Active surface waves analysis

Methods

Most popular methods

SASW : Spectral Analysis of Surface Waves ⇔ 1 source, 2 receivers
MASW: Multichannel analysis of surface waves ⇔ 1 source, several receivers

=> *Validated and reliable methods*

Recent methods

RoadSide MASW ⇔ source = road traffic
REMI (REfraction MIcrotremor analysis) ⇔ source = microtremor

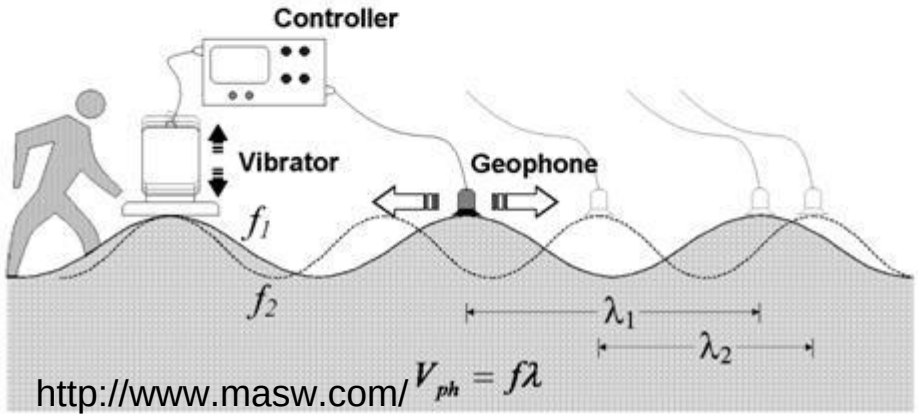
=> *Methods under validation*

Pioneer work

Steady State Method in 1950s

UK 1950s

Van der Poel (1951)



http://www.masw.com/

Vibrator exciting a single frequency f_i

Scan of the ground surface with a sensor

Evaluation of the distance x_i between 2 consecutive amplitude maxima

Estimation of phase velocity
$c = x_i * f_i$

Repeat measurement for different frequencies to construct a dispersion curve.

<u>Implicit assumption:</u>
<u>one single surface wave mode</u>

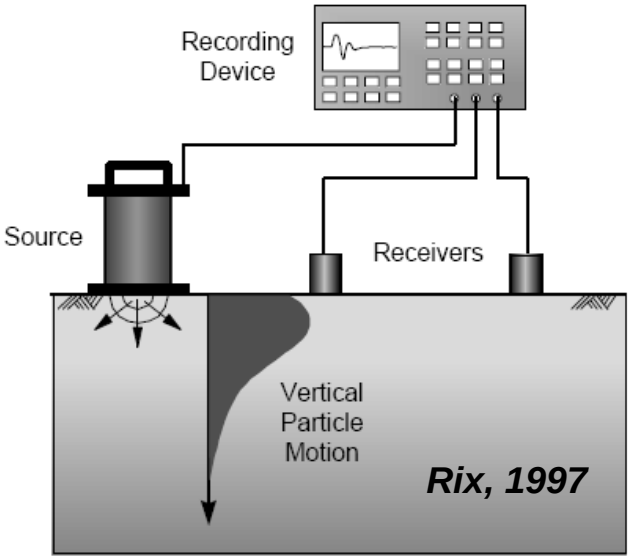
SASW
Spectral Analysis of Surface Waves

Photo: R. Kayen

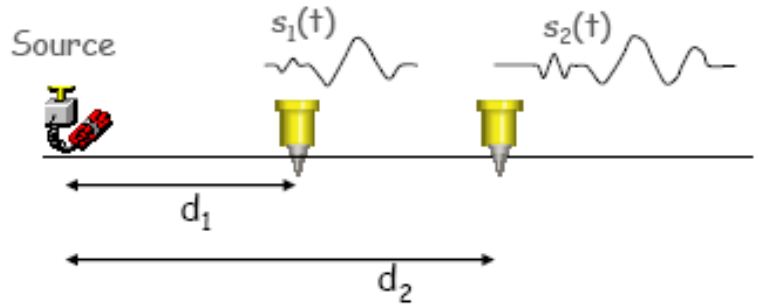
Method introduced by Heisey et al., 1982 et Nazarian et al., 1983

Main references:
Nazarian et Stokoe (1984, 1986)
Stokoe and Nazarian 1985
Stokoe *et al.* 1988, 1994
Roesset *et al*. 1991
Gucunski and Woods 1991
Tokimatsu *et al*. 1992
Rix et al., 1991

SASW
Spectral Analysis of Surface Waves



- 2 geophones
- Source: hammer, vibrator, etc.
- Distance between geophones is varying in order to sample different wavelengths



Computing the Fourier spectra of $s_1(t)$ and $s_2(t)$

$$S_1(\omega) = A_1(\omega)e^{i\omega t_1} \qquad S_2(\omega) = A_2(\omega)e^{i\omega t_2}$$

