ShakeAlert™

Evaluating ShakeAlert™ performance in the Cascadia subduction zone region

Dr. Renate Hartog

jrhartog@uw.edu, www.pnsn.org

UNIVERSITY of WASHINGTON

PNSN Pacific Northwest Seismic Network

ANSS Advanced National Seismic System

ShakeAlert™

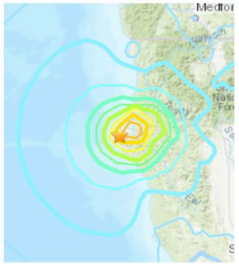
ANSS Earthquake situational awareness products

M 6.4 - 15km WSW of Ferndale, CA

2022-12-20 10:34:24 (UTC) | 40.525°N 124.423°W | 17.9 km depth

EARTHQUAKE.USGS.GOV

Interactive Map



Contributed by NC.[5]

Regional I… n

3-5 minutes reviewed within 10-20 minutes

Felt Report - Tell Us!

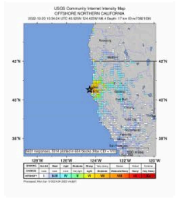
0 0 5 9 3 1

Responses

Contribute to citizen science. Please tell us about your experience.

Citizen Scientist Contributions

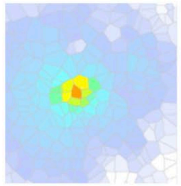
Did You Feel It? VIII



Cor…tensity

within minutes

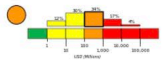
ShakeMap VIII



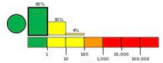
Estimated Intensity Map

10-15 minutes

PAGER ORANGE



Estimated Economic Losses



E…s

15-30 minutes

Ground Failure

Landslide Estimate

Limited area affected

Limited population exposed

Liquefaction Estimate

Limited area affected

Limited population exposed

30 minutes

Origin

Review

REVI

Magni…

6.4 …

Dept…

17.… km

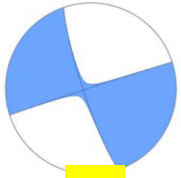
Time

2022-…

3-5 minutes reviewed within 10-20 minutes

Contributed by NC.[5]

Moment Tensor

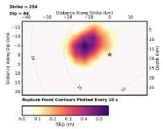


Fault …lution

45 minutes

Contributed by NC.[5]

Finite Fault



Cross-section of slip dist…

>45 minutes

Contributed by US.[6]

Aftershock Forecast

Be ready for more earthquakes.

Our model of the expected numbers and odds of future earthqua…

20 minutes

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

≥ 3.0

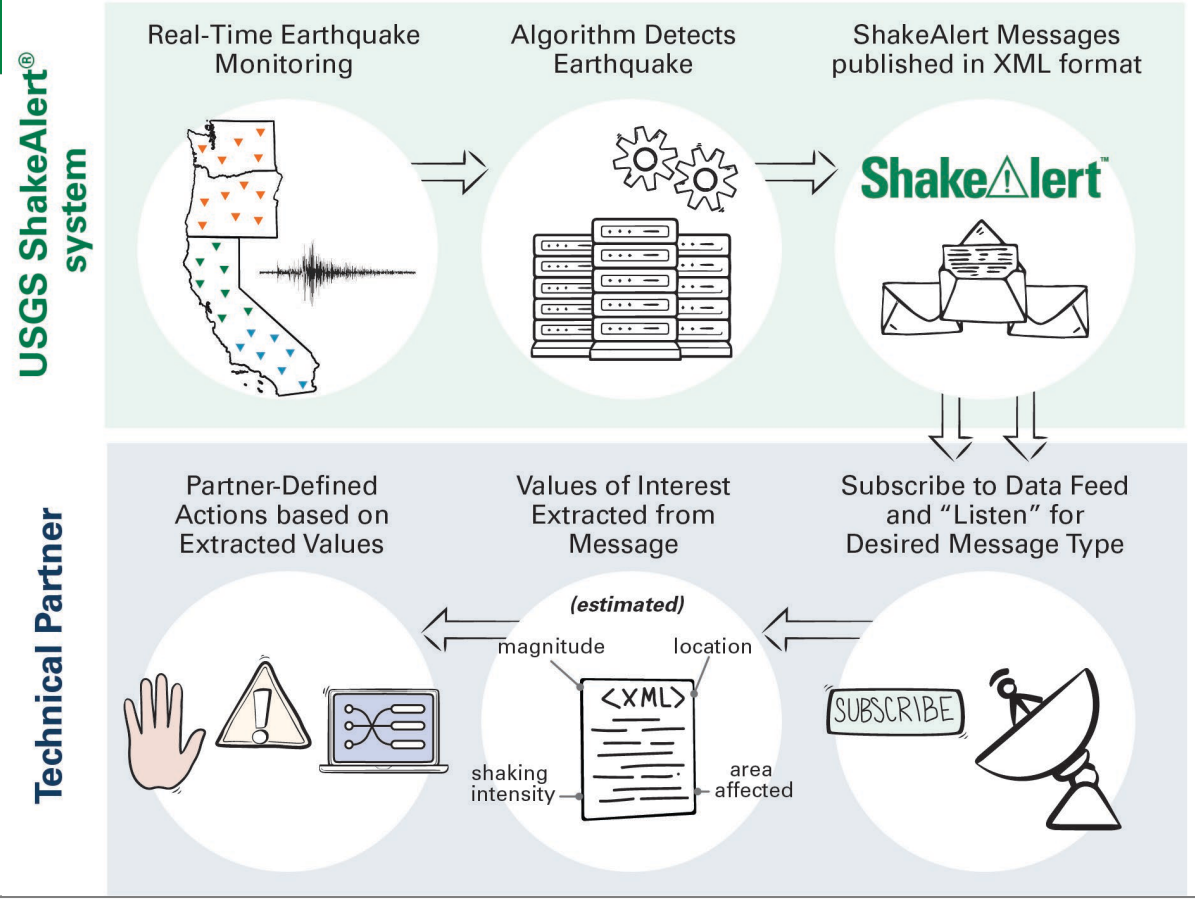
ANSS Comcat

ShakeAlert ®

5-25 Seconds

Contributed by EW.[4]

USGS ShakeAlert EEW System



ShakeAlert® Messages have three components

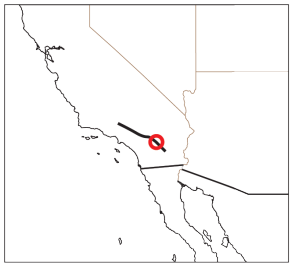
Technical Partners can subscribe to one or more components

System Overview

1

EVENT ONLY

ActiveMQ "topic": *eew.dm.data*



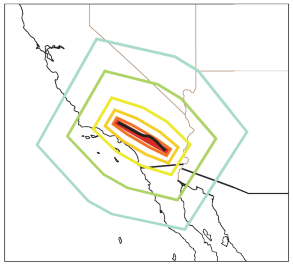
Provides estimated earthquake **magnitude** and **location**, along with uncertainty. For earthquakes M6.0+, **fault geometry** is included.

Technical Partner must calculate shaking effects and affected areas.

