



ShakeAlert® System Technical Updates

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Web: ShakeAlert.org

X: @USGS_ShakeAlert

06 December 2023

Topics Covered During USGS Update:

- Magnitude Overestimation for 10/18/23 M4.2 Isleton Earthquake (Doug)
- High Latencies and other issues around ShakeAlert-powered WEA Alert Deliveries for 8/20/23 M5.1 Ojai Earthquake (Bob)

M 4.2 - 5 km SW of Isleton, CA

- 2023-10-18 16:29:14 (UTC)
- 38.127°N 121.643°W
- 8.5 km depth

Post-ShakeAlert® Message Summary

ShakeAlert Messages Issued (after origin time):

Initial: 5.0 sec

Peak magnitude: 5.0 sec

Final: 21.0 sec

ShakeAlert System Magnitude Estimates:

Initial: M 5.7

1.5 units too high

Peak: M 5.7

Final: M 4.4

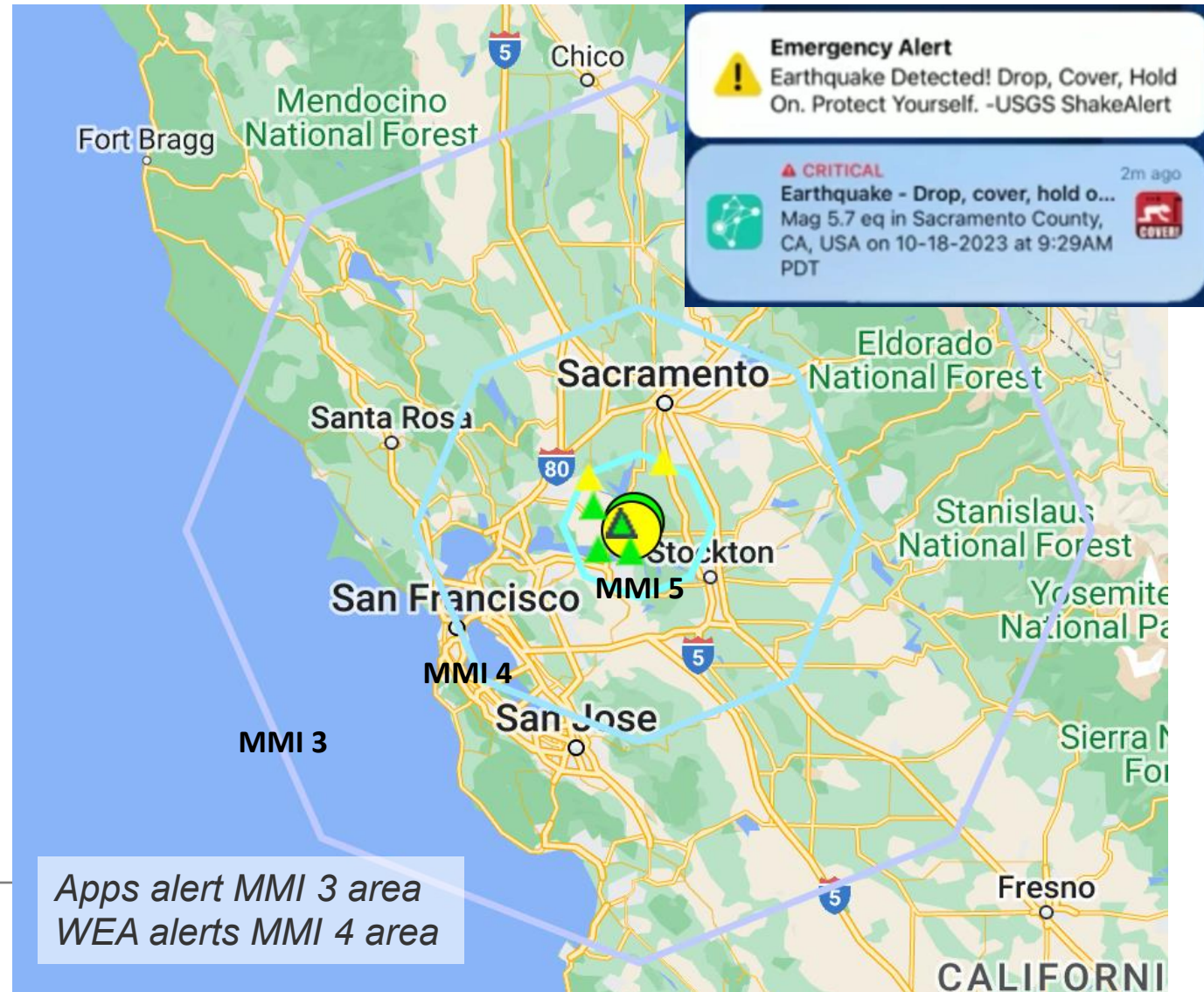
ShakeAlert System Location Accuracy:

