Environmental Noise Measurements at Sos Enattos

A. Allocca, G. Ballardin, D. Barrale, A. Cardini, A. Contu, R. De Rosa, L. D'Onofrio, L. Errico, V. Fanti, I. Fiori, K. Janssens, C. Migoni, D. Mura, F. Paoletti, R. Romero, D. Rozza, M. C. Tringali, L. Trozzo, …

Outline

- Status of Environmental Monitoring at Sos Enattos
- Focus on Magnetic Noise Measurements
  - Underground long-term measurement
  - Surface vs Underground
  - New measurements at Bitti (P2)
  - In Time Analysis
  - Magnetic noise projection
- Next steps

Status of EnvMon at Sos Enattos

Underground probes

- Apart from seismic probes there is still a single magnetic probe at -111 m): Metronix MFS-06 sampled at 250 Hz: SOE2
- New hermetic rack installed, hosting the electronics, including two acquisition systems;

Status of EnvMon at Sos Enattos

Surface Probes

- The surface magnetometer (SOE0: Metronix MFS-06e sampled at 250 Hz, N-S orientation) is now active.
- Several stops during the last year.
- Data taking periods:
  - 1 - 2020 August 6 to November 9;
  - 2 – 2021 March 13 to April 30;
  - 3 – 2021 July 27 to September 14;
  - 4 – 2021 October 16 ongoing

Status of EnvMon at Sos Enattos

Weather Station

- The station is regularly collecting data since June 6 2020
- Data summary available on web

Magnetic Noise Measurements

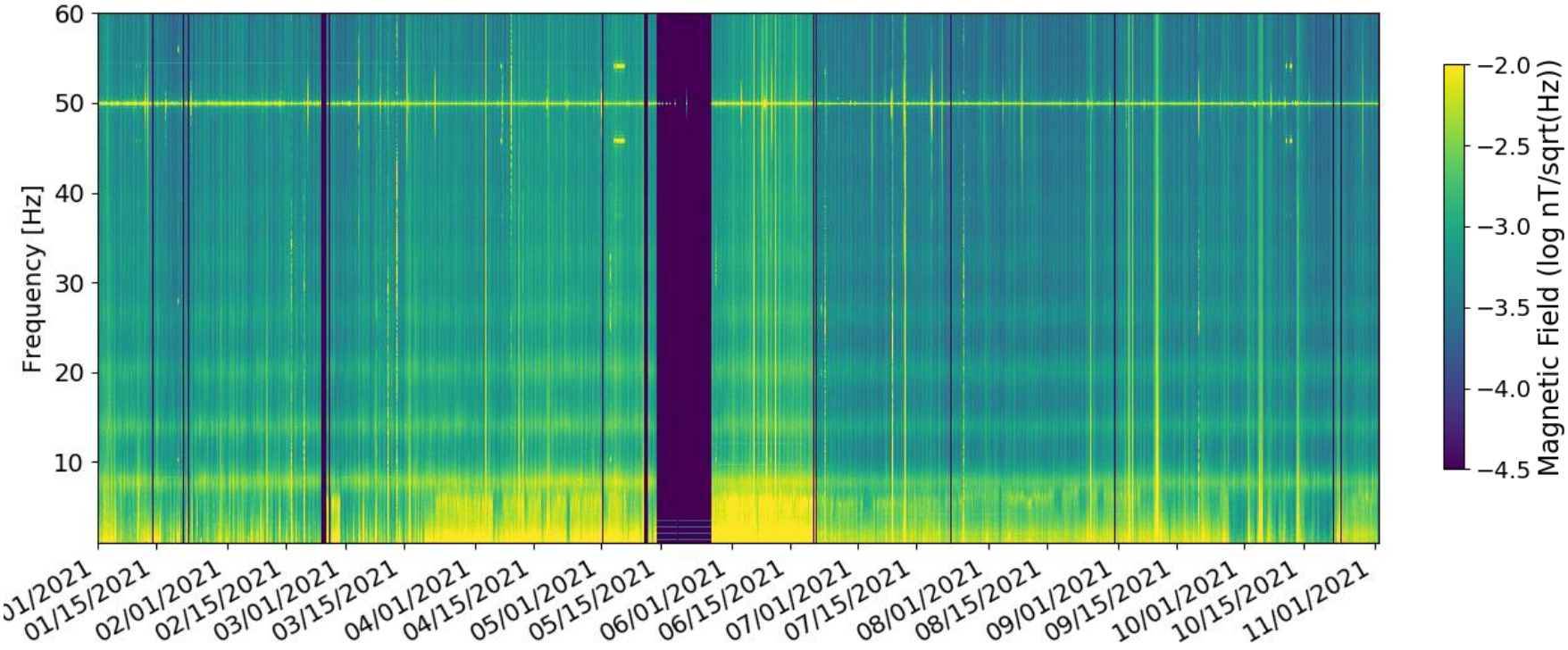
Motivation

- The noise from natural or anthropogenic electromagnetic fields can affect the sensitivity of a gravitational wave interferometer in different ways:
  - Direct coupling with magnet actuators of the mirror and suspension systems;
  - Coupling with electronic devices managing the interferometer;
- A special role, among the possible noise sources, is played by the Schumann resonances: a world-wide electromagnetic field sustained by the lightning discharges between the Earth surface and the ionosphere.
- Due to their global character, the Schumann resonances could set a strong limit in the detection capability of selected class of sources (e.g GW stochastic noise);

Magnetic Noise Measurements

About One Year Long Measurement

- Data from the SOE2 (-111 m) magnetometer;
- Schumann Resonances peaks (SR) from 1st to 7th (SR1
- ... SR7) clearly visible;

