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Repeating earthquakes: finding small signals in Big Data

Roseanne Clement, Ian Main, and Andrew Bell

University of Edinburgh, Earth and Planetary Sciences, School of GeoSciences, Edinburgh, United Kingdom (r.clement@ed.ac.uk)

Numerous catastrophic failure events, e.g. large earthquakes, landslides and volcanic eruptions, occur after multiple sets of smaller repeating earthquakes. Such events also occur when no larger event follows. Nevertheless, they have the potential to reveal underlying processes such as the nucleation of large events, or stable repeated slip, and hence could improve probabilistic forecasts of the likelihood of catastrophic events. The problem with finding these repeating events is that they are often small, hidden within the ambient noise, and sometimes only picked up by one seismometer.

Here we develop an optimised algorithm to extract a catalogue of repeating events and to determine their evolution in different seismic signals. By enhancing the short-time-average/long-time-average (STA/LTA) approach for finding events with a moving cross-correlation window, we discover new repeating events automatically. Subsequent tracking of how these events change through time then allows us to resolve the processes taking place. Building our algorithm using synthetic data allows us to establish and optimise a reliable method, and to explore the effect of several conditions, e.g. ambient noise. We evaluate the algorithm's success in finding repeating events statistically with hits, false alarms and misses, similar to clinical trials. Preliminary studies show that our method works significantly more successfully than the conventional STA/LTA approach on its own, with more hits and more accurate pick times, especially when there is a low signal-to-noise ratio.

We demonstrate the success of our algorithm in real cases of past earthquake sequences and volcanic eruptions. From this, we can: 1) evaluate how the repeating events change with respect to the volcanic eruption, and 2) identify large earthquakes which have had (or not had) nucleating foreshocks in the form of repeating events, aiding to the understanding of the pre-earthquake mainshock processes and their forecasting power.