Monitoring performance for hydraulic fracturing using synthetic microseismic catalogue at the Wysin site (Poland)

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European Geosciences Union General Assembly
Vienna – April 23-28, 2017

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1. Monitoring network

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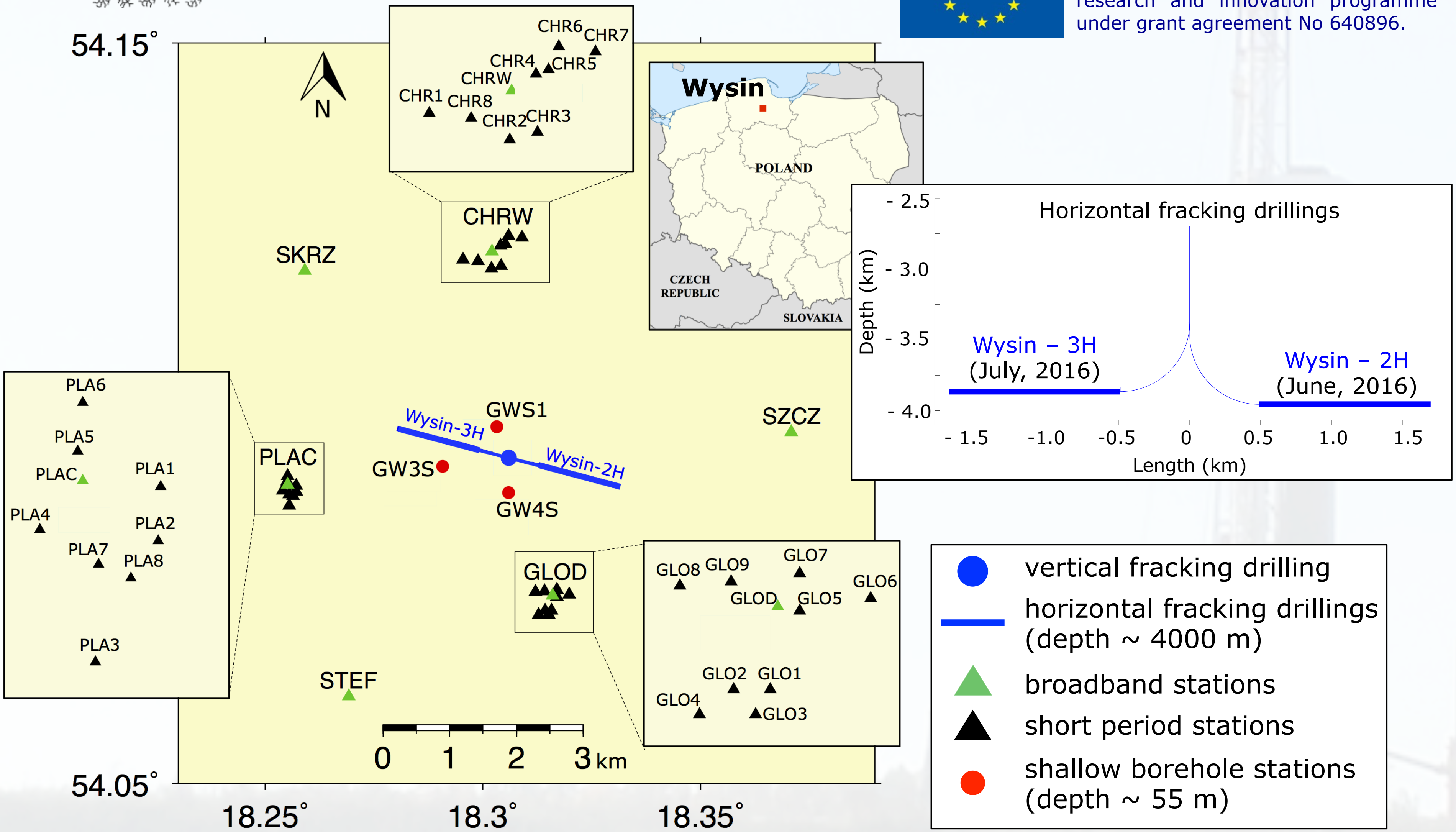
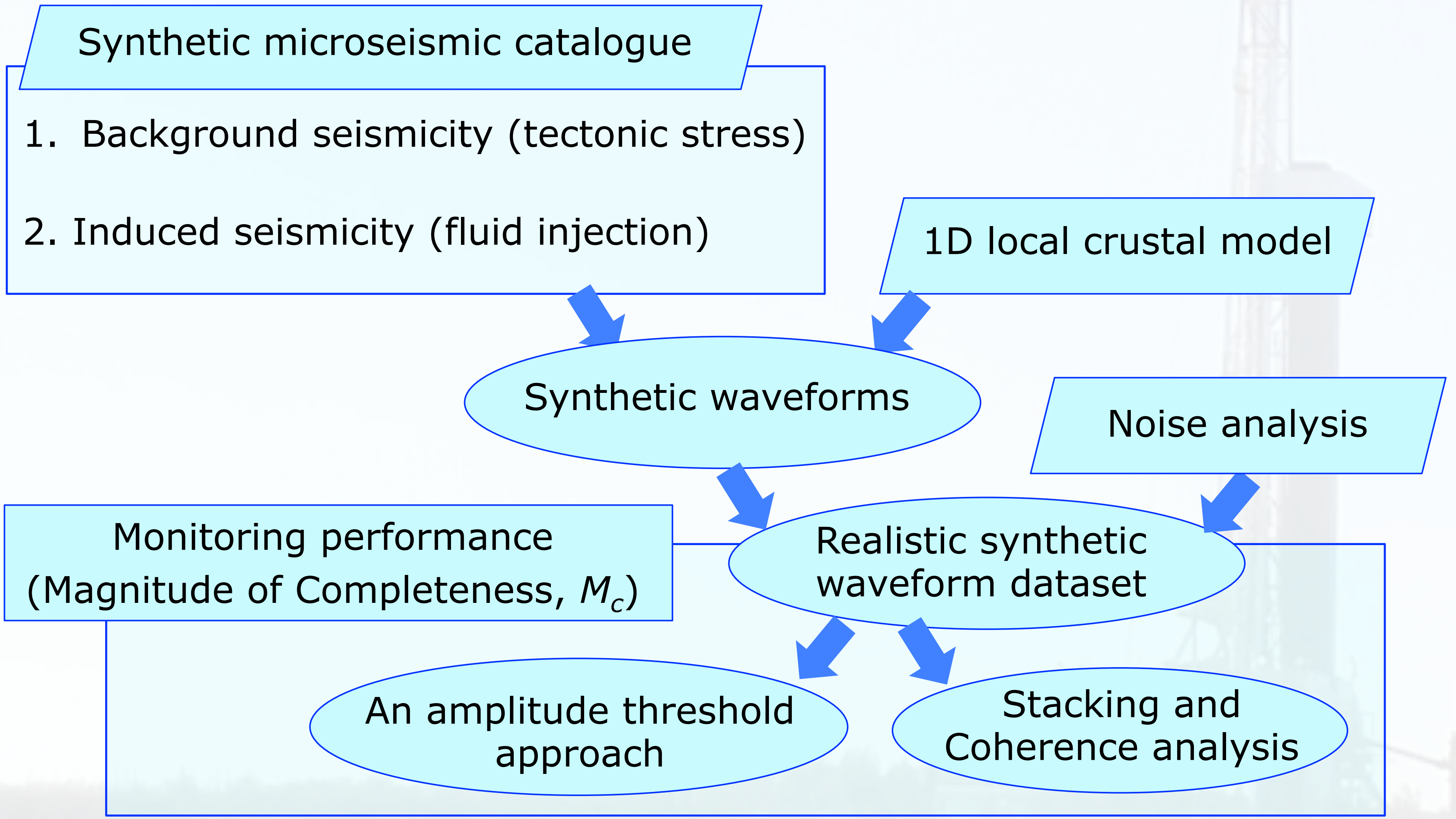
This project has received funding from the *European Union's Horizon 2020* research and innovation programme under grant agreement No 640896.

