Evaluation of shear wave velocity profile of soil

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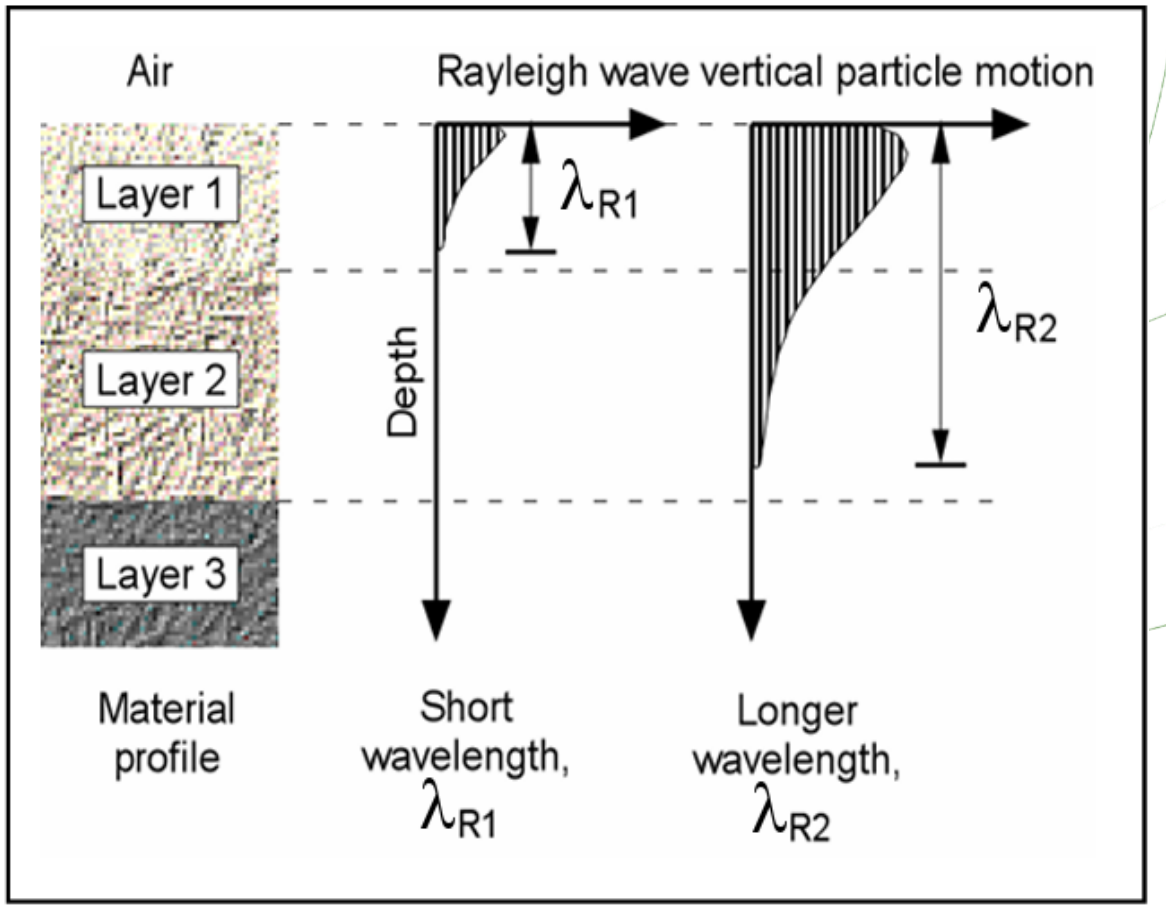
Methods to estimate the shear wave velocity profile

- **Down-hole and cross-hole** (require access to a drilled borehole)
- **Seismic refraction** (active methods - require increasing velocity with depth)
- **Seismic reflection** (active methods - requires a controlled source of energy)
- **Surface wave analysis methods** (based on the dispersive properties of surface waves propagating through a heterogeneous medium - active methods end passive methods)

