Constraining GMPEs in Critical Ranges for Complex Ruptures Using Strong Motion Simulation Procedures on the SCEC Broadband Platform

A collaborative study for the Southwestern U.S. (SWUS) Ground Motion Characterization (GMC) SSHAC Level 3 study for the Diablo Canyon Power Plant (DCPP)

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Overview

- Purpose
- Scenario Events
- Approach
- Results
- Conclusions
- (?) Apology for going slightly over time limit

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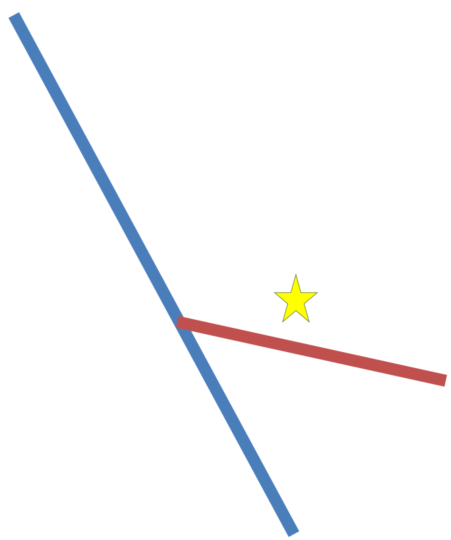
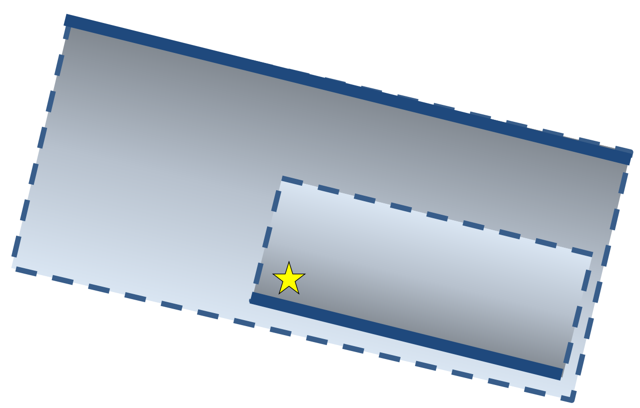
Purpose of this study

- To address the technical issue of how to utilize existing GMPEs in important ranges for complicated ruptures; areas where there is very little recorded data.

Example:



(a basic case)



(a more complicated case)

Purpose cont.

- To address the technical issue of how to utilize 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

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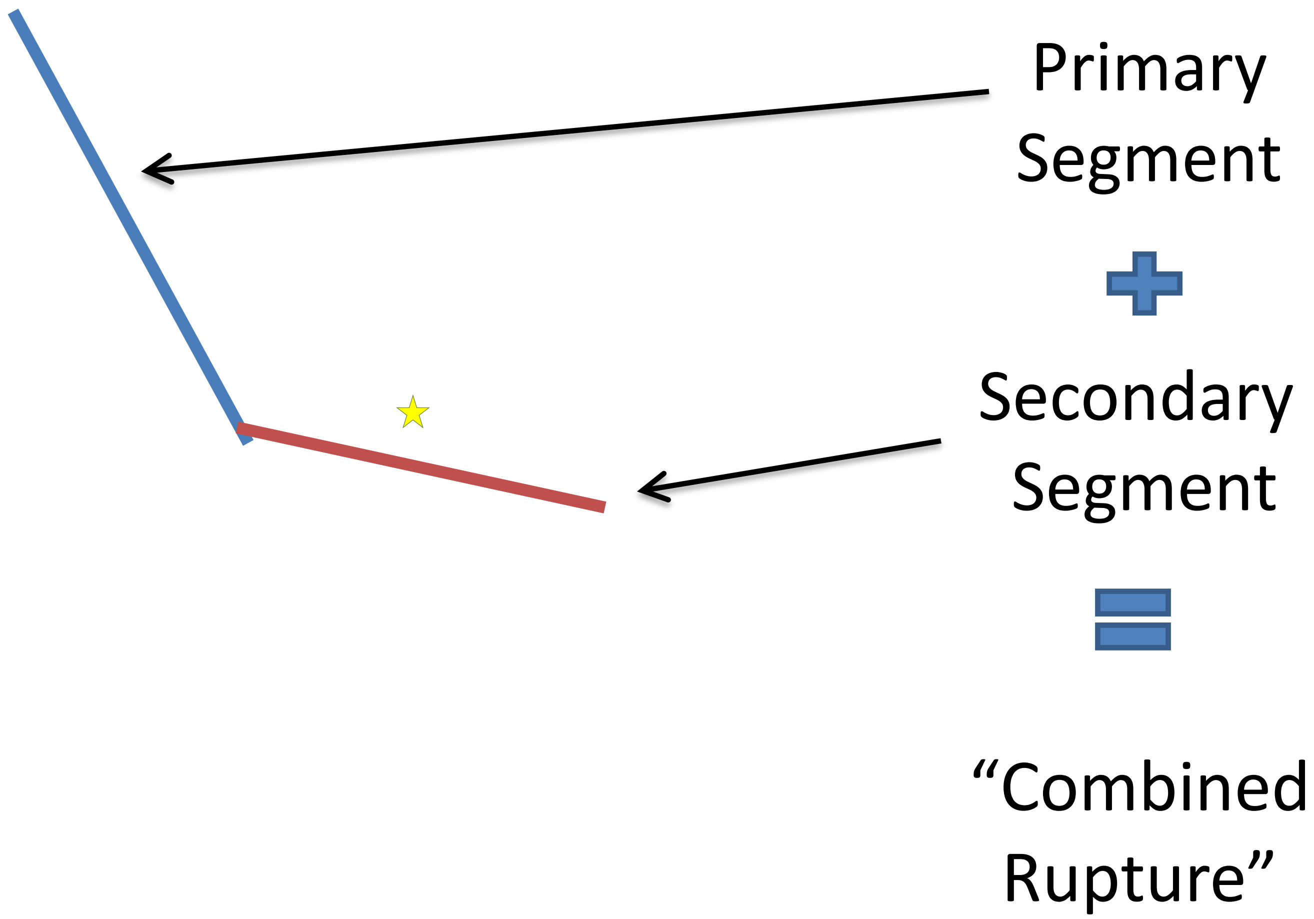
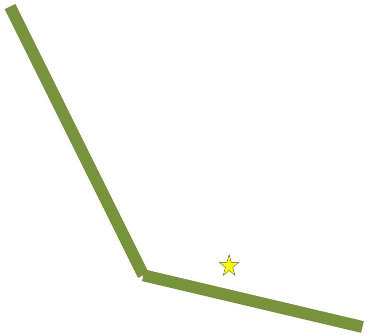
Terminology



Scenarios

(each with 32 randomized source realizations, for Mw 7.0, 7.2, 7.4)

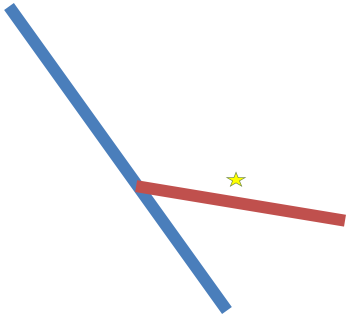
1) Type 1



1a) Hosgri rupture, linking to Shoreline fault
1b) Hosgri rupture, linking to Los Osos fault
1c) Shoreline rupture, linking to San Luis Bay fault

