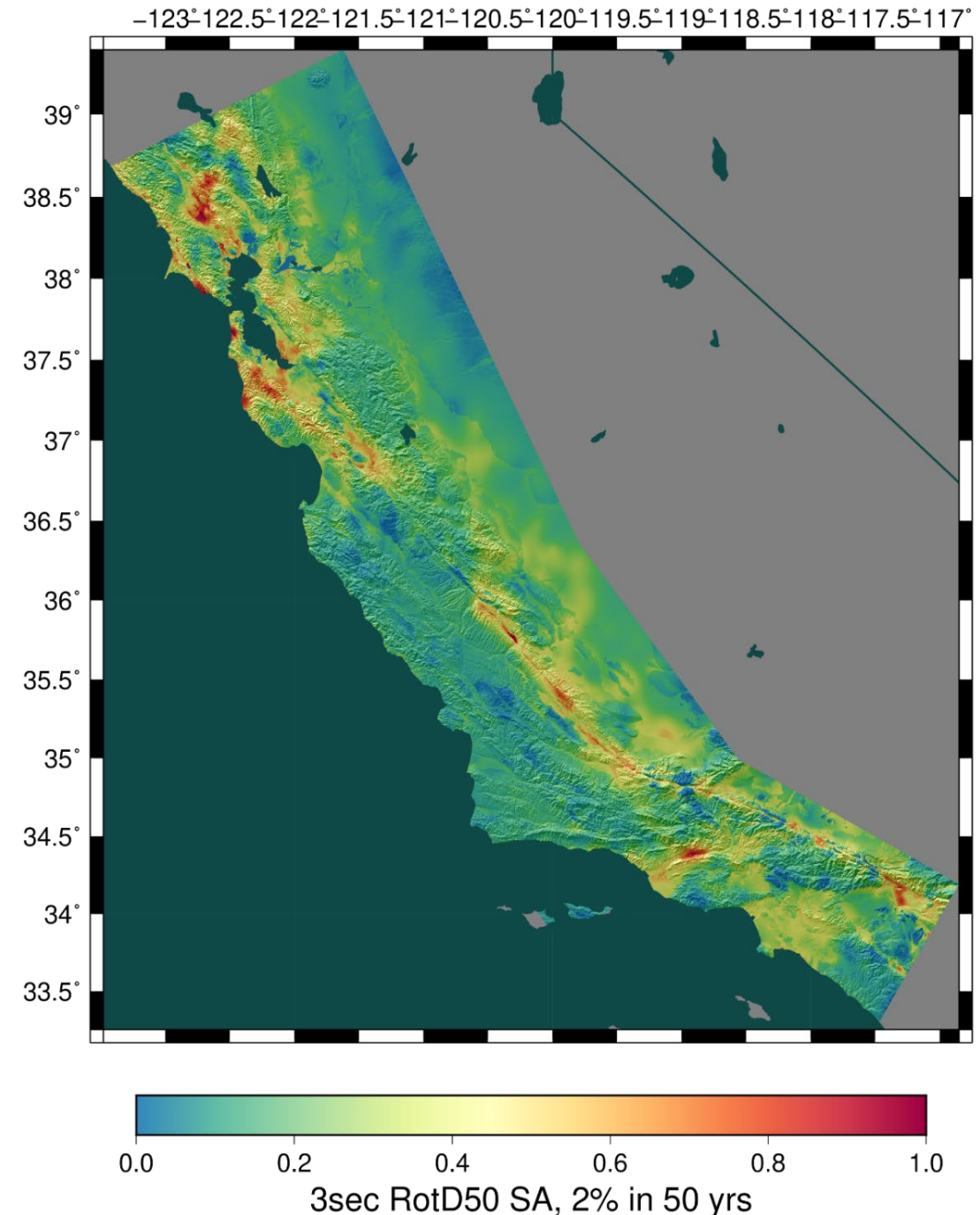


# Verification and Validation of the Broadband CyberShake Platform Using Observations

Scott Callaghan, Christine A. Goulet, Fabio Silva, Philip J. Maechling,  
Robert W. Graves, Kim B. Olsen, Te-Yang Yeh, Albert Kottke, and  
Yehuda Ben-Zion

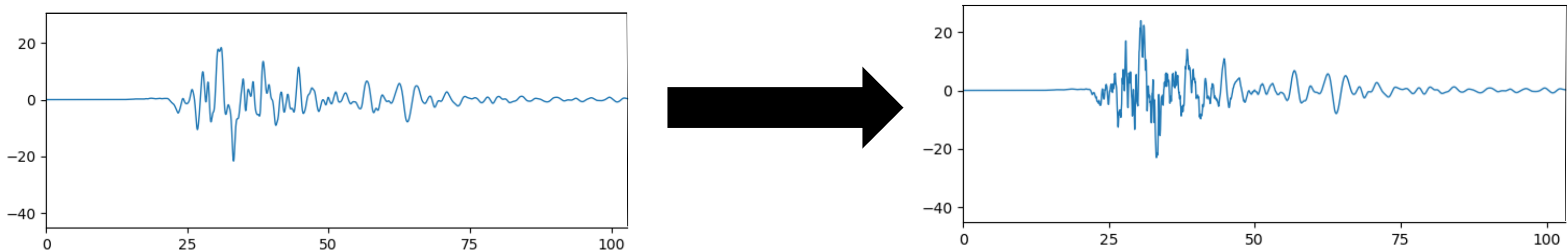
# *CyberShake Platform*

- Southern California Earthquake Center's 3D physics-based probabilistic seismic hazard analysis (PSHA) platform
- UCERF2 or RSQSim earthquake simulator ERF
  - 75,000-500,000 events per site
- Reciprocity-based approach to simulate seismograms
- Intensity measures derived from seismograms
- Hazard results from individual sites interpolated with GMPE basemap

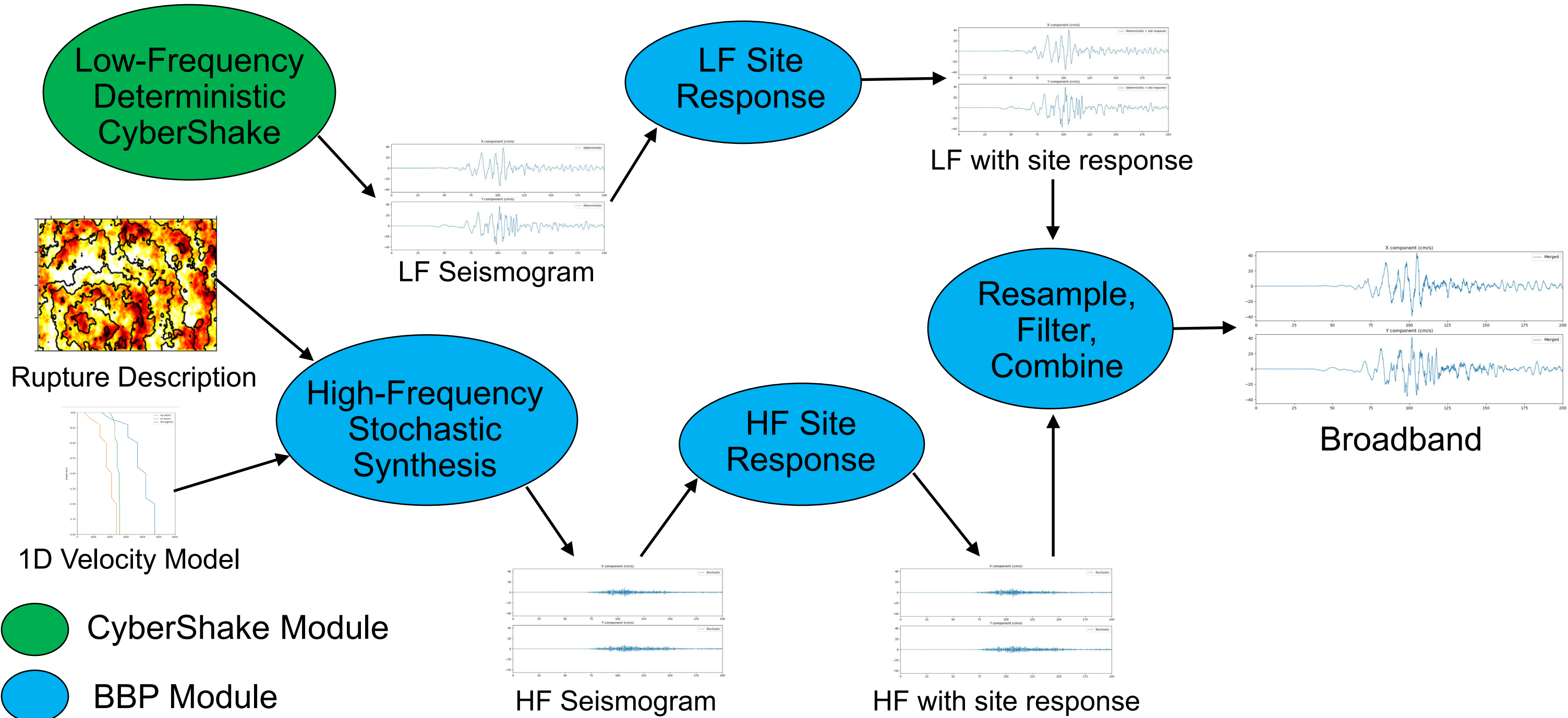


# *Broadband CyberShake*

- Deterministic CyberShake currently limited to 1 Hz
- Computational cost scales as  $(frequency)^4$
- Additional physics required
- Higher frequencies desirable for many applications
- Alternatively, combine SCEC Broadband Platform (BBP) high-frequency stochastic modules with CyberShake low-frequency deterministic



