Karlsruhe Institute of Technology

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA

GRAN SASSO SCIENCE INSTITUTE

SCHOOL OF ADVANCED STUDIES

Scuola Universitaria Superiore

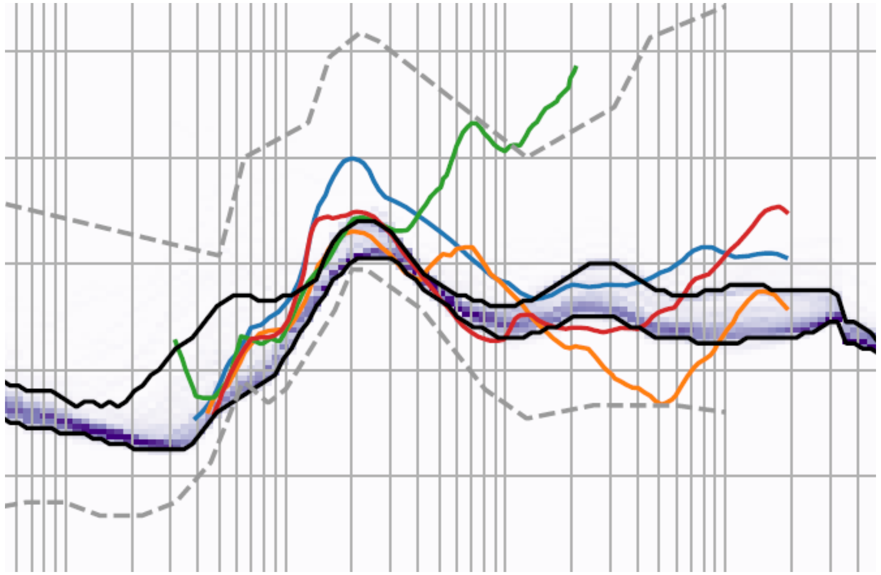
Istituto Nazionale di Fisica Nucleare

Koninklijk Nederlands Meteorologisch Instituut

Ministerie van Infrastructuur en Waterstaat

Seismic noise characterisation at ET candidate sites

Andreas Rietbrock[1], Michael Frietsch[1], Carlo Giunchi[2], Thomas Forbriger[1], Matteo Di Giovanni[3], Luca Naticchioni[4], Shani Kadmiel Shahar[5] ([1]KIT, [2]INGV, [3]INFN, [4]GSSI, [5]KNMI)



Outline

- Short primer on calculating PPSD
- Proposed ET candidate sites in:
  Sardinia, Euregio-Meuse-Rhine and Lausitz
- Comparison of seismic noise observations
- Conclusions / Outlook

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- **Short primer on PPSD**
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Collection of Jupyter notebooks

Quantile statistics for PSD

Intention of this notebook

Welch's (1967) algorithm for the computation of power spectral density (PSD) for time series data splits the time series into many segments, computes the FFT for each segment, scaled to units of PSD and takes the average over all segments. This is equivalent to taking the FFT for the entire time series and then taking the average over adjacent Fourier coefficients. This notebook demonstrates that a percentile statistic which extracts the median values for the coefficients in all segments cannot replace the averaging. Resulting values of PSD would systematically be too small. Quantile statistics may only be applied to PSD spectra, which are obtained by proper averaging prior to analyzing quantiles (this is demonstrated at the very end of this notebook).

Check consistency of PSD computation using white noise

Intention of this notebook

We check the validity of power spectral density (PSD) levels computed by different implementations. The test data is white noise. The time series is computed by randomseries. These data shall be analyzed by different approaches to demonstrate that they all provide the same values of PSD. Additionally the computations in the Fourier domain are compared with the levels computed in the time domain by means of Parceval's theorem (which is only possible for white noise).

PSD values are computed in three ways:

1. from the rms-amplitude in the time domain according to Parceval's theorem
2. The results of the function `scipy.signal.welch` as used in CONRAD.
3. by the program croposp
4. by the program foutra
5. PSD data extracted from an instance of `obspy.signal.PPSD`

Testing evaluating PSD(PPSD) implemetations:

Collection of Jupyter notebooks (lead by Thomas Forbriger)

https://gitlab.kit.edu/kit/gpi/seis/PSDbenchmark

Work in progress

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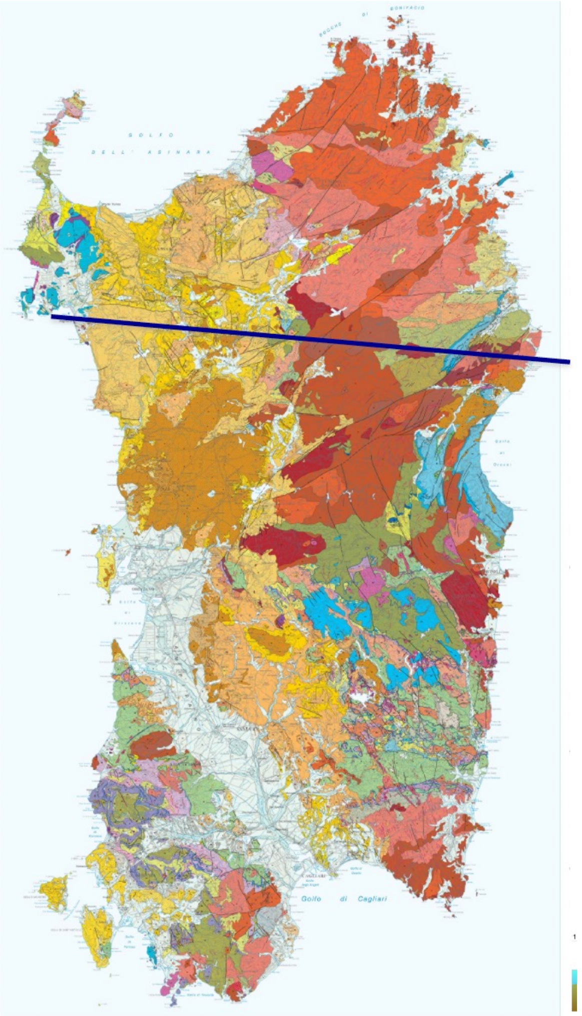
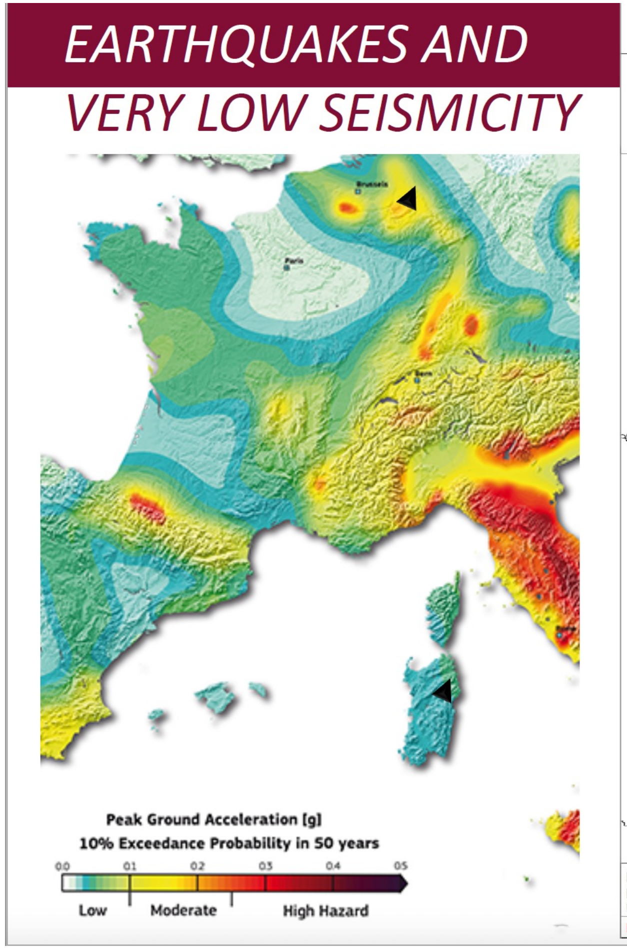
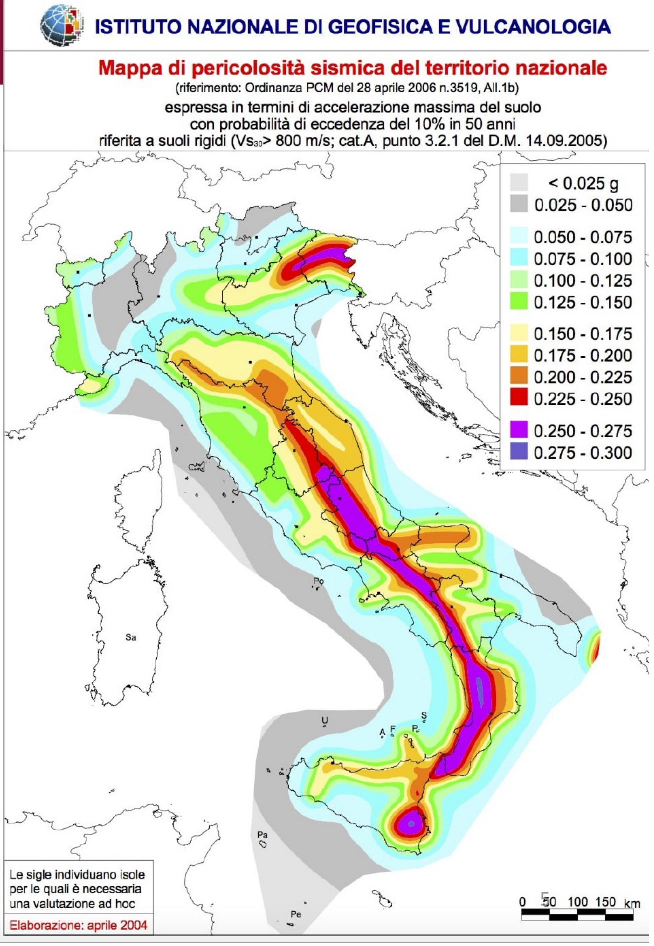
Sardinia ET site



