

Status of the WD1 – Physical variables and characterization division

L. Naticchioni – INFN

S. Shani-Kadmiel – KNMI

on behalf of SPB-WD1



Cagliari, 8th May 2023

SPB WD1

Physical Variables & Characterization

WP 1.1 – Seismic noise

Chairs: C. Giunchi & S. Shani-Kadmiel

WP 1.2 – Gravimetry, Geodesy & Geodynamics

Chairs: R. Devoti & R. Hanssen

WP 1.3 – Magnetic noise

Chair: R. De Rosa

WP 1.4 – Other environmental noises

Chairs: T. Bulik & S. Shani-Kadmiel

SPB-WD1: Expected output

What we expect from the division, in a few words:

- Definition of the **needed physical variables** for the site characterization and for their possible impact on the detector performances (*link with ISB*);
- Definition of **surface and underground** (and/or borehole) accurate **noise measurements**, with procedures and standards;
- **Coordination of the measurements campaigns** at the candidate sites (ongoing and planned) → *interaction with the host teams* to have comparable long/short-term, active/passive measurements;
- Definition of **standard data formats**, repository and (open) **analysis tools**.

SPB-WD1: the path followed

- Characterization activities at the two sites started before the establishment and start of the SPB: *need to standardize and coordinate many activities ex post*;
- First “SPB” workshop in Nuoro, Oct. 2021;
- SPB structure and division chairs defined in mid-2022;
- WD1 activities started last year (Q3 2022);
 - WP chairs appointed;
 - Milestones defined;
 - Preparation of ET wiki pages:
 - <https://wiki.et-gw.eu/SPB/WebHome> , <https://wiki.et-gw.eu/SPB/PhysicalVariables>
 - Division meetings + dedicated WP meetings on Wednesday 4pm CET/CEST (antiphase with SPB meeting);
 - Delivering of the (urgent) documents related to the division milestones (see next slides).
- Fruitful 2nd SPB Workshop in Maastricht on January 2023!

Division Milestones:

- M1.1: physical variables needed for the site characterization and for the evaluation of their impact on the detector performances;
- M1.2: measurements recommendations and standards (setup, sensors, procedures, best practices...).
- M1.3: data format standards and analysis tools.



➤ Draft ready

Division Deliverables:

- D1.1: quantification of noise sources impacting ET performances.

➤ Q3 2024?

Division Milestones:

- **M1.1: physical variables:**

ET-0012A-23, discussed and finalized at the II SPB Workshop (Jan 2023)

<https://apps.et-gw.eu/tds/?content=3&r=18113>

- **M1.2: measurements recommendations and standards:**

ET-0013A-23, discussed and finalized at the II SPB Workshop (Jan 2023)

<https://apps.et-gw.eu/tds/?content=3&r=18114>

- **M1.3: data format standards and analysis tools (*draft*):**

Draft delivered,

<https://drive.google.com/file/d/1EmddYQSZYxmJHMwvOYq6E3b2FIJkNcN/view?usp=sharing>

M1.3: data format standards and analysis tools:

Writing team designed, coordinated by M. Di Giovanni; draft circulated; final version to be delivered right after the ET Symposium

M1.3 Report: common data formats and analysis tools

Matteo Di Giovanni^{1,2}, Shahr Shani-Kadmiel³, Carlo Giunchi⁴, Rosario De Rosa^{5,6}

¹ Gran Sasso Science Institute I-67100 L'Aquila, Italy

² INFN, Laboratori Nazionali del Gran Sasso I-67100 Assergi (AQ), Italy

³ KNMI NL-3731 De Bilt, Netherlands

⁴ INGV, sezione di Pisa, I-56123 Pisa, Italy

⁵ Università degli Studi di Napoli Federico II, I-80126 Napoli, Italy

⁶ INFN, sezione di Napoli, I-80126 Napoli, Italy

Keywords: (min 3, max5) keyword1, keyword2, keyword3, keyword4, keyword5.

Abstract. This document is aimed at defining the standards for data format and analysis tools that are and will be used for Einstein Telescope site characterization studies. The goal is to provide the appropriate tools and methods to make the analysis easily replicable to facilitate the comparison between the candidate sites.

1 INTRODUCTION

The identification of two candidate sites to host the future 3rd generation gravitational wave (GW) detector Einstein Telescope (ET) prompted, at the end of last decade, extensive long-term site characterization campaigns aimed at the assessment of the suitability of the aforementioned sites to host ET. This meant that a plethora of research groups, from different research institutes all over Europe, each with its own data analysis methods and tools, had to find a way to define common data formats and analysis tools in order to compare the two sites as uniformly as possible and to make the analyses easily replicable by any scientist. Today, the amount of data collected during several years of observations and the number of observables involved (seismic, acoustic, magnetic, etc...) require uniformity and ease of access. Therefore, the goal of this document is to define the standard data formats and tools for site characterization studies.

