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Constraining GMPEs in Critical Ranges for Complex Ruptures using Strong Motion Simulations on the SCEC BBP

URS

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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 crustal event validation exercises. This project (and the associated BBP version) only considers planar finite fault source descriptions. The study presented here utilizes the validated version of the SCEC BBP, in conjunction with some modifications to account for complex rupture geometries, in order to study the behavior of GMPEs near these complexities.

(II) Objectives

- To address the technical issue of how to best utilize existing GMPEs in important ranges for complicated ruptures; areas where there is very little recorded data.
  - Applicable when: changes in geometry and faulting style can result in unclear definitions for many GMPE input parameters *(dip, rake, depth, distance, magnitude etc.)*
- We use **SCEC BBP** finite fault simulations to predict ground motions for a set of scenarios…
- …and use the results as a guide for how to address these special conditions with existing GMPEs.
- We compare the simulation results to the GMPE predictions using multiple rules for defining GMPE input parameters for our case study.

(1) BBP Simulations

Source Description: Mw, Length, Width, Strike, Rake, Dip, Ztor, Hypocenter

- 3 simulation techniques: GP, SDSU, ExSim
- 32 source realizations of each scenario with randomized hypocenter locations
- 5 scenarios
- 3 magnitudes per scenario: 7.0, 7.2, 7.4
- 2 segments per scenario

(2) Approach

1. Simulations were performed for each segment separately (primary and secondary; terminology explained to the right)
2. Simulated waveforms are combined in the time domain, with appropriate time lag based on hypocenter location, to obtain the combined rupture solution.
3. GMPE estimates are obtained for the primary and combined segment ruptures, using the 4 GMPE approaches for complex ruptures listed below.
4. FACTORS are computed. FACTORS are a ratio between the RotD50 of the combined rupture and the RotD50 of the primary rupture alone (ln units):

$$\text{Factor} = \ln\left(\frac{RotD50_{combined}}{RotD50_{primary}}\right)$$

5. We compare factors derived from the simulations with factors computed from the GMPEs using the 4 approaches explained below.
6. These comparisons inform our decision about which GMPE approach to use for the case study.

GMPE approaches for calculating FACTORS

Method 1: SRSS SINGLE SEGMENTS

- Compute Sa for each segment independently (using that segment's dip, rake, width, distance, and magnitude)
- take the square root sum of squares (SRSS) of the Sa of the two segments.

Method 2: AVG PARAMETERS (AREA)

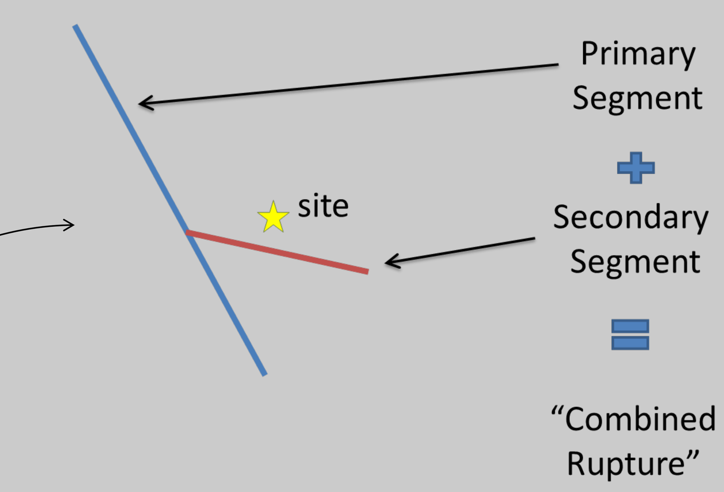
- weight the fault parameters (rake, dip, width) based on their respective area
- use the total combined magnitude
- use the closest distance to either segment

Method 3: AVG. PARAMETERS ($1/R^2$)

- discretize the fault and compute weighted average fault parameters based on their distance to the site ($1/R^2$)
- use the total combined magnitude
- use the closest distance to either segment

