Exaggerated Claims About Earthquake Predictions

The perennial promise of successful earthquake prediction captures the imagination of a public hungry for certainty in an uncertain world. Yet, given the lack of any reliable method of predicting earthquakes [e.g., *Geller*, 1997; *Kagan and Jackson*, 1996; *Evans*, 1997], seismologists regularly have to explain news stories of a supposedly successful earthquake prediction when it is far from clear just how successful that prediction actually was. When journalists and public relations offices report the latest 'great discovery' regarding the prediction of earthquakes, seismologists are left with the much less glamorous task of explaining to the public the gap between the claimed success and the sober reality that there is no scientifically proven method of predicting earthquakes.

A striking example of this situation occurred when NASA posted a feature article on its Web site in 2004 in which an earthquake prediction project it funded was heralded as an "amazing success" (see http://www.nasa.gov/vision/earth/environment/0930_earthquake.html).

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Because this kind of hyperbole is a constant source of frustration for scientists at Weston Observatory (Boston College, Weston, Mass.), where seismologists try to accurately report the state of the art of research on earthquake prediction to the public, we decided to test just how amazing this particular success was.

Analysis of NASA's method

The NASA announcement claimed that a Rundle-Tiampo (RT) forecast [*Rundle et al.*, 2002; *Tiampo et al.*, 2002] has "accurately predicted the locations of 15 of California's 16 largest earthquakes this decade…." The Jet Propulsion Laboratory's QuakeSim Web site (http://quakesim.jpl.nasa.gov/) publishes updated 'scorecards' to illustrate how well the RT forecasts are performing [*Jet Propulsion Laboratory,* 2006]. Here, the scorecard that was posted at the time of the 2004 announcement is analyzed.

If the RT method is an amazing success, then it should perform much better than a reasonable 'least astonishing' null hypothesis. The success of the RT forecasts is evaluated here against the null hypothesis that future earthquakes will occur in the vicinity of past earthquakes. The number of forecast events discussed in the NASA announcement is given as 15 in one part of the announcement and 16 in another part. For the purpose of this analysis, the discussion is limited to the 15 events that are shown in the scorecard on the NASA Web announcement. These 15 events are referred to as the 'after' catalog because the earthquakes occurred after 1999.

We applied the 'cellular seismology' method of *Kafka* [2002, 2007] to investigate whether proximity to past earthquakes is a sufficient hypothesis to yield the same level of success as the RT method. To define the area of prior seismicity upon which this forecast is based (i.e., the 'before' catalog), the Advanced National Seismic System earthquake catalog from 1932 to 1999 with magnitude $M \geq 4.0$ was used, declustered of foreshocks and aftershocks following *Gardner and Knopoff* [1974]. The $M4.0$ cutoff was chosen based on inspection of the recurrence relation for this catalog, where we identified a change in slope for earthquakes with magnitude lower than 4.0, suggesting that this catalog is complete down to 4.0 since 1932.

This analysis used the 'before' catalog with $M4.0$ as the lower-magnitude cutoff. The QuakeSim scorecards show an 11-kilometer 'margin of error.' Applying the cellular seismology method using the 'before' catalog with $M \geq 4.0$, and circles of radius 11 kilometers, this analysis successfully forecast 14 of 15 (93%) of the 'after' earthquakes. The lower-magnitude cutoff was then systematically increased until 14 of the 'after' earthquakes (with an 11-kilometer radius) were no longer forecast. By using $M \geq 4.3$, only 13 of the 'after' earthquakes were forecast, but with $M \geq 4.2$ 14 of those earthquakes were forecast (Figure 1, left). In this case, the cellular zones cover 25% of the map area, and the locations of 14 of 15 of the future earthquakes were successfully forecast based on the simple assumption that they tend to occur near past earthquakes.

The cellular seismology method, as presented above, is purely statistical and is not based on any physical model of earthquake processes. To investigate the physical basis underlying the cellular seismology forecasts, the cellular method was revised to account for the distance surrounding a 'before' earthquake of a given magnitude within which future earthquakes might be governed by static stress triggering associated with that 'before' earthquake. This model uses the relationships between magnitude and fault size from *Wells and Coppersmith* [1994] to define a circular region around each epicenter

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where event triggering due to static stress changes might take place.

Applying this model to the entire 'before' catalog yields a map (covering 6% of the map area) that forecasts the locations of 11 of 15 (73%) of the 'after' earthquakes (Figure 1, right). If an additional five-kilometer margin of error is then added around the cellular zones for this case, the same 14 of 15 earthquakes are forecast with the cellular method as were forecast with the RT method (and the cellular zones cover 22% of the map area). Furthermore, the margin of error is only five kilometers, as opposed to the 11-kilometer margin of error of the RT method.