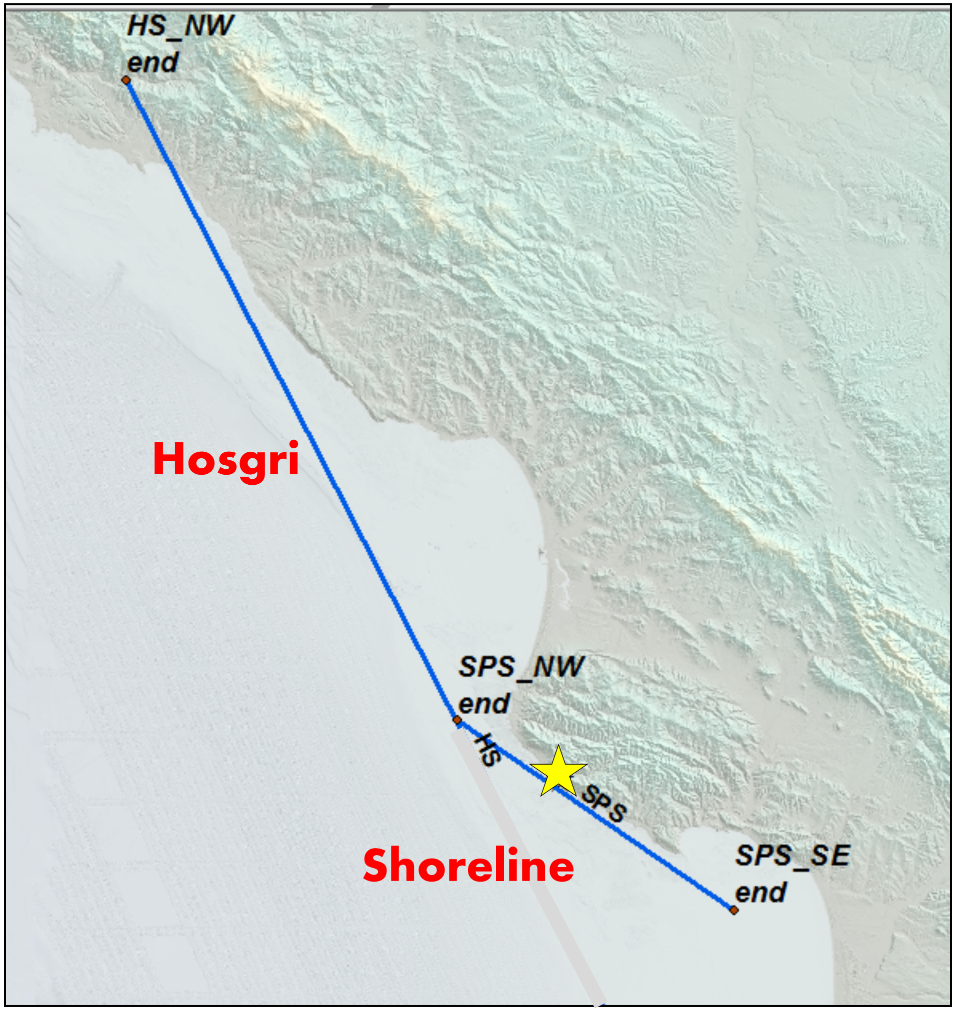
2) Type 2

2a) Primary Hosgri rupture; secondary Shoreline rupture
2b) Primary Los Osos rupture; secondary San Luis Bay rupture



1a: Hosgri - Shoreline

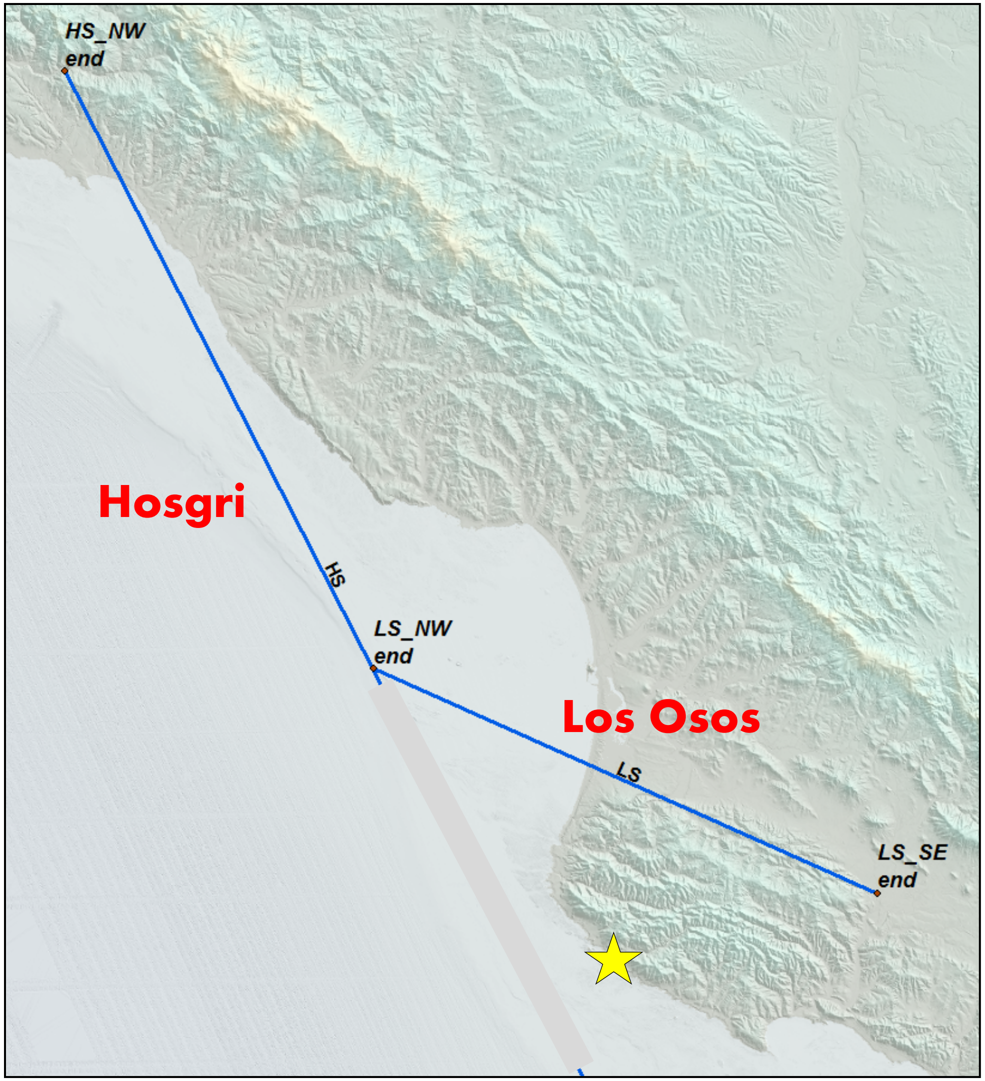
- Lengths
  - Shoreline = 25.5 km (fixed)
  - Hosgri (HS) = varies w/ Leonard 2010
- Dip = 90
- Rake = 180 (RL SS)
- Depth to top: 0 km
- Site within 3km of Shoreline



1b: Hosgri – Los Osos

- Lengths
  - Los Osos (LS) = 33.2 km (fixed)
  - Hosgri (HS) = varies w/ Leonard 2010
- Dip of Los Osos = 50 SW
- Dip of Hosgri = 90
- Rake of Los Osos = 90 (Rev)
- Rake of Hosgri = 180 (RL SS)
- Depth to top: 0 km

- Site within 8km of Los Osos
  (Rrup=7.8, Rjb=0)
- Site on LO HW



1c: Shoreline - SLB

- Lengths
  San Luis Bay = 7.8 km
  Shoreline = varies

- Dip of SLB = 70 N
- Dip of Shoreline = 90

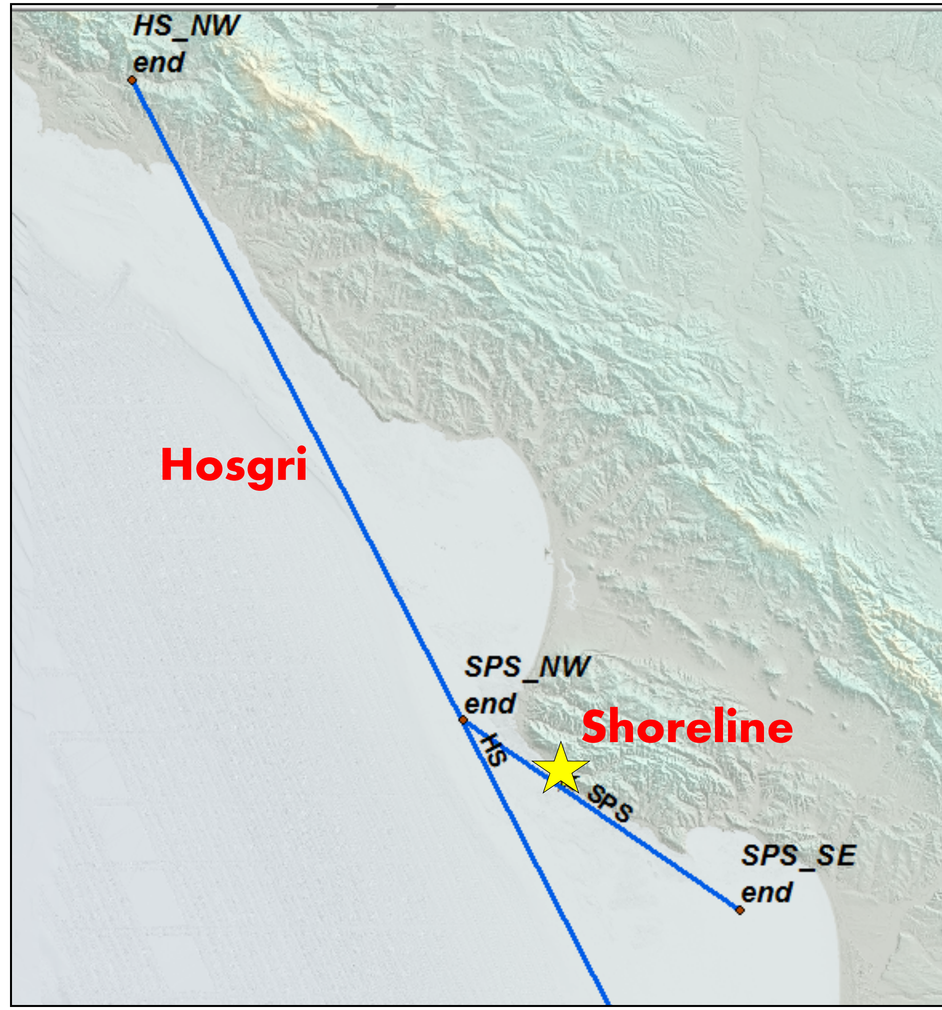
- Rake of SLB = 90 (Rev)
- Rake of Shoreline= 180 (RL SS)
- Depth to top: 0 km

