GRAIZER-KALKAN GROUND MOTION ATTENUATION MODELING

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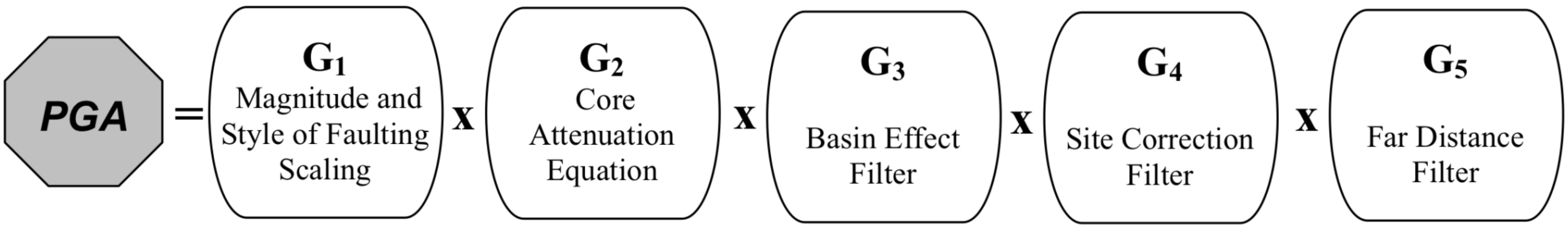
MODULAR FILTER-BASED APPROACH IS AN ALTERNATIVE WAY TO MODEL GROUND MOTION ATTENUATION



$$ln(PGA) = ln(G_1) + ln(G_2) + ln(G_3) + ln(G_4) + ln(G_5) + \sigma_{ln(PGA)}$$

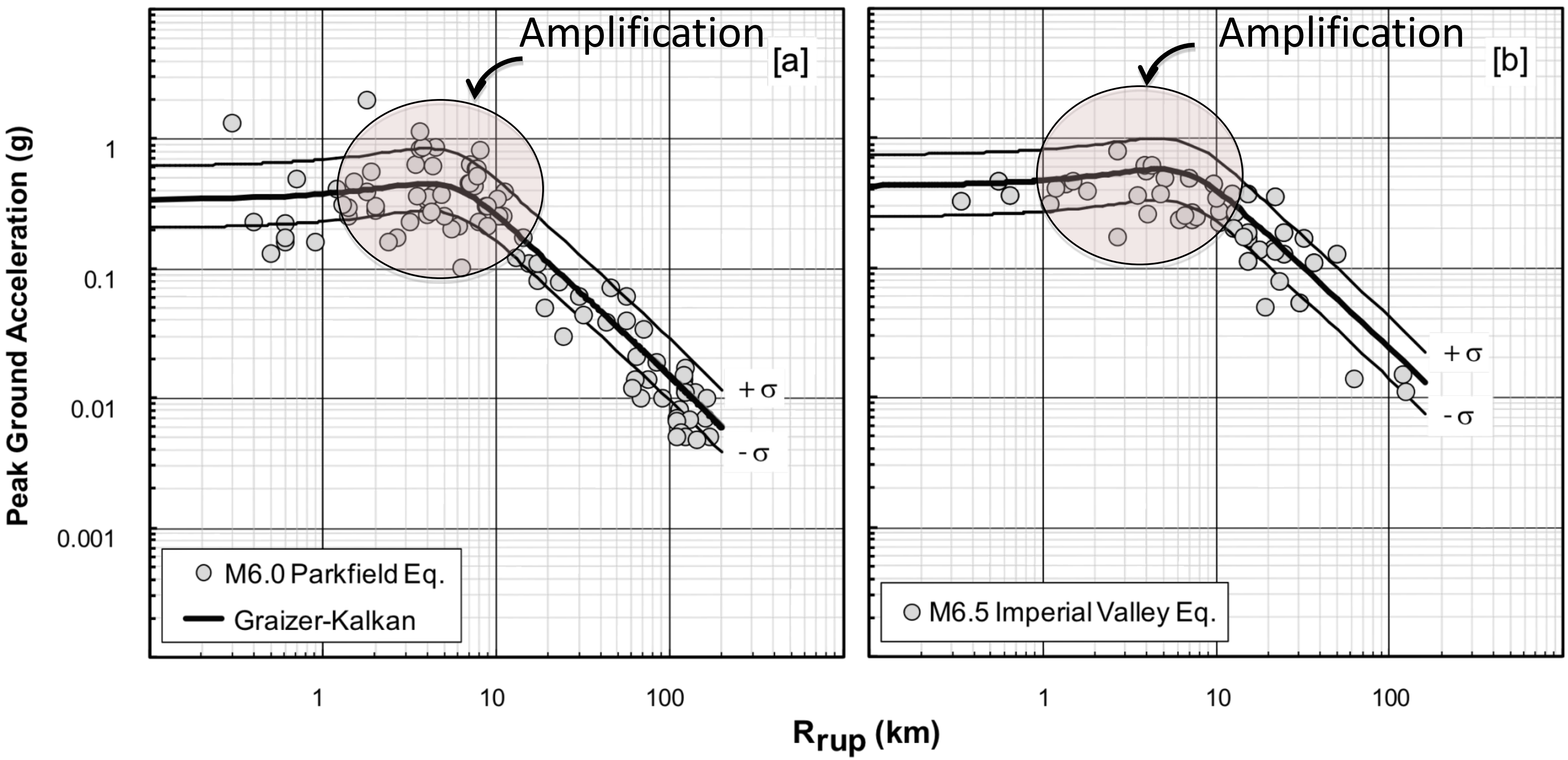
where, G is a filter function, modeling a certain physical phenomenon on seismic radiation.

