

SCEC's Physics-Based Seismic Hazard Modeling Platforms

Scott Callaghan (USC)



Broadband Platform: Fabio Silva, Robert Graves, Kim Olsen,
Christine Goulet, Philip Maechling

CyberShake: Xiaofeng Meng, Robert Graves, Kim Olsen, Mei-Hui Su,
Akash Bhatthal, Kevin Milner, Morgan Moschetti, Albert Kottke,
Philip Maechling, Tom Jordan, Ahmed Elbanna

And many others over the years...

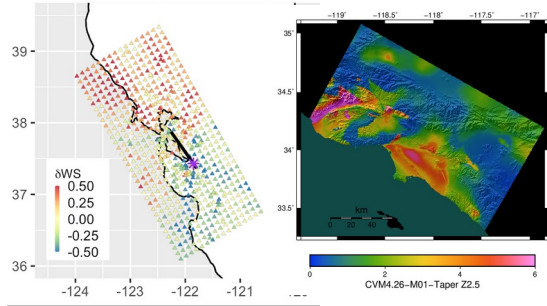
September 1, 2026

SCEC Annual Meeting, Palm Springs, California

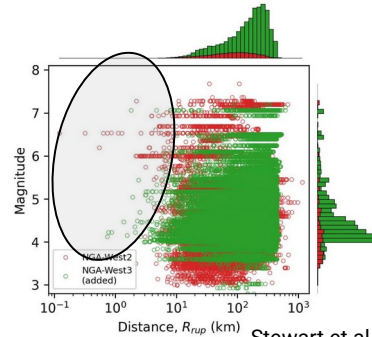


What does physics-based simulation offer?

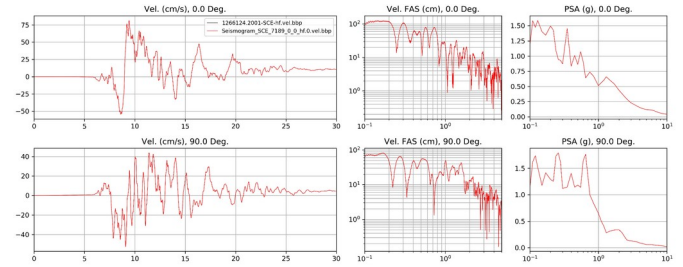
Captures complex effects



Fills data gaps

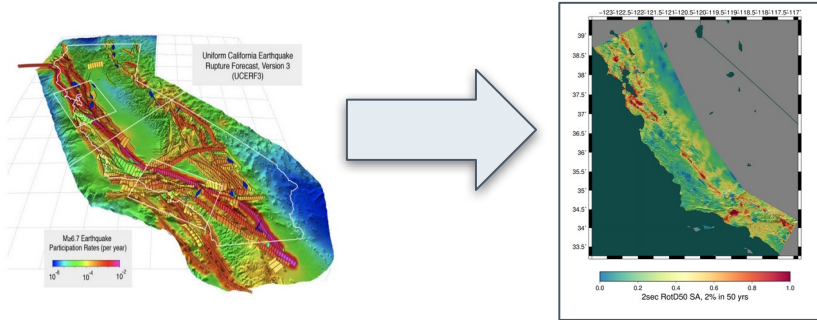


Produces synthetic seismograms

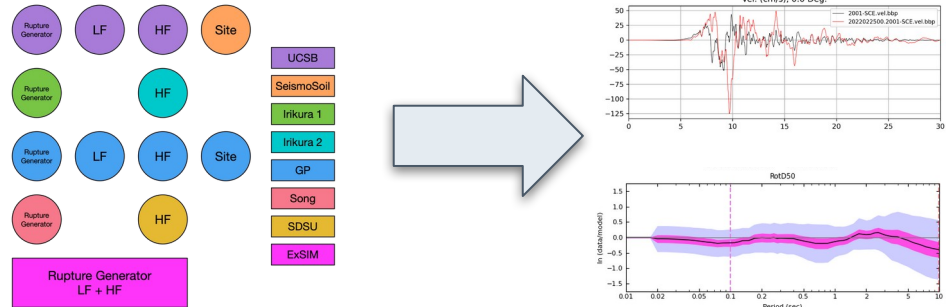


Stewart et al., 2024

CyberShake (suites of events)