Initial: 3.5 km (2.2 mi) N

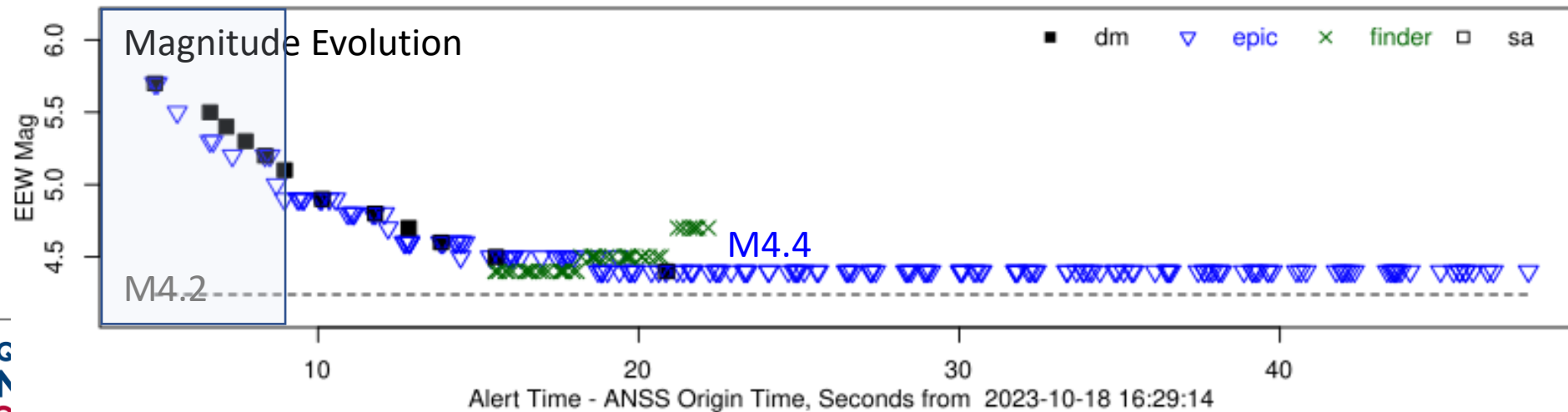
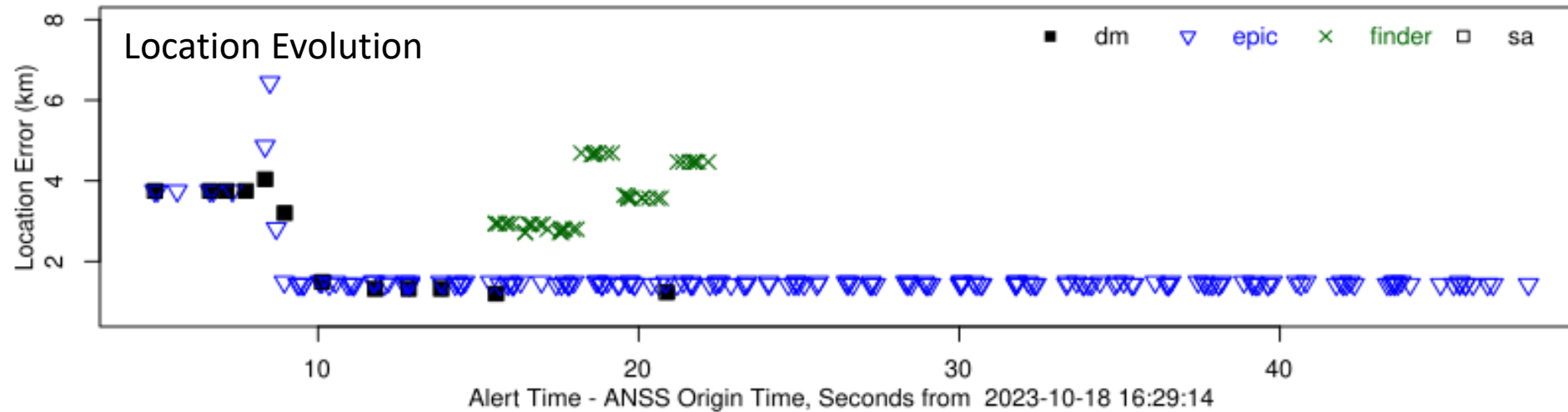
At peak mag.: 3.5 km (2.2 mi) N