# Broadband CyberShake Processing Stages



 CyberShake Module

 BBP Module

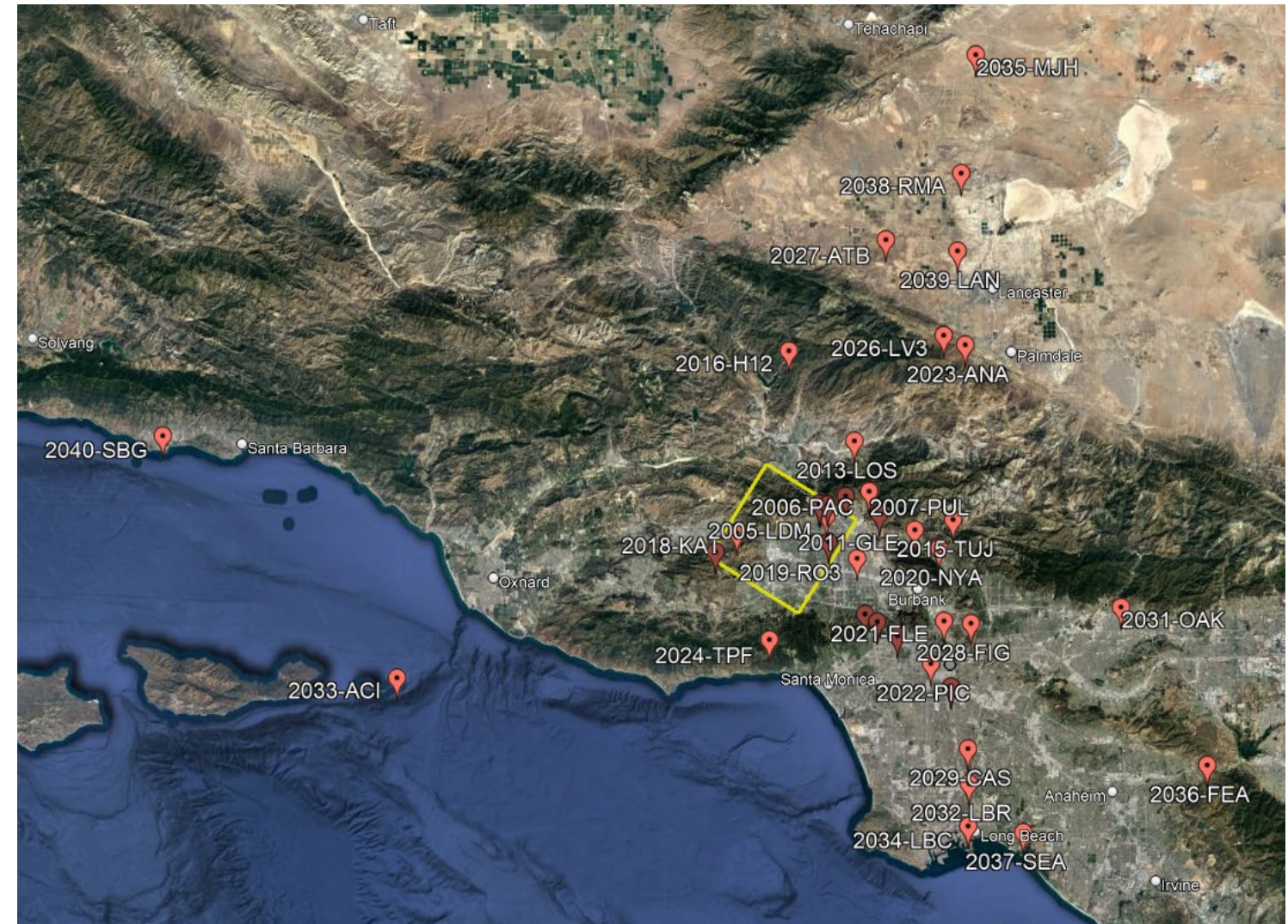
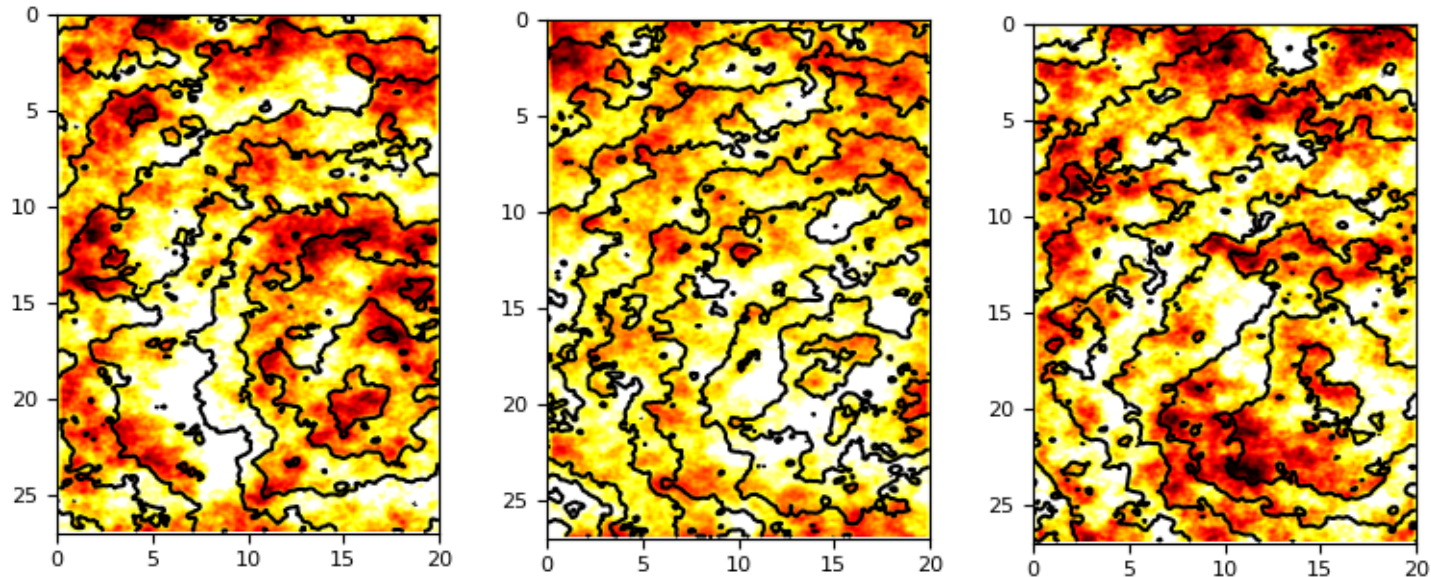
# *Verification and Validation Motivation*

- Develop simulation platform for use in engineering applications
- Show that the method works
  - Produce reasonable ground motions for both historic and hypothetical events
- Historic events
  - Can get very good low-frequency agreement with tuning
  - Here, want to validate entire method on known and unknown events
  - Goal is to get reasonable results on realization sweeps