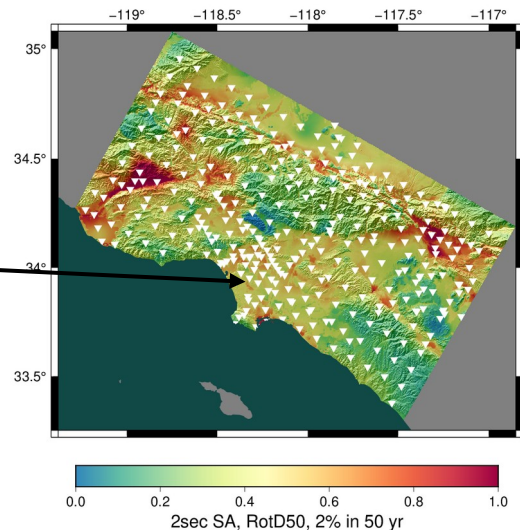
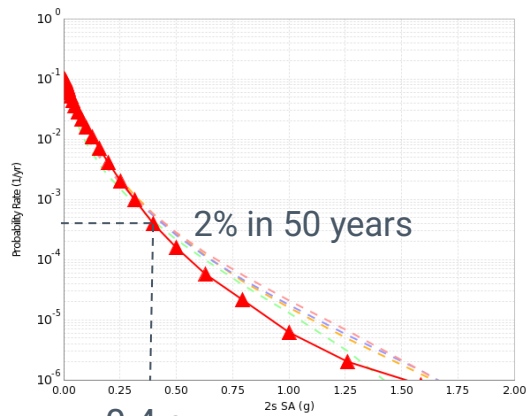


Broadband Platform (individual events)



Probabilistic Seismic Hazard Analysis

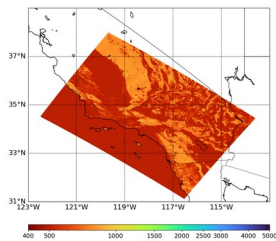
- What ground motions can I expect at a location over the next N years?
 - Building codes
 - Insurance rates
 - Disaster planning
- The PSHA process:
 1. Obtain a list of all earthquakes of interest (ERF)
 2. Determine the shaking each earthquake causes
 3. Combine shaking with probabilities to produce hazard products



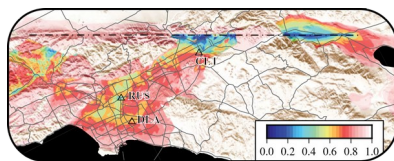
CyberShake

- 3D physics-based PSHA platform: uses simulated ground motions to determine the shaking from each event

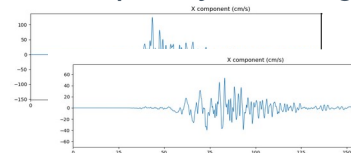
Velocity Model
(UCVM)



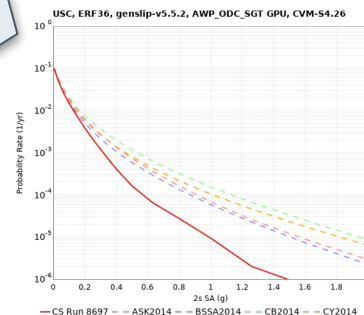
Wave Propagation
(AWP-ODC)



