SCEC

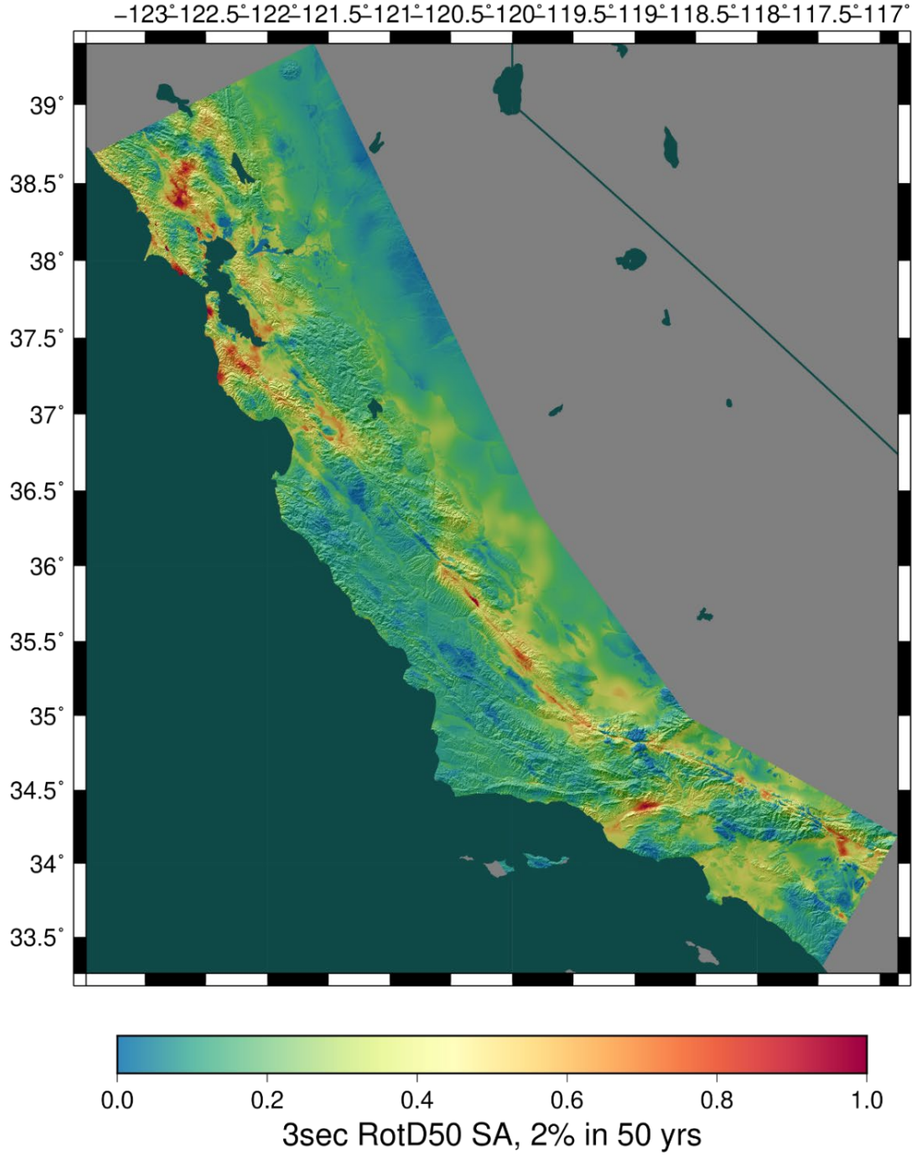
Non-ergodic PSHA Using Fully-Deterministic Physics-based Models for Southern California

Scott Callaghan, Kevin R. Milner, Christine A. Goulet, Bruce E. Shaw, Philip J. Maechling, Kim B. Olsen, Robert W. Graves, Karan Vahi, Ewa Deelman, Thomas H. Jordan, and Yehuda Ben-Zion

2022 SSA Annual Meeting
Thursday, April 21, 2022

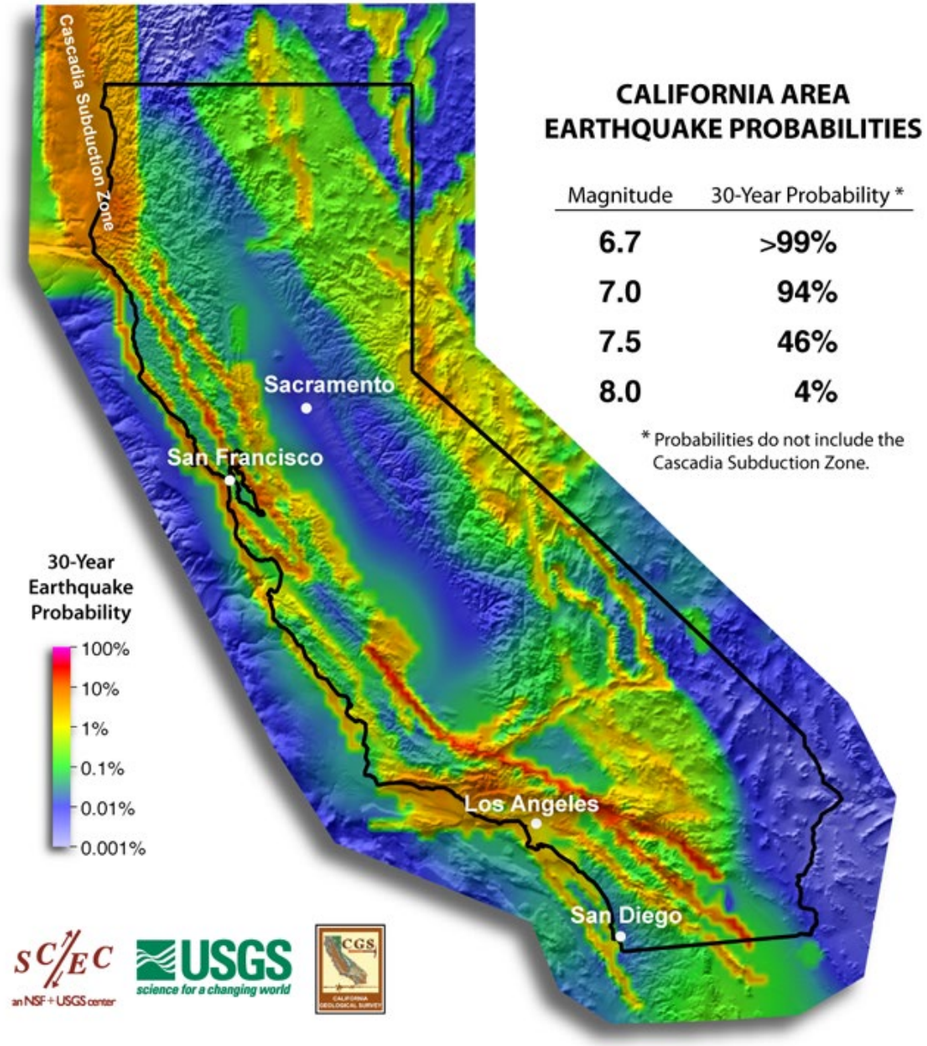
CyberShake Platform

- SCEC's 3D physics-based probabilistic seismic hazard analysis (PSHA) platform
- Earthquake Rupture Forecast (ERF) provides list of relevant events with probabilities
  - 70,000-500,000 events per site
- Reciprocity-based approach to simulate seismograms
- Intensity measures derived from seismograms
- Hazard results from individual sites interpolated with GMPE basemap
- Deterministic simulations to 1 Hz



