

Mitigation of the effect of changes of atmospheric pressure on gravity detectors

Edit Fenyvesi

Theoretical Physics Department, Wigner Research Centre for Physics, 1121 Budapest, Konkoly-Thege Miklós út 29-33.,
Budapest, Hungary

fenyvesi.edit@wigner.hu

Introduction

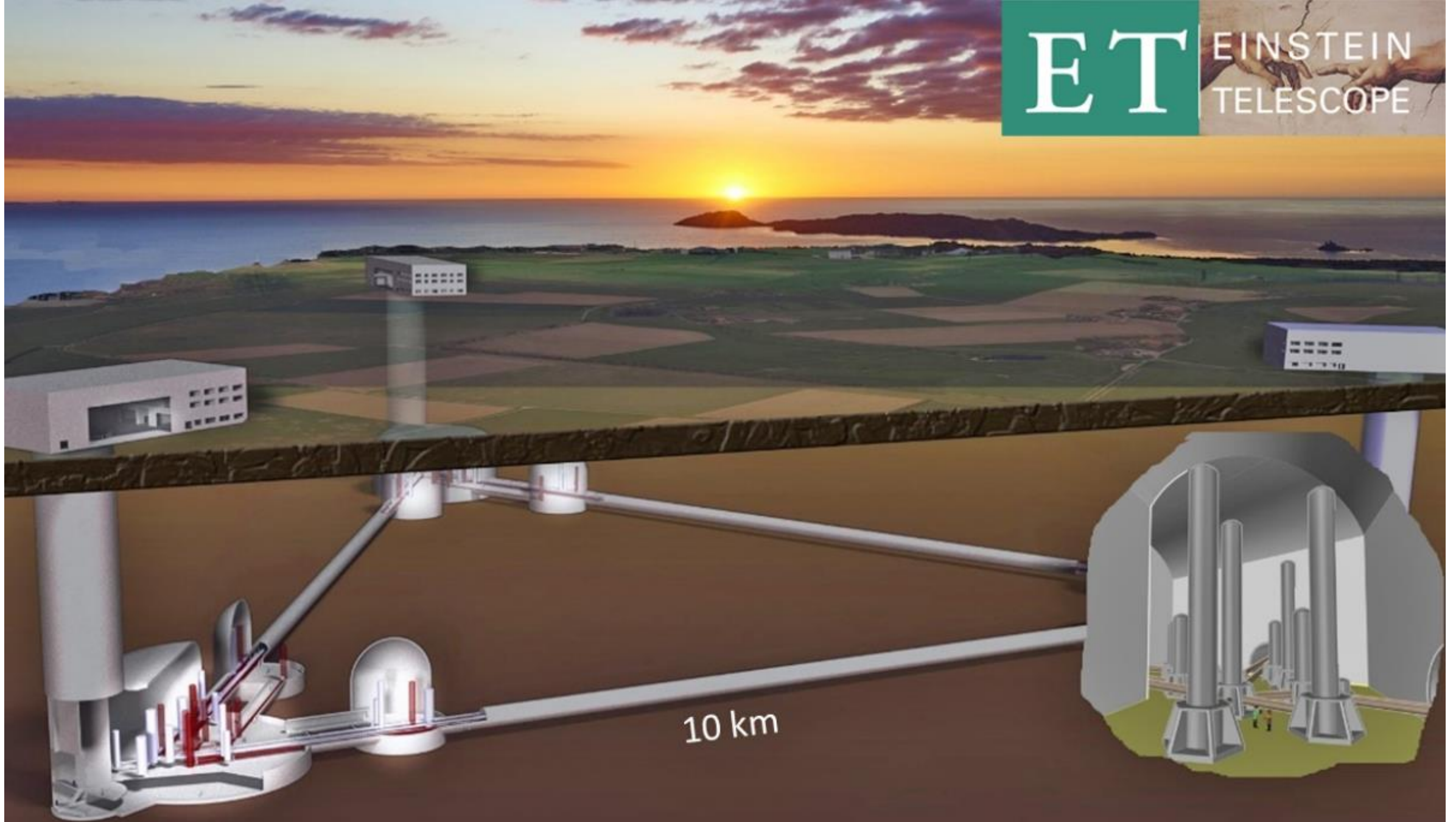
- Detectors
 - Einstein Telescope:
 - a planned third-generation gravitational-wave detector
 - Eötvös-balance:
 - an almost 100 years old instrument
 - measures gravity gradients (was modernized a few years ago)
- Changes of atmospheric pressure:
 - Wind: can be eliminated by installing the detector under the ground
 - Infrasound (vibrations of air below 20 Hz):
 - expected to contribute to the measurement noise of Einstein Telescope
 - Slow changes of atmospheric pressure (<1 Hz):
 - cause tilt of the ground
 - the effects are present 30 meters below the surface
 - ET will be sensitive at higher frequencies

Einstein Telescope (ET)

- Fundamental limitations at low frequency of the sensitivity of the second-generation gravitational-wave detectors are given by:
 - seismic noise
 - gravitational gradient noise (so-called Newtonian noise)
 - thermal noise of the suspension last stage and of the test masses
- Seismic and Newtonian noise can be decreased by installing the detectors under the ground
- ET Collaboration was established in 2022 (<https://www.et-gw.eu/index.php/the-et-collaboration>)
- This research is part of the activities of the ET SPB - Physical Variables & Characterization Division (WP1.4: Other Environmental Noises)