2 DATA FORMATS

2.1 MiniSeed

The IRIS (Incorporated Research Institutions for Seismology) consortium provides several



<https://drive.google.com/file/d/1EmddYQSZYxmJHMwvOYq6E3b2FIJkNcN/view?usp=sharing>

First goal of the division reached:
common ground and game rules defined.

Now we have to proceed with the characterization activities.

Urgent tasks:

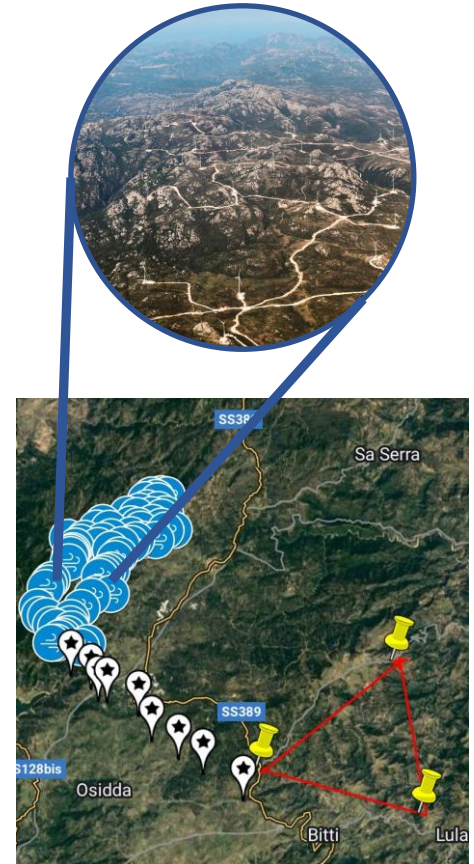
- Characterize the impact of existing wind farms on the environmental noise (vibrational, magnetic, acoustic) at the candidate sites;
- Characterize the impact of existing local infrastructures (e.g. powerlines, bridges...)
- *Still missing measurements:* gravimetric monitoring (Sardinia), magnetic noise (in borehole, vertical direction; at surface 3 directions at EMR), acoustic noise at surface (both sites)...

General achievements:

- Long-term seismic monitoring of both sites started and going on;
- Borehole drilled at both (three) sites;
- First results published in several papers.

Sardinia updates:

- Temporary seismometer deployments to study the vibration input and decay due to wind farms;
- Ambient noise characterization (just published: M. Di Giovanni et al., *Temporal variations of the ambient seismic field at the Sardinia candidate site of the Einstein Telescope*, Geophysical Journal International, <https://doi.org/10.1093/gji/ggad178>);
- New long-term seismic stations will be deployed in the area;
- **Talks of Carlo and Matteo in this session.**

