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Comparison of STA/LTA and Power Spectral Density (PSD) methods for Microseismic Event Detection

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Summary

We have compared the performance of two microseismic event detectors, namely the STA/LTA and PSD methods. We conclude that the PSD technique outperforms the STA/LTA method by detecting a higher number of weak microseismic events that are obscured by background noise. The PSD method has the advantage over STA/LTA method that no prior bandpass filtering is required to enhance the SNR and also permits for detection of signals with characteristically different frequency contents if the background noise spectrum is stationary.

Introduction and Theory

Reliability of microseismic interpretations is very much dependent on how robustly microseismic events are detected and picked. Various event detection algorithms are available but detection of weak events is a common challenge. In this paper we compare the performance of a time- and a frequency-domain microseismic event detection method. The first technique is the Short-Term Average/Long-Term Average (STA/LTA) method (Allen, 1978; Trnkoczy, 2002), which is the most commonly used technique in industry, in which the ratio of average energy (or envelope or amplitude) in a short-term window and a subsequent long-term window (STA/LTA ratio) is used as a criterion for picking. The second method is a modified version of a newly introduced method by Vaezi and van der Baan (2014) that is based on the Power Spectral Density (PSD) measurements. The PSD method proposed here differs from their technique in the sense that instead of a simple summation of normalized individual PSD misfits from the background average PSD, a weighting average scheme is adopted. This helps better detect both transient and persistent events.

Data and Results

The microseismic data we have used for this study are from a borehole array consisting of 12 3C conventional 10 Hz geophones deployed in a vertical monitoring borehole, which is located between the two injection wells. We have applied both event detection techniques to a 1-hour segment of the vertical component of raw (unfiltered) continuous data recorded at the shallowest borehole geophone. The sampling time interval is 0.25 ms. Figure 1 shows the data segment that we have used for the current analysis.

The parameters shown in Tables 1a and b are used for the STA/LTA and PSD methods, respectively, and Figures 2a and b show the corresponding STA/LTA ratios and PSD criterion, respectively. The detection thresholds are plotted as red dashed lines in each figure. The detection thresholds in both methods are selected in such a way that minimizes the number of false alarms.

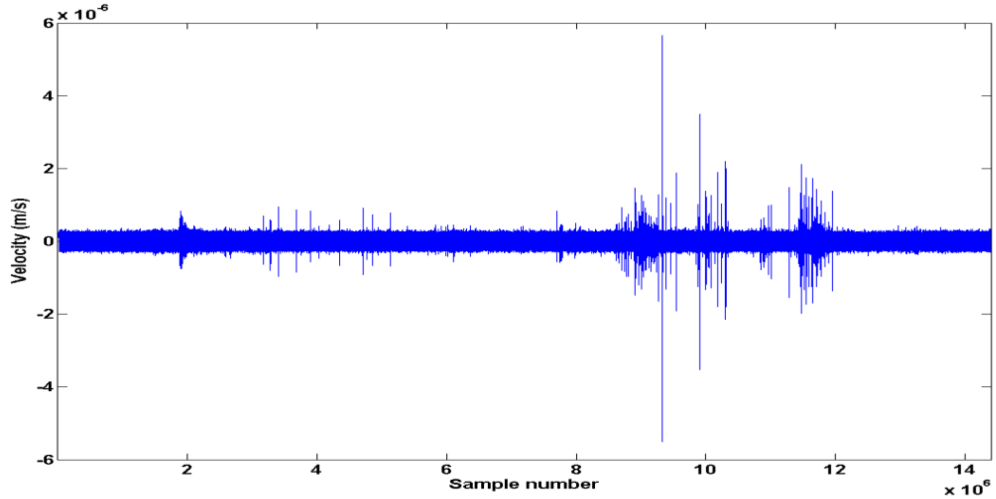

Figure1. The Z-component of 1-hr long segment of the raw continuous microseismic data.

Table 1a: The STA/LTA parameters

STA window length	30 ms (120 samples)
LTA window length	100 ms (400 samples)
STA/LTA detection threshold	2

Table 1b: The PSD method parameters

PSD window length	0.25 s (1000 samples)
Window overlap	50 %
PSD detection threshold	1.6

