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The impact of uncertainty in Magnitude-Area scaling relations on SCEC BBP Simulations

an NSF + USGS center

Poster #44 (Friday)

(I) Background

The Southern California Earthquake Center (SCEC) Broadband Ground Motion Simulation Platform (BBP) is an important resource for researchers and practitioners who wish to use strong ground motion simulations. The BBP allows a user to generate ground motions for earthquake scenarios using a variety of physics-based simulation methods, with components including earthquake rupture description and generation, low- and high-frequency wave propagation, and options for non-linear site effects.

Recently, a large validation exercise was completed for four methodologies implemented on the BBP (Goulet et al., 2015). During the validation, the model developers selected magnitude-area (M-A) scaling relations from which to derive the finite fault dimensions. In general, the selected fault dimensions for this exercise roughly followed the Leonard (2010) scaling relations.

We perform simulations with version v15.3 of the BBP for a set of large magnitude validation events and forward scenarios using different M-A scaling relations and assess the results using the median rotated pseudo-spectral acceleration (RotD50) intensity measure.

(II) Objectives

- Quantify the differences and the impact of the different types of M-A scaling relations on the different simulation methods.
- Provide the modelers a tool with which to assess their models, and to refine the way in which they handle different types of M-A scaling relations.
- Provide guidance to the modelers for the simulation of future earthquake scenarios, in Phase 2 of the Validation effort, and in other forward simulations.

(1) Introduction

- The unresolved debate about the way in which the rupture areas of large crustal earthquakes scale with seismic moment is exemplified in Hanks and Bakun (2002; 2008, hereafter HB) who proposed bilinear source-scaling relations to match the M-log(A) observations of Wells and Coppersmith (1994).
  - constant stress-drop scaling for **M**≤6.7 and a transition to non-self-similar scaling following the L-model (Scholz, 1982) scaling for **M**>6.7
  - L-models have large displacements and small areas and do not have self-similar scaling of magnitude with area above the transition
- In self-similar models (e.g. Leonard, 2010), average fault displacement, fault length and fault width all increase uniformly together.
  - the average displacement on a fault rupture surface changes at the same rate as its change in fault dimension, yielding constant stress drop

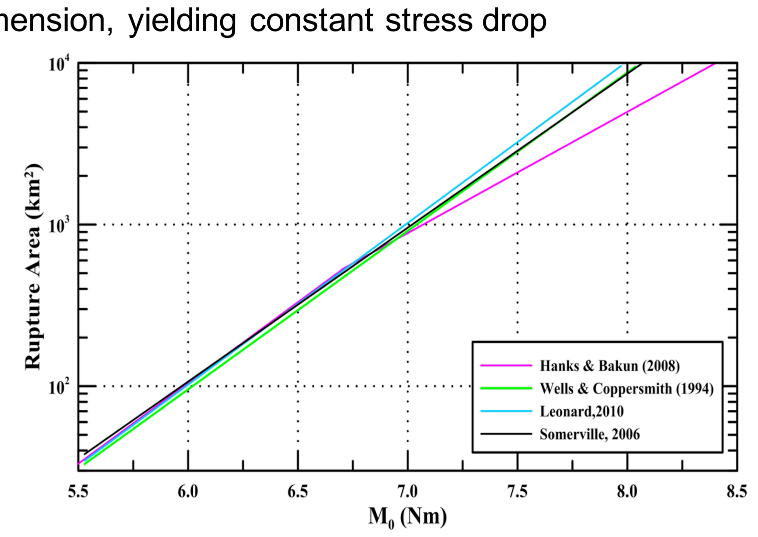

Figure 1: M-Area scaling relations for strike-slip faults in active tectonic regions

(2) Simulation Events and Scenarios

- To utilize the simulations from the BBP Phase 1 validation project (Dreger et al., 2013), we recompute the events listed in Table 1, using the HB scaling relation. We limit our study to events with magnitudes **M**>6.7.
  - In determining fault dimensions, we accommodate the smaller HB faults areas by keeping the fault length from the Leonard dimensions, and reducing the fault width (since W is relatively less constrained than L)
- We base our evaluation on both:

  Type A : previously validated events, and

  Type B : a suite of selected forward scenarios.
- For Type A, results are evaluated using the bias of simulated RotD50 with respect to observations (termed goodness of fit, or GOF)
- For Type B, we compare results for scenarios, at stations located on Rrup bands of 20 and 50 km.
- The simulations use pre-computed 1D GF's appropriate for southern CA, using reference site condition of rock
- We use the GP, EXSIM, UCSB, and SDSU simulation methods, listed with references in Table 2.