2

EVENT + CONTOUR

ActiveMQ "topic": *eew.gm-contour.data*



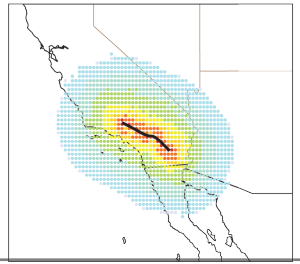
Contains **EVENT COMPONENT** plus data for **contours of shaking intensity**.

Polygons enclose areas according to estimated Modified Mercali Intensity (MMI), Peak Ground Acceleration (PGA), and Peak Ground Velocity (PGV).

3

EVENT + GRID

ActiveMQ "topic": *eew.gm-map.data*



Contains **EVENT COMPONENT** plus data for a **grid map of shaking intensities**.

Grid cells are 0.2 x 0.2 degree (~20 x 20 km) identified by latitude and longitude.

Earthquake point-source integrated code

Finite-Fault Rupture Detector

G-FAST PGD magnitude (soon)

Solution Aggregator combines the source estimates

eqInfo2GM takes source information from the SA then uses a GMM and GMICE to determine GM contours and a 0.2° x 0.2° GM grid map

PNSN Pacific Northwest Seismic Network

Figures derived from: Given, D.D. et al, "Revised technical implementation plan for the ShakeAlert system—An earthquake early warning system for the West Coast of the United States" (2018), https://doi.org/10.3133/ofr20181155

ShakeAlert™

Alert Thresholds

To Alert People

	Who is Alerted	Magnitude Threshold	Intensity Threshold
 **Wireless Emergency Alert (WEA)**	General public with WEA-capable devices	5.0+	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+

We evaluated the accuracy of the ground motion contour product

ShakeAlert™

ShakeAlert™

As of June 2021

Thompson et al., (2022). *Effect of Fixing Earthquake Depth in ShakeAlert Algorithms on Performance for Intraslab Earthquakes*, Seism. Res. Lett.

Thompson, M. (2022). *Using Local, Global, and Simulated Earthquakes to Inform Earthquake Resilience Efforts in the Pacific Northwest* (Order No. 29061275). Available from ProQuest Dissertations & Theses Global. (2652067864). https://www.proquest.com/dissertations-theses/using-local-global-simulated-earthquakes-inform/docview/2652067864/se-2

Böse, M., Andrews, J., O'Rourke, C., Kilb, D., Lux, A., Bunn, J., & McGuire, J. (2023). Testing the ShakeAlert earthquake early warning system using synthesized earthquake sequences. *Seismological Society of America*, *94*(1), 243-259.

McGuire, J. J., Smith, D. E., Frankel, A. D., Wirth, E. A., McBride, S. K., & de Groot, R. M. (2021). *Expected warning times from the ShakeAlert earthquake early warning system for earthquakes in the Pacific Northwest* (No. 2021-1026). US Geological Survey.

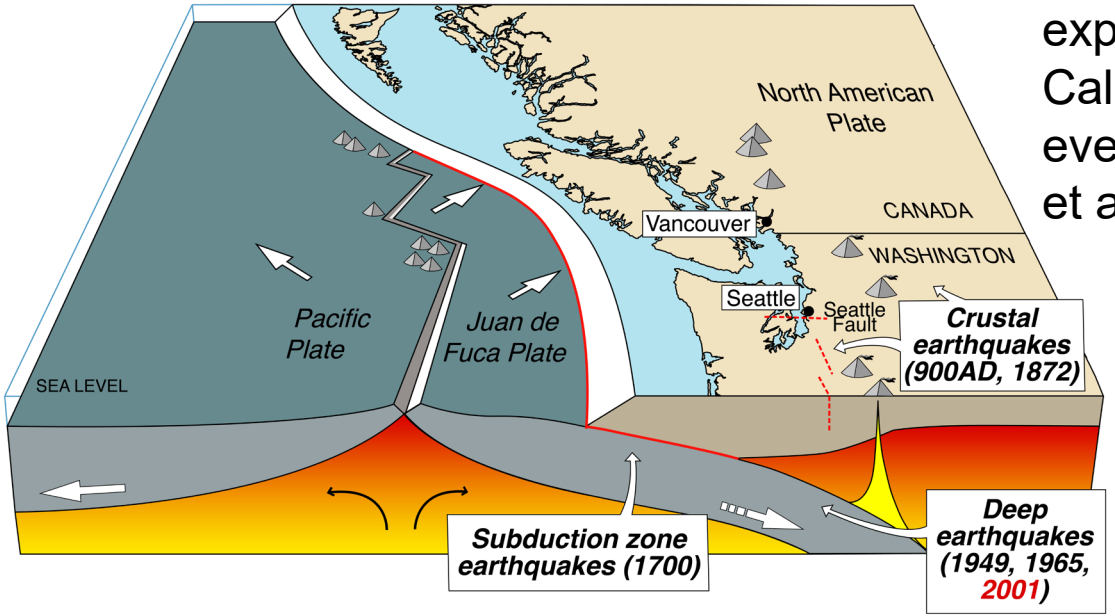
Meier, M. A., Kodera, Y., Böse, M., Chung, A., Hoshiba, M., Cochran, E., ... & Heaton, T. (2020). How often can earthquake early warning systems alert sites with high-intensity ground motion?. *Journal of Geophysical Research: Solid Earth*, *125*(2), e2019JB017718.

Cochran, E. S., Kohler, M. D., Given, D. D., Guiwits, S., Andrews, J., Meier, M. A., ... & Smith, D. (2018). *Earthquake early warning ShakeAlert system: Testing and certification platform*. *Seismological Research Letters*, *89*(1), 108-117.

Hartog, J. R., Kress, V. C., Malone, S. D., Bodin, P., Vidale, J. E., & Crowell, B. W. (2016). Earthquake Early Warning: ShakeAlert in the Pacific Northwest. *Bulletin of the Seismological Society of America*, *106*(4), 1875-1886.

USGS PNSN

Cascadia earthquake sources



The same performance is expected as in California for crustal events (e.g., Hartog et al., 2016)

