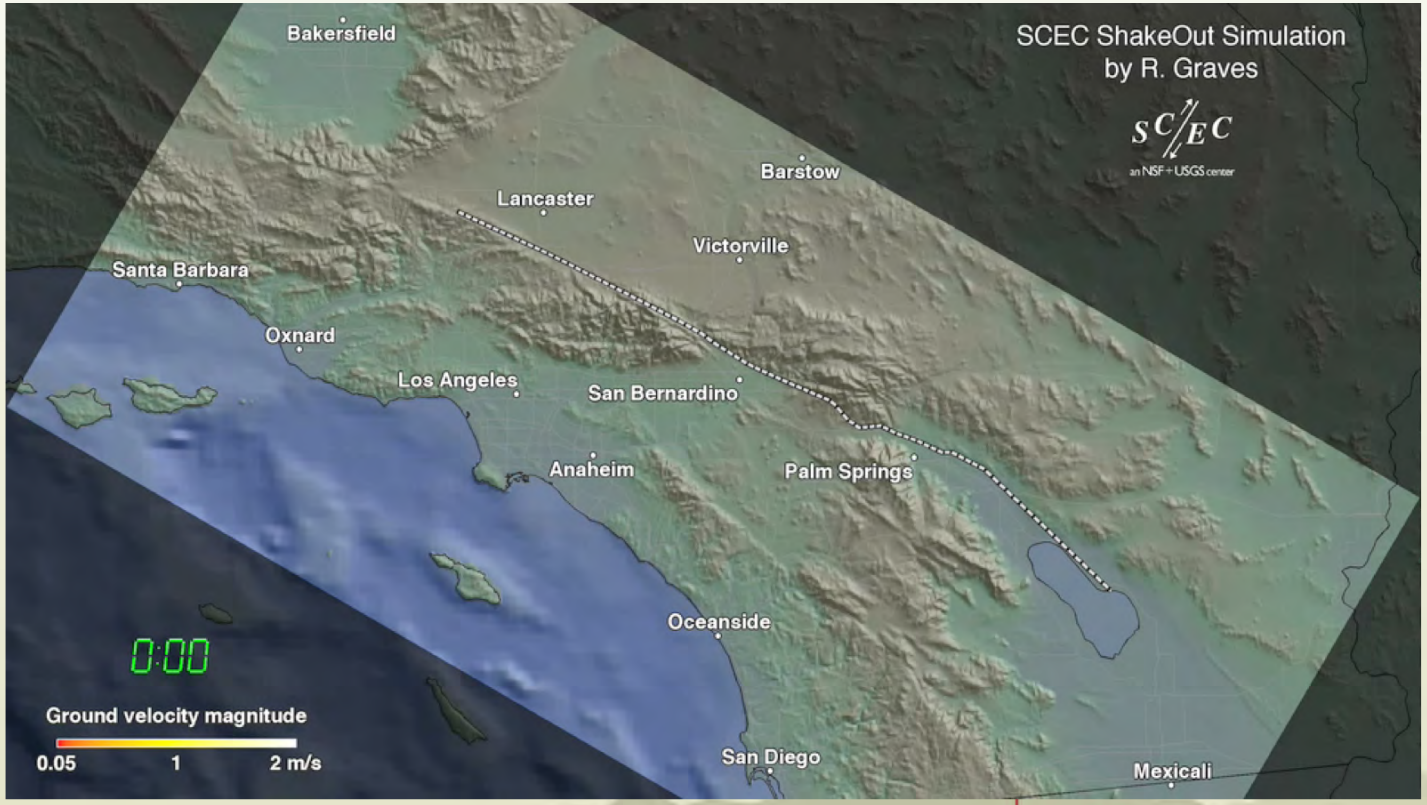
The Science of Earthquake Forecasts

John E. Vidale



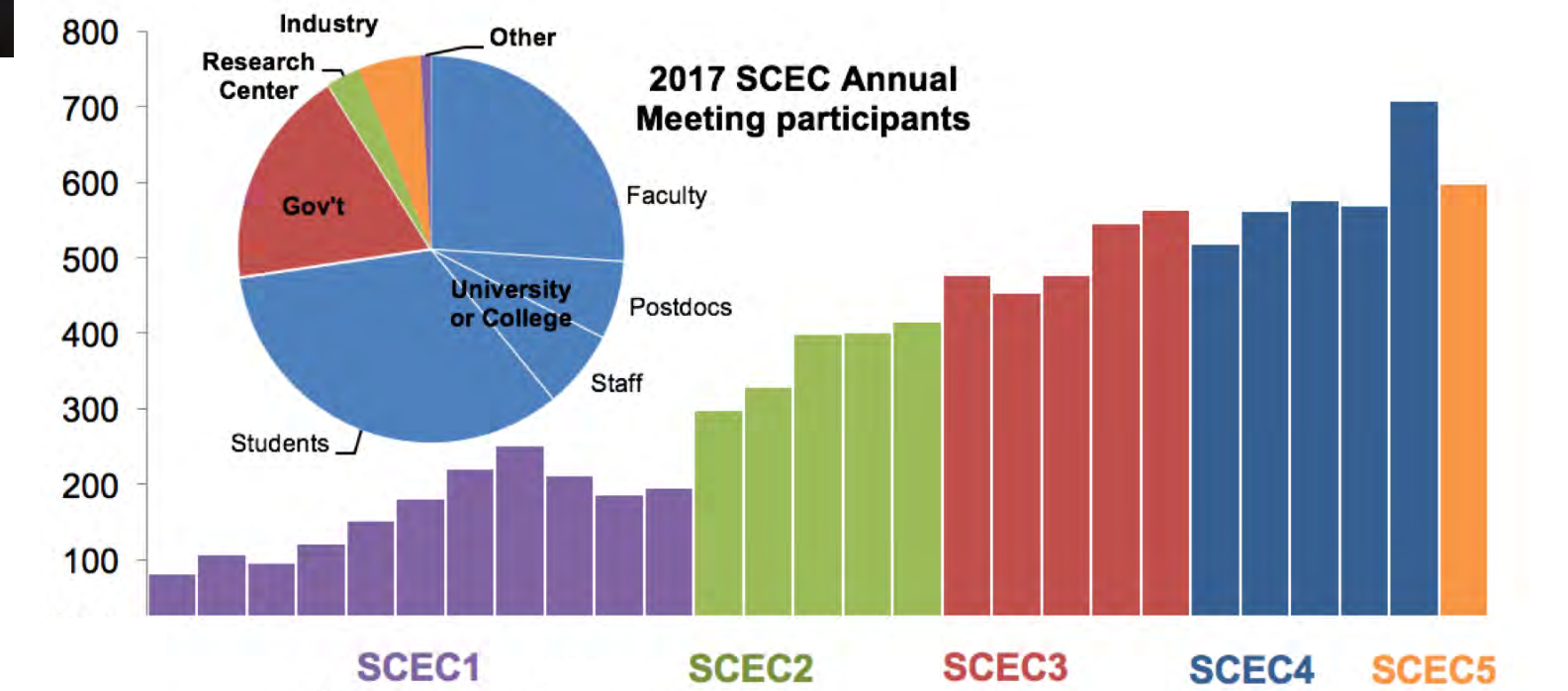
SCEC Mission Statement

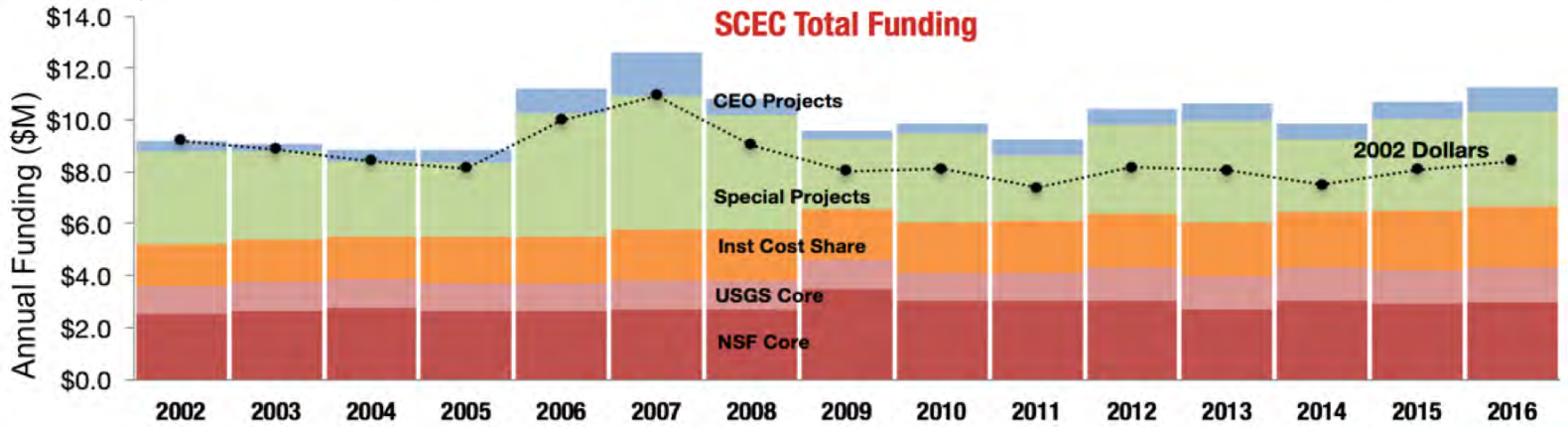
- **Gather data** on earthquakes in Southern California and elsewhere
- **Integrate information** into a comprehensive, physics-based understanding of earthquake phenomena
- **Communicate understanding** to end-users and society at large as