Advances in CyberShake Physics-Based Probabilistic Seismic Hazard Analysis

Scott Callaghan (SCEC), Phil Maechling, Fabio Silva, Christine Goulet, Kevin Milner, Mei-Hui Su, Xiaofeng Meng, Camilo Pinilla-Ramos, Kim Olsen, Rob Graves, Norm Abrahamson, Albert Kottke, Karan Vahi, Ewa Deelman, Tom Jordan, Yehuda Ben-Zion

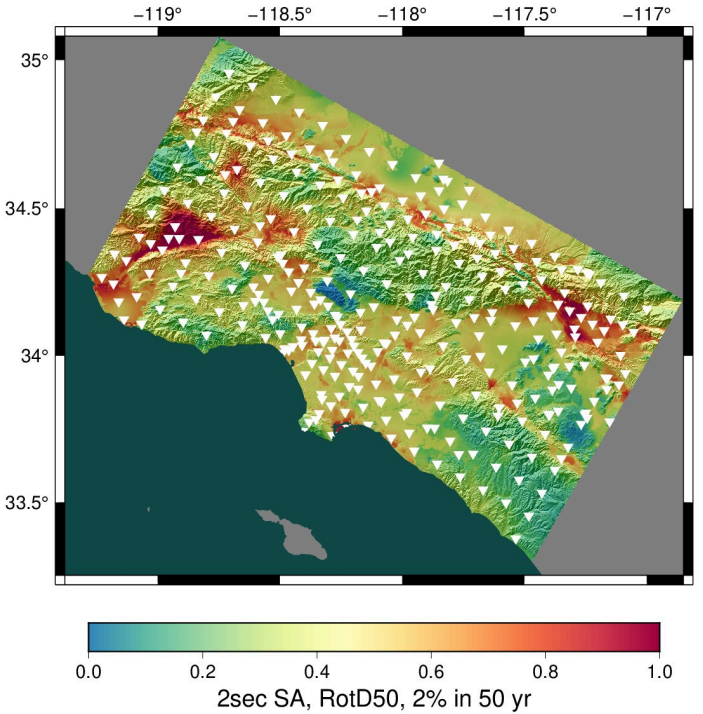
December 9, 2024

AGU24: S21B – Probabilistic Seismic Hazard Analysis: Advances and Applications

scottcal@usc.edu

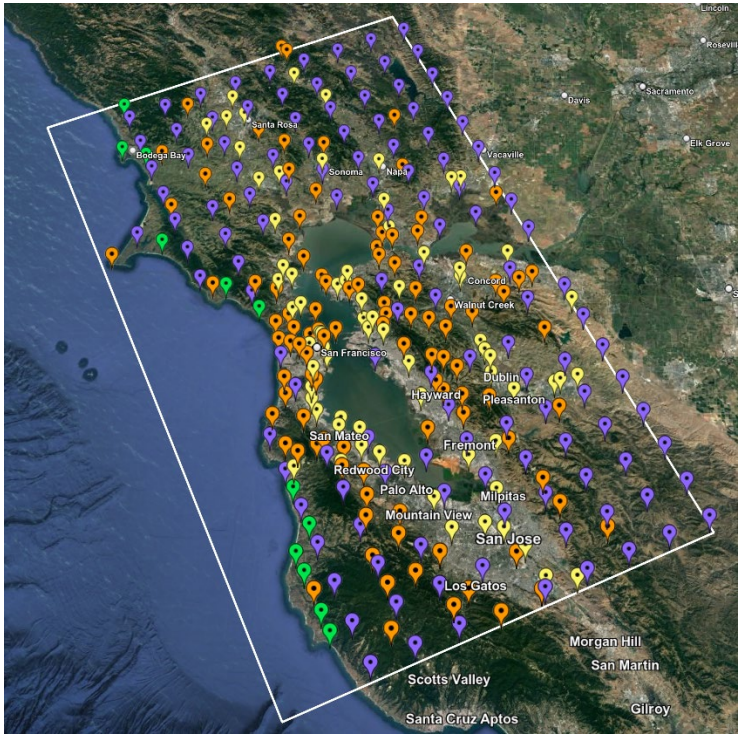
CyberShake overview

- SCEC-developed 3D physics-based probabilistic seismic hazard analysis (PSHA) platform
- Earthquake rupture forecast (ERF) provides list of relevant events + probabilities
- Reciprocity-based approach to simulate low-frequency seismograms for sites of interest
- Intensity measures derived from seismograms
- Hazard results from sites interpolated for map
- Stochastic high-frequency simulations added to produce broadband models



Hazard map from most recent Southern California CyberShake Study, 22.12. Each triangle is a site location.