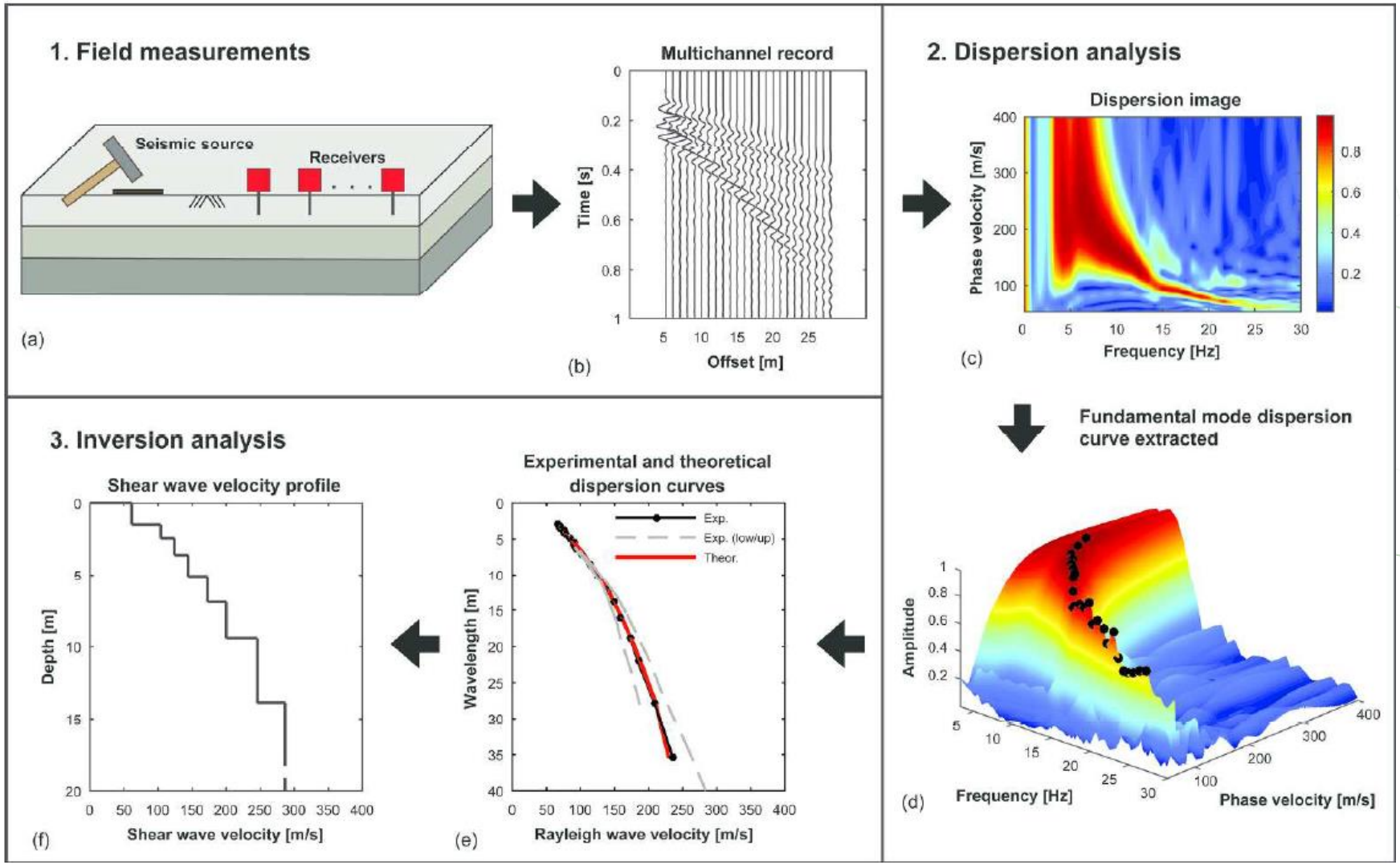
Surface wave analysis methods

The basis of surface wave techniques is the ***dispersive*** characteristic of Rayleigh waves when traveling through a layered medium. Rayleigh wave velocity is determined by the material properties (primarily shear wave velocity, but also to a lesser degree compression wave velocity and material density) of the subsurface.

Longer wavelengths penetrate deeper and their velocity is affected by the material properties at greater depth. Surface wave testing consists of measuring the surface wave dispersion curve at a site and modeling it to obtain the corresponding shear wave velocity profile

