First results from a borehole network for the seismic characterization of the Einstein Telescope Euregio Meuse-Rhine candidate site

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Narrative and scope

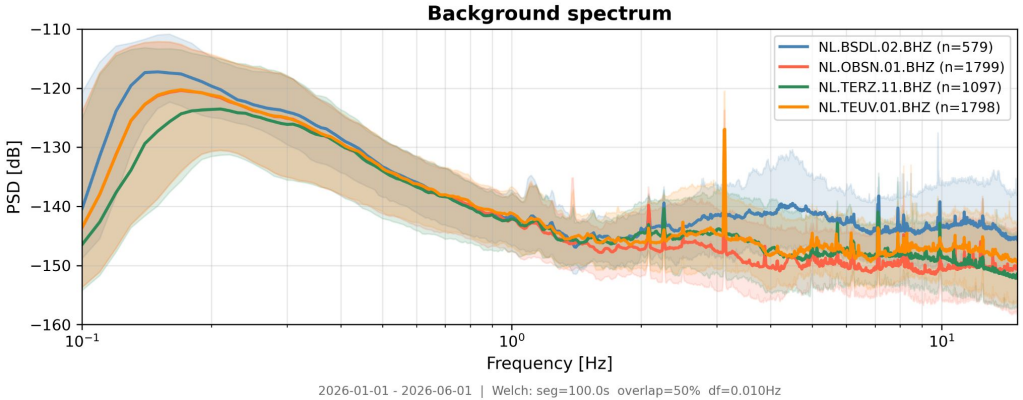
- First analysis on the **borehole network in the Terziet area**: OBSN, TEUV, TERZ, BSDL (Jan–Jun 2026)
- Explicit separation of **stationary background** vs **transients**
- The *SiteChar* package: a general-purpose Python framework for site characterization
  - available on git (we are ready for a multi-site comparison!)
- Modelling (TRAFFIC) and mitigation (Soumen) of transients
- **Framing:** boreholes sited next to the railway *on purpose*. We have developed a python package for site characterization and we have a simple algorithm to detect “transients”. Modelling and mitigation of these transients is possible but this is not the scope of this work. We will say that we are working on it, showing promising results.

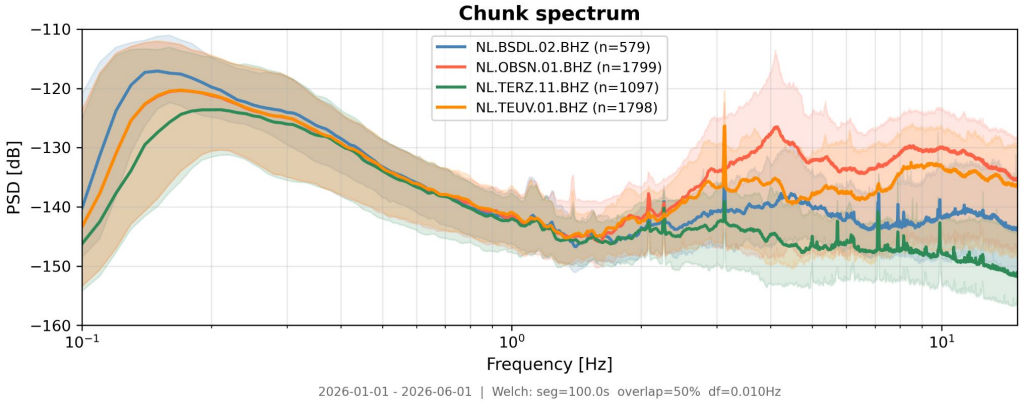
Trigger detection

- Data processed in sequential **2h chunks**; raw samples discarded after each chunk
- SpectrogramS(f,t): Hann, 20s segments, 50% overlap → $\Delta t = 10$ s, $\Delta f = 0.05$ Hz
- Per-frequency standardization: median and MAD of $\log_{10} S(f,t)$, estimated **on each block (from Soumen's codes)**
- Statistic: median of the standardised spectrogram over 2–15 Hz → **z(t)**
  - Trigger: $z > 2.5$ for ≥ 10 s; adjacent columns merged; 30 s guard margin
  - 1 unit of $z \approx 3.5$ dB → threshold ≈ 9 dB above the local floor
- Duration = FWHM of z(t), not time above threshold
- Three spectra per chunk: **chunk** (everything), **background** (longest quiet stretch), **event** (single transient, always as ratio to background)

