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The QuakeMatch Toolbox: Using waveform similarity to enhance the analysis of microearthquake sequences at Swiss geothermal projects

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Many Swiss microearthquake sequences have been analyzed using relative location techniques. While these methods have often been effective in identifying active fault planes and the tectonic processes driving the seismic activity, several sequences present a limited number of located events. This limitation often hampers the detailed analysis of their space-time evolution, seismicity patterns, and driving mechanisms.

To address this challenge, we introduce a nearly automatic workflow that combines established seismological analysis techniques to enhance the completeness of detected and located earthquakes within a sequence. Starting with a manual catalog (magnitude of completeness, $M_c \approx$ 1.0−1.5 M_L), we compile a template set and conduct a matched filter analysis on a single station with the highest signal-to-noise ratio (SNR). This approach enables the detection of events with local magnitudes $M_{L□}$< 0.0, with waveform similarity further leveraged to determine consistent magnitudes for these detections. The enhanced catalog is statistically analyzed to obtain high-resolution temporal evolutions of the Gutenberg−Richter a- and b-values, and consequently, the occurrence short-term probability of larger events. Finally, strong events are relocated by the double-difference technique, typically improving the final number of relocated events by a factor of 2-5.

The proposed workflow significantly improves the analysis of the spatiotemporal behavior of natural and induced microearthquake sequences. Notably, we employ it for semi real-time monitoring of commercial and scientific fluid-injection projects. The QuakeMatch workflow is implemented in Python and PostgreSQL. We discuss the capabilities of QuakeMatch through examples involving induced microearthquake sequences associated with various geothermal projects monitored by the Swiss Seismological Service within the GEOBEST2020+ project.