A summary of seismic data analyses at the ET candidate site in Sardinia (Italy)

Gilberto Saccorotti

on behalf of the ET Sardinia Characterization Team

This Talk:

A summary of the passive seismic data analysis

1. The Sos Enattos site
    - Single-station & underground measurements
    - Small-aperture array
    - velocity models

2. The P2 and P3 corners: borehole spectra

3. Summary, and some considerations

Main targets of site characterization

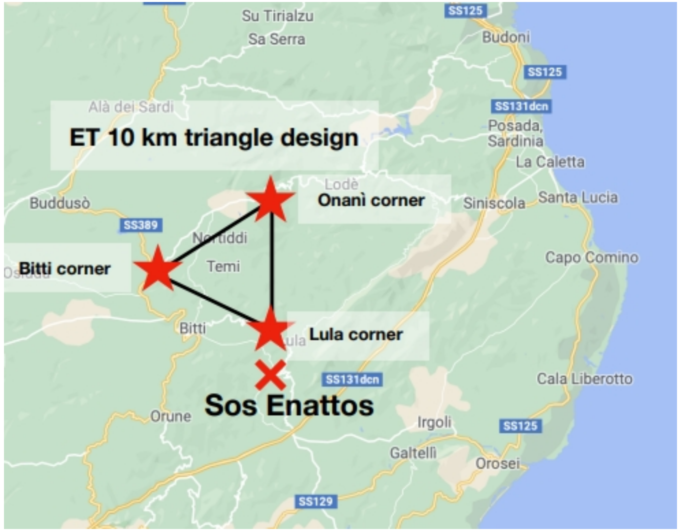
Determine wavefield properties in terms of:

- Propagation direction → **Source identification**
  - * Transient vs stationary
  - * Can be mitigated / eliminated

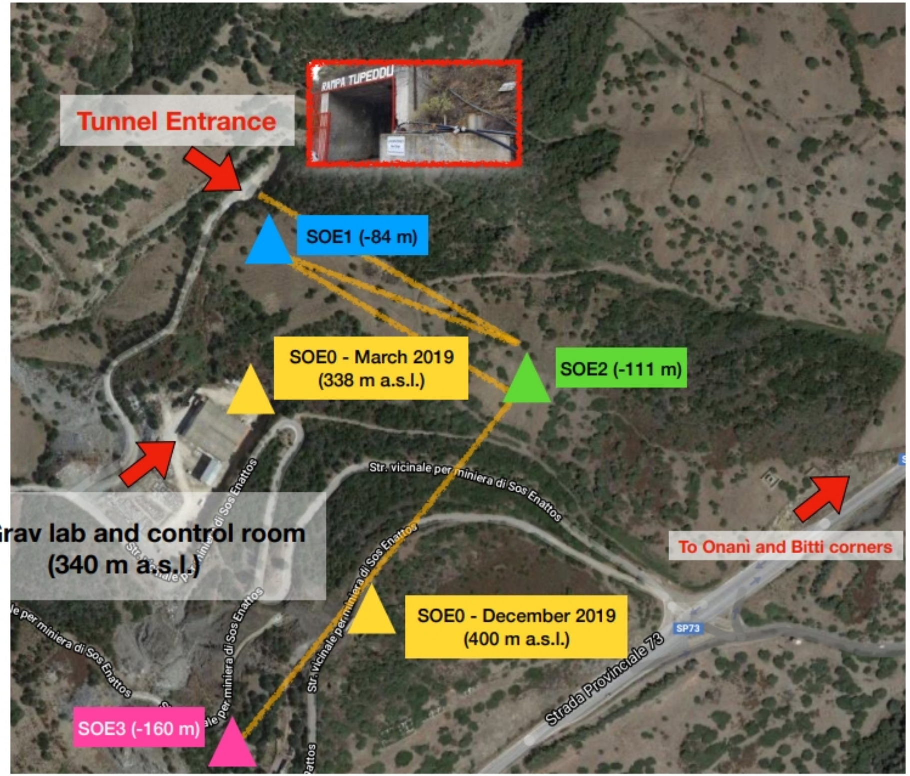
- Propagation velocity → **Wave-type (body vs surface)**
  - Medium properties
    - * Velocity
    - * Attenuation

- Long-term behaviour

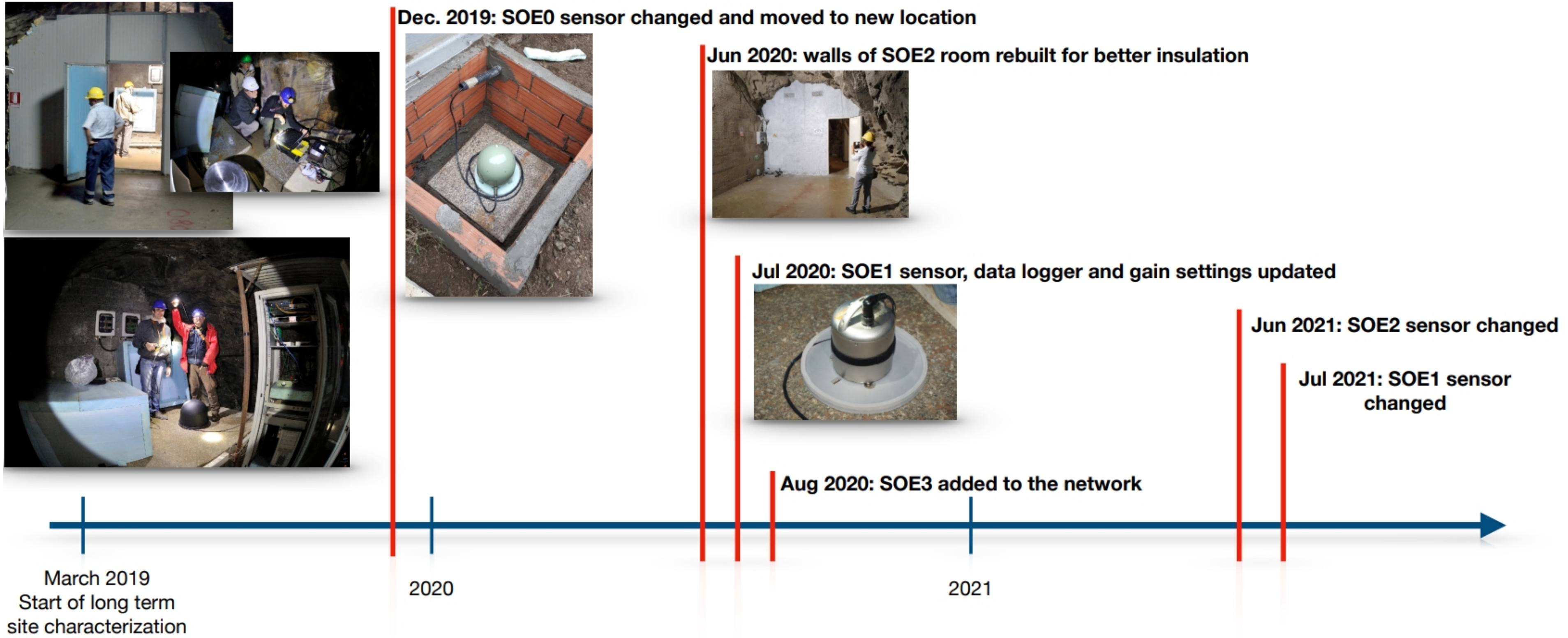
Sos Enattos Corner



- Seismic characterization of Sos Enattos was first established in 2010 with temporary installations.
- Since 2019: 4 permanent seismic stations for long term studies.
- Surface: **SOE0,** underground: **SOE1, SOE2, SOE3**
- All stations are equipped with broadband seismometers



Credits: Matteo di Giovanni, this workshop



Credits: Matteo di Giovanni, this workshop

Station SOE2 part of INGV's earthquake monitoring program.