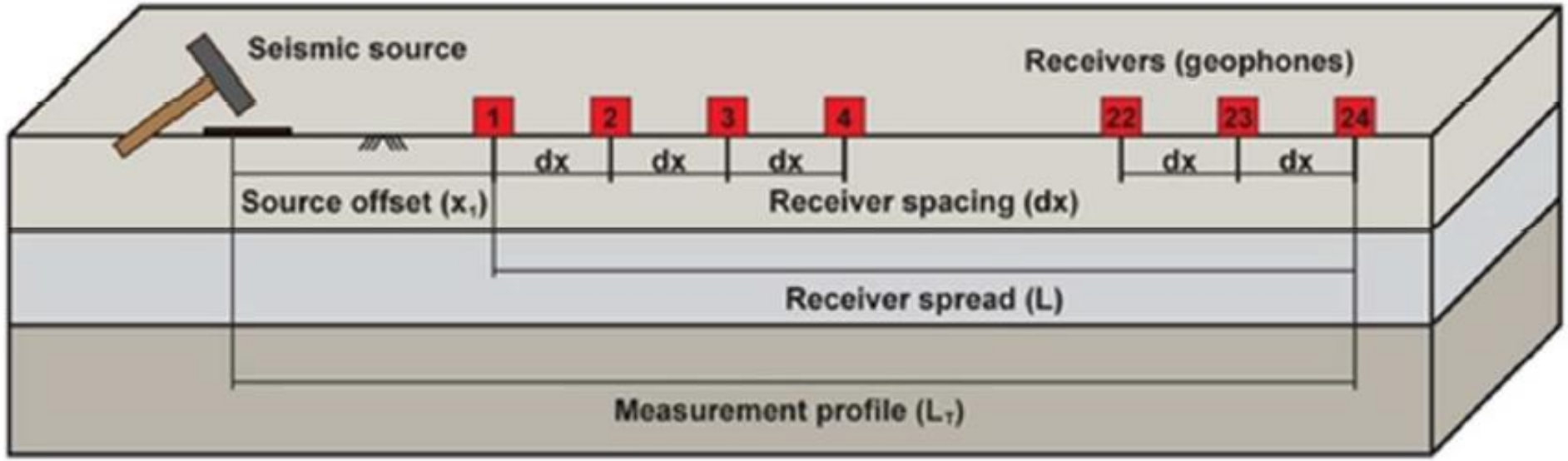


Surface Wave Analysis Phases



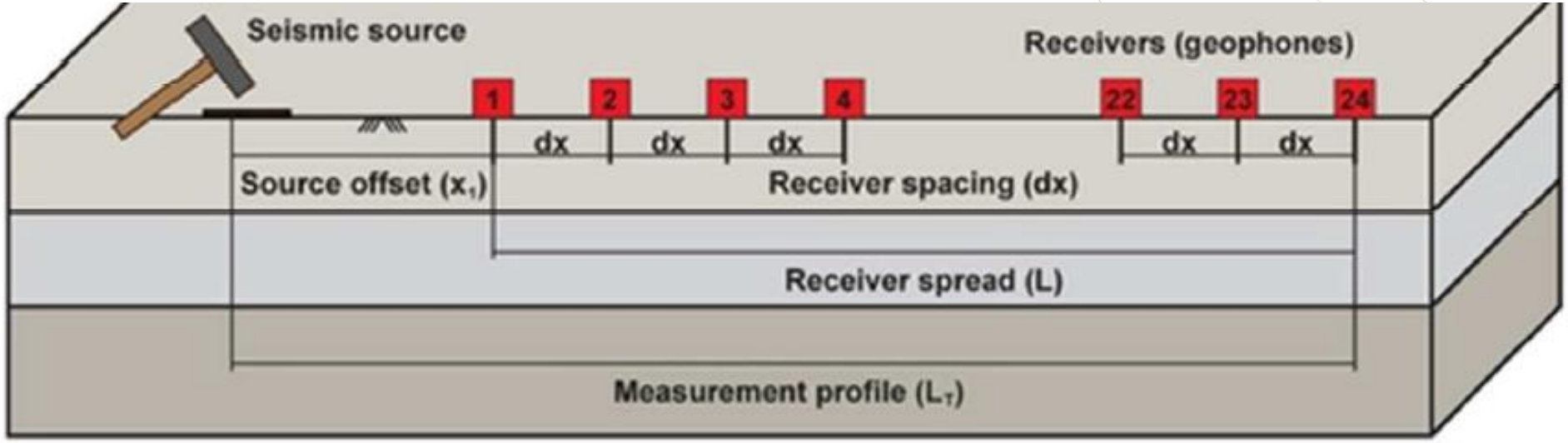
Surface wave analysis: Active methods

Multichannel Analysis of Surface Waves (MASW) is **active**, low-cost and environmentally friendly technique to estimate shear wave velocity profiles of soil sites.



Multichannel Analysis of Surface Waves

The investigation depth is determined by the longest Rayleigh wave wavelength that is retrieved.



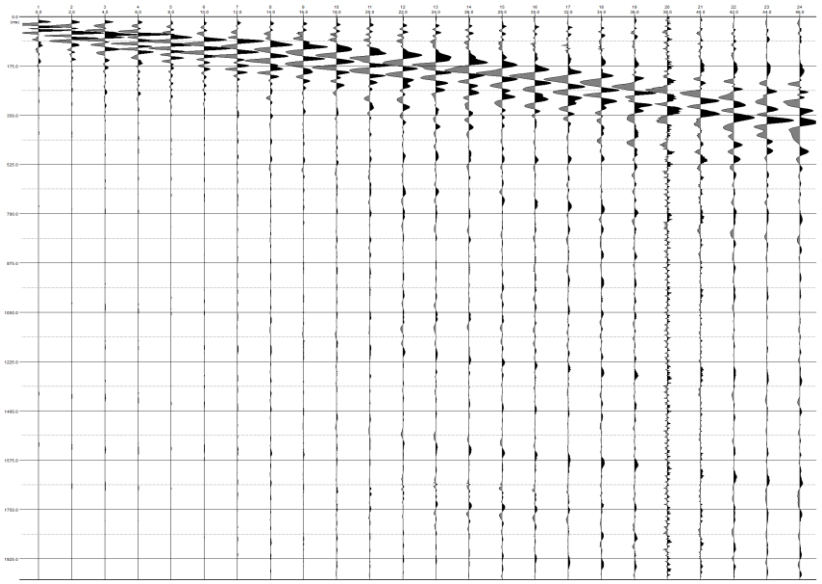
$$z_{max} \approx 0.5\lambda_{max}$$

Typical MASW measurement profile

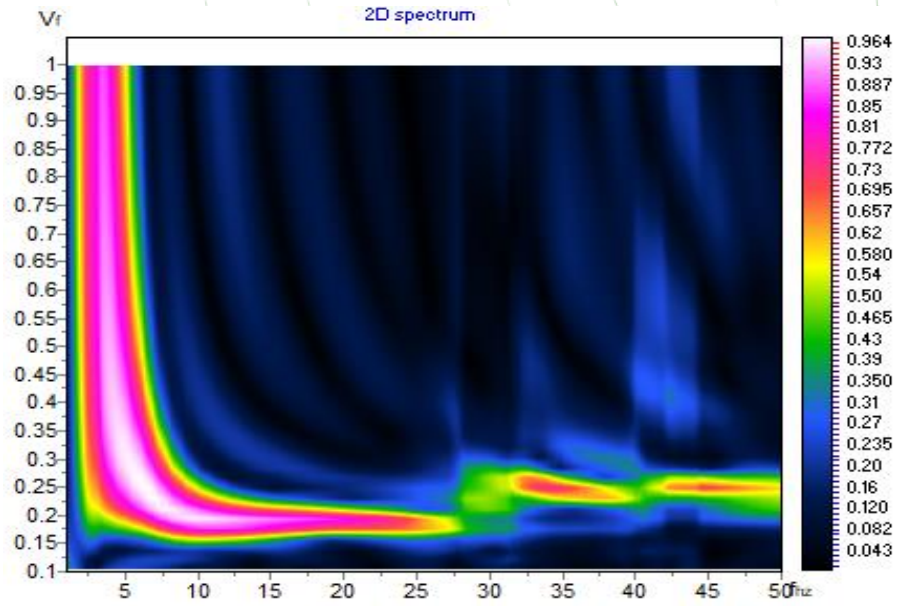
- ***Number of receivers***: 24
- ***Receiver spacing (dx)***: 2 m
- ***Source offset (x_1)***: 2 – 4 dx
- ***Length receiver spread (L)***: 46 m
- ***Length profile (L_T)***: 50 – 60 m
- ***Sampling rate (fs)***: 400 Hz
- ***Recording time (T)***: 2 s

