

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

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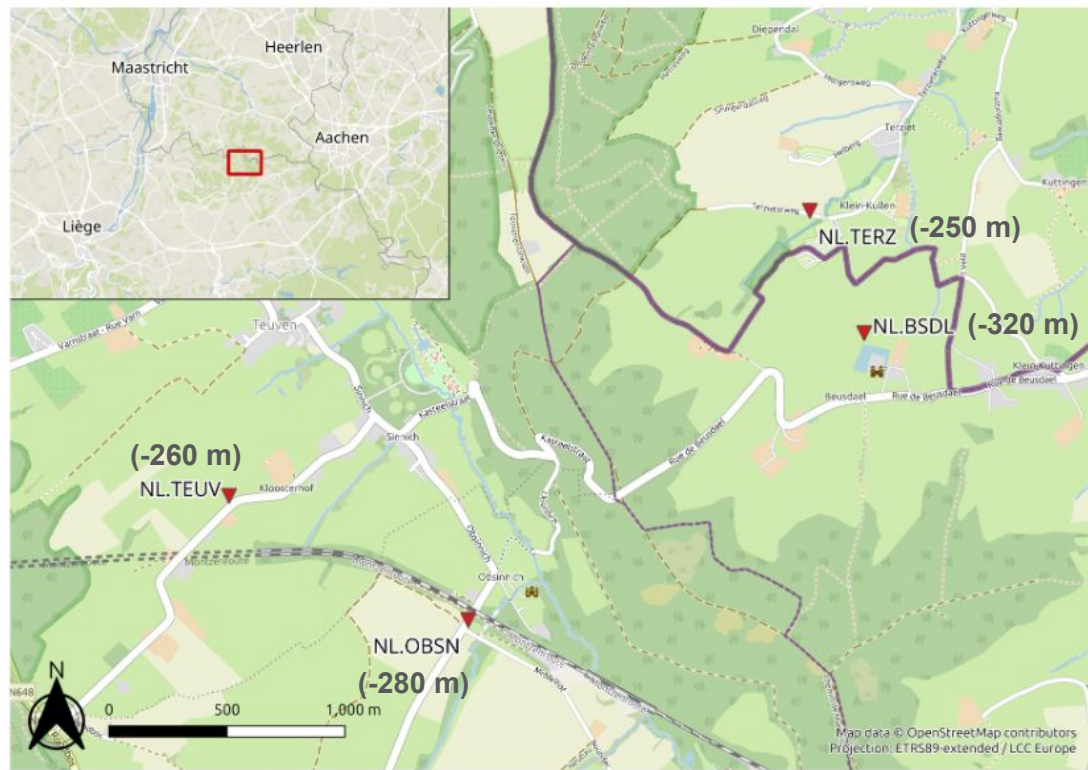
Luca D'Onofrio
Belgian-Dutch Gravitational Wave Meeting
7-9/10/2026

Narrative and scope

- First results from the borehole network in the Terziet area: OBSN, TEUV, TERZ, BSDL **(Jan–Aug 2026)**
- Boreholes sited next to the railway **on purpose** → we measure how anthropogenic noise is generated and attenuated in this geology, not corner-point levels
- A step in the EMR effort towards an integrated noise model: 3D geology + measured field + propagation → numerical NN → mitigation
- NO NN estimation in this paper!

What's new in the paper

- **SiteChar**: a general-purpose Python framework for site characterization, agnostic to sensor and scale; on git.et together with the catalogue (private for now, just ask me)
- Explicit separation of background vs transients, with a simple detection algorithm
- Characterization of the transient catalogue and a tentative classification
- Tentative modelling with TRAFFIC (tool by KULouvain)



SiteChar

Dataset → 2-hours chunk → triggers → background

- **The chunk spectrum** “what does the ambient seismic field look like overall, transients included, averaged over this period?”
- **The background spectrum** “what is the seismic field like in the absence of the fast disturbances that were detected?”
- **The event spectrum** “how much a given transient elevates the noise level above the ambient background?”

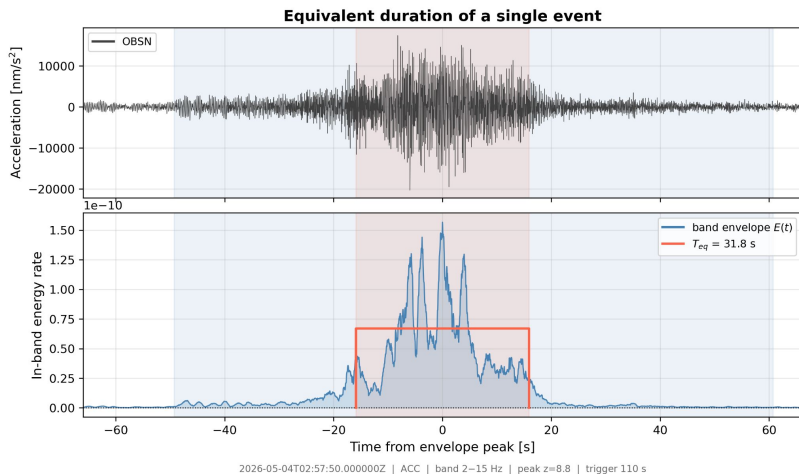
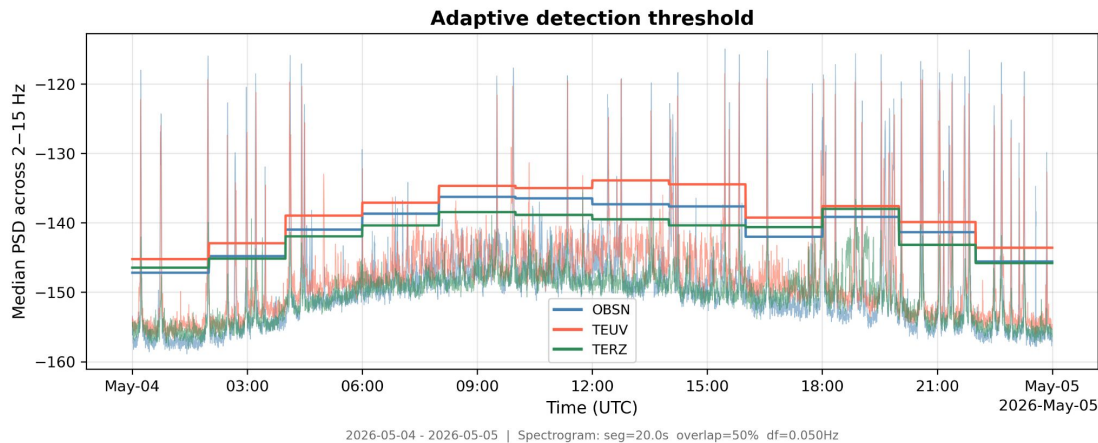
triggers → catalog → analysis single-event → population analysis

