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# Improving microseismic data quality with noise attenuation techniques

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## Summary

Microseismic data always contains noise and its effect is to reduce the quality and content of the microseismic catalog. As such noise attenuation techniques should be of paramount importance when designing microseismic processing flows. However, this is often not the case and all too often noise attenuation methods are either not applied or only examined through artificial synthetic tests. The purpose of this paper is to describe two very simple noise attenuation methods which can be applied to sparse surface microseismic surveys. Rather than focusing on properties of the methods themselves, here we assess their impact on the SNR of arrivals from real microseismic events and the resulting catalog enhancements gained. The results show that higher quality catalogs can be obtained by applying relatively simple procedures prior to STA/LTA trigger detection and that classical assumptions regarding the expected gains based on the uncorrelated nature of noise may not be valid.

## Time Frequency Despiking

The first noise attenuation technique considered is a time-frequency domain despiking procedure. The method is similar to the winsorization deployed by Blunda and Chambers (2013) where by:

1. Traces for a given time window are transformed into the frequency domain
2. The frequency amplitude is then examined across the array
3. Base on a threshold large frequency amplitudes are deemed outliers and are clipped back to the median value.

In principle any threshold value for determining an outlier can be used, we find that robust results are obtained using 3 times the median amplitude values at each frequency.

To test the efficacy of the despiking procedure we show a 24-hour period which included periods of hydraulic fracture treatment monitored using a sparse surface network in figure 1. The figure shows locations obtained applying a standard processing flow (black) as well as the additional events obtained by applying the despiking procedure prior to STA/LTA trigger detection (red). The application of the despiker lead to a 20% increase in the event count over this treatment as a whole and that the distribution of the events follows a similar pattern to the existing detection (but importantly it is not required to), resulting in a more complete description of the hydraulic fracture seismicity.

## Super Station Stacking

We also investigate the stacking of waveforms from adjacent sensors in order to construct “super-stations”. This procedure is similar to what has been used in exploration and large array surface microseismic for a number of years (for example see Sheriff and Geldart 1995, Duncan and Eisner 2010). However, in this case we store the individual traces prior to group forming, thus allowing us to examine the efficacy of the method in SNR enhancement.

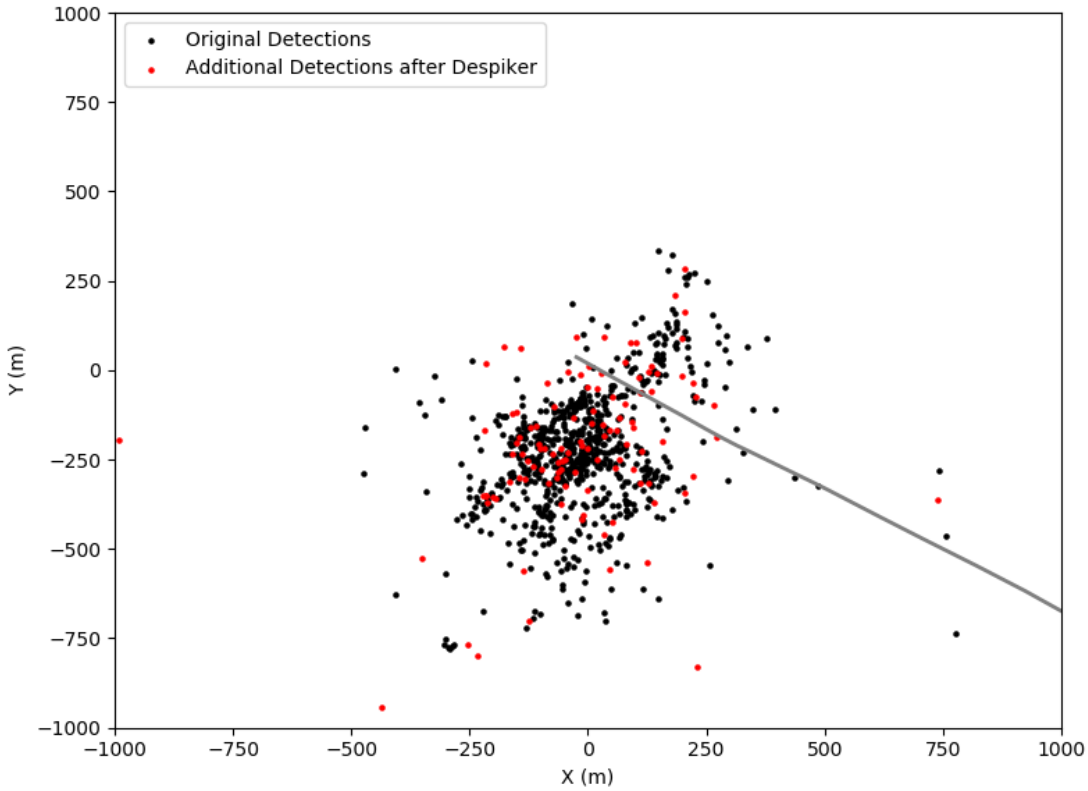


*Figure 1 - Map view of locations for a 24-hour period including periods of hydraulic fracture treatment. (black) Events identified using a standard workflow, and (red) additional events identified by applying the despiker prior to STA/LTA trigger detection. Apart from the prior addition of the despiker both datasets were subject to the same workflow, namely STA/LTA trigger detection, manual review and template selection, subspace analysis, initial grid search locations and location refinement using a double difference method.*

The test dataset for this section is a sparse surface microseismic dataset that included 3 super stations deployed with varying positions and inter-sensor spacings. Figure 2 shows an example event recording from one such super-station. It can be seen that the stack trace presents a clearer arrival on all components. However, there is some noise contamination present in the stack traces, for example longer period signals are observed just before the S wave arrival on component H1 which are not completely attenuated by the stacking process.