The phase difference is given by:

$$\Delta\phi(\omega) = \omega(t_2 - t_1) = \omega\left(\frac{d_2 - d_1}{c(\omega)}\right)$$

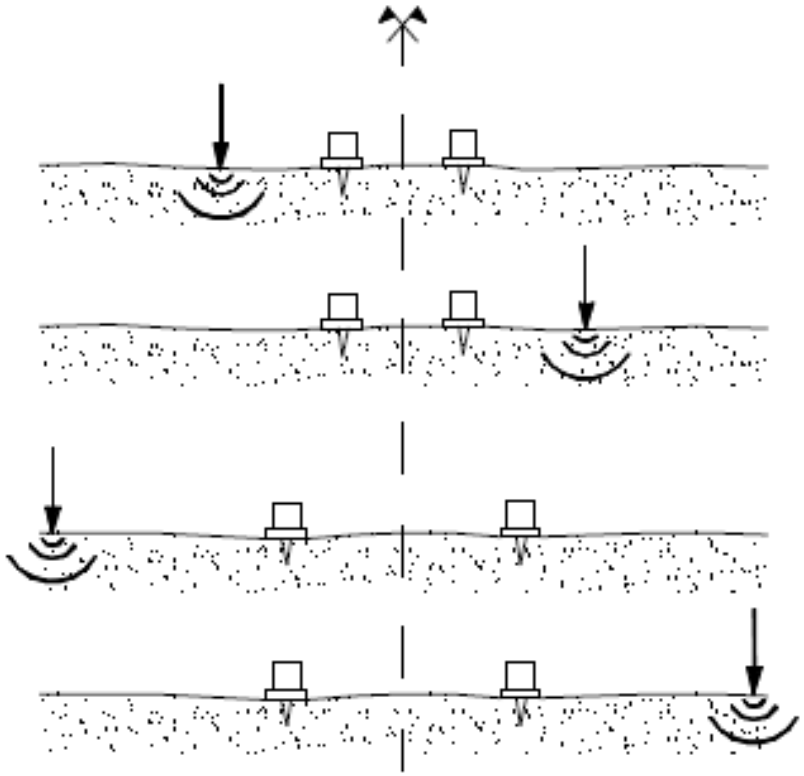
and

$$c(\omega) = \frac{d_2 - d_1}{\Delta\phi(\omega)}\ \omega$$

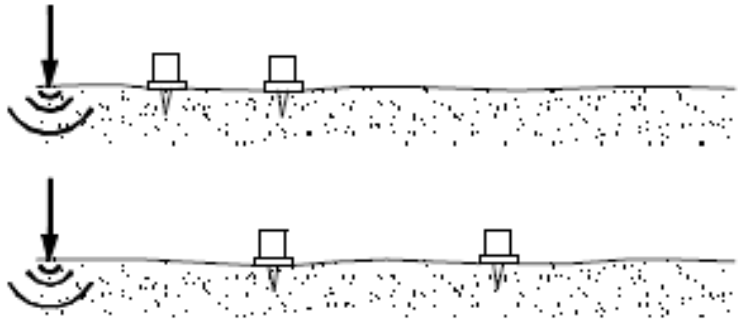
Pros:
- simplicity
- controled sources

Cons:
- One mode only
- penetration depth (depends on source)

