The SCEC Broadband Platform: Open-Source Software for Strong Ground Motion Simulation and Validation

Fabio Silva[1], Sajan K C[2], Choonhan Youn[3], Philip Maechling[1], Chukwuebuka Nweke[2], Amit Chourasia[4], Ahmed Elbanna[1], Yehuda Ben-Zion[1]

[1]Statewide California Earthquake Center, [2]University of Southern California,
[3]San Diego Supercomputer Center, [4]University of California Los Angeles

Overview

- Open-Source scientific software that can calculate broadband (0-20Hz) ground motions at user specified sites for historical and scenario earthquakes
- Collaborative software development project involving
  - SCEC Geoscientists
  - Graduate Students
  - Civil Engineers
  - SCEC Research Computing
- Integrates complex scientific modules including
  - Rupture Generation
  - Seismogram Synthesis
  - Site Effects Calculation
  - Visualization
- Provides ground motion models from seven different research groups
- Features command-line interface for interactive use and scripting interface
- Distributed as open-source package for Linux and as a Docker Image
- Available on Quakeworx gateway, supporting validation and scenario events

Features

Validation Simulations

- Calculate seismograms for a historical earthquake
- Use sites where recorded strong motion data is available
  - Northridge
  - Whittier Narrows
  - Landers
  - North Palm Springs
  - Loma Prieta
  - Chuetsu-Oki
  - Ridgecrest A/B/C
  - Mineral
  - Saguenay
  - Tottori
  - Niigata
  - Iwate
  - L'Aquila
  - La Habra
  - Chino Hills
  - Alum Rock
  - Riviere du Loup
  - Parkfield
  - San Simeon
  - Hector Mine

Scenario Simulations

- Calculate seismograms for a hypothetical earthquake
- User provides event description (location, magnitude, mechanism)
- 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

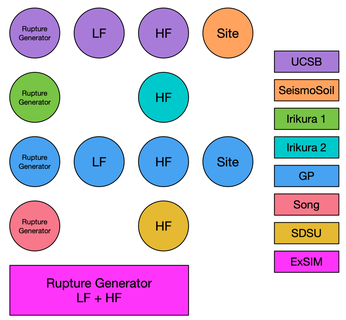


Figure 1: List of modules available on the Broadband Platform, showing what codes each method provides.

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

Broadband Platform Data Products

For both validation and scenario simulations, the SCEC 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.

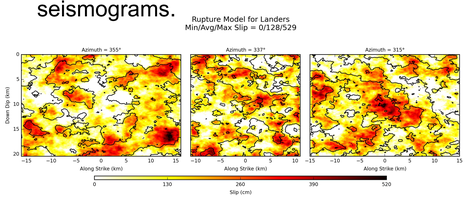


Figure 2: Slip distribution plot showing the 3 rupture segments for the 1992 Landers earthquake.

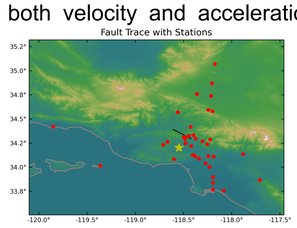


Figure 3: Northridge (1994) station map showing fault trace, projection of hypocenter on the surface, and stations.

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

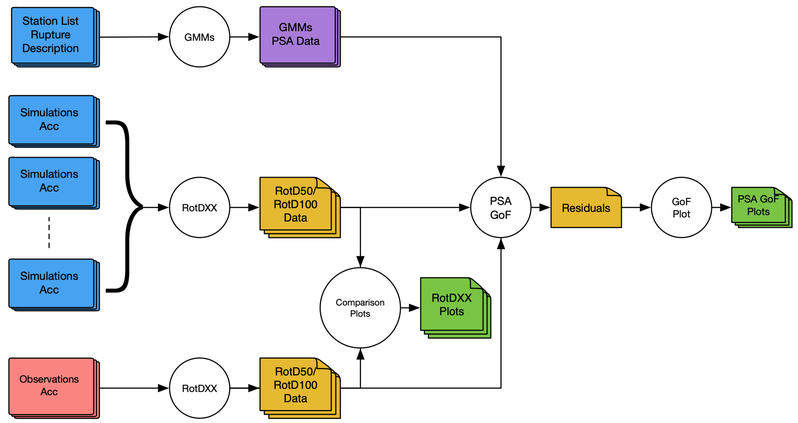
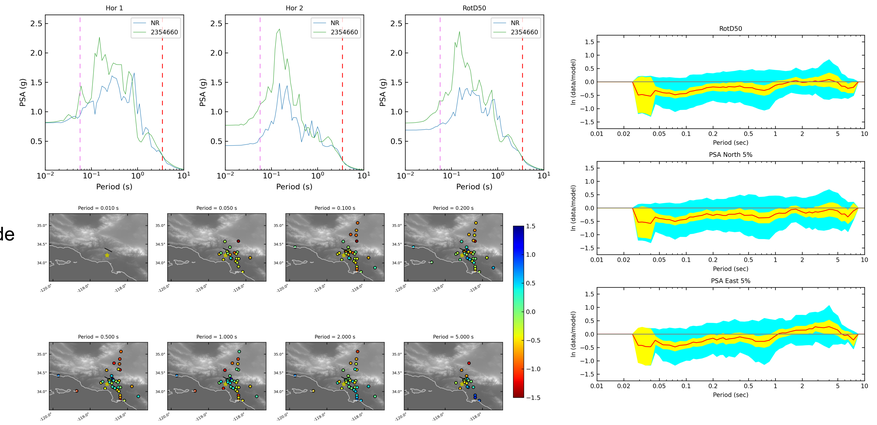