ET

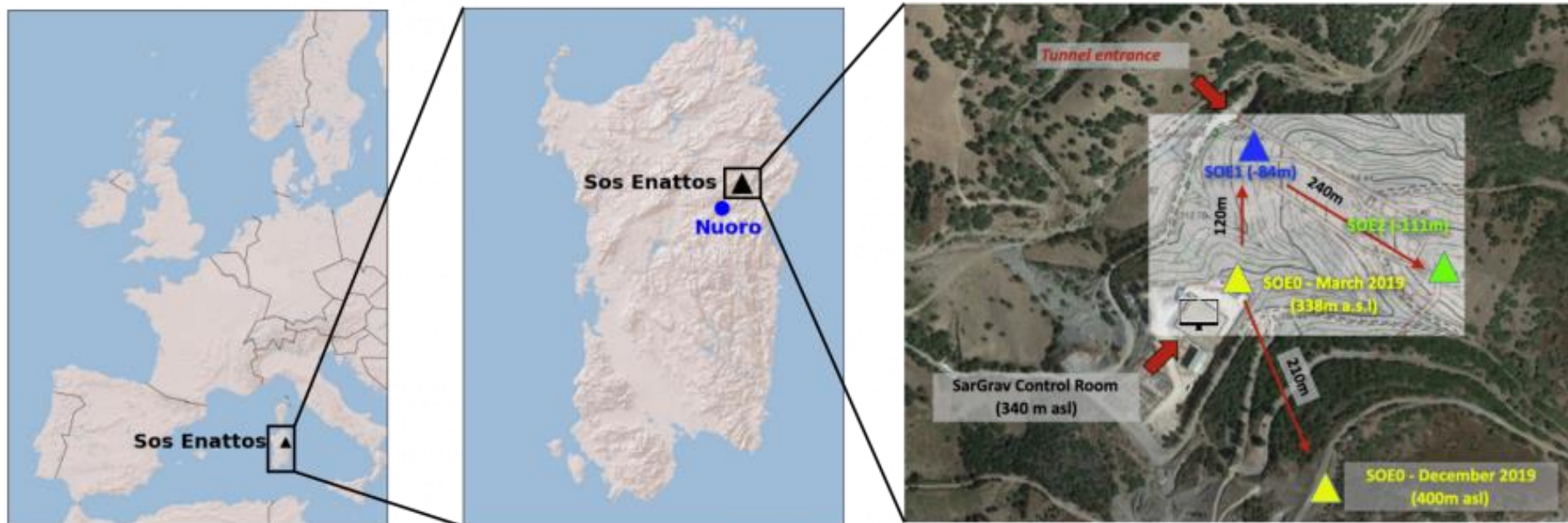
EINSTEIN
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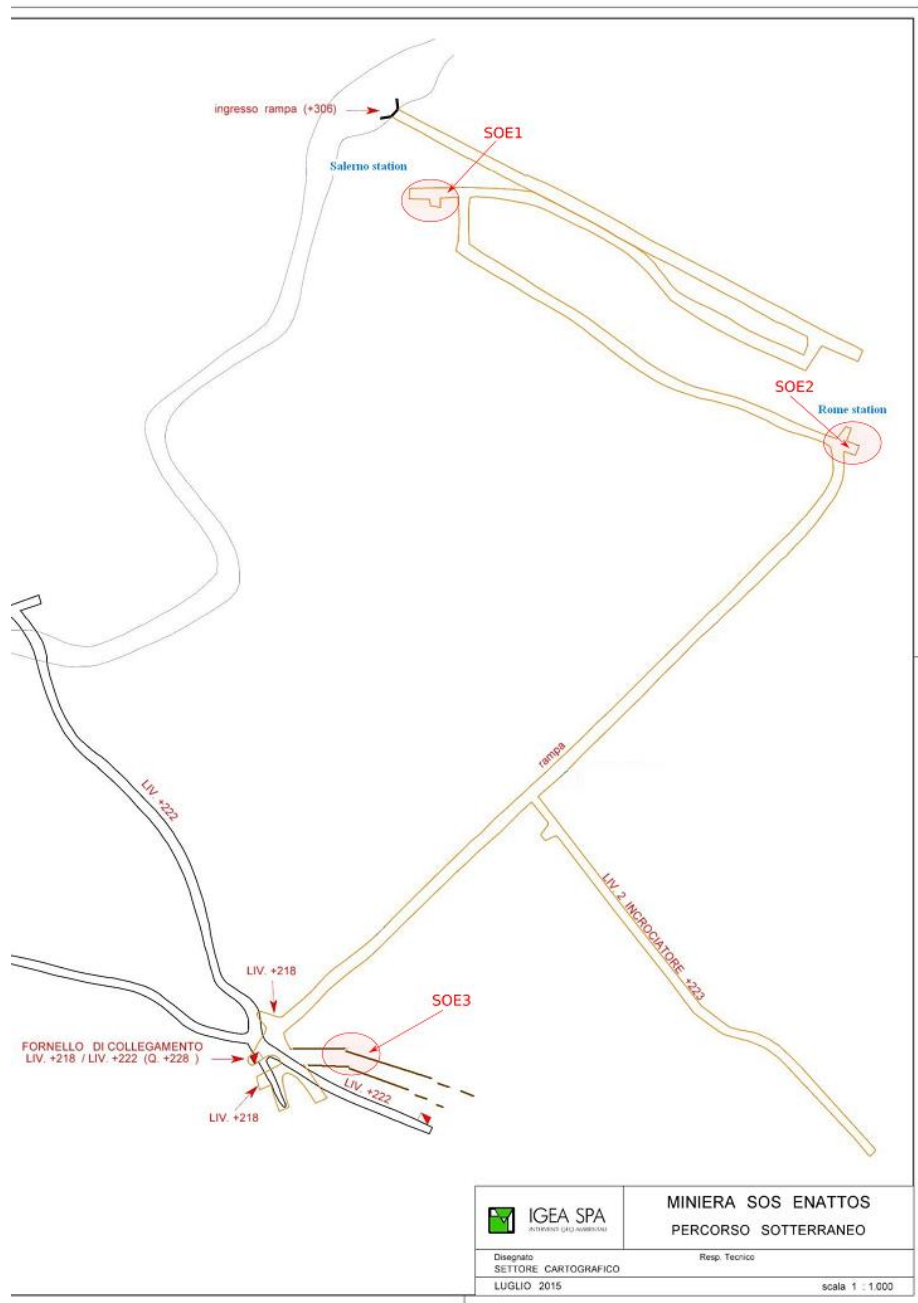


<https://iopscience.iop.org/article/10.1088/1475-7516/2023/07/068/pdf>

Infrasound studies at Sos Enattos mine (Sardinia, Italy)

- Sardinia: one of the candidate sites of ET
- Site characterization activities at Sos Enattos mine are going on
- Infrasound is one contributor to Newtonian noise
- The attenuation of infrasound by depth is investigated at four stations