Acquisition layout



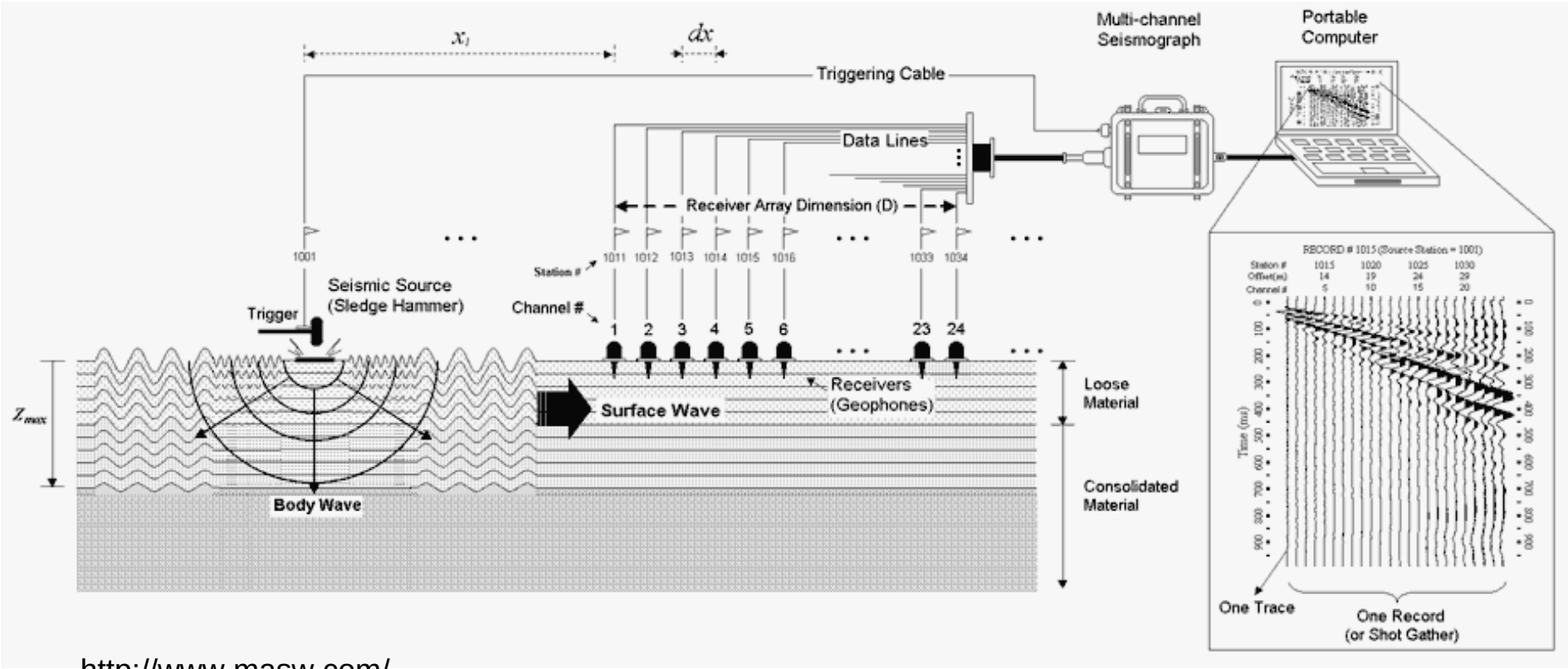
Common receiver midpoint array



Common source array

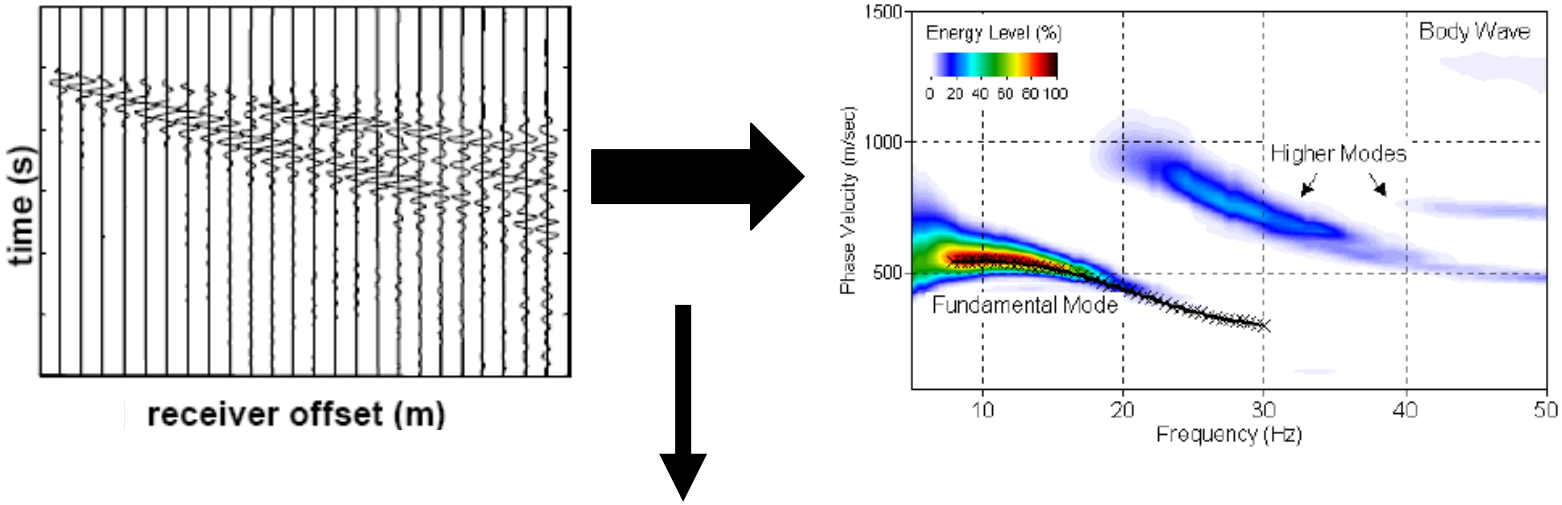
MASW
Multichannel analysis of surface waves

First studies : Al-Husseini et al., 1981; Mari, 1984; Gabriels et al., 1987
Popularized by: Park et al. (1999) (http://www.masw.com/)



http://www.masw.com/

MASW
Multichannel analysis of surface waves



FK or Slant stack methods
(similar to FK analysis presented yesterday for 1D linear array)