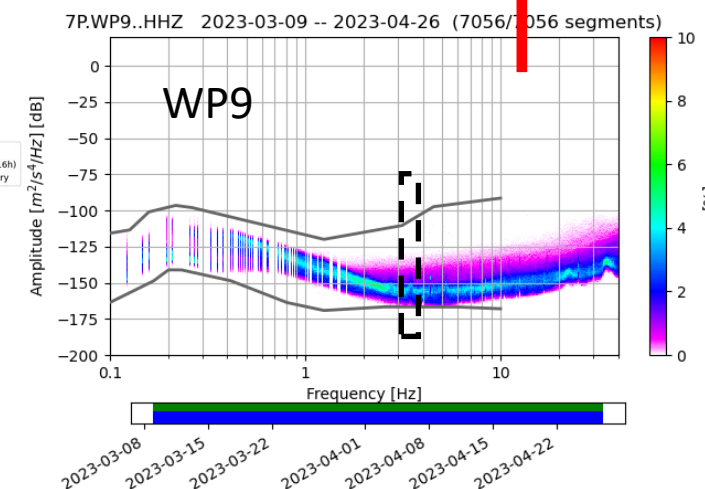
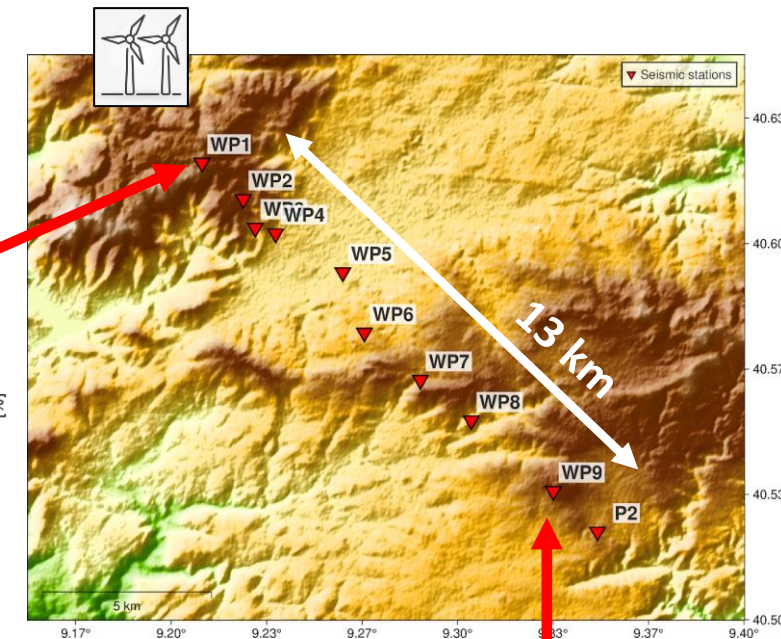
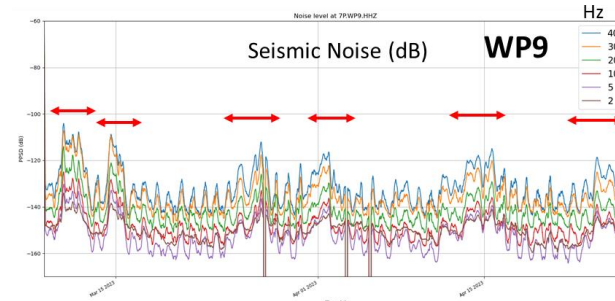
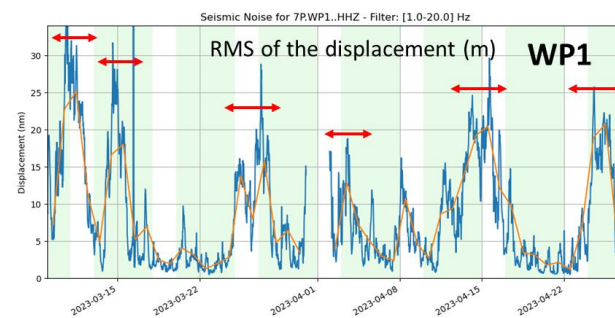
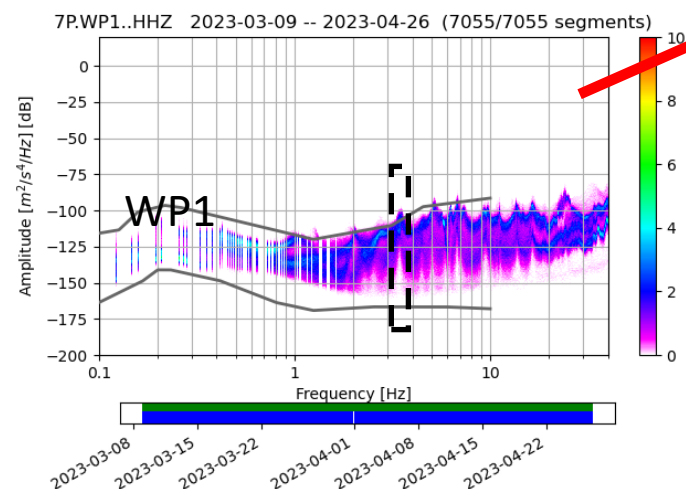


SPB-WD1 – WP1

C. Giunchi & S. Shani-Kadmiel

Wind farm study in Sardinia: a first look at data

- Main peak at 3Hz + harmonics close to the wind farm;
- Only main peak + first few harmonics close to P2, visible wrt to the low background (NLNM);
- Wind-correlated increase of noise rms;
- Analysis ongoing: spectral features and correlation with wind measured at weather stations close to the windfarm and with rotational speed of wind turbines.

