SCEC CyberShake Study 22.12 Methods, Results, and Plans

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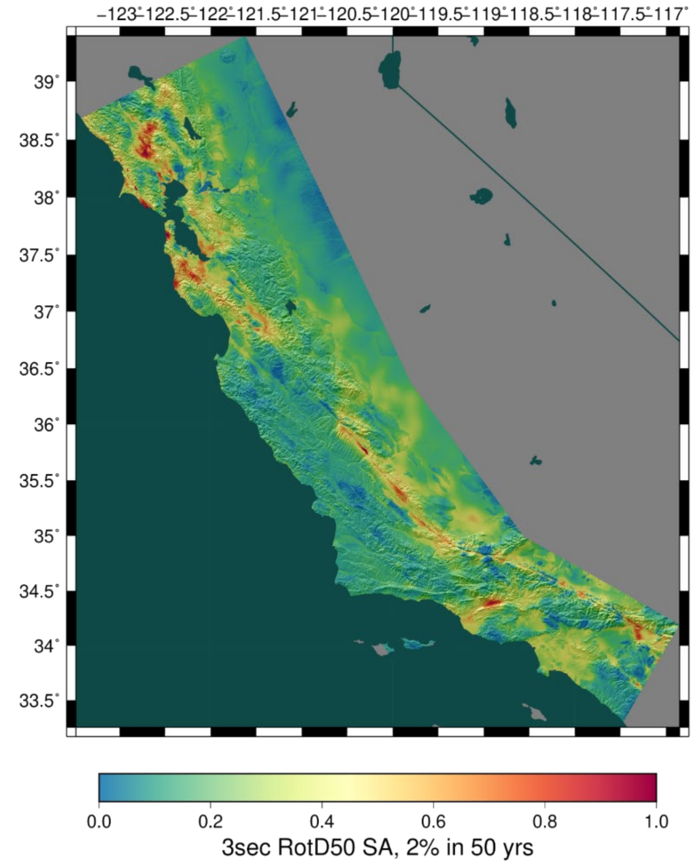
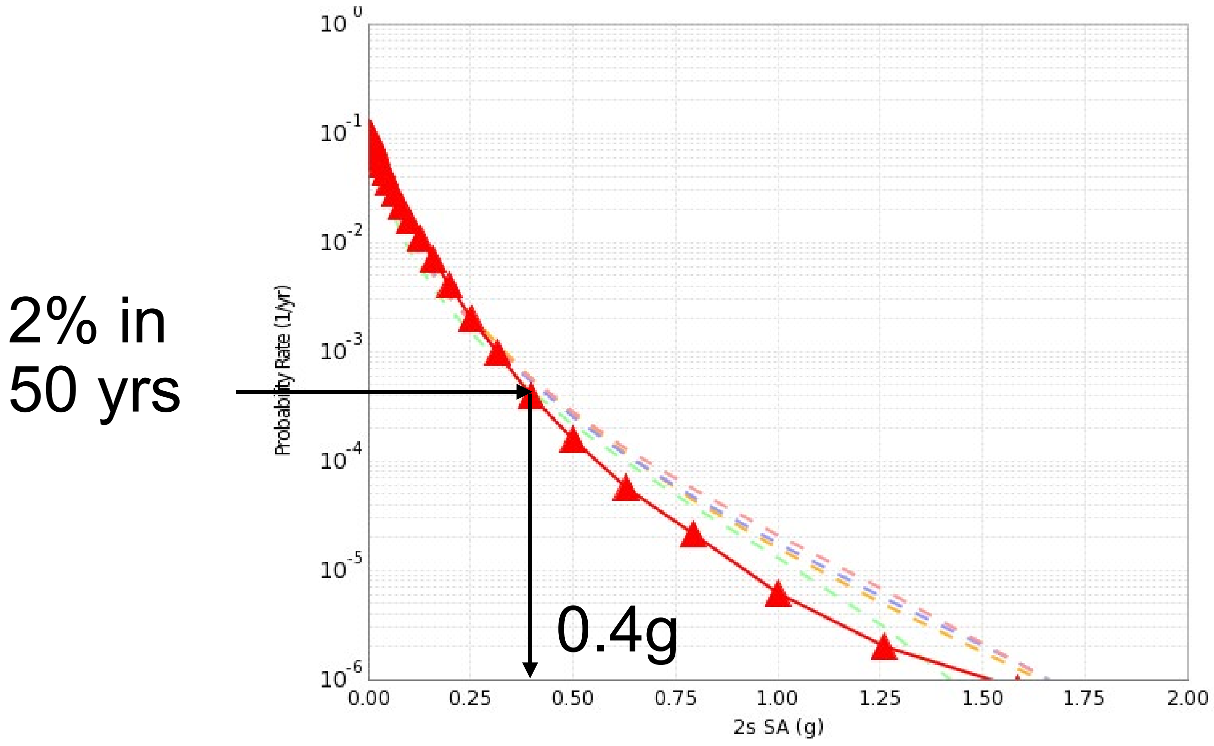
SCEC Staff Meeting
Thursday, December 7, 2023

What is CyberShake, again?

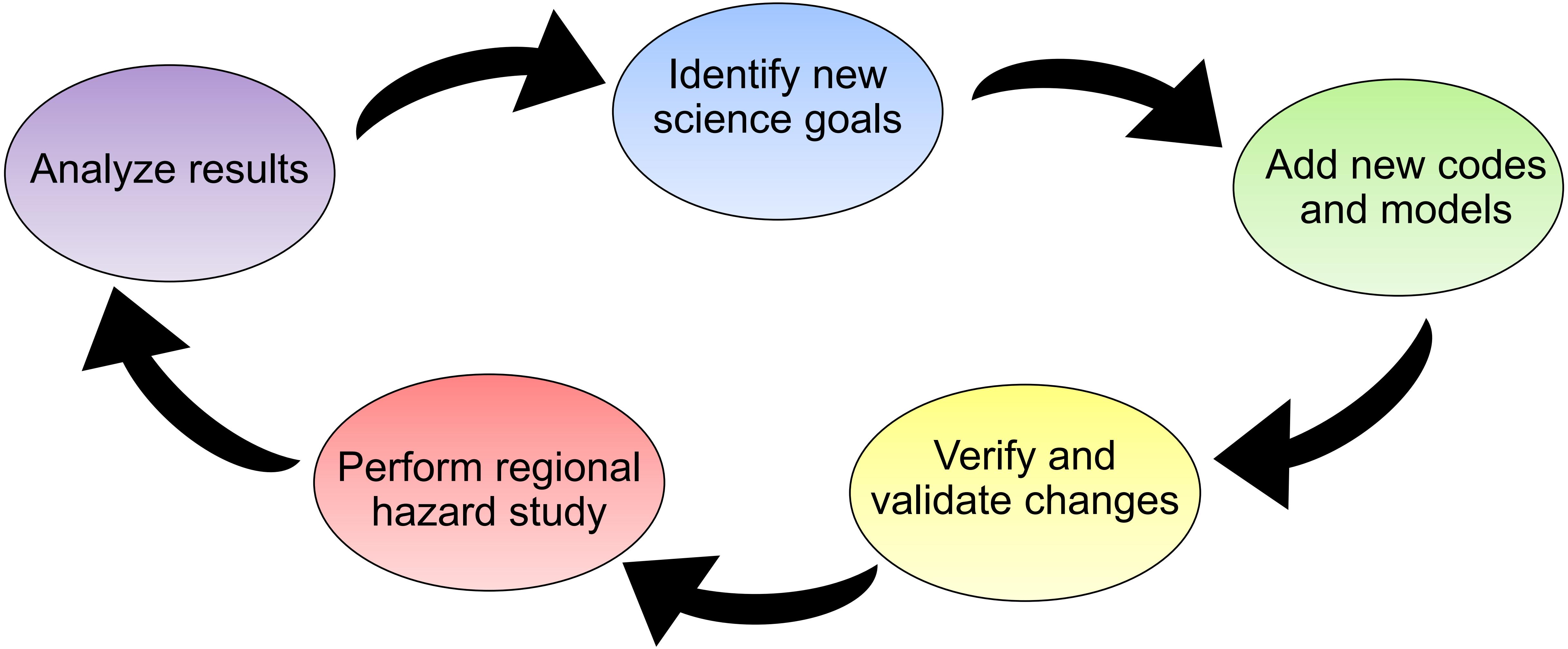
- SCEC's 3D physics-based probabilistic seismic hazard analysis (PSHA) platform
  1. Pick a location of interest.
  2. Get a list of all possible earthquakes from an earthquake rupture forecast that might affect the site, along with their probabilities.
  3. Calculate the amount of shaking each earthquake would cause at the location, by running simulations.
  4. Combine the shaking values with probabilities to produce a hazard curve.





What is a CyberShake Study?