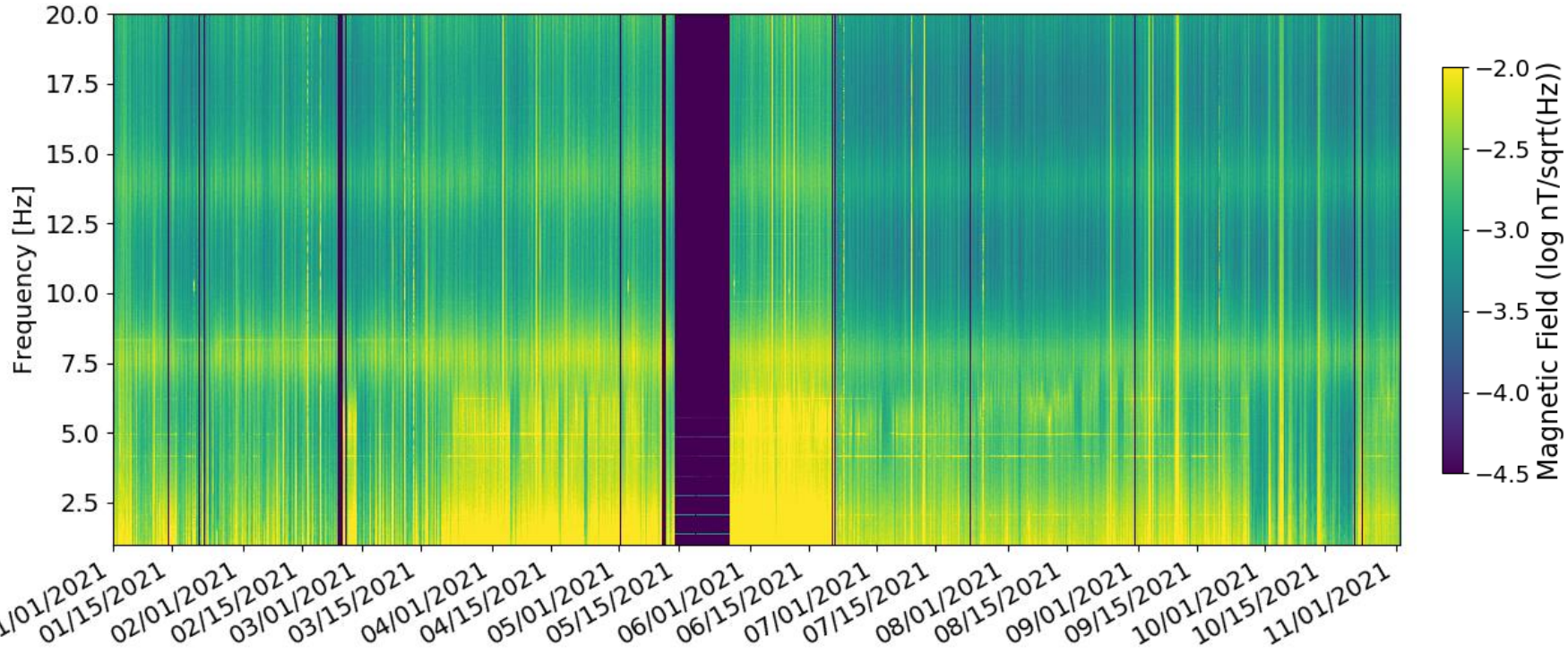


SR1 ~ 7.8 Hz, SR2 ~ 15.6 Hz, SR3 ~ 23.4 Hz, …

Magnetic Noise Measurements

About One Year Long Measurement

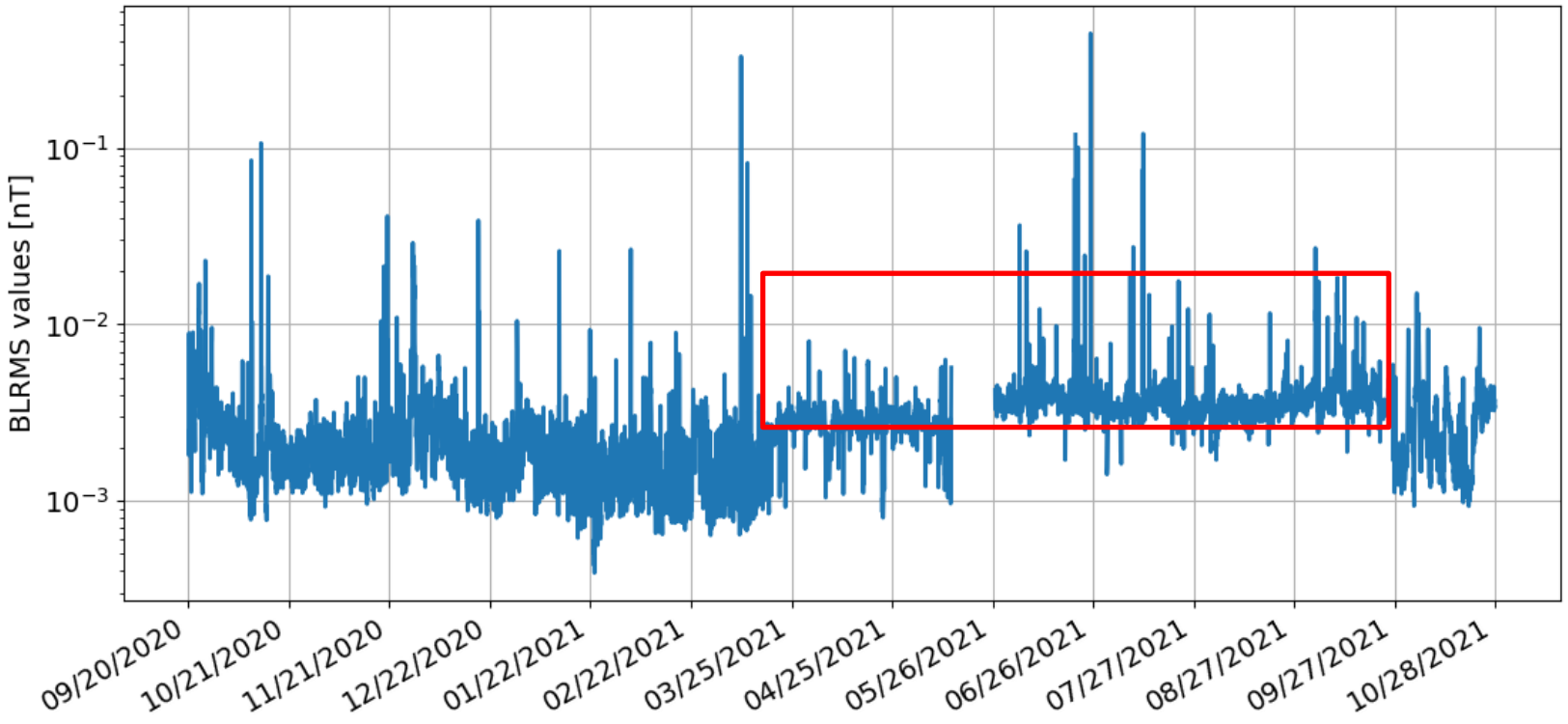
- Zoom at low frequency;
- Higher low frequency noise (up to about 6 Hz) from mid march to end of September;



Magnetic Noise Measurements

About One Year Long Measurement

- More clear looking at BLRMS (integrated from 1 to 5 Hz);
- Note the different time scale (more than one year);
- Excess noise not yet really understood investigation in progress with auxiliary sensors;

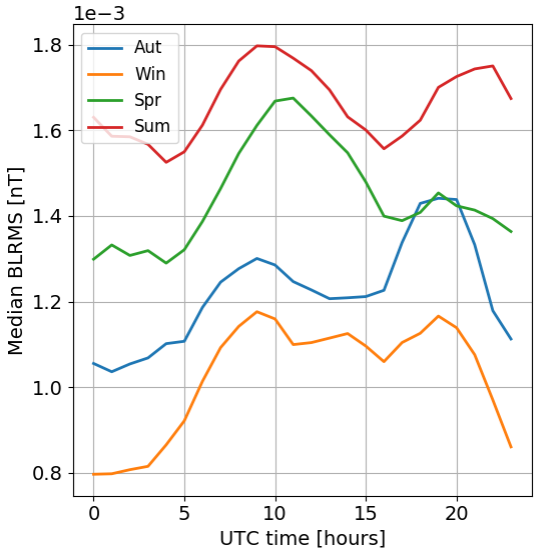


Magnetic Noise Measurements

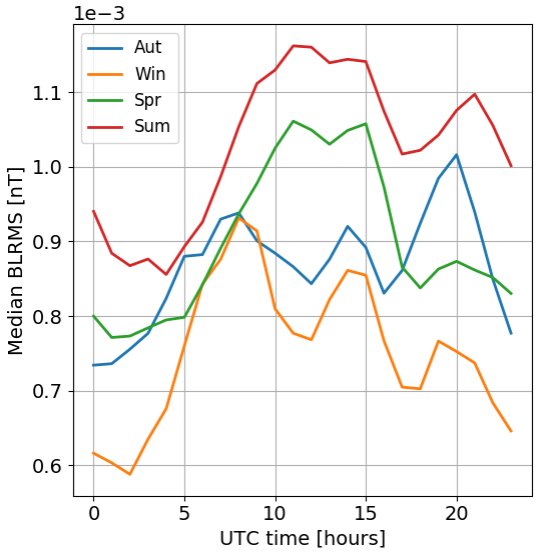
Schumann Resonance variability

- Apart the anomalous low frequency noise, the SR show their characteristic variability;
- For any season, the minimum value is reached during night (about1-2 UTC);