ShakeAlert™

Intraslab Events

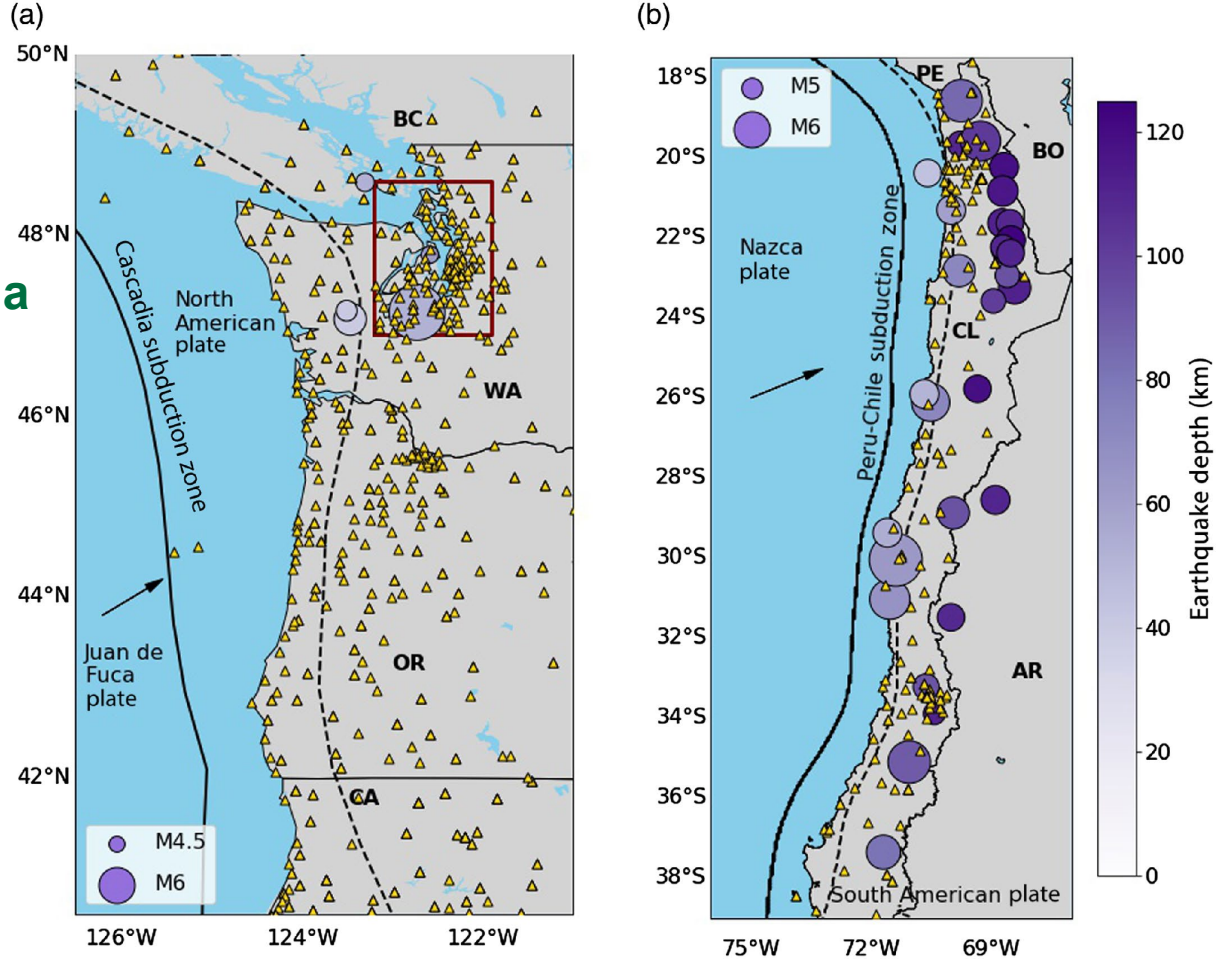
How bad is it that we assume a fixed shallow depth?

5 PNW and 32 Chilean events

Play data through the ShakeAlert algorithms EPIC, SA, eqInfo2GM (GMPE: Zhao, 2006) in two ways:

1. Assume 8 km earthquake depth
2. Assume catalog earthquake depth

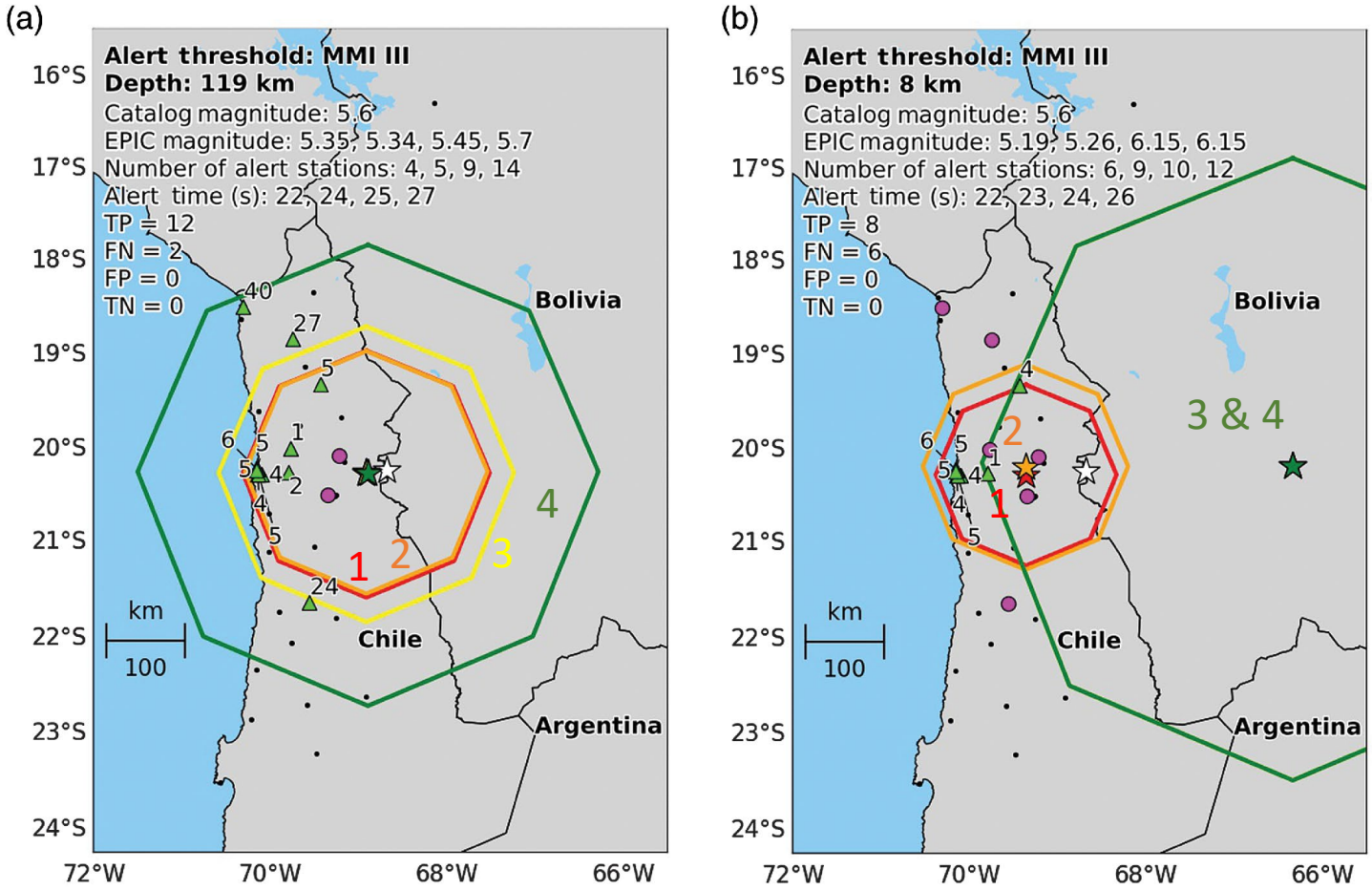
Compare the performance of the MMI III and IV contours