useful knowledge for reducing earthquake risk and improving community resilience

SCEC Participation and Growth

Tran Huynh

John McRaney





- ~600 attendees
- ~300 posters

- 160 first-time attendees
- 285 students & post-docs

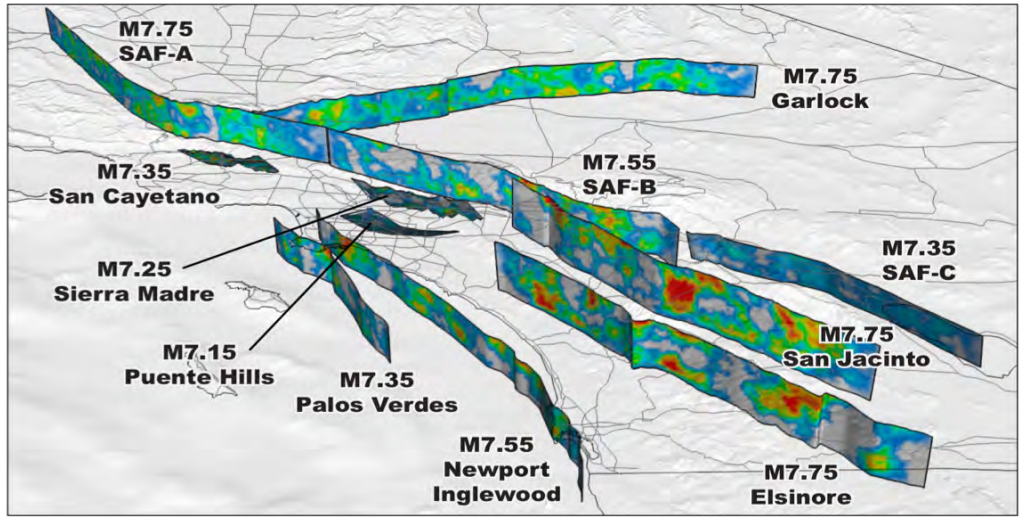
- 18 core institutions
- 57 participating institutions
  - 44 domestic
  - 13 international

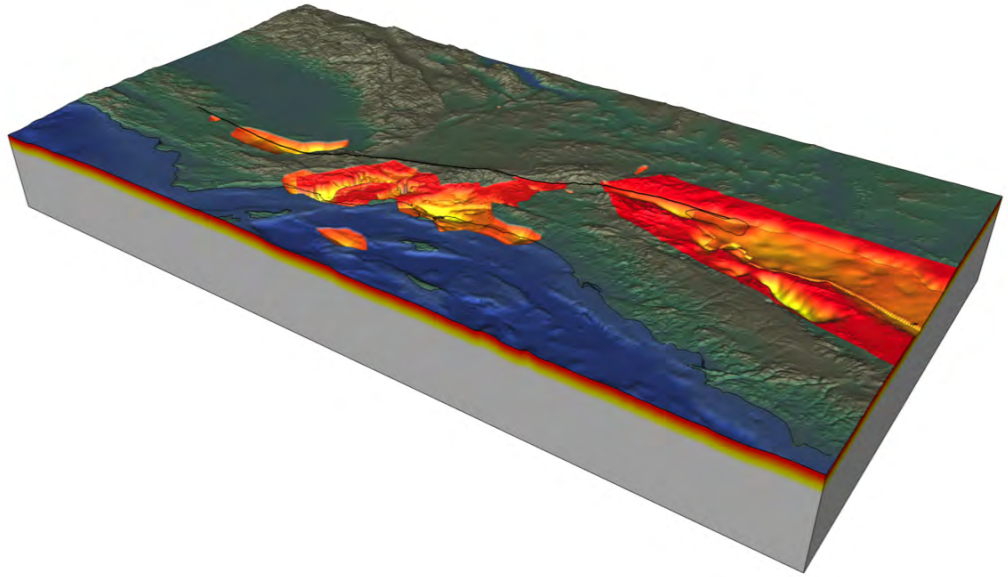
Ingredients for Ground Motion Computations

