PASSIVE-AGGRESSIVE SEISMIC HAZARD ANALYSIS

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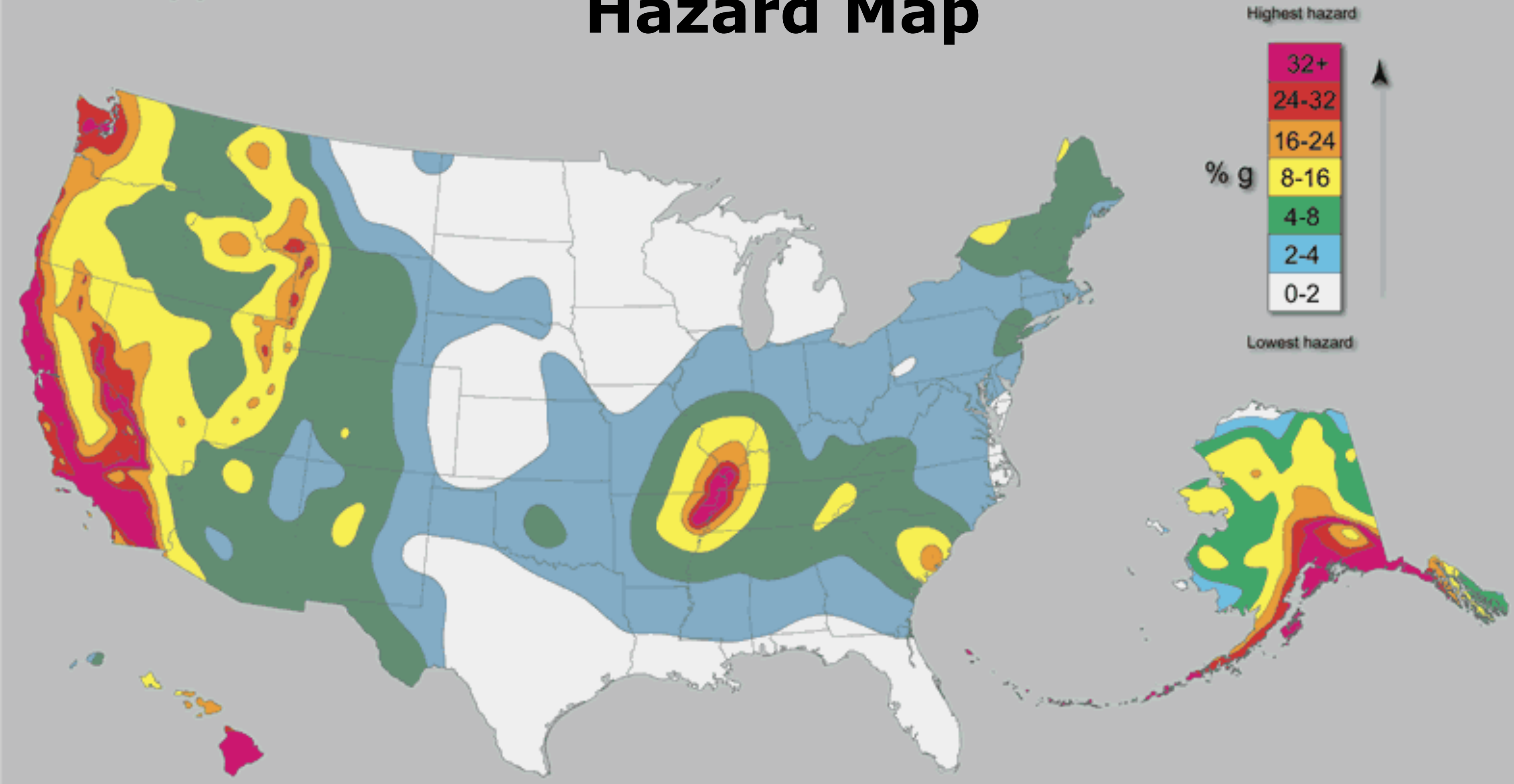
Stanford University

Active Uses of Passive Seismic Data Meeting
June 3, Houston, TX

USGS
science for a changing world

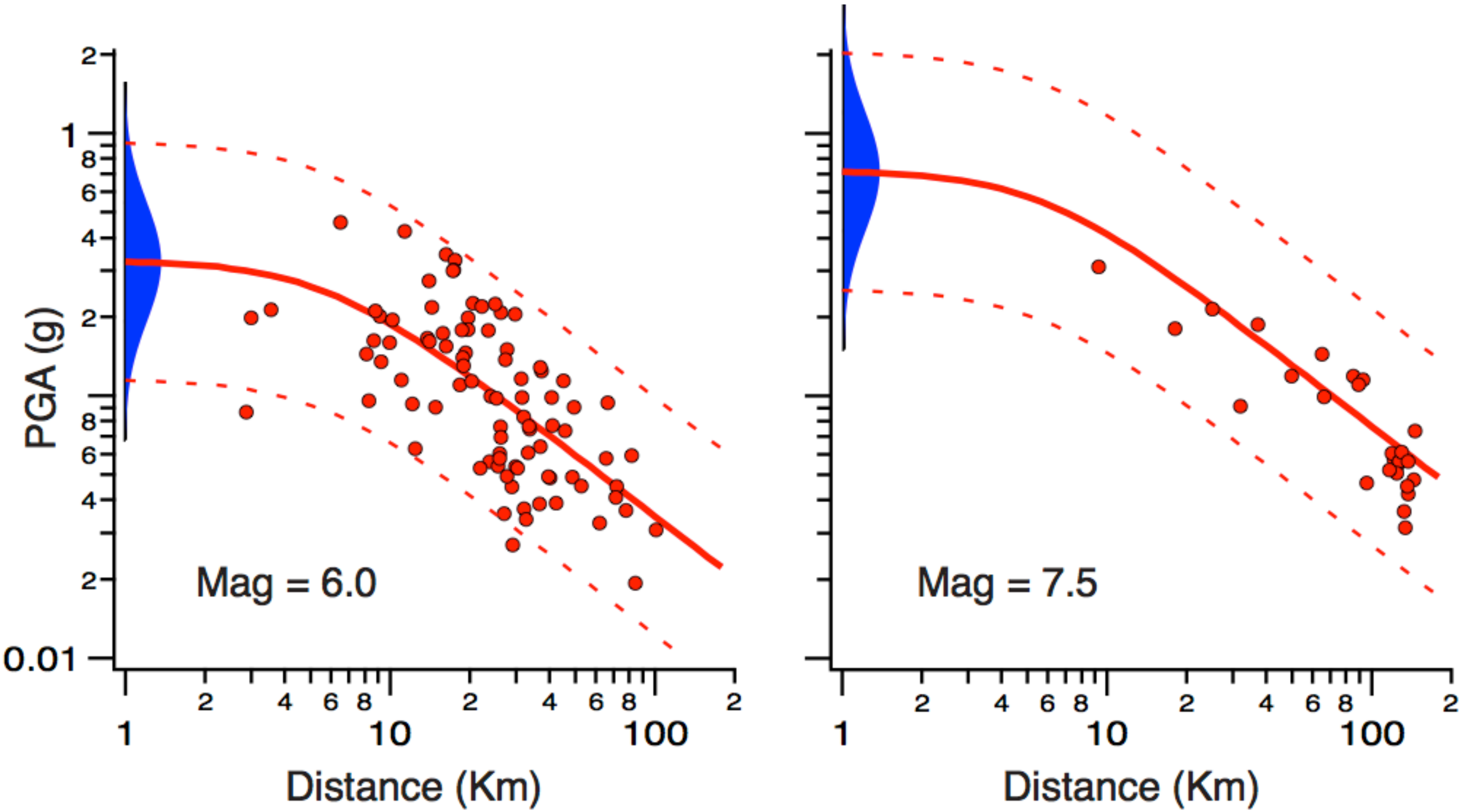
National Seismic Hazard Map



Influences over $1 trillion in construction.

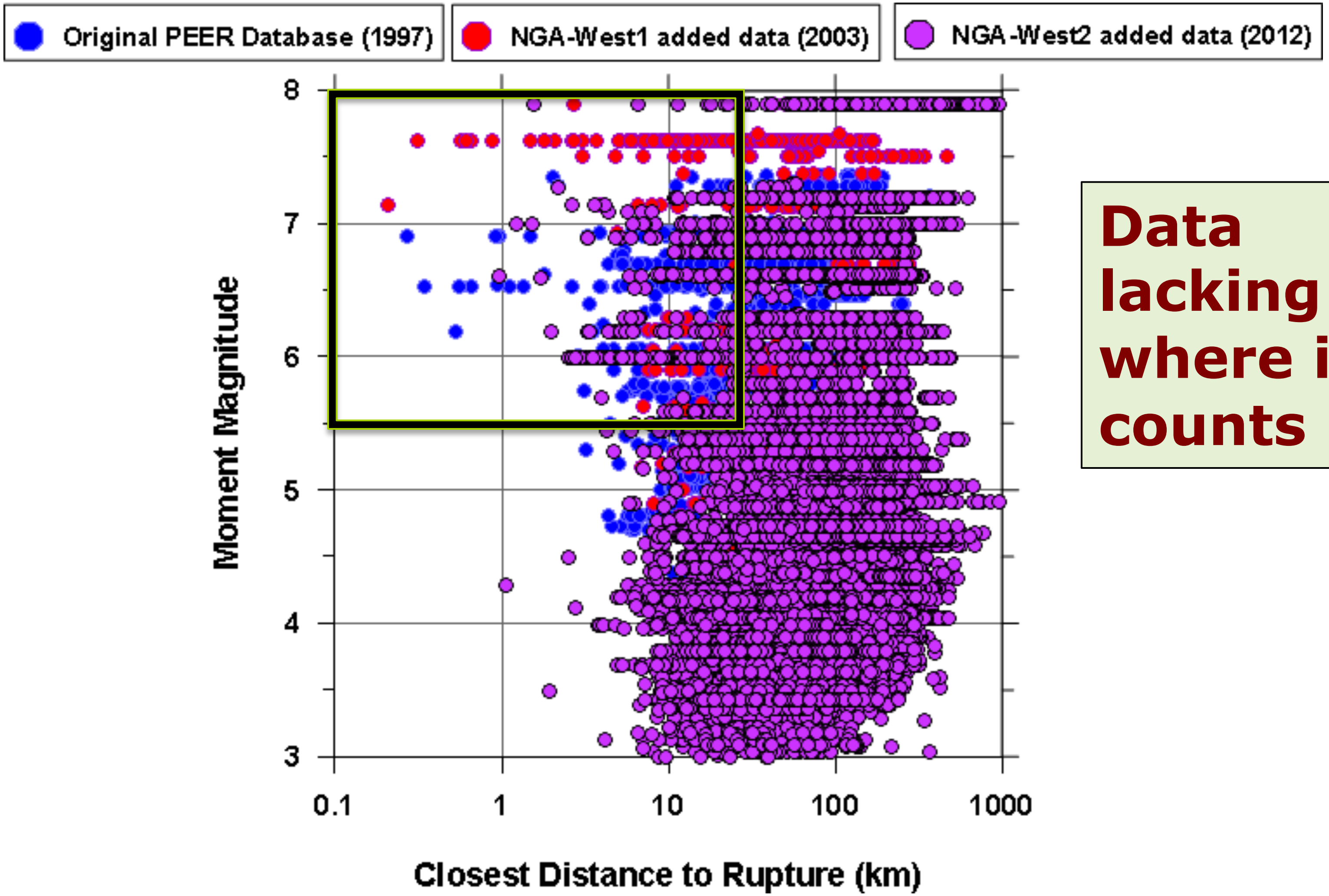
It’s a ground motion map, so accuracy depends on our ability to predict strong ground motion.