PNSN Pacific Northwest Seismic Network

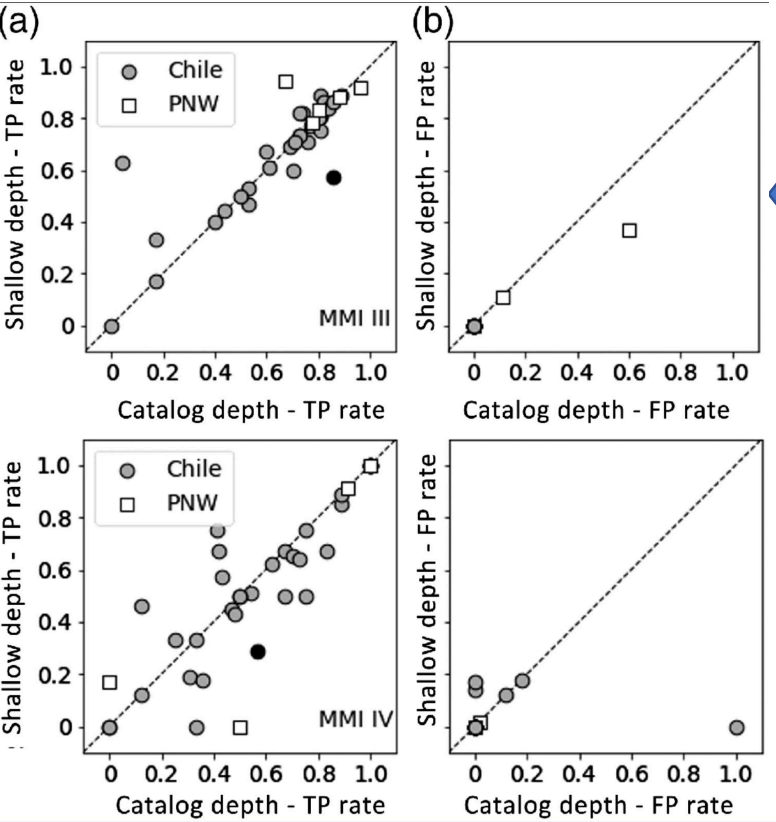
Thompson et al., Effect of Fixing Earthquake Depth in ShakeAlert Algorithms on Performance for Intraslab Earthquakes, SRL 2022

ShakeAlert™



Bad location errors when the event is on the edge or outside of the network

Station density for the Chilean events is low



MMI III

MMI IV

Alert Accuracy by MMI level

Desired number of alerts: all stations where the MMI level was exceeded

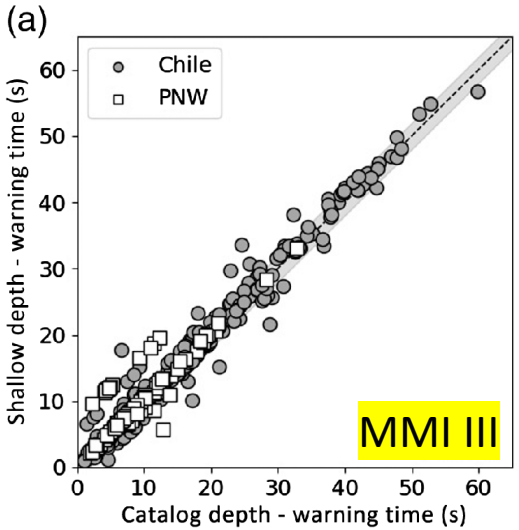
True Positive rate: fraction of sites for which a timely alert was issued for this MMI level

False Positive rate: fraction of sites for which an alert was not needed for this MMI level

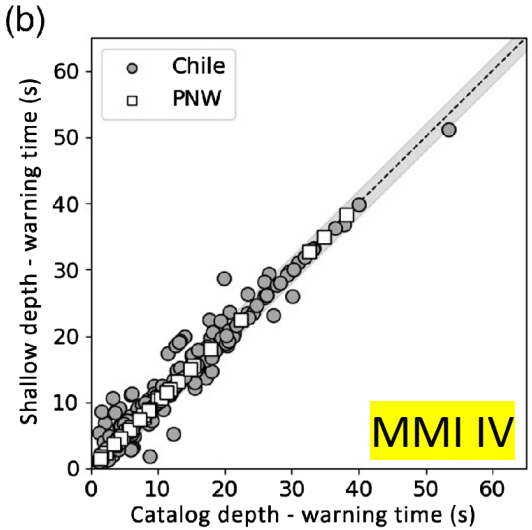
No clear advantage by assuming catalog depth

Effects on Timeliness

Assuming shallow depth



Assuming catalog depth



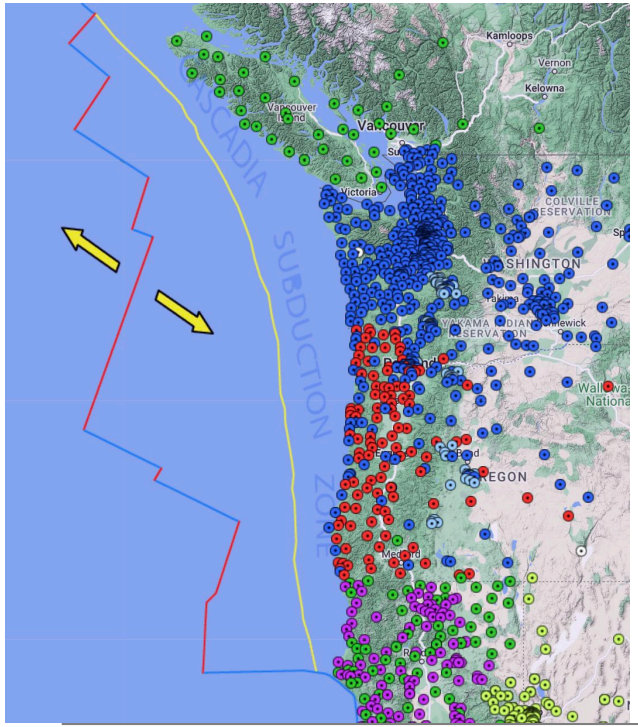
Assuming catalog depth

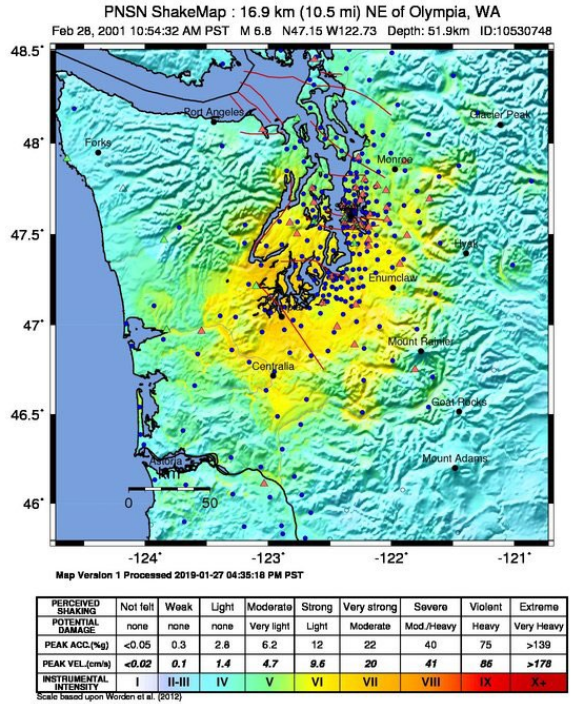
Time between the release of MMI III or IV alert contour and arrival of that level of shaking

