Statewide California Earthquake Center

Validation for CyberShake in Northern California

Scott Callaghan (SCEC), Xiaofeng Meng, Rob Graves, Kim Olsen, Mei-Hui Su, Morgan Moschetti, Albert Kottke, Camilo Pinilla-Ramos, Kevin Milner, Fabio Silva, Phil Maechling, Norm Abrahamson, Tom Jordan, Yehuda Ben-Zion, Ahmed Elbanna

April 17, 2026

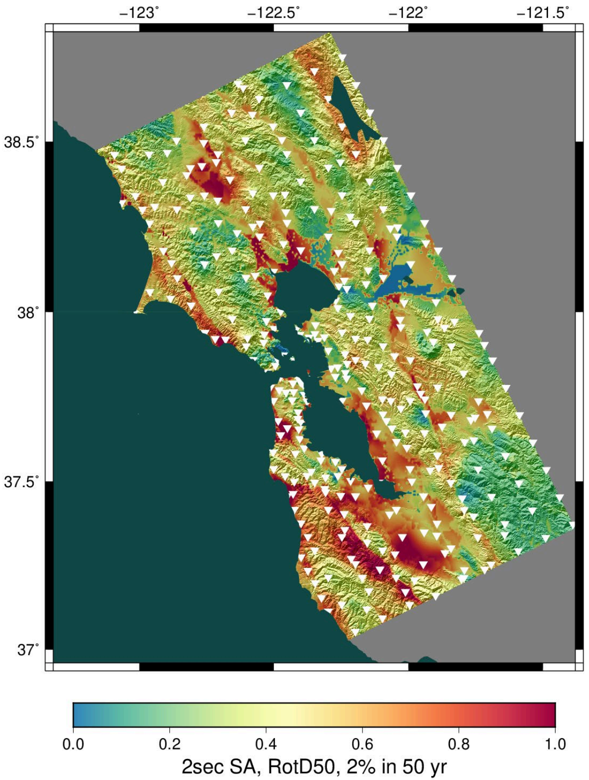
SSA 2026 Annual Meeting

scottcal@usc.edu

CyberShake overview

- SCEC-developed 3D physics-based PSHA platform
- Reciprocity-based approach simulates low-frequency seismograms from ERF
- Intensity measures derived from seismograms
- Hazard products calculated at sites
- Stochastic high-frequency simulations up to 25 Hz added to produce broadband hazard models
- Today, discussing validation work:
  - Focus on Northern California study (24.8), with context of Southern California study (22.12).

Study 24.8 hazard map

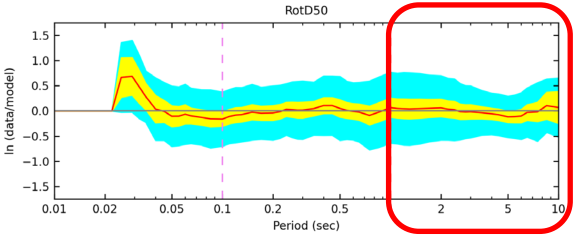


Historical earthquake validation

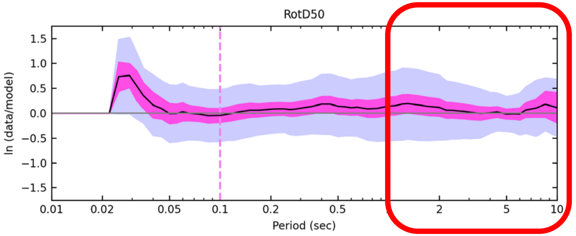
- Create 64 realizations of a historical event
  - Same fault area, hypocenter, and magnitude
  - Different slip distributions
- Simulate ground motions for all realizations for ~40 stations with recordings
- Compare simulated ground motions to recordings
- Intent is not to reproduce historical event exactly; instead, confirm that the ground motions of the event are captured in the distribution

