Update on Seismic ambient noise studies in Sardinia for the Einstein

MATTEO DI GIOVANNI ON BEHALF OF THE SARDINIA SITE CHARACTERIZATION TEAM

SPB WORKSHOP AMSTERDAM 2023

Introduction

Over the years, the Italian candidate site to host the 3rd generation gravitational wave (GW) detector Einstein Telescope (ET) has been the subject of thorough characterization studies that are still ongoing.

The most significative results obtained so far are included in the following set of publications

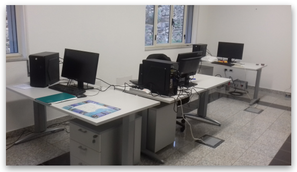
- Naticchioni et al. (2014) **DOI** 10.1088/0264-9381/31/10/105016
- Naticchioni et al. (2020) **DOI** 10.1088/1742-6596/1468/1/012242
- Allocca et al. (2021) **DOI** 10.1140/epjp/s13360-021-01450-8
- Allocca et al. (2021) **DOI** 10.1140/epjp/s13360-021-01993-w
- Di Giovanni et al. (2021) **DOI** 10.1785/0220200186
- Di Giovanni et al. (2023) **DOI** 10.1093/gji/ggad178
- Saccorotti et al. (2023) **DOI** 10.1140/epjp/13360-023-04395-2
- Naticchioni et al. (2023) Submitted to PoS

The Sardinia site

- in 2010, during the preparation of the first conceptual design of ET, several sites in Europe were studied for a 3G GW observatory. Among them, Sos Enattos in Sardinia appeared to be one of the most promising;
- The mine, although closed, was not abandoned. Therefore it provided the adequate manpower, infrastructure and experience to start underground characterization studies in 2014;
- Today, the mine is considered a regional heritage site and is open to guided tours. It also hosts the SarGrav laboratory and the Archimedes experiment;

Main well

Former mineral processing unit



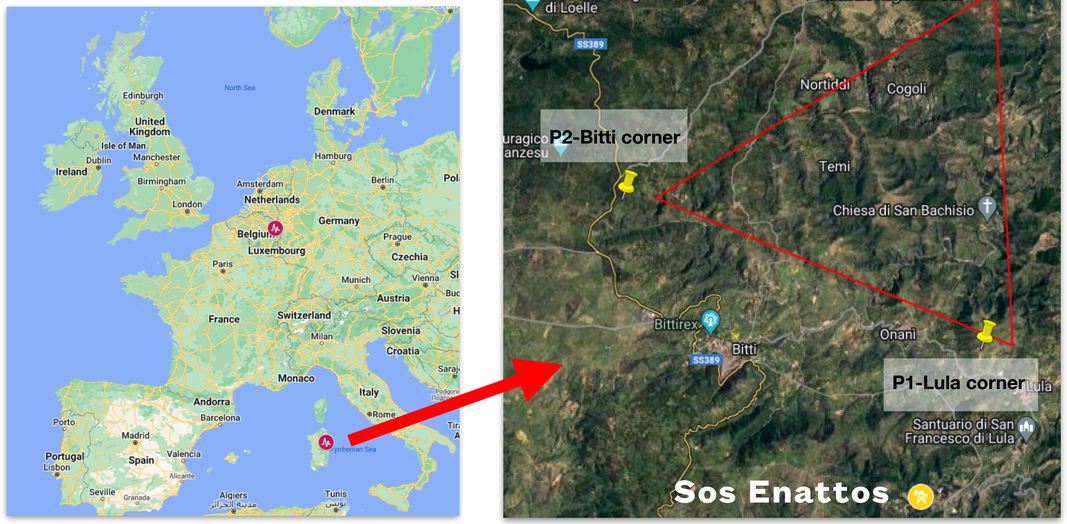
SarGrav laboratory

The Sardinia site

According to the current proposed orientation for the ET Triangle, the sites to host the actual vertices of the interferometer have also been identified.

The Onanì corner

The Bitti corner

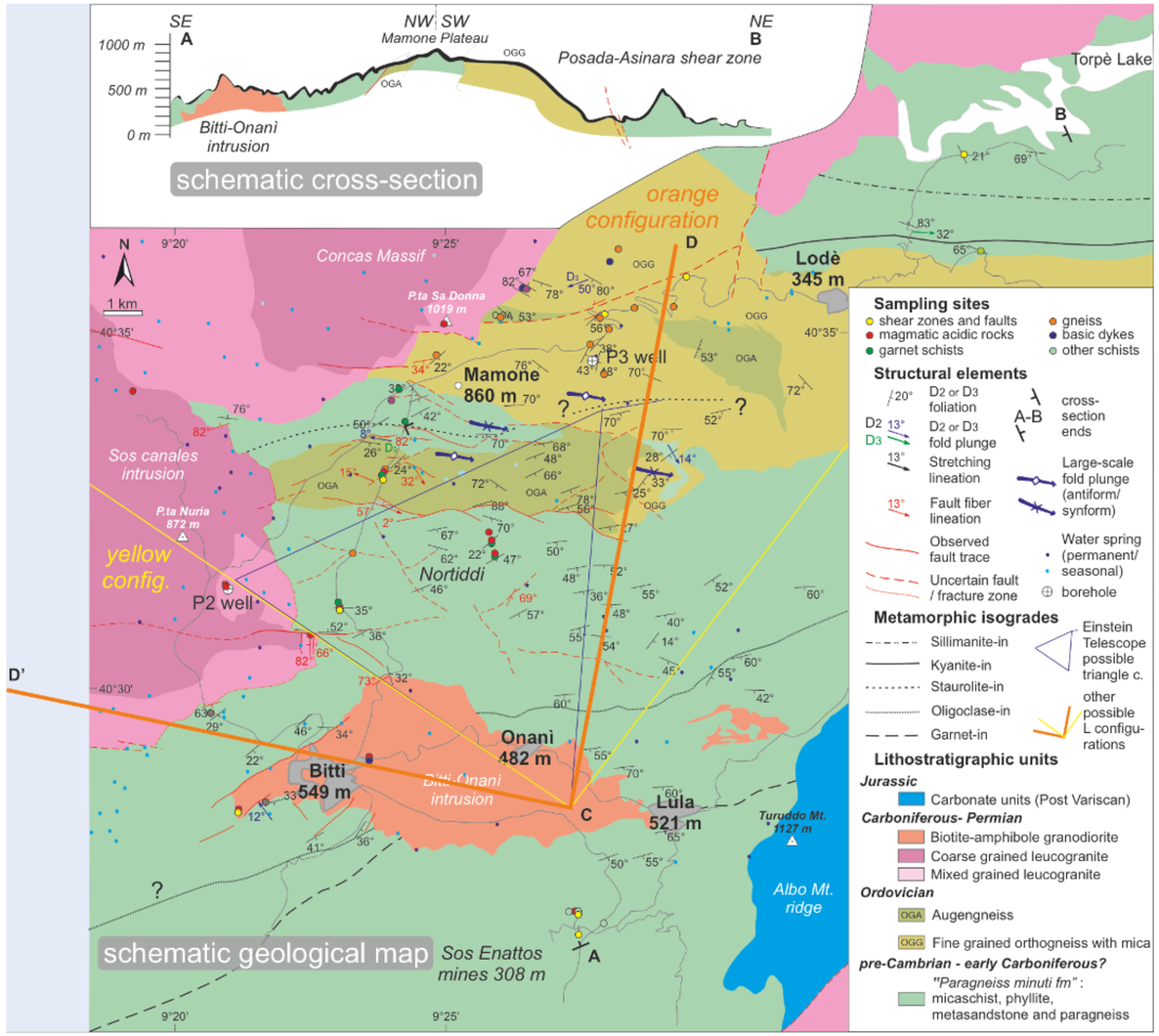


Proposed ET triangle orientation at the Sardinia Site.