(3) Results

- For the Type A simulations (Figure 2), we aggregate the GOF (averages over all simulation stations and hypocenter realizations.) In each panel, the top GOF is using Leonard (2010) M-A scaling, the second GOF is using HB scaling, and the bottom ratio shows the difference between the two, where positive values represent increased levels for the HB scaling simulations.
- For the Type B simulations (Figure 3), we aggregate the results in a similar manner. Since there are no recordings from which to calculate residuals, we instead take the following approach. At each station, we average the RotD50 at each period over the 50 source realizations, effectively getting the "average" spectrum for that site. This is done both for the HB08 and L10 simulations, and then the log-ratio of the average spectra are taken for each site. We perform the statistics on this quantity, and present the results in a similar plot to the Type A results.

Table 1: Simulation Events and Scenarios

Type A							
		Leonard (2010)			Hanks & Bakun (2008)		
Event	**M**	**Area**	**L**	**W**	**Area**	**L (from BBP)**	**W = A/L**
Landers	7.22	1698	77.19	22	1295.7	80	16.2
Northridge	6.73	537	20	26.85	555.9	20	27.8
Loma Prieta	6.94	891	46.17	19.3	798.8	40	20.0
Type B							
		Leonard (2010)			Hanks & Bakun (2008)		
Scenario	**M**	**Area**	**L**	**W**	**Area**	**L (from BBP)**	**W = A/L**
SoCal SS	6.6	407.4	28.9	14.1	416.9	28.2	14.8
SoCal Reverse	6.6	398	25.95	15.34	416.9	28.2	14.8
SoCal SS	7.0	1023.3	50.2	20.4	886.1	50.2	17.65
SoCal Reverse	7.0	1000	45.1	22.17	886.1	45.1	19.65

Table 2: Simulation Methods

Method name	Short-hand identifier(s)	Latest Reference
EXSIM	EXSIM, EX	Atkinson and Assatourians [2015]
Graves and Pitarka	GP	Grave and Pitarka [2015]
San Diego State University	SDSU, SD	Olsen and Takedatsu [2015]
University of California Santa Barbara	UCSB, SB	Crempien and Archuleta [2015]

(5) Acknowledgements

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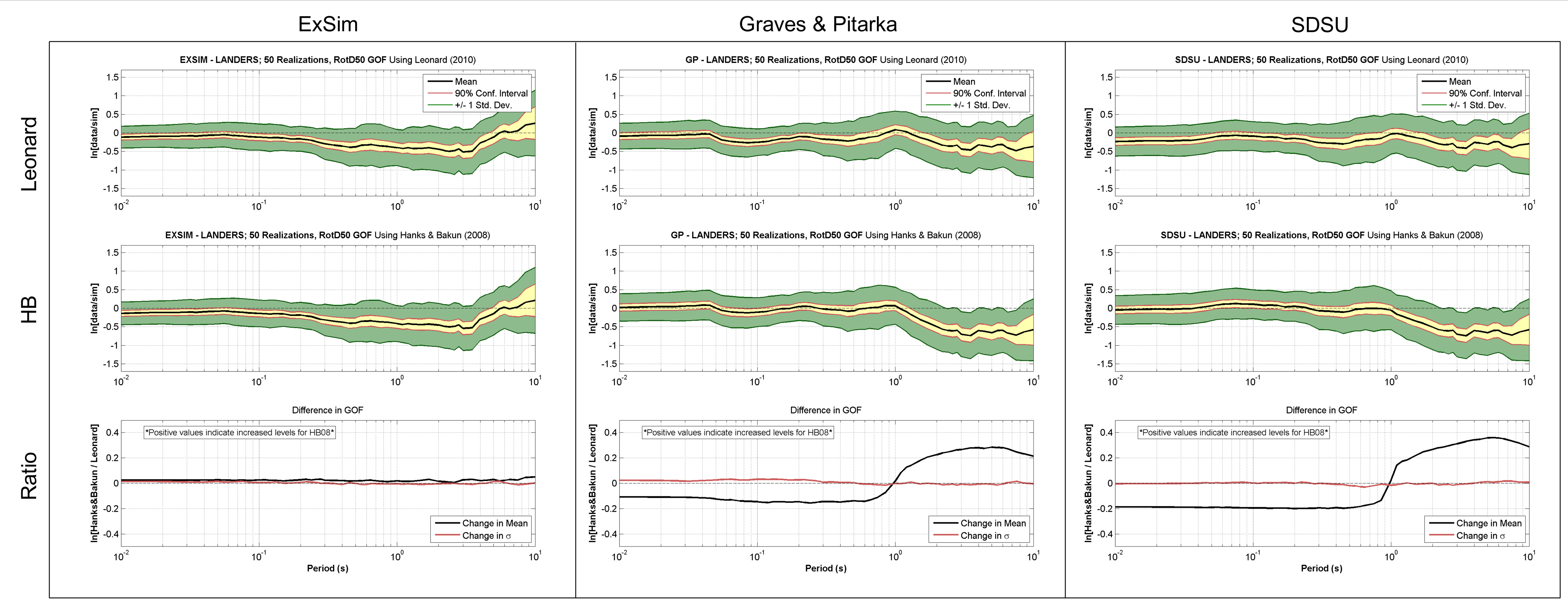