Client: **INGV**

Net code: **IV**

Station code: **SENA**

http://cnt.rm.ingv.it/instruments/station/SENA

Stazione Sismica SENA Sos Enattos Mine

Rete: IV
Data Inizio: 2019-10-18T00:00:00
Data Fine: --
Latitudine: 40.4444
Longitudine: 9.4566
Altitudine: 338
Download StationXML

Numero di canali: 6

General Assessment and Long-term Characterization

RESEARCH ARTICLE | NOVEMBER 04, 2020

A Seismological Study of the Sos Enattos Area—the Sardinia Candidate Site for the Einstein Telescope

Matteo Di Giovanni; Carlo Giunchi; Gilberto Saccorotti; Andrea Berbellini; Lapo Boschi; Marco Olivieri; Rosario De Rosa; Luca Naticchioni; Giacomo Oggiano; Massimo Carpinelli; Domenico D'Urso; Stefano Cuccuru; Valeria Sipala; Enrico Calloni; Luciano Di Fiore; Aniello Grado; Carlo Migoni; Alessandro Cardini; Federico Paoletti; Irene Fiori; Jan Harms; Ettore Majorana; Piero Rapagnani; Fulvio Ricci; Michele Punturo

Seismological Research Letters (2021) 92 (1): 352–364.

https://doi.org/10.1785/0220200186 **Article history**

IOP Publishing Classical and Quantum Gravity

Class. Quantum Grav. **31** (2014) 105016 (20pp) doi:10.1088/0264-9381/31/10/105016

Microseismic studies of an underground site for a new interferometric gravitational wave detector

L Naticchioni[1,2], M Perciballi[2], F Ricci[1,2], E Coccia[3,4], V Malvezzi[3], F Acernese[5,6], F Barone[5,6], G Giordano[5], R Romano[5,6], M Punturo[7], R De Rosa[6,8], P Calia[9] and G Loddo[9]

Eur. Phys. J. Plus (2021) 136:511
https://doi.org/10.1140/epjp/s13360-021-01450-8

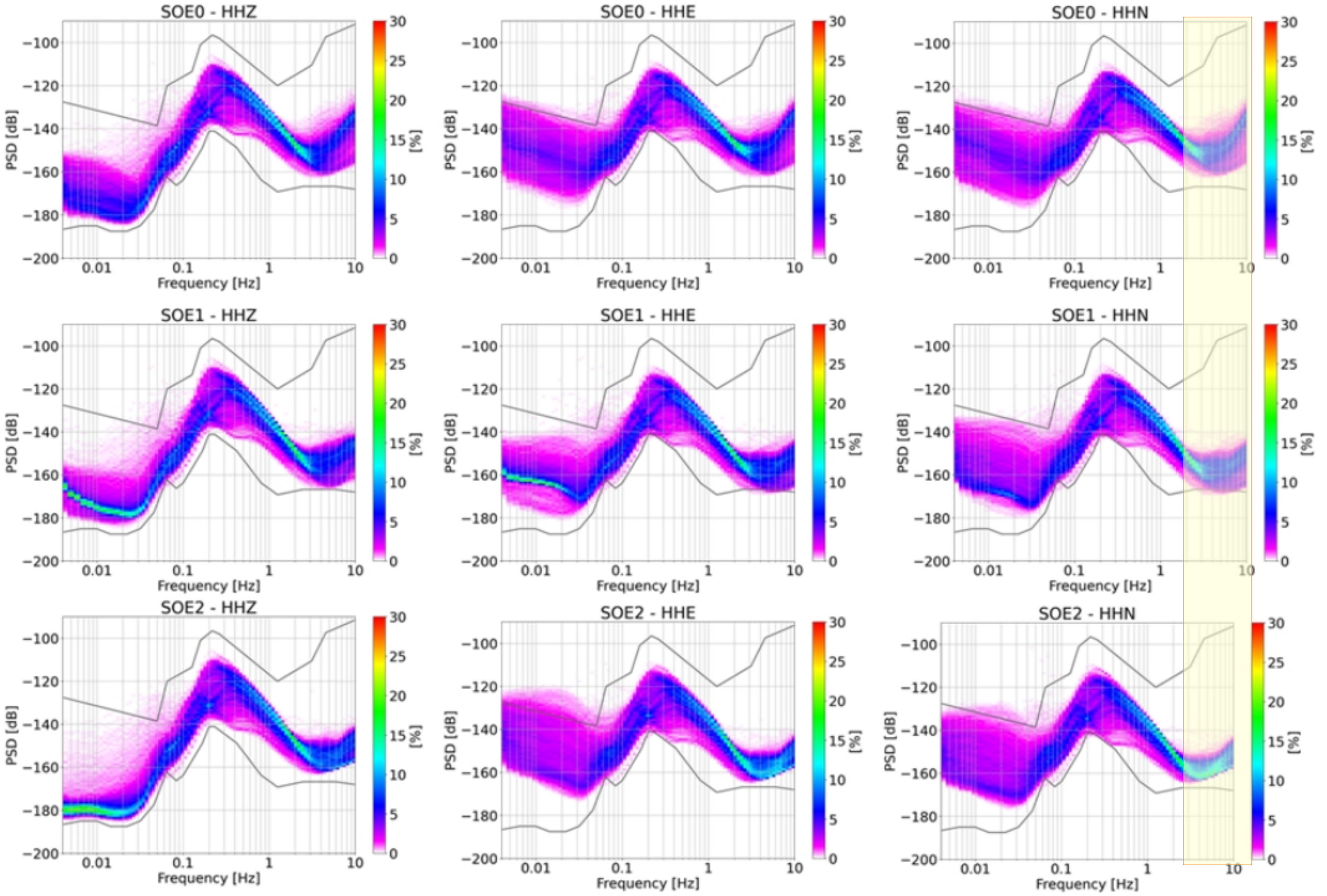
THE EUROPEAN PHYSICAL JOURNAL PLUS

Regular Article

Check for updates

Seismic glitchness at Sos Enattos site: impact on intermediate black hole binaries detection efficiency

A. Allocca[1,2], A. Berbellini[3], L. Boschi[3,4,5], E. Calloni[1,2,a], G. L. Cardello[6,7], A. Cardini[8], M. Carpinelli[6,7,9], A. Contu[8,10], L. D'Onofrio[1,2], D. D'Urso[6,7], D. Dell'Aquila[6,7], R. De Rosa[1,2], L. Di Fiore[2], M. Di Giovanni[11,12,13], S. Di Pace[14,15], L. Errico[1,2], I. Fiori[9], C. Giunchi[11], A. Grado[16], J. Harms[12], E. Majorana[14,15], V. Mangano[14,15], M Marsella[14,15], C. Migoni[8], L. Naticchioni[14,15], M. Olivieri[3], G. Oggiano[6,7], F. Paoletti[17], M. Punturo[18], P. Puppo[15], P. Rapagnani[14,15], F. Ricci[14,15], D. Rozza[6,7], G. Saccorotti[11], V. Sequino[1,2], V. Sipala[6,7], I. Tosta E Melo[6,7], L. Trozzo[2]

