

Improved microseismic event detection with CATS: A case study of the QUEST CO₂ storage facility, Alberta.

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Summary

The QUEST facility in Fort Saskatchewan, Alberta, has successfully injected over 7.7 million tonnes of CO₂ as of December 2022, and is on track to meeting its goal of injecting ~27 million tonnes of CO₂ within 25 years (Shell Canada Energy, 2023). The monitoring, measurement and verification (MMV) plan for the facility includes microseismic monitoring of an area within 10 km radius from the injection site (known as the Area of Review, AOR). This is achieved by a string of eight downhole geophones.

We present the results of a novel microseismic event detection method operating in the time-frequency domain, the Cluster Analysis of Trimmed Spectrograms (CATS), on two months of downhole geophone data. The advantage of CATS over other traditional energy- and spectral-based detection methods lies in its ability to automatically determine the changing noise level of the signal as a function of time and frequency. We compare the detection results with an event catalog derived using the STA/LTA (Short-Term-Average/Long-Term-Average) method (Trnkoczy, 2009) during the same period. CATS detects ~83% more events within the AOR during this period, lowers the minimum magnitude of detected events from M -1.25 to M -2.18, lowers the detectable minimum Signal-to-Noise-Ratio (minSNR) of events, and identifies microseismic events that overlap with other signals on the basis of their frequency characteristics (e.g. vibroseis sweeps), that were previously discarded/missed in the STA/LTA detection. Our results show that CATS provides improved microseismic event detection capabilities on the downhole geophone network compared to the STA/LTA method, in relatively noisy environments. This improvement is significant and beneficial to the MMV implementation in large-scale carbon storage sites affected by various sources of anthropogenic noise. We will further refine the CATS detections with a template matching algorithm derived from subspace decomposition, which will eliminate false events and identify events with highly similar waveforms.

Method

The Cluster Analysis of Trimmed Spectrograms (CATS; Grubas et al., 2023) event detection method is a simple, fast and accurate method that consists of three stages and only requires eight free parameters. First, the method applies a Short Time Fourier Transform (STFT) to the data to obtain its amplitude spectrogram. Secondly, it applies an automatic noise estimation method (B-E-DATE; Mai et al., 2015) to the spectrogram to determine the noise level and trims the spectrogram to keep the signals above the minimum Signal-to-Noise-Ratio threshold. Finally, it clusters the trimmed spectrograms by neighboring pixels, and computes the likelihood and detection of the clustered signals based on the minimum cluster size and separation required in time and frequency. We apply the CATS event detection method to two months of data (26 November 2021 – 28 January 2022) recorded by the downhole geophones at QUEST. We then compare the microseismic events detected by CATS within the AOR to those previously detected

by the STA/LTA method within the same period. To further refine the CATS detection results, we apply a template matching algorithm derived from subspace decomposition, which will reduce false detections due to anthropogenic signals and identify microseismic events with highly similar waveforms.

Results, Observations, Conclusions

The CATS method detected ~83% more events within the AOR compared to those detected by the STA/LTA method (33 events vs. 18 events) within the two-month period (e.g. Fig. 1a). The additional 15 events detected by CATS range from $-2.18 < M_L < -0.98$, which are mostly lower than the smallest event magnitude detected by the STA/LTA event catalog ($M_L -1.25$). These additional events also have lower minSNR compared to the minSNR of STA/LTA-detected events. In addition, several of these additional events overlapped with other anthropogenic signals (e.g. vibroseis sweeps), that caused these events to be missed or discarded from the previous STA/LTA detection. CATS was able to detect and distinguish these events based on their time-frequency characteristics (e.g. Fig. 1b). Our results show that the CATS method, combined with the template matching algorithm derived from subspace detection, have improved the microseismic event detection capabilities on the downhole geophone network at QUEST compared to the STA/LTA detection method.

