Source Parameter Determination Using a Spectral Decomposition Approach in the central-southern Europe

M-H Yen[1,2], D. Bindi[1], R. Zaccarelli[1], A. Oth[3], B. Edwards[4] and F. Cotton[1,2]

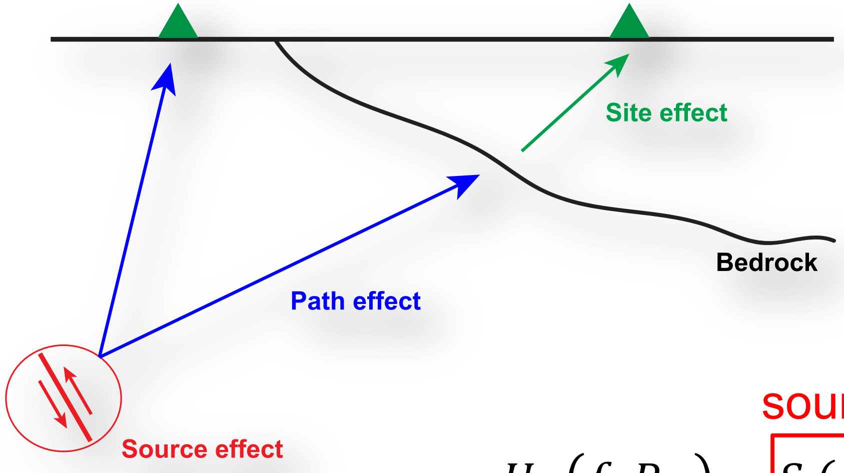
[1] GFZ-German Research Centre for Geosciences, Germany
[2] University of Potsdam, Germany
[3] European Center for Geodynamics and Seismology, Luxembourg
[4] University of Liverpool, England

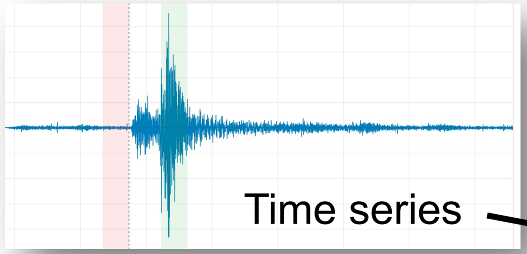
GFZ Helmholtz Centre Potsdam

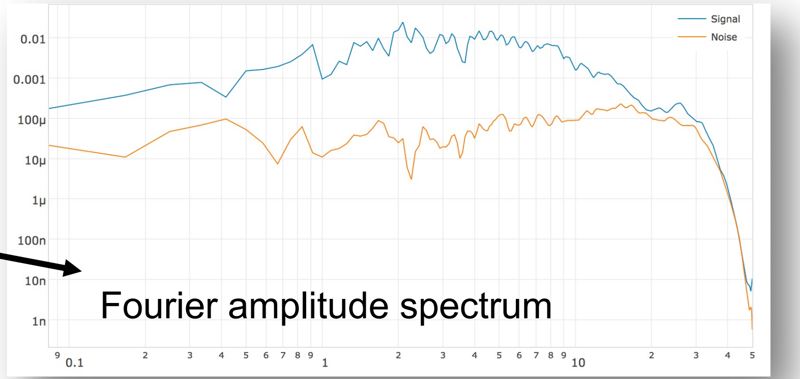
HELMHOLTZ

Overview of the study

- **Motivation:** source parameter, stress drop, is a key parameter estimating strong ground motion, as it controls the level of peak ground acceleration and the high frequency shaking.
- **Target:** deriving the variability of the source parameters in the central-southern Europe for future physical based simulations
- **Strategy:** performing a non-parametric spectral decomposition approach to isolate the source, path, and site contribution, fitting source spectra with an ω^2-model