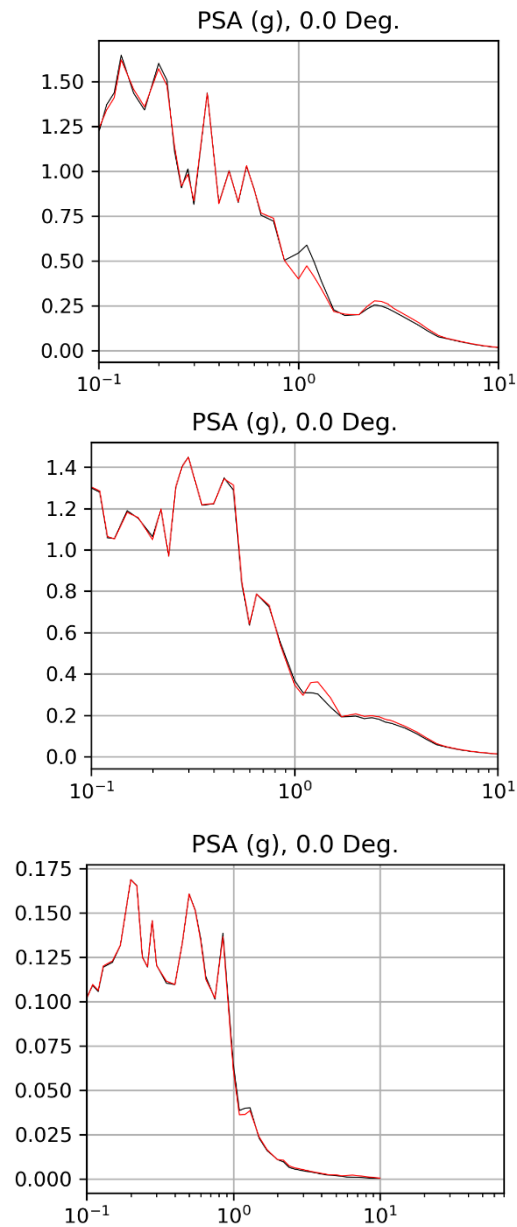
# Verification and Validation Events

- 1994 Northridge event
- 38 stations in Southern California
- Multiple realizations
  - Hypocenter and magnitude preserved
  - Variations in slip

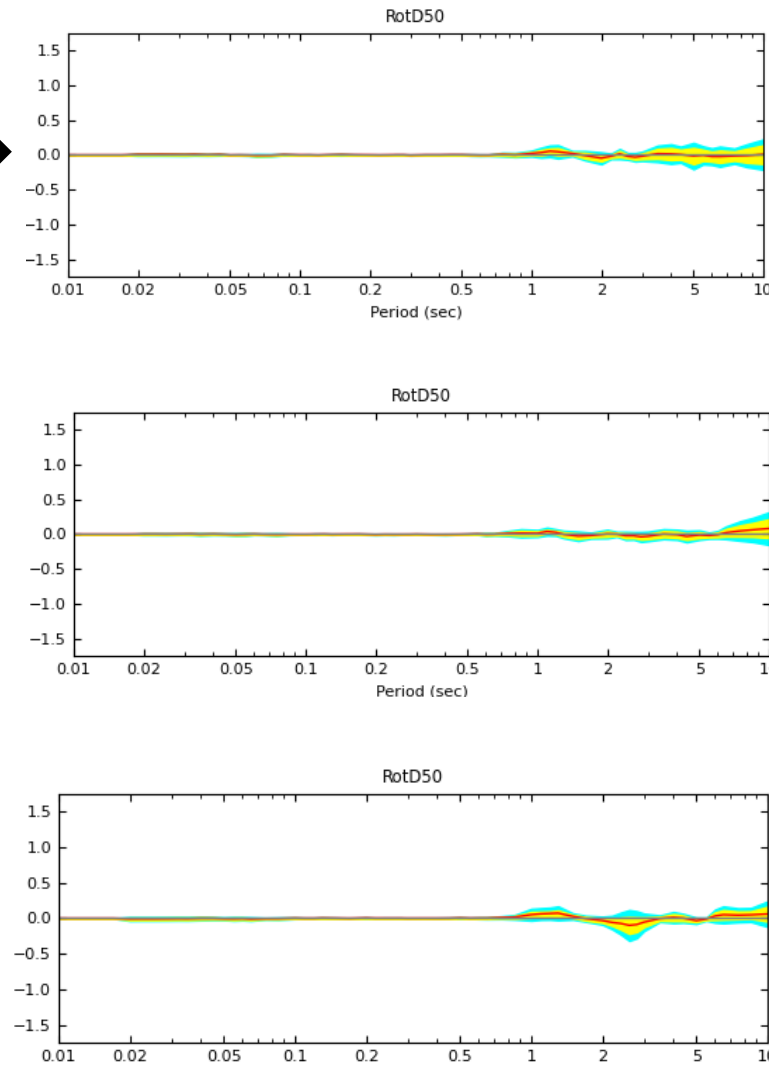




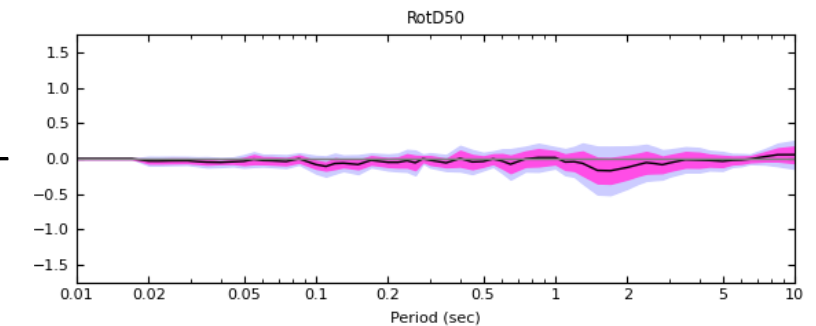
# Comparison Data Products



RotD50 PSA comparisons,  
1 station, 1 realization



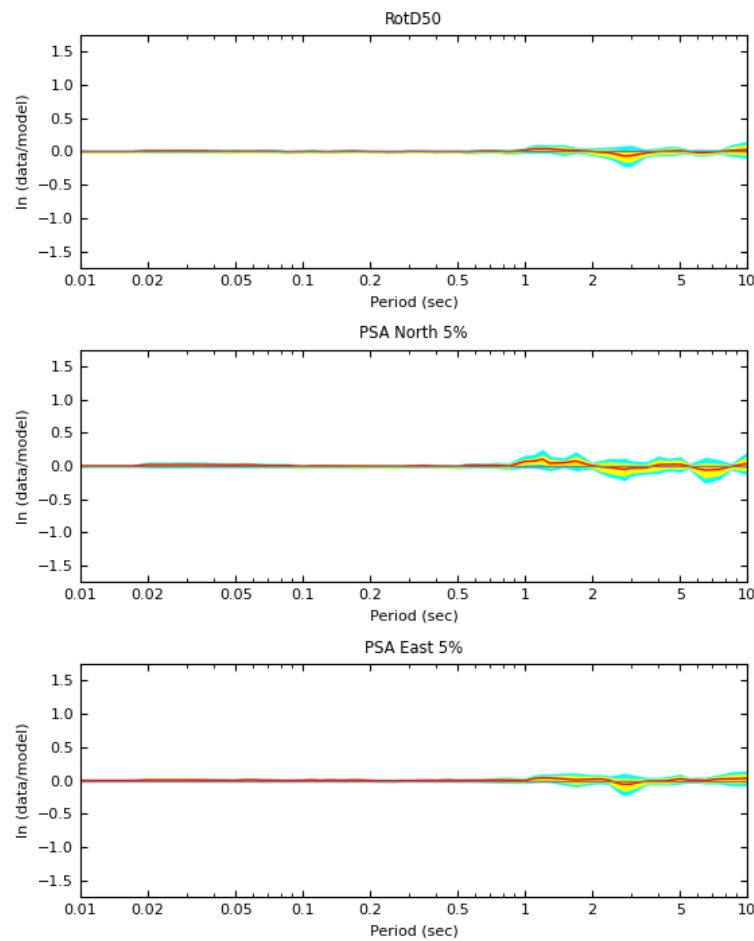
Goodness-of-fit, 1 realization,  
aggregated across stations