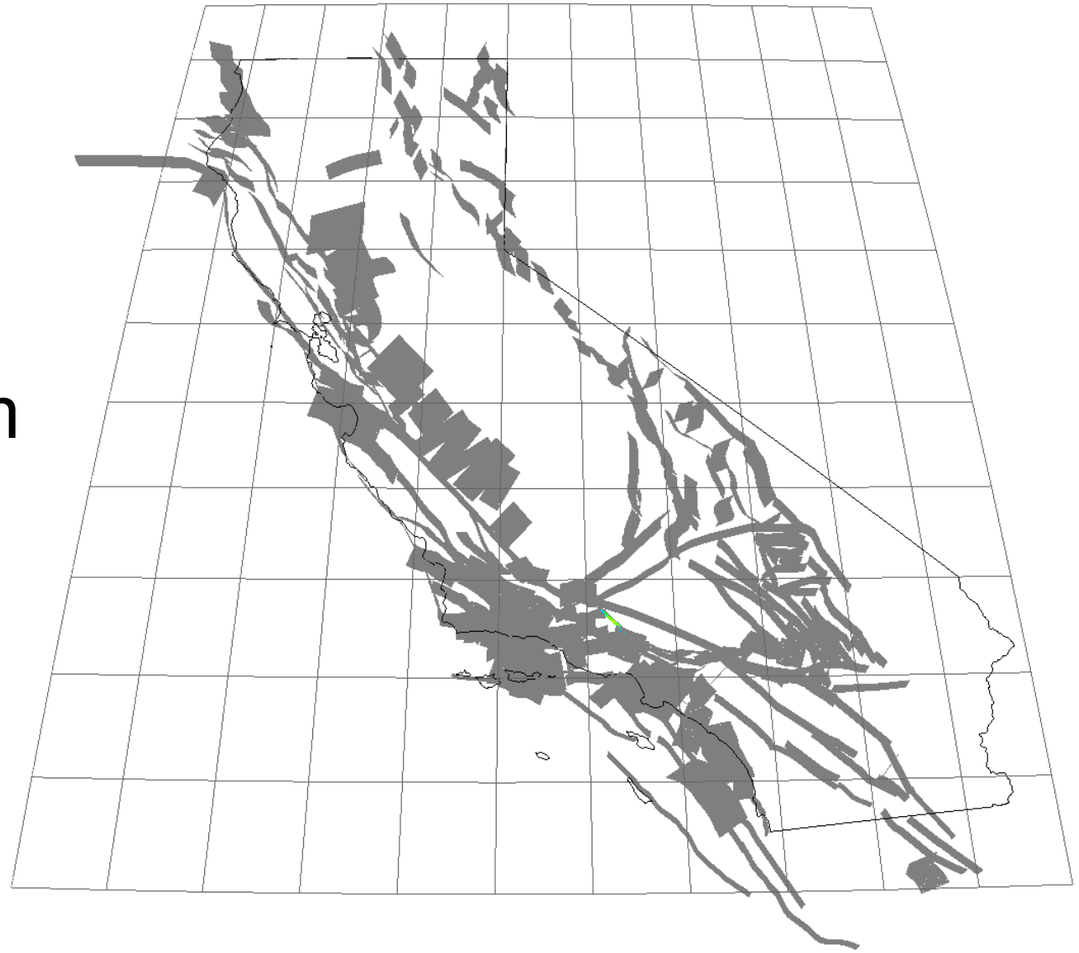
Earthquake Rupture Forecast

- List of events to simulate + probabilities
- To date, all CyberShake studies use UCERF2 ERF
  - Derived from empirical data
  - Average of logic tree branches
  - Includes aleatory magnitude uncertainty
- Investigated impact of using deterministic ERF generated with earthquake simulator



RSQSim

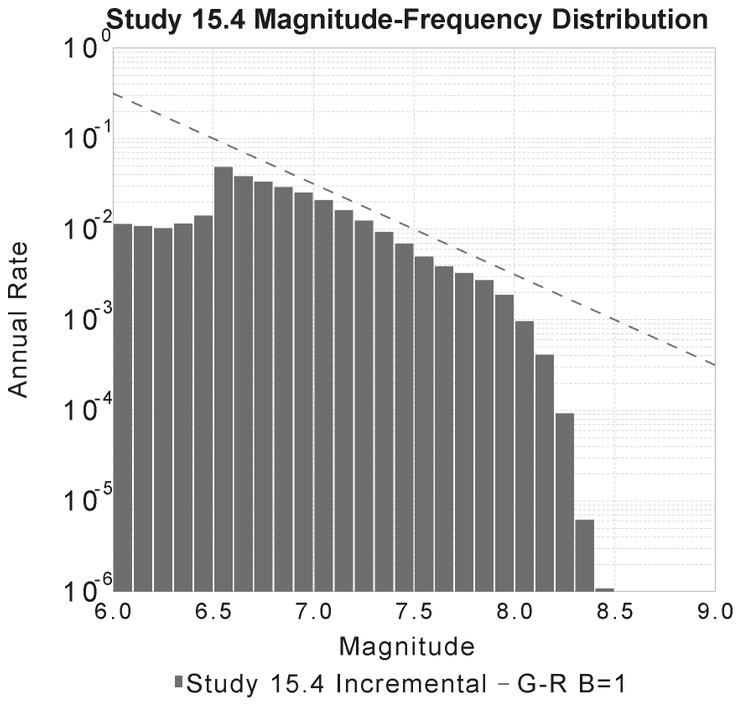
- Rate-State Earthquake Simulator
- Physics-loaded multi-cycle simulator
- Simulates hundreds of thousands of years of earthquakes on CA fault system
- Generates full slip-time histories for all events
- Can use as an ERF for CyberShake
  - Catalog provides list of events
  - Uniform probability, 1/(catalog length)