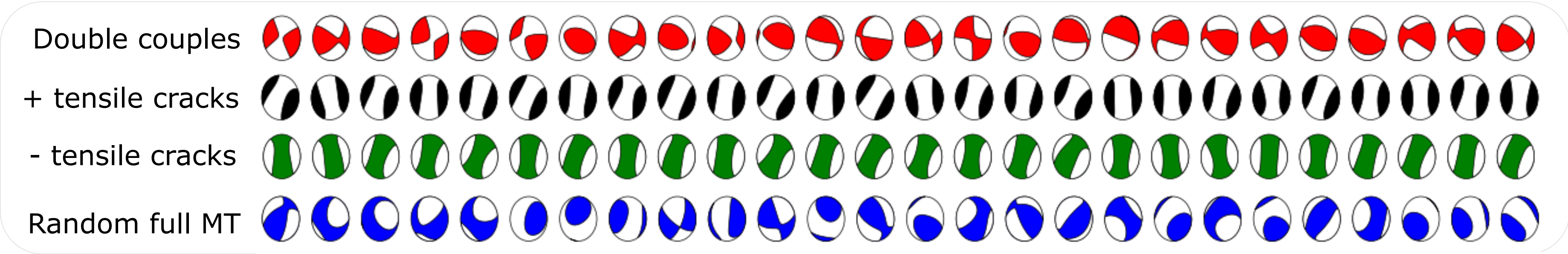


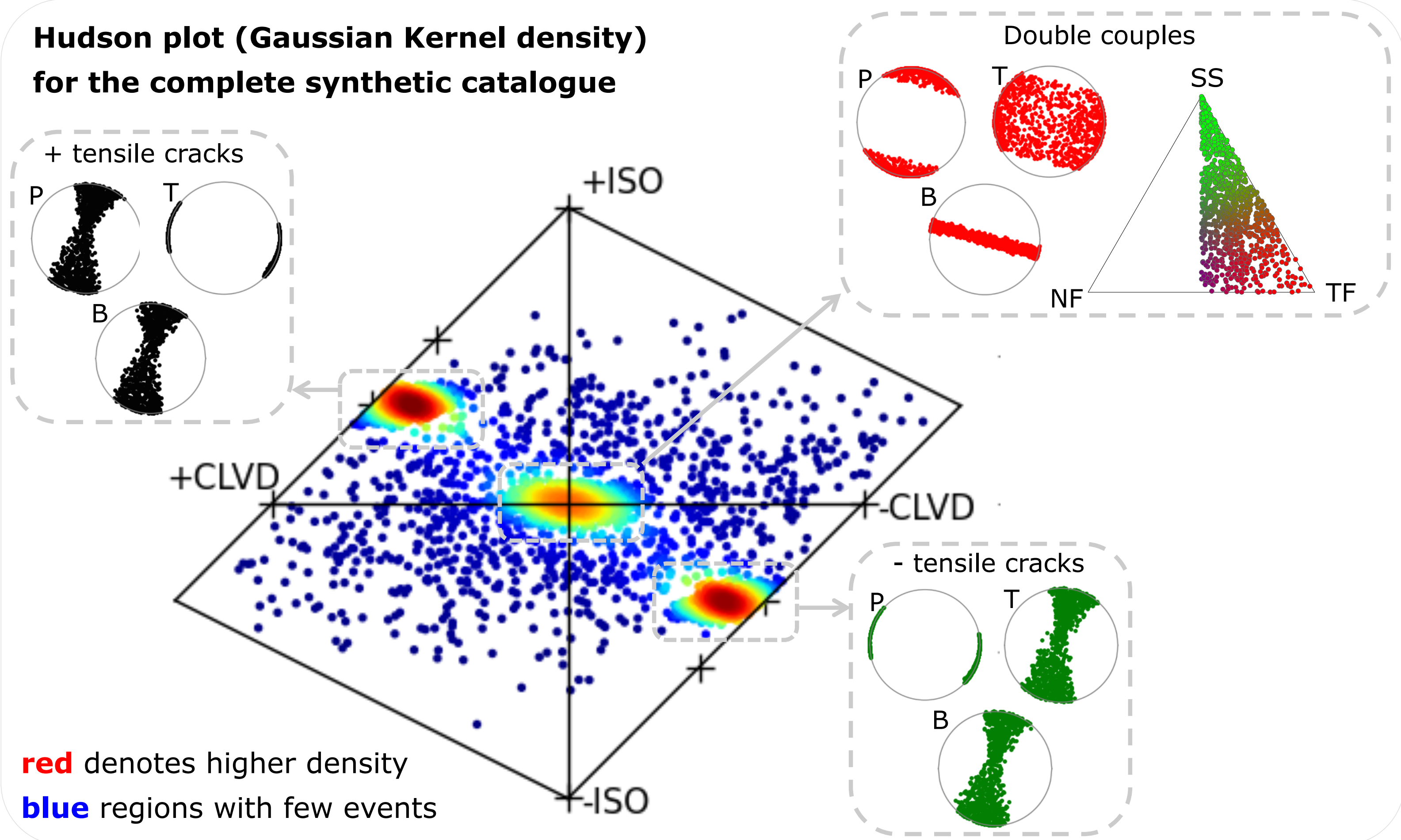
2. Methodology

Assessing the monitoring performance before the target hydraulic fracturing using a synthetic dataset