Ground Motion Prediction for California Earthquakes



From “PSHA: A Primer” [*Field*]

NGA-West2 Database

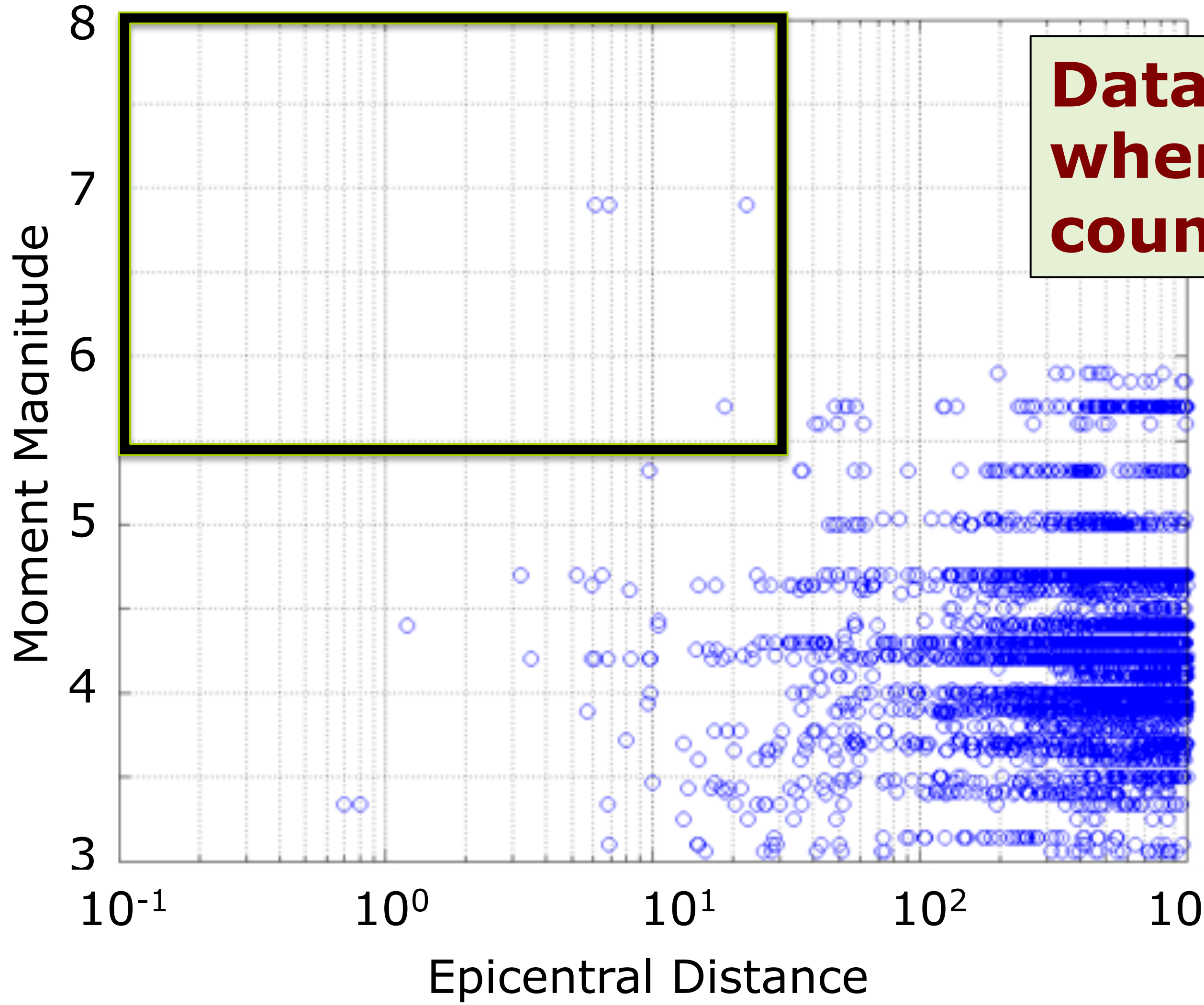


Data lacking where it counts

[*Courtesy of Yousef Bozorgnia*]

Stable Continental Regions

(CEUS, Eastern Canada, Gazli)



Data absent where it counts

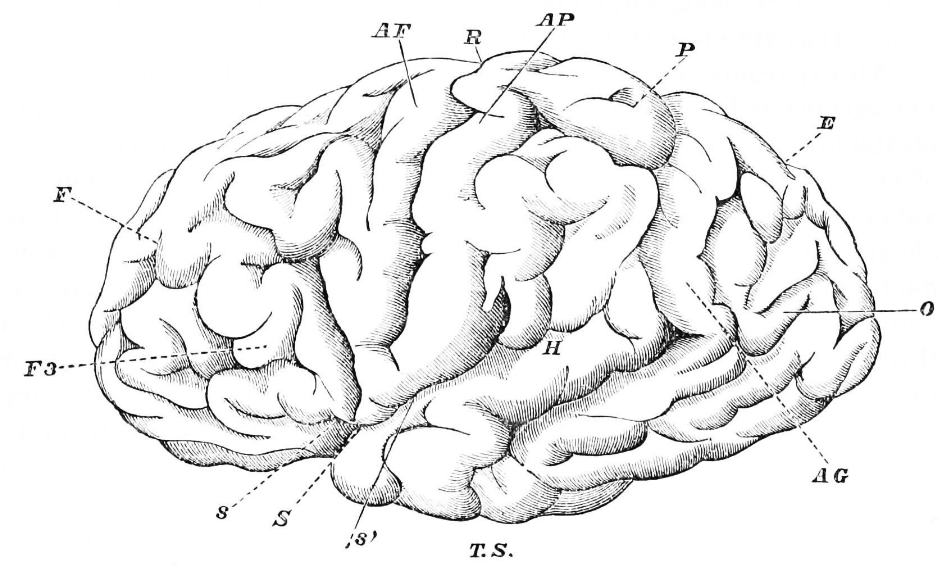
[*Courtesy of Christine Goulet*]

In addition to the national maps, critical facilities depend on data that we don’t have.

This is untenable.

We need to collect orders of magnitude more strong ground motion data.

Epistemic Uncertainty

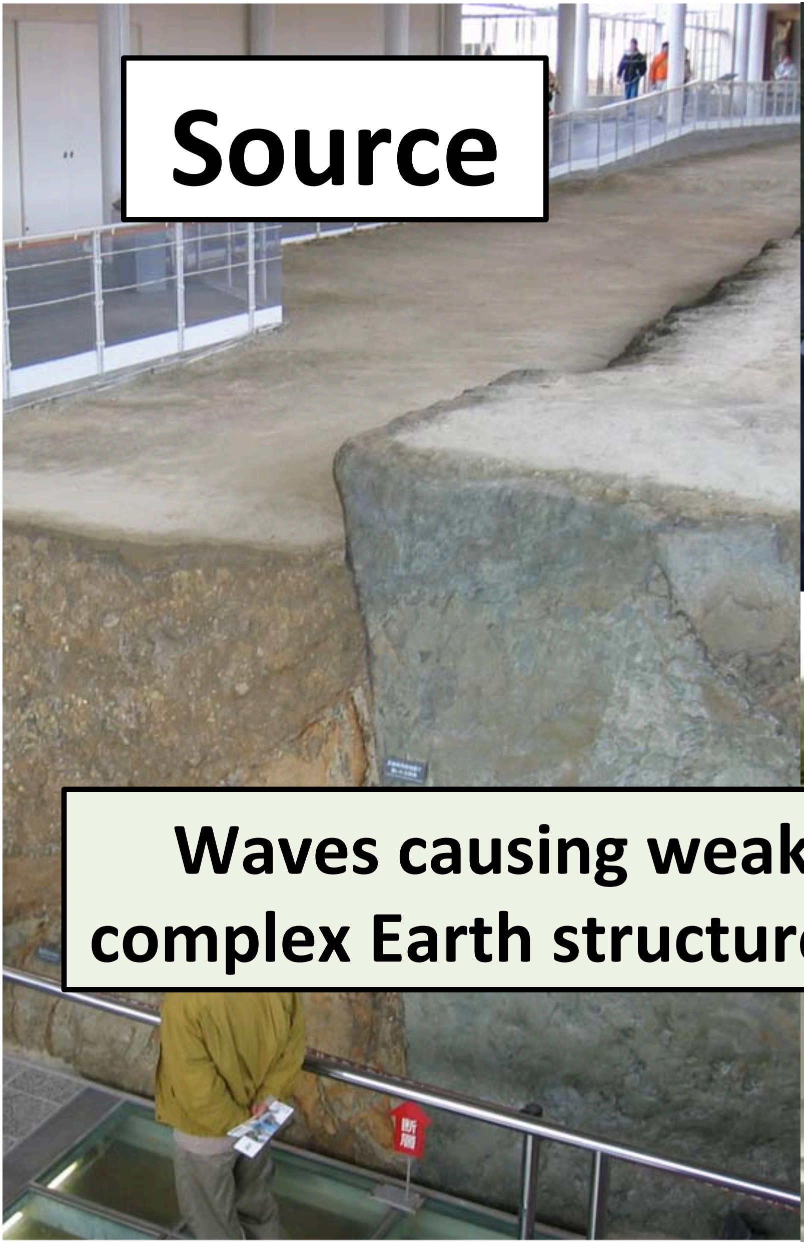


Can be reduced through improved knowledge and understanding (e.g. better crustal models).