Final: 1.0 km (0.6 mi) S

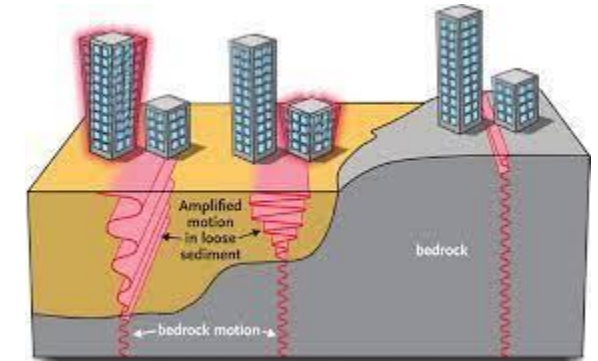
ShakeAlert Estimate



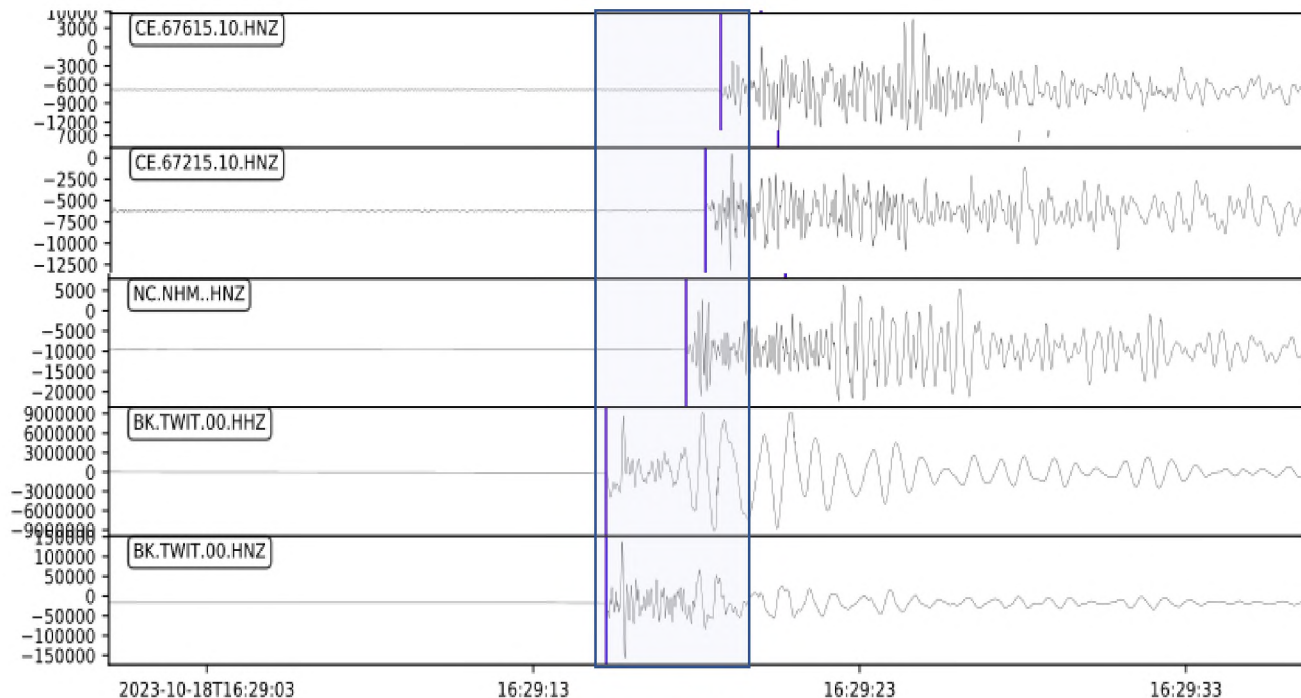
System Location and Magnitude Evolution



Network.Station.Channel	Data Available (sec)	logPd	Distance to initial EPIC location estimate (km):	PdMag Using Initial EPIC Location Estimate	Distance to ANSS Epicenter (km)	PdMag Using ANSS Location	MI Correction Factor (if available)	PdMag Using ANSS Location + MI Correction Factor
BK.TWIT.HHZ	4.73	-4.02E-01	8.4	6.17	4.8	5.84	-0.652	5.18
BK.TWIT.HNZ	4.72	-4.53E-01	8.4	6.11	4.8	5.77	-0.652	5.12
NC.NHM.HNZ	4.7	-1.77E+00	15.5	4.86	14.5	4.82	N/A	
CE.67215.HNZ	4.55	-1.91E+00	18.5	4.79	15	4.67	N/A	
CE.67615.HNZ	3.99	-1.48E+00	22.2	5.43	18.7	5.33	N/A	