Pros and Cons of MASW technique

PROS

Simplicity

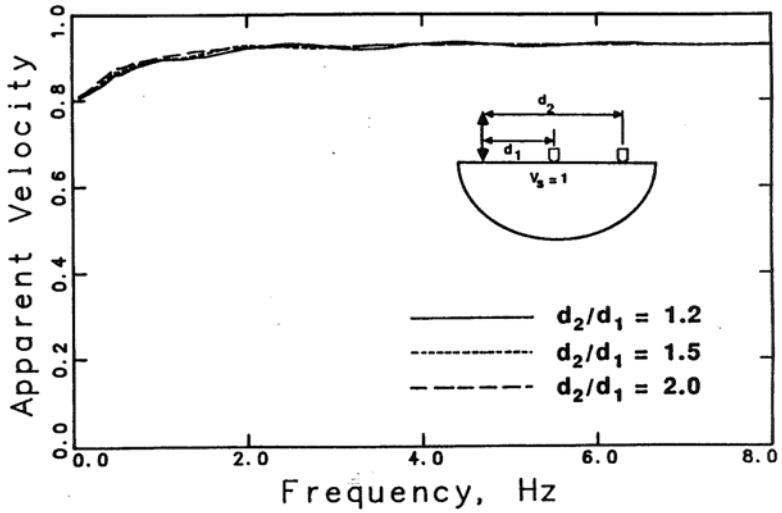
Identification of several modes

CONS

Near field effect

- Influence of body waves (Tokimatsu, 1997; Sanchez-Salinero, 1987)
- Cylindric propagation (Zywicki, 1999)

⇒ *Bias to low phase velocities, especially at low frequency*



Far field effect

- Attenuation of high frequencies versus signal-to-noise ratio
- Body head waves

Near-field effect

In order to avoid near-field effects, Park, 1999 and Stockoe et al., 1994 suggest to interpretate wavelengths lower than 2 times the source offset:

$$\lambda_{max} = 2x_1$$

x_1 source offset

λ_{max} maximum intepretable wavelength

O'Neill (2004) suggest to interpret wavelengths lower 0.4 times the profile length:

$$\lambda_{max} = 0.4L$$

L profile length

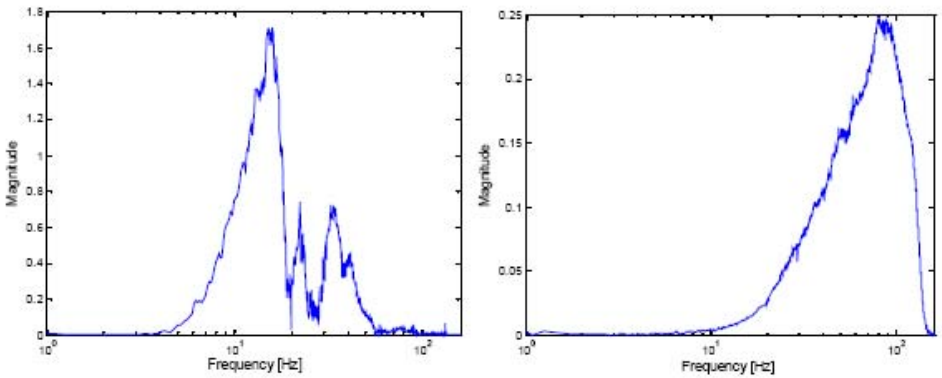
Socco and Strobbia, 2004

band. These two phenomena are strongly dependent on the site and the experimental conditions, and in general cannot be predicted to determine the best source-offset. Possible solutions are the acquisition with different source-offsets to recognize the near-field, or the use of a small offset and the filtering of the near-field during processing. On the other hand, some rule of thumb has

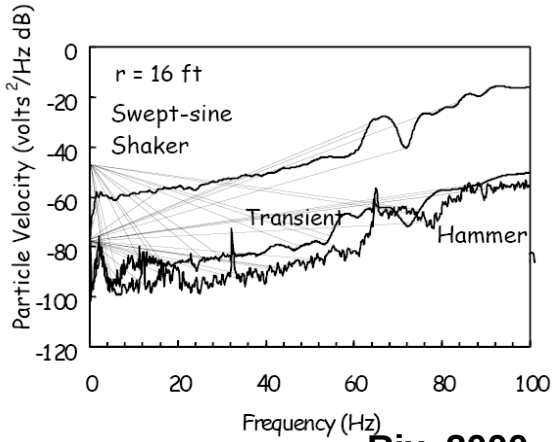
Source energy content

(a)

(b)



