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

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Broadband Platform 22.4 Overview

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

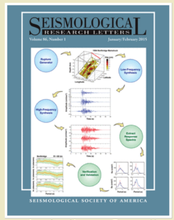
Broadband Platform Features

Validation Simulations

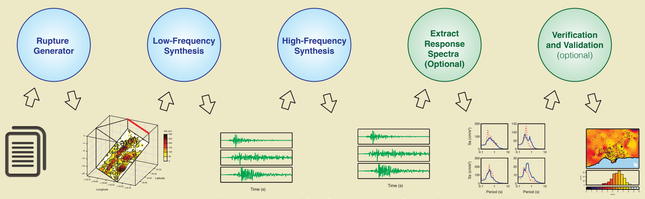
- **Calculate seismograms for a historical earthquake**
- **Use sites where recorded strong motion data is available**

Scenario Simulations

- **Calculate seismograms of a hypothetical earthquake**
- **User provides event description**
  - **Earthquake location**
  - **Magnitude and Mechanism**
- **Use sites specified by the user**
- **1D Green's Functions Available**
  - **California (5), Japan (2)**



SRL Special Issue Including a Broadband Platform Review and Detailed Model Descriptions



Broadband Platform Workflow Showing Simulation Steps

Simulation Methodologies

- **Stochastic Method: EXSIM (UWO)**
- **Broadband Using 1D Green's Functions: UCSB, Composite Source Model (CSM)**
- **Hybrid - Green's Functions LF, Stochastic HF: Graves & Pitarka (GP), SDSU, SONG, Irikura Recipe Methods 1 and 2**

Good Software Engineering Practices

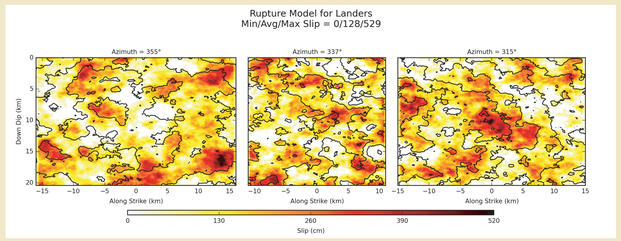
- **BSD-3 open-source license with support for method-specific open-source licenses**
- **Modular architecture with common data formats**
  - **Supports code integration from multiple sources with minimal changes to original code**
- **Continuous Integration (CI) set up on GitHub**
  - **Unit tests confirm modules are working properly**
  - **End-to-end acceptance tests ensure user installation produces expected results**
- **Formal 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**

Recent Broadband Platform Developments for 2019-2022

- **Migrated Broadband Platform to Python 3.7+ and GNU 8.0+ compilers**
- **Added FAS validation for a better seismological interpretation of ground motions**
- **Implemented multi-segment rupture capabilities into most BBP simulation methods**
- **Updated GP low-frequency module, resulting in a 10x performance improvement**
- **Revised the UCSB source generator to assume a double-corner frequency source spectrum**
- **Included Central California, Central Italy, and Southern Walker Lane simulation regions**
- **Established common BBP codebase by merging CyberShake BBP changes into this release**
- **Added Hector Mine and Ridgecrest 2019 A/B/C validation events**
- **Used to simulate ground motions produced by large magnitude (M7.5+) ruptures**
  - **Used in study of building response to strong ground motions**
- **Integrated RSQsim-generated rupture slip-time histories into BBP workflow**
  - **Used to calculate large collection of ground motion parameters for M6 to M8 ruptures**

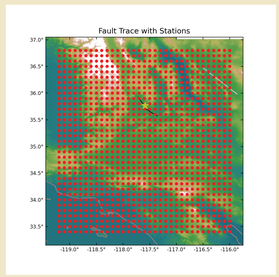
Broadband Scenario Simulations

- **Data products**
  - **Rupture slip time histories**
  - **Station and fault trace plots**
  - **Seismograms (velocity and acceleration)**

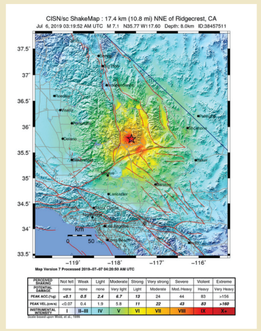


Landers Earthquake (1992) Multi-Segment Slip Distribution

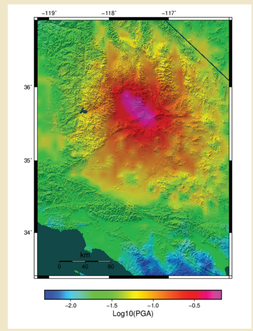
- **Ridgecrest M7.1 July 5th 2019 Simulation (GP method)**
  - **Use about 1,200 stations distributed uniformly in a grid**
  - **Export PGA and PGV data into OpenSHA**
  - **Create ground motion intensity maps**