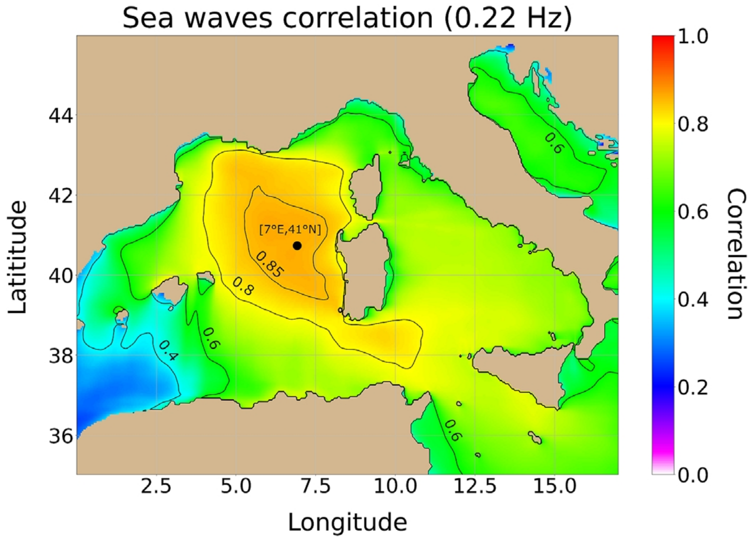


Surface, low gain

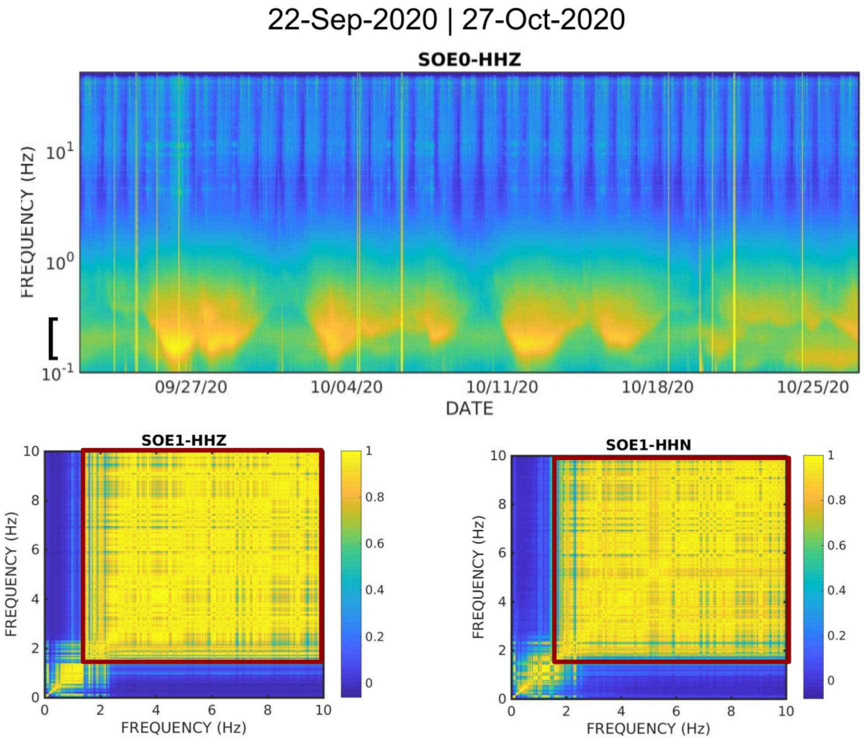
Underground, high gain

Underground, low gain

Separation of Noise Sources from the correlation of the spectral power at distinct frequencies & correlation with wave height

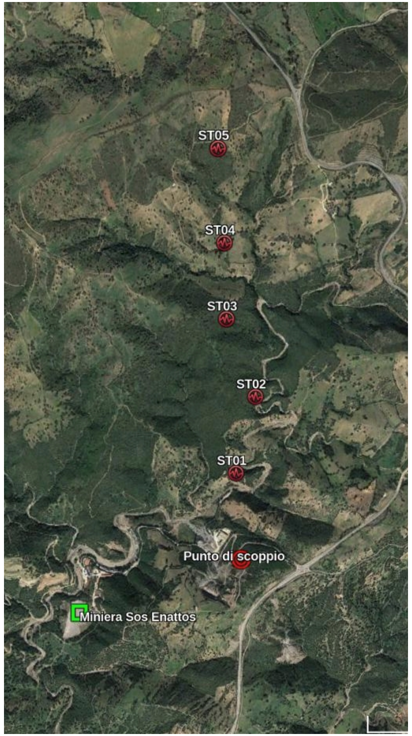


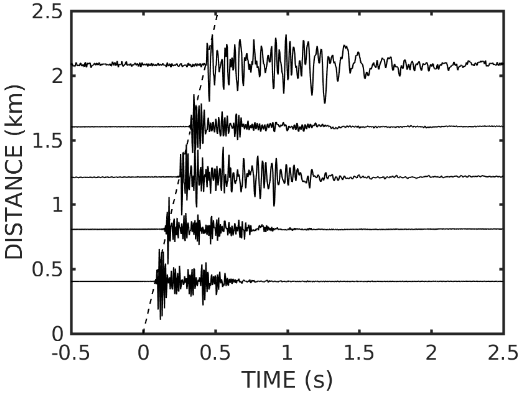
Source of microseism identified in the Western Mediterranean Sea

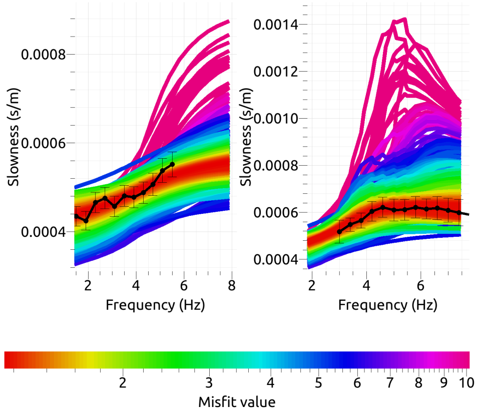


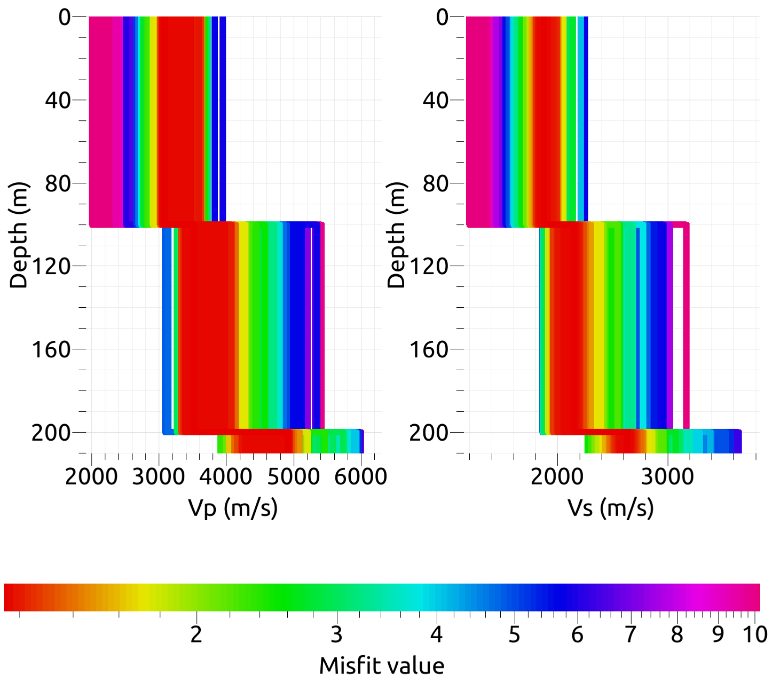
0.1-1.5 Hz : Microseism
1.5-2 Hz : overlapping region
>2 Hz : Anthropogenic

Velocity models from Rayleigh wave dispersion curves (mine blast)