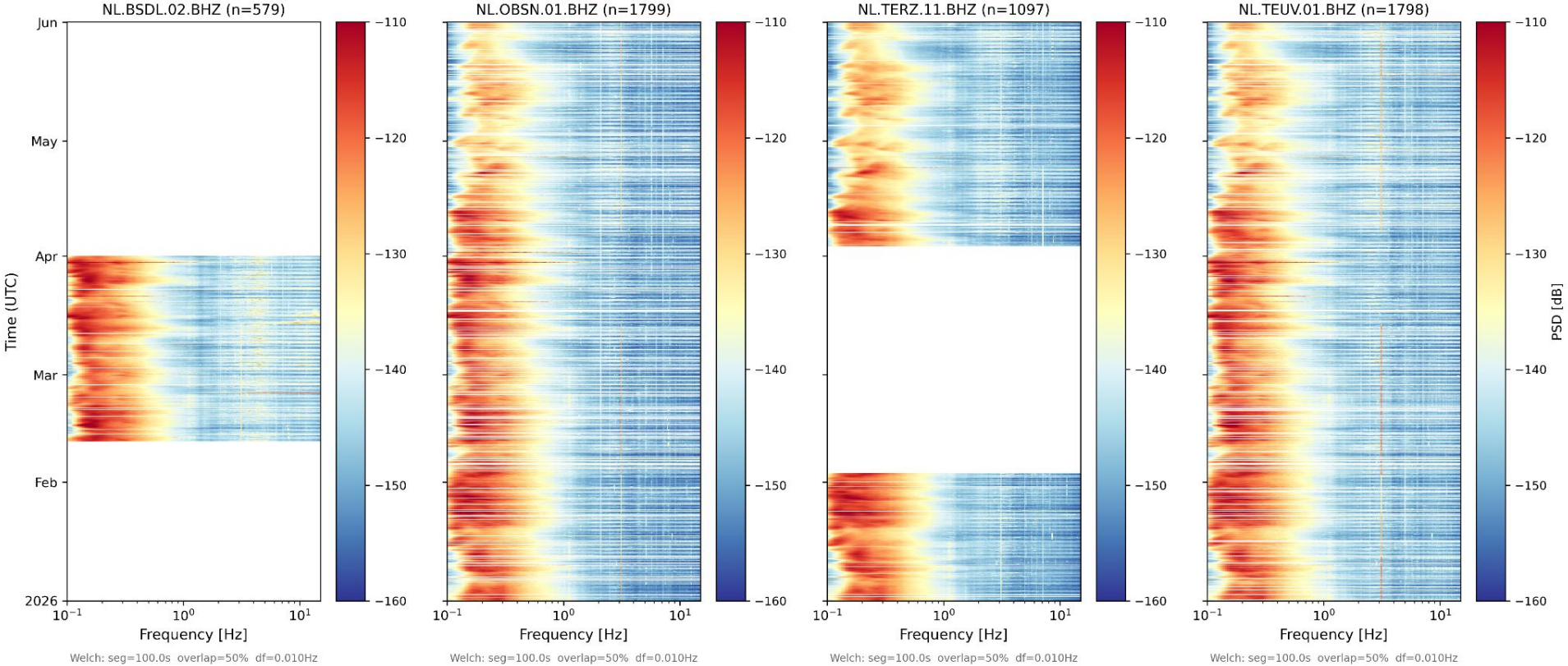
Background analysis

- **Vertical component only**
- Coverage differs between stations
- Δt = 100 s, Δf = 0.01 Hz
- BSDL: 30 m channel only (320 m unreliable)