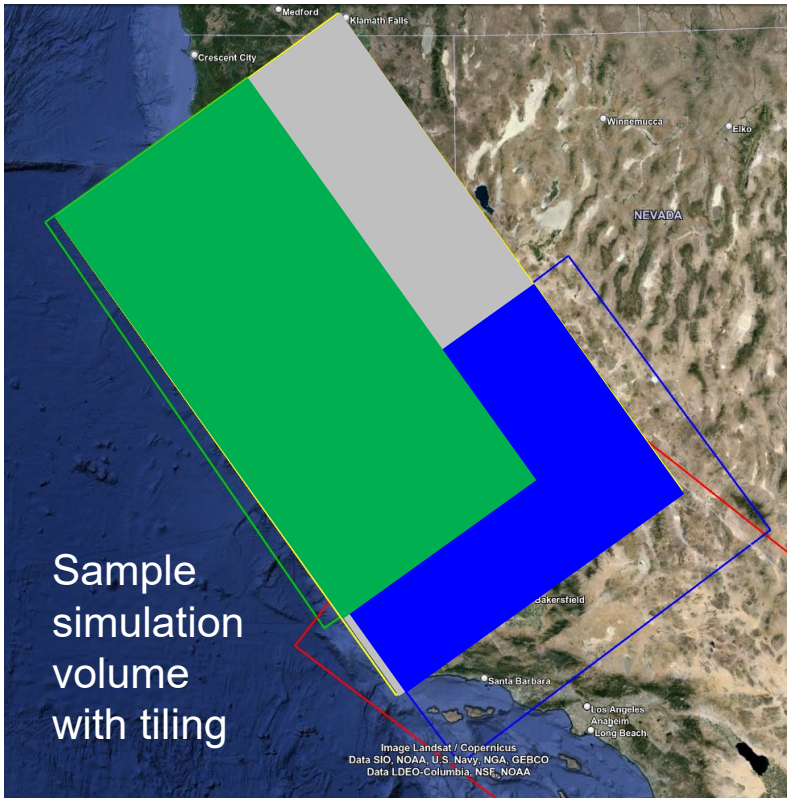
CyberShake Study 24.8: Northern California



Map of 315 Study 24.8 sites

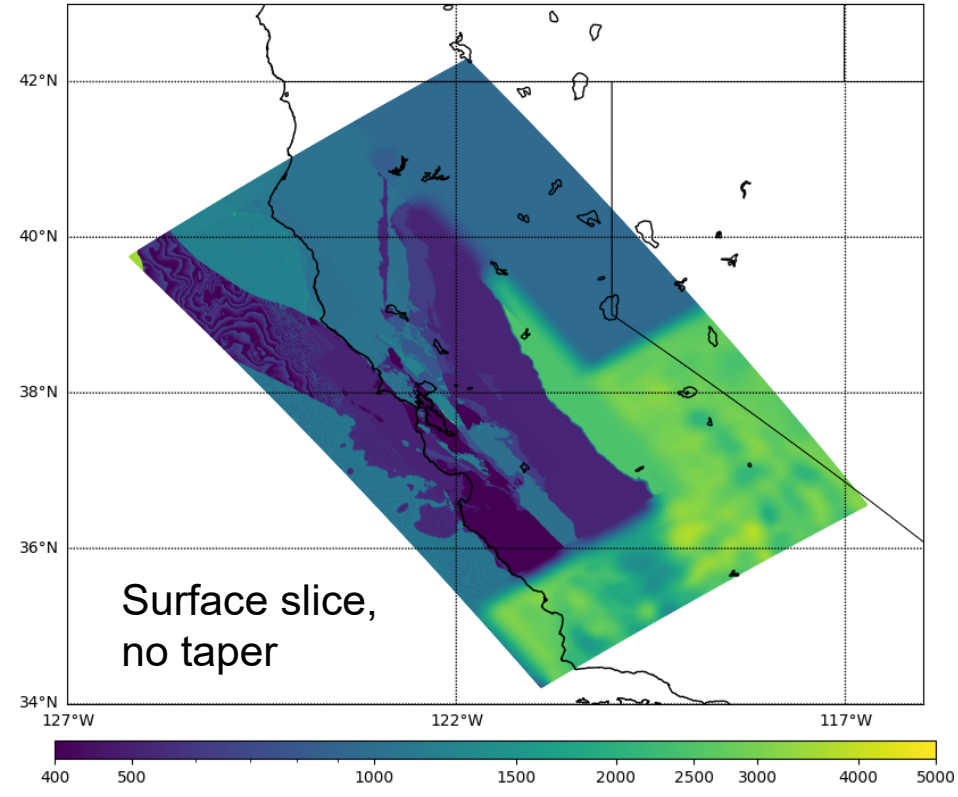
- Changes and updates:
  - Minimum Vs = 400 m/s
  - Removal of southern San Andreas events from ERF
  - Vertical component seismograms
  - Vertical response spectra
  - Period-dependent durations
- Consistent with Southern CA Study 22.12:
  - UCERF2-derived ERF
  - Graves & Pitarka (2022) rupture generator
    - ~200,000 events per site
  - 1 Hz deterministic, 50 Hz broadband using modules from the SCEC Broadband Platform