The Sardinia site

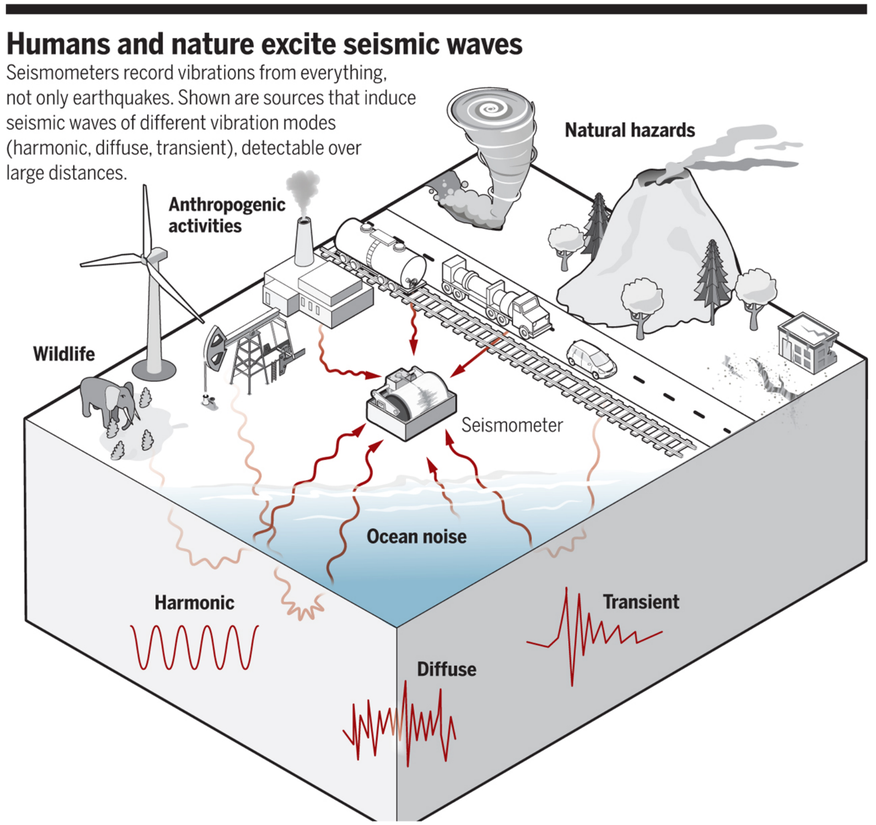
The call for tender will also ask to study the L configuration.

At the end of the call, the precise locations of the triangle corners and of the L end stations will be identified.



Understanding noise contributions

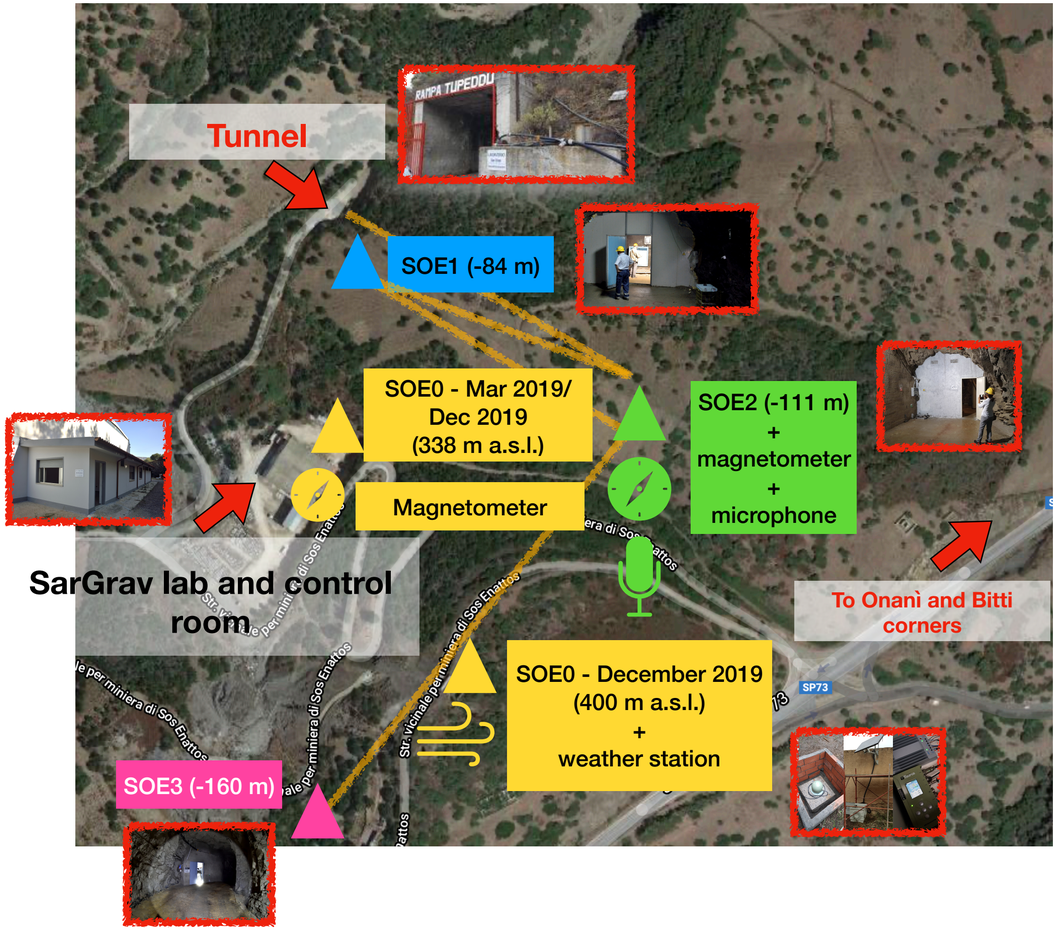
- ET will be much more susceptible to ambient noise;
- Characterization of ambient, seismic in particular, noise sources at low frequency is paramount;
- Seismic ambient noise can be of natural and human origin;
- Understanding the sources of seismic noise provides important information to design and adapt the detector's seismic isolation and control systems;



Permanent Instrument Network

Since 2019, in Sos Enattos there are:

- 4 permanent seismic stations for long term studies:
  - Surface: SOE0;
  - Underground: SOE1, SOE2, SOE3;
- 1 weather station;
- 1 microbarometer;
- High precision tilmeter as part of the Archimedes experiment;
- 2 microphones;
- 1 movable array composed of 8 short-period tri-axial seismometers;
- 3 magnetometers;
  - Surface: control room;
  - Underground: SOE2;
- All permanent seismic stations are provided with broadband seismometers (Trillium 240, 360 and 120 Horizon, Guralp 360);



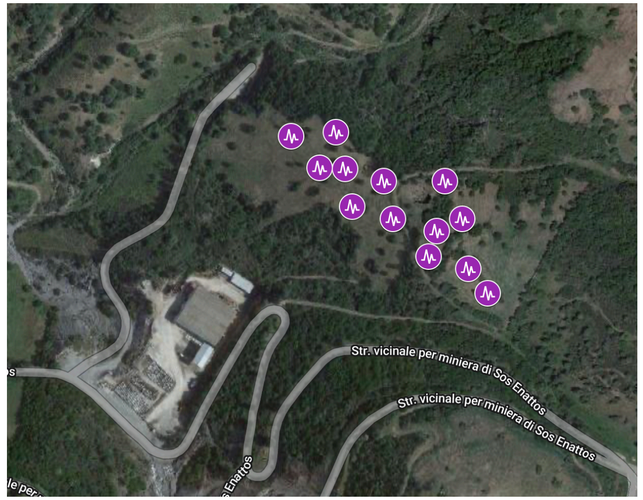
Permanent Instrument Network

In 2021, more permanent sensors have been installed at 2 of the proposed vertices (P2/3):

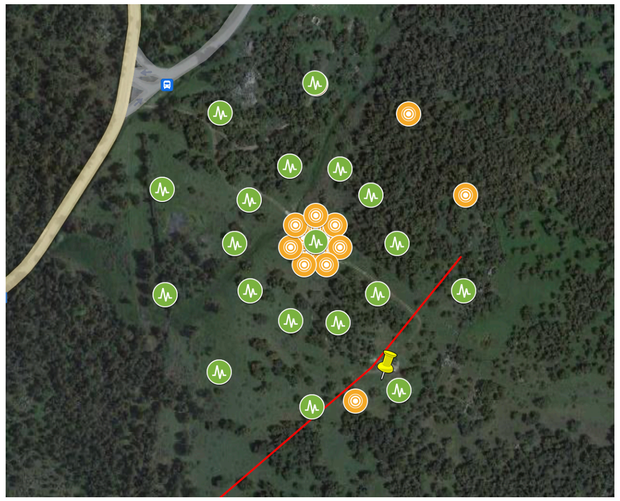
- 2 broadband seismometers on surface;
- 2 broadband seismometers in borehole;
- 2 magnetometers at P2

In the near future, more sensors will be installed at P1 as well.