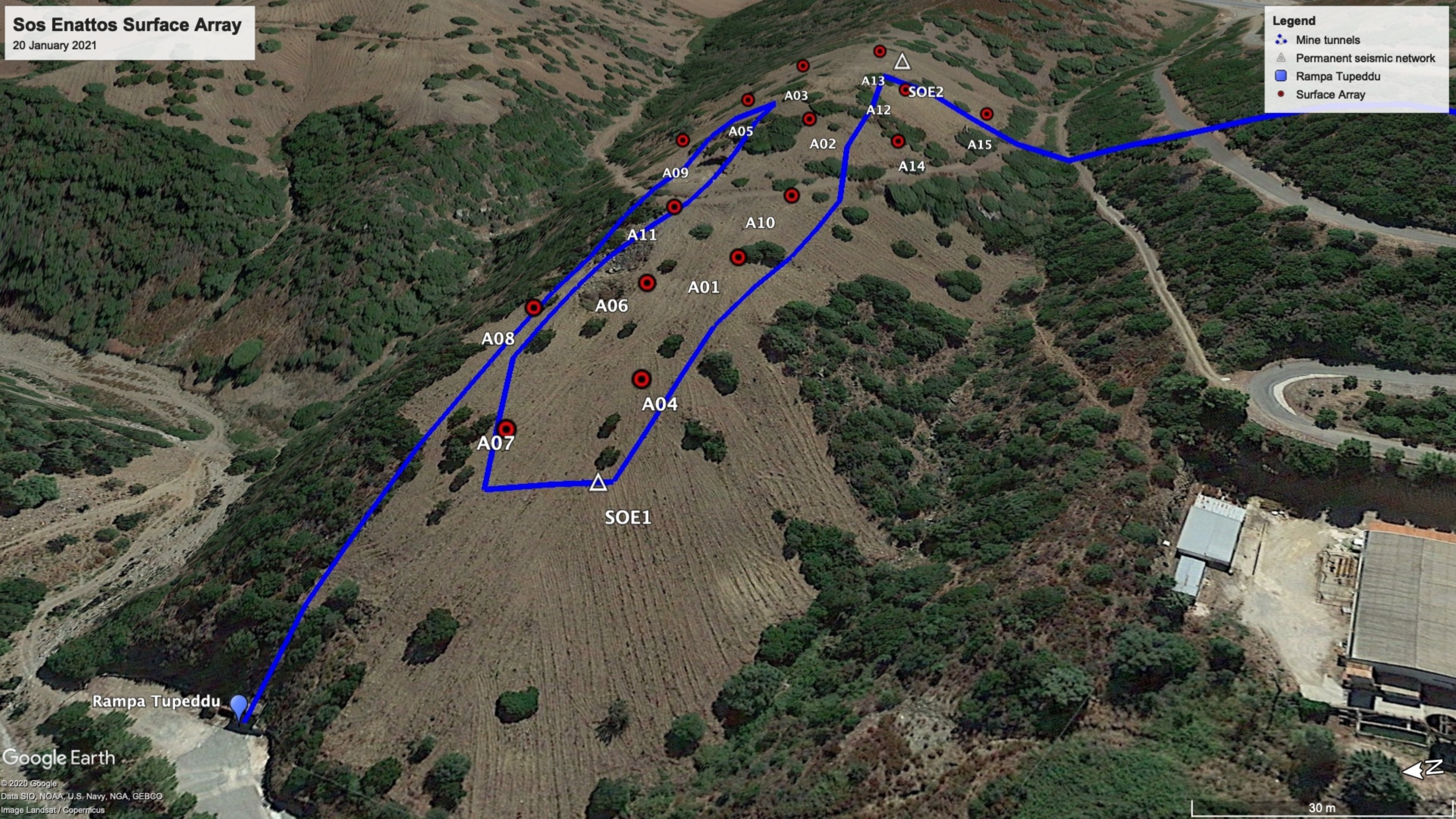








- Uncertainties cannot be neglected
- Averaged over a 2-km-long path

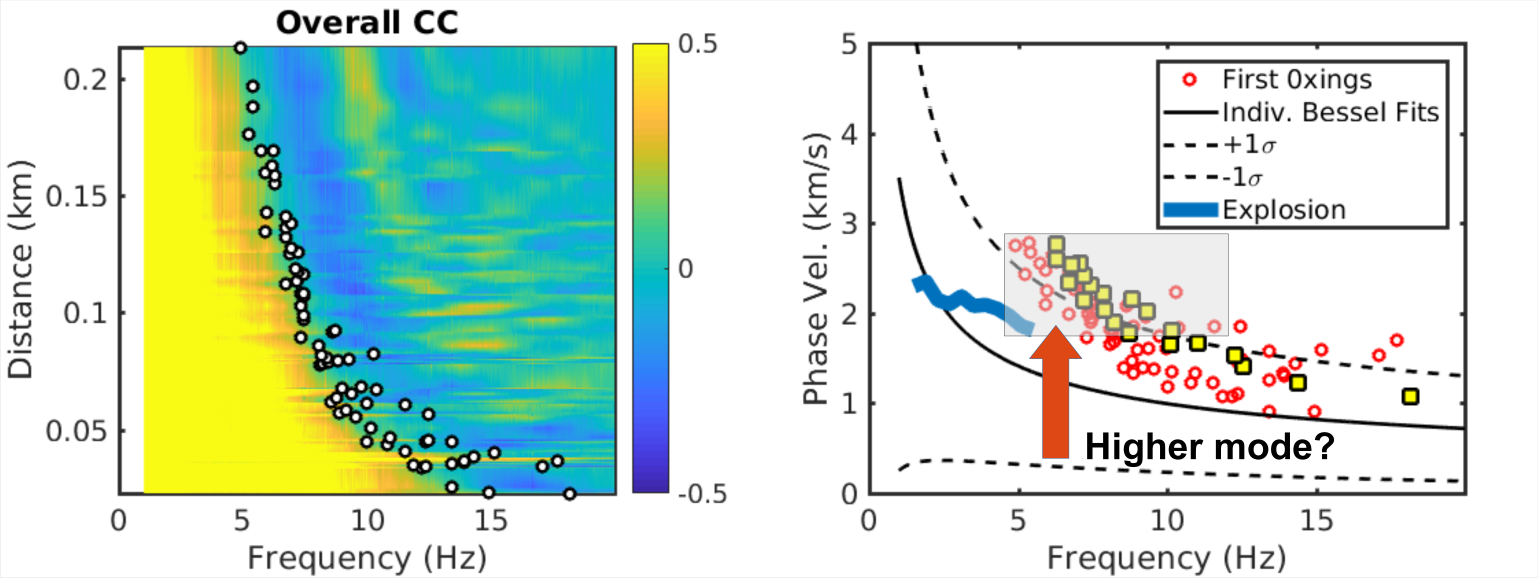


Sos Enattos Surface Array
20 January 2021
Legend
Mine tunnels
Permanent seismic network
Rampa Tupeddu
Surface Array
A01
A02
A03
A04
A05
A06
A07
A08
A09
A10
A11
A12
A13
A14
A15
SOE1
SOE2
Rampa Tupeddu
Google Earth
© 2020 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
30 m
N

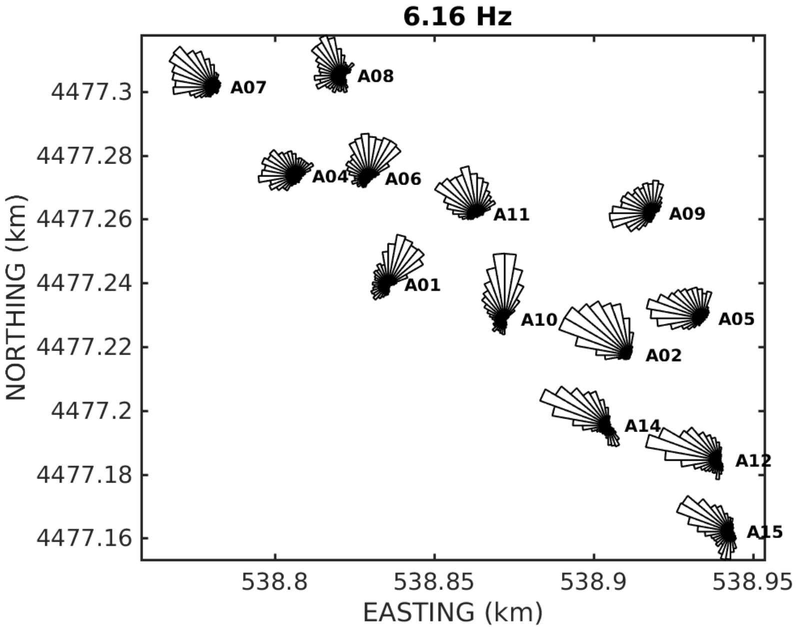
SPatial AutoCorrelation

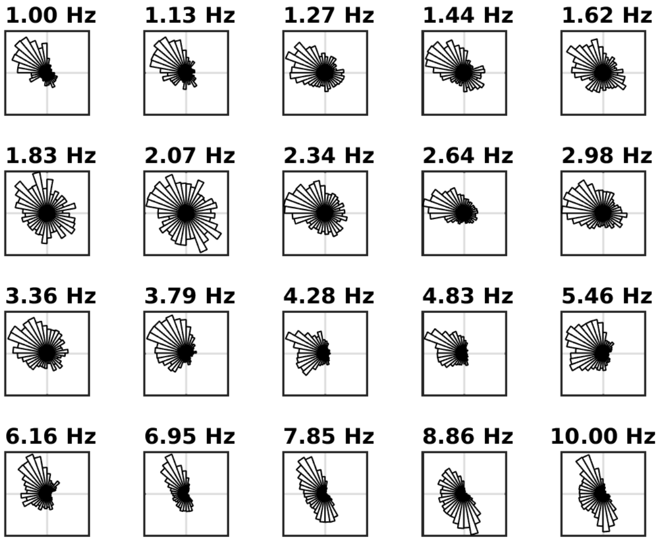
Here c(f) is derived by the first 0-xing of the correlation curves, with and without averaging ρ(f,r) over consecutive r +/-dr intervals.