Sungsoo, 2005

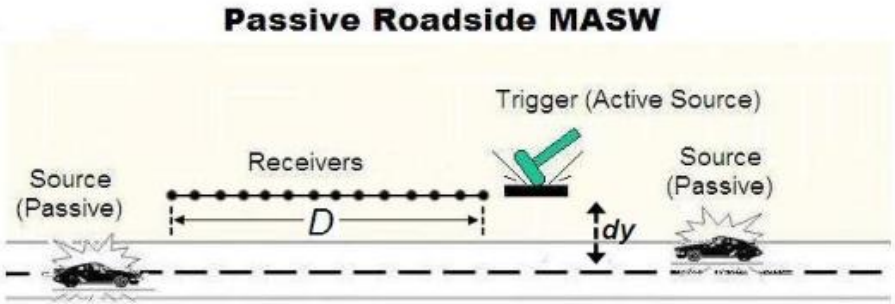


Rix, 2000

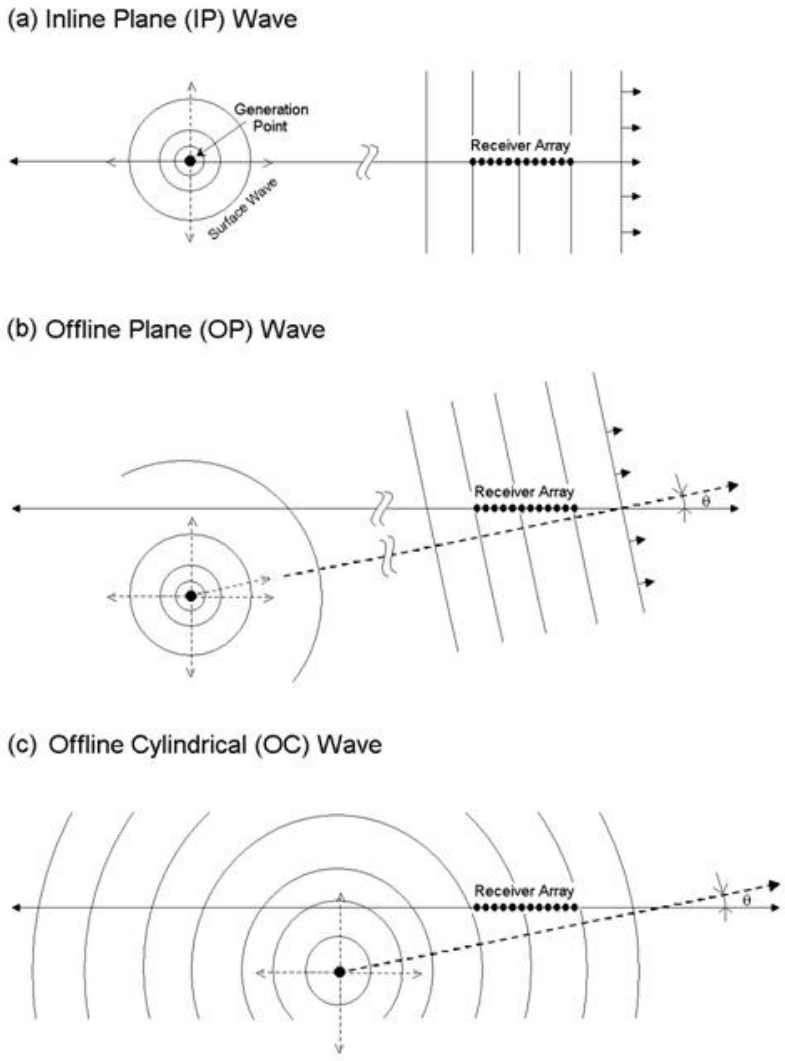
Excitation of the structure depends on:

- source type: hammer, dynamite, vibrator, ...
- velocity and attenuation structure

“Roadside MASW”

