Remaining Issues and Development of Preliminary GMPEs

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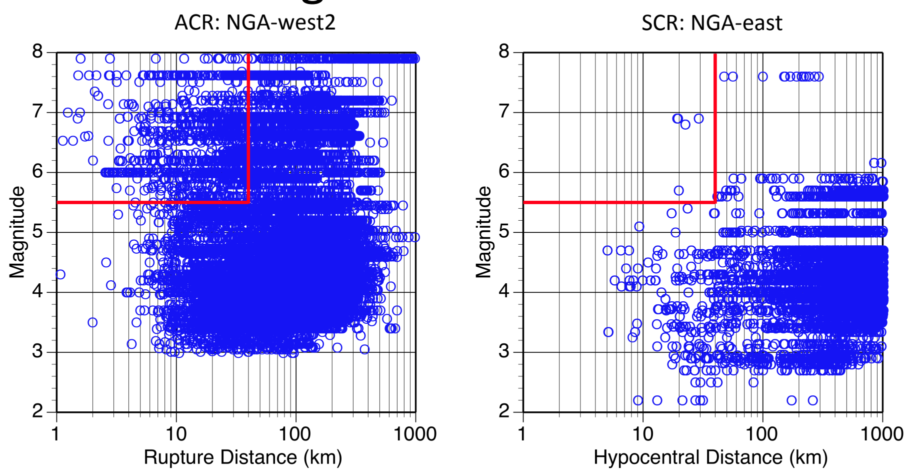
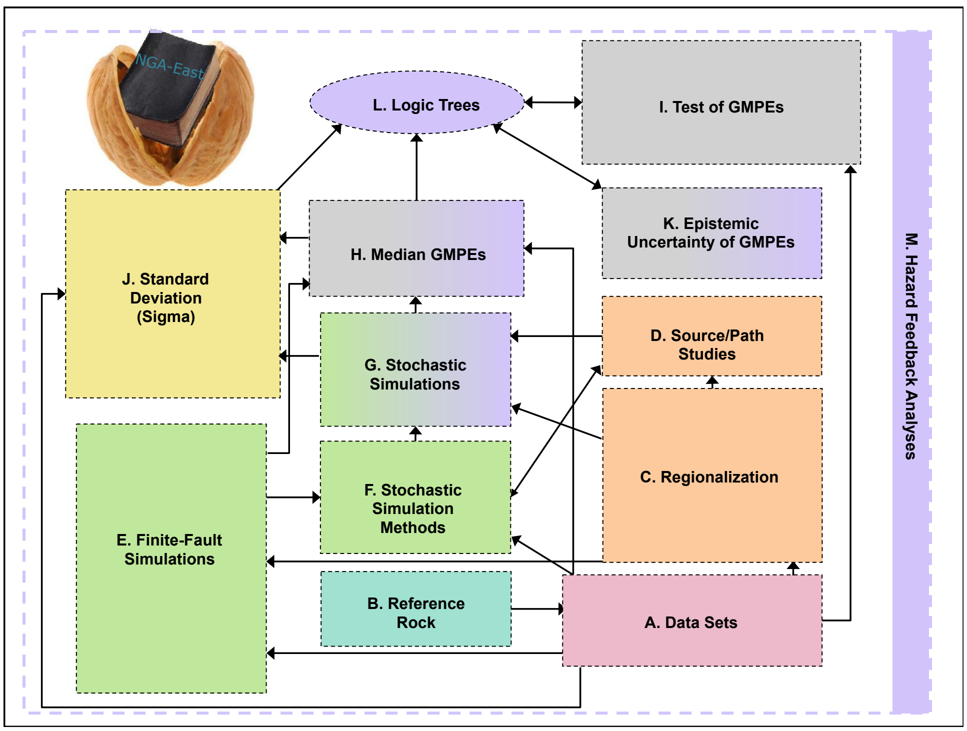
Active Crustal and Stable Continental Regions Data Sets



Regionalize distance attenuation
Extrapolate using seismological models

Issues for GMPEs

- Extrapolation to large magnitudes
  - Magnitude Scaling from ACRs
  - Finite-fault simulations
- Regionalization
  - Up to 4 regions
  - Consider different reference rock in Gulf Coast
  - How to handle ray paths that cross region boundaries
- Kappa as a site term in the GMPE
  - Allow for variation in kappa across the CEUS
  - Need map of kappa value for CEUS
- Standard deviation
  - Traditional sigma and single-station sigma



