Broadband Ground Motion Simulation Plans

Paul Somerville
URS

SCEC Ground Motion Simulation Validation Progress Workshop

Sept 9, 2012
Outline

• Summary of participating simulation modules
• Selection of reference velocity and Q models
• Selection of reference source geometry (SRC)
• Generation of multiple rupture models (SRF)
• Running broadband simulations
• Goodness of fit based on best fitting rupture model
• Goodness of fit based on average rupture model
Participating Simulation Modules

http://scec.usc.edu/scecpedia/Broadband_Platform_Meeting_-__7_March_2012

GREENS FUNCTION BASED MODELS
• SDSU – Olsen/Mai – operational
• UCSB – Archuleta et al – operational
• URS – Graves/Pitarka – operational

• Irikura/Miyake asperity source model – to be implemented
• Zeng/Anderson composite source model - to be implemented

NON-GREENS FUNCTION BASED MODULES
• Point source stochastic model – Boore - to be implemented
• Finite-fault stochastic model – Atkinson - to be implemented

GMPE
• Empirical GMPE with event terms - to be implemented
Reference Velocity Models for Green’s Function Calculations

• Use regional velocity models for rock site conditions
• e.g. a southern California model
• e.g. a Japan model
• Use a standard shallow velocity profile with $Vs30 = 863$ m/s
• Data are corrections for basin conditions using $Z1.0$ in the C&Y 2008 GMPE
Southern California Velocity Models
Japan Velocity Models
from Koketsu 3D Model of Japan
Source Geometry (SRC file)

- MAGNITUDE = 6.9
- FAULT_LENGTH = 40.0
- DLEN = xxx
- FAULT_WIDTH = 17.5
- DWID = xxx
- DEPTH_TO_TOP = 3.85
- STRIKE = 128
- RAKE = 145
- DIP = 70
- LAT_TOP_CENTER = 37.0789
- LON_TOP_CENTER = -121.8410
- HYPO_ALONG_STK = 0.0
- HYPO_DOWN_DIP = 14.75
- DT = xxx
- SEED = xxx
- CORNER_FREQ = xxx
- SEISMIC MOMENT = xxx
- HYPO LAT = xxx
- HYPO LONG = xxx
- HYPO DEPTH = xxx
Selection of Reference SRC Models

• Review alternative published rupture models (Mai website and newer sources)
• Retain significant multi-segment and branching characteristics, because one role of the simulations it to model these effects because they are hard to represent in GMPE’s
## Earthquake Event List

<table>
<thead>
<tr>
<th>Eq Number</th>
<th>YEAR</th>
<th>REGION</th>
<th>EQ NAME</th>
<th>EQID</th>
<th>Multiple Fault Segments</th>
<th>Martin Mai Website</th>
<th>Author of Reference Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2010</td>
<td>WUS</td>
<td>El Mayor Cucapah</td>
<td>280</td>
<td>yes</td>
<td>no</td>
<td>Wei et al., 2001</td>
</tr>
<tr>
<td>2</td>
<td>1994</td>
<td>WUS</td>
<td>Northridge</td>
<td>127</td>
<td>no</td>
<td>yes</td>
<td>Hartzell et al., 1996</td>
</tr>
<tr>
<td>3</td>
<td>1999</td>
<td>WUS</td>
<td>Hector Mine</td>
<td>158</td>
<td>yes</td>
<td>yes</td>
<td>Kaverina and Dreger, 2002</td>
</tr>
<tr>
<td>4</td>
<td>1992</td>
<td>WUS</td>
<td>Landers</td>
<td>125</td>
<td>yes</td>
<td>yes</td>
<td>Wald &amp; Heaton, 1994</td>
</tr>
<tr>
<td>5</td>
<td>1987</td>
<td>WUS</td>
<td>Whittier Narrows</td>
<td>113</td>
<td>no</td>
<td>yes</td>
<td>Hartzell &amp; Iida, 1990</td>
</tr>
<tr>
<td>6</td>
<td>1992</td>
<td>WUS</td>
<td>Big Bear</td>
<td>126</td>
<td>no</td>
<td>no</td>
<td>Jones and Hough, 1995; NGA Event 126</td>
</tr>
<tr>
<td>7</td>
<td>2004</td>
<td>WUS</td>
<td>Parkfield</td>
<td>179</td>
<td>no</td>
<td>yes</td>
<td>Custodio et al., 2005</td>
</tr>
<tr>
<td>8</td>
<td>1989</td>
<td>WUS</td>
<td>Loma Prieta</td>
<td>118</td>
<td>no</td>
<td>yes</td>
<td>Wald et al., 1991</td>
</tr>
<tr>
<td>9</td>
<td>1986</td>
<td>WUS</td>
<td>North Palm Springs</td>
<td>101</td>
<td>no</td>
<td>yes</td>
<td>Hartzell, 1989</td>
</tr>
<tr>
<td>10</td>
<td>1983</td>
<td>WUS</td>
<td>Coalinga</td>
<td>76</td>
<td>no</td>
<td>no</td>
<td>NGA Event 76</td>
</tr>
<tr>
<td>11</td>
<td>2003</td>
<td>WUS</td>
<td>San Simeon</td>
<td>177</td>
<td>no</td>
<td>no</td>
<td>Ji et al., 2004</td>
</tr>
<tr>
<td>12</td>
<td>1988</td>
<td>CENA</td>
<td>Saguenay</td>
<td>CENA-5</td>
<td>no</td>
<td>yes</td>
<td>Hartzell et al., 1994</td>
</tr>
<tr>
<td>13</td>
<td>2005</td>
<td>CENA</td>
<td>Riviere-du-Loup</td>
<td>CENA-32</td>
<td>no</td>
<td>no</td>
<td>Herrmann</td>
</tr>
<tr>
<td>14</td>
<td>2011</td>
<td>CENA</td>
<td>Mineral, VA</td>
<td>CENA-88</td>
<td>no</td>
<td>no</td>
<td>Chapman, 2012</td>
</tr>
<tr>
<td>15</td>
<td>2000</td>
<td>JAPAN</td>
<td>Tottori</td>
<td>176</td>
<td>no</td>
<td>yes</td>
<td>Iwata &amp; Sekiguchi, 2001</td>
</tr>
<tr>
<td>16</td>
<td>2007</td>
<td>JAPAN</td>
<td>Chuetsu-Oki</td>
<td>278</td>
<td>no</td>
<td>no</td>
<td>Aoi et al., 2008</td>
</tr>
<tr>
<td>17</td>
<td>2004</td>
<td>JAPAN</td>
<td>Niigata</td>
<td>180</td>
<td>no</td>
<td>no</td>
<td>Asano &amp; Iwata, 2009</td>
</tr>
<tr>
<td>18</td>
<td>2008</td>
<td>JAPAN</td>
<td>Iwate</td>
<td>279</td>
<td>no</td>
<td>no</td>
<td>Yoshida et al., 2011</td>
</tr>
<tr>
<td>19</td>
<td>1999</td>
<td>TURKEY</td>
<td>Kocaeli</td>
<td>136</td>
<td>yes</td>
<td>yes</td>
<td>Sekiguchi &amp; Iwata, 2002</td>
</tr>
<tr>
<td>20</td>
<td>1999</td>
<td>TAIWAN</td>
<td>Chi-Chi</td>
<td>137</td>
<td>yes</td>
<td>no</td>
<td>Ji et al., 2003</td>
</tr>
<tr>
<td>21</td>
<td>2009</td>
<td>ITALY</td>
<td>L’ Aquila</td>
<td>274</td>
<td>no</td>
<td>no</td>
<td>Cirella et al., 2009</td>
</tr>
<tr>
<td>22</td>
<td>2011</td>
<td>NEW ZEALAND</td>
<td>Christchurch</td>
<td>346</td>
<td>yes</td>
<td>no</td>
<td>Beavan et al., 2012</td>
</tr>
<tr>
<td>23</td>
<td>2010</td>
<td>NEW ZEALAND</td>
<td>Darfield</td>
<td>281</td>
<td>yes</td>
<td>no</td>
<td>Beavan et al, 2012</td>
</tr>
</tbody>
</table>
Source Rupture Model (SRF file)
Tottori eq: Graves SRF from Iwata and Sekiguchi
Approaches to Rupture Modeling