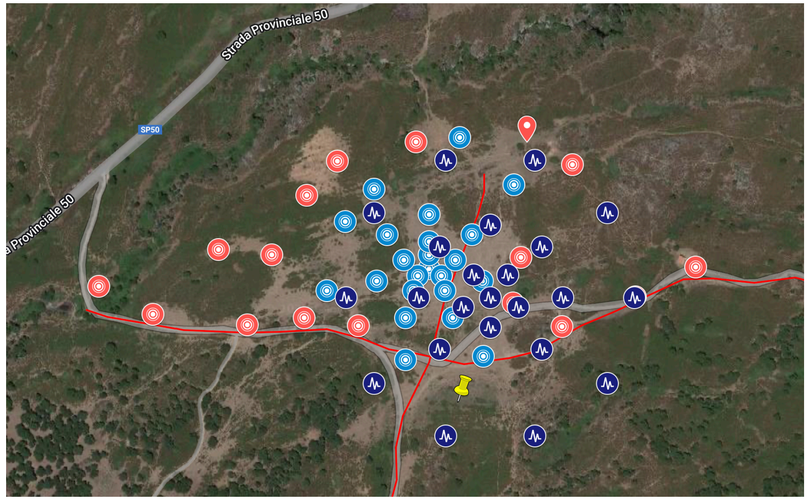
Temporary Deployments



Sos Enattos - Broadband array (January 2021)

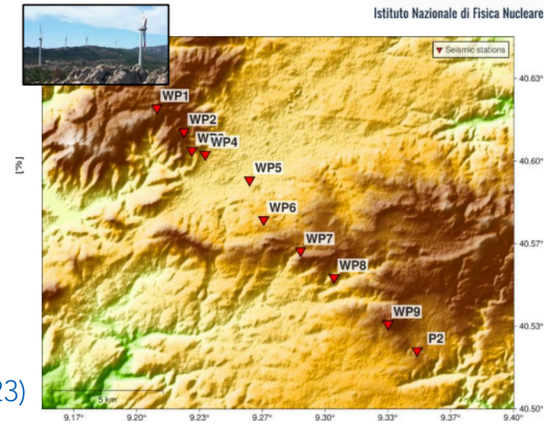


P2 broadband array + geophones (September 2021)



P3 broadband array + geophones (July & Oct 2021)

Aimed at characterization of the corners for seismic noise properties and NN purposes (correlation analysis).

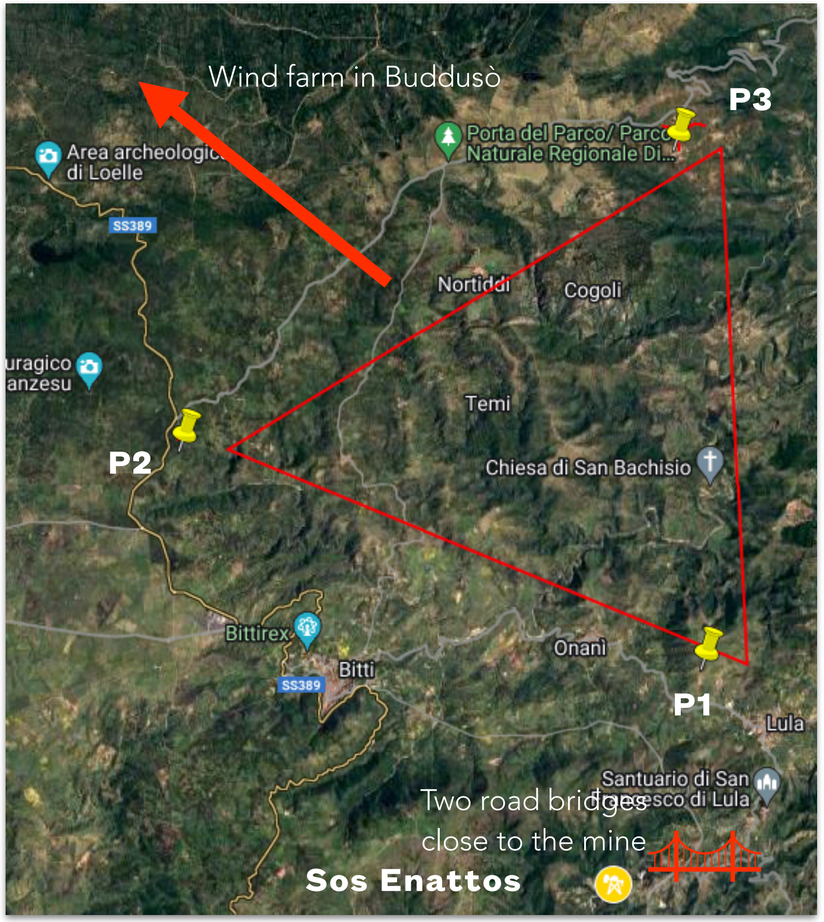


Broadband array (early 2023)

Potential noise sources

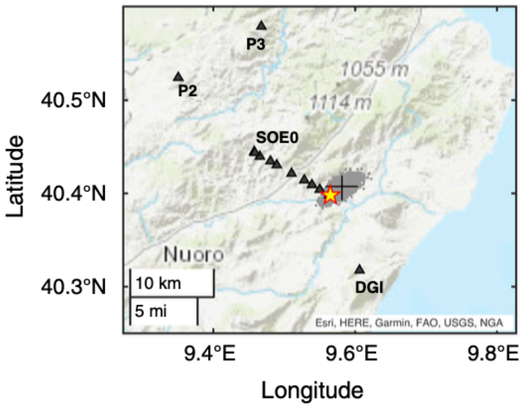
We identified some potential noise sources, both of natural and anthropic origin. Some of them have been clearly identified and characterized. Other are still being investigated to assess their contribution to the overall background noise in Sos Enattos.

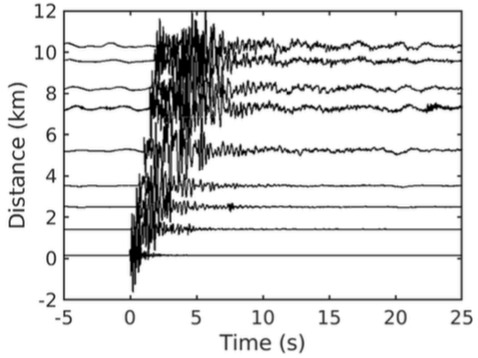
- Natural:
  - microseisms;
  - wind;
- Anthropic:
  - day/night cycle from human activities (mainly farming activities);
  - two road bridges in the neighborhood of the mine;
  - wind farms;
  - no other relevant infrastructures in the area.

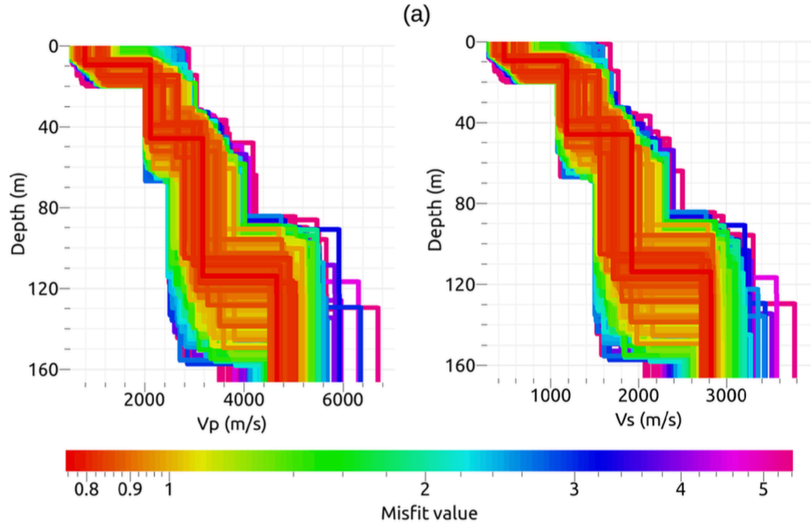


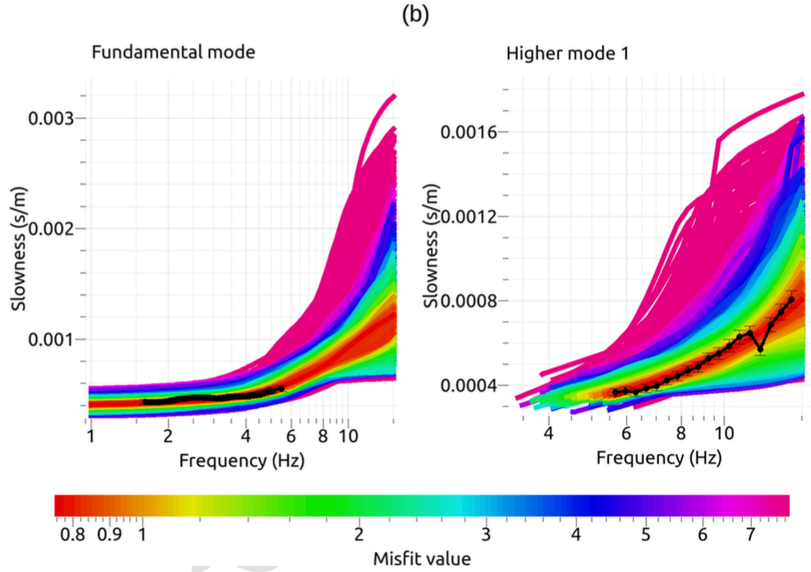
Seismic velocities

Saccorotti et al. 2023 updated and improved the resolution of the dispersion curves for compressional and shear wave velocities;

