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Parkfield microrepeater predictability experiments

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For the project, 34 repeating earthquake sequences (including the 3 San Andreas Fault Observatory at Depth (SAFOD) target sequences) were selected from previous studies in the Parkfield area (Nadeau & McEvilly, 1999, 2004), Thirty-one of the sequences were selected to provide depth and along-fault coverage of the SAF at Parkfield. The remaining 3 SAFOD sequences were chosen due to their relevance to the SAFOD project.

Updates of the sequences' repeats were carried out through 10 April 2010. To optimize completeness and objectivity of the repeater identification process (particularly problematic during the 2003 San Simeon and 2004 Parkfield aftershock sequences), a waveform based reference event pattern matching algorithm was developed and applied. Algorithm development included the empirical determination of "locked-in" waveform and spectral identification criteria based on the earlier sequence data. Pattern matching scans through continuously recorded seismograms were then carried out and the "locked-in" selection criteria were applied to objectively identify the new sequence repeats. Precise double-difference relocations and relative magnitudes (using low-frequency spectral ratio analyses) were also determined.

The total number of repeats in the 34 sequences numbers 845, which covers the period 1987 through 1998.5 and July 25, 2001 through April 10, 2010 (HRSN data was unavailable from 1998.5 to July 25, 2001). The number of events per sequence ranged from 5 to 71, with larger numbers of repeats generally corresponding to the smaller magnitude sequences).

We used the events in these sequences (and other previously identified sequences) in a series of retrospective forecast experiments. For a given sequence, we calculated the elapsed time between the first five events in the sequence and fit four candidate models to these data: Weibull, inverse Gaussian (Brownian passage time), exponential, and lognormal. From these candidates, we used the Akaike Information Criterion to determine the best fitting model and the corresponding model parameter values. We then considered the corresponding hazard function (the probability density normalized by the survivor function) as an alarm function (Zechar & Jordan, 2008) for the remaining events in the sequence.

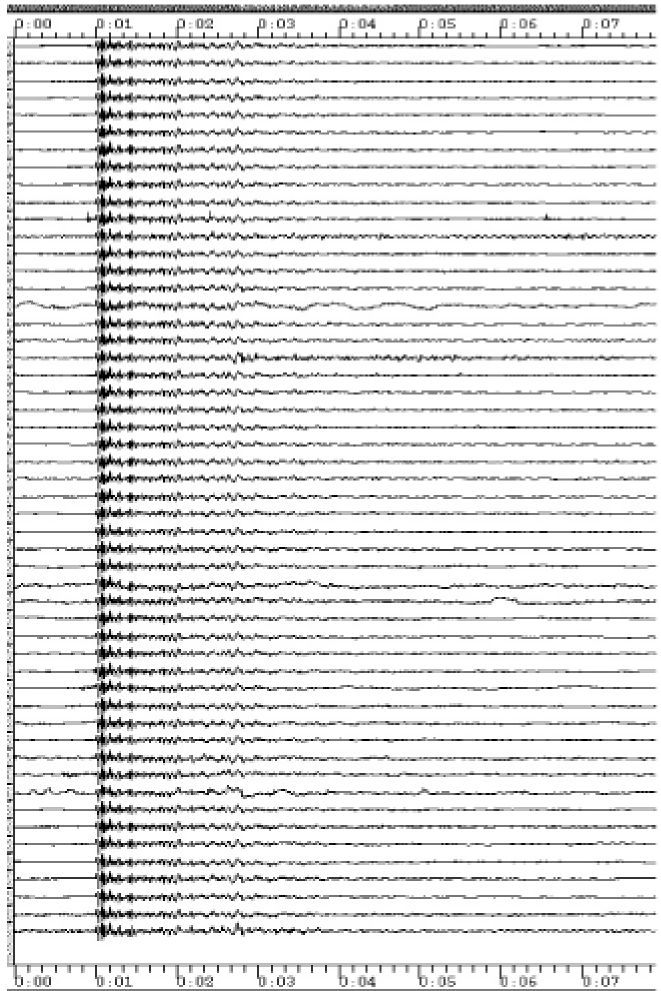

Figure 1. Example of 53 repeats of a M-0.5 sequence on the vertical component of HRSN station VCAB. Repeats occurred over the time periods cited in the text. To ensure robustness of the repeater identification process, data from multiple channels are used.

We tested three variants of this approach and we call these the static, dynamic-cumulative, and dynamic-moving window, respectively. In the static approach, the hazard function form and parameter values are not allowed to change after the first five events in the sequence—the hazard function resets after each new event in the sequence but it then grows identically. In the dynamic-cumulative approach, after each new event in the sequence all models are again tested to determine the best fitting model for all preceding intervals. In the dynamic-moving window approach, the same happens, but only for the most recent four intervals.