These are:

- distance attenuation,
- magnitude scaling,
- site-correction,
- basin effect, etc.

Each module may be calibrated separately to adjust for different tectonic regions based on actual data.

GK MODEL PREDICTS AMPLIFICATION OF PGA AT NEAR-FIELD



Near-field Attenuation Approximation (Core Equation)

Transfer function of a SDOF oscillator:

$$G(\lambda) = \frac{A}{\sqrt{(1-\lambda^2)^2 + 4D_0^2\lambda^2}}$$

According to this analogy, distance *R* replaces square of frequency

$$G(R) = \frac{A}{\sqrt{(1-\frac{R}{R_0})^2 + 4D_0^2\frac{R}{R_0}}}$$

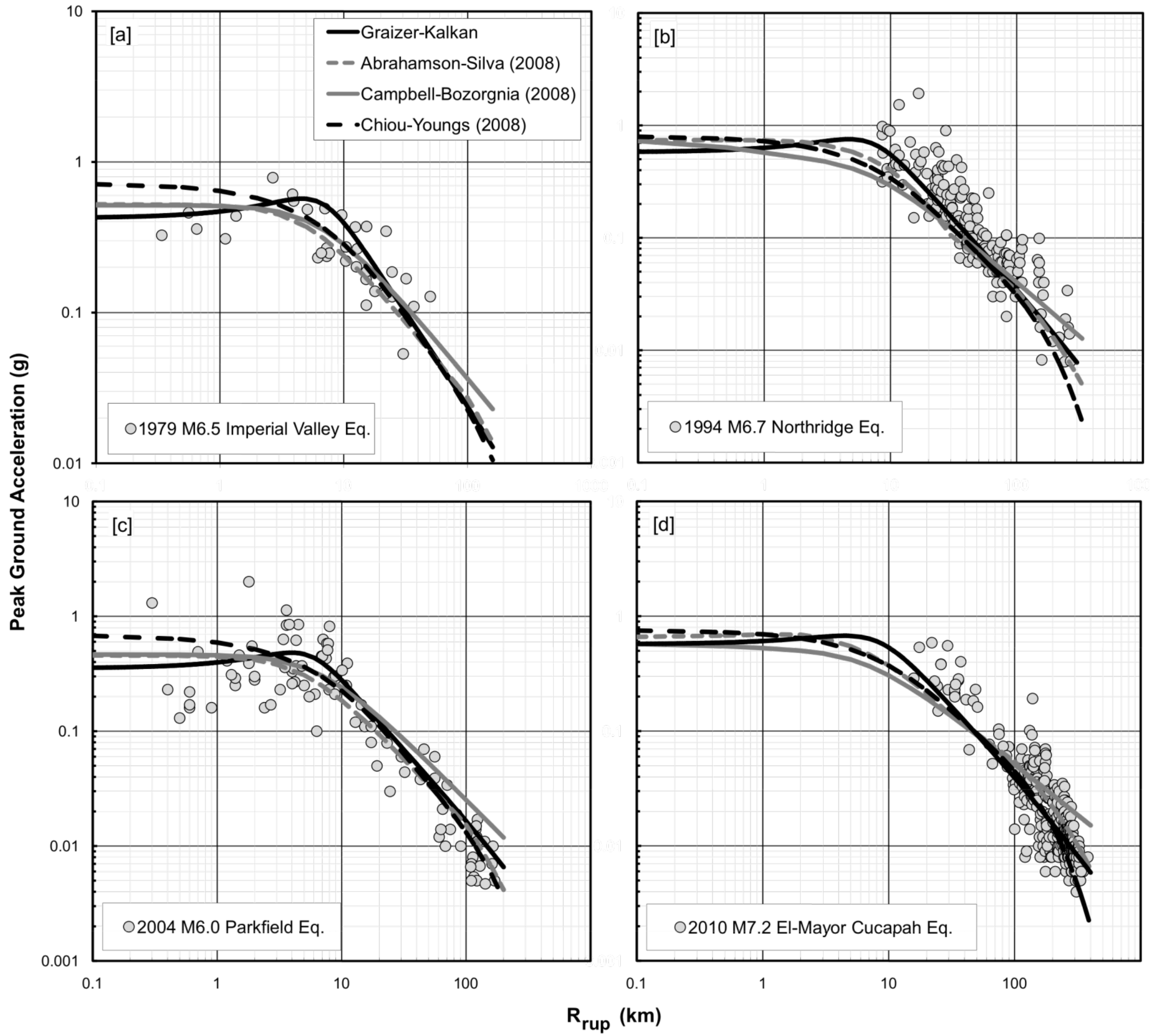
Physical meaning of *Ro* – corner distance (proportional to magnitude).