Z-score

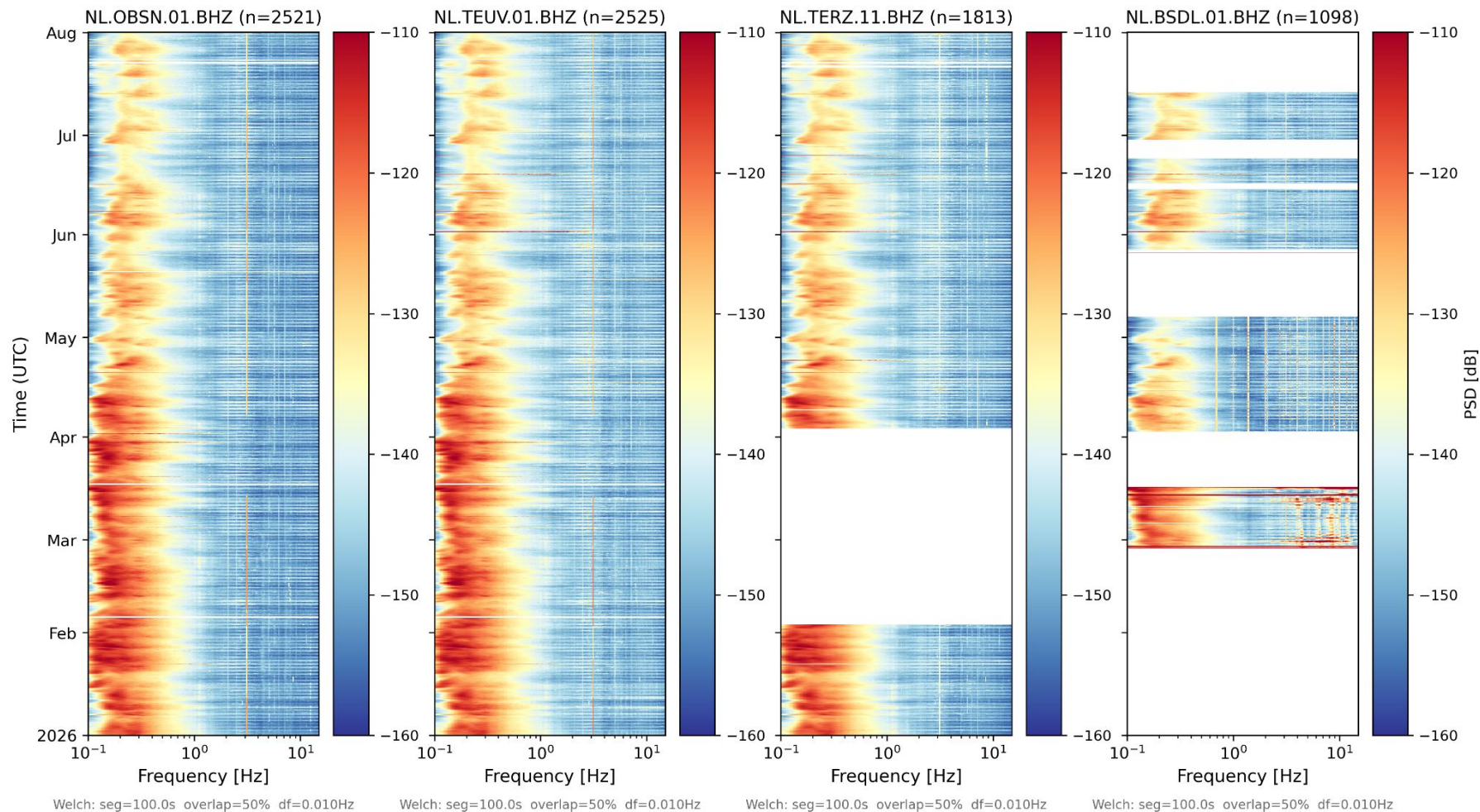
$$z(t) = \underset{f_1 \leq f \leq f_2}{\text{med}} \frac{\log_{10} S(f, t) - m(f)}{\text{MAD}(f)}$$