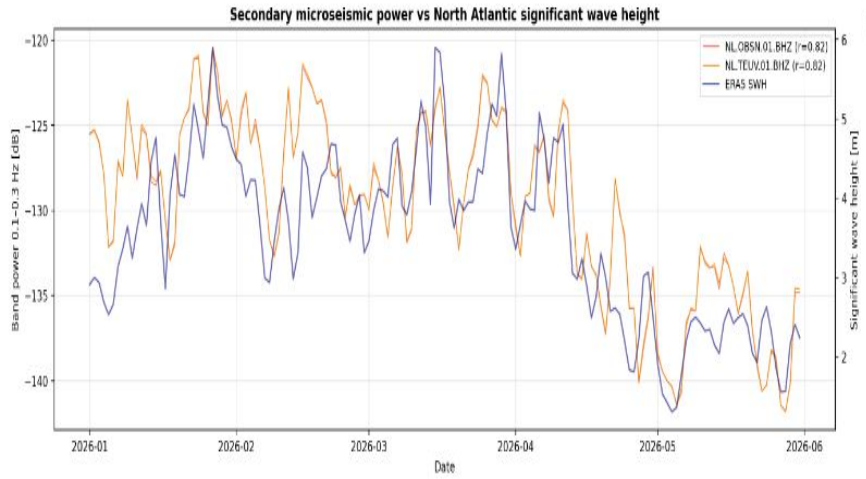


Background PSD over time

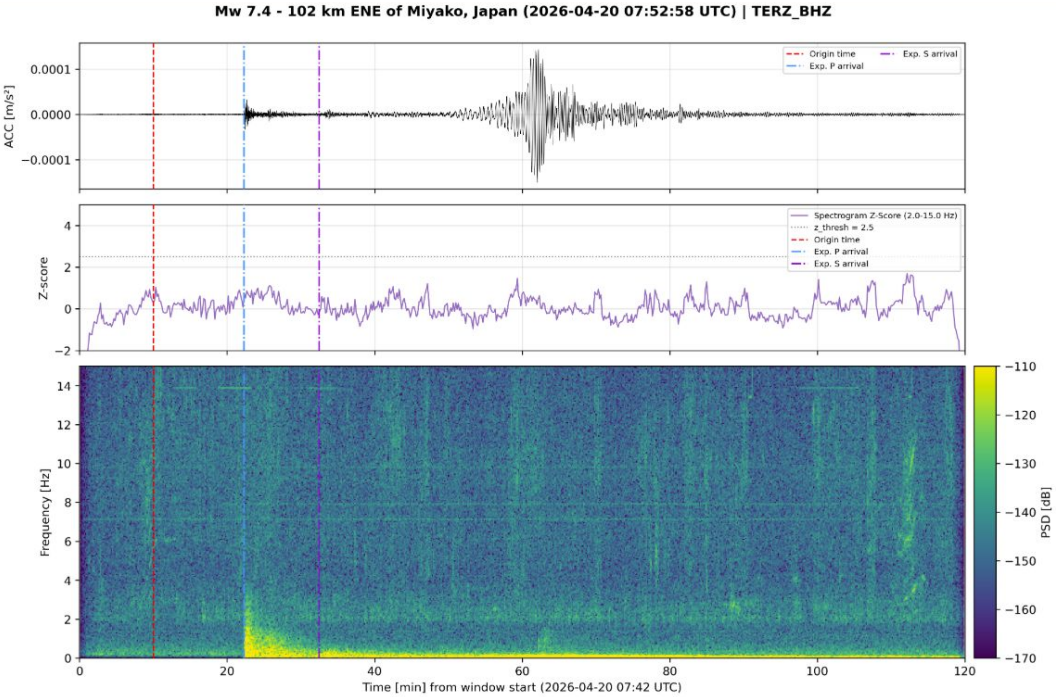


Microseism region

North Atlantic wave correlation



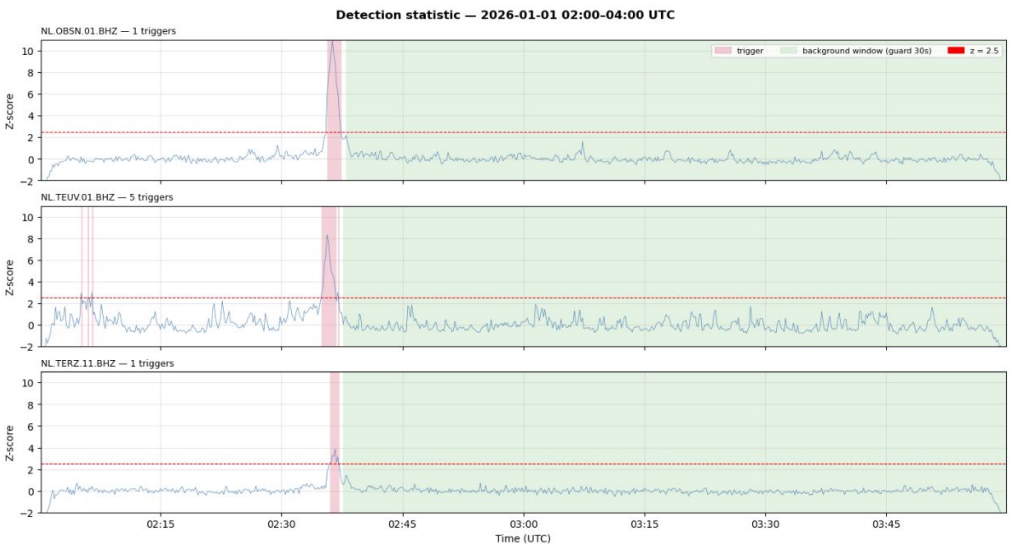
Strong earthquake

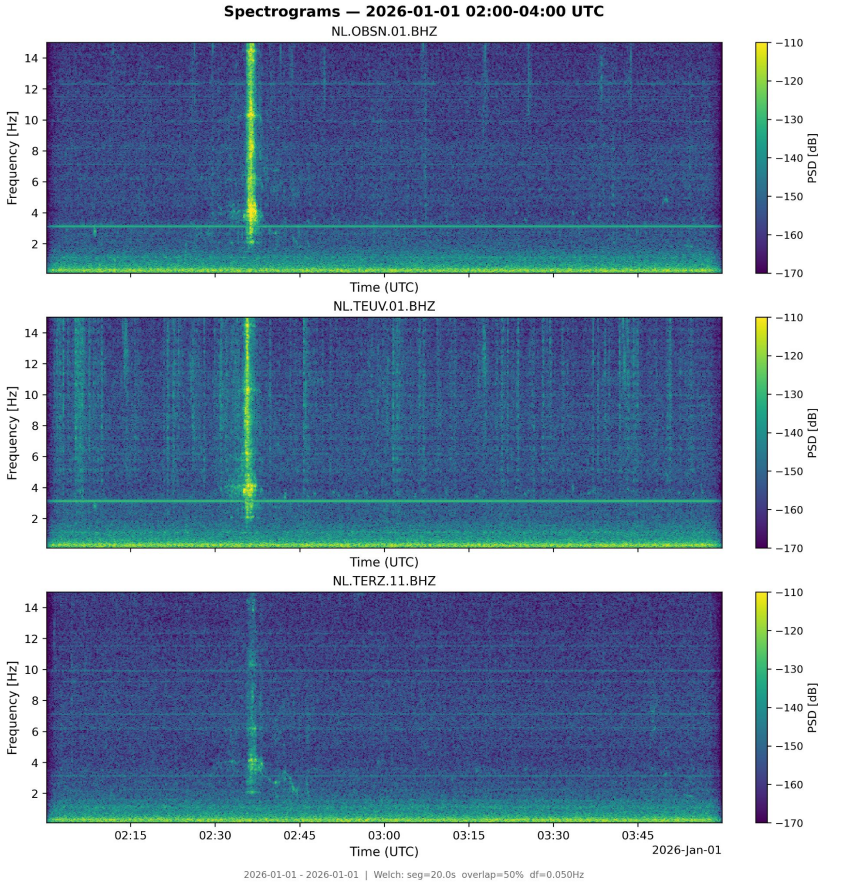


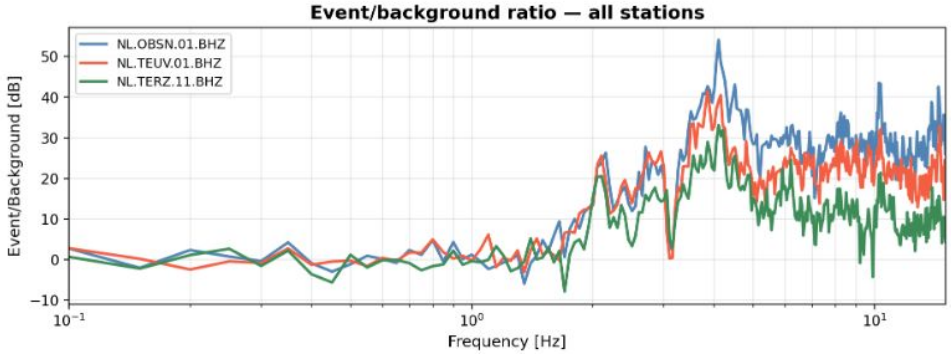
Local earthquake are instead clearly detected in the 2-15 Hz band and included in the event catalogue…