Extraction of dispersion curves

space–time domain



frequency–wave number domain

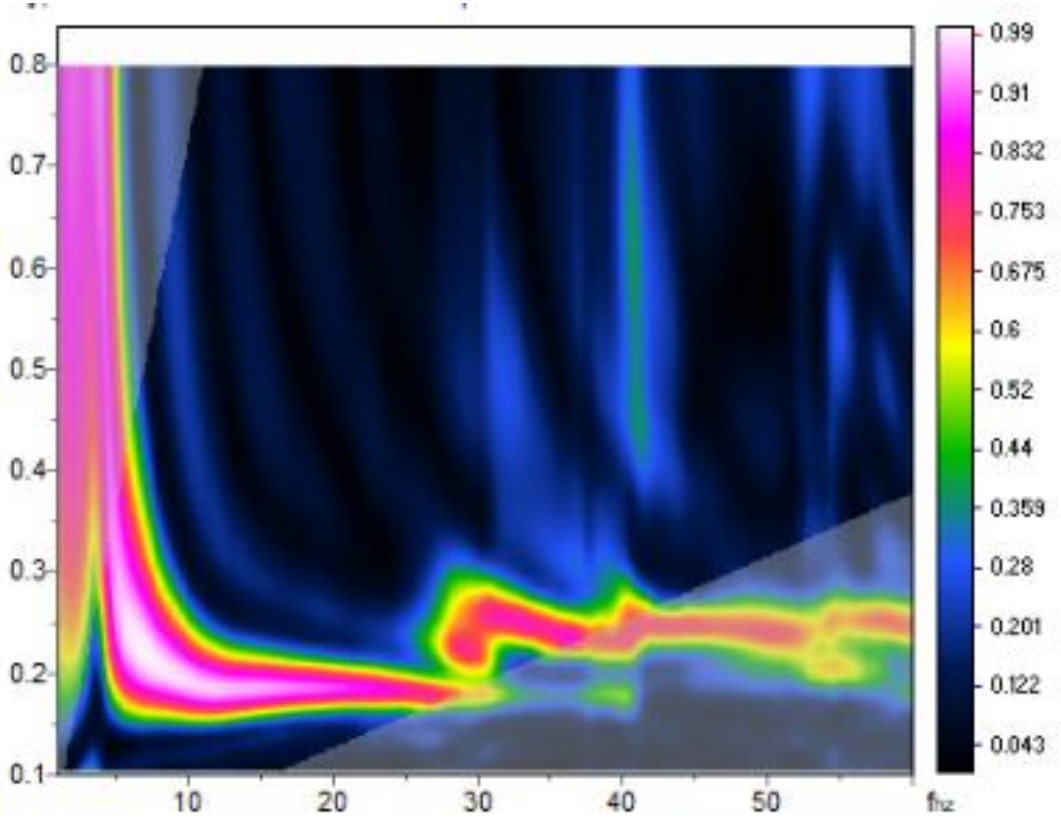


Time series are transformed from the space–time domain into a different domain. There are different methods:

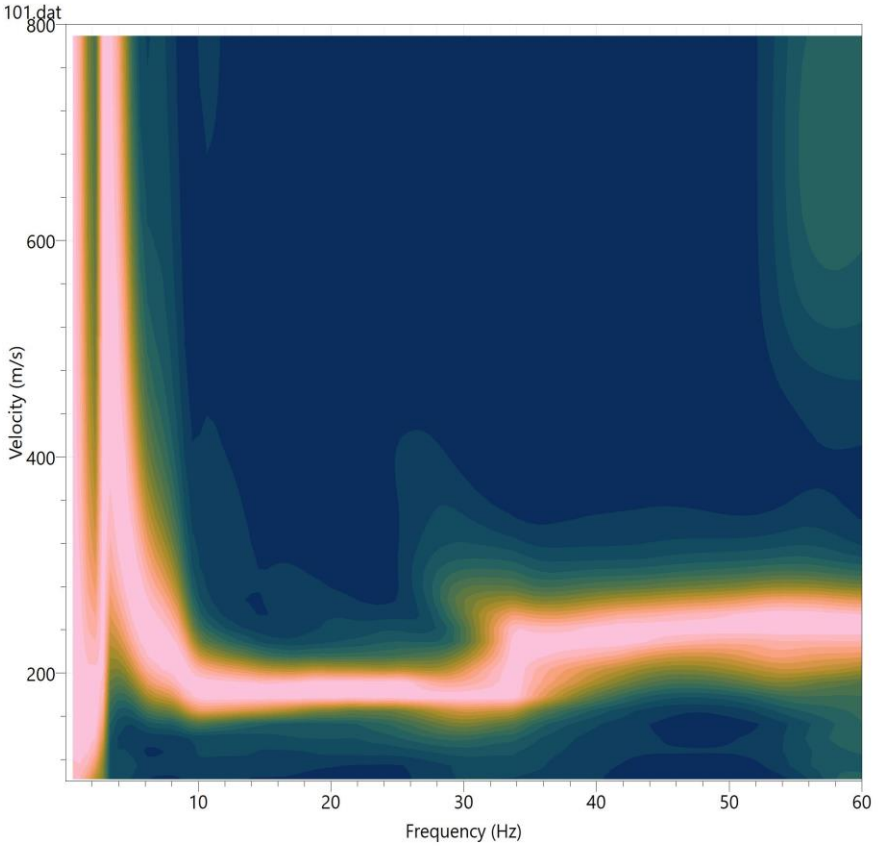
1) **phase shift method**
2) frequency–wave number (f-K) transform (Geopsy)
3) slowness–frequency (p-ω) transform

