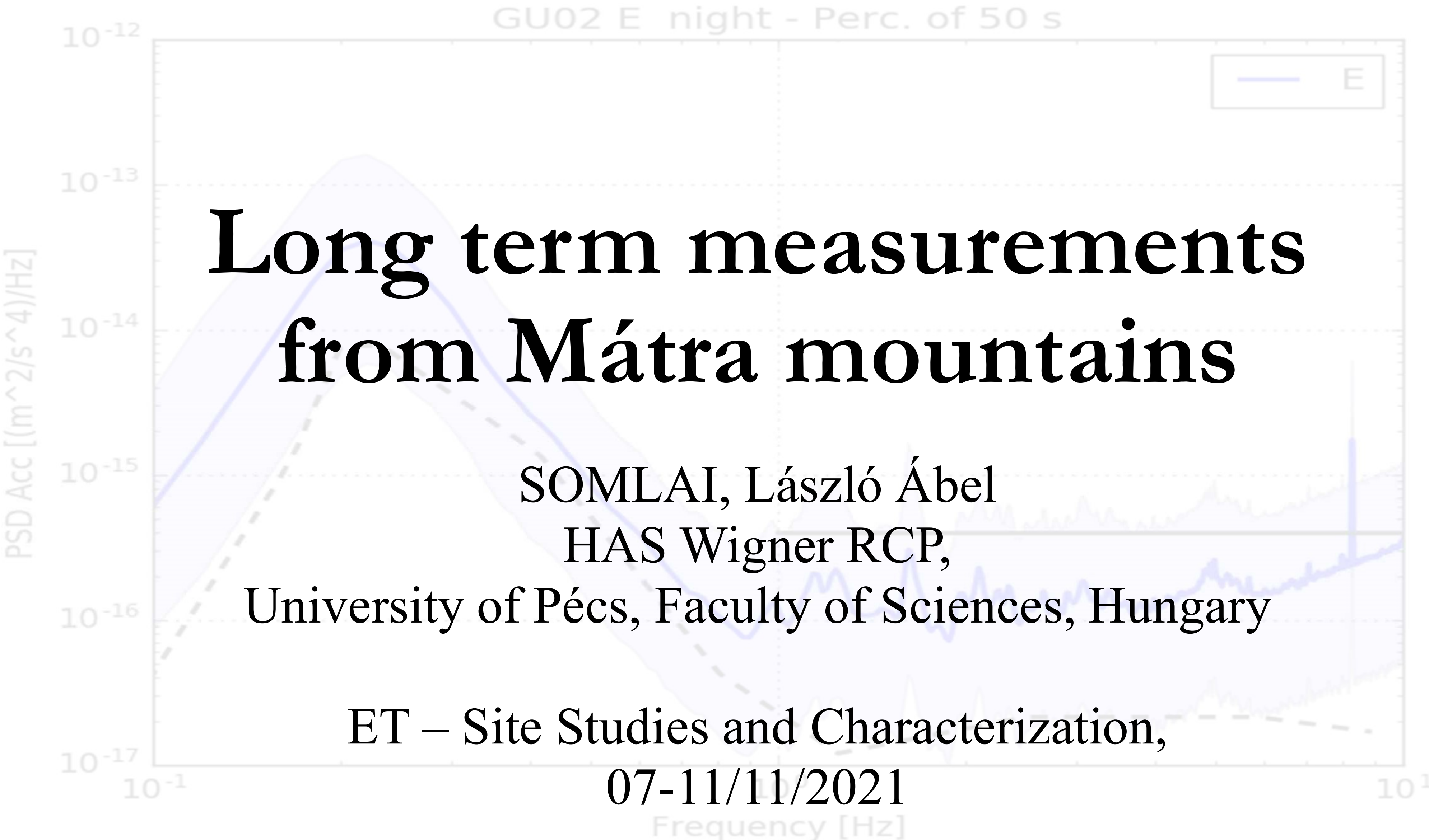

Long term measurements from Mátra mountains

SOMLAI, László Ábel
HAS Wigner RCP,
University of Pécs, Faculty of Sciences, Hungary

ET – Site Studies and Characterization,
07-11/11/2021

Outline

- Mátra mountains was a site candidate
- The European Physical Journal, Special Topics 228, 1693-1743 (2019)
- More than 2ys of seismic data was analysed
  - Suggesting use median instead of mode
  - Suggesting intrinsic averaging (INA)
  - Suggesting use both rms_2-10Hz and rms_1-10Hz
  - Use a selected baseline (e.g. Black Forest line) in the visualization to be more comparable
- Use short time averages (STA) as a smallest time window for seismic data
  - in our work 300sec
  - in Beker`s work 0.5 hour

Median instead of mode

- Mode is highly depends on the discretization
- ET1H is one of our seismogram (-88m), East direction

Let us consider the half-hour PSD-s calculated for one-week interval. Then we have about 350 samples. Then a PSD bin with 0.1dB, and 10dB difference between the 10th, 90th percentiles, we obtain 100 bins for calculating the mode. Therefore 4 values could define mode.

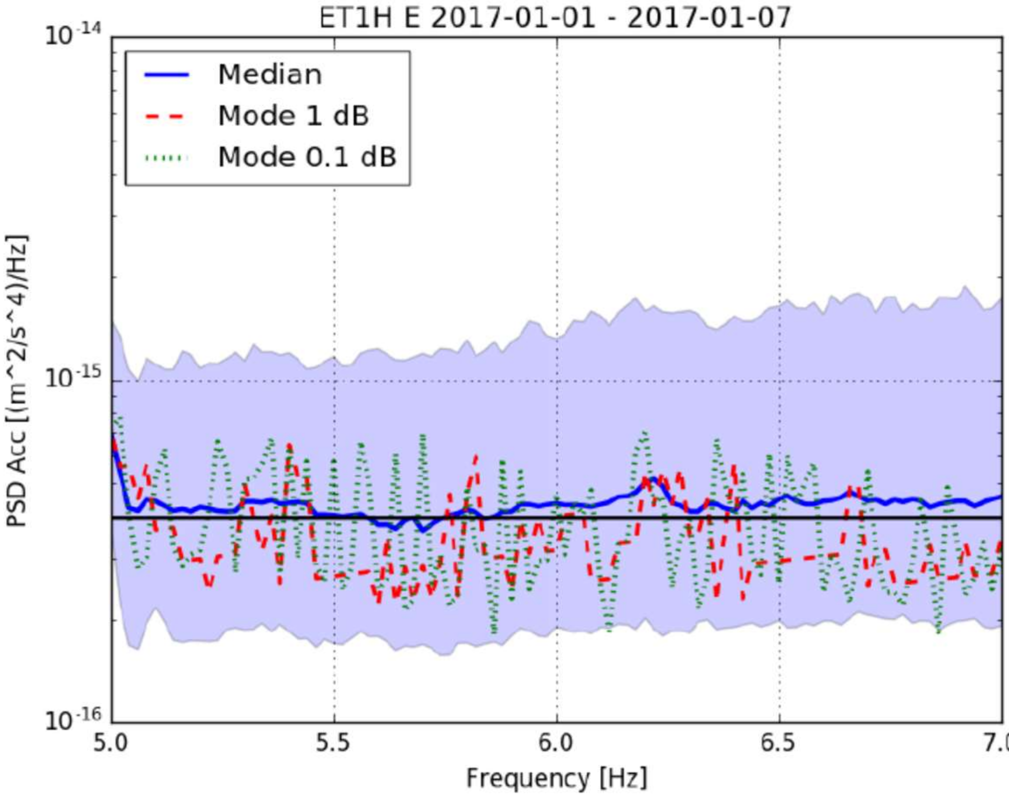

FIGURE 2. In this figure the median (solid blue line) and the modes (dashed and dotted lines) with $1\,dB$ and $0.1\,dB$ bins are compared. The solid black horizontal line represents the Black Forest line and the blue area indicates the 10th-90th percentiles.

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Median instead of mode

- Which STA we should use?
- Different short time averages can be computed for the same 1week
- Median is more stable

Upper figure displays the median with different short time averaging lengths. Lower figure shows the mode of the same data with the same different STA lengths. The Black Forest line is solid black. The data is from the first week of January in 2017.