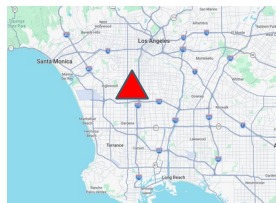
Low-frequency seismograms



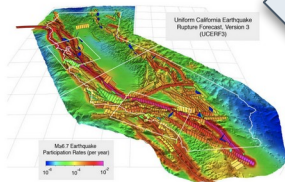
Hazard curves



Site of interest

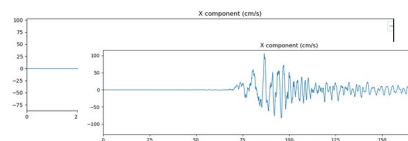


ERF



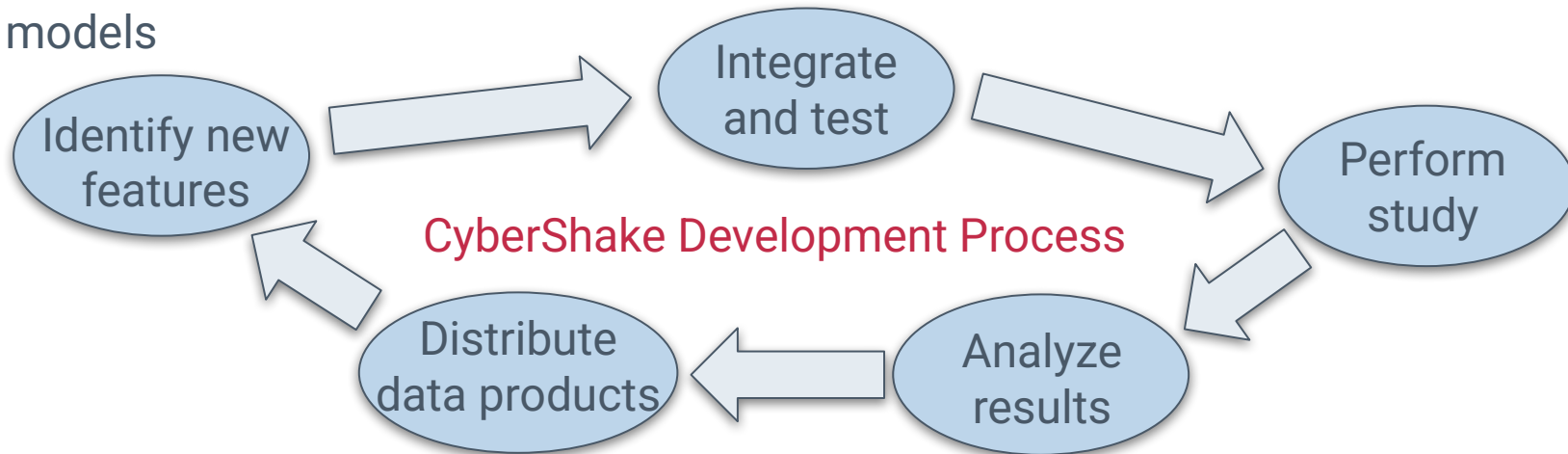
High-frequency
stochastic
module

Broadband seismograms



CyberShake Model Development

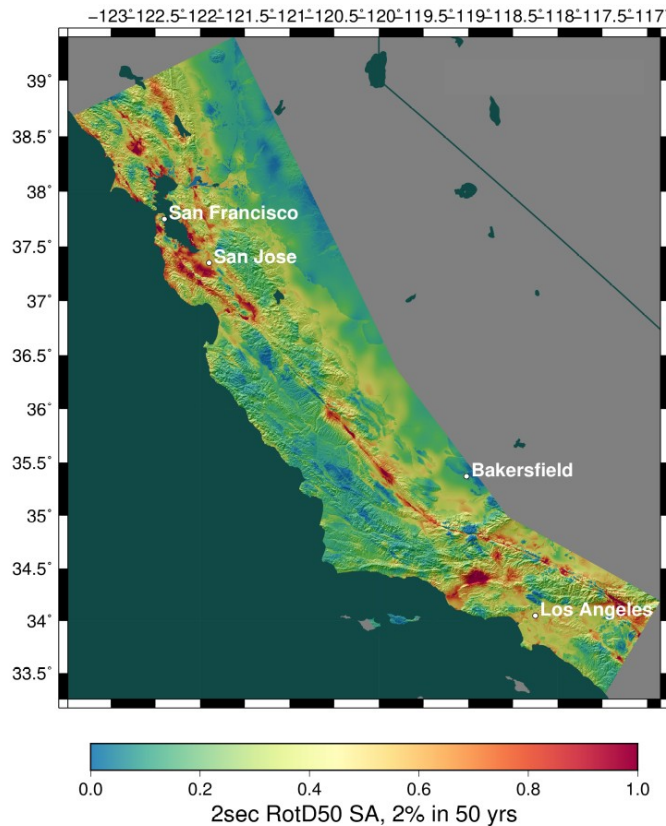
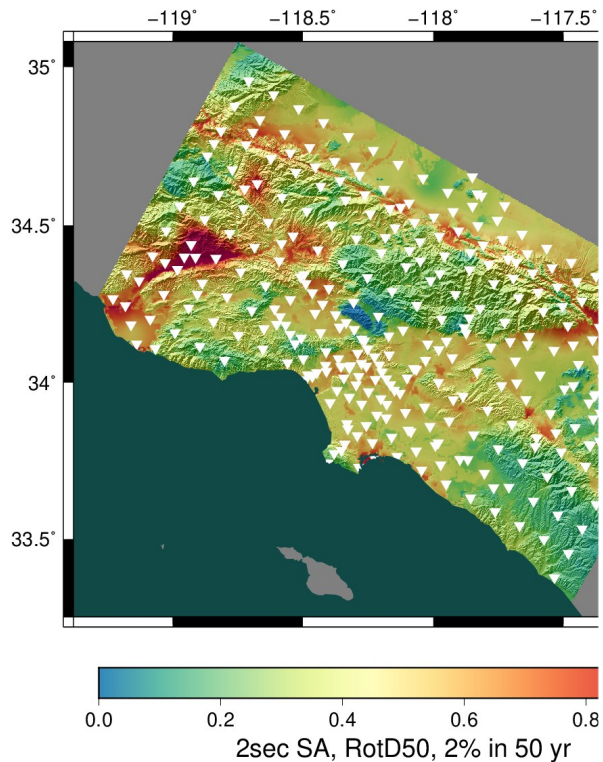
- Performs integrative science: advances in source descriptions, velocity models, and physics codes are integrated into the platform to improve hazard models