Comparison of phase shift method and F-K method

Dispersion curve using Phase-shift method

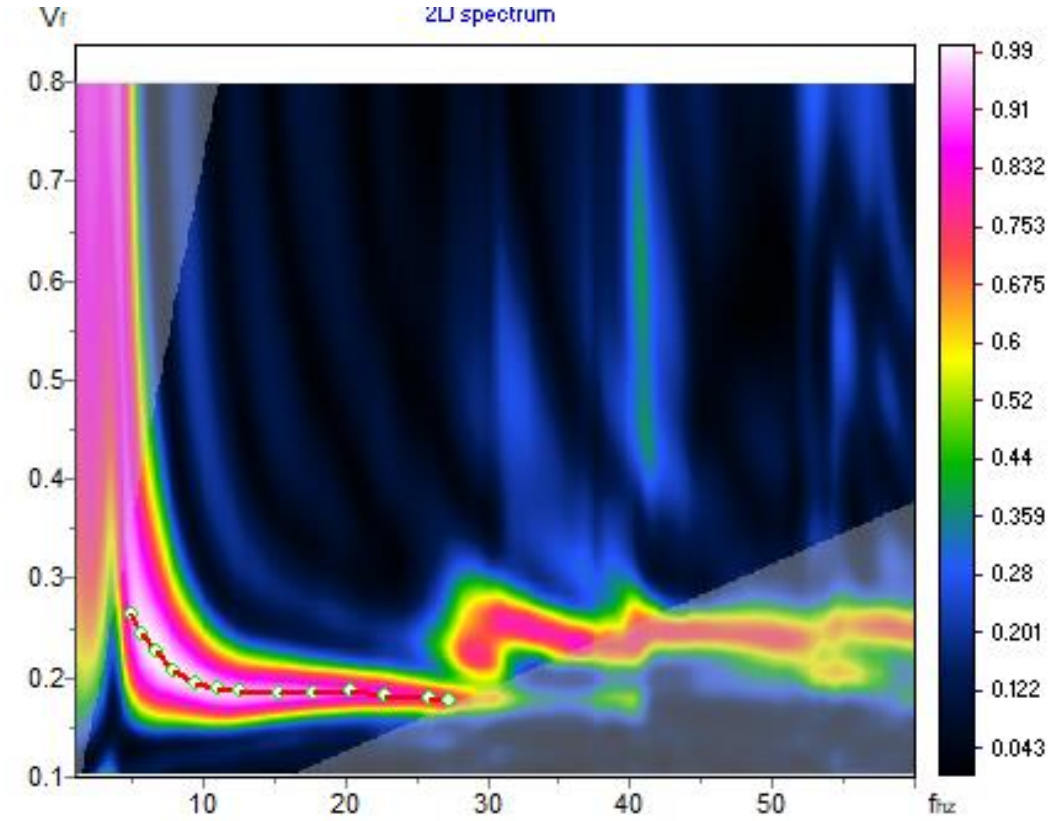


Dispersion curve using F-K method

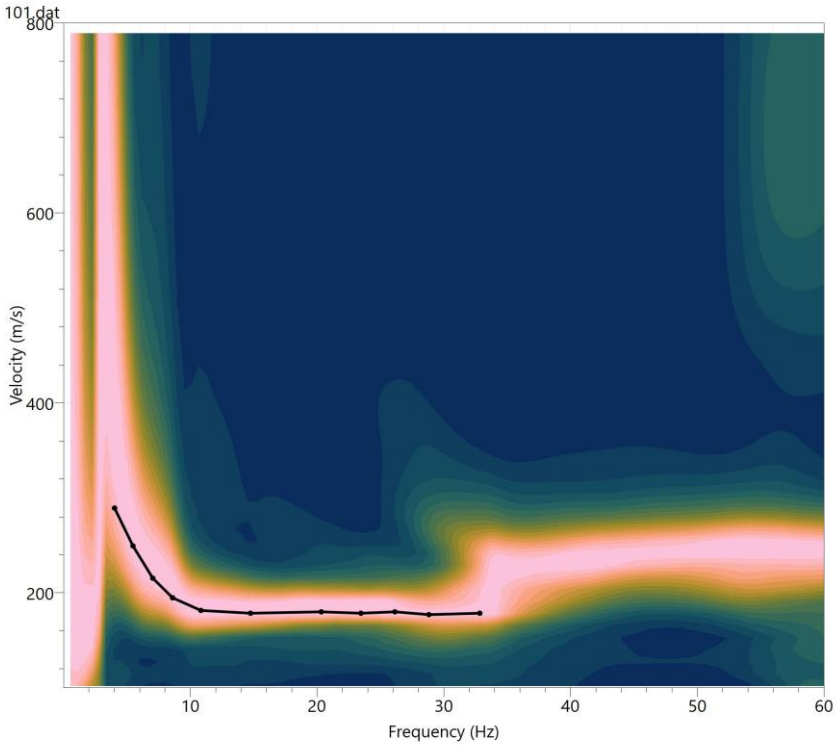


Fundamental mode dispersion curve extracted

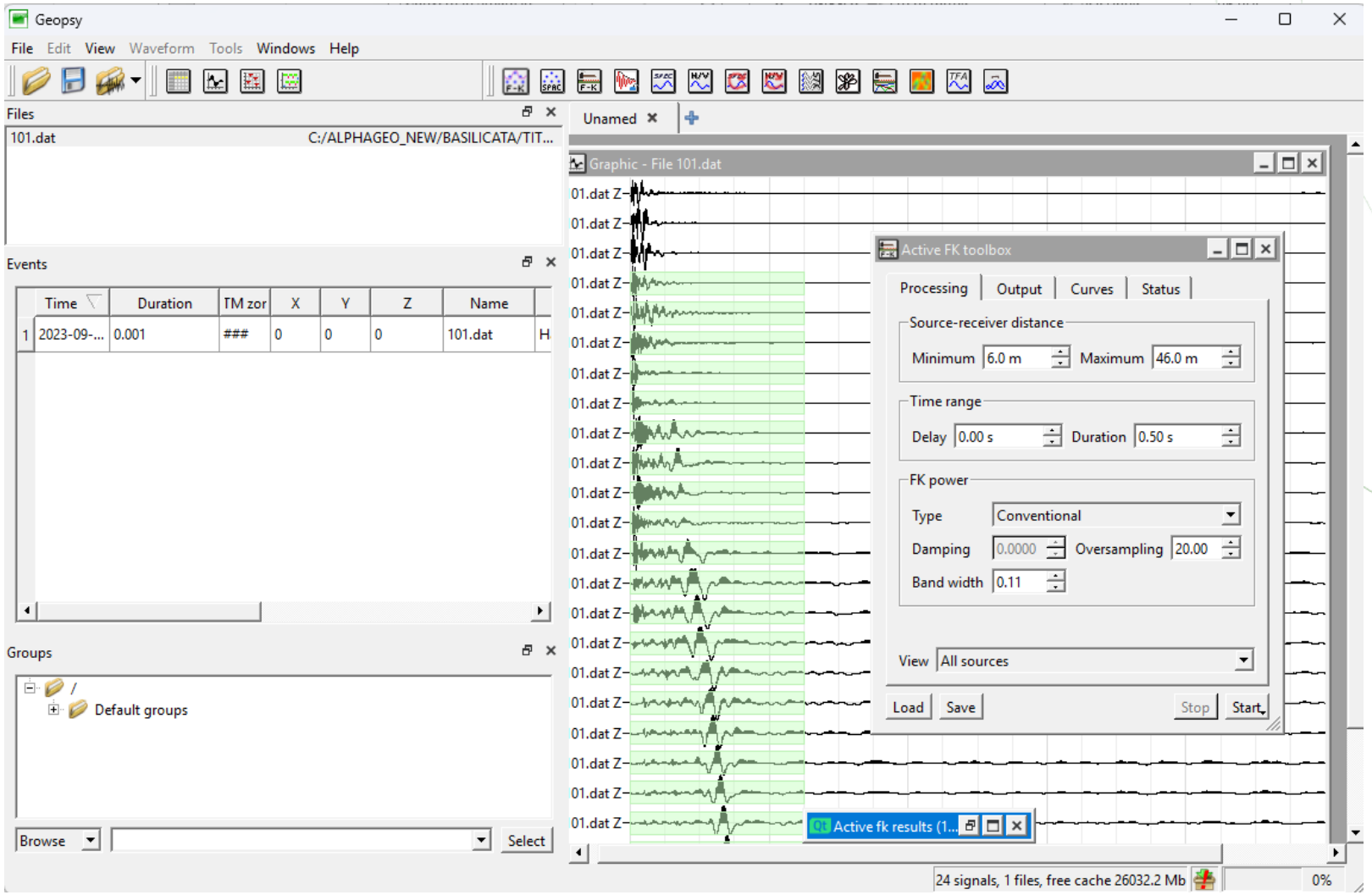
Dispersion curve using Phase-shift method