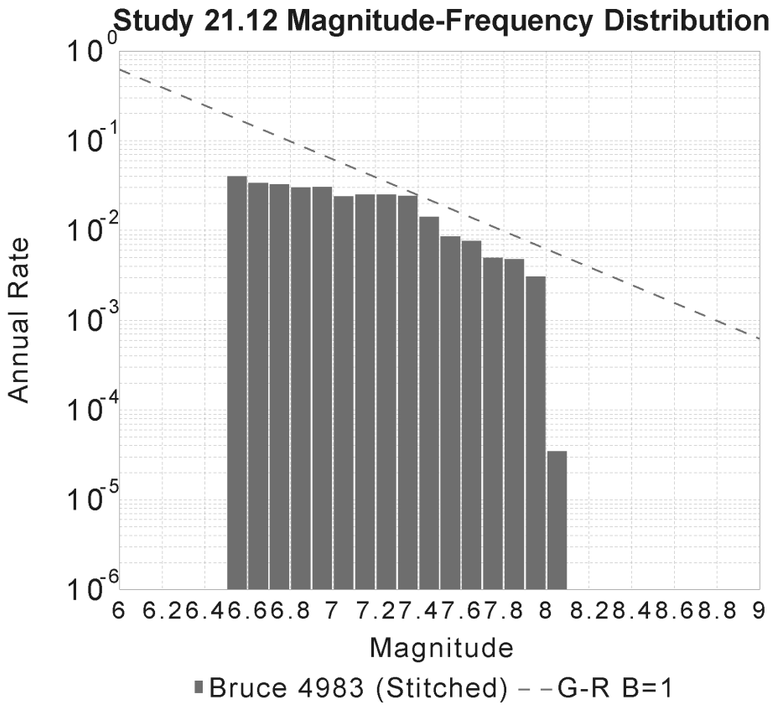
Visualization of 3,000 year RSQSim catalog

RSQSim CyberShake ERF

- Generated 779,523 year catalog, 13.5 million events
  - Discarded first 65kyrs as spinup
  - Selected events M≥6.5 (220,927 events)
  - Same cutoff rule (200 km from site)
- UCERF3 fault surfaces
- Triangular discretization of ruptures, 1 km/side
- Non-uniform hypocenter distribution