- Abrupt transition from strike-slip Shoreline to reverse San Luis Bay

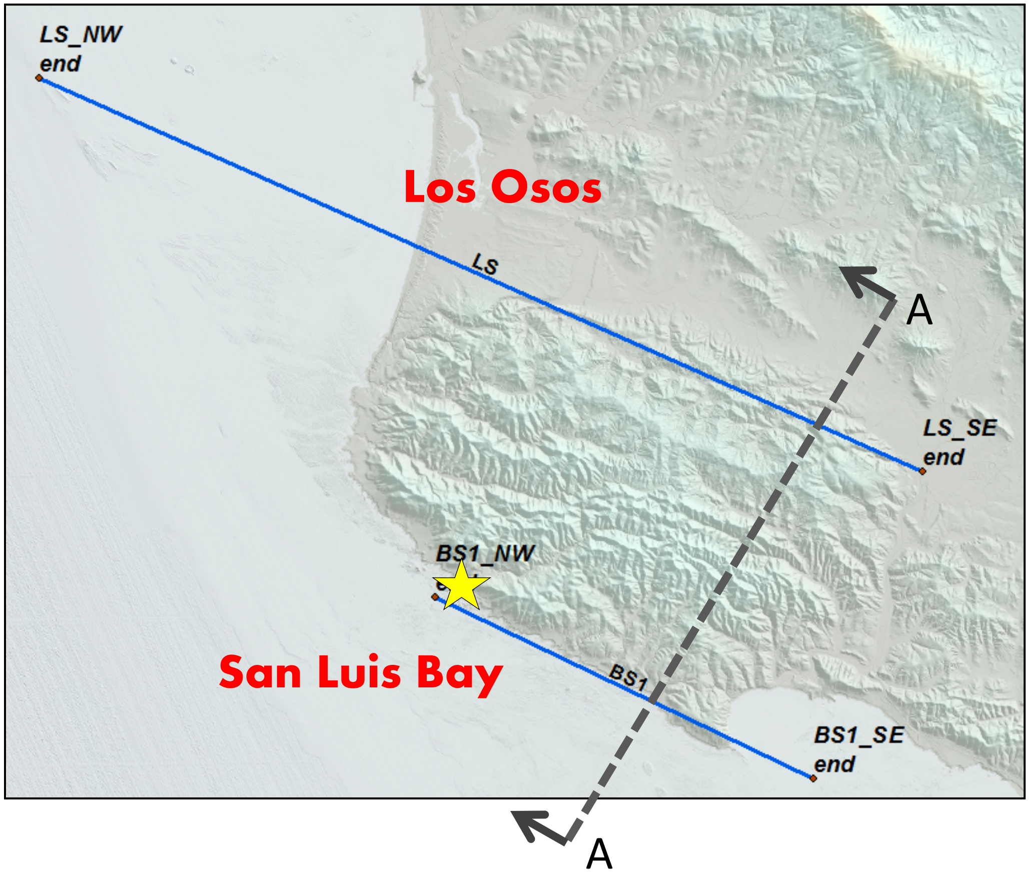
2a: Hosgri - Shoreline

- Lengths
  - Hosgri = varies
  - Shoreline = 25.6 km

- Dip = 90
- Rake = 180 (RL-SS)

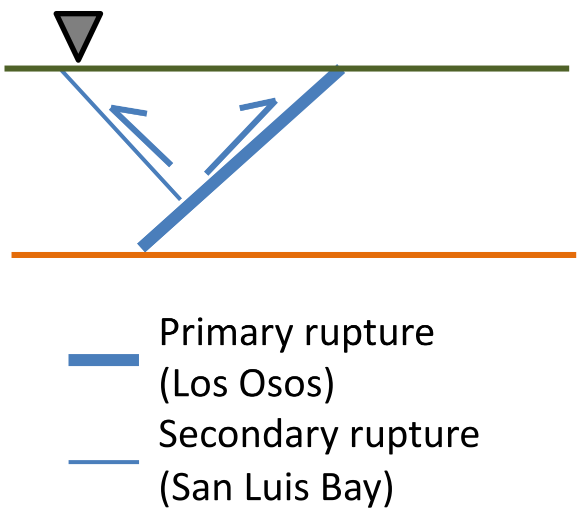


2b: Los Osos – San Luis Bay



- Dip of Los Osos = 50 SW
- Dip of San Luis Bay = 70 NE
- Rake (both faults) = 90 (Rev)
- Ztor = 0 km

Cross-section A-A:



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Approach: Simulations on the BBP

- We use the validated version: 13.6.1 (Dreger et al, 2013)
  - 3 simulation techniques: GP, SDSU, ExSim
  - 32 source realizations
  - 5 scenarios
  - 3 magnitudes: 7.0, 7.2, 7.4
  - 2 segments per scenario

2,880
simulation
cases

- BBP sources described by (for one segment):
  - Mw, Strike, Dip, Rake, Dimensions, Hypocenter Location

Approach cont.

- Simulations were performed for each segment separately (**primary** and **secondary**)

- Waveforms **combined** in the time domain
  - With appropriate time lag based on hypocenter location

- RotD50 computed from 2 horizontal components
  - This is the **combined** rupture ground motion (simulated)

- Average of 32 source realizations

- Compute the ground motion "factors"

Factors, you ask?

Factors are a ratio between the RotD50 of the **combined** rupture and the RotD50 of the **primary** rupture alone (ln units):

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

- Compare factors derived from the simulations with factors computed from four GMPE approaches for the **combined** rupture (GMPEs for primary rupture are straightforward)
- These comparisons inform our decision about which GMPE approach to use.

Approaches for GMPEs

1. 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.

2. 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

3. 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

4. Method 4: **CLOSEST SEGMENT**
    - use the total combined magnitude
    - use fault parameters of the closest segment

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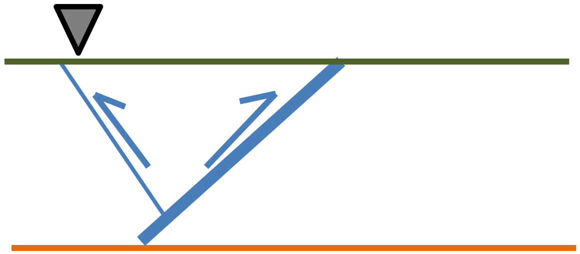
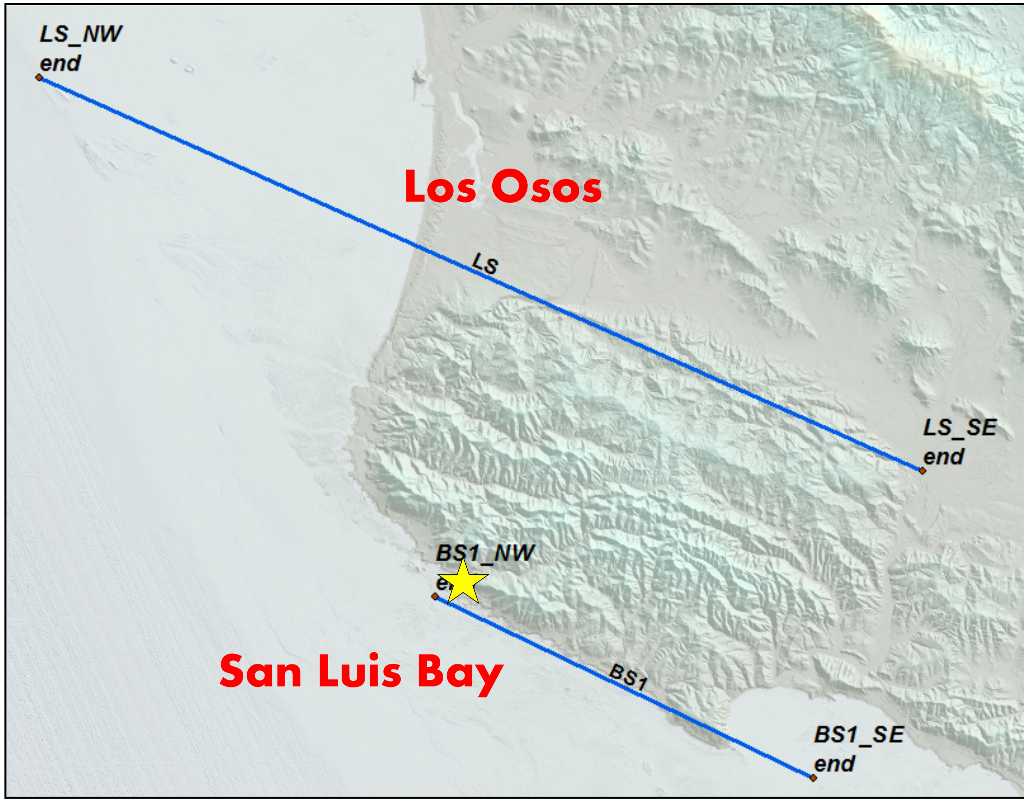
2b: Los Osos – San Luis Bay

This presentation will focus on results for the:

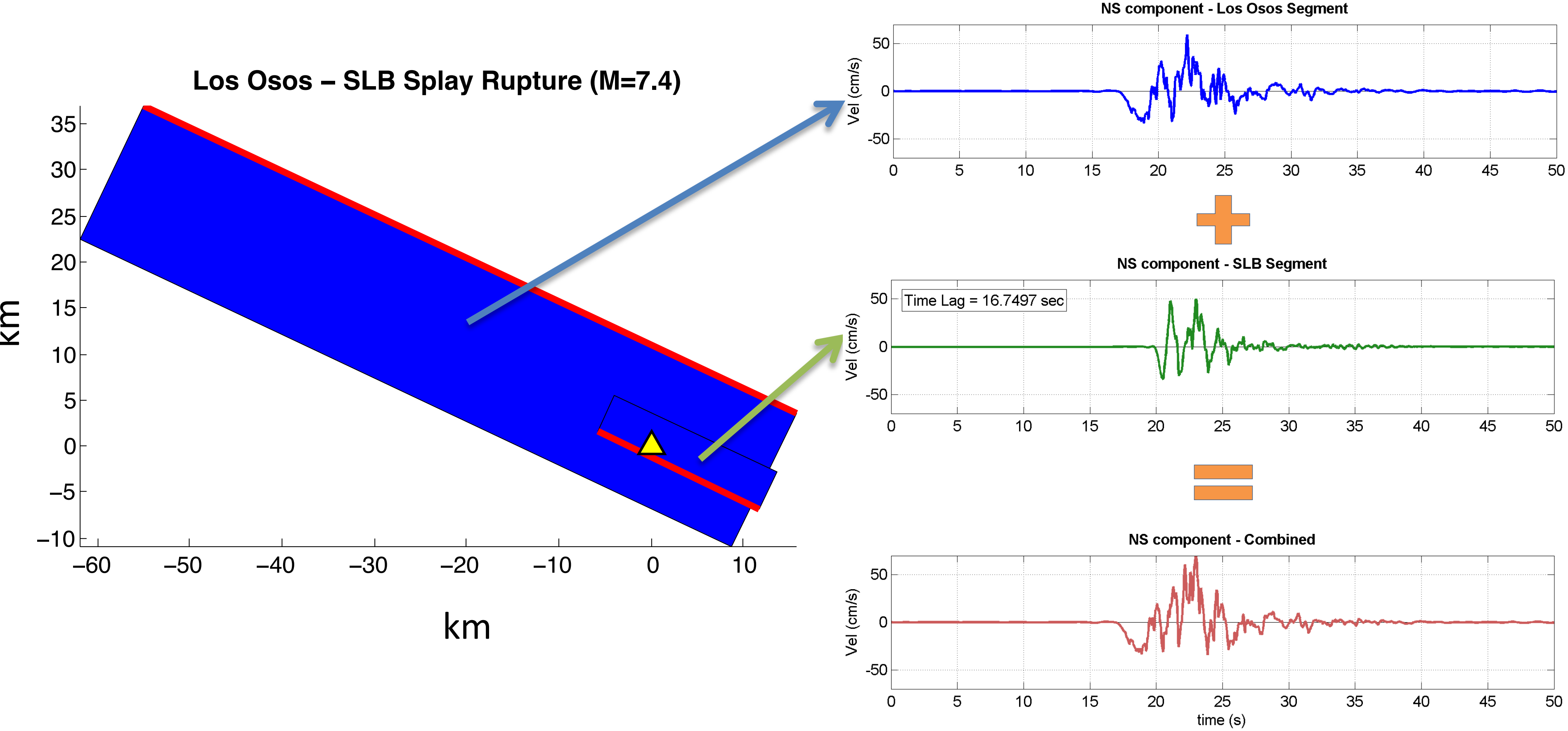
Los Osos primary (Mw = 7.4)

San Luis Bay secondary (Mw = 6.39) case





2b: Los Osos – San Luis Bay



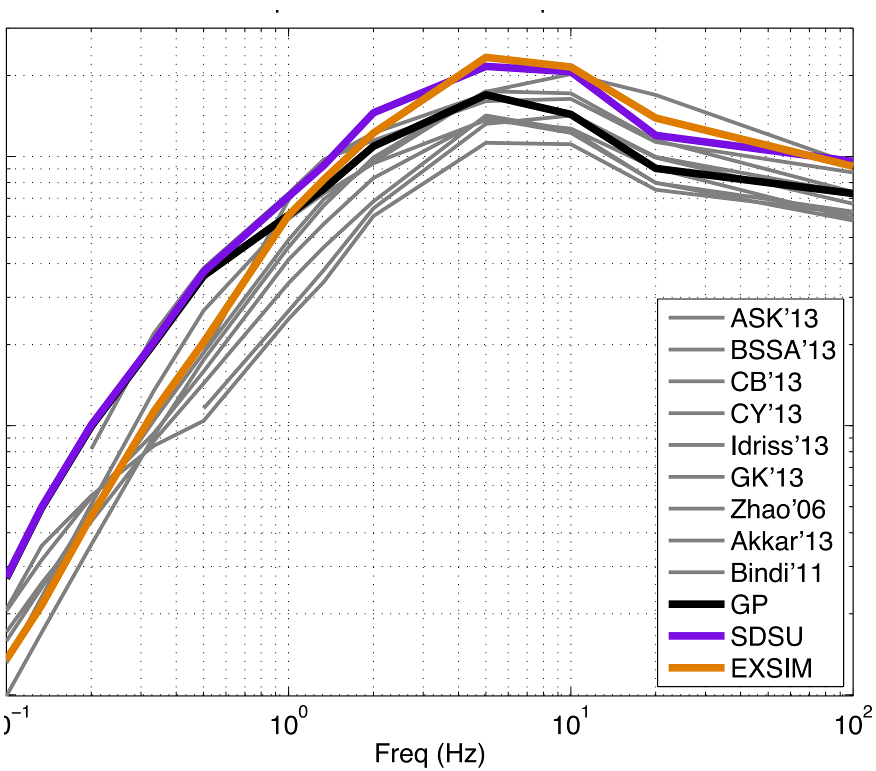
	Rrup (km)	Rjb (km)	Rx (km)	Mag	dip	rake	W (km)
Los Osos	8.57	0.0	9.90	7.40	60	90	32.00
San Luis Bay	1.00	0.0	1.07	6.40	70	90	12.70