Dispersion curve using F-K method



Tools for Analysis of Surface Waves



1) Import signals
2) Set receivers
3) Active F-K
4) Set Source distance
5) Time range
6) Start

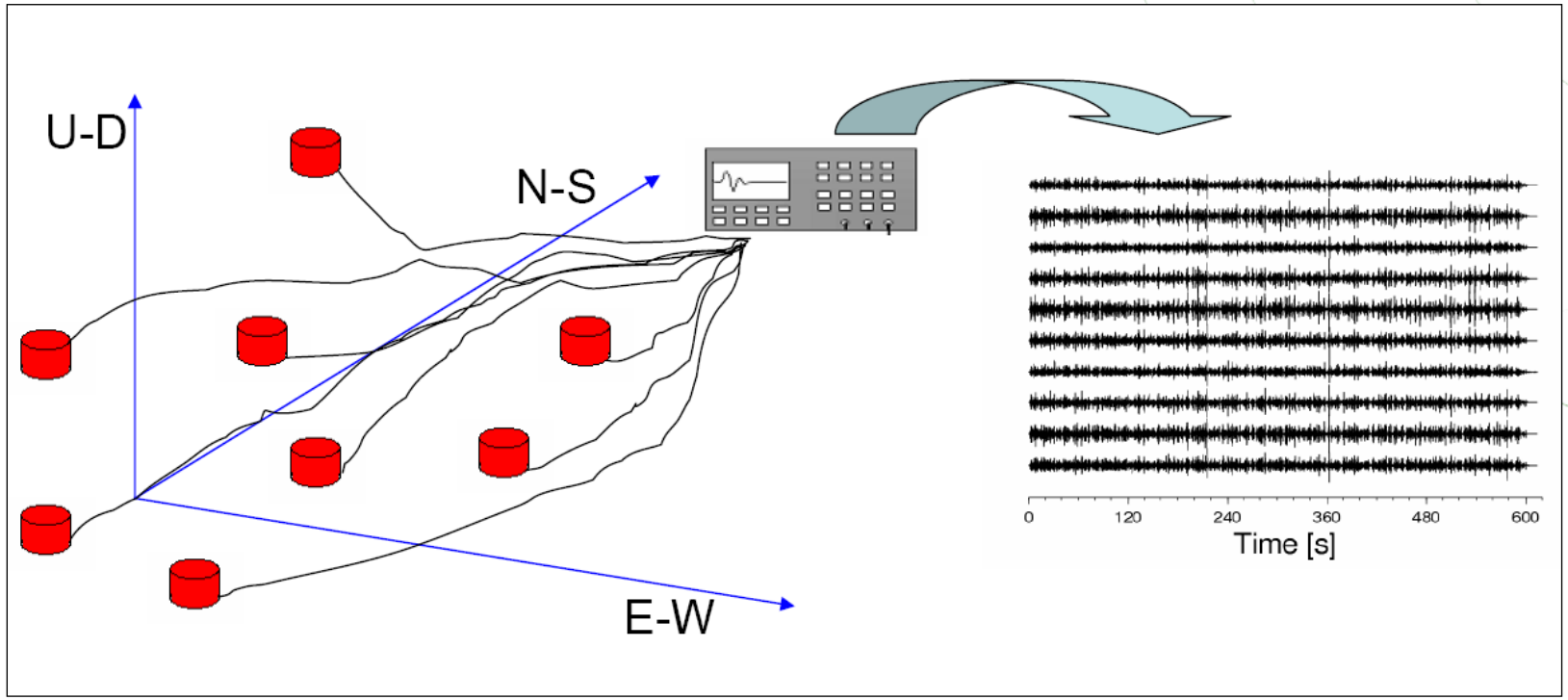
Surface wave analysis: Passive methods

Vertical profiles of the shear-wave velocity (Vs) inverted through the ESAC method, from passive noise measurements of the array.

	Gutenberg (1958)	Asten (1978-1984)
Waves striking the coast	0.05-0.1 Hz	0.5-1.2 Hz
Moonson / large scale meteorological perturbations	0.1-0.25 Hz	0.16-0.5 Hz
Cyclones over the ocean	0.3-1 Hz	0.5-3 Hz
Local meteorological conditions	1.4-5 Hz	
Volcanic tremor	2-10 Hz	
Urban	1-100 Hz	1.4-30hz

ESAC methods Array Configuration

The extended spatial autocorrelation (ESAC) method, which makes it possible to design arbitrarily shaped arrays.