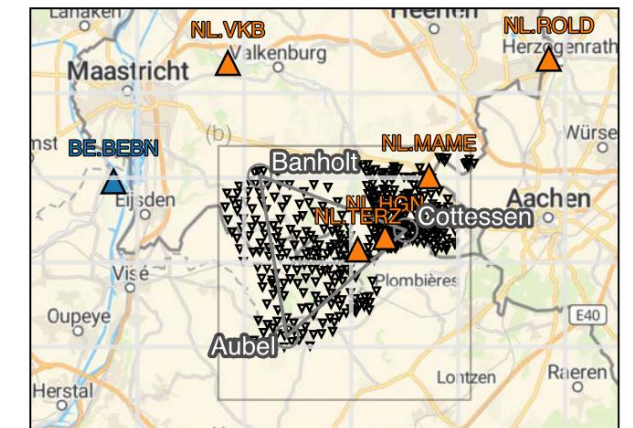


SPB-WD1 – WP1

C. Giunchi & S. Shani-Kadmiel

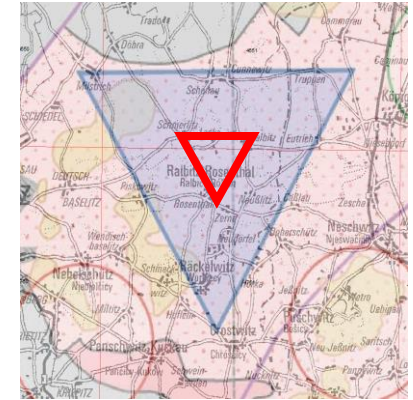
EMR updates:

- *Cottessen borehole* drilled (250m), reduced diameter due to casing issues, surface and borehole seismometers installed;
- *Banholt borehole* drilled (250m, but drill pipes stuck remained as casing. Usable depth reduced to 200m), borehole seismometer installation not successful due to data cable breaking, new installation planned.
- *Extensive ambient noise studies* at surface in the area, some sources identified. New nodes to be installed close to suspected sources of ambient noise to serve as pilot signals with surface and borehole stations.
- **Talks of Shahar, Soumen and Achim in this session.**

