Behavior of Multiple Broadband Ground Motion Simulation Techniques on the SCEC Broadband Platform

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(I) Background

The SCEC Broadband Ground Motion Simulation Platform (BBP) is an important resource for researchers and practitioners who need to use strong ground motion simulations.

The BBP allows a user to generate ground motions for a particular earthquake scenario using physics-based simulation methods, with components including earthquake rupture description and generation, modeling low- and high-frequency wave propagation, and options for incorporating non-linear site effects.

The BBP project recently completed its first phase after a large-scale set of validation exercises and a panel was convened to review the results, concluding that 3 methods are suitable for simulation of spectral acceleration (Sa) from 0.01 to 3 seconds (see posters #209 and #203).

(II) Objectives

- To provide insight as to how the accepted simulation methods, in their default form, compare given the same rupture scenarios. These insights will serve as a baseline for referencing the future differences observed between models;
  - a) when default settings are adjusted in next year's SCEC study and,
  - b) for earthquake validations and forward simulations, to allow for meaningful comparisons.
- To perform forward scenario simulations as an outside user on the SCEC BBP and provide feedback to SCEC IT.

(III) Procedure

1) Develop a suite of earthquake scenarios (largely adopted from the BBP Validation project.)
2) Perform simulations for the 3 methods utilized in this project:
   - GP = Graves & Pitarka (Graves and Pitarka, 2010)
   - EX = ExSim (Motazedian and Atkinson, 2005)
   - SE = SDSU-ETH (Mai et al., Mena et al., 2010)
3) Compare RotD50 Sa predictions between techniques over the period range of 0.01-10 seconds for each scenario.
4) Compare RotD50 Sa predictions between techniques spatially (in map form) both to compare techniques with each other, and with GMPE predictions.

(1) Earthquake Scenarios

Five earthquake rupture scenarios were evaluated, all using southern CA region 1D velocity model and associated Green's Functions. Hypocenters were places at the center of the rupture plane. One realization (i.e. seed) of each rupture generator was used.

Scenario Name	Mechanism	Mw	L (km)	W (km)	Ztor (km)	Strike (deg)	Rake (deg)	Dip (deg)
EQ1	Strike-Slip	6.2	17.8	8.9	4.0	0	180	90
EQ2	Strike-Slip	6.6	28.2	14.1	0.0	0	180	90
EQ3	Reverse	6.6	28.2	14.1	3.0	0	90	45
EQ4	Reverse	7.0	50.9	21.2	0.0	0	90	45
EQ5	Strike-Slip	7.0	71.9	15.0	0.0	0	180	90