- CyberShake goes through cycles, usually lasting 1-2 years
- A study produces a new hazard model for hundreds of sites

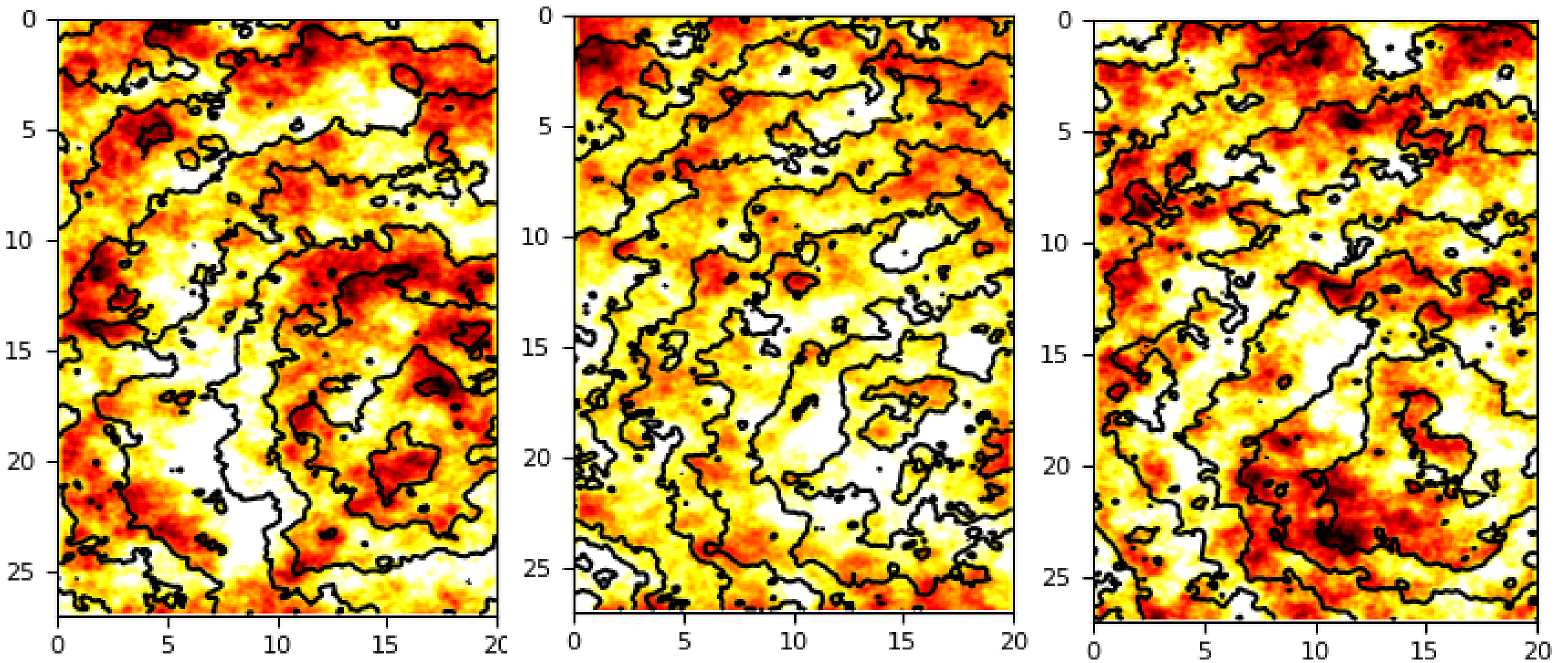


New Features in CyberShake Study 22.12

- Update to previous Southern California Studies (15.4 and 15.12)
- Broadband simulations (up to 25 Hz)
  - Wave propagation simulations for 0-1 Hz
  - Code from Broadband Platform for 1-25 Hz
  - Validated against historic events
- Modifications to 3D velocity model
  - To resolve issues with high velocities at the surface
- Updates to rupture generation for individual events
  - Migration to more recent rupture code
  - Sampling of additional variability

Broadband Validation

- Selected validation events from the SCEC Broadband Platform
  - Northridge, Whittier, Chino Hills, Landers
- 64 realizations created for each event
  - Hypocenter and magnitude preserved
  - Different slip realizations
- CyberShake workflows run for sites with recordings in BBP
  - Usually ~40 stations per event
- Calculate goodness-of-fit metrics using the BBP