PGA PREDICTION MODEL

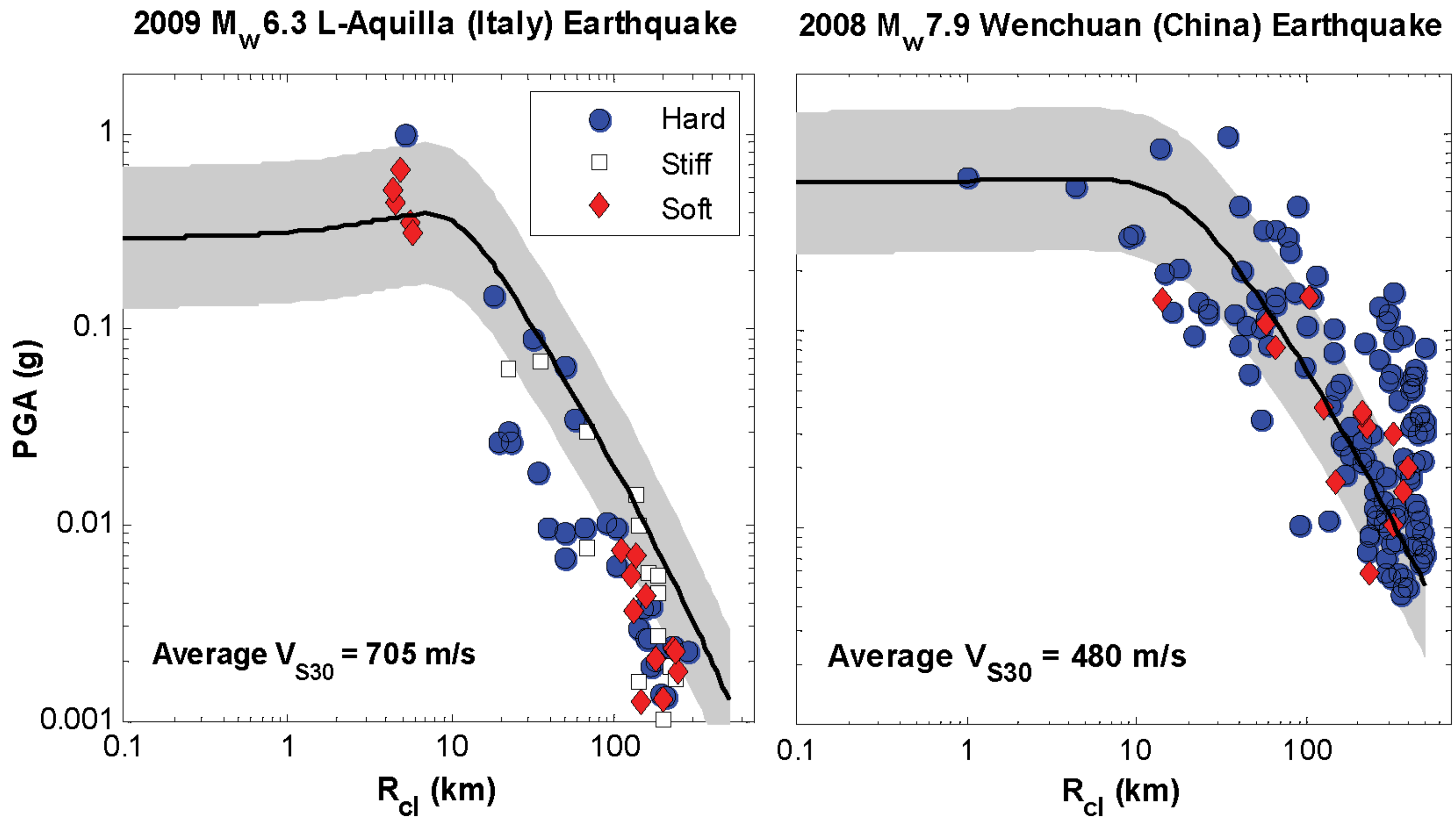
Our PGA model's main features are:

- Based on modular filter-based approach
- Structured on single-degree-of-freedom oscillator transfer function
- Based on full NGA-West1 database with additional data (a total of approximately 2,500 data points)
- Applicable for 5<M<8 and distances <250 km

MAJOR CALIFORNIAN EARTHQUAKES



2009 L'AQUILLA (ITALY) AND 2008 WENCHUAN (CHINA) EARTHQUAKES



PREDICTION OF SPECTRAL ACCELERATION

Our spectral acceleration model has following features:

- SA is computed by anchoring spectral shape (that is, normalized spectrum) to PGA

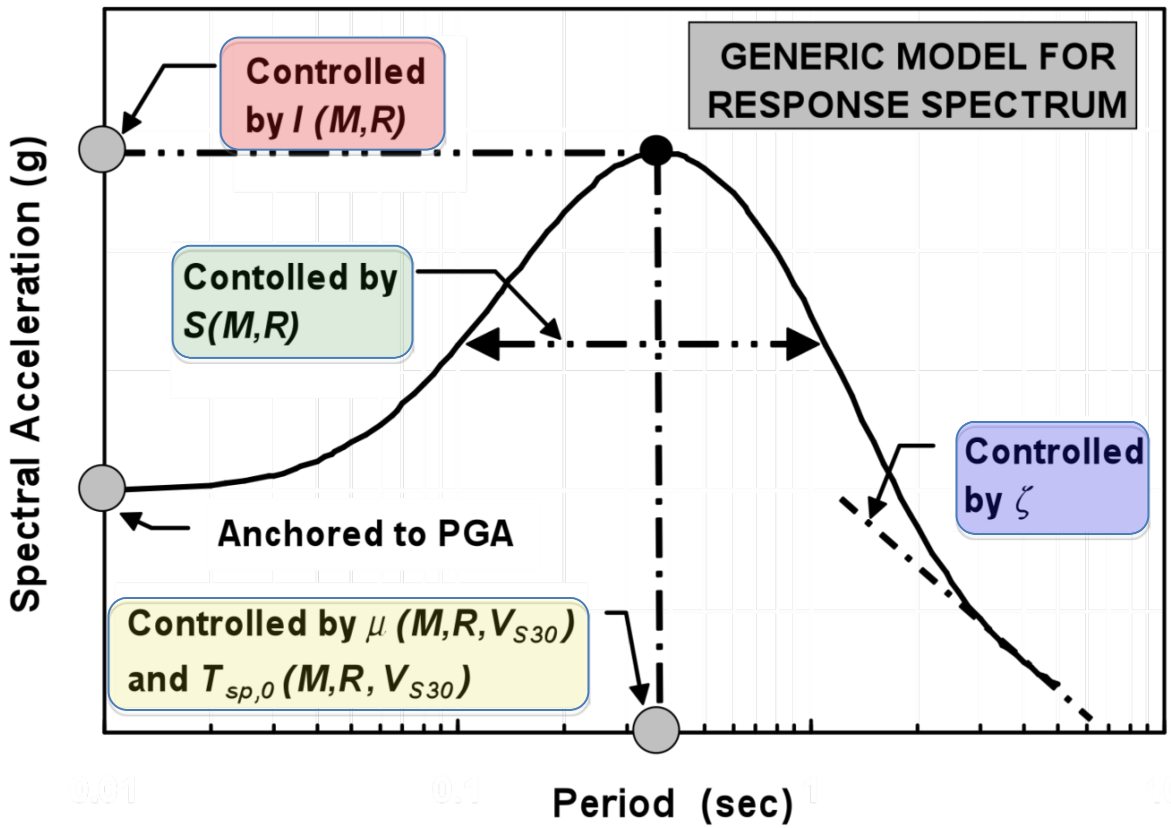
$$SA(T) = PGA \times \left[SA_{norm}(T / M, R, V_{S30}) \right]$$

