Simulated Motions in Earthquake Early Warning System Evaluations

PEER LBNL Workshop
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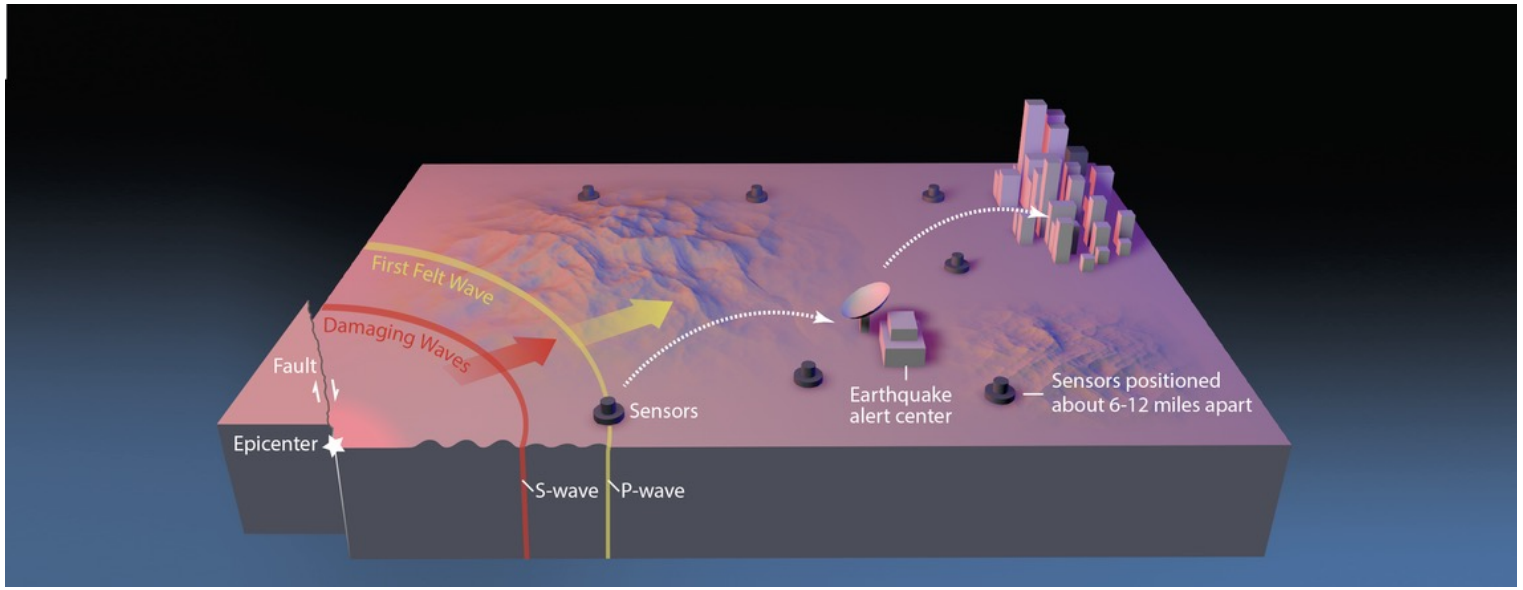
Angie Lux (BSL), Ivan Henson (BSL), Andrei Akimov (BSL), Richard Allen (BSL),
David McCallen (LBNL), Houjun Tang (LBNL), Arben Pitarka (LLNL)

What is Earthquake Early Warning?

ShakeAlert™ Earthquake Early Warning System



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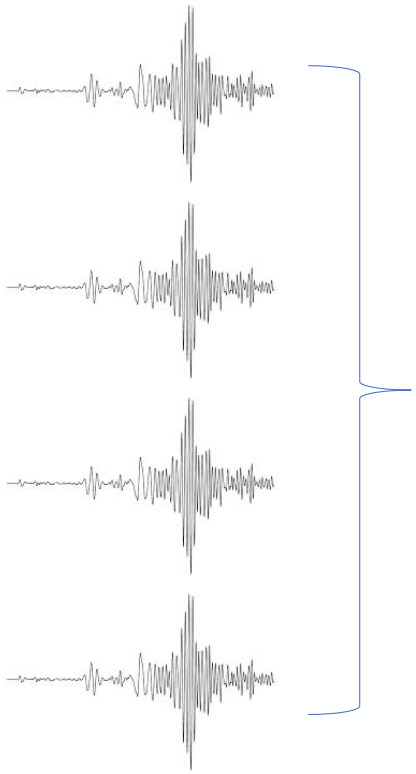
ShakeAlert Seismic Algorithms



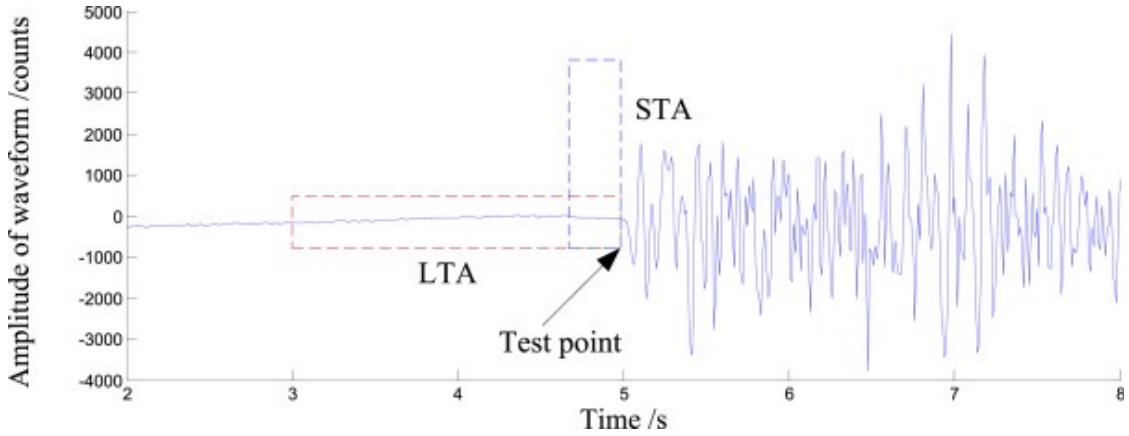
EPIC → Earthquake location and magnitude

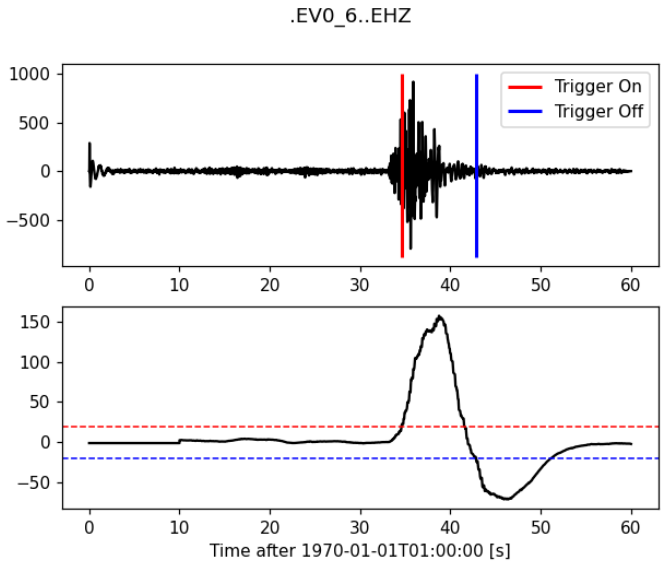
EPIC – Earthquake Point-source Integrated Code

- Formerly ElarmS.
- Point-source algorithm.
- Generally the fastest algorithm with most accurate location.
- Network-based algorithm: Requires triggers from 4 stations to alert.
- Uses up to 4 sec data at each station to estimate magnitude/location.

EPIC – Triggering

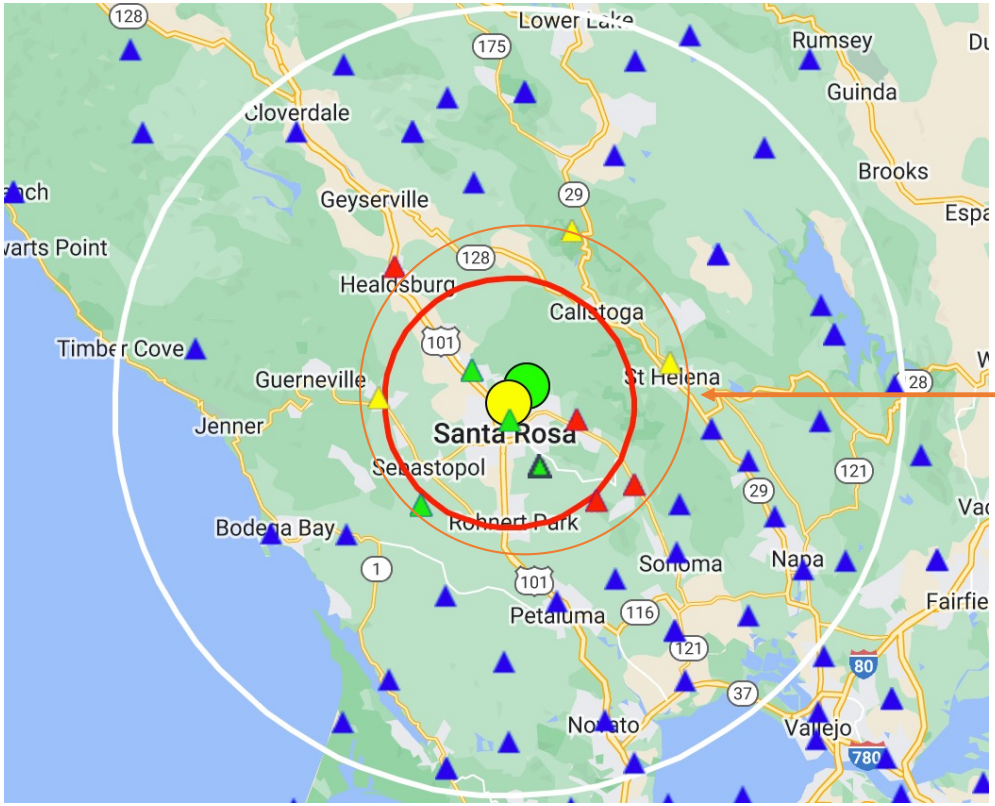
- Triggers using Short-Term Average/Long-Term Average (STA/LTA) method.
- Short-term window: 0.05 sec
- Long-term window: 5 sec
- Not allowed to trigger more than once every 10 sec.