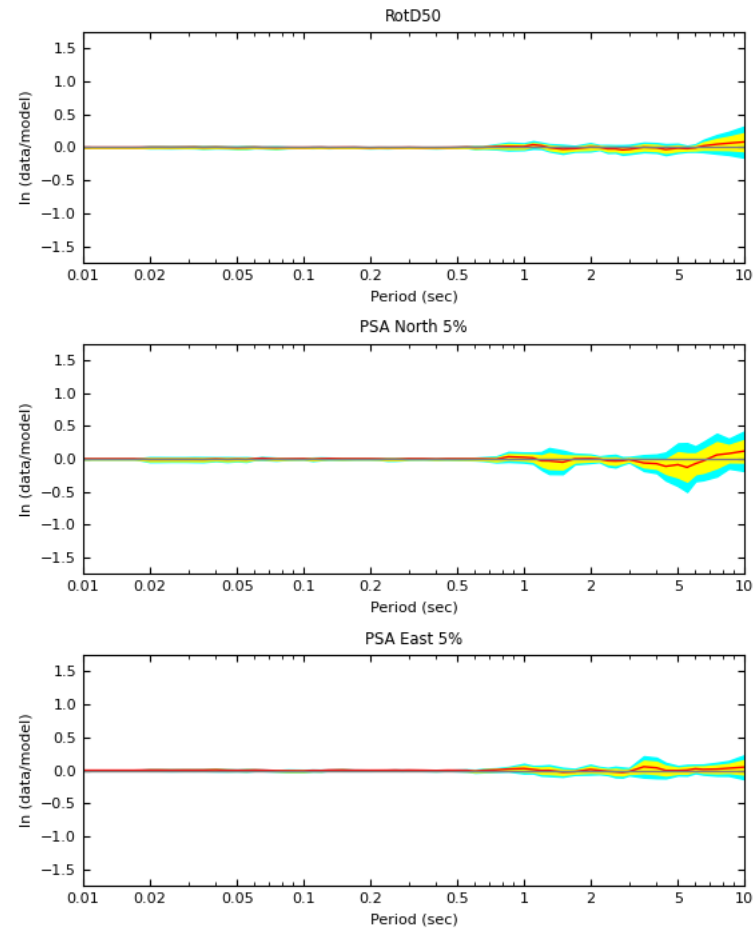
Goodness-of-fit, across all  
stations and realizations

# 1D Broadband CyberShake vs 1D BBP

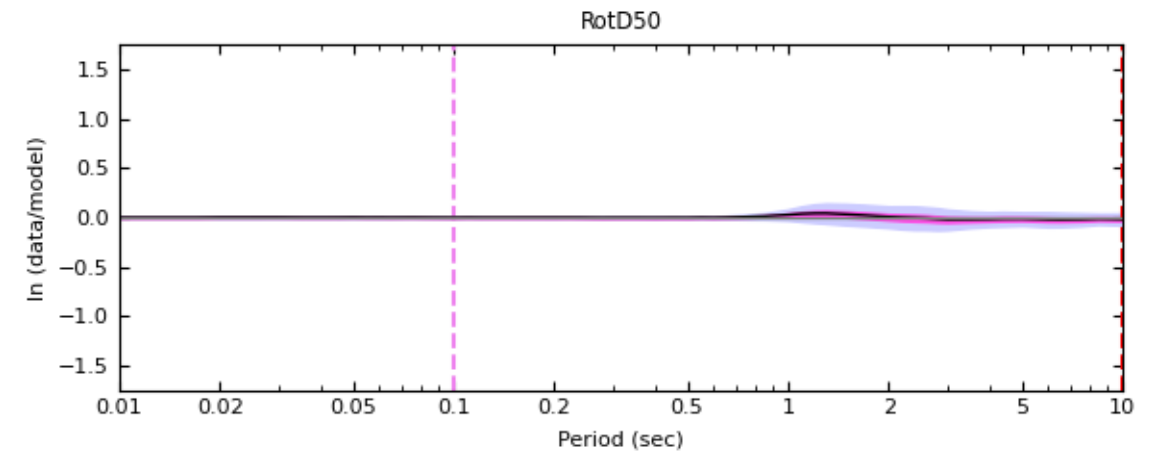
- 38 stations, 10 realizations
- High degree of agreement



Realization 4



Realization 8

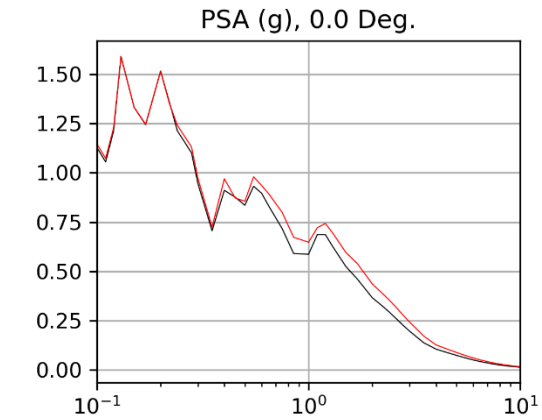
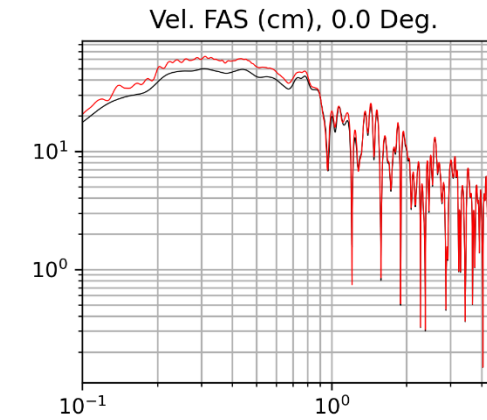
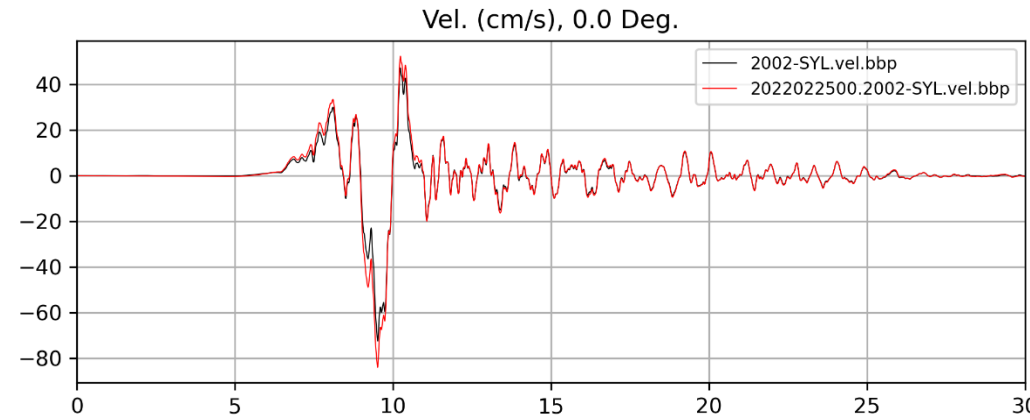


Combined goodness-of-fit

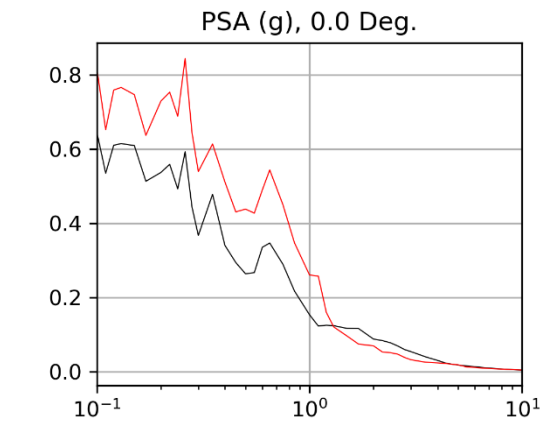
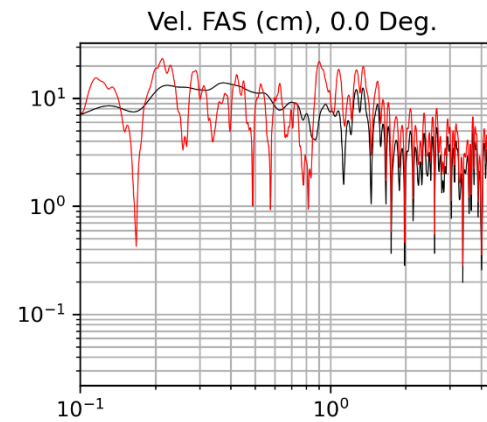
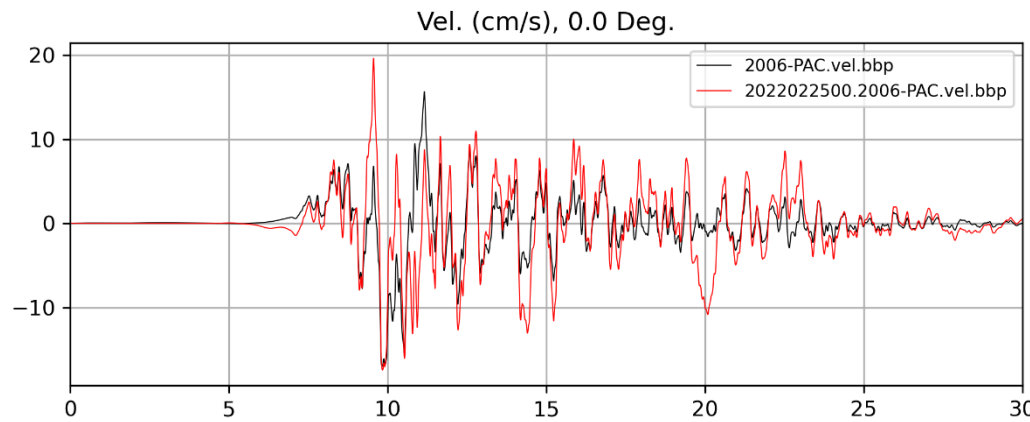