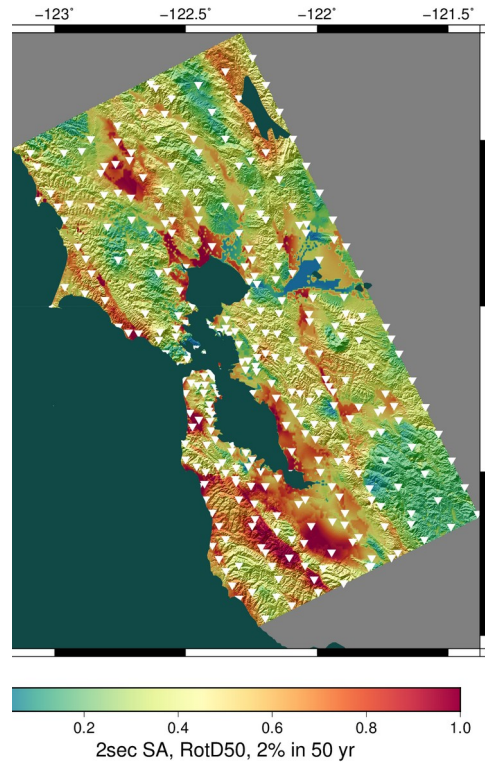
- Requires high performance computing: last study ran for 45 days, used 180,000 node-hours, and generated 1 PB of data

Recent CyberShake results

Study 22.12



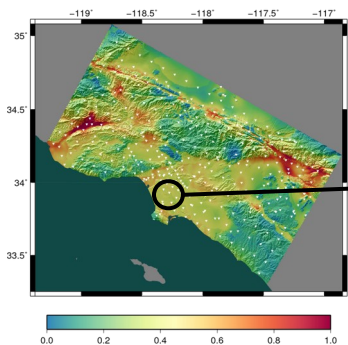
Study 24.8



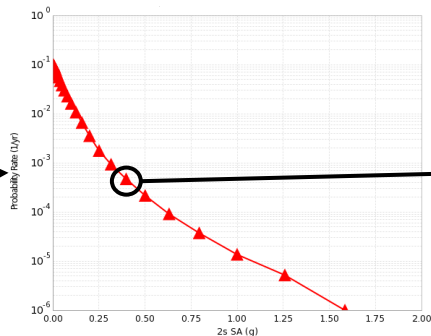


Layered Dataset of Hazard Products

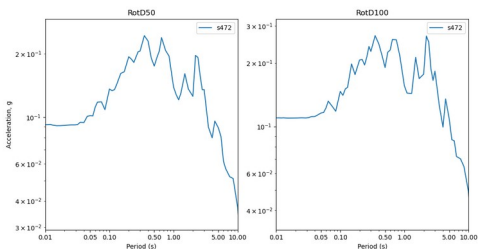
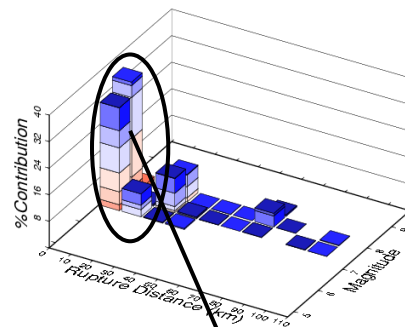
Hazard Maps
(multiple periods)



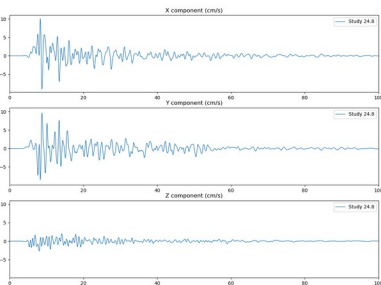
Hazard Curves
(100s of sites)