EPIC – Creating an Alert

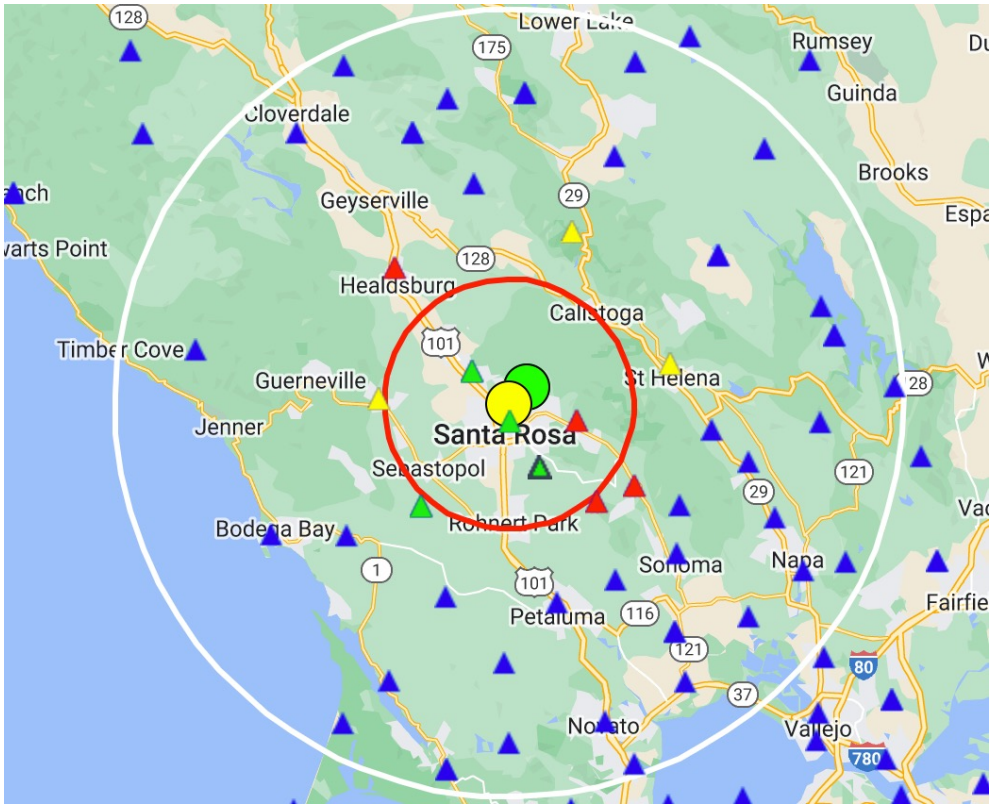
- Triggers from 40% of nearby online stations required to alert.



4 stations offline/suspended (not counted) (red)
4 stations online (green)
Triggers not yet received from 3 stations (yellow)

→ 4/7 = 57% of stations online ✅

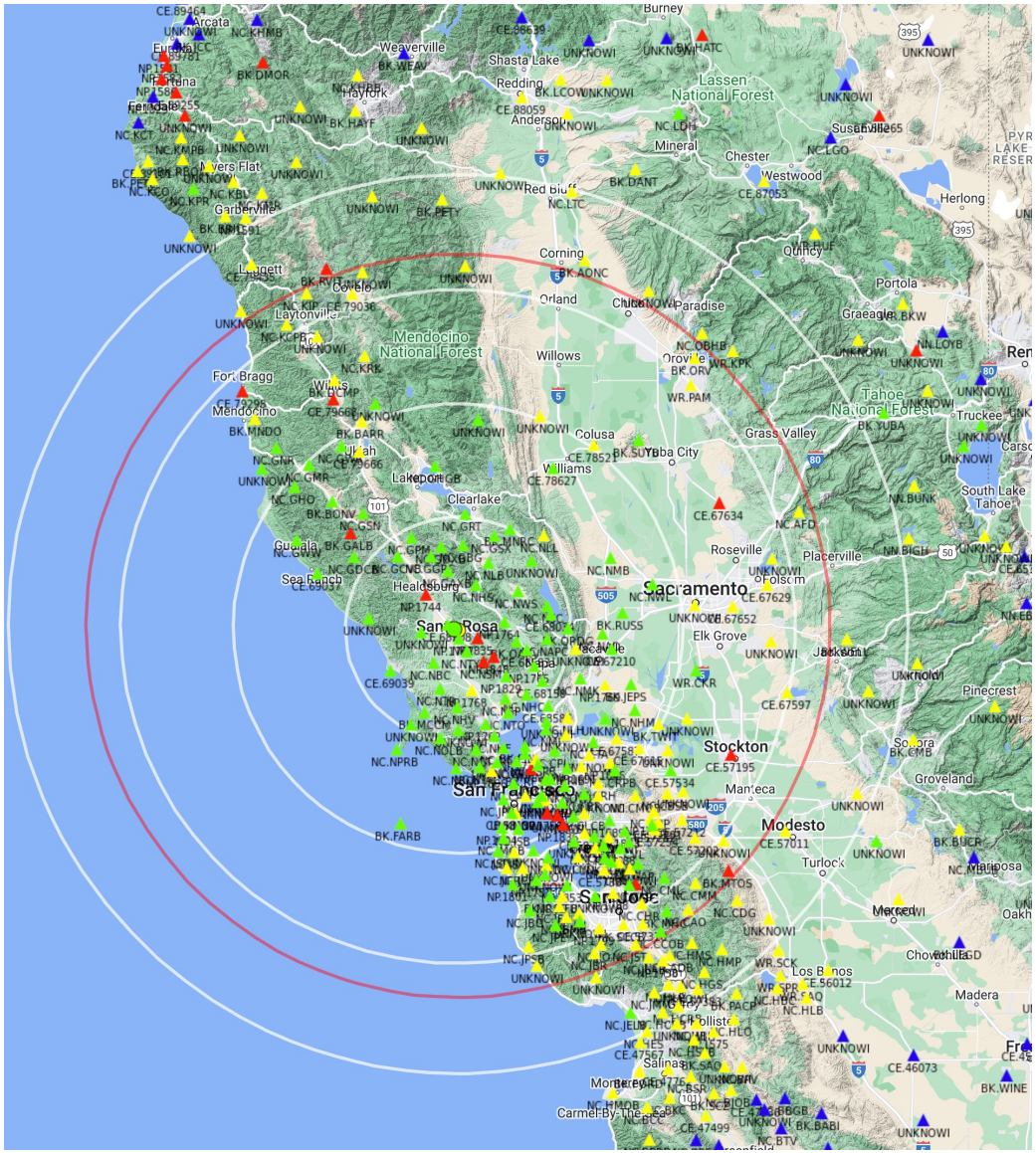
EPIC – Creating an Alert



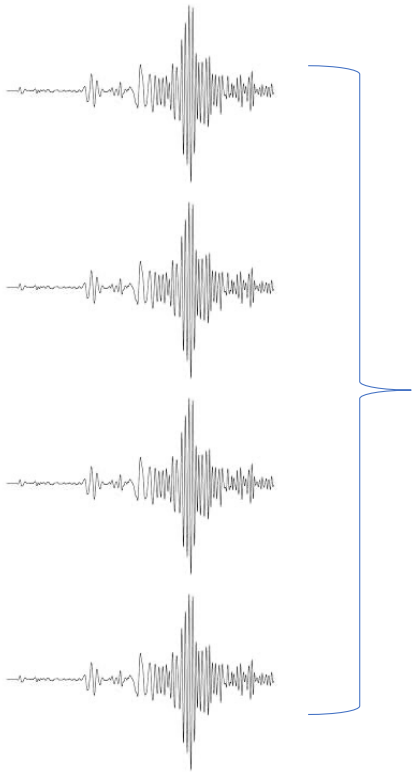
- **Location**: Uses P-wave arrival times from triggered stations and grid search to locate earthquake.
- **Magnitude**: Calculated using observed displacement (Pd) and station-epicenter distance.

EPIC – Creating an Alert

- Once alert is created…
  - Location and magnitude updated as more stations trigger and are associated