# 3D Broadband CyberShake vs 1D BBP

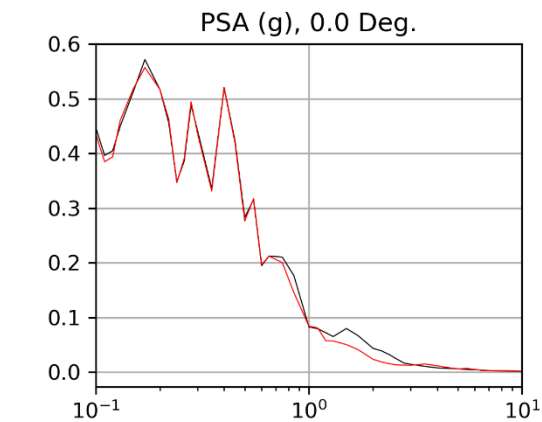
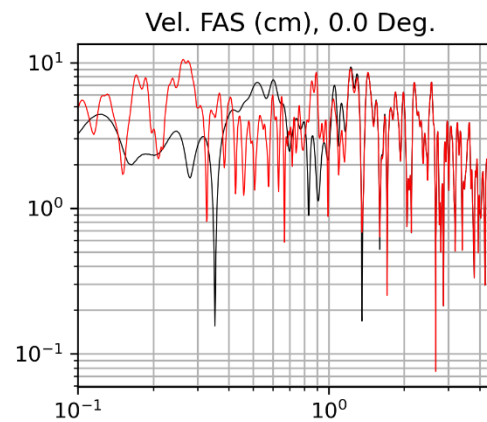
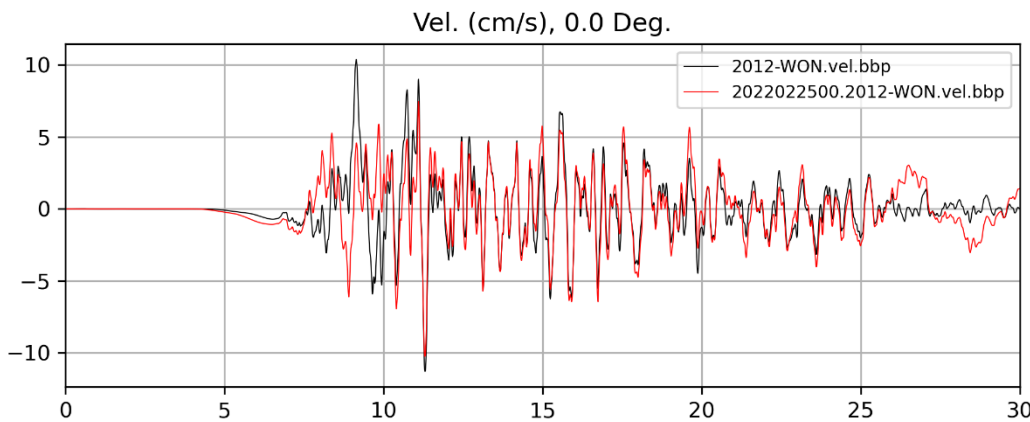
Station SYL



Station PAC



Station WON

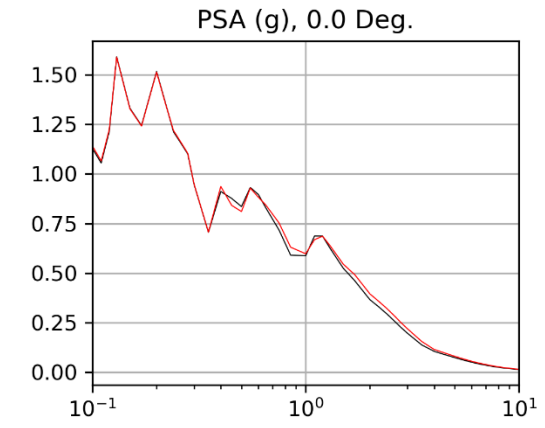
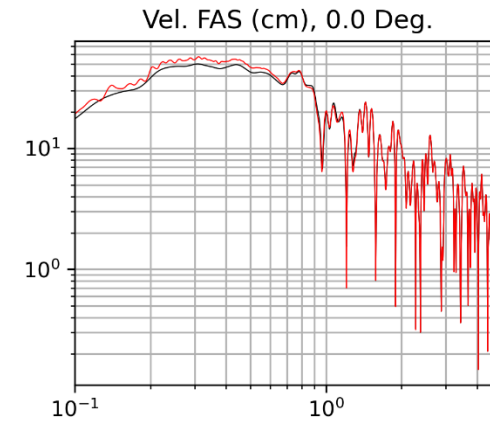
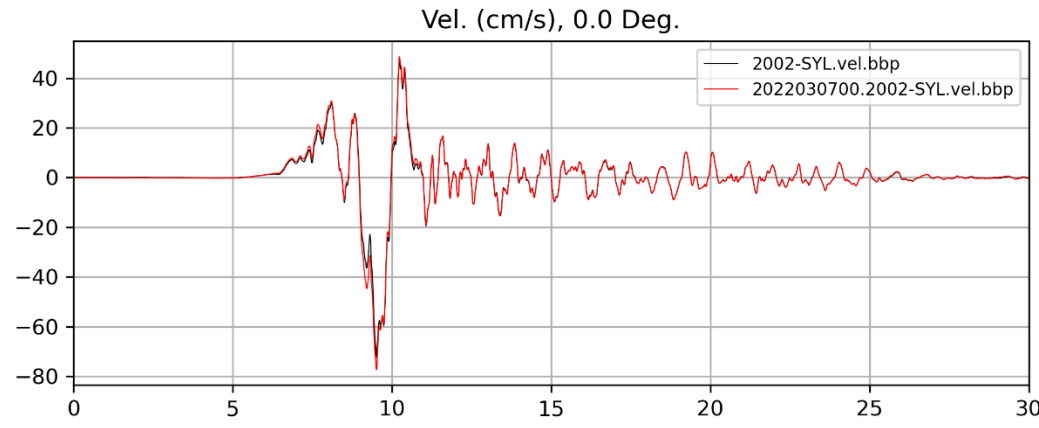


— 3D CyberShake

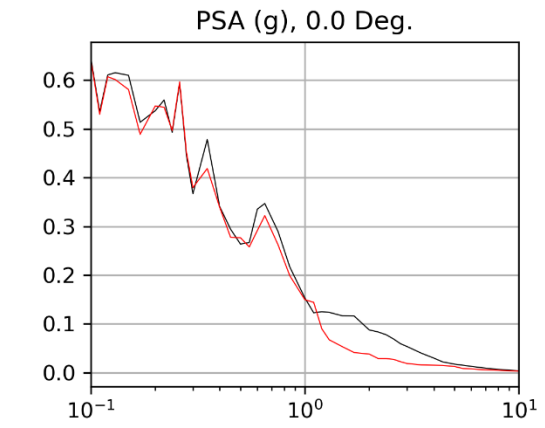
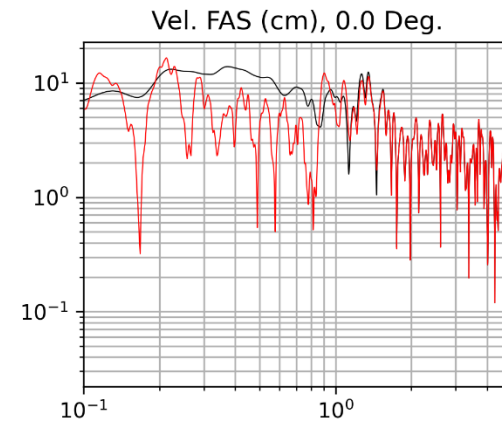
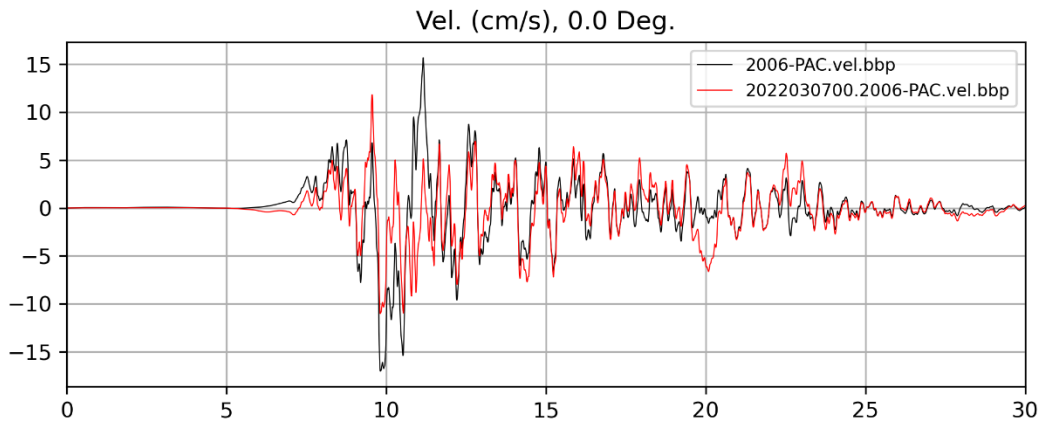
— 1D BBP