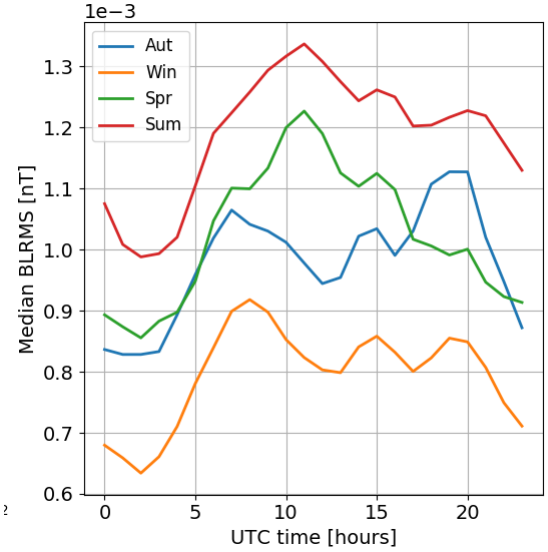
SR1



SR2



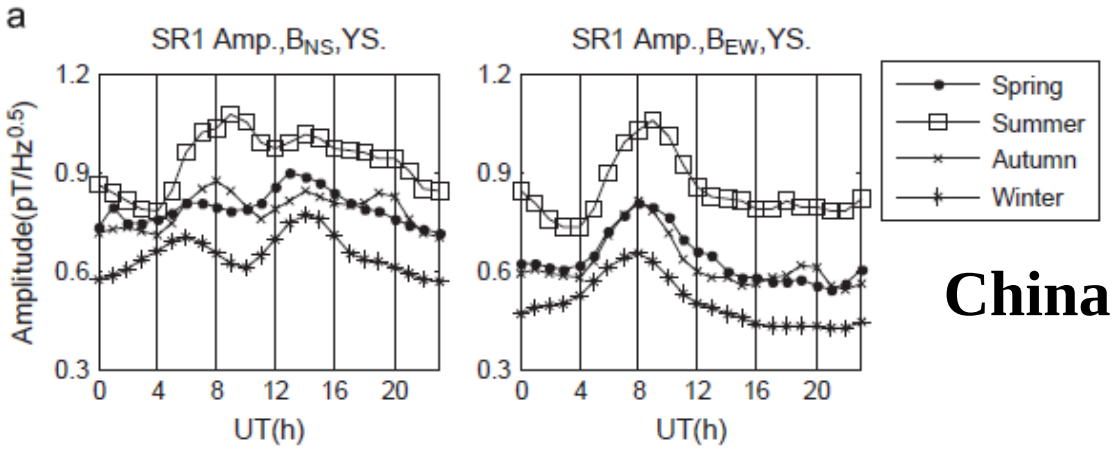
SR3



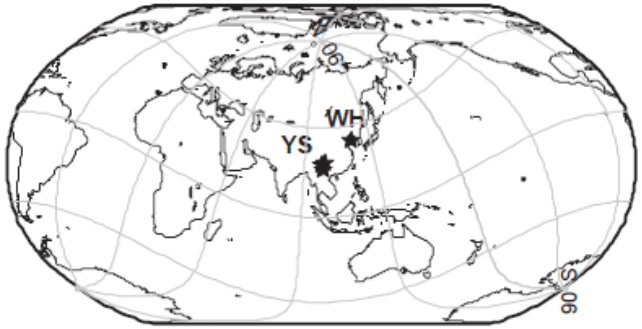
Magnetic Noise Measurements

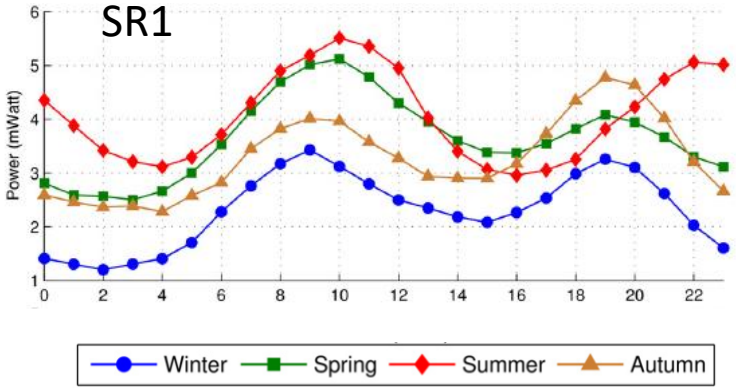
Schumann Resonance variability

- The observed variability is compatible with other measurements performed in other observatories