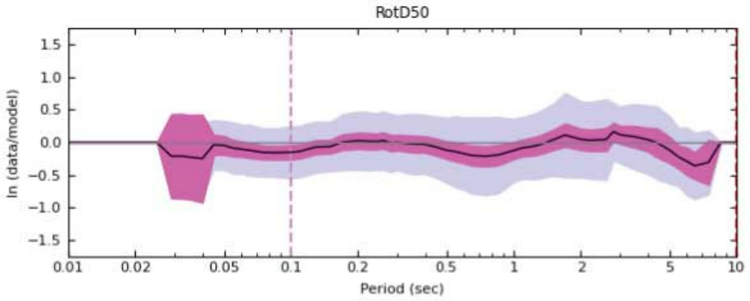


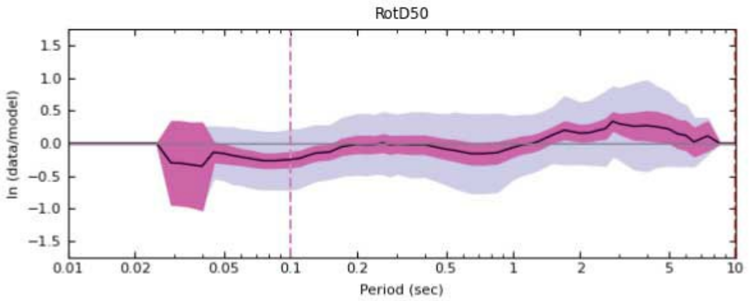
3 slip realizations for 1994 Northridge

Northridge

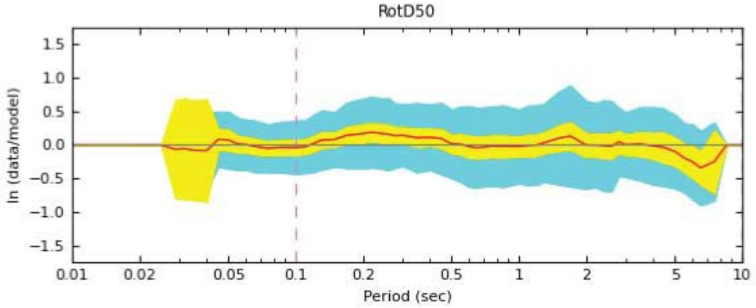
3D CyberShake | 1D BBP | GMMs

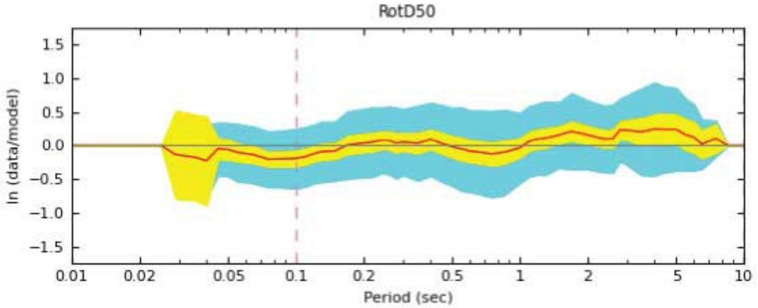
Overall GoF

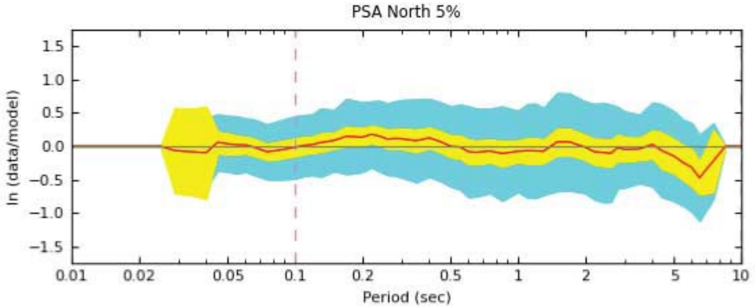


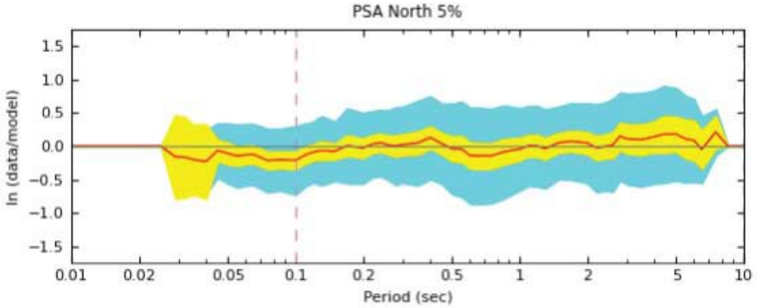


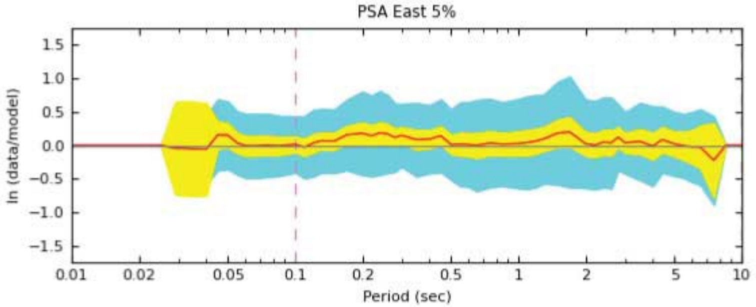
Best Realization

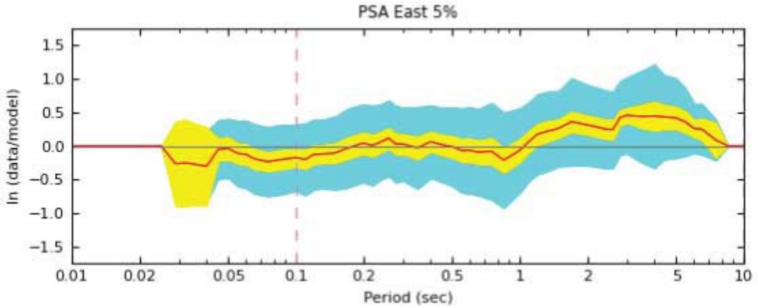




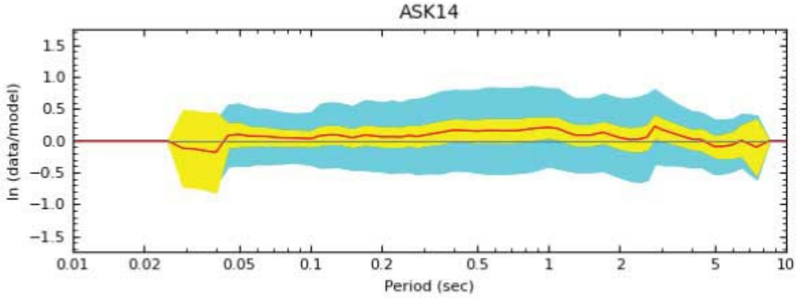


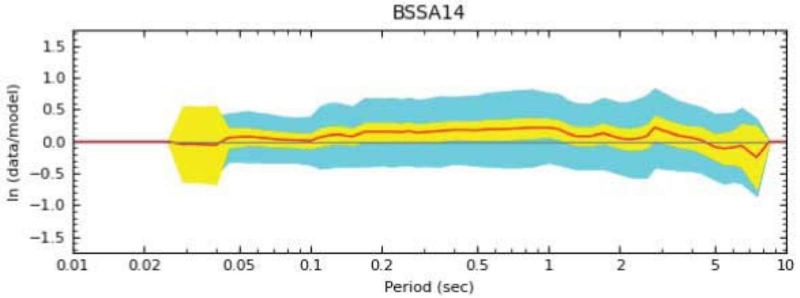


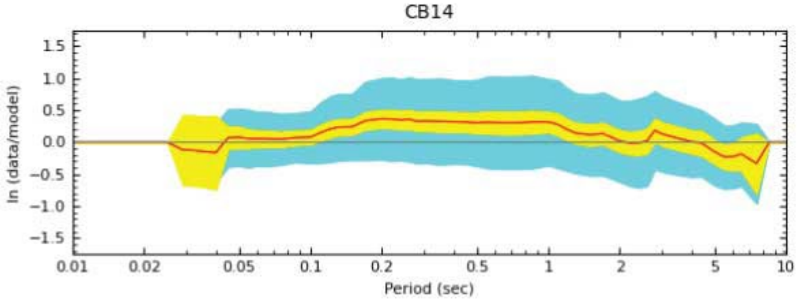


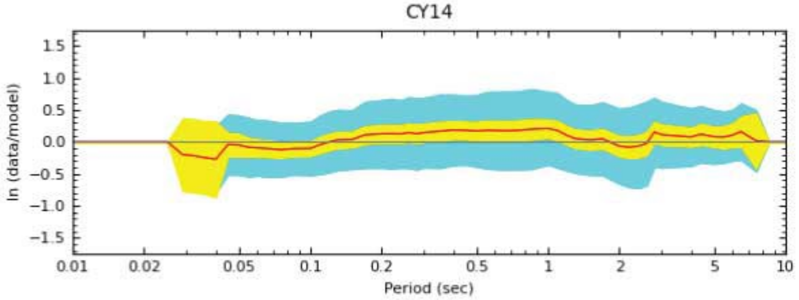


GMMs









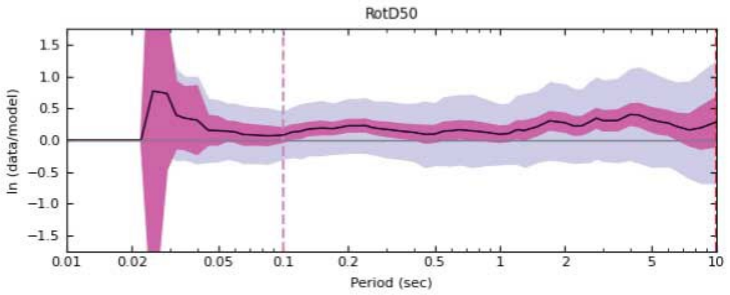
Landers (multi-segment)