Loma Prieta results

3D CyberShake

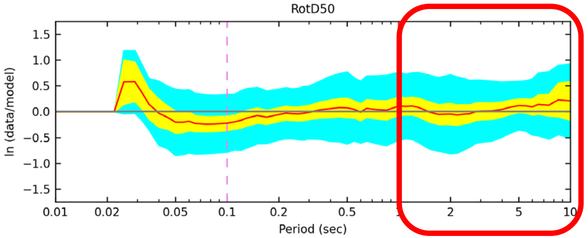


Best fit realization, all sites

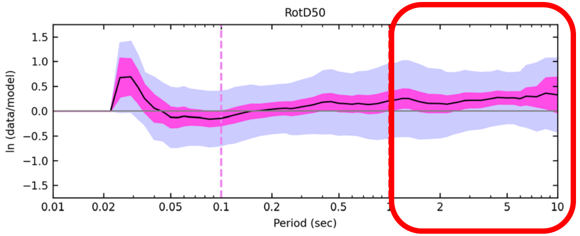


All realizations, all sites

1D Broadband Platform

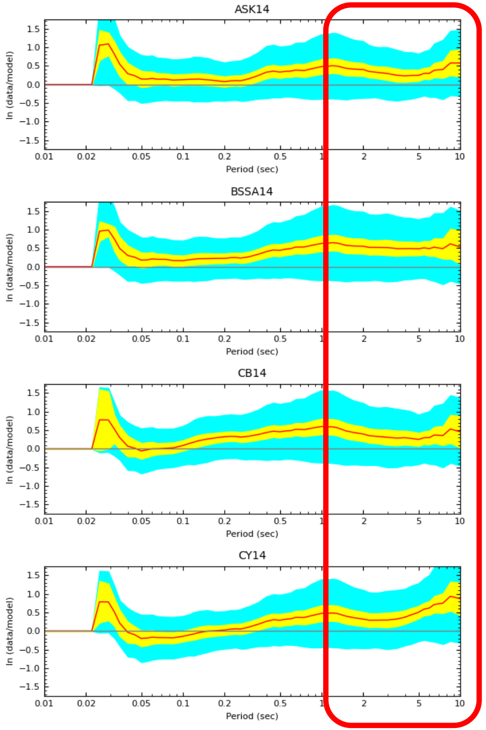