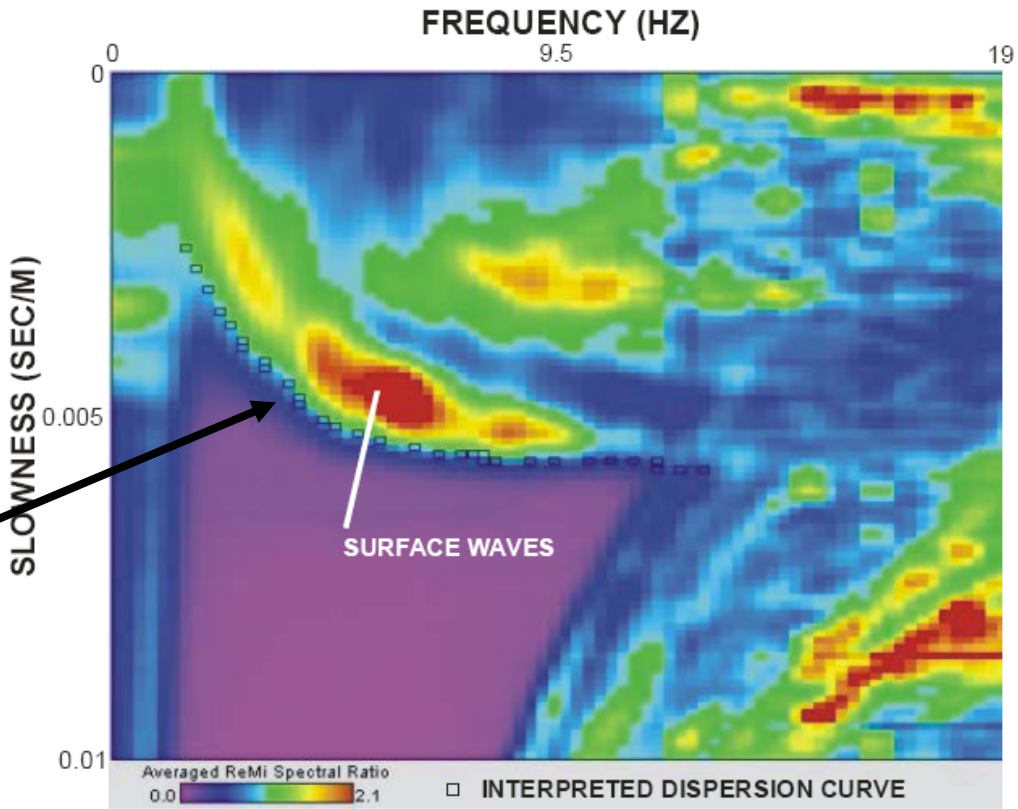


Park and Miller, 2008

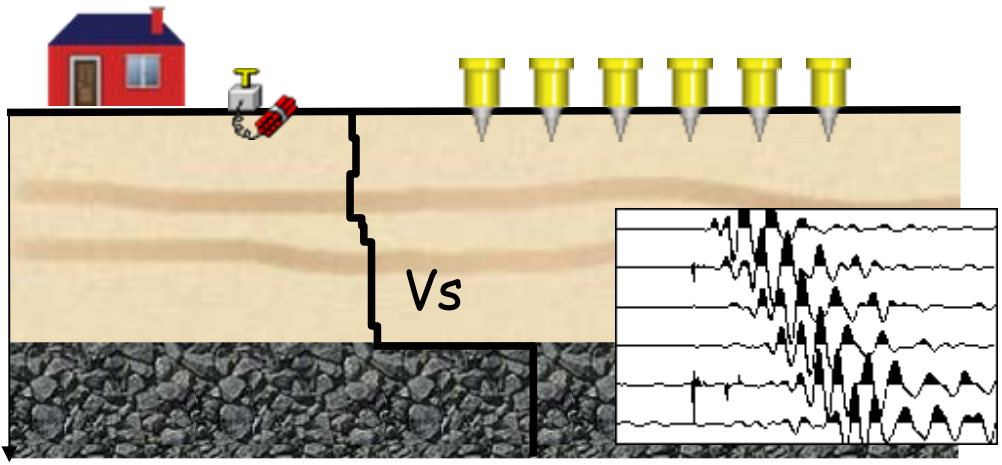
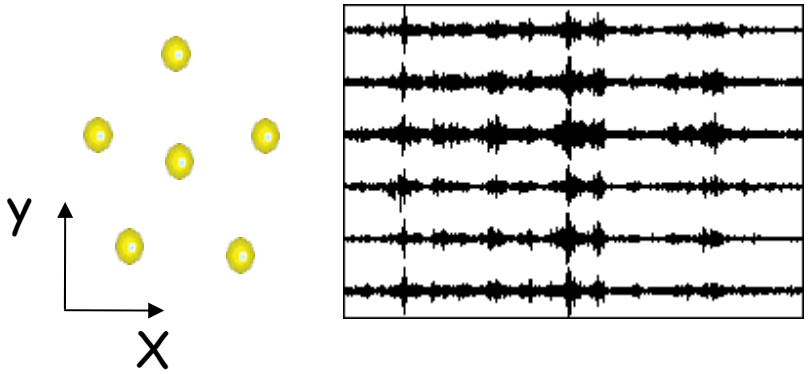


