## Assessing the induced seismicity by hydraulic fracturing GFZ at the Wysin site (Poland) J. A. López-Comino<sup>1\*</sup>, S. Cesca<sup>1</sup>, M. Kriegerowski<sup>1,2</sup>, S. Heimann<sup>1</sup>, T. Dahm<sup>1</sup>, J. Mirek<sup>3</sup> & S. Lasocki<sup>3</sup> Helmholtz Centre <sup>1</sup> GFZ German Research Centre for Geosciences, Telegrafenberg, D-14473 Potsdam, Germany (\*jalopez@gfz-potsdam.com) POTSDAM <sup>2</sup> University of Potsdam, Institute of Earth and Environmental Sciences, Potsdam-Golm, Germany EGU2017-1874 <sup>3</sup> Institute of Geophysics, Polish Academy of Sciencesia, Warsaw, Poland www.sheerproject.eu **1. INTRODUCTION** 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 Induced seismicity related to industrial processes including shale gas and oil stations (Lassie, https://ditxt.dfz-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 exploitation is a current issues that implies enough reasons to be concerned. This 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). 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 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). Wysin site, located in the central-western part of the Peribaltic synclise of Pomerania, Few events could be assigned to the volume potentially affected by the fracking a) Lassie using all stations Poland. A specific network setup has been installed combining surface installation operations, however other signals recorded in the closest stations could reveal more very Wysin-2H Wysin-3H with three small-scale arrays and a shallow borehole installation (Figure 1). The weak events (Figure 3b). fracking operations were carried out in June (Wysin-2H) and July (Wysin-3H) 2016 at c) a depth 4000 m. The monitoring has been operational before, during and after the • Other signals: 16 STEELC CE 2000 termination of hydraulic fracturing operations. 1800 5500 LSZCZ.LC.C Ξ 54.15° CHR4 CHR5 160/ 5000 SKRZ.LC.C -2000 CHR1 CHR8 CHR2CHR3 vertical fracking drilling horizontal fracking drillings (depth ~ 4000 m) 1400 -2000 2000 4000 POLAND broadband stations 1500 d) short period stations CHDW 225 1200 shallow borehole stations (depth ~ 55 m) SKB7 2000 4000 1750 1000 1500 0 103 05 07 09 11 13 15 17 19 21 23 25 27 29 01 03 05 07 09 11 13 15 17 19 21 23 25 27 29 01 03 05 07 09 11 13 15 17 19 21 23 25 27 29 01 03 04 06 08 10 12 14 16 18 20 22 24 26 28 30 01 03 05 07 09 11 13 15 17 19 21 23 25 27 29 01 SLOVAK 1250 b) Lassie using 6 closest stations c) Local detections per hours 3500 PLA6 100 Wysin-2H GW35 CE Wysin-3F GWS1 650 SZCZ 750 PLA5 GWS1 CF PLAC 500 600 PLA1 PLAC\_ 2 0 **4** 3 -4 -2 0 2 4 Time (s) GW4S Time In Time In -V 550 LA4 PLAZ 500 PLA7 Figure 2. Example of synthetic event detected by the automatic detector "Lassie" (López-Comino PI A8 GLO8 GLO9 GLO7 GLOD 1.1.14 GLOD GLOS GLOE al., 2017a). a) Waveforms sorted by hypocentral distance for some example sta n de la 450 ÷., 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 6 H.V.H 149 19 19 1 N de PLA3 indicate the (best-fit) synthetic arrival time of the respective phases at each sensor. c) Coherence International Content of the second s 01 03 05 07 09 11 13 15 17 19 21 23 25 27 29 01 03 05 07 09 11 13 15 17 19 21 23 25 27 29 31 02 04 06 08 10 12 14 16 18 20 22 24 GLO2 GLO1 (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 STEF July August GLO4 Figure 3. Detected signals showing the maximal coherence (amplitude of the characteristic function) as a function of time and manual revision detector level function in a processing time window from -8 to +4 seconds around the origin time of 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 the detected event. The cut-out time window used for the coherence map is shown in gray color. 2 0 3 kr 1 White stars indicate this detection within the same processing time window, exceeding a detector least in the shallow borehole stations. The cut-out time windows for the fracking operations are shown in yellow color. c) Local detections per 54.05° level threshold of 1000 hours according a period from June, 1st to August, 15t 18.25° 18.3° 18.35° Figure 1. Map of seismic monitoring by hydraulic fracturing at the Wysin site (Poland). **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. 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).

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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 (5) is shown on the x-axis and the reference time is displayed in the lower right correr of each box.

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