Best fit realization, all sites



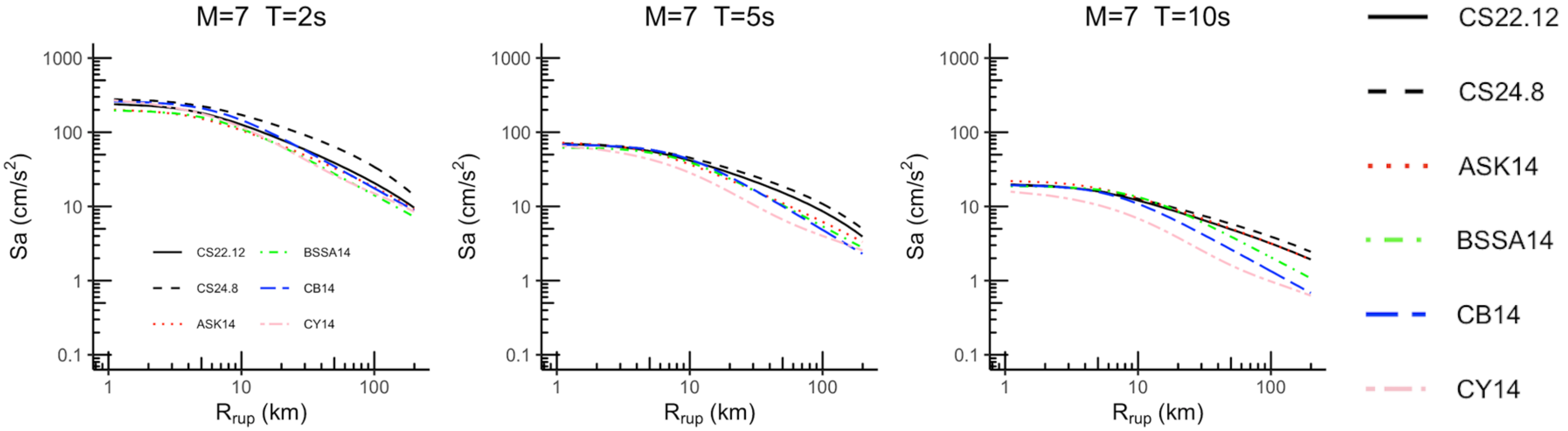
All realizations, all sites

NGA-West2 GMMs



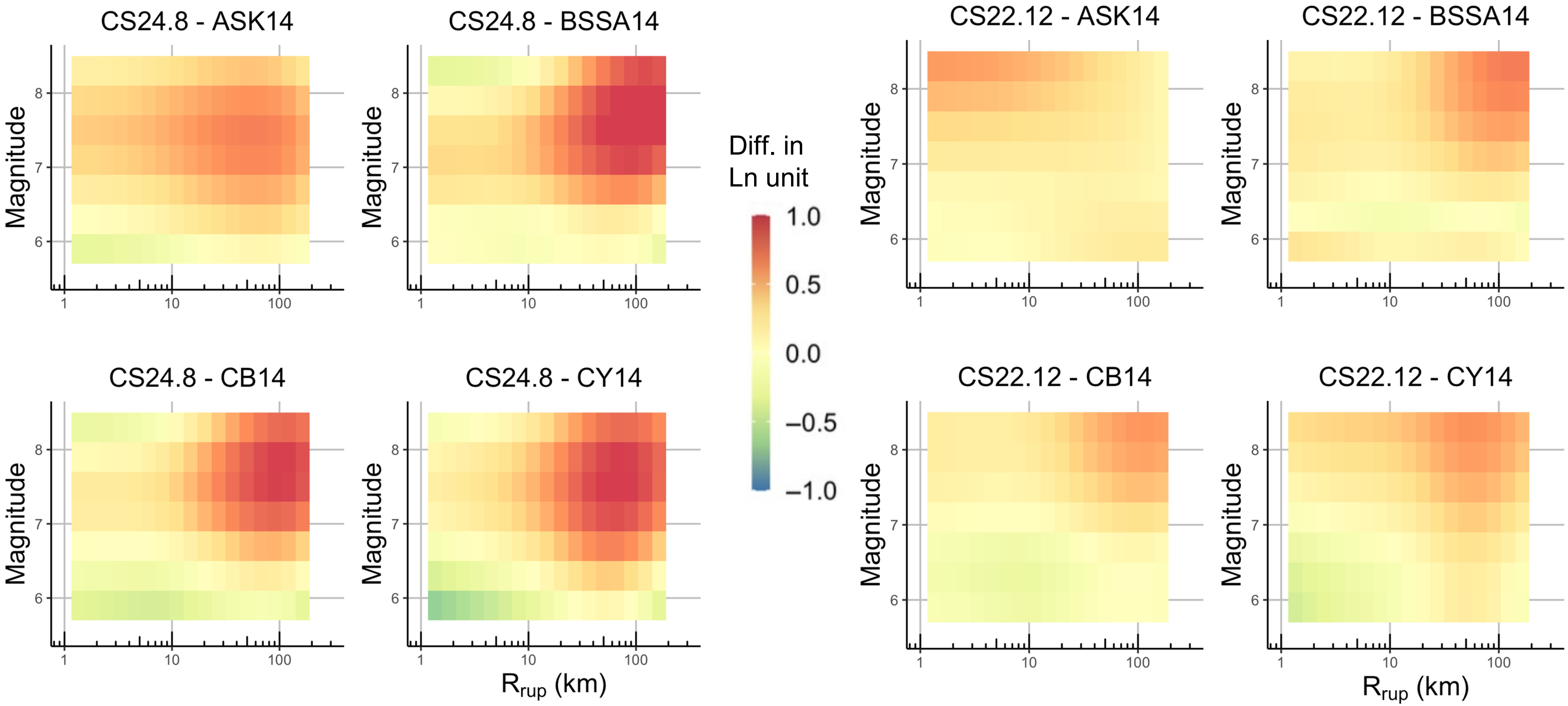
CyberShake-derived GMM

- To facilitate comparisons, we create a partially non-ergodic GMM based on CyberShake