1. **Earthquake rupture forecasts (ERFs)**
   - detailed representation of fault geometry
   - rupture models that capture the complexities of dynamic fault failure

2. **3D models of geologic structure**
   - large-scale crustal heterogeneity
   - sedimentary basin structure
   - geotechnical layer based on V_{S30}

3. **Calculation of wave propagation and attenuation**
   - efficient anelastic wave propagation codes
   - nonlinear models of near-surface response

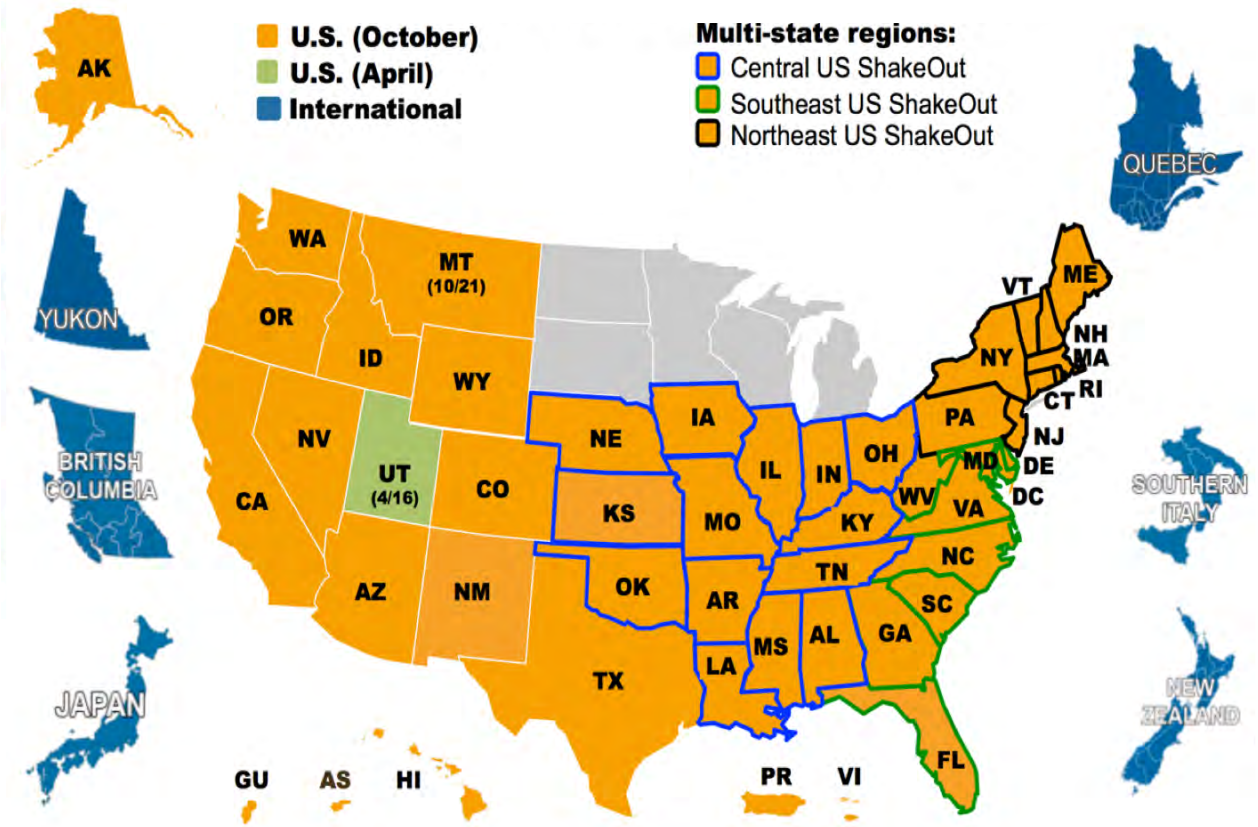




2016 ShakeOut Earthquake Drills

Mark Benthien

States, Territories, Provinces & Countries Participating in the 2015 Great ShakeOut Earthquake Drills



2016 Official ShakeOut Regions

28 Regions worldwide
22 U.S. regions spanning 51 states & territories
70 additional countries with independent registrations (individuals, schools, etc.)

Participation History (worldwide)

2016: 55.9 million (+ major drills in MX, PH, etc.)
2015: 43.8 million (+ TX, IA, LA, NE, global growth)
2014: 26.5 million (+ NM, KS, FL, Quebec, Yukon, more)
2013: 25.0 million (+ Southeast, Northeast, MT, WY, CO)
2012: 19.5 million (+ Japan, New Zealand, UT, WA, AZ)
2011: 12.5 million (+ Central US, BC, OR)
2010: 8.0 million (+ Nevada and Guam)
2009: 6.9 million (+ Northern California)
2008 5.4 million (Southern California)

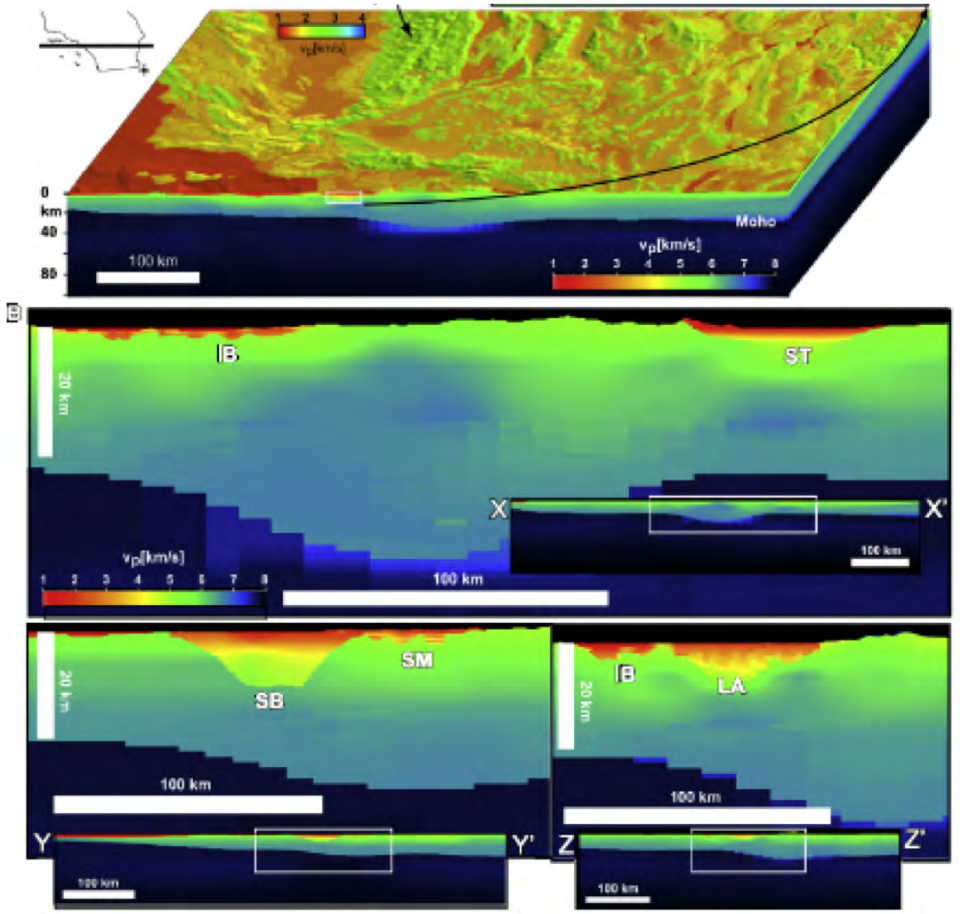
Key Facts

- Participants practice "Drop, Cover, and Hold On" and other aspects of their emergency plans.
- Register at www.ShakeOut.org