Station Map Using Station Grid



CISN ShakeMap - Instrumental Intensity

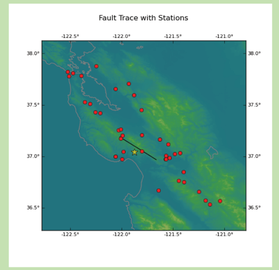


PGA Map Using Simulated Data

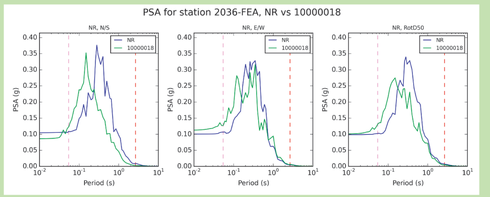
Broadband Validation Simulations

Simulation methods validated using the following events:

- **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**



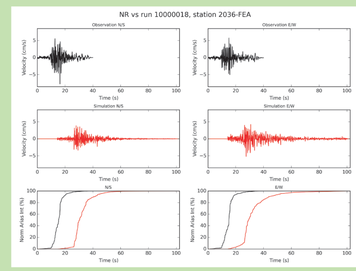
Loma Prieta EQ Map Showing Epicenter, Fault Trace and Stations



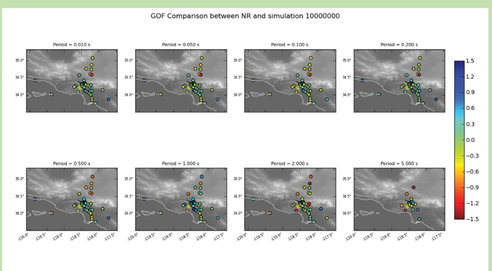
PSA Comparison for a Single Station

BBP Data products

- **Rupture slip time histories**
- **Station and fault trace plots**
- **Seismograms (velocity and acceleration)**
- **Comparison of recorded strong ground motions against calculated seismograms**
  - **Timeseries, PSA, and FAS**
  - **Arias Duration**



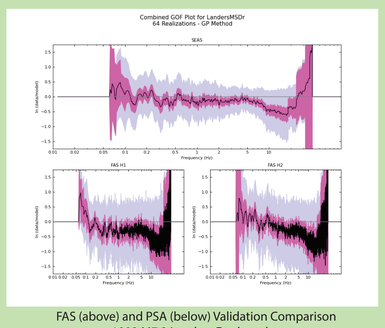
Comparison of Observed and Simulated Timeseries



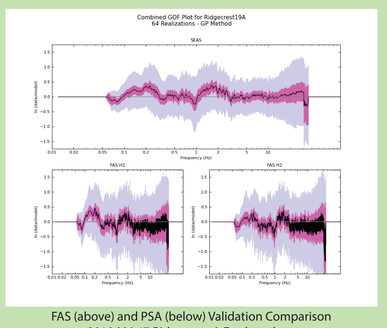
Northridge Earthquake Bias GoF Map Plot Showing 38 Stations

Goodness-of-Fit measurements

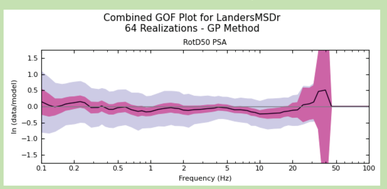
- **PSA comparisons by period, distance, and location**
- **Anderson GoF (2004)**
- **Fourier Amplitude Spectra (FAS) module**
  - **Smoothed Effective Amplitude Spectrum (SEAS)**
- **FAS GoF comparison against data**
- **RZZ2015 parameters**
- **Comparison of simulations against GMPEs**
  - **NGA West 1 (AS08, BA08, CB08, CY08)**
  - **NGA West 2 (ASK14, BSSA14, CB14, CY14)**
  - **CENA Group 1 (PZT11, A0811E, S03SCVS)**
- **Combine data from multiple realizations**
  - **PSA GoF plots (period, distance, location, Vs30)**
  - **FAS GoF plots (frequency)**
  - **Ranking of PSA/FAS GoFs for all realizations**
- **Mayhew-Olsen GoF calculates up to 12 GoF metrics**

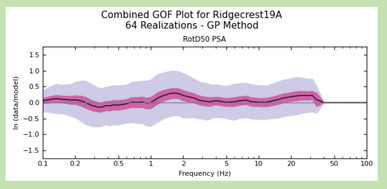


FAS (above) and PSA (below) Validation Comparison
1992 M7.2 Landers Earthquake



FAS (above) and PSA (below) Validation Comparison
2019 M6.47 Ridgecrest A Earthquake





The Broadband Platform software development is supported by the Southern California Earthquake Center (SCEC), which is funded by NSF Cooperative Agreement EAR-1600087 and USGS Cooperative Agreement G17AC00047. Additional support was provided by Pacific Gas and Electric.

BBP 22.4 available for download at https://github.com/SCECcode/bbp