Analysis of single event

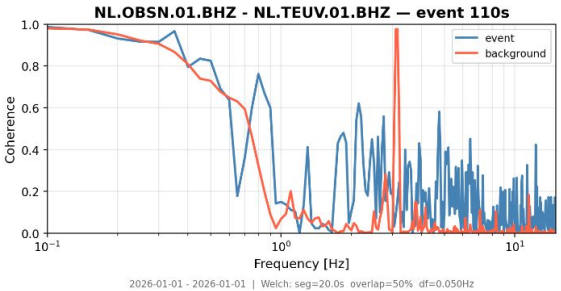
- One of the first coincident events
- Likely a train, first seen in TEUV
- Trigger length ≈ 110 s
- Background length depends on the sensor:



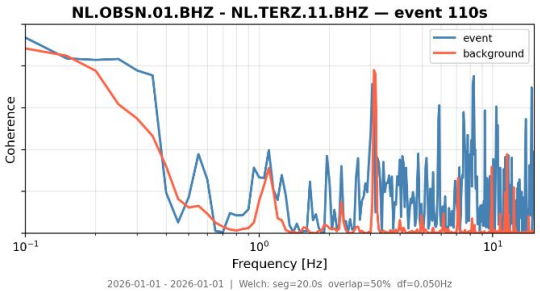




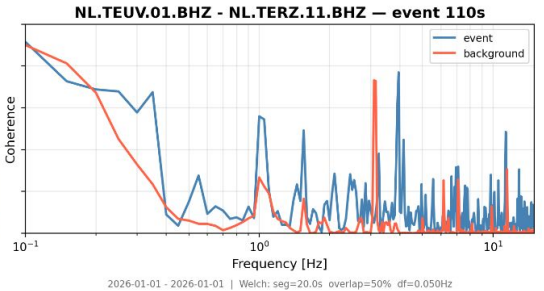
Inter-station coherence (borehole sensors)