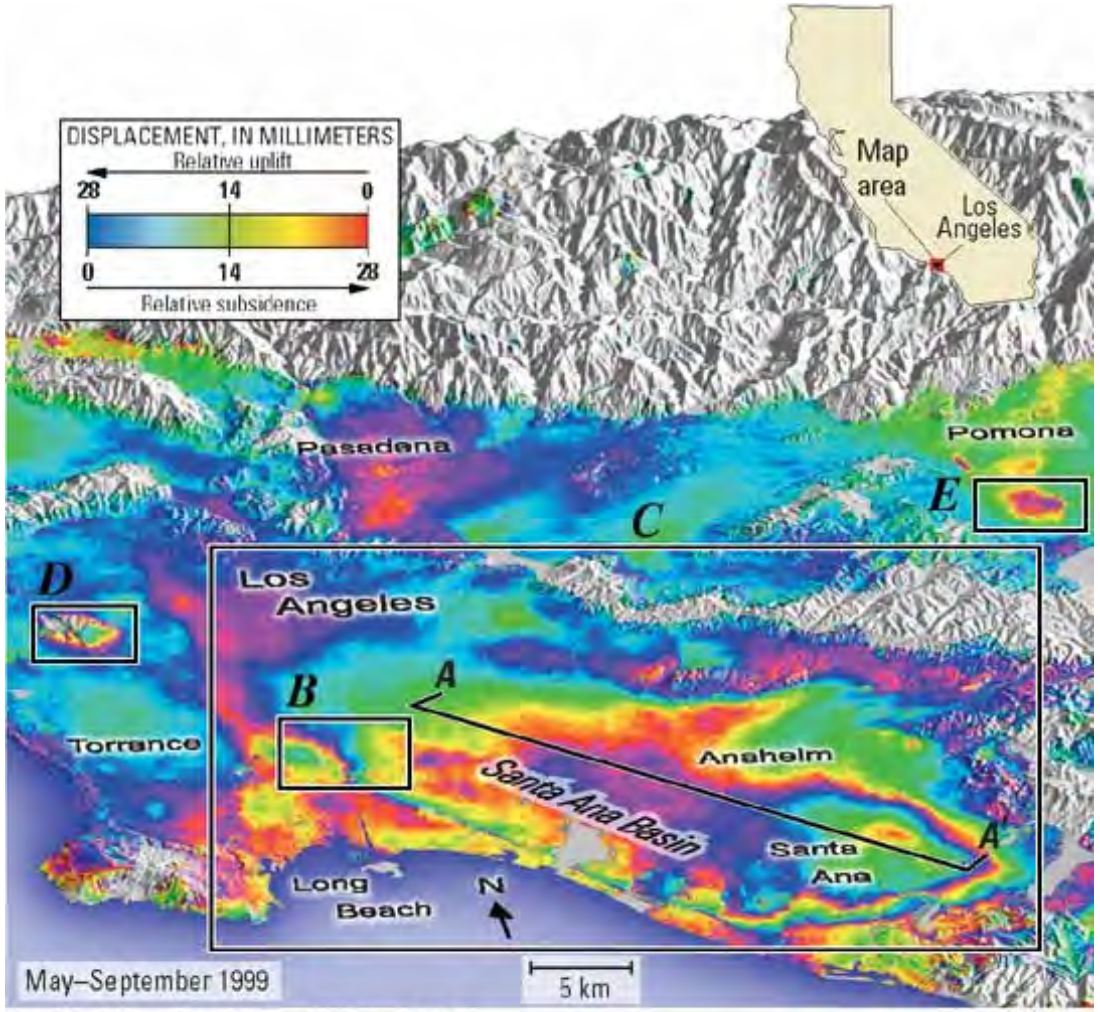
In 2016, more than 55 million people were registered to participate in ShakeOut drills

Core product #1
Community geophysical models

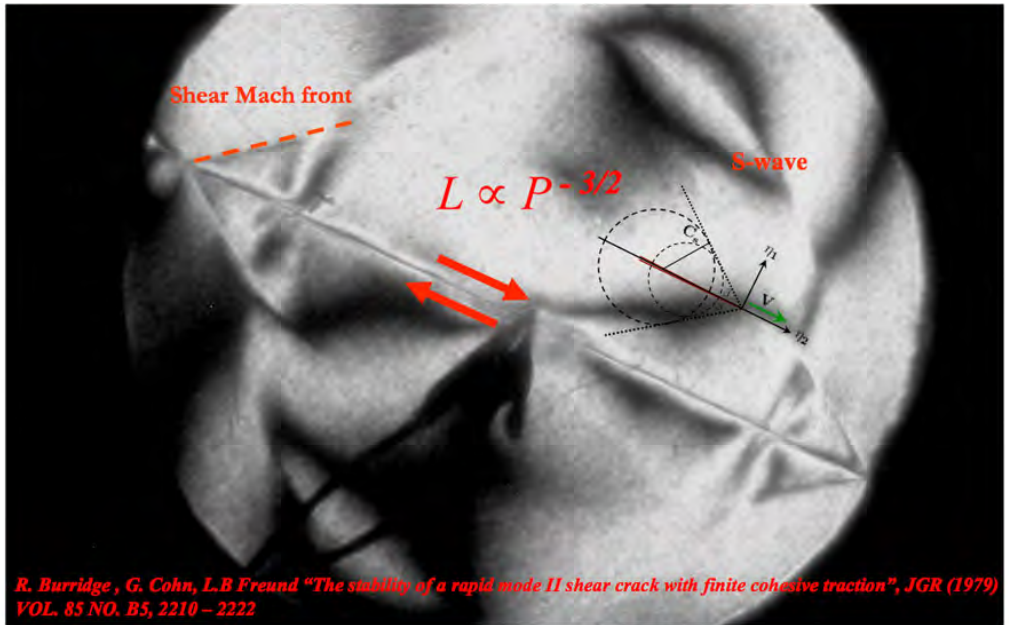
- Fault surfaces
- Stress, strain rate
- Paleoseismic earthquake history
- Surface deformation
- 3D Vp, Vs, density structure
- Rheology – viscosity, plasticity, strength
- Temperature, Composition