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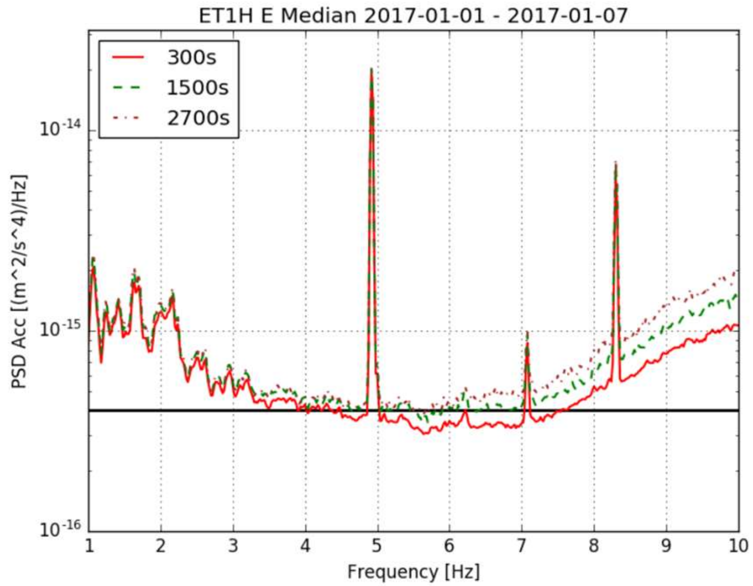
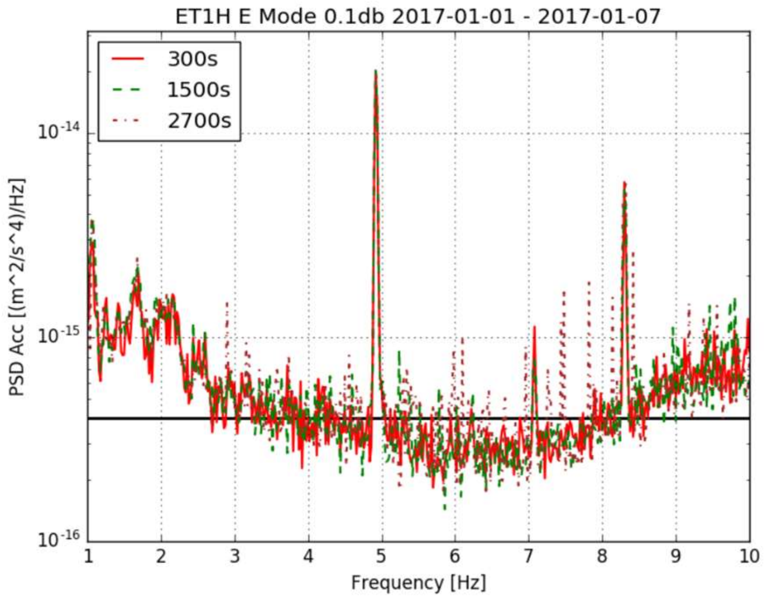
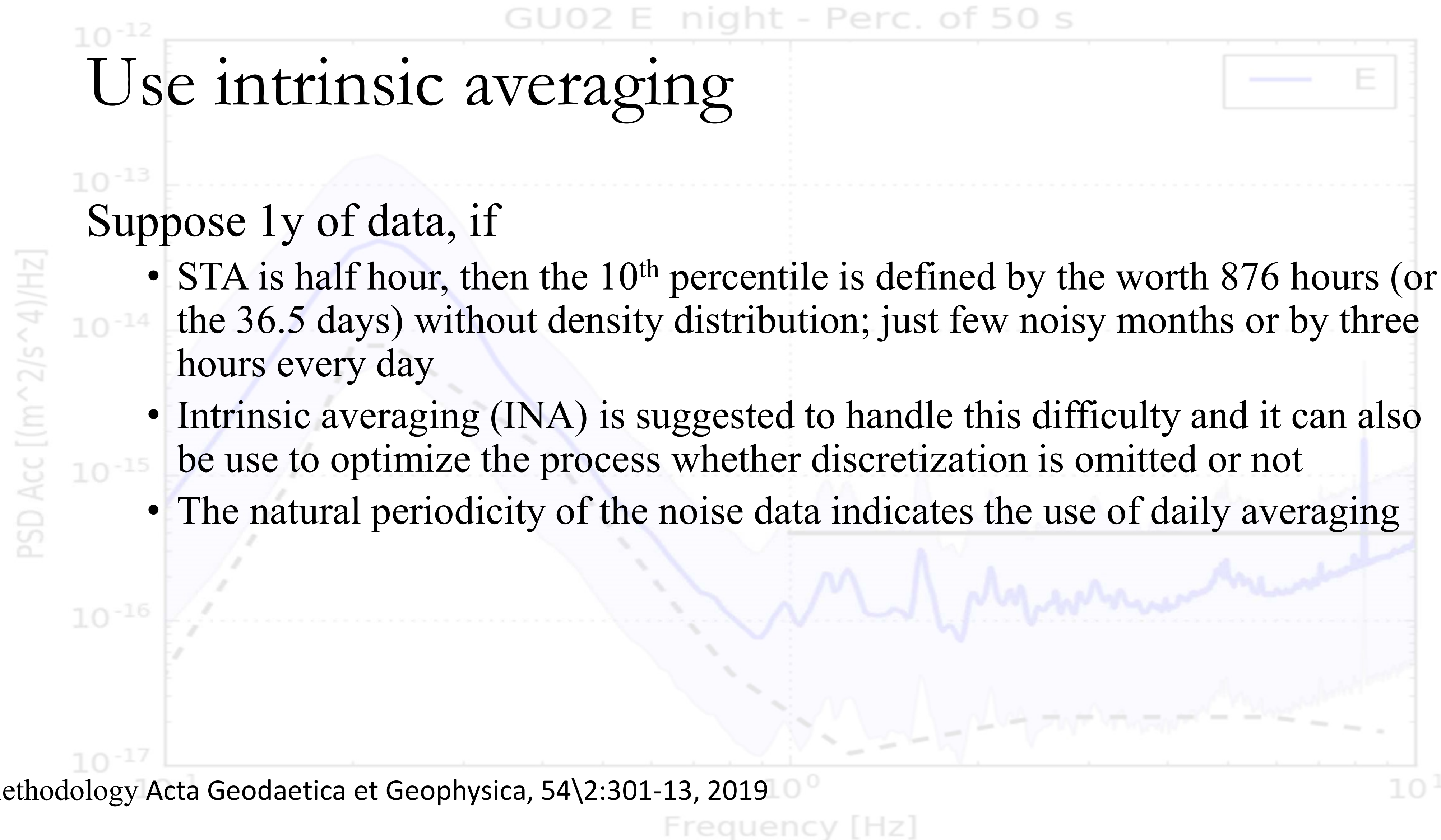




Use intrinsic averaging

Suppose 1y of data, if

- STA is half hour, then the 10th percentile is defined by the worth 876 hours (or the 36.5 days) without density distribution; just few noisy months or by three hours every day
- Intrinsic averaging (INA) is suggested to handle this difficulty and it can also be use to optimize the process whether discretization is omitted or not
- The natural periodicity of the noise data indicates the use of daily averaging



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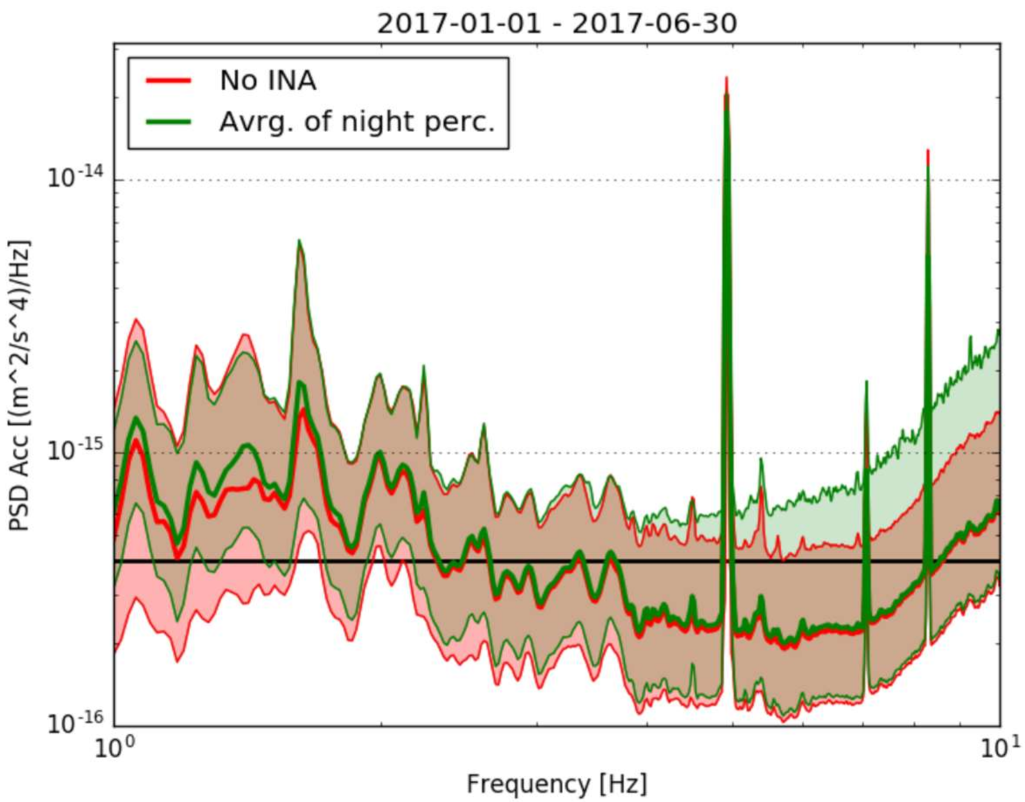
Use intrinsic averaging

Here the differences of spectra with and without intrinsic averaging (INA) are shown. Red curves belong to no INA and green ones to the averages of night percentiles – averages of 10th, and 90th percentiles are the upper and lower limits of the shaded area. The median is shown with green and red lines in the middle.