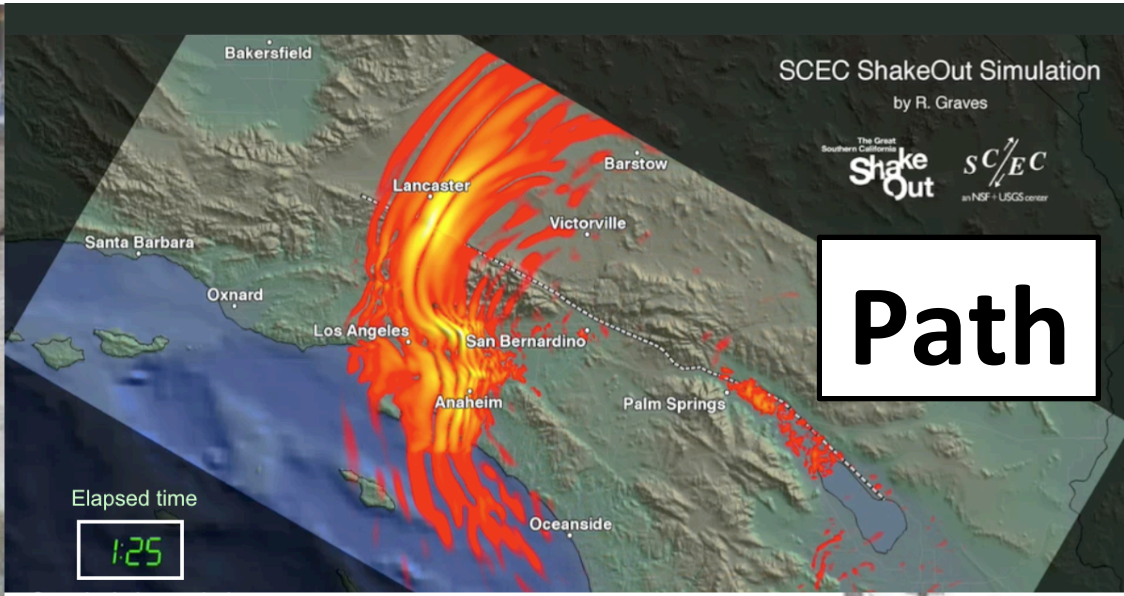
Alleatory Variability

Inherent randomness – irreducible, but can be characterized.
(e.g., variability of earthquake stress drop)

Predicting Strong Ground Motion



Source

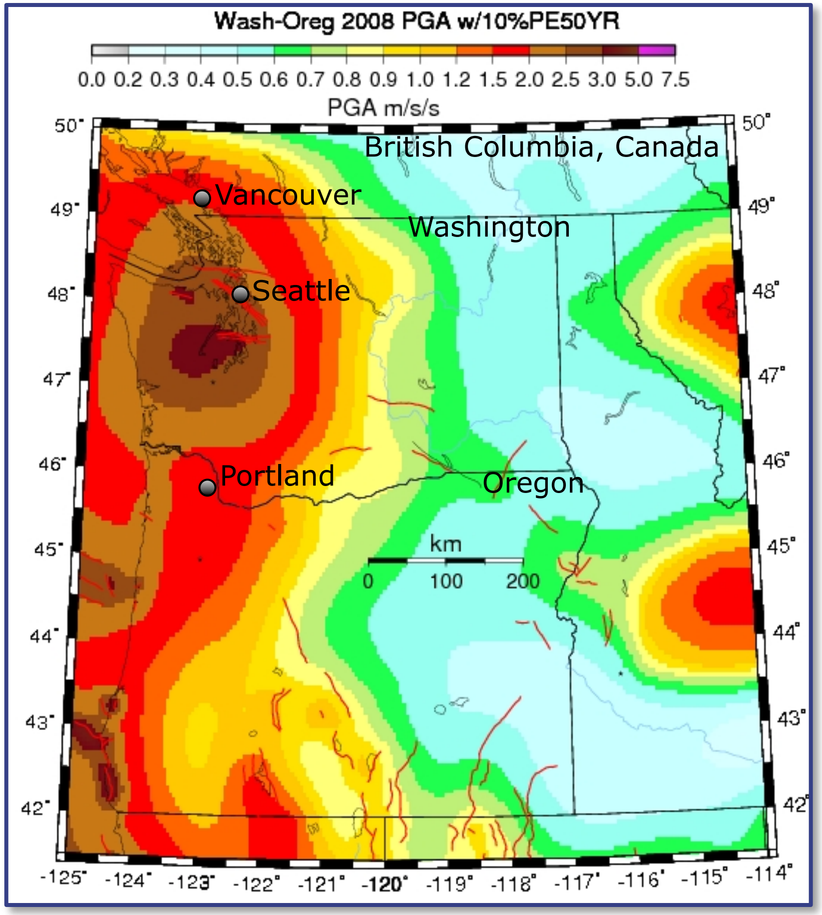


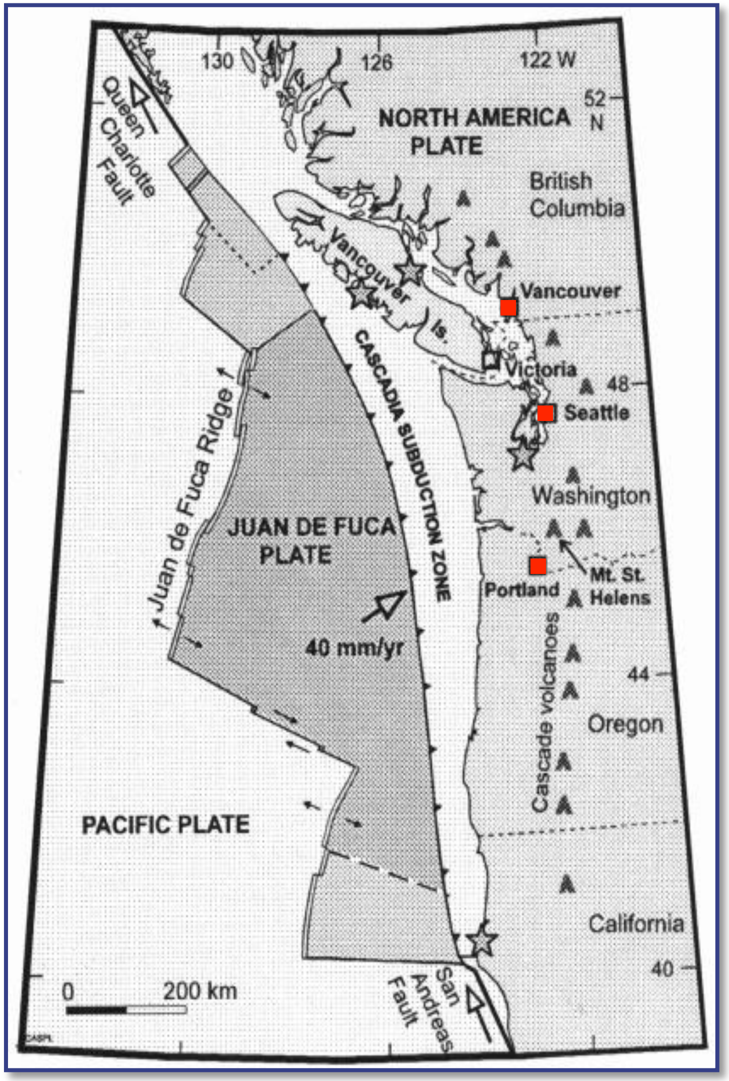
Path

Site

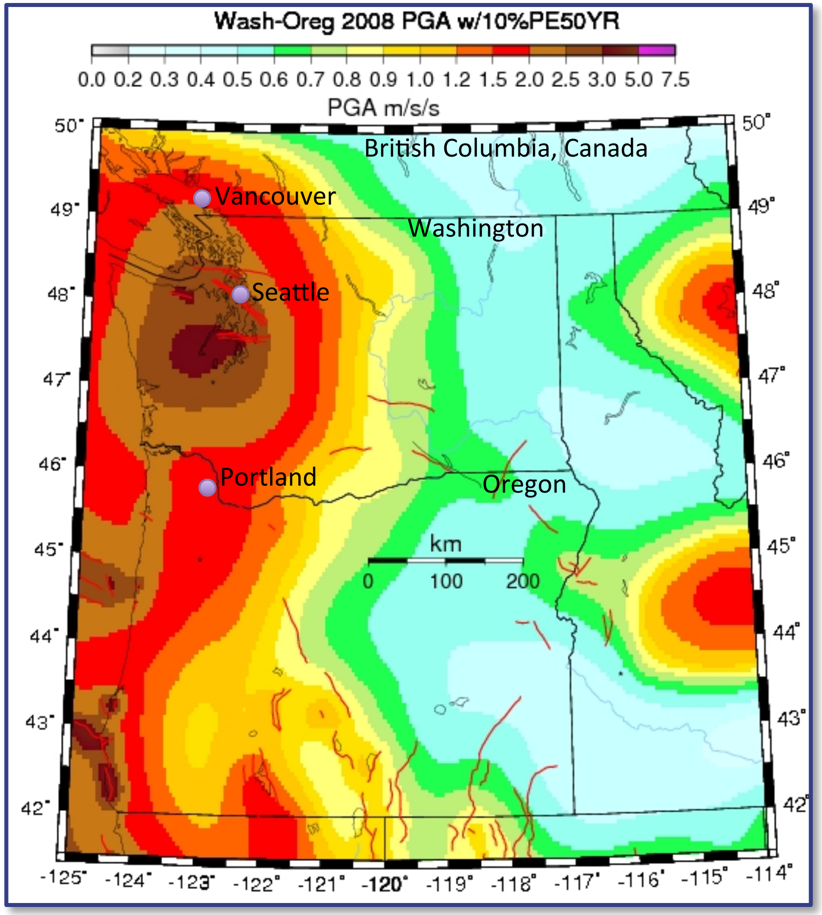
Waves causing weak motion interact with the same complex Earth structure as waves causing strong motion.