Figure 3 shows a histogram of SNR values for arrivals from 873 events observed at 3 different patches, before and after super station stacking. The influence of the super station stacking is to shift the mean SNR from 1.7 to 2.24, similarly the median values has changed from 1.44 to approximately 1.8. Thus the expected SNR gain from super station stacking is a factor of approximately 1.3.

It is worth noting that the SNR gain is less than what would be expected following the conventional wisdom that stacking increases SNR proportional to the square root of the number of traces in the stack. This is the so called square-root-N rule, which predicts a factor of 2.4 improvement in the resulting SNR.

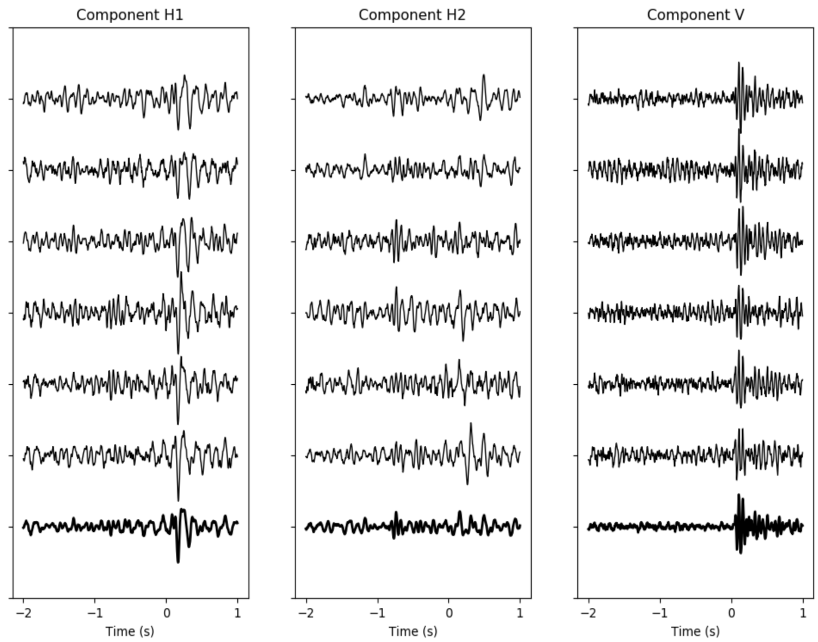


*Figure 2 : Example microseismic event detection at a super station consisting of 6 3C sensors. LHS and Centre show the horizontal components, RHS shows the vertical component. The records are aligned to the S-wave arrival time on the verticals and the P-wave arrival time on the horizontals. The top 6 traces are the individual sensor recordings and the bottom trace (in bold) is the stack trace.*

However, the square-root-N rule assumes that the noise (or inter-trace variability) is random and uncorrelated, however this assumption is a statistical ideal and is rarely if ever valid (Cieslik et al., 2016; Birnie et al., 2016, in prep). This is confirmed by inspection for figure 2 where we see that there are correlated signals between the traces which are not effectively removed by the stacking process. Nonetheless the super station stacking provides a definite SNR enhancement and could well form the basis for more sophisticated procedures.

## Conclusions

In this study we focus on the application of two very simple noise attenuation procedures to microseismic monitoring using a sparse network. In both cases we find that the resulting SNR is increased and hence the resulting microseismic catalog is enhanced. In particular, the application of the despiking procedure prior to trigger detection provided a substantial increase in the number of events, which otherwise would have been considered undetectable. Whereas the super-station stacks demonstrated a factor of 1.3 SNR enhancement, which although less than the statistical ideal determined from the square-root-N rule still provides a significant improvement on event detection. As such we believe these two methods form valuable additions to the geophysical toolset and could form the basis for more sophisticated methods in the future.

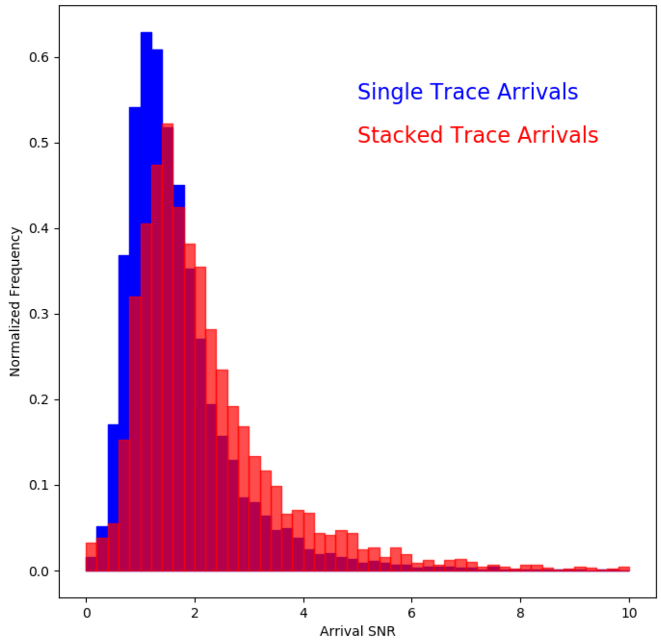


*Figure 3 - Histograms of SNR values for arrivals on 15931 individual and 7175 stacked traces (super-stations). SNR was measured as the ratio of RMS in windows 0.125s and 0.25s following P and S onsets respectively to a 1s window prior to the arrival. The mean SNR for single trace arrivals is 1.72 with median 1.44 whilst the corresponding values for the stacked traces are 2.24 and 1.84.*

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