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MALMI: towards combining machine learning and waveform migration for fully automated earthquake detection and location

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Automatic event detection and location is key to real-time earthquake monitoring. With the increase of computing power and labeled data, automated workflows that utilize machine learning (ML) techniques have become increasingly popular; however, classical workflows using ML as phase pickers still face challenges for seismic events of short inter-event time or low signal-to-noise ratio (SNR). Full waveform methods that do not rely on phase pick and association are suitable for processing these events, but are computationally costly and can lack clear event identification criteria, which is not ideal for real-time processing. To leverage the advantages of both methods, we propose a new workflow, MALMI, which integrates ML and waveform migration to perform automated event detection and location. The new workflow uses a pre-trained ML model to generate continuous phase probabilities that are then back-projected and stacked to locate seismic sources using migration.

We applied the workflow to a microseismic monitoring dataset collected in a borehole at the Utah FORGE geothermal laboratory site. The proposed workflow can automatically detect and locate induced microseismic events from continuous geophone recordings. Different ML models are evaluated for detection capability and phase classification accuracy. We expect that better performance should be possible if a customized ML model re-trained using local dataset would be used in the MALMI workflow. Further comparison with conventional migration methods confirms that MALMI can produce much clearer stacked images with higher resolution and reliability, especially for events with low SNR. The workflow is freely available on GitHub, providing a complementary tool for automated event detection and location from continuous data.