Implementation and Validation of the Newly Developed Rupture Model Generator at SCEC Broadband Platform

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Project Overview

Abstract
In the box below, describe the project objectives, methodology, and results obtained and their significance. If this work is a continuation of a multi-year SCEC-funded project, please include major research findings for all previous years in the abstract. (Maximum 250 words.)

This project was funded in 2009-2010 and 2012-2015 by SCEC. The main (long-term) research objective is to develop a full description of probabilistic model for finite faulting process to generate physics-based rupture scenarios for simulating ground motions. We also aim to understand the effect of complex source processes on near-source ground motion characteristics. We developed a stochastic model that governs the finite source process with 1-point and 2-point statistics of kinematic source parameters and also a pseudo-dynamic rupture model generator (SongRMG, Ver 1.0). In the project year, we implement the newly developed rupture model generator at the SCEC broadband platform (BBP) and performed validation tests against ground motion recordings for individual events and empirical ground motion prediction equations (GMPEs). The rupture model generator developed by this project is going to be included in the new release (Ver. 16.3) of SCEC BBP.

SCEC Annual Science Highlights
Each year, the Science Planning Committee reviews and summarizes SCEC research accomplishments, and presents the results to the SCEC community and funding agencies. Rank (in order of preference) the sections in which you would like your project results to appear. Choose up to 3 working groups from below and re-order them according to your preference ranking.

- Ground Motion Prediction (GMP)
- Ground Motion Simulation Validation (GMSV)
- Community Modeling Environment (CME)
Exemplary Figure
Select one figure from your project report that best exemplifies the significance of the results. The figure may be used in the SCEC Annual Science Highlights and chosen for the cover of the Annual Meeting Proceedings Volume. In the box below, enter the figure number from the project report, figure caption and figure credits.

![Exemplary Figure](image)

Figure 3. Validation (left) and sensitivity test (right) results at the SCEC BBP (Song 2016)

SCEC Science Priorities
In the box below, please list (in rank order) the SCEC priorities this project has achieved. See [https://www.scec.org/research/priorities](https://www.scec.org/research/priorities) for list of SCEC research priorities. For example: 6a, 6b, 6c

6b, 6c, 4c

Intellectual Merit
How does the project contribute to the overall intellectual merit of SCEC? For example: How does the research contribute to advancing knowledge and understanding in the field and, more specifically, SCEC research objectives? To what extent has the activity developed creative and original concepts?

Rupture dynamics enables us to understand earthquake rupture process in a physics-based way. We can study many interesting and complicated features of earthquake rupture by dynamic modeling. On the other hand, earthquake statistics enables us to quantify the variability of earthquake rupture for future events. We aim to develop a stochastic model for finite source process with simple correlation structures. This is an exciting research work because we can simulate finite source models by stochastic modeling in addition to dynamic rupture modeling.
Broader Impacts
How does the project contribute to the broader impacts of SCEC as a whole? For example: How well has the activity promoted or supported teaching, training, and learning at your institution or across SCEC? If your project included a SCEC intern, what was his/her contribution? How has your project broadened the participation of underrepresented groups? To what extent has the project enhanced the infrastructure for research and education (e.g., facilities, instrumentation, networks, and partnerships)? What are some possible benefits of the activity to society?

Seismologists and earthquake engineers can use stochastic finite source modeling tools developed in this project and generate a number of rupture scenarios for simulating ground motions. They can also study the effect of finite source process on near-source ground motion characteristics in a systematic sense.

Project Publications
All publications and presentations of the work funded must be entered in the SCEC Publications database. Log in at http://www.scec.org/user/login and select the Publications button to enter the SCEC Publications System. Please either (a) update a publication record you previously submitted or (b) add new publication record(s) as needed. If you have any problems, please email web@scec.org for assistance.
Technical Report

In the project year, a generalized version of pseudo-dynamic source model was developed for Mw 6.5 – 7.0 by analyzing 165 dynamic rupture models. And they are tested against recorded ground motion data at the SCEC Broadband platform (BBP).

1. Earthquake Source Modeling

In this study, finite source process is characterized in the framework of 1-point and 2-point statistics of kinematic source parameters (Song et al. 2014). If we assume the multi-variate Gaussian distribution, we need an input model for 27 parameters as described in Figure 1. Six parameters are assigned to 1-point statistics and twenty-one parameters are assigned to 2-point statistics. Six parameters related to response distance are excluded in the study, thus input models for 21 parameters are constructed by analyzing 165 dynamic rupture models (Song 2016). Since we generate a generalized version of pseudo-dynamic source model, we can simulate a number of rupture scenarios, given basic information about a target event such as magnitude and rupture dimension (length/width). It is important to note that three scenario events in Figure 2 share the same input source statistics (1-point and 2-point statistics). Thus, the variation observed among the three models is caused by random realization for each individual event.

