Introduction to the SCEC Ground Motion Simulation Validation (GMSV) Technical Activity Group (TAG)

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Validation of Simulations

Simulation methods can be validated by comparisons to “data from past earthquakes” or to “empirical models” based on such data (e.g., GMPEs). This can be done at various levels:

- Model Components (e.g., velocity model)
- Seismogram Waveforms
- Response Spectra (Sa)
- Simple proxies beyond Sa for building response (e.g., Duration, max/median-direction Sa, …)
- Building response analysis results
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Usually done by simulation modelers

e.g., BBP Validation project for PSA (previous presentation by Wooddell)

Of more interest to engineering users (focus of GMSV TAG in the past)

May have different results for different engineering applications
Established in 2010, led by Nico Luco (USGS), to develop and implement testing/rating methodologies for validation of simulation methods

- Collaboration between ground motion modelers and engineering users

- Activities focused on 3 broad engineering applications:
  1. Validation based on SDOF / Simple Proxies for more complicated responses
  2. Validation based on MDOF responses
  3. Validation based on geotechnical systems

- Multi-PI projects started in 2015 to build on the knowledge from previous projects to:
  1. Implement validation parameters on SCEC BBP
  2. Demonstrate effectiveness of validation parameters for building response analysis

- Recent SCEC Workshop (Feb 2018) to start communicating with practicing engineers
  → Scenario simulations

Specific engineering application
Motivation for Scenario Simulations

(Nonlinear Response History Analysis):

16.2.2 Ground Motion Selection. A suite of not less than 11 ground motions shall be selected for each target spectrum. Ground motions shall consist of pairs of orthogonal horizontal ground motion components and, where vertical earthquake effects are considered, a vertical ground motion component. Ground motions shall be selected from events within the same general tectonic regime and having generally consistent magnitudes and fault distances as those controlling the target spectrum and shall have similar spectral shape to the target spectrum. For near-fault sites, as defined in Section 11.4.1, and other sites where $MCR$ shaking can exhibit directionality and impulsive characteristics, the proportion of ground motions with near-fault and rupture directivity effects shall represent the probability that $MCR$ shaking will exhibit these effects. Where the required number of recorded ground motions is not available, it shall be permitted to supplement the available records with simulated ground motions. Ground motion simulations shall be consistent with the magnitudes, source characteristics, fault distances, and site conditions controlling the target spectrum.

16.2.3 Ground Motion Modification. Ground motions shall either be amplitude-scaled in accordance with the requirements of Section 16.2.3.2 or spectrally matched in accordance with the
Motivation for Scenario Simulations

- **From PEER NGA-West2 Database**
  - $M \geq 6.5$, $R \leq 20$ km
  - Recordings

11th National Conference on Earthquake Engineering (11NCEE), Los Angeles, CA, June 25-29, 2018
### Current Differences

<table>
<thead>
<tr>
<th></th>
<th>CyberShake</th>
<th>Broadband Platform</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Purpose</strong></td>
<td>PSHA</td>
<td>Scenarios</td>
</tr>
<tr>
<td><strong>Methods</strong></td>
<td>Graves &amp; Pitarka</td>
<td>Several (7)</td>
</tr>
<tr>
<td><strong>Basin effects</strong></td>
<td>3-dimensional</td>
<td>1-dimensional</td>
</tr>
<tr>
<td><strong>Frequency band</strong></td>
<td>&lt; ~1 Hz</td>
<td>0-100 Hz</td>
</tr>
<tr>
<td><strong>Computer needed</strong></td>
<td>Supercomputer</td>
<td>Personal computer</td>
</tr>
<tr>
<td><strong>Validations</strong></td>
<td>Relatively limited</td>
<td>Relatively extensive</td>
</tr>
</tbody>
</table>

For this workshop, we only used Graves&Pitarka simulations from SCEC BBP version 17.3
Objective: Select a suite of hazard-consistent ground motions for nonlinear building response analysis (i.e., large M and/or close R). Per ASCE 7-16 guidelines.

Ref: PEER TBI (2011).
**Selected Sites & Scenarios**

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**Two Archetype Buildings:**

**20-story RC frame**

- **Archetype ID:** 1020 (FEMA P695)
- **Modeling:** Cyclic hinge model for beams and columns in the lateral frame + leaning system (gravity frame)
- **Period:** $T_1 = 2.6$ sec, $T_2 = 0.9$ sec

**42-story RC frame**

- **Archetype ID:** simplified from TBI building 1C (H1 direction)
- **Modeling:** force-based fiber element for shear wall + leaning system (gravity frame)
- **Period:** $T_1 = 4.2$ sec, $T_2 = 1.0$ sec

Ref: PEER TBI (2011).
Objective: Select a suite of hazard-consistent ground motions for nonlinear building response analysis (i.e., large M and/or close R). Per ASCE 7-16 guidelines.