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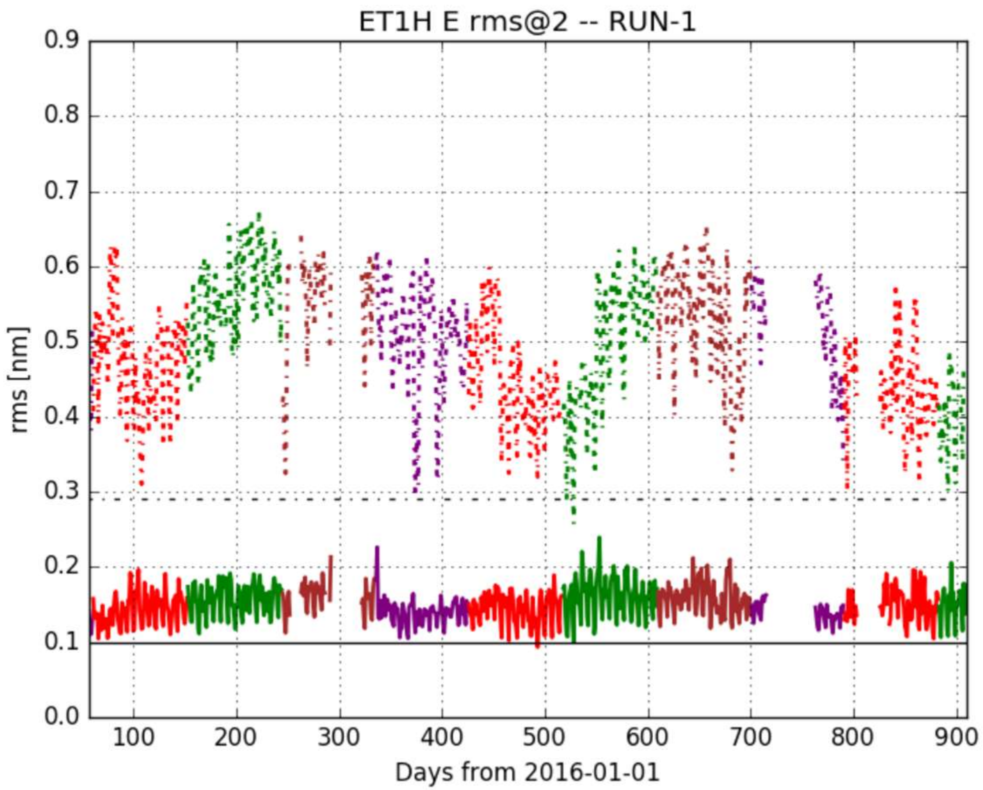
Using rms_1-10Hz

- Using other cumulative values

In the figures the mode related rms_2Hz is the solid line and the rms?1-10Hz from median is the dashed one. The colours red, green, brown and purple are for the spring, summer, autumn and winter periods, respectively.



Methodology Acta Geodaetica et Geophysica, 54\2:301-13, 2019

Thank you for your attantion!

Acknowledgments

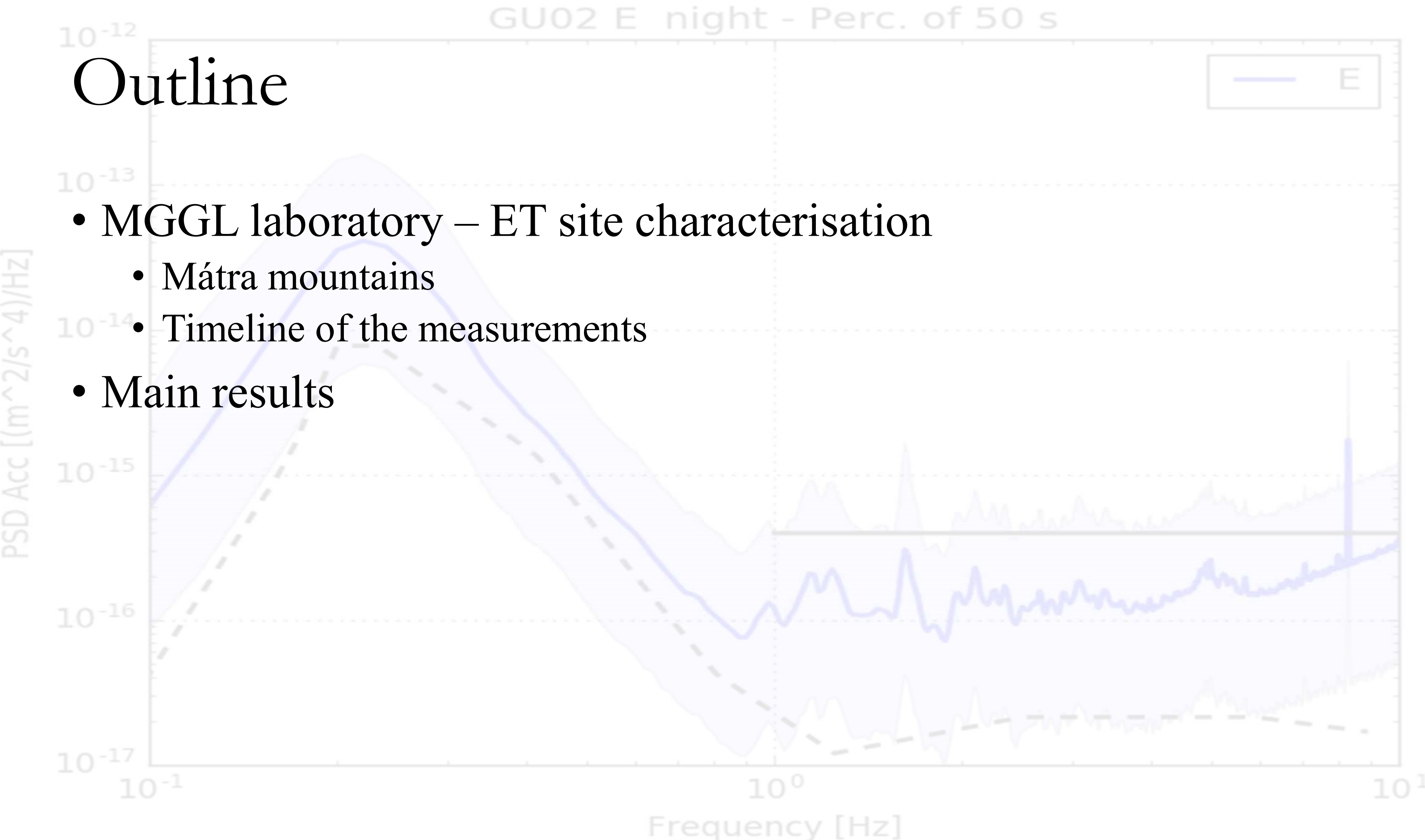
Nitrokémia Zrt.,

Geofaber Zrt.