Figure 2: Type A simulation results for the Landers event.

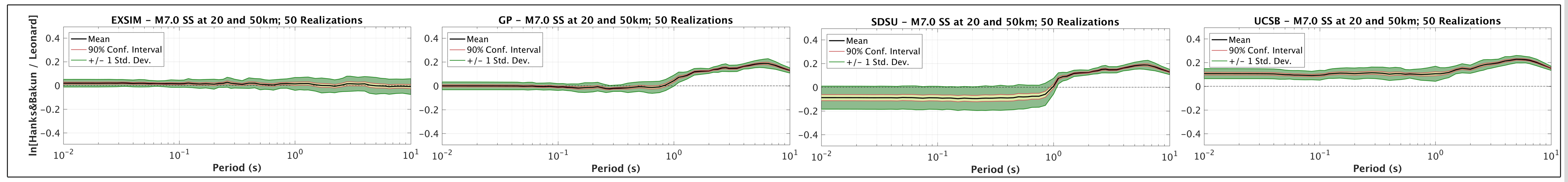

Figure 3: Type B simulation results for the **M**7.0 strike-slip scenario.

(4) Conclusions

- The **EX** method is largely unaffected by the decrease in fault width associated with HB08 scaling – both for Type A simulations, and the Type B scenarios.
  - We have contacted the developers of EX, and they both commented that these results are as expect for EX (Gail Atkinson and Karen Assatourians, pers. comm.). Specifically, Gail Atkinson noted "the main finite-fault effects in EXSIM are geometric (location of fault relative to stations)." Karen Assatourians specified "as long as the moment of the earthquake remains identical and seismic stations distances (or the average of distances) are not very short and in the range of source size, the source finiteness effects are not that significant."
- For the **UCSB** method, the change to smaller fault areas results in a minor increase in the average level of simulations across all oscillator periods for the Loma Prieta event. The Landers event was not completed in the BBP v15.3 simulations, so that comparison was not made. For the Type B scenarios, a larger increase in the average level of simulations is observed for the smaller fault areas, and this increase is consistent across all oscillator periods. The increase relative to the L10 simulations peaks at periods longer than 3 seconds, at about 20% increase.
  - We have contacted the UCSB modelers to discuss possible explanations for the substantial increase observed in the Type B scenarios. One explanation is the fact that Loma Prieta was modeled as a buried rupture (Ztor = 4km) and the Type B scenarios were modeled as surface ruptures.
- For **GP**, at short periods (<1 sec) the change to smaller fault area results in a slight decrease in the level of simulated motions.
  - Based on communication with Rob Graves, this reflects an attribute of the stochastic approach where the results can have a slight dependence on N*dl, where N is the total number of subfaults, and dl is the average subfault dimension. Since we have slightly reduced N, the product N*dl is smaller, resulting in the observed decrease in short period amplitudes.
- The **SDSU** and **GP** methods behave similarly at long periods, which is expected since both methods use the same code for long periods. The change to smaller fault area results in an increase (up to about 30% for Landers and 20% for the M 7.0 scenario events) in the level of simulated motions.
  - Explanation: since the magnitude (and therefore seismic moment) is fixed for an event, decreasing the fault area requires that the average slip on the fault be increased, which is responsible for the observed increase in long period amplitudes.