2026-01-01 - 2026-01-01 | Welch: seg=20.0s overlap=50% df=0.050Hz

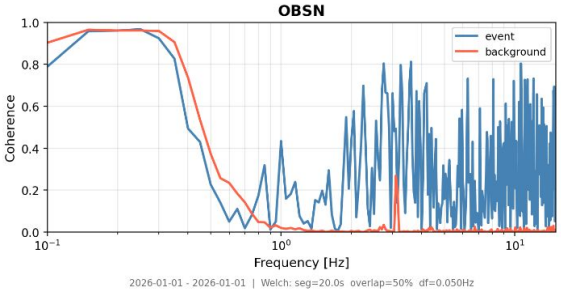


2026-01-01 - 2026-01-01 | Welch: seg=20.0s overlap=50% df=0.050Hz

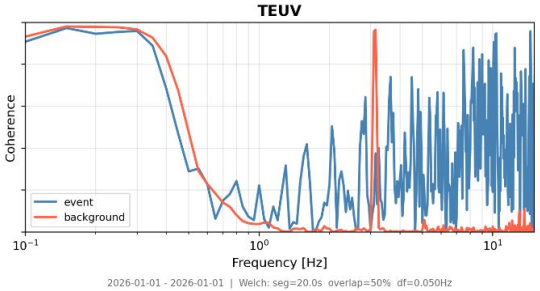


2026-01-01 - 2026-01-01 | Welch: seg=20.0s overlap=50% df=0.050Hz

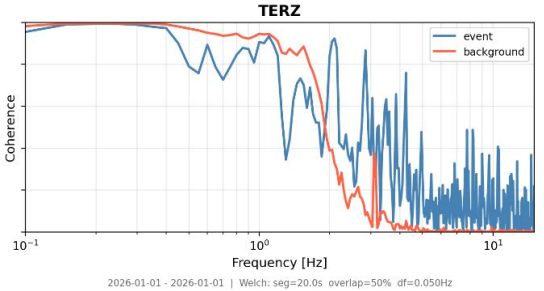
Intra-station coherence: borehole vs surface