Issues and Approach

- Empirical data
  - Most data is small magnitude (linear)
- Seismological studies
  - Finite-fault simulations (FFS)
  - Source/path studies
  - Site amplification terms
- Kappa
  - Key parameter for CEUS ground motions
  - Straight-forward for FAS, complicated for PSA
- Initial model for FAS
  - To improve interface, use Fourier amplitude instead of response spectra
  - For engineering applications, convert FAS model to a PSA GMPE

Approach for Median GMPEs

- Develop FAS GMPEs for each region
  - FAS for reference-rock site condition (scaling with M, R, SOF, ZTOR, HW, kappa)
- Forward application of the FAS GMPE to generate FAS for wide range of scenarios
  - M, R, SOF, ZTOR, HW, kappa
- Use RVT to convert FAS to PSA
  - Well behaved data set of PSA values
- Develop median GMPE for PSA from the FAS-based data
  - Check resulting model against empirical PSA data set for bias

Advantages of the FAS Approach

- GMPE – Seismology interface
  - FAS provides a better interface with seismological studies and models than SA
- Estimation of site terms
  - FAS site terms are simple (Linear site amplification is linear in FAS, but not always linear in SA)
  - Allows for use of the site amplification from small magnitude earthquakes more directly
- Incorporation of Kappa
  - Straight-forward dependence on kappa

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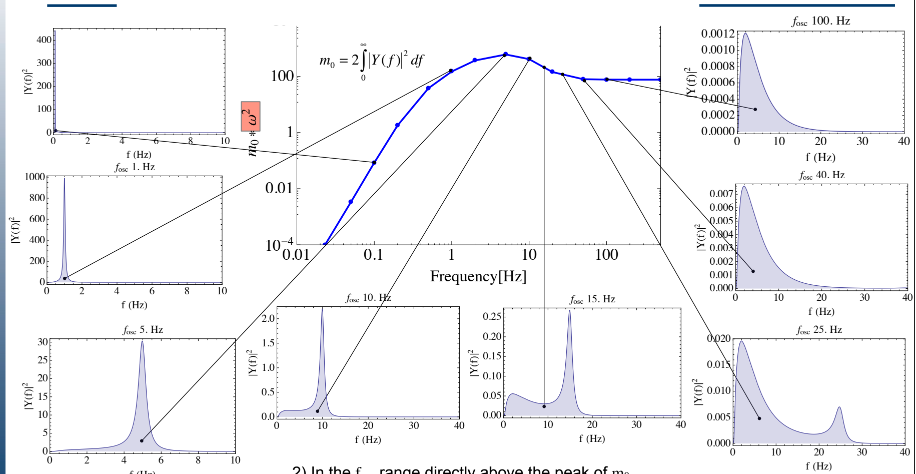
FAS Frequency Contribution to PSA



1) For low f_{osc}, (below the peak of m_0 but above f_c), m_0 is dominated by the Fourier spectrum at f_{osc}.

2) In the f_{osc} range directly above the peak of m_0, the influence of the low frequency range of the Fourier spectrum increases and takes over for high oscillator frequencies f_{osc}.

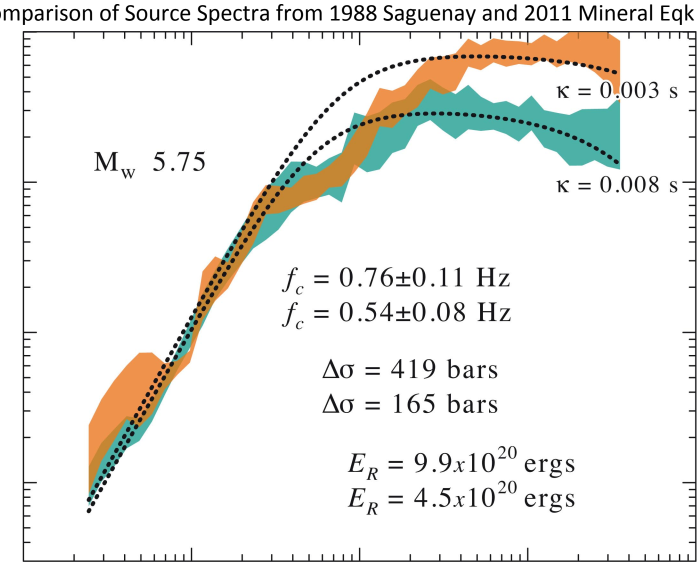
3) For high f_{osc}, m_0 seems to be dominated by the Fourier spectrum between the source corner f_c (0.2 Hz) and kappa and Q generated corner frequencies.