Larger ground motions with Study 24.8 (dashed line), especially at short periods

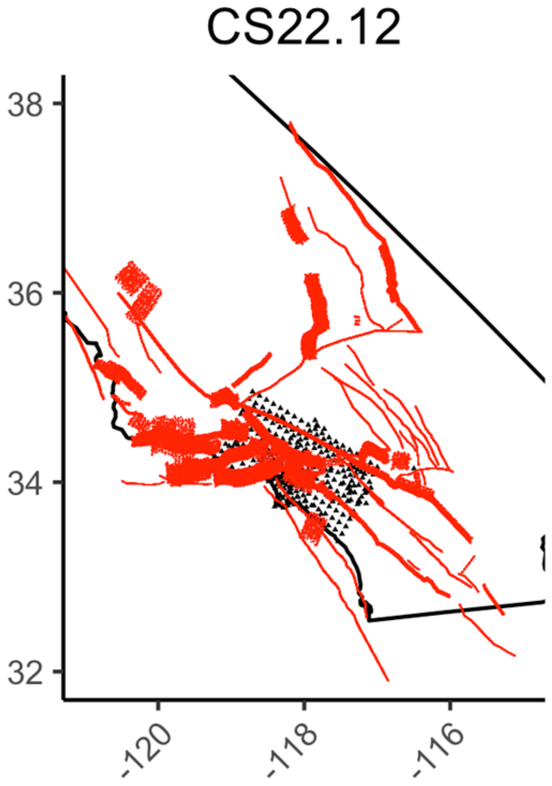
CyberShake comparisons with NGA-W2

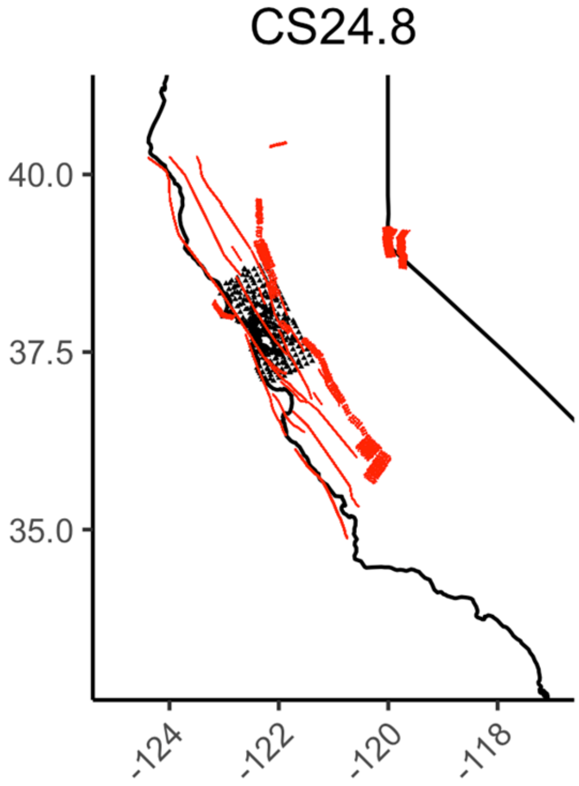


Study 24.8 differences

- We believe higher Northern California CyberShake ground motions are the result of a more coherent velocity model and increased directivity
- Increased directivity in Study 24.8 attributable to:
    - Fault / site geometry
    - Velocity model
    - Fault smoothness