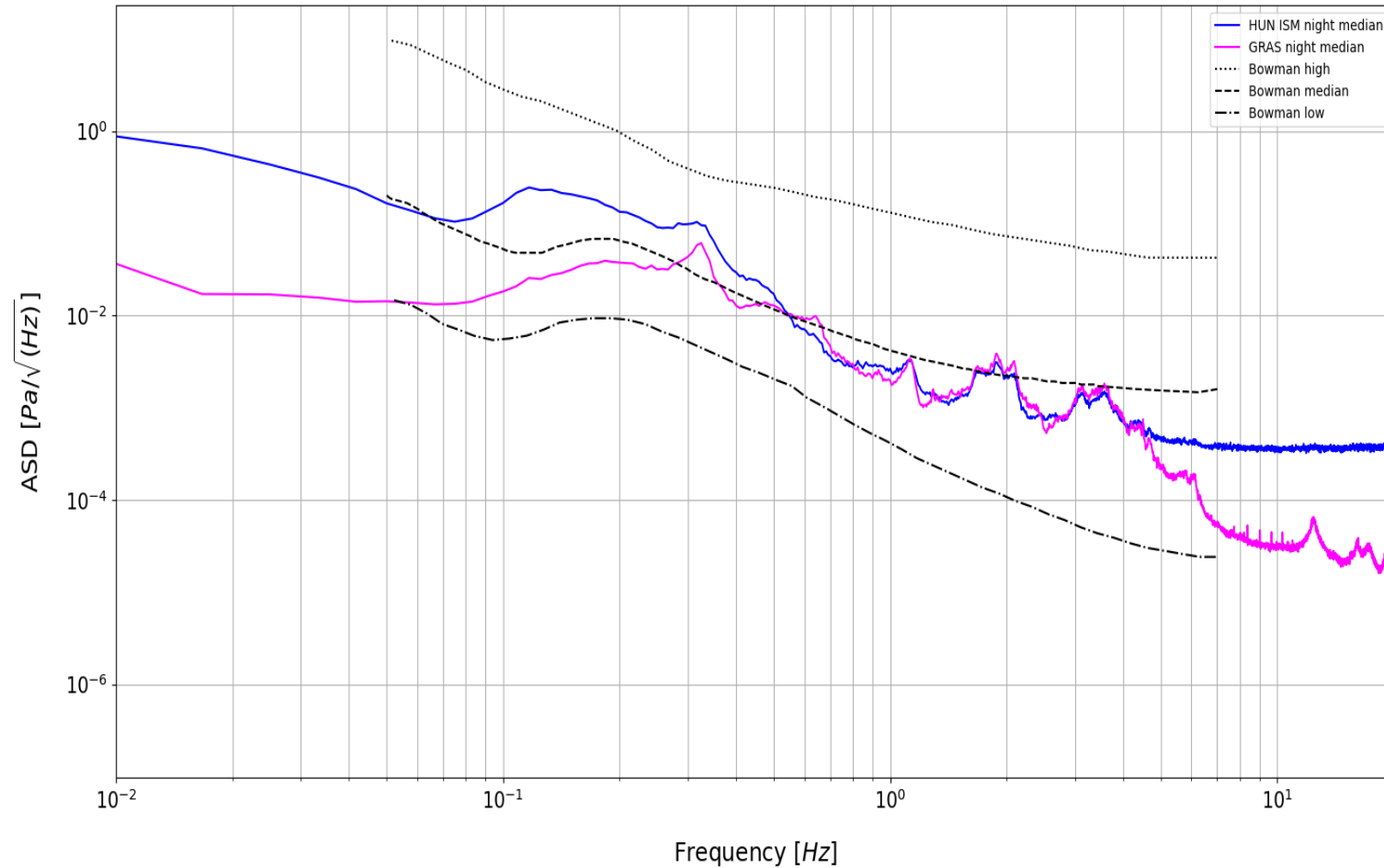




Station	Depth (m)	Microphones	Start of data collection
SOE0	400	GRAS, Astrocent	Nov26, 2022
SOE1	-84	GRAS, Astrocent	Nov26, 2022
SOE2	-111	GRAS, ISM1802*	Nov26, 2022
SOE3	-160	GRAS, Astrocent	Nov26, 2022

*short measurement campaign from 2022-11-23 03:00:00 to 2022-11-25 08:59:59

Comparison of ISM1802 and GRAS



GRAS 47AC:

Freq range (± 3 dB): 0.09 Hz to 20 k Hz

Sensitivity: 8 mV/Pa

ISM1802:

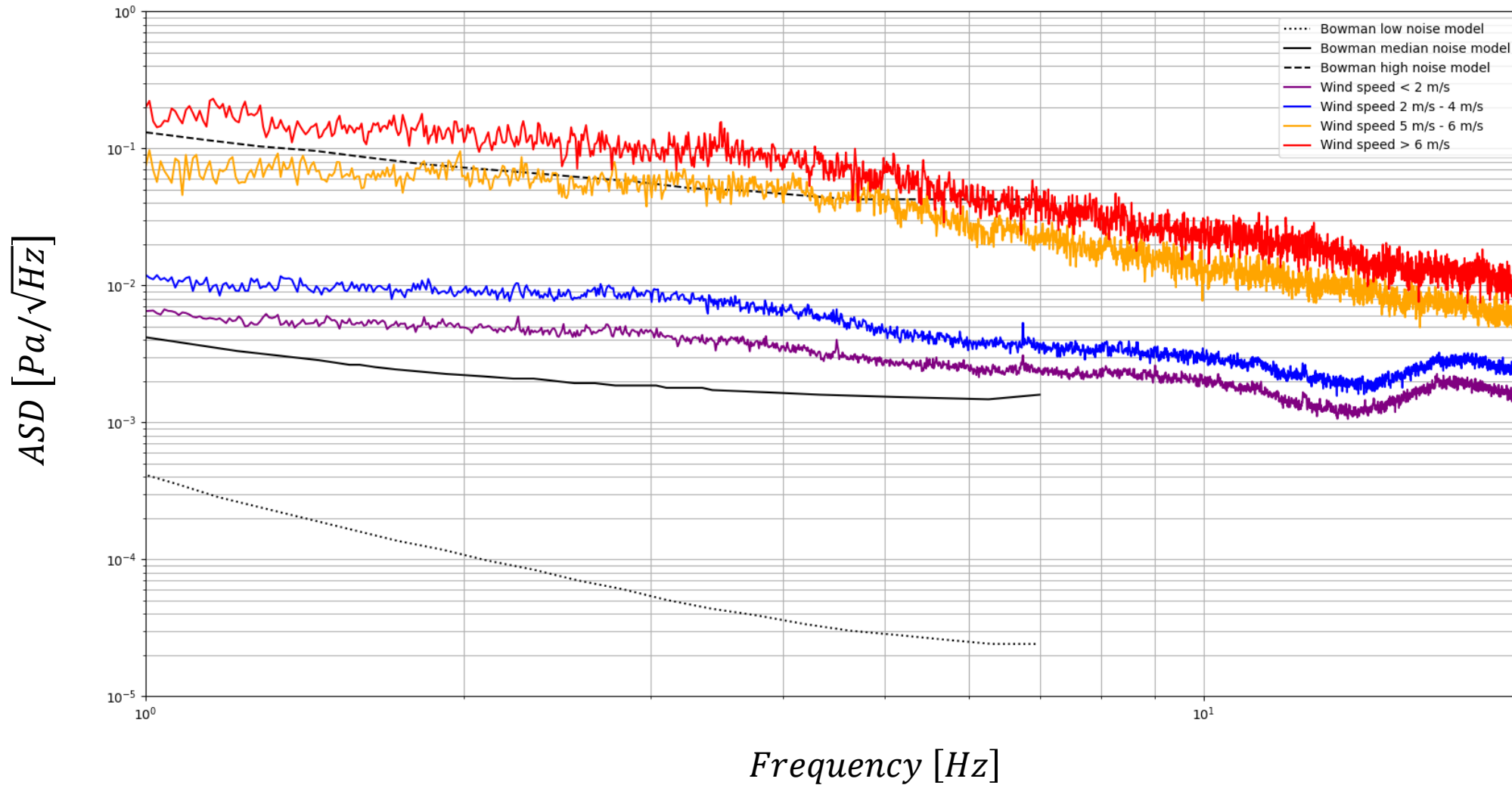
Freq range (± 3 dB): 0.01 Hz to 30 Hz

Sensitivity: 1 mV/Pa

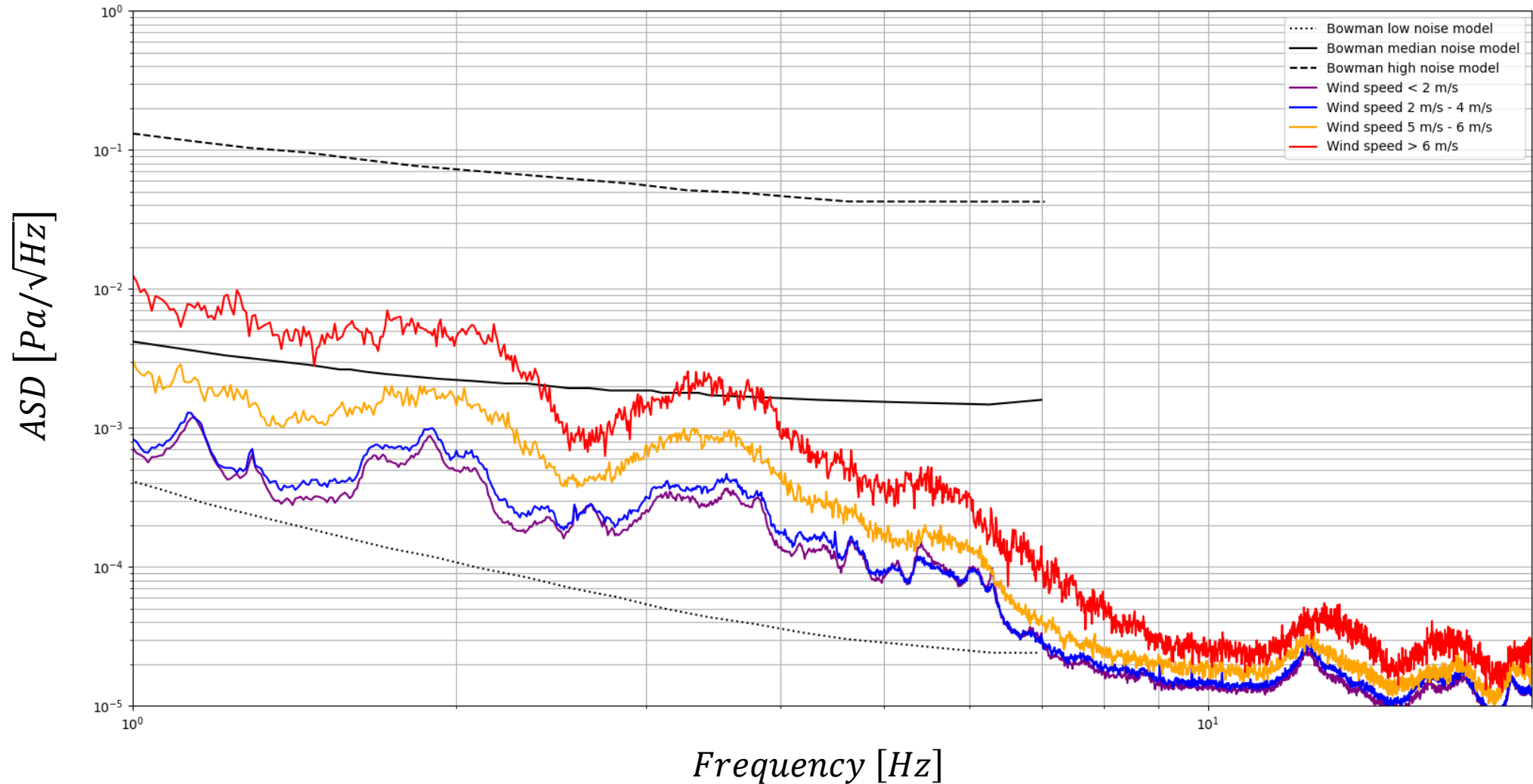
Self noise: 1 mPa



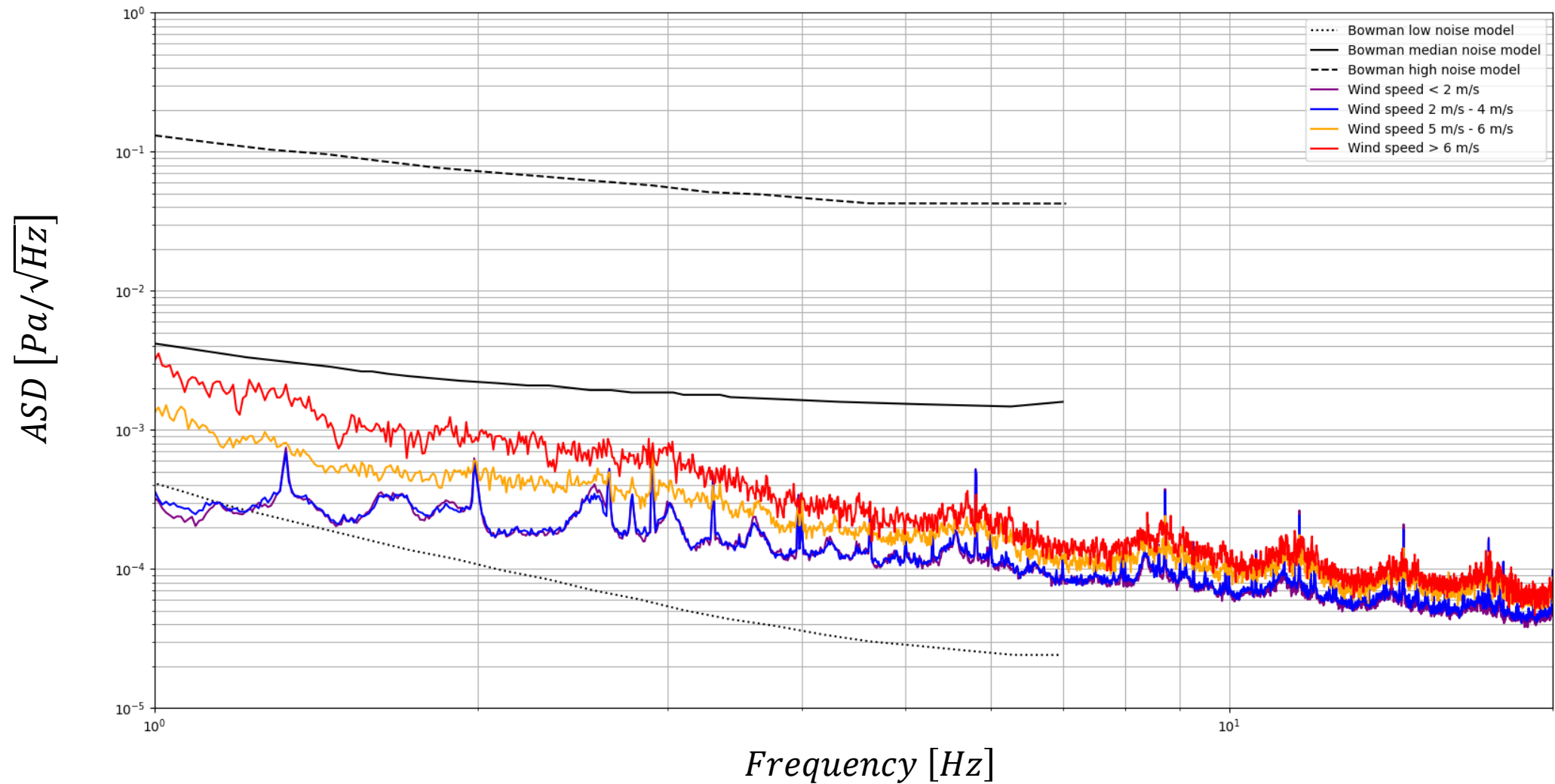
Measurements with GRAS: the effect of wind at SOE0 (in Dec 2022)