The ρ(f,r) function.



Polarization analysis



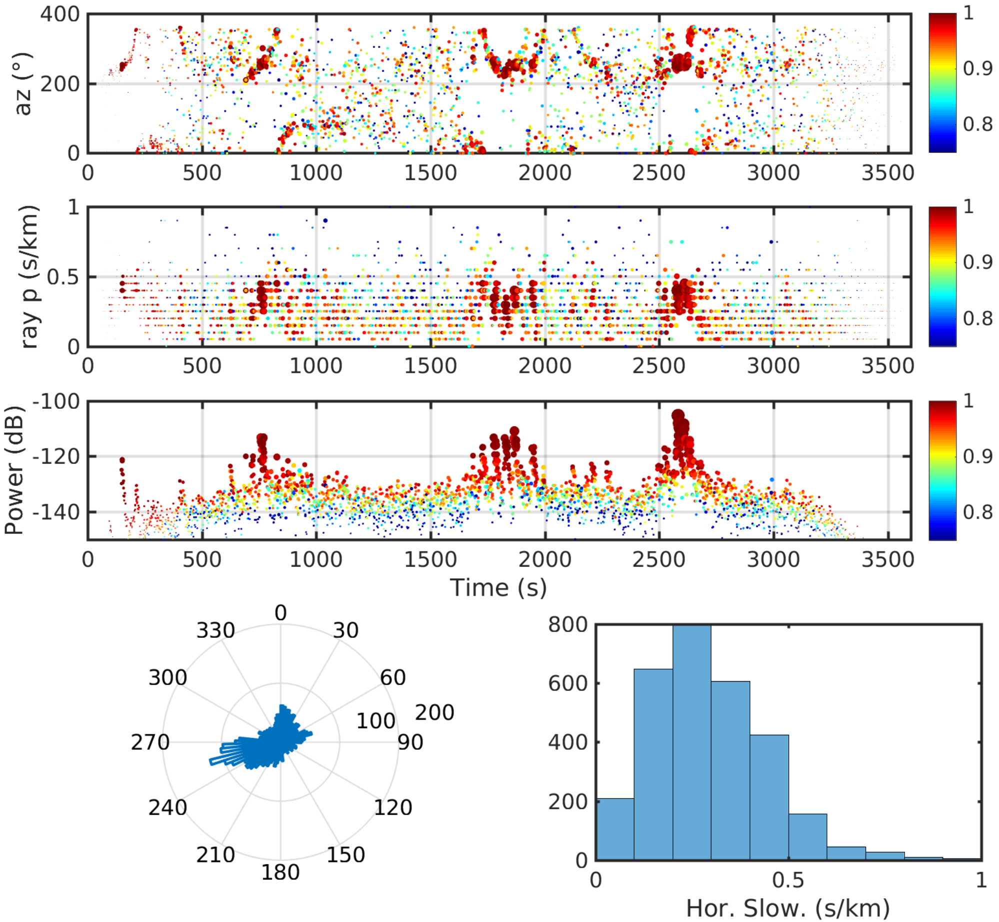


Polarization depends markedly on space and frequency → Topographic effects?

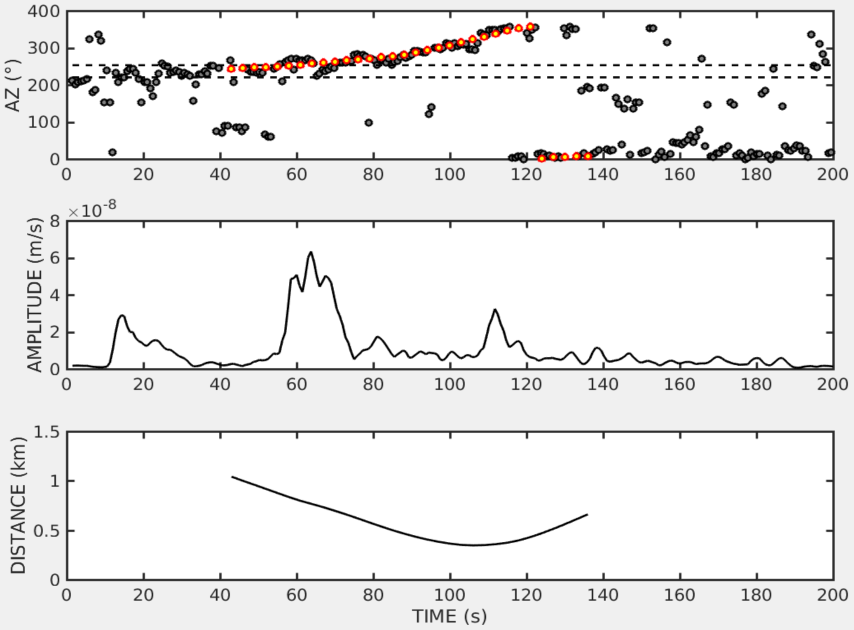
FK-Analysis (Capon's High-Res)

@ f = 4.5 Hz, Propagation azimuths directed WSW (i.e., main sources located ENE of the array). High velocities (> 2.5 km/s).

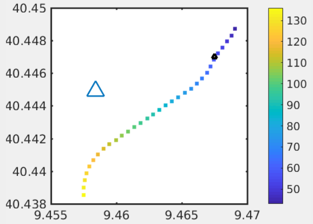
Largest-amplitude arrivals exhibit time-varying DOA, suggestive of a moving source.

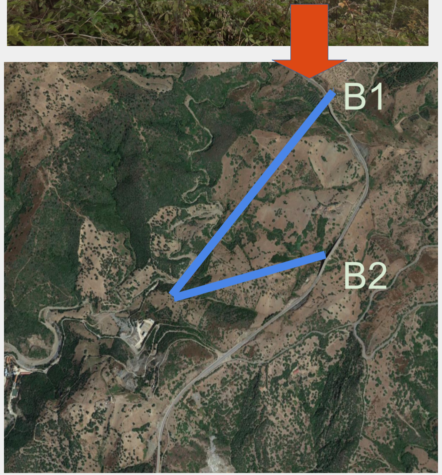


Vehicle Tracking



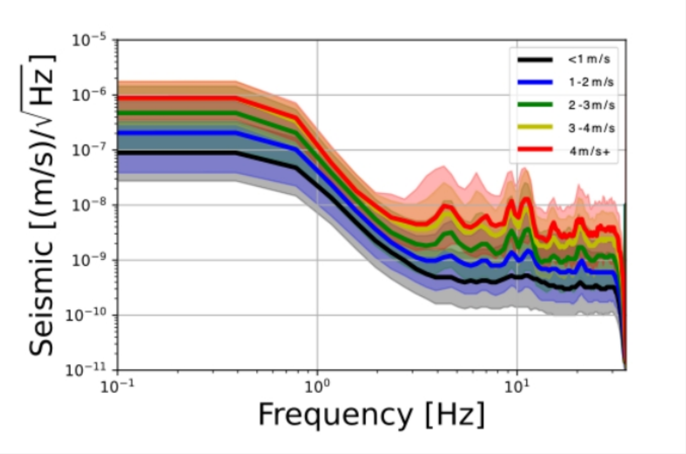
B2
B1



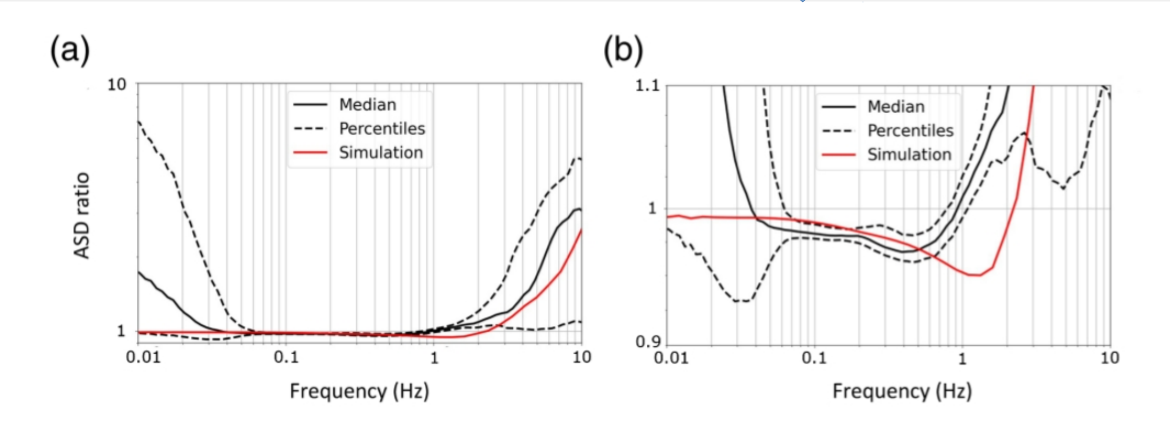


Time evolution of azimuth compatible with a vehicle traveling at 60 km/h southward along SP73. Largest signal amplitude is NOT associated when the vehicle is closest to the array, but when it traverses bridge B2

