Ground-motion regionalization

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On Behalf of the TI team
Summarizing work of NGA-E team investigators,
(especially Dreiling/Mooney crew)
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Overall Summary of Ground-Motion Regionalization Approach

- Ground-motion regions are based on the analyses and reports of Mooney’s team.
- TI team modified the regionalization map slightly from Mooney’s draft report to:
  1) include Canada and important recorded events and stations
  2) extend offshore slightly (to capture events otherwise missed and to address the PPRP comment)
What is the basis for this regionalization?

- Started with four regions of distinct geologic structure and tectonic history
- Characterize representative crustal velocity structure for each region, including Q
- Use simulations to explore effect of crustal structure and Q on ground motion
- Define regions based on statistically-significant differences in ground motion (compared to CNA base region)
Central North America (reference)
Appalachian
Atlantic Coastal Plains
Gulf Coast/Mississippi Embayment
All regions
Analysis Method: Mooney et al. analyzed and synthesized a large volume of data on crustal structure

whole crustal models (red), shallow (≤10km) crustal profiles (blue)
Data records include:

1) Latitude & Longitude of measurement point
2) Structure of entire crust:
   - P-wave velocity
   - S-wave velocity (where available)
   - sediment thickness
   - thickness of crystalline crust
   - detailed description of crustal layering
3) Crustal Type (such as basins, shields, orogens, etc)
4) Tectonic Age
5) Experimental details
Synthesis of data: contour maps

Thickness of Sediments

[Map showing contour maps of thickness of sediments across North America.]
CEUS 2012 Avg. Crustal Shear Vel. (km/s).

6/6/2012 (a)
Compilation of velocity profiles: Example for CNA
CNA velocity profiles
Representative seismic velocity-depth profiles of the four regions of interest. Vs was calculated using a Poisson’s ratio of 1.73.

<table>
<thead>
<tr>
<th>Atlantic Coastal Plain</th>
<th>Appalachians</th>
<th>Central North America</th>
<th>Mississippi Embayment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Depth (km)</strong></td>
<td><strong>Vp (km/s)</strong></td>
<td><strong>Vs (km/s)</strong></td>
<td><strong>Depth (km)</strong></td>
</tr>
<tr>
<td>0.0</td>
<td>6.0</td>
<td>3.46</td>
<td>0.0</td>
</tr>
<tr>
<td>20.5</td>
<td>6.7</td>
<td>3.87</td>
<td>12</td>
</tr>
<tr>
<td>36</td>
<td>8.1</td>
<td>4.68</td>
<td>20</td>
</tr>
<tr>
<td>37</td>
<td>8.1</td>
<td>4.68</td>
<td>34</td>
</tr>
<tr>
<td>40</td>
<td>8.1</td>
<td>4.68</td>
<td>41</td>
</tr>
</tbody>
</table>
Representative velocity structures for the four Regions of interest: Atlantic Coastal Plain, Appalachians, Central North America and the Mississippi Embayment/Gulf Coast Plain. Illustrated are seismic shear-wave velocities ($V_s$).
Consider impact of alternative crustal models for reference region of CNA. (box-and-whiskers for seismic velocity uncertainties with box interval of ±25 % and whiskers (blue “error bars”) at ±45 %)
Evaluate variability of Q across regions (controls frequency-dependent anelastic attenuation, important at large distances).

Example $Q_0$ map of the United States of America (Baqer and Mitchell 1998).
Assign a median Q value function to each region, based on literature review

Comparison of Q(f) within Central North America. Illustrated are ten studies (continuous lines) and their Q-f estimates, if available (crosses). The dashed line (yellow highlight) shows the median of all Q-f relations.
Quality-factors (Qs and Qp) of the four Regions of interest, extracted from the previous analyses. Using a reference frequency of 5 Hz.

<table>
<thead>
<tr>
<th>Quality-Factor</th>
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<th>Appalachians</th>
<th>Central North America</th>
<th>Mississippi Embayment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q(f)</td>
<td>628 $f^{0.38}$</td>
<td>713 $f^{0.39}$</td>
<td>630 $f^{0.40}$</td>
<td>614 $f^{0.32}$</td>
</tr>
<tr>
<td>Qs</td>
<td>1157</td>
<td>1335</td>
<td>1200</td>
<td>1027</td>
</tr>
<tr>
<td>Qp</td>
<td>2314</td>
<td>2670</td>
<td>2400</td>
<td>2054</td>
</tr>
</tbody>
</table>
Generate ground-motion synthetics

(Zhu frequency-wavenumber code) for 0.5 to 20 Hz; regionalization defines the velocity model (1st steps), used to calculate Greens functions. Convolved with simple triangular source-time function, for M=6, at focal depths 5, 10, 20, 30km. Compute PSA from synthetic accelerograms. Compare PSA vs. distance for different regions.
PSA for different frequencies (1.5, 3, 5, 10, 15, 20 Hz) within Central North America for an event at 10 km depth. Computed at a range of distances to 500 km.
Effect of alternative velocity models within CNA; this defines representative within-region variability, against which results from other regions can be compared.
Representative mean comparison: Atlantic Coastal Plain compared to CNA mean and std.dev.

Frequency bin: 0.5 – 1 Hz. Focal depth: 10 km (repeat for 5-10 Hz frequency, focal depths 5, 10, 20, 30 km).
Representative mean comparison: MEM and CNA

Frequency bin: 0.5 – 1 Hz. Focal depth: 30 km.
Differences in ground motion for other regions (compared to CNA) are considered significant if (following EPRI 1993):

- Differences in medians are significant at 95% confidence level
- Differences in medians are greater than 20%
- These criteria are met for 3 consecutive distances and frequencies, with the polarity of the difference in medians being consistent over this distance and frequency range (distance criterion gives a 30 km range)
- **Key variables are mean and standard deviation of ground motions for each region, in comparison to that for CNA (i.e. does the mean PSA for a region fall within the std.dev. for CNA?)**
Conclusions

• There are two distinct attenuation groups
  – GROUP 1: Central North America, Appalachians, Atlantic Coastal Plain
  – GROUP 2: Mississippi Embayment/Gulf Coast

• Seismic velocity structure has more effect regionally than does Q