Symbols denote station observations

No clear advantage by assuming catalog depth

Conclusion for PNW intraslab events

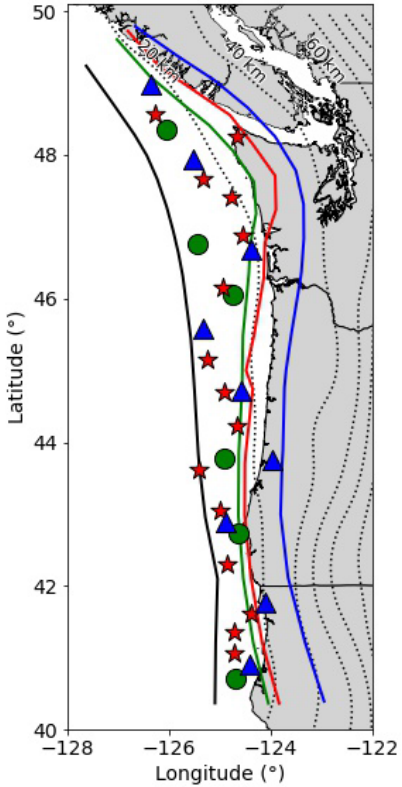




PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden et al. (2012)

Using a fixed shallow depth for intraslab earthquakes in the PNW does not have a significant impact on alert accuracy and timing for alert thresholds of MMI III and IV because intraslab events occur beneath dense parts of the network



Megathrust events

There have been no large Cascadia subduction interface events in instrumental history

We used 30 M9 simulations for Cascadia (Frankel et al., 2018; Wirth et al., 2018)

We evaluated the MMI III, IV, and V contours

PNSN Pacific Northwest Seismic Network

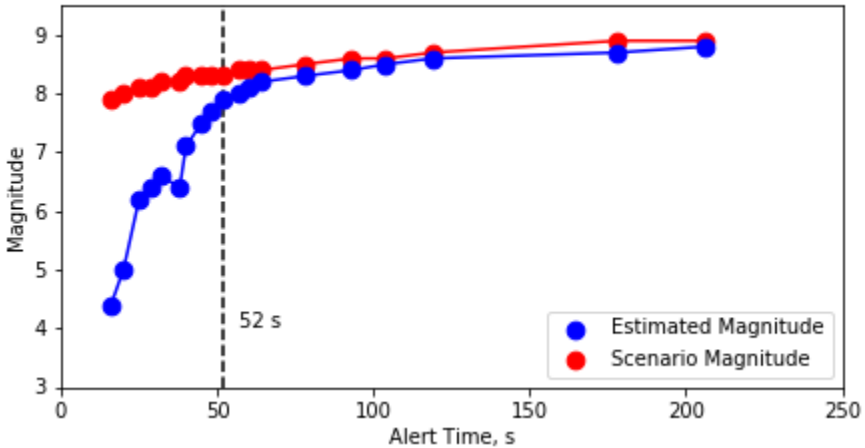
PGAs and Source Estimates

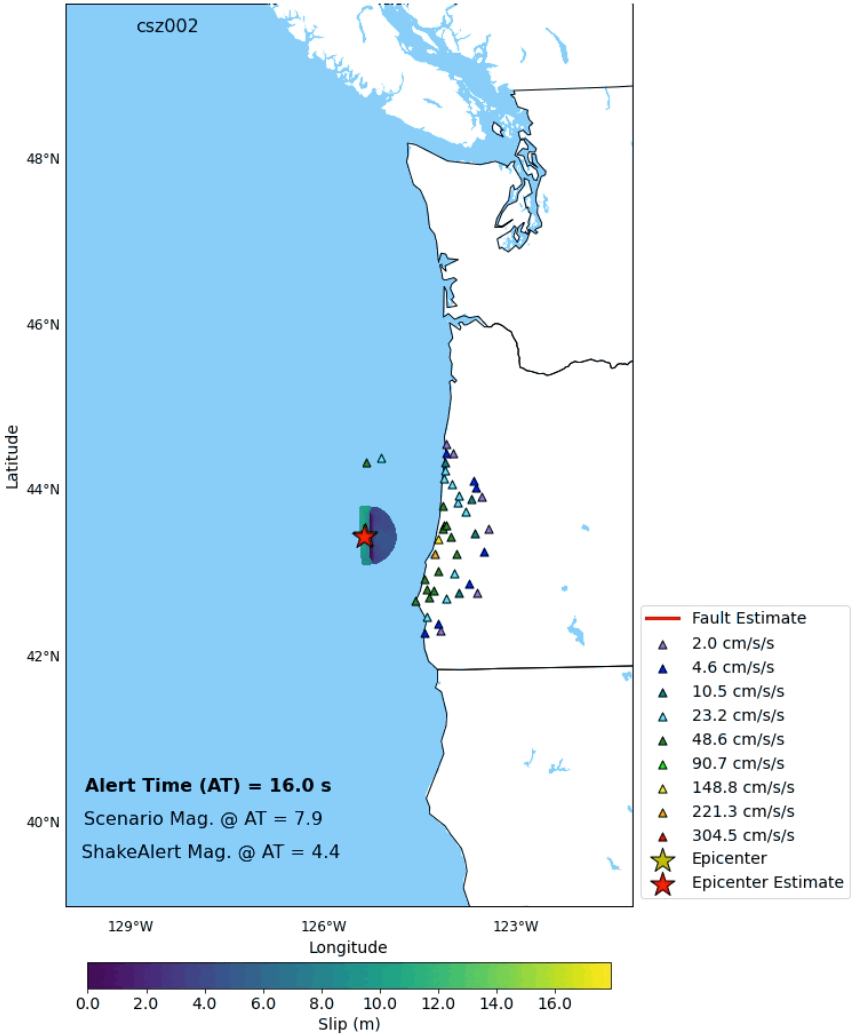
Hypocenter: **central OR** (csz002)

Final magnitude estimate: 8.8

Final alert time: 206 s (3.4 min.)

Fault rupture ends: 318 s (5.3 min.)