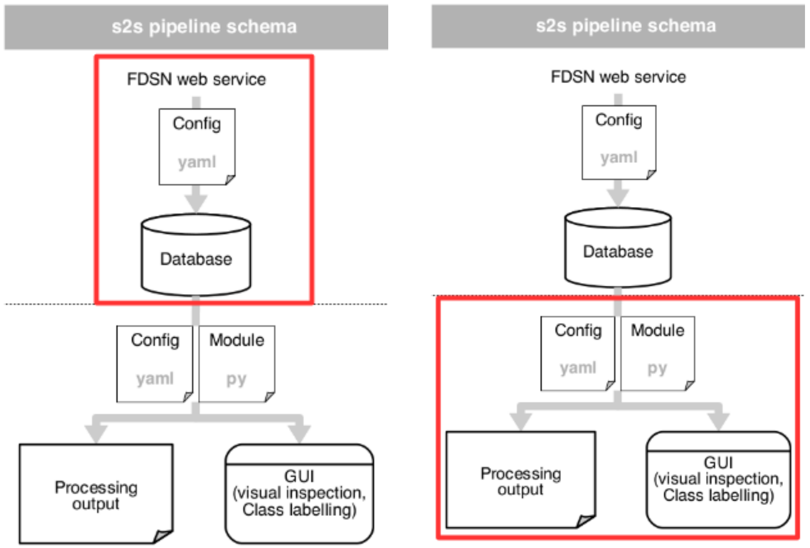


source path site

$$U_{ij}(f,R_{ij}) = \boxed{S_i(f)} \cdot \boxed{A(f,R_{ij})} \cdot \boxed{G_j(f)}$$

Data Collection

✓ Take advantage of easy & fast accessible large volume of seismic data (FDSN compliant web-services)
→ *development of harmonized model over wide areas including regional attributes*