China



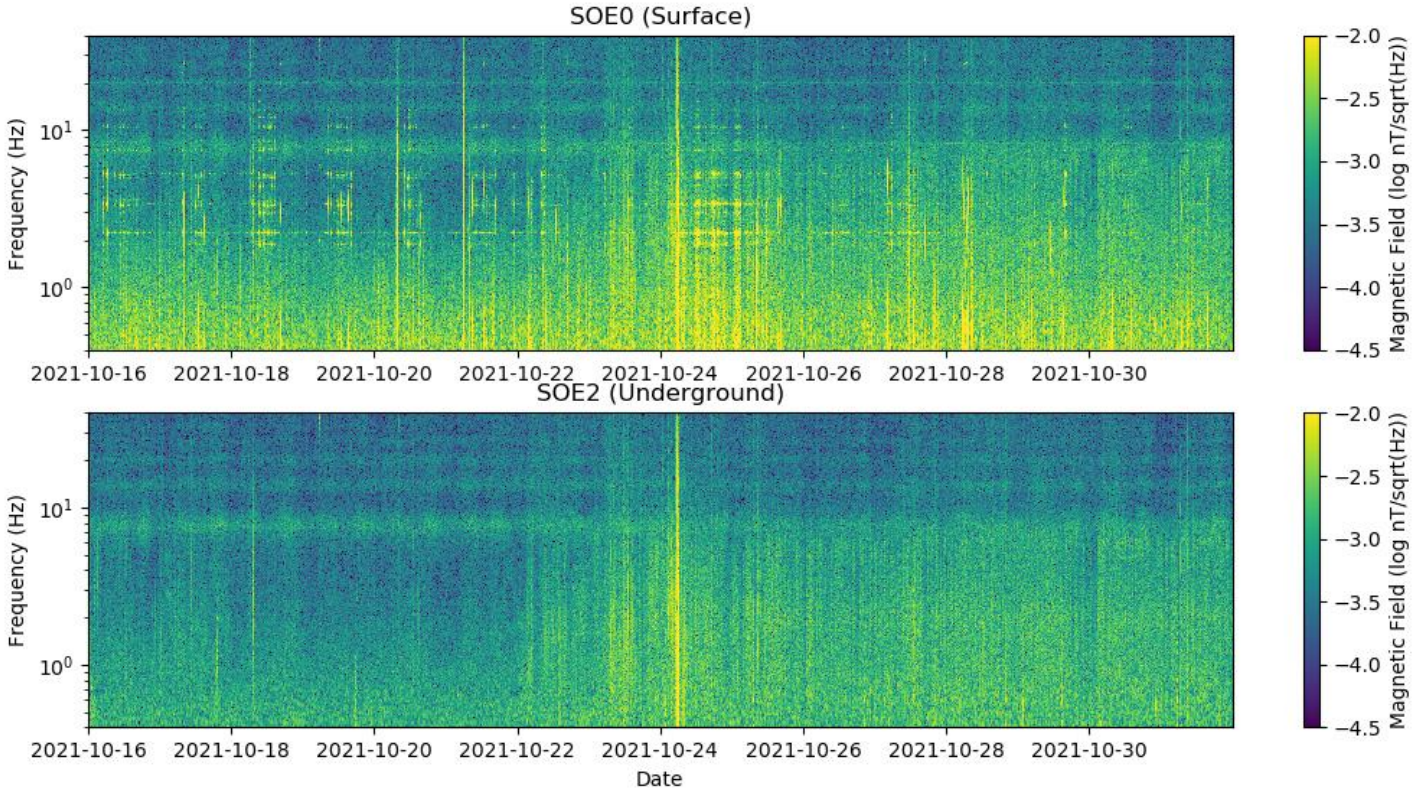


Greece

Magnetic Noise Measurements

Surface vs. Underground comparison

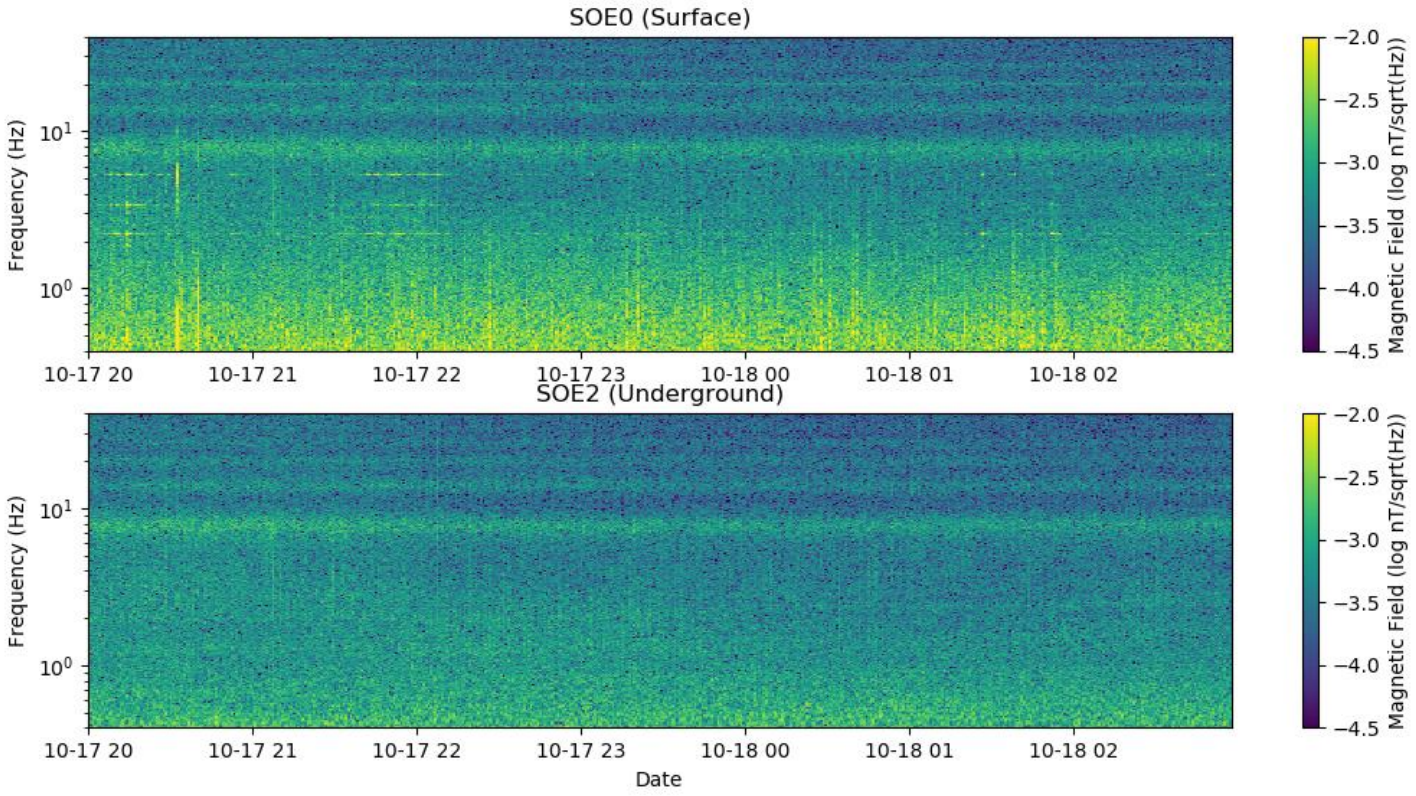
- Comparison between SOE2 and SOE0 in the period 16-31 October 2021
- Larger noise, in surface, below 10 Hz;



Magnetic Noise Measurements

Surface vs. Underground comparison

- A comparison between underground and surface during a quiet period (7 hours from 17 October 2021);
- Very quiet data both at SOE2 and SOE0:

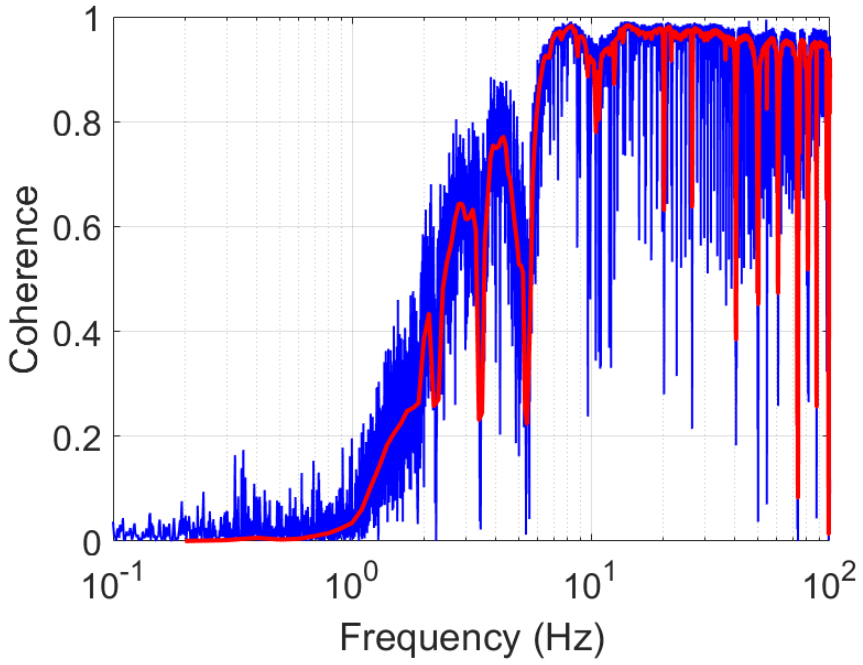


Magnetic Noise Measurements

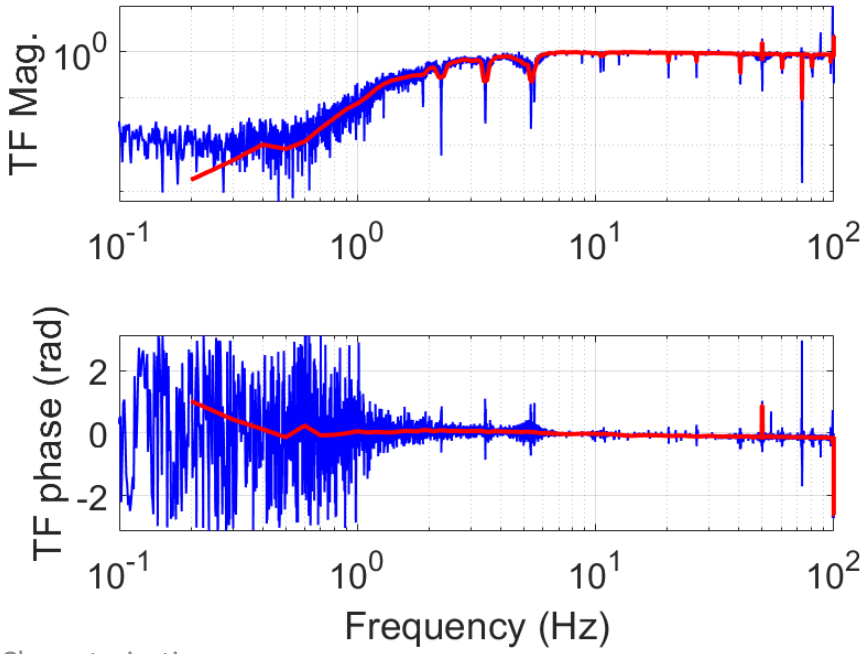
Surface vs. Underground comparison

- Last data were used to perform a more detailed comparison between surface and underground;
- Good coherence from 1 Hz and almost flat and unitary TF in the SR region;