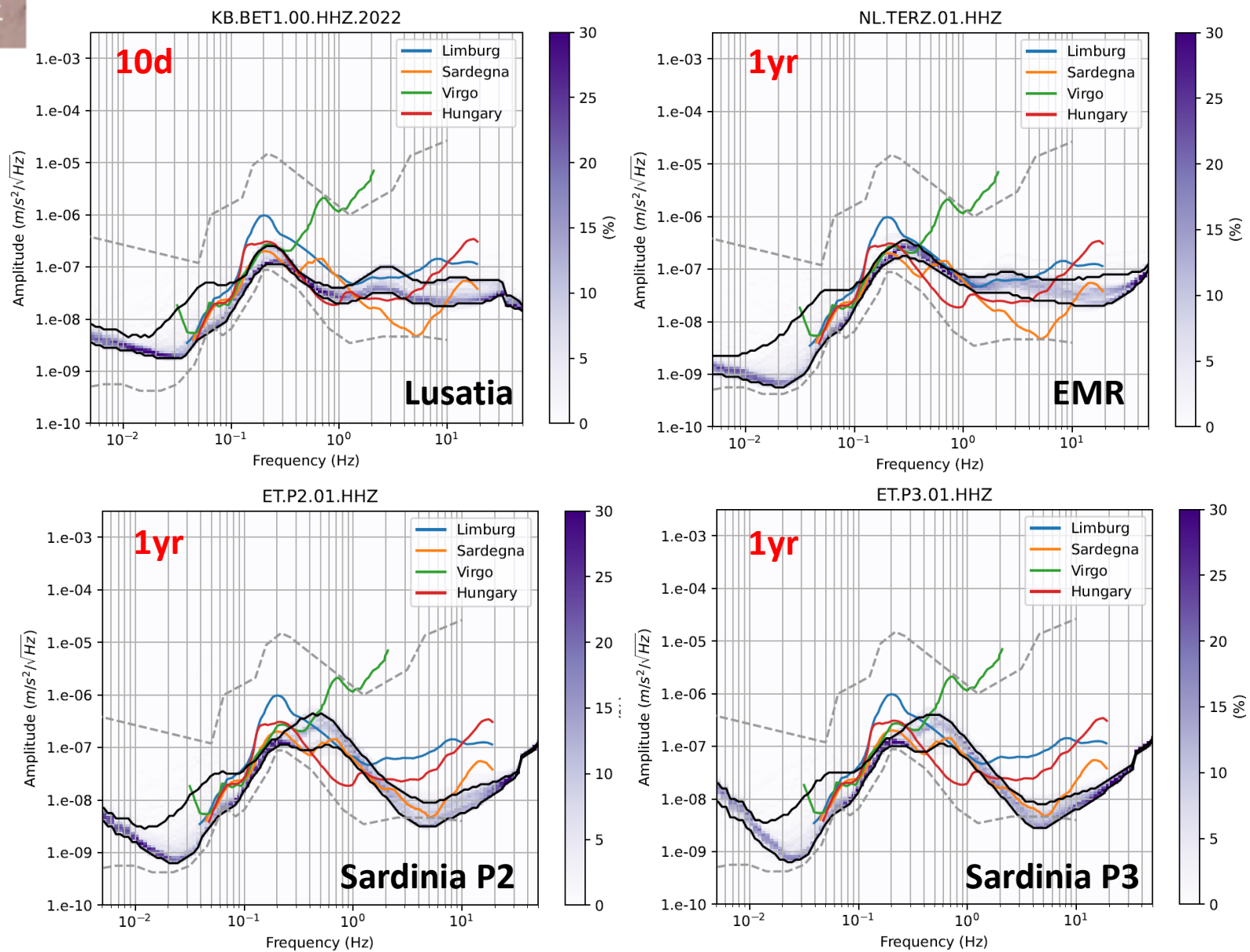


Lausitz Update:

- Currently 1 surface station running, 1 borehole station at 160m depth and 1 borehole station at 165m depth. The station at 165m depth will be lowered to 245m depth in the next couple of months. Additionally, there is one barometer running to monitor air pressure.
- The geophysical/geological site investigation is planned, currently waiting for the funding to be released. This will entail:
 - *Ambient noise monitoring* in the area of the possible ET location to have a 3D image of the contact between granodiorite and sedimentary rocks;
 - *Shallow reflection seismics* around the current borehole;
 - *Identify 3-4 further borehole locations*;
 - *Constructing a 3D geological model* based on all literature data;
 - *Characterisation of the cores*.
- The plan is to start in early summer with first results early 2024.



SPB-WD1 – WP1



Courtesy of A. Rietbrock, 2nd SPB Workshop 2023

WP1.2 Gravity, Geodesy and Geodynamics roadmap:

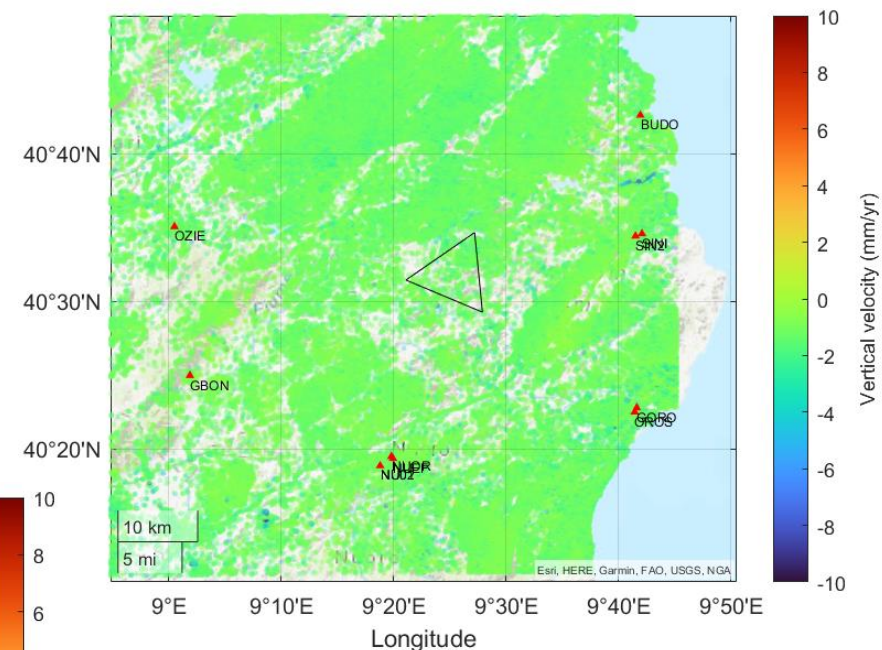
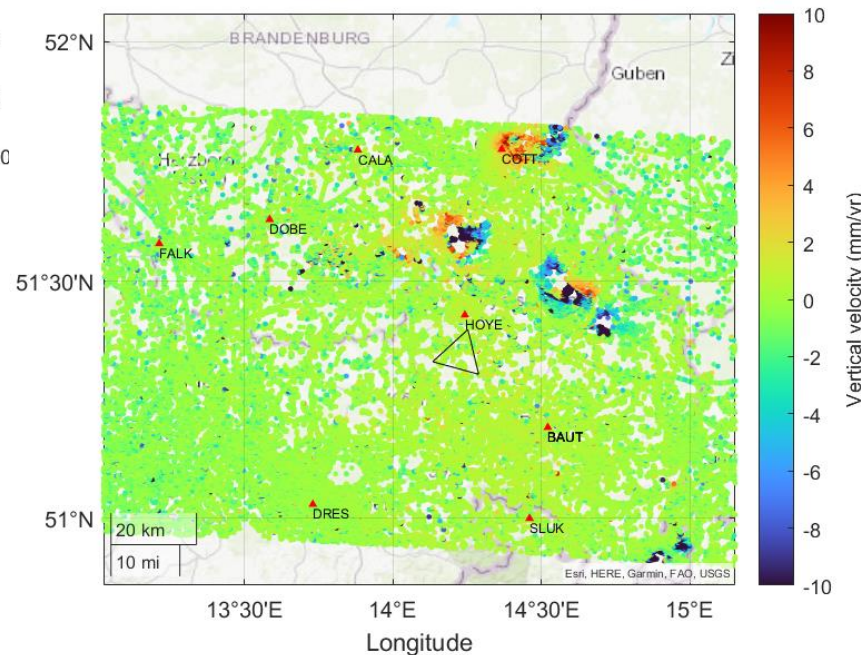
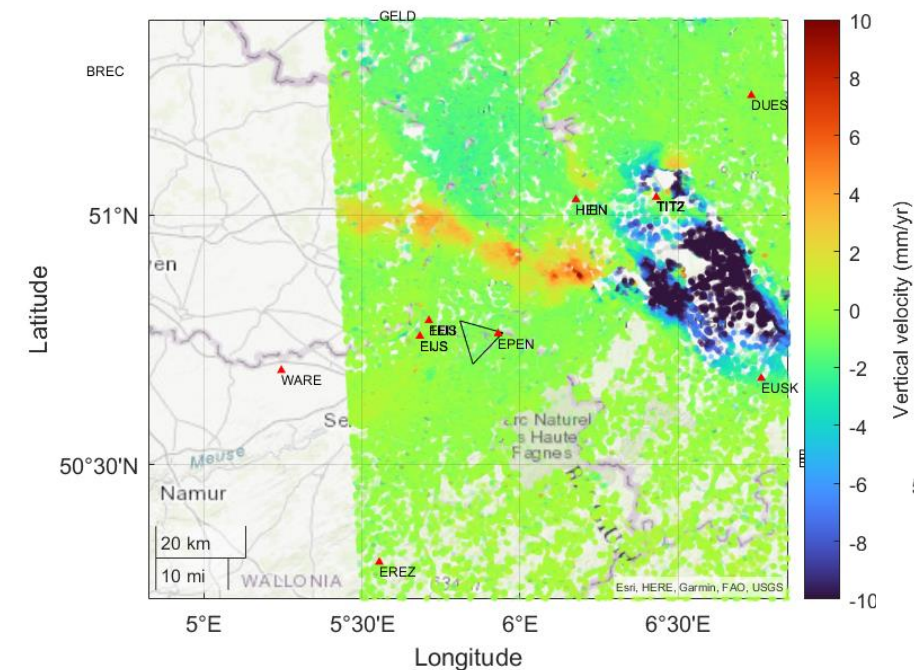
- **Analysis of historical seismicity.**
- **Analysis of GNSS (INGV database) and InSAR (EGMS) time series.**
- **Regional deformation & strain-rate maps, centered at three proposed sites.**
- **Supporting the construction of new GNSS and gravimeter stations to monitor annual cycle.**