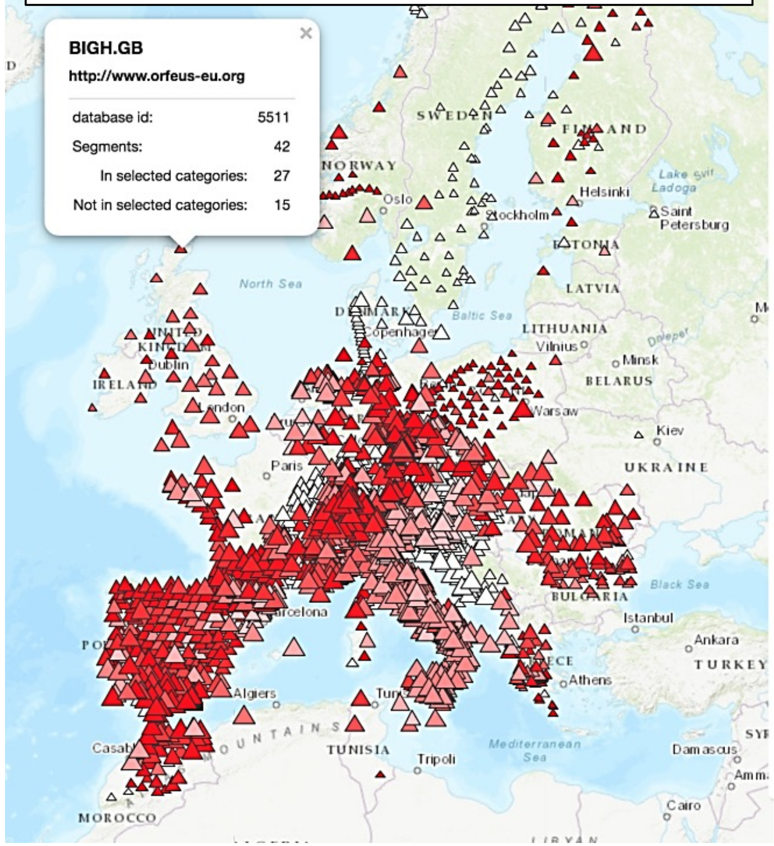


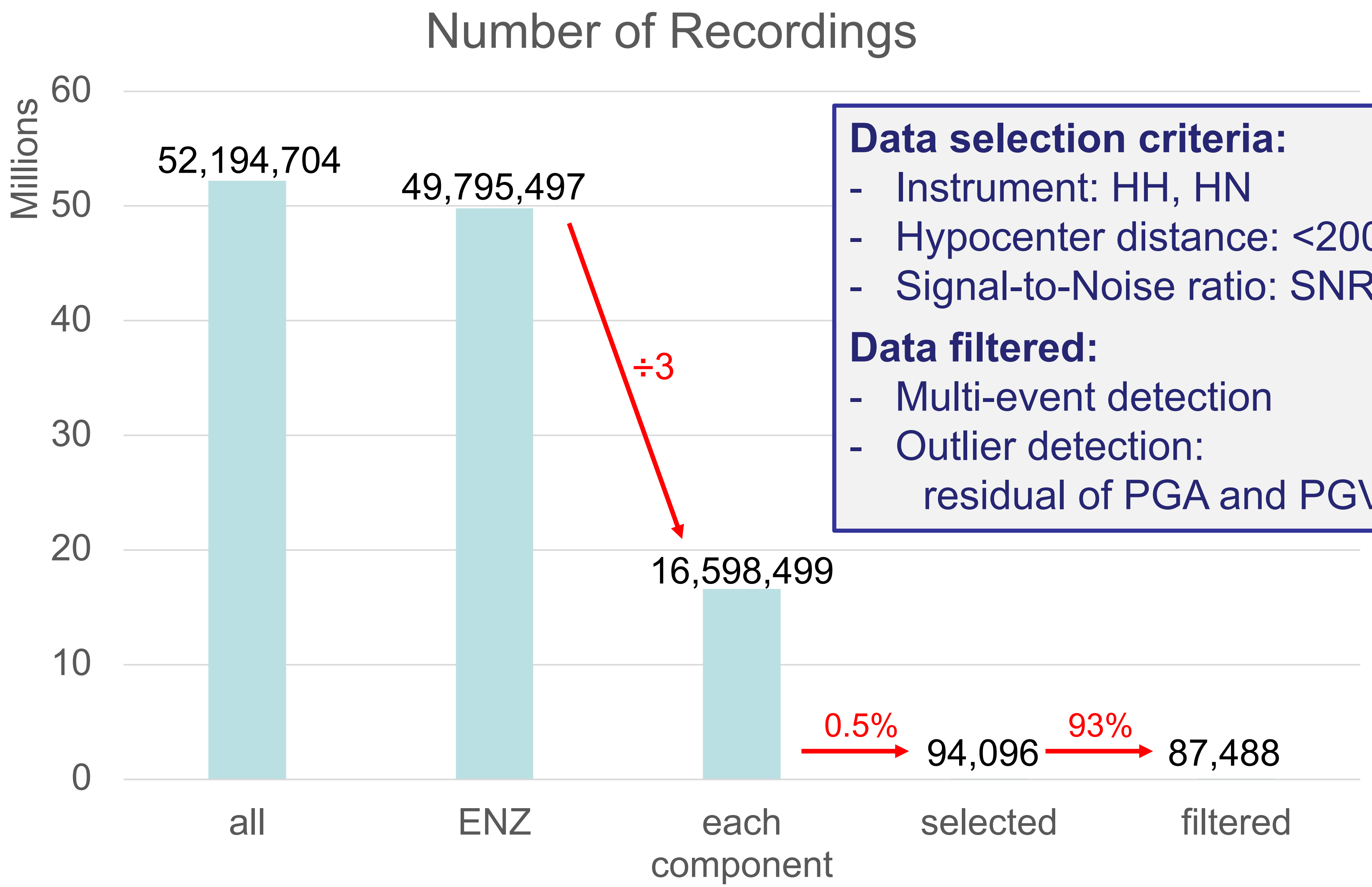
(Zaccarelli et al., 2019; Bindi et al., 2019)

Datasets on our server:

- Website: EIDA
- Catalog: ISC event service
- Time: 1990/01/01-2020/05/30
- Magnitude: M<7.0
- Events: 145,004
- Stations: 13,575
- Segments: 52,194,704

https://geofon.gfz-potsdam.de/software/stream2segment/





Data selection criteria:

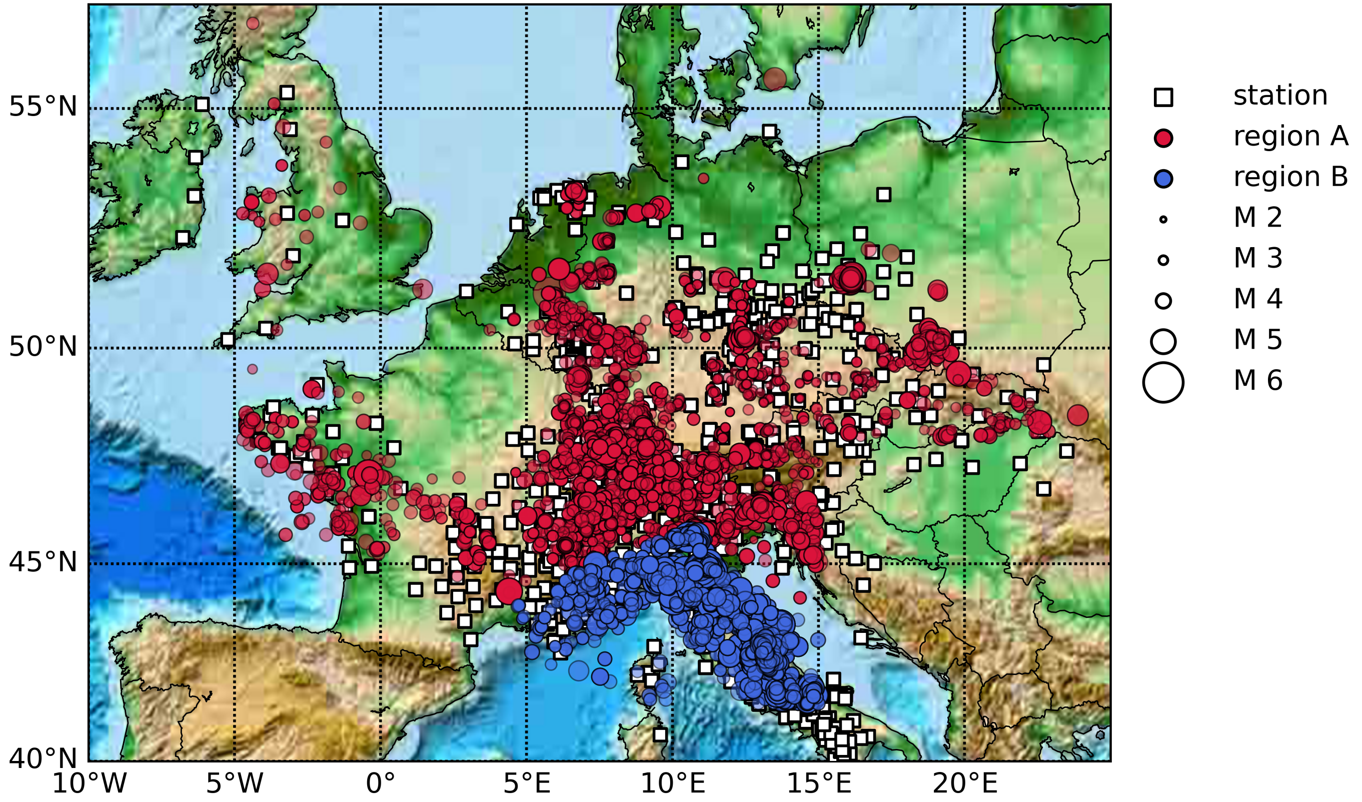
- Instrument: HH, HN
- Hypocenter distance: <200km
- Signal-to-Noise ratio: SNR>20

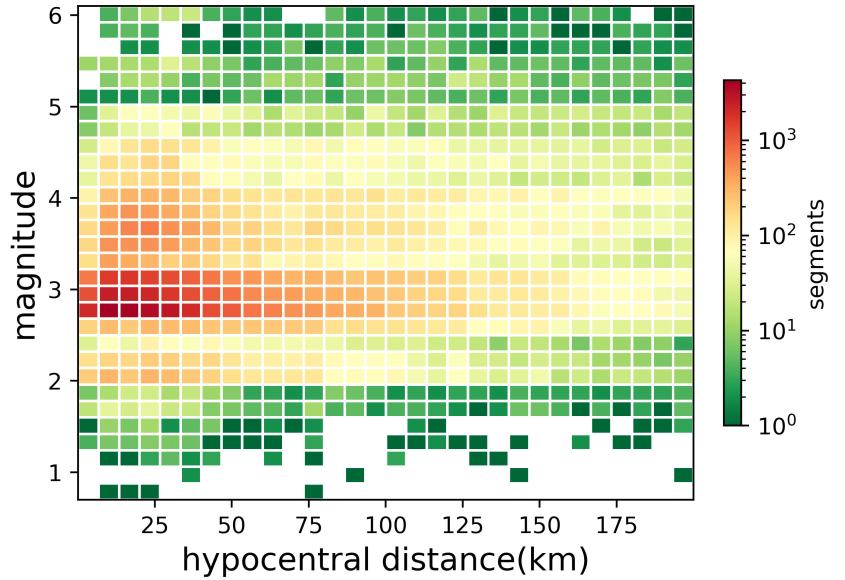
Data filtered:

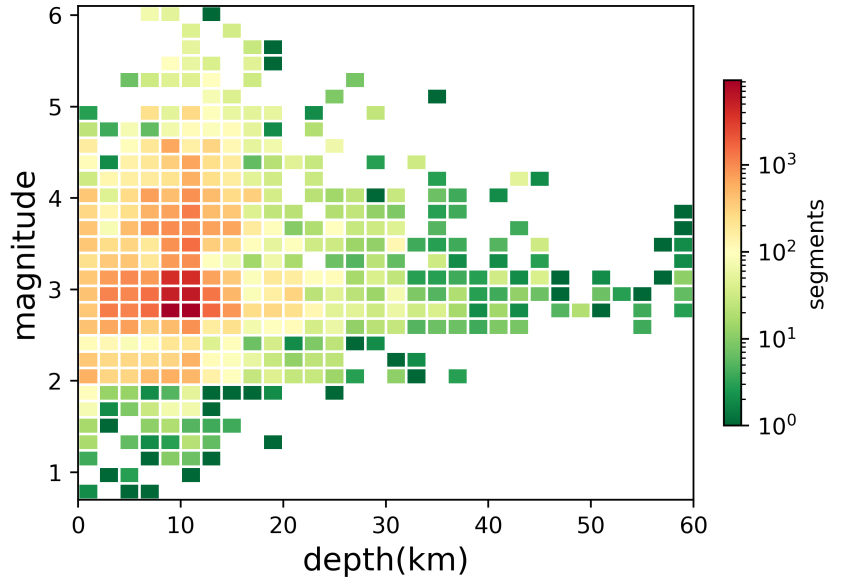
- Multi-event detection
- Outlier detection:
  residual of PGA and PGV (Bindi et al. 2014)

Datasets

- Time: 1990/01/01-2020/05/30
- Recordings: 84,755, Events: 5,230, Stations: 1,200
- Regionalized by event locations to derive different attenuations models between the ”stable” and “active” Europe