3. Synthetic microseismic catalogue





3. Synthetic microseismic catalogue

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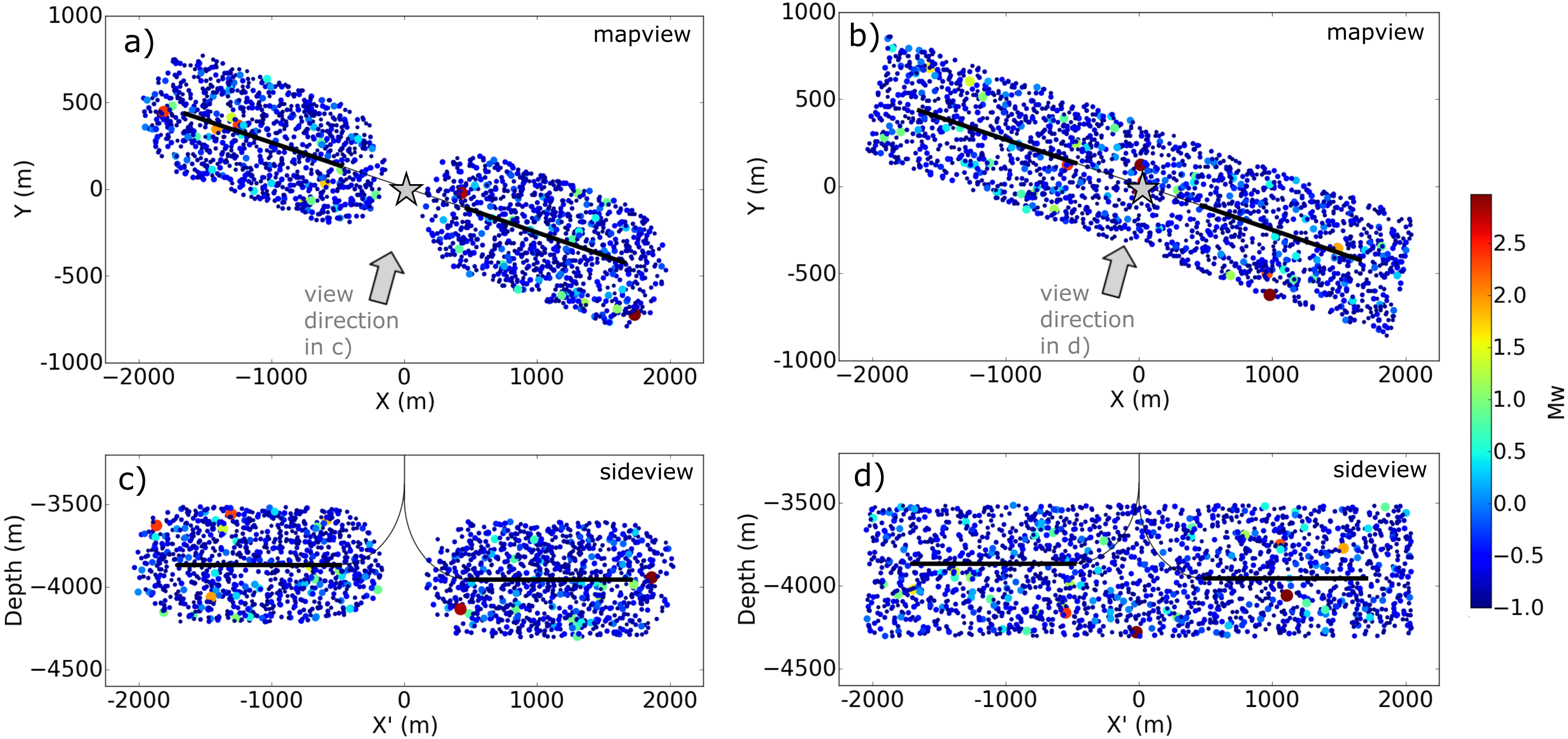
Distribution of hypocenters and magnitudes in the fracturing area

Positive and negative tensile cracks | **Double couples and Random full MT**



- Frequency-magnitude distribution (**-1 < Mw < 3**) follows a **Gutenberg-Richter law** with **b = 1** and **a = 1.84** according 1000 events for each family
- **Maximum rupture length = 350 m** (considering a circular fault model of Madariaga, 1976 and stress drop average = 2.7 Mpa, Kwiatek et al., 2011). Reasonable value according other experiences (Davies et al., 2012; Fisher and Warpinski 2012)

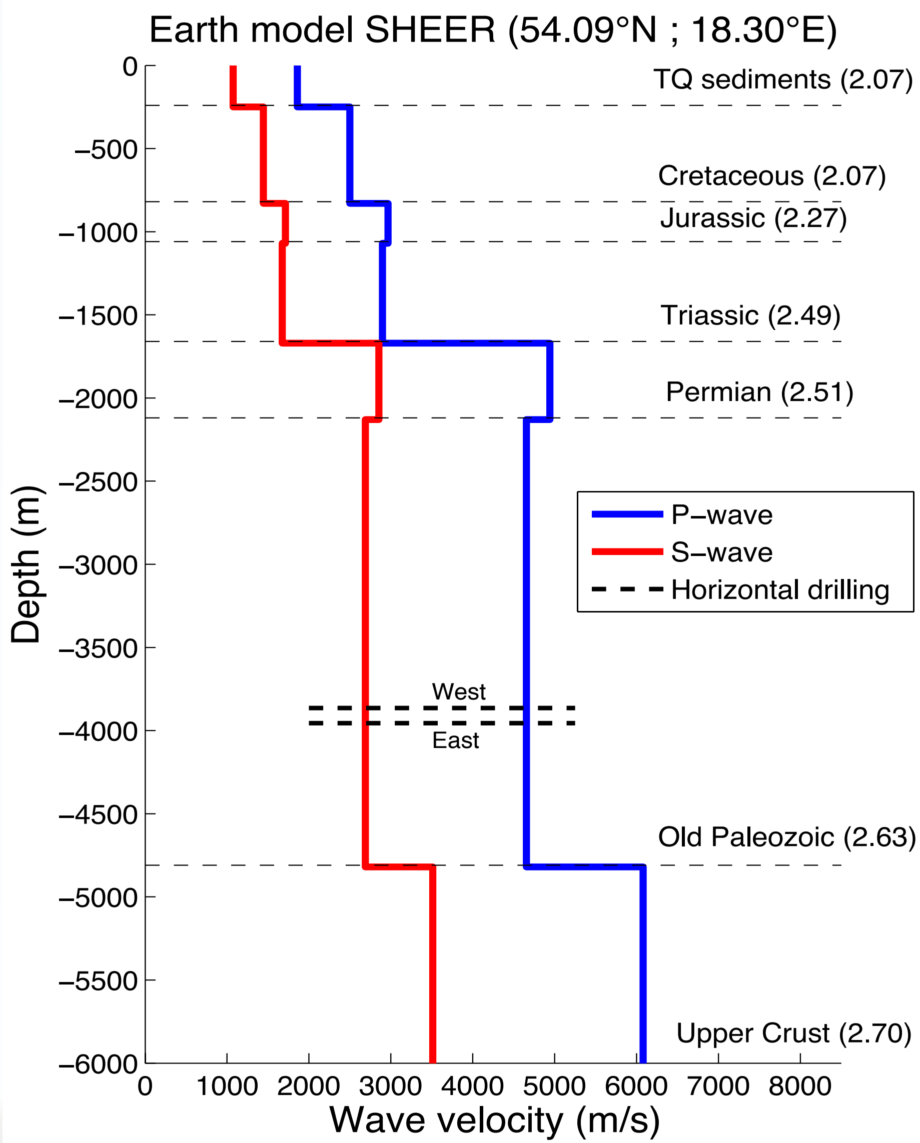
4. Local crustal model

A priori, we do not dispose of such information and relied on previous studies on the broader region of interest.