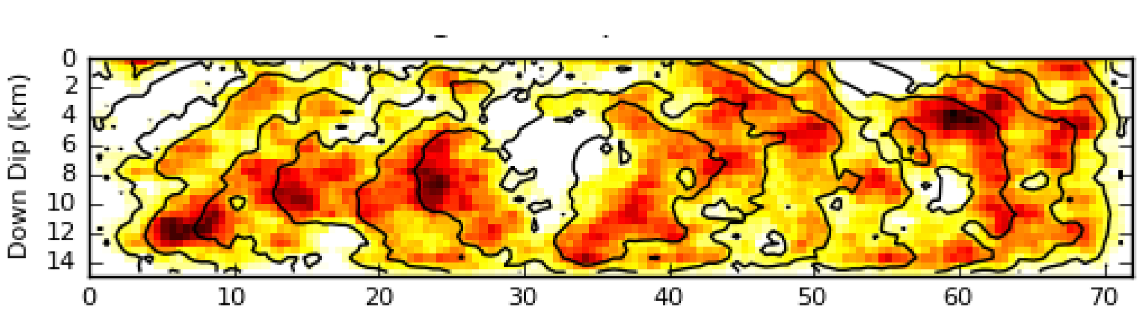
(2) BBP Simulations

Required Inputs

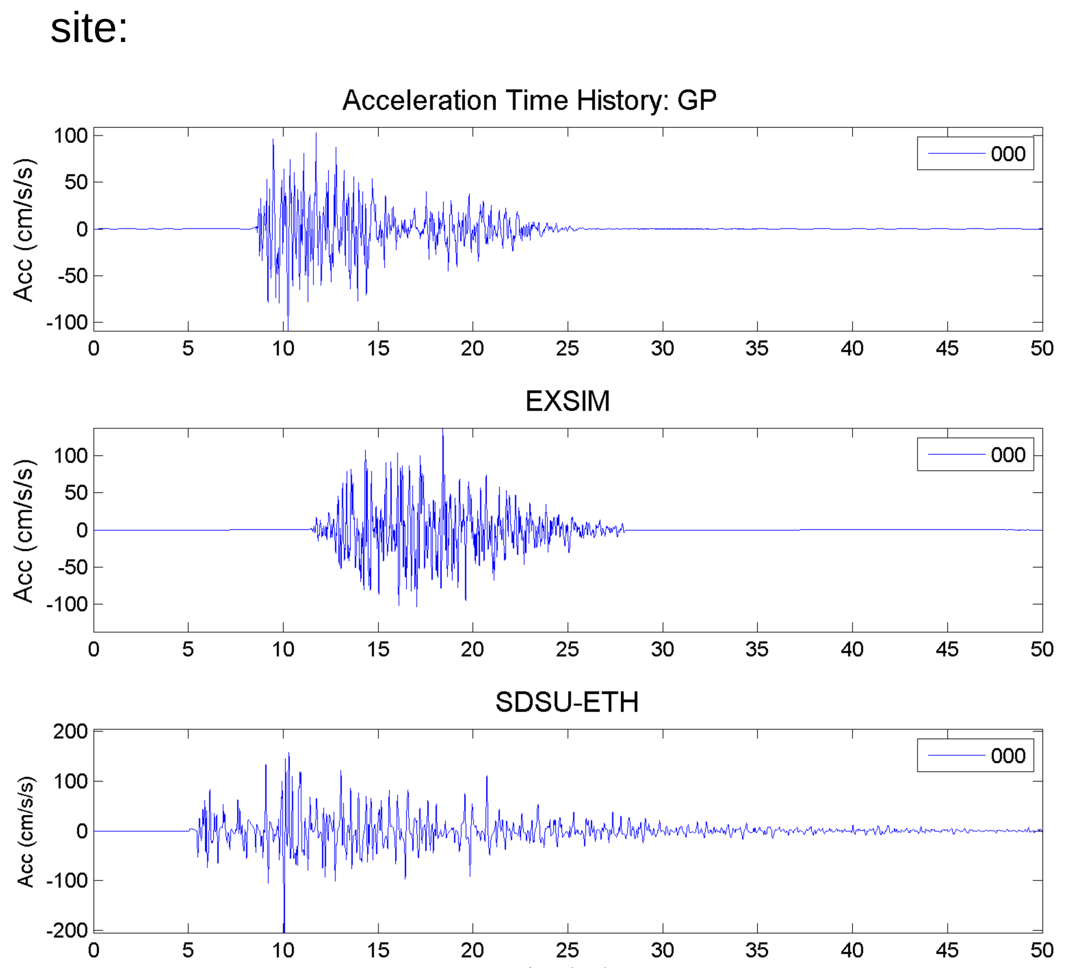
1) Source Description
   - Mw, Length, Width, Strike, Rake, Dip, Ztor, Hypocenter
2) Station list
   - Latitude, Longitude, Station ID
3) Simulation Region – for selection of pre-computed Green's Functions.
4) Simulation technique
5) No site response (rock site simulations)

Outputs

5) Rupture Model (used in GP and SDSU techniques):



6) Simulated two-component time histories at each site:



(3) Analysis of Results

The Rotd50 component of 5% damped pseudo-spectral acceleration (Sa) is calculated over the range of 0.1-100 Hz. Results comparing the different techniques are presented as "Sa Ratio" plots for each scenario event. The Ratio plots represent the natural log of the ratio of RotD50 spectral acceleration at a given period (T) calculated from one simulation technique (j) relative to another (k), averaged over all recording stations (i):

