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Microseismic monitoring at a shallow CO_2 injection site, the CaMI Field Research Station in Newell County, AB

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Summary

The Containment and Monitoring Institute (CaMI) Field Research Station (FRS), based in Newell County in southern Alberta, was established in 2017 by the CMC Research Institutes Inc. in collaboration with the University of Calgary. The FRS serves as an experimental laboratory for the development and assessment of robust seismic monitoring approaches for the early detection of CO_2 leakages and for the accurate tracking of subsurface fluid migration. The injection target is a thin water filled sandstone formation located at 300 m depth, 75 m below the aquifer. As of March 30 2020, a total volume of 20 825 kg of CO_2 was injected. Bottom well pressures were kept constant since January 2020 and appear to have triggered the onset of microseismic activity in the same month. In this presentation, we will characterize the microseismic activity which was continuously recorded since February 2019 on 3 components by a 2D surface array of 10 Hz geophones and a downhole array in an observation well 20 m away from the injector.

Method and preliminary results

The passive seismic monitoring network consist of a downhole array of 24 3-C 10 Hz geophones in the 195-275 m depth range along with a 2D surface array comprised 24 INOVA Hawk nodal systems paired with 3-C 10 Hz geophones, deployed in a “X” configuration within a 1 by 1 km area centered on the injection well. Different detection methods were explored to capture the small micro-earthquakes. The time dependence of noise levels, interference from other fieldwork activities, animal disturbances and generally weak signal amplitudes all posed some challenges for establishing a robust detection workflow on this continuous dataset. Detection methods employed include recursive STA-LTA (e.g. Trnkoczy, 2012) and earthquake similarity search approaches such as Fingerprint And Similarity Thresholding (FAST) (Yoon et al., 2015), matched-filter detection (e.g. Chamberlain et al., 2017) and the Matrix Profile approach, a fast time series mining analysis technique deployed on GPU clusters (Zimmerman et al., 2019) that we have adapted to our dataset. Pros and cons of each approaches are explained in this presentation. Between January and May, nearly 20k events were detected by this ensemble of methods. Events have high S-wave energy while P-wave amplitudes are weak to absent/undetected on the recorded waveforms, and most often only observed on the downhole geodes. This poses some challenges in event location and source mechanism analysis. Moreover, S-P interval times are small, in the range of 0.2 - 0.5 s, an additional challenge for automated event arrival time determination. Arrivals were determined by waveform cross-correlation relative to a reference waveform templates, and located using a nonlinear probabilistic approach (Lomax et al., 2009). Events are largely located in the shallower 150 m, above the reservoir. Preliminary analyses of local magnitudes using the coda-duration method (Rodriguez-Padrilla and Eaton, 2019) suggest these weak events are M << 1. High S/P ratios indicate events may be dominated by a shear failure mechanism (Eaton et al., 2014b). High seismicity rates shows some correlations with bottom well injection pressure and CO_2 flow rate. During periods of high microseismic activity, we also observed long period, long duration signals with dominant frequency in the 10-15 Hz range. These signals last from a few minutes to almost half an hour. Polarization analysis using the downhole array shows high signal rectilinearity, suggesting a superposition of body waves. Polarization directions are predominantly N-S, with inconsistent incidence angles that may suggest a diffuse wavefield. These tremor-like signals may indicate resonance phenomena such as observed during some hydraulic-fracturing experiment from pumping operations or eigen-vibrations of fracture networks (Tary et al., 2014).

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