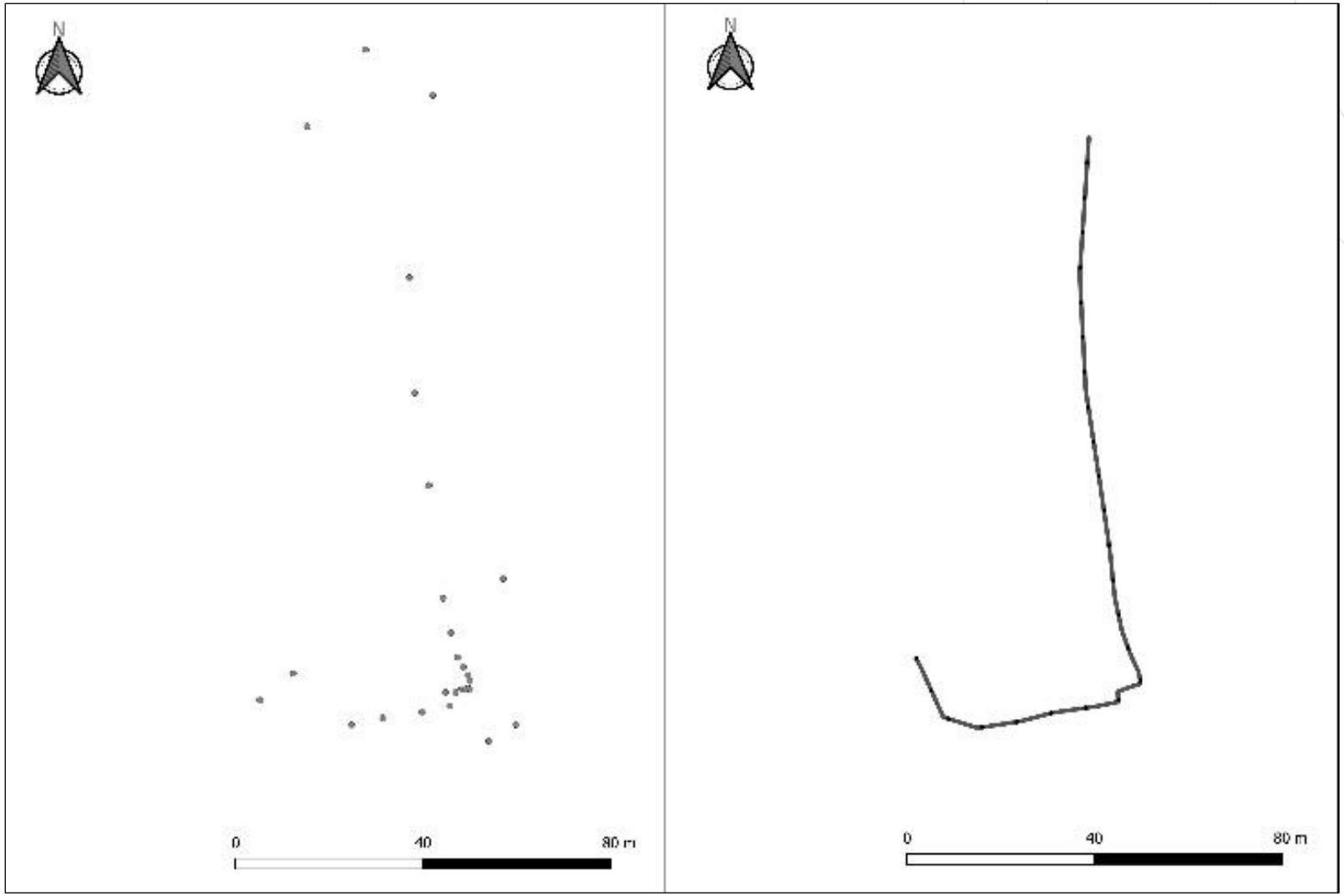


ESAC methods Measuring instruments

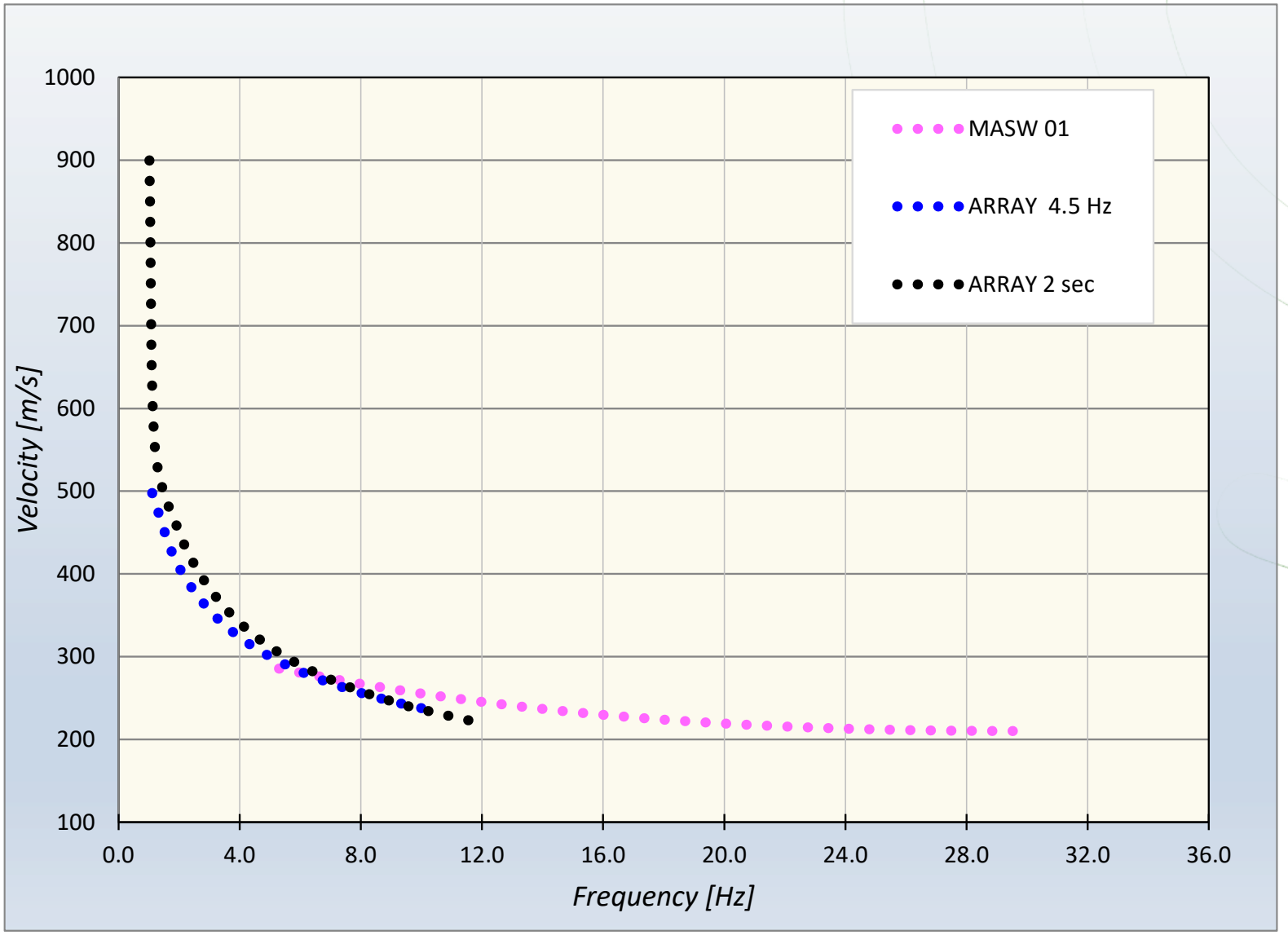
Geometrics” - “Geode” (24 geofoni verticali della 4,5 Hz)