G. G. BARNAFÖLDI, M. SZŰCS, L. KOVÁCS, ZS. BERNÁT, T. BULIK, M. CIESLAR, E. DÁVID, M. DOBRÓKA, E. FENYVESI, D. GONDEK ROSINSKA, Z. GRÁCZER, G. HAMAR, G. HUBA, Á. KIS, R. KOVÁCS, I. LEMPERGER, P. LÉVAI, J. MOLNÁR, D. NAGY, A. NOVÁK, L. OLÁH, P. PÁZMÁNDI, D. PIRI, P. RACSKÓ, Á. ROMÁN†, L. SOMLAI, T. STARECKI, M. SUCHENEK, G. SURÁNYI, S. SZALAI, P. VÁN, D. VARGA, B. VÁSÁRHELYI, P. VASS, M. VASÚTH, Z. WÉBER, V. WESZTERGOM, N. MITSUI

Outline

- MGGL laboratory – ET site characterisation
  - Mátra mountains
  - Timeline of the measurements
- Main results



MGGL

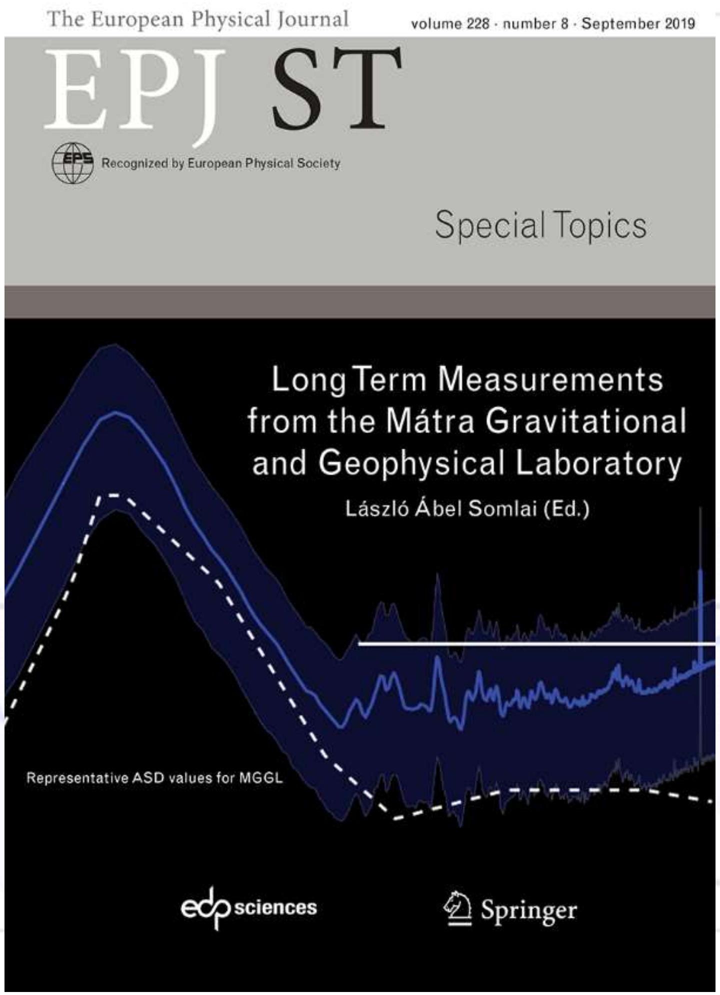
The Mátra Gravitational and Geophysical Laboratory is **to collect and to study data** from Mátra mountains

- Collaboration (31 participants) with many Institutions
  - Wigner FK
  - MTA CSFK GGKI
  - Atomki
  - Univ. of Miskolc
  - BME
  - ELTE
  - Univ. of Warsaw
  - Univ. Of Zielona Góra

- Report of the first data collection period,

(Class. Quantum Grav. 2017, V34, 114001)

The European Physical Journal, Special Topics 228, 1693-1743 (2019)

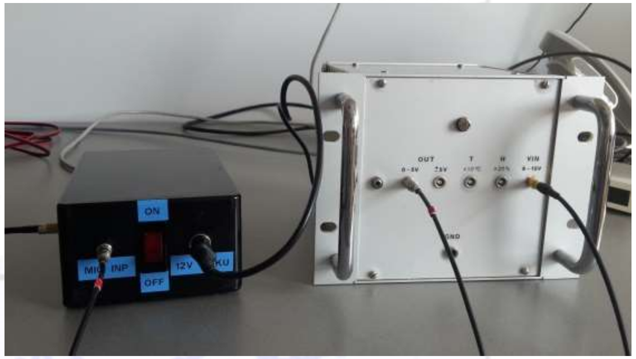


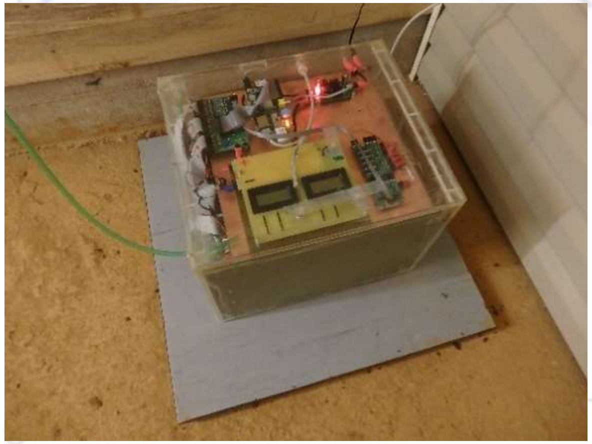
Mátra mountains (location)

remediation

MGGL instruments and experiments

- Guralp CMG-3T seismometer
- Seismometer from the Warsaw University
- Infrasound detector
- Lemi-120 magnetometer
- Muon detector (Muontomograph)



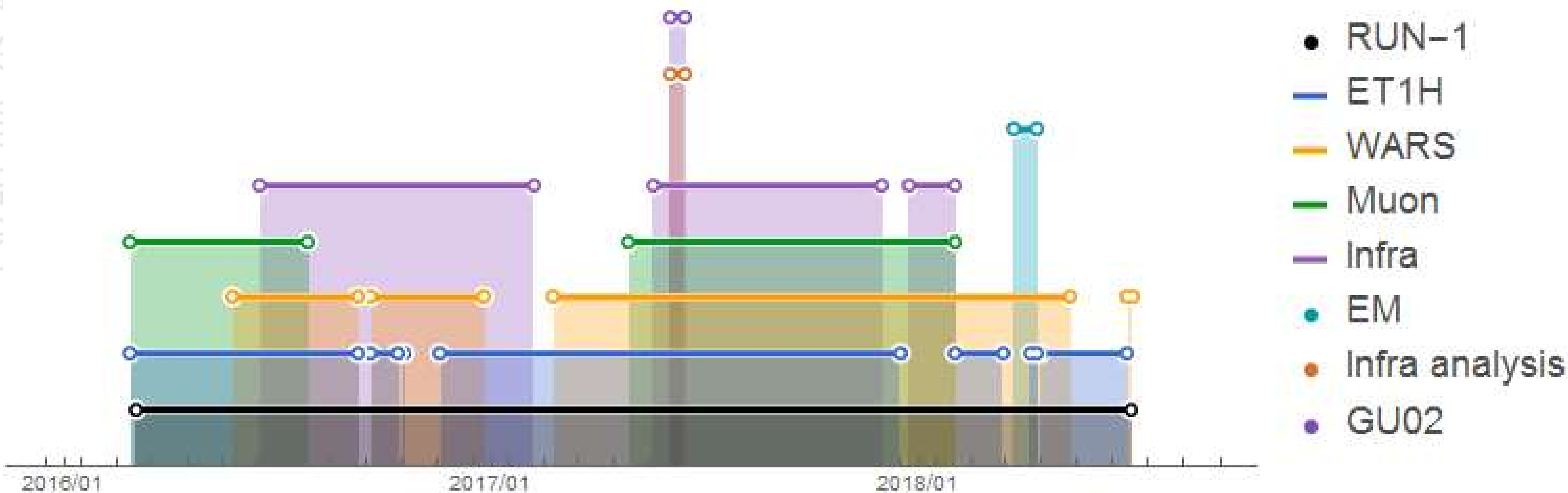


Timeline

More than 2 ys of seismic data avialable to study
More than a year of muon and infra

RUN-0: Class. Quantum Grav. 2017, V34, 114001

RUN-1: The European Physical Journal, Special Topics 228, 1693-1743 (2019)



Seismicity of the Mátra Mountains and the surrounding areas

- The seismic activity is low [1]
- Seismic hazard was studied [2]
- Hazard values using Euro-Mediterranean Seismic Hazard Model (ESHM13)