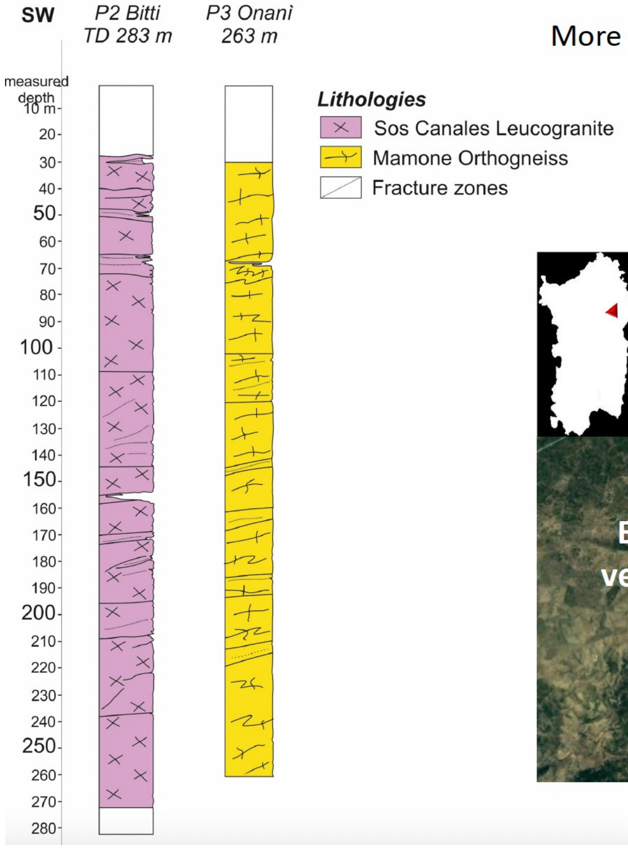
Geological map



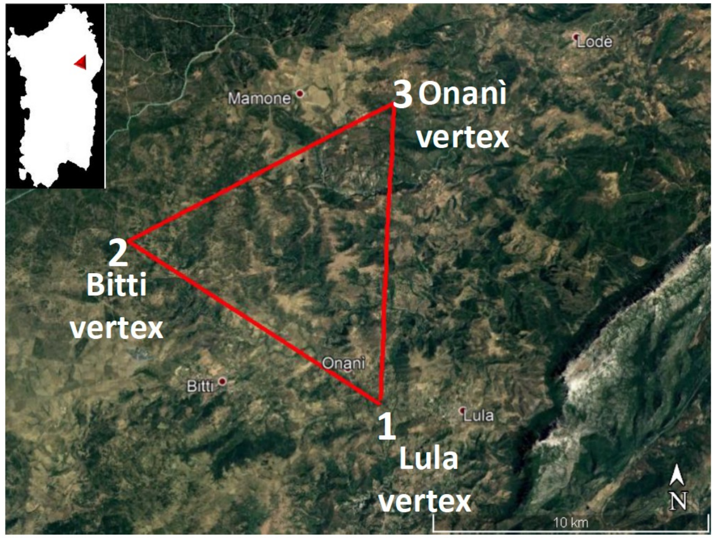


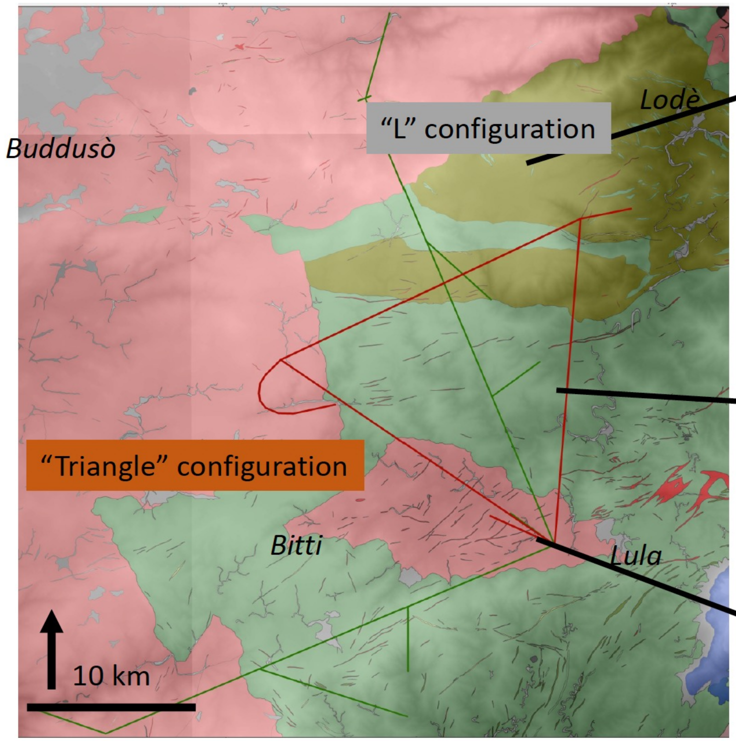
Low seismicity, seismic hazard

Proposed location



More data and insights in the Luca Naticchioni's talk

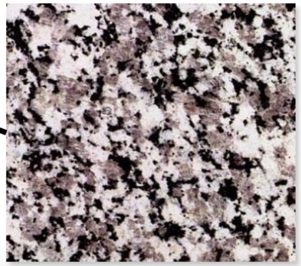




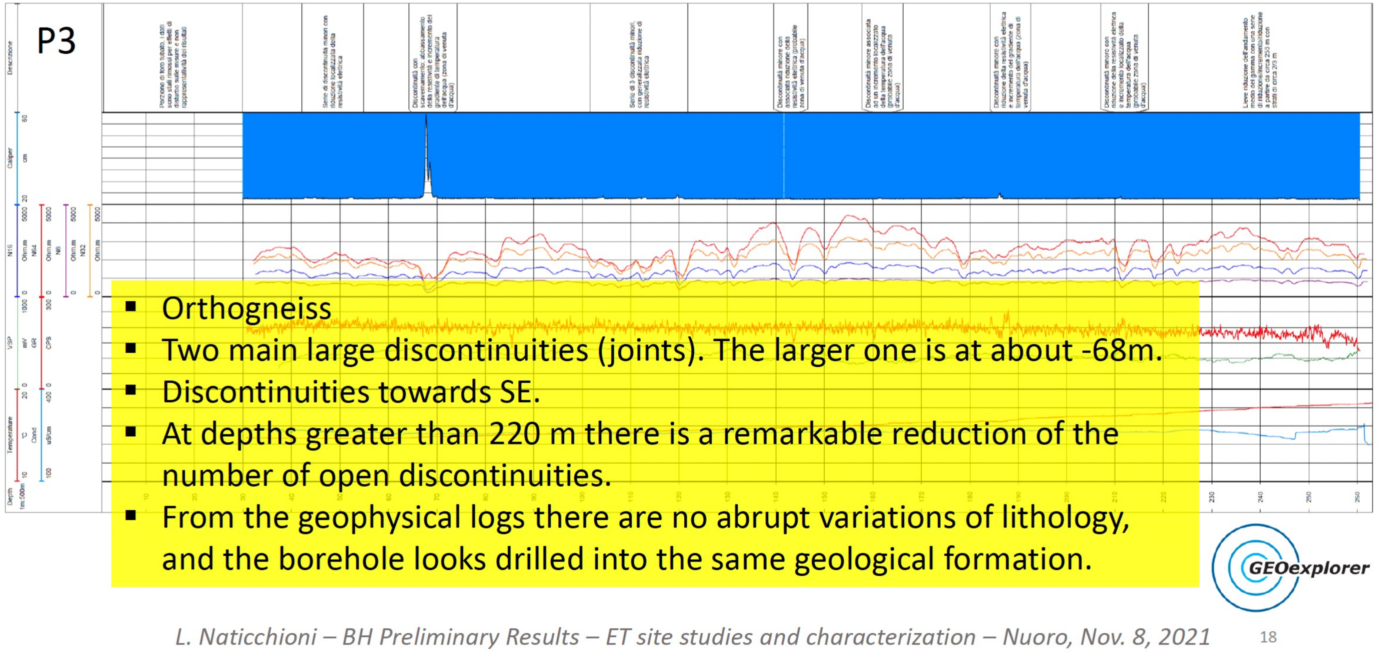
Orthogneiss
"Lodè type"
UCS: 92.6 / 60.8 Mpa

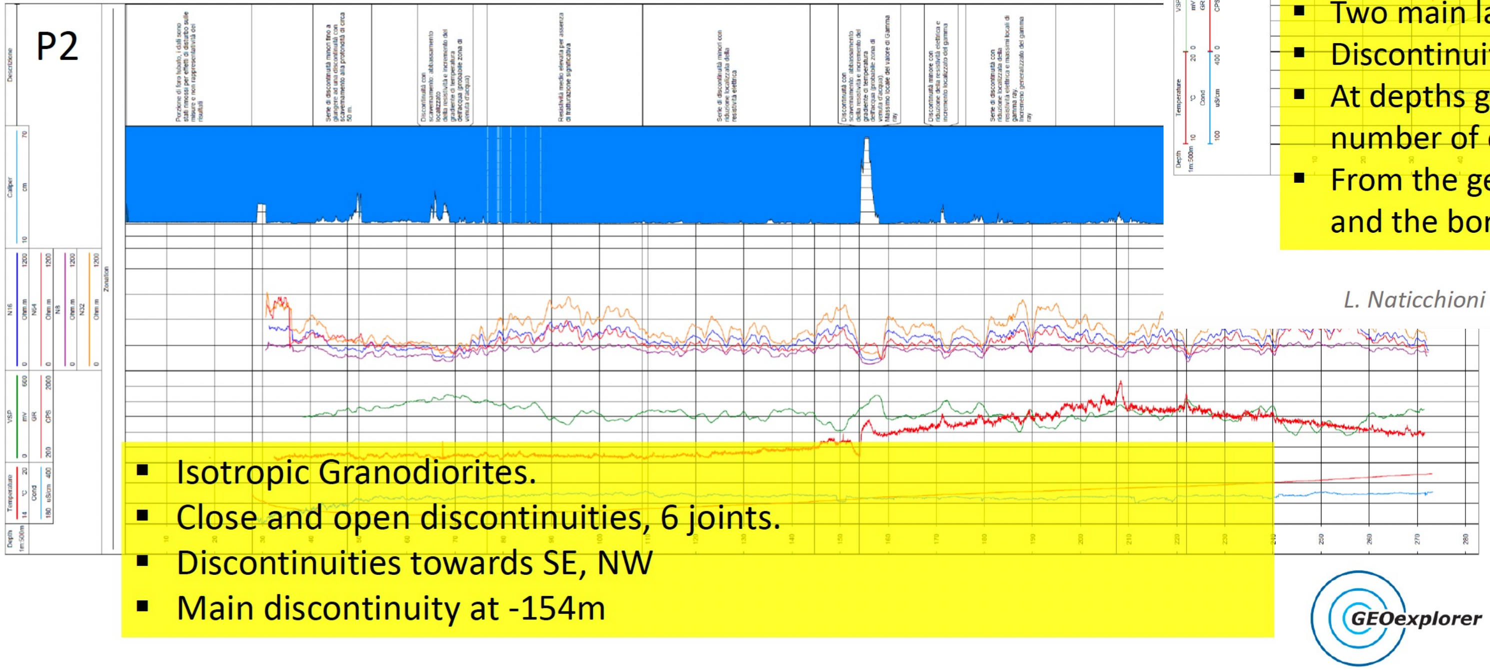
Micaschist/
paragneiss/quartzite
UCS: 9.9/8.8 Mpa

Granodiorite
"Bitti type"
UCS: 72.1 Mpa



Borehole logs



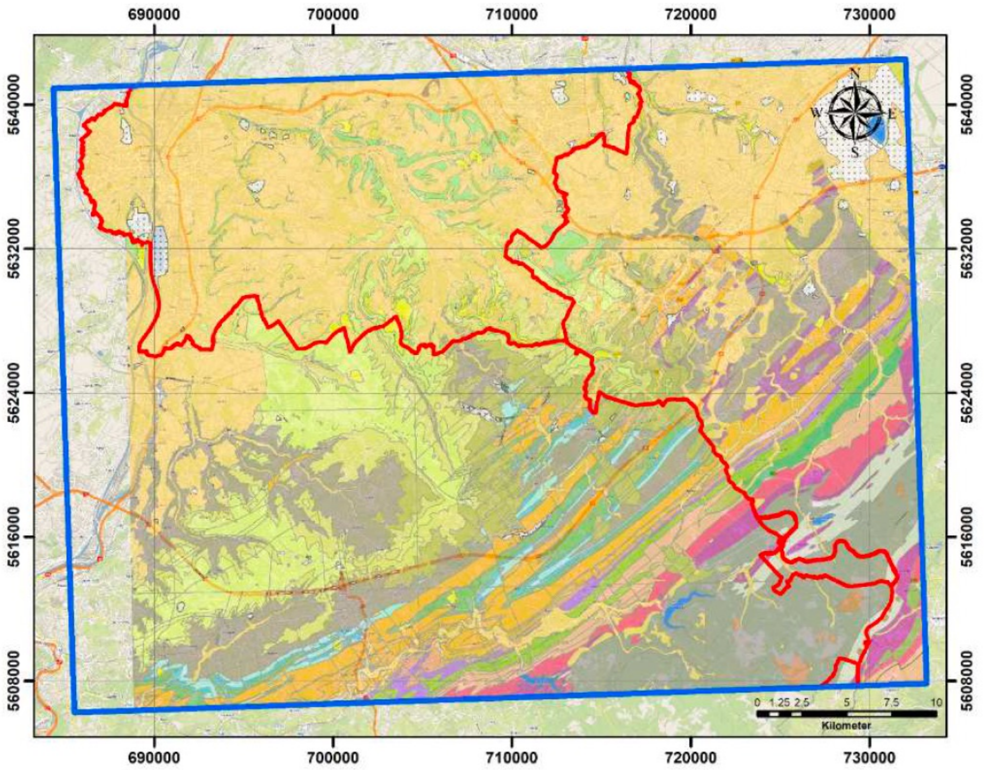


Euregio-Meuse-Rhine (EMR) site

Rocks in the EMR Region

- Rocks of Paleozoic age
  - Carboniferous (361-300 Mio. years)
  - Upper Devonian (383-361 Mio. years)
- Rocks of Upper Cretaceous age
  - 85-66 Mio. years
- Distribution of rocks varies throughout EMR region

- General information from literature and outcrop studies
- Local subsurface information from drill cores



E-TEST Einstein Telescope EMR Site & Technology

Interreg Euregio Meuse-Rhine European Regional Development Fund EUROPEAN UNION

3

Complex geology

Geological Assessment of Representative Rocks within ET-Project

MASTER THESIS

The present work was submitted to the Department of Engineering Geology and Hydrogeology

EINSTEIN TELESCOPE – ENGINEERING GEOLOGICAL ASSESSMENT OF VISÉAN, NAMURIAN AND WESTPHALIAN FORMATIONS THROUGH IN-SITU SITE INVESTIGATIONS, REMOTE SENSING AND LABORATORY TESTING

presented by

Raphael Borchartz

303032

Prof. Dr. Florian Amann (principal supervisor and first examiner)

Dr. Pooya Hamdi (co-supervisor and second examiner)

26 March 2021

MASTER THESIS

The present work was submitted to the Department of Engineering Geology and Hydrogeology