and the science they require and enable

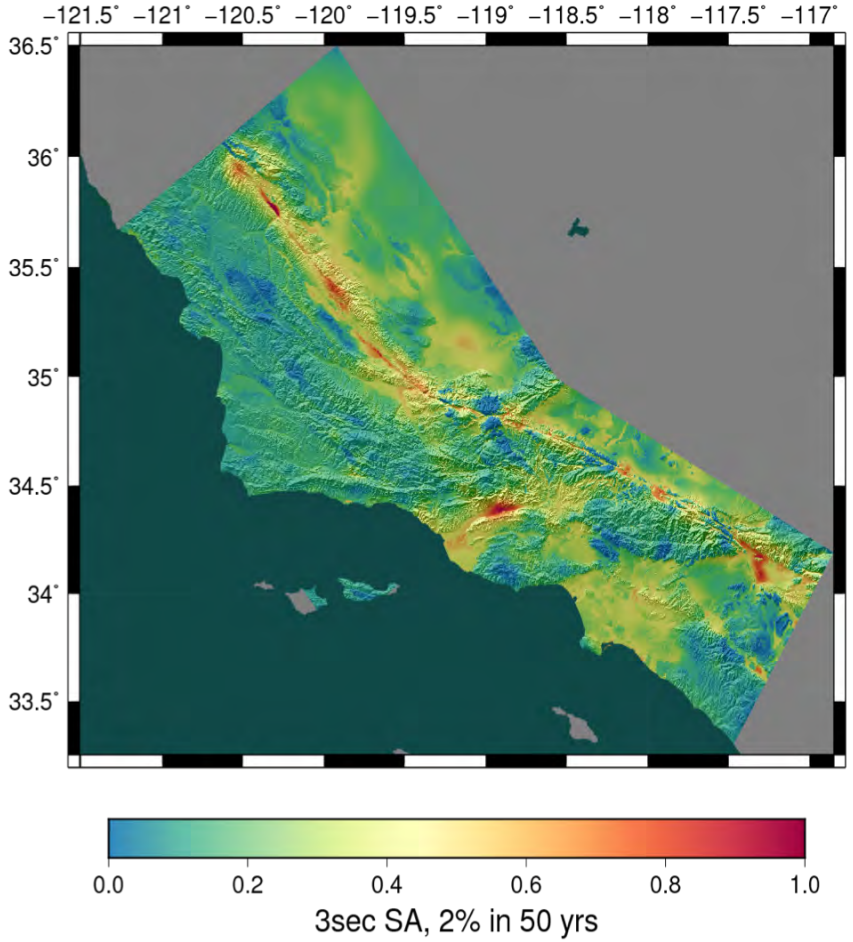


(modified from Bawden and others, 2001)

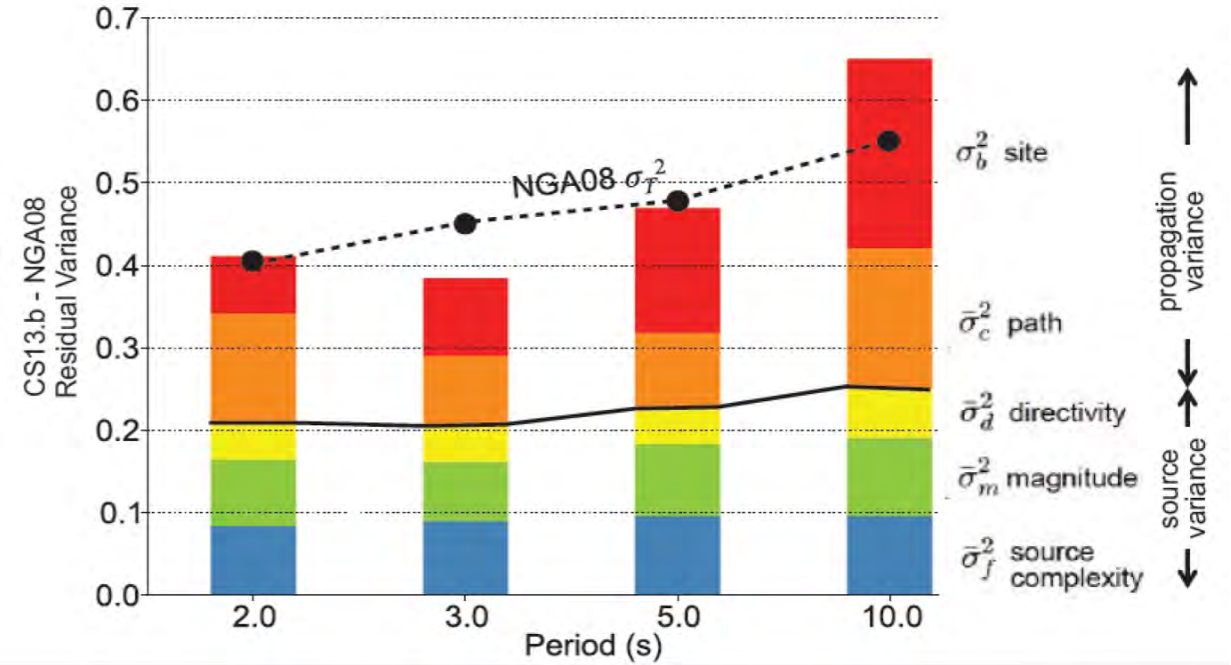


Core product #2

Using product #1 to reduce hazard uncertainty (enabling safety and savings)