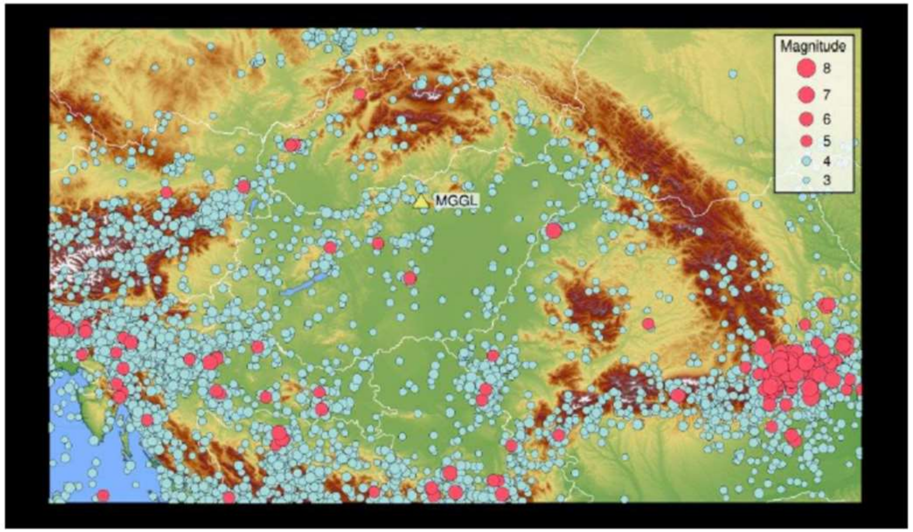


FIGURE 3. Seismic activity in the Carpatho-Pannonian area. The triangle shows the location of the MGGL. The circles mark the epicentres of the known earthquakes occurred between the years 1800 and 2010. Blue circles: earthquakes with magnitudes $3.0 \leq M < 5.0$, red circles: earthquakes with magnitudes $M \geq 5.0$.

TABLE 1. Observed maximum ground displacement values for frequencies larger then 1 Hz in the case of four characteristic events.

Station	Event	Z [μm]	N [μm]	E [μm]
ET1H	2016-05-10 10:47 (explosion; Gyöngyössolymos; dist= 7.4 km)	0.88	0.66	0.53
ET1H	2017-05-30 10:43 (explosion; Kisnána; dist=21.5 km)	0.10	0.07	0.08
ET1H	2017-06-22 11:21 (explosion; Recsk; dist=16.8 km)	0.34	0.78	0.43

[1] MTA CSFK GGI, Earthquake Catalogue, Geodetic and Geophysical Institute, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Sopron, Hungary, 2018.
[2] D. Giardini et al. Mapping Europe's seicmic hazard. Transactions American Geophysical Union, 95(29):261-262,2014

Long term seismic results

Seismic study:

- Long term measurements (almost 2 ys of data)
- Use intrinsic averaging

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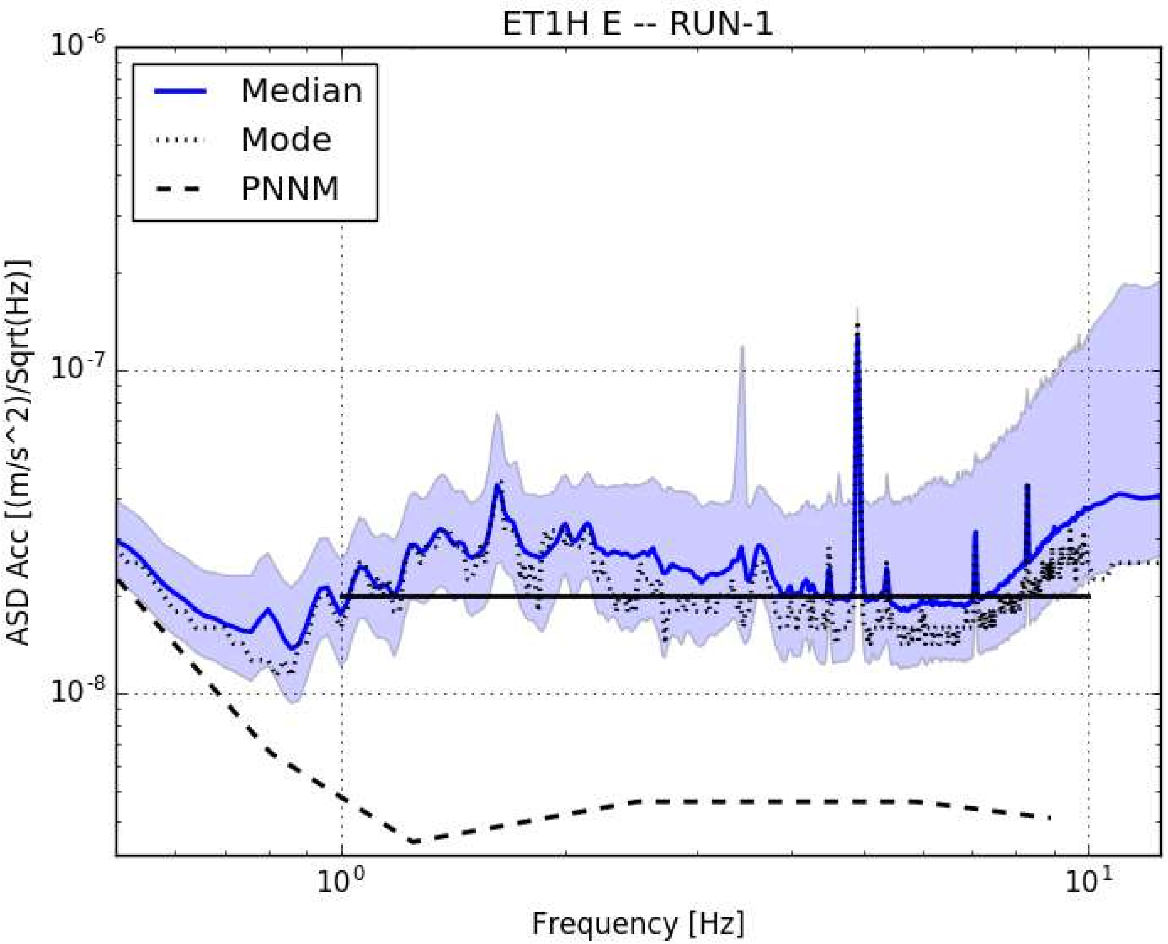


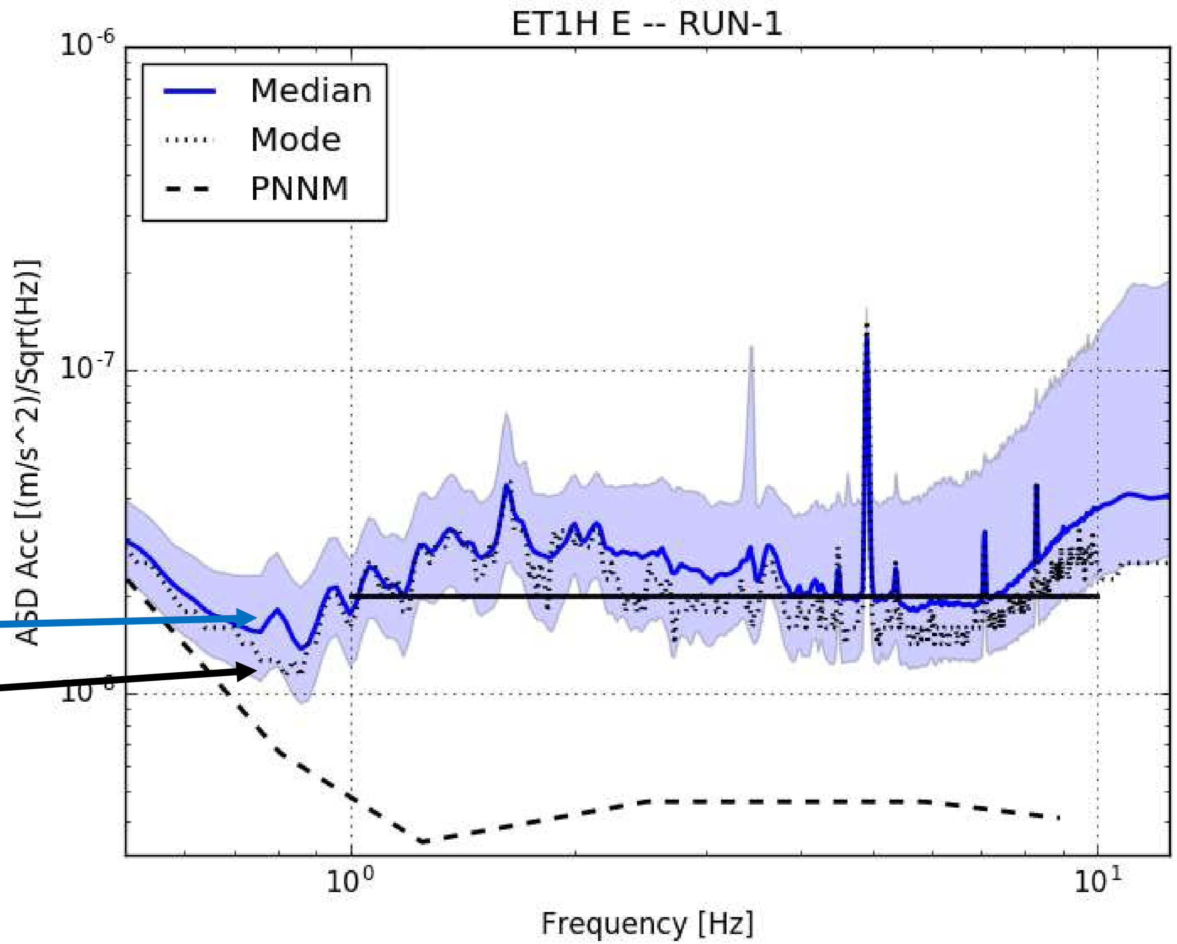
Long term seismic results

Seismic study:

- Long term measurements (almost 2 ys of data)
- Use intrinsic averaging
- Mode/Median

Median (50th percentile)

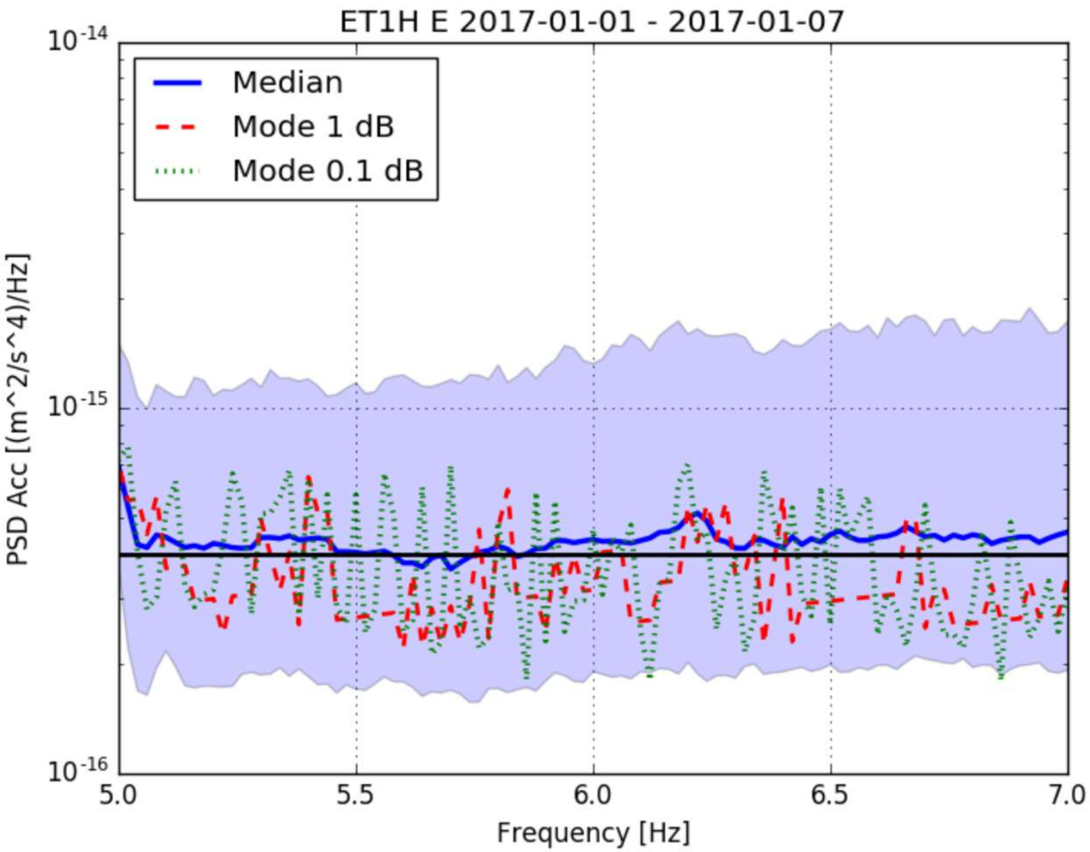
Mode (most often)



Long term seismic results

Seismic study:

- Long term measurements (almost 2 ys of data)
- Use intrinsic averaging
- Mode/Median



Long term seismic results

Seismic study:

- Long term measurements (almost 2 ys of data)
- Use intrinsic averaging
- Study annually, seasonally changes

ET1H ~88m depth

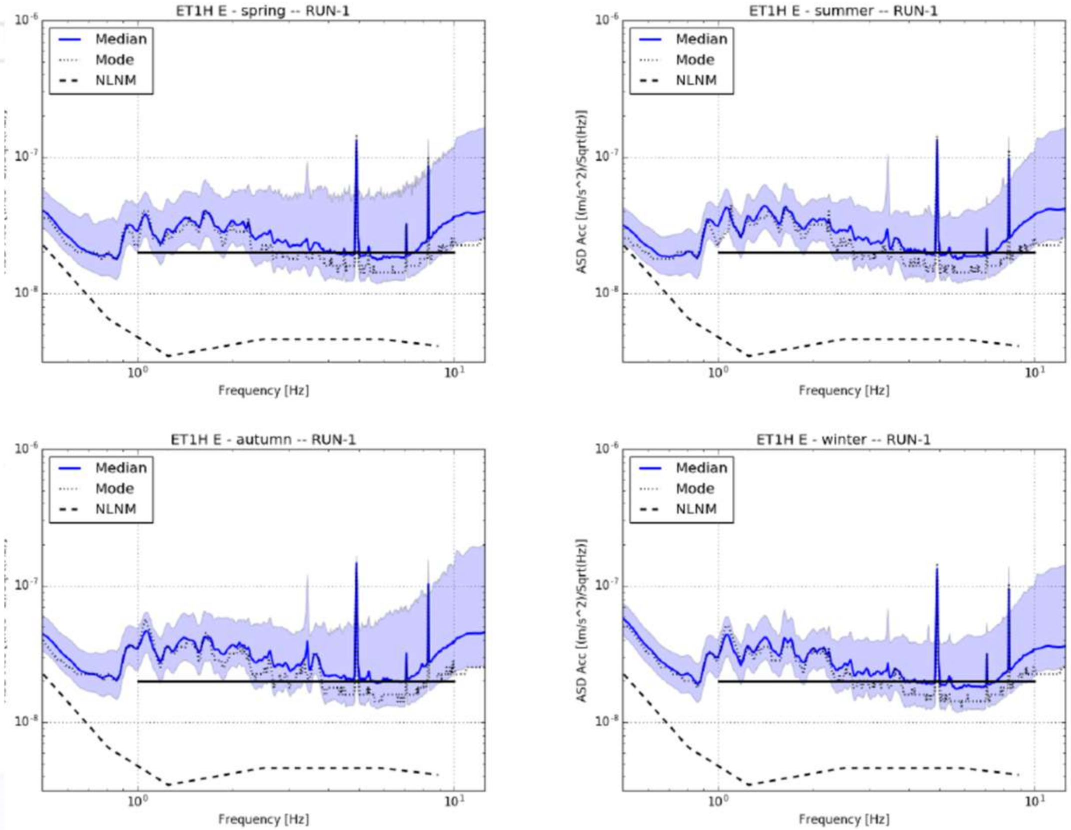


FIGURE 11. The acceleration ASD of the different seasons for a horizontal component calculated is shown here from whole-day periods. The solid blue and the dotted black lines indicate the median and the mode of the data, respectively. The borderlines of the blue colored area are the 10th and 90th percentiles. The Black Forest line is solid black and the dashed black lines are NLNM curves.