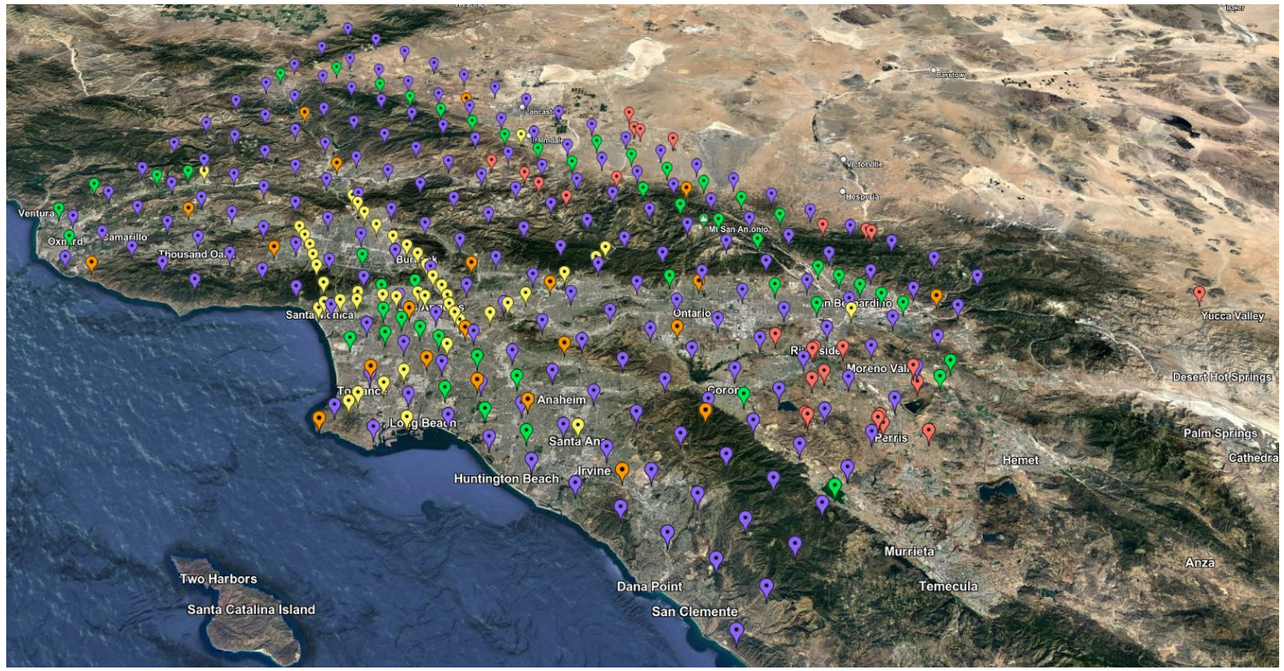
UCERF2 ERF



RSQSim ERF

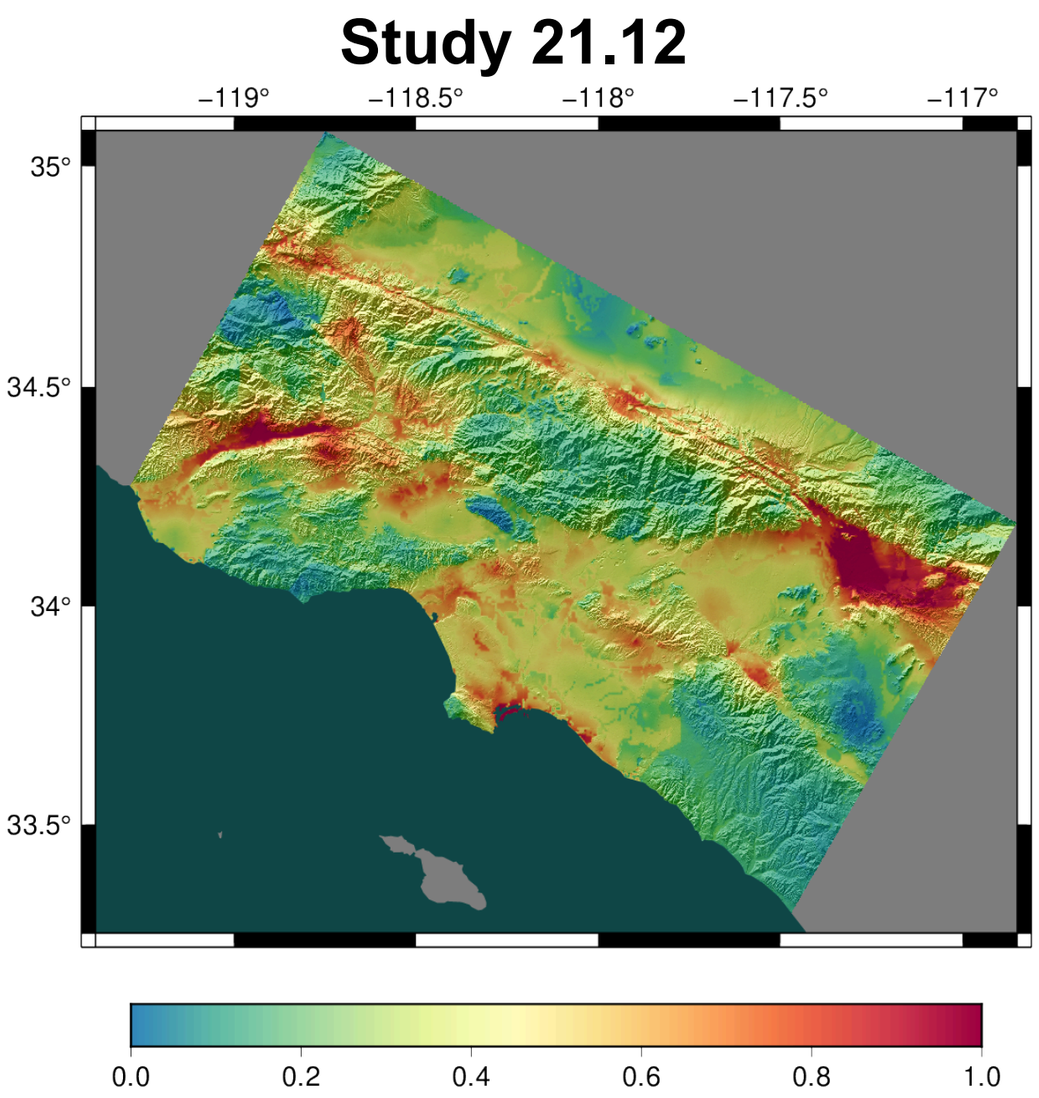
CyberShake Study 21.12

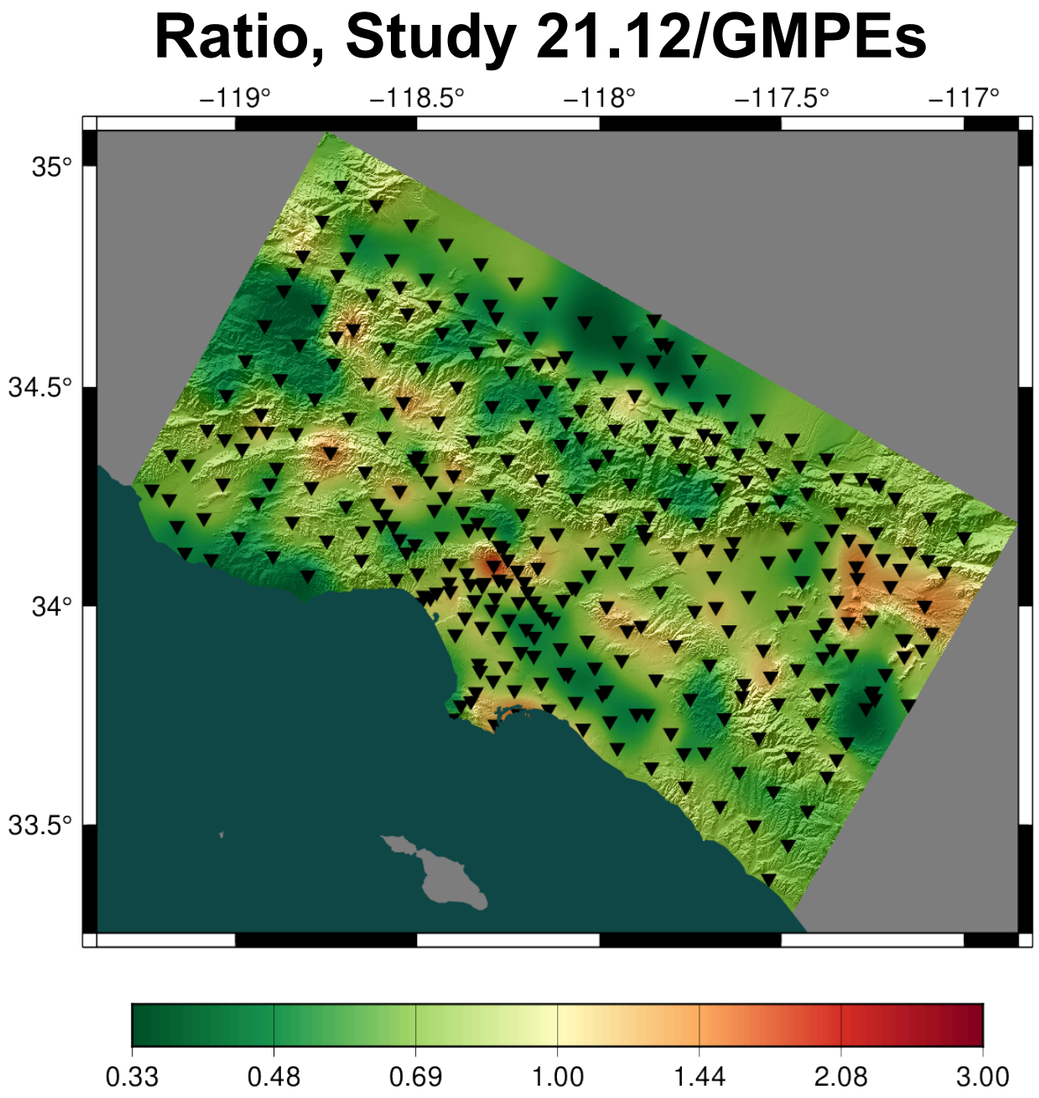
- RSQSim ERF
- 335 sites in Southern California
  - About 75,000 events per site
- Study performed over 29 days
  - Used OLCF *Summit* supercomputer
- 65,500 node-hours used
  - At peak, 46% of *Summit*
- Synthesized 25.7 million two-component seismograms