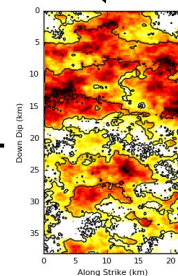
Disaggregation
(arbitrary level)



Intensity Measures
(100s per seismogram)



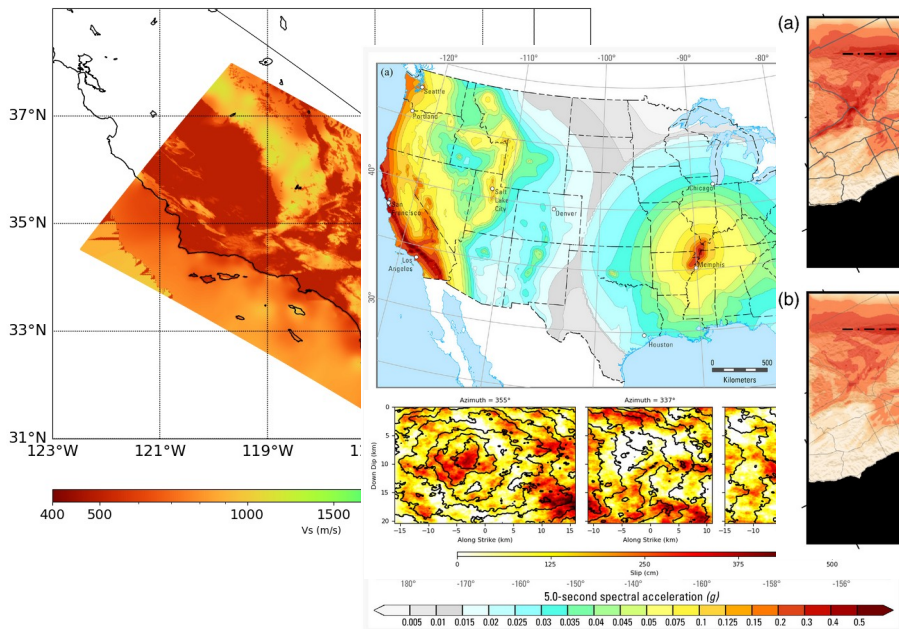
Seismograms
(~500,000 per site, 3-component)



Earthquake Realizations
(~1M events per hazard model)