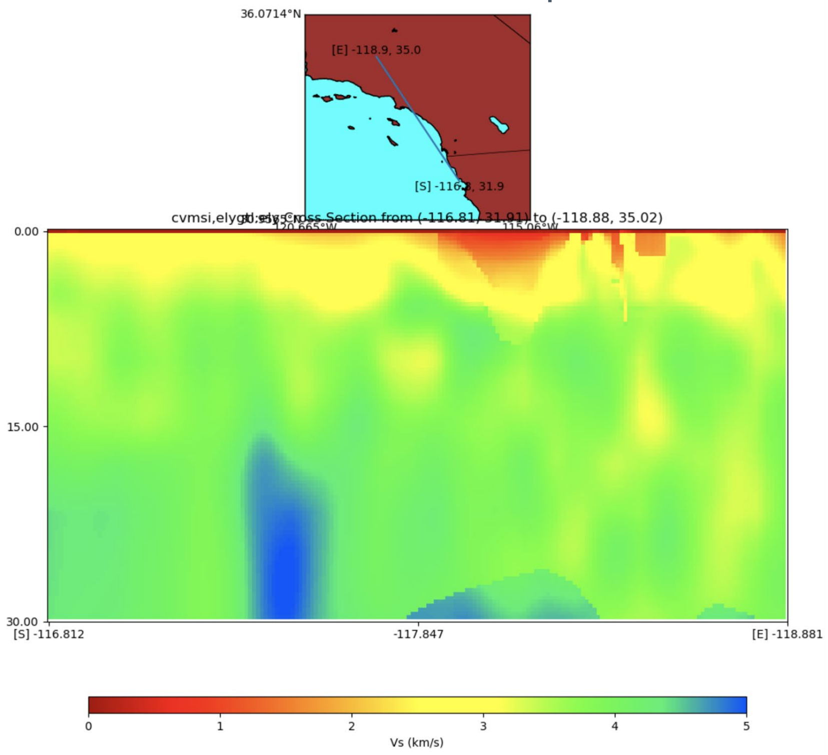
Geometry of faults and sites



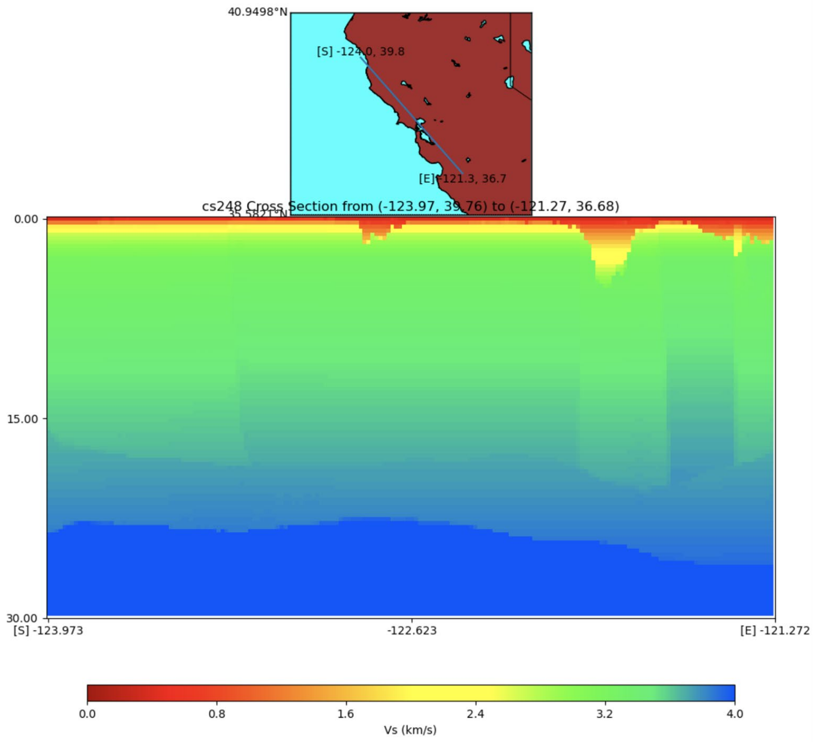


Velocity Model Comparisons

Study 22.12: CVM-S4.26.M01 (tomographic)
+ near-surface taper

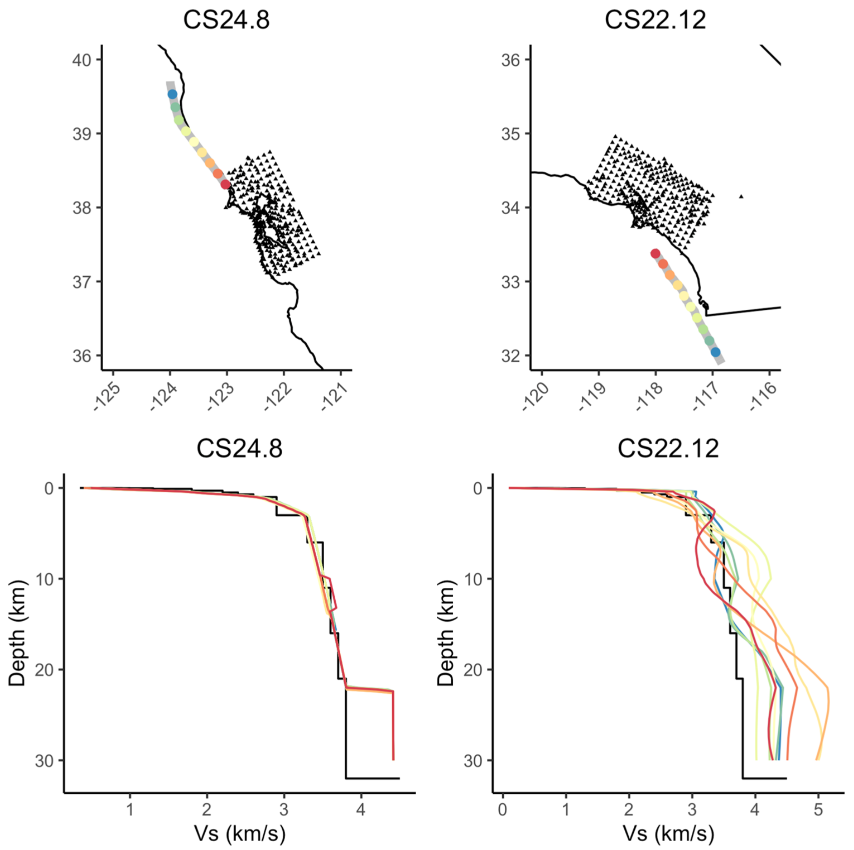


Study 24.8: USGS SFCVM (geologic)
+ near-surface taper