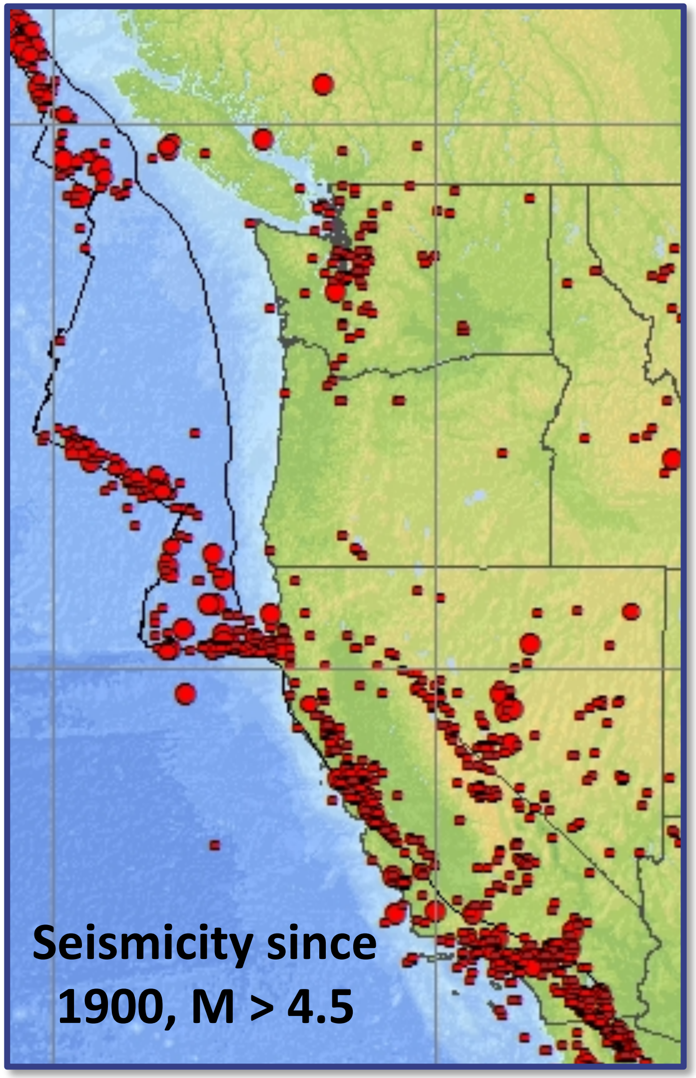
Hazard in Cascadia





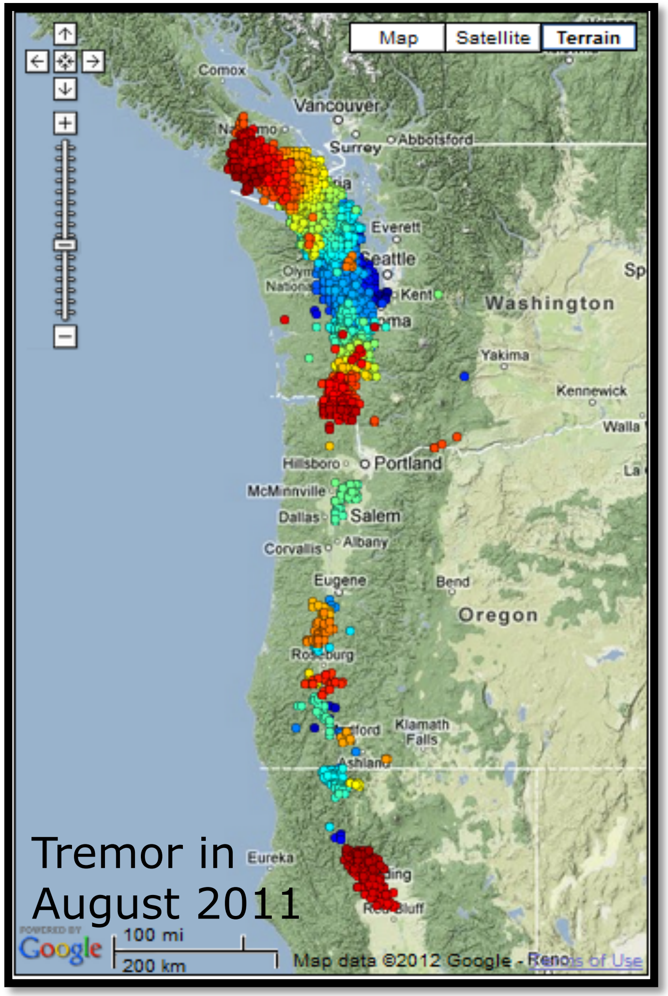
Little earthquake data, …



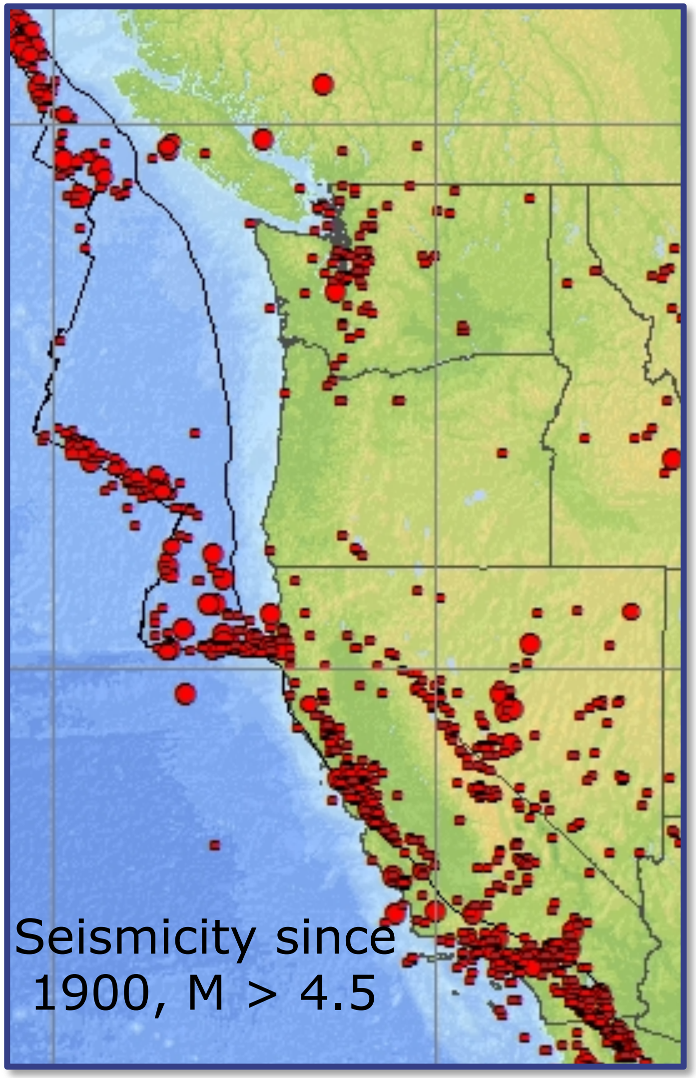


Seismicity since 1900, M > 4.5

but lots of tremor

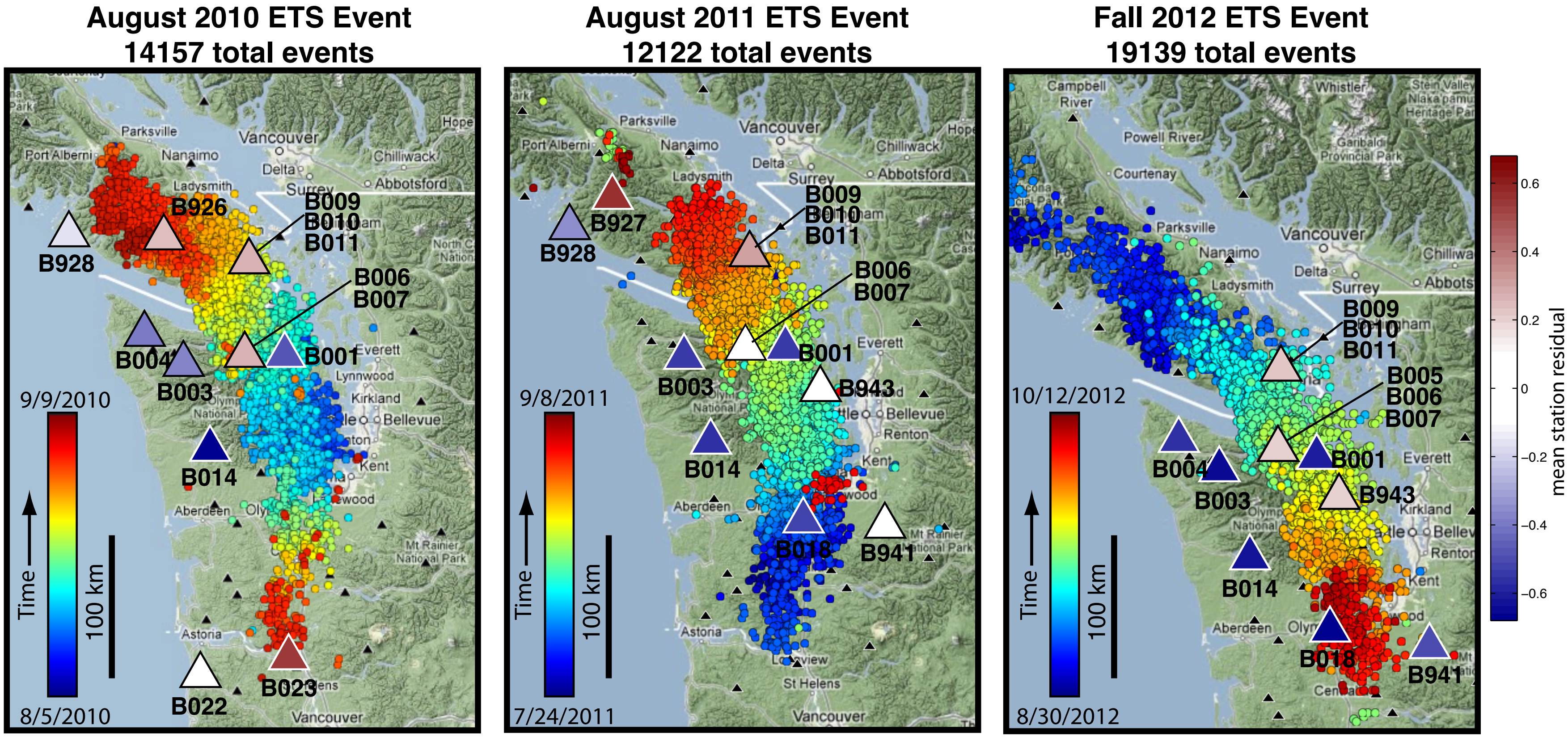


Tremor in August 2011



Seismicity since 1900, M > 4.5

Tremor in Cascadia



August 2010 ETS Event
14157 total events

August 2011 ETS Event
12122 total events

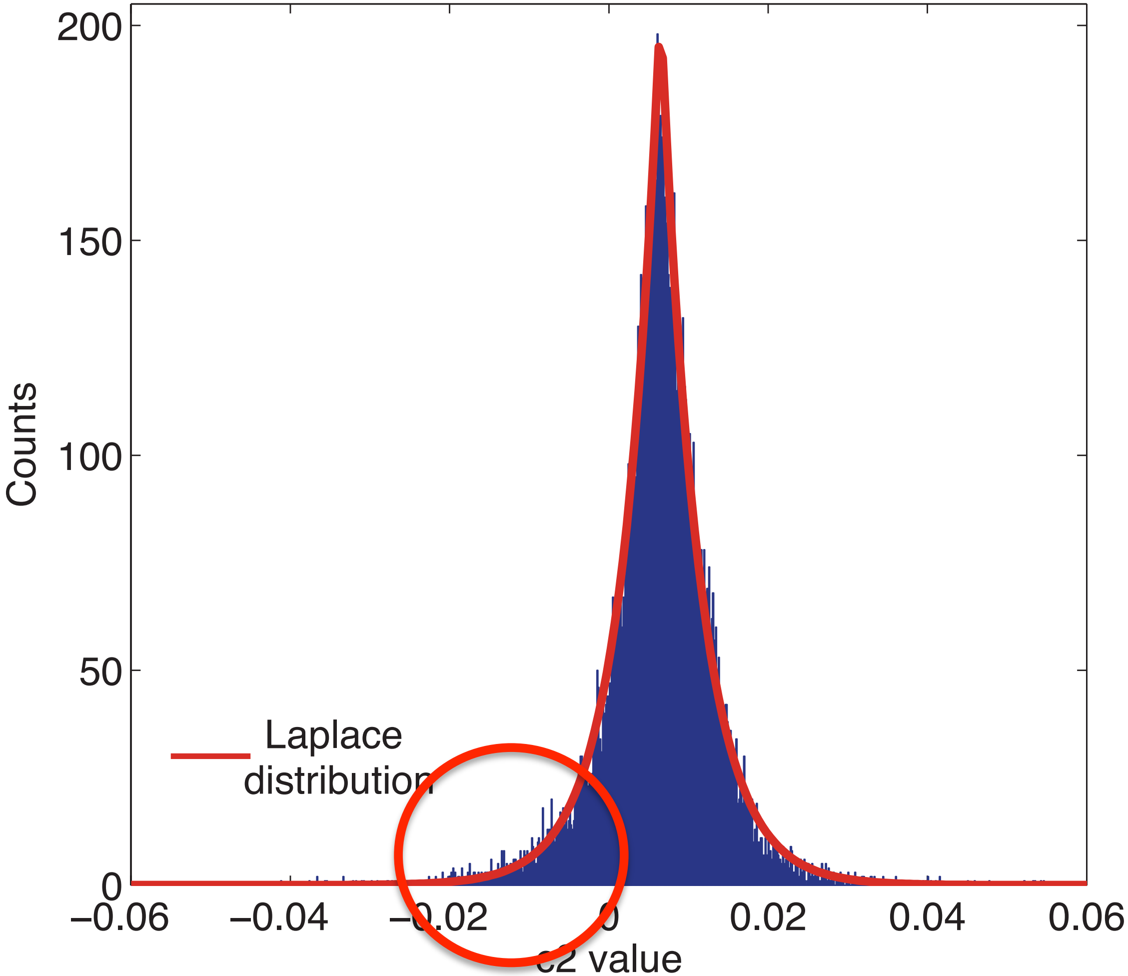
