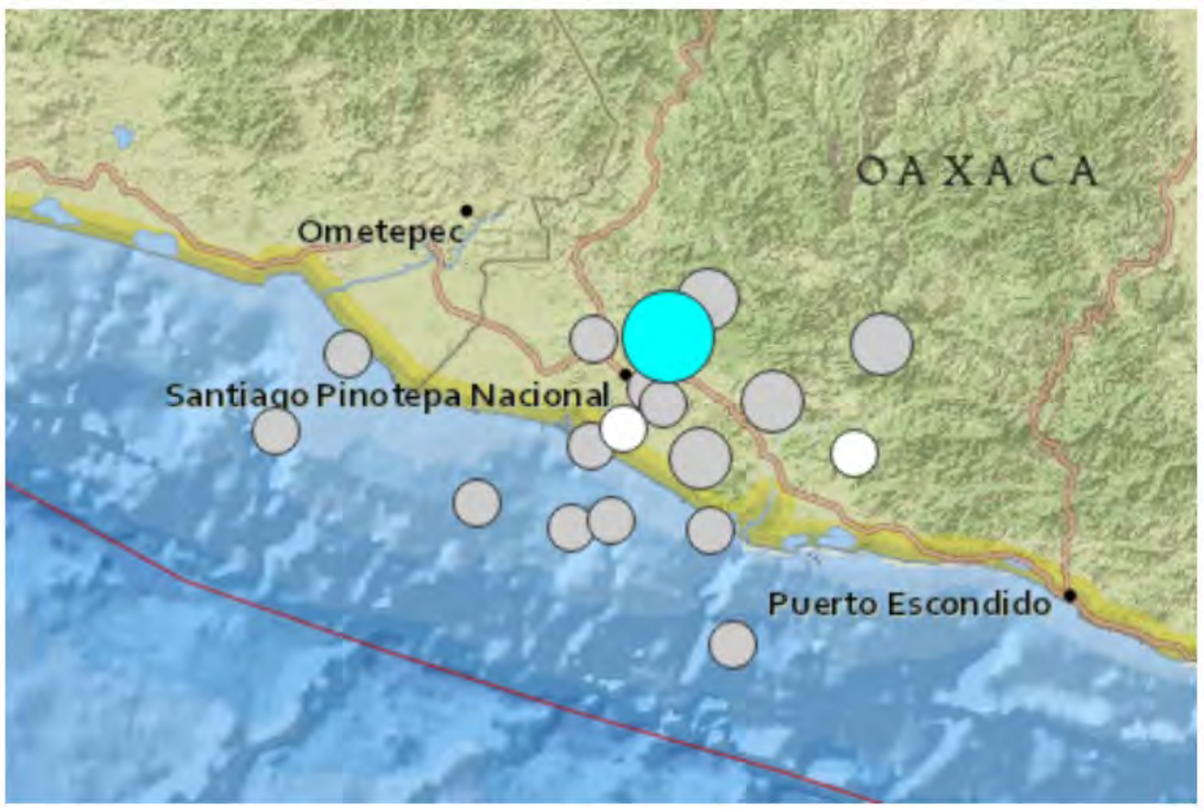
The Past Holds the Key to the Future of Aftershock Forecasting