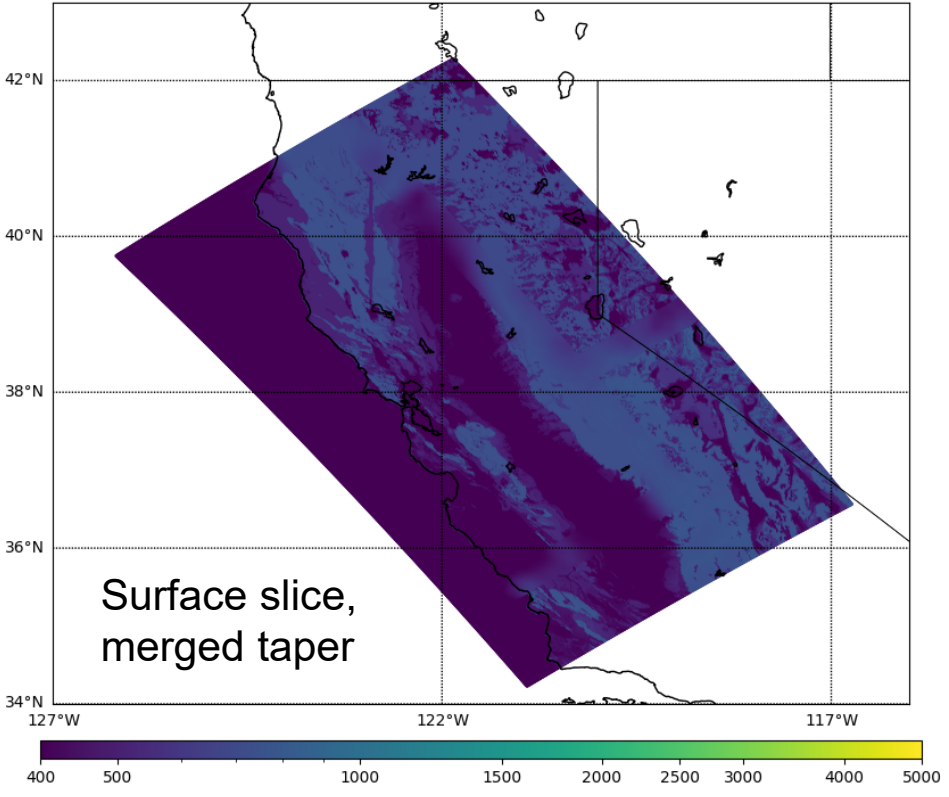
Velocity Model



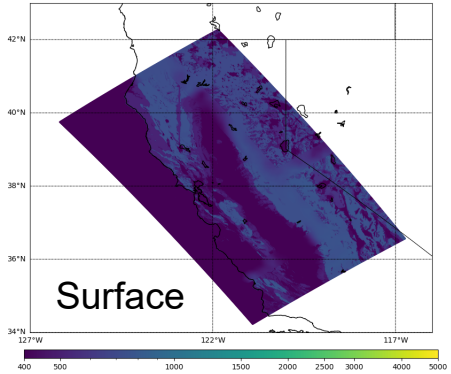
- Model consists of 3 tiled models
  - USGS SFCVM, v21.1
  - CCA-06 (tomographic model)
  - 1D background model, based on Sierra geologic region in SFCVM
- San Leandro Gabbro modification applied to SFCVM to reduce near-surface velocities
- Smoothing applied 20km from all interfaces
- Surface point populated at depth of 20m (80m grid spacing)
- Vp/Vs ratio capped at 4