Fall 2012 ETS Event
19139 total events

Lots of data where we want it – dense sources

- 1-10 Hz *S* Waves – ideal for earthquake engineering
- Entire subduction zone
- Predictable in time

Wech and Creager

Distribution of Decay Parameter for PGA



Laplace Distribution

15,113 measurements

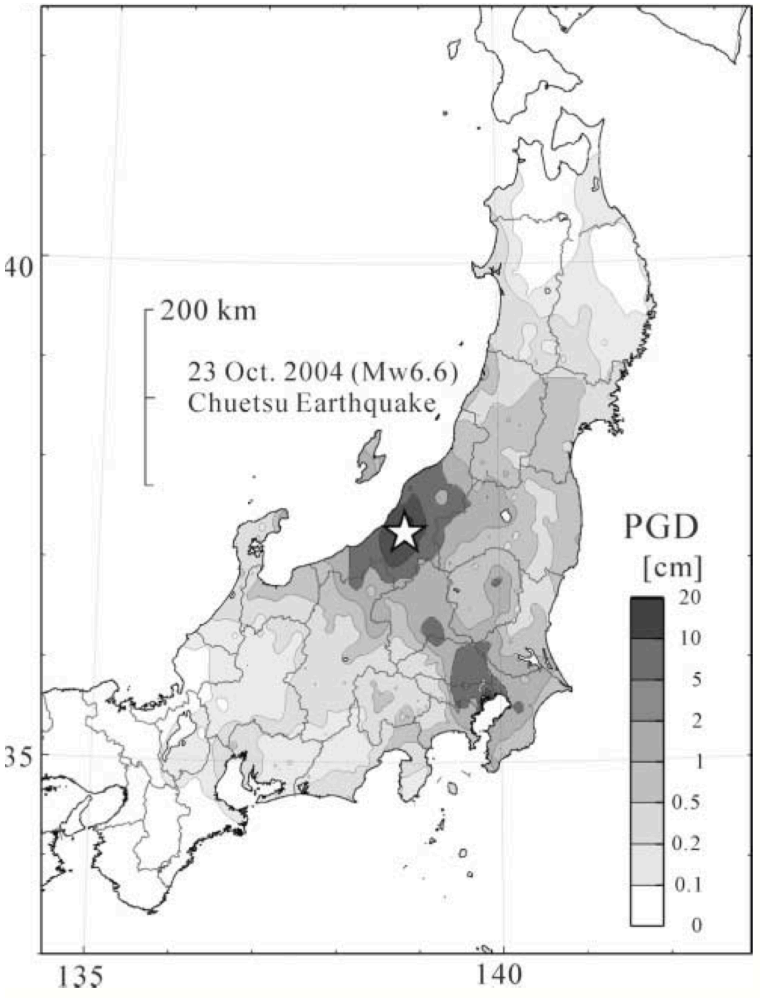
We find: C2 = 0.00647

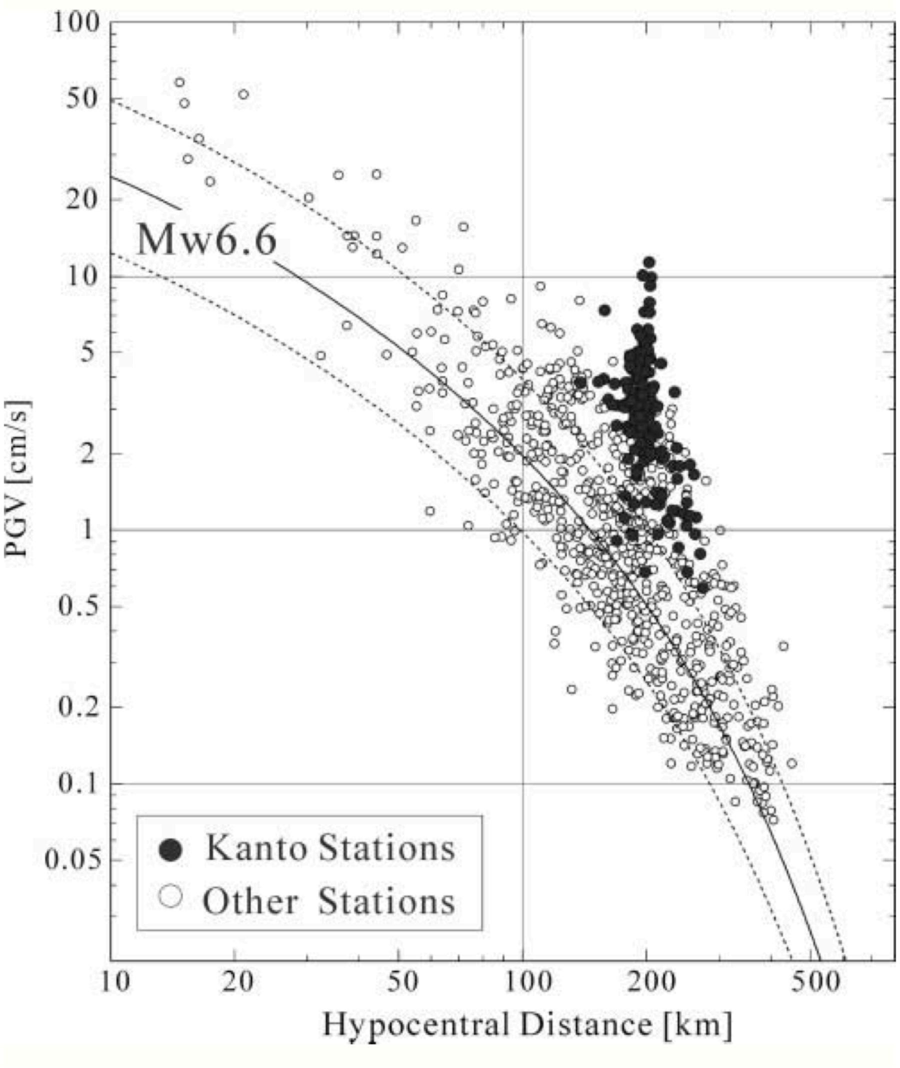
AB1997: C2 = 0.00645

Negative values indicate *increase* of amplitude with distance!