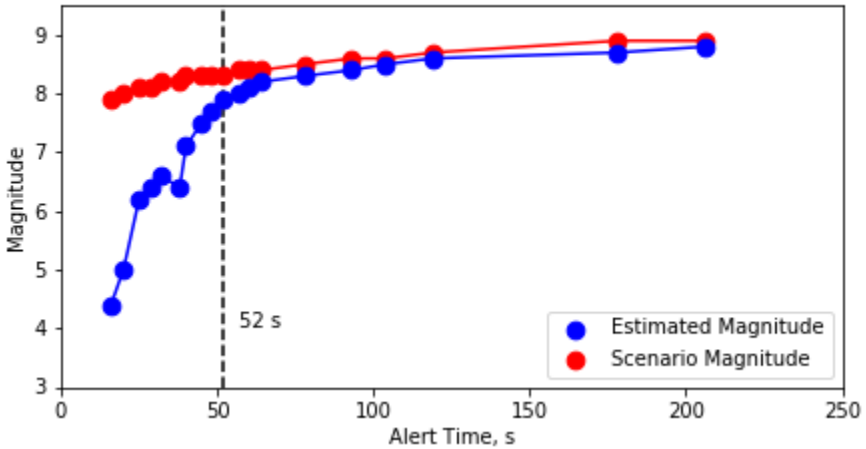
MMI V Contours and Warning Times

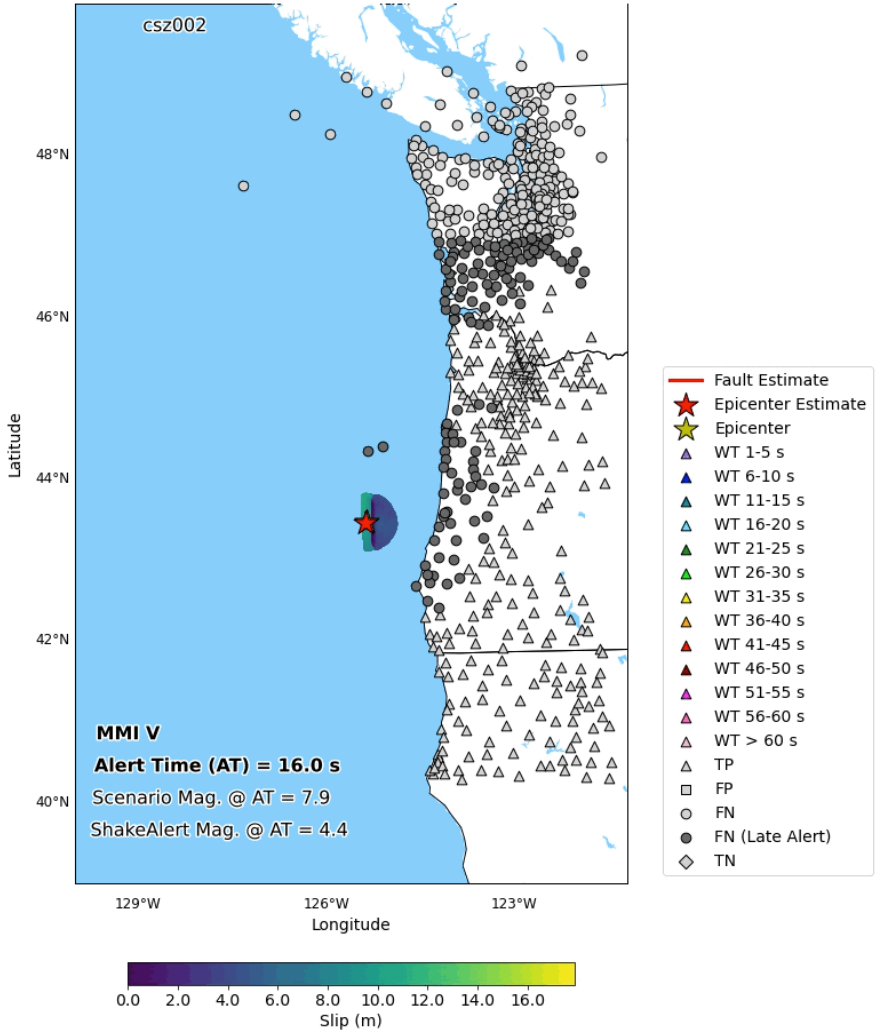
Hypocenter: **central OR** (csz002)

Final magnitude estimate: 8.8

Final alert time: 206 s (3.4 min.)

Fault rupture ends: 318 s (5.3 min.)