Other aspects

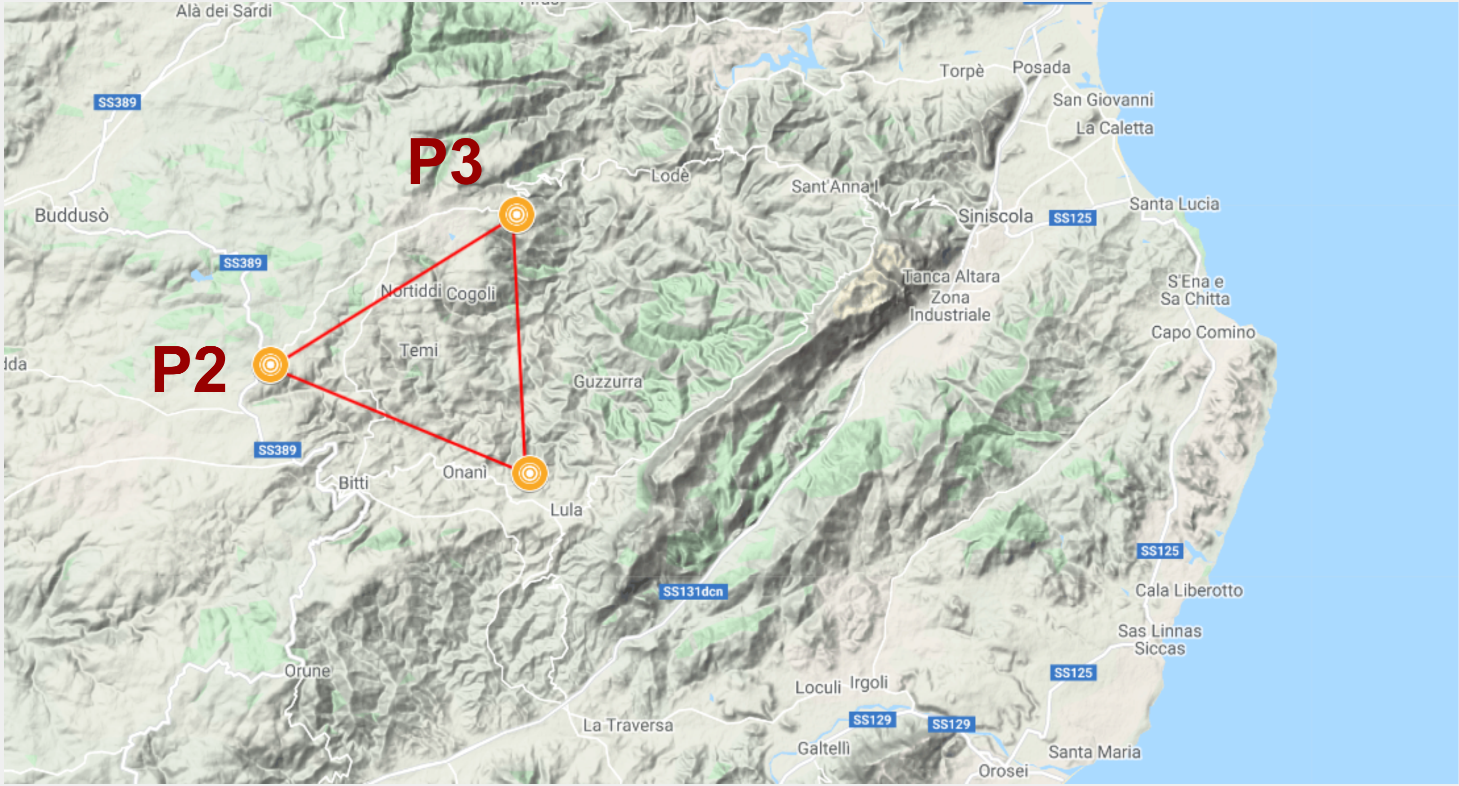


Amplitude decay w/ depth not fully consistent with Rayleigh penetration



Correlation with wind speed (*from M. di Giovanni's talk*)

The Autumn Experiments: corners P2 and P3



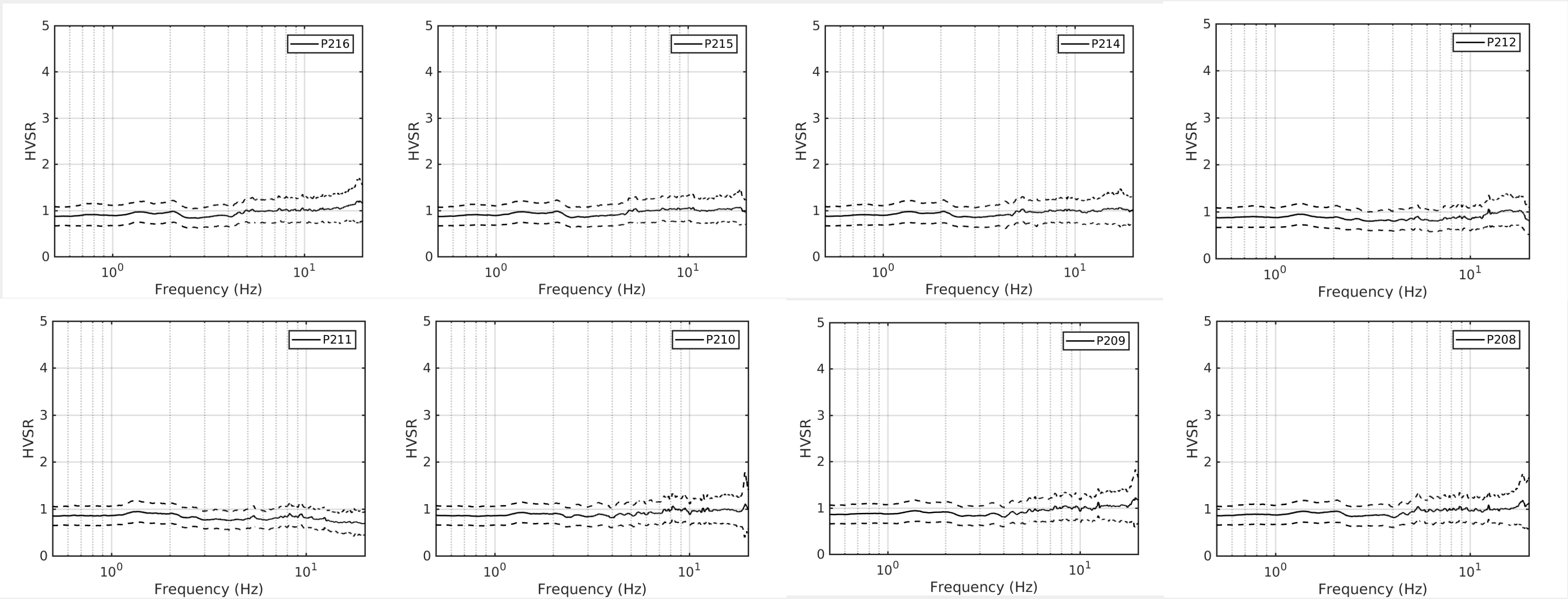
ET - Site Studies and Characterization Workshop.
Nuoro, 8-11 November 2021