NASA's 'Remarkably Unremarkable' Success Rate

On the basis of the analysis presented above, the success rate referred to in the NASA announcement is perhaps better characterized as 'remarkably unremarkable' rather than amazing. The simple analysis presented here suggests that the RT method does not predict the locations of future earthquakes any better than merely assuming that future earthquakes occur near past earthquakes. There may be something more significant to the RT method than just proximity to past earthquakes, and this analysis does not demonstrate that there is not. However, the amazing success of predicting 14 of 15 of the earthquakes listed in the scorecard is not a very rigorous test of their method.

In education and outreach efforts at Weston Observatory and in courses at Boston College and other universities, scientists are often approached by people who tell them they heard or read a news report about a scientist who figured out how to predict earthquakes. Now, more than two years after the NASA announcement was posted on the Web, some people still refer to it and the news stories that followed it. A public hungry for certainty in an uncertain world can be quick to interpret NASA's exaggerated claim as an example of a successful short-term 'prediction' (i.e., the specified time, location, and magnitude of an impending event).

However, as demonstrated above, the RT forecast did not perform any better than merely forecasting that future earthquakes will occur near past earthquakes. This leaves scientists with the challenging yet necessary task of explaining the scientific reasons as to why the NASA claim is exaggerated, and of emphasizing as accurately as possible how difficult (if not impossible) it is to scientifically predict earthquakes at the present time.

Charles Richter lamented that he "had a horror of predictions and predictors" and that "journalists and the general public rush to any suggestion of earthquake prediction…" [*Richter,* 1977]. This situation remains today, and seismologists who are involved in earthquake prediction research ought to be careful to assure that their public statements convey an accurate picture of the true level of success of their predictions.

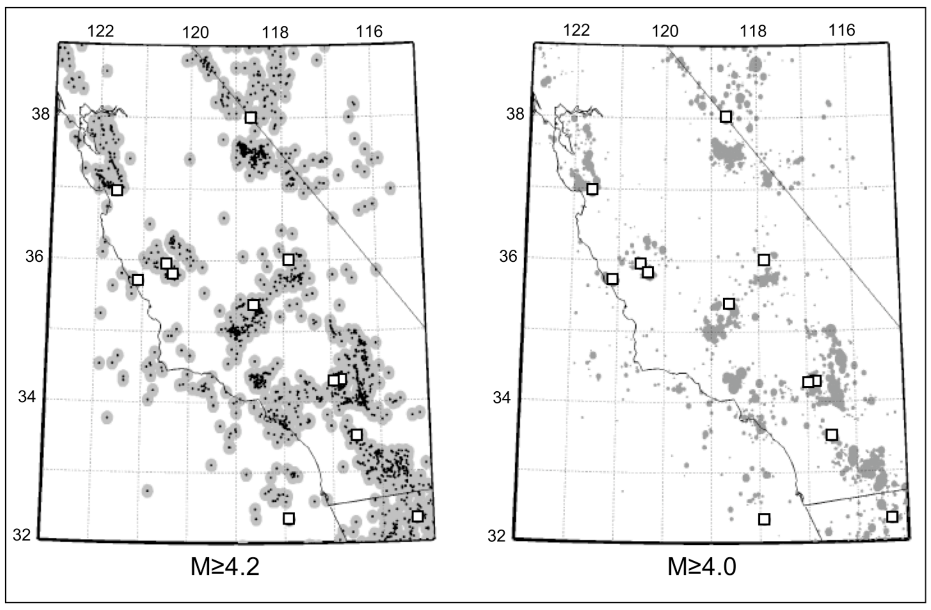

Fig. 1. (left) Black dots are epicenters of 'before' earthquakes (1932–1999, M ≥ 4.2), and shaded zones are constructed by filling in an 11-kilometer radius around those epicenters (i.e., adding an 11-kilometer 'margin of error'). Open squares (both left and right) represent 'after' earthquakes, i.e., locations of the 15 earthquakes listed in the Jet Propulsion Laboratory scorecard. Shaded zones cover 25% of the map area and capture 93% (14 of 15) of the 'after' earthquakes. (right) Shaded zones are constructed by filling in a radius around 'before' epicenters (1932–1999, M ≥ 4.0) using a relationship between magnitude and radius as described in the text. As plotted, this map forecasts the locations of 11 of 15 (73%) of the 'after' earthquakes (with 6% of the map area). Though not pictured, by allowing for a five-kilometer margin of error, 14 of 15 of the 'after' earthquakes are successfully forecast (and the cellular zones cover 22% of the map area).

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EOS
Transactions of the
American Geophysical Union
Volume 88, Number 1, January 2007