2026-01-01 - 2026-01-01 | Welch: seg=20.0s overlap=50% df=0.050Hz



2026-01-01 - 2026-01-01 | Welch: seg=20.0s overlap=50% df=0.050Hz



2026-01-01 - 2026-01-01 | Welch: seg=20.0s overlap=50% df=0.050Hz

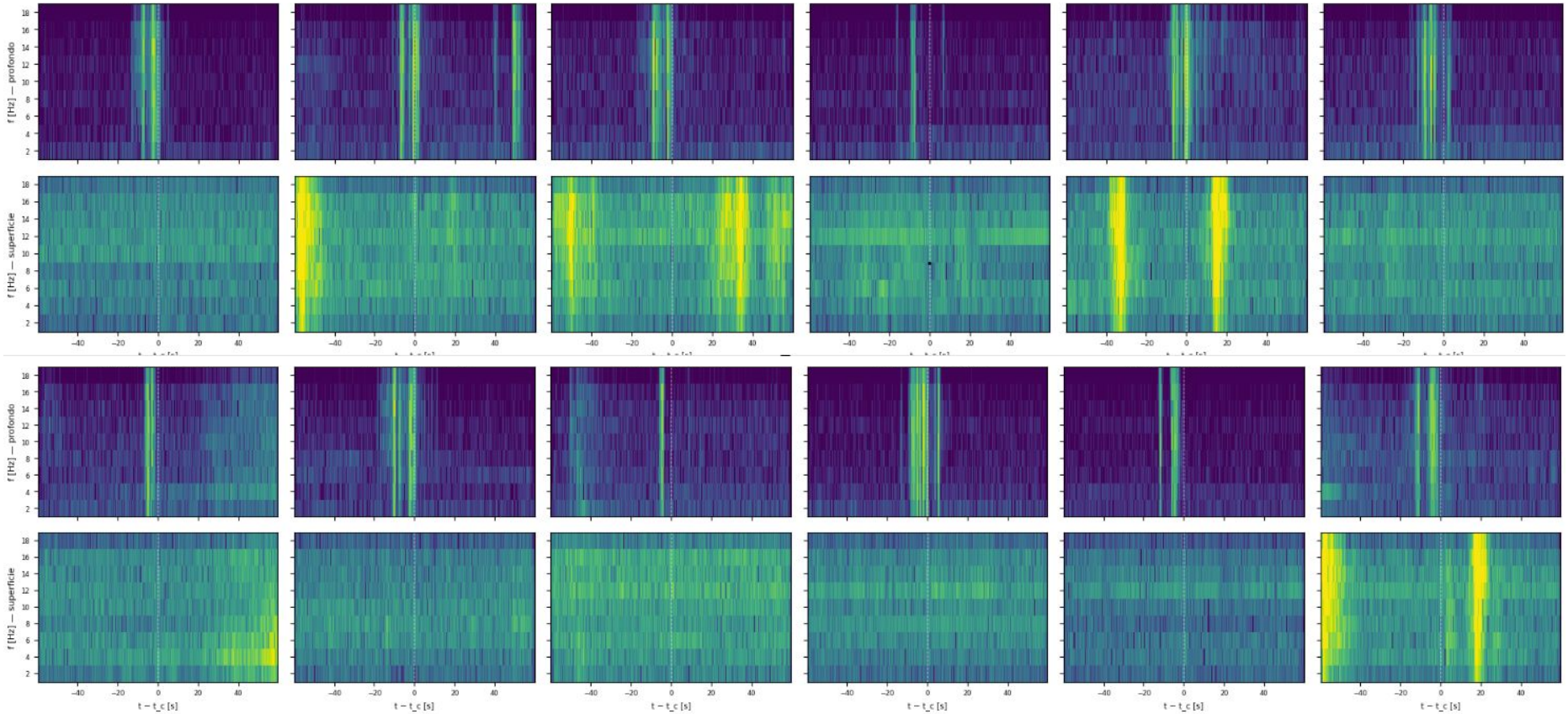
“All events” plots

Preliminar results…

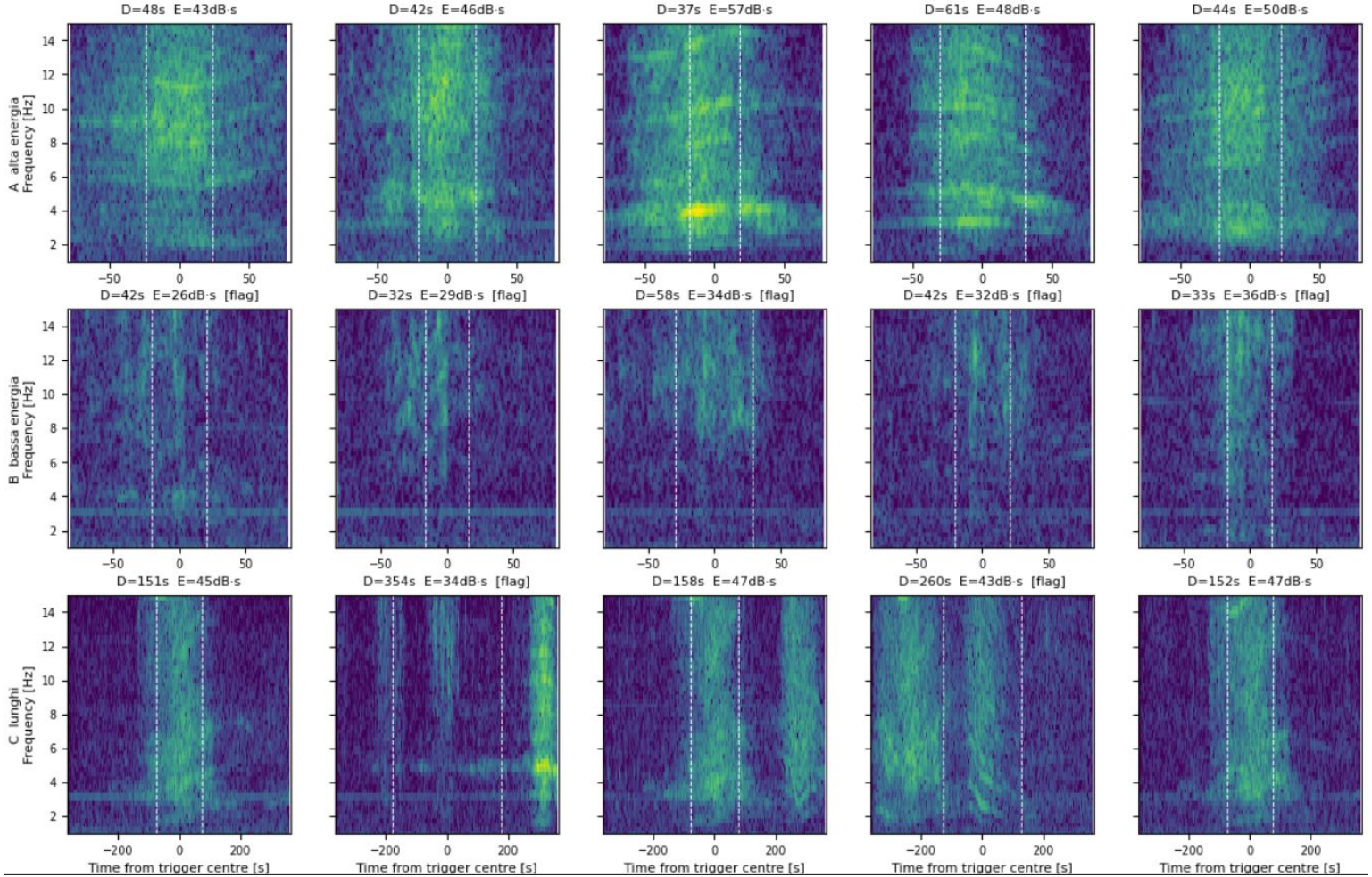
BIAS: only dur > 20s

Short events at OBSN

1s resolution, much shorter than the 10 s of the z(t)



OBSN



Inter-station coincidence

Intra-station coincidence

no coincidence but strange…

Open problems

- I am not convinced on the estimation of the trigger duration
  - running on mock injections with known duration in real background
  - In OBSN and TEUV, close triggers complicate the analysis
- Identification of the origin of thousands of triggers is not possible today
  - no (reliable) Infrabel database
  - populations depends on the sensors (see OBSN short transients)
  - I can not look at thousands of spectrograms individually…
- Rough classification using coincidence
  - no coincidence with surface → borehole trigger
  - only coincidence with surface → local trigger
  - intra-station coincidence → train (or local earthquake)
- From this rough classification → analyze spectral shape, duration, hour/week distribution that must have a clear signature

If you would like to contribute,

- **testing SiteChar**
- **working on tutorials**
- **proposing new analysis**
- **reviewing the draft paper**
- **searching stranger things**

please contact me!