Lunitek” - “Sentinel GEO MKII (2 sec, 24 bit, 120 dB)

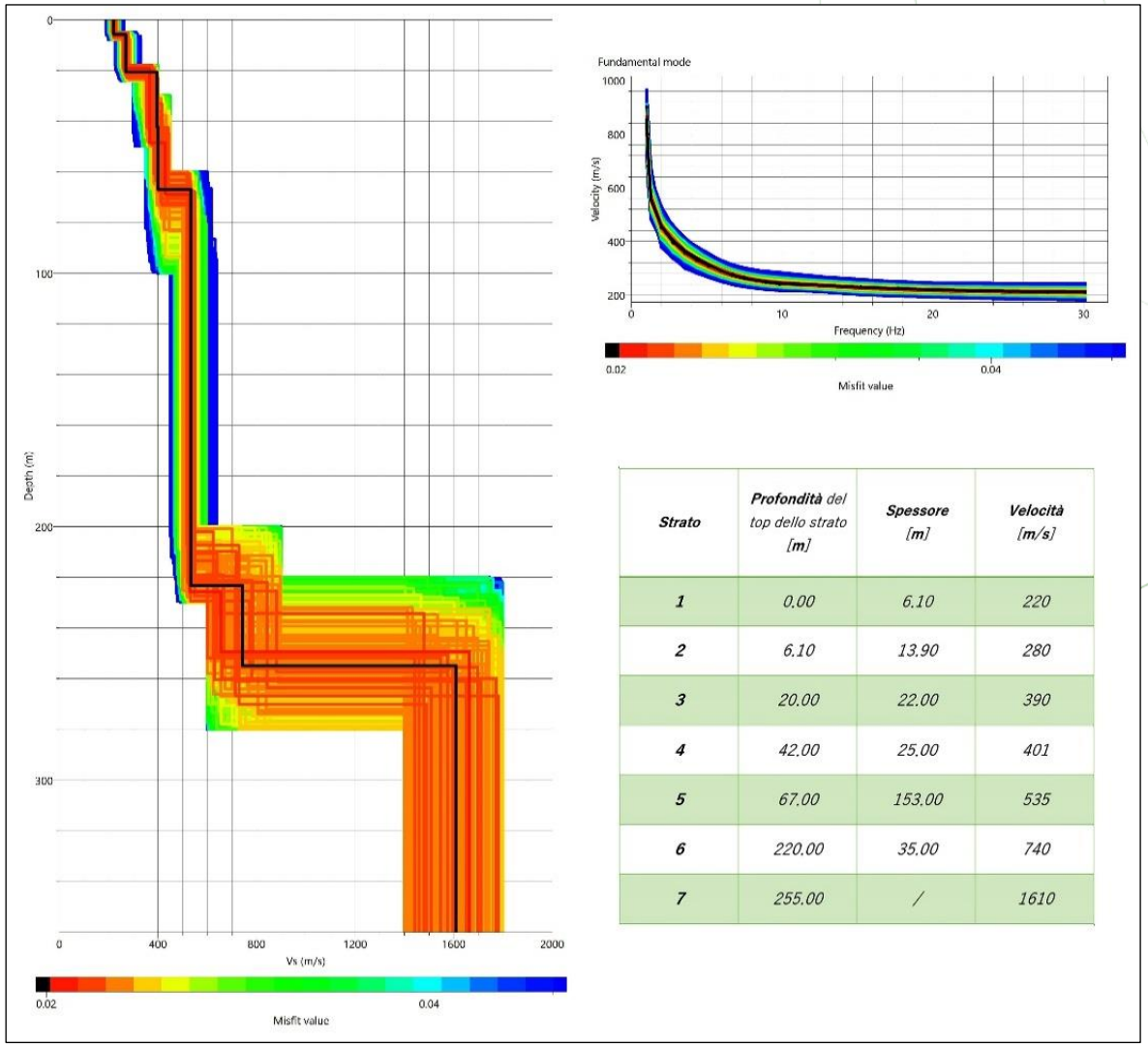
ESAC methods Array configurations



ESAC methods dispersion curves



ESAC methods Shear wave velocity profile



Strato	***Profondità** del top dello strato [m]*	***Spessore** [m]*	***Velocità** [m/s]*
1	*0.00*	*6.10*	*220*
2	*6.10*	*13.90*	*280*
3	*20.00*	*22.00*	*390*
4	*42.00*	*25.00*	*401*
5	*67.00*	*153.00*	*535*
6	*220.00*	*35.00*	*740*
7	*255.00*	*/*	*1610*

FIELD MEASUREMENTS

Data processing.....

THANKS!

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