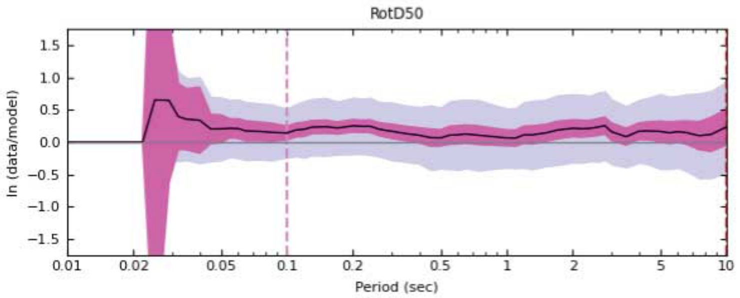
3D CyberShake

1D BBP

GMMs

Overall GoF





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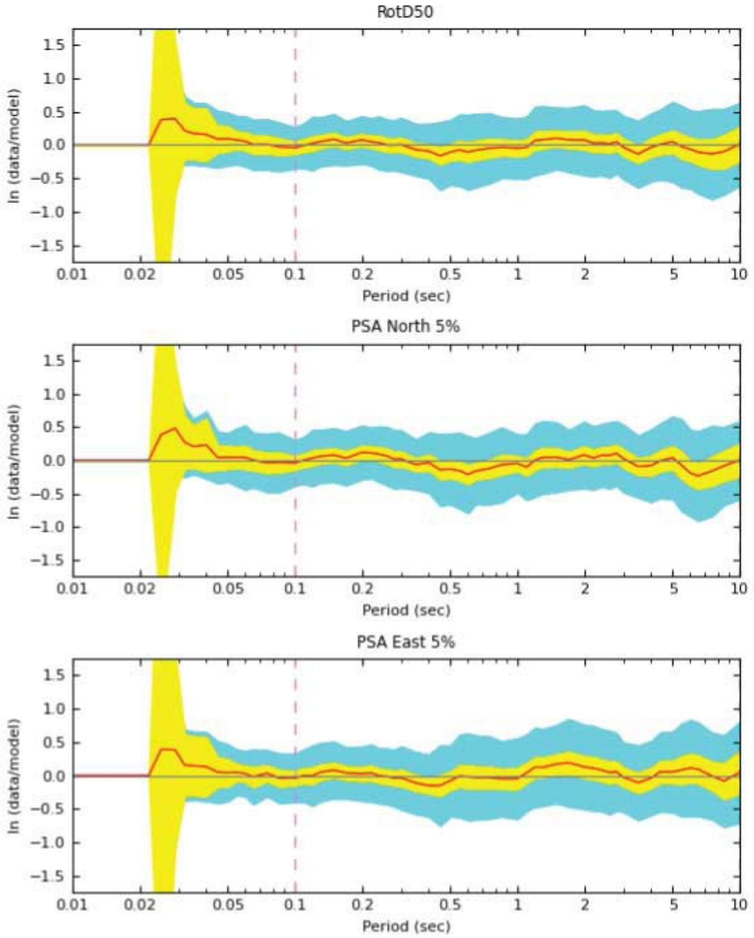
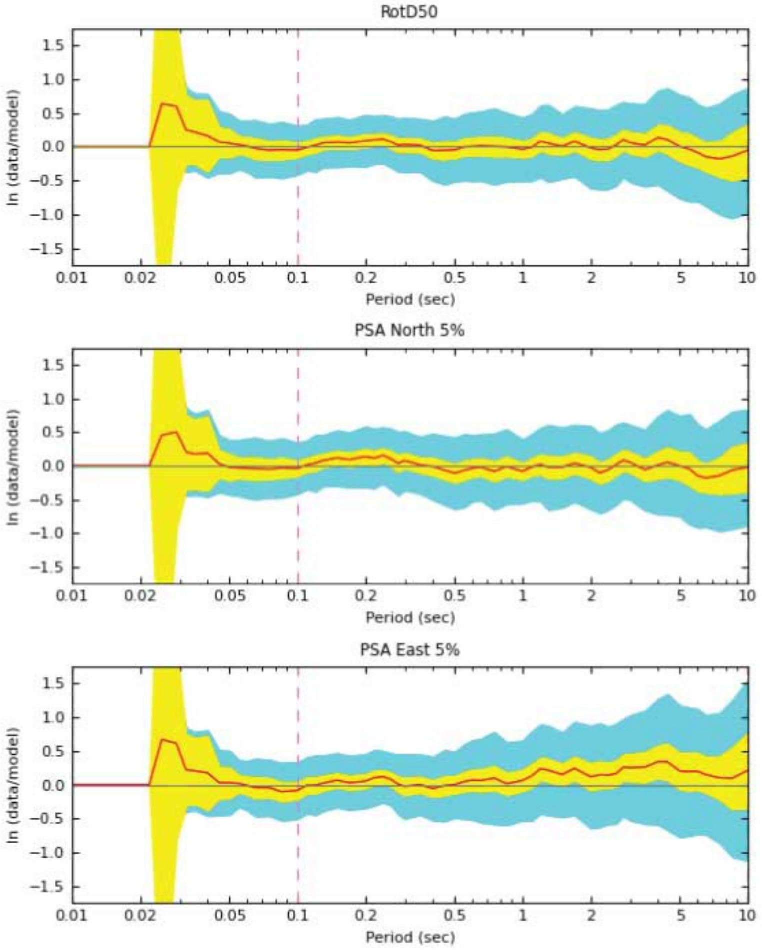
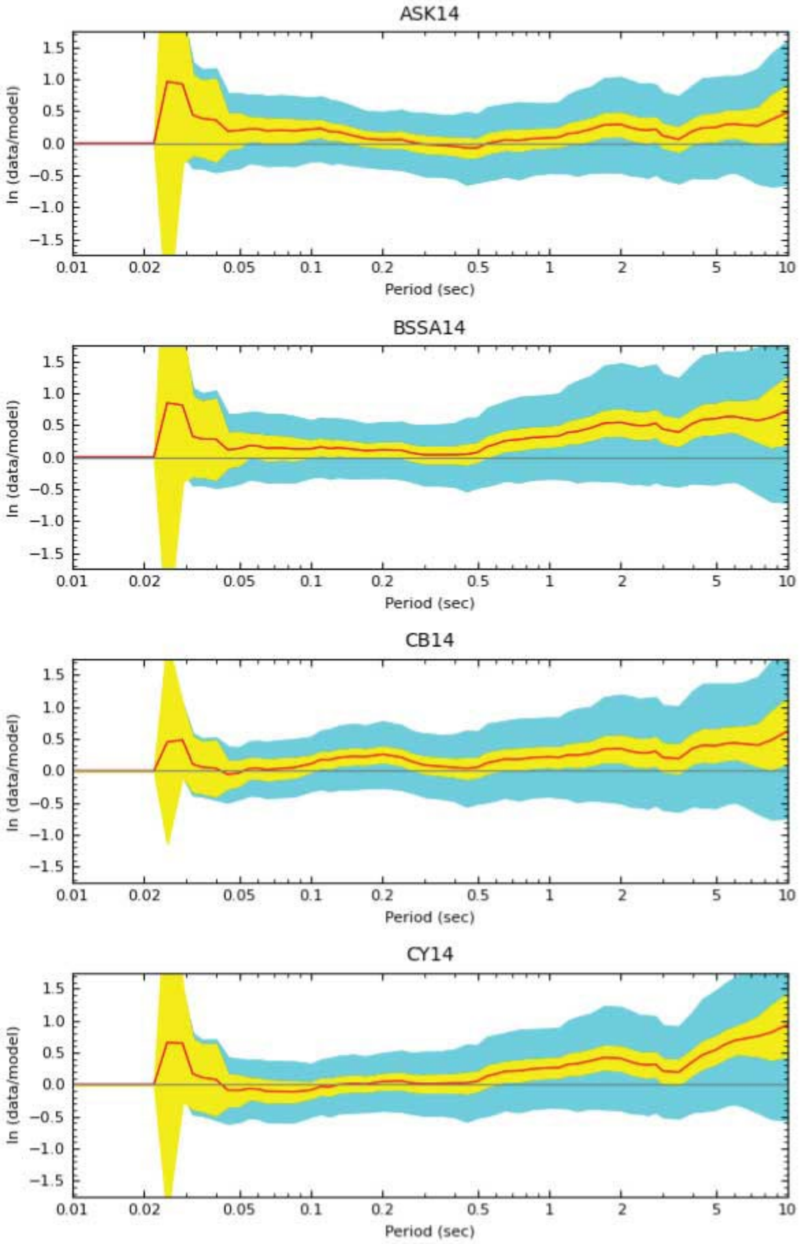


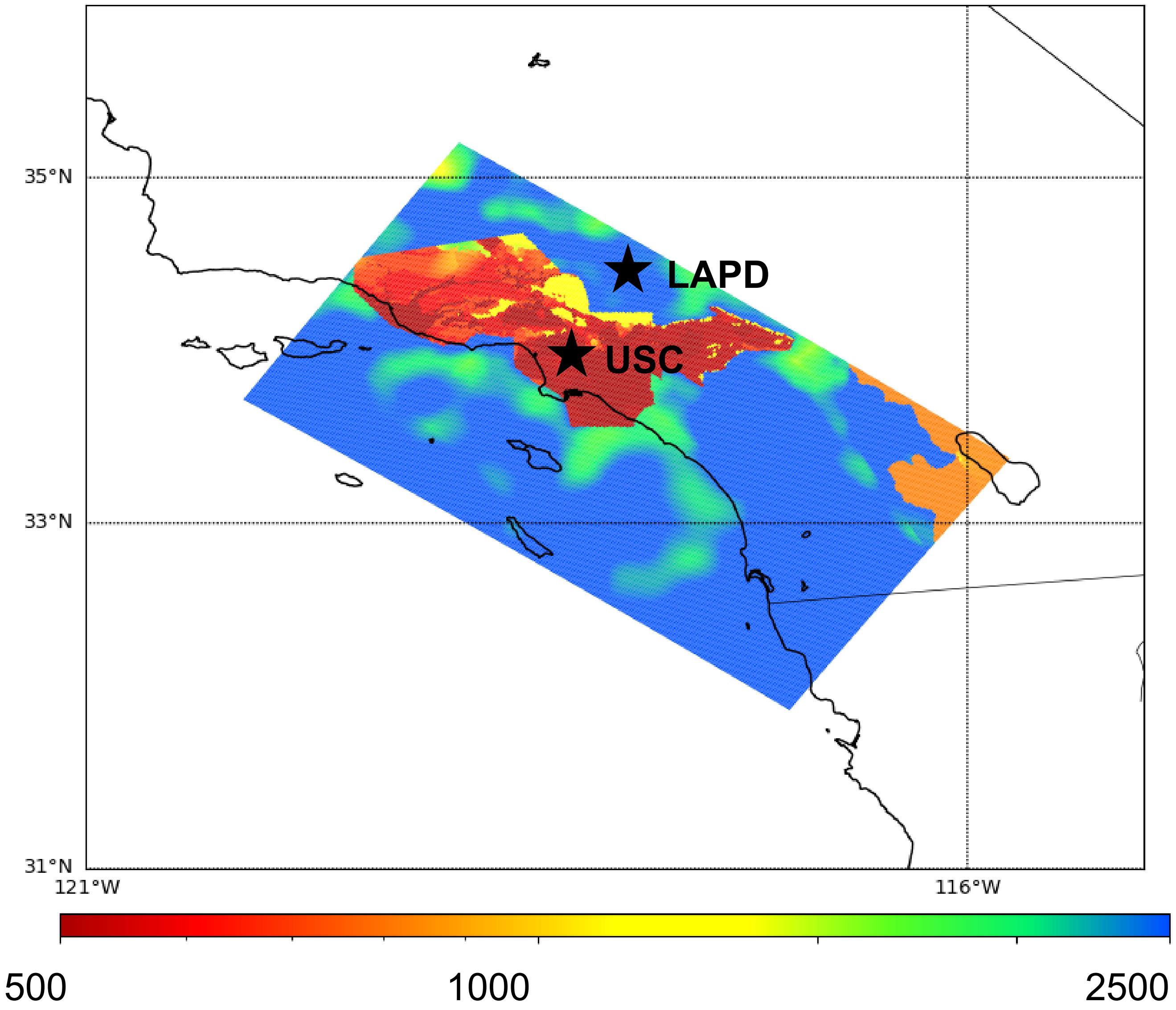




Velocity Model Updates

- Previous studies used CVM-S4.26.M01 velocity model
  - High Vs values outside of basins
- Used Vs30-based taper approach to reduce Vs values outside of basins
  - Calculate properties with and without taper
  - Select smaller properties
  - Only affects top 700m