Extract a P-wave velocity profile for the fracking area according:

High-resolution 3D seismic model of the crustal and uppermost mantle structure in Poland (Grad et al, 2015)

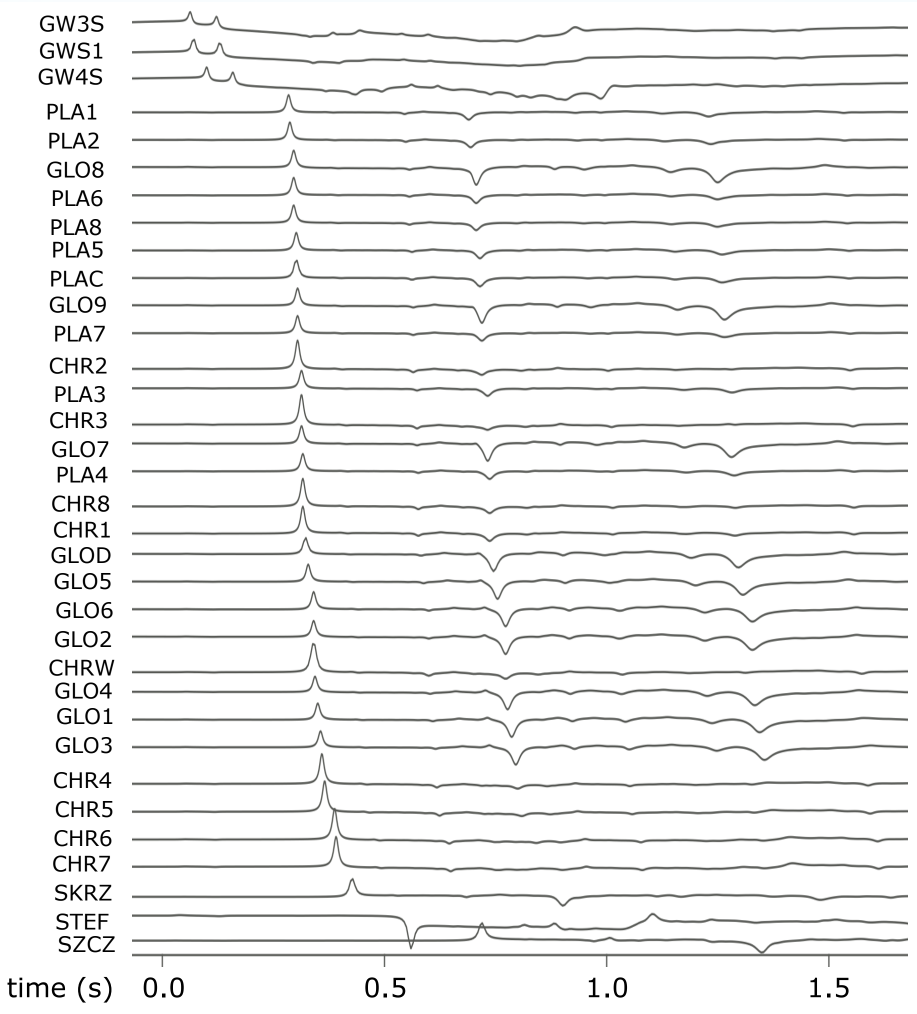
P-wave velocity	Grad et al., 2015
S-wave velocity	$v_p = 1.73\ v_s$
Density (Mg/m^3)	Grabowska et al., 1998
Attenuation	Król et al, 2013 $Q_p = 120$ $Q_s = 60$



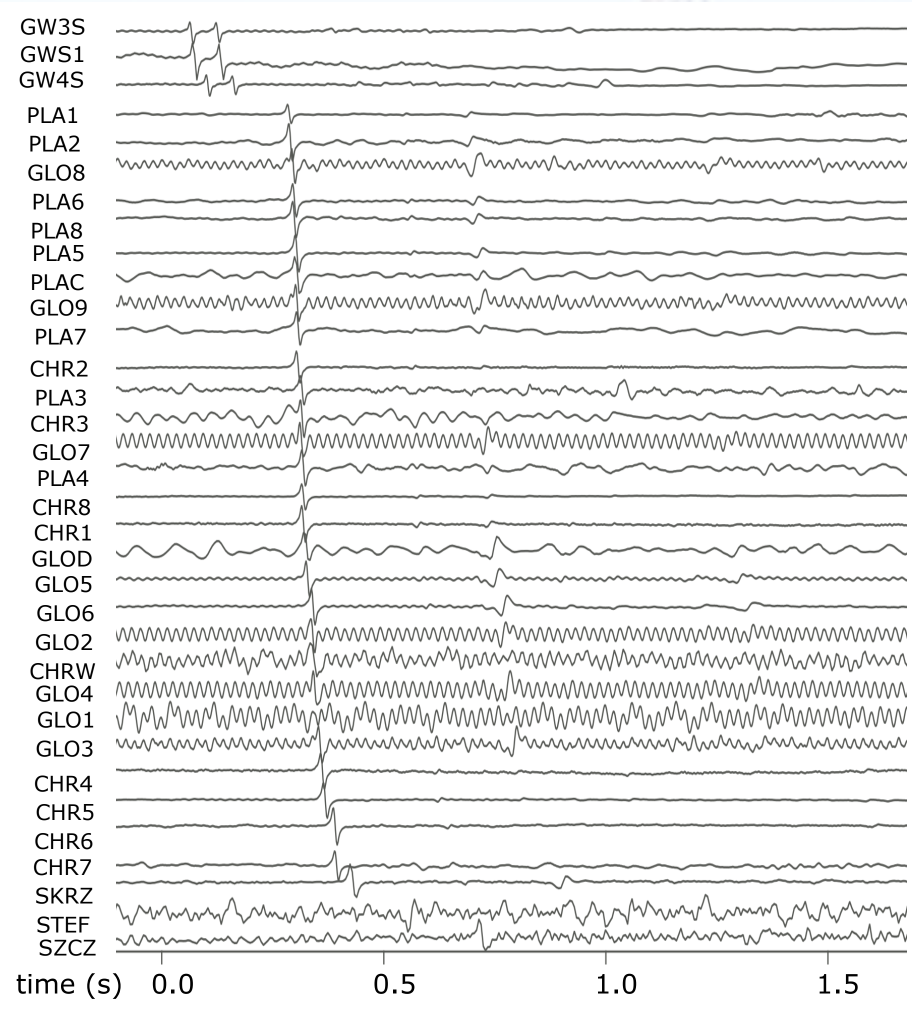
5. Synthetic waveforms

Pyrocko package (*http://emolch.github.io/pyrocko/*)

Raw synthetic waveforms (displacement)



Real noise contaminated continuous seismograms (velocity)