Experiment @ P2: HVSR

B1

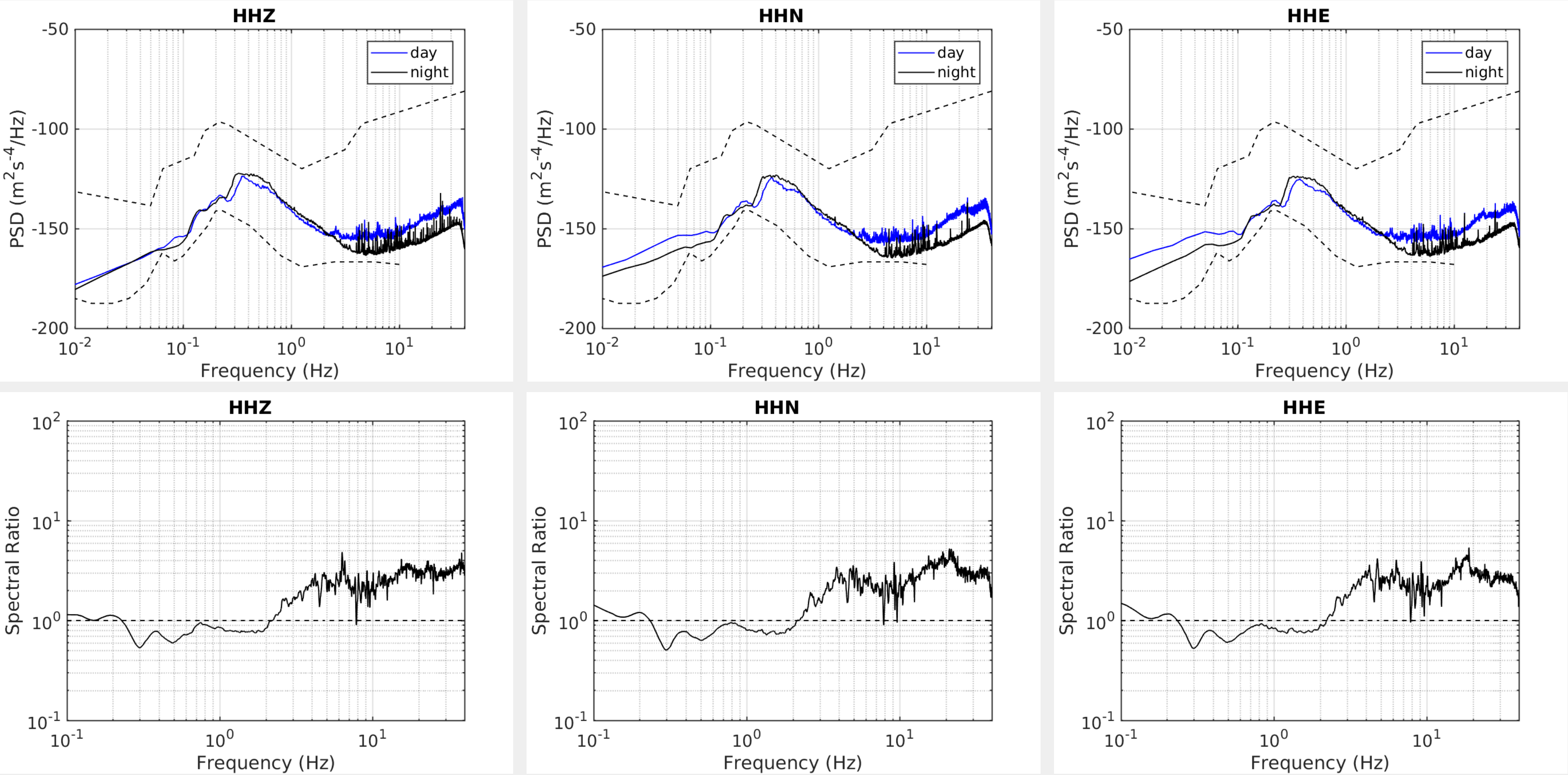
Complete lack of local effects => subsurface materials are homogeneous and stiff