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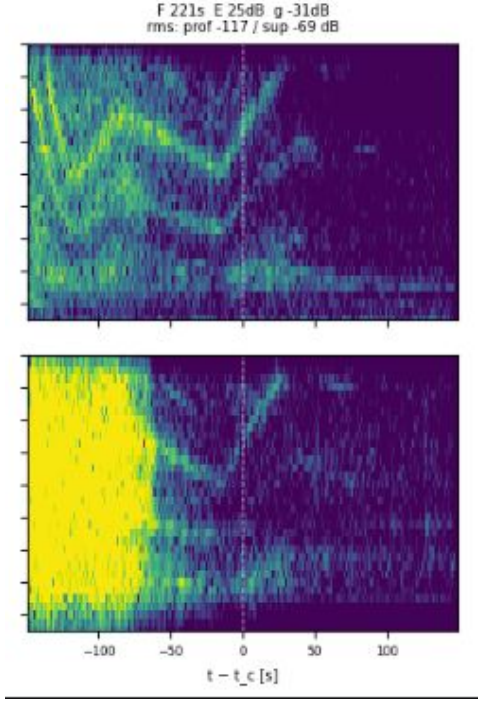
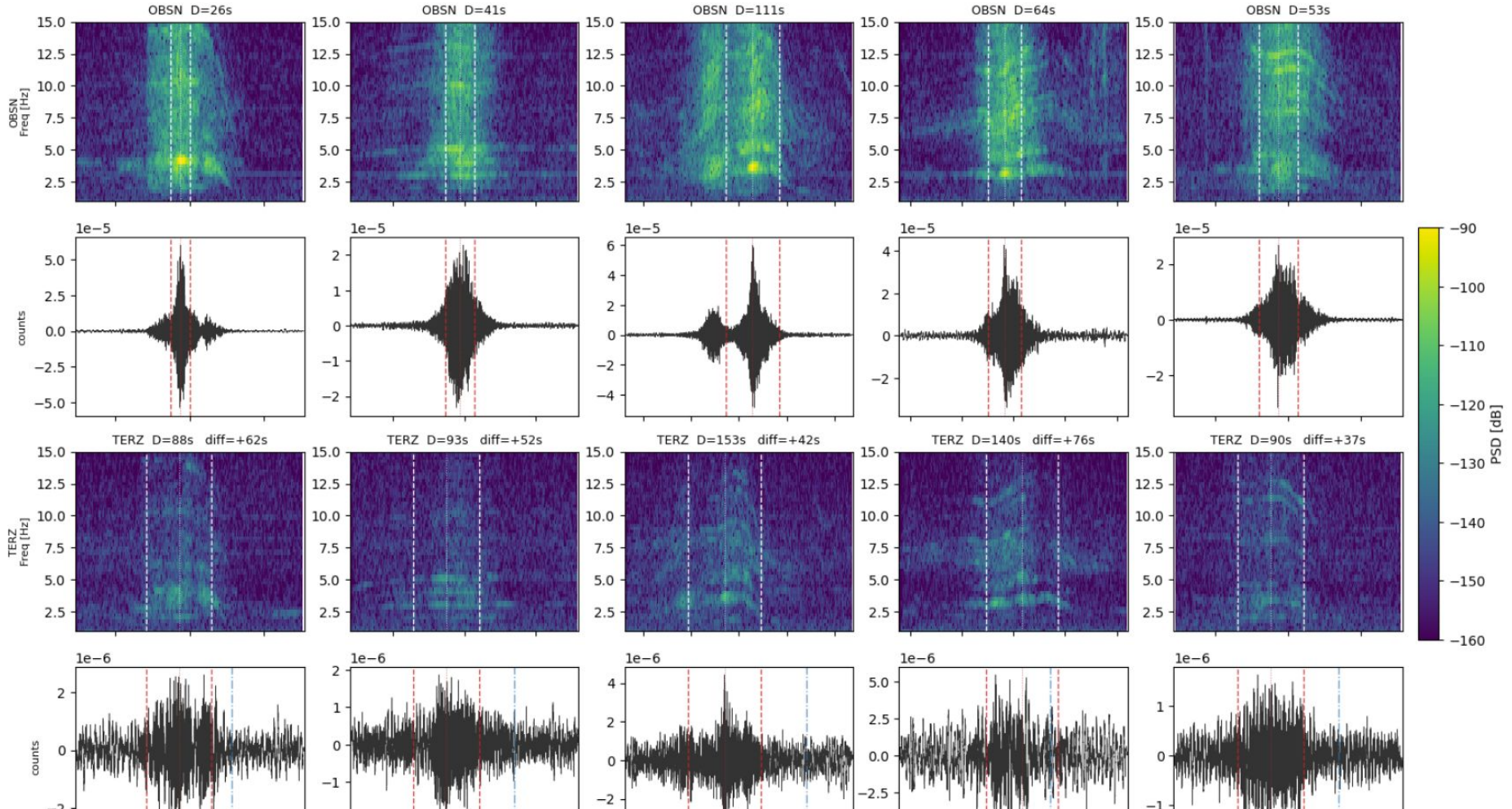
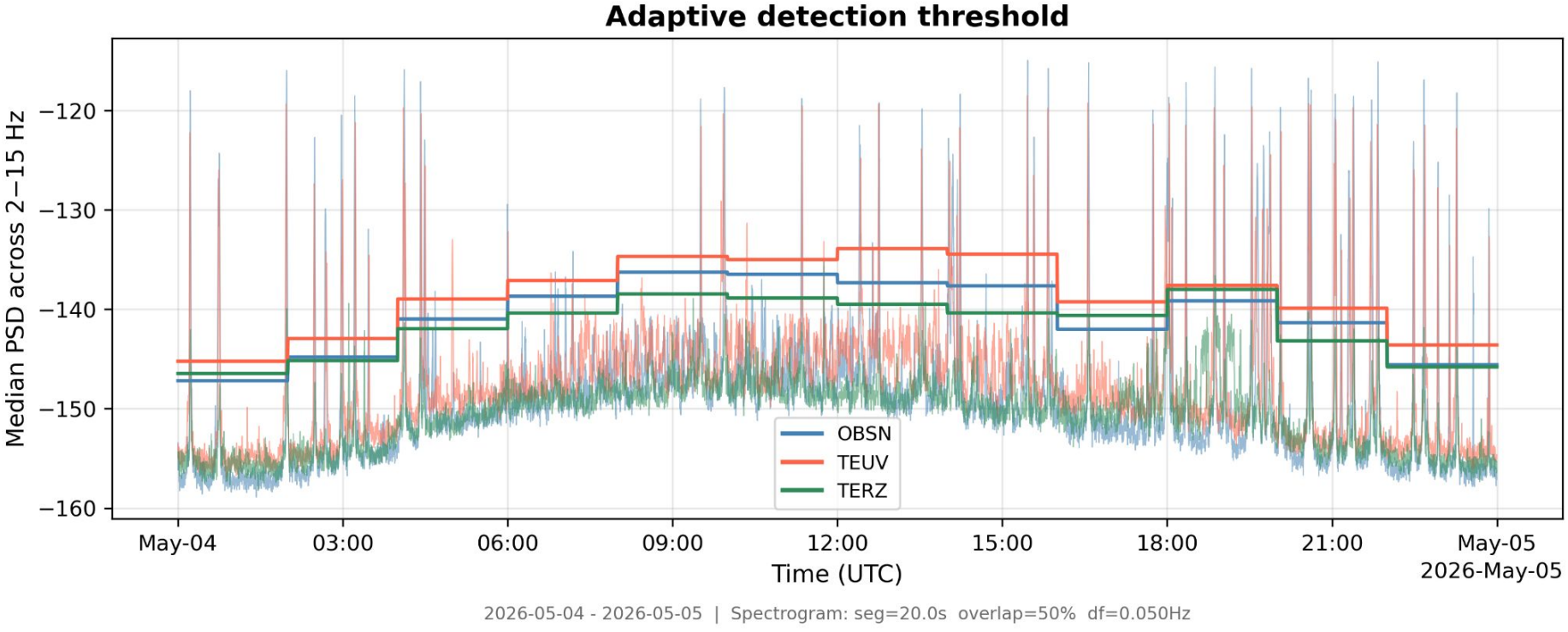