Study 21.12 site map

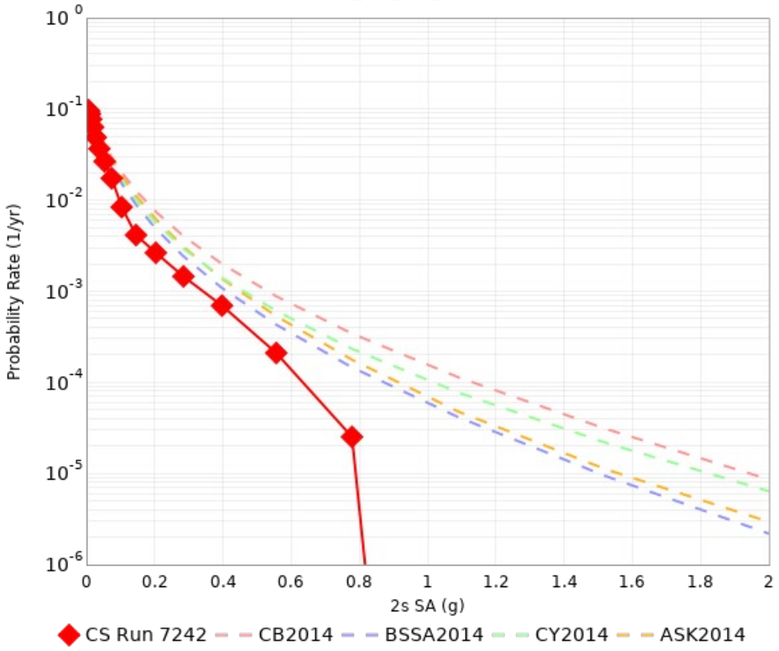
Study 21.12 Results

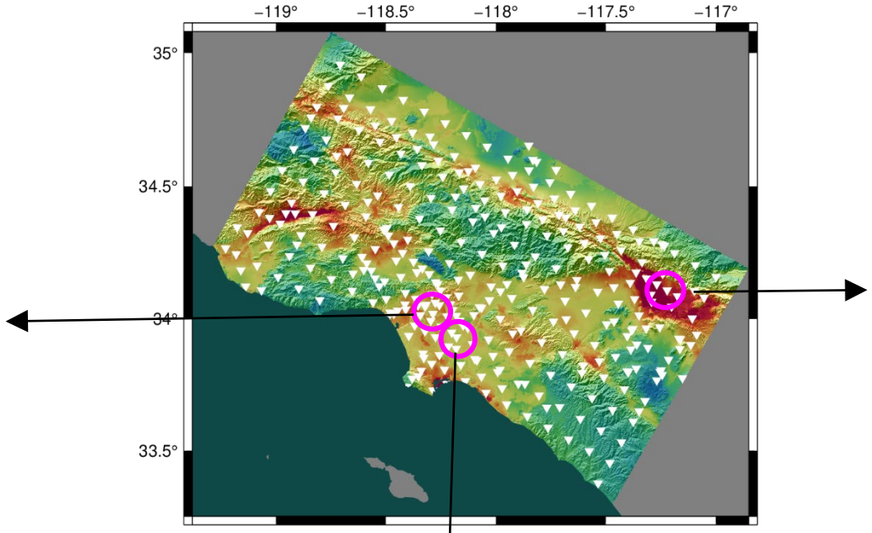




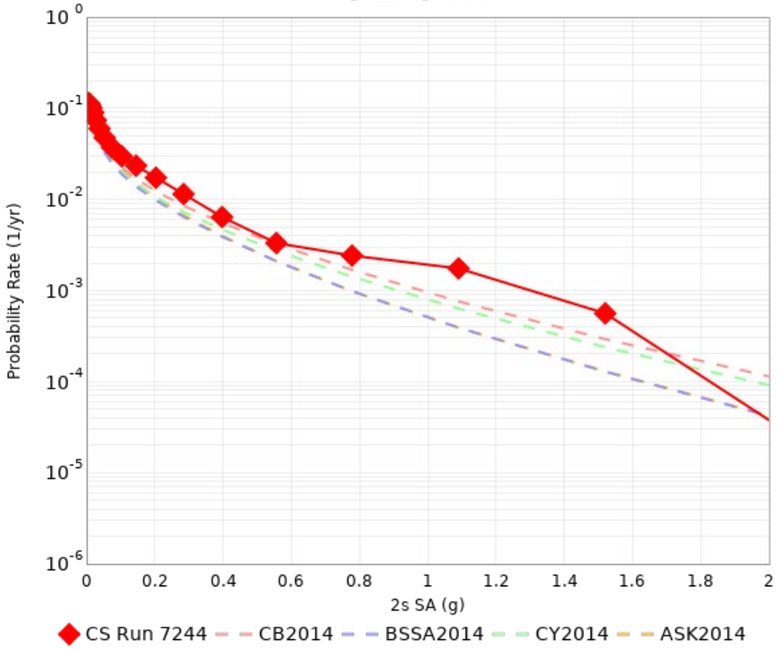
Study 21.12 Hazard Curves

USC

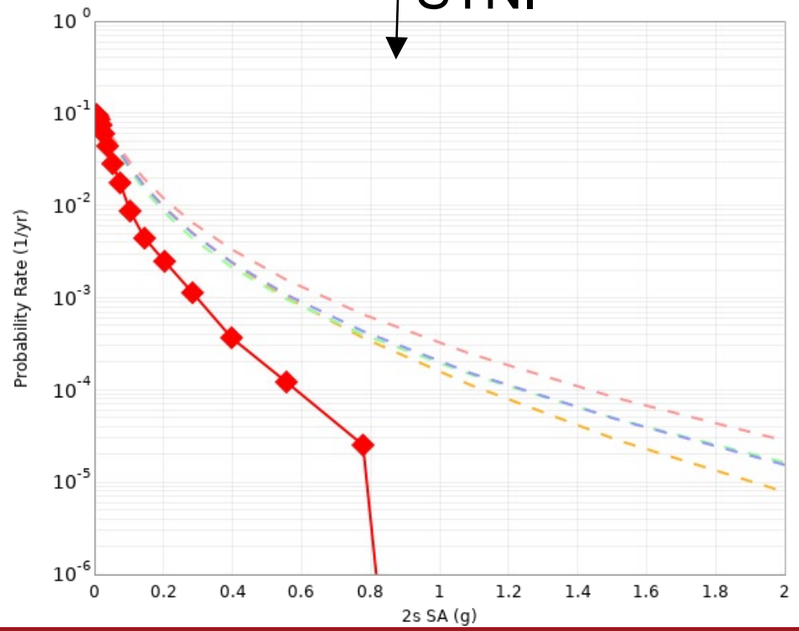




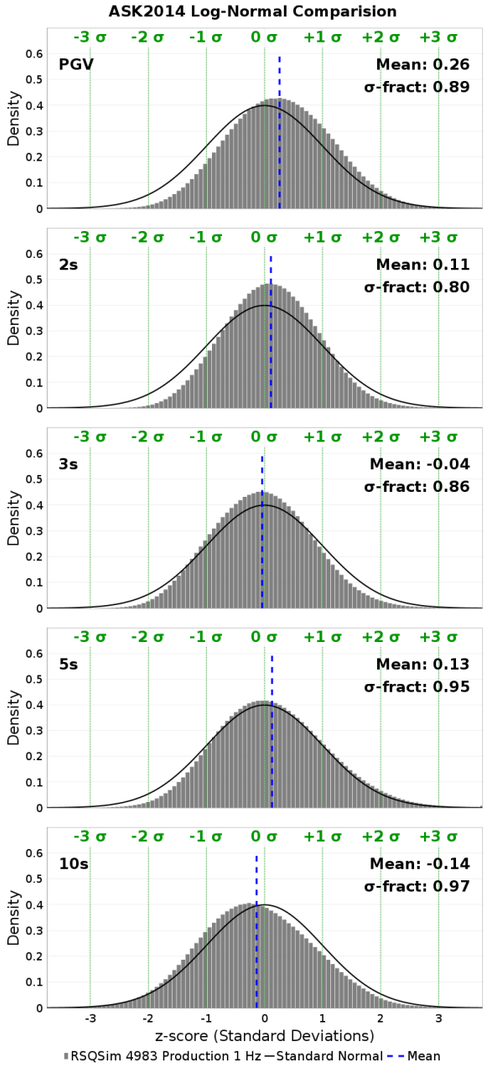
SBSM



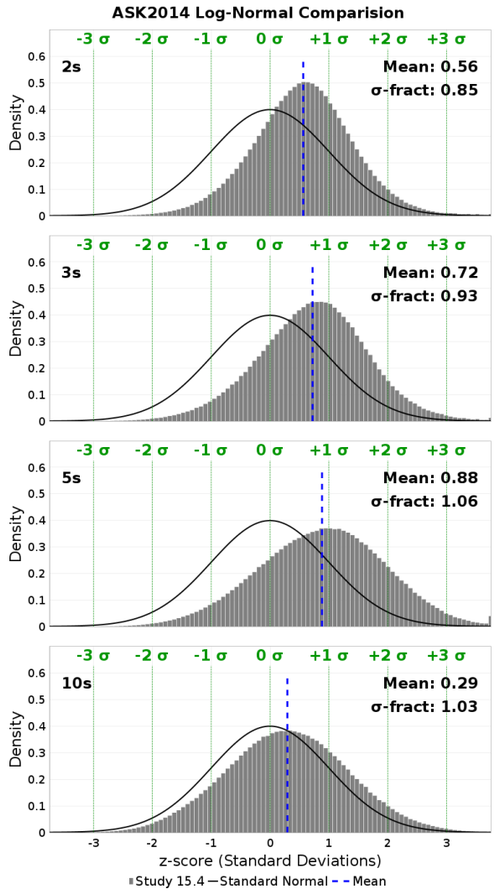