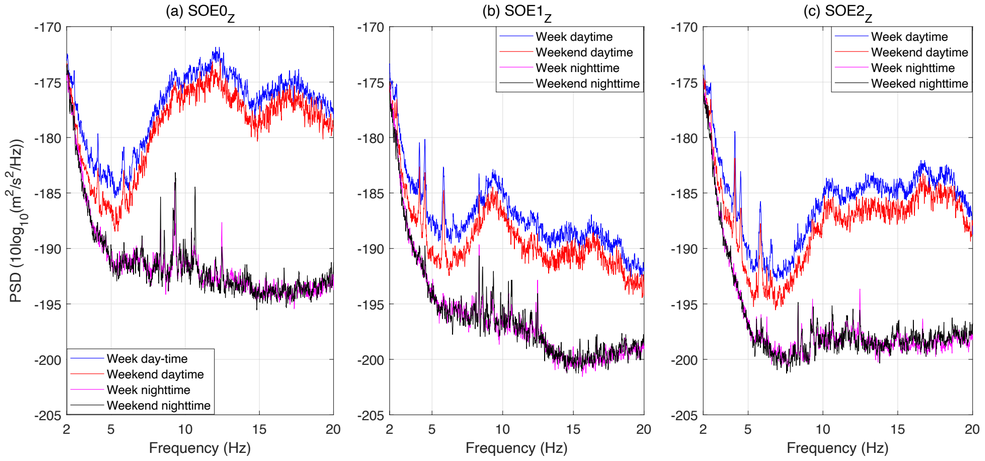






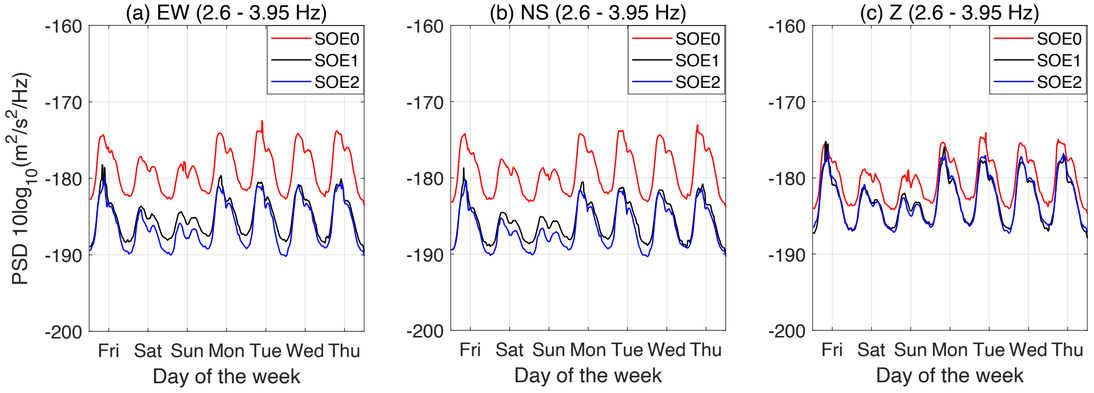


Noise levels

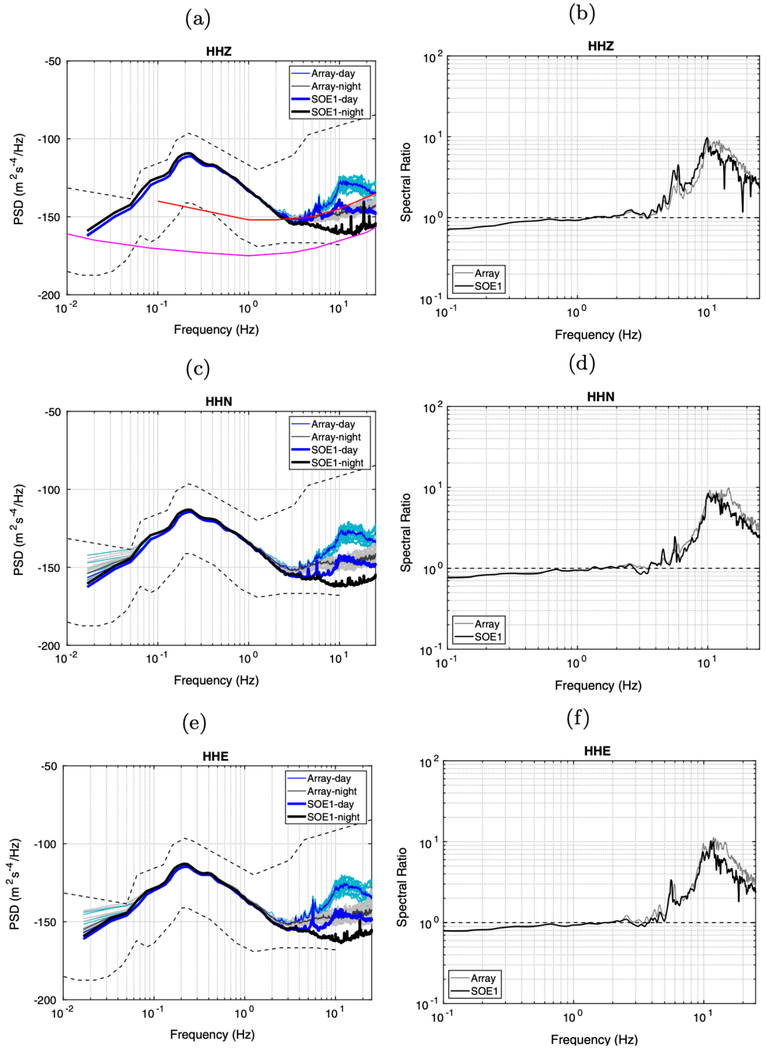


Di Giovanni et al. 2023

Data from the seismic array deployed in January 2021 (acceleration ps).



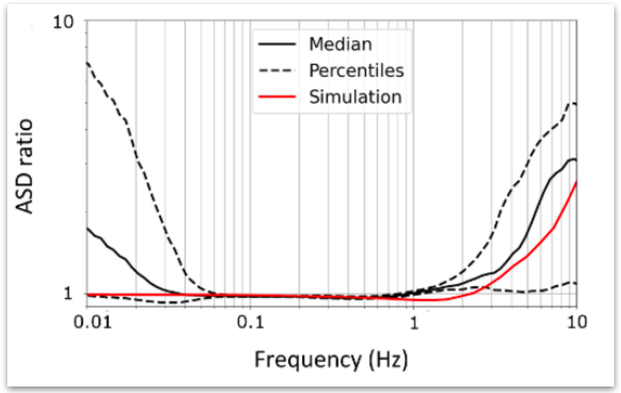
Data from 1 year (velocity ps)