- Randomly generate 50 SRF’s from the SRC
- Perform simulations for each SRF
- Measure goodness of fit for each SRF

**PATH 1**
- Find the best fitting SRF
- Use its goodness of fit to represent modeling uncertainty
- Include uncertainty in SRF specification when forward modeling future scenarios

**PATH 2**
- Use the average goodness of fit of 50 SRF’s to represent modeling uncertainty
- No need to include uncertainty in SRF specification when forward modeling future scenarios

• Randomly generate 50 SRF’s from the SRC
• Perform simulations for each SRF
• Measure goodness of fit for each SRF
Validations: Part A

• Compare simulations to observed ground motions
  – 20 shallow crustal earthquakes (M>6)
• Set up validation exercises for each earthquake
  – Path description
    • 1-D GF
  – Source description
    • Simple geometry and mechanism
    • Sets of alternative slip models
  – Site description
    • Locations
    • Site response factors – including non-linear factors
  – Observed ground motions
    • 5% damped response spectral values
    • Arias intensity
    • 5-75% Duration
• Compute bias (mean misfit) and standard deviation of misfit
Validations – Part B

- Compare to empirical GMPEs in range that is well constrained by data
  - M6-7
  - Distances 15-50 km
- Set up validation cases
  - M6.0, M6.5, M7.0
  - R 15, 20, 30, 40, 50 (multiple station locations along strike)
  - SS and RV (45 dip)
  - VS30=750 m/s
- For each case, run forward simulations for multiple realizations of the source model (e.g. 30-50) to give stable estimates of median and standard deviation
  - Compute bias (mean misfit) and standard deviation from simulations
SCEC Tasks

- New module development
- Validation Cases
  - Set up the validation exercises
    - Part A
    - Part B
- Conduct validation
  - Developers test and revise modules
- IT support for implementation for large suites of forward simulations
  - Does not cover costs for person to run simulations under QA
- Review forward simulation results
  - Workshop with module developers to understand the differences
Sponsor Objectives

• Broadband platform modules
  – Magnitudes: M6 – M8
  – Rupture Distances: 0-15 km
  – Mechanisms: Strike-slip, reverse, normal
  – Frequency Band: 0.1 to 30 Hz (can get by with 5-10 hz if it captures the peak in the acceleration response spectrum
  – Crustal structure: 1-D

• Validations
  – (A) test simulation methods for event-specific source models (optimized)
  – (B) test method for generating source models for future earthquakes

• Forward Simulations
  – Generate sets of ground motions for large suites of future earthquakes
  – Be able to conduct simulations under QA