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Not My Fault: Seismographs aren't the only instruments that measure earthquakes

Lori Dengler/For the Times-Standard
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For nearly a century, seismographs were the only instruments used to record and measure earthquakes. Seismographs employ mechanical or electronic sensors to measure ground motion as a function of time. Modern seismographs, called broad-bands, can measure a wide range of frequencies, from rapid vibrations that oscillate many times in a second to long rolling waves with periods of several minutes.

Why is it important to record such a range? An earthquake is like a symphony. If all you could hear were the middle frequencies of the viola and oboe, you would get a very narrow view of Beethoven's Ninth. When faults slip, they produce multitude of vibrations ranging from slow to very fast, all of which are important to gaining a full understanding of the size of the quake and how it ruptured.

Early seismographs recorded a narrow range of frequencies. By the 1960s, seismic stations typically had two sets of instruments: short periods that peaked around one second and long periods designed to respond to surface waves with periods around 20 seconds. I remember how exciting it was when the Berkeley Seismic Lab installed an 'ultra-long period' seismograph in 1973 that could capture 100 second vibrations.

Modern broad-bands are not peaked around a single frequency. They can record rapid vibrations and much longer ones equally well. But they still have limits. They can't record oscillations on the order of tens of minutes and they can't detect the permanent ones – when the site where the seismograph is sitting is displaced inches or tens of feet by the fault rupture.

Enter GPS. Today's Global Positioning Satellite systems is a network of about 30 satellites that can precisely track the position of many points on earth including your smart phone. Developed by the US military in the 1960s to aid in navigation and location, the satellites continuously broadcast information on where they area. The signals are captured by ground- based receivers and converted into distance. The position of the receiver can be triangulated by knowing the distances of three or more satellites in the system.

In the 1980s, a colleague of mine Ken Hudnut was a graduate student at Columbia studying earthquakes in California. He established a number of survey points (monuments) and measured their positions very precisely using the GPS satellites at the time was able to map subtle changes in ground motion near faults. His dissertation earned him a permanent position with the USGS.

The M6.9 Loma Prieta earthquake provided Ken and his USGS colleagues the first opportunity to use GPS in post-earthquake investigations. They were able to compare the pre- and post-quake GPS data to determine the pattern of slip on the fault plane.

Excitement over GPS in earthquake studies quickly grew and new networks were established in many parts of California. In 1989, 12-station set of GPS monuments was established in the Cape Mendocino area. The network helped to decipher the surface deformation associated with the 1992 Cape Mendocino earthquake, and along with a survey of coastal uplift, provided the most detailed picture of how a thrust fault changes surface topography.

These early earthquake applications of GPS were not done in real time. The monument sites were established, and revisited at monthly, yearly, or longer intervals to record how the locations had changed. GPS campaigns were labor intensive as they required scientists to visit each monument and spend several hours carefully gathering the data. With the proper protocol, the monument sites could be located to a horizontal accuracy of less than an inch. The USGS team revisited the Cape Mendocino GPS network after the September 1, 1994, M7.0 Mendocino fault earthquake and found that earthquake had moved some of the stations more than a foot to the east.

By the 1990s, GPS had been shown a valuable tool in studying plate motions and post-earthquake deformation. But it wasn't useful in recording what was happening during the earthquake itself. To do so requires much more frequent sampling of ground position. The 21st century ushered in the era of continuous GPS, instruments that are in constant contact with the GPS satellite network and, at 15 second intervals, send data to a repository. These new systems are called GNSS (Global Navigation Satellite Systems) and are capable of providing earthquake information as it is happening, just like a seismograph.

The most exciting application of GNSS is in estimating the size of earthquakes as the ground is still rupturing. Really big quakes of magnitude 8.5 to 9.5 are a problem for even broad-band seismographs. The Japanese seismic network, the most sophisticated in the world, gave an initial magnitude of 7.8 for the March 11, 2011, Great East Japan earthquake. The seismograph signals tend to saturate at magnitudes over 8.

GNSS can quickly capture the scale of great earthquakes by showing the size and the amount of ground displacement. The Japanese Meteorological Agency had GPS network in 2011 but it was not integrated into their earthquake early warning or tsunami alert systems. It is now and JMA scientists will rely on both seismographs and the Continuous GPS sensors.

JMA has now incorporated GNSS into their Earthquake Early Warning (EEW) system. EEW relies on detecting the earthquake rupture soon after it begins and sending alerts to areas further away that strong shaking will be coming soon. It allows a crucial few seconds to slow/stop trains and other critical facilities and for people to Drop, Cover, and Hold On before the strongest seismic waves arrive. Over the next year, GNSS will be folded into US earthquake early warning systems as well.

Just this week a paper by a team of scientists from University College London and Japanese Universities propose a new application of GNSS – satellite detection of the atmospheric vibrations caused by a tsunami as it forms and travels across the ocean: https://techcrunch.com/2022/05/05/gps-signals-could-detect-tsunamis-better-and-faster-than-seismic-sensors/. Stay tuned – I can't wait for the next GPS chapter.

Lori Dengler is an emeritus professor of geology at Humboldt State University, an expert in tsunami and earthquake hazards. The opinions expressed are hers and not the Times-Standard's. All Not My Fault columns are archived online at https://kamome.humboldt.edu/resources and may be reused for educational purposes. Leave a message at (707) 826-6019 or email rctwg@humboldt.edu for questions and comments about this column, or to request a free copy of the North Coast preparedness magazine "Living on Shaky Ground."