Shaking is amplified in sedimentary basins



5 sec window

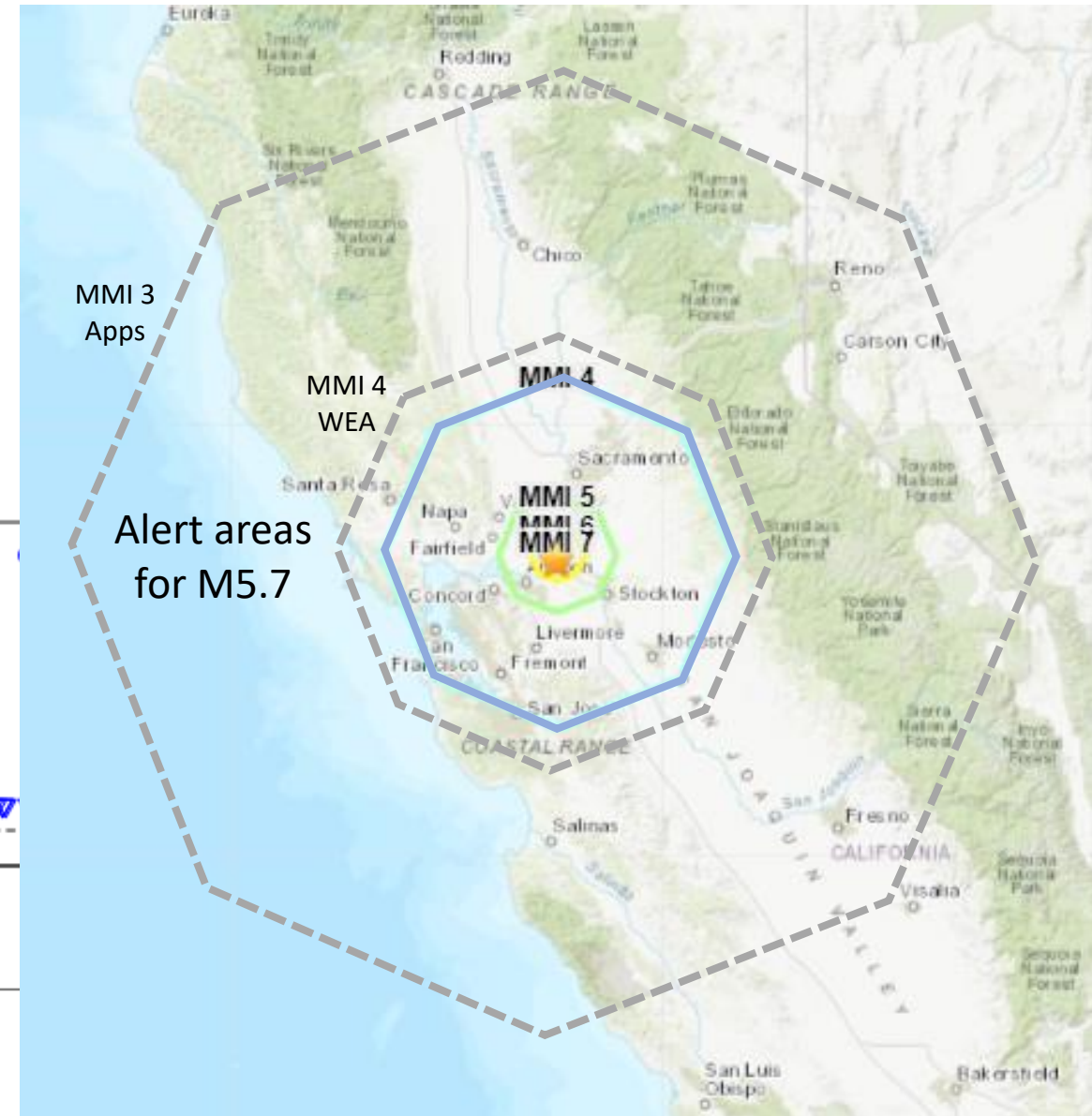
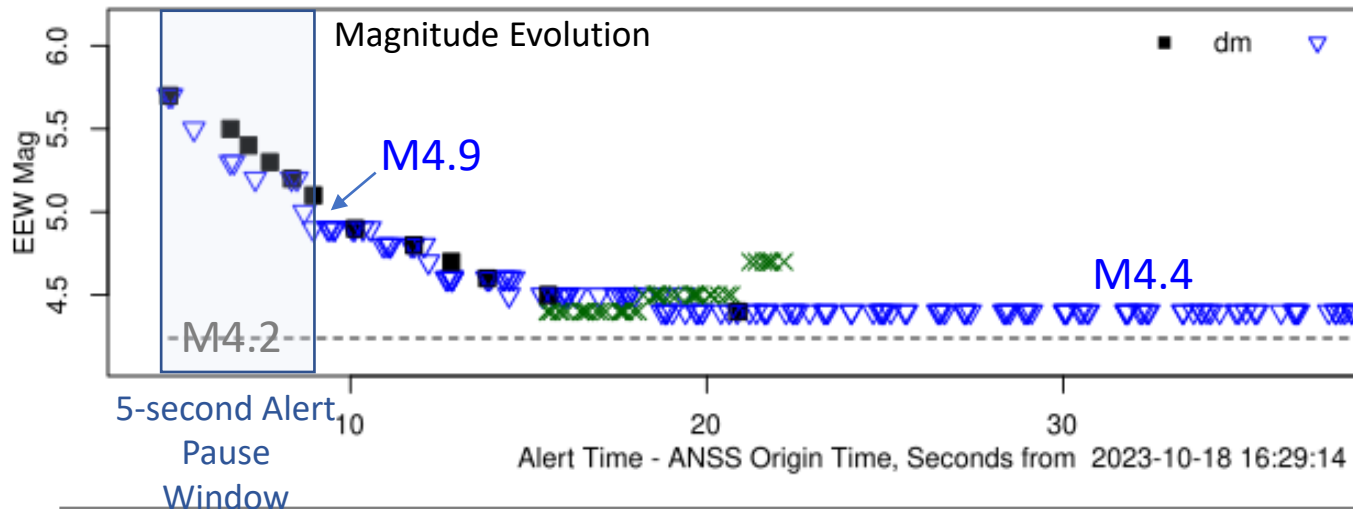
- BK.TWIT was 4.8 km from the epicenter. EPIC's 1st location estimate had a 3.4 km **location error**, this accounts for a 0.33 magnitude unit increase.
- Ground motion was amplified by soft sediments** of the Sacramento Delta at all close stations. This accounts for a 0.65 magnitude unit increase.
- Because BK.TWIT was so close, the **S-wave** was inside EPIC's 5-second long Pd calculation window, driving up the magnitude.
- "Mag weighting" gives greater weight to Pd estimates with more data, i.e. closer stations.