# 3D BB CS vs 1D BBP, same Vs30

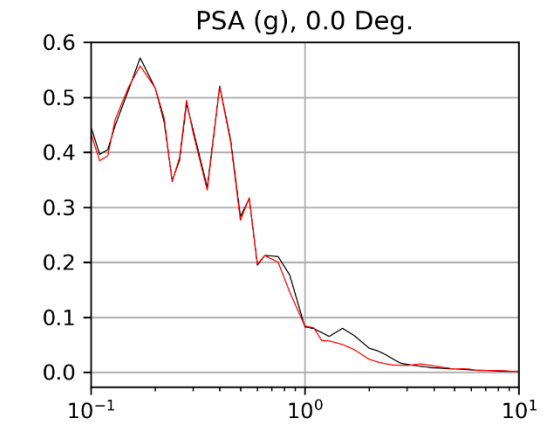
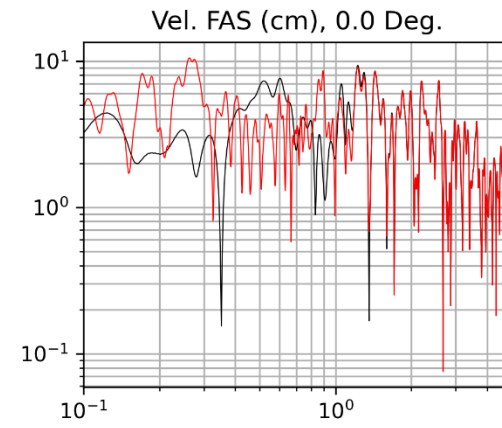
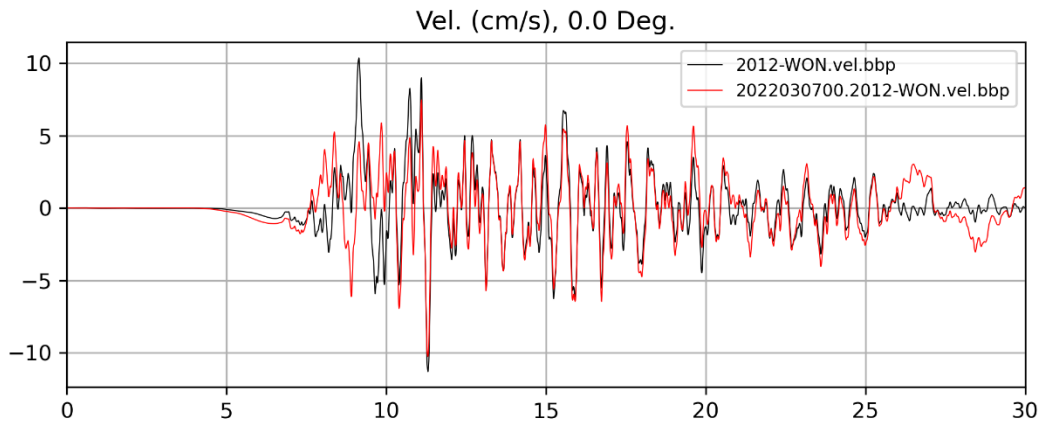
Station SYL



Station PAC



Station WON

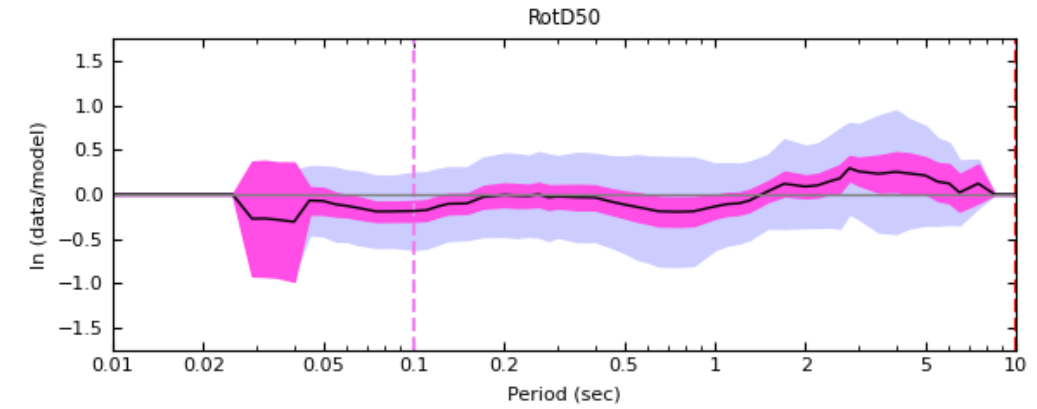
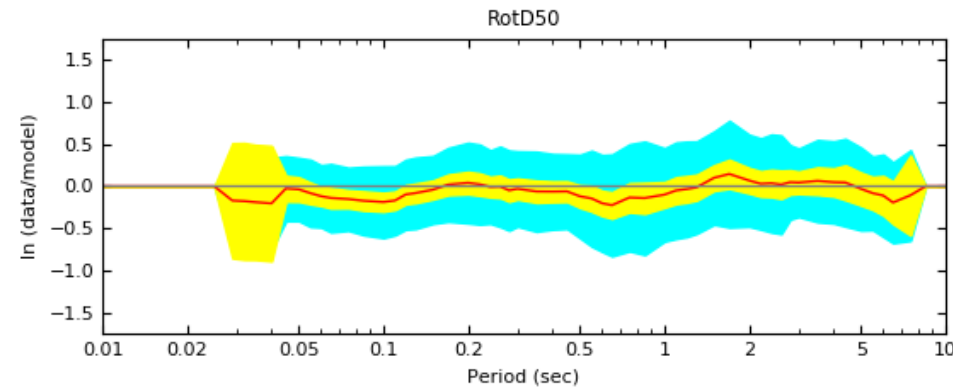
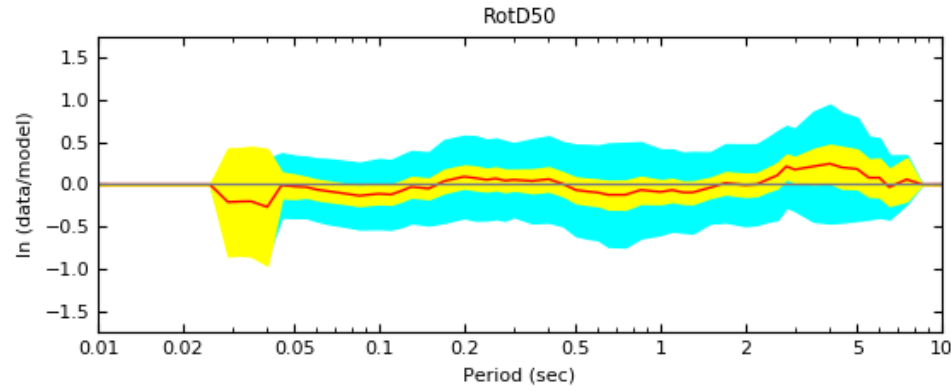