Scherbaum et al.: Vs-Kappa Correction 31. August 2011

RVT Models

- Use RVT to convert FAS GMPE to Sa GMPE
- RVT models will likely need to be improved for some scenarios
  - RVT parameters need improvement for application to resonance frequency of soil (Rathje, 2013)
  - Calibration of RVT parameters may be needed for some near-fault ground motions
    - Duration models

Comparison of Source Spectra from 1988 Saguenay and 2011 Mineral Eqk



From Boatwright (presented at NGA-east workshop, Oct 2011)

PS Validation

- Need for double corner model
  - PS validation for 7 ACR earthquakes also showed that a double-corner model is needed to match the low frequency ground motions

Point Source Model

Source Parameters – 2 corner model

M Moment magnitude
fc1 low frequency corner
$\Delta\sigma$ Stress-drop (high freq level)

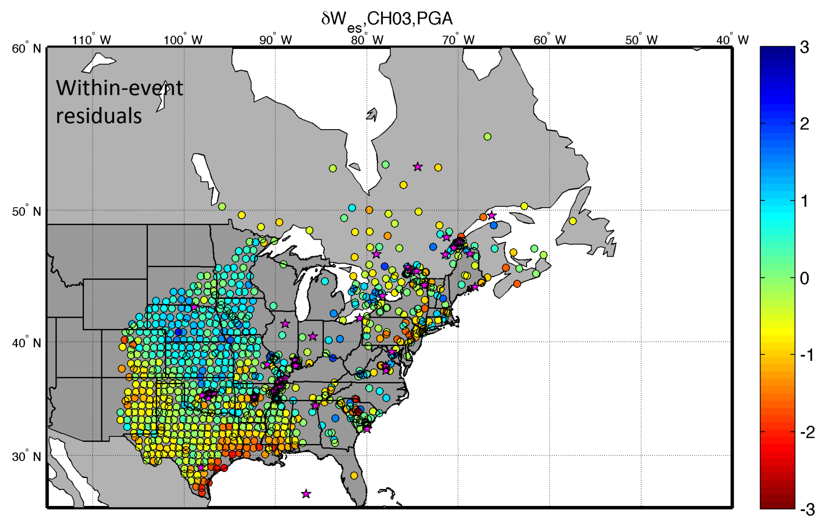
Path Parameters

$N(R)$ Distance-dependent geometrical spreading coefficient
$Q(f)$ Frequency dependent elastic attenuation along ray path

Site Parameters

kappa Accounts for damping in shallow rock
$A(f)$ Amplification factor for the impedance contrast from source to site

Range of Site Terms



Median GMPE Process

- PEER will develop a suite of alternative candidate GMPEs (University research)
- Outside reviewers of suite of models
  - Does the suite fully capture the range of candidate models

Median GMPE Methods

- Point source model (PS)
  - Double corner models
    - Informed by FFS, ACR validation
  - Range of models based on uncertainties of PS input parameters
- Hybrid empirical model (HEM)
  - Transferring the large magnitude short distance scaling from WUS to CEUS
- Finite-fault simulations (FFS)
  - Directly use FFS results

Model Complexity

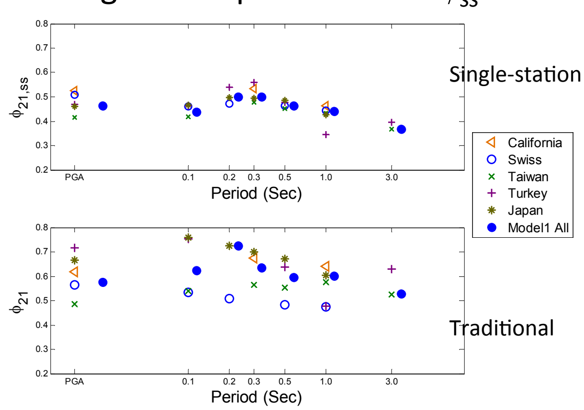
- Model complexity will be driven by seismological constraints
  - Large simulated data sets will show trends not seen in empirical data
  - Capturing those trends with a parametric GMPE will likely cause complex functional forms

