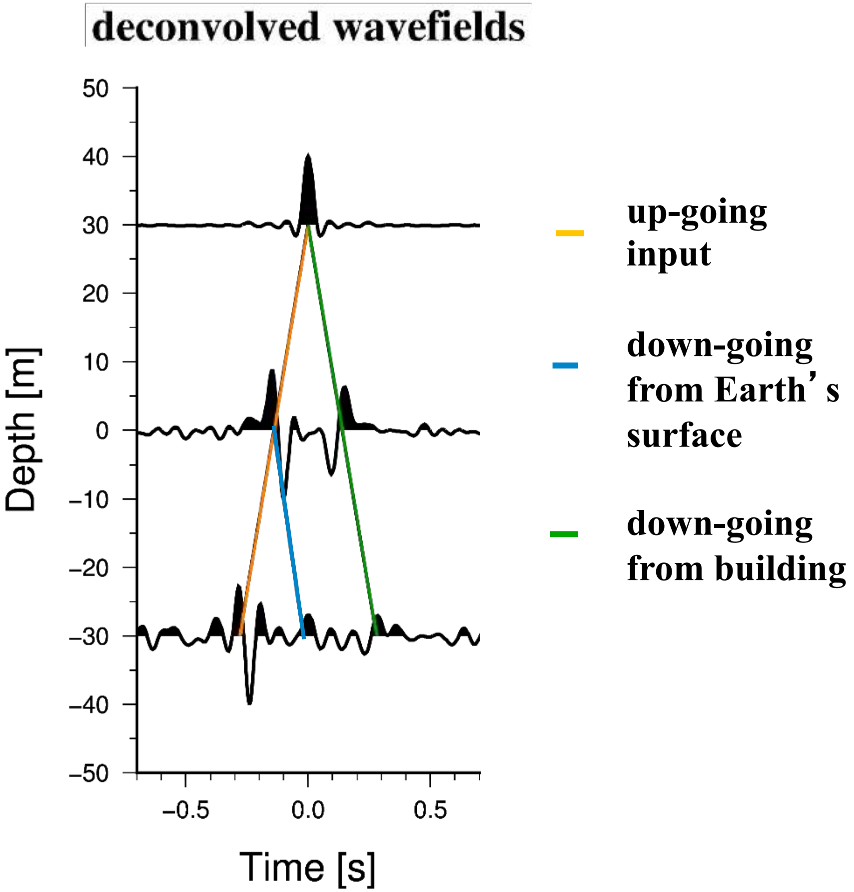
$$F(\omega) = \frac{\hat{u}^*_{ref}\,(\omega)}{|\widehat{u}_{ref}(\omega)|^2 + \varepsilon}$$



[Bindi et al., 2015]

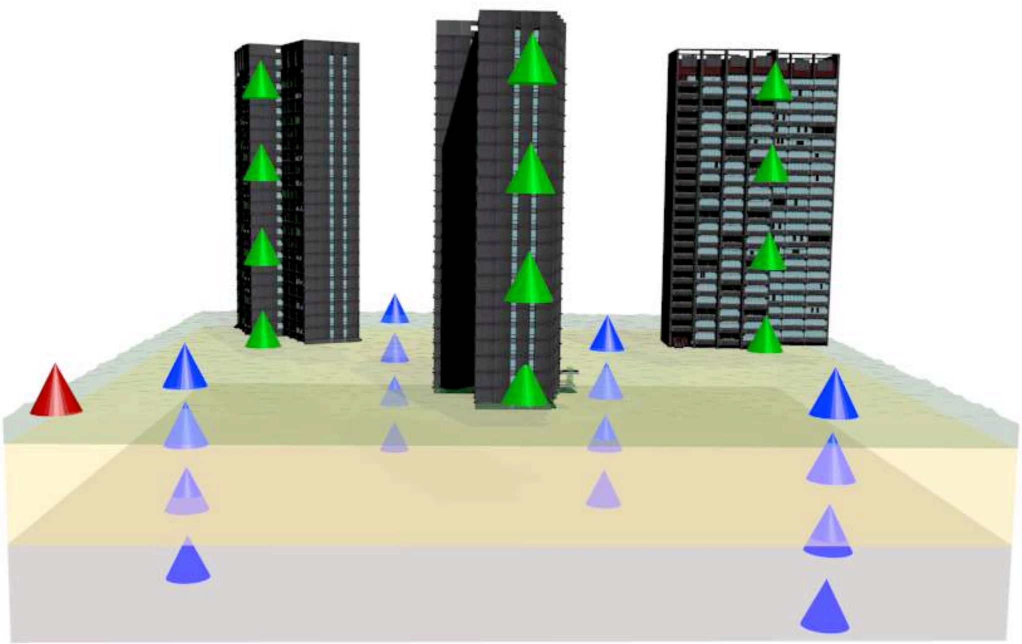
Methodology: Joint deconvolution of borehole and building recordings





Petrovic and Parolai, (2017)

Outlook: Studying site-city interaction effects



Quantification of energy being radiated back contributes to a better comprehension of interactions taking place between buildings and soil

- Better understanding of already existing urban areas, identification of regions of higher seismic risk
- Improvement of the building design and planning of urban areas
- Improvements in seismic risk assessment and mitigation by taking these I nteractions into account

Petrovic and Parolai, (2017)

Grazie per l'attenzione