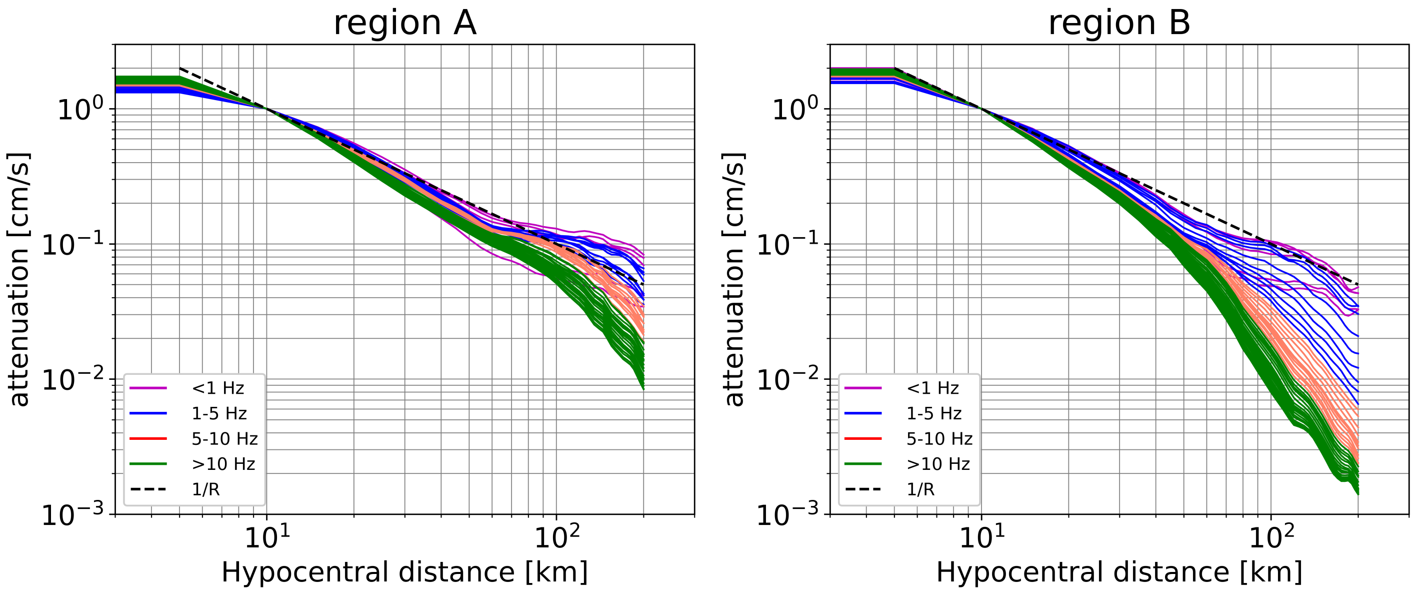






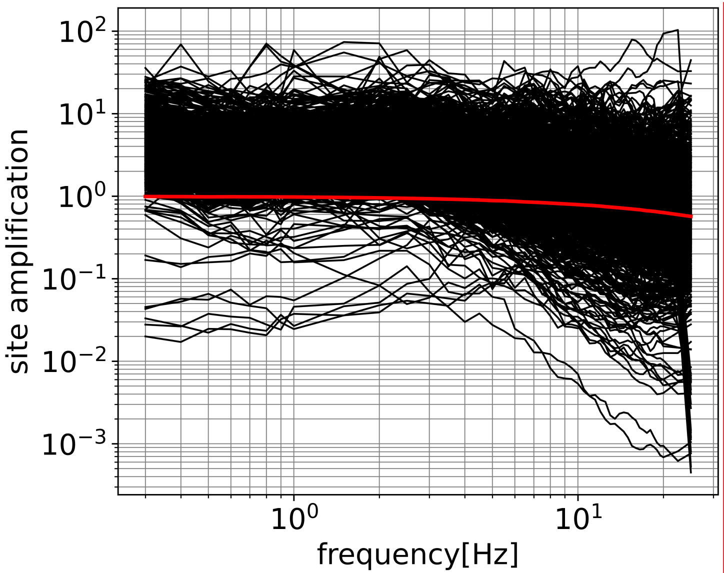
Attenuation models

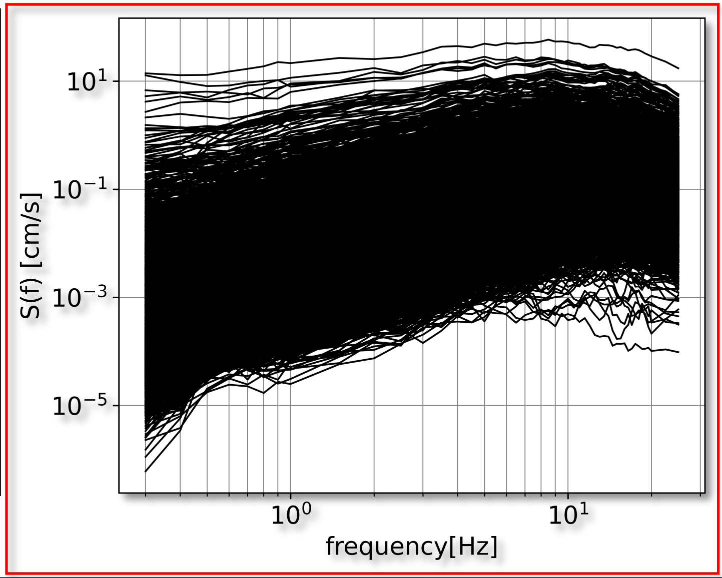
- Frequency range: 0.3-25 Hz
- Reference distance for attenuation: 10 km
- Distance bin for attenuation model: 5 km
- Smoothing weighting applied: weight 25



Site amplification and source spectra

- Reference site: CH.LLS (Vs_{30}=2925m/s)
- Reference for site amplification:
  κ_0 = 0.007s above 10 Hz (Pilz et al., 2019)
- Minimum number of events per station: 3
- Minimum number of recordings per event: 3





Spectral fitting - ω^2 model

- ω^2-model (Brune, 1970,1971):

$$S(f) = (2\pi f)^2 \frac{R^{\theta\emptyset} F}{4\pi\rho {v_s}^3 R_0} \dot{M}(f)$$