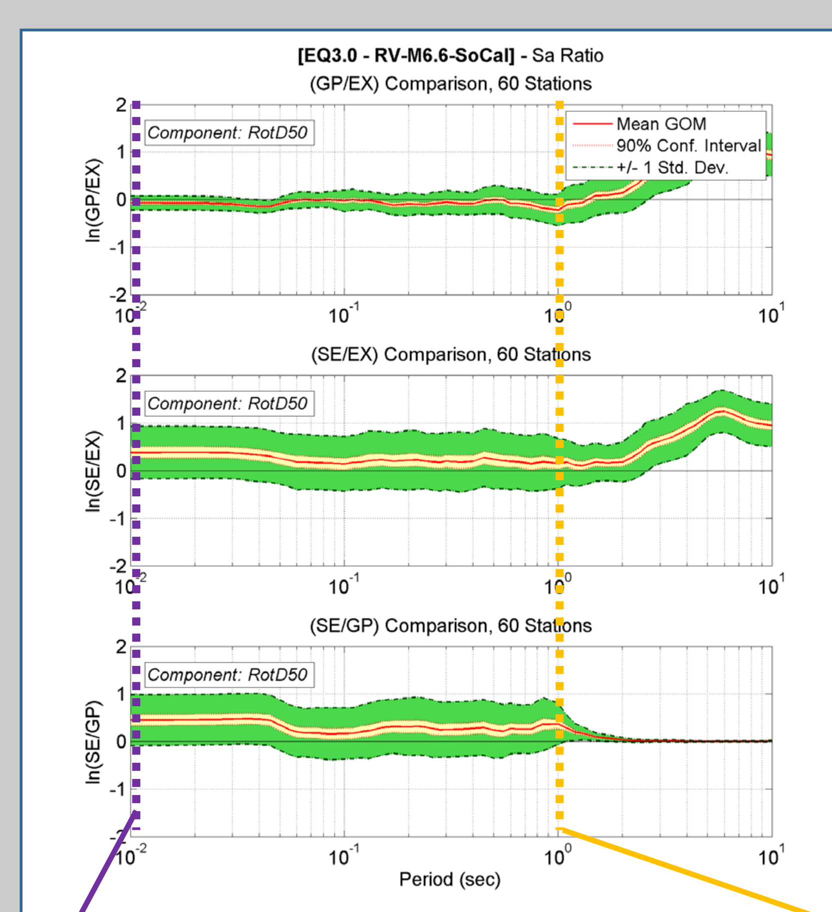
$$Sa\ Ratio(T,j,k) = \frac{1}{N}\sum_{N}^{i=1} ln\left(\frac{Sa(T)_{i,j}}{Sa(T)_{i,k}}\right)$$

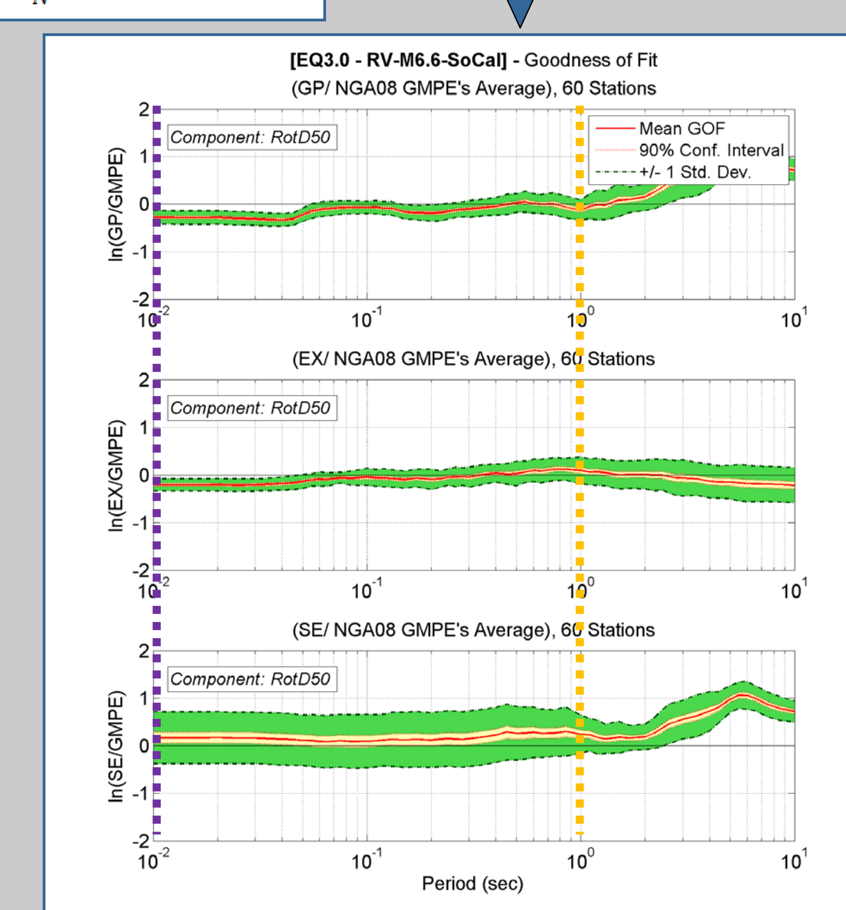
Results are also presented as the log ratio of the simulated Sa to the Sa predicted from the average of the NGA GMPEs (using rock site conditions.) This is a good test to see which methods are performing well, if the GMPE predictions are taken as "ground truth."