Einstein Telescope – Engineering geological assessment of Frasnian, Famennian and Tournaisian formations through in-situ site investigations, remote sensing and laboratory testing

presented by

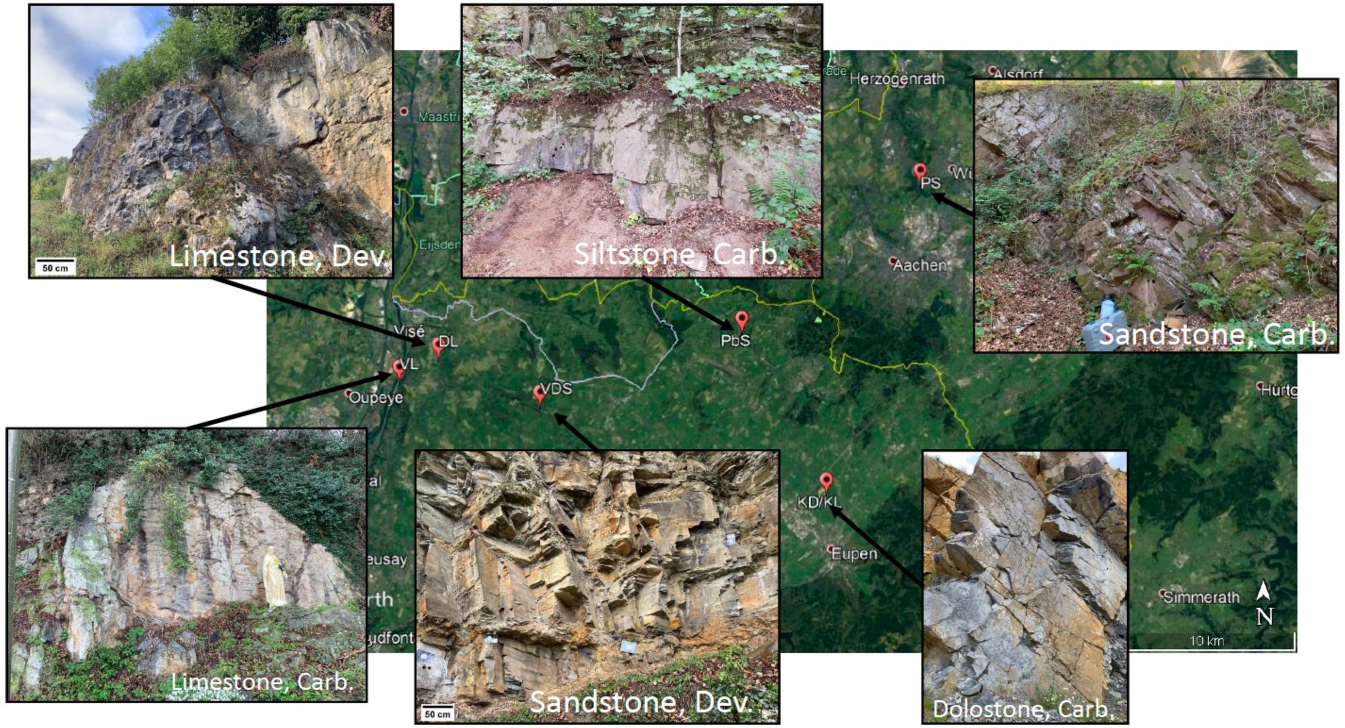
Alexander Polisk

393866

Prof. Dr. Florian Amann (principal supervisor and first examiner)

Dr. Pooya Hamdi (co-supervisor and second examiner)

29 March 2021



E-TEST Einstein Telescope EMR Site & Technology

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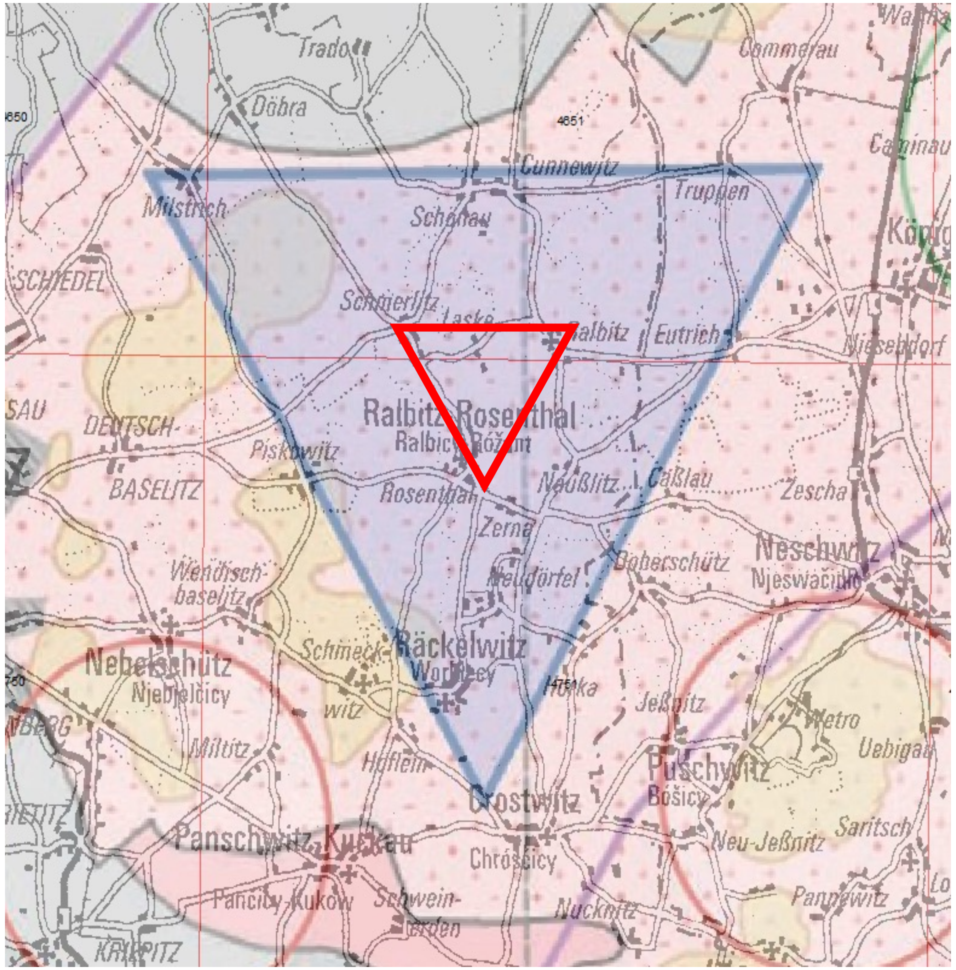
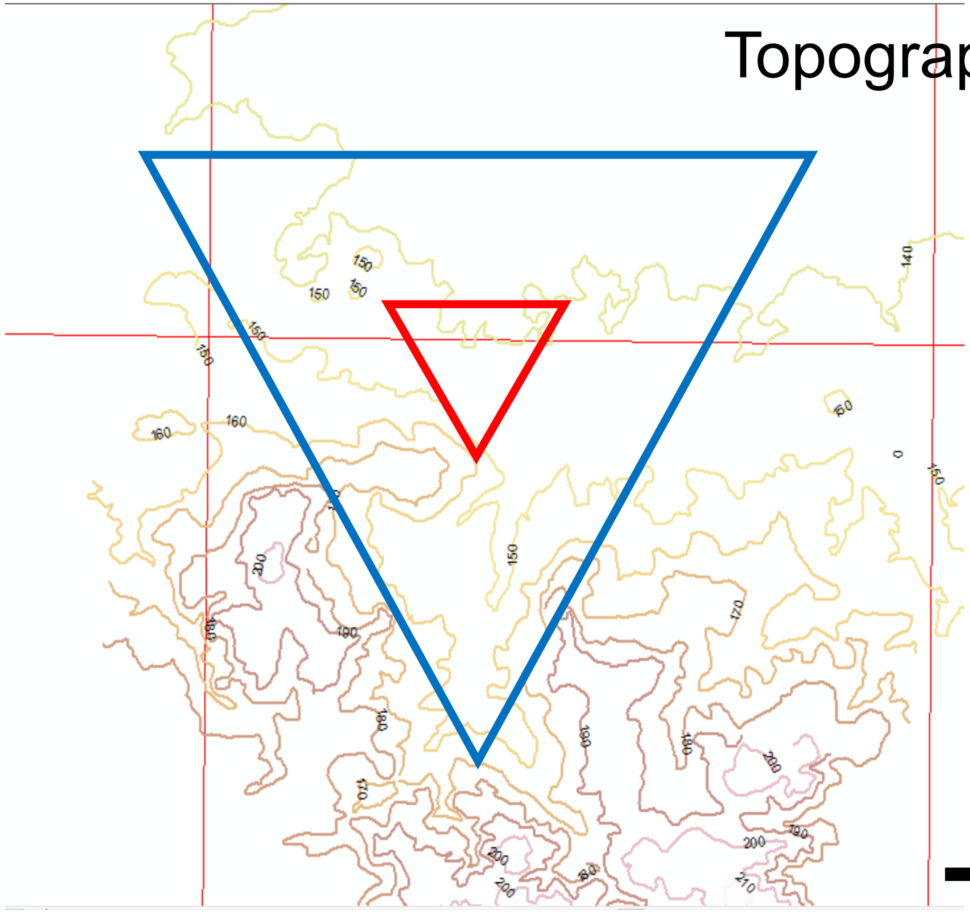
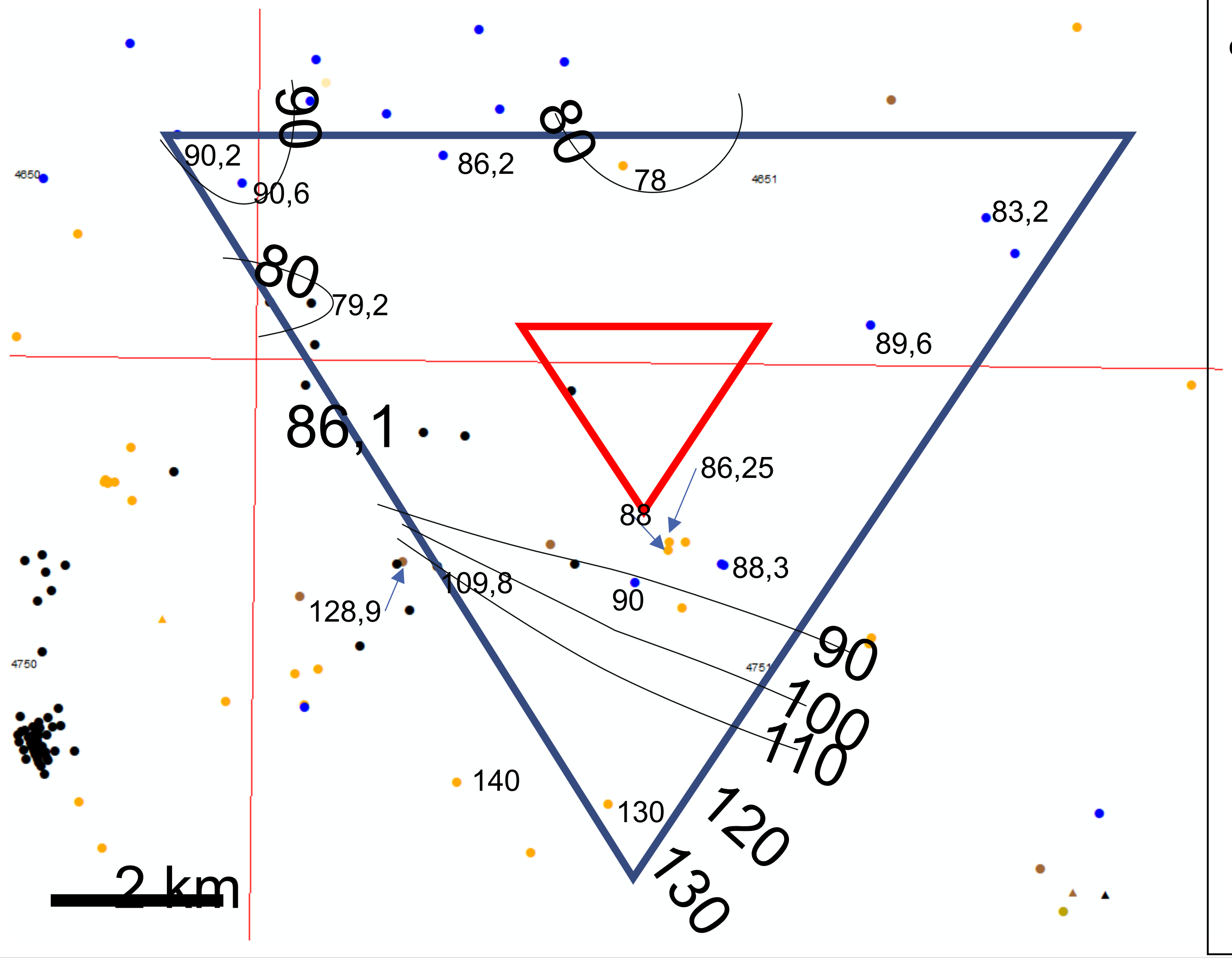
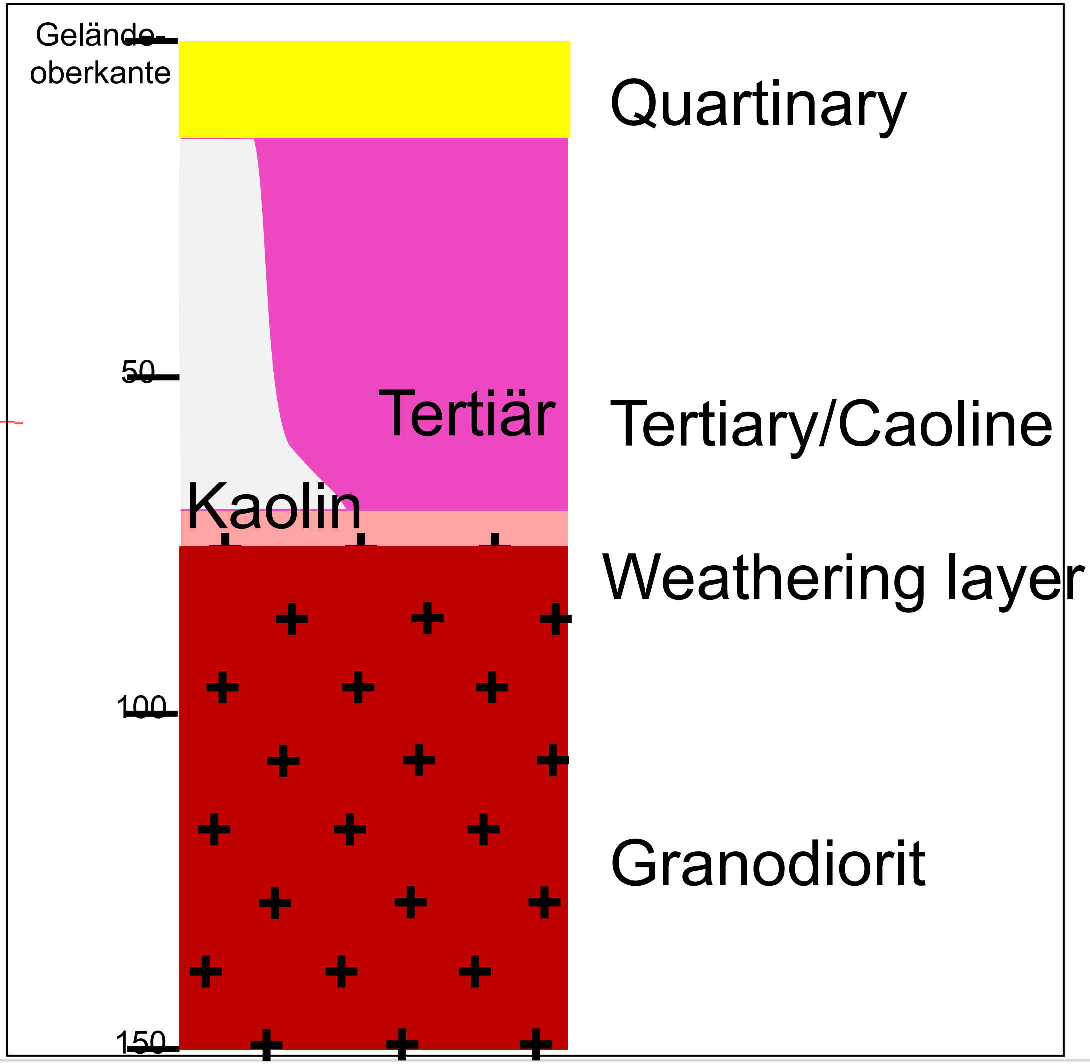
Lausitz ET site