ShakeAlert Seismic Algorithms

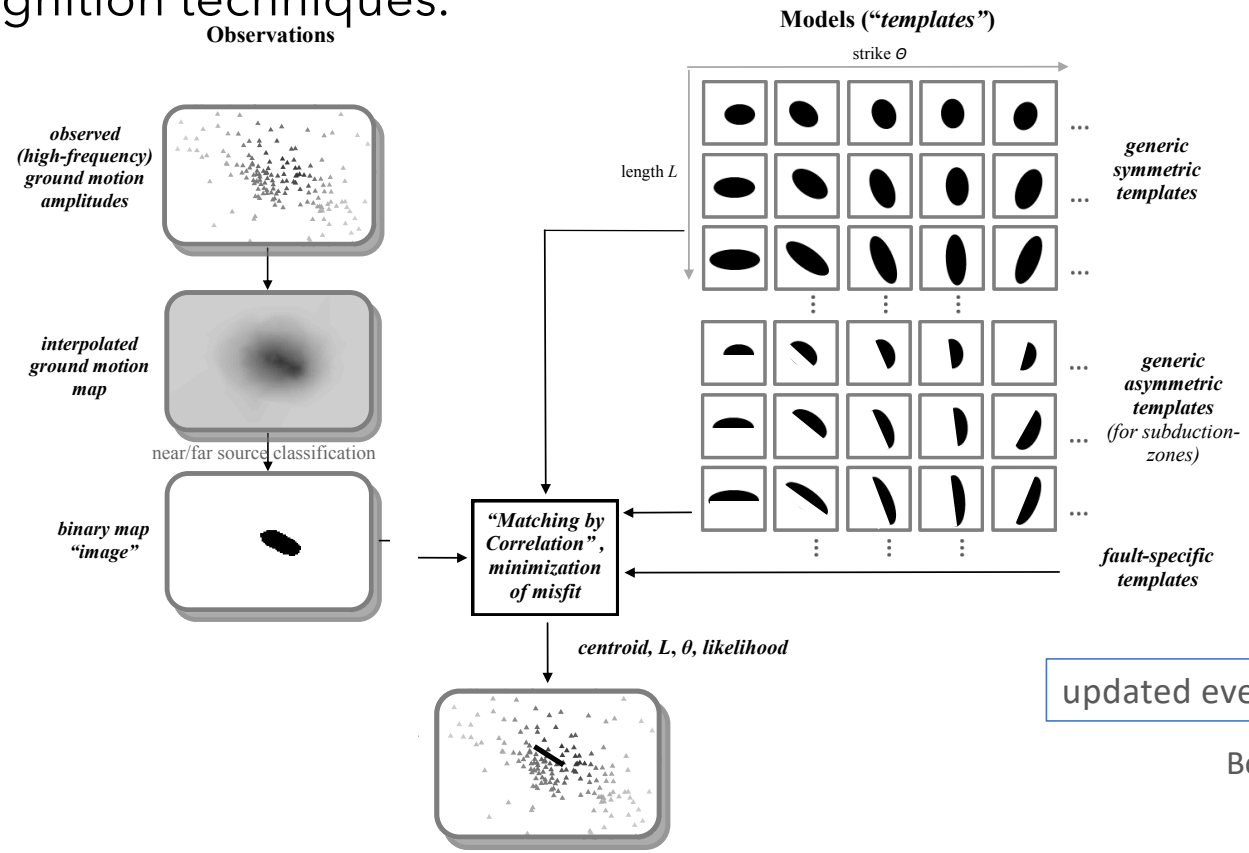


EPIC → Earthquake location and magnitude

FinDer → Fault location, length, and orientation

FinDer – Finite-Fault Rupture Detector

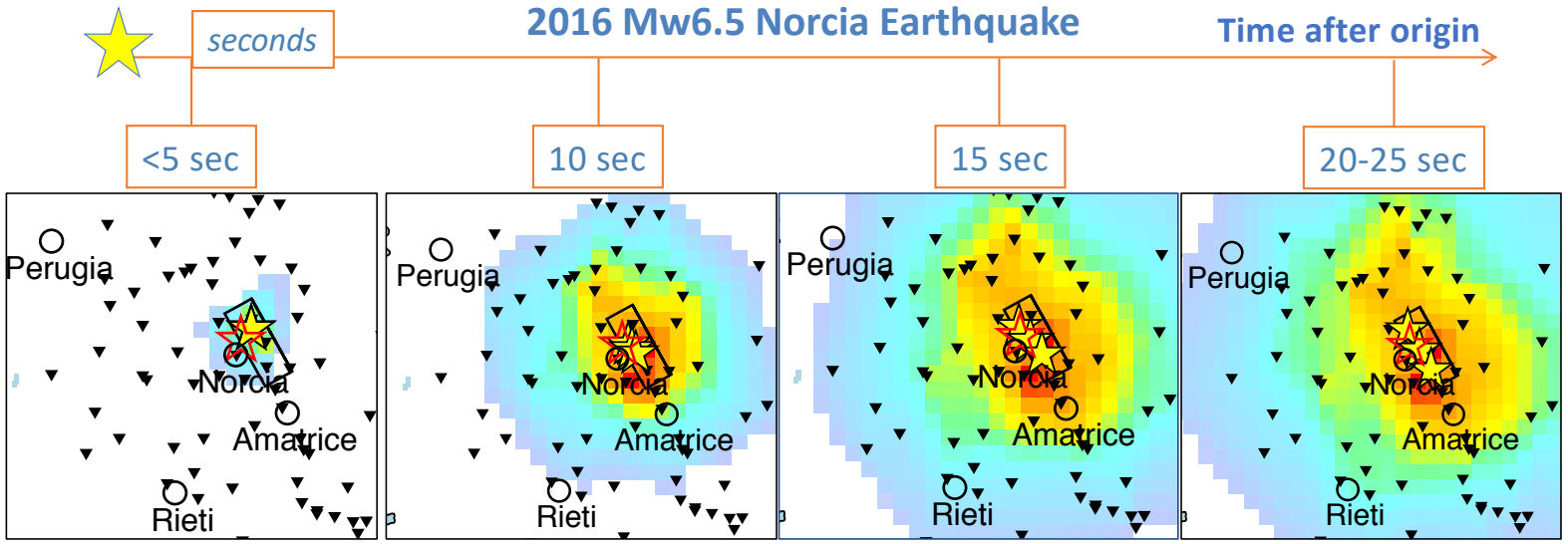
- Estimates location, size, and orientation of rupturing fault using image recognition techniques.



updated every < 1 second

Böse *et al.*, 2012

FinDer Event Evolution



ShakeAlert System

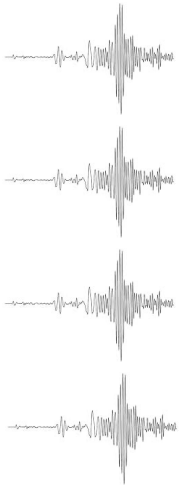
EPIC
Earthquake location and magnitude

FinDer
Fault location, length, and orientation

GFAST
Earthquake magnitude (from GNSS)

Solution Aggregator
Single unified solution

ShakeAlert System



EPIC
Earthquake location and magnitude

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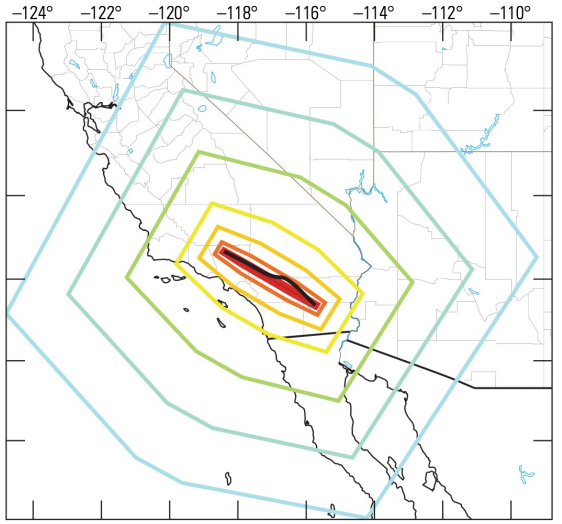
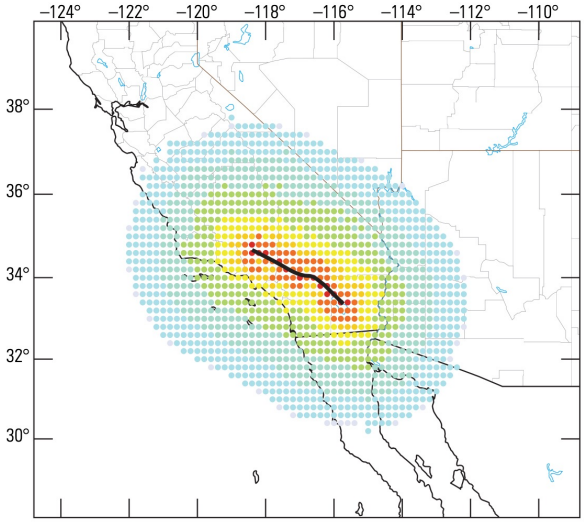
Solution Aggregator
Single unified solution

EQinfo2GM
Ground motion estimate

Ground Motion Estimation - EQinfo2GM

- Estimates shaking distribution based on combined source solution.
- Currently outputs 2 products: Contour Maps and Grid Maps
  - Contour Maps:
    - Polygons that define areas of MMI Intensity
  - Grid Maps:
    - MMI peak ground acceleration (PGA) and peak ground velocity (PGV) at grid points with space of 0.2 degrees (22 km).

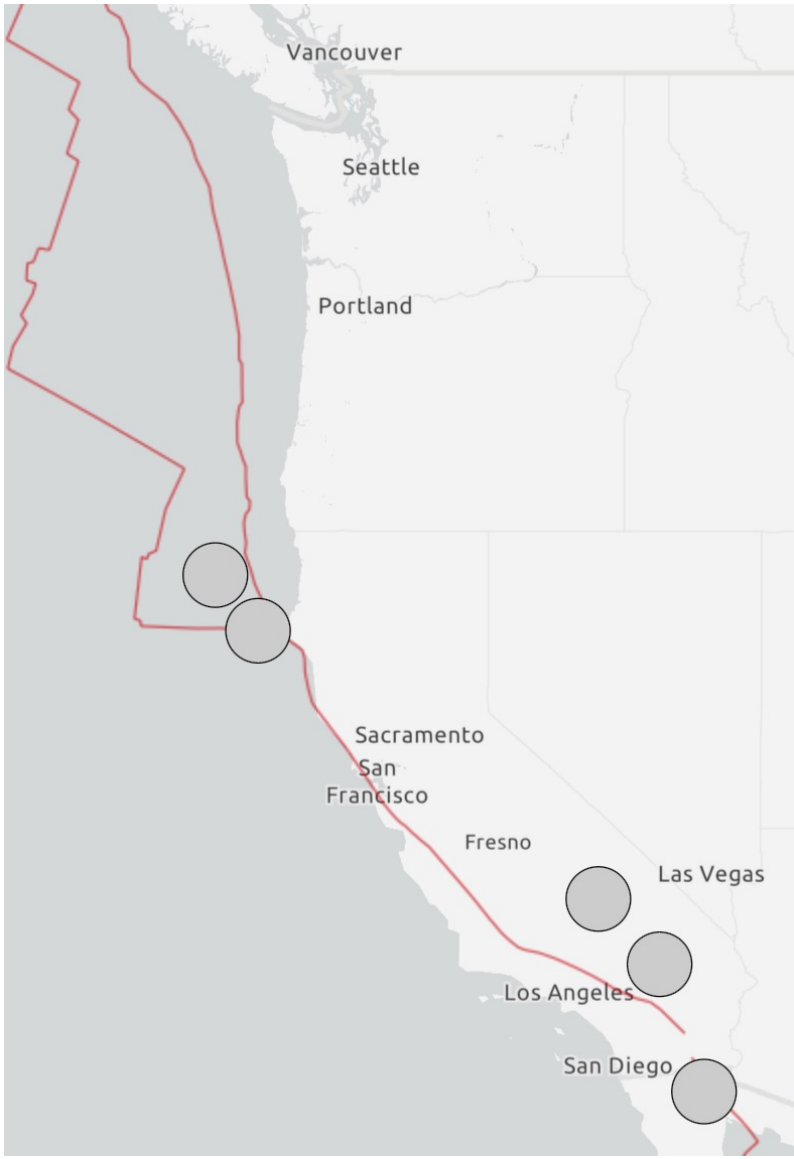




EEW Evaluations

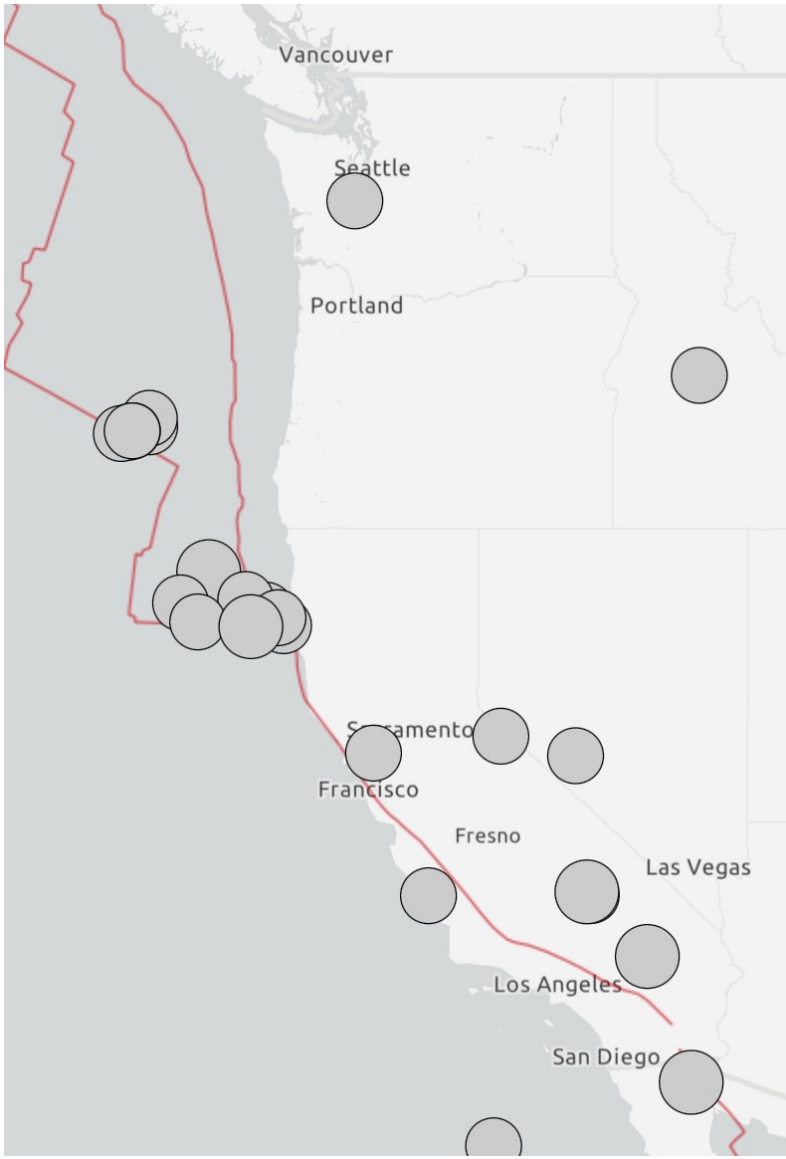
Current Challenges for EEW

- Not many earthquakes
  - **5 M7+ earthquakes since 1995**



Current Challenges for EEW

- Not many earthquakes
  - **5 M7+ earthquakes since 1995**
  - **25 M6.5+ earthquake since 1995**