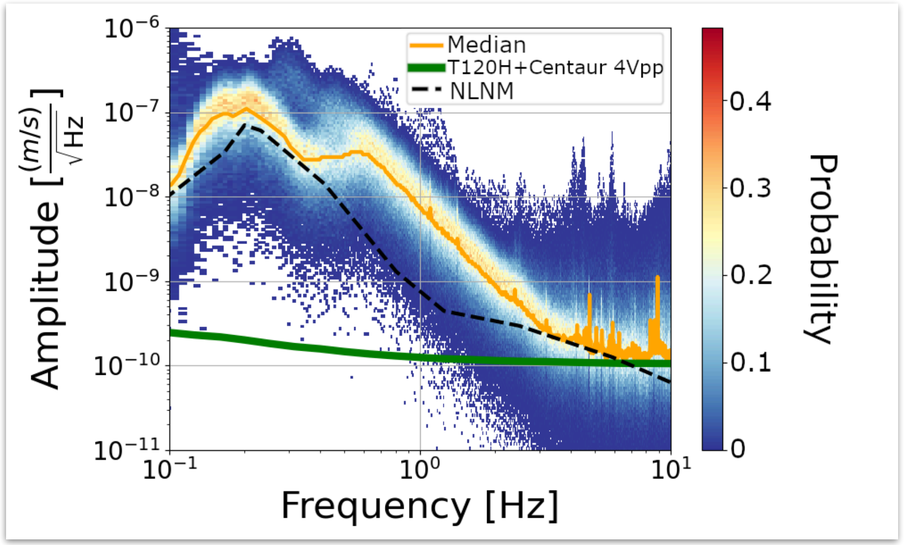


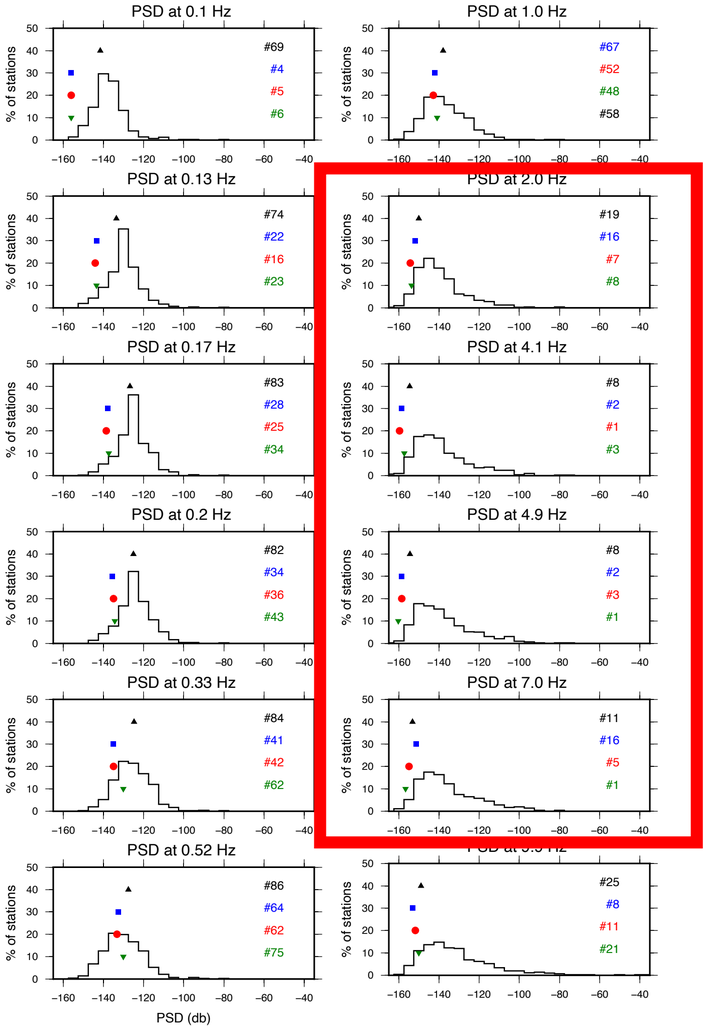
Saccorotti et al. 2023

Noise levels

- Noise level in Sardinia are very low and hit the self noise of the seismometers;
- The seismic stations have an excellent ranking when compared against other quiet seismic stations all around the world;

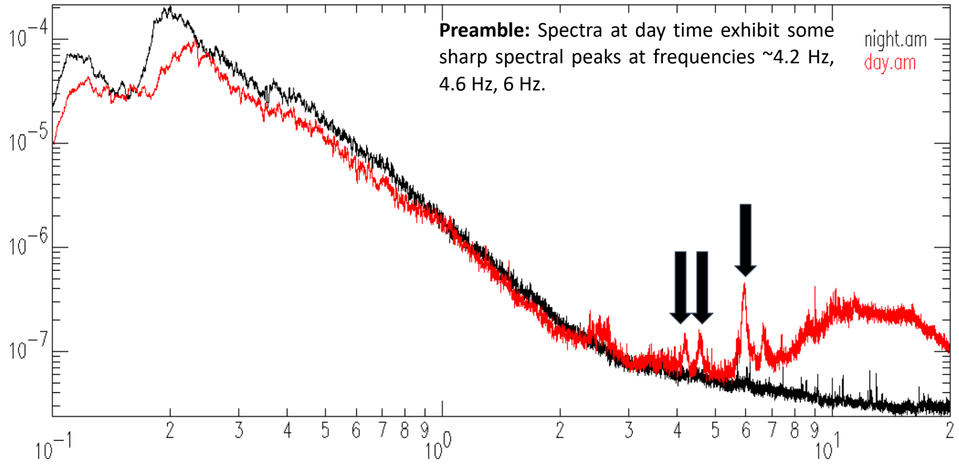


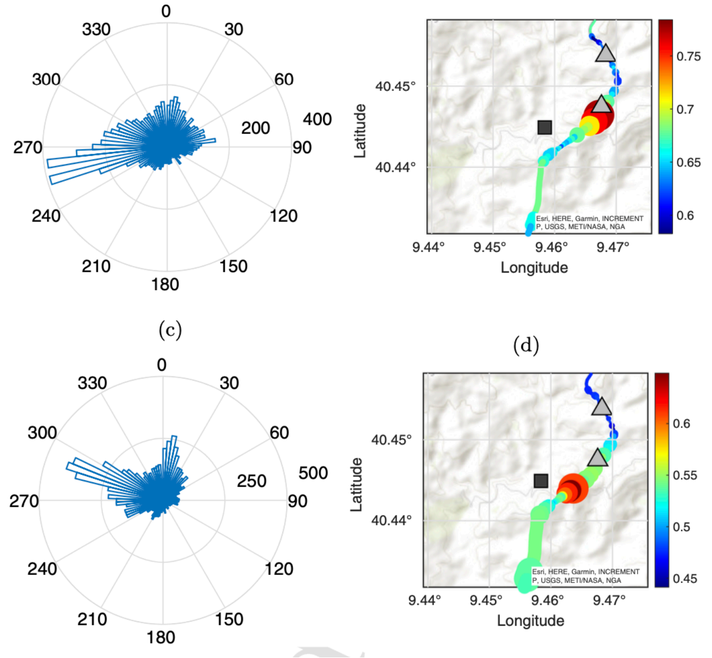




Identification of a noise source in Sos Enattos

The array deployed in 2021 allowed for the identification of the noise contribution from two bridges in the vicinity of Sos Enattos (Saccorotti et al.)



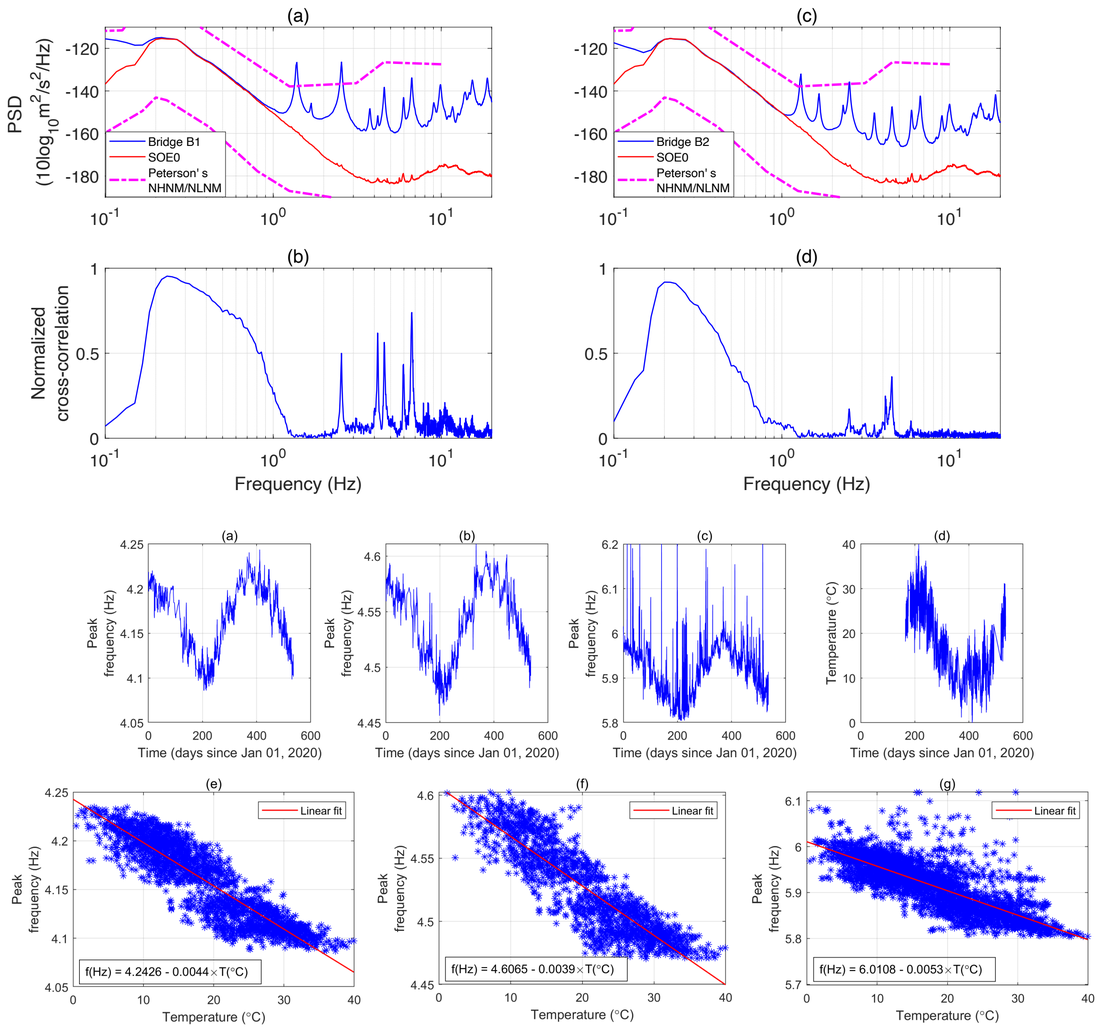


Identification of a noise source in Sos Enattos

Di Giovanni et al. 2023 confirmed the findings using a different approach, deploying geophones in November 2021.