REMI: REfraction MIcrotremor analysis

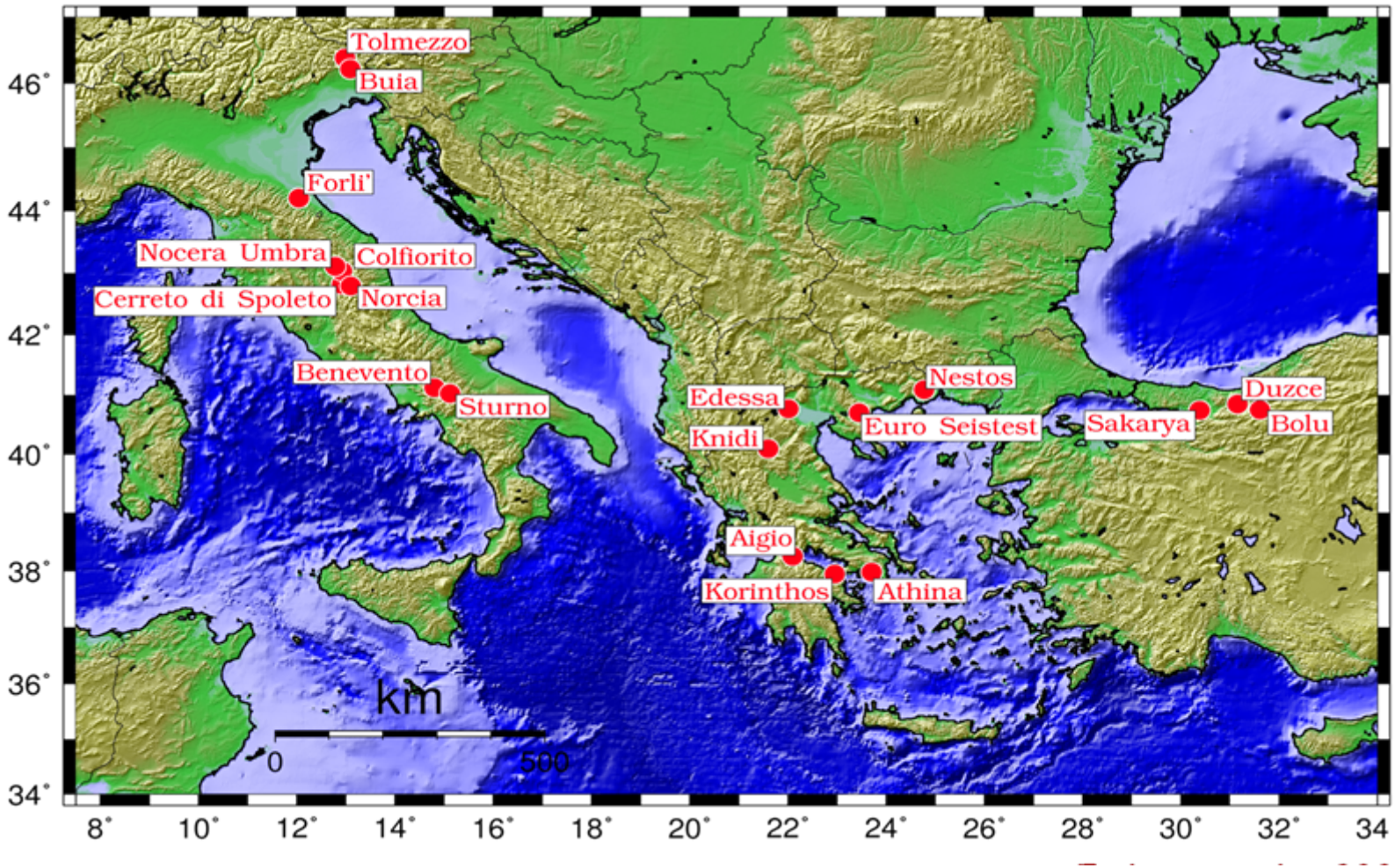
Introduced par Louie (2001)