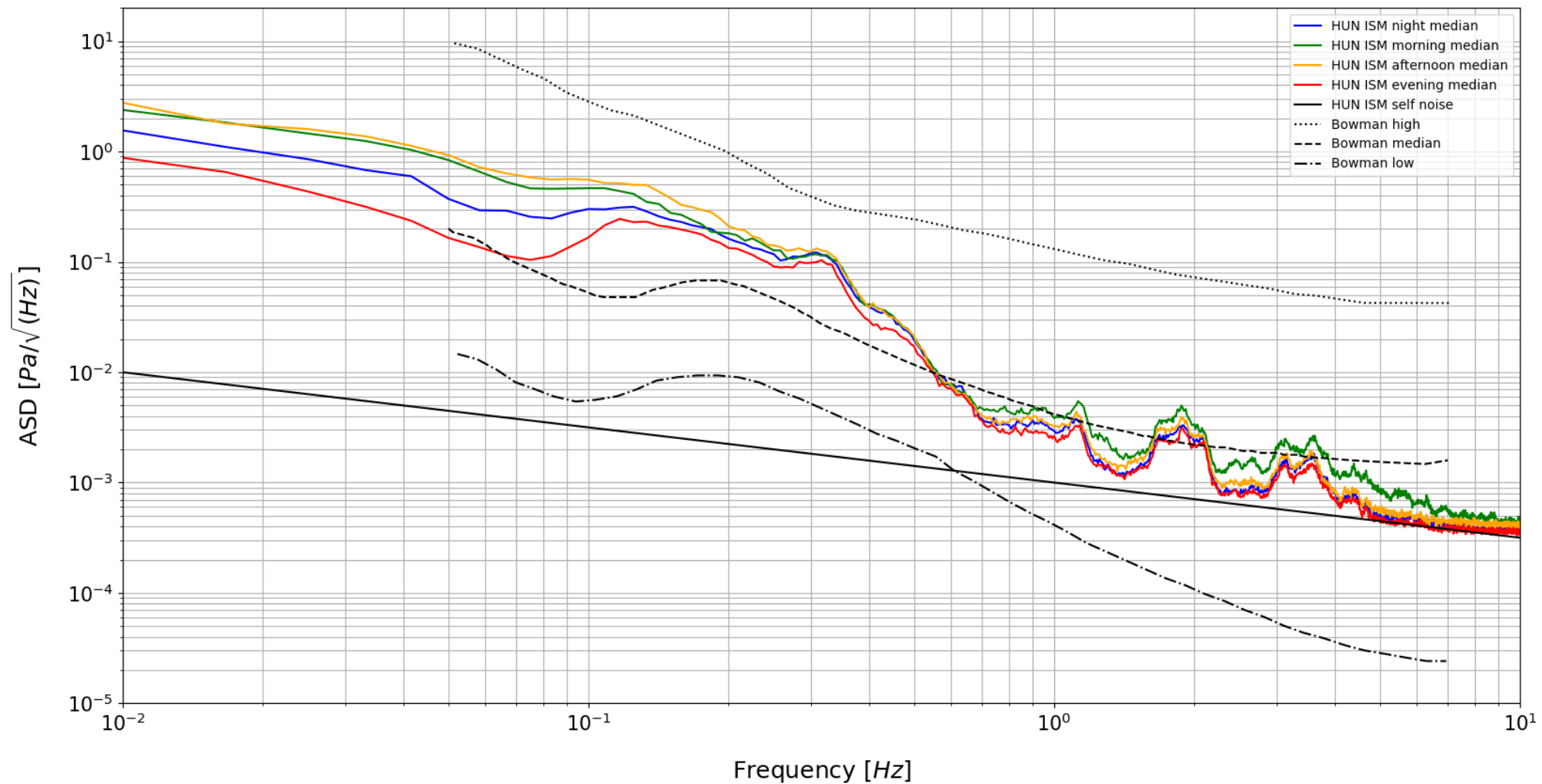
Measurements with GRAS: the effect of wind at SOE2 (in Dec 2022)



Measurements with GRAS: the effect of wind at SOE3 (in Dec 2022)

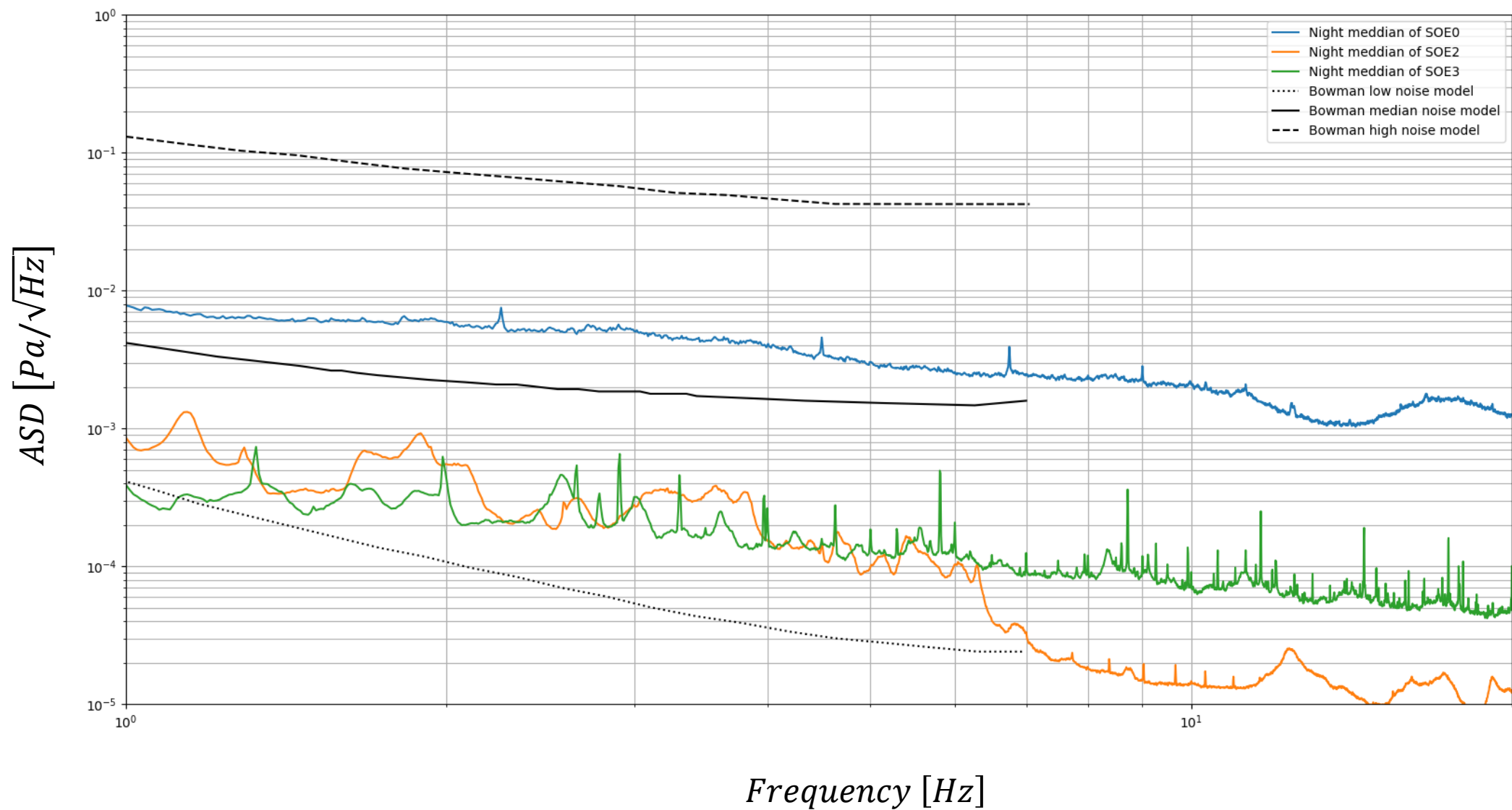


Results for different parts of days (ISM1802 at SOE2)