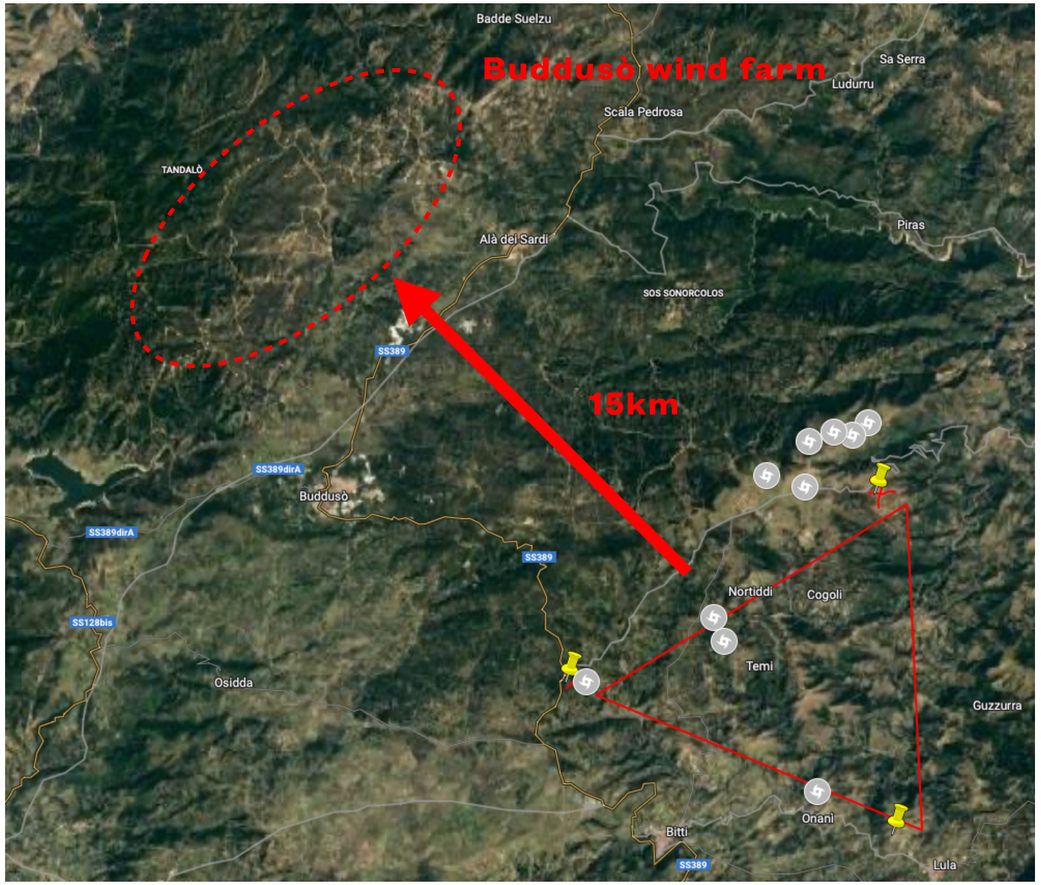
Identification of a noise source in Sos Enattos

- Spectral correlation confirmed the origin of those peaks;
- The distance of the bridges from the site is no more than 1.5 km;
- Those peaks also have a seasonal frequency drift with different rates;
- This may be caused by temperature variations that change the vibrational properties of the structures;
- Engineers observe drift to lower frequencies as the temperature increases and vice-versa as the temperature decreases;



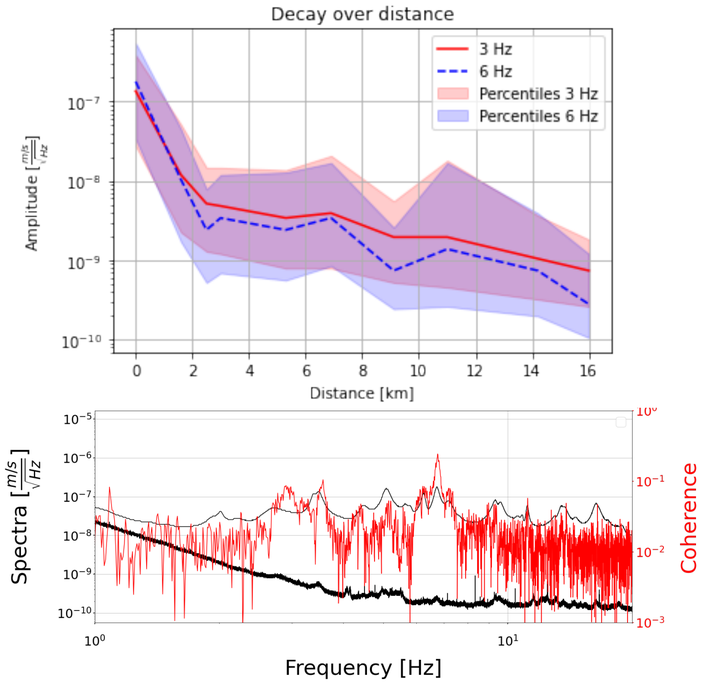
Wind turbines

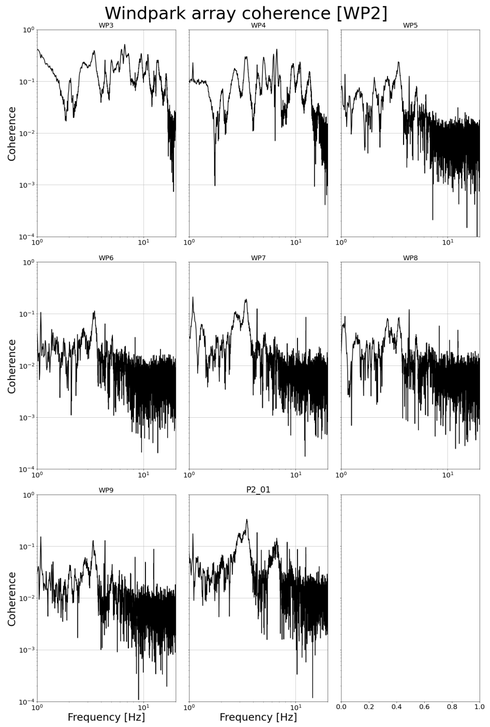
- Some small wind turbines are located in the area close to P2 and P3;
- According to *Westwood et al. 2015*, noise from small low-power turbines exhibits a significant attenuation already at 200m;
- At the moment, the our attention is devoted to the Buddusò wind park, 15 km away;
- According to studies for the Virgo site (Saccorotti et al. 2011), big wind parks can produce peaks at less than 2.5 Hz and visible up to 10 km.

