Using the similarity Matrix Profile to investigate foreshock behavior of the 2004 Parkfield earthquake

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Abstract

The town of Parkfield, located near the transition zone of northern creeping and southern locked zone of the San Andreas fault, was heavily instrumented in the 1980s based on previous observations of 5 quasi-periodic M 6 earthquakes since 1857. The expected event occurred over a decade 'late' in 2004, but was recorded in excellent detail by a dense array of high sensitive borehole seismometers. Although the seismic records were remarkable for this event, no precursors were reported at the time (e.g. Bakun et al., 2005). After the discovery of non-volcanic tremor (NVT), some evidence of NVT activity before the main shock has been reported (e.g. Shelly et al 2009), but the relationship with the mainshock remains cryptic. Here for the first time we use a new, efficient time series similarity search method, called the similarity Matrix Profile (MP) to search for foreshocks of the Parkfield event. The MP is essentially a report of the index (i.e. location in the time series) and correlation coefficient (CC) value of the nearest neighbor for any subwindow of continuous data. Using new novel algorithms and GPU hardware, it is now possible to calculate the MP for time series containing up to 1 billion data points (equivalent to 579 days of waveform data at 20 Hz). As the nearest neighbor CC values for background noise tend to be comparatively low, the MP is an effective way of detecting both high and low signal-to-noise ratio events. At Parkfield, we find multiple new repeating families of seismic events that were activated 2-3 weeks prior to the mainshock. Some of these families stay active until 1 month after the main shock and then shut off, others shut off at the mainshock. Our results show the most active time period of these families was 48 hours before the mainshock. A template matching effort for one of these families showed that beside the activity window mentioned above, there is no sign of recurrence from mid-2001 to mid-2010. The signals for these families are mostly visually detectable in nearby borehole stations but hardly distinguishable in nearby non-borehole stations. Our aim in this study to explore these foreshocks temporal behavior in more detail (i.e. locations, magnitude, mechanism, relationship with the mainshock).

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