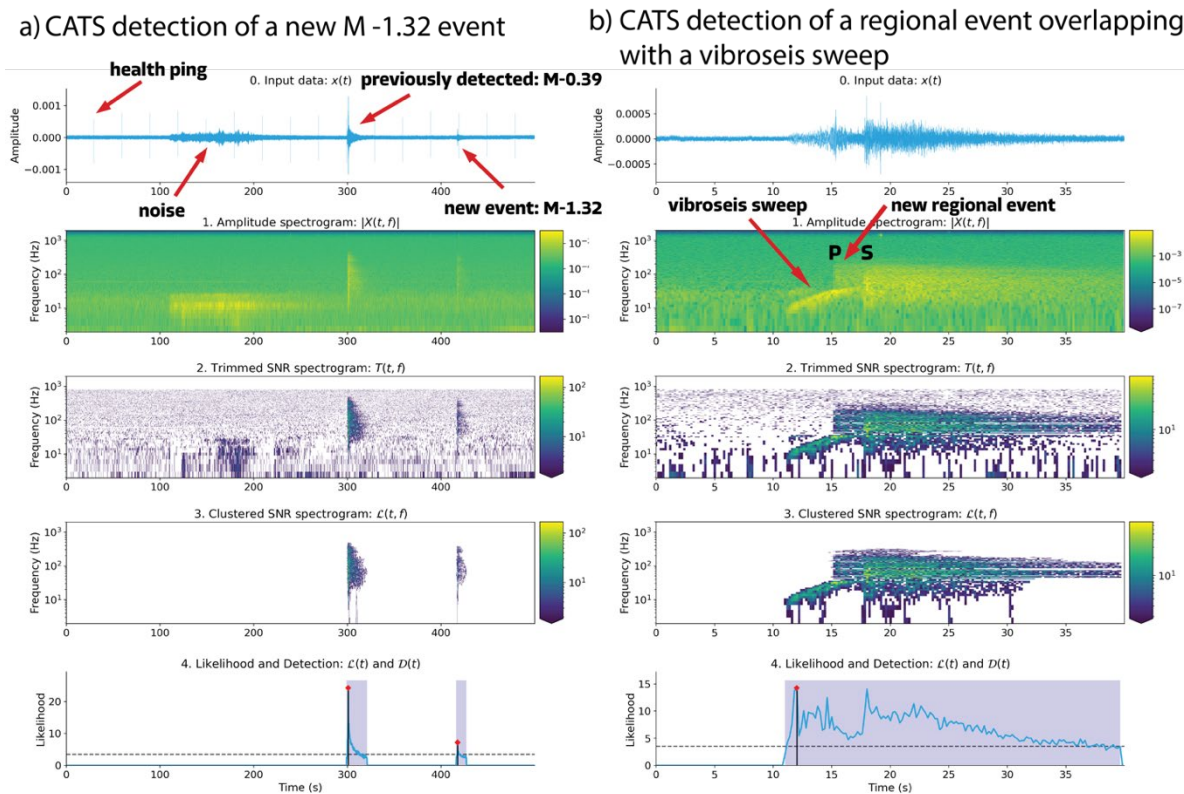


Figure 1. a) Example of the CATS detection result on an 8-min geophone trace, showing two detected events; one previously detected by the STA/LTA method and a smaller newly detected event. b) Example of the CATS detection result on a 40-sec geophone trace, showing detection of a new regional event

overlapping with a vibroseis sweep. The spectrogram shows the characteristic frequency range of the vibroseis sweep and the clear arrivals of the P- and S-waves of the regional event.

Novel/Additive Information

Our study involves the application of a novel microseismic event detection method (CATS) to a downhole geophone network installed at the first, large-scale, onshore CO₂ storage facility at an oil sands upgrader. Our results show significant improvements in the event detection capabilities of this new method, compared to the traditional STA/LTA event detection method. In addition, the application of the template matching algorithm derived from subspace decomposition provides an efficient and accurate method for quality control of the detection results for identification of highly similar waveforms that belong to the same cluster of events.

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