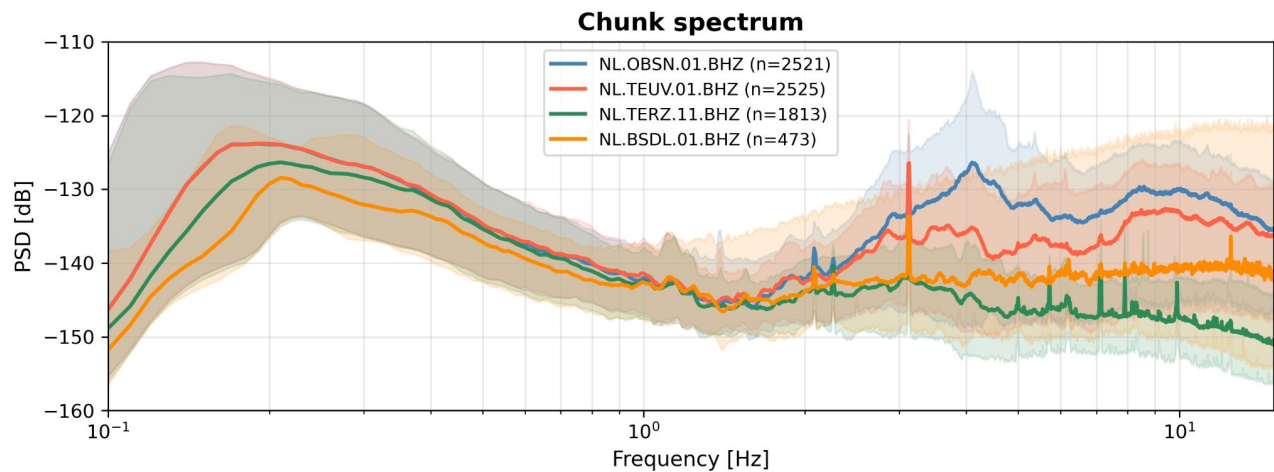
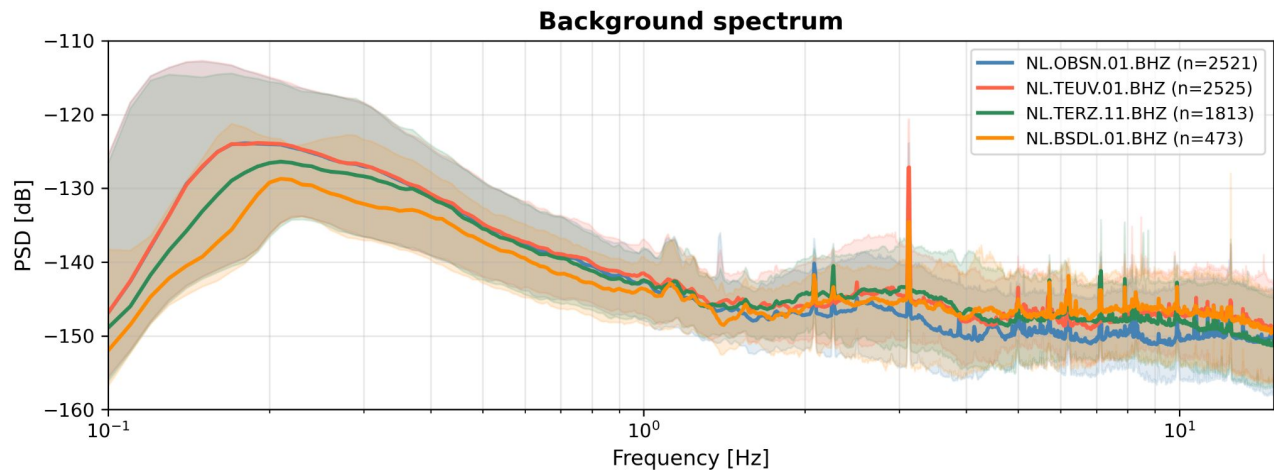
Equivalent duration

the duration of a rectangular pulse with the same (90%) energy and effective power as the observed transient