***Baltay and Beroza* (2013)**

2004 Chuetsu Earthquake: Stronger Shaking than Expected in Tokyo

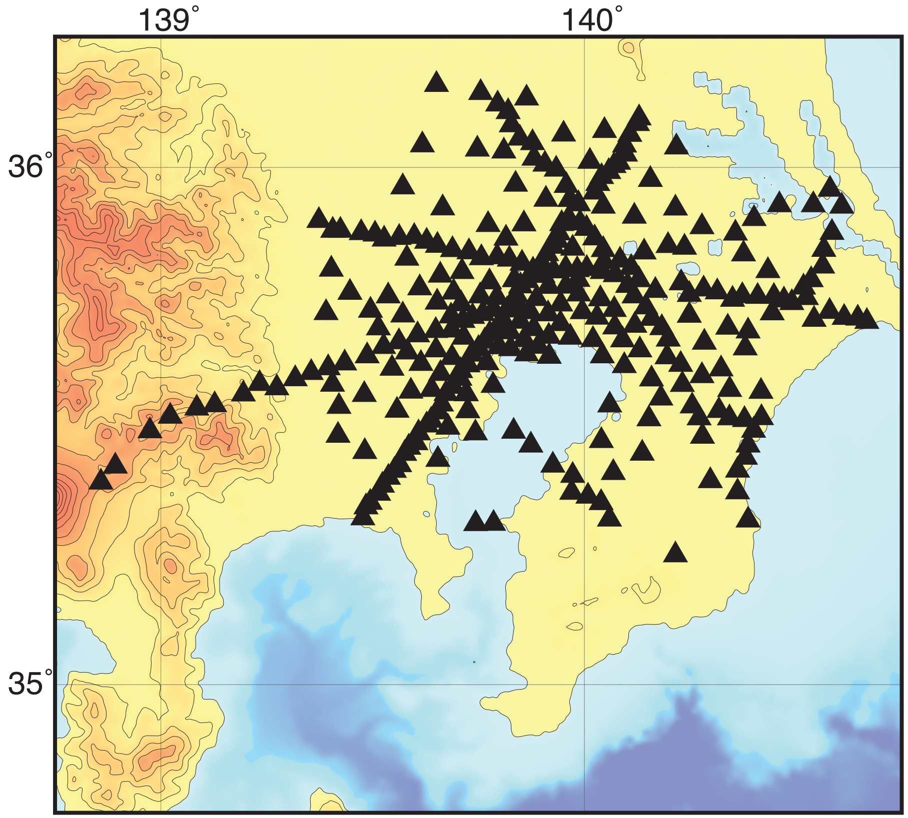




***Furumura and Hayakawa* (2007)**

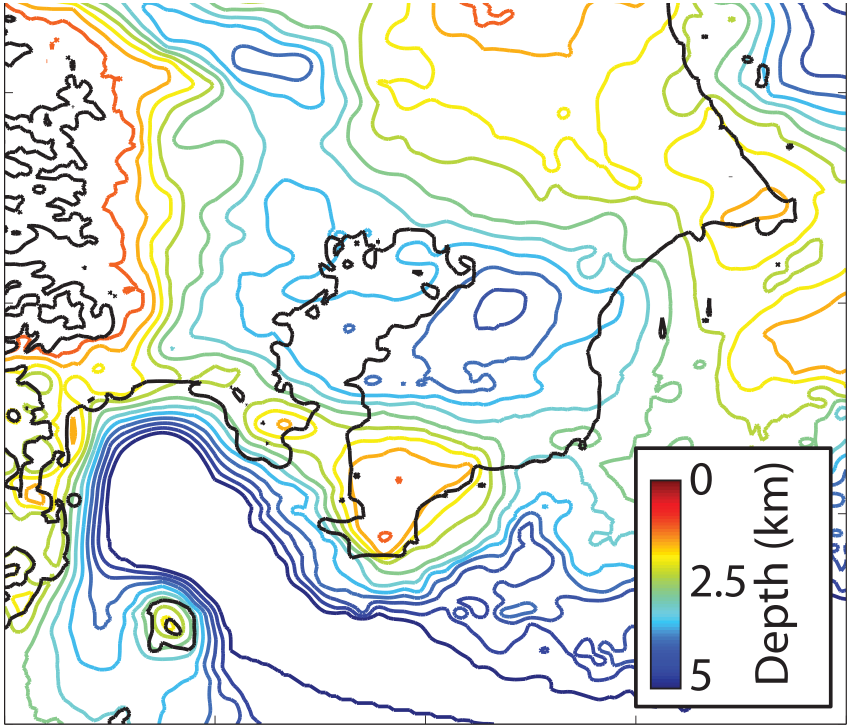
Kanto Basin, Japan: Tokyo

Metropolitan Seismic Observatory Network (MeSO-net)



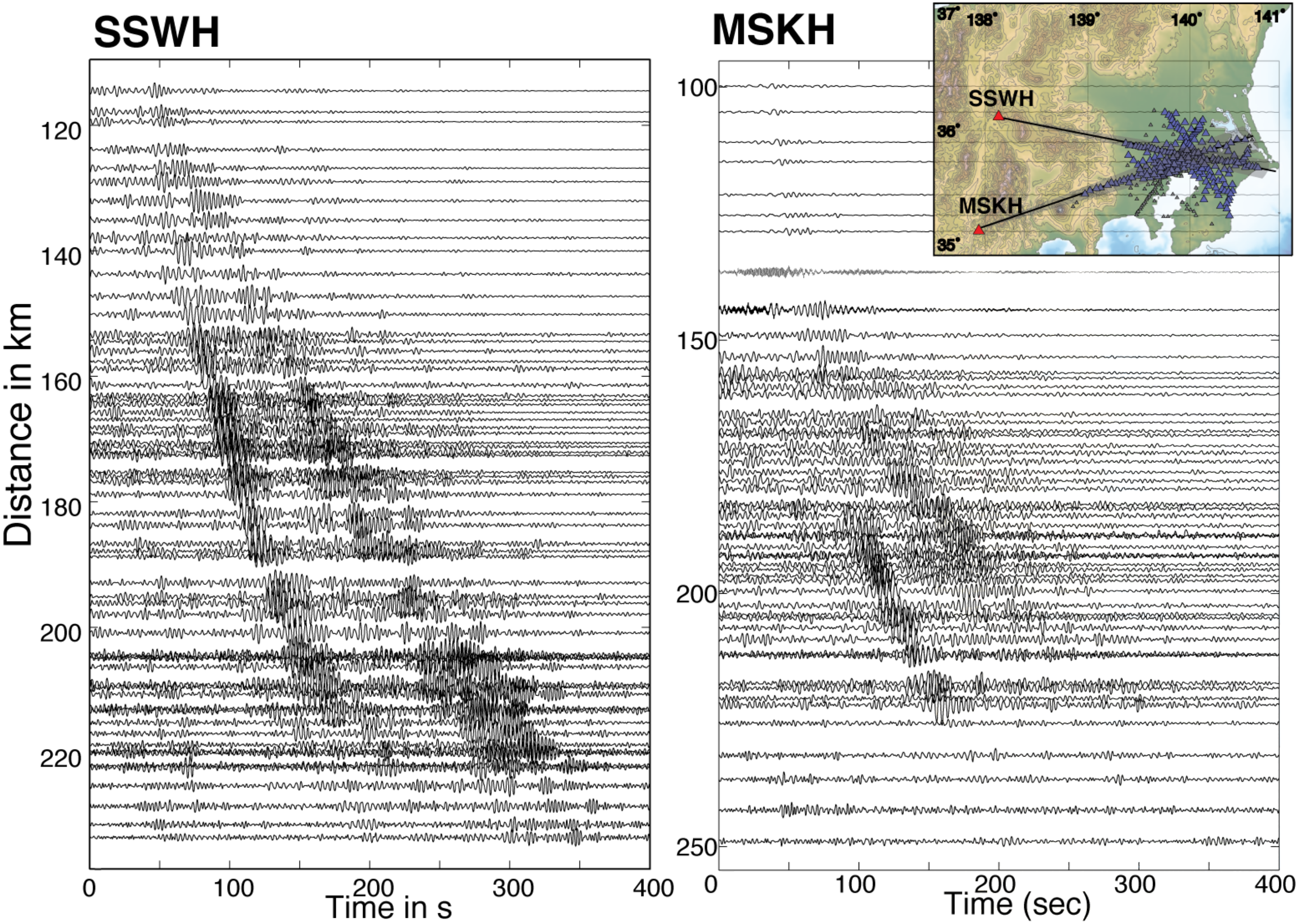
<u>~290</u> shallow-boreholes 3-channel accelerometers *in the basin*

Kanto Basin basement

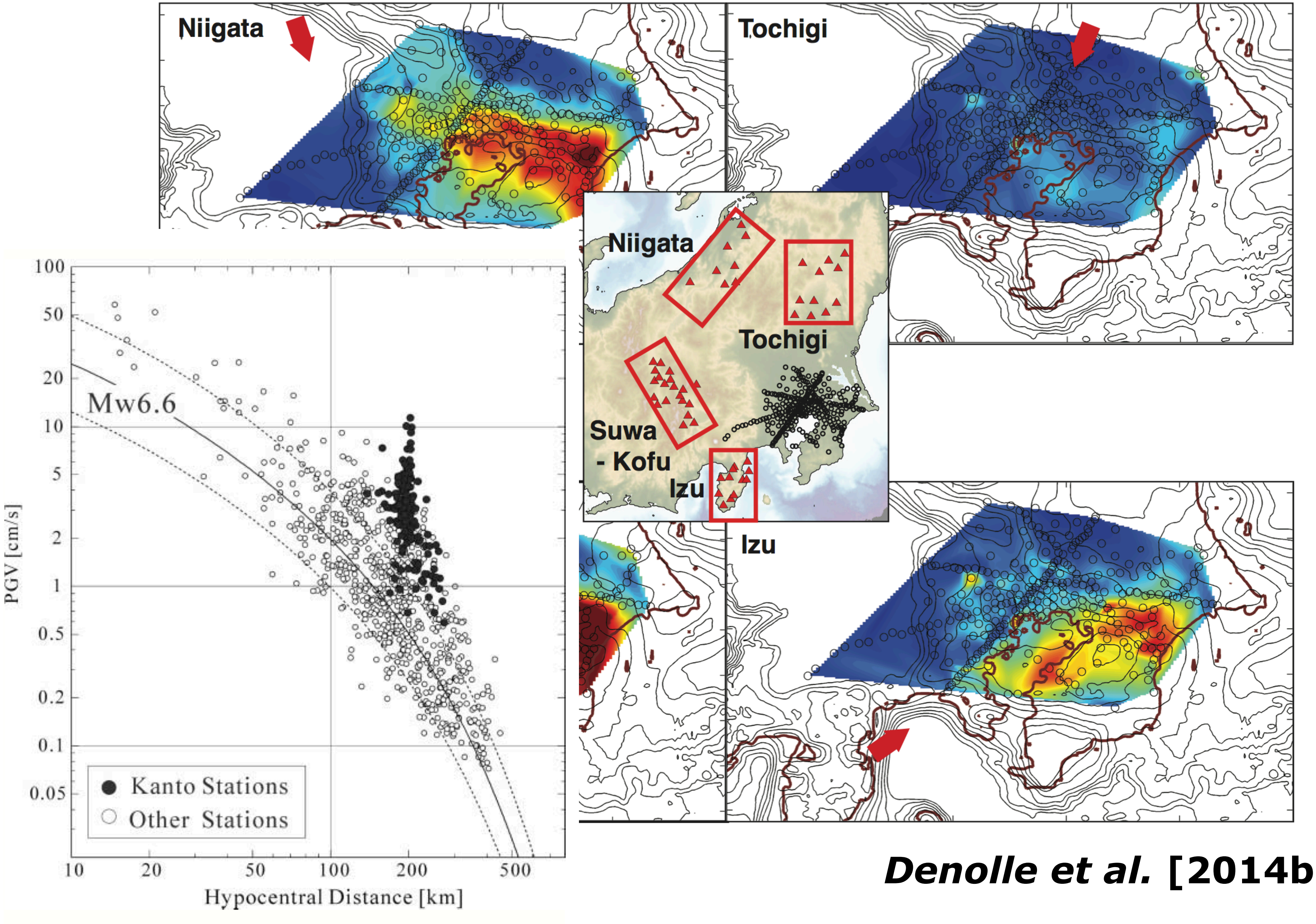


Adapted from Tanaka *et al.* (2006)