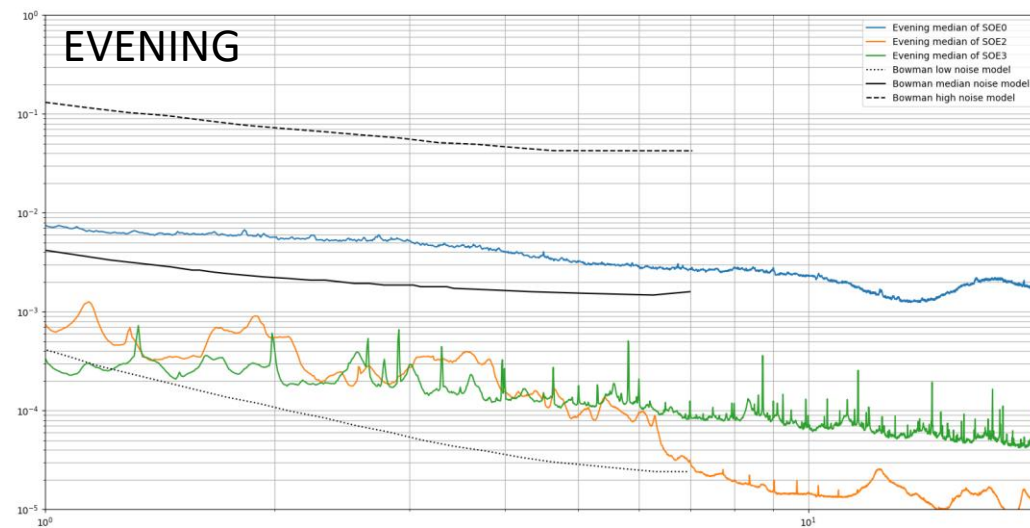
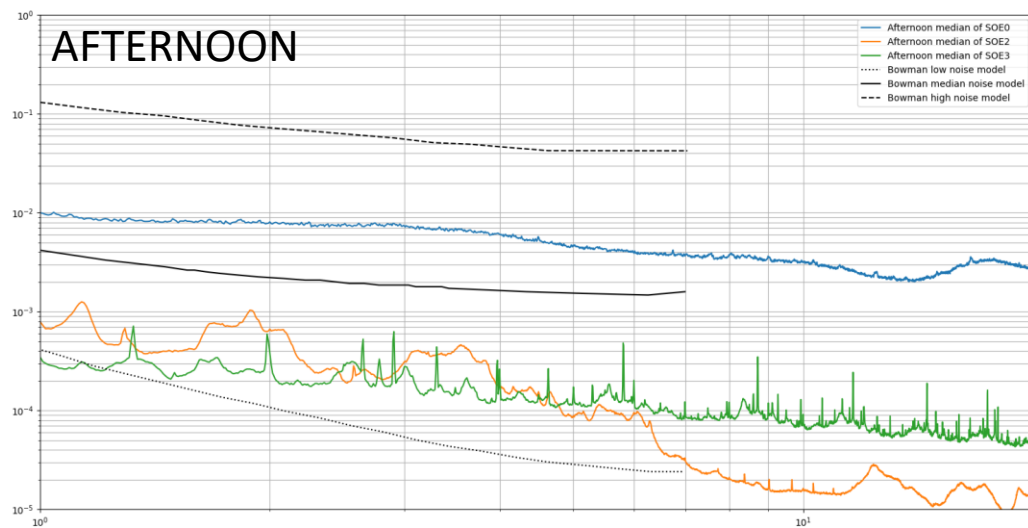
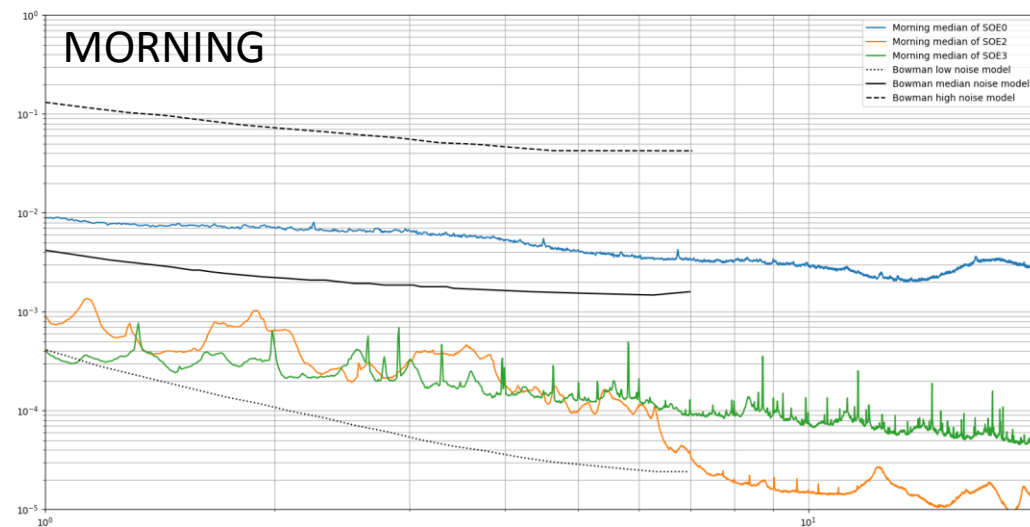
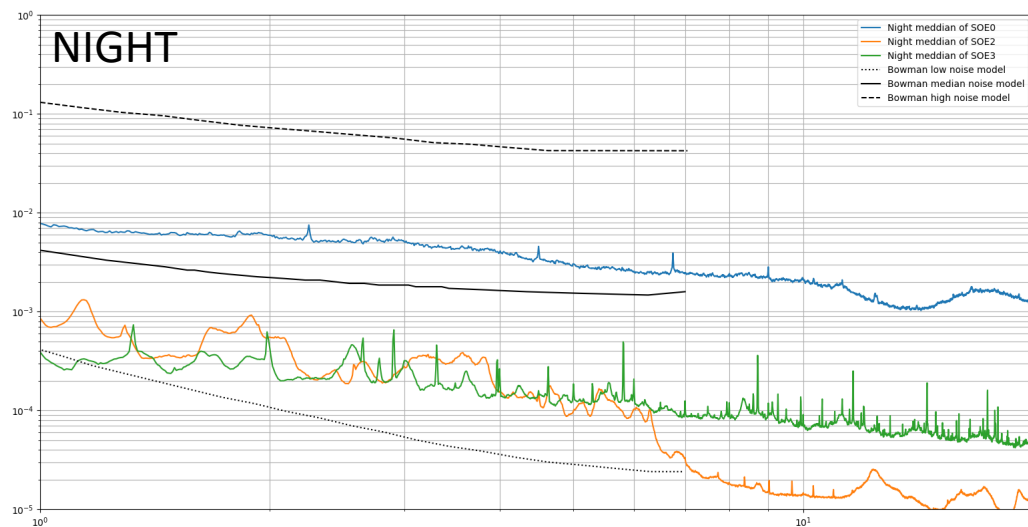