Background PSD over time

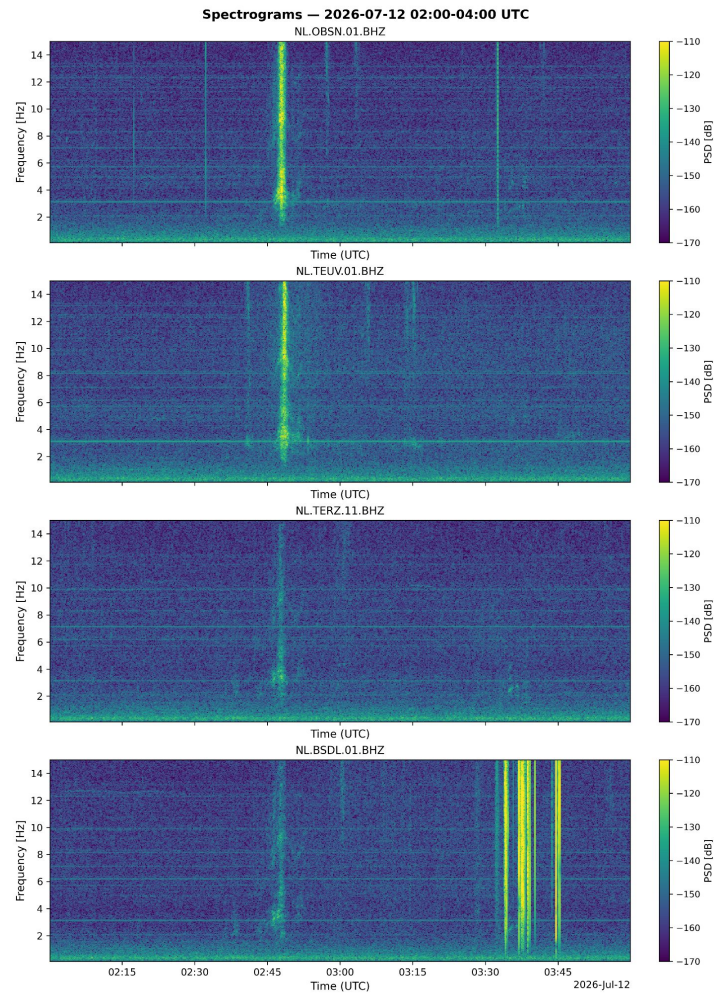




Single-event analysis

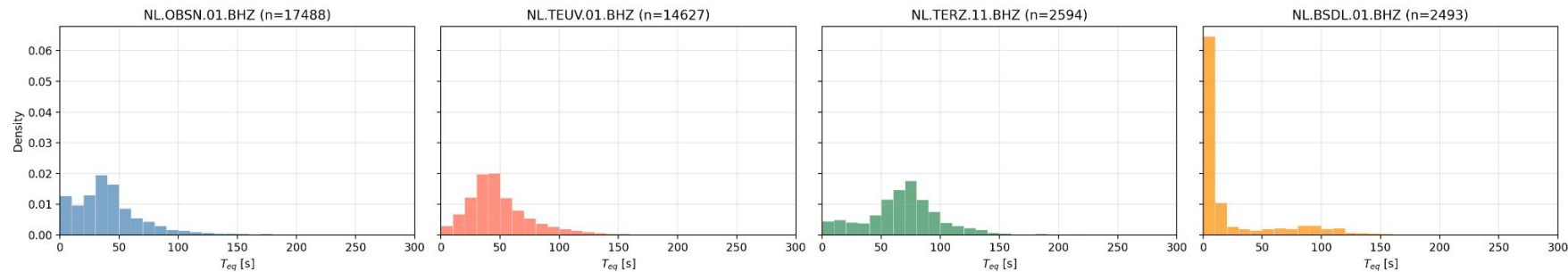
- Timeseries, narrowband spectrum, event/background ratio
- Including corresponding surface sensor for each station: coherence, attenuation, detection statistic
- Details of this and other 4-sensors coincident events at the public link: https://www.nikhef.nl/~ldonofri/single_events/index.html

station	triggers [$z > 2.5$]	analyzed hours	rate [h^{-1}]	flagged time
OBSN	17 488	5042	3.5	7.5%
TEUV	14 627	5050	2.9	5.9%
TERZ	2594	3626	0.7	0.5%
BSDL	2493	946	2.6	1.8%

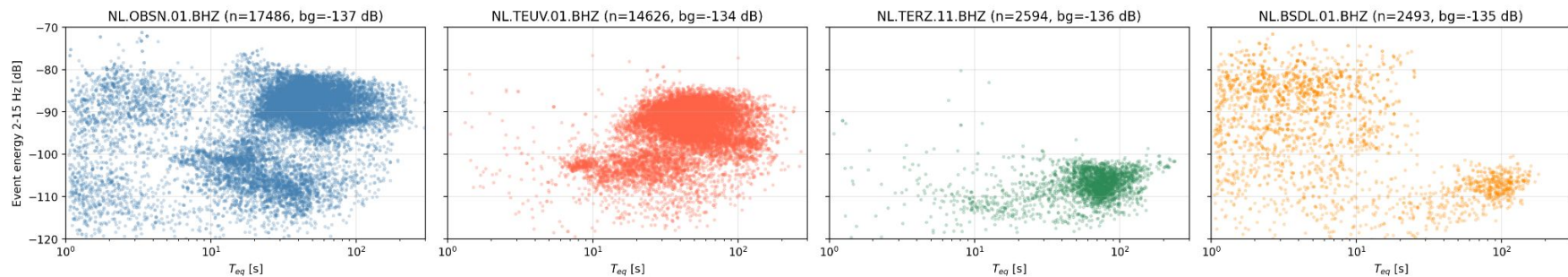


Catalog analysis

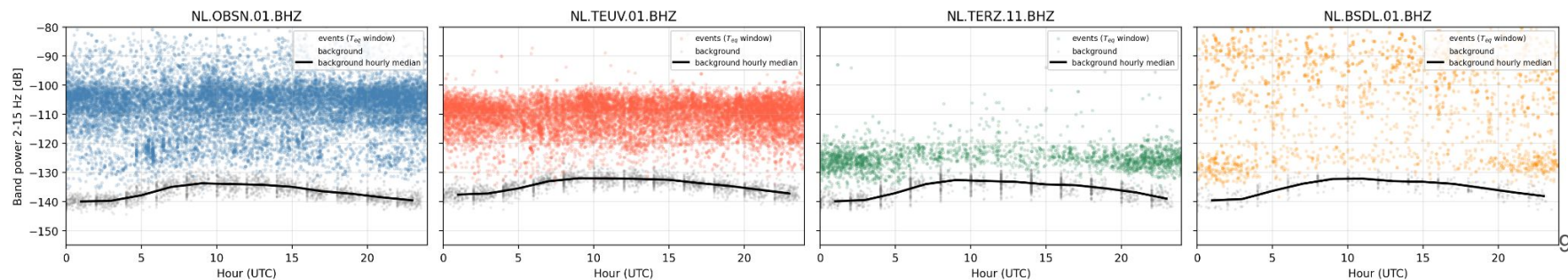
Transient duration (T_{eq})