Alert Pause Feature (Alert Limit)

The “Alert Pause” feature limits the area of the first alert to a radius of 100km. (Blue polygon)

After 5 seconds the limit is removed.

By then the magnitude estimate was M4.9



After-action and Mitigation

Immediate

- Began analysis of the issue
- Consultation between USGS and BSL
- Removed BK.TWIT from station list
- Posted explanation on USGS Event Page

M 4.2 – 5 km SW of Isleton, CA

2023-10-18 16:29:14 (UTC) | 38.127°N 121.643°W | 8.5 km depth

i The ShakeAlert Earthquake Early Warning System was activated for this earthquake. Seismic station data available to the ShakeAlert processing center during the first few seconds of the earthquake resulted in a magnitude estimate of 5.7. As a result, USGS partners including FEMA's Wireless Emergency Alert system delivered alerts to regions that included Sacramento and the cities and communities in the San Francisco Bay Area. After several minutes and more data from additional seismic stations, the USGS/ANSS determined that the final magnitude was 4.2.

During this event those receiving alerts on their phones may have felt little or no shaking. Successful earthquake early warning is a balance between speed and accuracy with a goal to maximize public safety. The ShakeAlert System is in a constant state of improvement. Today's earthquake provides critical information on how to optimize rapid processing of earthquake data within seconds after detection. ShakeAlert can save lives and reduce injuries by giving people time to take a protective action like Drop, Cover, and Hold On.

After-action

- Deeper analysis by System Performance WG, two event reports
- Created a short-term working group to recommend steps to prevent future occurrences. Will report before next update cycle in Feb.
- The working group will consider:
 - Recalibration of Pd scaling relationship
 - Use of a two-part scaling relationship
 - Implementing per-station mag corrections
 - S-wave identification and rejection
 - Bias correction based on azimuthal gap
 - and others...

Alert Thresholds

To Alert People



Wireless Emergency Alert (WEA)

Who is Alerted

General public with WEA-capable devices

Magnitude Threshold

5.0+

Intensity Threshold

MMI IV+



Cell Phone Apps

People who have downloaded a cell phone app

4.5+

MMI III+
(user selectable)



Android Operating System

Android cell phone users through push notifications

4.5+

MMI III -
MMI IV

Android cell phone users through full-screen takeover

4.5+

MMI V+



Automated Alerts through Public Address Systems, Lights, Sirens, In-House Apps, etc.

Institutions that use ShakeAlert to alert people to take a protective action

4.0+

MMI III+

To Alert Systems and Machines



Automated "Machine-to-Machine" Alerts

Institutions that use ShakeAlert to automate actions to mitigate damage to vital equipment, systems, and infrastructure

4.0+

MMI III+



Earthquake Intensity Scale Modified Mercalli Intensity (MMI)

Alert Thresholds

To Alert People








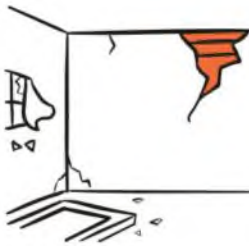




Wireless Emergency
Alert (WEA)



Who is Alerted	Magnitude Threshold	Intensity Threshold
General public with WEA-capable devices	5.0+	MMI IV+



 Not felt except by very few.	I	Not Felt	 Felt only by a few persons at rest, especially on upper floors of buildings.	II	Weak	 Felt indoors, though many people do not recognize it as an earthquake. Standing cars may rock slightly.	III	Weak	 Felt indoors by many, outdoors by few. Dishes and windows are disturbed.	IV	Light	 Felt by nearly everyone, many awakened if at night. Dishes and windows are broken.	V	Moderate
 Felt by all; many frightened. Some heavy furniture moved. Damage is slight.	VI	Strong	 Slight to moderate damage in ordinary construction. Some chimneys broken.	VII	Very Strong	 Considerable damage to ordinary construction. Chimneys, columns, and walls may fall.	VIII	Severe	 Damage is great in substantial buildings, with partial collapse. Buildings shifted off foundations.	IX	Violent	 Some well-built wooden structures destroyed; most masonry and structures are destroyed.	X+	Extreme

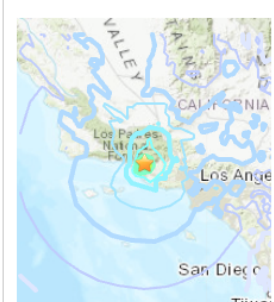


EARTHQUAKE
WARNING
CALIFORNIA

M 5.1 – 7 km SE of Ojai, CA

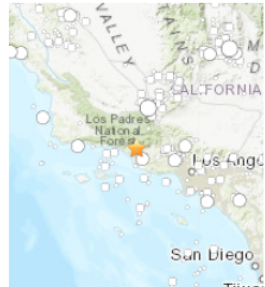
2023-08-20 21:41:00 (UTC) | 34.409°N 119.188°W | 4.8 km depth

[Interactive Map](#)



Contributed by [CI](#)⁴

[Regional Information](#)



Contributed by [CI](#)⁴

[Felt Report - Tell Us!](#)

0 1 4 1 1 8

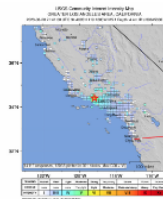
Responses

Contribute to citizen science.
Please [tell us](#) about your experience.