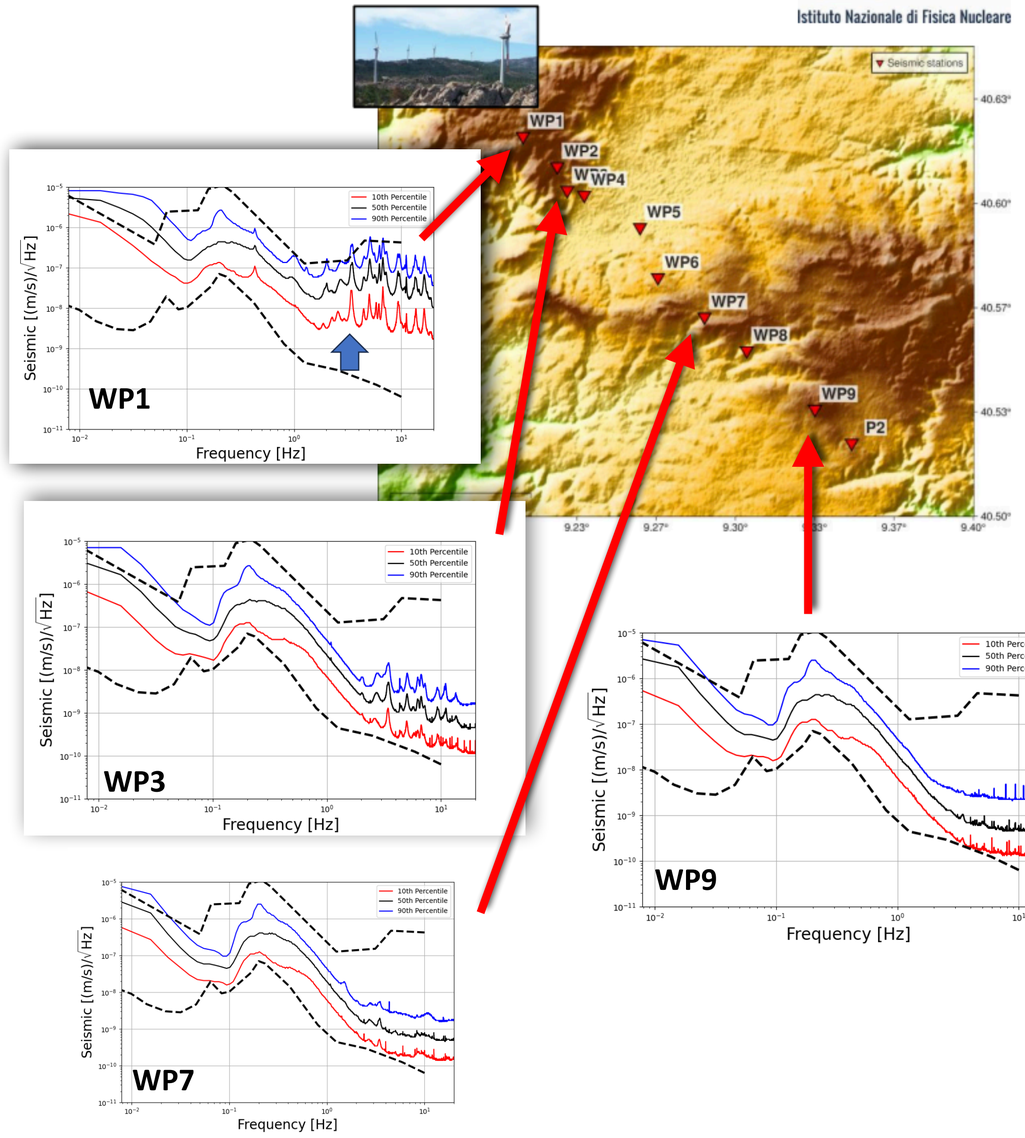


Wind turbines

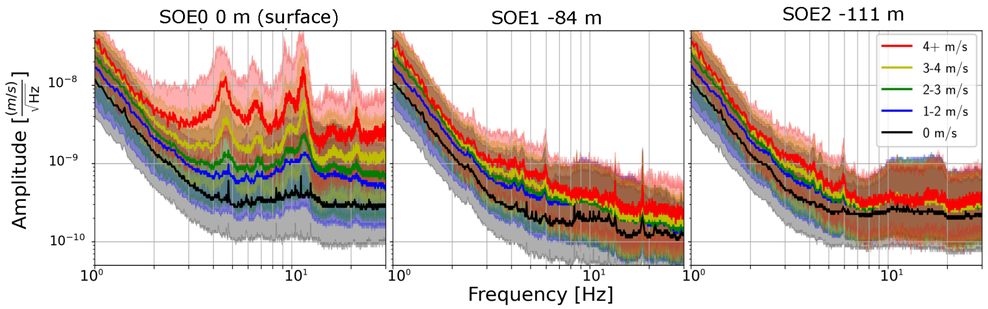
- Recent deployment of a seismic array between the wind park and P2 issued the first results;
- Main peak at 3 Hz + harmonics