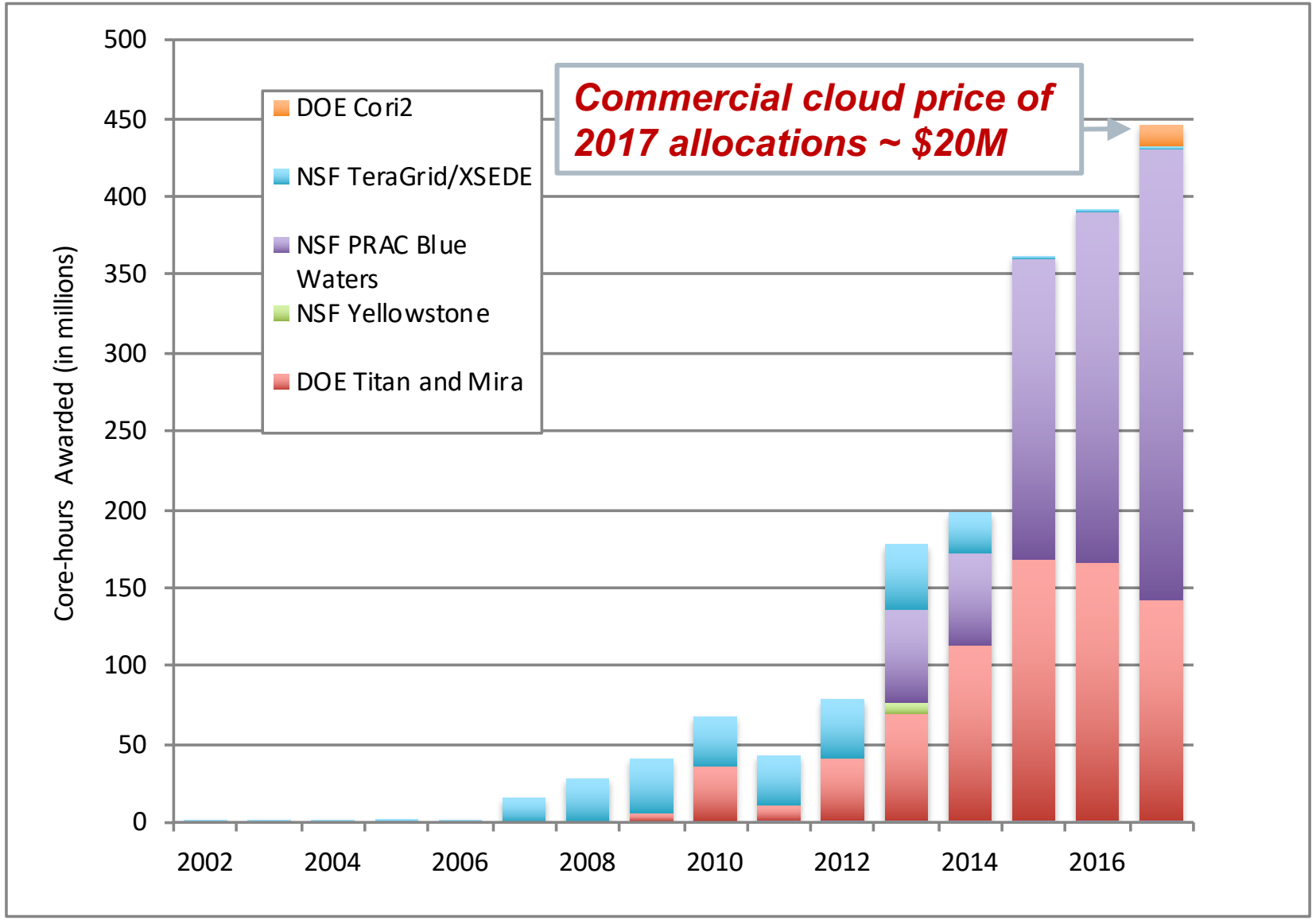


Combined CyberShake Map



After Wang & Jordan, 2014

SCEC HPC Allocations

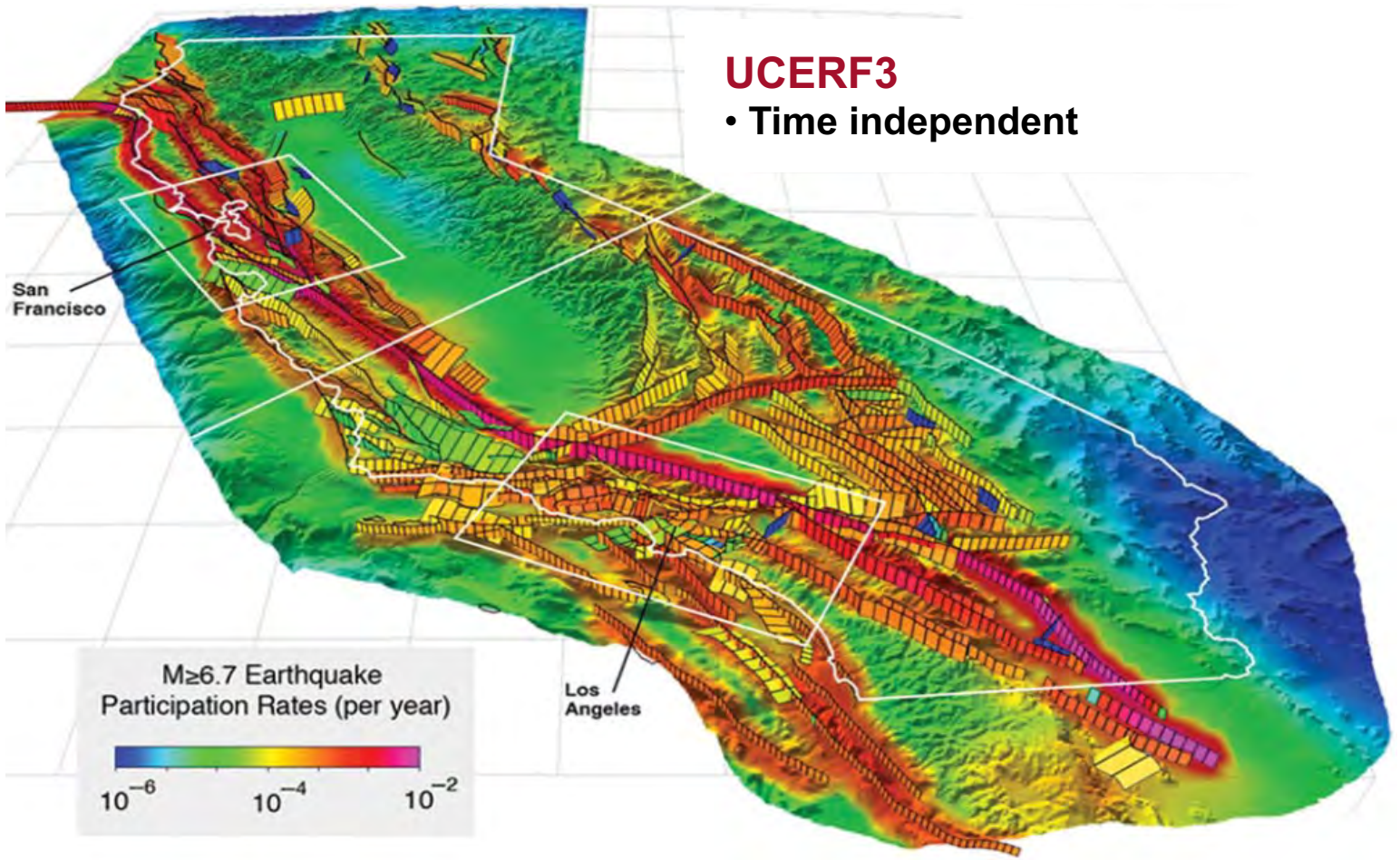


Phil Maechling

Christine Goulet

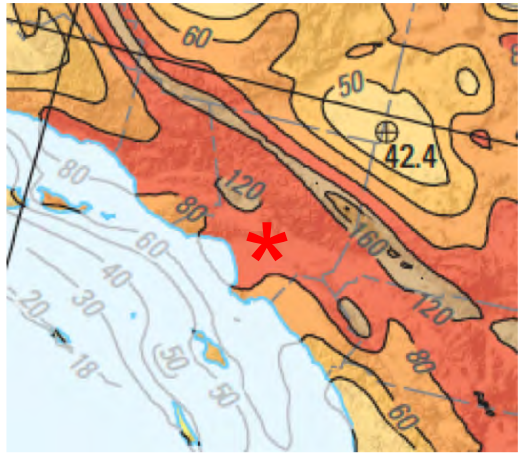
Latest faulting model – UCERF3

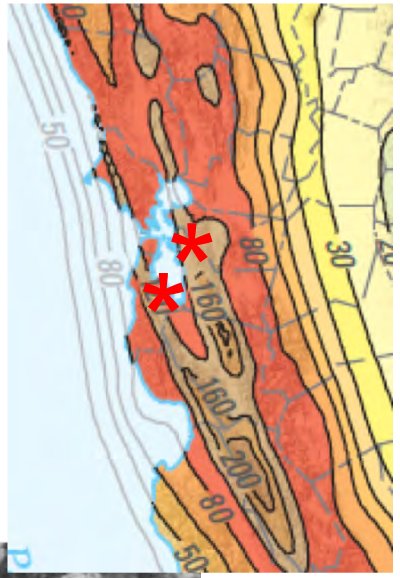
- 2014, Old UCERF2 2008.
- Uniform California earthquake rupture model.
- **In LA,** an M6 every 10 years,
- An M7 every 61 years, and
- An M7.5 every 100 years.