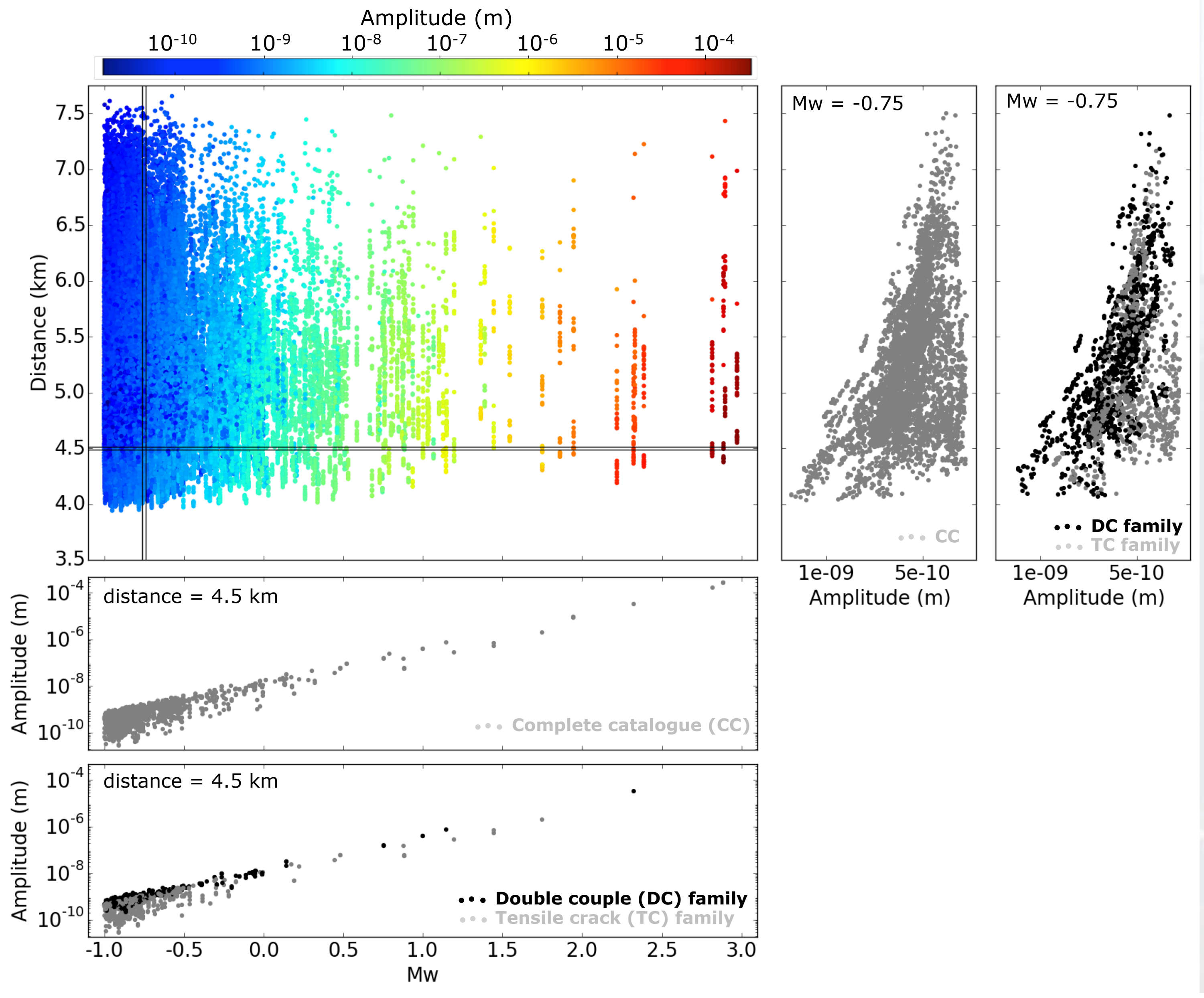


An amplitude threshold approach

Stacking and Coherence analysis

6. An amplitude threshold approach

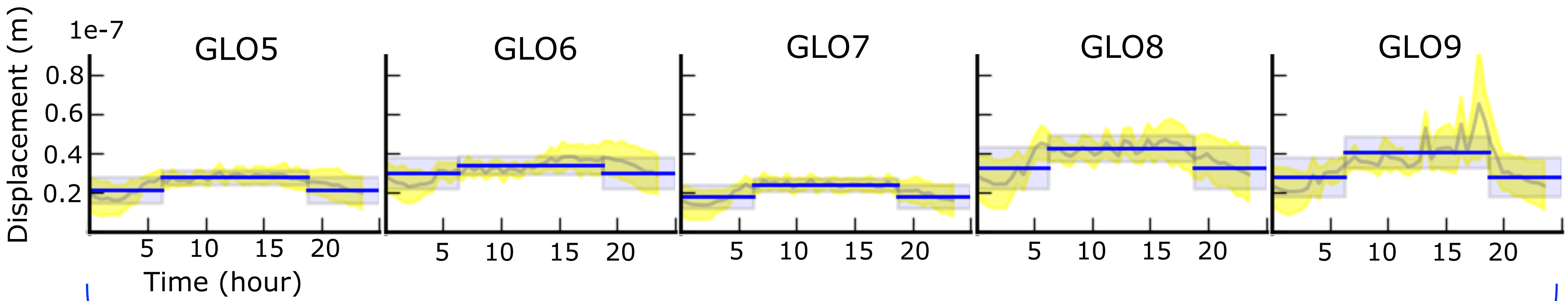
Maximum amplitudes according to the M_W and the hypocentral distance for each station

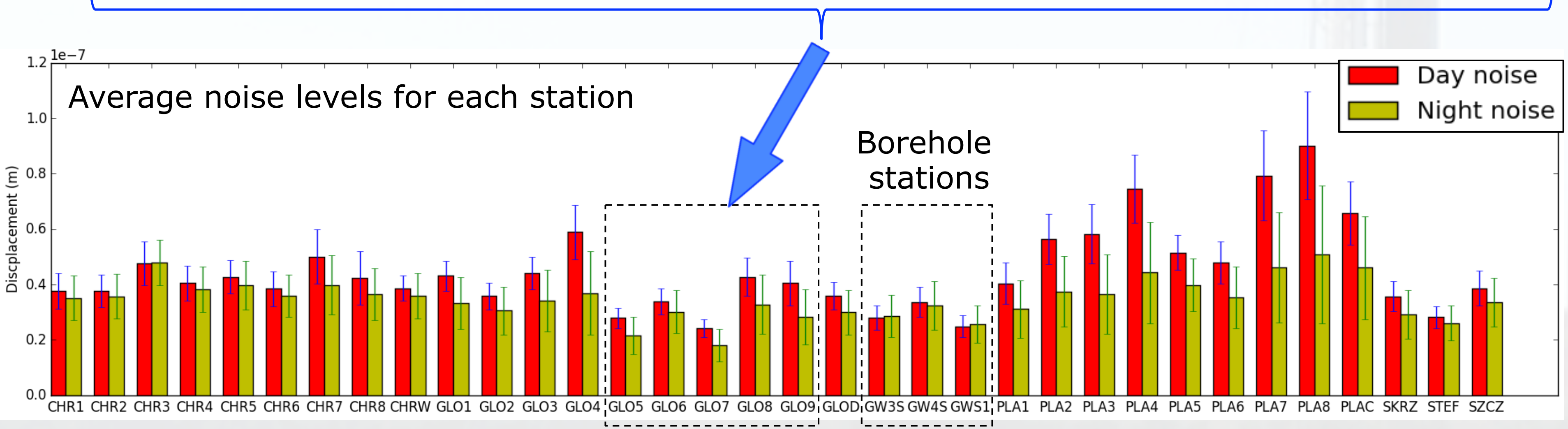


6. An amplitude threshold approach

Noise analysis

- Band pass filtered 2 - 80 Hz and a notch filter at 50 Hz.
- Mean and standard deviation values in displacement are obtained from the **random noise sampling (one-month data) taking into account the different hours of the day**.
- Larger noise levels during day hours (6.00 - 18:00 hours) are found as a general pattern.