Event energy vs duration



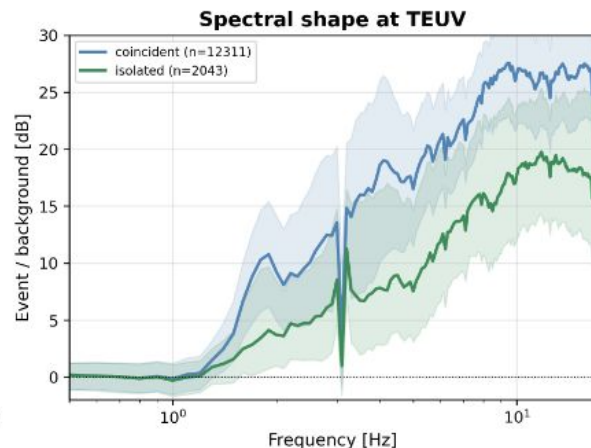
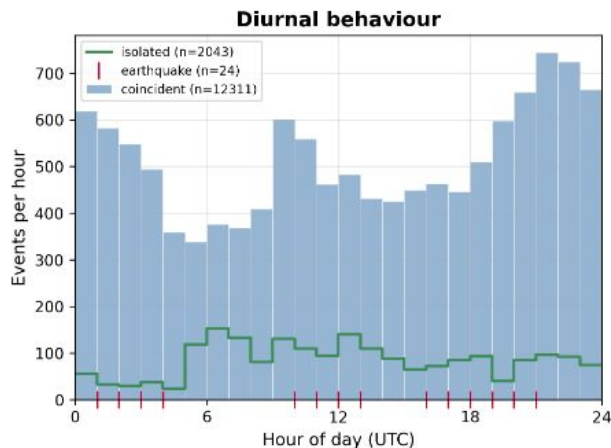
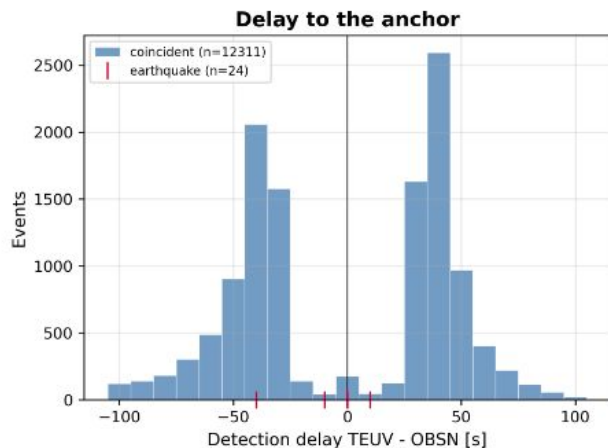
Event intensity and background level vs hour of day



Coincidence: Two triggers at different stations are coincident if their z-score peaks are within 100 s; pairs are formed one-to-one, starting from the smallest delay.



TEUV - OBSN coincidences

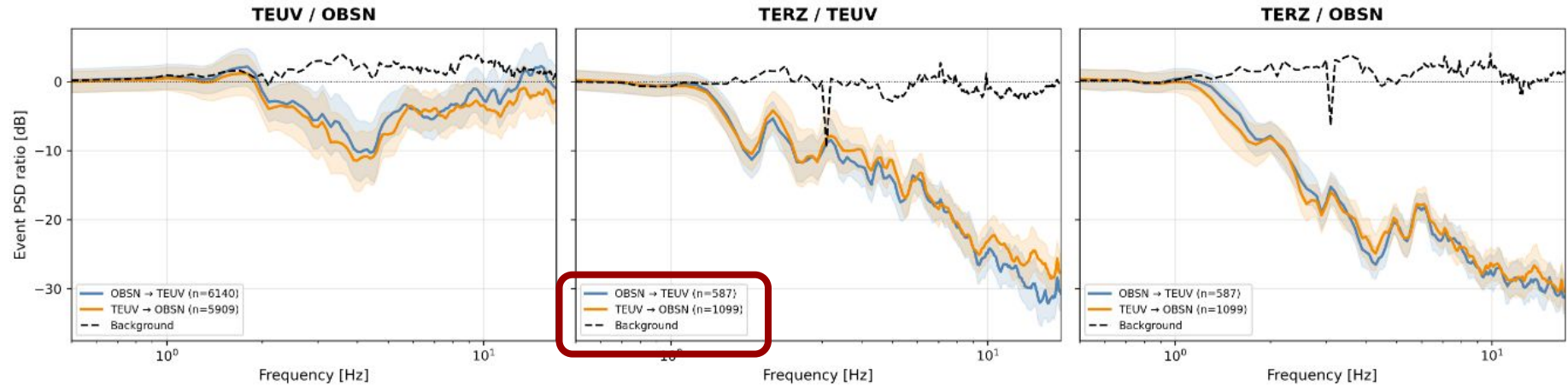


maxima at ± 40 s $\rightarrow v \approx 90$ km/h

85% of TEUV events are coincident with OBSN



Event PSD Ratio for Coincident Triggers



Conclusion

- **First analysis of a borehole network:** 4 boreholes, first 7 months of 2026
 - **SiteChar:** common analysis framework for site characterization
 - Catalog of detected triggers
- Once fast non-stationarities are excluded, the four boreholes describe essentially the same stationary field. **The background is itself non-stationary:** 5–8 dB diurnal cycle above 1 Hz, while the seasonal microseism follows the North Atlantic swell
- **Trains dominate the transient catalog** and are seen at all stations, including TERZ (2.5 km away). Short glitches at OBSN and BSDL to be understood
- Coincidence resolves the transit along the line and splits the catalog into classes, but single events cannot be labelled without traffic data
- **Transients exceed the local background by tens of dB, a few times per hour** → NN mitigation schemes designed against a stationary field will need also this population as input (for seismic we should be safe but experts opinion is needed)

Thanks!

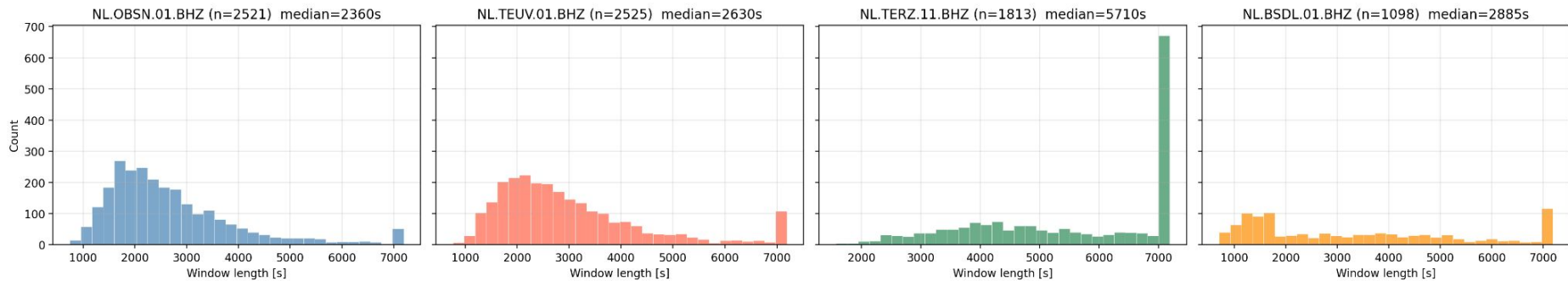
public page to single event analysis:

https://www.nikhef.nl/~ldonofri/single_events/index.html

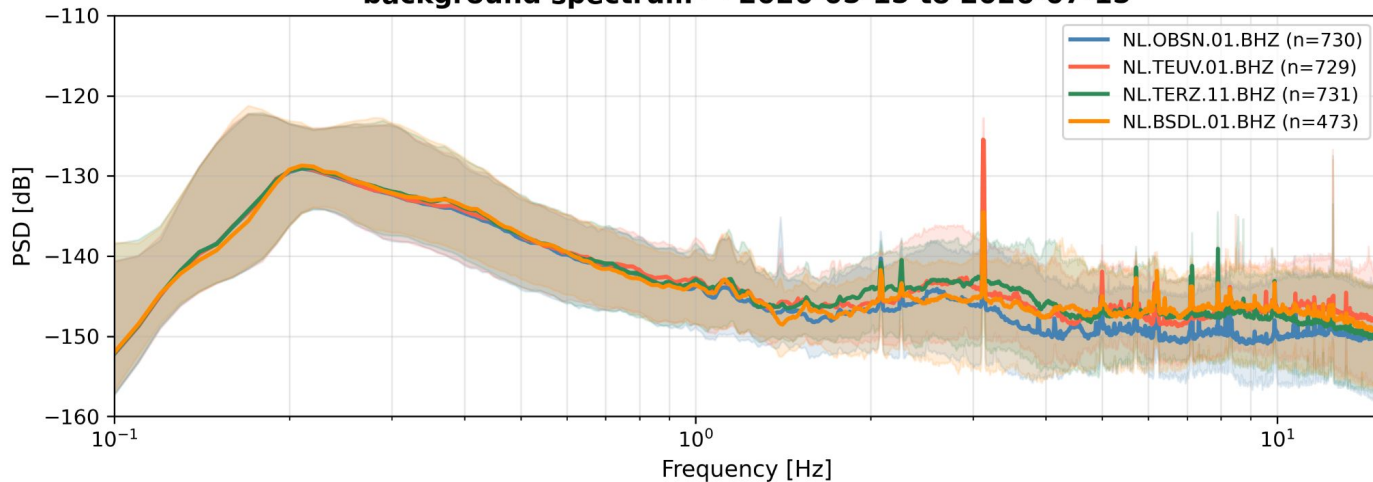
git SiteChar: <https://gitlab.et-gw.eu/donofrio/SiteChar>
(for now private, ask me to have access)

