GMPE Proponent Model: Empirical ENA Model

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Summary

• Combining intensity based estimates of ground motion with the NGA East ground motion database provides observational coverage from M2.5 to M7.7 over a distance range of less than 10 km to 2000 km.
• The intensity based estimates help constrain empirical ENA GMPEs at M≥6, although with greater uncertainty.
Acknowledgements

• Norm Abrahamson for the suggestion of developing an empirical GMPE for ENA using NGA East data.
• USGS NEHRP grant G13AP00030 supporting the development and use of ground motion estimates from historical intensity observations for ENA GMPEs.

Overview

• Data sets used
• Empirical GMPE development
• Results
Datasets Used

- NGA East ground motion database (2014 RotD50 5% damped flat file)
- 2011 Bhuj, India 5% damped observations (Cramer and Kumar, 2003) with geology based Vs30 estimates
Ground Motion Data Selection

• Avoid Gulf Coast and WUS higher attenuation
  – North of 35N Latitude
  – East of 100W Longitude

• Include 1985 M6.9 Nahanni, 1976 M6.8 Gazli, and 2001 M7.6 Bhuj data
Intensity Data Selection

- Convert to ground motion using Dangkua and Cramer (2011) relations
- Checked conversion using 1988 M5.9 Saguenay and 2011 M5.7 Mineral VA observations
- Reviewed available M>5.6 median ground motion estimates vs. median distance
- Selected M>6 ground motions estimated from intensity observations

![PGA Ground Motion vs. MMI](From Dangkua and Cramer (2011))
Historical Earthquake Magnitudes

- M7s – Historical Earthquake Magnitude Estimates from Cramer and Boyd (2014):
  - New Madrid 12/1811 mainshock -> M7.5
  - New Madrid 1/1812 mainshock -> M7.3
  - New Madrid 2/1812 mainshock -> M7.7
  - Charleston, SC 1886 mainshock -> M7.0
    - 95% conf. limit uncertainty of ± 0.3 magnitude units
- Historical Earthquakes with Instrumental Magnitude:
  - Grand Banks 1929 -> M7.2 (Bent, 1995)
  - 1925 Charlevoix earthquake -> M6.2 (Bent, 1992)
  - 1988 Saguenay earthquake -> M5.9 (GSC)
Using All Observations Carries Uncertainty Into GMPE

It Also Provides Ground Motion Estimates At Closer In Distances (less than 100 km)

Empirical GMPE

• Approach

• Functional Form

• Results
Approach

• Two-stage regression of Joyner and Boore (1993, 1994)

• Provides both between event and within event variability. Event and site terms also determined.

Functional Form of Regressions

• \( \log Y = f(R) + f(M) \)

• \( f(R) = (c_1 + c_2M) \log R + c_3(R - R_0) + d_1 \log(Vs30/760) + \phi \)

• \( f(M) = a_1U + a_2RR + a_3SS + b_1M + b_2M^2 + \tau \)

• \( R^2 = R_{epi}^2 + h^2 \), \( h \) fixed at 10 km

• \( R_0 = 1; SS = 1 \) for Strike Slip or Normal, \( RR = 1 \) for Reverse, \( U = 1 \) for Undefined Focal Mechanism and zero otherwise

• \( \sigma^2 = \phi^2 + \tau^2 \)
Results

- GMPE vs. Observations
- Sigma Comparisons
- Single Station Sigma
GMPE with and without Intensity Data vs. Observations
GMPE with and without Intensity Data vs. Observations

GMPE with and without Intensity Data vs. Observations
Sigma Comparisons

<table>
<thead>
<tr>
<th>Period</th>
<th>Within Event Uncertainty ($\sigma_{\text{log10}}$)</th>
<th>Between Event Uncertainty ($\sigma_{\text{log10}}$)</th>
<th>Total Uncertainty ($\sigma_{\text{log10}}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Without Intensity</td>
<td>With Intensity</td>
<td>Without Intensity</td>
</tr>
<tr>
<td>PGA</td>
<td>0.32</td>
<td>0.38</td>
<td>0.31</td>
</tr>
<tr>
<td>PGV</td>
<td>0.30</td>
<td>0.36</td>
<td>0.30</td>
</tr>
<tr>
<td>0.3 s</td>
<td>0.32</td>
<td>0.41</td>
<td>0.30</td>
</tr>
<tr>
<td>1.0 s</td>
<td>0.31</td>
<td>0.39</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Single Station Sigma (SSS)

- For stations (31) with 30 or more observations
- Log base 10 values

<table>
<thead>
<tr>
<th>Period</th>
<th>Ave. SSS</th>
<th>Total Sigma</th>
</tr>
</thead>
<tbody>
<tr>
<td>PGA</td>
<td>0.320</td>
<td>0.449</td>
</tr>
<tr>
<td>PGV</td>
<td>0.290</td>
<td>0.411</td>
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<tr>
<td>0.2 s</td>
<td>0.291</td>
<td>0.468</td>
</tr>
<tr>
<td>1.0 s</td>
<td>0.293</td>
<td>0.430</td>
</tr>
</tbody>
</table>
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Earthquake Locations and MMI III Isoseismals in New England

MMI III to 1200 - 1400 km.
Qualitatively, New Madrid and Charleston earthquakes have similar or greater magnitudes to 1929 Grand Banks eqk.

1811-1812
New Madrid

1886
Charleston, SC

1929
Grand Banks