Assessing the induced seismicity by hydraulic fracturing at the Wysin site (Poland)

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1. INTRODUCTION

Induced seismicity related to industrial processes including shale gas and oil exploitation is a current issue that implies enough reasons to be concerned. This work is focused on a hydrofracking experiment monitored in the framework of the SHEER (SHale gas Exploration and Exploitation induced Risks) EU project at the Wysin site, located in the central-western part of the Peribaltic synclise of Pomerania, Poland. A specific network setup has been installed combining surface installation with three small-scale arrays and a shallow borehole installation (Figure 1). The fracking operations were carried out in June (Wysin-2H) and July (Wysin-3H) 2016 at a depth 4000 m. The monitoring has been operational before, during and after the termination of hydraulic fracturing operations.

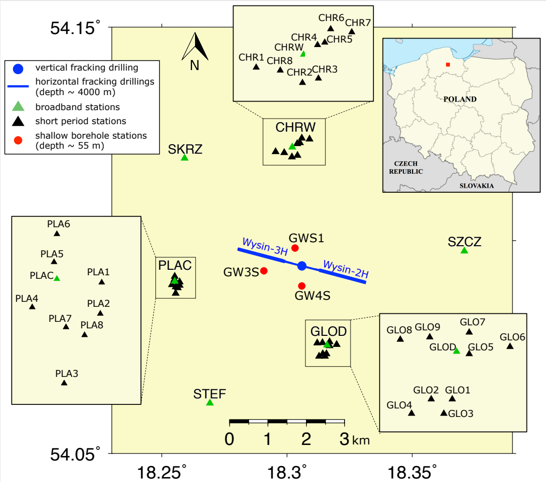


Figure 1. Map of seismic monitoring by hydraulic fracturing at the Wysin site (Poland).

2. AUTOMATED FULL WAVEFORM DETECTION AND LOCATION ALGORITHM USING COHERENCE (*LASSIE*)

We apply a recently developed automated full waveform detection algorithm based on the stacking of smooth characteristic function and the identification of high coherence in the signals recorded at different stations (*Lassie*, https://gitext.gfz-potsdam.de/heimann/lassie, Heimann et al., 2017). This python-tool earthquake detector is 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 (Figure 2). An unsupervised detection catalogue is generated with real data for a time period June-September 2016 (Figure 3 and 4). A manual revision of the detected signals reveals that most detections are associated to local and regional seismic signals, decreasing this activity after two months of the last fracking operations (Figure 3a). Few events could be assigned to the volume potentially affected by the fracking operations, however other signals recorded in the closest stations could reveal more very weak events (Figure 3b).

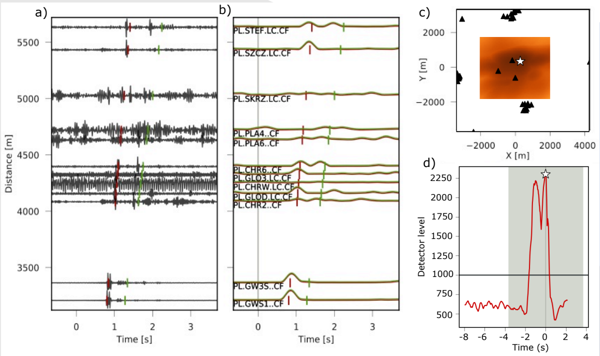


***Figure 2**. Example of synthetic event detected by the automatic detector "Lassie" (López-Comino et al., 2017a). a) Waveforms sorted by hypocentral distance for some example stations. b) Characteristic function (normalized amplitude envelopes) for each trace. These are used for travel-time stacking corrected with P-wave speed (red lines) and S-wave speed (green lines). The markers indicate the (best-fit) synthetic arrival time of the respective phases at each sensor. c) Coherence (stack) map for the search region. Dark colors denote high coherence values. A white star marks the location of the detected event. Sensor locations are shown with black triangles. d) Global detector level function in a processing time window from -8 to +4 seconds around the origin time of the detected event. The cut-out time window used for the coherence map is shown in gray color. White stars indicate this detection within the same processing time window, exceeding a detector level threshold of 1000.*