Geological profile





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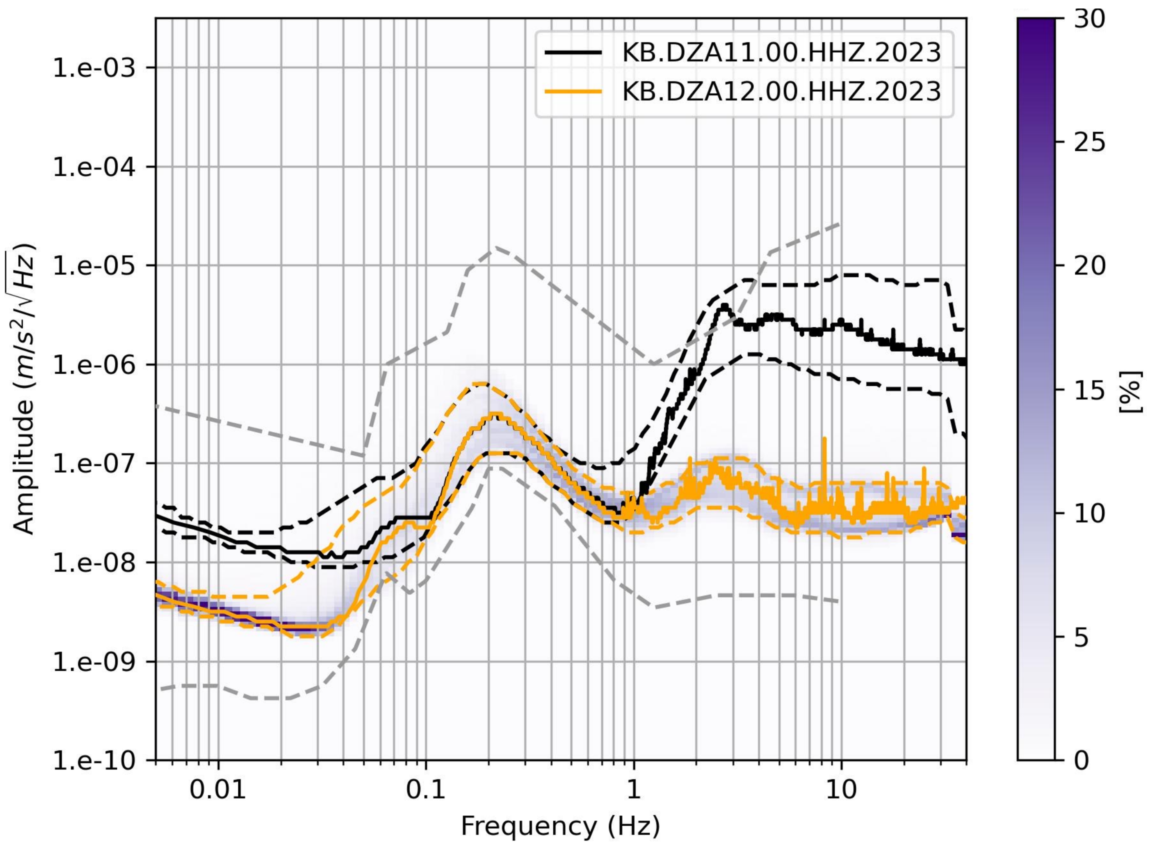
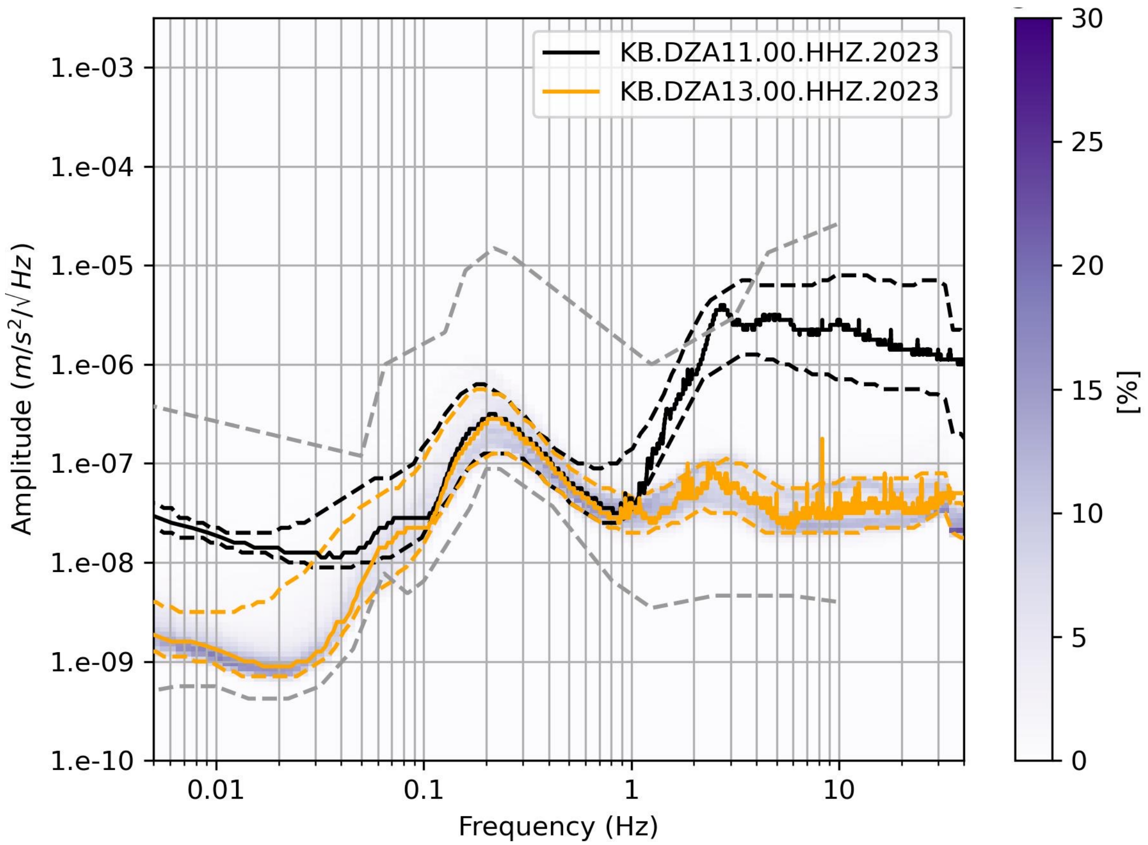
Lausitz – Comparison surface to borehole

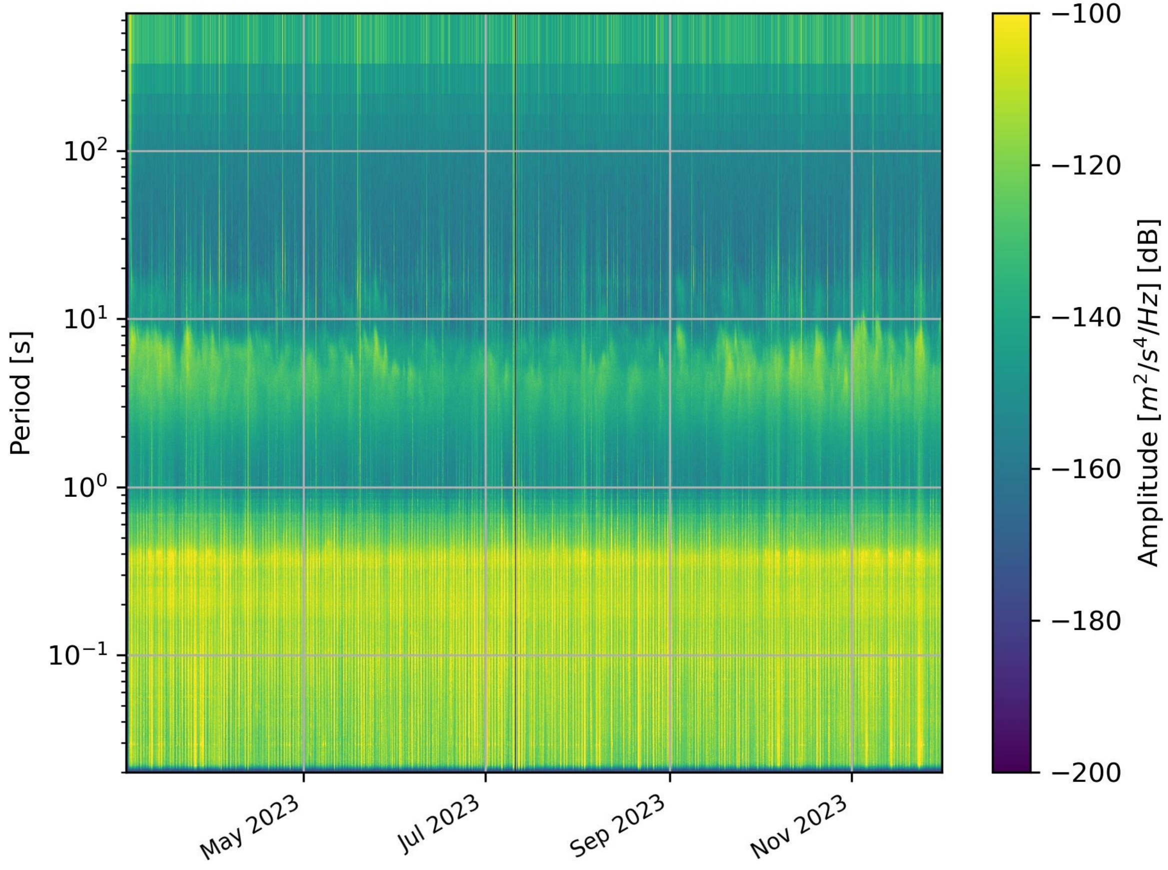
Spring 23 to Nov. 23; borehole with lower amplitudes (100), clear day/night cycle