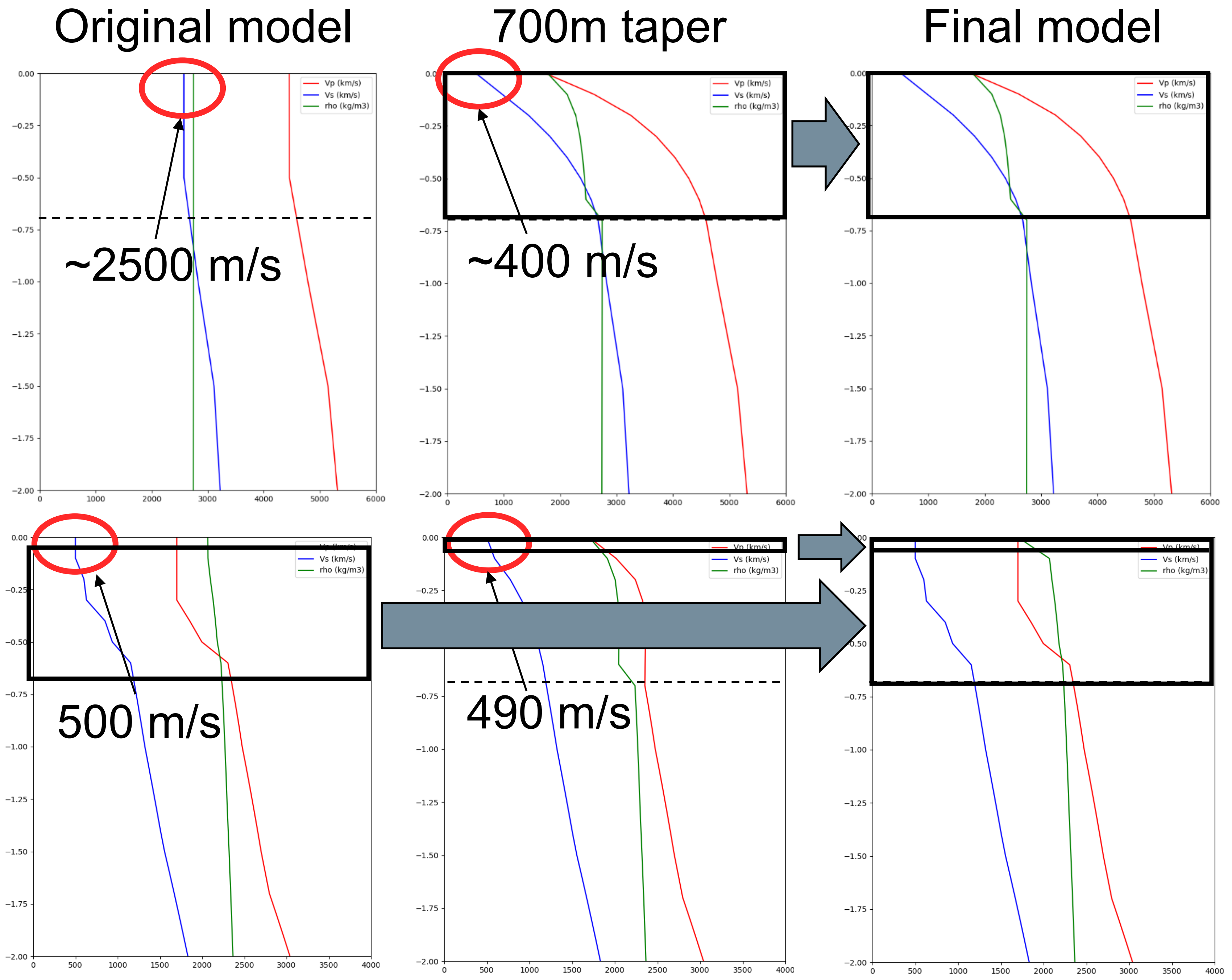
CVM-S4.26.M01, surface Vs



Site Velocity Profiles

LAPD
(outside basin)

USC
(in basin)