— 3D CyberShake

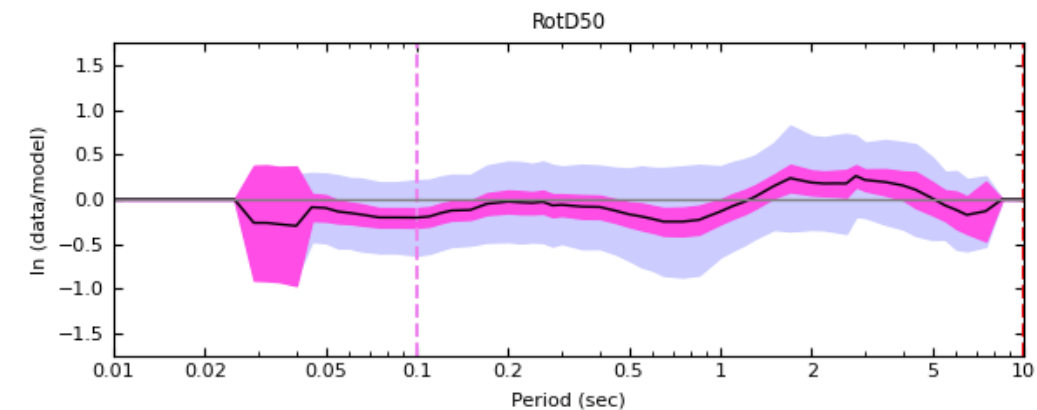
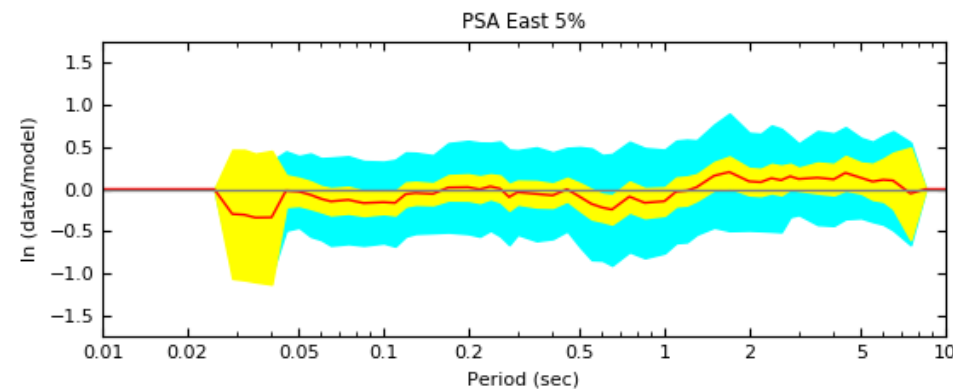
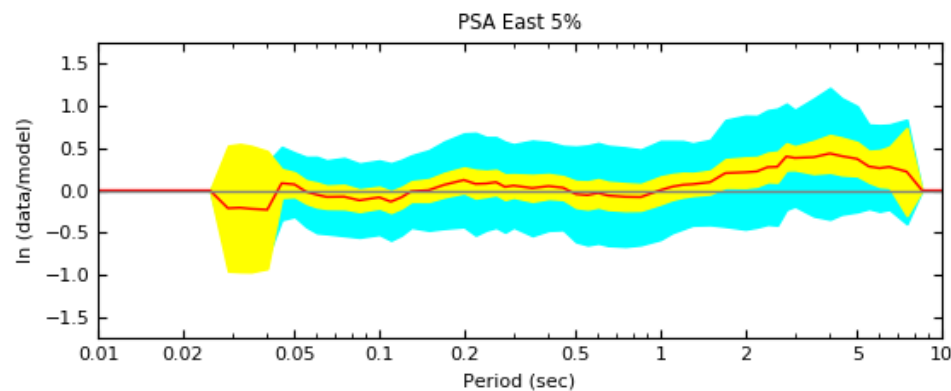
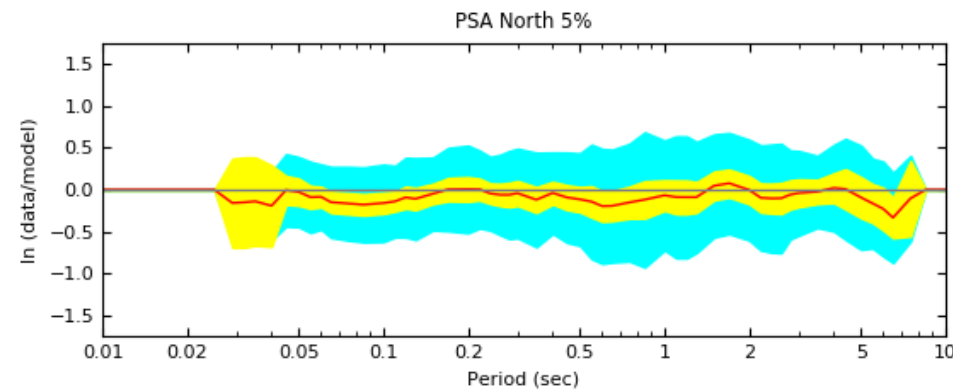
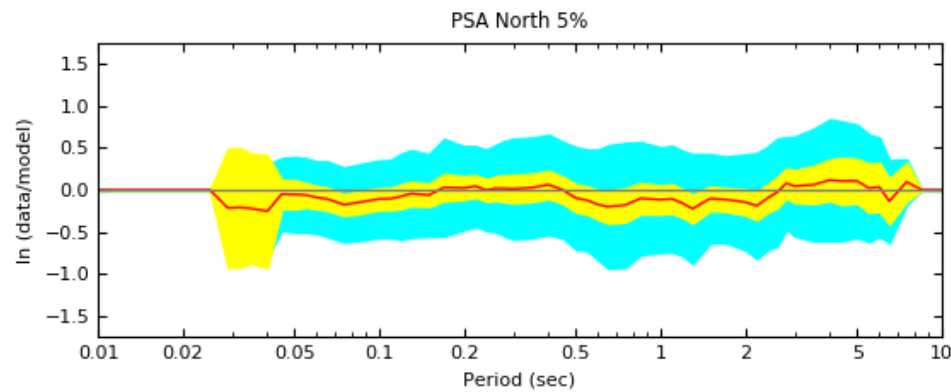
— 1D BBP