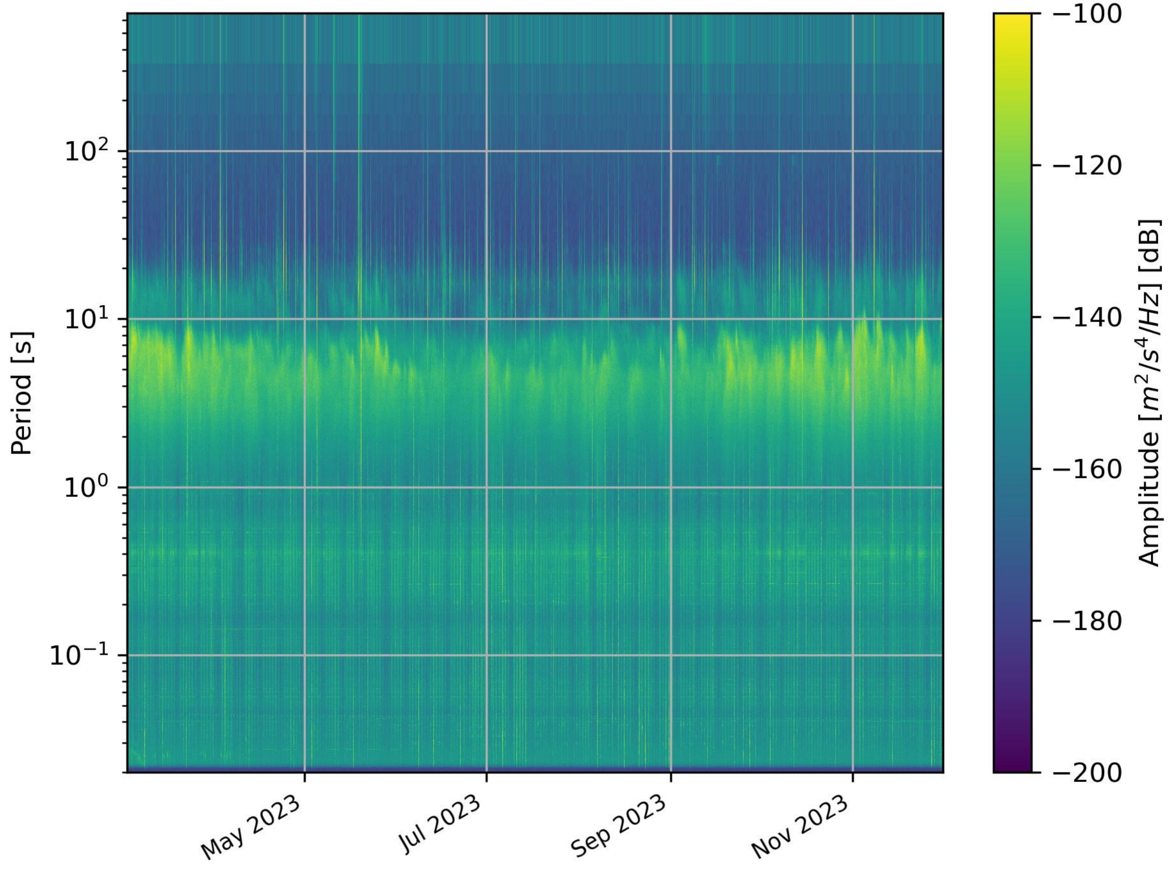


Lausitz – Comparison surface to borehole

DZA11 - surface



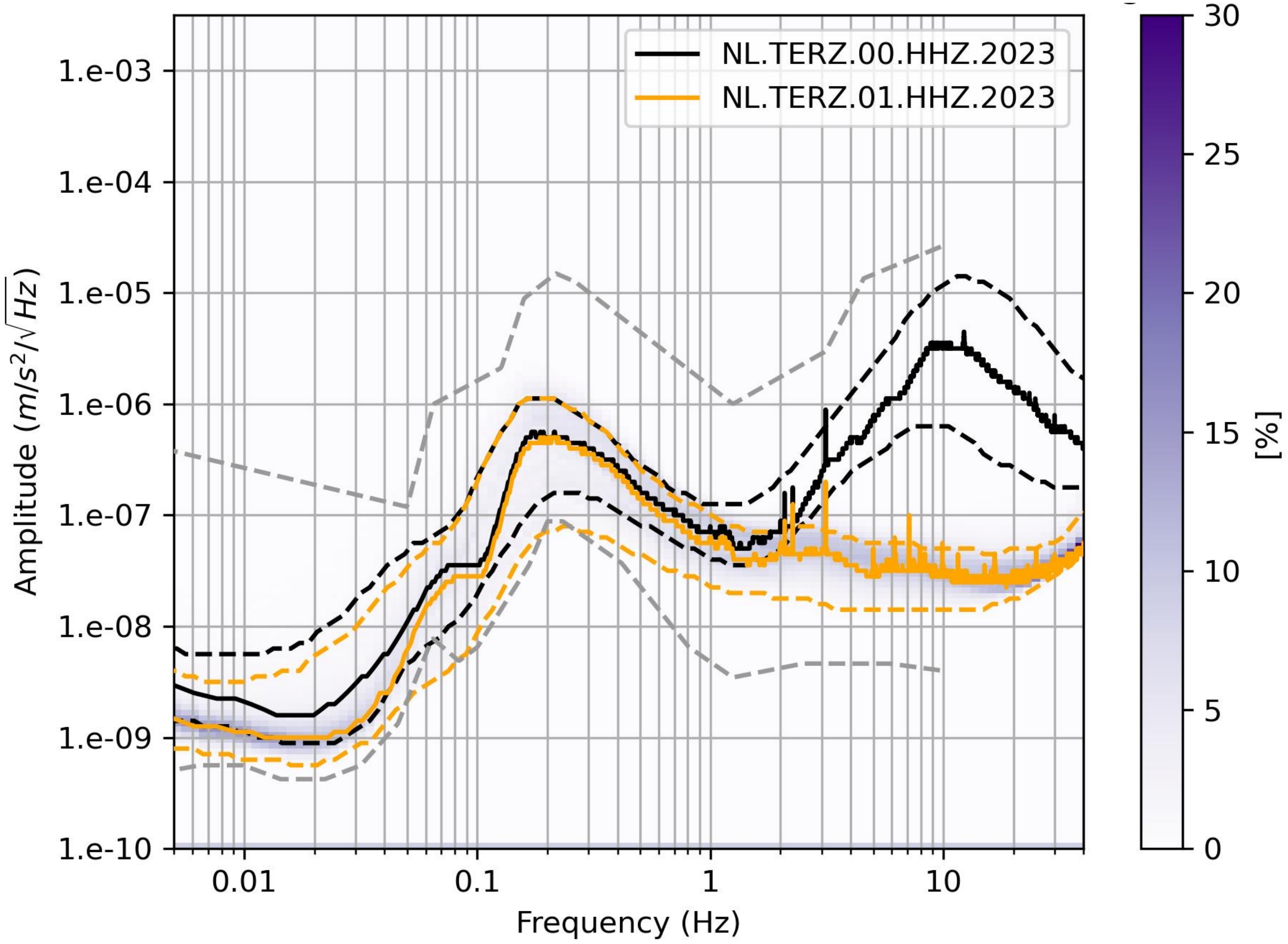
DZA12 - borehole



EMR - Comparison surface to borehole

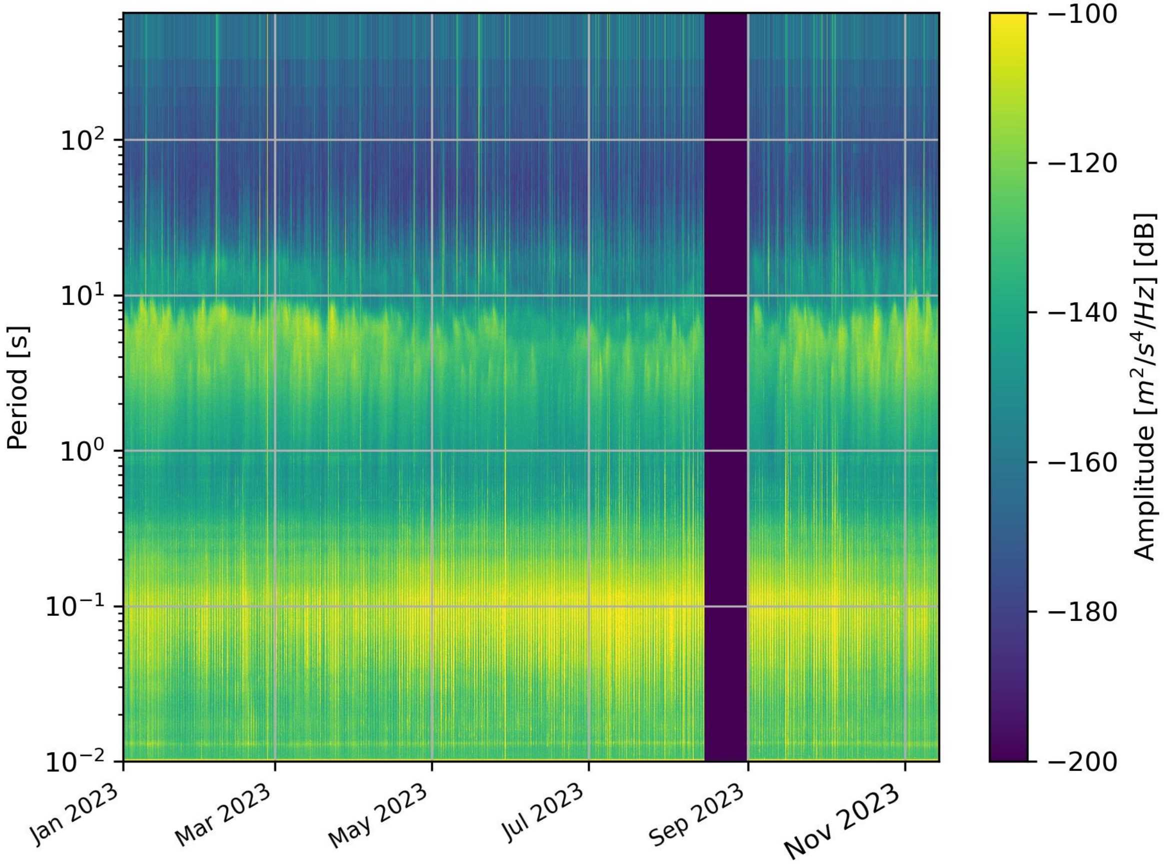
Borehole and surface data for the whole year 2023

Borehole station with lower amplitudes (100 at 10Hz), especially for frequencies higher 2 Hz

