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CONSTRAINING GMPES IN CRITICAL RANGES FOR COMPLEX RUPTURES USING STRONG MOTION SIMULATION PROCEDURES ON THE SCEC BROADBAND PLATFORM

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The Southern California Earthquake Center (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 (who need not be the developer of any simulation procedure) to generate ground motions for a particular earthquake scenario using physics-based simulation methods. The BBP provides the user with the flexibility to select from various alternative approaches for generating the earthquake rupture description, modelling low- and high-frequency wave propagation, and options for incorporating non-linear site effects. The end product of a BBP simulation is a set of three-component broadband synthetic seismograms at the desired station locations.

The BBP is part of the SCEC Community Modelling Environment in which SCEC scientists collaborate in the construction of shared data bases and computational platforms. While the BBP is under continuous ongoing development, the first validation phase of the BBP was recently evaluated by Dreger et al. (2013) for simulated pseudo-spectral acceleration (Sa) using version 13.6.1 of the BBP code. The validated methods, their developers, and references are listed in Table 1.

As a part of the Southwestern U.S. (SWUS) Ground Motion Characterization (GMC) SSHAC Level 3 study for the Diablo Canyon Power Plant (DCPP), broadband ground motion simulations have been performed for a variety of scenario and validation earthquakes using the validated version of the SCEC BBP. A BBP user generates broadband ground motions using physics-based simulation methods by prescribing fundamental earthquake scenario parameters. We address the hazard-significant technical issue of how several critical Ground Motion Prediction Equation (GMPE) input parameters are best defined in important ranges for complex ruptures; areas where there is very little recorded data. More specifically, we study which adjustments to these GMPEs relative to their simple, single-strand planar rupture predictions most closely match the relative adjustments observed using the BBP simulations.

We define "complex" ruptures as those having a significant change in strike, rake, or dip along strike. We also consider a set of "splay" ruptures, which we define as one primary fault with a secondary branching fault. Simulations are evaluated for three complex and two splay scenarios over the range Mw 7.0 to 7.4. The changes in geometry and faulting style are located near the site of interest, where the definition of many GMPE input parameters (including dip, rake, depth, distance, magnitude etc.) is unclear. Using nine GMPEs developed for active tectonic regions, we show that the differences in these selections can have a significant impact on the predicted ground motion levels, and that these impacts are closely related to the geometry of the complicated fault scenario. We present multiple methods for defining GMPE input parameter rules, and these multiple methods are

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compared with the response spectra obtained using the three BBP simulation techniques validated by Dreger et al. (2013).

Table 1. BBP Validated Methods

Method identifier	Developers (affiliations)	Key references (Latest published documentation)
EXSIM	Gail Atkinson, Karen Assatourians (UWO)	Motozedian and Atkinson (2005), Atkinson et al. (2009), and Boore (2009)
GP: Graves and Pitarka	Robert Graves (USGS), Arben Pitarka (LLNL)	Graves and Pitarka (2010)
SDSU Method	Kim Olsen, Rumi Takedatsu (SDSU)	Mai et al. (2010), and Mena et al. (2010)

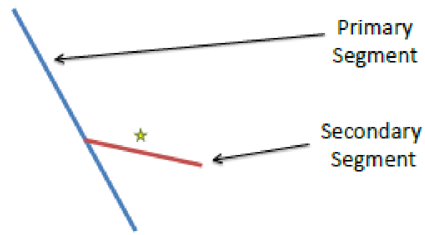

Figure 1. Distinction between the primary and secondary segments for a combined splay rupture scenario. The site, denoted with the gold star, has multiple GMPE input parameters which are undefined due to the complex geometry surrounding the site.