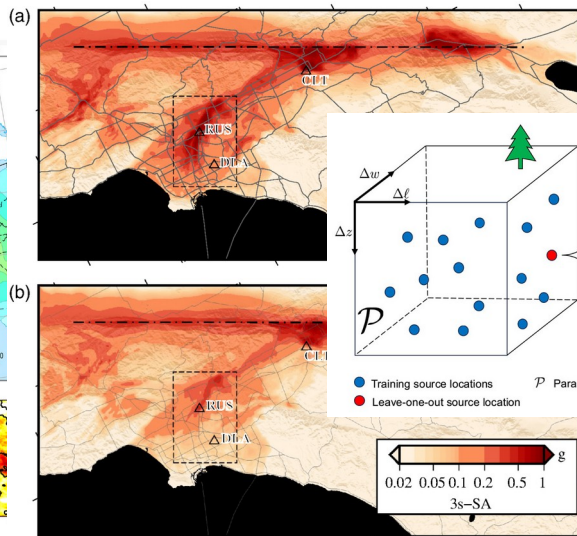
CyberShake: Next Steps

Updated velocity models



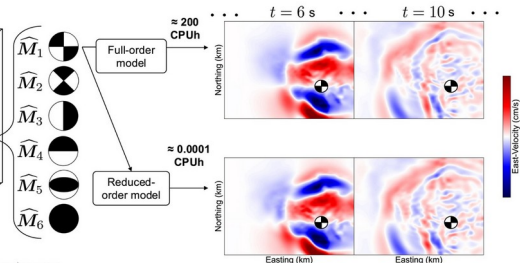
New ERFs with multi-fault ruptures

Nonlinearity



Roten et al., 2023

Surrogate models

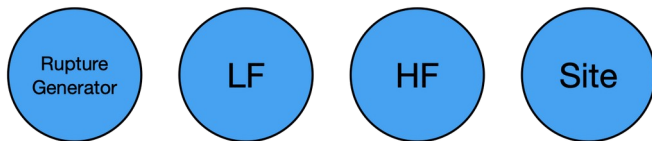


Rekoske et al., 2025

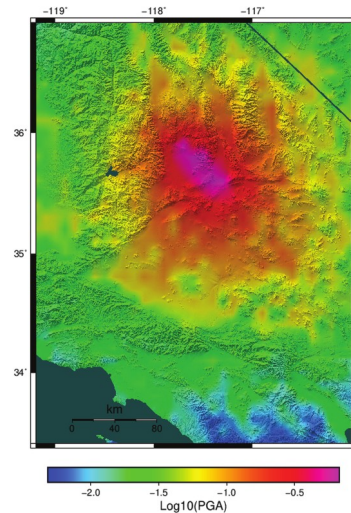
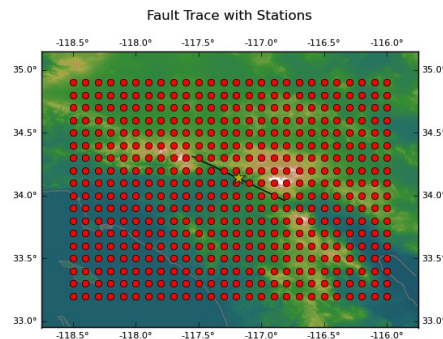
...as well as technical improvements to support all this!

Broadband Platform (BBP)

- The SCEC Broadband Platform produces simulated ground motions for events of your choosing
 - 1D deterministic (<1 Hz) + stochastic (1-20 Hz)
 - Produces seismograms and intensity measures
- Supports both user-defined and historical earthquakes
- Multiple modules for each simulation stage



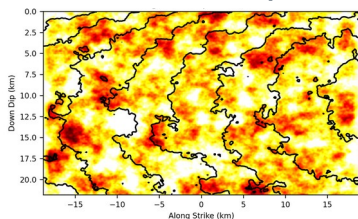
- Lightweight computational footprint – can run on your laptop



Scenario Simulations

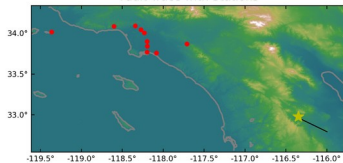
- User-defined simulations using pre-computed 1D Green's functions
- Simulations supported throughout California and Japan

Source description

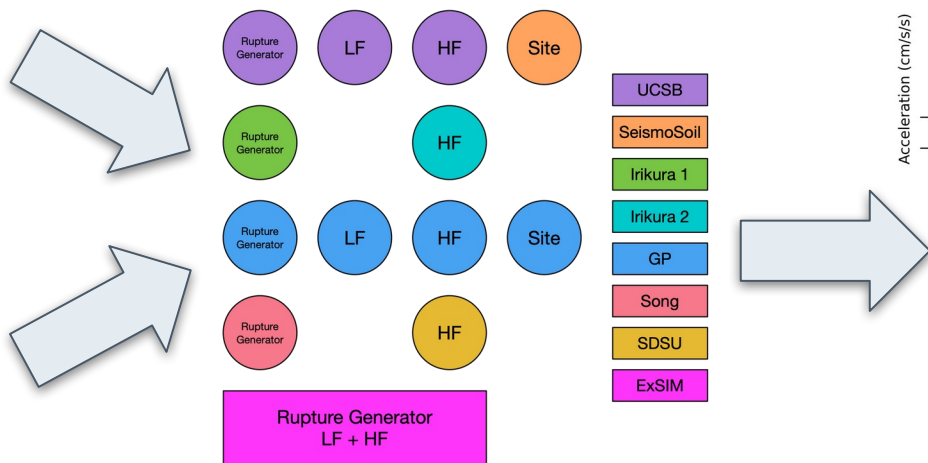


Station list

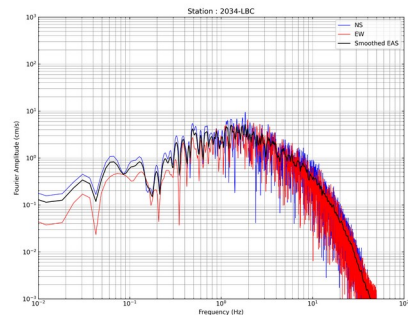
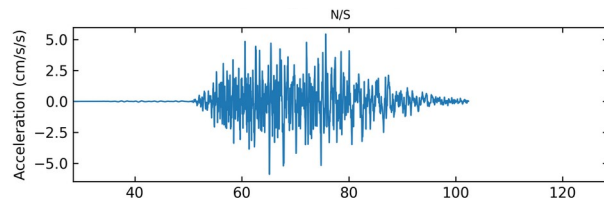
Fault Trace with Stations



BBP Modules



Data products



Validation Simulations

- Platform provides historical earthquake description and stations with recordings