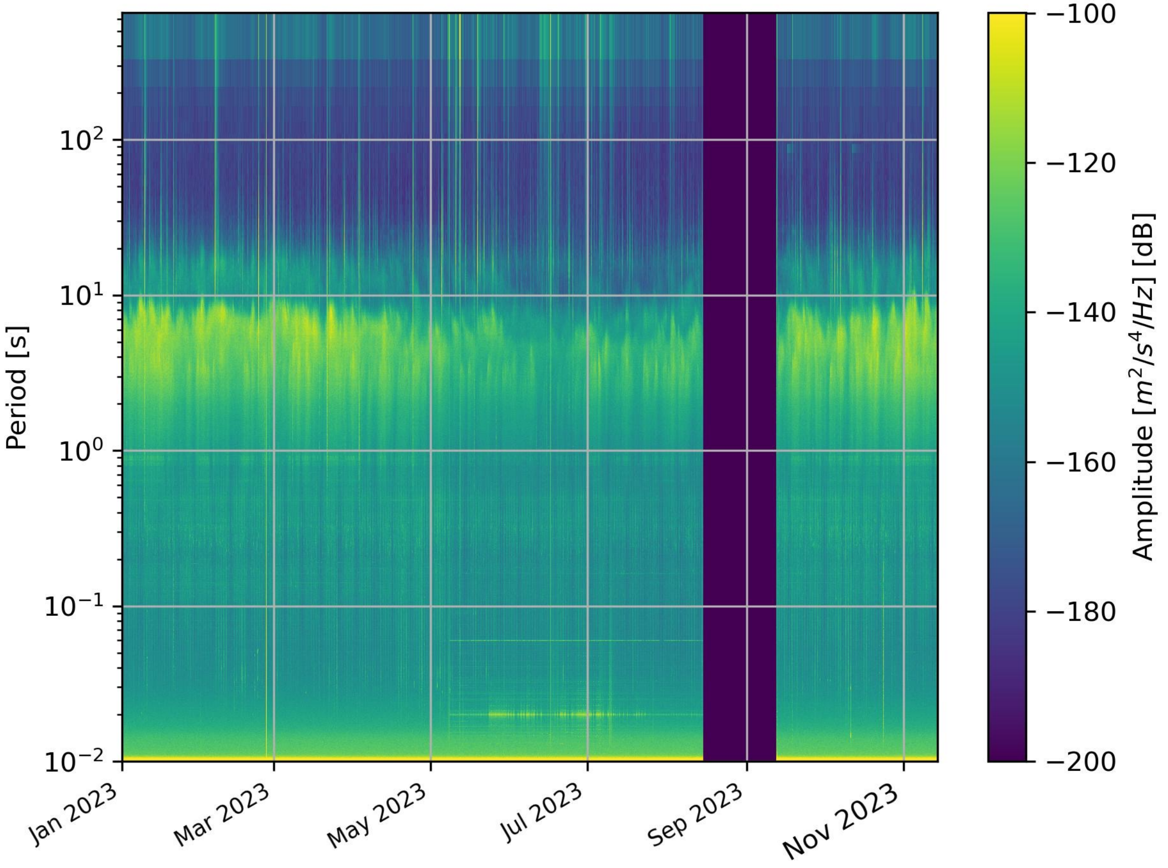


EMR - Comparison surface to borehole

TERZ - surface

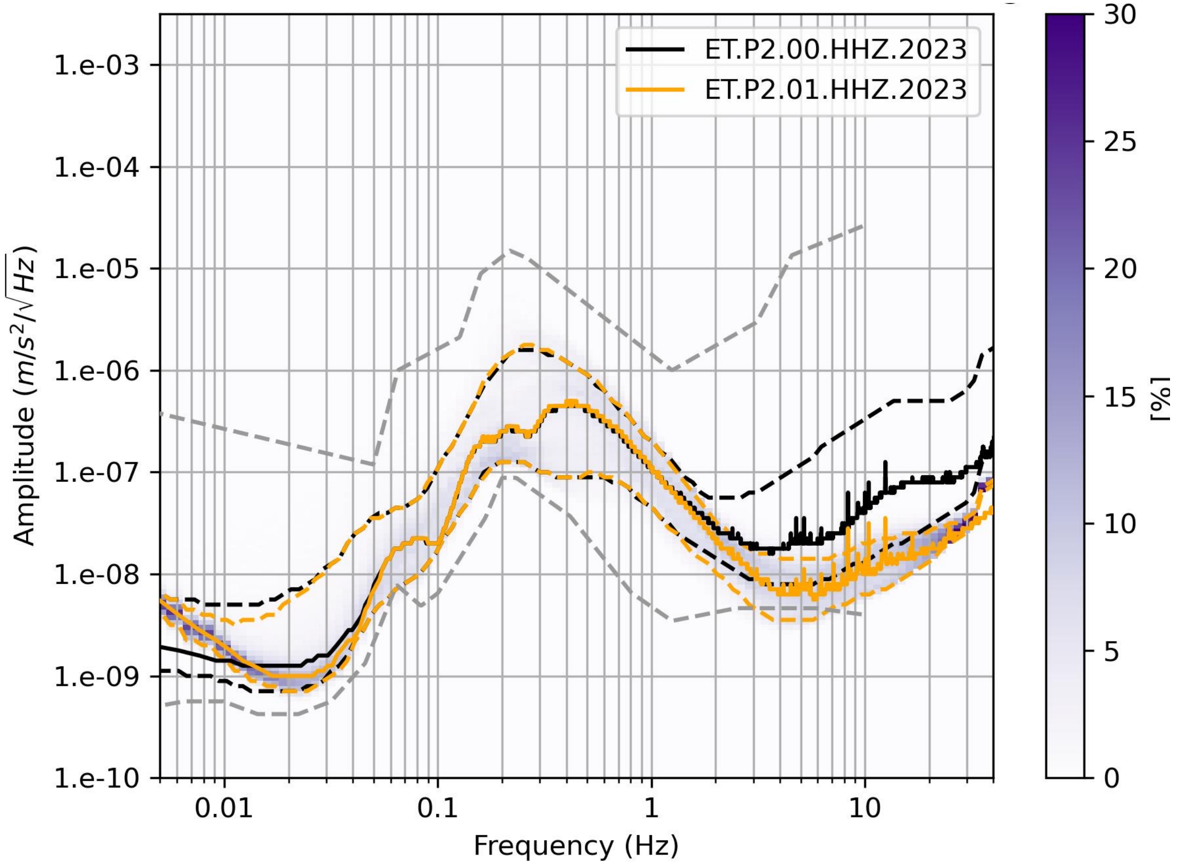


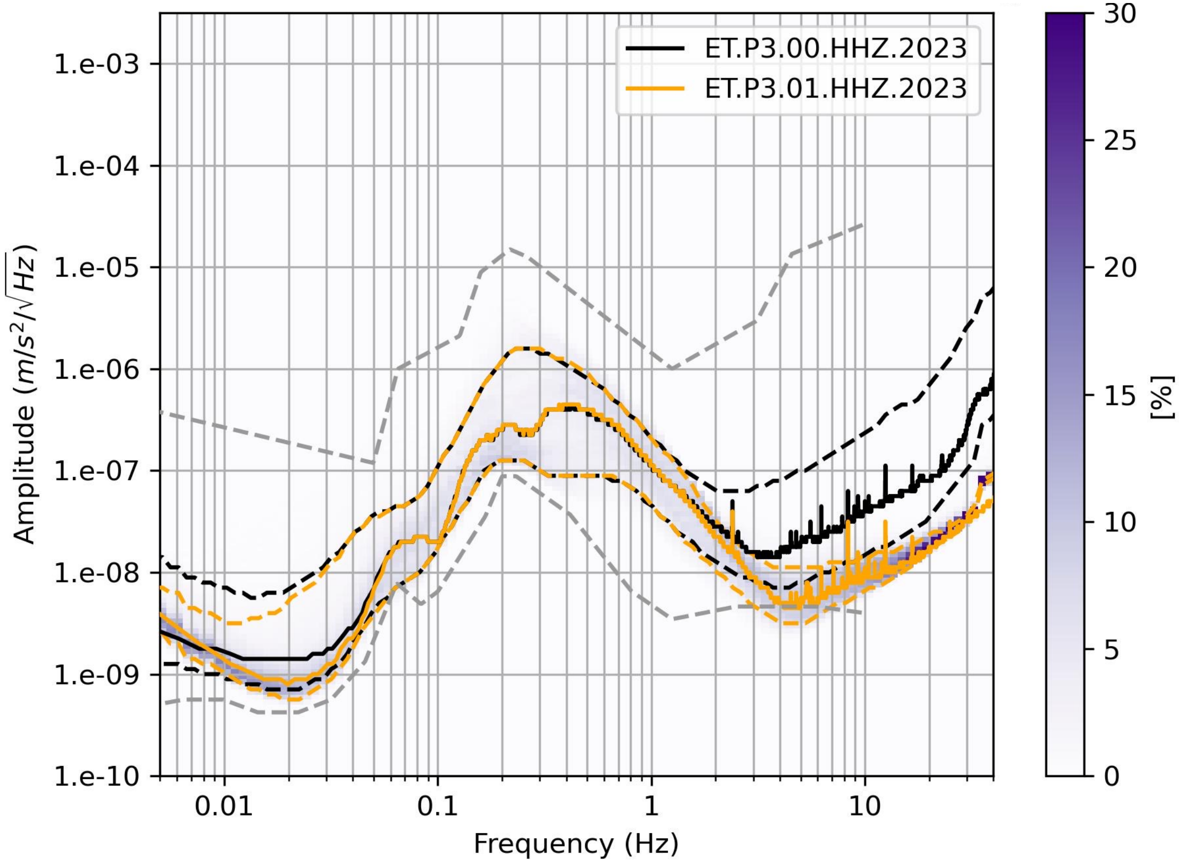
TERZ - borehole



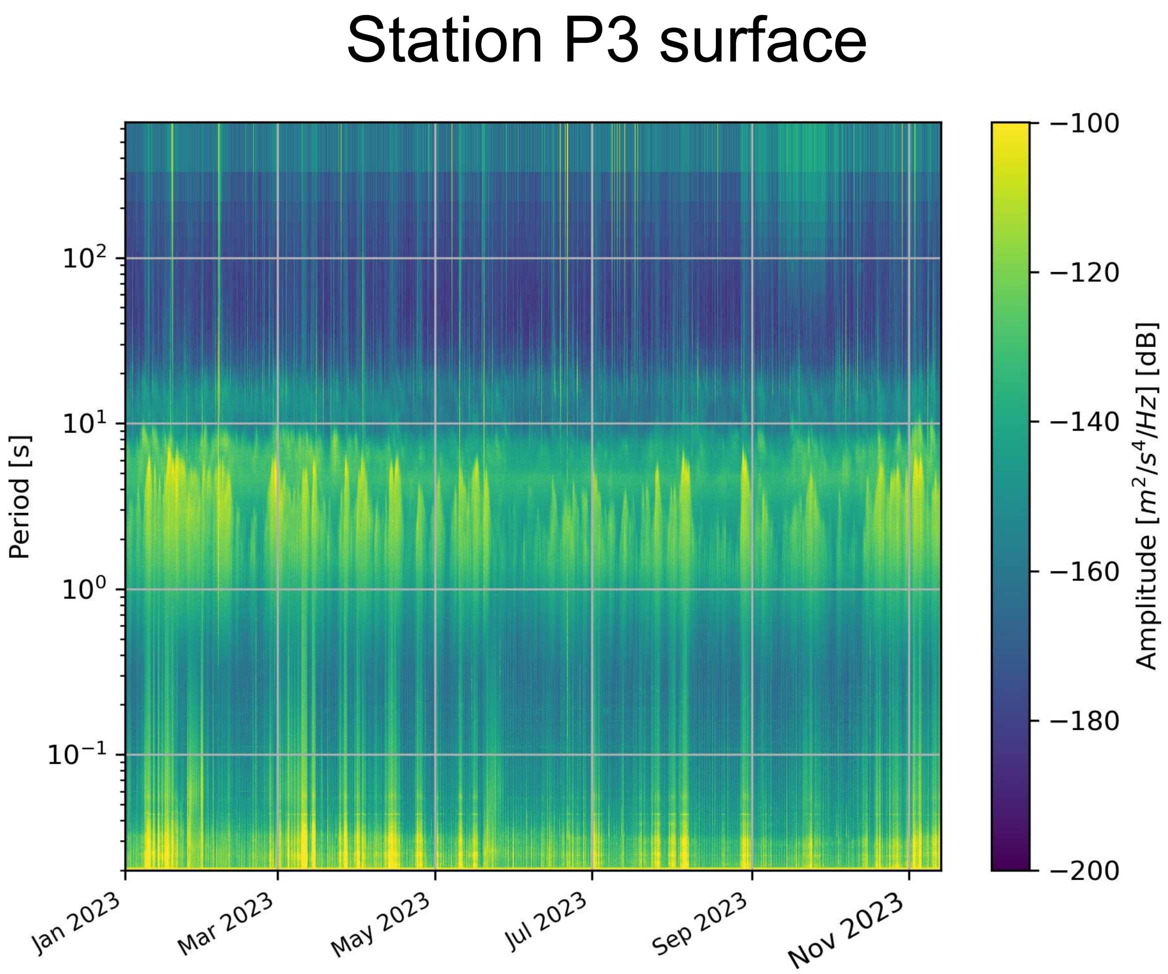
Sardinia – Comparison surface to borehole