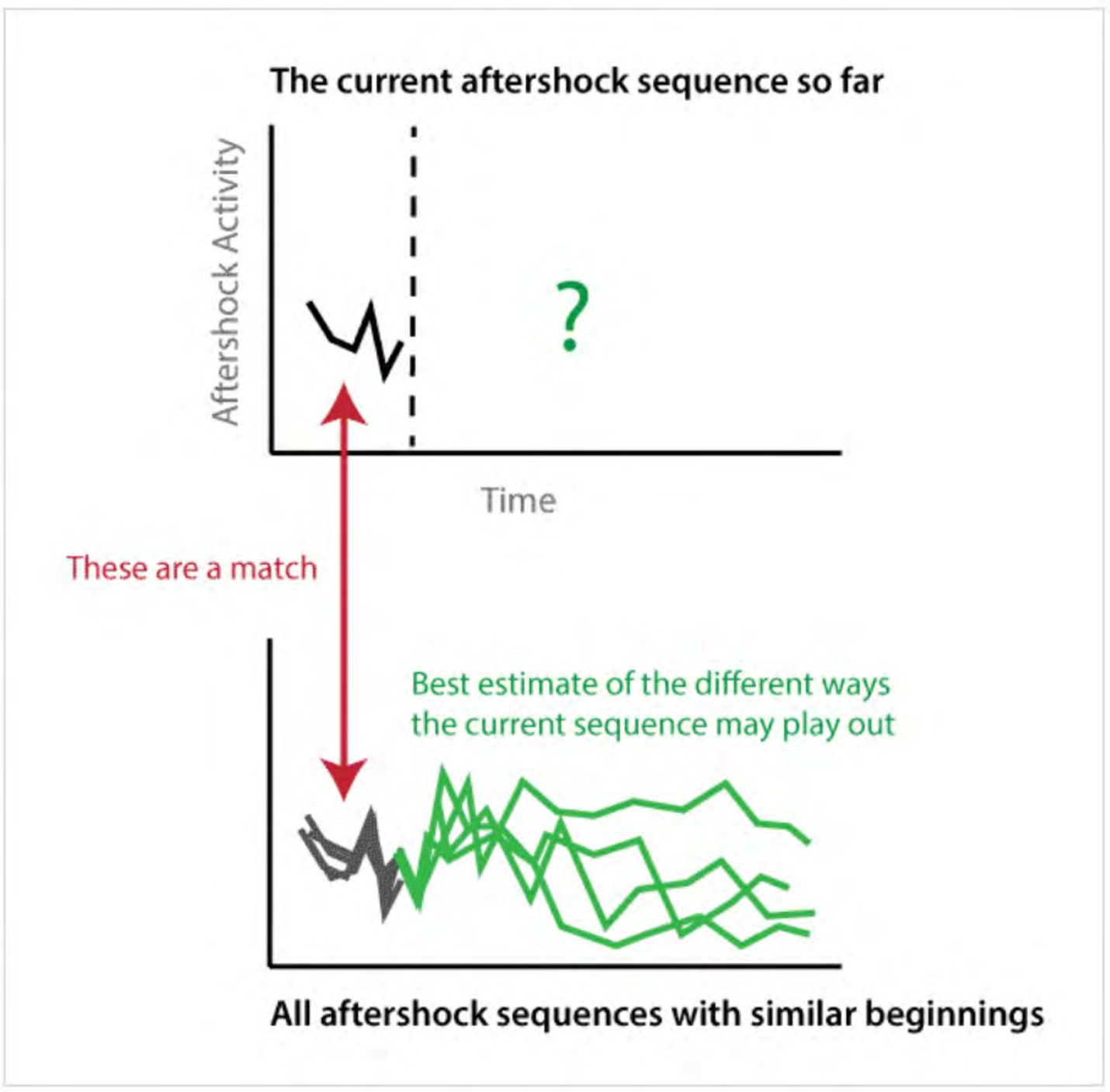
Aftershock sequence from the M7.8 Oaxaca, Mexico earthquake on February 16, 2018. The blue circle is the mainshock and the gray and white smaller circles are the aftershocks through April 3, 2018.

No one can predict earthquakes, but after a large earthquake, it's a pretty safe bet that there will be aftershocks. Aftershocks are "triggered" earthquakes that occur during the days, months, and even years after the mainshock. Aftershock sequences tend to start strong and die off slowly, although in some cases activity can pick up again if a large enough aftershock occurs. USGS scientists Nicholas van der Elst and Morgan Page wanted to see if a very simple method could give an accurate answer to the question – "Given the number of aftershocks we've observed so far, how many more are we likely to see in the future?"

There are a variety of different methods for forecasting the behavior of an aftershock sequence, but most of them rely on inputting data into a statistical model of aftershock behavior and then projecting that model into the future. The result depends on the model used and the input data, and although these models can capture the average behavior seen in aftershock sequences, they don't necessarily take into account the full range of possible outcomes. Sometimes we see more aftershocks than the models predict; sometimes less.

A **model**, in this sense, is a set of mathematical equations that represents what we know about a physical system and how it generally works.

Van der Elst and Page decided to try something completely different. Their idea was to directly compare the beginning of a new aftershock sequence with all past aftershock sequences in the region, and look for sequences with similar beginnings. The outcomes of those past sequences are then used to describe the range of possibilities for the new sequence. By using a huge catalog of past aftershock sequences, van der Elst and Page were able to accurately forecast how many aftershocks were likely to occur in any new sequence.



The black line in the top graph represents the beginning of the aftershock activity following an earthquake that just happened. The graph at the bottom represents the 4 aftershock sequences in the earthquake catalog that had a sequence beginning that matches the current sequence. The green lines show how each of those aftershock sequences continued.

So the new technique worked... but was it better? The scientists found that in most cases their "similarity method" for aftershock forecasting worked about as well as one of the standard statistical models. However, in one important aspect it was even better: there were many fewer "surprises" where the number of observed aftershocks exceeded the upper limit given by the forecast. It is especially important to accurately forecast

these very active aftershock sequences, because the larger the number of aftershocks, the larger the chance that one of those aftershocks will itself turn out to be a large, damaging earthquake. Having a better sense of the true aftershock possibilities can help prevent emergency responders and the public from being caught flat-footed.

- written by Lisa Wald, U.S. Geological Survey

For More Information

- FAQ: Foreshocks, aftershocks - what's the difference?
- Nicholas J. van der Elst, Morgan T. Page; Nonparametric Aftershock Forecasts Based on Similar Sequences in the Past. Seismological Research Letters ; 89 (1): 145–152. doi: https://doi.org/10.1785/0220170155

The Scientists Behind the Science

Nick van der Elst at the beach.

Nicholas van der Elst has been a geophysicist with the USGS since 2015, where he works on earthquake physics and aftershock forecasting. When not in the office, he can be found enjoying the less destructive side of California geology through mountaineering, caving, and rock climbing.

Morgan and her daughter Emmy at Santa Monica Pier.

Morgan Page has worked at the USGS for ten years researching in areas where statistics and seismology intersect. She loves solving puzzles of all kinds, not just science-related.