ET internal review ongoing, paper on arxiv soon

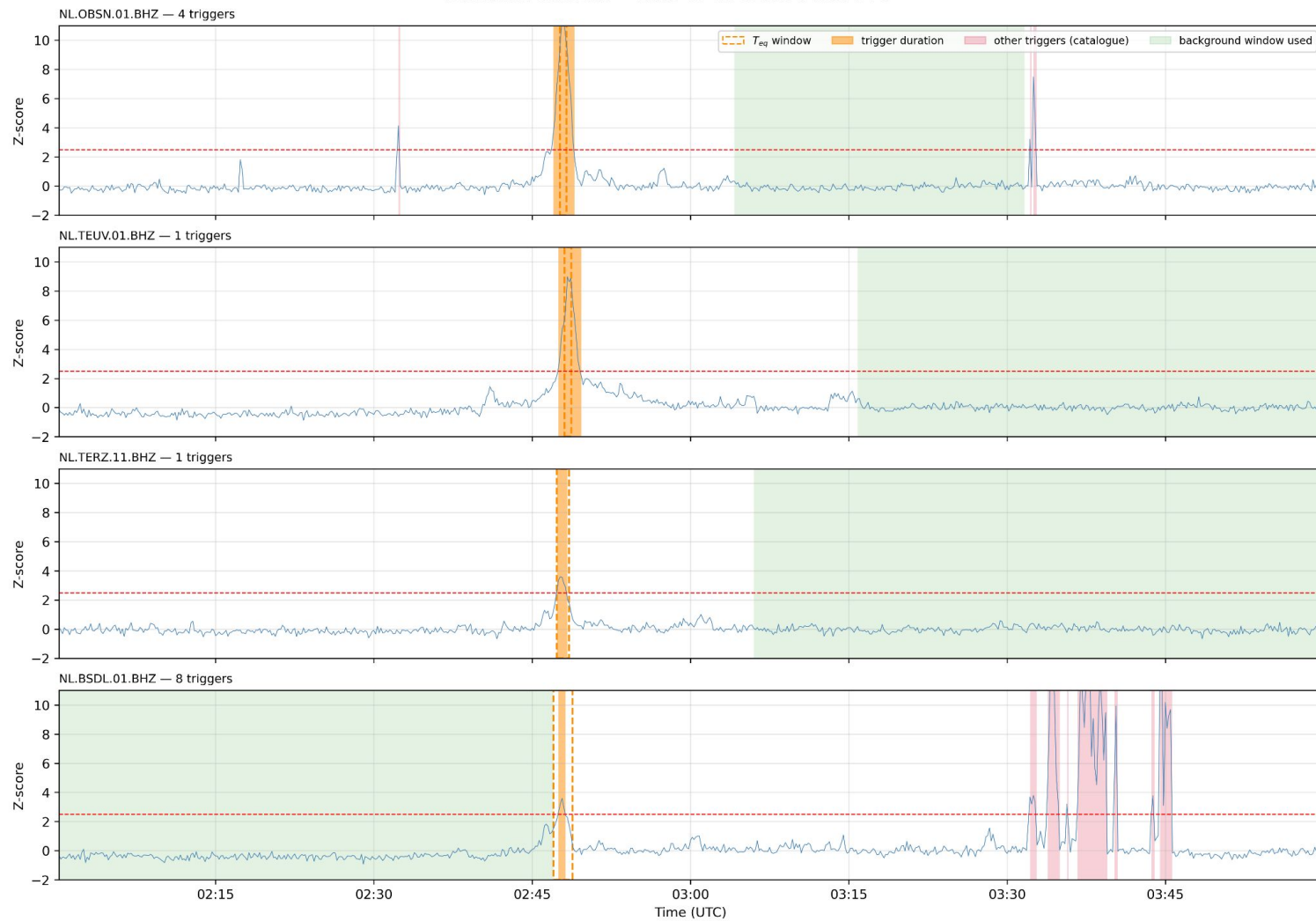
Background window length distributions



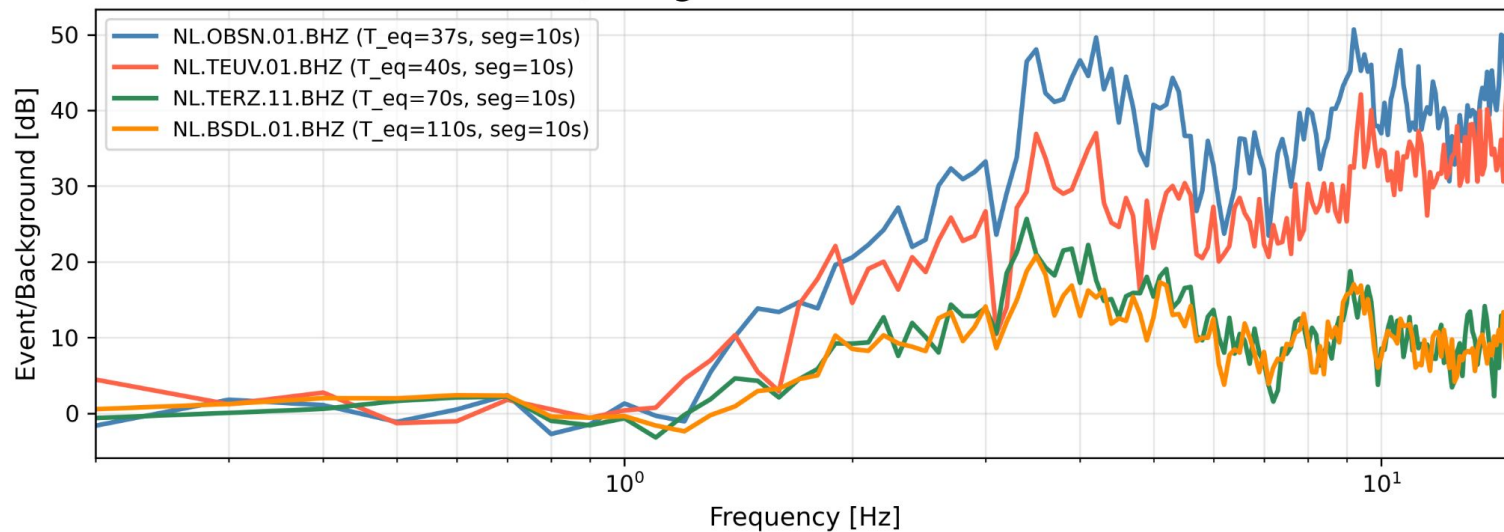
background spectrum — 2026-05-15 to 2026-07-15



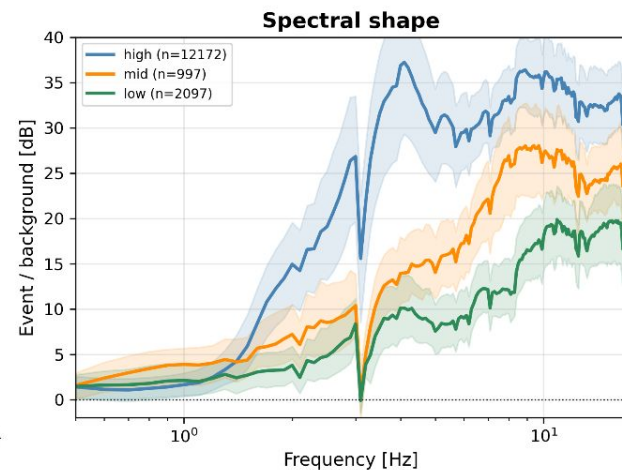
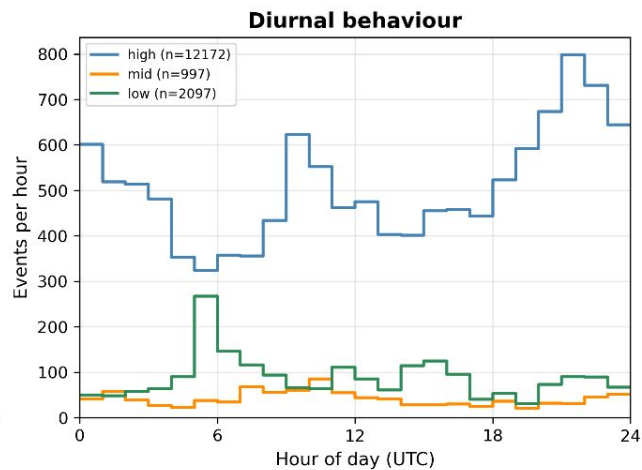
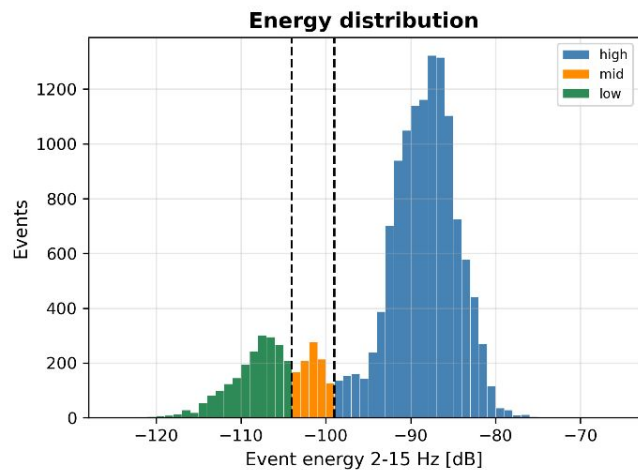
Detection statistic — 2026-07-12 02:00-04:00 UTC