Night: 00:00 – 06:00, morning: 06:00 – 12:00, afternoon: 12:00 – 18:00, evening: 18:00 – 24:00

Spectra at night (GRAS, Dec 2022)

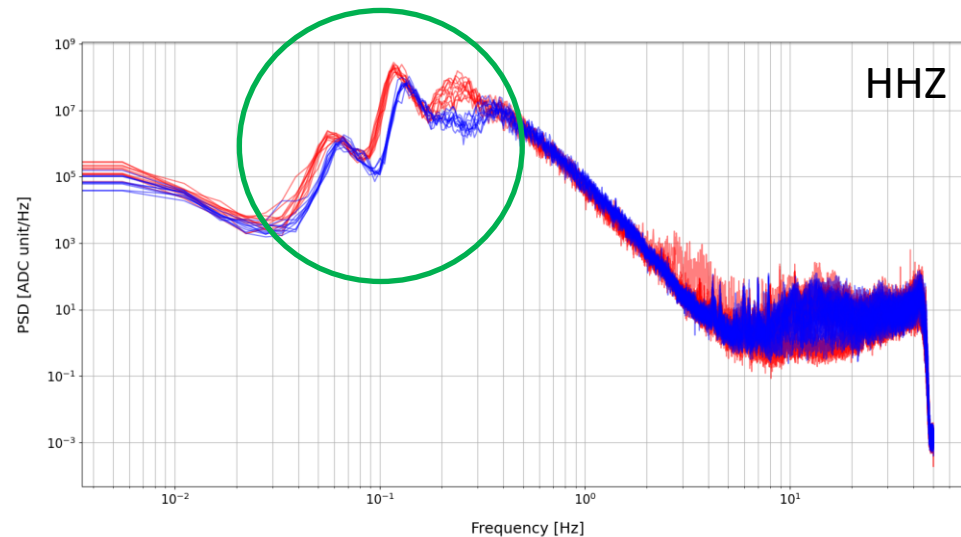
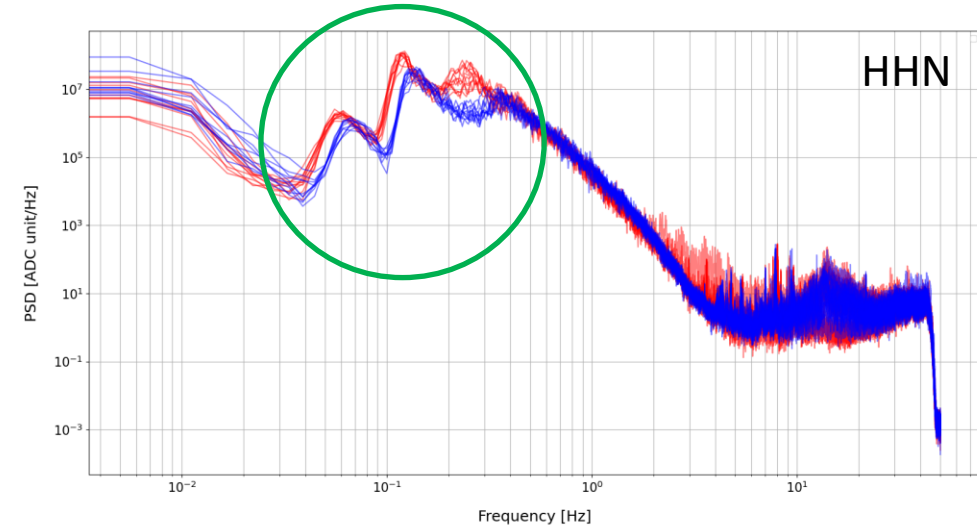
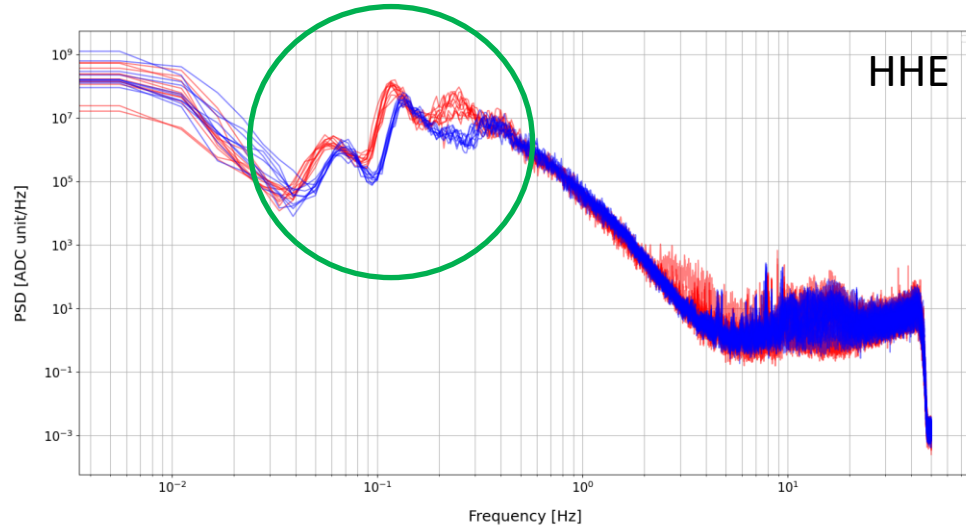


ASD $[Pa/\sqrt{Hz}]$



Frequency [Hz]