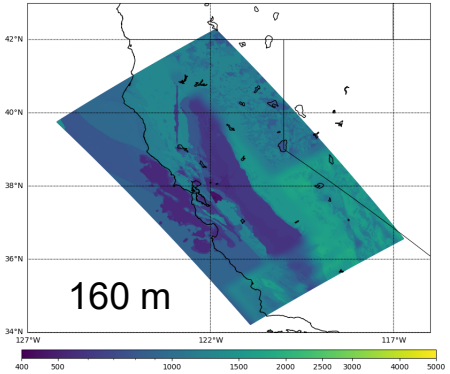
Merged Taper

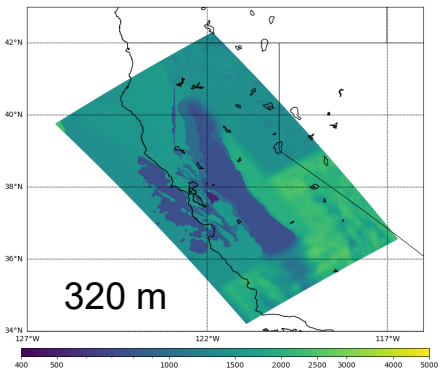


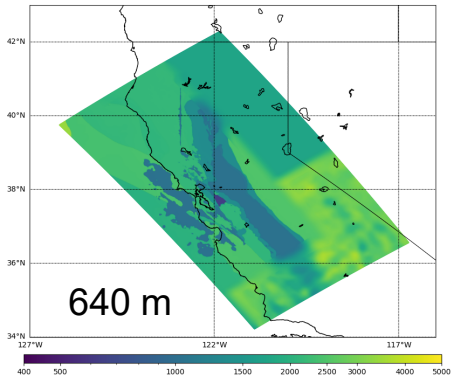


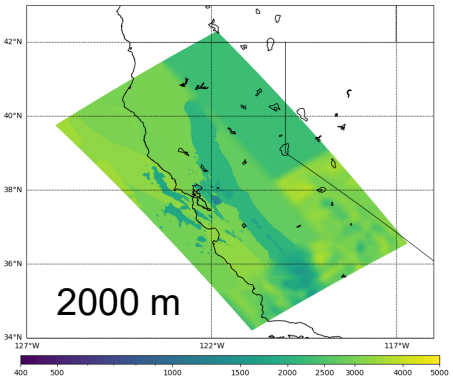
Velocity Model Slices

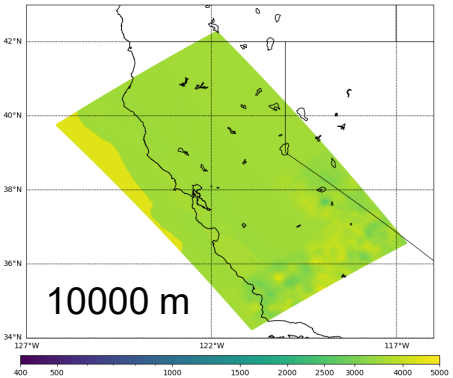








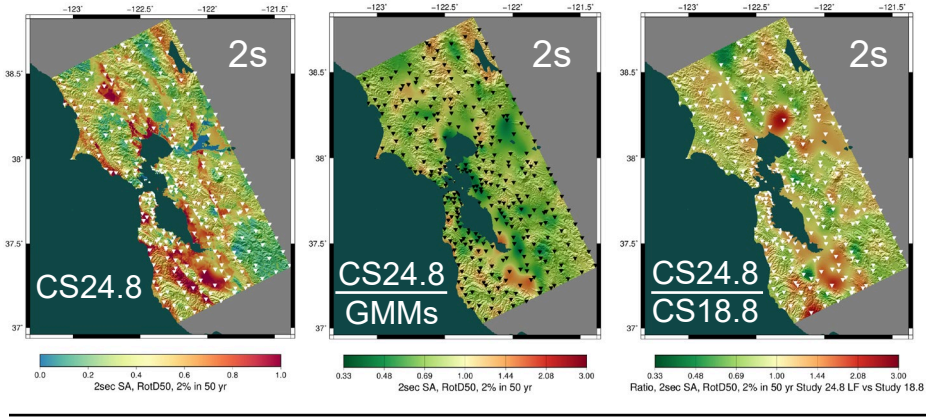


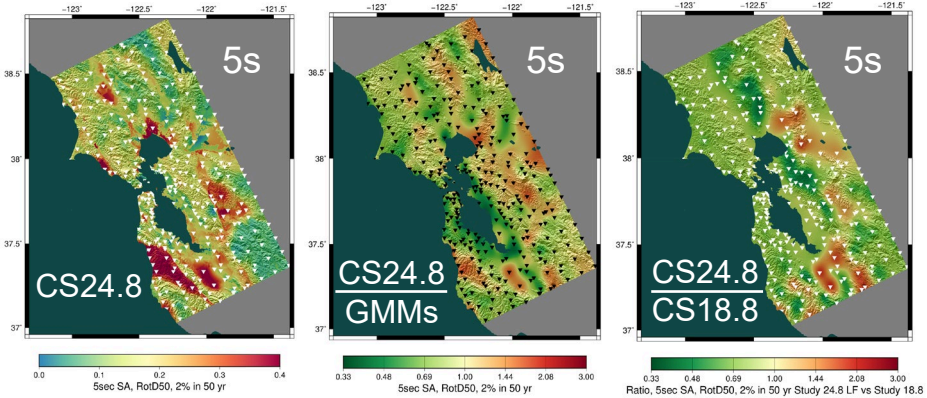


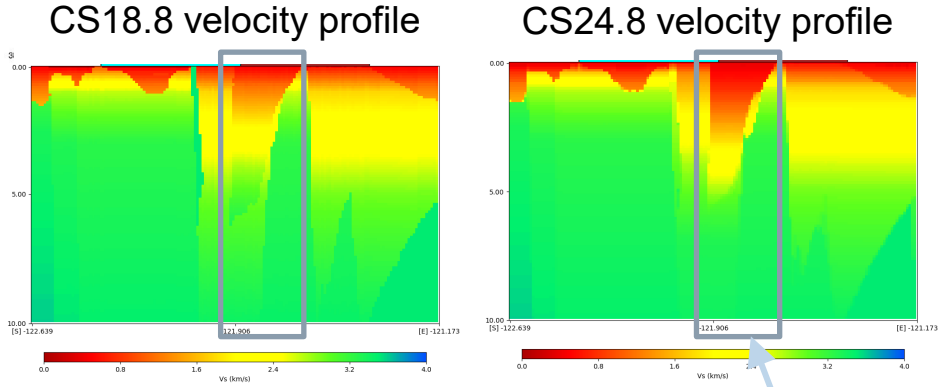
Study 24.8 Statistics

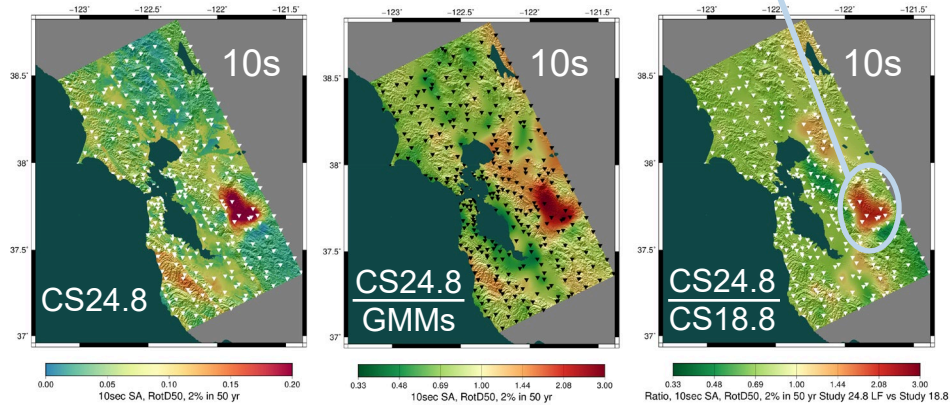
- September 24 – November 8 (45 days)
- Ran wave propagation calculations on OLCF *Frontier* and low-frequency synthesis and stochastic simulations on TACC *Frontera*
- Used about 180,000 node-hours, including up to 44% of *Frontier*
- Ran 27,800 jobs using Pegasus-WMS and HTCondor workflow tools
- Managed 1 PB of data
- Produced 36 TB / 9 million files of output data products
- Generated 126.8 million three-component seismograms and 34.3 billion IMs