Results: Simulations

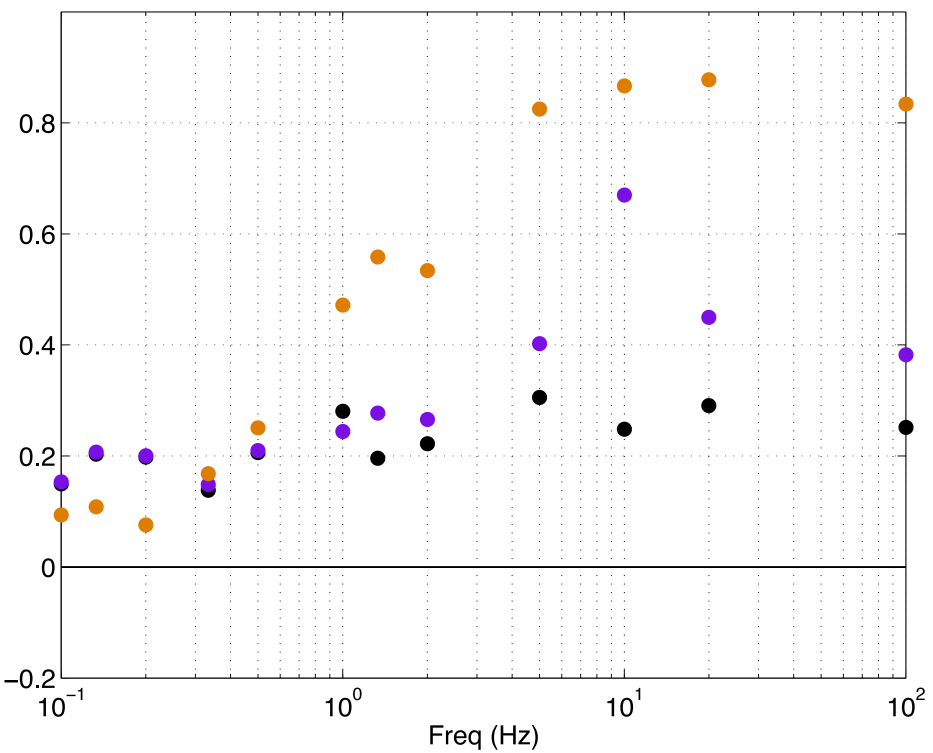
2b: Los Osos – San Luis Bay

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

Combined Rupture Spectra



Simulation Factors

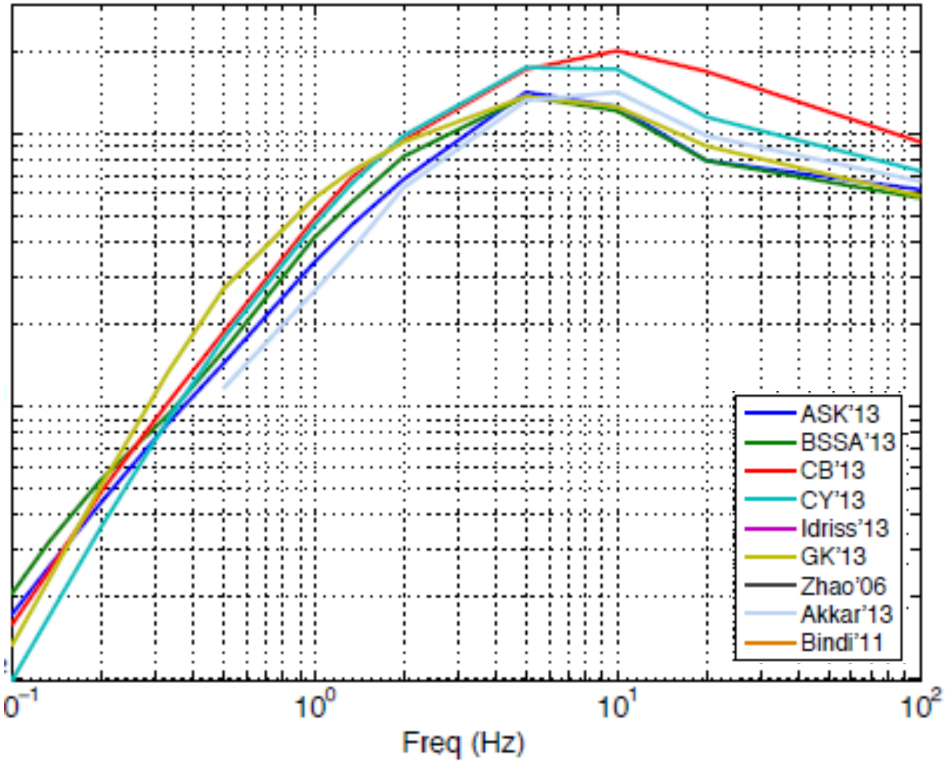


Results: GMPEs

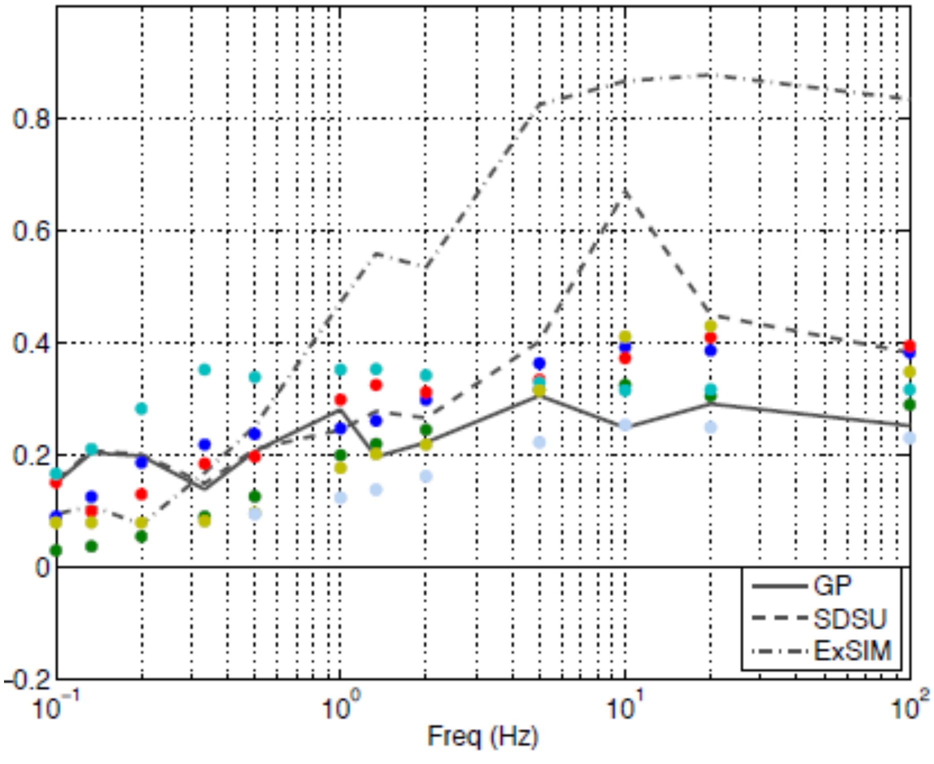
2b: Los Osos – San Luis Bay

METHOD 1: SRSS SINGLE SEGMENT SPECTRA

Combined Rupture Spectra



Simulation and GMPE Factors

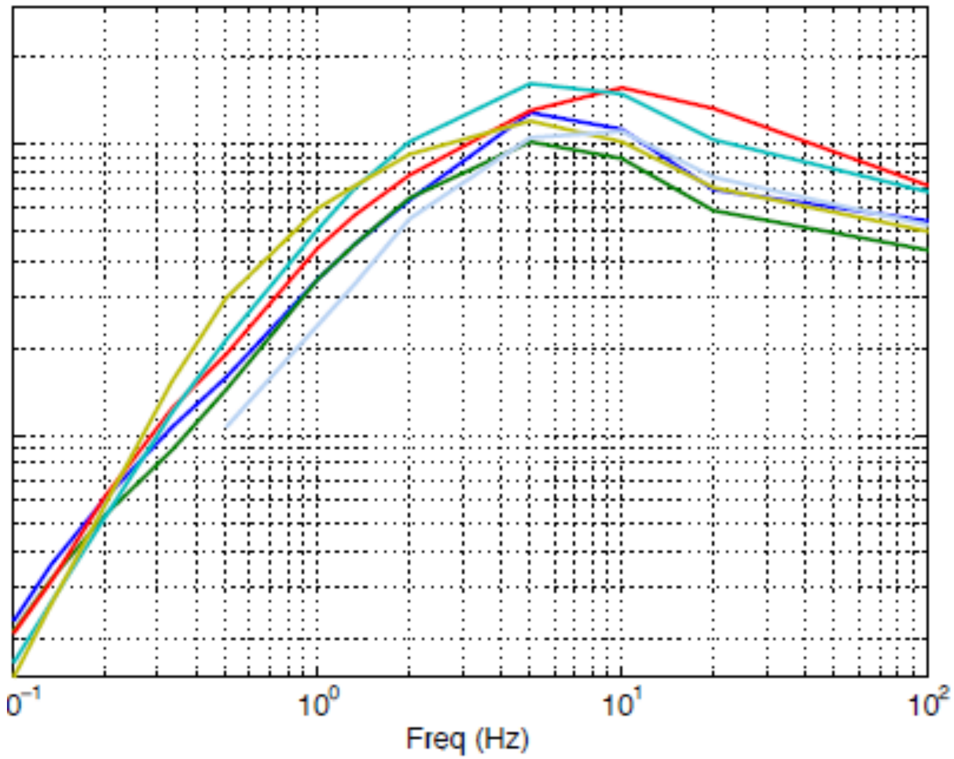


Results: GMPEs

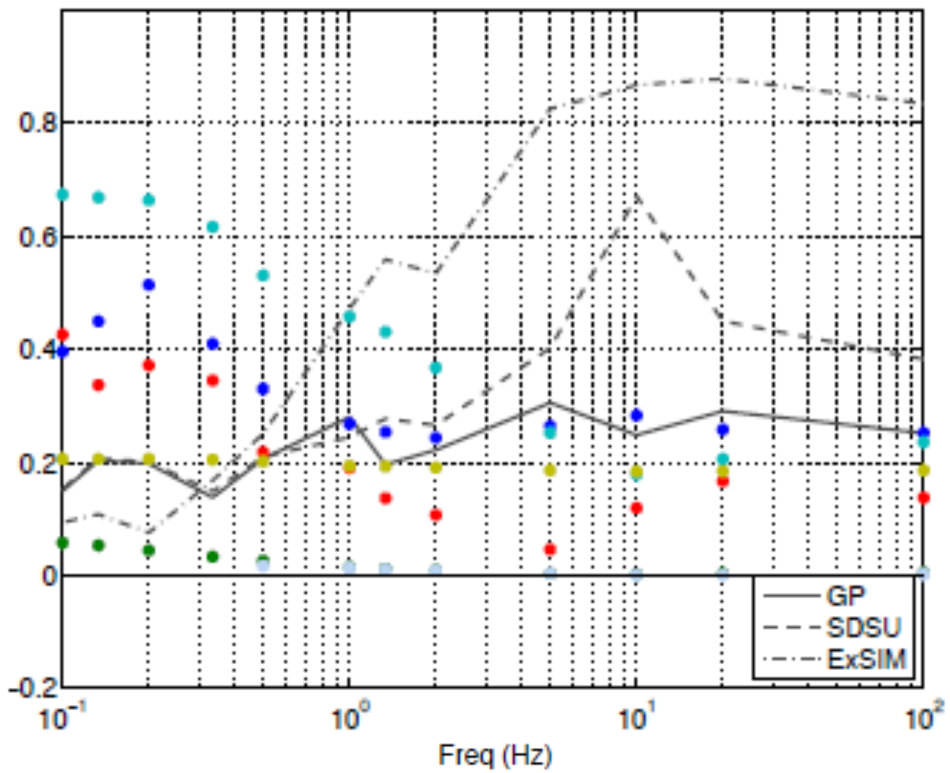
2b: Los Osos – San Luis Bay

METHOD 2: AVG. PARAMETERS (AREA)

