SCEC Open-Source Tools for Strong Ground Motion Simulation and Validation

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Abstract

The Statewide California Earthquake Center's (SCEC) Broadband Platform (BBP) is a collection of open-source scientific software modules that can simulate broadband (0-20+ Hz) ground motions through a 1D layered velocity structure for earthquakes at regional scales, compare simulation results between methods, and validate simulation results against observations. The Ground Motion Simulation Validation (GMSV) Toolkit contains software components from the Broadband Platform for the uniform re-processing of recorded and/or simulated seismograms to enable 1) one-to-one comparisons in time and frequency domains, 2) statistical computations of various validation metrics, and 3) plotting of ground motion data products. It maintains full compatibility with the original codes, and reproduces metric computation, statistics, and plot results obtained in previous BBP studies.

Broadband Platform

Validation Simulations

- Calculate seismograms for a historical earthquake
- Use sites where recorded strong motion data is available

• Northridge	• Mineral	• Chino Hills
• Whittier Narrows	• Saguenay	• Alum Rock
• Landers	• Tottori	• Riviere du Loup
• North Palm Springs	• Niigata	• Parkfield
• Loma Prieta	• Iwate	• San Simeon
• Chuetsu-Oki	• L'Aquila	• Hector Mine
• Ridgecrest A/B/C	• La Habra	

Scenario Simulations

- Calculate seismograms for a hypothetical earthquake
- Use sites specified by the user
- 1D Green's Functions Available (5 in California, 2 in Japan, 2 in Central Eastern North America, 1 in Italy)

Simulation Methodologies

- Stochastic method: EXSIM
- Broadband using 1D Green's Functions: UCSB
- Hybrid - Green's Functions LF, Stochastic HF: Graves & Pitarka (GP), SDSU, Song, Irikura Recipe Methods 1 and 2
- Site response modules: Graves & Pitarka (GP), PySeismoSoil

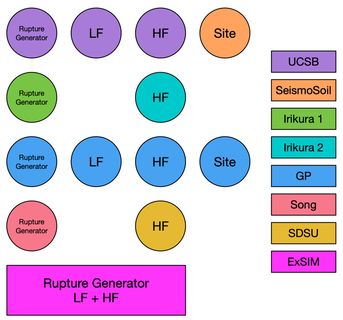


Figure 1: List of modules available on the Broadband Platform, showing what codes each method provides.

Good Software Engineering Practices

- BSD-3 open-source license, supporting code-specific open-source licenses
- Modular architecture with common data formats
  - Supports code integration from multiple sources with minimal changes to original code
- Continuous Integration (CI) set up on GitHub
  - Unit tests confirm modules are working properly
  - End-to-end acceptance tests ensure user installation produces expected results
- Software releases with DOIs for software distribution and validation dataset
  - Version control to track software changes and versions using GitHub
  - Ticketing system to document and resolve issues, documentation available on wiki

GMSV Toolkit Data Products

For both validation and scenario simulations, the Broadband Platform generates plots for the slip distribution of the source, a map showing the stations in relation to the fault, and plots for both velocity and acceleration seismograms.

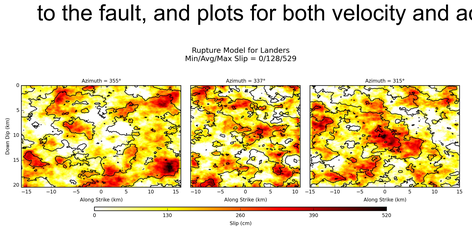


Figure 2: Slip distribution plot showing the 3 rupture segments for the 1992 Landers earthquake.

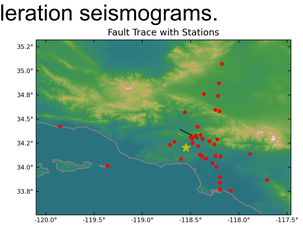


Figure 3: Northridge (1994) station map showing fault trace, projection of hypocenter on the surface, and stations.

The GMSV Toolkit includes several validation metrics that can be used to compare simulated seismograms against recorded data. The two main validation workflows available are the Fourier Amplitude Spectra (FAS) and Pseudo-Spectral Acceleration (PSA), shown in the diagram below:

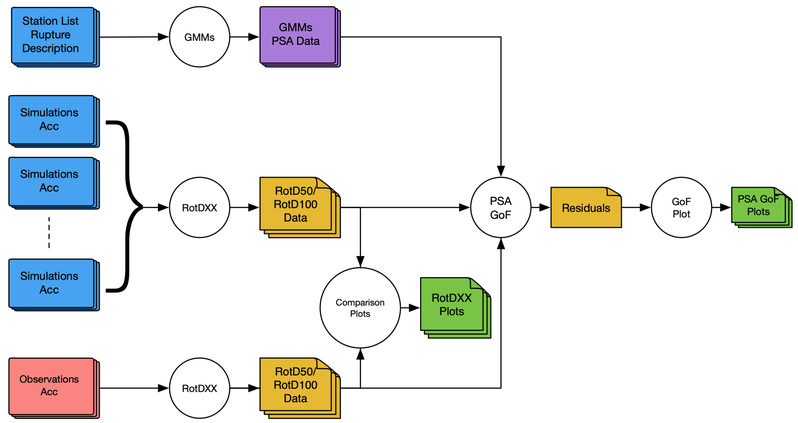
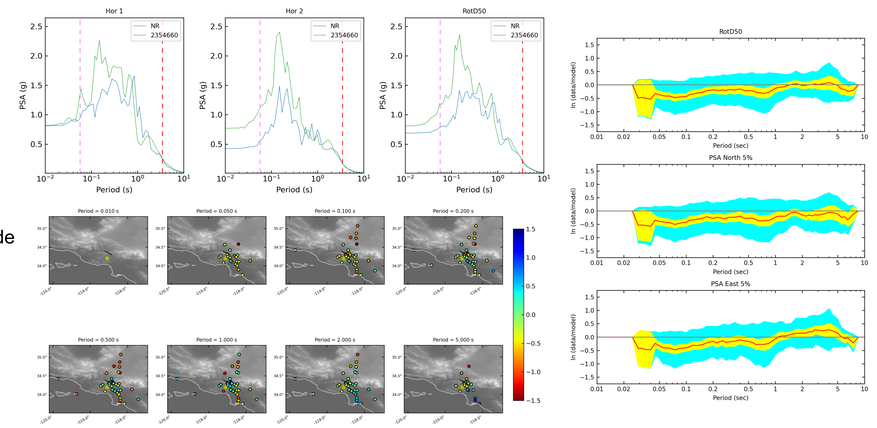


Figure 4: PSA validation workflow (above): First, RotD50 is computed for both simulations and recorded data. Then, the PSA values of the horizontal components and RotD50 are compared station by station (below left). In the PSA GoF (below right), the results are aggregated across all stations and compared against recorded data at different periods. The solid red line shows the mean, the narrow band is the 90% confidence interval of the mean, and the wide band shows the standard deviation centered around the mean. PSA Map GoF plot (bottom left), is useful for checking bias related to station location and directivity effects.



Quakeworx

The Broadband Platform is available on Quakeworx, providing users a turnkey solution for running both validation and scenario simulations at SDSC Expanse computing cluster. See poster #206 for more details!

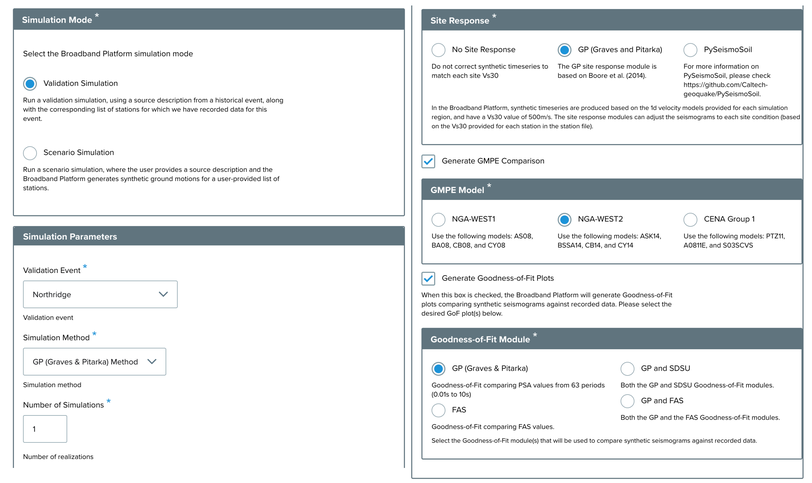


Figure 5: Quakeworx web application for the Broadband Platform (above). Users can launch the Broadband application on the Quakeworx Gateway and select running either a validation or scenario simulation. For validation runs, users can select one of the 20 available validation events along with a simulation method. For scenario simulations, users are able to upload files containing the source description, and a list of stations to compute ground motions.

Broadband Platform Summary

- Open-Source scientific software that can calculate broadband (0-20Hz) ground motions at user specified sites for historical and scenario earthquakes
- Provides ground motion models from seven different research groups
- Distributed as open-source package for Linux and as a Docker Image
- Available on Quakeworx gateway, supporting validation and scenario events

GMSV Toolkit Summary

- Provides standalone, well-verified, open-source tools for calculating per-station metrics and generating multiple Goodness-of-Fit comparison plots
- Features both a command-line interface and Python APIs for ease to use
- Includes extensive documentation, examples, and Jupyter notebook tutorials
- Available on GitHub as an open-source package for Linux/GNU compilers

References

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SCEC GMSV Tools are available at:

https://github.com/SCECcode/bbp
https://github.com/SCECcode/gmsvtoolkit
https://quakeworx.org

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