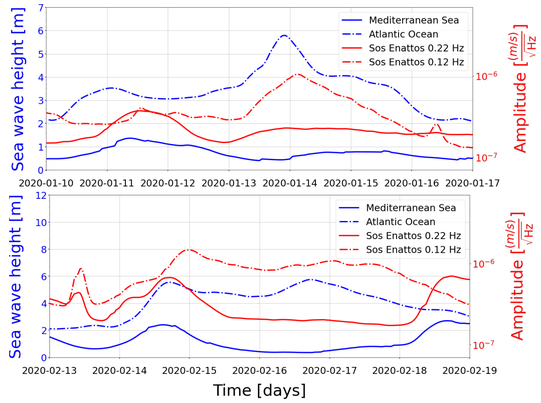


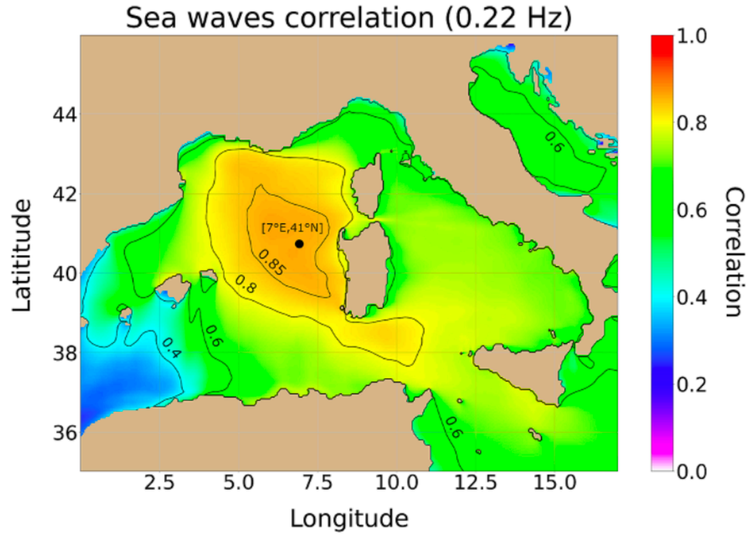


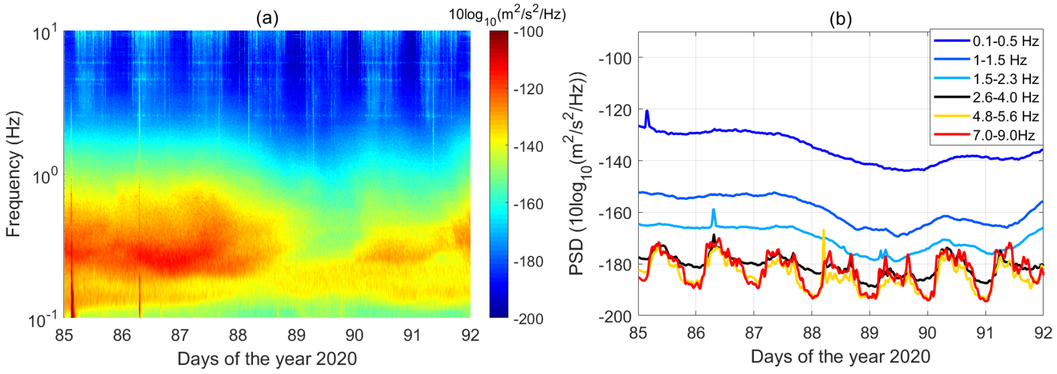


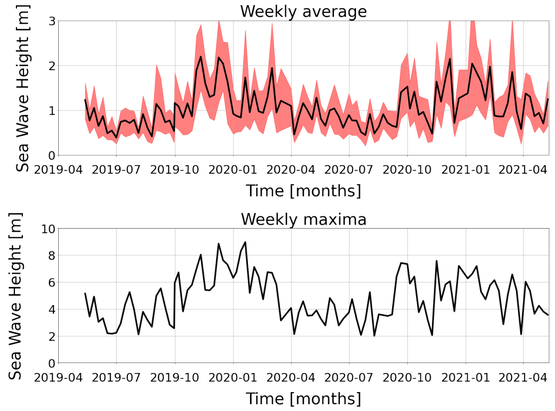
Natural sources

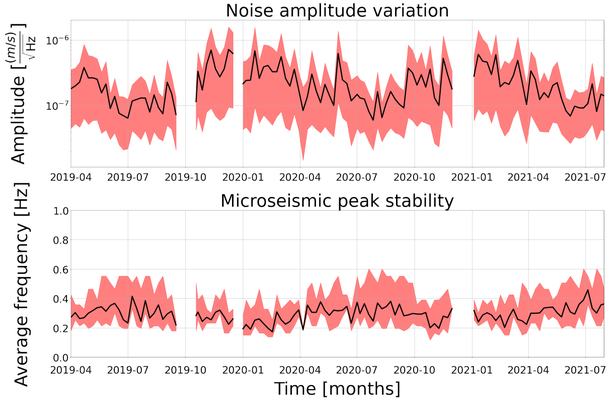




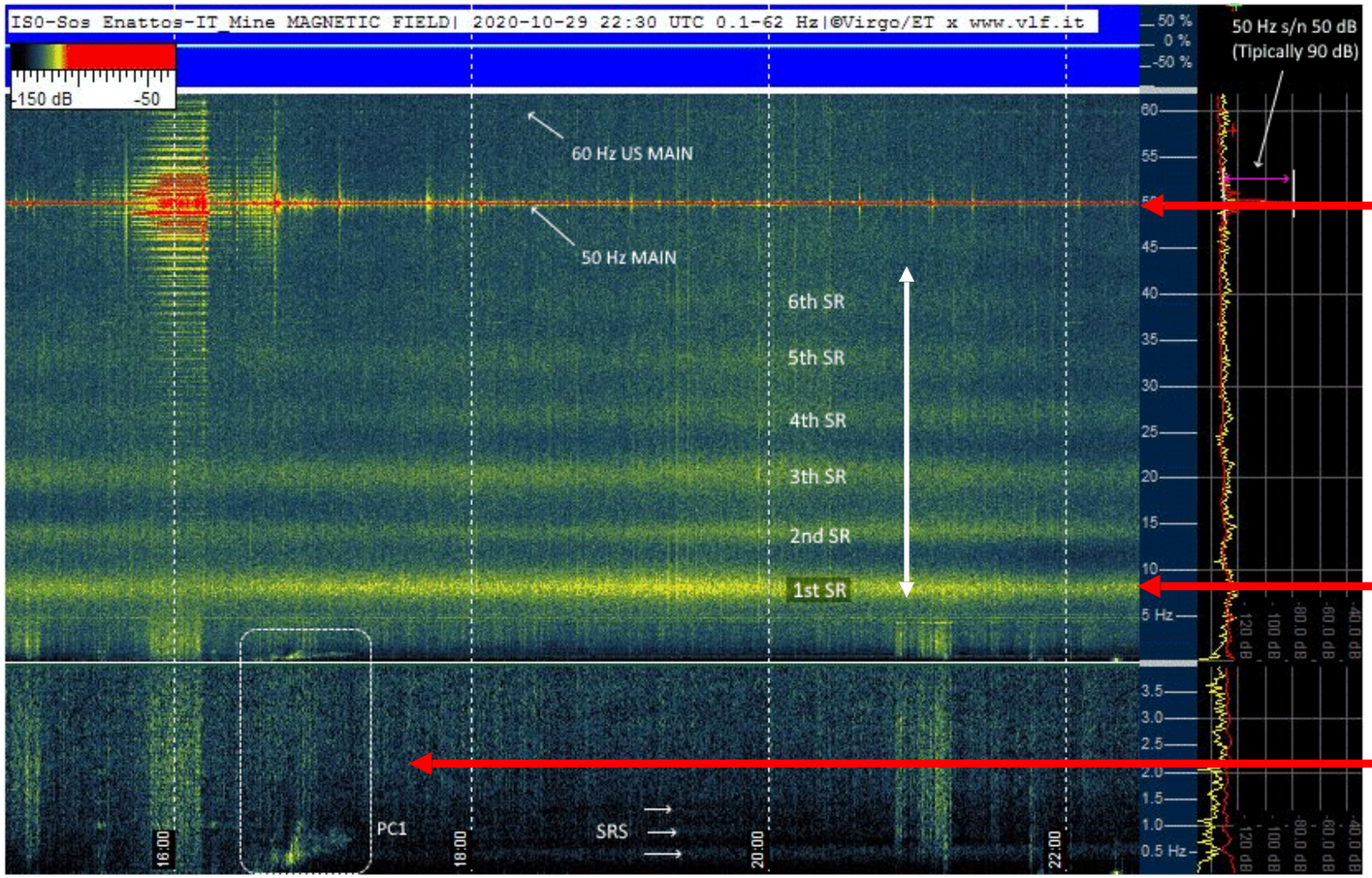








Magnetic noise measurements



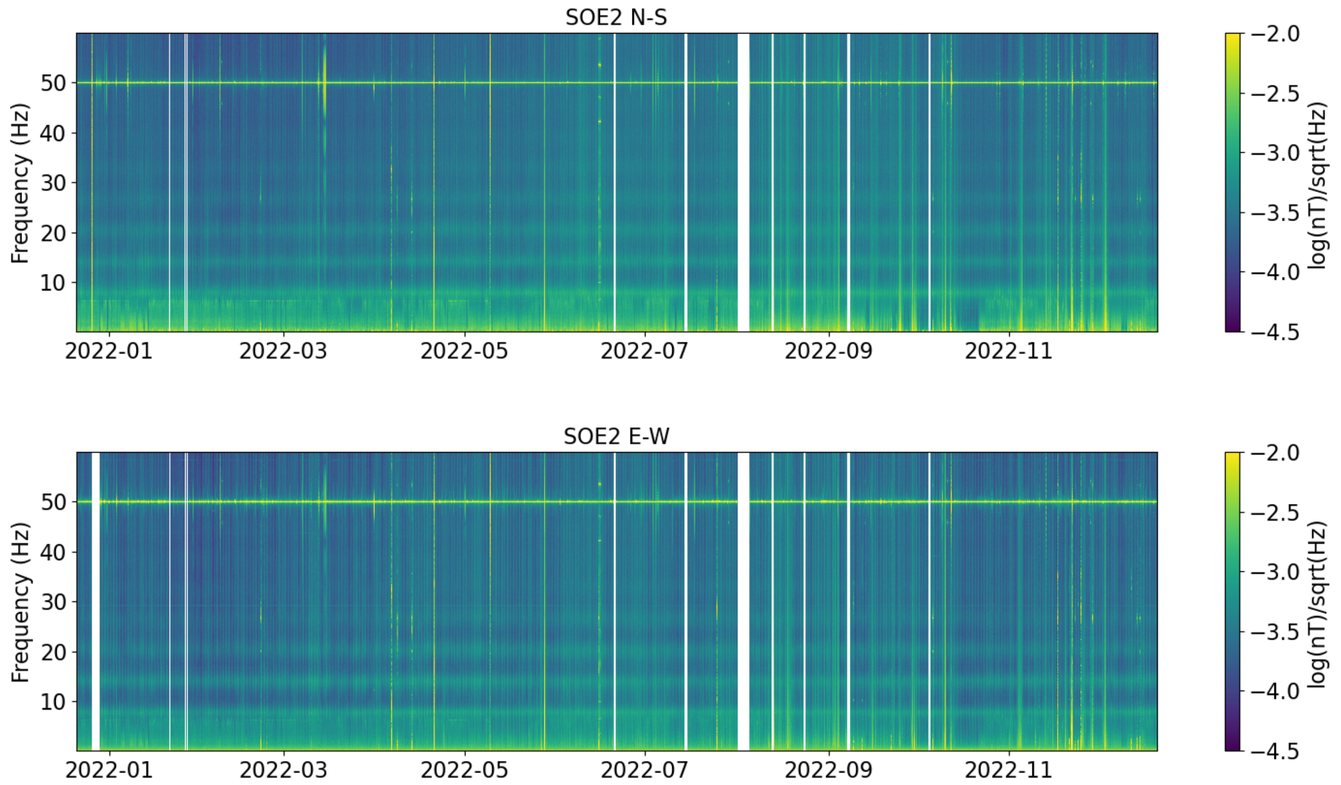
Power line (50 Hz)

Schumann resonances

Geomagnetic pulsation

Magnetic noise measurements

The long-term monitoring in a such quiet site, allows to clearly detect regular structure or periodic variability (mainly Schumann Resonances);



Conclusions

- The Sardinia site is the object of a thorough site characterization campaign (see also other presentation of this session);
- Noise levels generally very low in the frequency band of interest for ET;
- Seismic ambient noise studies revealed which are the dominant noise sources at the site;
- Up to now, besides the day night cycle of normal human activities, the only clear source of noise of anthropic origin at the site are the two bridges at Sos Enattos;
- Studies to asses the contribution of the wind turbines are still underway.

The End