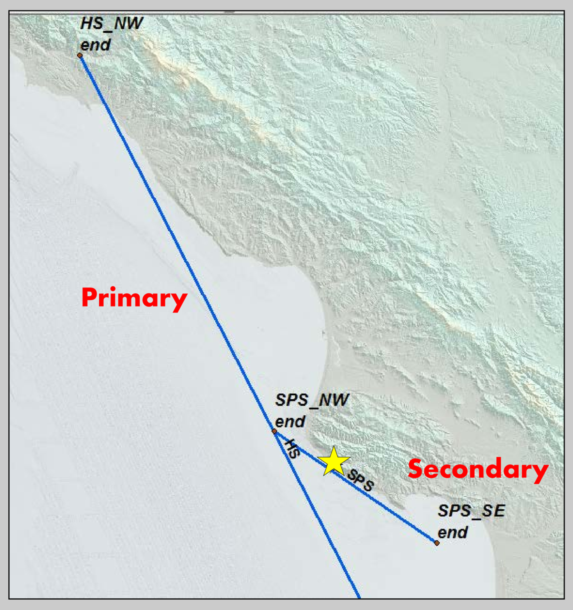
Method 4: CLOSEST SEGMENT

- use the total combined magnitude
- use fault parameters of the closest segment

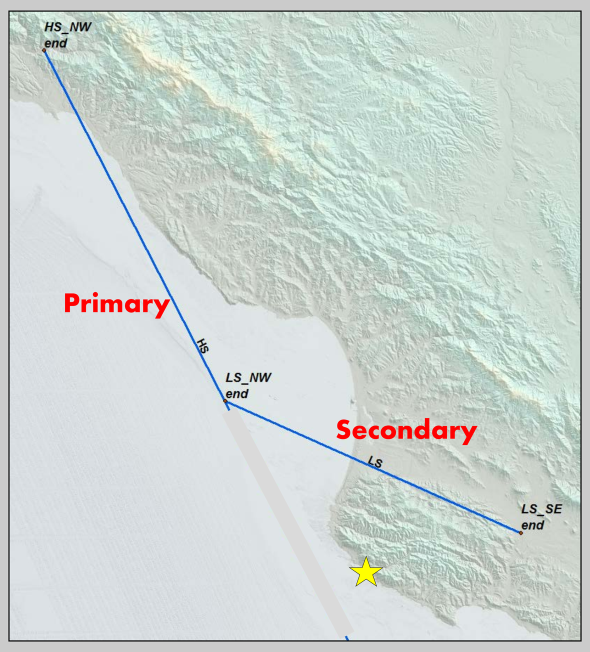


(3) Earthquake Scenarios

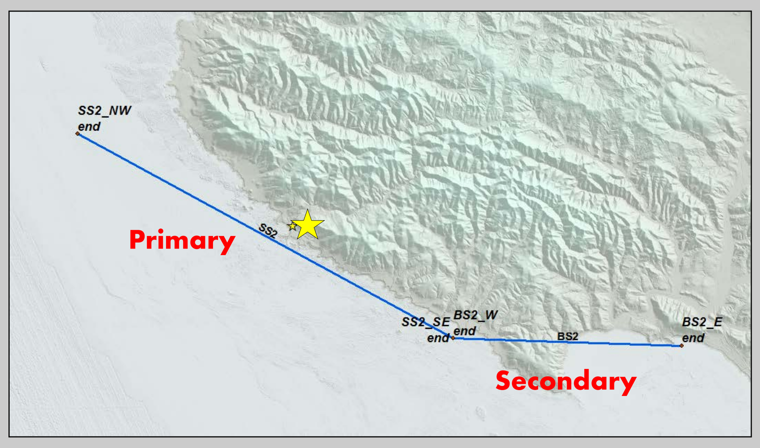
- Lengths
  Secondary = 25.5 km (fixed)
  Primary = varies w/ Leonard 2010
- Dip = 90
- Rake = 180 (RL SS)
- Depth to top: 0 km
- Site within 3km of Secondary