<table>
<thead>
<tr>
<th>Model parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu_{\text{slip}} )</td>
<td>Mean slip</td>
</tr>
<tr>
<td>( \mu_{\text{ru}} )</td>
<td>Mean rupture velocity</td>
</tr>
<tr>
<td>( \mu_{\text{psv}} )</td>
<td>Mean peak slip velocity</td>
</tr>
<tr>
<td>( \sigma_{\text{slip}} )</td>
<td>Standard deviation of slip</td>
</tr>
<tr>
<td>( \sigma_{\text{ru}} )</td>
<td>Standard deviation of rupture velocity</td>
</tr>
<tr>
<td>( \sigma_{\text{psv}} )</td>
<td>Standard deviation of peak slip velocity</td>
</tr>
<tr>
<td>( a_x )</td>
<td>Correlation length in the along-strike direction (six parameters: slip versus slip, slip versus ( V_{\text{ru}} ), slip versus ( V_{\text{psv}} ), ( V_{\text{ru}} ) versus ( V_{\text{psv}} ), ( V_{\text{ru}} ) versus ( V_{\text{ru, max}} ) and ( V_{\text{psv}} ) versus ( V_{\text{psv, max}} ))</td>
</tr>
<tr>
<td>( a_z )</td>
<td>Correlation length in the along-dip direction (six parameters: slip versus slip, slip versus ( V_{\text{ru}} ), slip versus ( V_{\text{psv}} ), ( V_{\text{ru}} ) versus ( V_{\text{ru, max}} ), ( V_{\text{psv}} ) versus ( V_{\text{psv, max}} ) and ( V_{\text{ru}} ) versus ( V_{\text{psv, max}} ))</td>
</tr>
<tr>
<td>( \rho_{\text{max}} )</td>
<td>Maximum correlation coefficient (three parameters: slip versus ( V_{\text{ru}} ), slip versus ( V_{\text{psv}} ) and ( V_{\text{ru}} ) versus ( V_{\text{psv, max}} ))</td>
</tr>
<tr>
<td>( RD_x )</td>
<td>Response distance in the along-strike direction (three parameters: ( \text{slip} ) versus ( V_{\text{ru}} ), ( \text{slip} ) versus ( V_{\text{psv}} ) and ( V_{\text{ru}} ) versus ( V_{\text{ru, max}} ))</td>
</tr>
<tr>
<td>( RD_z )</td>
<td>Response distance in the along-dip direction (three parameters: ( \text{slip} ) versus ( V_{\text{ru}} ), ( \text{slip} ) versus ( V_{\text{psv}} ) and ( V_{\text{ru}} ) versus ( V_{\text{psv, max}} ))</td>
</tr>
</tbody>
</table>

For autocorrelation, \( \rho_{\text{max}} \) is one and \( RD_x \) and \( RD_z \) are zero by definition. \( RD_x \) and \( RD_z \) are excluded in this study. Thus, 21 model parameters are considered in total (6 for 1-point statistics and 15 for 2-point statistics).
2. Ground Motion Modeling

The newly developed rupture model generator was implemented at the SCEC broadband platform (BBP) with the support from the SCEC BBP technical group during the project year. Following the guidelines of the SCEC BBP validation project (Goulet et al. 2015), we validate our source modeling method against empirical ground motion prediction equations (GMPEs). Ground motions are simulated by combining scenario rupture models generated in this study with low and high wave propagation modules developed by Graves and Pitarka (2010). Figure 3 shows some preliminary results for M 6.6 events in southern California. In general, simulated ground motions are located within the acceptance range over a broad period range. The simulated ground motions tend to under-predict GMPEs at the period of 1-3 second, in particular for the reverse faulting. We also perform additional sensitivity analysis to understand the effect of 1-point and 2-point statistics on ground motion characteristics by perturbing 1-point and 2-point statistics systematically. The left panel in Figure 3 shows one example obtained by perturbing 2-point correlation structures. We demonstrate that it is an efficient modeling method to simulate finite earthquake process based on 1-point and 2-point statistics of source parameters and simulated rupture scenarios produce ground motions consistent with empirical GMPEs.
Figure 3. Validation (left) and sensitivity test (right) results at the SCEC BBP
References