SCEC Simulation Validation for Southern California Basins using Ground Motion Recordings

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Background and Objectives

Cybershake-based ground motions are being actively considered for engineering application in the greater Los Angeles area (Crouse and Jordan, 2016; https://data2.scec.org/ugms/) and nationally (Moschetti et al. 2017). One of the principal motivations for this application is a *belief* that Cybershake-based estimates of basin effects on long-period ground motions in Southern California and elsewhere are more accurate than those from semi-empirical ground motion models (GMMs), such as those from the NGA-West2 project. The two estimates are indeed different, as shown for example by Moschetti et al. (2017), Crouse and Jordan (2016), and Wang and Jordan (2014). Figure 1 shows basin effects as inferred from Cybershake simulations (Part a) and an NGA-West1 model (Part b). While both models show the presence of long-period amplification (as indicated by hotter colors) in similar locations, the severity of the basin effect is clearly stronger in the Cybershake simulations.

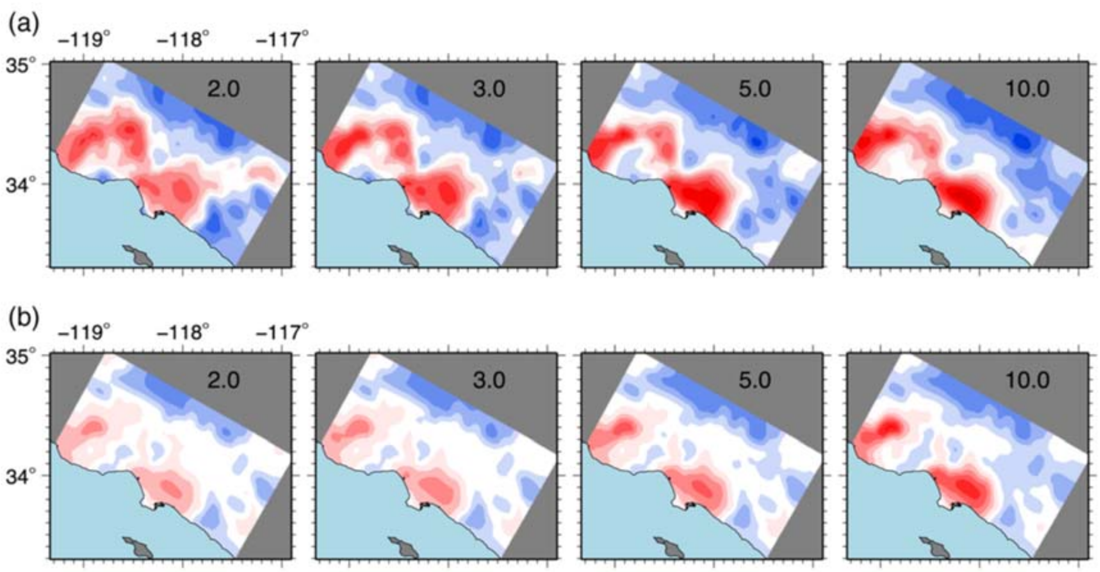

Figure 1. Inferred basin effect, derived using Averaging-Based Factorization approach of Wang and Jordan (2014), for: (a) Cybershake simulations, (b) an NGA-West1 model. The numbers in each cell are the oscillator period for which the amplification factors are computed. Figure from Wang and Jordan (2014).

We plan to extend previous validation approaches applied for ShakeOut (Star et al. 2011) and Broadband Platform simulations (Dreger et al. 2015) for application to Cybershake simulations, with a particular emphasis on long-period site effects. We intend to apply this approach for the specific purpose of testing Cybershake-based basin amplification estimates.

Scope

Task 1: Analysis of Site Effects from Ground Motion Observations

We are evaluating observed site response at a variety of sites throughout southern California, which is termed F_S in natural log units. This is done through analyses of recording ground motions, using procedures given in Stewart et al. (2017)

Task 2: Analysis of Site Effects from Models

Site effects from models will be developed from Cybershake simulations and GMMs. We will undertake the following process to evaluate site effects from Cybershake simulations:

1. Perform simulations using procedures recommended by SCEC (Cybershake or High-F) for magnitudes and source locations similar to those that produced the recordings in the previous section.
2. Perform a second set of simulation using identical source models but a 1D crustal model (similar to that used in the Broadband Platform). Compute ground motions at the same locations as in (1).
3. Take the site amplification as the difference of the natural log intensity measures between the motions from (1) and (2) for the same geodetic coordinate.
4. Average the site amplification computed by the above process across multiple events.