Current ShakeAlert Testing Dataset

Magnitude Range	Number of Events
$M \geq 7$	5
$6 \leq M < 7$	16
$5 \leq M < 6$	33
$4 \leq M < 5$	108

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Name	Magnitude	Year
El Mayor Cucupah	7.2	2010
Gorda Plate	7.2	2005
Hector Mine	7.1	1999
Anchorage	7.1	2018
Ridgecrest	7.1	2019
Loma Prieta	6.9	1989
Offshore Eureka	6.8	2014
Nisqually	6.8	2001
Northridge	6.7	1994
Offshore Ferndale	6.6	2016
San Simeon	6.5	2003
Offshore Ferndale	6.5	2010
Off Vancouver Island	6.5	2014
Offshore Ferndale	6.4	2022
Vancouver Island	6.4	2011
Ridgecrest	6.4	2019
Las Brisas	6.2	2022
Petrolia	6.2	2021
Parkfield	6	2004
South Napa	6	2014
Antelope Valley	6	2021

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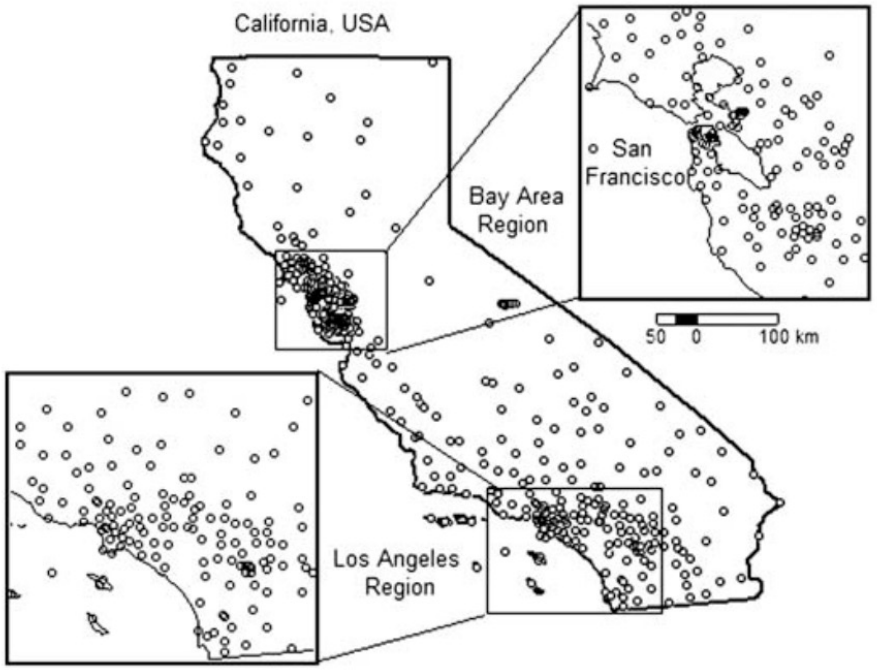
Seismic Network



▲ **Figure 1.** Station distribution of CISN/EEWS (377 locations) throughout California, U.S.A. CISN networks are described in Table 1.

Kuyuk and Allen, 2013

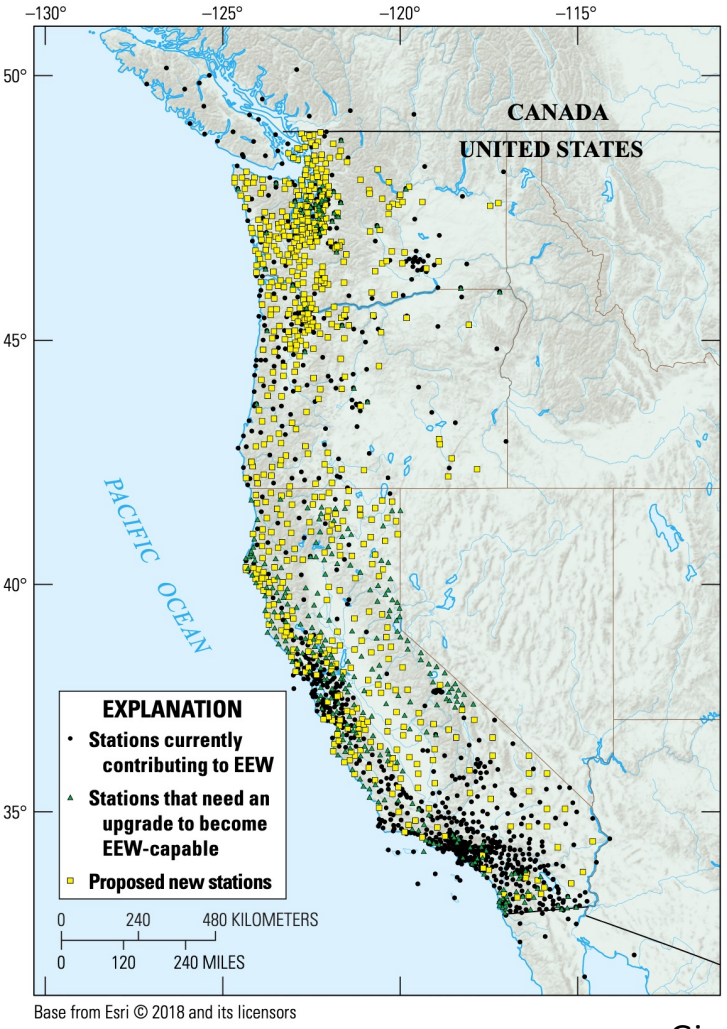
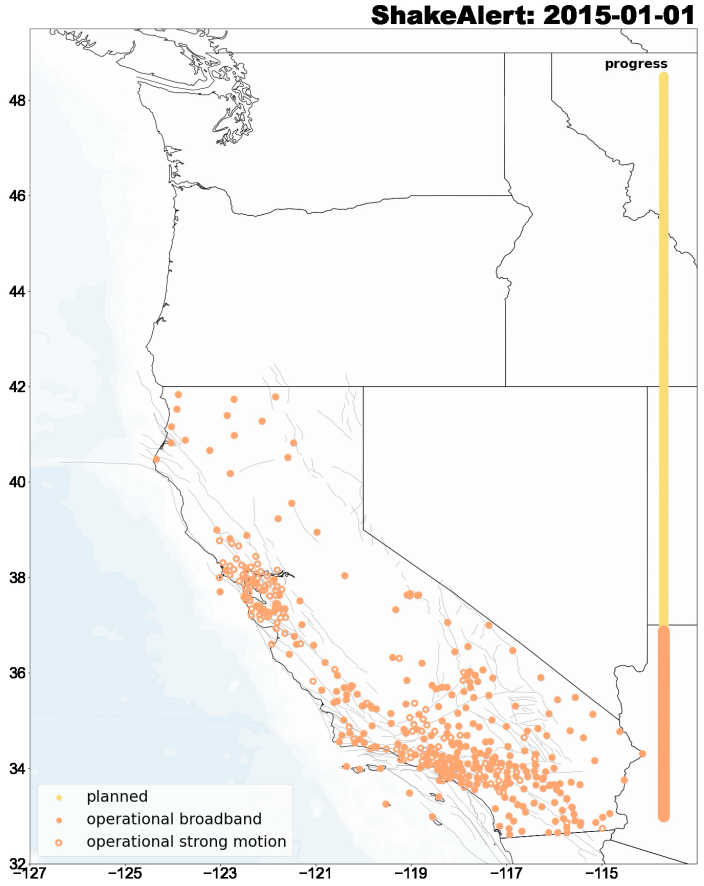


Figure 2. Map of the western United States showing current and proposed locations of seismic stations needed for ShakeAlert as of March 2018. Black dots show currently contributing stations (some may need upgrades), green triangles show currently active stations that must be upgraded to become earthquake early warning (EEW) capable, and yellow squares show approximate locations of proposed new stations.

Given et al., 2018

Seismic Network



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Name	Magnitude	Year
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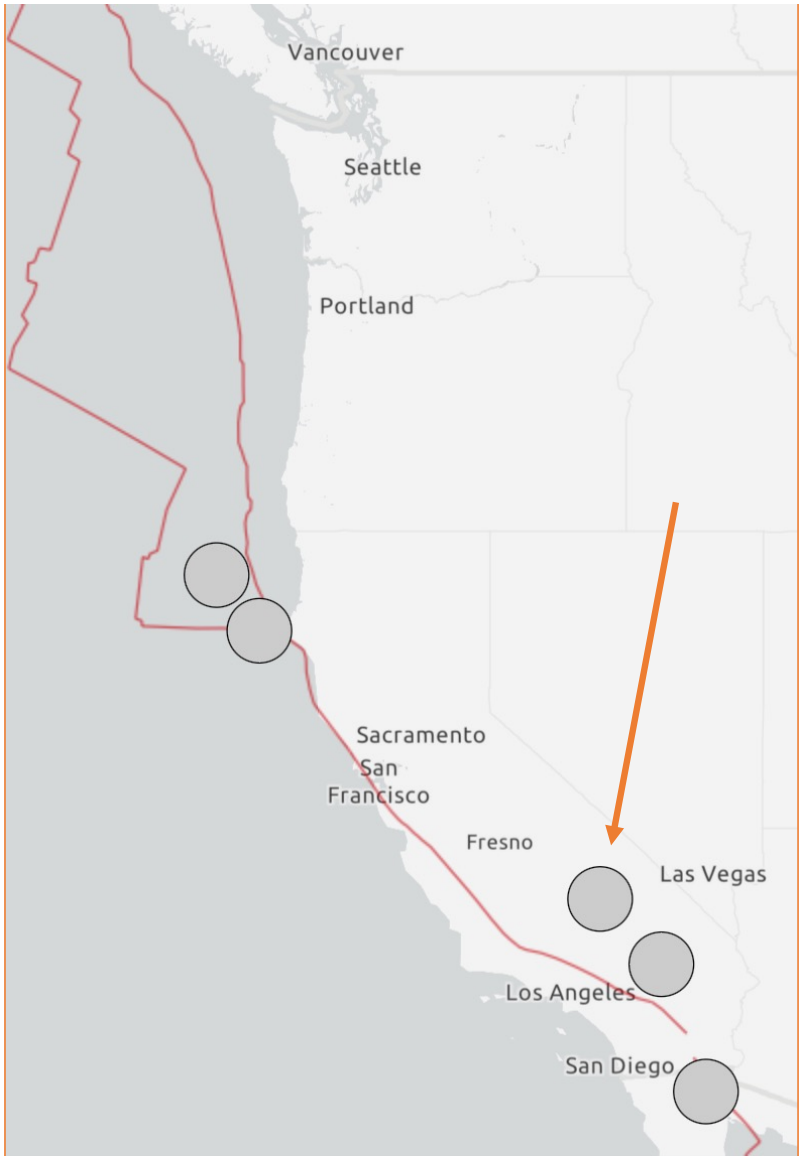
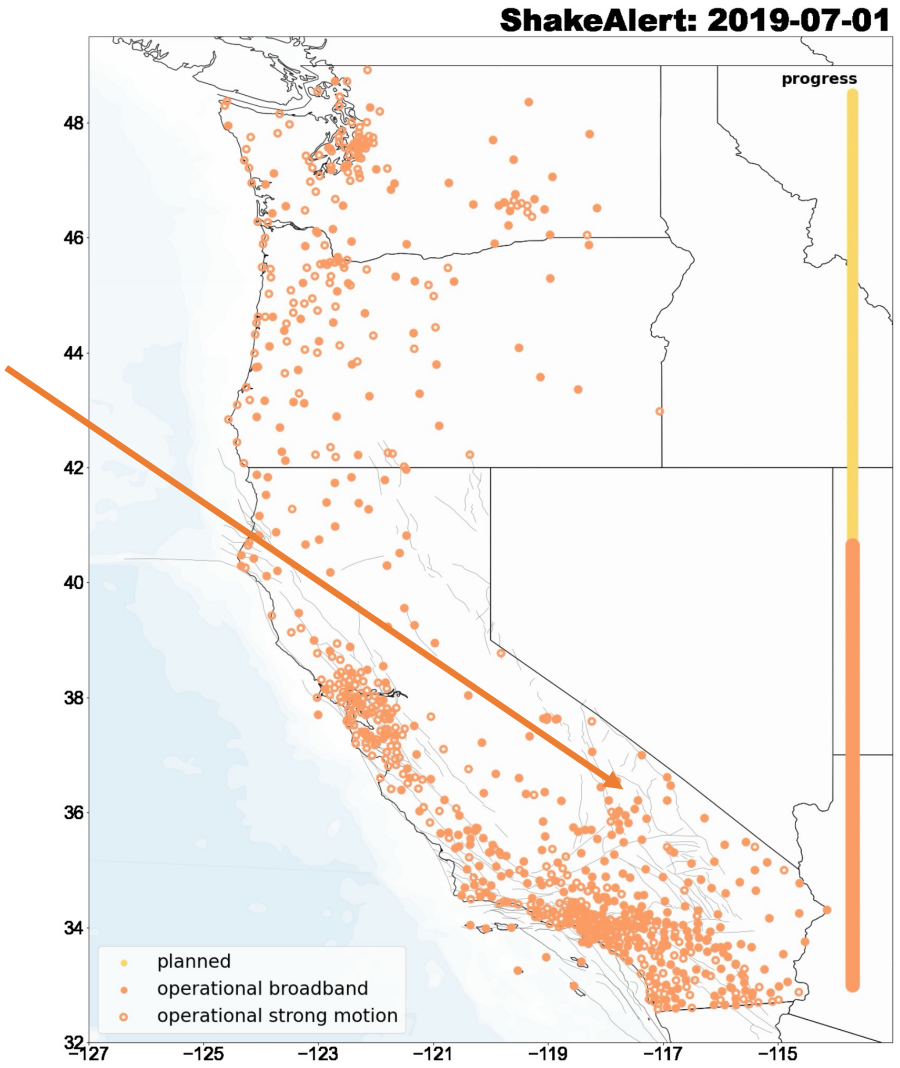