Citizen Scientist Contributions

[Did You Feel It?](#)

V



Community Internet Intensity Map

Contributed by [US](#)⁶

[ShakeMap](#)

VI



Estimated Intensity Map

Contributed by [CI](#)⁴

[Moment Tensor](#)



Fault Plane Solution

Contributed by [CI](#)⁴

[Aftershock Forecast](#)

Be ready for more earthquakes.

Our model of the expected numbers and odds of future earthquakes.

Contributed by [US](#)⁶

[Tsunami](#)



U.S. Tsunami Warning System

To view any current tsunami advisories for this and other events please visit <https://www.tsunami.gov>.

NOAA

[View Nearby Seismicity](#)

Time Range

± Three Weeks

Search Radius

250.0 km

Magnitude Range

≥ 2.0

ANSS Comcat

[ShakeAlert®](#)



Contributed by [EW](#)⁵

WEA Alert Message Content:

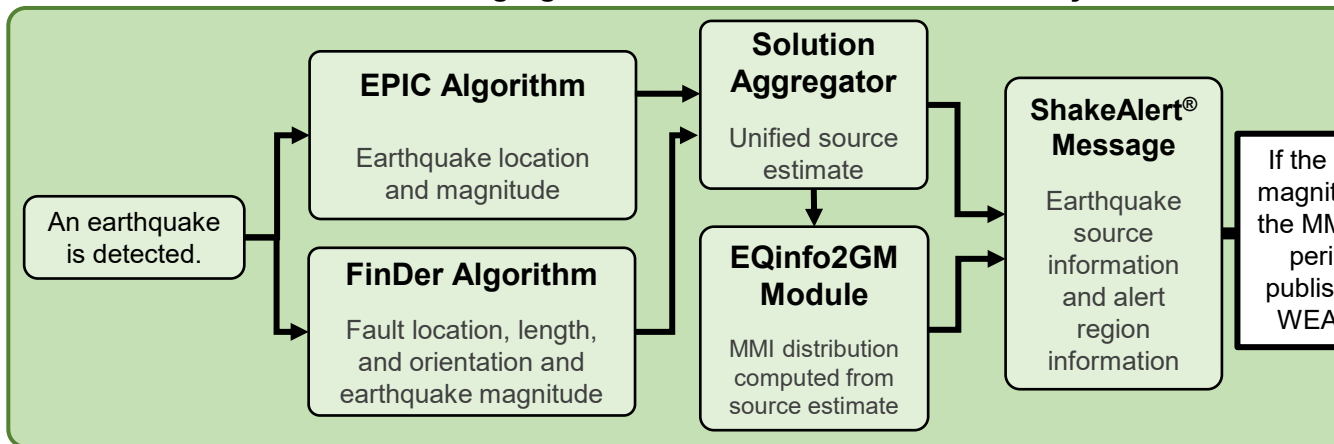
Earthquake Detected! Drop, Cover, Hold On. Protect Yourself. -USGS ShakeAlert

Terremoto detectado! Agachese, cubrase, sujetese. Protejase. -USGS ShakeAlert

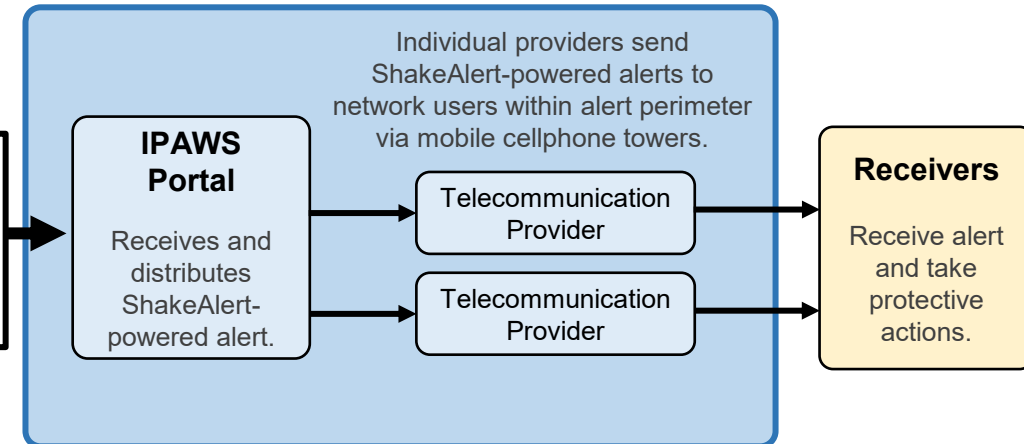
90-character messages

Over 5.6M ShakeAlert-powered alerts were delivered for this event.

ShakeAlert[®] Message generation via USGS ShakeAlert system



Alert delivery via Wireless Emergency Alert system



First ShakeAlert Message published 5.5 s after origin time. Depth = 3 miles.