Low-frequency Hazard Maps

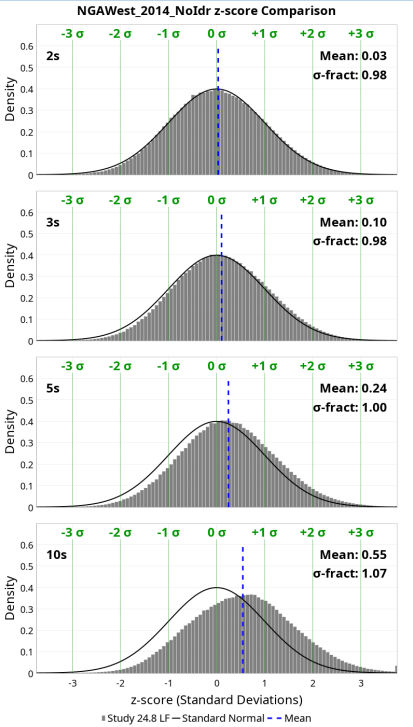






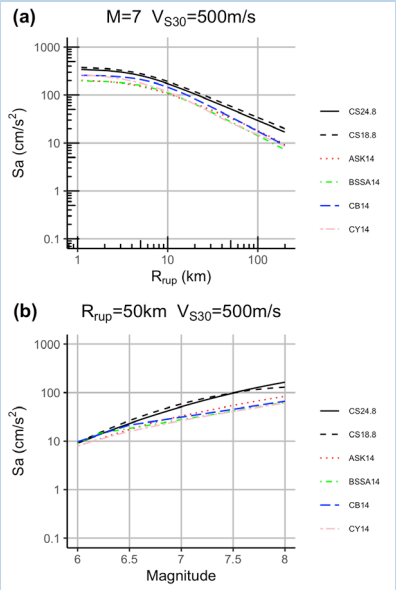


Low-frequency Aggregate Analyses

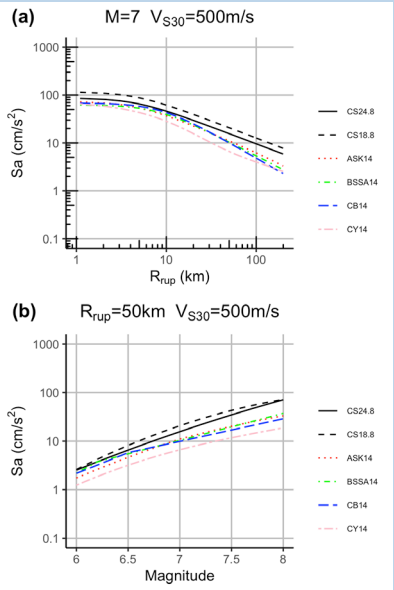


Z-score distribution

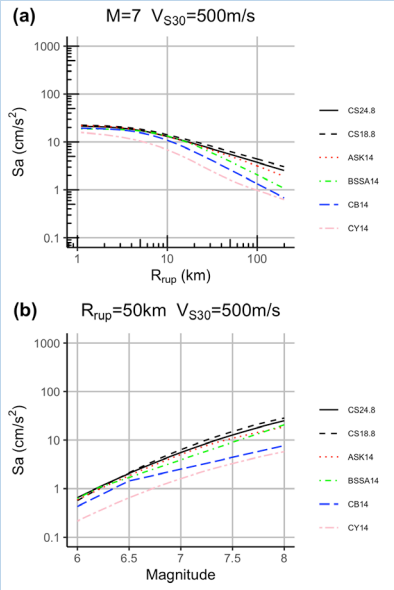
2 sec



5 sec



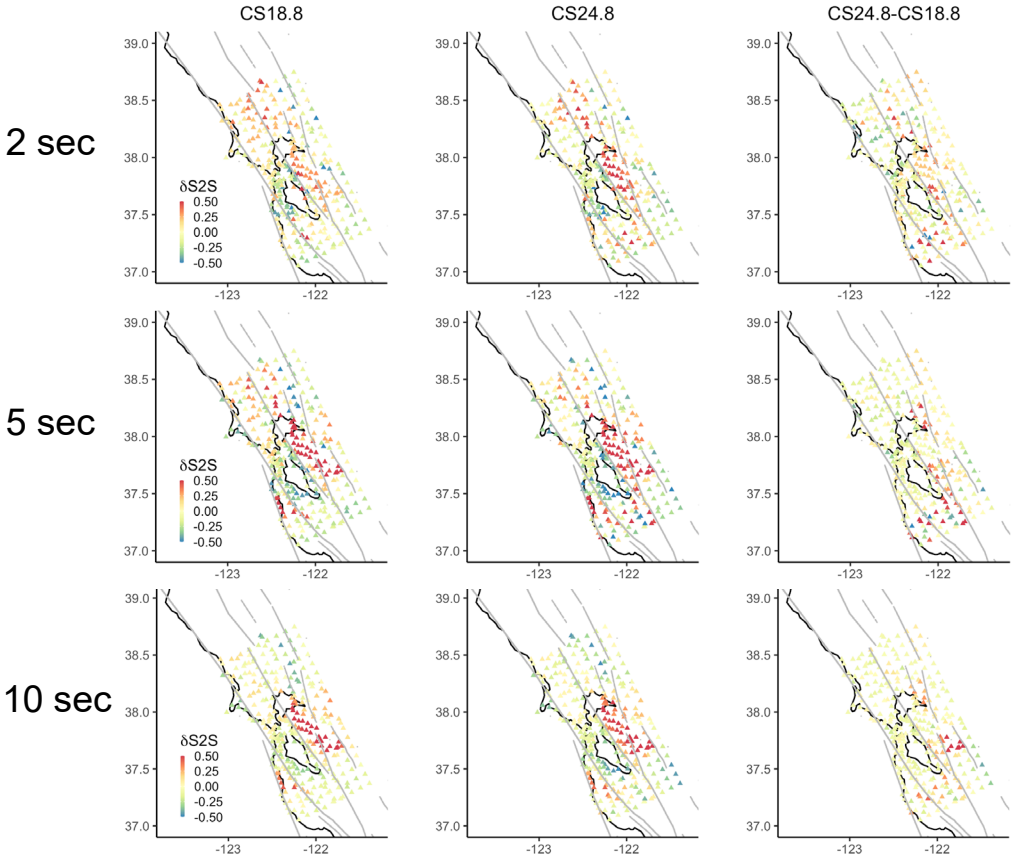
10 sec



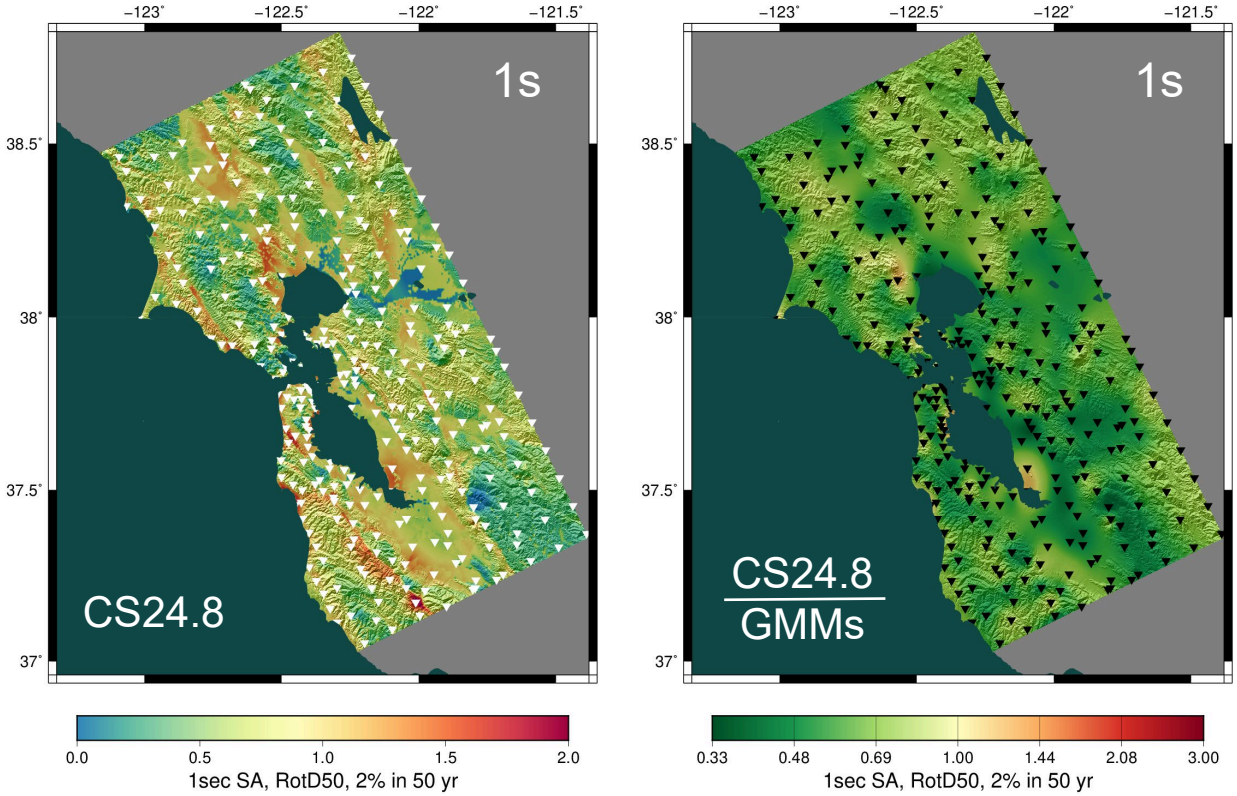