with $$\dot{M}(f) = \frac{M_0}{1 + (f/f_c)^2}$$

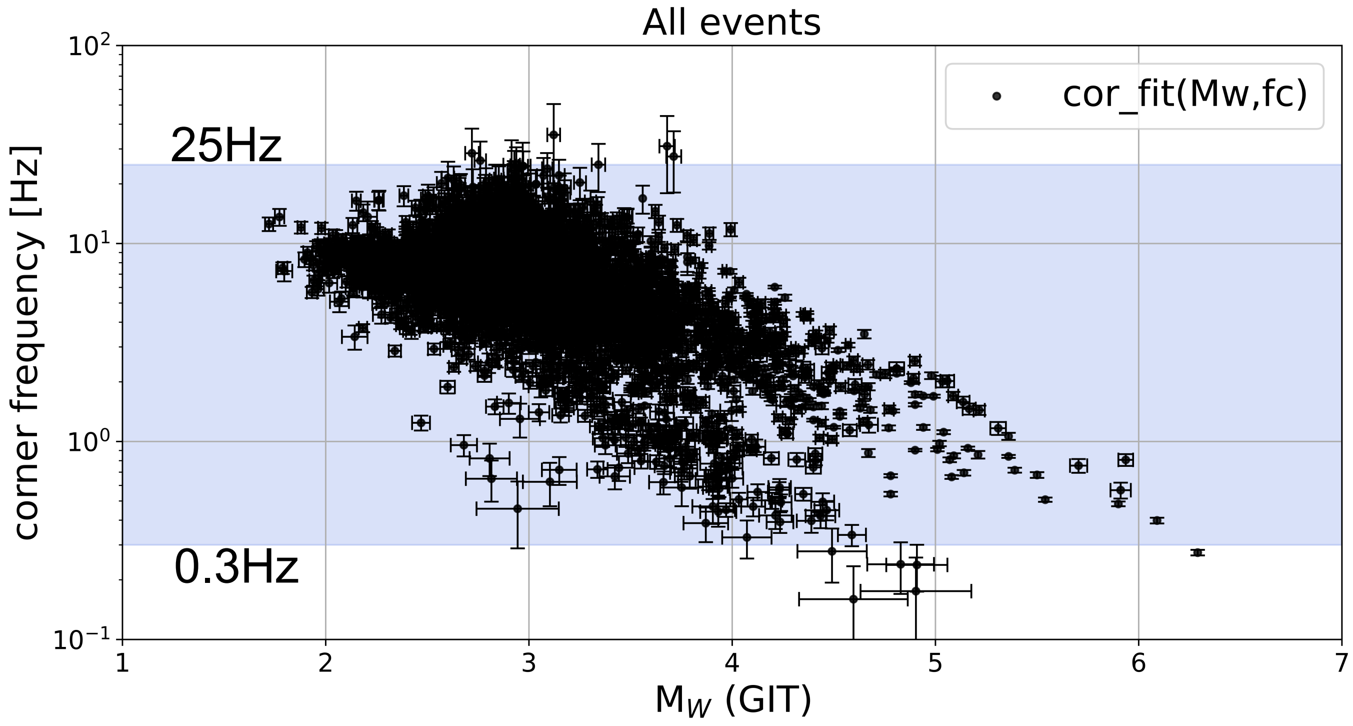
- Stress drop (Hanks and Thatcher, 1972):

$$\Delta\sigma = 8.5 M_0 \left(\frac{f_c}{v_s}\right)^3$$

Parameter setting :

- **R_0: 5km**
- **$R^{\theta\emptyset}$: 0.55**
- **F: 2**
- **V_S: 3.3 km/s**
- **ρ: 2.7 g/cm^3**

- The magnitude of events (M>5) is constrained by the EMEC magnitude during the spectral fitting
- The scaling of the corner frequency and magnitude show the slope is 0.33



Variability of stress drop according to regions and source origins

- In region A (”stable Europe”), stress drops of tectonic earthquakes do not follow a scaling with magnitude. In region B (“active Europe”), the scaling of stress drops show a clear increase with magnitude.
- Induced events show a constant stress drop (self similarity).

