The Stress-Parameter, Geometrical Spreading Correlation

David M. Boore
Gail M. Atkinson

USGS National Seismic Hazard Map (NSHMP) Workshop on Ground Motion Prediction Equations (GMPEs) for the 2014 Update
December 12-13, 2012
I-House, Berkeley, CA
Plus two additional topics

• The measure of ground motion used by NGA-West2
• Computing response spectra for low-kappa, low-sample rate records (a teaser only)
Δσ-attenuation model
correlation

“When we try to pick out anything by itself, we find it hitched to everything else in the universe”—John Muir
Δσ from fits to T=0.1 and 0.2 s PSA from the Val des Bois earthquake.

geometrical spreading ($1/R^p$)
Note separation of motion by azimuth; stress fits are for all data combined.

Note dependence of stress on Q model for same geometrical spreading (215 bars for A04 Q model, 1026 bars for BS11 Q model)

Note generally poor fit of T=2 s PSA
Use eGf to resolve ambiguity

• Objective: Discriminate between attenuation models that fit observed short-period response spectra

• Strategy:
  • Generally too few observations at close distances to discriminate
  • Remove path effect by using empirical Green’s function (eGf)
  • Find range of stress drops consistent with eGf
  • Find range of attenuation models fit to response spectra consistent with this range of stress drops

• Limitations:
  • Spectra too noisy at low frequencies to allow a good determination of the corner frequency of the larger event
  • Azimuthal dependence complicates analysis

• Use both H and V motions
# Event information for the Val des Bois Earthquake

<table>
<thead>
<tr>
<th></th>
<th>Year</th>
<th>M</th>
<th>D</th>
<th>H</th>
<th>h(km)</th>
<th>Mn</th>
<th>M*</th>
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</table>
\(\Delta \sigma \approx 400\text{bars}\)
Note azimuthally dependent PSA

$\Delta \sigma \approx 400 \text{ bars}$ only consistent with $1/R$
\[ \Delta \sigma \approx 1600 \text{bars} \]
Δσ≈1600 bars only consistent with $1/R^p$, $p > 1.3$

$1/R^{1.3}$, $R_t=60$ km, not consistent with $T=2$ s data
Conclusions (stress-path correlation)

• Need consistency between model used to derive parameters and forward predictions using those parameters
• Pronounced azimuthal variation in motions around well-recorded ENA events
• eGf analysis has potential to resolve ambiguity due to stress-path correlation, but limited data bandwidth at low frequencies and azimuthal variations complicate the analysis
Relations between GM_AR, GMRotI50, and RotD50

David M. Boore

Presented at the
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Computing RotD50

- Project the two as-recorded horizontal time series into azimuth Az
- For each period, compute PSA, store Az, PSA pairs in an array
- Increment Az by δα and repeat first two steps until Az=180
- Sort array over PSA values
- RotD50 is the median value
- RotD00, RotD100 are the minimum and maximum values
- **NO geometric means are used**
To convert GMPEs using random component as the IM (essentially, the as-recorded geometric mean), multiply by RotD50/GM_AR

To convert GMPEs using GMRotI50 as the IM (e.g., 2008 NGA GMPEs), multiply by RotD50/GMRotI50
References


Conclusions (Ground-motion intensity measure)

• WNA-E should use RotD50 for consistency with NGA-West2

• A factor of 1.04 for T=1 s. Is this important?

• Converting GMPEs in terms of random horizontal component, geometric mean, or GMRotI50 to RotD50 can be done using correlations shown in the figure (although these were derived for NGA-W flatfile—should compare GM_AR, GMRotI50, and RotD50 for CENA data)
Response Spectra for Low Sample Rate Data: A Simulation Study

An issue discovered by Norm Abrahamson
M 6.5, R=30 km:

- no noise
- 1 gal white noise
- 2 gals white noise
- 4 gals white noise
- 8 gals white noise
- 16 gals white noise
- 16 gals, $f_c = 40$ Hz

Event: M 4.5, R=100 km (2008-10-14, 02:16:58, NOAA, Greece)

SMSIM, M 5.5, R=30 km WNA \( \Delta \sigma = 70 \) bars, rock \( \kappa = 0.04 \), no filter
SMSIM, M 6.5, R=30 km WNA \( \Delta \sigma = 70 \) bars, rock \( \kappa = 0.04 \), no filter
SMSIM, M 6.5, R=30 km ENA \( \Delta \sigma = 210 \) bars, rock \( \kappa = 0.005 \), no filter
SMSIM, M 6.5, R=30 km ENA \( \Delta \sigma = 414 \) bars, rock \( \kappa = 0.005 \), no filter
SMSIM, M 7.5, R=30 km WNA \( \Delta \sigma = 70 \) bars, rock \( \kappa = 0.04 \), no filter
SMSIM, M 6.5, R=30 km WNA \( \Delta \sigma = 70 \) bars, rock \( \kappa = 0.04 \), high-cut filter
Representative Fourier acceleration spectra (the first of 10 simulations) for unfiltered and filtered time series computed for a $M_5$ earthquake at 50 km, assuming model parameters appropriate for eastern North America, except for .
Average of 10 ratios of response spectra, for simulations spanning the range of used in this study, plotted vs frequency for ease of comparison with the FAS in Figure 1.
Conclusions (Computation of PSA)

• Standard method for computing PSA can lead to significant bias (underestimation) of response spectra for frequencies less than the antialiasing filter frequency

• This is of most concern for situations where high-frequencies are little attenuated (low-kappa sites, close distances) and low-sample rate dataloggers are used (thus leading to abrupt changes in spectral level near the anti-aliasing corner frequency)
Conclusions (Computation of PSA)

- Guidelines should be developed that can be used to decide on the usable short-period limit of the PSA
  - Simulation study should be extended to consider more $M$, $R$
  - Filtering, decimation, resampling steps should be done with data also
- Reprocess all records with resampling
End
eGf and PSA inversions for three earthquakes:

• Val des Bois
• Saguenay (eGf only)
• Riviere du Loup
Saguenay
$\Delta \sigma \approx 1600 \text{bars}$
Val des Bois
Riviere du Loup
Event information for the Riviere du Loup Earthquake

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<th>Hour</th>
<th>Min</th>
<th>Sec</th>
<th>eve-lat</th>
<th>eve-lon</th>
<th>Depth(km)</th>
<th>Mn</th>
<th>M* (bars)</th>
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Δσ≈400 bars
\( \Delta \sigma \approx 400 \text{ bars} \) only consistent with \( 1/R \)

\( 1/R^{1.3} , \ R_t = 60 \text{ km}, \text{ not consistent with} \ T = 2 \text{ s data} \)
Not enough non-SW stations for eGf analysis
$1/R^{1.3}$, $R_t=60$ km, not consistent with $T=2$ s data