European Seismic Hazard Map, ESHM2020

First look to Ground Motions

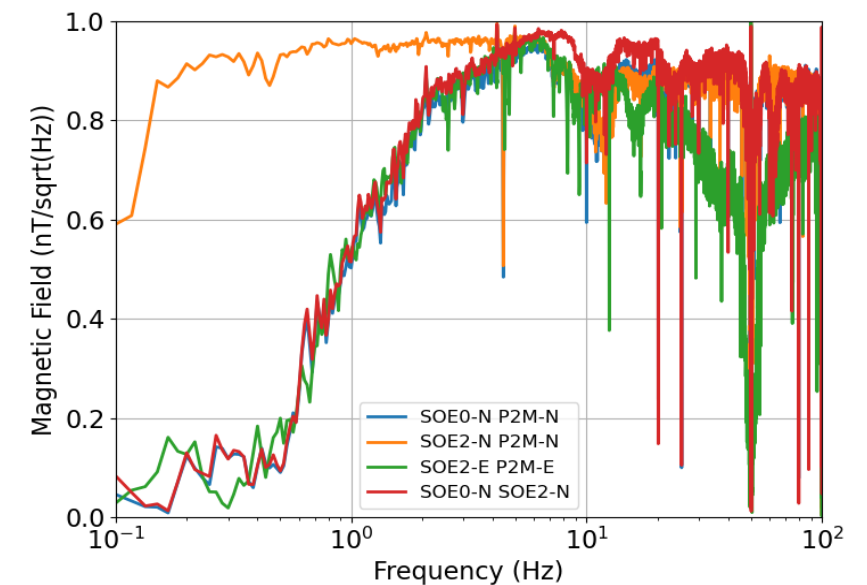
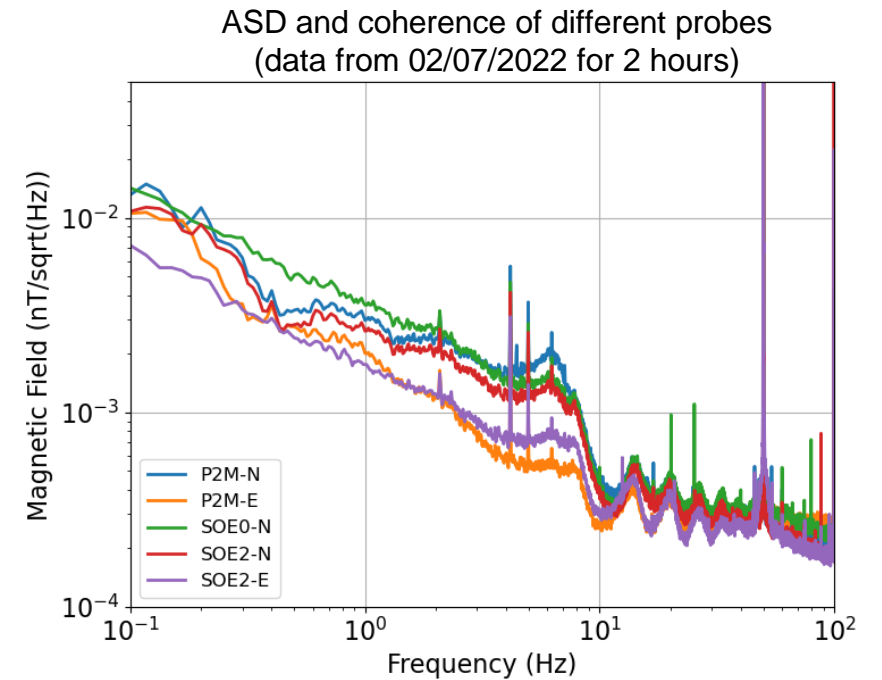
Lausitz



Sites Characterization

Currently there are:

- 1 mag. probe (N-S direction) in surface at Sos Enattos (SOE0)
- 2 mag. probes (N-S and E-W directions) at -111 m underground at Sos Enattos
- 2 mag. probes (N-S and E-W directions) in surface at Bitti (P2)