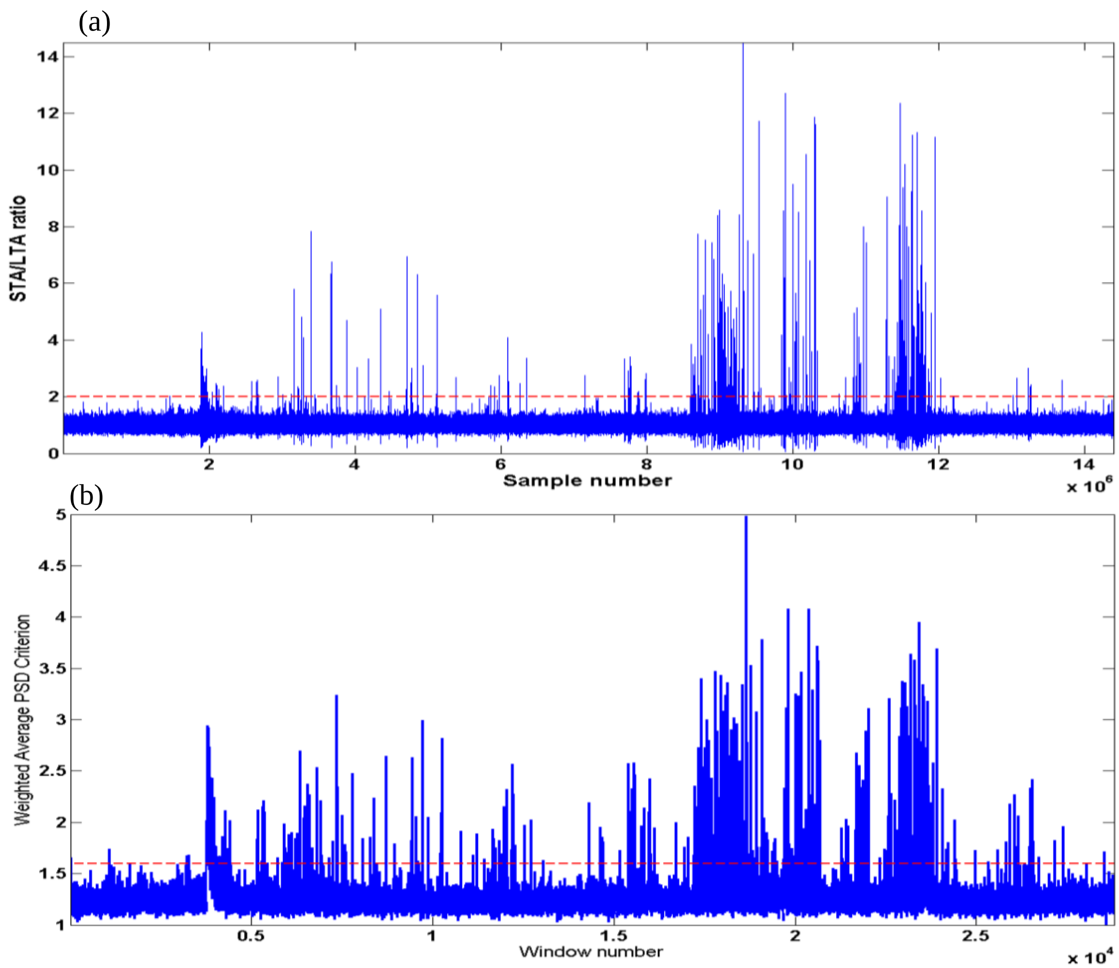

Figure 2. (a) The time-frequency representation of raw PSD ratios calculated using equation 4. (b) The same as (b) for PSD ratios.

The number of declared events by the PSD technique is 467, which is more than 2 times the number of events declared by the STA/LTA method that is 281 events. Figures 3a and b show two raw 1-second long vertical component data segments each including a potential weak microseismic event in the middle, which are obscured by the background noise. Therefore, they are not detectable by STA/LTA technique. On the contrary, the modified PSD detection method has successfully detected these events due to their anomalous PSD estimate over some frequency band compared to that of the background noise. In order to ensure these are indeed microseismic events, they are bandpassed over their dominant frequency band, [10 50] Hz, deduced from their time-frequency representations at their equivalent times (Vaezi & van der Baan, 2014). Figures 3c and d show the corresponding bandpassed Z-component time series at all the geophone levels (RCV1 is the shallowest receiver and so on). The coherent waveforms appearing at all geophone levels confirm that they are actually microseismic events.