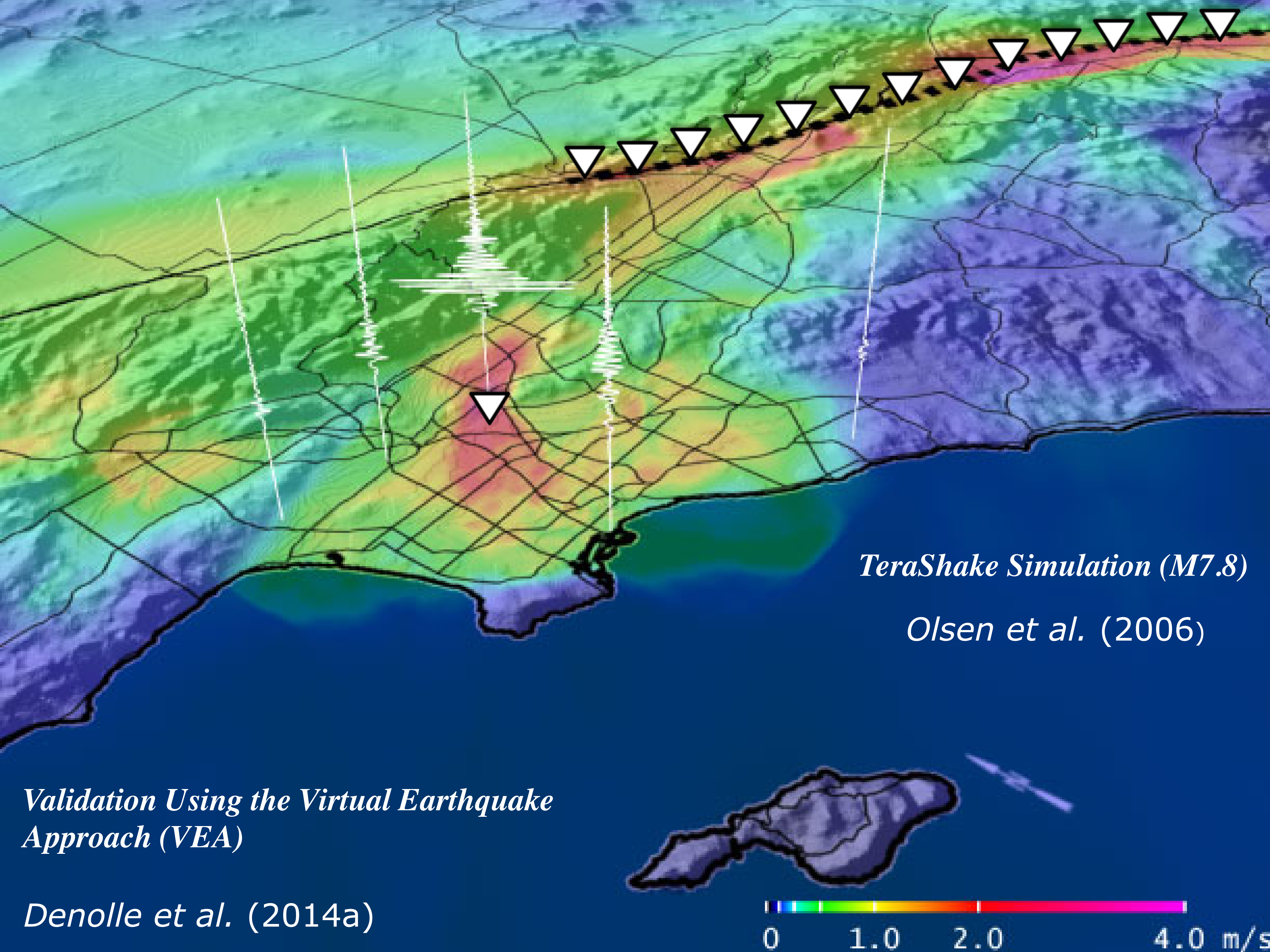
Ambient-Field Green's Functions



Strongly Directional Basin Excitation



Denolle et al. [2014b]



TeraShake Simulation (M7.8)

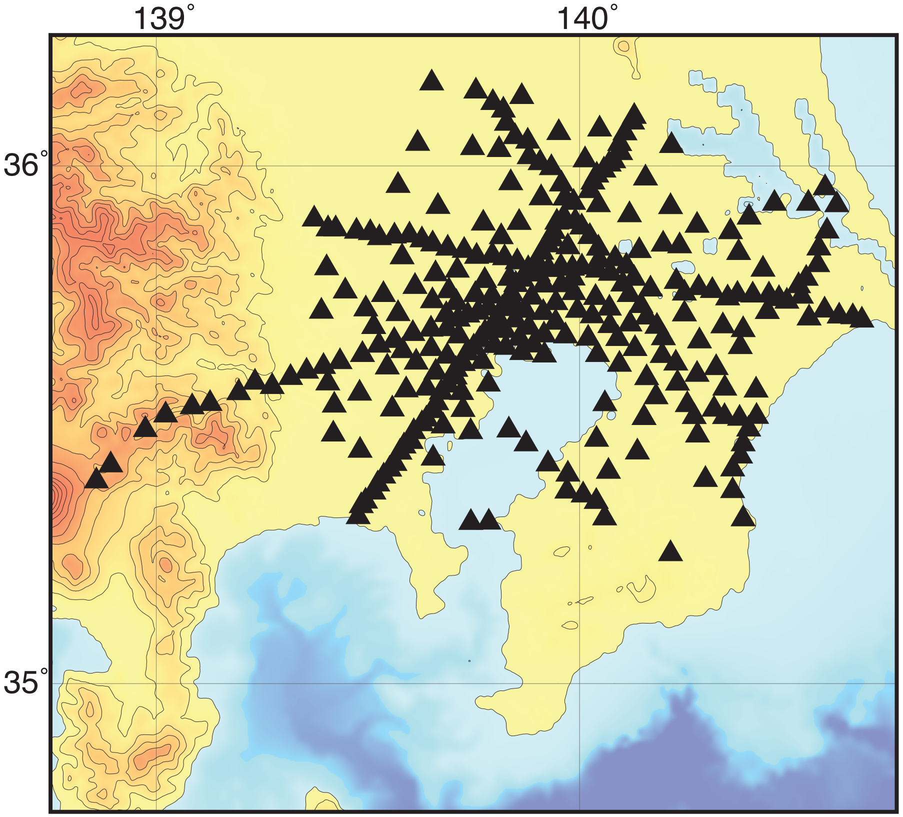
Olsen et al. (2006)

Validation Using the Virtual Earthquake Approach (VEA)

Denolle et al. (2014a)

Tokyo

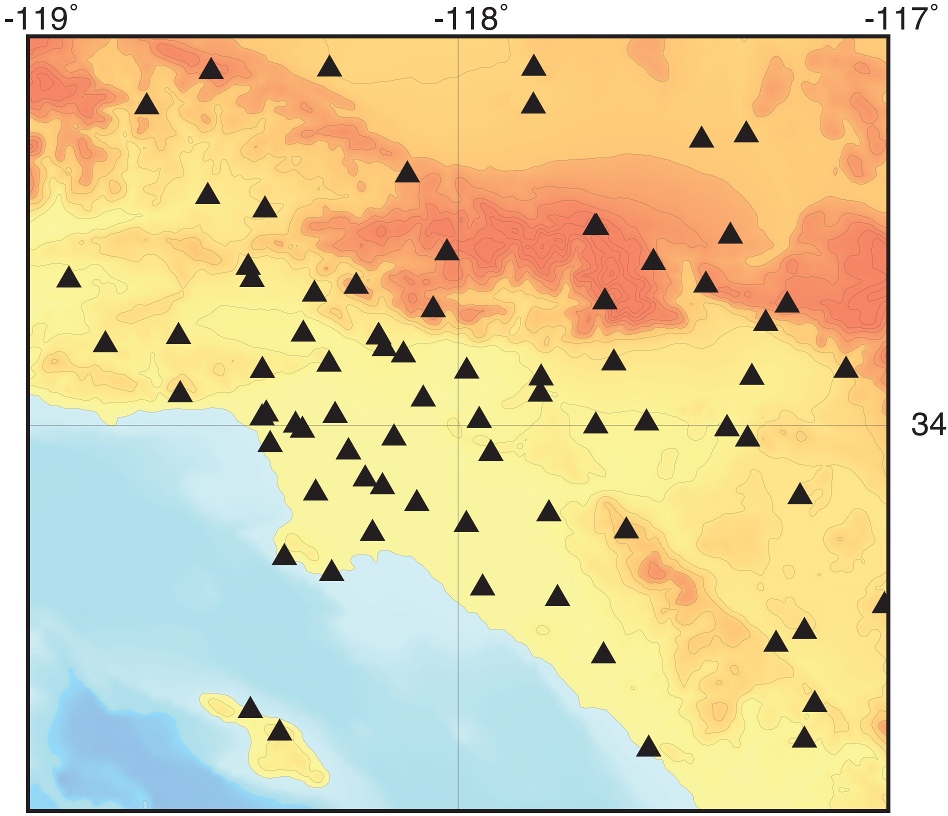
Metropolitan Seismic Observatory Network (MeSO-net)