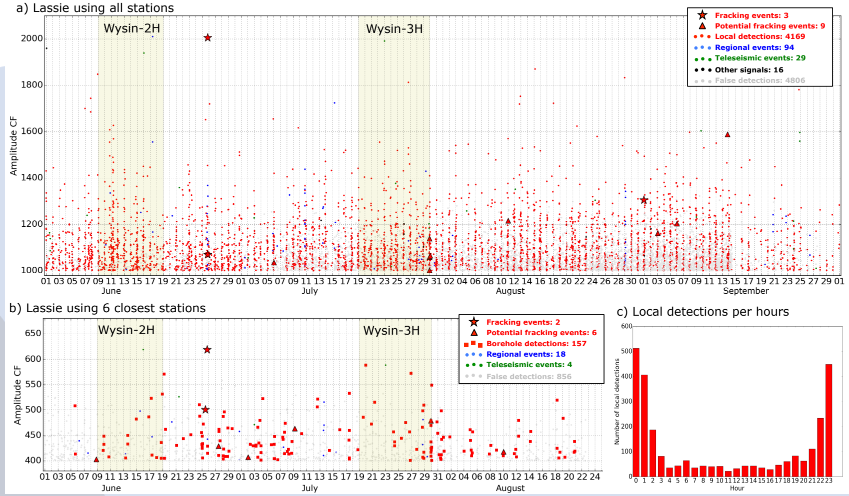
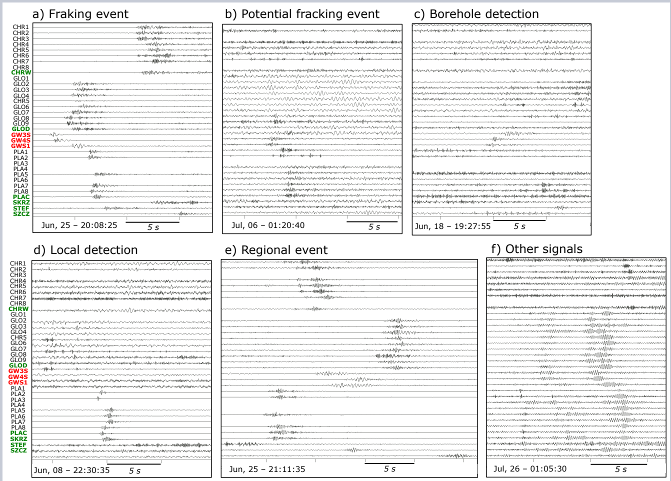


***Figure 3.** Detected signals showing the maximal coherence (amplitude of the characteristic function) as a function of time and manual revision of the catalogue, according to the chosen event classification (see legend and Figure 4). We apply two approaches: a) the automatic detector "Lassie" runs using the recording for all seismic stations and b) using the 6 closest stations in order to detect very weak events recording at least in the shallow borehole stations. The cut-out time windows for the fracking operations are shown in yellow color. c) Local detections per hours according a period from June, 1st to August, 15th.*

3. DISCUSSION & CONCLUSIONS

- The application of this novel automated detection algorithm, based on the detection of coherence signals at multiple stations, is successfully applied for monitoring induced.
- We identify strong temporal changes (day/night) of the detection performance according the most detections associated to local signals (Figure 3c).
- The hydraulic fracturing at the Wysin site reflected very low seismic activity where the largest event was recorded after the fracking operations in Wysin-2H with M_w of 1.15 ± 0.06.
- This approach can be easily adapted to other environments implying the detection and characterization of induced microseismicity (López-Comino et al., 2017b).



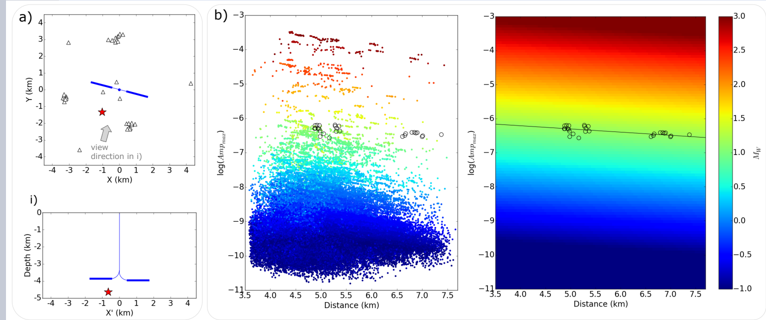


***Figure 5.** a) The location of the largest event (Figure 4a) is refined using an accurate waveform stacking and coherence method which uses both P and S phases (Grigoli et al., 2014). b) A synthetic microseismic catalogue generated in López-Comino et al., (2017a) is used to estimate the moment magnitude (M_w). Maximum amplitudes according to the hypocentral distance for each station and the M_w for each source are plotted for this synthetic catalogue (left). This domain is extrapolated with a plane that fits the synthetic data and allows a more accurate estimation of the M_w (right). Black open circles indicate the values of maximum amplitudes recording in different seismic stations for the largest event, revealing a M_w of 1.15 (black line). Note the maximum amplitudes are calculated in terms of ground displacement (meters) removing the instrumental response.*

***Figure 4.** Examples of different detections by the Lassie algorithm using continuous recording. Waveforms are band-pass filtered in the frequency range 2 – 15 Hz. The time (s) is shown on the x-axis and the reference time is displayed in the lower right corner of each box.*

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