- Across state, an M6 every year, an M7 every 10 years, and an M7.5 every 50 years.

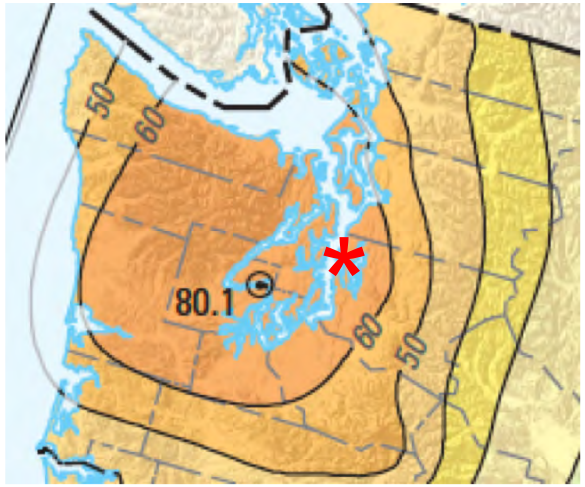


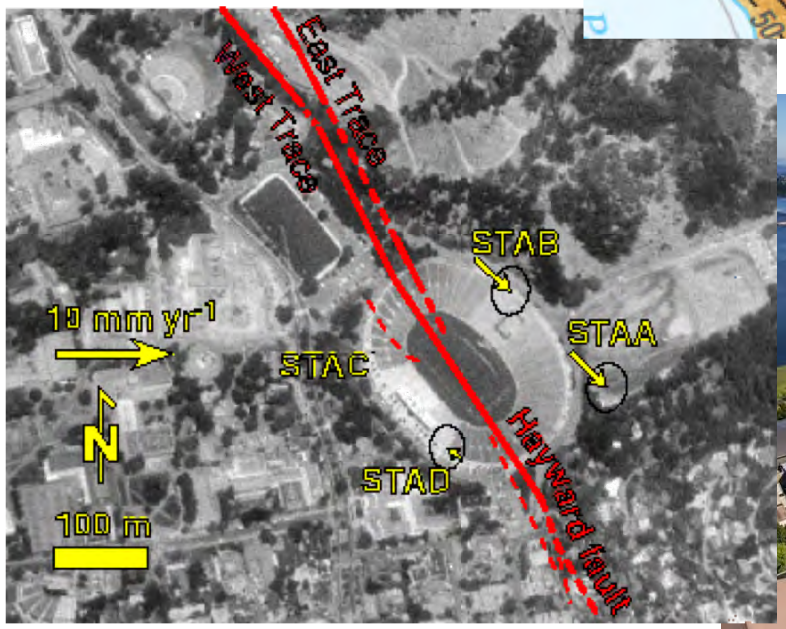
USC vs Cal vs Stanford vs UW hazard

- **USC (UCLA) 100%**
- **UCB & Stanford 130%,**
- **UW 65%,**
- **Doesn't count soil amplification**
  - **Most campuses variable**
- **10% exceedance in 50 years**
  - **0.2s period (5 Hz) spectral acceleration**
  - **% of g (gravity)**
  - **INSIDE typical small building, which amplifies**