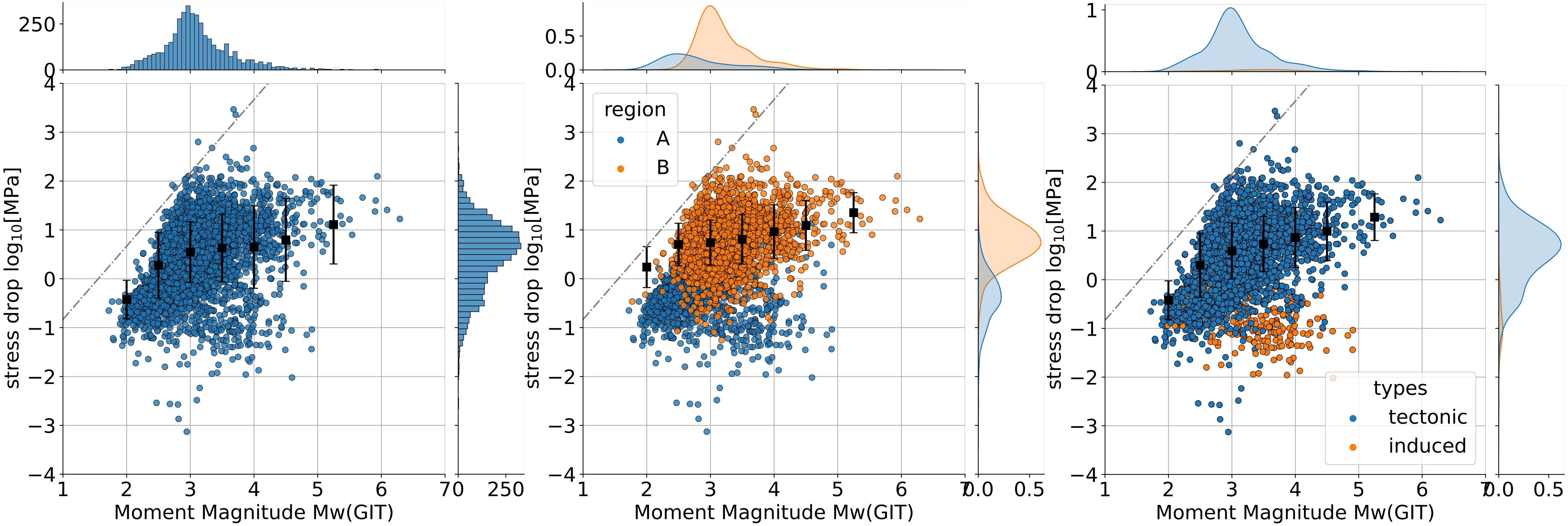


Table 1: Stress drops and variability from spectral studies (M_0, f_C)

Source study	Region	Mean Brune stress-drop $(\Delta\tau)$ (MPa)	Stress-drop variability $Ln(\Delta\tau)$	No. earthquakes
Allmann and Shearer, 2009	Interplate $5.5 \leq M_W \leq 8$	0.84*	1.67	799
Allmann and Shearer, 2009	Intraplate $5.5 \leq M_W \leq 8$	1.50*	1.46	61
Oth et al, 2010	Japan (crustal) $2.7 \leq M_{JMA} \leq 8$	1.1	1.38	1951
Rietbrock et al., 2012	UK	1.8	1.38	273
Edwards and Fah, 2012	Switzerland (foreland)	0.2	1.83	161
Edwards and Fah, 2012	Switzerland (alpine)	0.12	1.43	351
Shearer et al., 2006	Southern California $1.6 \leq M_L \leq 3.1$	0.52*	1.52	64800
Margaris and Hatzidimitriou, 2002	Greece $5.2 \leq M_W \leq 6.9$	6.3	0.57	18
Johnston et al., 1994	Intraplate	10	0.7	?

*Published results are divided by 3.95 to take into account the difference between a Madariaga (1976) corner frequency/source radius compared to that of Brune (1970,1971) and the difference in shear wave velocity.

(Cotton et al., 2013)

This study:
Region: 1.5 < M <6.5
Mean Brune stress drop $(\Delta\tau)$ = 3.01 MPa
Stress drop variability (Ln $\Delta\tau$) = 1.86
No. earthquakes: 5,230

region	Mean(MPa)	Variability(Ln)
1.5<M<2.5	0.38	0.91
2.5<M<3.5	3.55	1.43
3.5<M<4.5	4.47	1.95
4.5<M<6.5	12.88	1.86

Summary

- The attenuation is stronger in the active part of Europe (e.g. Italy) than in the stable part of Europe (e.g. Germany) at high frequencies.
- Stress drops of tectonic events in region A (“stable Europe”) show a self-similar trend (constant stress-drop) but tectonic events in region B (“active Europe”) follow a scaling (increasing stress-drop) with magnitude.
- Induced events follow a self-similar trend (constant stress-drop)
- The variability of stress drop values remain large. The variability reflects the natural variability of earthquakes properties. However, it might need more local path corrections and further check by different source origins.

Thank you for your attention!