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Using Multiplets to Examine the Nucleation Processes of Different Catastrophic Failure Events

Roseanne Clement, Ian Main, and Andrew Bell
University of Edinburgh, The King's Buildings, School of GeoSciences, Edinburgh, United Kingdom (r.clement@ed.ac.uk)

Multiple sets of events with high waveform similarity (multiplets) have often occurred prior to different types of catastrophic failure events, e.g. large earthquakes, landslides and volcanic eruptions. This similarity indicates the source locations are restricted to a very localised zone. Hence, analysing multiplets has 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 different catastrophic events. By resolving the processes taking place, we can determine their relationship to the catastrophic failure event as foreshocks, aftershocks or independent processes. The problem with finding multiplets is that they are often small, obscured in ambient noise, and sometimes only picked up by one seismometer.

We have developed an optimised detection and analysis technique to extract a catalogue of multiplets and determine their temporal 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 events automatically in a dedicated high Random-Access Memory computational engine. Subsequent temporal tracking and statistical analysis of these events then allows us to examine their occurrence and resolve the processes taking place. The algorithm's success in finding events is evaluated statistically with hits, false alarms and misses, analogous to clinical trials in medicine. Our method works significantly more successfully than the STA/LTA approach on its own, with more hits and more accurate pick times in different catastrophic failure settings. We demonstrate the success of our algorithm in real cases of past earthquake sequences and other catastrophic failure type events. From this, we can identify large earthquakes which have had (or not had) nucleating foreshocks in the form of multiplets, aiding to our understanding of the nucleation process. We can also use this technique for other types of catastrophic failure type events, such as volcanic eruptions, to determine the underlying processes taking place based on the evolution of multiplets prior to failure. Our current analysis on large earthquakes show no clear nucleation pattern between different cases; however, we do obtain a more complete view of the pre-mainshock seismicity taking place, helping to better understand pre-failure processes.