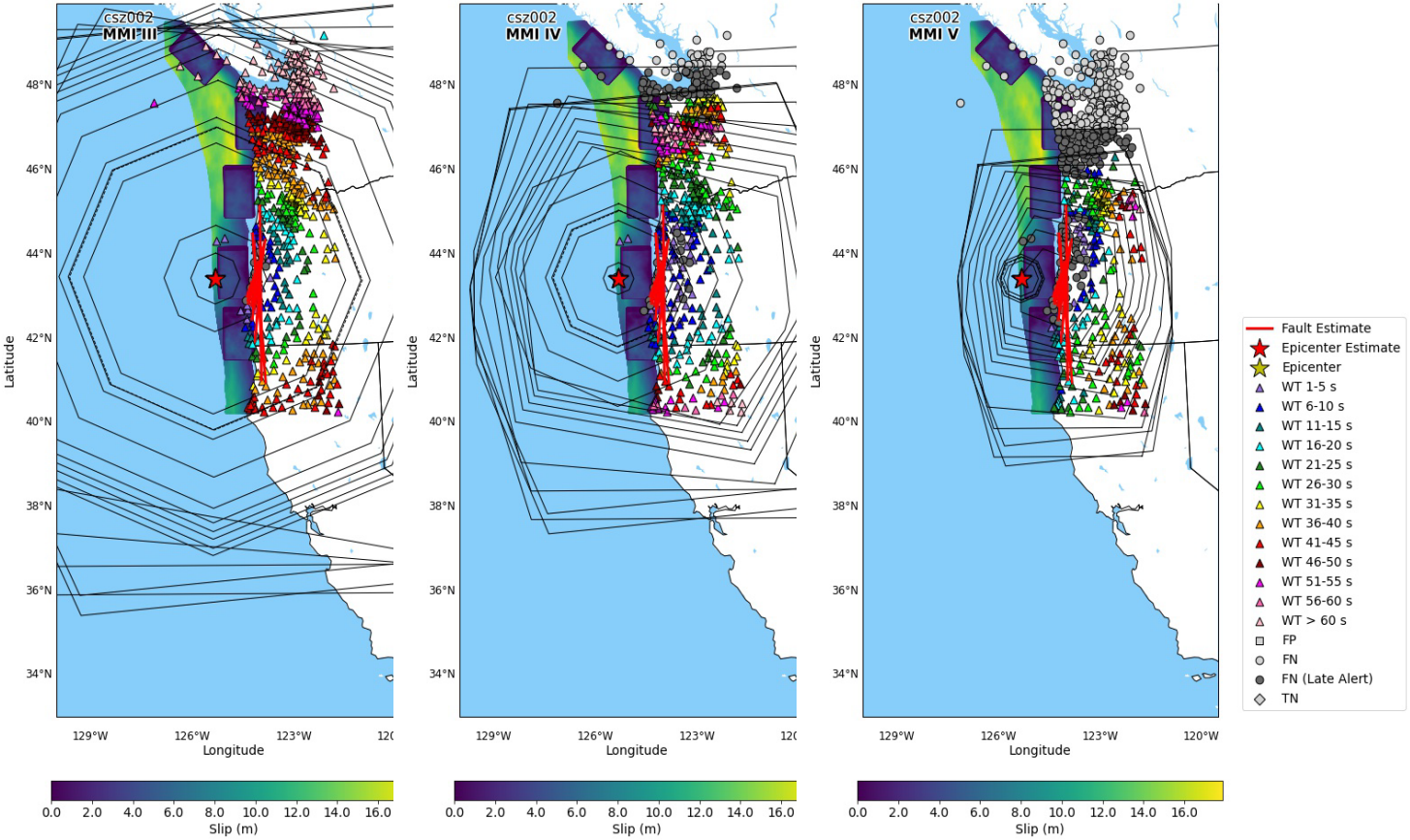
ShakeAlert™

MMI III
WTs: 1 – 77 s

MMI IV
WTs: 1 – 78 s

MMI V
WTs: 1 – 60 s

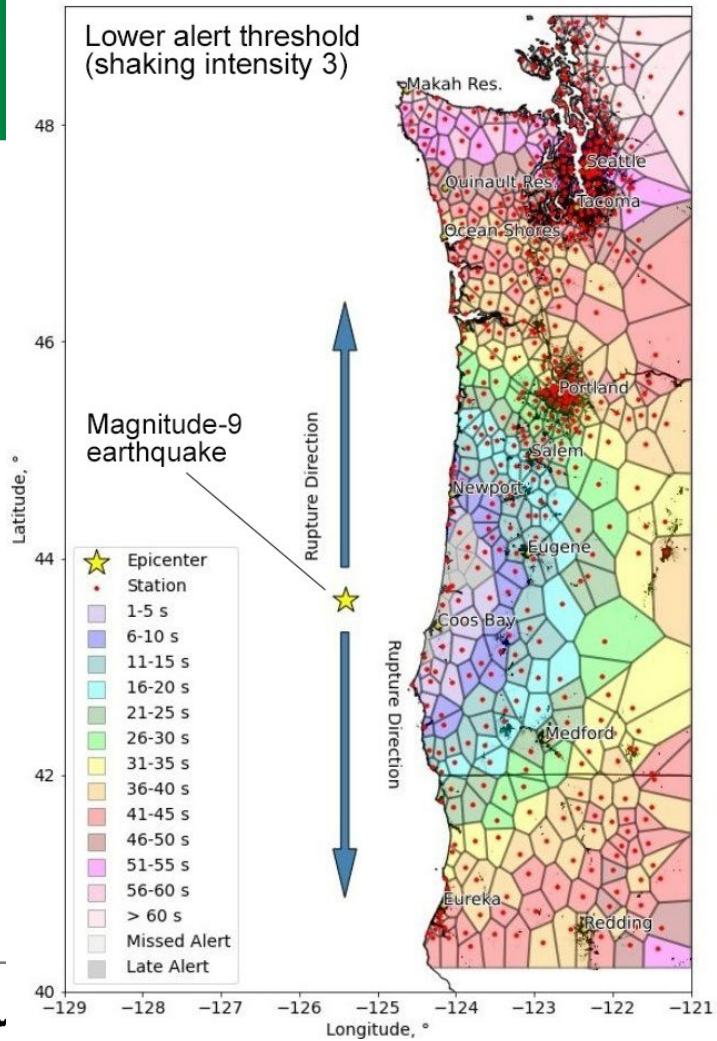
Using higher MMI level contours leads to more late and missed alerts