M5.1 Ojai 8/20/23 (ShakeAlert system max magnitude = M6.0)
Elapsed time from 1st ShakeAlert Message to when it was distributed to cell carriers = 2.0 sec (preliminary, non-reviewed)

Modified from McBride et al. (2023)

- Settings on end-user phone prevent alert delivery (e.g. WEA is disabled intentionally or unintentionally)
- Message arrived “broken” and cannot be displayed.
- Message was received but there was an error in processing on the device (factors include age and type of phone).
- Transmission of data on cellular network is compromised or there was a momentary drop in service.
- WEA has a resend cycle, phone could have missed first alert and received a later broadcast (perceived as late alert delivery). Resend interval varies from carrier to carrier.
- If end-user in motion they could have moved out of an alert area and missed an alert or moved into an area in between resend cycles.
- WEA Rule: No alert delivery during a data session (not clear what this means), likely during a phone call. What breaks through may differ carrier to carrier.

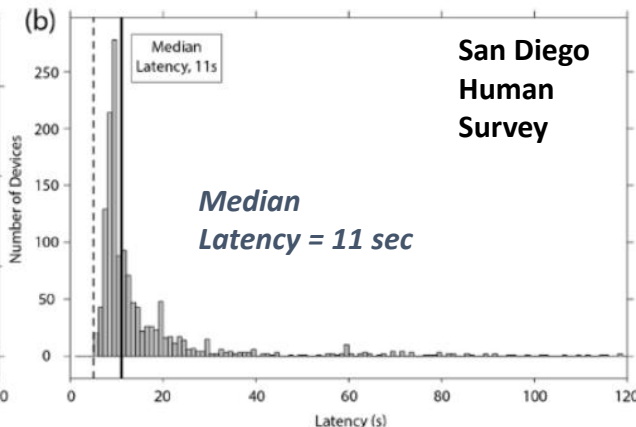
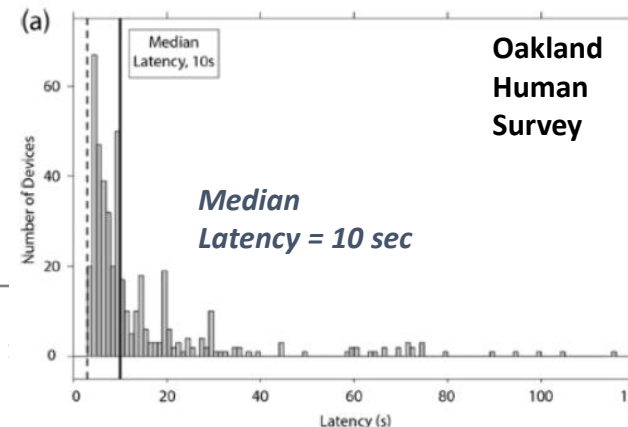
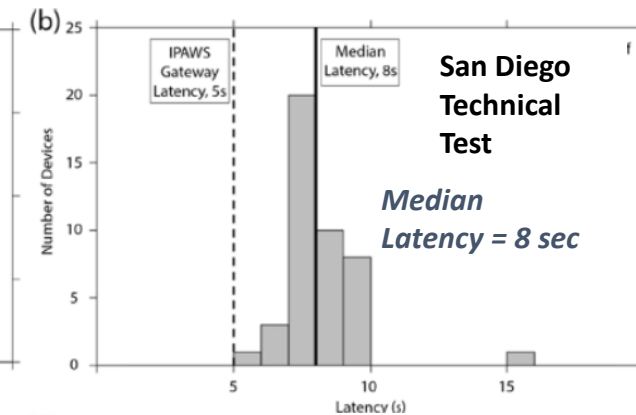
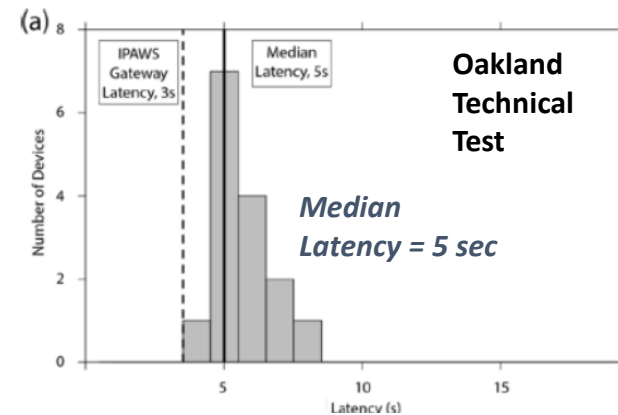
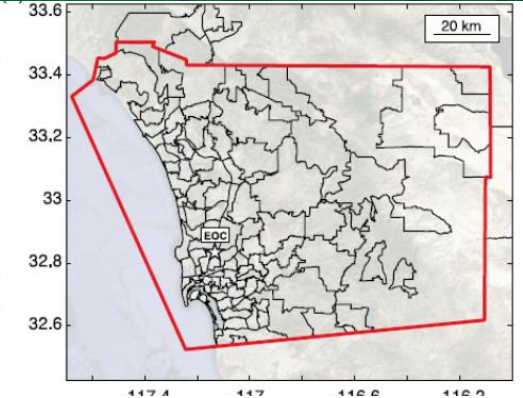
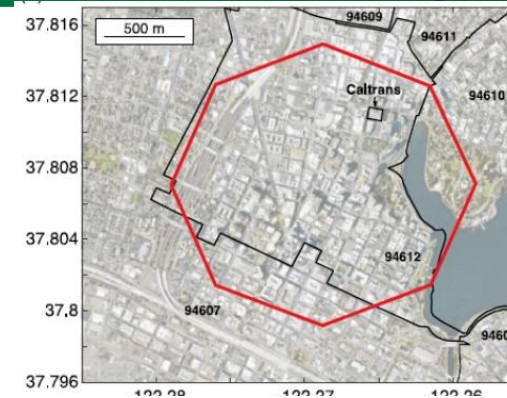