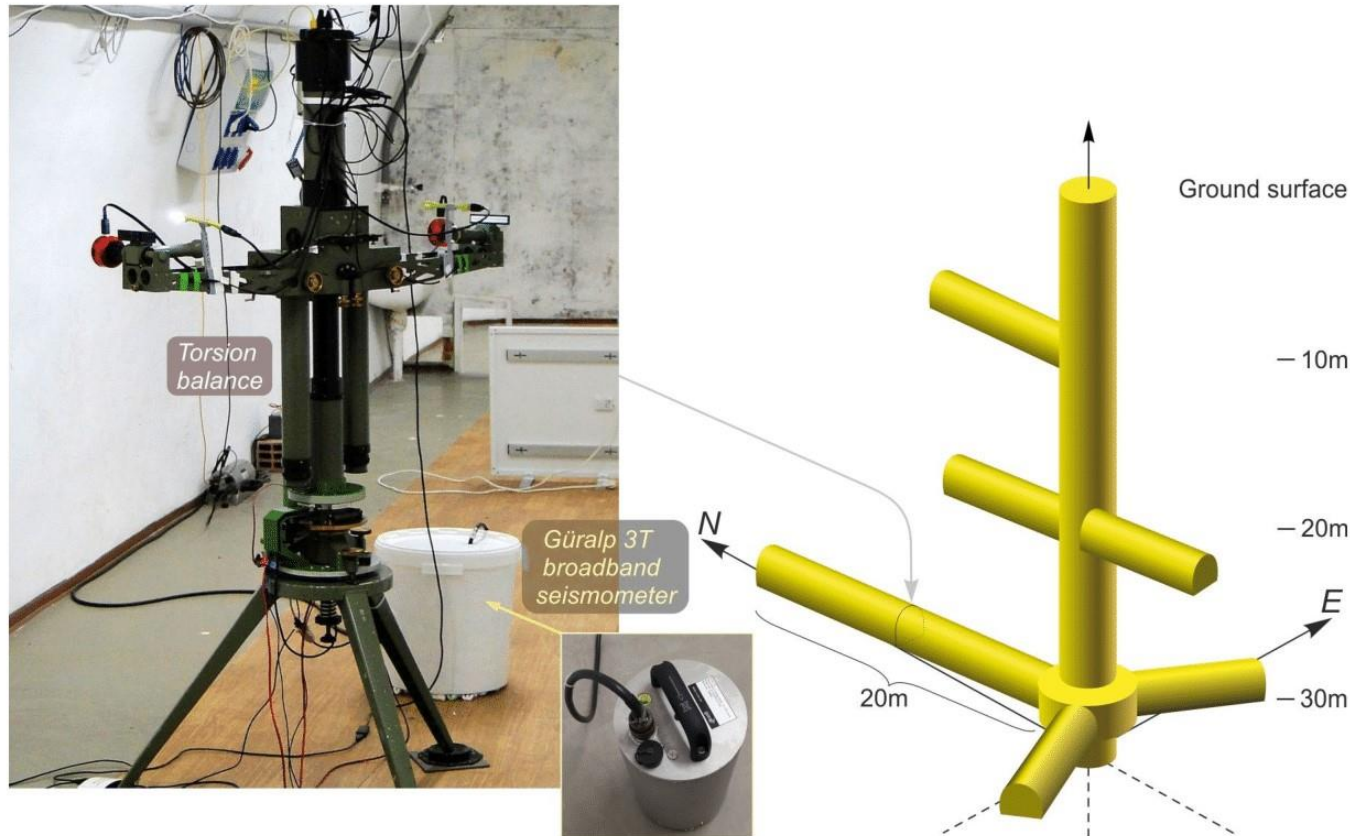
The effect of atmospheric pressure on the seismometer at SEO2



Red: $p < 30$ inHg , blue: $p > 30$ inHg

Not calibrated data!

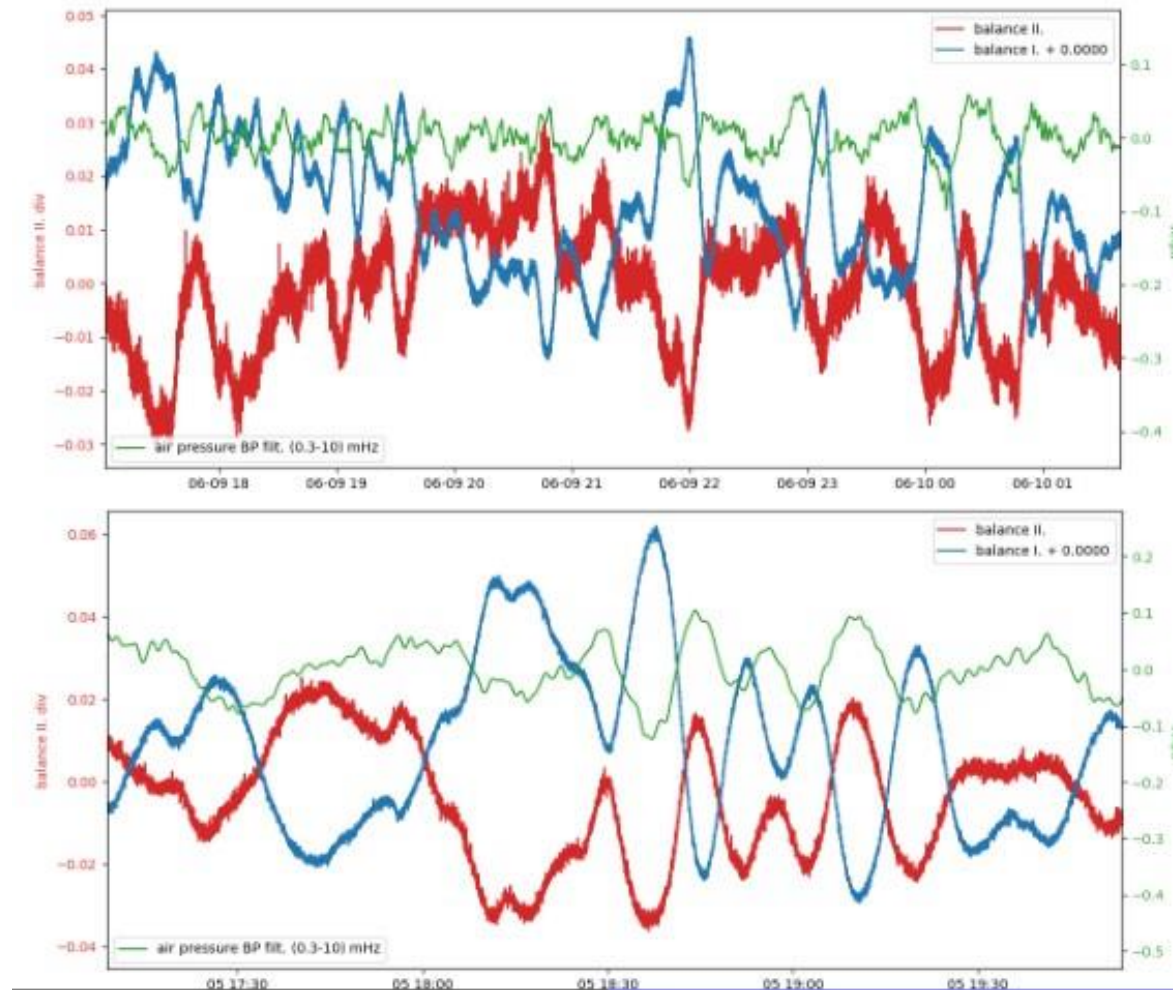
Re-measurement of the Eötvös experiment



- Project started in 2017
- Institutes:
 - Wigner research Centre for Physics
 - Budapest University of Technology and Economics
 - ETTE (Association for the Unity of Science and Technology)
- Site: Jánosy Underground Research Laboratory (Csillebérc, Hungary)



Measurement noise of E-balance from low-frequency changes of atmospheric pressure



The changes of atmospheric pressure cause the tilt of the ground below the balance

Conclusions, future plans

- Sos Enattos:
 - Infrasound can be mitigated by increasing the depth
 - Windspeed has a significant effect on the spectra
 - The part of the day has less significant effect between 1 Hz and 20 Hz
 - Atmospheric pressure has an effect of seismic noise, but only below 0.3 Hz
 - Deeper investigation is needed to describe the spectral lines, for example
- Jánosgy Underground Research Laboratory
 - The tilt is planned be reproduced by a hydraulic machine
 - status: programming of the control of the machine
 - A tiltmeter will be monitoring the tilt of the ground