~290 shallow-boreholes 3-channel accelerometers *in the basin*

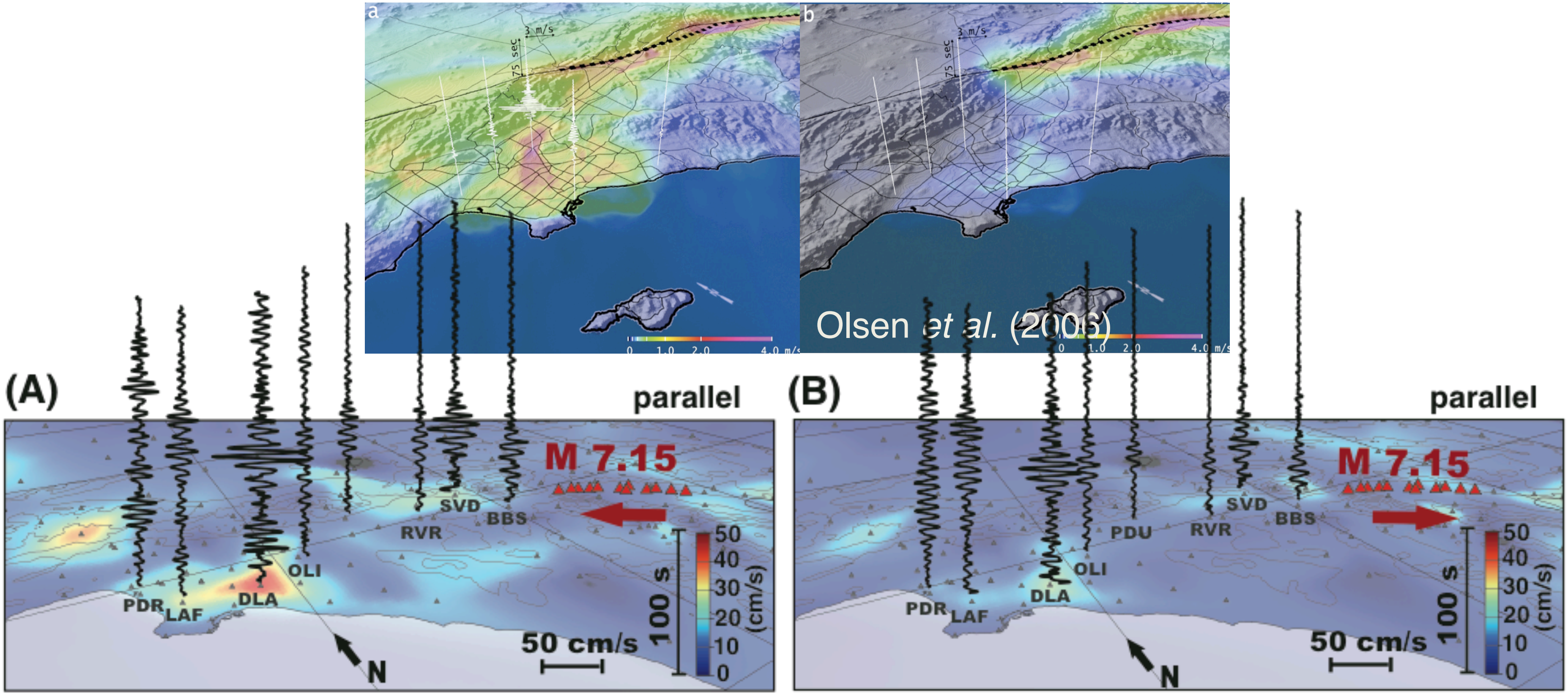
Los Angeles

Southern California Seismic Network (SCSN)



~40 3-channel broadband seismometers *in the basin*

Ambient-Field GFs Confirm Waveguide-to-Basin Effect


Olsen *et al.* (2006)

Details of Amplification are Different

Caveat: both methods assume linearity

Denolle *et al.* (2014a)

Expected seismic shaking in Los Angeles reduced by San Andreas fault zone plasticity

D. Roten[1], K.B. Olsen[2], S.M. Day[2], Y. Cui[3] and D. Fäh[1]

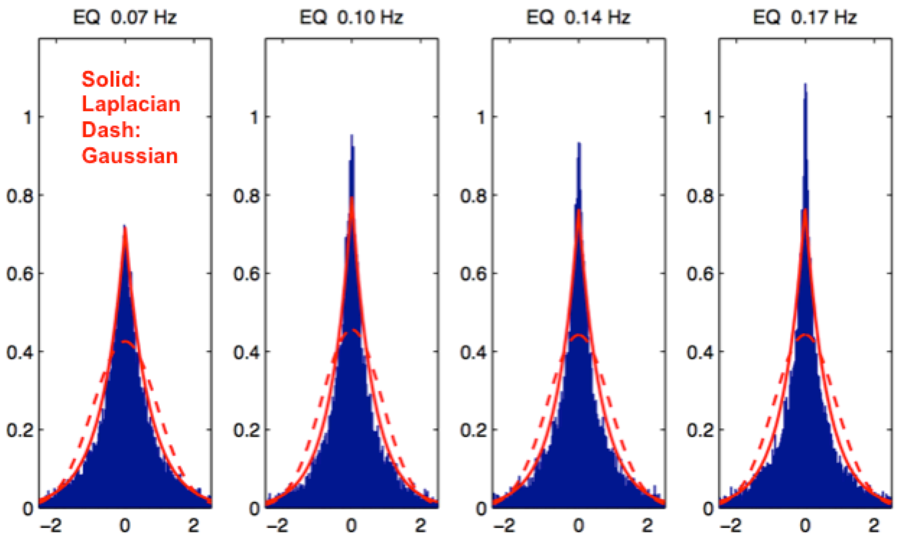
"By simulating the ShakeOut earthquake scenario (based on a kinematic source description) for a medium governed by Drucker-Prager plasticity, we show that nonlinear material behavior could reduce the earlier predictions of large long-period ground motions in the Los Angeles basin by up to 70% as compared to viscoelastic solutions."

(no substitute for real observations)

[*Roten et al.*, 2014]

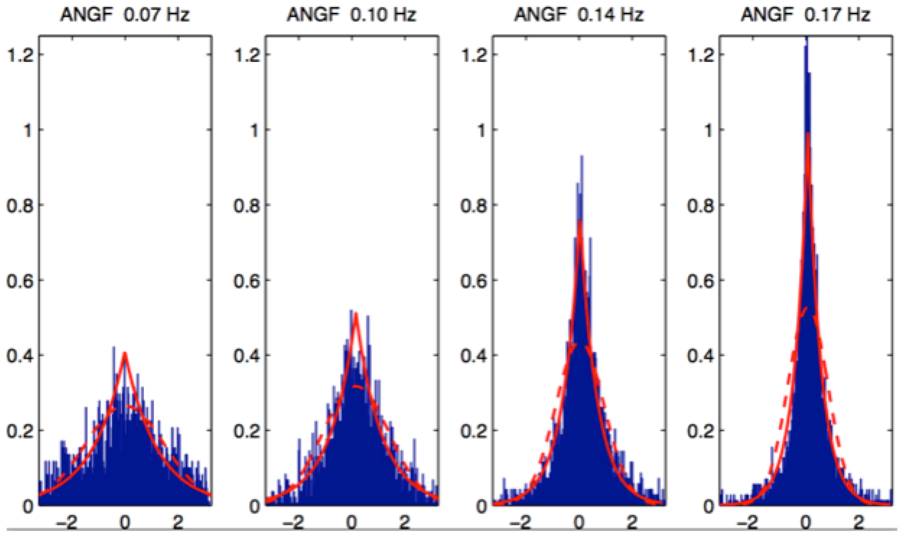
Full 3D Waveform Tomography

Earthquake Residuals



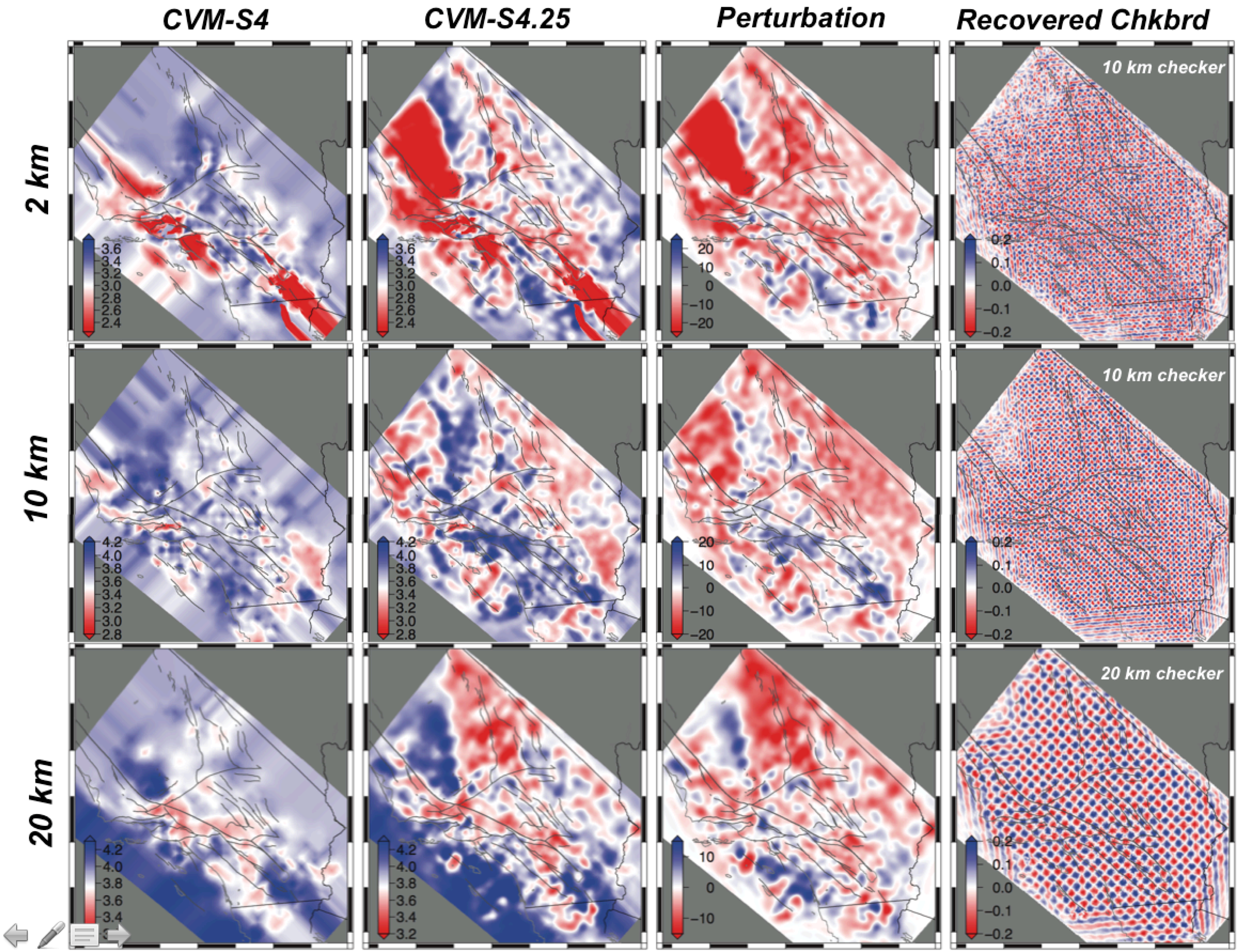
- Improved areal coverage
- Large differences at shallow depth
- >25% max differences

Ambient-Field Residuals



[*Lee et al*., 2014]

Full Waveform Inversion



[*Lee et al.*, 2014]

CONCLUSIONS

Predicting strong ground motion is important.

We can do useful things with weak motion data, but important effects (nonlinearity) are not represented.

We need to be aggressive about collecting ***much*** more strong motion data.