Combined Rupture Spectra



Simulation and GMPE Factors

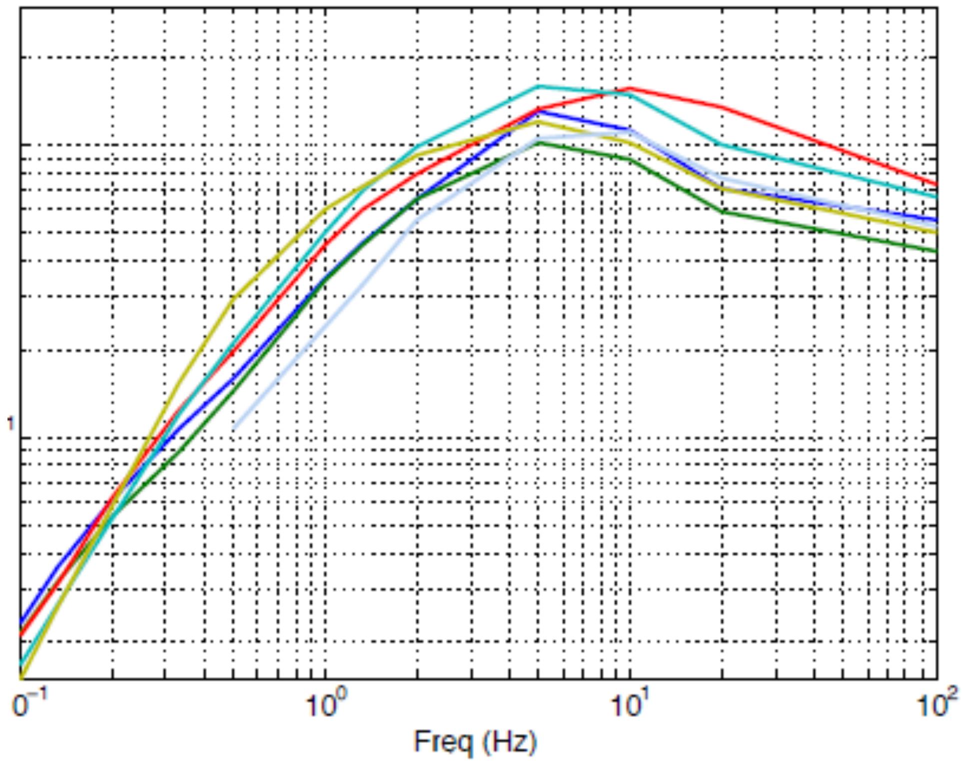


Results: GMPEs

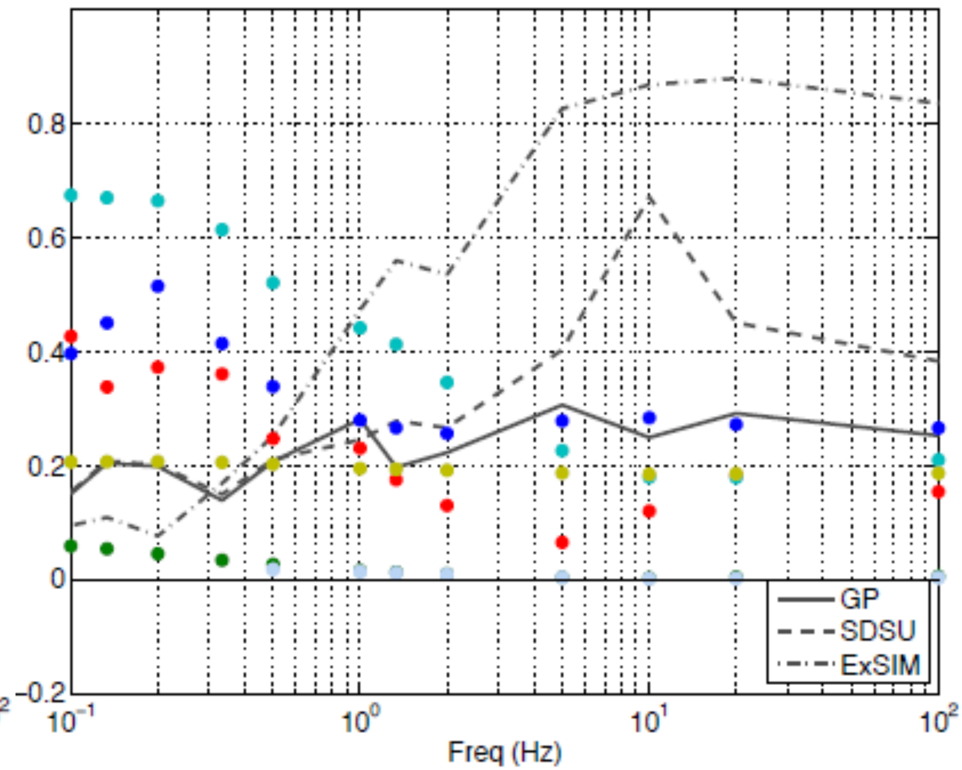
2b: Los Osos – San Luis Bay

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

Combined Rupture Spectra



Simulation and GMPE Factors

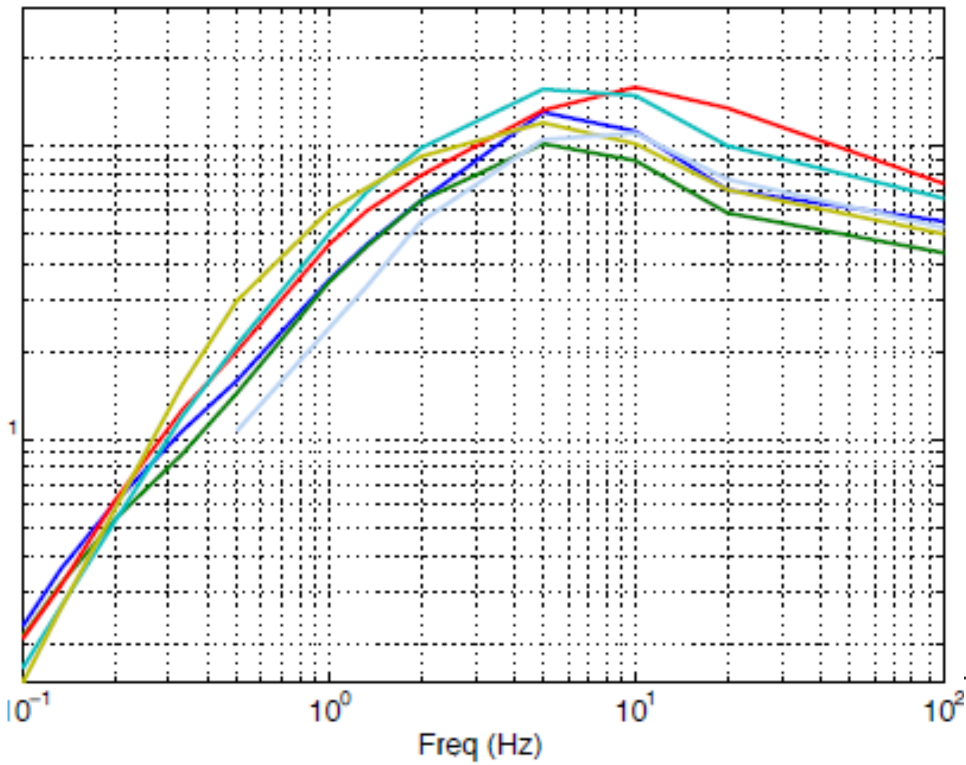


Results: GMPEs

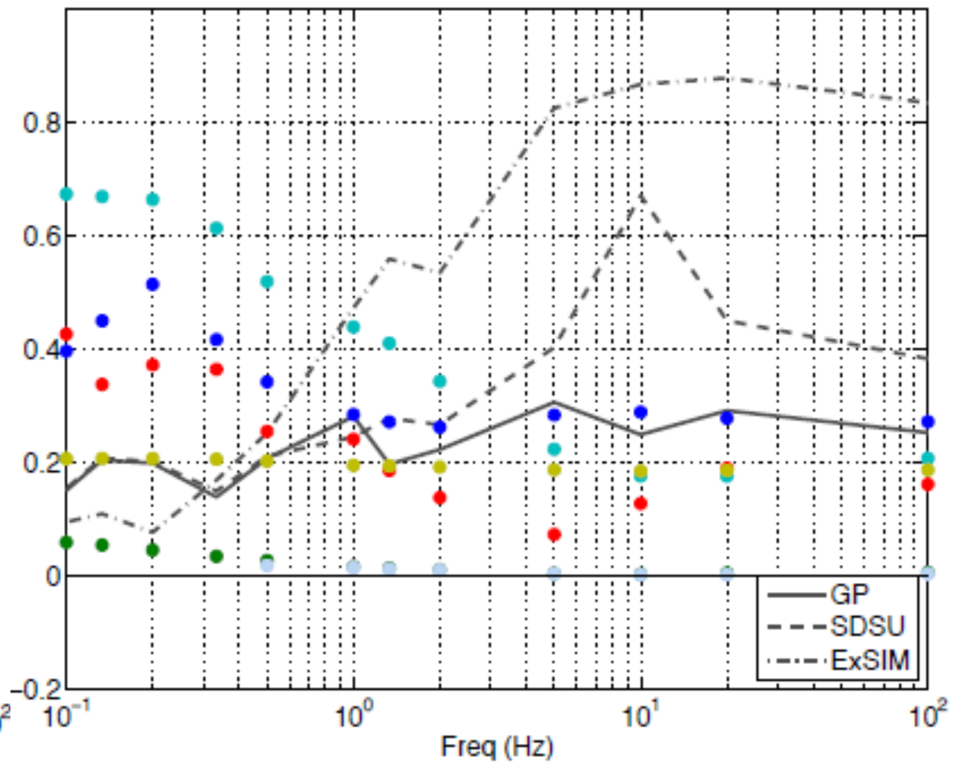
2b: Los Osos – San Luis Bay