6. An amplitude threshold approach

The **magnitude of completeness (*M_c*)** can be calculated straight by the **lowest magnitude** above which all synthetic events are **detected by at least 4 stations.**

Imposing **different signal-to-noise ratio (*SNR*) requirements**, we can estimate detected and undetected events at each station.

A **potential empirical law** can adjust this relation with fit parameters d_1 and d_2:

$$M_c = d_1 SNR^{d_2} - d_0$$

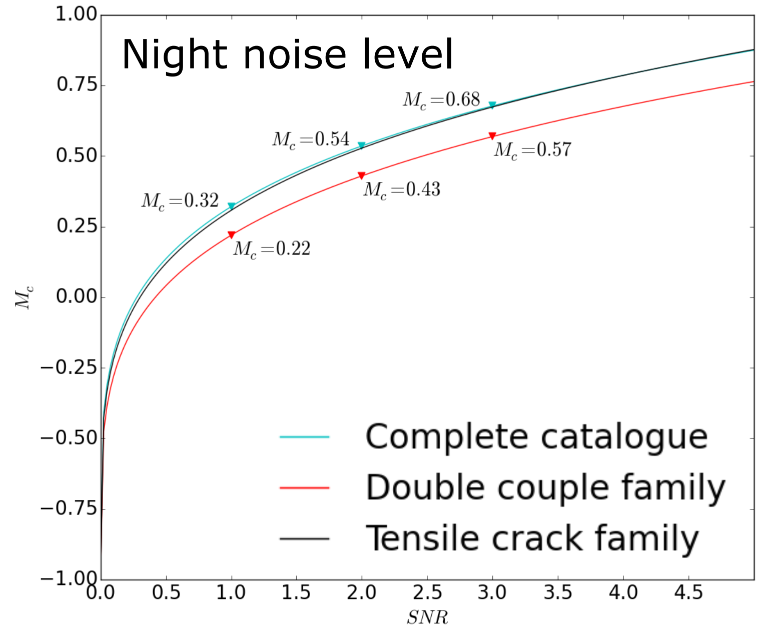
- **Array consideration:**

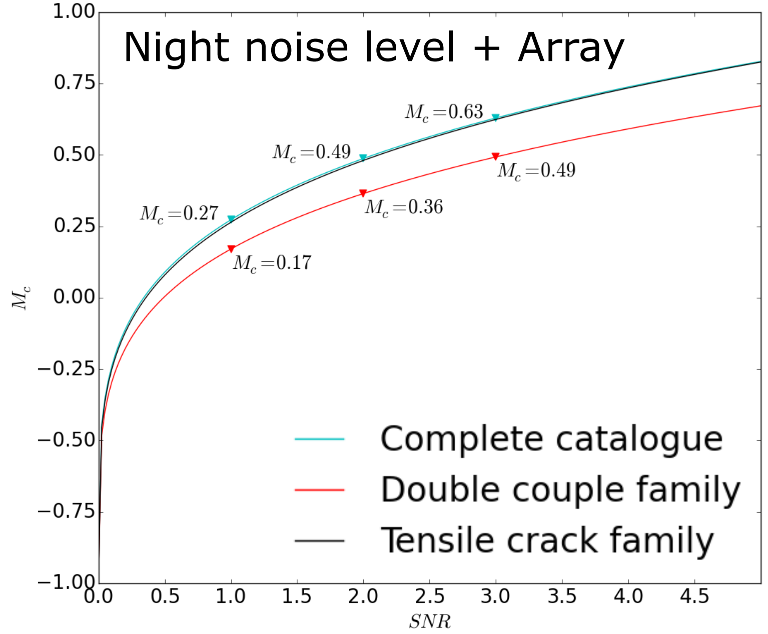
We can add **fictitious stations** located in the **centre of each array.**

In general, **SNR improves with the square root of the number of stations** belonging to an array.

M_c differs for different source processes

Tensile-cracks are more difficult to detect than double couple sources with the same magnitude.





6. An amplitude threshold approach

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- Extending spatially the previous values of M_c around the fracking area for a realistic case of SNR = 2.

