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The application of automated seismic location method to locate injection induced and triggered volcano-tectonic microseismic events

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Locating microseismic events is essential for many areas of seismology including volcano and earthquake monitoring and reservoir engineering. With the proliferation of dense seismic networks sampling the full seismic wavefield, recorded seismic data volumes are getting bigger and automated analysis tools to detect seismic events are essential. Here, we propose a novel Multichannel Coherency Migration (MCM) method to detect earthquakes in continuous seismic data and reveal the location and origin time of seismic events directly from recorded waveforms. By continuously calculating the coherency between waveforms from different receiver pairs, MCM greatly expands the available information which can be used for event location. MCM does not require phase picking or phase identification, which allows fully automated waveform analysis. By migrating the coherency between waveforms, MCM leads to improved source energy focusing. Tests and analysis show that MCM is noise resistant (low to signal-to-noise ratio 0.025) and can achieve more accurate location results compared to other migration-based methods. MCM is able to suppress strong interference from other seismic sources occurring at a similar time and location. It can be used with arbitrary 3D velocity models and is able to obtain reasonable location results with a smooth but inaccurate velocity model. MCM exhibits excellent location performance and can be easily parallelized giving it large potential to be developed as an automatic and real-time location method for very large datasets.

We have compared MCM to other migration-based methods using noisy synthetic dataset and volcano-tectonic dataset. Real drilling noise has been added into the synthetic dataset to mimic injection induced seismic dataset. Our event location example of the synthetic dataset with real drilling noise shows that continuous and coherent drilling noise at a reservoir will pose great challenges for source imaging. However, automatic quality control techniques such as filtering in frequency domain and weighting can effectively remove the continuous drilling noise and improve the source imaging quality. The volcano-tectonic dataset involves lots of microseismic events triggered by a remote large earthquake. We located two triggered microseismic events with local magnitude below 1 using 15 temporarily deployed local seismometers. Compared to other migration-based methods MCM performs better for sparse and irregular receiver arrays and reduces directivity uncertainty. The location performance of the MCM method on the synthetic and real volcano-tectonic dataset demonstrates that the MCM method can perform as a reliable and automatic seismic waveform analysis tool to locate induced and triggered microseismic events.