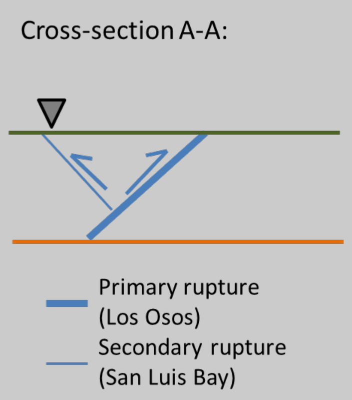
- Lengths
  Secondary = 33.2 km (fixed)
  Primary = varies w/ Leonard 2010
- Dip
  Secondary = 50 SW
  Primary = 90
- Rake
  Secondary = 90 (Rev)
  Primary = 180 (RL SS)
- Depth to top: 0 km
- Site within 8km of Secondary
  (Rrup=7.8, Rjb=0)
- Site on Secondary HW

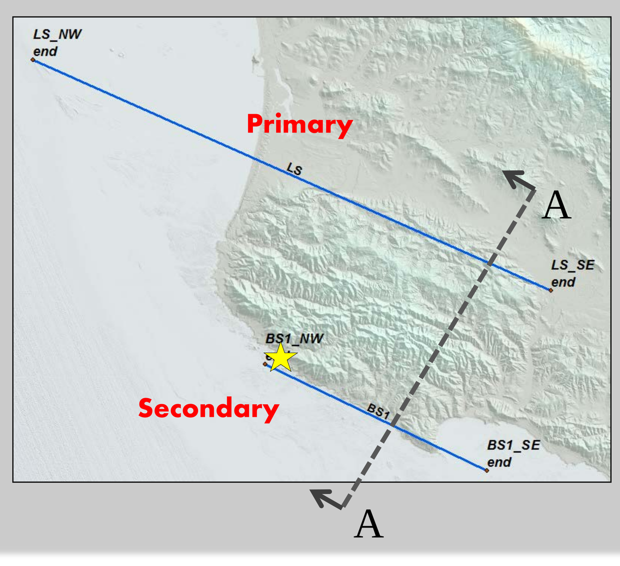


- Lengths
  Secondary = 7.8 km
  Primary = varies w/ Leonard 2010
- Dip
  Secondary = 70 N
  Primary = 90
- Rake
  Secondary = 90 (Rev)
  Primary = 180 (RL SS)
- Depth to top: 0 km



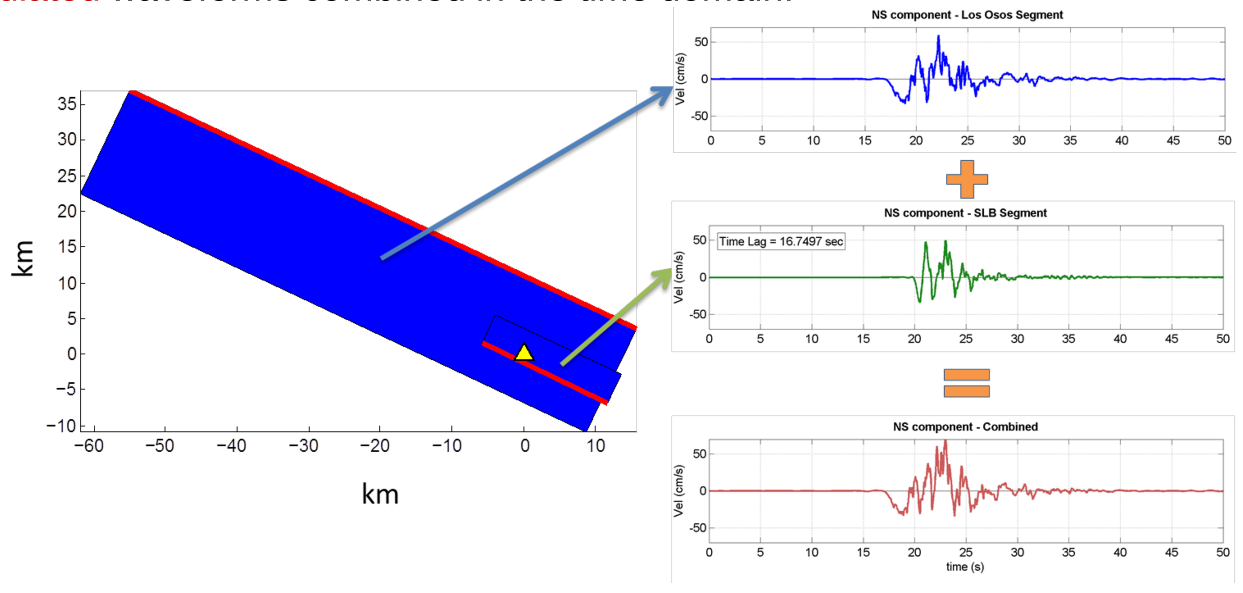
- Dip
  Secondary = 70 NE
  Primary = 50 SW
- Rake (both faults) = 90 (Rev)
- Ztor = 0 km
- Site on HW of both