Vancouver
Seattle
Portland
Sacramento
San
Francisco
Fresno
Las Vegas
Los Angeles
San Diego

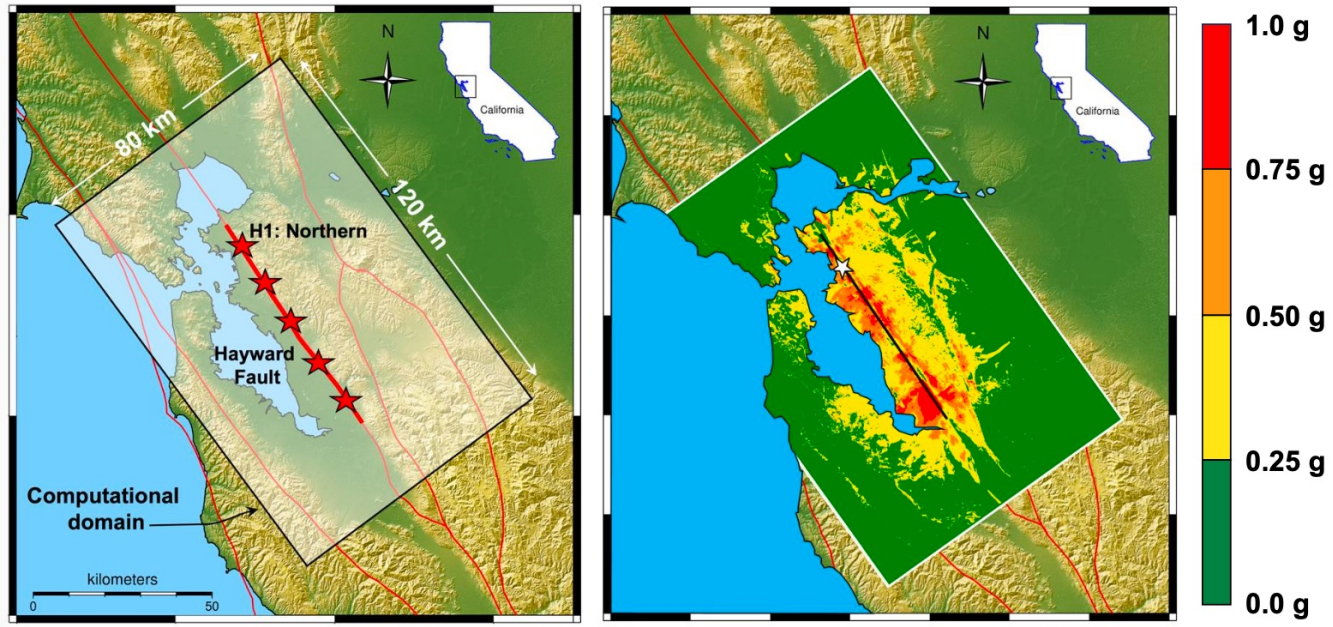

ShakeAlert: 2019-07-01
progress
48
46
44
42
40
38
36
34
32
−127
−125
−123
−121
−119
−117
−115
planned
operational broadband
operational strong motion

How to improve testing?

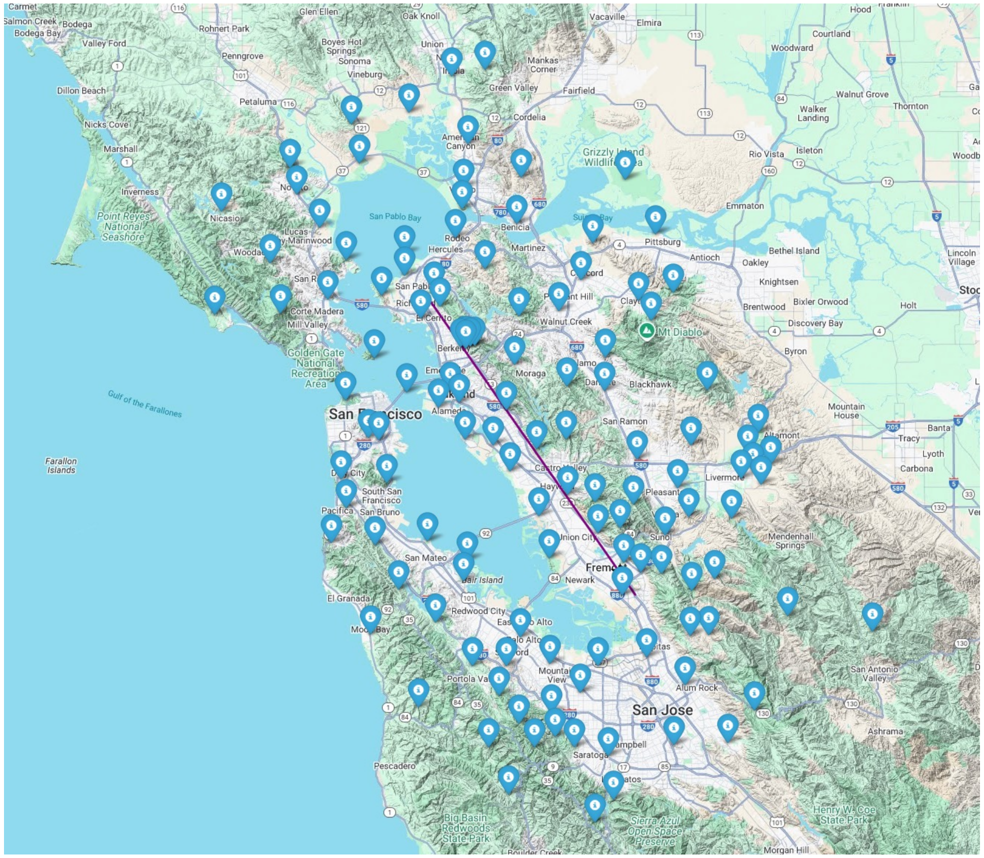
- Use high-resolution simulations!

Hayward Fault Synthetics Simulations

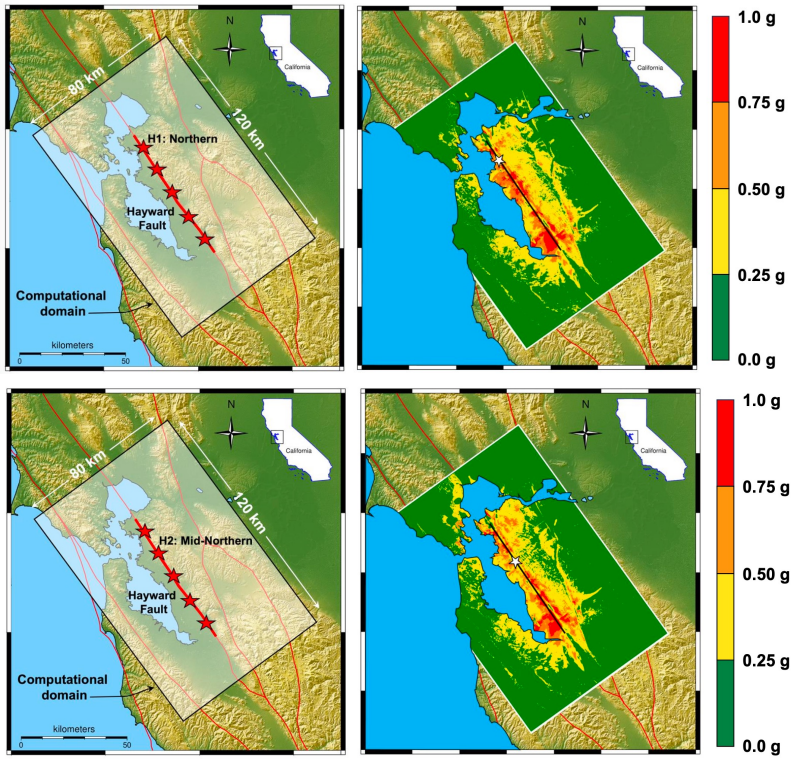
- Very high-resolution simulations of M7 Hayward fault rupture