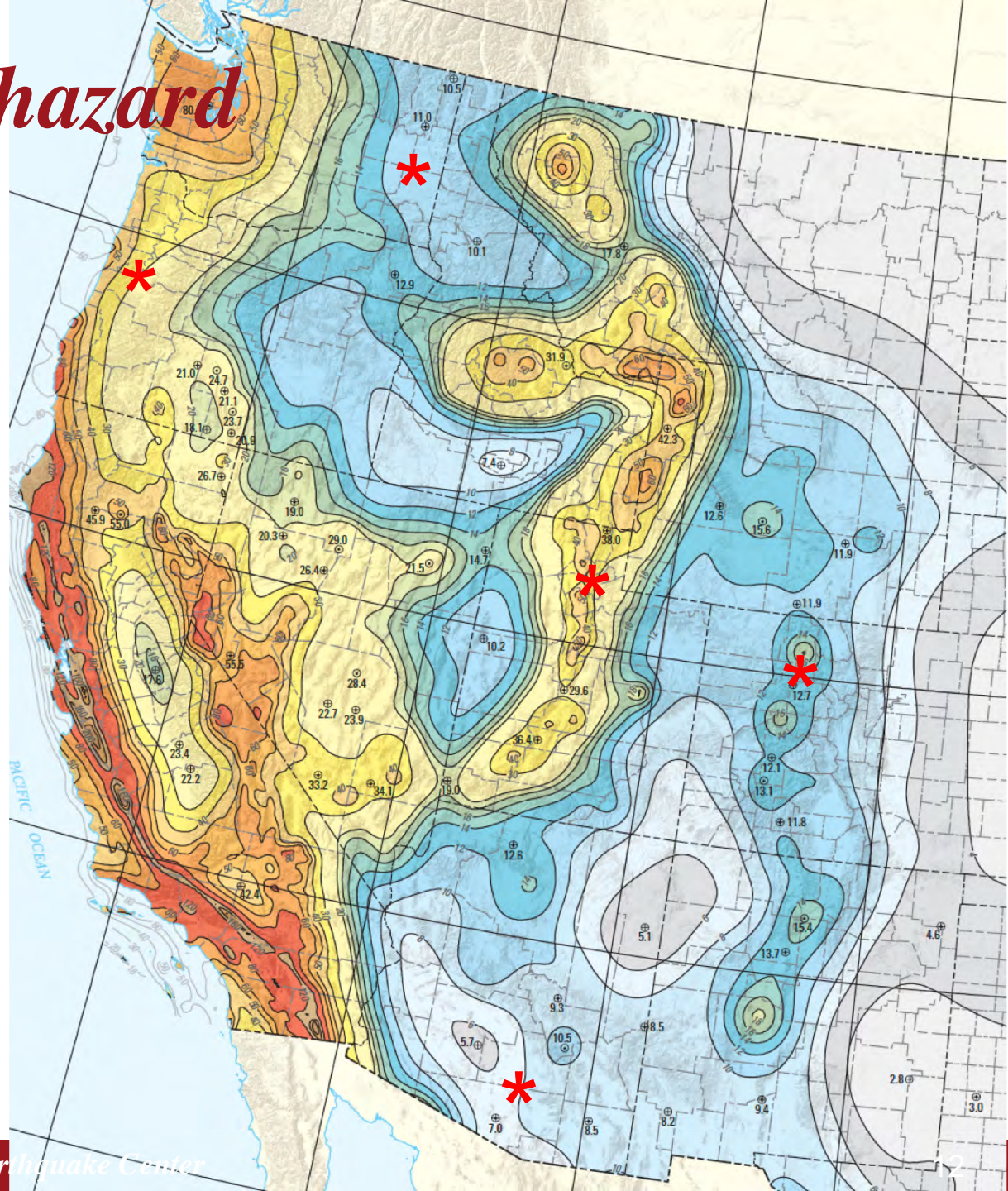




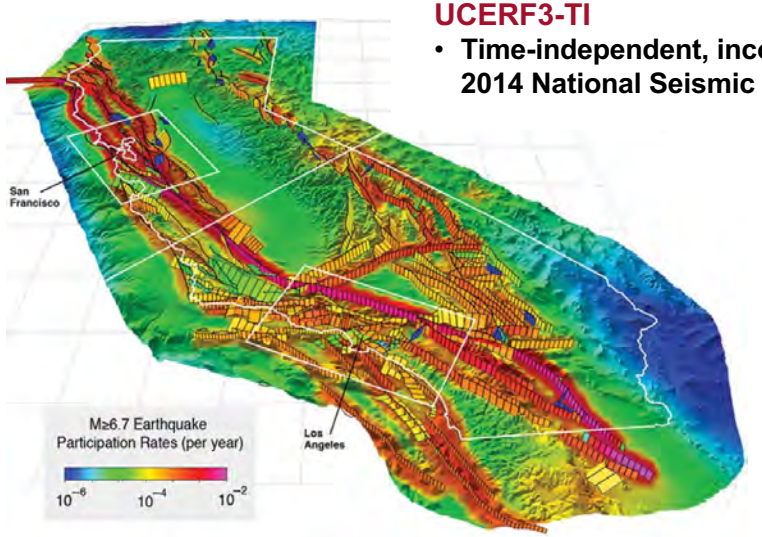


UO vs UA vs UU vs CU hazard

- OSU & UO about 30% g
- U Utah 40% - Wasatch Fault
- WSU, UA, UColorado, & ASU ~10% g
- Short period acceleration
  - % of g, gravity, in typical building
- 10% chance of exceedance in 50 years
- 2% in 50 years is most often used for buildings, and longer period motions for big structures.

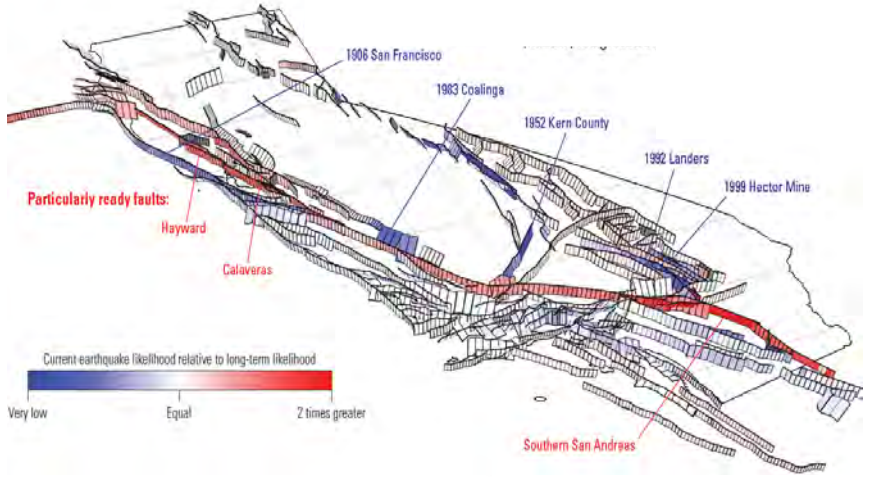


Next – Time-dependent hazard maps



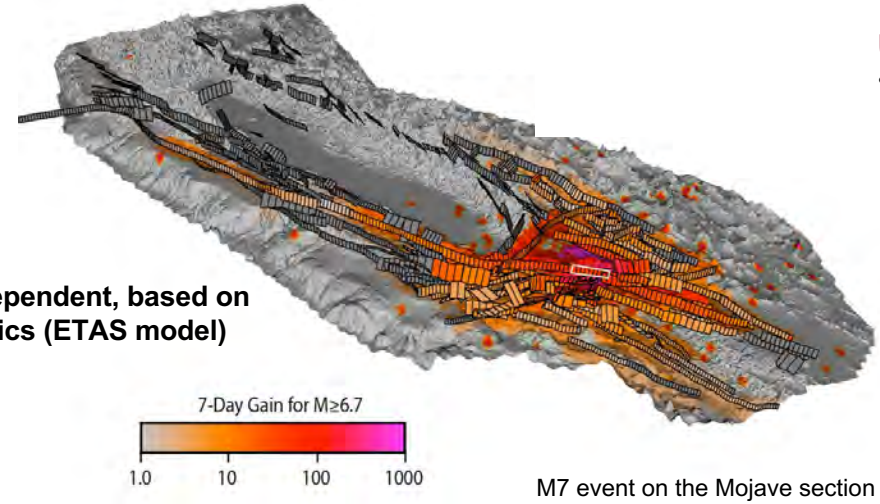
UCERF3-TI

- **Time-independent, incorporated into 2014 National Seismic Hazard Map**



UCERF3-TD

- **Long-term time-dependent, based on a Reid renewal statistics**



UCERF3-ETAS

- **Short-term time-dependent, based on Omori-Utsu statistics (ETAS model)**

M7 event on the Mojave section of the San Andreas Fault

Field et al. (2014, 2015, 2017)

SCEC

Challenges

Geology is not yet well enough known.

Stretching to move north, capturing higher frequencies.

Near-surface softening, liquefaction in strong shaking.

We'd love to know which faults will go next (but don't).

Best methods are still beyond our best computers.