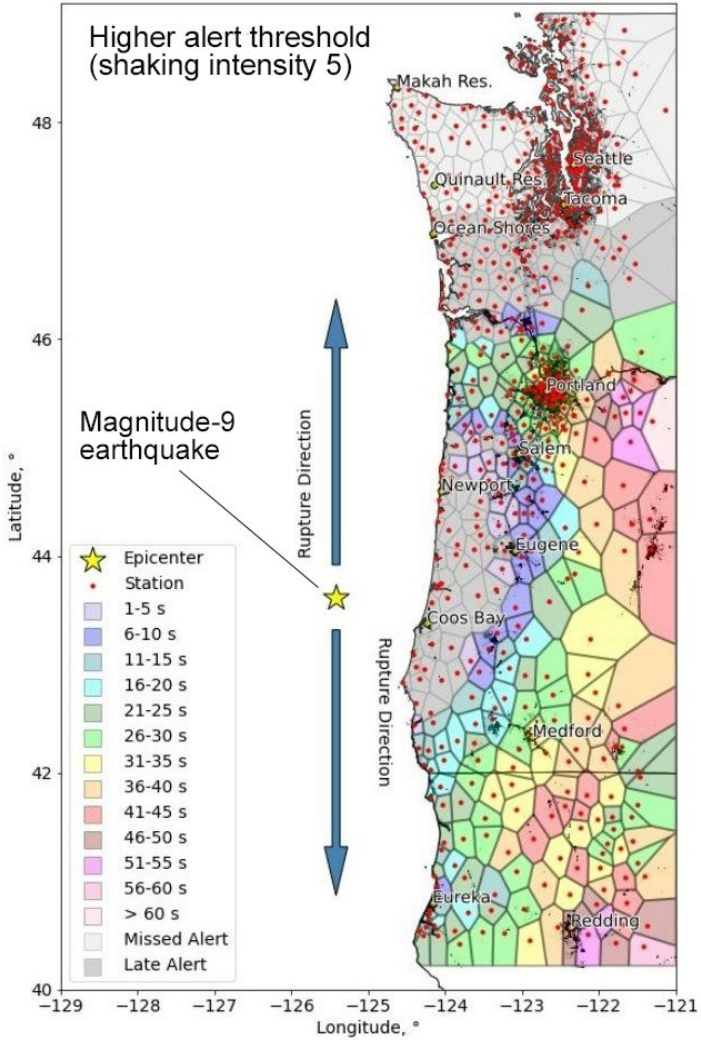


PNSN
Pacific Northwest Seismic Network

ShakeAlert™

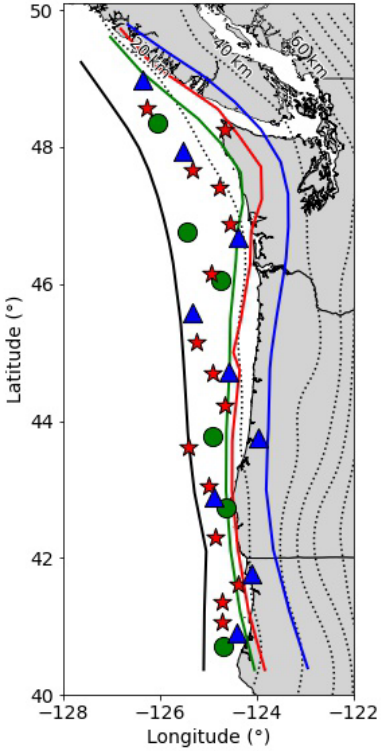
Population based assessment

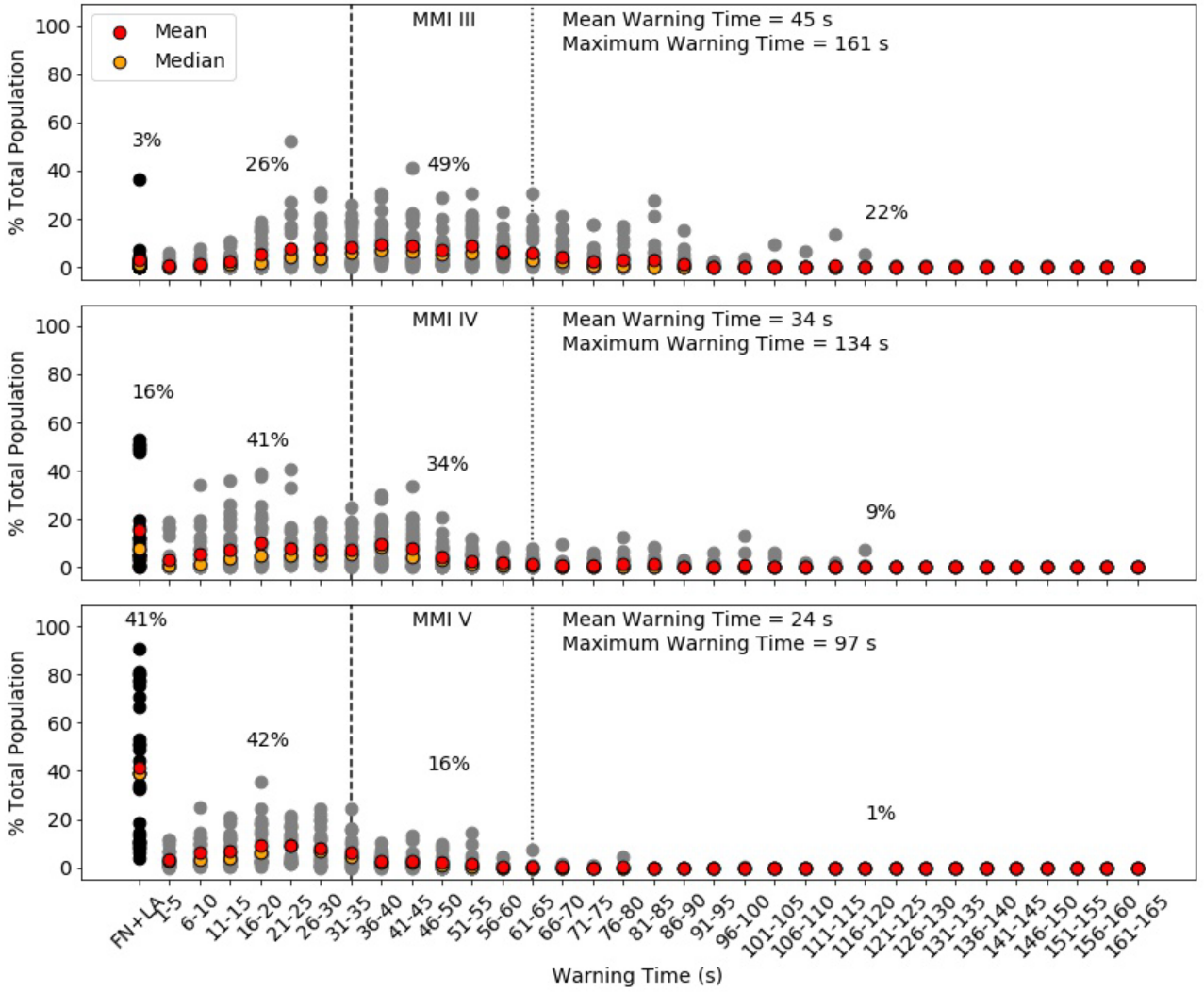




PNSN
Pacific Northwest Seismic Network

ShakeAlert™

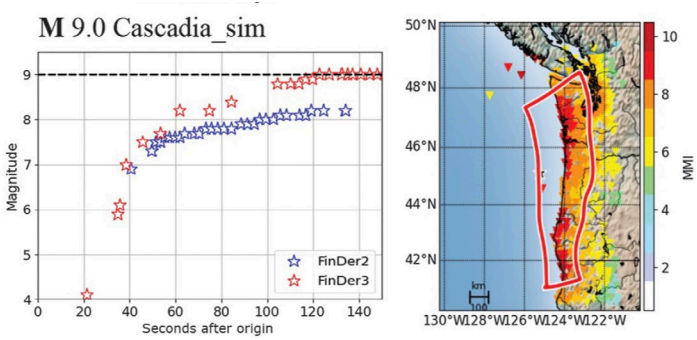




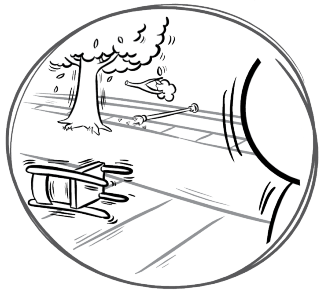
PNSN
Pacific Northwest Seismic Network

Coming soon to ShakeAlert?

- Megathrust fault-specific templates for FinDer (in testing)
- Crowell, B. W., Schmidt, D. A., Bodin, P., Vidale, J. E., Gomberg, J., Renate Hartog, J., ... & Jamison, D. G. (2016). Demonstration of the Cascadia G-FAST geodetic earthquake early warning system for the Nisqually, Washington, earthquake. *Seismological Research Letters*, *87*(4), 930-943.
- Murray, J. R., Crowell, B. W., Grapenthin, R., Hodgkinson, K., Langbein, J. O., Melbourne, T., ... & Schmidt, D. A. (2018). Development of a geodetic component for the US West Coast earthquake early warning system. *Seismological Research Letters*, *89*(6), 2322-2336.
- Saunders, J. K., Minson, S. E., Baltay, A. S., Bunn, J. J., Cochran, E. S., Kilb, D. L., ... & Kodera, Y. (2022). Real-time earthquake detection and alerting behavior of PLUM ground-motion-based early warning in the United States. *Bulletin of the Seismological Society of America*, *112*(5), 2668-2688.
- Ghahari, S. F., Baltay, A., Çelebi, M., Parker, G. A., McGuire, J. J., & Taciroglu, E. (2022). Earthquake Early Warning for Estimating Floor Shaking Levels of Tall Buildings. *Bulletin of the Seismological Society of America*, *112*(2), 820-849.



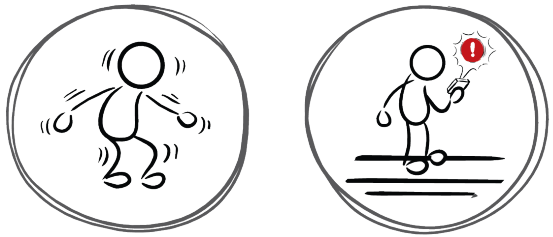
Things to know about ShakeAlert®



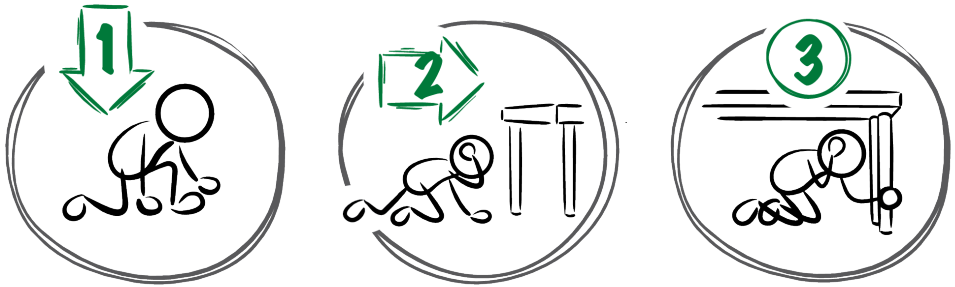
You may feel shaking and not get an alert.

You may get an alert after you feel shaking.

You may get an alert and not feel strong shaking or any shaking at all.



If you FEEL SHAKING or GET AN ALERT...



DROP! **COVER!** **HOLD ON!**

ShakeAlert™

Contact Information

Dr. Renate Hartog
jrhartog@uw.edu

@PNSN1

www.pnsn.org