California

- M_w 5.5 Alum Rock
- M_w 5.4 Chino Hills
- M_w 7.1 Hector Mine
- M_w 7.2 Landers
- M_w 6.9 Loma Prieta
- M_w 6.1 North Palm Springs
- M_w 6.7 Northridge
- M_w 6.0 Parkfield
- M_w 6.5 Ridgecrest A
- M_w 5.4 Ridgecrest B
- M_w 7.1 Ridgecrest C
- M_w 6.6 San Simeon
- M_w 5.9 Whittier Narrows

Japan

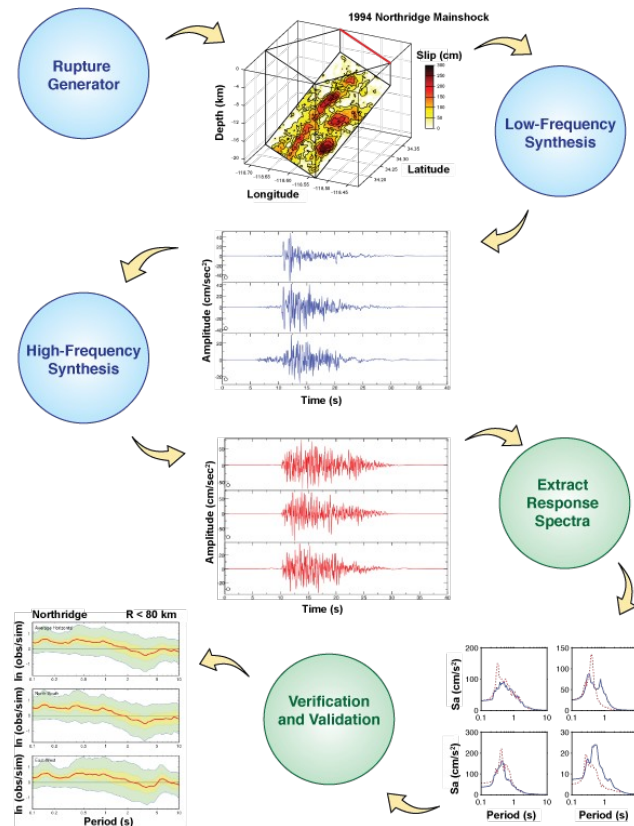
- M_w 6.7 Chuetsu-Oki
- M_w 6.9 Iwate
- M_w 6.7 Niigata
- M_w 6.6 Tottori

Italy

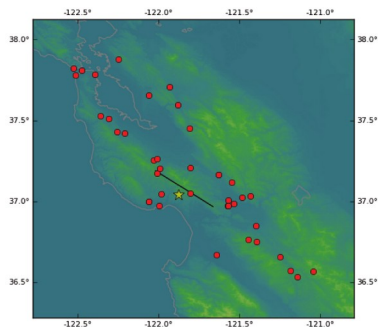
- M_w 6.3 L'Aquila

Eastern North America

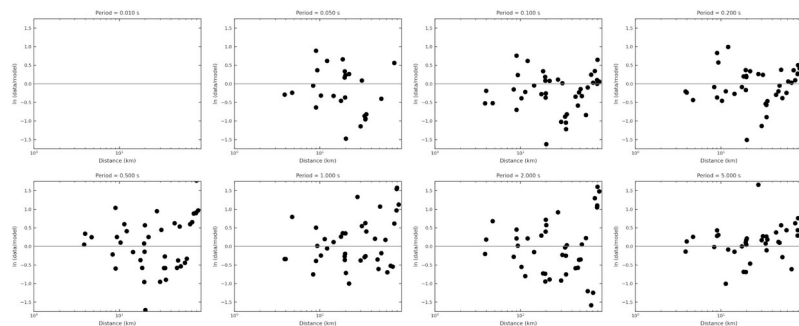
- M_w 5.7 Mineral
- M_w 4.6 Riviere-du-Loup
- M_w 5.8 Saguenay



