20 ShakeAlert: A Unified EEW System for California

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20.1 Introduction

Earthquake Early Warning (EEW) is a method of rapidly identifying an earthquake in progress and transmitting alerts to nearby population centers before damaging ground shaking arrives. The first few seconds of the initial P-wave arrivals at one or more stations are used to detect the event, and predict magnitude and peak shaking. Detections from several stations are combined to locate the event. A warning of imminent shaking can be used to activate automatic safety measures, such as slowing trains, isolating sensitive equipment, or opening elevator doors. Warnings can also be sent directly to the public via cell phone, computer, television, or radio.

With support from the United States Geological Survey (USGS), the California Integrated Seismic Network (CISN) hosted a three-year proof of concept project for EEW algorithms in 2006-2009. Following that successful project, the Berkeley Seismological Laboratory (BSL) together with its CISN EEW partners, the California Institute of Technology (Caltech), and the Swiss Institute of Technology Zürich (ETH), is collaborating on an integrated, end-to-end demonstration system for real-time EEW in California. The new system, called CISN ShakeAlert, is capable of continuous long-term operation and rapidly provides alerts to test users in the state.

20.2 Project Status

The ShakeAlert system combines the best aspects of the three methods from the proof-of-concept project. Caltech's OnSite algorithm uses P-wave data from the single station nearest the epicenter to provide extremely rapid estimates of likely ground shaking. The BSL's ElarmS algorithm and ETH's Virtual Seismologist algorithm use data from several stations around an event epicenter to produce a slightly slower but more reliable estimate of magnitude and location. Combining these methods produces an algorithm which has the speed of a single-station method but is then promptly confirmed and adjusted by additional station data to form a more accurate description of the event. When an identified event exceeds a defined combination of magnitude, ground shaking intensity and statistical likelihood, information is broadcast to system users. Currently, during the development phase, only project participants receive event information. In January 2012, test users outside the seismological community began to receive alert information. The recipients include the state's emergency operations center at the California Emergency Management Agency (CalEMA). A schematic diagram of the end-to-end system is shown in Figure 2.38.

20.3 ElarmS Developments

During the past year, we have worked extensively to improve UC Berkeley's contribution to the system, ElarmS and the Decision Module (see Section 21). We implemented updated and streamlined waveform processing software. As a result, data are now available several seconds earlier than before, especially data from Q330 data loggers. This new waveform processing system is now on our operational computers, improving robustness and reliability. In addition, we have released and are operating a revised version of the ElarmS code, ElarmS-2. During the proof of concept phase, the code detecting earthquakes and preparing alerts was simply the original research software. During the current project, we have rewritten and modernized the ElarmS software. The new version has been the operational version since March 2012, and is producing and publishing alerts for the entire state. Elarms-1 only published alerts for the greater San Francisco Bay Area. Results from Elarms-2 are shown in the map of Figure 2.39. We have also been working hard to exclude false alerts from distant earthquakes.

20.4 Perspectives

July 2012 marks the end of the current USGS-funded project. We look forward to continuing to maintain, operate and improve the demonstration EEW system with continued support from the USGS, with particular emphasis on the interaction with EEW users. During the past year, we received support from the Moore Foundation, together with Caltech and the University of Washington, to begin development of a West Coast Earthquake Early Warning system. Important tasks for this project include the development of tools to quickly evaluate large and great earthquakes using GPS measurements and finite fault analysis. We envision including these new tools in our current operational system.

20.5 Acknowledgements

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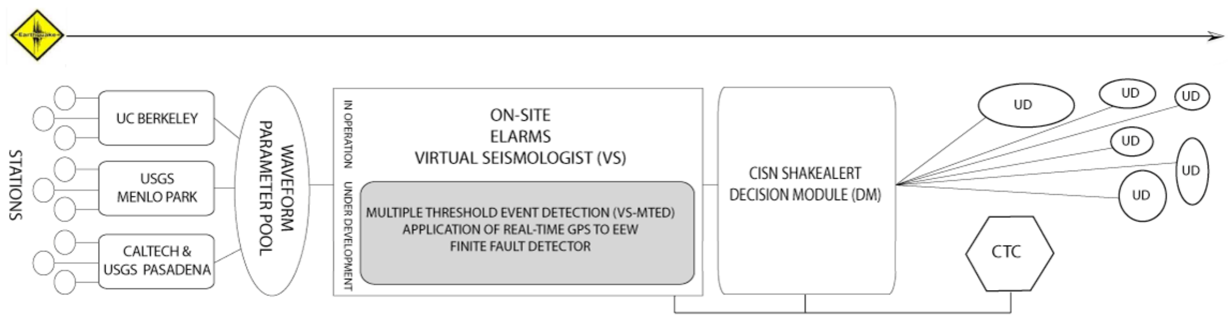

Figure 2.38: Components of the ShakeAlert EEW System. From left to right, the elements of the system are waveform processing, event detection, decision module (DM), CISN ShakeAlert user displays (UD), and the CISN testing center (CTC) software. *Waveform Processing*: Each data center processes telemetered digital waveform data collected from seismic stations throughout California. Critical waveform parameters are calculated from this data, then dumped into a statewide parameter pool. *Event Detection*: From the parameters, CISN's EEW algorithms rapidly detect and characterize an event within seconds of its initiation. Several EEW detection algorithms run in parallel to provide the Decision Module with the best available source parameters. *Decision Module*: The DM combines earthquake information from each algorithm and delivers a "ShakeAlert" xml message about an earthquake in progress to subscribed users. *CISN ShakeAlert User Displays*: The ShakeAlert UD receives xml messages from the DM and displays their content in a simple and easily understandable way. *CISN Testing Center Software*: The CTC Software provides automated and interactive performance evaluations of ShakeAlert forecasts.

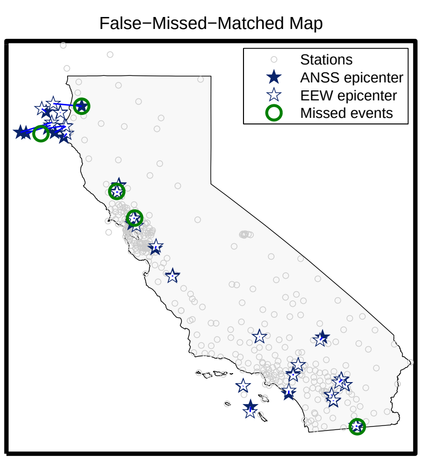

Figure 2.39: Map of California showing earthquakes from 6 Dec 2011 - 11 Jun 2012 with M>3.4 for which ElarmS-2 produced alerts. Solid stars - ANSS epicenter; hollow stars - ElarmS-2 epicenter; circles - missed events. There were no false events (ElarmS-2 alerts when no earthquake was reported by CISN network operators) during this interval. At the edges of the network where station coverage is poor, like Cape Mendocino in Northern California, ElarmS-2 may mislocate events, but in most cases it still detects and reports them.