Comparison of distance and magnitude scaling between CyberShake-derived GMM and other GMMs

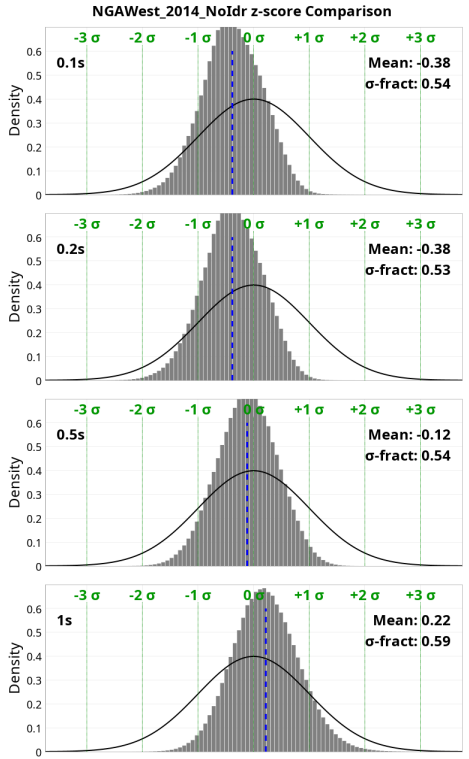
Low-Frequency Site Terms

- Site terms derived from CyberShake-derived GMM
- At 2 and 5 sec, slightly higher in South and East Bay
- At 10 sec, higher site terms in Livermore basin



Broadband Data Products





Z-score distribution

Next Steps

- Short-term:
  - Continue Study 24.8 analysis
  - Improve community access to data products
  - Calculate Fourier spectra for all events
- Medium-term:
  - Perform 2 Hz tests in small region of interest (will require code modifications)
  - Look at reducing minimum Vs
- Long-term:
  - Ways to integrate non-linearity with reciprocity
  - Include topography
- Let me know if you'd like access to data!

Thanks!

U.S. National Science Foundation