B2



Day-Night Spectral Ratios

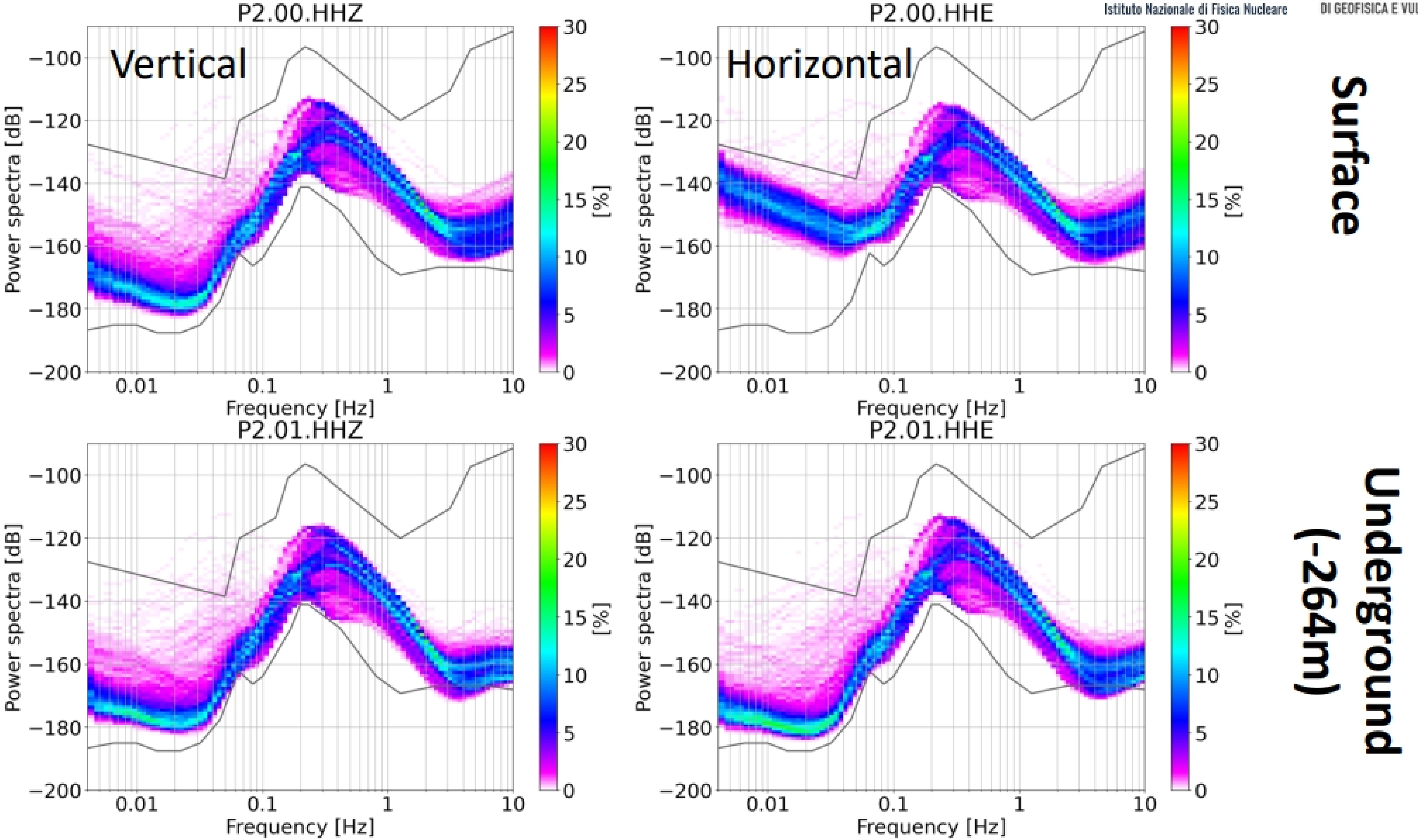
B1



Preliminary Results

P2

October 2021



Preliminary Results

EINSTEIN TELESCOPE

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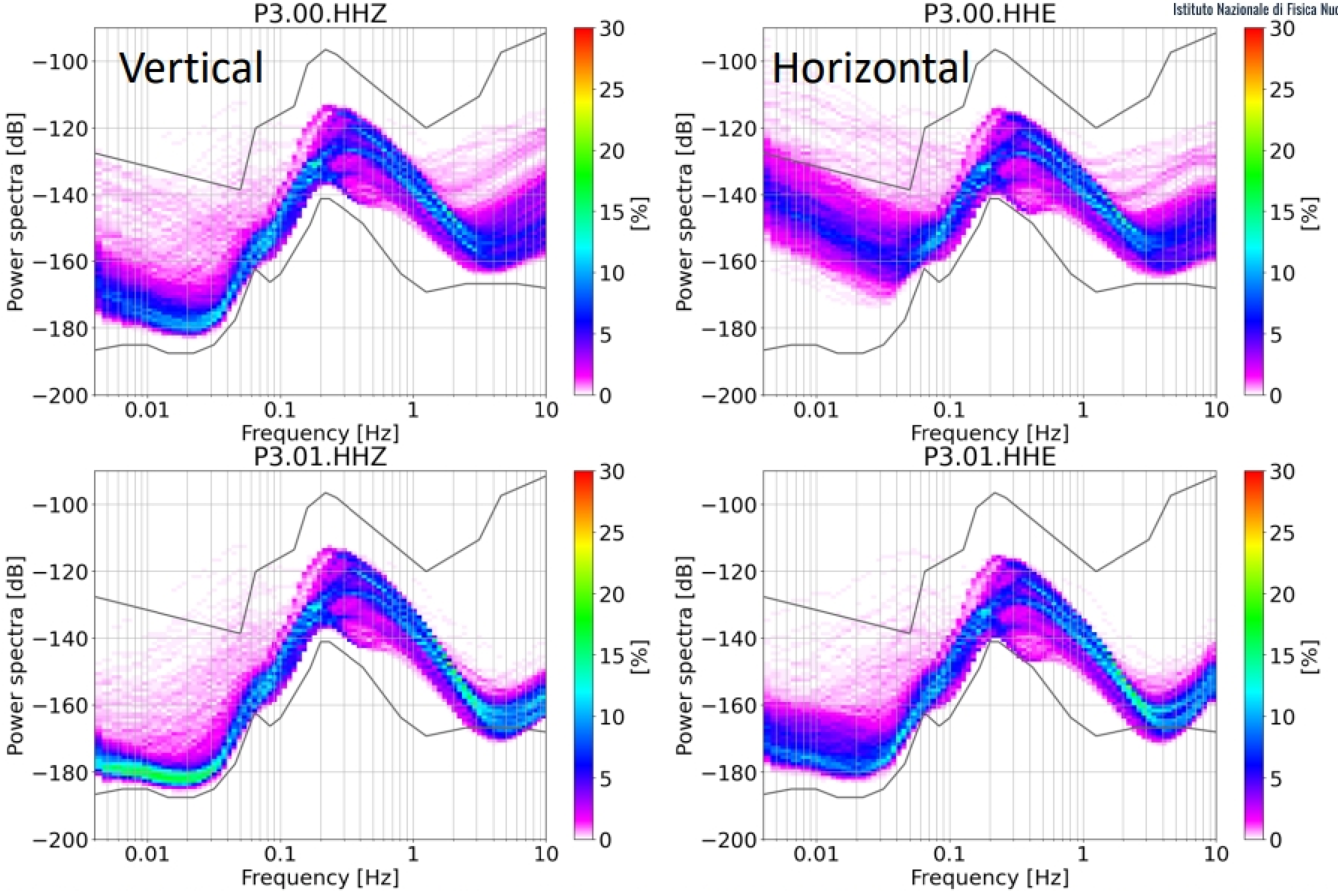
P3

October 2021



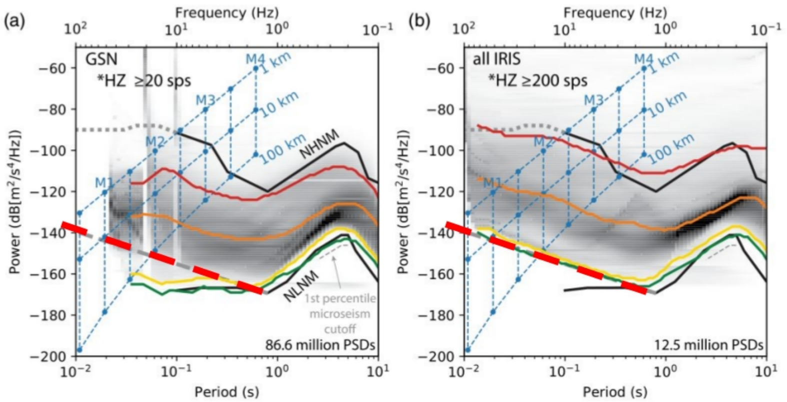
Surface

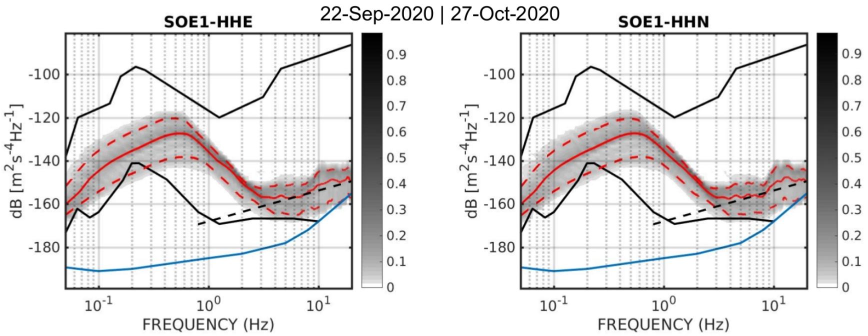
Underground (-252m)

Establishing High-Frequency Noise Baselines to 100 Hz Based on Millions of Power Spectra from IRIS MUSTANG

Emily Wolin*[1,2] and Daniel E. McNamara[3]

www.bssaonline.org Volume 110 Number 1 February 2020





About the NLNM

"[...], and instead ***the low-noise floor is defined by a handful of stations that are consistently extremely quiet****.* ***Borehole sensors at IU.QSPA near the South Pole regularly match or*** ***<u>even drop below</u>*** ***the NLNM in this frequency band [2-10 Hz]****".*

"Peterson noted that ***the NLNM above 2 Hz was drawn based on what he considered to be a clearly inadequate number of spectra****, and that it could be subject to revision as new data became available".*

[...] Our portable low-noise baseline represents current limitations of the instrumentation commonly selected for high-sample rate deployments, rather than a physical lower bound on the high-frequency ambient noise field.

SUMMARY

Sos Enattos

● At depth ~110 m: factor ~10 attenuation for F < 0.07 Hz and F > 1 Hz, partially consistent with Rayleigh waves*;
● Tough geological materials (Vp > 4000 m/s, Vs > 2000 m/s)
● No stratigraphic site effects
● At 110m depth: ~NLNM over the 2-5 Hz frequency band
● Microseism band (0.1-1 Hz) correlated with wave climate in the western Mediterranean Sea
● Measured noise amplitude must be considered as an upper bound, since anthropogenic activities at the mine are still ongoing;
● For the (crucial) 2-10 Hz frequency band:

- * Spectral ratios with the surface stations < 1 and the detailed analysis of glitches indicate the existence of local disturbances, likely due to human operations

SUMMARY - II

P2 and P3 corners: At depth 250-m, the 2-10 Hz noise is among the lowest ever observed on the Earth

HOMEWORK:

- Improve assessment of PATH EFFECTS:
- Attenuation, Anisotropy
- Account for transient (Glitches)

SUMMARY - III

- At f = 10 Hz c(f) =1500 – 2000 m/s => λ ~ 150-200 m => **Need to resolve the propagation medium @ 50 m resolution**.
- Sources may be widely distributed
- Images of the subsurface are affected by large uncertianties
- Additional medium properties should be accounted for

All these factors should be accounted for by the time of modeling (predicting) the seismic wavefield.
Is that achievable ?

Thank you for listening