STNI



Study 21.12 comparisons to Study 15.4

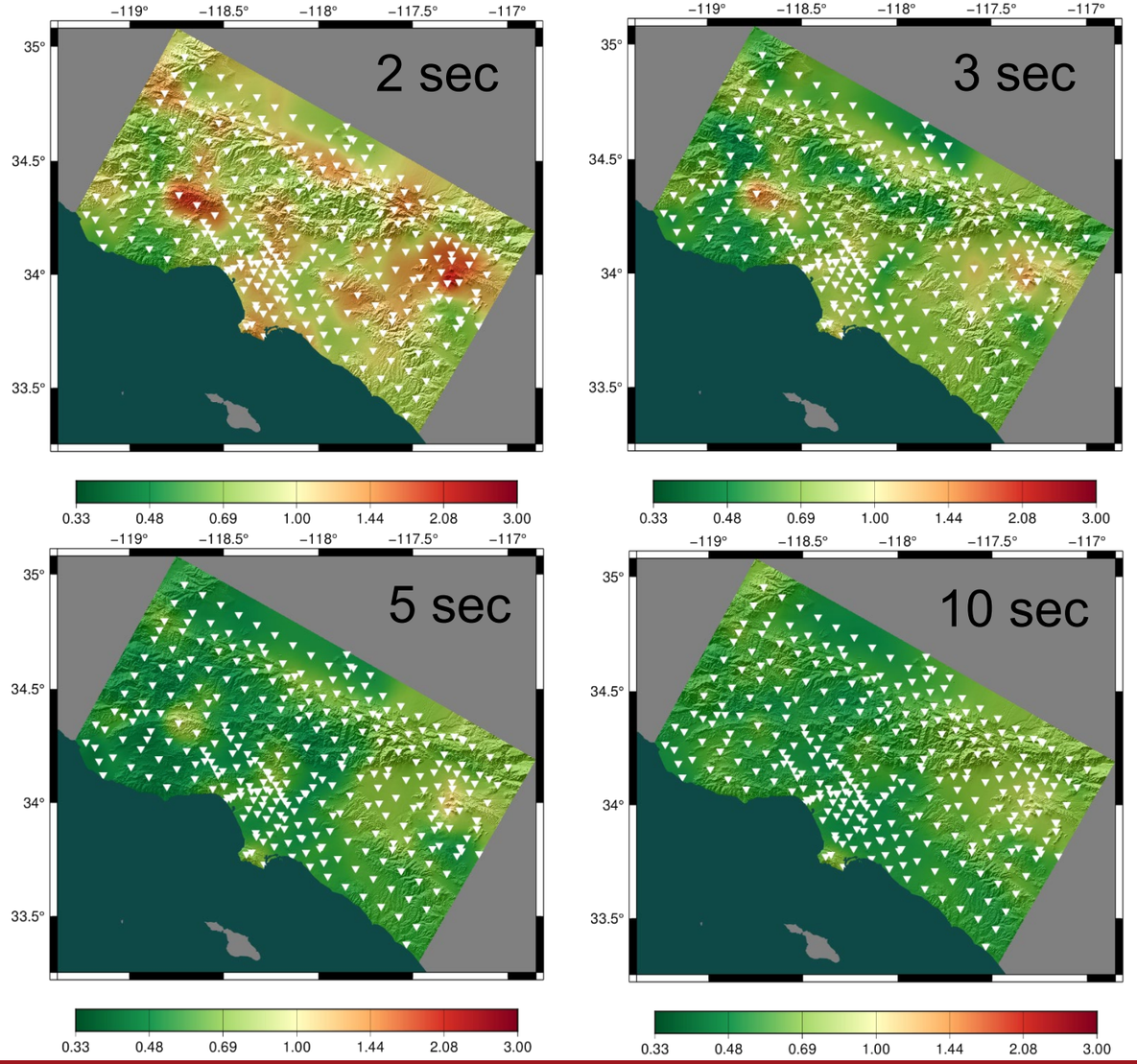


Study 21.12 vs ASK2014



Study 15.4 vs ASK2014

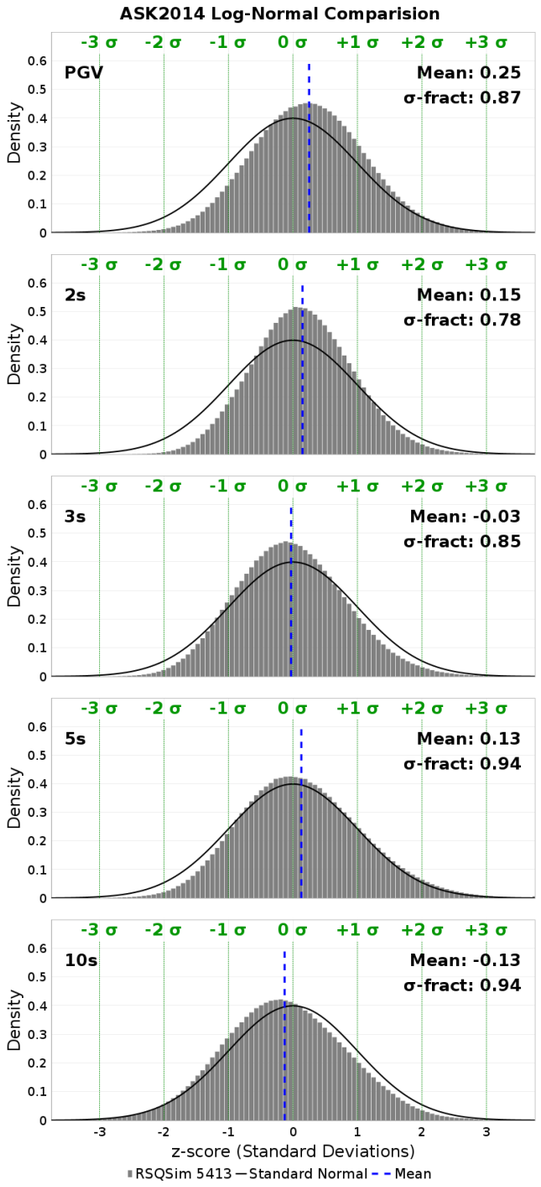
Ratio, Study 21.12/Study 15.4

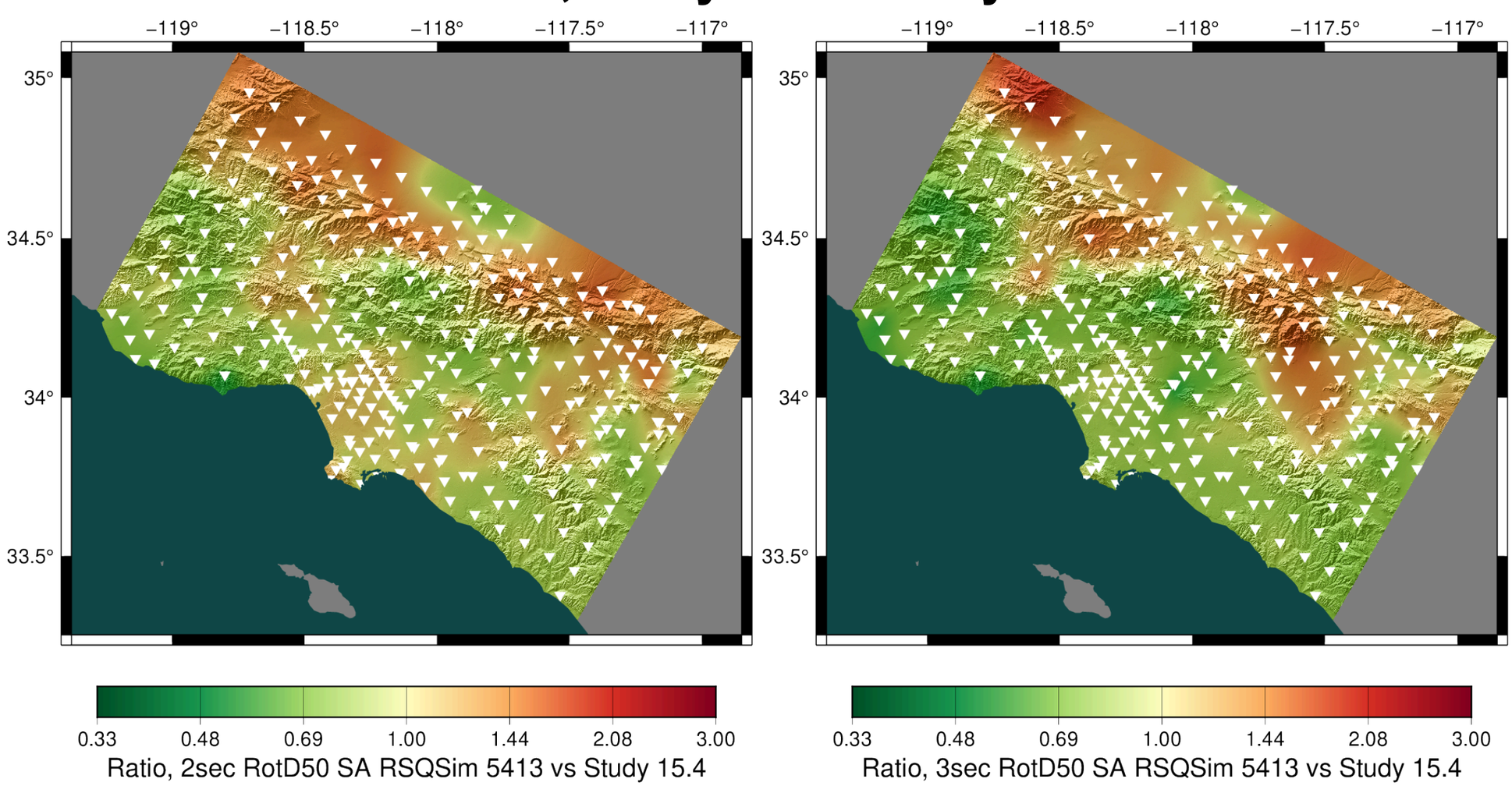


Study 21.12b

- Interested in impact of RSQSim rupture modifications
- Adjusted RSQSim frictional parameters
  - Reduced *b* above 3 km to mimic velocity strengthening layer and reduce near-surface stress drops
- Generated new catalog, 240 kyr (64,291 selected events)
- Reran CyberShake seismogram synthesis with new catalog
  - Since same rupture geometry, no need to rerun wave propagation