In these retrospective experiments, we stacked the sequences and their hazard alarm functions and found a very high degree of predictability (Figure 2). In particular, both dynamic approaches yielded performance that was significantly better than random guessing (a naïve but appropriate reference in this setup). The consistency of these findings across several sets of sequences motivated us to attempt some preliminary prospective forecasts of the 34 sequences.

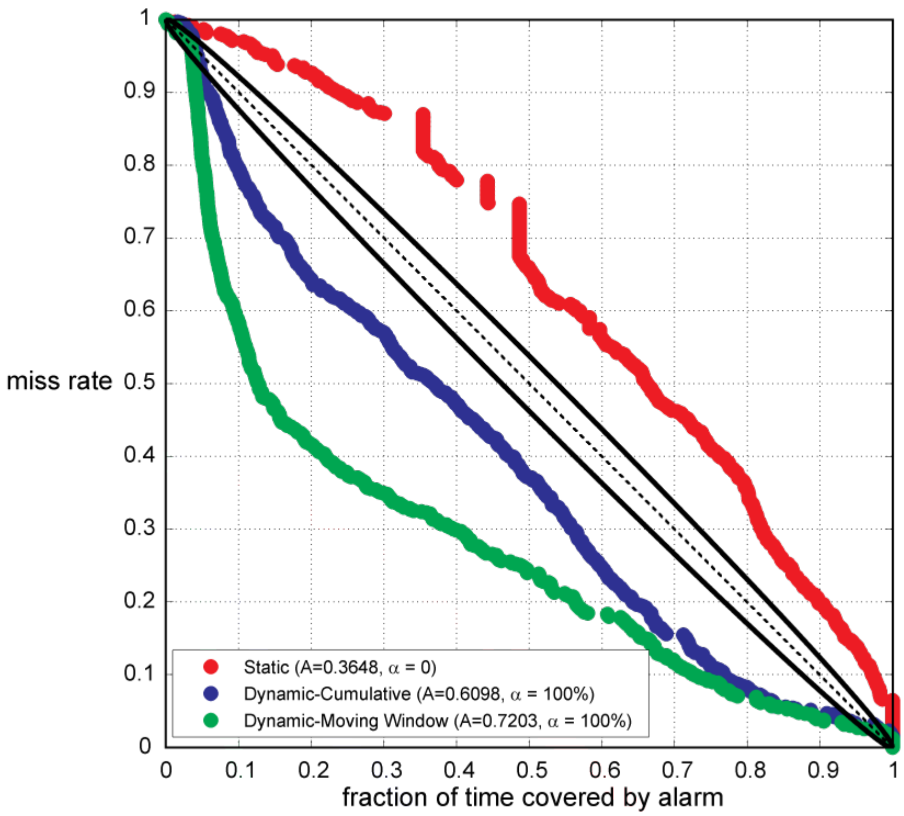

Figure 2. Results of retrospective forecast experiment with the 34 sequences mentioned in the text. Dashed line shows expected performance of declaring alarms at random—green and blue dots indicate that the dynamic approaches are significantly better.

In advance of the 2010 Seismological Society of America (SSA) meeting, PI Nadeau provided PI Zechar with catalogs of the 34 sequences complete up to 14 November 2009. Using these catalogs and some simple exploratory data analysis, Zechar formulated two types of prospective forecasts: one that gave the probability that a new repeat would occur before the SSA meeting (one probability for each sequence), and one that provided a relative ranking of the sequences (the highest rank interpreted as the most likely to repeat). These forecasts were archived as an electronic supplement to the submitted meeting abstract (http://tinyurl.com/ZecharNadeauSSA2010) and evaluated in a preliminary fashion for presentation at the meeting, using the updated catalogs mentioned above. Unfortunately, these forecasts were not very successful, but we plan to use the codes developed during this funding cycle to conduct a similar experiment in advance of this year's SCEC meeting; we will present the results in Palm Springs.

References

Nadeau, R.M., & McEvilly, T.V., 1999. Fault slip rates at depth from recurrence intervals of repeating microearthquakes, *Science*, 285, 718–721.

Nadeau, R.M., & McEvilly, T.V., 2004. Periodic pulsing of characteristic microearthquakes on the San Andreas fault, Science, 303, 220–222.

Zechar, J.D., & Jordan, T.H., 2008. Testing alarm-based earthquake predictions, Geophysical Journal International, 172(2), 715-724. doi:10.1111/j.1365-246X.2007.03676.x.

Conference abstracts resulting from this project

J.D. Zechar & R.M. Nadeau. Forecasts of repeating earthquakes near Parkfield, California, *SSA 2010 Meeting*, Portland, OR.

J.D. Zechar & R.M. Nadeau. Predictability experiments with repeating microearthquakes, *SSA 2009 Meeting*, Monterey, CA.