3D fault information improves alert accuracy for earthquake early warning

December 3 2021

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Three-dimensional fault models are generally more accurate than two-dimensional line models at sending ground shaking alerts to the correct areas as part of an earthquake early warning system, according to a new study.

The benefits of 3D fault models vary depending on the fault style (a strike slip versus a reverse fault, for instance), whether the event is a subduction or crustal earthquake, and the level of shaking that triggers the alert, according to Jessica Murray and colleagues at the U.S. Geological Survey.

They suggest 3D models would be an improvement over 2D models for an alert threshold of MMI 4.5, meaning that the alert would be triggered for shaking exceeding the "light" intensity category, where most people indoors would feel some shaking. In their study, 3D models also substantially improved alert accuracy for all subduction zone earthquakes at MMI 4.5 and MMI 2.5 (weak motion felt only by a few people) thresholds.

The study's findings could be useful for earthquake early warning systems like the U.S. West Coast's ShakeAlert, the researchers note in the *Bulletin of the Seismological Society of America*.

For now, ShakeAlert's algorithms use seismic data to characterize an earthquake source as a point or line. But researchers are already looking at ways to incorporate 3D source information, gleaned from fault displacement data collected by Global Navigation Satellite Systems

(GNSS), into ShakeAlert.

"The expectation has been that such information would improve alerting because it would offer a better characterization of large earthquake sources compared to a point source," Murray explained. "This assumption has not been explored in terms of how a more realistic source characterization would translate to ground motion estimates, so that is one thing we set out to do."

The researchers used synthetic data generated from hypothetical 3D and line sources in their study. While 3D source models were generally more accurate overall than line sources for alerting the correct regions, the improvement provided by 3D models was most pronounced for subduction interface earthquakes. The researchers also uncovered some interesting outcomes within the more detailed set of findings. For instance, at the MMI 2.5 alert threshold, the outcomes for a strike-slip or reverse crustal earthquake are similar whether 3D or point source representations are used, as long as the location, magnitude and depth to the top of the seismic rupture are well-known.

In this case, adding a 3D representation would not offer much of advantage over a point source representation, the researchers say, although GNSS data could be useful in places with poor seismic station coverage or seismic data outages, as in the 2019 California Ridgecrest earthquake sequence.

Murray and colleagues also noted that if a line source representation is used, and the earthquake's magnitude is calculated from the estimated length, an incorrect length can significantly diminish the alert region accuracy.

"Estimated ground motion depends both on earthquake magnitude and a user's distance to the source, so it's not too surprising that simultaneously changing both those parameters would have a strong influence on the alert outcomes," said Murray.

When magnitude estimates made from line source models in ShakeAlert don't match earthquake catalog magnitude, however, it might be reflecting "actual variations in stress drop, which would, in turn, affect shaking," she added. "It is especially important to explore this topic further using data from real events, which is one focus of our ongoing work."

More information: Jessica R. Murray et al, The Impact of 3D Finite-Fault Information on Ground-Motion Forecasting for Earthquake Early Warning, *Bulletin of the Seismological Society of America* (2021). DOI: 10.1785/0120210162

Provided by Seismological Society of America