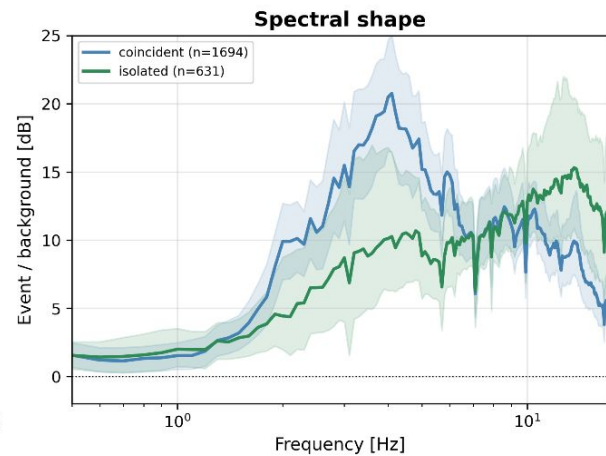
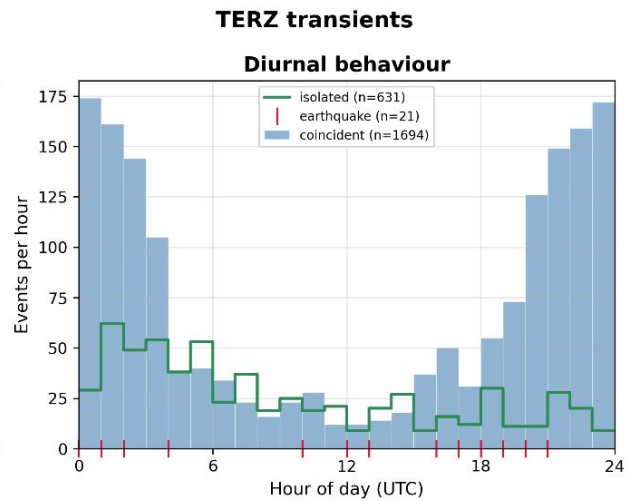
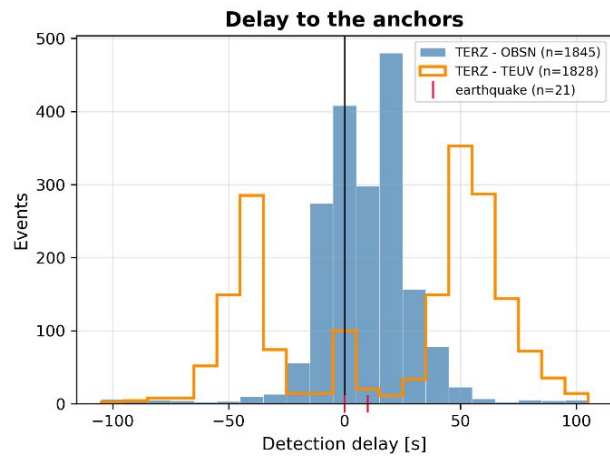


Event/background ratio — all stations



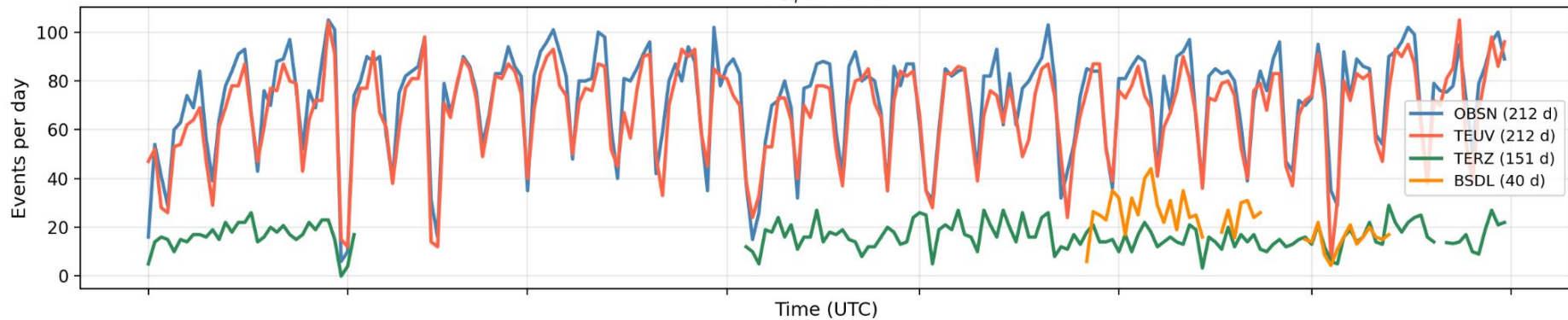
OBSN (teq ≥ 10 s), no coincidence used





Daily detection rate

$T_{eq} \geq 10$ s



$T_{eq} < 10$ s