Figure 4: PSA validation workflow (above): First, RotD50 is computed for both simulations and recorded data. Then, the PSA values of the horizontal components and RotD50 are compared station by station (below left). In the PSA GoF (below right), the results are aggregated across all stations and compared 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 SCEC Broadband Platform is available on Quakeworx, providing users a turnkey solution for running both validation and scenario simulations at SDSC Expanse computing cluster.

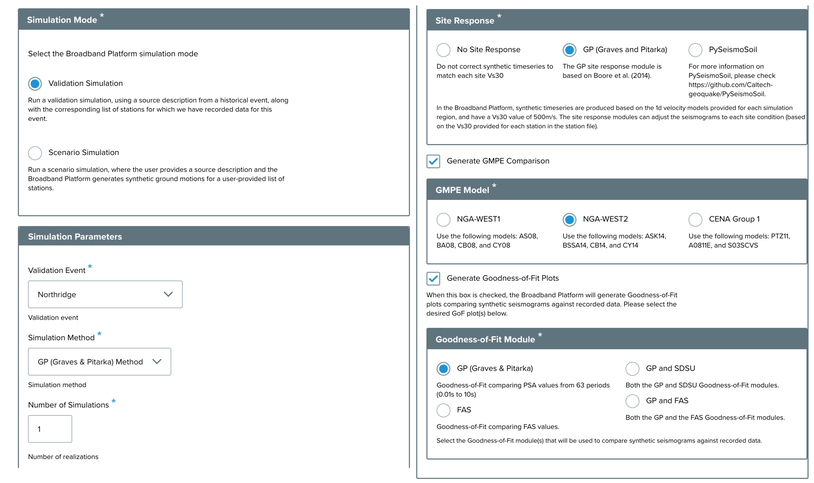


Figure 5: Quakeworx web application for the Broadband Platform (above). Users can launch the Broadband application on the Quakeworx Gateway and select running either a validation or scenario simulation. For validation runs, users can select one of the 20 available validation events along with a simulation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

Recent Updates

- Added support for using externally calculated low-frequency 3D seismograms
- Updated FAS workflow to match the codes used by the NGA-West 3 project
- Revised station list format to accept $Z_{1.0}$ values that can be used by the PySeismoSoil module to adjust calculated seismograms to site conditions

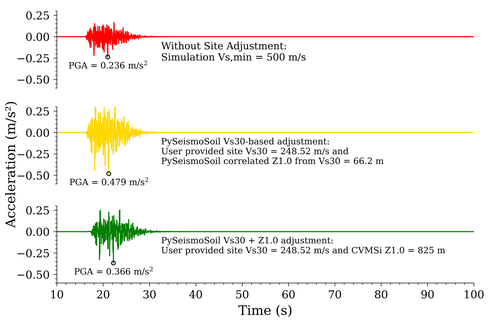


Figure 6: Broadband Platform users are now able to provide either or both Vs_{30} and $Z_{1.0}$ values for each station. In the top (red) plot, we have the original calculated timeseries for station ID 525 for the Mw 5.27 1987 Whittier Narrows-02 earthquake. The second plot (yellow) shows the correction applied by PySeismoSoil based only on the Vs_{30} value of 248.52 m/s. In the bottom plot (green), we show the correction applied by PySeismoSoil when the user provides both a Vs_{30} value of 248.52 m/s and a $Z_{1.0}$ value of 825 m.

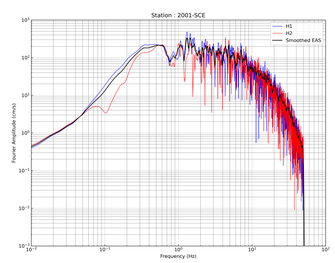


Figure 7: We have recently updated the Fourier Amplitude Spectra (FAS) validation pipeline for both the Ground Motion Simulation and Validation Toolkit (GMSV Toolkit) and the Broadband Platform to match the codes used by the NGA-West 3 project. The plot on the right shows the FAS calculated for the two horizontal components, along with Smoothed Effective Amplitude Spectra (SEAS). Using the NGA-West 3 codes makes it easier to compare data products across projects. We also plan to use the updated FAS codes to process seismograms generated in Cybershake studies.

The Broadband Platform is available at:

https://github.com/SCECcode/bbp

https://quakeworx.org

Acknowledgements

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