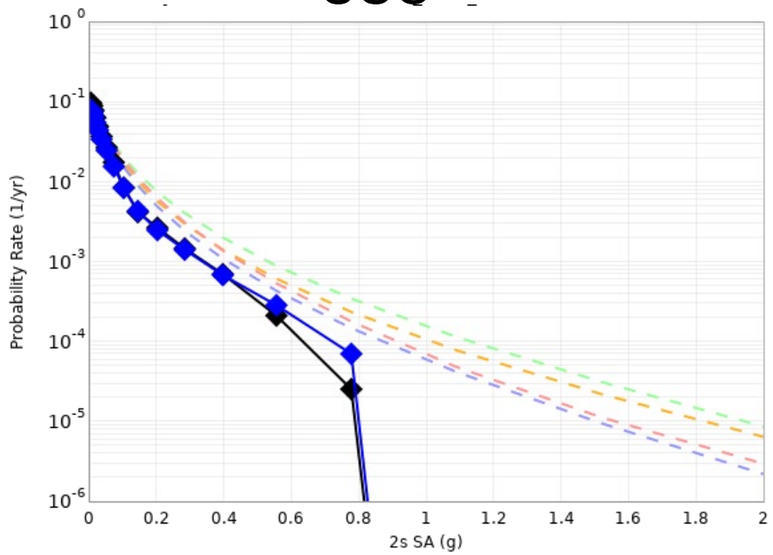
Study 21.12b Results

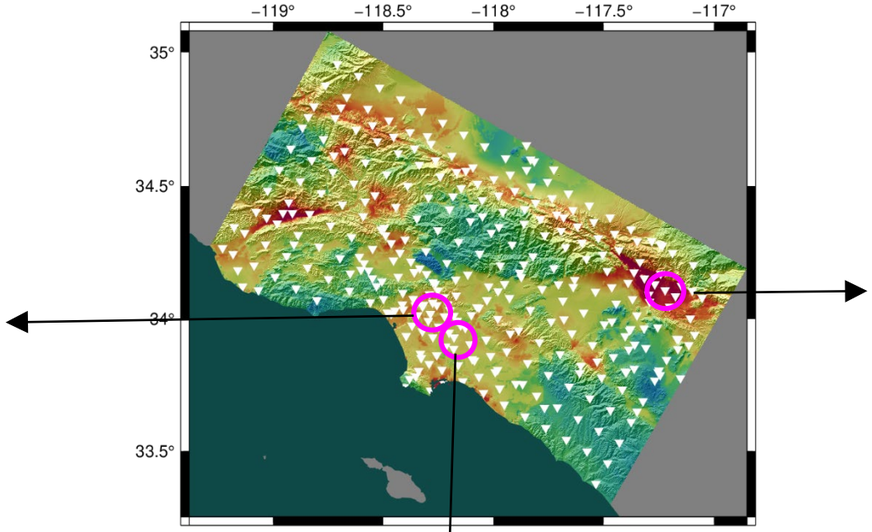




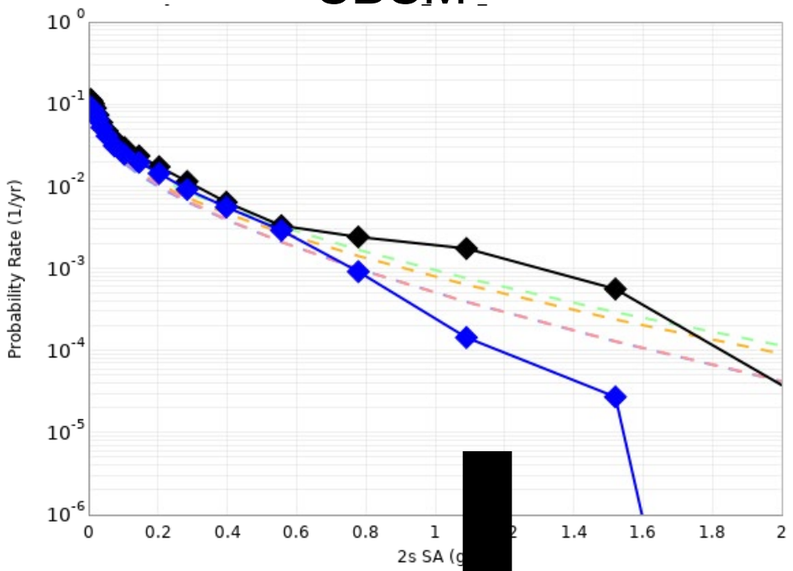
Study 21.12b Hazard Curves

USC

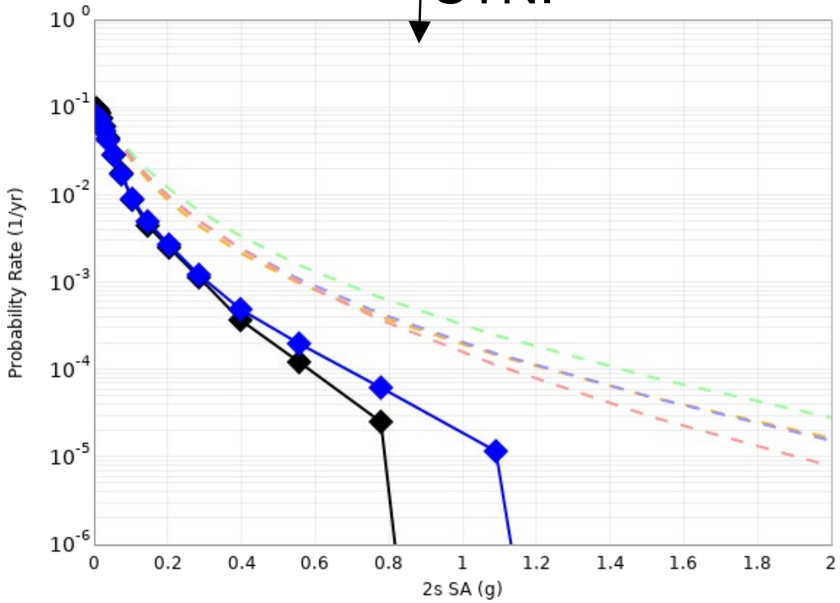


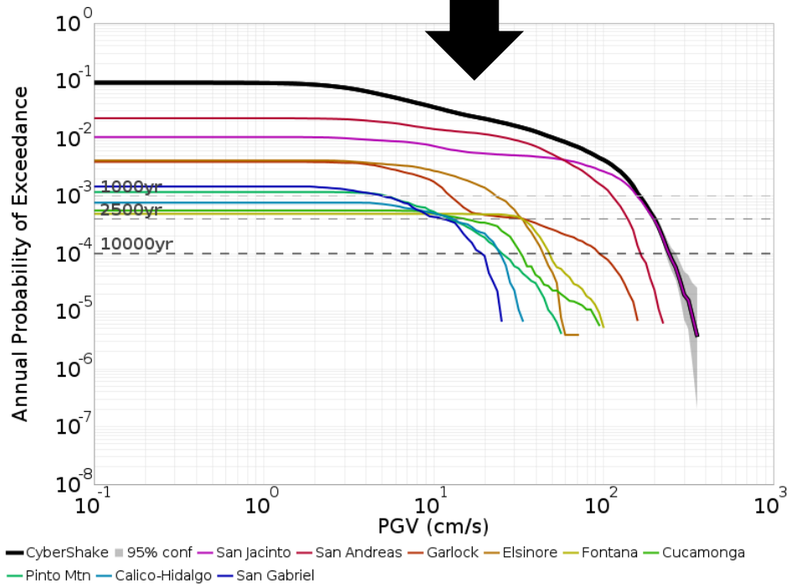


SBSM



STNI





Study 21.12 (black)

Study 21.12b (blue)

Summary

- RSQSim-generated ERFs coupled with CyberShake provide an approach for fully physics-based PSHA
- Ground motion distribution of RSQSim CyberShake closely resembles GMPEs
- Inclusion of velocity strengthening layer reduces large ground motions at 2 sec
- Future plans:
  - Look at ground motion radiation patterns and compare to kinematic models
  - Increase rupture surface resolution

Thanks!


USGS
science for a changing world


National
Science
Foundation


PG&E


U.S. DEPARTMENT OF
ENERGY


SCEC
AN NSF+USGS CENTER


U.S. DEPARTMENT OF ENERGY
INCITE
LEADERSHIP COMPUTING


OAK RIDGE
National Laboratory
LEADERSHIP
COMPUTING
FACILITY


ISI
Information Sciences Institute


Pegasus


TACC


USC
Advanced Research Computing
Enabling scientific breakthroughs at scale