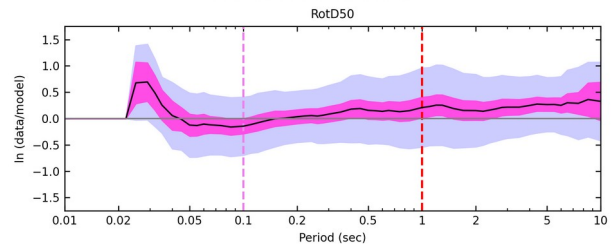
Validation Simulation Data Products



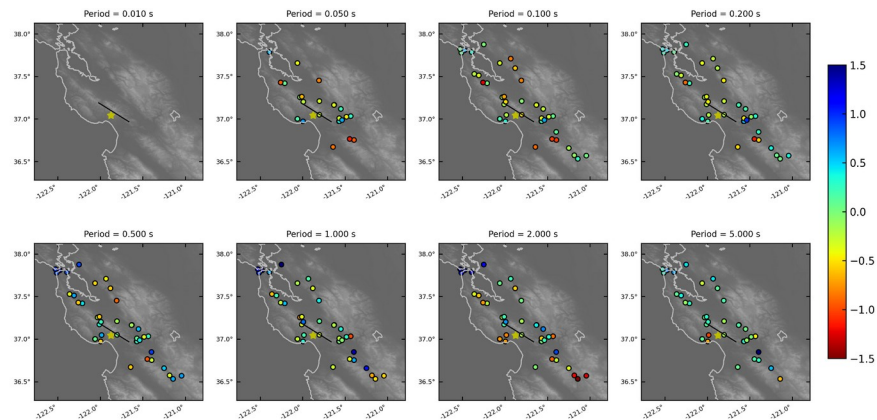
Fault trace and station map



Residuals by period and distance



Goodness-of-fit plots



Goodness-of-fit by period and station



Using the Broadband Platform



Simulation Mode *

Select the Broadband Platform simulation mode

☐ Validation Simulation

Run a validation simulation, using a source description from a historical event, along with the corresponding list of stations for which we have recorded data for this event.

☐ Scenario Simulation

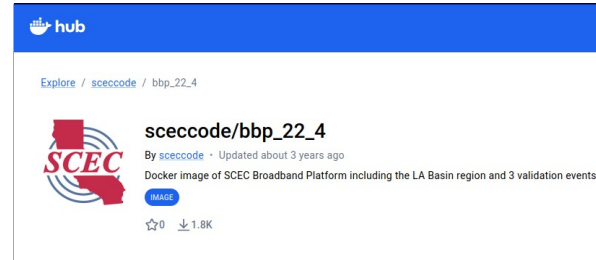
Run a scenario simulation, where the user provides a source description and the corresponding list of stations for which we have recorded data for this event.

Simulation method

GP (Graves & Pitarka) Method
UCSB Method
EXSIM Method
SONG Method
Irikura Recipe Method 1
Irikura Recipe Method 2

Number of Simulations *

1



Docker
Container

```

Welcome to the SCEC Broadband Platform version 22.4.0.
=====
Please select the Broadband Platform mode of operation:
  * Validation - Simulates a historical event
  * Scenario   - Runs a user-defined hypothetical event
Do you want to perform a validation simulation (y/n)? n
=====
The Broadband Platform provides the following velocity models, which also include several method-
specific and region-specific parameters.
Please select a velocity model (either number or name is ok):
(1) SouthernSierra500-2
(2) LABasin500
(3) CentralCal500
(4) MOCAL500
(5) Mojave500
? 2
=====
The Broadband Platform includes several scientific methods that can be used to calculate synthetic
seismograms.
Choose a Method to use in this Broadband scenario simulation:
(1) GP (Graves & Pitarka)
(2) UCSB
(3) SONG
(4) EXSIM
(5) Song
(6) Irikura Recipe Method 1 (Irikura1)
(7) Irikura Recipe Method 2 (Irikura2)
? 1
  
```

Local install

HPC install

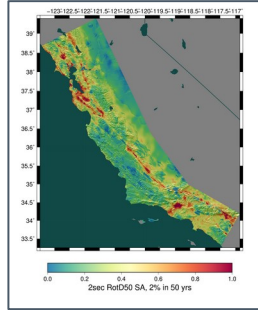




SCEC's Physics-based Seismic Platforms

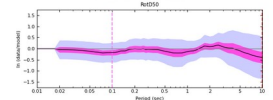
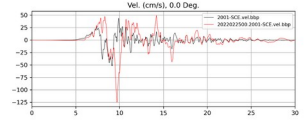
CyberShake

- 3D PSHA
- Hundreds of thousands of events at hundreds of sites
- Large-scale computations
- Access CyberShake data via the CyberShake data access tool:
<https://github.com/SCECcode/cs-data-tools>



Broadband Platform

- 1D single-event simulations (with 3D on the way!)
- Scenario and historical events
- Lightweight computations
- Access the Broadband Platform here:
<https://github.com/SCECcode/bbp>



These platforms enable SCEC to transform research into applied data products.

Ideas for future development? Come tell us!



Thanks!