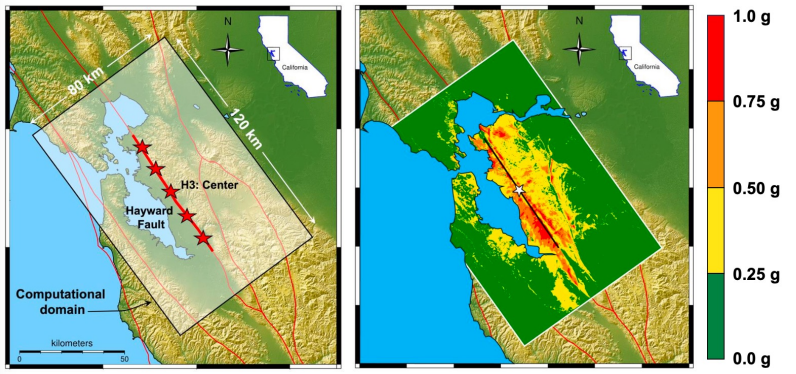


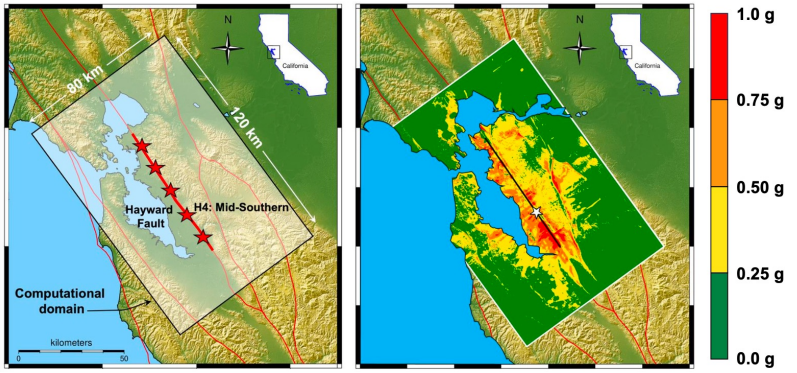
Network

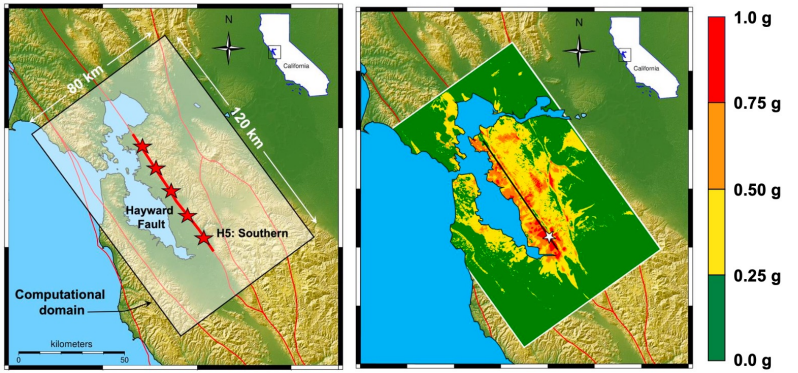

San Francisco
San Jose
Oakland
Fremont
Mt Diablo
San Pablo Bay
Gulf of the Farallones
Farallon Islands