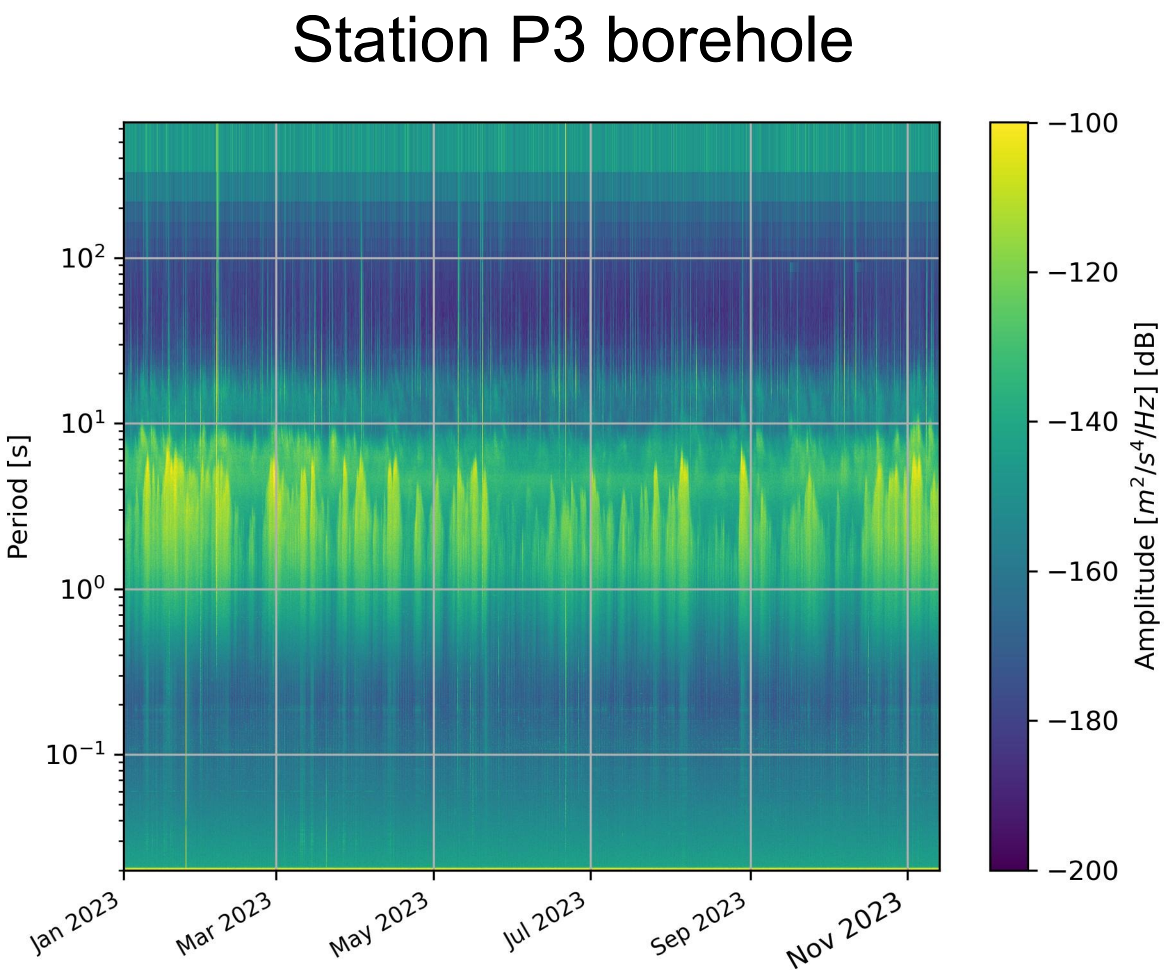
Whole year of 2023; lower amplitudes (10) borehole; lower range influenced by instrumentation





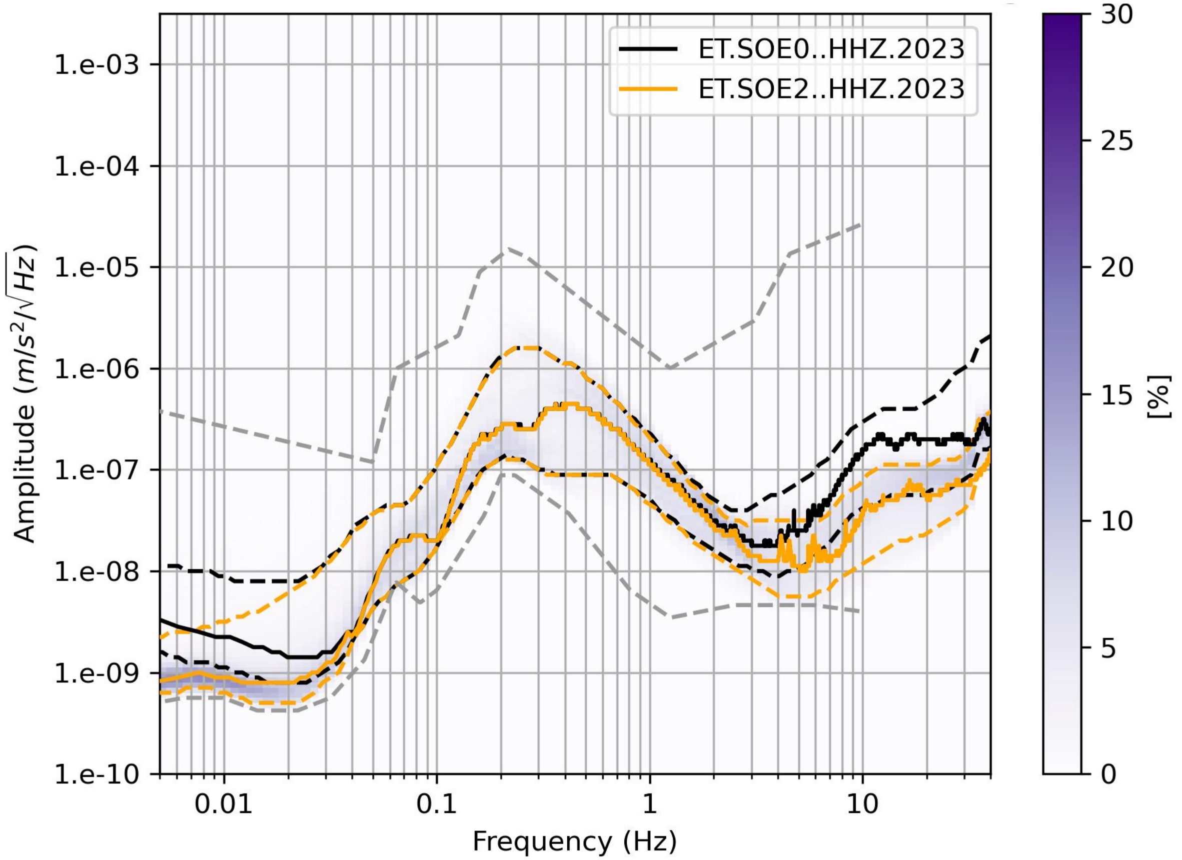
Sardinia – Comparison surface to borehole



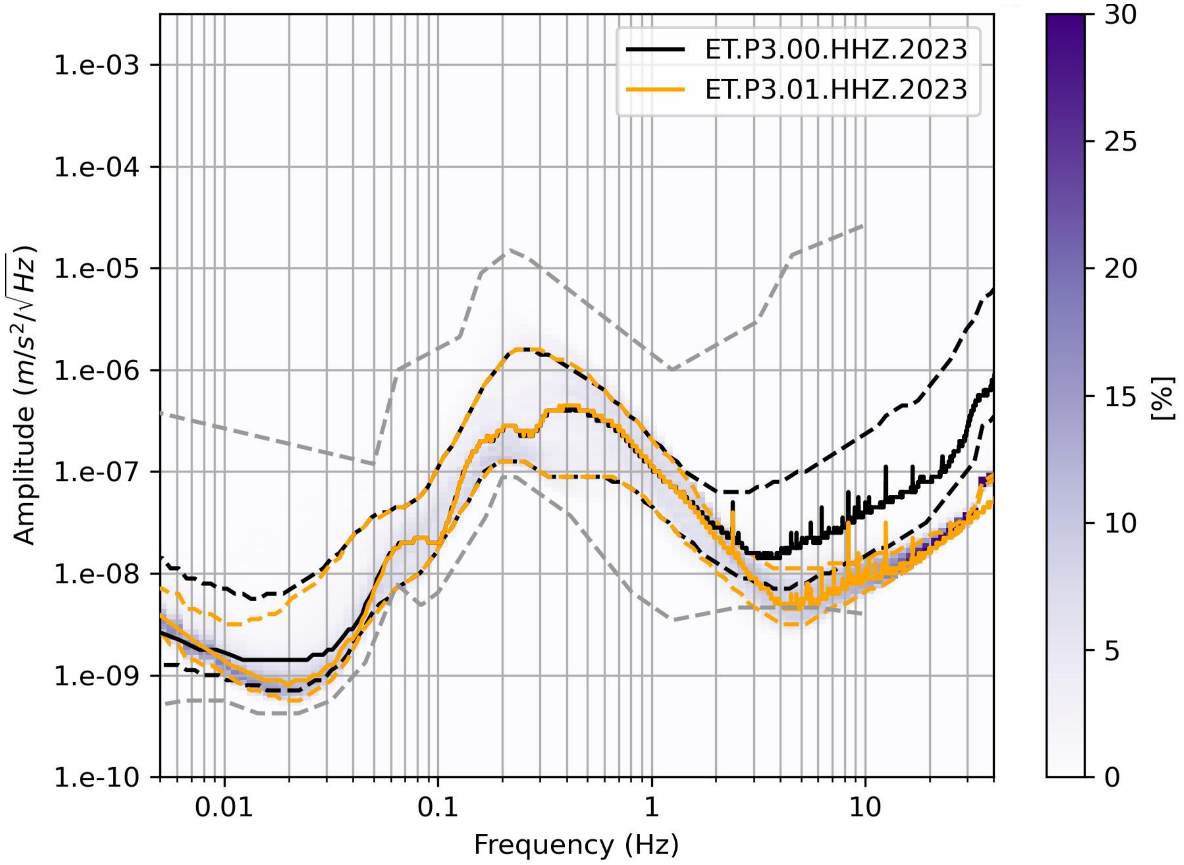


Sardinia – Comparison Sos Enattos Mine to P3

Sos Enattos Mine



Station P3



Comparison surface stations 2023

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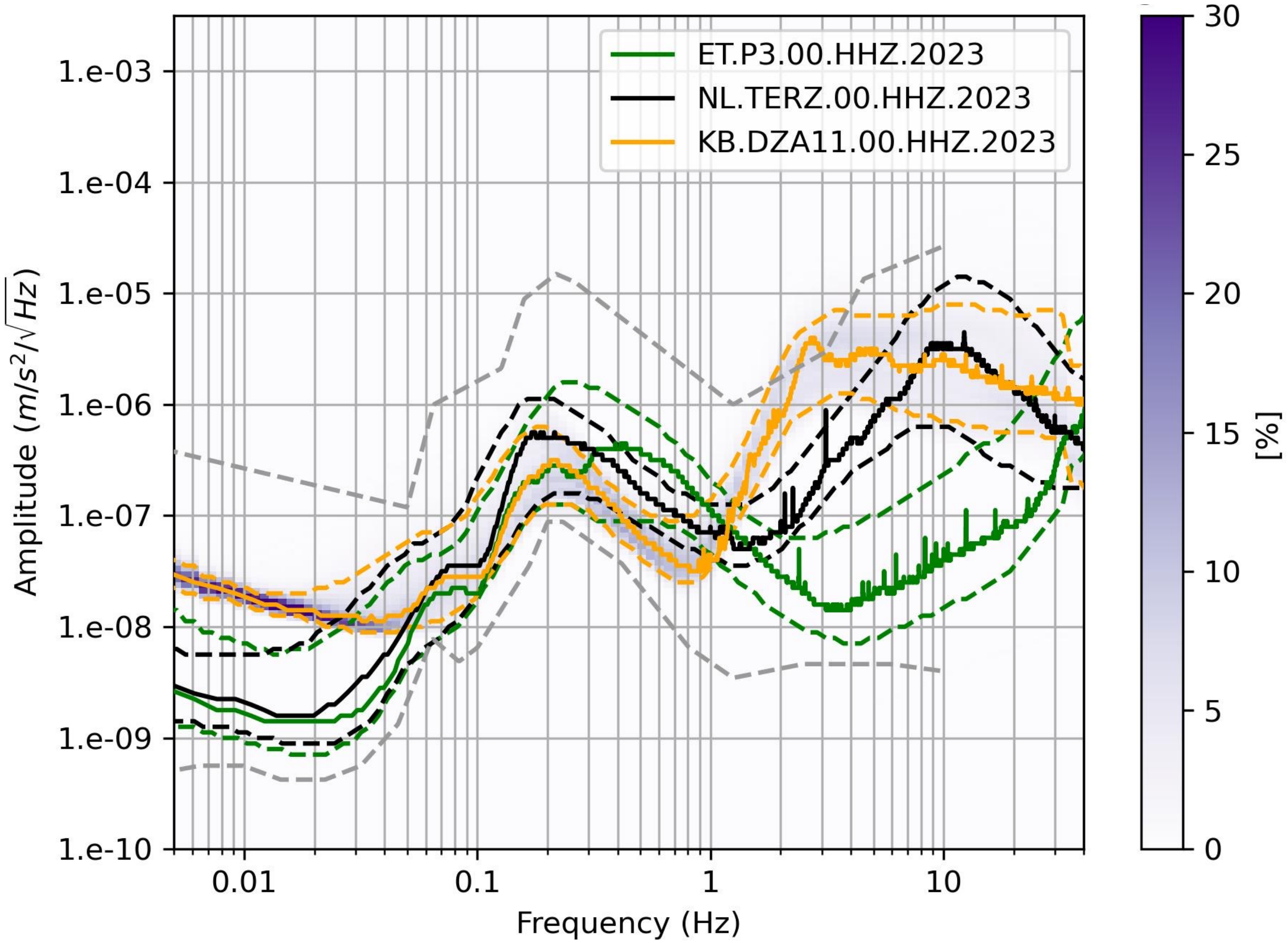
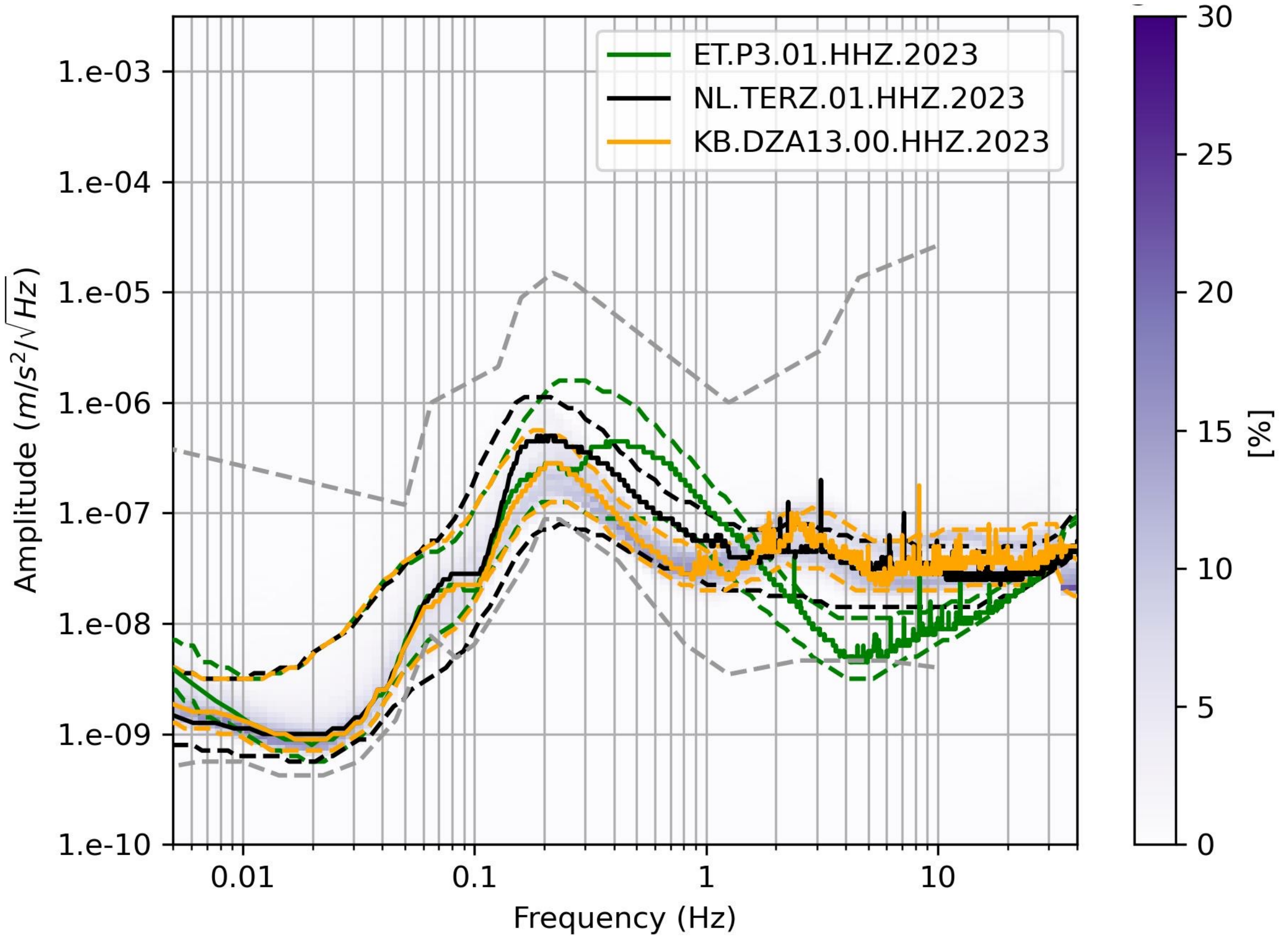
- Lower amplitudes at Sardinia P3 for frequencies higher than 2Hz,
- but higher noise levels between 0.3 Hz and 1Hz in comparison to EMR and Lausitz



