Improving earthquake early warning systems for California and Taiwan

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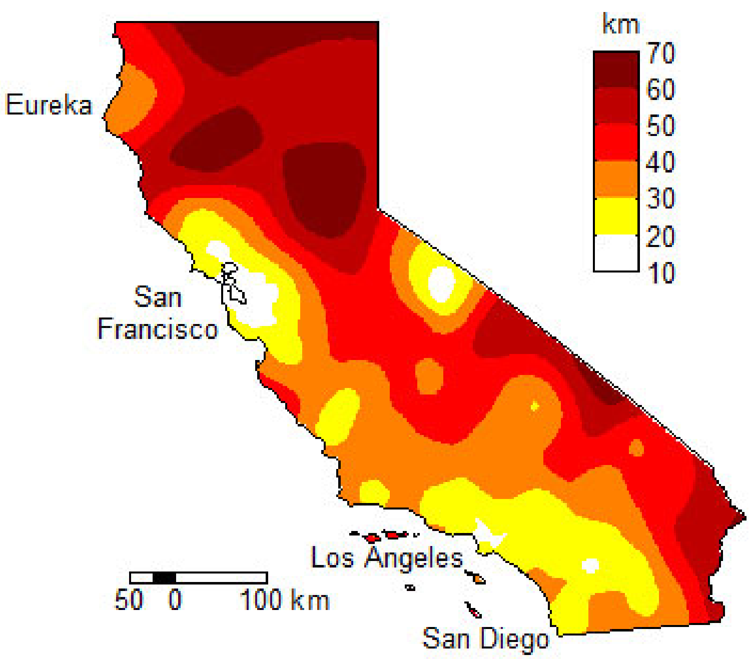

This is a map of the blind-zone radius for California. Yellow and orange colors correspond to regions with small blind zones and red and dark-red colors correspond to regions with large blind zones. Credit: *SRL*

Earthquake early warning systems may provide the public with crucial seconds to prepare for severe shaking. For California, a new study suggests upgrading current technology and relocating some seismic stations would improve the warning time, particularly in areas poorly served by the existing network – south of San Francisco Bay Area to north Los Angeles and north of the San Francisco Bay Area.

A separate case study focuses on the utility of low cost sensors to create a high-density, effective network that can be used for issuing early warnings in Taiwan. Both studies appear in the November issue of the journal *Seismological Research Letters* (*SRL*).

"We know where most active faults are in California, and we can smartly place seismic stations to optimize the network," said Serdar Kuyuk, assistant professor of civil engineering at Sakarya University in Turkey, who conducted the California study while he was a post-doctoral fellow at University of California (UC), Berkeley. Richard Allen, director of the Seismological Laboratory at UC Berkeley, is the co-author of this study.

Japan started to build its EEW system after the 1995 Kobe earthquake and performed well during the 2011 magnitude 9 Tohoku-Oki earthquake. While the U.S. Geological Survey(USGS)/Caltech Southern California Seismic and TriNet Network in Southern California was upgraded in response to the 1994 Northridge quake, the U.S is lagging behind Japan and other countries in developing a fully functional warning system.

"We should not wait until another major quake before improving the early warning system," said Kuyuk.

Noting California's recent law that calls for the creation of a statewide earthquake early warning (EEW) system, Kuyuk says "the study is timely and highlights for policymakers where to deploy stations for optimal coverage." The approach maximizes the warning time and reduces the size of "blind zones" where no warning is possible, while also taking into account budgetary constraints.

Earthquake early warning systems detect the initiation of an earthquake and issue warning alerts of possible forthcoming ground shaking. Seismic stations detect the energy from the compressional P-wave first, followed by the shear and surface waves, which cause the intense shaking and most damage.

The warning time that any system generates depends on many factors, with the most important being the proximity of seismic stations to the earthquake epicenter. Once an alert is sent, the amount of warning time is a function of distance from the epicenter, where more distant locations receive more time.

Areas in "blind zones" do not receive any warning prior to arrival of the more damaging S-wave. The goal, writes Kuyuk and Allen, is to minimize the number of people and key infrastructure within the blind zone. For the more remote earthquakes, such as earthquakes offshore or in unpopulated regions, larger blind zones can be tolerated.

"There are large blind zones between the Bay Area and Los Angeles where there are active faults," said Kuyuk. "Why? There are only 10 stations along the 150-mile section of the San Andreas Fault. Adding more stations would improve warning for people in these areas, as well as people in LA and the Bay Area should an earthquake start somewhere in between," said Kuyuk.

Adding stations may not be so simple, according to Allen. "While there is increasing enthusiasm from state and federal legislators to build the earthquake early warning system that the public wants," said Allen, "the reality of the USGS budget for the earthquake program means that it is becoming impossible to maintain the functionality of the existing network operated by the USGS and the universities.

"The USGS was recently forced to downgrade the telemetry of 58 of the stations in the San Francisco Bay Area in order to reduce costs," said Allen. "While our *SRL* paper talks about where additional stations are needed in California to build a warning system, we are unfortunately losing stations."

In California, the California Integrated Seismic Network (CISN) consists of multiple networks, with 2900 seismic stations at varying distances from each other, ranging from 2 to 100 km. Of the some 2900 stations, 377 are equipped to contribute to an EEW system.

Kuyuk and Allen estimate 10 km is the ideal distance between seismic stations in areas along major faults or near major cities. For other areas, an interstation distance of 20 km would provide sufficient warning. The authors suggest greater density of stations and coverage could be achieved by upgrading technology used by the existing stations, integrating Nevada stations into the current network, relocating some existing stations and adding new ones to the network.

The U.S. Geological Survey (USGS) and the Gordon and Betty Moore Foundation funded this study.

A Low-Cost Solution in Taiwan

In a separate study, Yih-Min Wu of National Taiwan University reports on the successful experiment to use low cost MEMS sensors to build a high-density seismic network to support an early warning system for Taiwan.

MEMS accelerometers are tiny sensors used in common devices, such as smart phones and laptops. These sensors are relatively cheap and have proven to be sensitive detectors of ground motion, particularly from large earthquakes.

The current EEW system in Taiwan consists of 109 seismic stations that can provide alerts within 20 seconds following the initial detection of an earthquake. Wu sought to reduce the time between earthquake and initial alert, thereby increasing the potential warning time.

The EEW research group at National Taiwan University developed a P-wave alert device named "Palert" that uses MEMS accelerometers for onsite earthquake early warning, at one-tenth the cost of traditional strong motion instruments.

From June 2012 to May 2013 Wu and his colleagues tested a network of 400 Palert devices deployed throughout Taiwan, primarily at elementary schools to take advantage of existing power and Internet connections and where they can be used to educate students about earthquake hazard mitigation.

During the testing period, the Palert system functioned similarly to the existing EEW system, which consists of the conventional strong motion instruments. With four times as many stations, the Palert network can provide a detailed shaking map for damage assessments, which it did for the March 2013 magnitude 6.1 Nantou quake.

Wu suggests the relatively low cost Palert device may have commercial potential and can be readily integrated into existing seismic networks to increase coverage density of EEW systems. In addition to China, Indonesia and Mexico, plans call for the Palert devices to be installed near New Delhi, India to test the feasibility of an EEW system there.

More information: "Optimal seismic network density for earthquake early warning: A case study from California," *Seismological Research Letters*, 2013.

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