$$GMPE\ Ratio(T,j,k) = \frac{1}{N}\sum_{N}^{i=1} ln\left(\frac{Sa(T)_{i,j}}{Sa(T)_{GMPE}}\right)$$

Sa Ratio and GMPE Ratio plots were created for each event scenario, showing the three simulation method combinations in separate rows.

Median ratios are in red, 90% confidence interval in yellow, and median +/- 1σ in green.

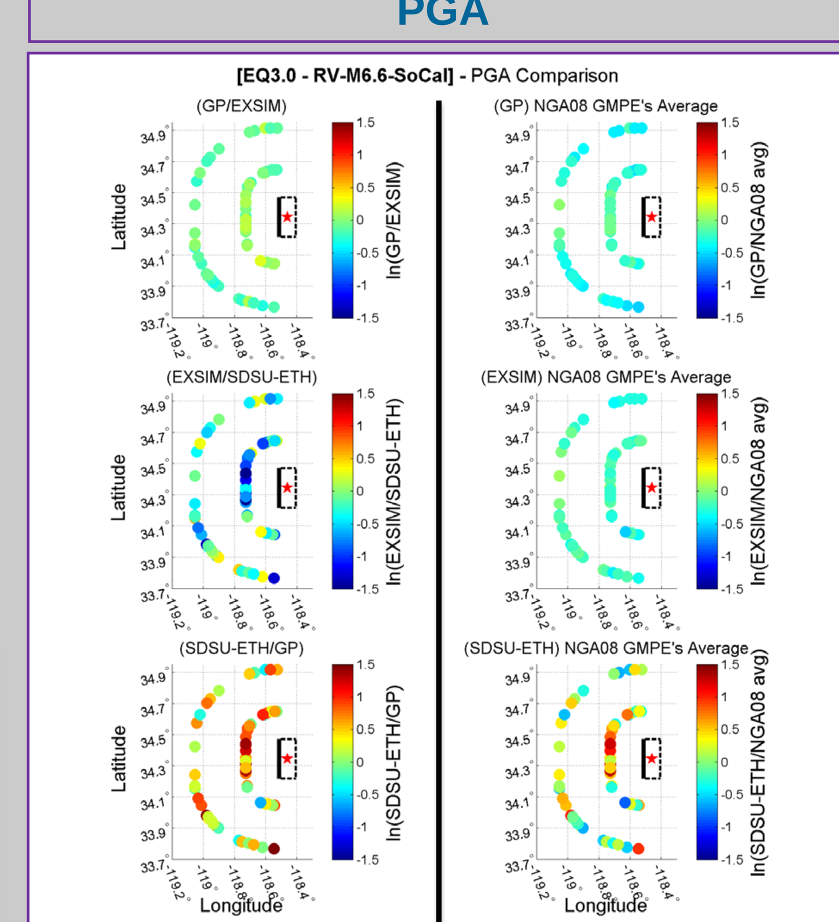




Maps

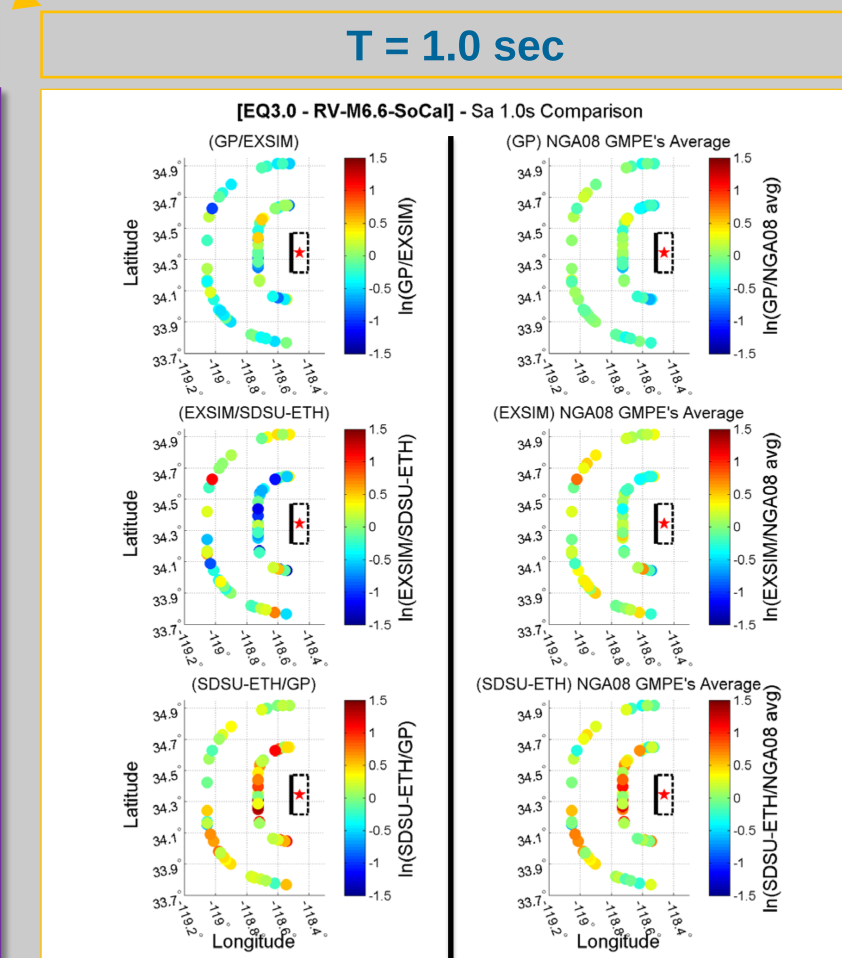
Maps of Sa Ratio and GMPE Ratio at each station were created to observe trends in the spatial behavior of the models. One plot is created per spectral period; the left column is Sa Ratio, and the right column is GMPE Ratio.

PGA



Sa Ratio | GMPE Ratio

T = 1.0 sec



Sa Ratio | GMPE Ratio

(5) Conclusions

- For a single realization of each EQ scenario, results match surprisingly well to GMPEs. (i.e. good results for not using the average/best of 30+ realizations.)
- Best match between all three methods at T < 2 seconds.
- The three methods give more similar results for Mw 7.0 than for Mw 6.6 and Mw 6.2.
- For Mw 6.2 and Mw 6.6 (EQ1-EQ3), GP and SE are larger than EX at periods longer than 1 second, where GP and SE tend to overpredict the GMPE and EX tends to underpredict.
- As short periods GP and EX are more similar than SE.
- Directivity is seen at long T for GP and SE but not EX:
  - updip from the hypocenter for RV 7.0 and
  - away from the hypocenter along strike for SS 7.0
- Different techniques exhibit varying degrees of dependence on rupture propagation direction. GP has the highest systematic distribution of Sa in space, where SE contains the highest amount of randomness in space, with EX somewhere in between.

(6) Acknowledgements

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