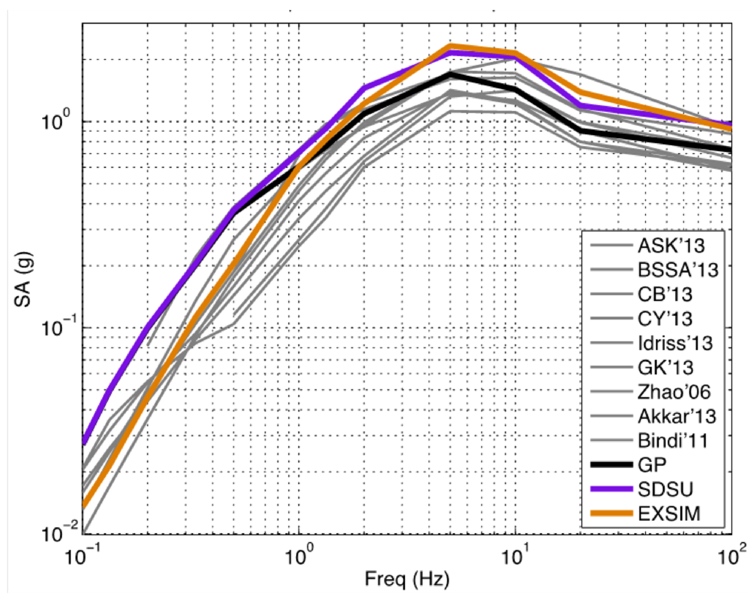


(4) Results of Simulations

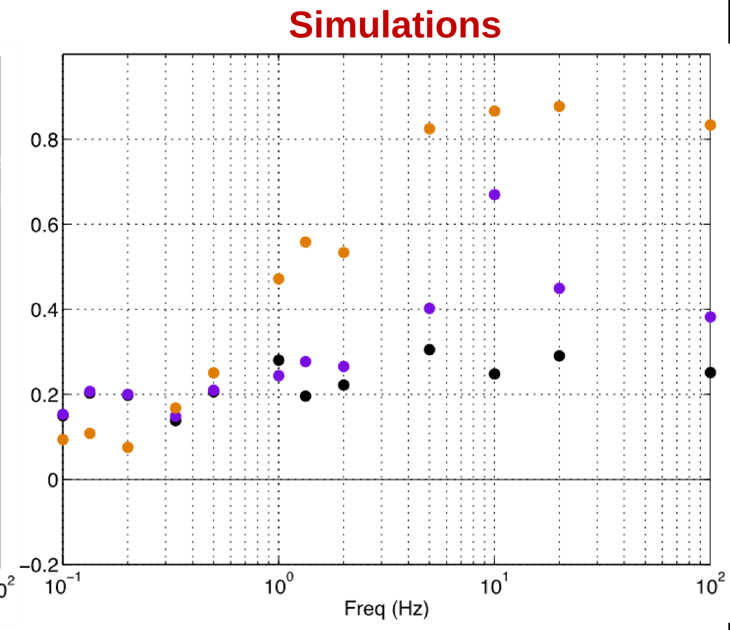
Simulated waveforms combined in the time domain:



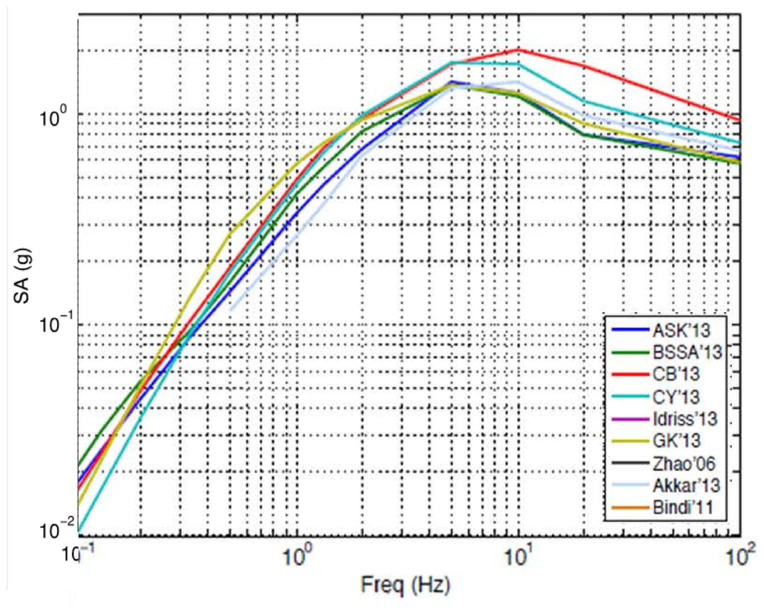
Simulations (RotD50 Spectra)



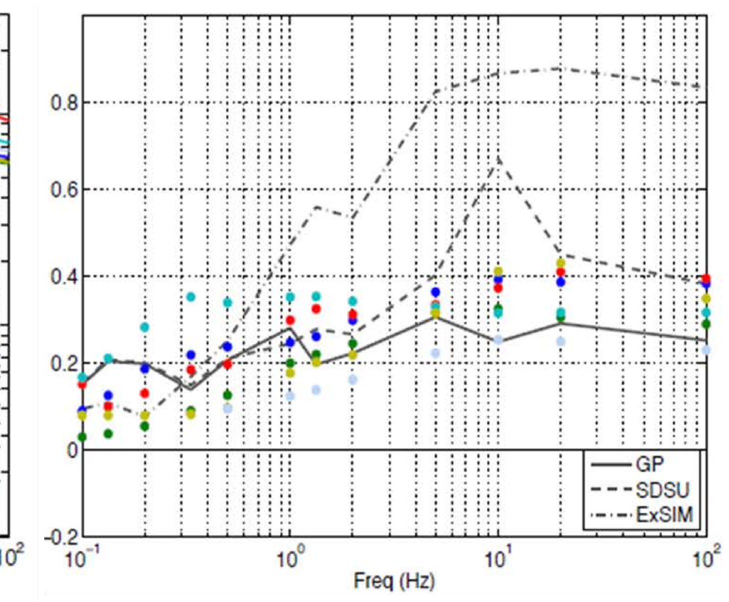
FACTORS: SRSS Method
Simulations



GMPEs (RotD50 Spectra)



FACTORS: SRSS Method
Simulations (dashes) & GMPEs (dots)



(5) Conclusions

- These conclusions are only applicable for the fault scenarios and the site location considered.
- Overall, the factors for GMPEs computed with **Method 1** (SRSS method) most closely follow the amplitude and trend of those computed with the simulations.
- This observation holds true for both for the strike slip and reverse scenarios.
- This observation holds true for all three simulation methods at low frequencies (<1 Hz) and for 2 of the 3 (GP and SDSU) at higher frequencies (>1 Hz). At high frequencies ExSim has a much stronger contribution from secondary ruptures with moderate Mw but very small rupture distance.

(6) Acknowledgements

We would like to thank the SCEC IT team – specifically Fabio Silva and Phil Maechling. Also thanks to the entire BBP Validation team for ongoing collaboration.