Hayward Fault Simulations

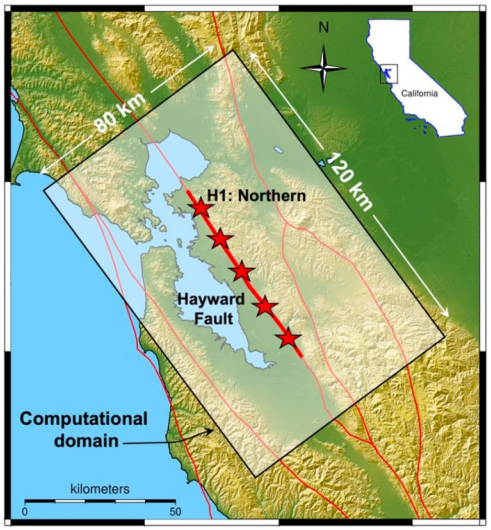


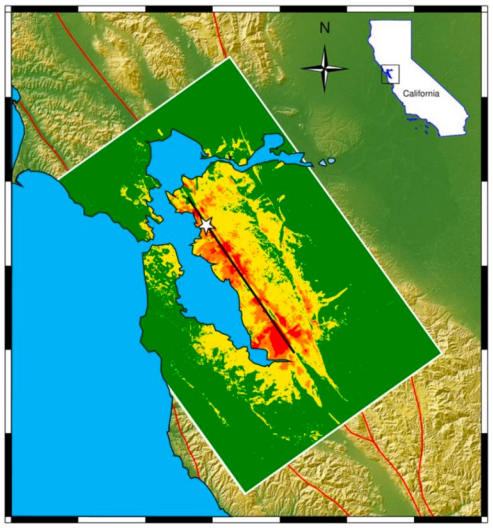


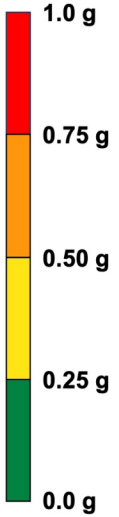


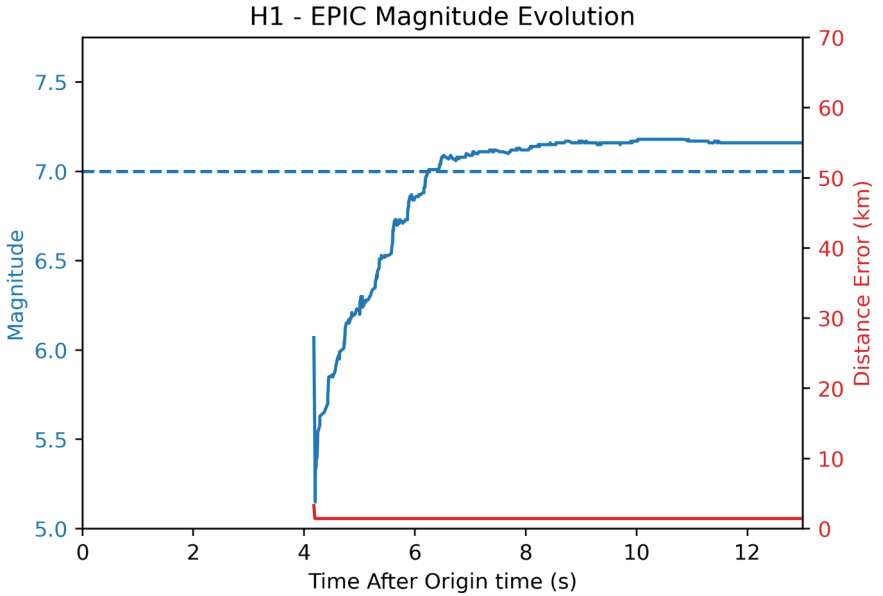


Hayward Fault Simulations – H1; M7.0

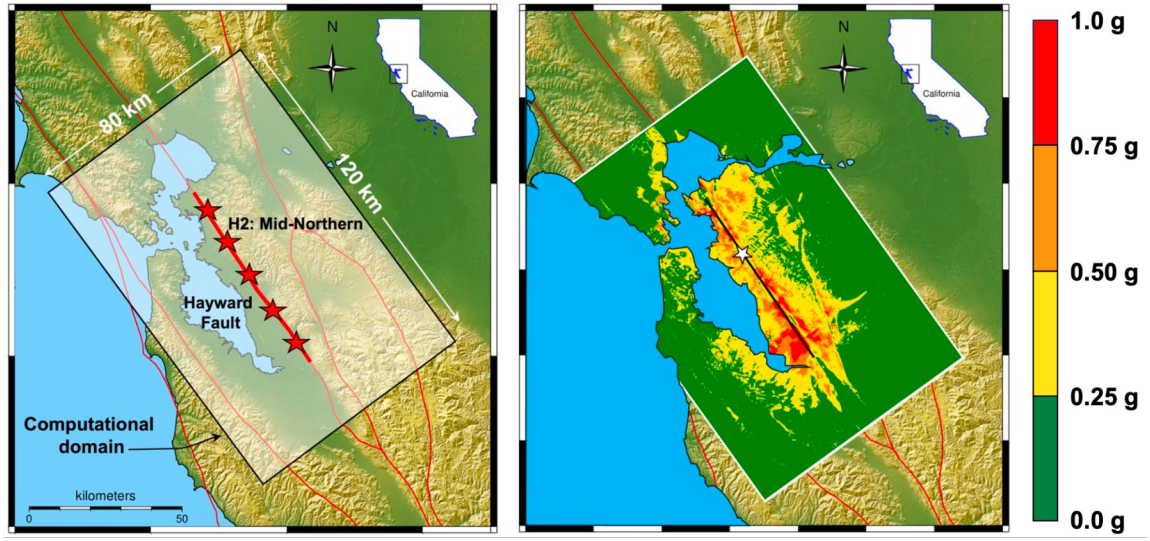


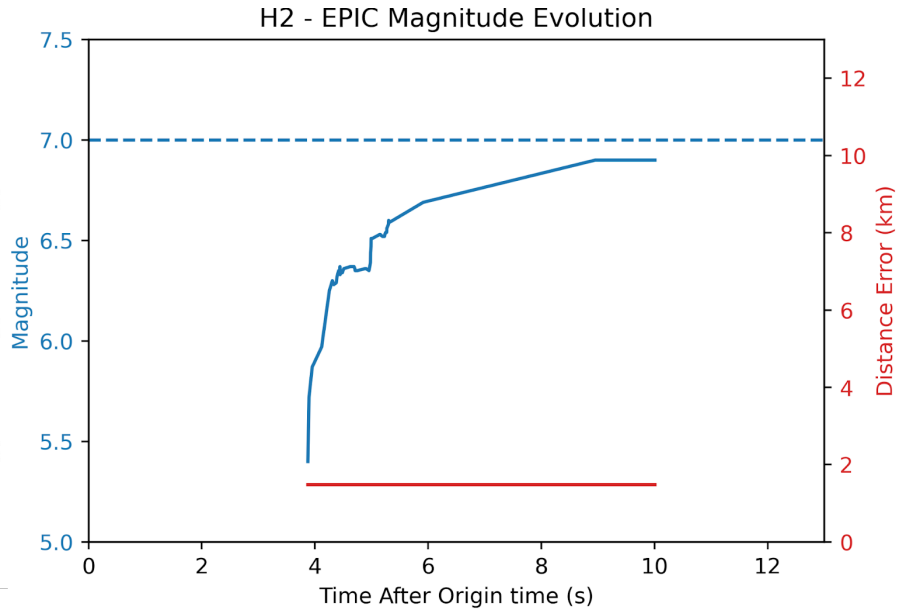




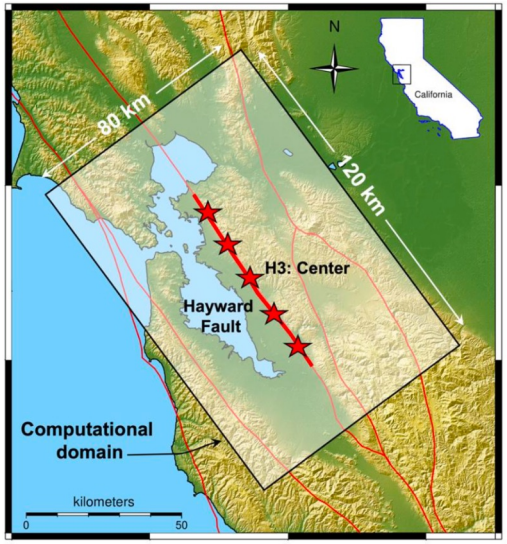


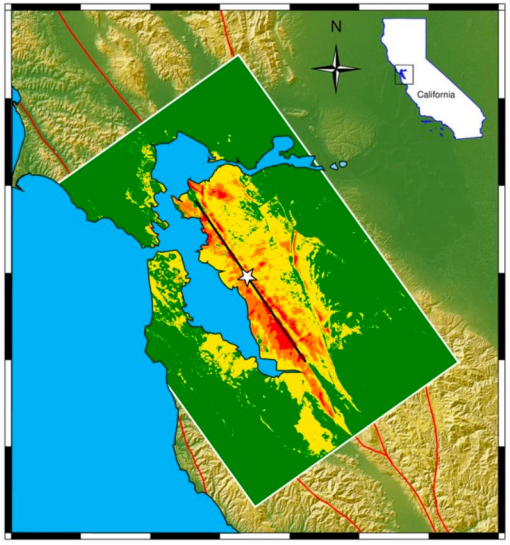
Hayward Fault Simulations – H2; M7.0

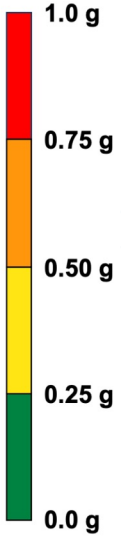


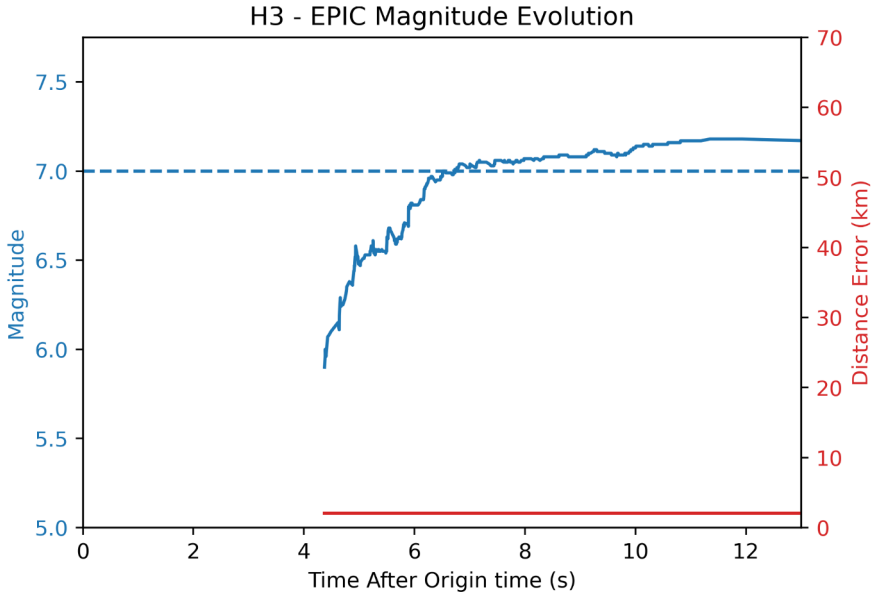


Hayward Fault Simulations – H3; M7.0

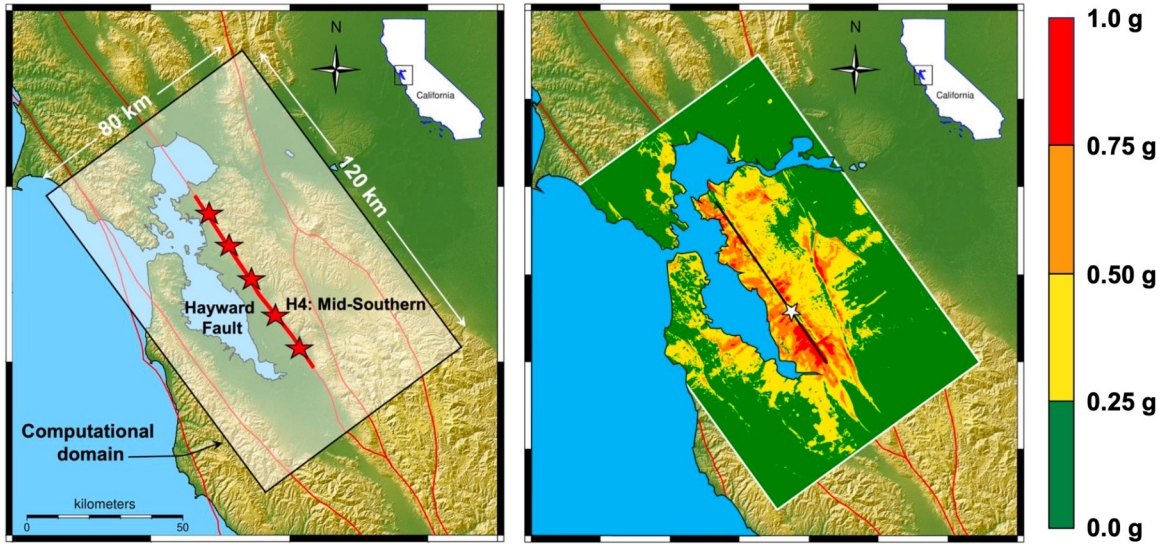


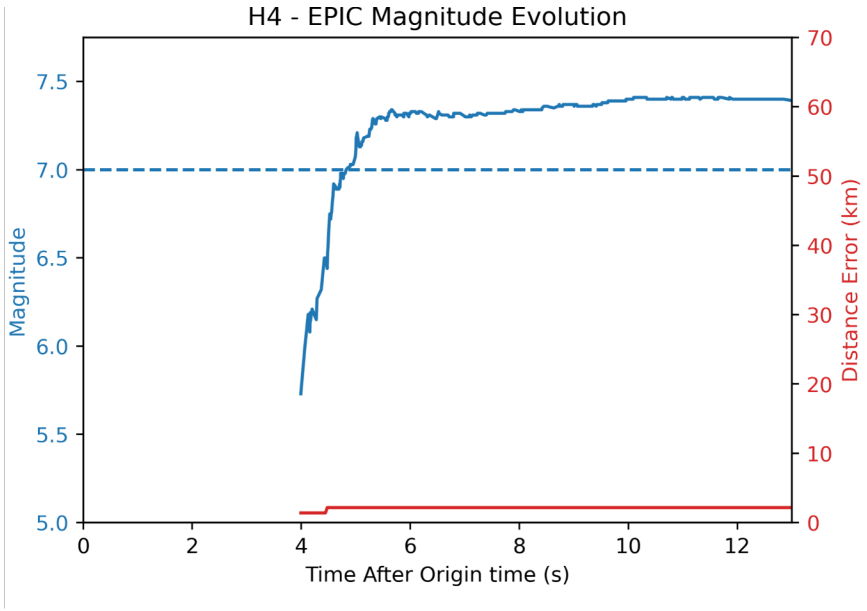




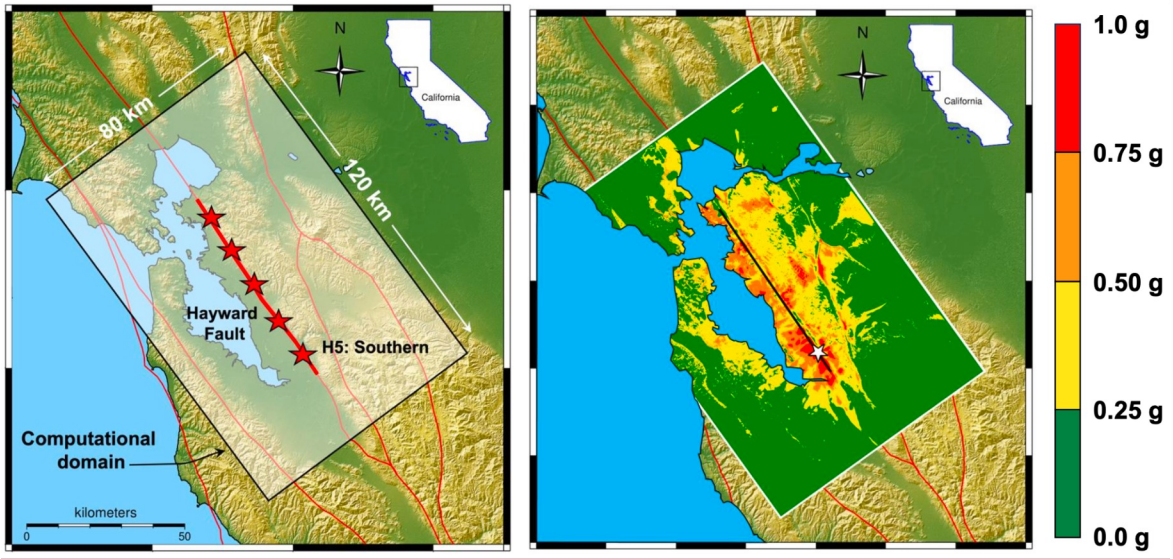


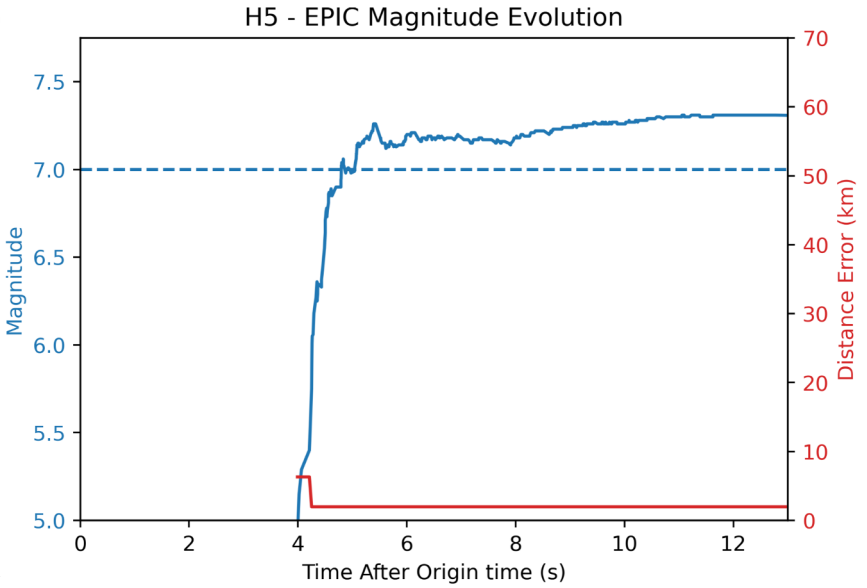
Hayward Fault Simulations – H4; M7.0