METHOD 4: CLOSEST SEGMENT PARAMETERS

Combined Rupture Spectra

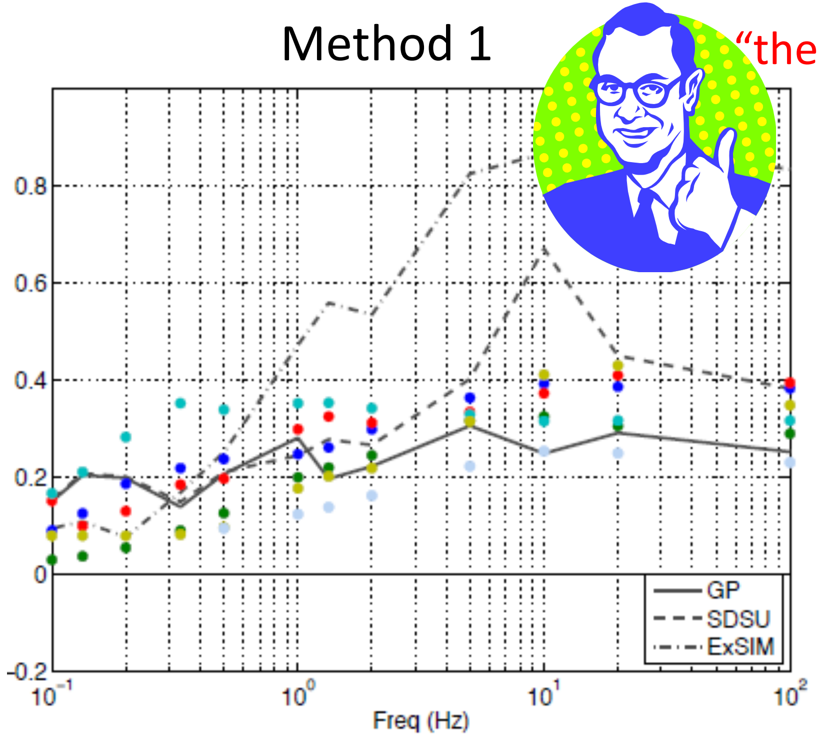


Simulation and GMPE Factors

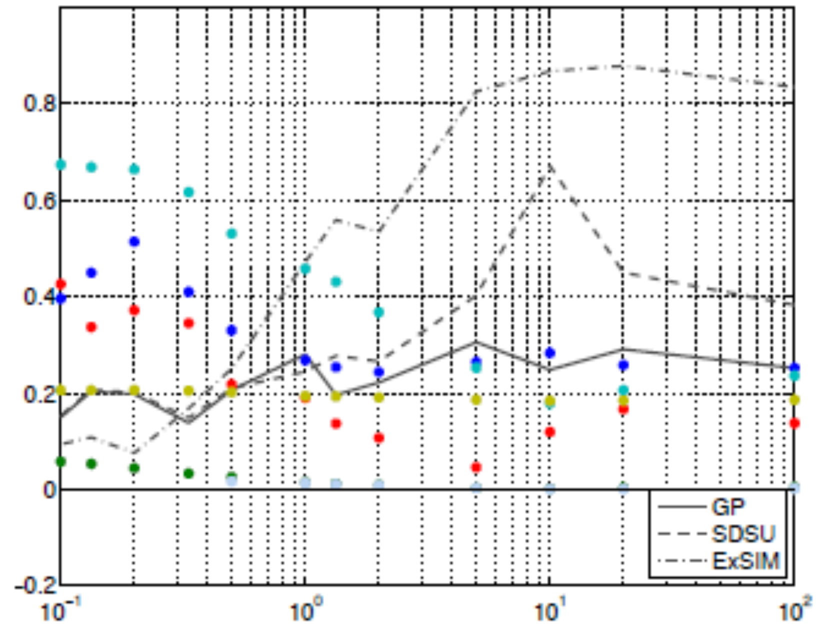


Method 1

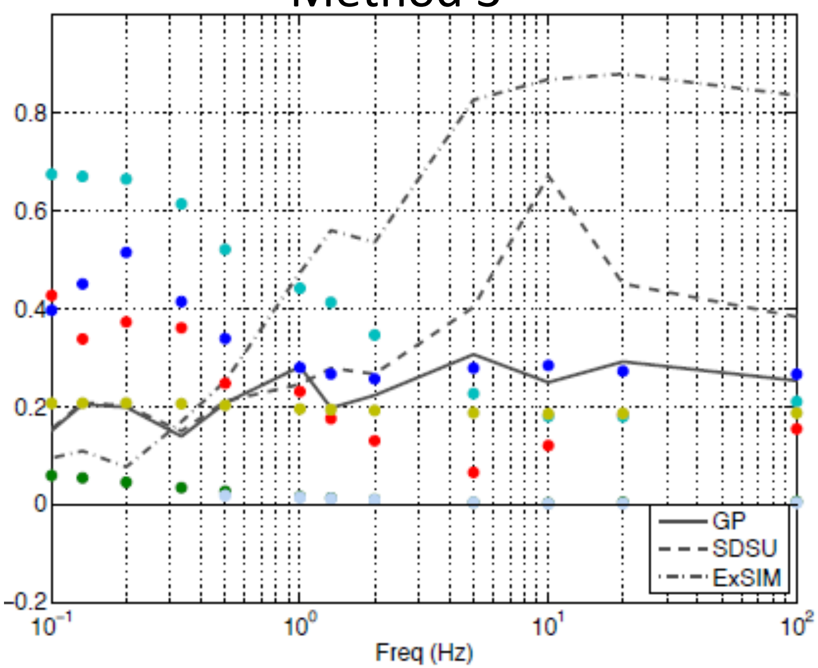
“the best”



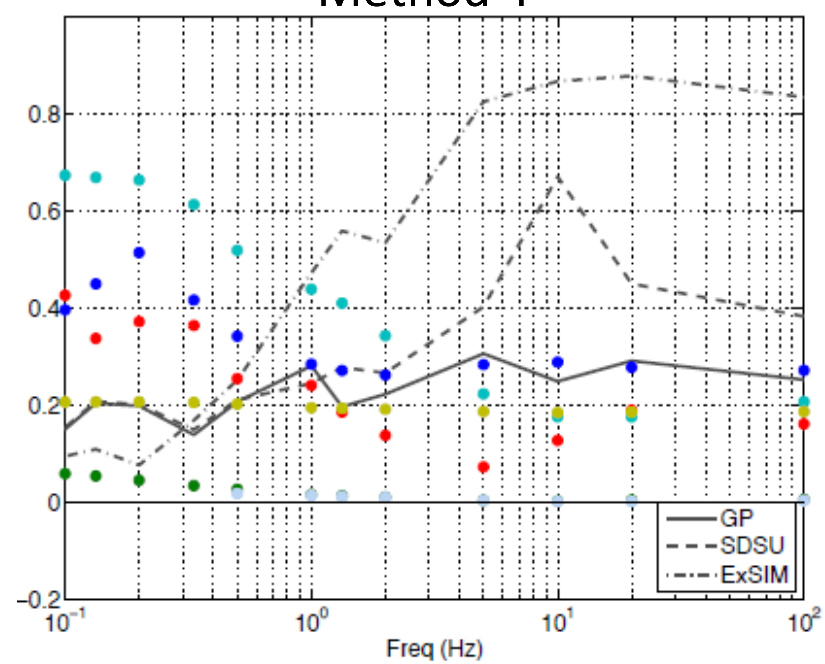
Method 2



Method 3



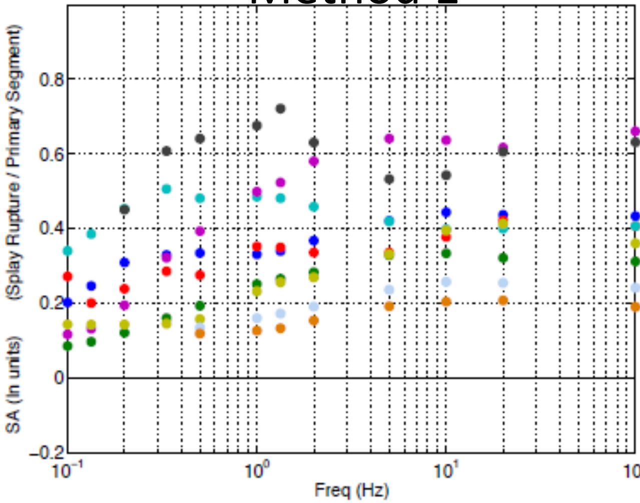
Method 4



COMPARISONS WITH OTHER MAGNITUDES (Los Osos + San Luis Bay Splay):