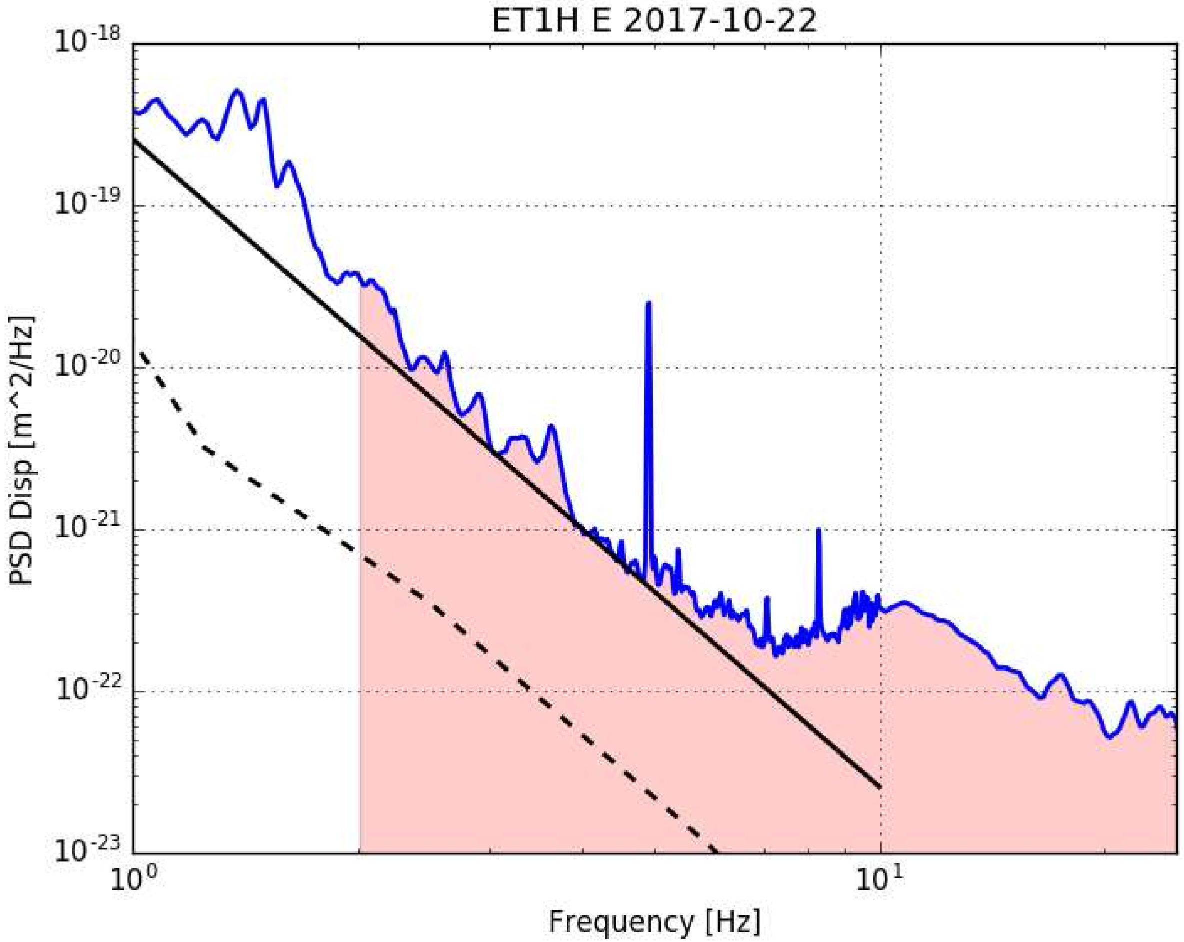
Long term seismic results

Calculate

- rms_2Hz
- rms_2-10Hz and
- rms_1-10Hz

Expresses different properties:

- Cultural/human noise
- Sea/ocean



Long term seismic results

Calculate

- rms_2Hz
- rms_2-10Hz and
- rms_1-10Hz

Night period	rms_{2Hz}	rms_{2-10Hz}	rms_{1-10Hz}
E	0.0748	0.0752	0.217
N	0.0746	0.0732	0.213
Z	0.0625	0.0619	0.304
Working period	rms_{2Hz}	rms_{2-10Hz}	rms_{1-10Hz}
E	0.143	0.135	0.318
N	0.150	0.135	0.326
Z	0.135	0.121	0.431

TABLE 10. The calculated rms values in nm for the night and working periods of the GU02 station, according to Fig. 16.

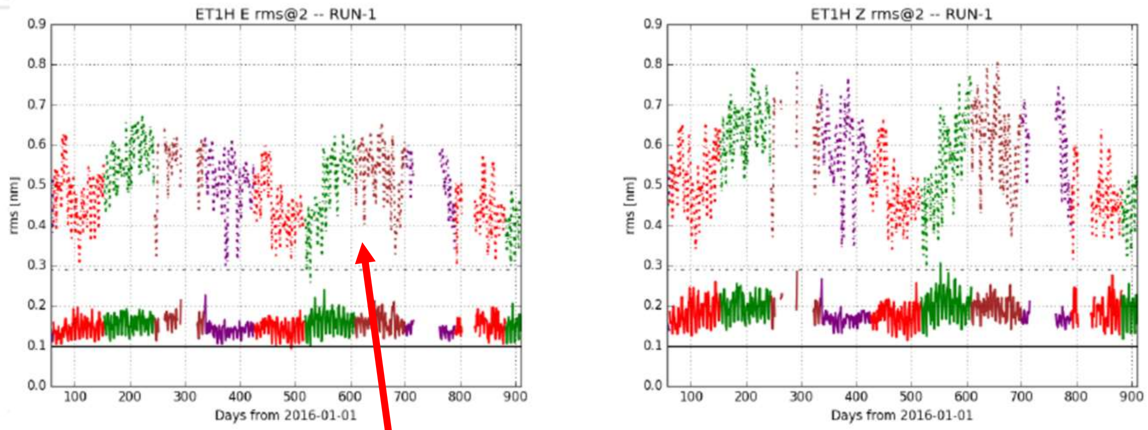


FIGURE 12. The timeline of the daily rms values for the whole Run-1 in a horizontal and in the vertical direction. In the figures the mode related rms_{2Hz} is the solid line and the rms_{1-10Hz} from median is the dashed one. The colours red, green, brown and purple are for the spring, summer, autumn and winter periods, respectively. The solid and dashed black lines are the referential Black Forest values, $rms_{2Hz} = 0.1nm$ and $rms_{1-10Hz} = 0.29nm$.

Seasonally changes for the rms_1-10Hz

Long term seismic results

Calculate

- rms_2Hz
- rms_2-10Hz and
- rms_1-10Hz

Night period	rms_{2Hz}	rms_{2-10Hz}	rms_{1-10Hz}
E	0.0748	0.0752	0.217
N	0.0746	0.0732	0.213
Z	0.0625	0.0619	0.304

Working period	rms_{2Hz}	rms_{2-10Hz}	rms_{1-10Hz}
E	0.143	0.135	0.318
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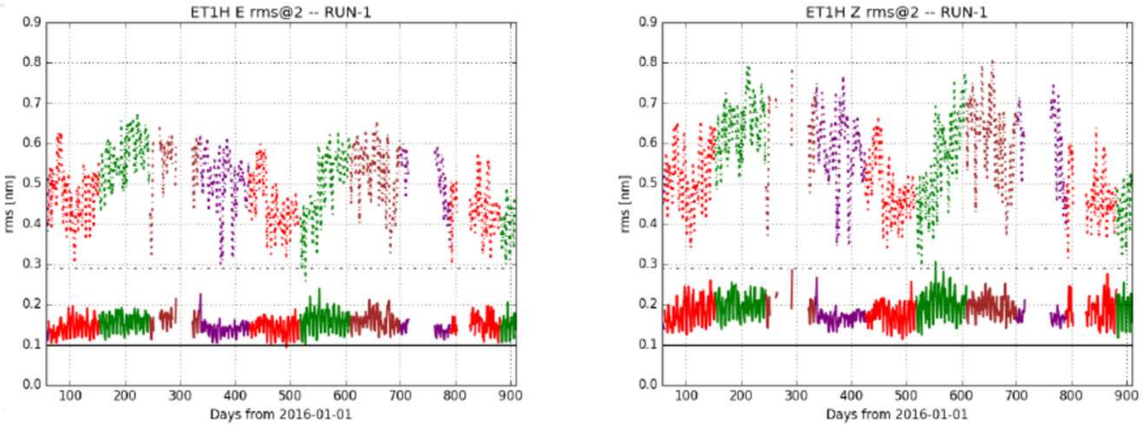