Task 3: Comparison and Interpretation

We will compare analysis and simulation results by Kriging site terms within sedimentary basins, producing maps for amplification at various periods as in Figure 1, but now supplemented with a row showing observed site response. We will also compute residuals between observed and computed site response, and look for trends with various predictive variables (e.g., basin depth, distance from basin edge, etc.). The results will be used to judge the relative effectiveness of the two models for predicting site amplification, including basin effects.

Preliminary work showing the impact of basin depth on the scaling of site terms is shown in Figure 2. The site terms in this figure represent the mean of residuals (i.e., difference between observed ground motions for a given site and the predictions of a GMM) across multiple events. The GMM in this calculations includes the effects of shallow site conditions but not basin geometry. As such, the site terms reveal features of site response that are not included in GMMs. Results are shown for using empirical data and Cybershake simulations. The scaling features of site terms with differential depth (i.e., difference between actual depth and average depth conditioned on V_{S30}) have some general similarity.

More detailed analyses will be conducted within this project. Work has not yet commenced, because the contact was received only a few weeks prior to the submittal of this report.

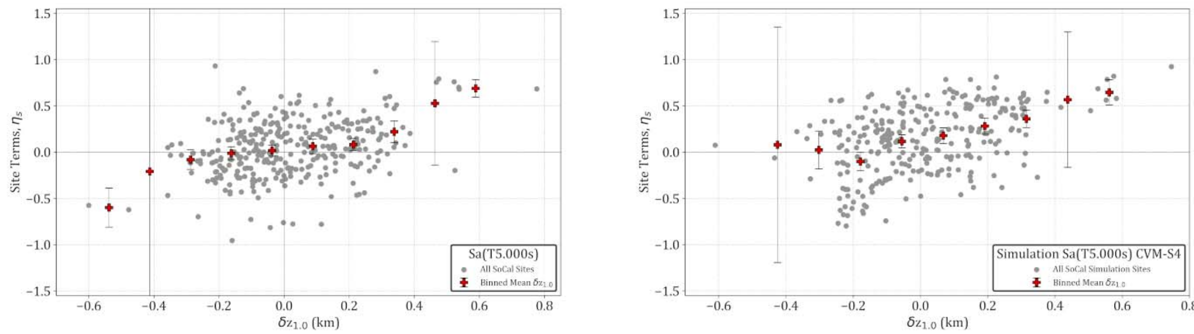

Figure 2. Trend of site terms with differential depth using Southern California data. The site terms represent average misfit of GMM from observed ground motions at Southern California sites. "Observations" for this figure are for small magnitude events as recorded from earthquakes and as computed from simulations. Differential depth is basin depth (depth to 1.0 km/s shear wave isosurface) minus average depth conditioned on V_{S30}.

References:

Crouse, CB, & TH Jordan, 2016. Development of new ground-motion maps for Los Angeles based on 3-D numerical simulations and NGA West2 equations, *Proc. SMIP2016 Seminar on Utilization of Strong Motion Data*, California Strong Motion Instrumentation Program, Irvine, CA (electronic file).

Dreger, DS, GC Beroza, SM Day, CA Goulet, TH Jordan, PA Spudich, and JP Stewart, 2015. Validation of the SCEC broadband platform V14.3 simulation methods using pseudospectral acceleration data, *Seismol. Res. Lett.*, **86**, 39-47.

Moschetti, MP, et al., 2017. Incorporating long-period (T>1 s) earthquake ground motions from 3-D simulations in the U.S. National Seismic Hazard Model, *Proc. 16th World Conf. on Earthquake Eng.*, Jan 9-13, 2017, Santiago, Chile. Paper No. 4423.

Star, LM, JP Stewart, and RW Graves, 2011. Comparison of ground motions from hybrid simulations to NGA prediction equations, *Earthquake Spectra*, **27**, 331-350.

Stewart, JP, K Afshari, CA Goulet, 2017. Non-ergodic site response in seismic hazard analysis, *Earthquake Spectra*, **33**, 1385-1414.

Wang, F & TH Jordan, 2014. Comparison of Probabilistic Seismic-Hazard Models Using Averaging-Based Factorization. *Bull. Seismol. Soc. Am.*, **104**, 1230-1257.