OBSN D=26s
OBSN D=41s
OBSN D=111s
OBSN D=64s
OBSN D=53s
OBSN Freq [Hz]
counts
1e−5
TERZ D=88s diff=+62s
TERZ D=93s diff=+52s
TERZ D=153s diff=+42s
TERZ D=140s diff=+76s
TERZ D=90s diff=+37s
TERZ Freq [Hz]
1e−6
PSD [dB]


Adaptive detection threshold
Median PSD across 2−15 Hz
−120
−130
−140
−150
−160
OBSN
TEUV
TERZ
May-04
03:00
06:00
09:00
12:00
15:00
18:00
21:00
May-05
2026-May-05
Time (UTC)
2026-05-04 - 2026-05-05 | Spectrogram: seg=20.0s overlap=50% df=0.050Hz

The instrument response is removed with output='ACC', so the underlying signal is in SI units (m/s^2) before the spectrogram is computed.

The dB conversion is 10*log10(PSD), with no explicit normalization constant, which corresponds to an implicit reference of 1 (m/s^2)^2/Hz. So the units are dB re 1 (m/s^2)^2/Hz (the same convention used for the Peterson NLNM/NHNM noise curves, so the values should be directly comparable to those).

-140 dB re 1 $(m/s^2)^2/Hz$ converts back to linear units as: PSD = 10^(-140/10) = $10^{-14}(m/s^2)^2/Hz$

$PSD2 = PSD1 \times 10^{9/10} = PSD1 \times 7.94$