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Full waveform approach for the automatic detection and location of acoustic emissions from hydraulic fracturing at Äspö (Sweden)

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A crucial issue to analyse the induced seismicity for hydraulic fracturing is the detection and location of massive microseismic or acoustic emissions (AE) activity, with robust and sufficiently accurate automatic algorithms. Waveform stacking and coherence analysis have been tested for local seismic monitoring and mining induced seismicity improving the classical detection and location methods (e.g. short-term-average/long-term-average and automatic picking of the P and S waves first arrivals). These techniques are here applied using a full waveform approach for a hydraulic fracturing experiment (Nova project 54-14-1) that took place 410 m below surface in the Äspö Hard Rock Laboratory (Sweden). Continuous waveform recording with a near field network composed by eleven AE sensors are processed. The piezoelectric sensors have their highest sensitive in the frequency range 1 to 100 kHz, but sampling rates were extended to 1 MHz. We present the results obtained during the conventional, continuous water-injection experiment HF2 (Hydraulic Fracture 2). The event detector is based on the stacking of characteristic functions. It follows a delay-and-stack approach, where the likelihood of the hypocenter location in a pre-selected seismogenic volume is mapped by assessing the coherence of the P onset times at different stations. A low detector threshold is chosen, in order not to loose weaker events. This approach also increases the number of false detections. Therefore, the dataset has been revised manually, and detected events classified in terms of true AE events related to the fracturing process, electronic noise related to 50 Hz overtones, long period and other signals. The location of the AE events is further refined using a more accurate waveform stacking method which uses both P and S phases. A 3D grid is generated around the hydraulic fracturing volume and we retrieve a multidimensional matrix, whose absolute maximum corresponds to the spatial coordinates of the seismic event. The relative location accuracy is improved using a master event approach to correct for travel time perturbations. The master event is selected based on a good signal to noise ratio leading to a robust location with small uncertainties. Relative magnitudes are finally estimated upon the decay of the maximal recorded amplitude from the AE location. The resulting catalogue is composed of more than 4000 AEs. Their hypocenters are spatially clustered in a planar region, resembling the main fracture plane; its orientation and size are estimated from the spatial distribution of AEs.

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