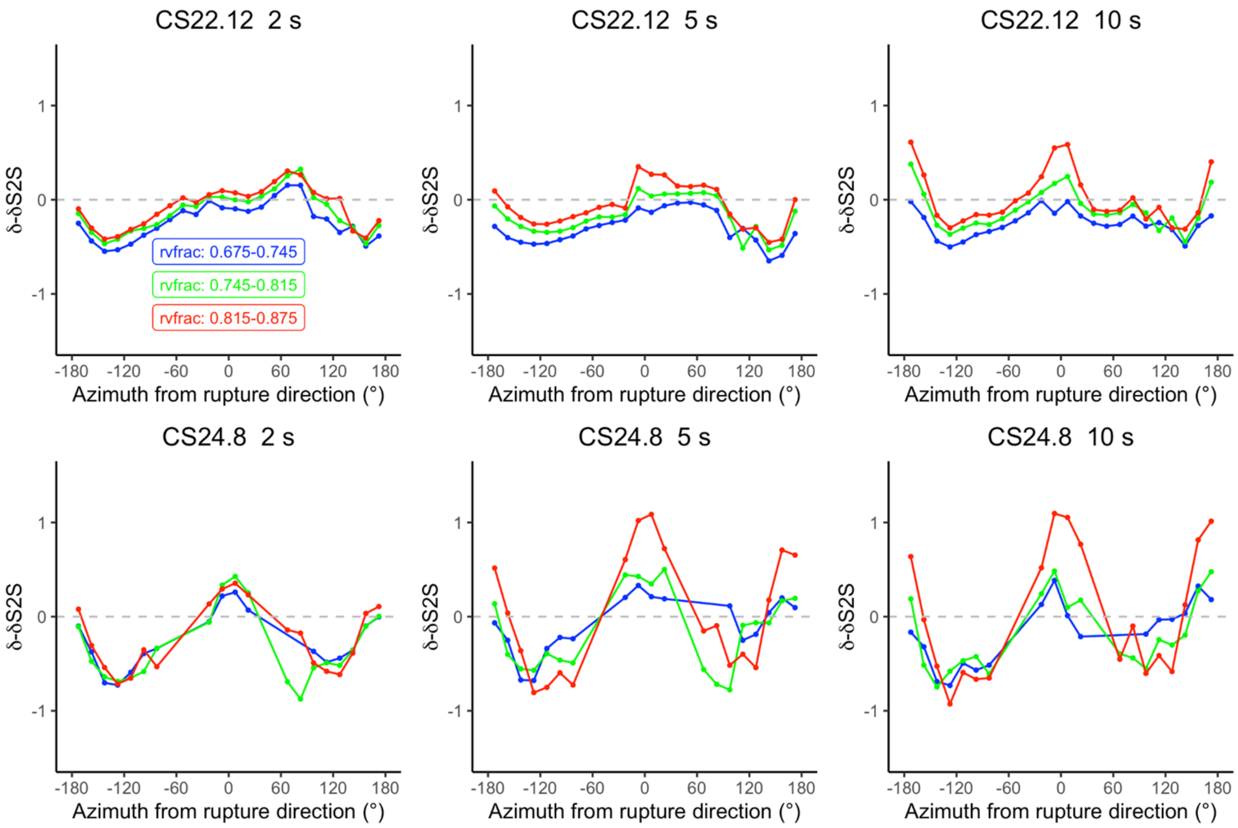
Velocity Model Comparisons

- Sampled velocity model profiles at 12 locations along the N. San Andreas and the Palos Verdes
- Profiles from 24.8 model are more similar than from 22.12 model
- Higher homogeneity in 24.8 leads to larger directivity effects