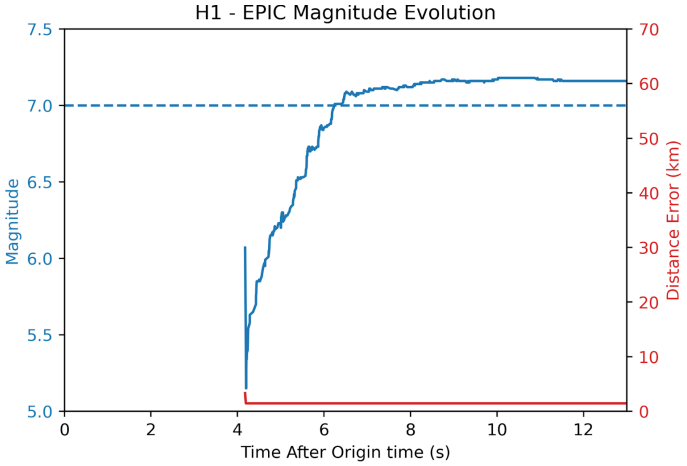


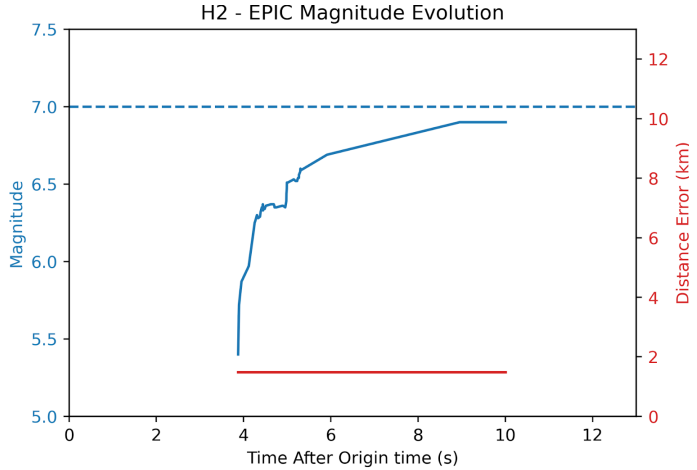
Hayward Fault Simulations – H5; M7.0

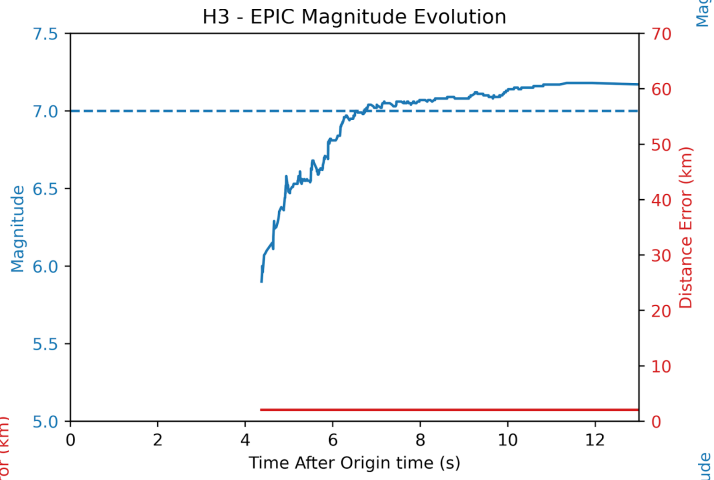


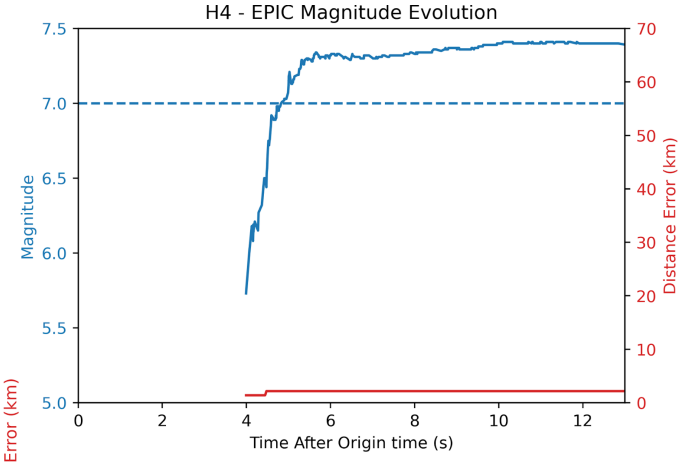


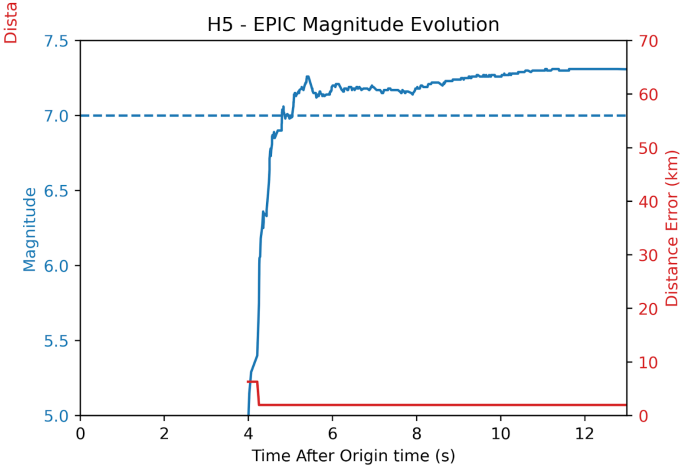
M7.0 Hayward Fault Simulations



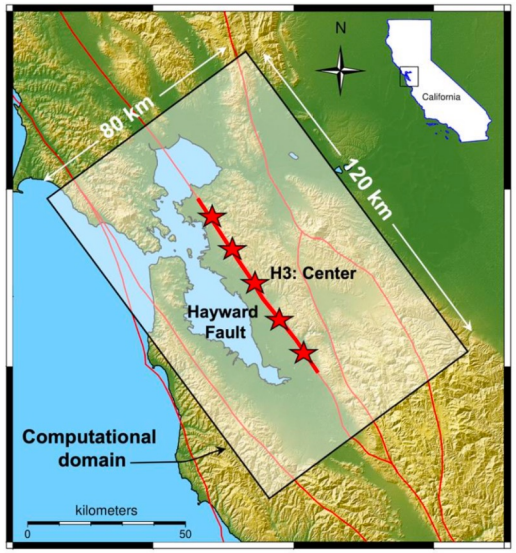


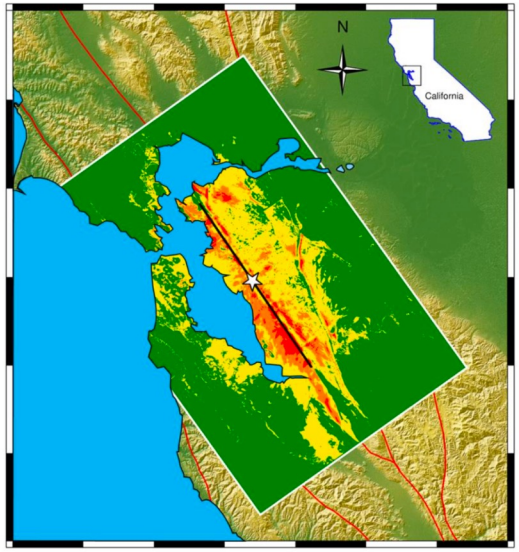


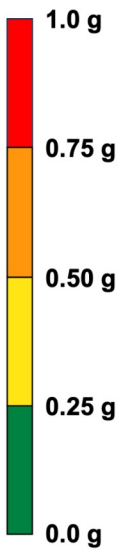


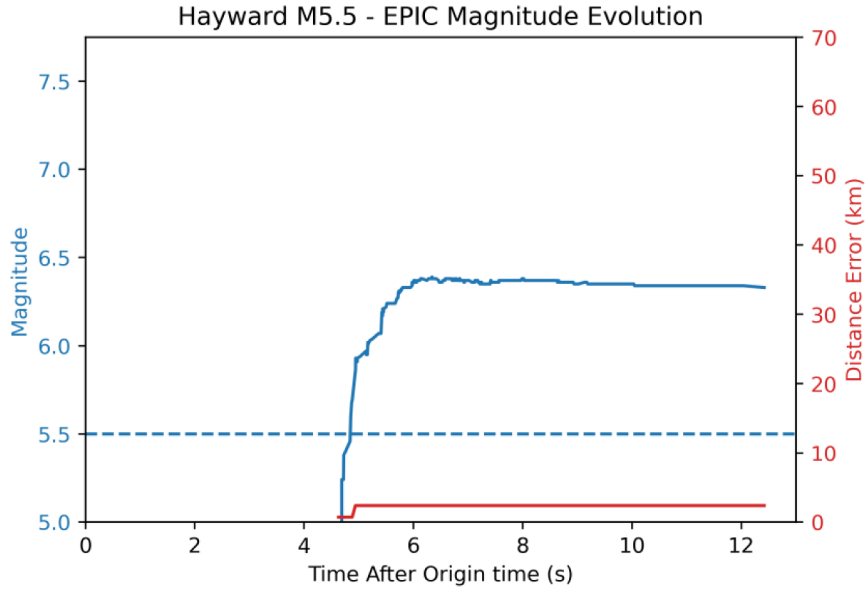


Hayward Fault Simulations – H3; M5.5







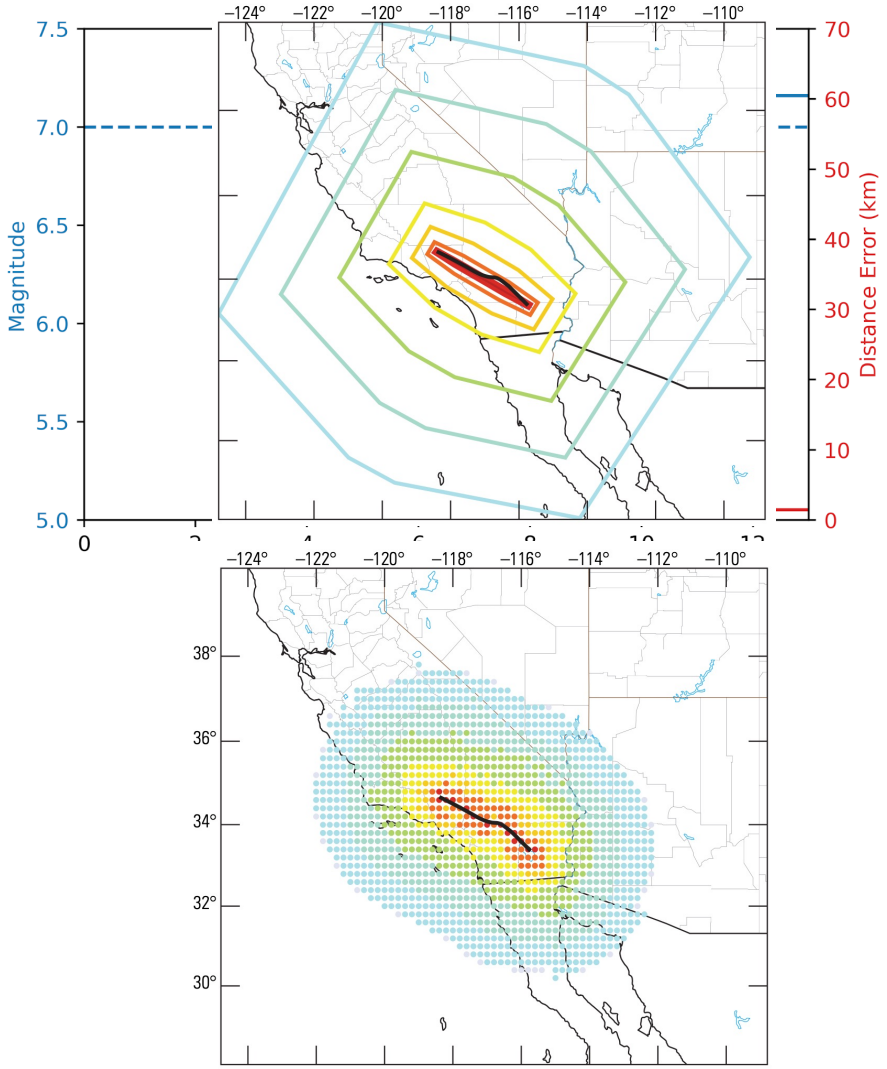


Conclusions

- Using high-resolution Hayward Fault simulations with EPIC worked well!

Next Steps

- Refine M5.5 simulation
- Run replays of other ShakeAlert algorithms
- Simulate network outages



Thank you!

angie.lux@berkeley.edu