WEA Test Results		Technical Test			Human Survey Results		
All in seconds	IPAWS Latency	# Phones Receiving	Minimum Time	Median Time	Surveys Usable	Minimum Time	Median Time
Oakland 3/27/19	3.5	15	4	5	481	3	10
San Diego 6/27/19	4.6	46	5	8	1,401	5	11

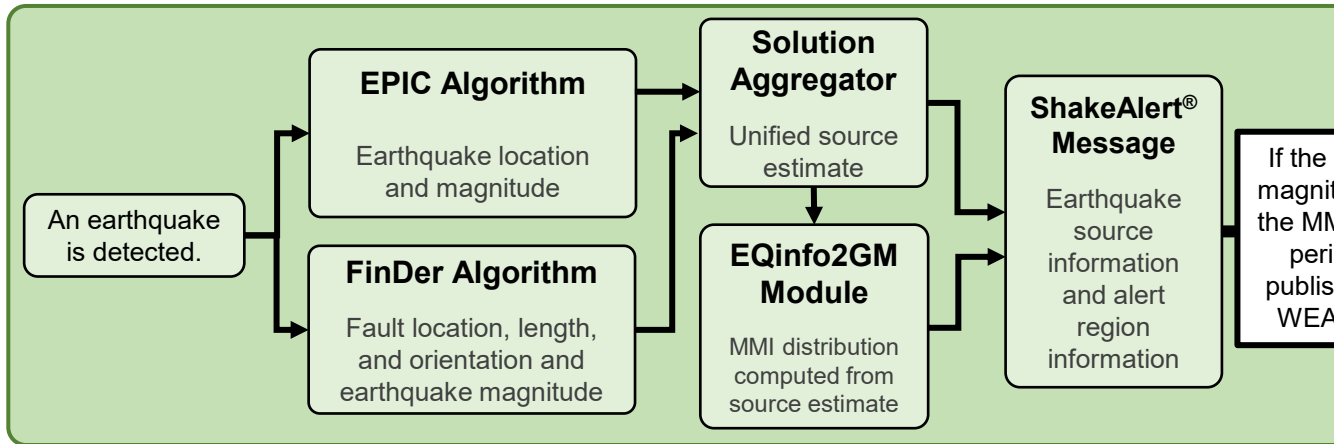
(McBride, et al., 2022)

Conclusions

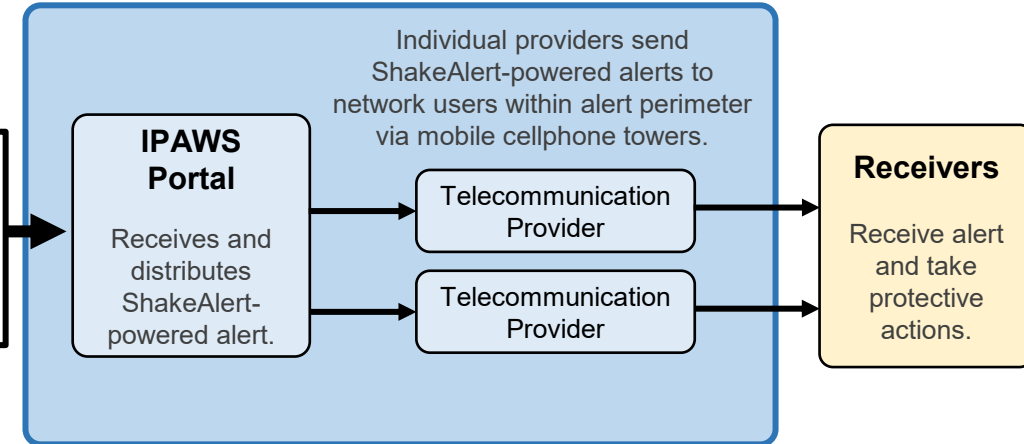
- Delivery by cell providers in ~4-5 sec is possible
- Delivery time is highly variable, has long "tail"
- ~25% do not receive the alert
- Total delivery time (IPAWS + Cell Carrier) >8+ sec



ShakeAlert[®] Message generation via USGS ShakeAlert system



Alert delivery via Wireless Emergency Alert system



First ShakeAlert Message published 5 s after origin time.
Depth = 5 miles.

M4.2 Isleton quake 10/18/23 (ShakeAlert system max magnitude = M5.7)
Elapsed time from 1st ShakeAlert Message to when it was distributed to cell carriers = 3.7 sec (preliminary, non-reviewed)

Modified from McBride et al. (2023)

Thank you!



Questions and Discussion