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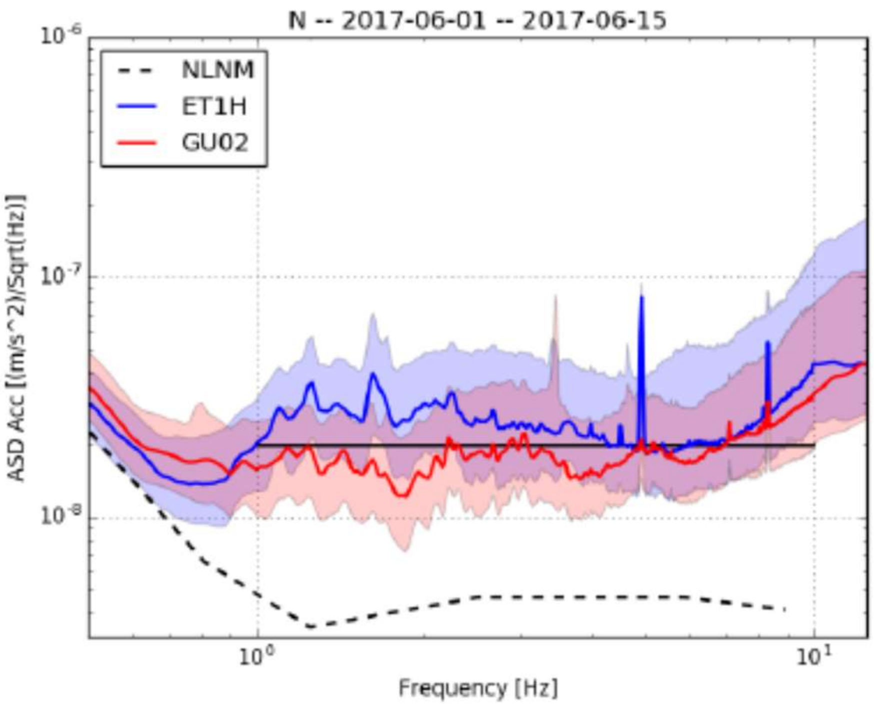
Long term seismic results

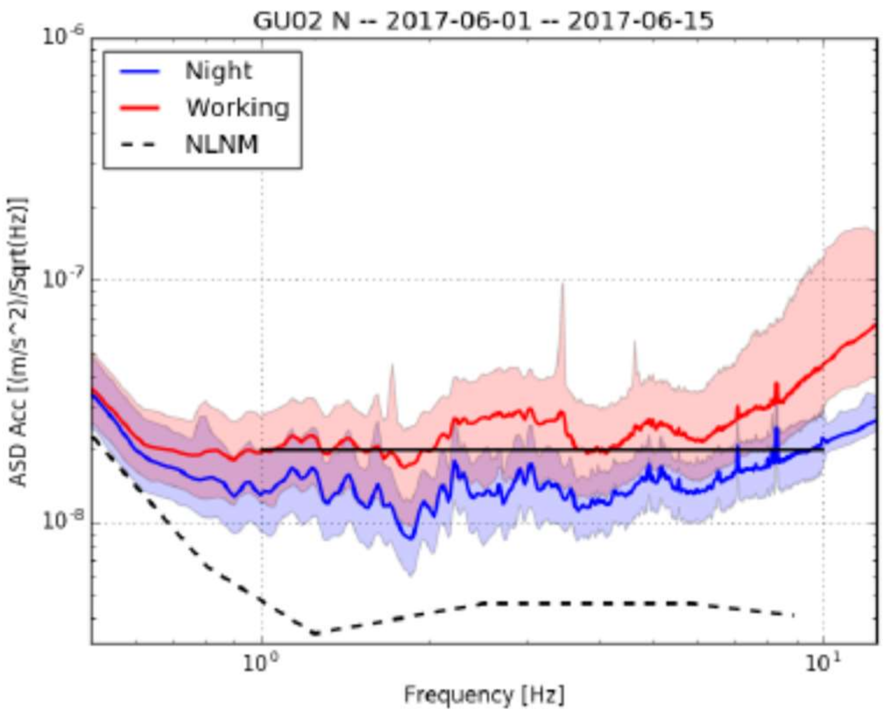
Study of 2 years: The European Physical Journal, Special Topics 228, 1693-1743 (2019)

2weeks data

ET1H ~88m depth
GU02 ~404m depth

GU02 Night
GU02 Working





Long term seismic results

Seismometer of the Warsaw University:

- 654 days were analysed (day, night, working period)
- Cumulative rms_2Hz was calculated

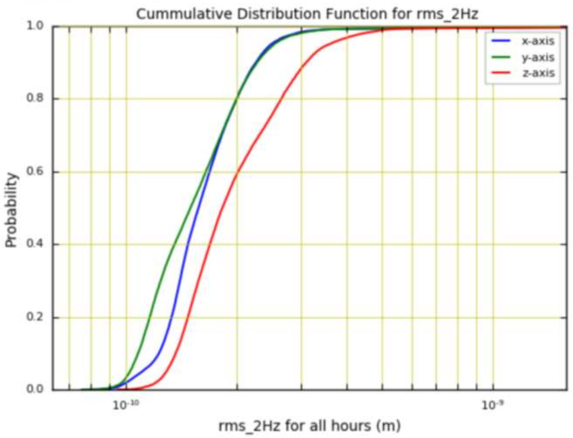


FIGURE 21. The cumulative distributions of the hourly rms_{2Hz}. We present the results for the three directions.

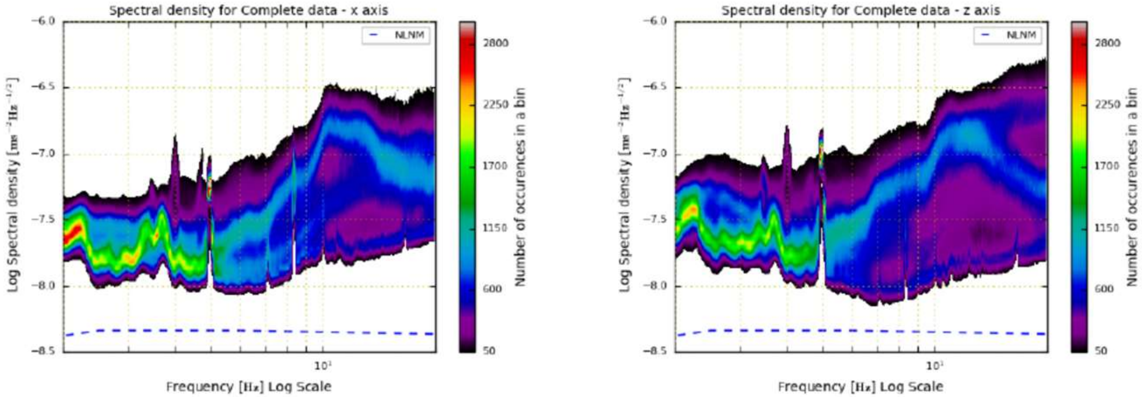


FIGURE 18. The density plots of the spectra in the vertical and horizontal directions. The blue dashed line is the NLNM.

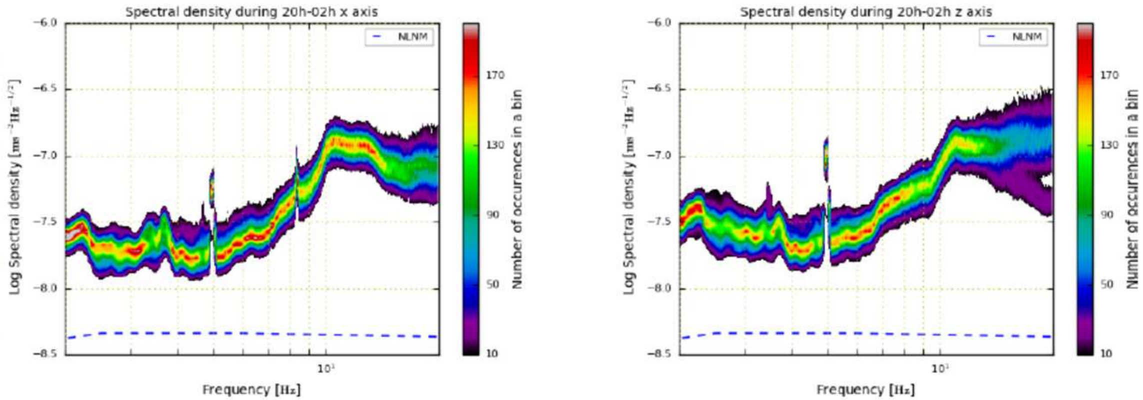


FIGURE 20. The daily variation of the seismic noise for the off work-shifts in the mine: corresponding to the time between 20:00 and 02:00 hours UTC. The blue dashed line is the NLNM.

Rock rheology

Dynamic and static elastic moduli of rocks are different [*Davrapanah et al, GGGG, (2020)*]

- Hard andesitic rocks of Mátra show clear anelastic effects → more refined NN models, tunnel convergence, in situ rock stress
- Direct laboratory measurements of dynamic and static elasticity coefficients confirm the difference and the Poynting-Thomson material model for andesitic rocks of Mátra.
- E.g. characteristic **stress relaxation times** are:

$\tau \quad = 9 \pm 0.5\ s, \ \ \tau \quad = 14 \pm 4\ s$