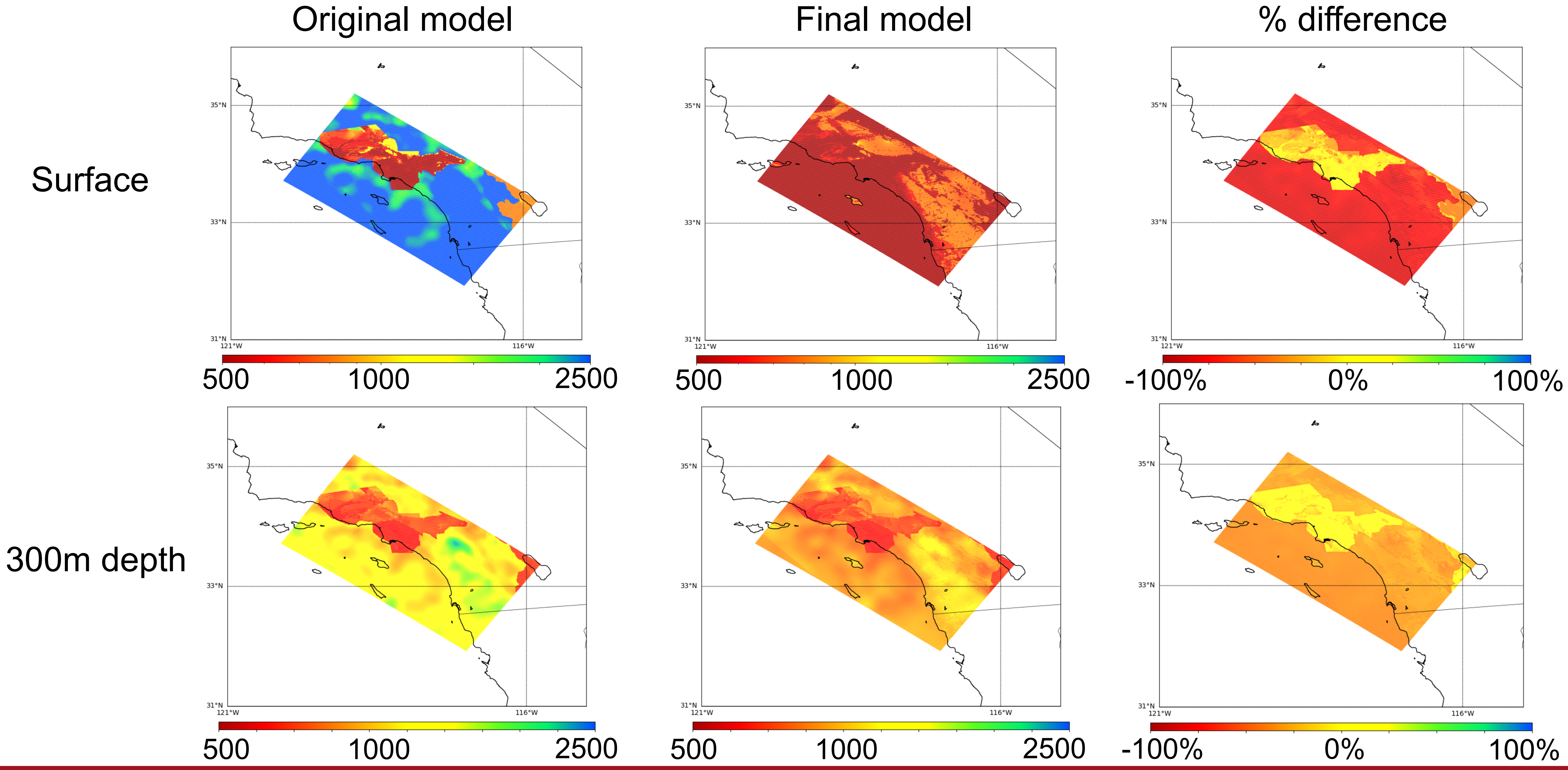
Taper is selected at all depths to 700m

Surface Vs: 2500->400 m/s

Taper is only selected at surface point

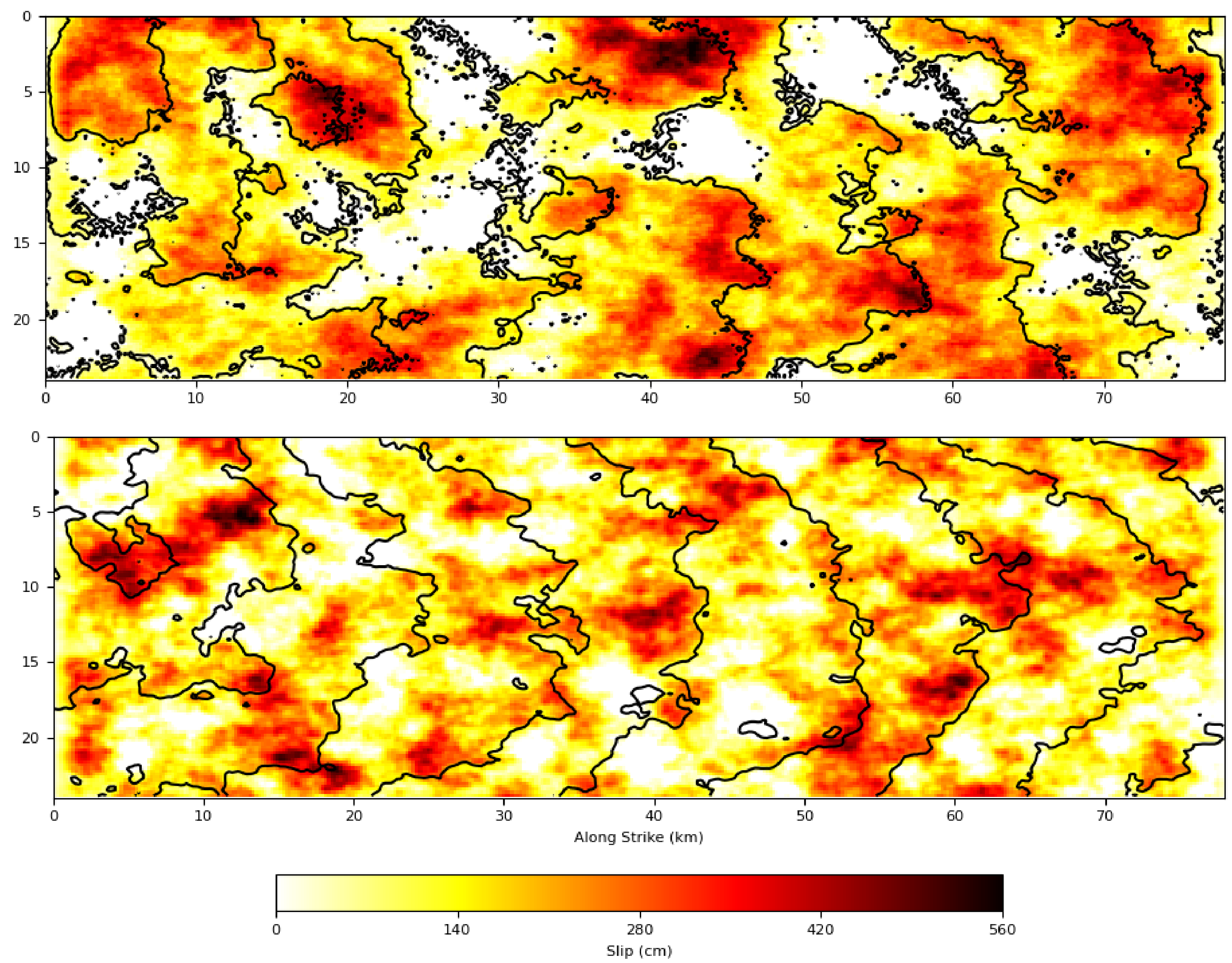
Surface Vs: 500->490 m/s

Merged Taper Cross-sections



Updates to Rupture Generation

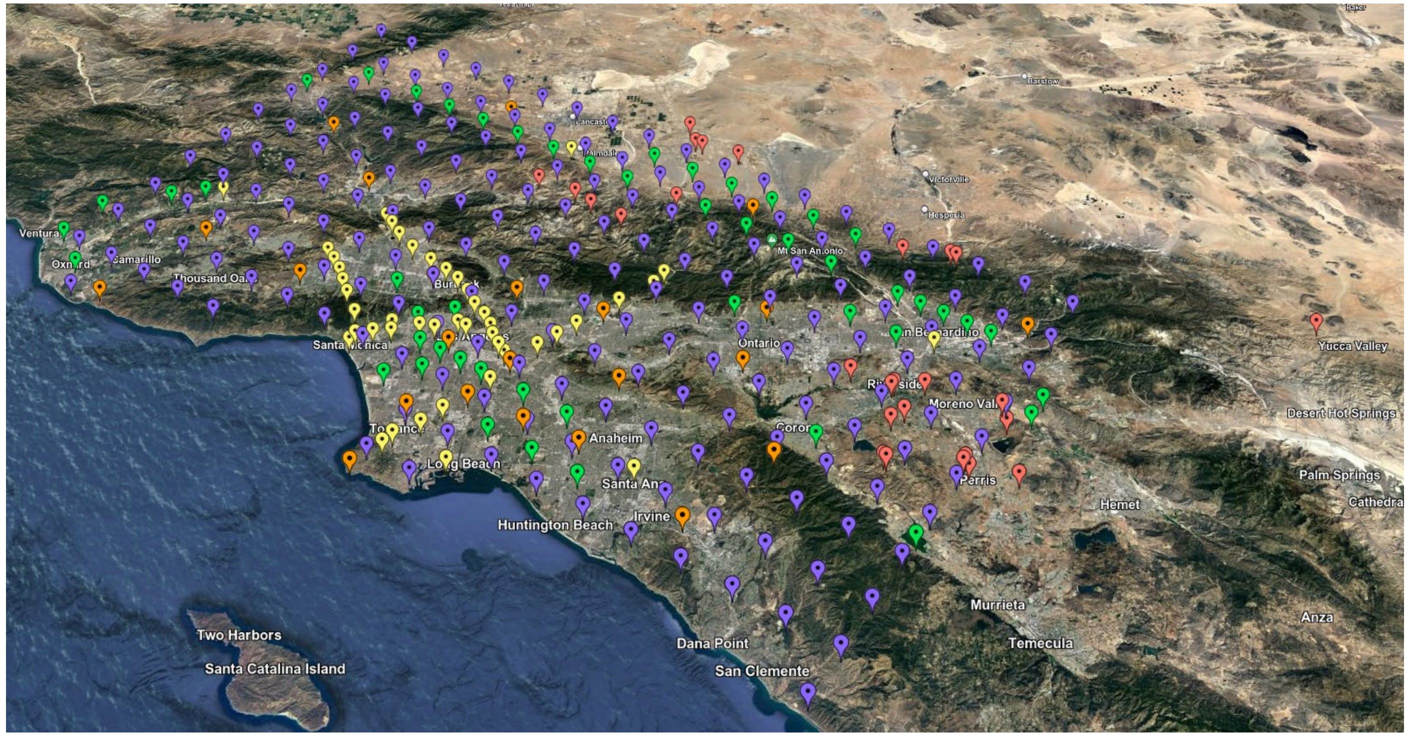
- New version of rupture generator, same as in latest BBP release
  - Reduced correlation between slip and risetime
  - Reduced shallow fault rupture speed
  - Slightly weaker directivity
  - Increased fault roughness
- Rupture velocity permitted to vary
- Denser hypocentral spacing
  - ~31% increase in number of events



Slip plot, old version from Study 15.4 (top); new version from Study 22.12 (bottom)

Study 22.12 Statistics

- Study ran from Dec 2022-Apr 2023
- 335 sites around SoCal
- 772,000 node-hrs on OLCF *Summit*
  - Equivalent to entire system for 1 week
  - Max of 73% of *Summit*
- Managed ~2.5 PB of data
- 74 TB of data copied back to USC storage
  - 420 million two-component low-frequency and broadband seismograms
  - 83 billion intensity measures and durations