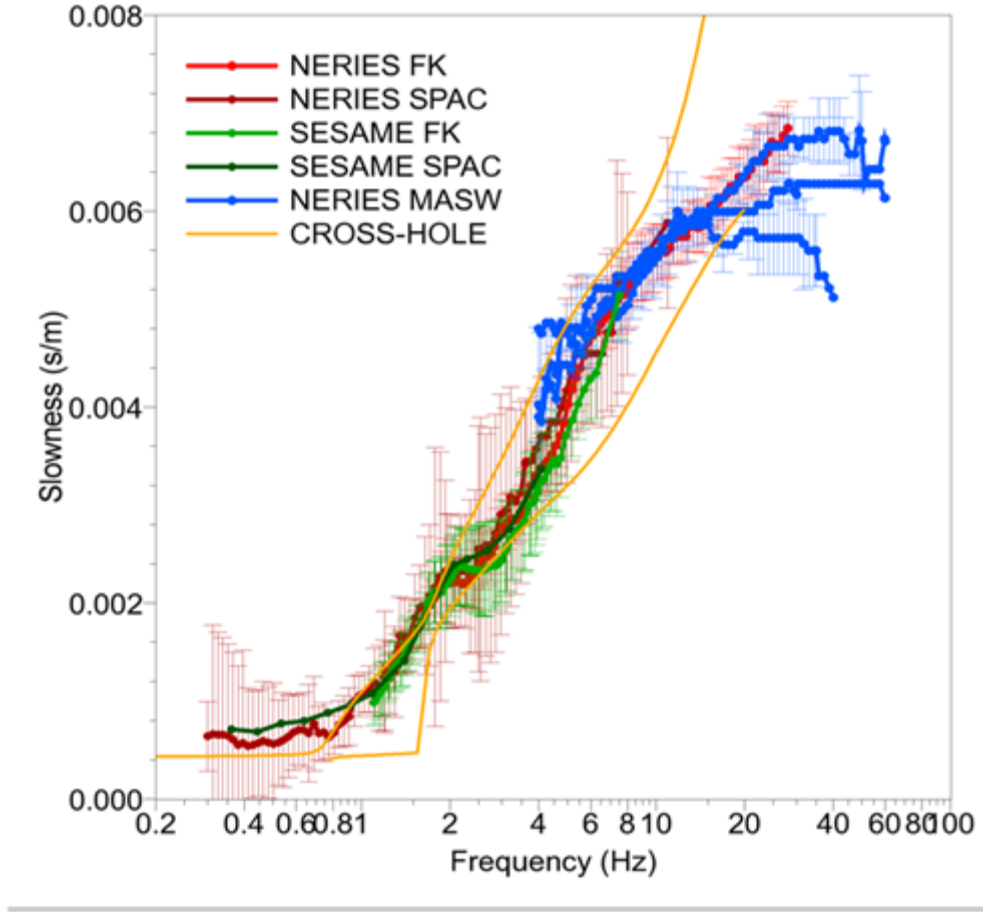


Phase picking

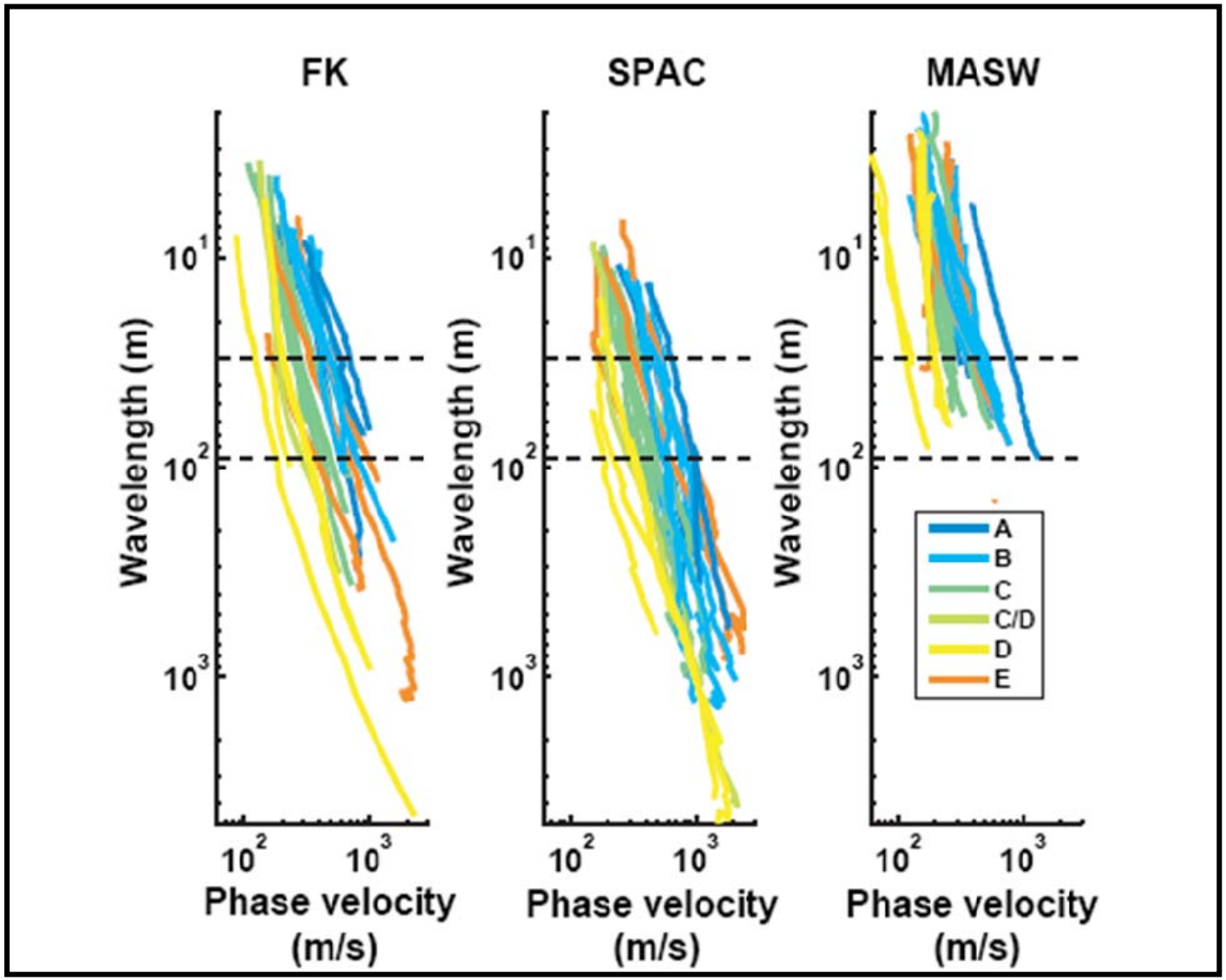
	Artificial source	Ambient noise
	 Depth	
Frequency range	High frequency	Low frequency
Penetration depth	Few tens of metres	Few hundreds of metres
Propagation	Only one direction	Multiple arrivals
Source localization	Yes	Unlocalized
Source function	Monitored	Unknown

Comparative studies on 19 accelerometric european sites (NERIES)




NERIES FK
NERIES SPAC
SESAME FK
SESAME SPAC
NERIES MASW
CROSS-HOLE
Slowness (s/m)
0.000
0.002
0.004
0.006
0.008
0.2
0.4
0.6
0.8
1
2
4
6
8
10
20
40
60
80
100
Frequency (Hz)

Depth penetration



Renalier, 2010