Probability of detection

$$P_D(M,L) = \frac{N_+}{N_+ + N_-}$$

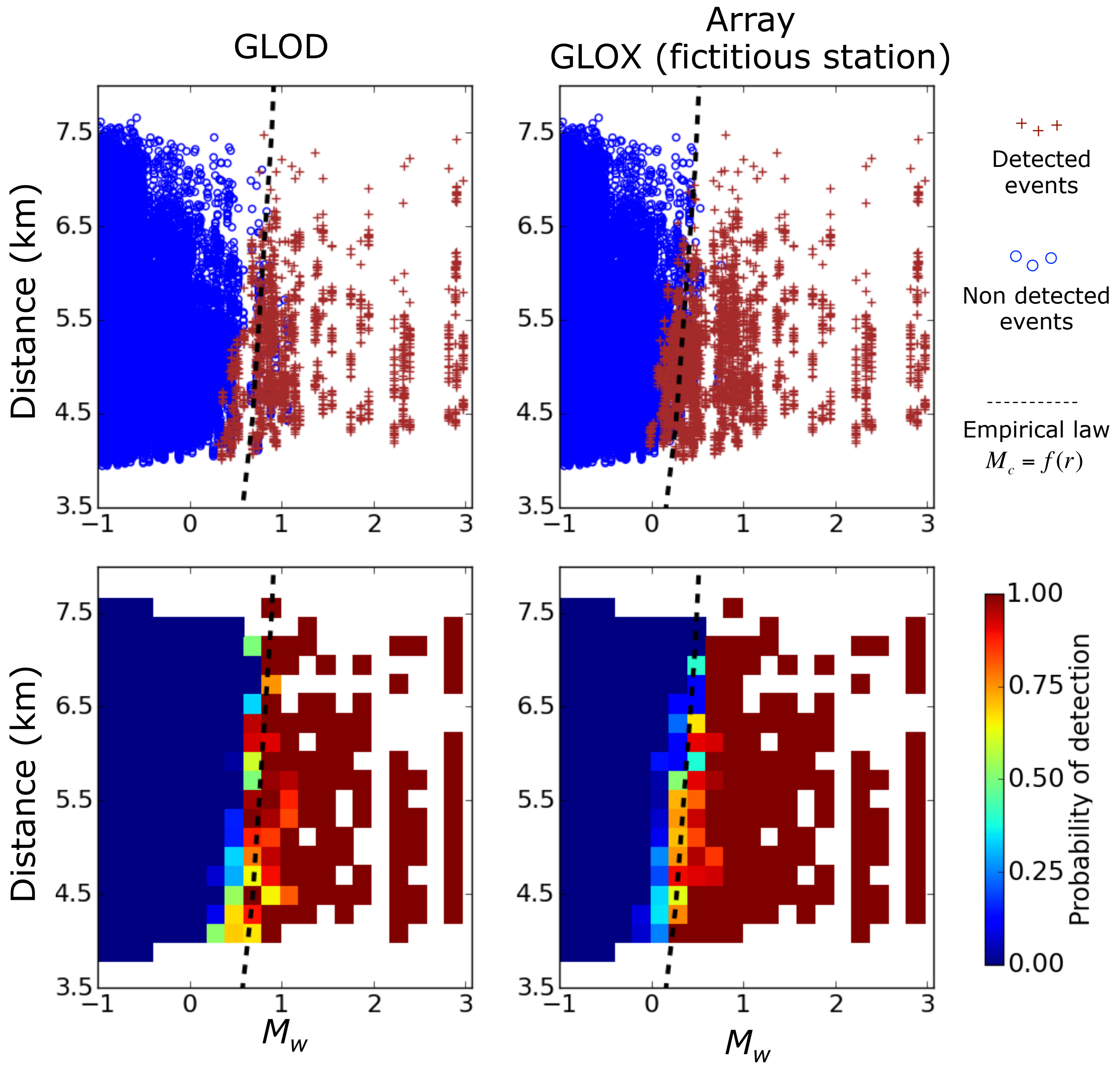
Schorlemmer and Woessner, 2008

M_c versus r

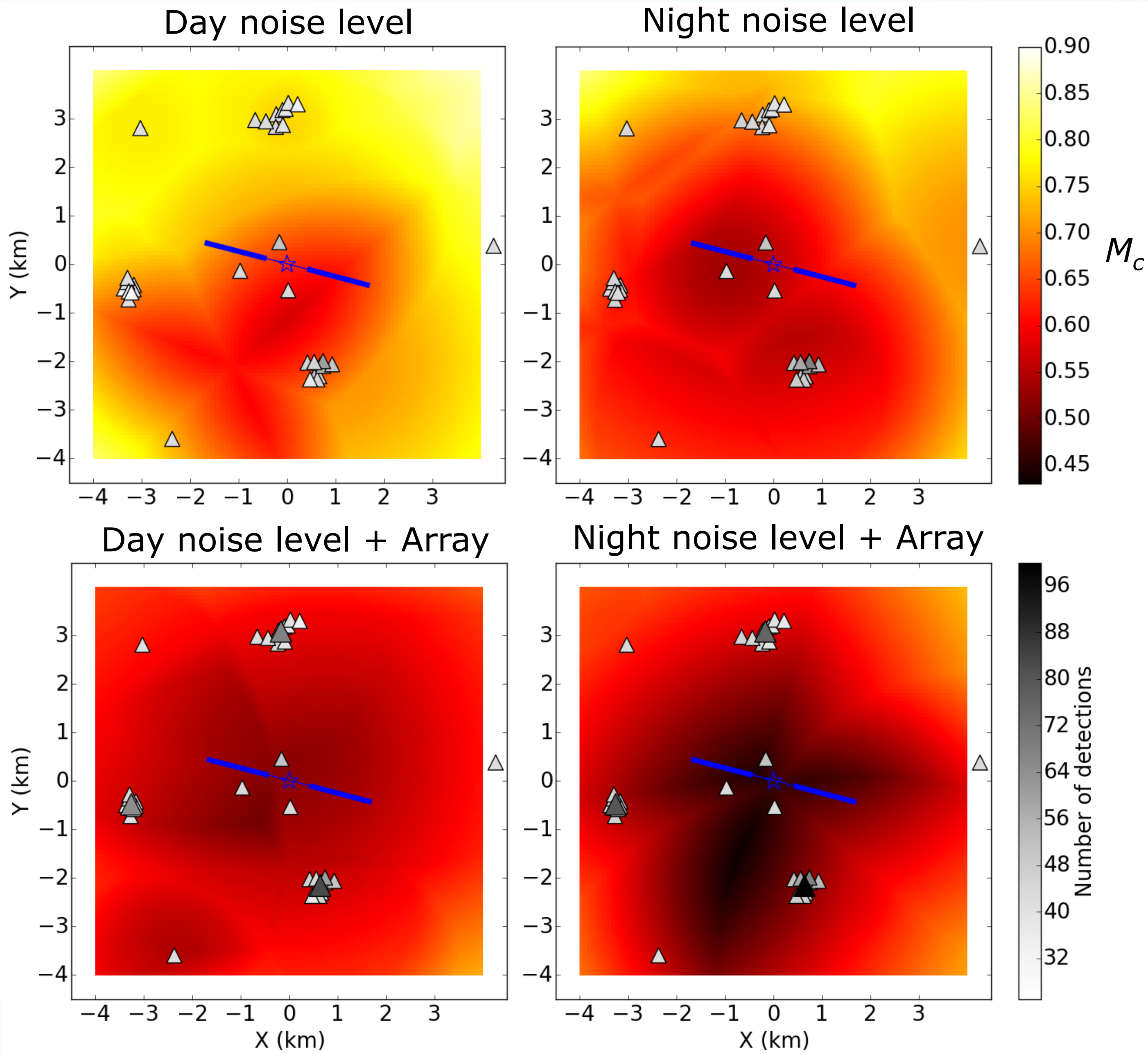
$$M_c(r) = C_1 r^{C_2} + C_3$$

fit parameters C_1 , C_2 , C_3

Mignan et al., 2011



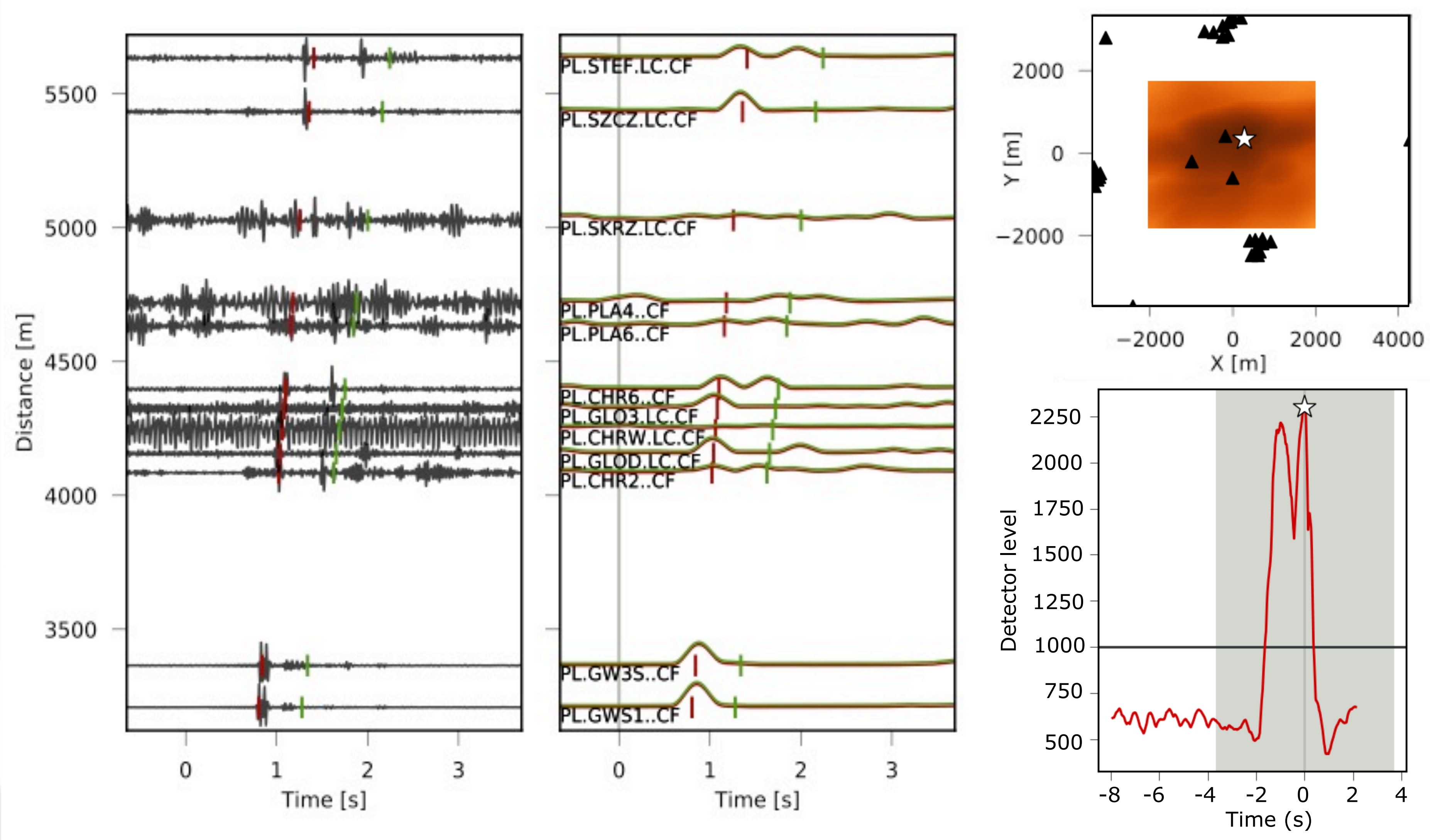
6. An amplitude threshold approach



7. Stacking and Coherence analysis

Lassie

- Automatic detector based on the stacking of characteristic functions of P- and S-waves according to the energy variations calculated from the square amplitudes of each trace.



7. Stacking and Coherence analysis

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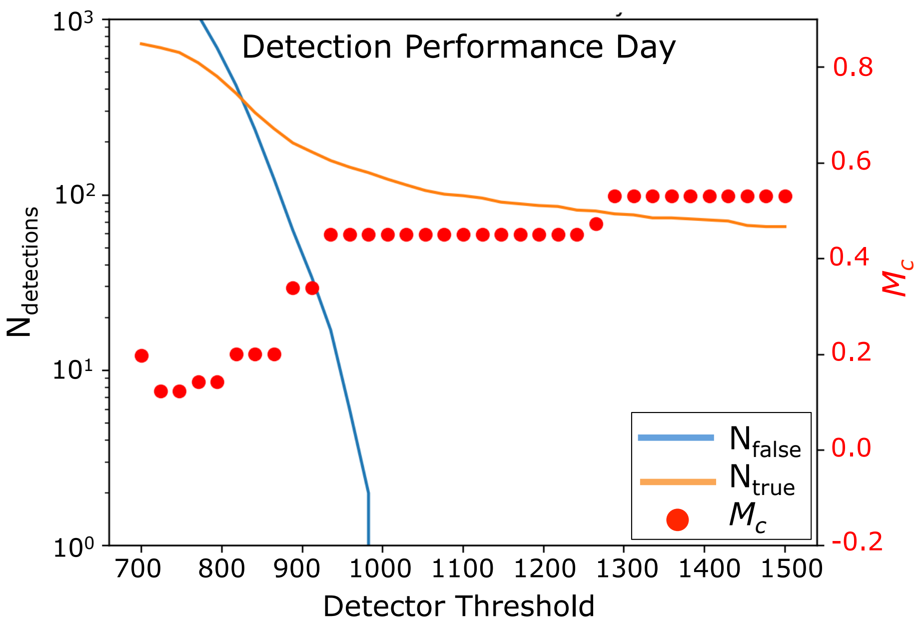
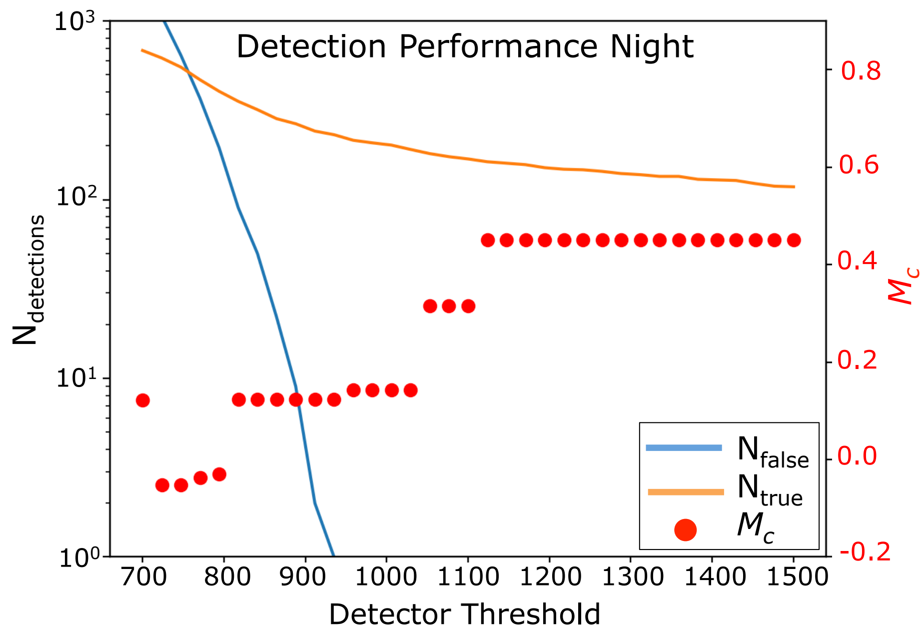
- We need to define an **optimal detector level**, able to detect weak events while not increasing excessively the number of false detections.

- **Reasonable threshold (e.g. 950)** where only 1% of false detections are accepted.





$\boldsymbol{M_c \sim 0.4}$

$\boldsymbol{M_c \sim 0.1}$

Poster session, EGU2017-1875. *Full waveform approach for the automatic detection and location of acoustic emissions from hydraulic fracturing at Äspö (Sweden)*

8. Conclusions

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- Realistic synthetic datasets before hydraulic fracturing to assess the monitoring performance (detection, location and moment tensor)

- Mapping the magnitude of completeness using synthetic seismograms and realistic noise

- M_c experiences significant changes during day hours, reaching values of $M_c \sim 0.1$ for the most favourable case.

- Background (DC) earthquakes more detectable than induced (tensile crack) earthquakes

- These results have been recently published: **López-Comino et al., 2017, *GJI***

  López-Comino, J. A., S. Cesca, M. Kriegerowski, S. Heimann, T. Dahm, J. Mirek and S. Lasocki (2017). Monitoring performance using synthetic data for induced microseismicity by hydrofracking at the Wysin site (Poland), *Geophys. J. Int.*, in press.

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Thank you very much

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