Three Intensity/Hazard Levels:

- 10% in 50 years “DBE”
- 2% in 50 years “MCE”
- 2% in 200 years

Three Sites:

- San Francisco Downtown (8029-RIN: 37.786 N, 122.391 W, Vs30 = 873 m/s)
- Los Angeles Downtown (LADT: 34.052 N, 118.257 W, Vs30 = 390 m/s)
- San Bernardino (S688: 34.104 N, 117.288 W, Vs30 = 280 m/s)
**Objective:** Select a suite of hazard-consistent ground motions for nonlinear building response analysis (i.e., large M and/or close R). Per ASCE 7-16 guidelines.

**Major Seismic Sources from Deaggregation of Hazard (5sec):**

*San Francisco:*
- San Andreas fault system (NSA)
- Hayward/Rogers Creek fault system

*Los Angeles:*
- Elysian Park (EP)
- Others
- San Andreas fault system (SSA)

*San Bernardino:*
- San Jacinto fault system (SJ)
- San Andreas I fault system (SSA)

SF and SB are dominated by two faults, whereas LA has a more complex set of contributors.
### GMSV BBP 17.3 Scenario Simulations:

<table>
<thead>
<tr>
<th>UCERF2 Name ; ID</th>
<th>M</th>
<th># of Hypocenters</th>
<th># of GM’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. San Andreas (SAO+SAN+SAP+SAS)</td>
<td>8.0</td>
<td>6</td>
<td>1152</td>
</tr>
<tr>
<td>Hayward - Rodgers Creek (HN+HS)</td>
<td>7.0</td>
<td>3</td>
<td>576</td>
</tr>
<tr>
<td>Elysian Park (Upper)</td>
<td>6.6</td>
<td>2</td>
<td>704</td>
</tr>
<tr>
<td>S. San Andreas (PK+CH+CC+BB+NM+SM)</td>
<td>7.9</td>
<td>8</td>
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<tr>
<td>San Jacinto (SBV+SJV+A+C)</td>
<td>7.8</td>
<td>4</td>
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**Simulated earthquakes: M-R scatter plot**

- $M \geq 6.5$,
- $R \leq 20\text{km}$

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Selected Sites & Scenarios

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6 Surrogate Stations (Vs30: 863 ~ 873 m/s):
Selected to have similar distances to the major faults and similar soil velocities with the corresponding main site, intended to represent spatial variations in wave propagations.

NorCal Scenarios:

- N. San Andreas (M8) 16 realizations
- Hayward (M7) 16 realizations

Several realizations/hypocenter were simulated with different faulting properties (e.g., slip distribution within the fault plane).
Selected Sites & Scenarios

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11 Surrogate Stations for Los Angeles (Vs30: 315 ~ 446 m/s), Elysian Park & SSA

8 Surrogate Stations for San Bernardino (Vs30: 280 ~ 500 m/s), SSA & San Jacinto

SoCal Scenarios:

- Elysian Park (M6.6) 16 realizations
- San Jacinto (M7.8) 16 realizations
- S. San Andreas (M7.9) 1 realization
BBP 17.3 Scenario Simulations

Features:

- High intensity levels (large M, close R) → require less scaling (more realistic)
- Represent local seismic sources
- Represent local soil velocity structures

Record Spectra vs. Target Spectra (San Francisco Downtown, $T_{\text{cond}} = 5$ sec)
Better coverage on target conditional mean spectra, especially for long periods.

NGA-West Records
Simulated BBP Records
Workshop Outcomes

➢ Presentations posted https://www.scec.org/workshops/2018/gmsv

➢ Engineers requested access to a selected set of simulations (rather than the thousands of Scenario Simulations in BBP 17.3 version) to start working with simulated motions in their own applications and provide feedback to our group and to modelers

➢ ~100 Selected Subset of Seismograms:
  posted on the workshop website w/ thanks to Ting Lin, Kuanshi Zhong, Christine Goulet
GMSV TAG continues in SCEC5 (starting Nov 2017):
Co-Lead by Sanaz Rezaeian & Jonathan Stewart

- Consider both validation related to “ground motion prediction” and “engineering applications” within the same group

- Validation related to ground motion prediction (Intensity Measures)
  - Identify areas of bias in ground motion predictions from simulations
  - Improve simulation procedures (BBP & Cybershake) and support GMPE development
  - Spatial correlations of IMs for application to distributed infrastructure

- Validation related to engineering utilization
  - More specific engineering applications similar to the Feb workshop
  - Help engineers to gain confidence in utilizing simulations (PSHA, RHA)

Update on specific activities to achieve these goals @ the SCEC annual meeting (Sept 2018)