Comparison borehole stations 2023

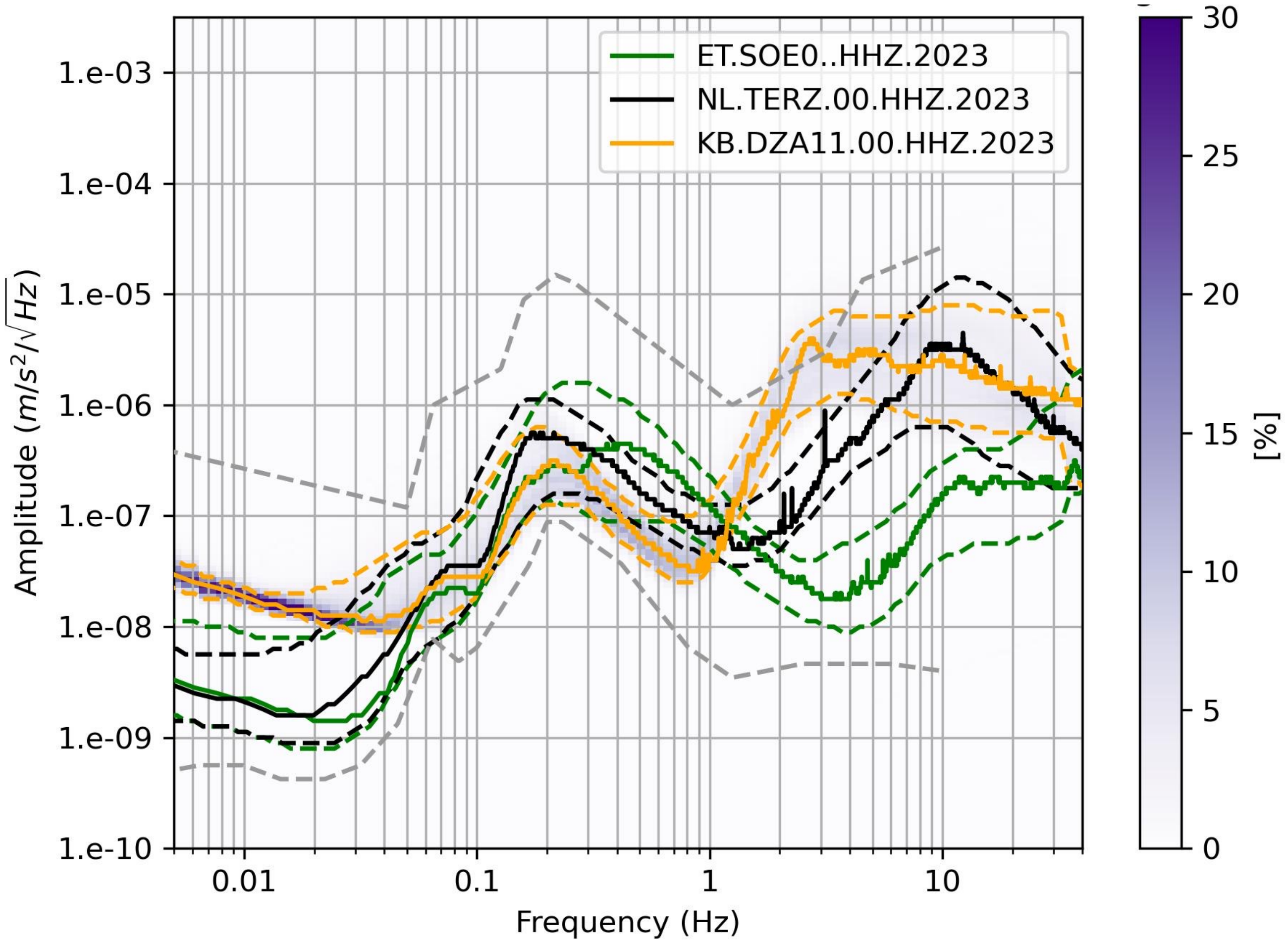
- Sardinia P3 up to a factor of10 below Euregio and Lausitz around 4 Hz
- Euregio TERZ and Sardinia P3 higher values than Lausitz DZA13 from 0.15Hz to 2 Hz
- Sardinia P3 rise of amplitude for frequencies higher 4 Hz due to instrumental noise



Comparison surface stations with mine 2023

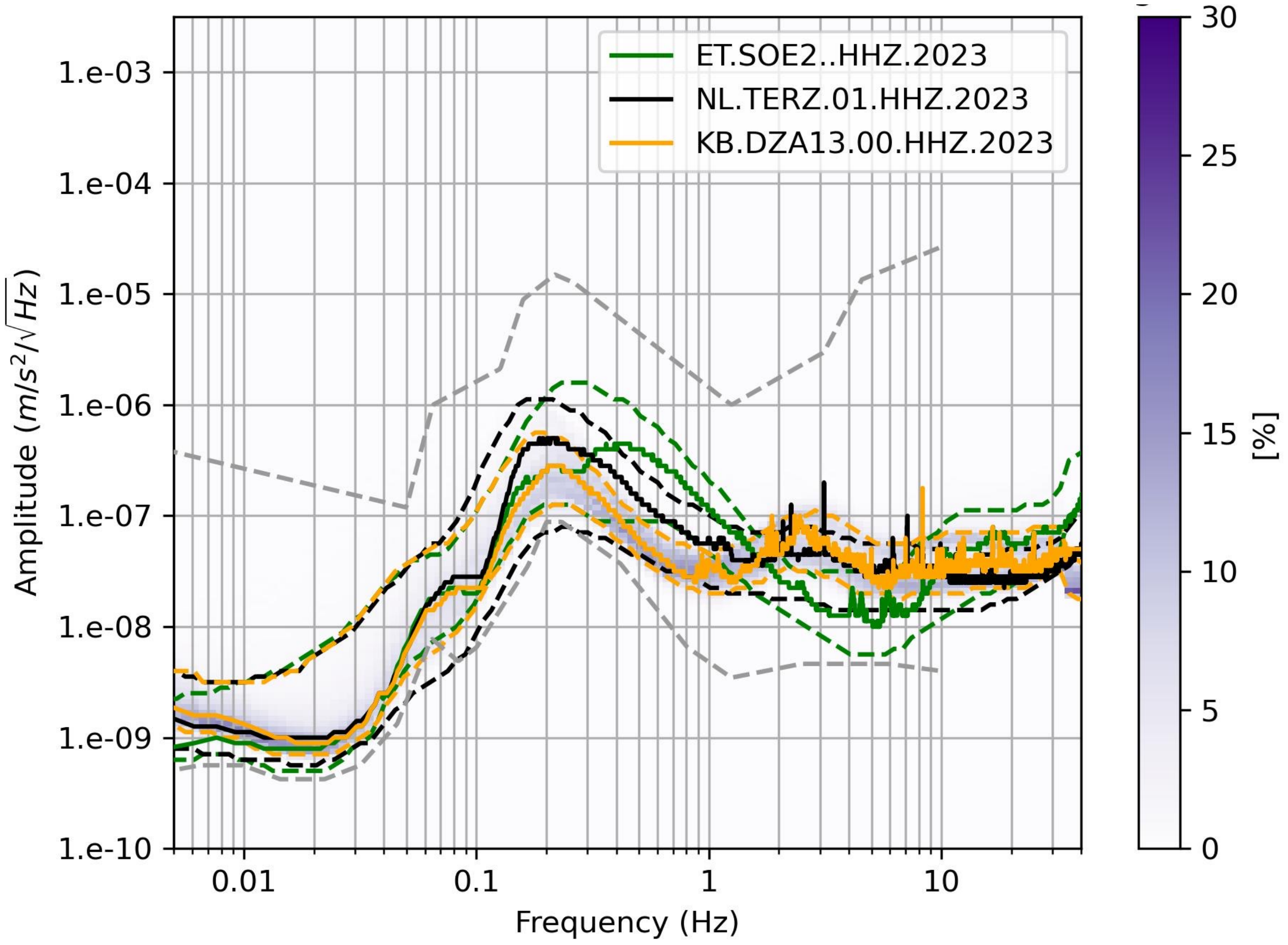
- Clear reduction of amplitudes for Sardinia Sos Enattos SOE0 for frequencies higher than 2 Hz,

- but higher noise levels between 0.3 Hz and 1 Hz



Comparison borehole stations with mine 2023

- Euregio TERZ and Sardinia SOE2 higher values than Lausitz DZA13 from 0.15 Hz to 2 Hz
- Sardinia SOE2 up to a factor below Euregio and Lausitz around 4 Hz
- Sardinia SOE2 rise of amplitude for frequencies higher 4 Hz due to instrumental noise



Conclusions/Outlook

- All candidate sites reach a noise level below 1e-7 $m/s^2/\sqrt{Hz}$ on average
- There are distinct frequency peaks in the PSD reaching higher values
- Sardinia shows the lowest noise values between 2-14Hz and shows a significant increase at lower frequencies
- EMR and Lausitz show a clear dependence on cultural noise (day-night, weekdays-weekends)
- At the underground laboratory at Sos Enattos the seismic noise level is increased but still below EMR and Lausitz
- There is a strong need for full characterisation of the incoming noise wave field for an evaluation of the sensitivity on the ET teleskope