Approach for the Standard Deviation

- Based on Empirical Data
  - Well constrained sigma models for WUS
  - Only small mag sigma for CEUS
  - Are WUS sigmas applicable to CUES?
    - Compare empirical sigma for comparable M,R
- Traditional Sigma
- Single-Station Sigma

Stability of Single-Station Sigma
(Rodriquez-Merek, 2013)

Lack of regional dependence for ϕ_{ss}



Comparison of single stations within-event standard deviation (ϕ_{ss}) and within event standard deviations (ϕ). Shown are data for M<=Mc1 and Rc21 <=R<=200 km

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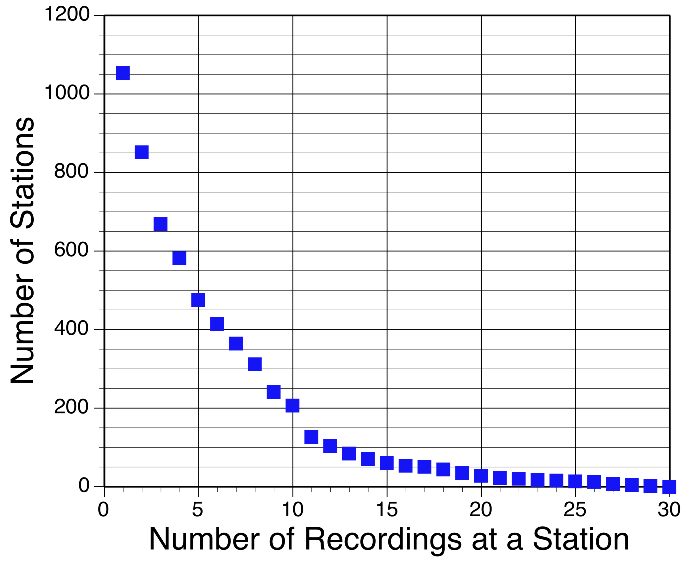
NGA-East Data Set for SigmaSS



Variability from FFS

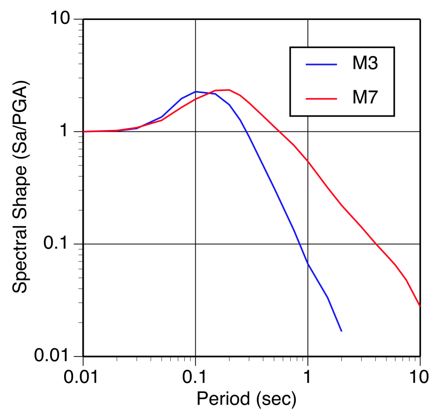
- Variability from FFS not validated yet
  - How much variability in source for future earthquakes?
  - Variability in path terms?
- Need improved understanding of the relation between event terms from GMPEs and source parameters in FFS
  - Event term variability in GMPEs is small
  - Variability from range of source parameters can be very small or very large in FFS

Summary

- Median GMPEs
  - Up to four region
  - Develop FAS GMPEs as first step
    - Helps the interface between seismological models and GMPE development
    - Allows to simple treatment of kappa
  - Convert to PSA using RVT and turn into PSA GMPE
- Reference rock
  - 3000 m/s except in Gulf Coast
  - May use 800 – 1000 m/s in Gulf Coast
- Kappa
  - Include as a term in the PSA GMPEs
  - Allows use of maps of kappa (regionalization of kappa)
- Standard deviation
  - Based on empirical data (WUS and CEUS)
  - Traditional and Single-station sigma

Use of Small Magnitude Data for Site Terms

- Large data sets with small magnitude data
- Linear site response
  - Greater use of small magnitude data to constrain site amp
  - Issues of linearity of Sa scaling
  - Affected by the spectral shape, even for linear response
  - FAS does not have this issue



Stability of Single-Station Sigma

(Rodriquez-Merek, 2013)

No apparent

Vs-dependency for ϕ_{ss}