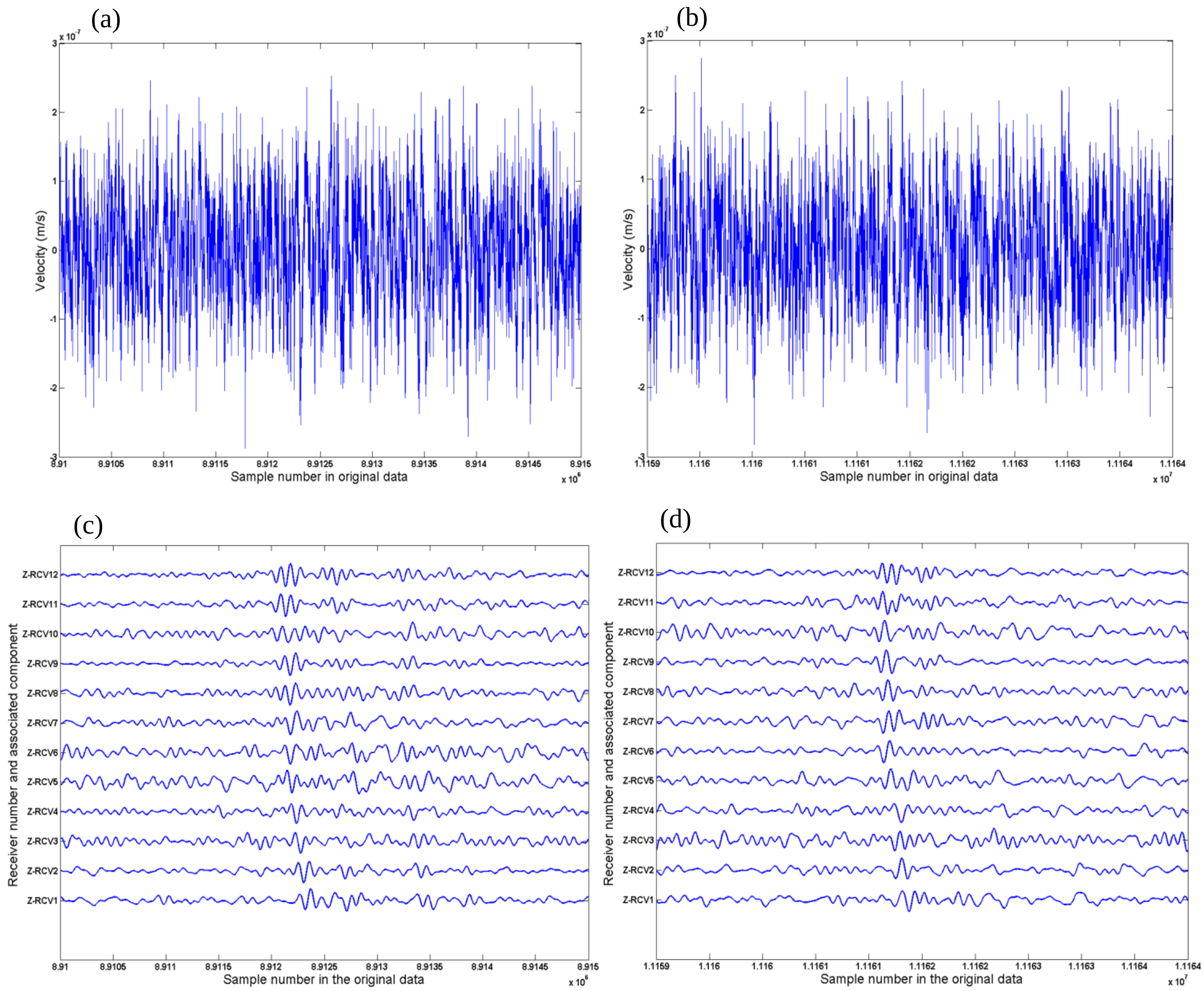

Figure 3. (a) and (b) Two events detected by PSD method and missed by the STA/LTA method. (c) and (d) The corresponding time series on at all geophone levels.

Discussions and conclusions

We have compared the performance of two microseismic event detectors, namely the STA/LTA and PSD methods. We conclude that the PSD technique outperforms the STA/LTA method by detecting a higher number of weak microseismic events that are obscured by background noise. The PSD method has the advantage over STA/LTA method that no prior bandpass filtering is required to enhance the SNR and also permits for detection of signals with characteristically different frequency contents if the background noise spectrum is stationary.

Compared with the STA/LTA algorithm, our suggested event detection method uses a similar number of parameters, namely a detection threshold and a sliding window of pre-specified length. As the PSD technique is based on the time-frequency representations, the window size should be chosen such that it trades-off between temporal and spectral resolutions. The window length should be small enough to make closely-spaced events distinguishable and large enough to allow long-period components to be adequately accounted for in the analysis. The PSD method is devised to be insensitive to variations in signal frequency content. Conversely, it does assume constant background noise levels (Vaezi & van der Baan, 2014). Time-frequency representations of the calculated PSD ratios can also be used to design a more suitable bandpass filter for further analysis of microseismic data whereas the STA/LTA method usually requires the data to be bandpassed prior to event detection.

However, it should be noted that onset-time picking and event detection are two different concepts. The former includes specifying the exact arrival time of the event whereas the latter implies only the presence of events. When the parameters are best set, the STA/LTA technique seems to better determine the onset-times while the PSD method works best in identifying the presence of an event. We suggest that the PSD method would relatively do better in detection of emerging events where the gradual amplitude increase can make the STA/LTA method fail.

Acknowledgement

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