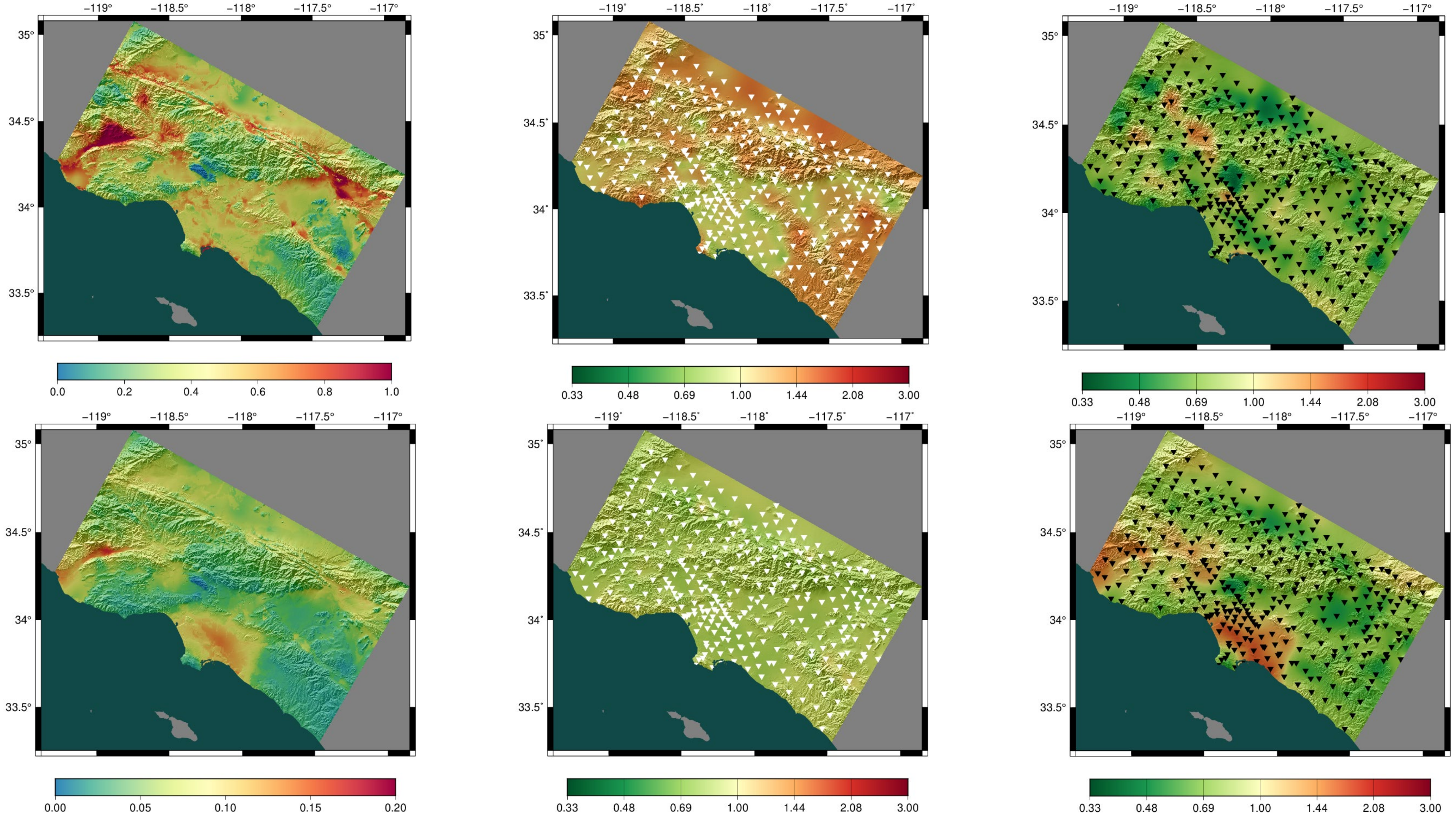
Study 22.12 site map

Study 22.12 Low-Frequency Results

Study 22.12 | **Ratio, 22.12/15.4** | **Ratio, 22.12/GMMs**

2 sec, RotD50

10 sec, RotD50

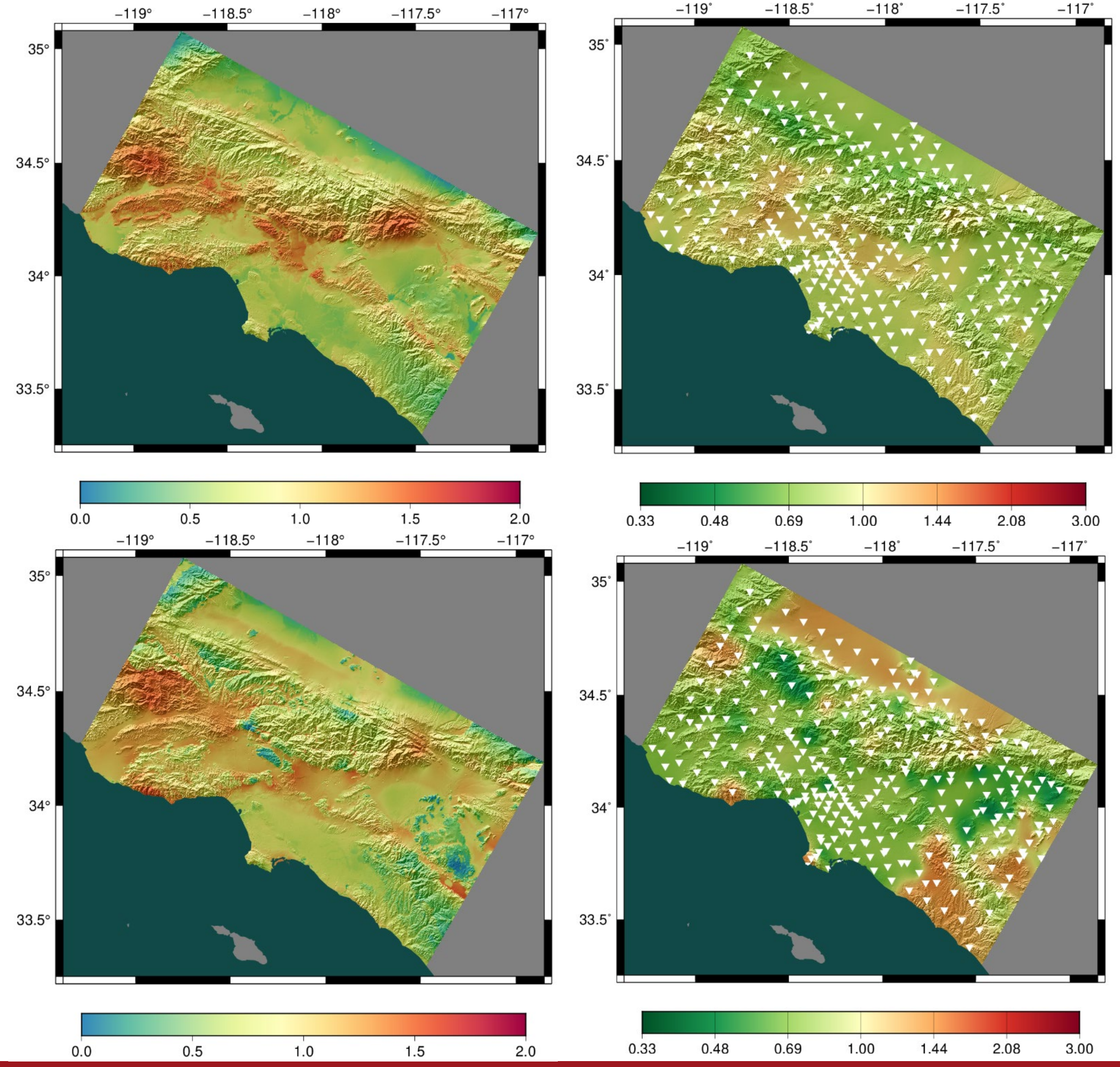


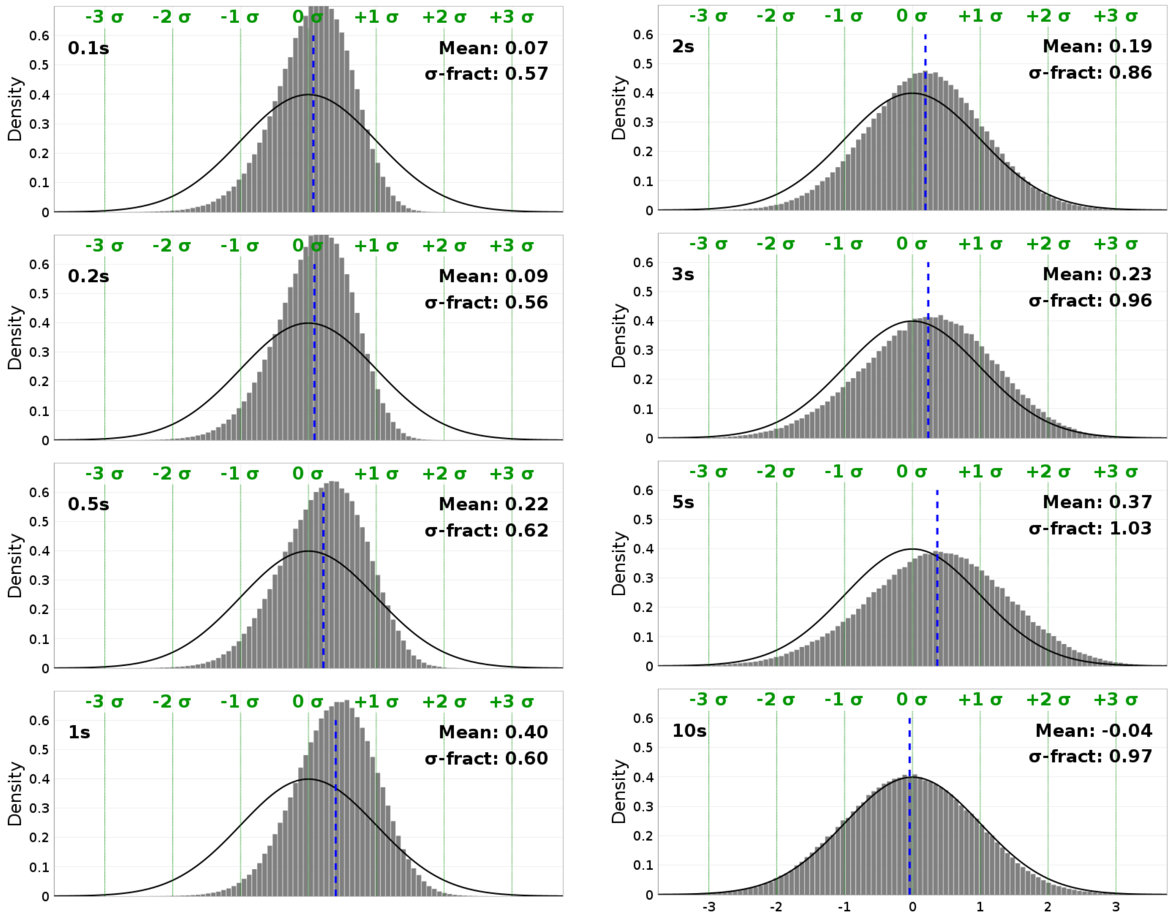
Study 22.12 Broadband Results

Study 22.12 | Ratio, 22.12/15.12

0.1 sec, RotD50

0.5 sec, RotD50

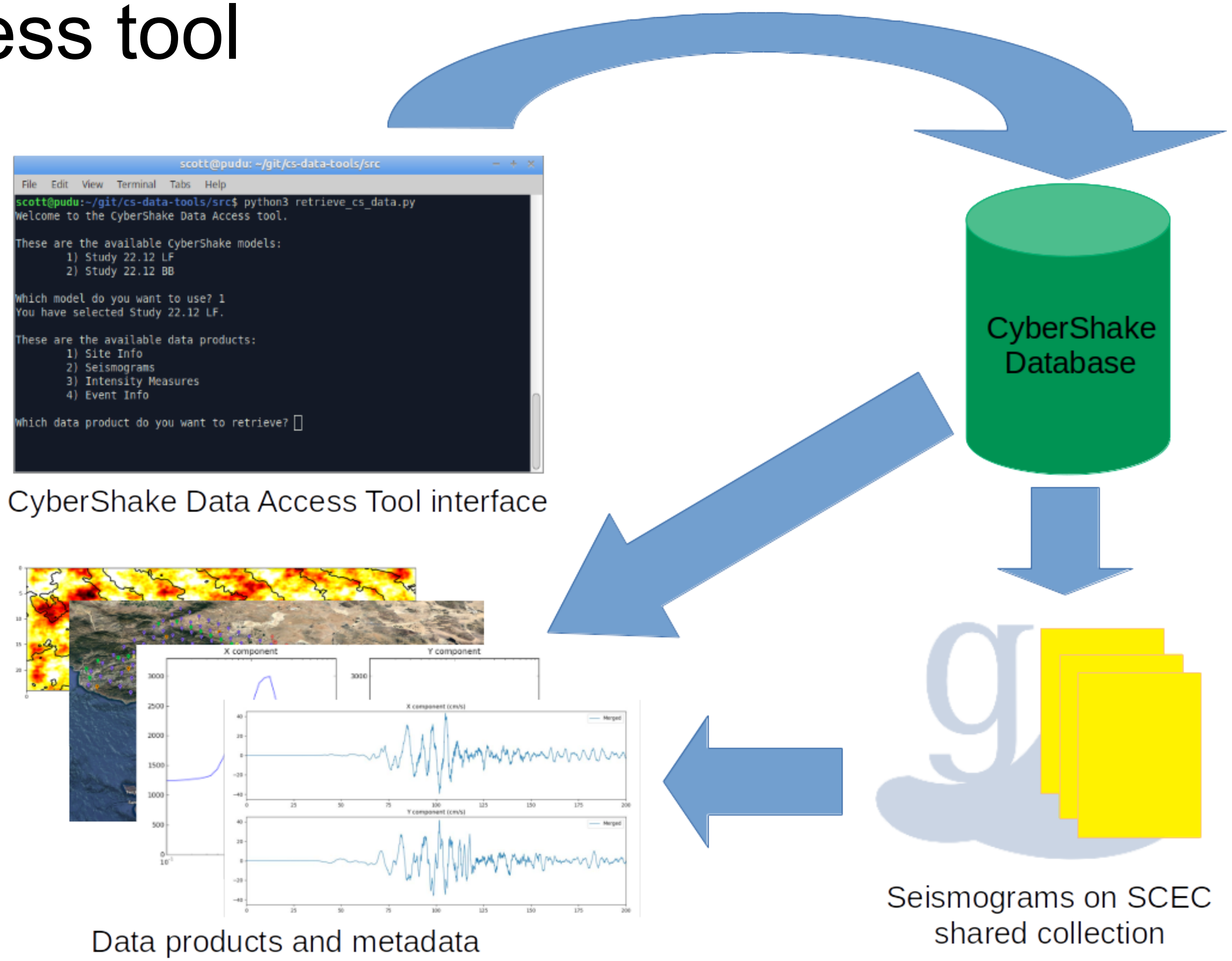




Distribution of z-scores between 22.12 BB and GMM

Study 22.12: Data Access

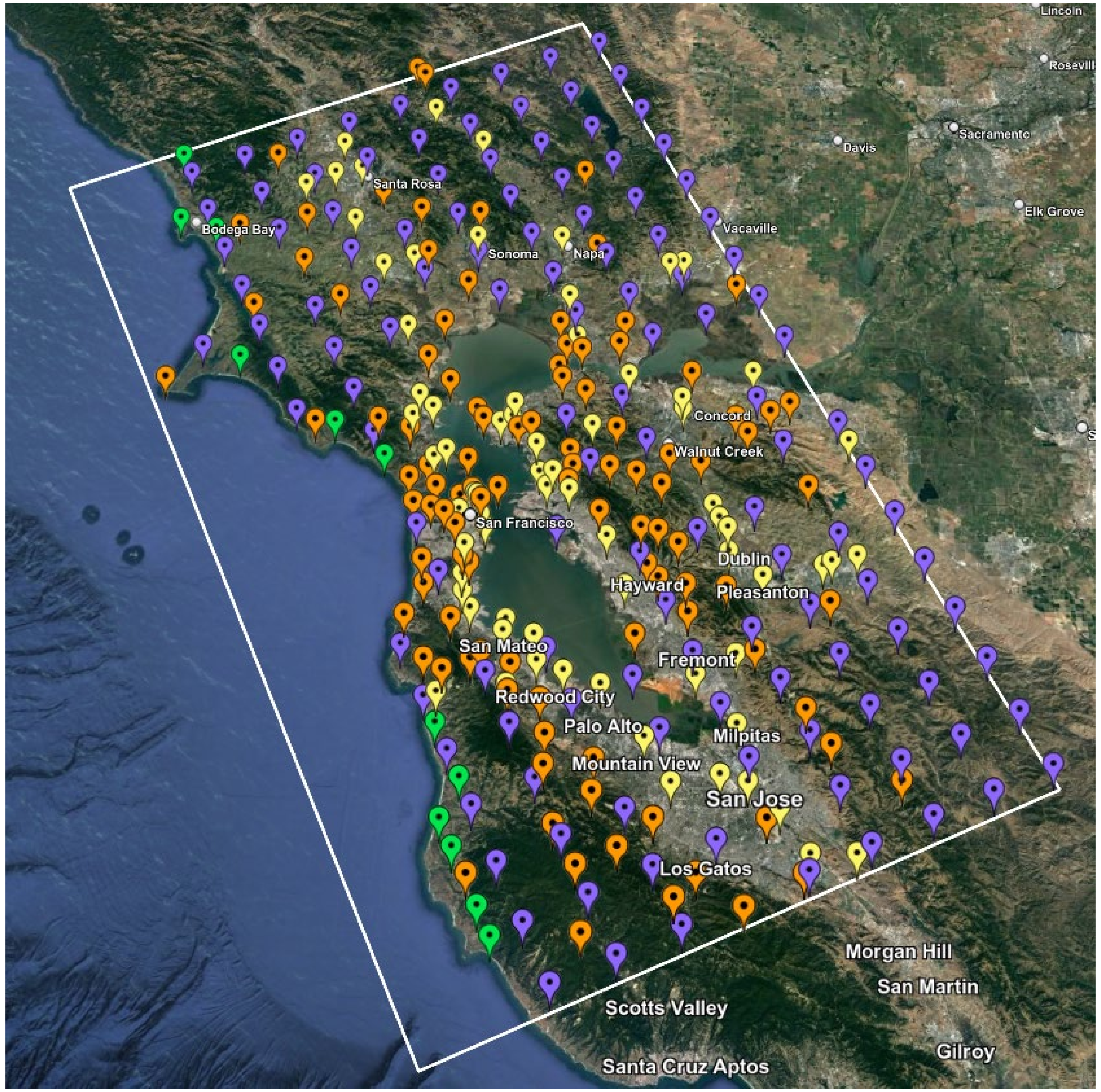
- Developed CyberShake data access tool
  - Python-based
  - Asks user series of questions
  - Applies filters to select subset
- Simplifies access to variety of CyberShake data products
  - Site metadata
  - Earthquake metadata
  - Intensity measures
  - Seismograms



- Available on github: https://github.com/SCECcode/cs-data-tools/

Next Study

- Preparing for next study
  - Greater Bay Area
  - Similar to Study 22.12
  - Will use world's first exascale computer, OLCF *Frontier*
- Currently evaluating 3D velocity models in this region
- Will validate with Central and Northern CA BBP validation events



Northern California site map

Future Plans

- Increase deterministic frequency to 2 Hz
  - Requires additional physics
  - These codes exist, but must be added to CyberShake and verified
- Include nonlinear simulations
  - Can have a big impact on ground motions, but is computationally expensive
  - Current CyberShake approach is linear
  - Identify subset of events for full nonlinear simulations
- Streamline process of integrating new codes and models
  - Goal is to support multiple codes for each stage
  - Supports improved quantification of uncertainty

Thanks!