Blue and red curves have different frequency resolutions



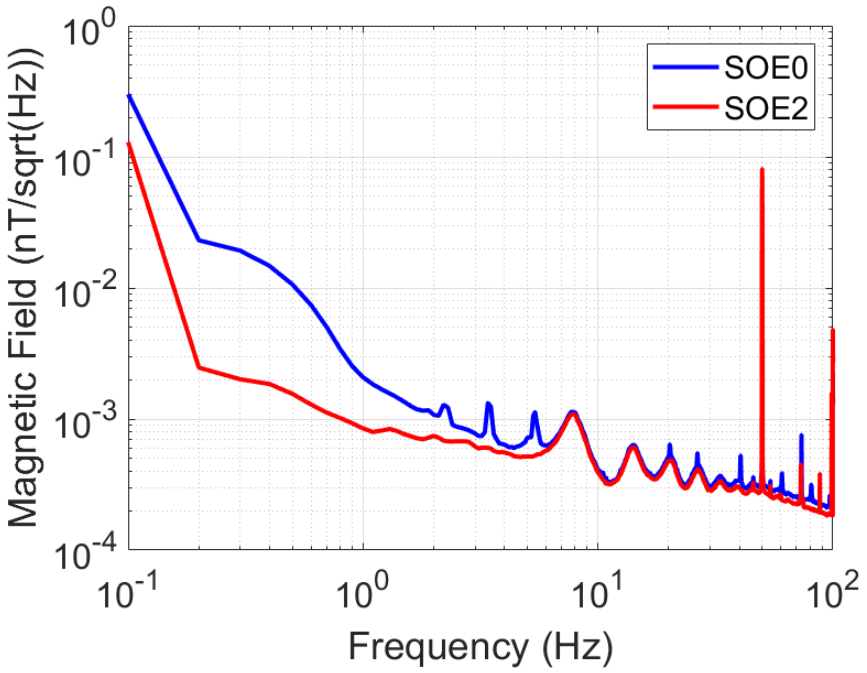
TF: SOE2/SOE0 (Underg./Surface)

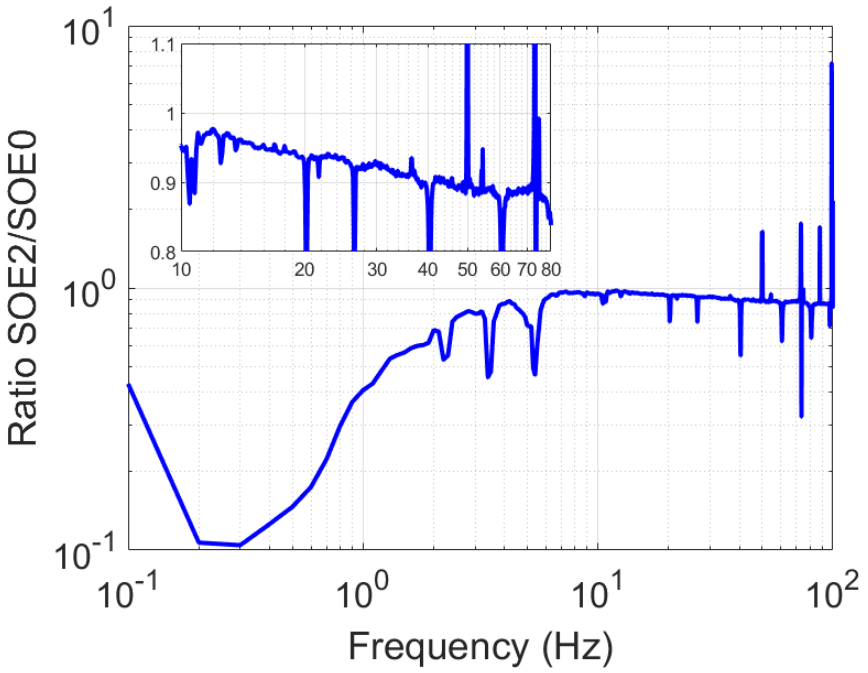


Magnetic Noise Measurements

Surface vs. Underground comparison

- Spectra and their ratio computed on the full quiet period;
- The ratio show a decrease of the magnetic field, in the SR band, for underground location;





Magnetic Noise Measurements

Surface vs. Underground comparison

- A simple model assuming a uniform conductivity of the soil and a slow varying field approximation for the magnetic field is enough to approximately explain the measured behavior;
- Surface to underground described by the transfer function;

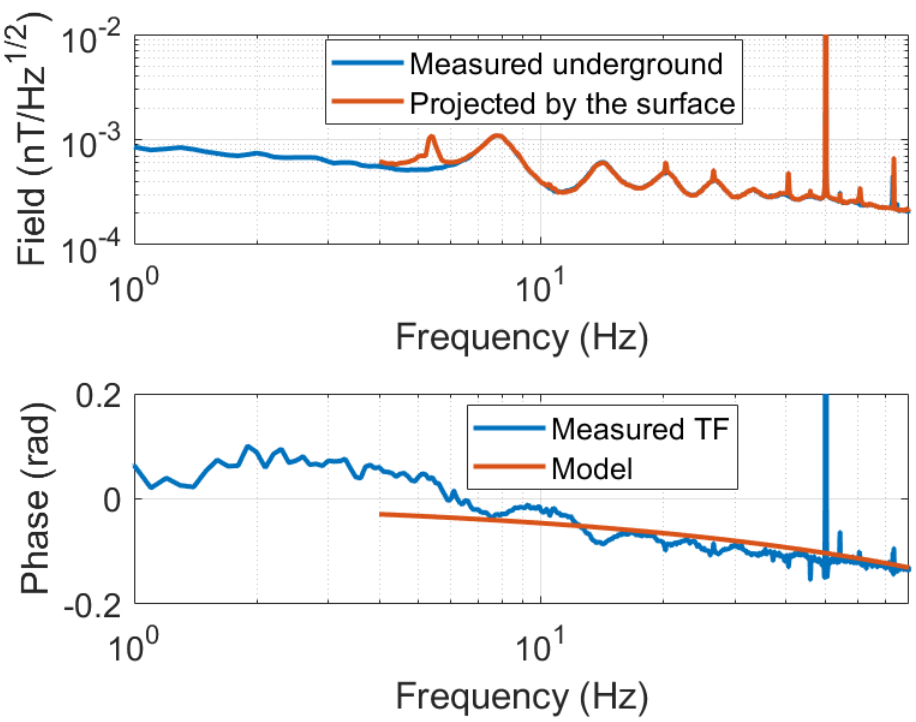
$$\mathrm{TF} = e^{-(1+i)d\sqrt{\pi\mu_r\mu_0\sigma f}}$$

The depth was fixed to:

d=110 m

The resulting conductivity was:

$\sigma = 4.5 \cdot 10^{-3}$ S/m



Magnetic Noise Measurements

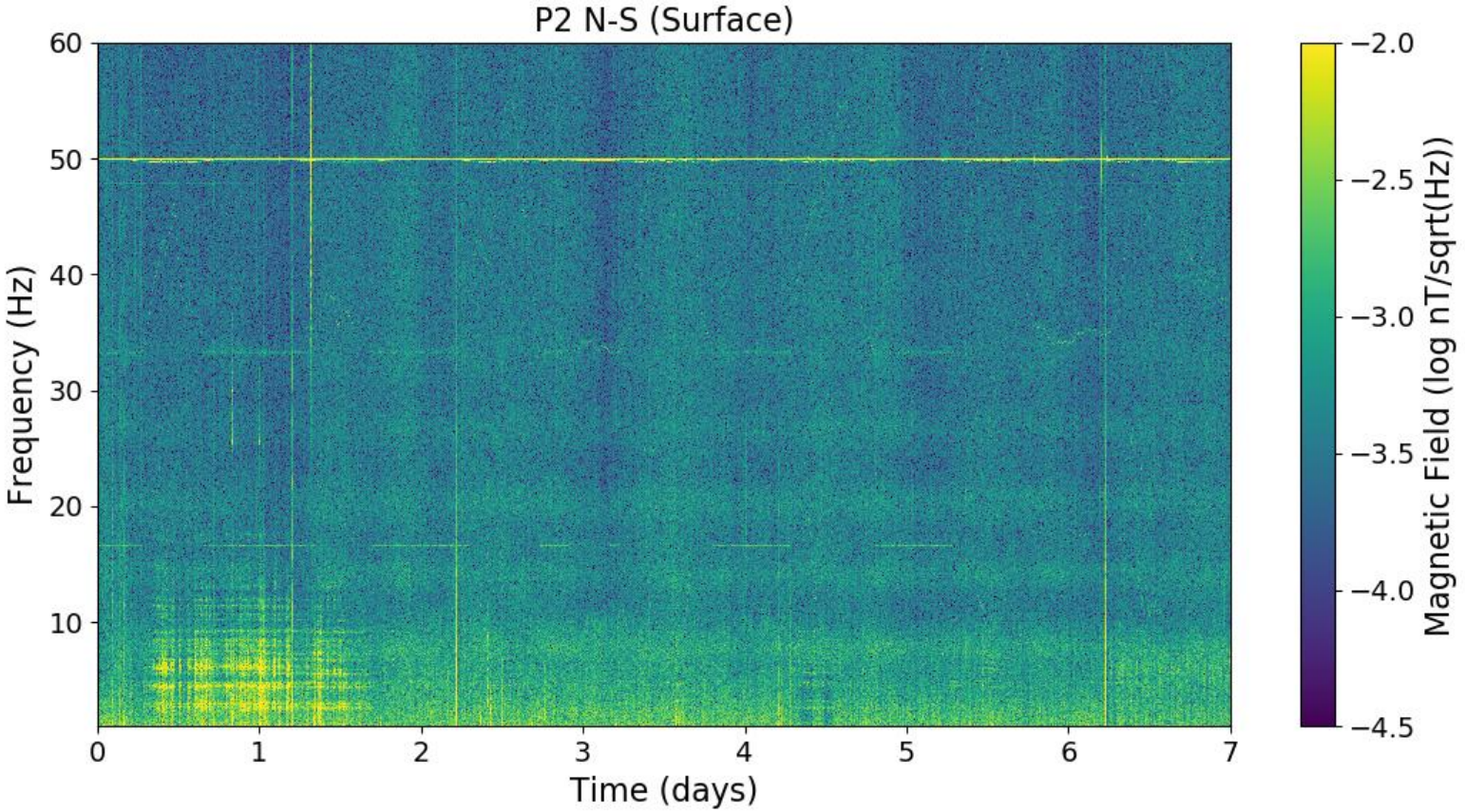
New Measurements at Bitti (P2)

- Last September 17 a couple of magnetometers were installed in P2 (Bitti – NU), N-S and E-W orientation;
- The probes are the same used for Sos Enattos, with a different data logger (Metronix ADU 08) sampling at 512 Hz;

Magnetic Noise Measurements

New Measurements at Bitti (P2)

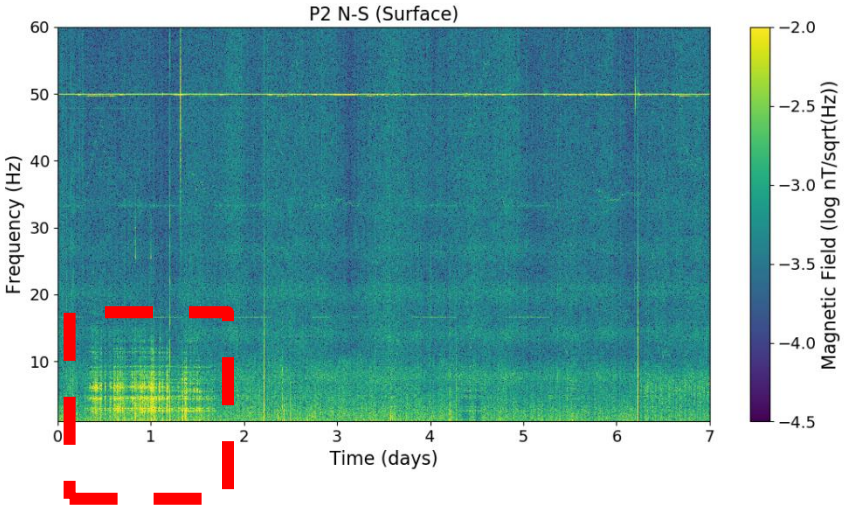
- Magnetic noise is low enough, but there are strong disturbances in the band 2-10 Hz. Not always present…



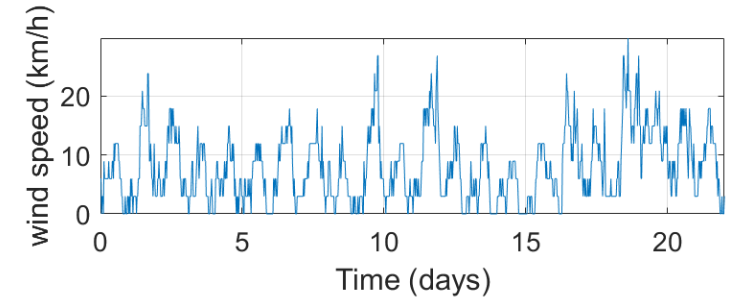
Magnetic Noise Measurements

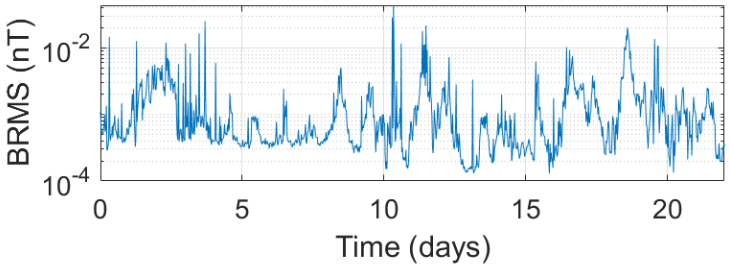
New Measurements at Bitti (P2)

- The disturbances are very likely due to wind induced vibrations of the metallic wire mesh placed all around the protected area;



- A little correlation is visible with the far (about 12 km) weather station at Sos Enattos…
- Plan to install a weather station in P2 also;

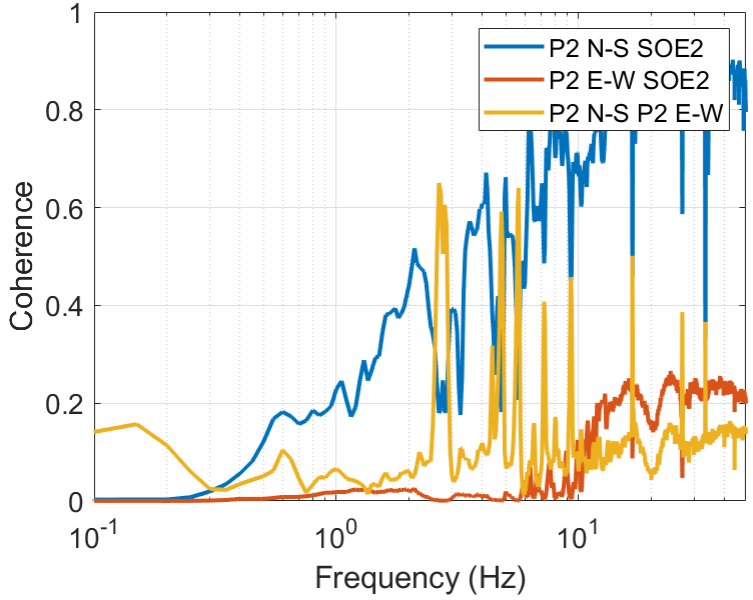


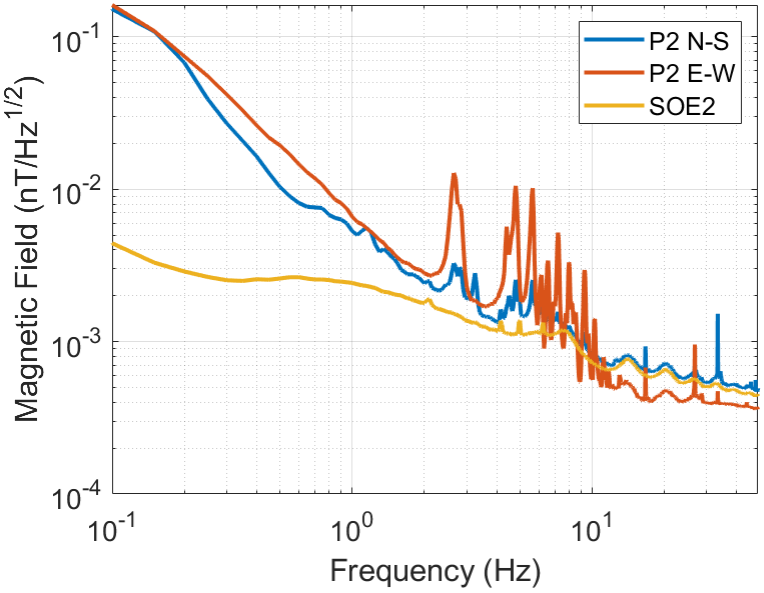


Magnetic Noise Measurements

New Measurements at Bitti (P2)