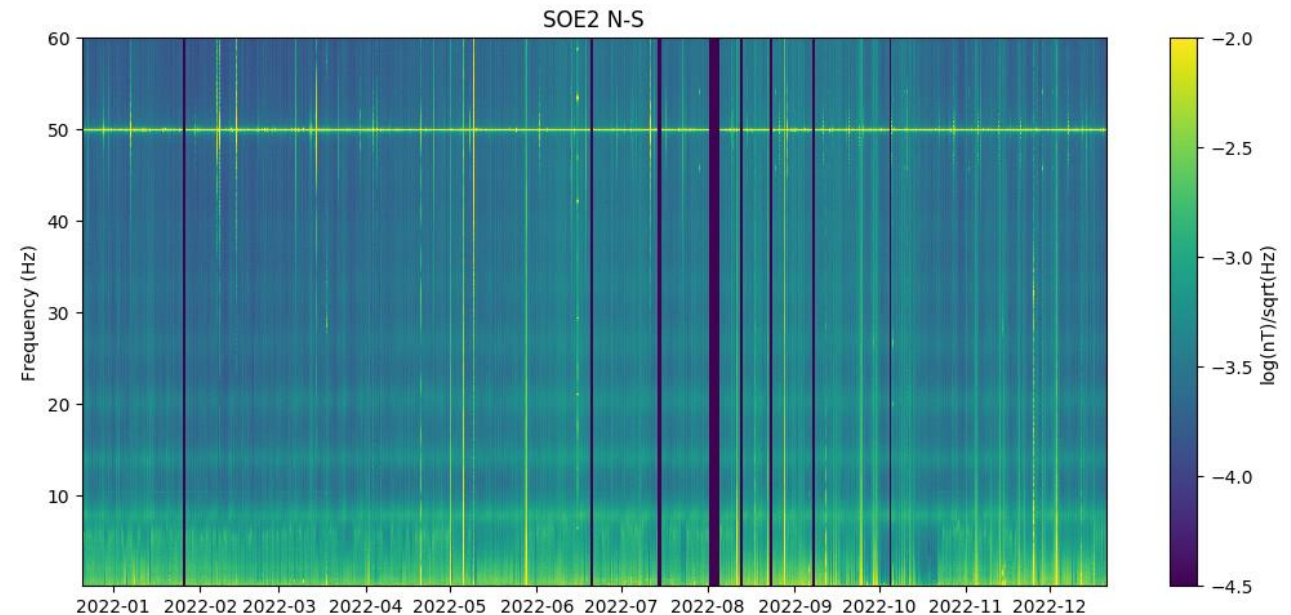


Measurement Campaign

- Long-term measurements are ongoing;
- SR are well visible in surface sensor too;
- Anyway, the underground EM noise is expected to be the same almost everywhere;
- Need quiet and significant probe for EM noise subtraction;

Next Steps

- Installation of vertical magnetometer at P2
- Installation of 3 magnetometers at P3
- Installation of a surface magnetometer at SOE0 (E-W direction)
- Centaur DAQ at P2 and P3 instead of ADU08 (more safe: require interface electronics already designed)
- Measurements at EMR: in borehole (V) and at surface



Spectrogram of data collected at SOE2 N-S from 21/12/2021 for one year

*Talks in SPB and NN/env sessions:
Rosario, Federico, Tatsuki*

❑ Studies concentrated on Sardinia (international collaboration):

- Installed microphones in the mine:

- Italian (EGO microphones)
- Polish UW (Astrocent microphones) - from Nov 26, '22
- Hungarian campaign - Nov 21-26, '22

- Installed microphones outside the mine:

- Astrocent from Nov 26, '22

❑ LNGS experiment with noise in large cavern - see talk by Bulik

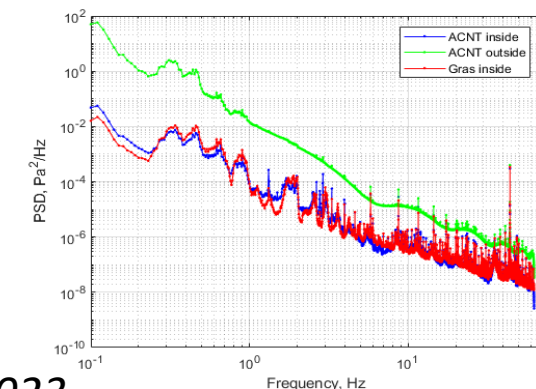
❑ No updates from the EMR side

❑ Planned GSSI campaign with new microphones and covers.

❑ Maintaining wiki site: <https://wiki.et-gw.eu/SPB/OtherEnvNoise>

❑ Data stored in: etrepo.df.unipi.it

Talks in SPB and NN/env sessions: Tomek, Mariusz, Edit



Future Plans:

- Further measurements in Sos Ennatos: microbarymetric measurements, weather monitoring.
- Clearing the situation in EMR. What measurements can be done? Who will do them?
- Data analysis:
 - estimates of the noise are difficult as no infrastructure exists yet;
 - search for correlations.

Talks in SPB and NN/env sessions: Tomek, Mariusz, Edit

SPB-WD1 – publication plan

First division paper: **Seismic comparison between borehole measurements at the sites.**

Following the preliminary seismic comparison work presented by A. Rietbrock at the SPB Workshop in Maastricht, a writing team has been appointed to prepare a first publication dealing with the seismic noise measured in the similar borehole drilled at the 2(+1) candidate sites.

Coordinator: Andreas Rietbrock

Writing team: Andreas Rietbrock, Shahar Shani-Kadmiel, Carlo Giunchi, Luca Naticchioni, Matteo di Giovanni, Michael Frietsch, Marco Olivieri.

Target journal: CQG or Seismica

Paper draft will be circulated once ready!



SPB-WD1 – Conclusions

- Even though WD1 started officially its activities only in the second part of 2022, a lot of work has been done in the last months.
- Common reference documents to harmonize and coordinate site characterization delivered.
- Useful SPB workshops with good participation of the host teams, and fruitful discussions.
- Comparable measurements and procedures allow for a fair site comparison.
- A good example: borehole seismic measurements at the 2+1 sites in preparation with a common SPB-WD1 analysis and writing team.
- Urgent tasks: study of wind farm noise (vibrational, EM, acoustic), measurement of ambient magnetic noise (surface and V-channel in borehole) and possible railway sources at EMR.