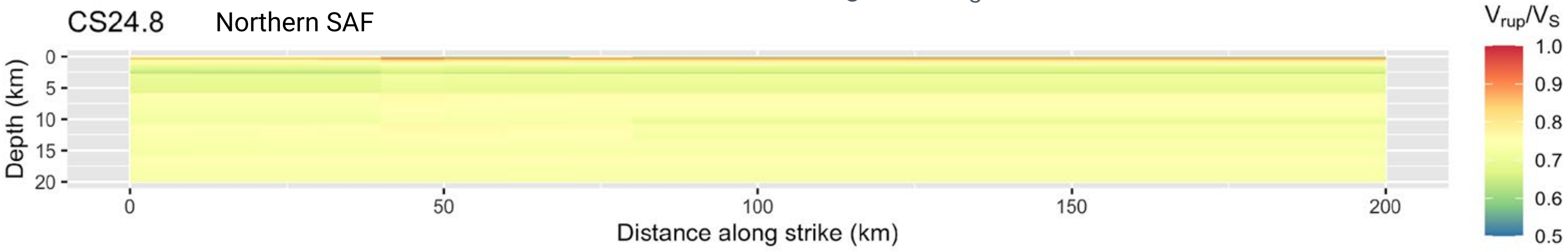
CyberShake rupture velocity

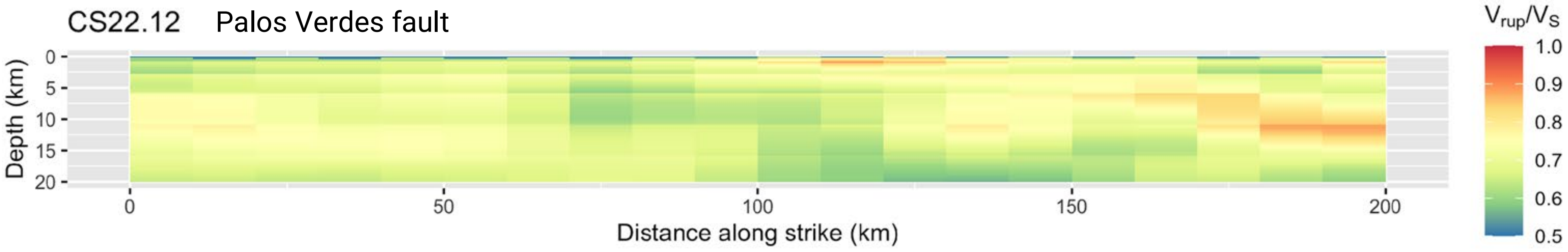
- CyberShake rupture velocities are determined by $V_{rup} = V_{s,1D} \times rvfrac$, where
  - $V_{s,1D}$ is the velocity from a 1D reference model
  - rvfrac is a parameter uniformly sampled from [0.675, 0.875]
- $V_{s,1D}$ is the same for all events for both studies
- rvfrac is unique for each event



Fault Smoothness

$V_{rup}=V_S$ from 1D reference model * rvfrac (0.75)
Background V_S is measured from the 3D model





The average V_{rup}/V_S ratios for CS24.8 and CS22.12 are 0.75 and 0.71, respectively.

Next Steps

- Calculate V_{rup} using 3D model instead of reference 1D
- New SCEC initiative: CyberShake NOVA
  - New velocity model: multi-scale statewide California velocity model, MUSCAL (Yeh et al., 2026)
    - More heterogeneity in northern California velocity model may reduce directivity
    - Potential quantification of velocity model uncertainty
    - Impacts on historical event validations
  - New validation efforts: explore validation beyond spectral acceleration
  - New earthquake rupture forecast based on NSHM23

Thanks!

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