- Comparison with the underground field (SOE2);
- Larger low frequency noise;
- SR from 2 very well visible;
- Probably the orientation is not really good;

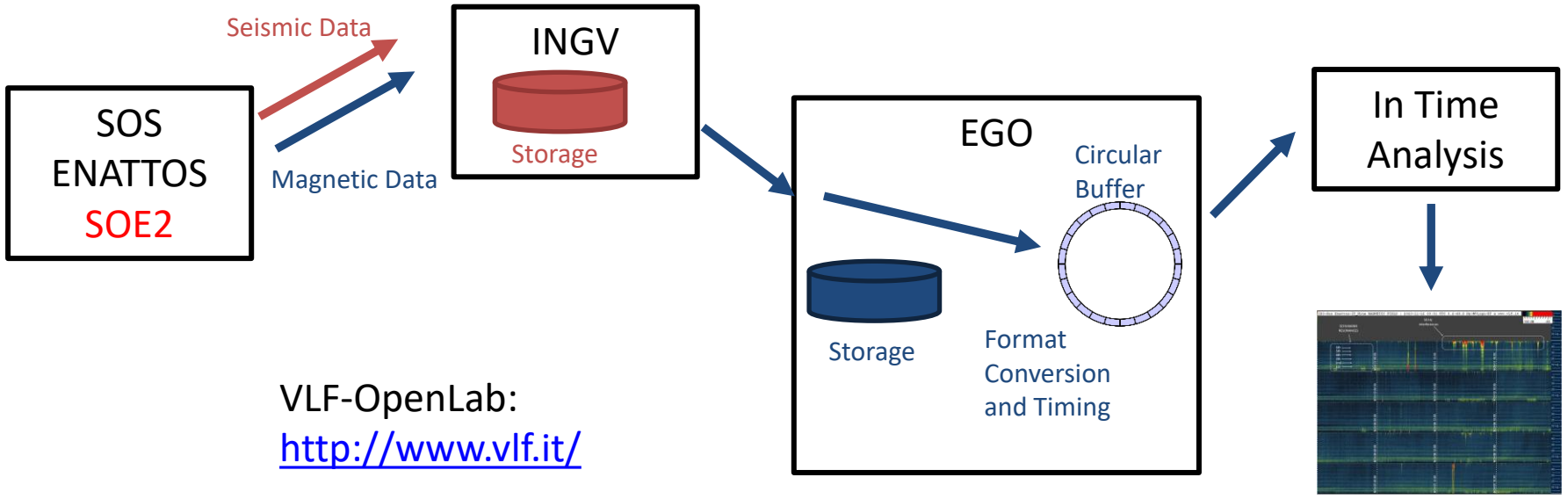




Magnetic Noise Measurements

Data repository and transmission

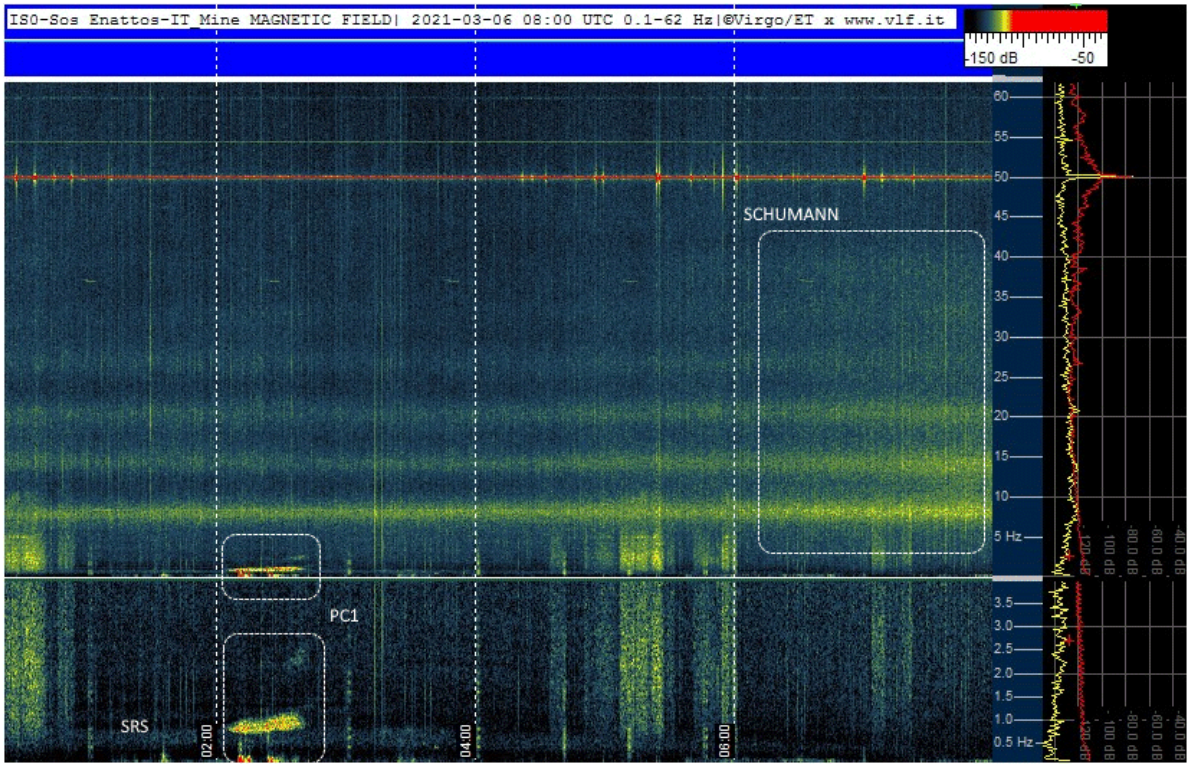
- Data from the underground magnetometer are sent to INGV together with the seismic signals from SOE2;
- Magnetic data are then stored at EGO (mseed format);
- Finally they are sent to VLF-OpenLab for the in-time analysis (wav format);