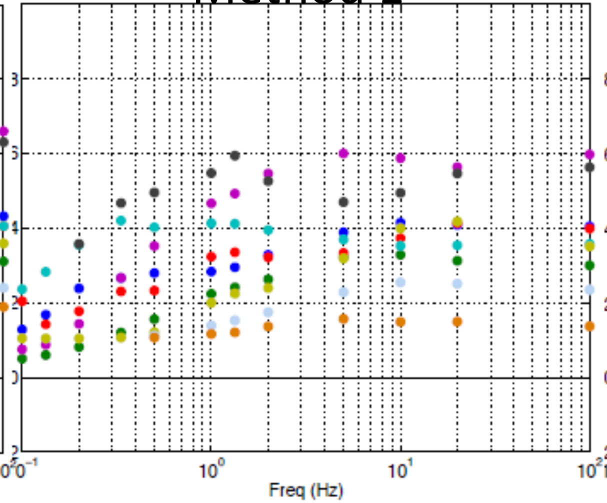
M7.0 on Los Osos

Method 1



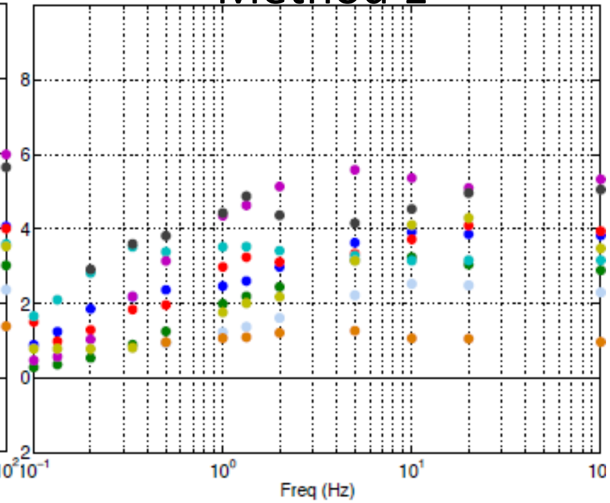
M7.2 on Los Osos

Method 1

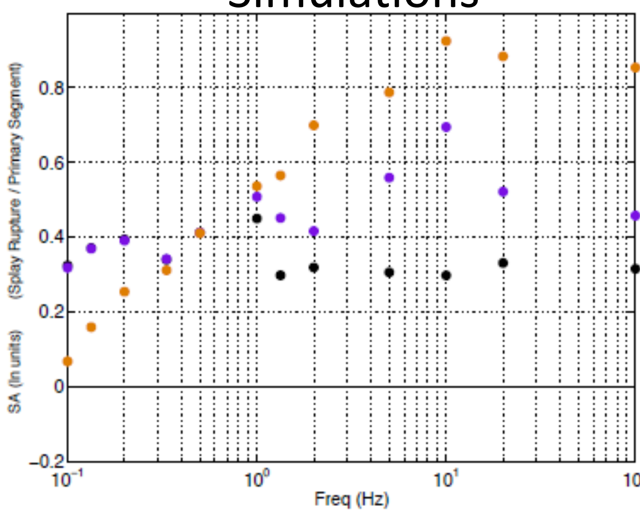


M7.4 on Los Osos

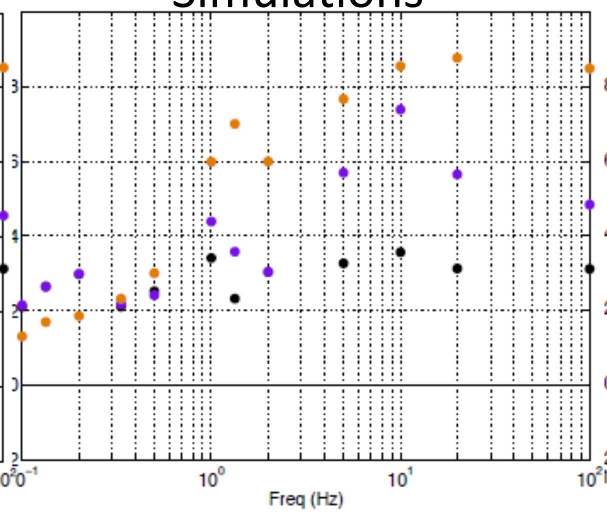
Method 1



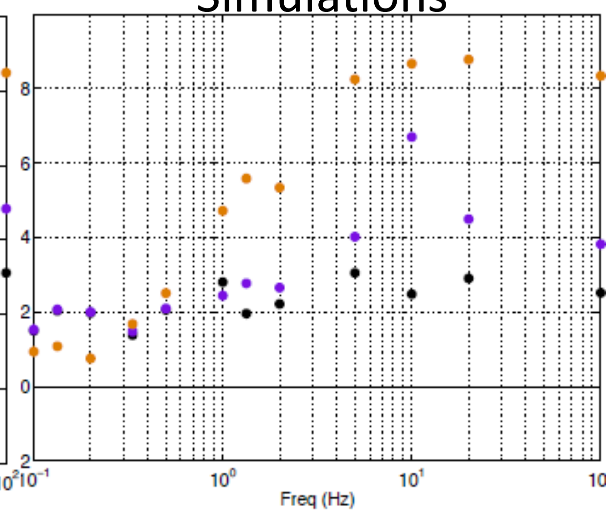
Simulations



Simulations

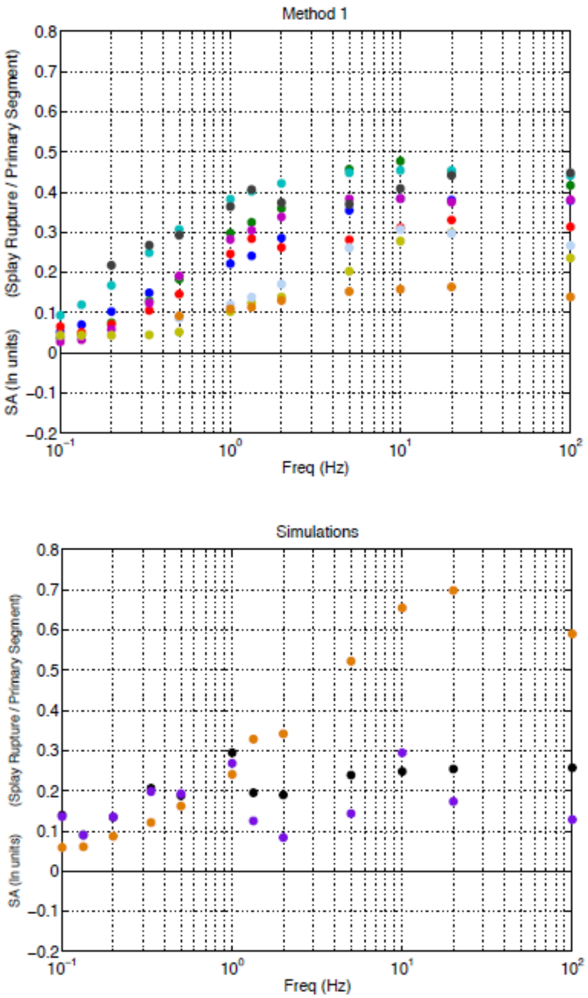


Simulations

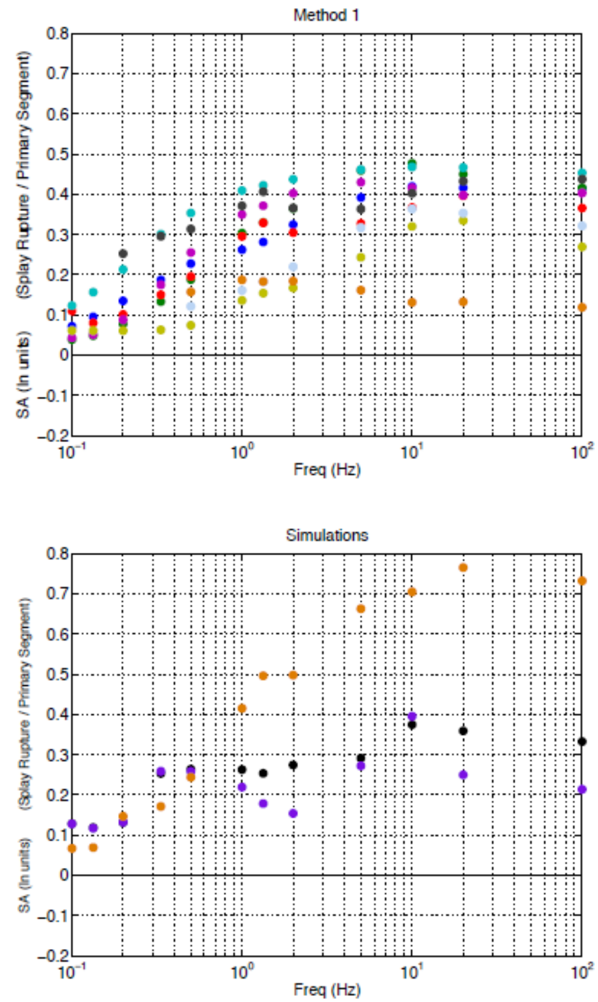


COMPARISONS WITH OTHER MAGNITUDES (Hosgri + Shoreline Splay):

M7.2 on Hosgri



M7.4 on Hosgri



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Conclusions**

** only for the fault scenarios and the site location considered

- Overall, the Sa factors for GMPEs computed with **Method 1 (SRSS method)** most closely follow the amplitude and trend of those computed with the simulations.
  - True for both for the strike slip and reverse cases
  - 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).
- These results are conclusive for the splay scenarios considered.
- Recommend using the **SRSS method** for applying existing GMPEs in the complicated rupture geometry scenarios in the vicinity of DCPP

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