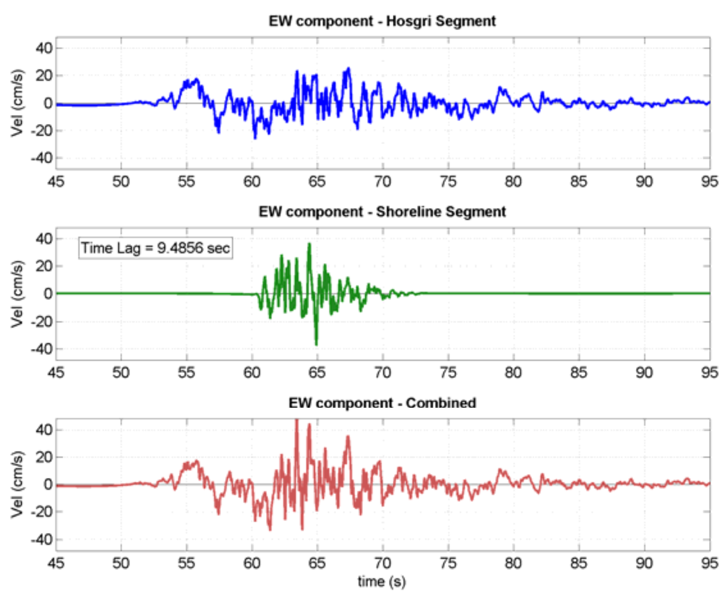

Figure 2. Example velocity time series for the Hosgri (primary), Shoreline (secondary), and combined splay rupture.

Results are presented as ratio factors. These factors are computed by taking the ratio of the Sa at the site of interest, with the primary segment (Figure 1) as the denominator, and the combined segments as the numerator. The combined segment Sa is computed by combining the acceleration time series in the time domain, with an appropriate time lag, which is calculated based on the hypocentre locations and an assumed velocity (Figure 2). This is possible because the synthetics are generated for both the primary and secondary ruptures individually. All ruptures utilize 32 random realizations of the source representation, including randomized hypocentre locations.

Besides the simulation results we have developed four methods for computing these factors using the GMPEs. In Method 1, we compute response spectrum for each segment (or fault) at the closest point (using that segment's dip, rake, width, distance, and magnitude), and then take the square root sum of squares (SRSS) of the two segments. This method essentially treats the two segments separately and combines them. In Method 2, we weight the fault parameters (rake, dip, width) based on their respective area, use the total combined magnitude, and compute the response spectrum using the closest distance to either segment. In Method 3, we perform the same calculations as Method 2, except by discretizing the fault and computing weighted average fault parameters based on their distance to the site. Finally, in Method 4 we use magnitude of the combined rupture, but the parameters (including distance) from only the closest segment.

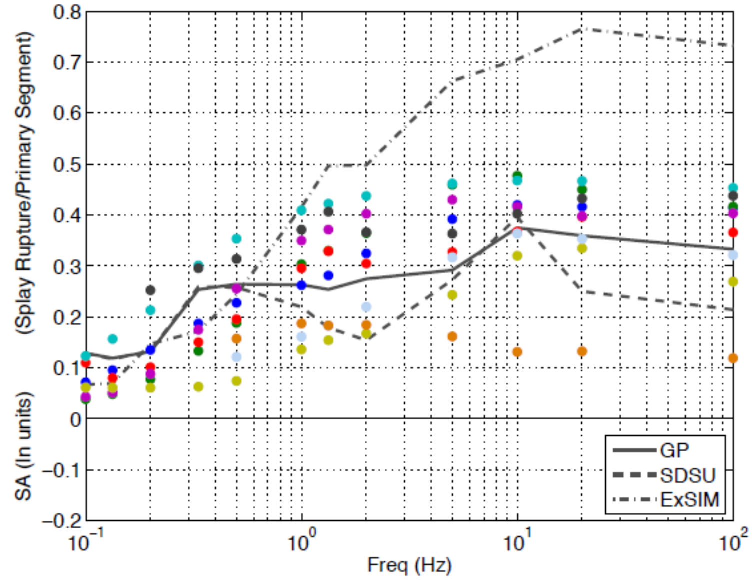

Figure 3. Plot of the Sa Ratio calculated from three simulation methods (lines) and using Method 1 for 9 GMPEs (colored dots) over the frequency range 0.01-100 Hz. This result is for the Hosgri-Shoreline scenario.

Plots of the Sa Ratio are created for each of these comparison methods, and compared with the trend observed using simulations (Figure 3). Overall, the Sa Ratio factors computed with Method 1 most closely follow the amplitude and trend of those computed with the simulations for the fault scenarios and site location considered (both for strike slip and reverse cases). This was true for all three simulation methods at low frequencie (<1 Hz) and true for 2 of the 3 (GP and SDSU) at higher frequencies (>1 Hz). In future studies, we may come to a more solid conclusion by considering a wider range of earthquake scenarios, and also by considering more than just one site locations.

Note that these simulations are an aid for improving GMPE implementation and are not representative of realistic hazard levels for the area.

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