Magnetic Noise Measurements

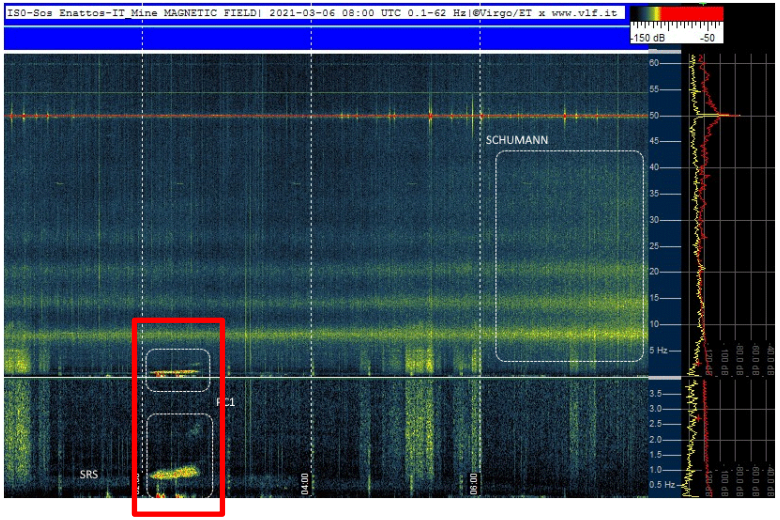
In time analysis

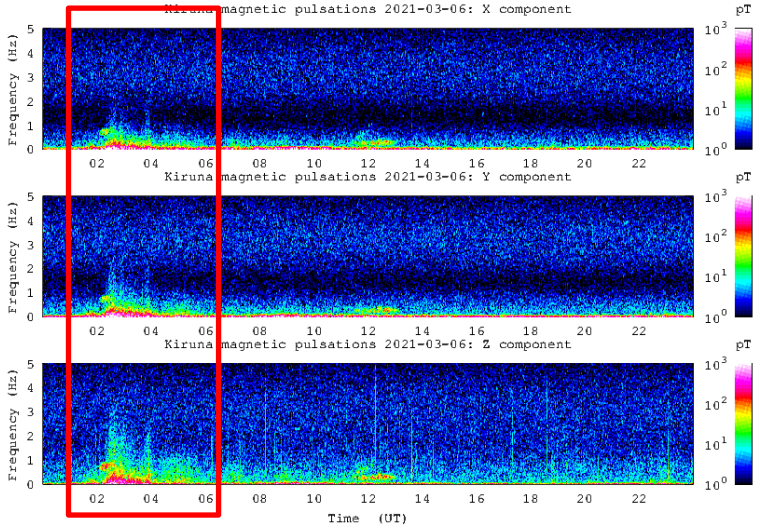
- A detail showing SR (up to 6th), 50 Hz disturbances, a Magnetic Pulsation (PC1) and Spectral Resonance Structures (SRS) observed on 6 March 2021;



Magnetic Noise Measurements

In time analysis



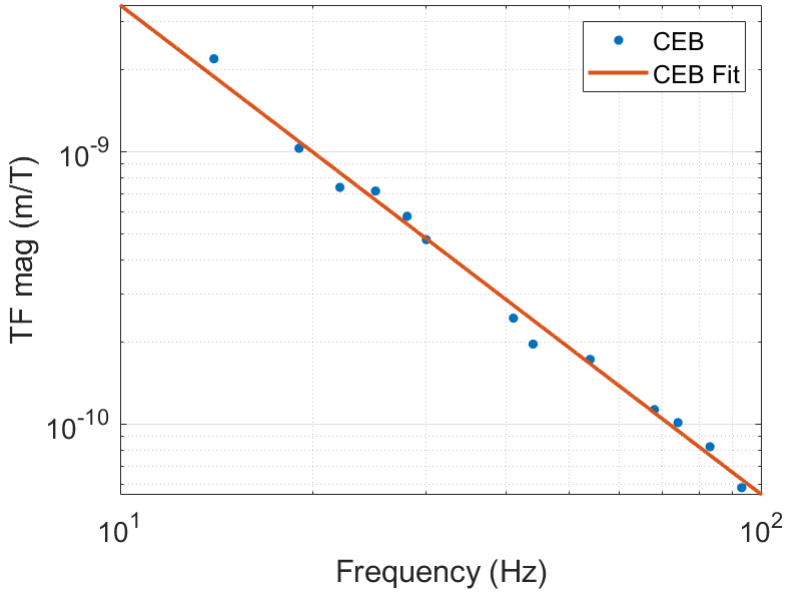


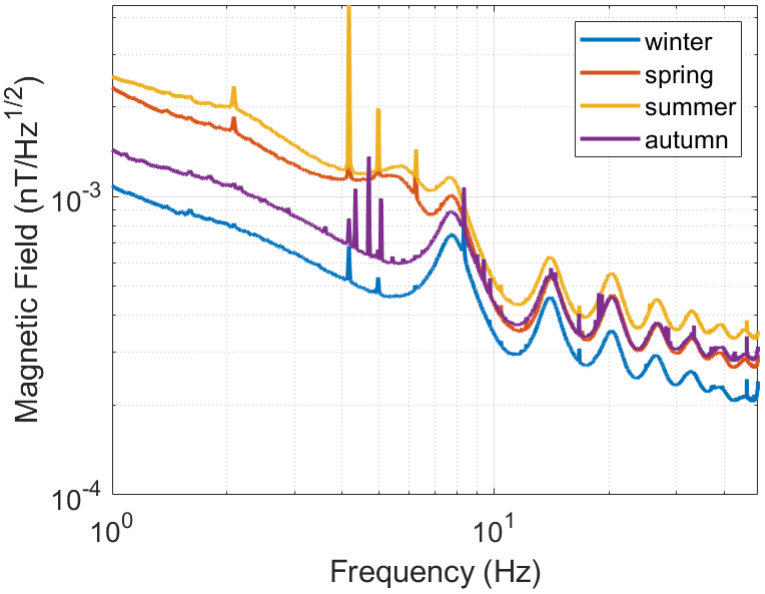
- Magnetic pulsation are produced inside the magnetosphere and their detection, on Earth, requires very quiet environment;
- The same pulsation detected in SOE2 was detected at Atmospheric and Geophysical Observatory. (Sweden)

Magnetic Noise Measurements

Magnetic Noise Projection

- The Magnetic field measured at SOE2 was used to estimate the effect of this noise on the ET floor;
- The coupling function was estimated by the result of the magnetic noise injections performed in Virgo during O3 (VIR-0291A-20). Warning: no direct measurement under 10 Hz;

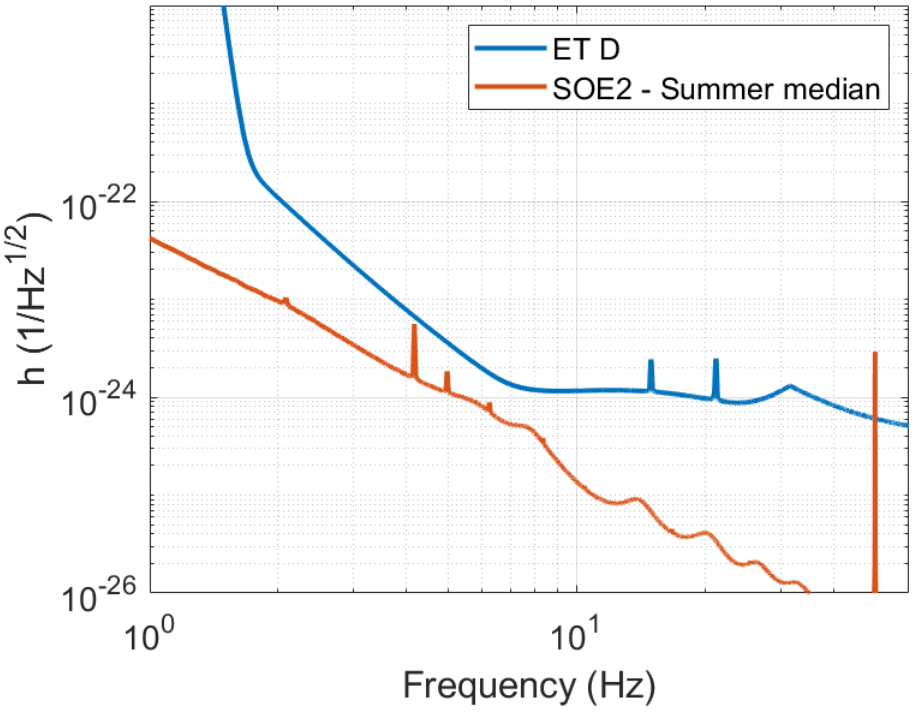




Magnetic Noise Measurements

Magnetic Noise Projection

- With this assumption the magnetic noise (measured at SOE2) does not limit the ET sensitivity, but…
  - This is, of course, only a conservative projection in a very quiet environment;
  - Coupling below 10 Hz was just extrapolated by the fit;
  - We expect a significant background noise increase in the final ET environment;
  - More inputs are needed to estimate the magnetic coupling, both at low as at high frequencies;



Next Steps

Beginning of next year

- Installation of the microphones: initially in surface, inside the control room for test, and then at level -2 for correlation with seismometer;
- Installation of a third magnetometer in SOE3;

Middle 2022

- Displacement of the magnetic probes from P2 to P3;