# Northridge GoF Comparisons

- 38 stations, 64 realizations



BBP combined goodness-of-fit

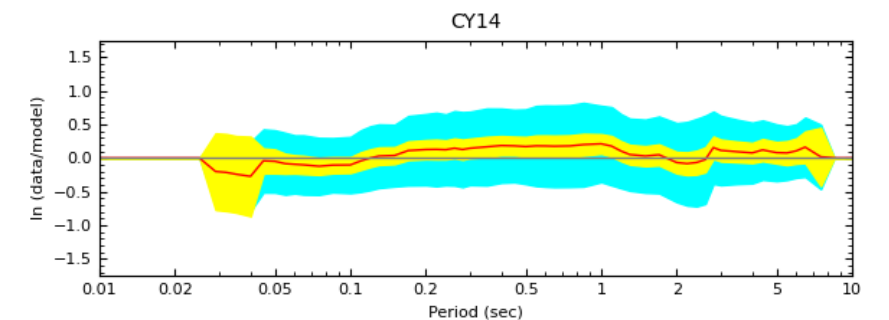
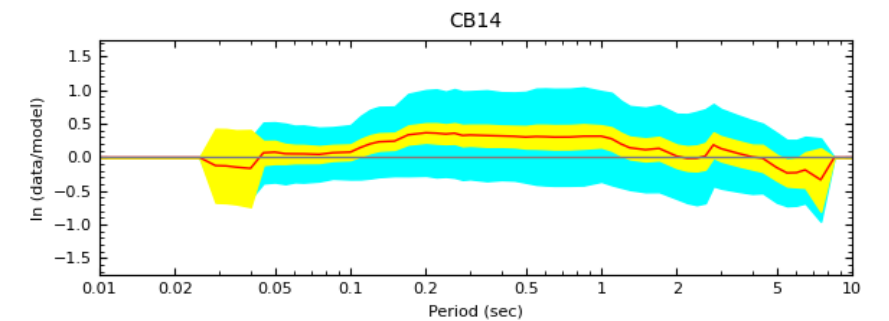
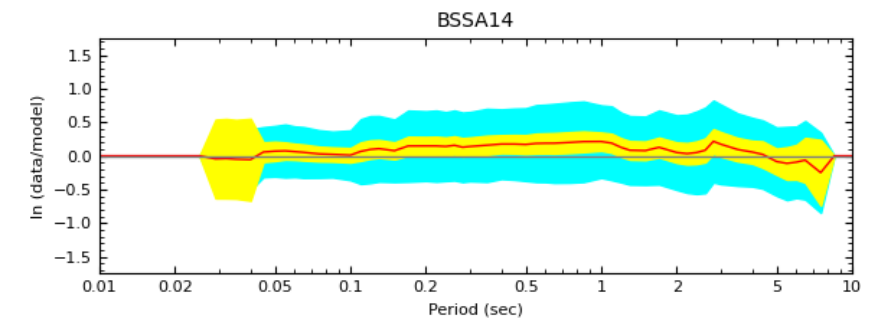
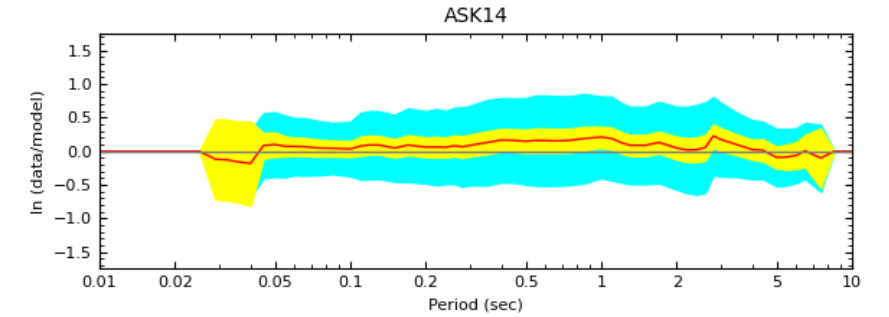
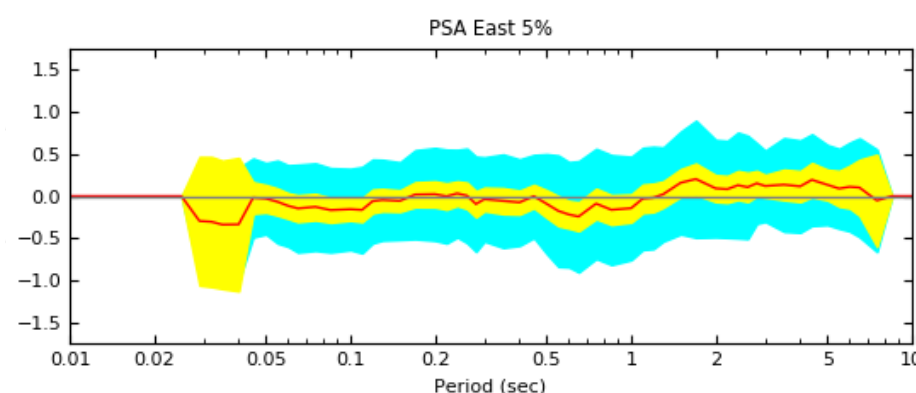
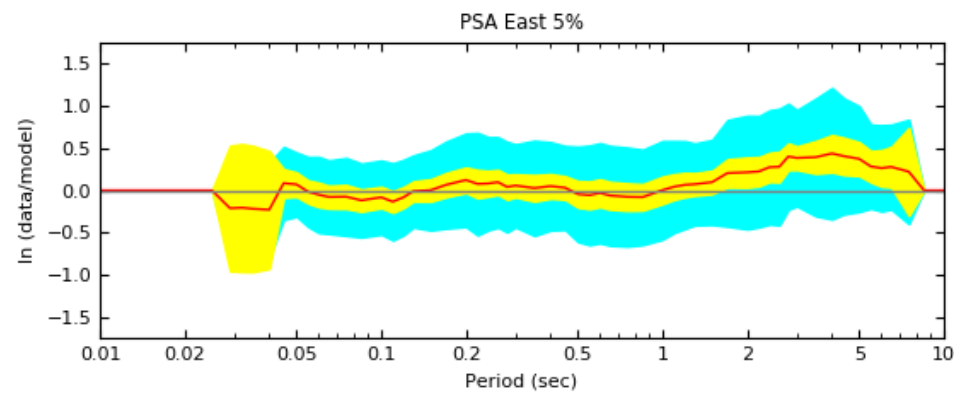
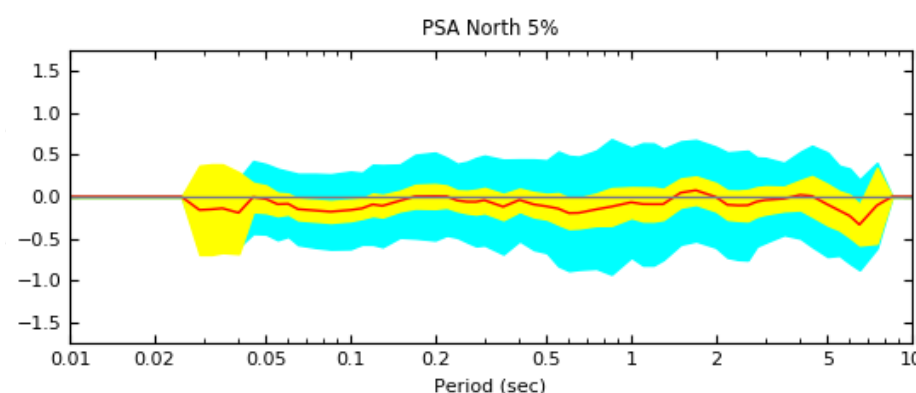
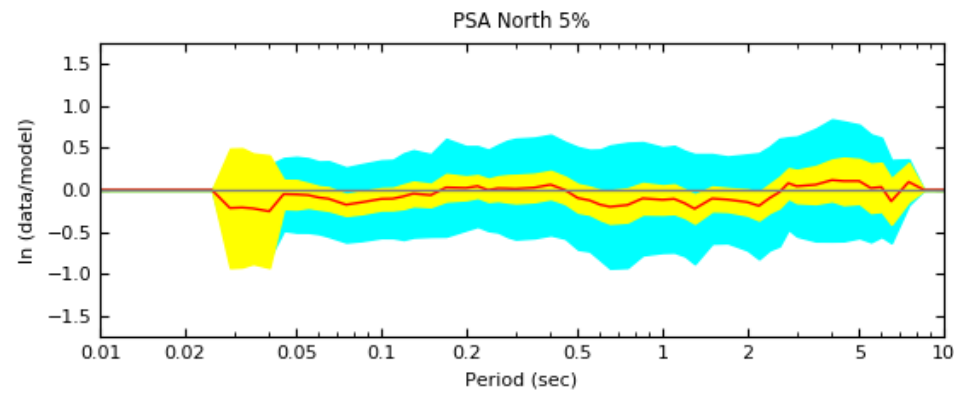
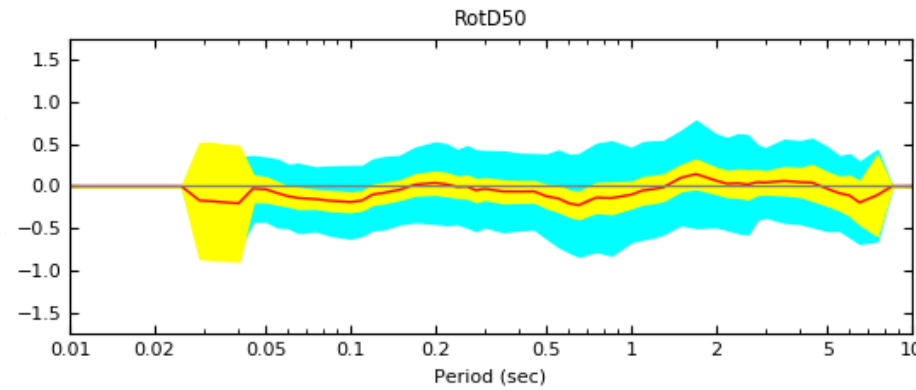
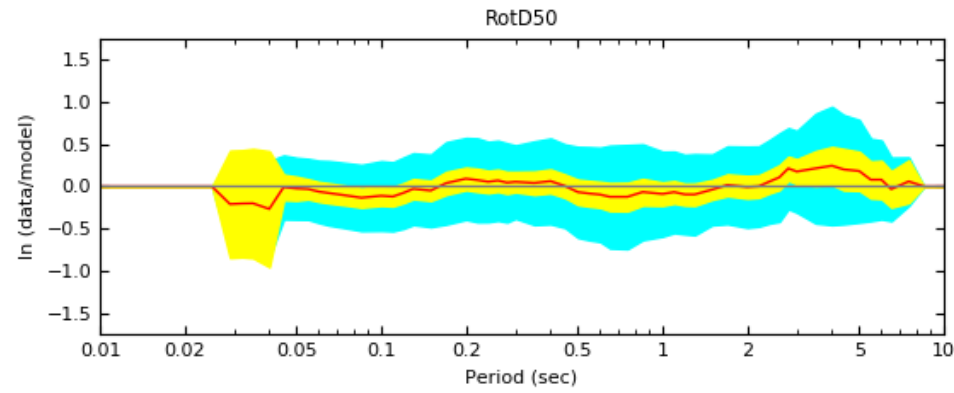


CyberShake combined goodness-of-fit

Smallest bias, BBP

Smallest bias, CyberShake

# Northridge GoF Comparisons



Smallest bias, BBP

Smallest bias, CyberShake

4 NGA West2 GMMs



# *Future Plans*

- Continue investigating Northridge results
- Broadband CyberShake validation with other historic events
  - Landers
  - North Palm Springs
  - Whittier
  - Chino Hills
- Broadband CyberShake hazard map for Southern California

*Thanks!*