PGA MODEL SPECTRAL SHAPE MODEL

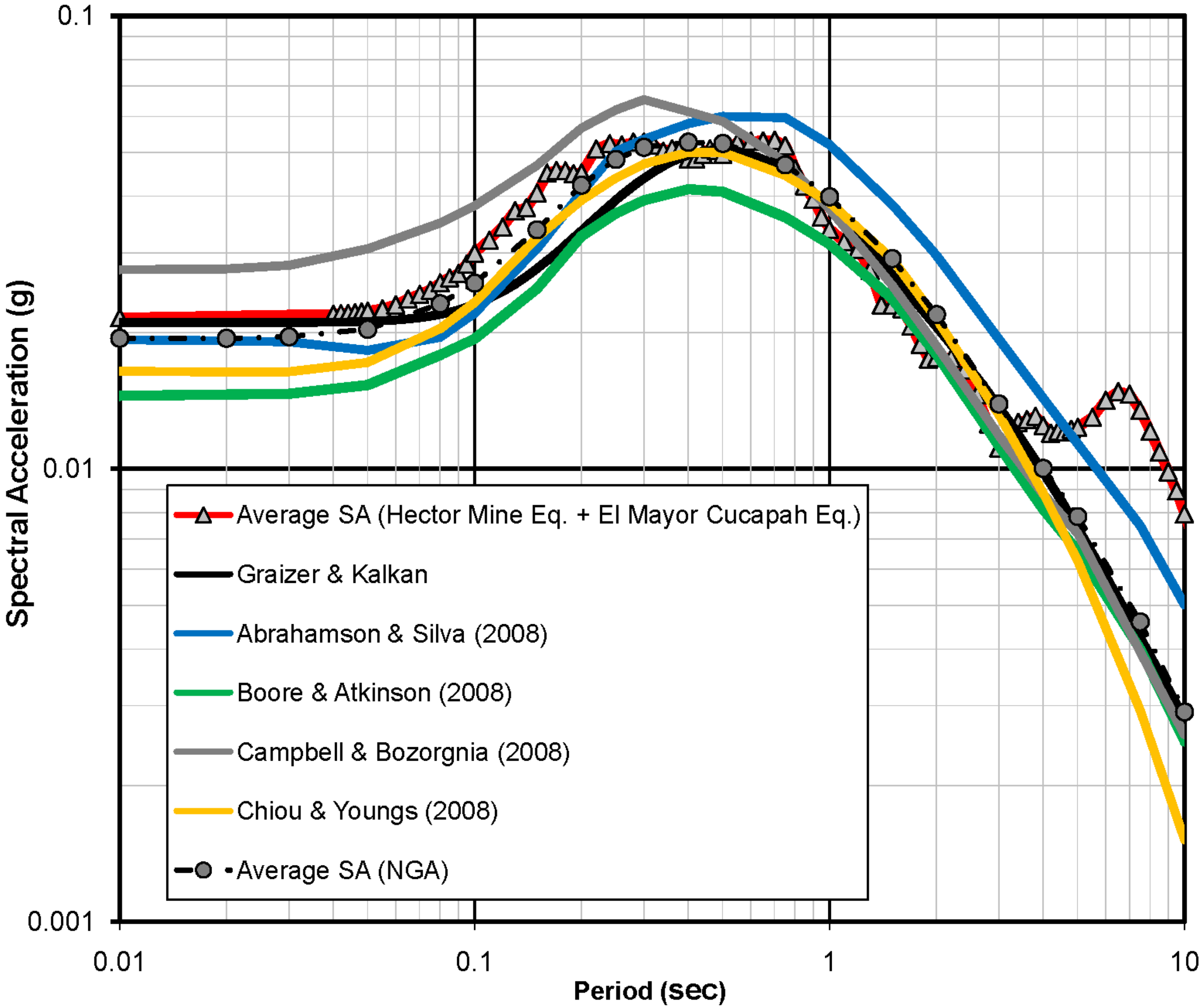
- It is a <u>continuous</u> function of period (T)
- It has only 16 estimator coefficients
- Any PGA attenuation equation can be used

GK09 MODEL CONTROLS SPECTRAL SHAPE

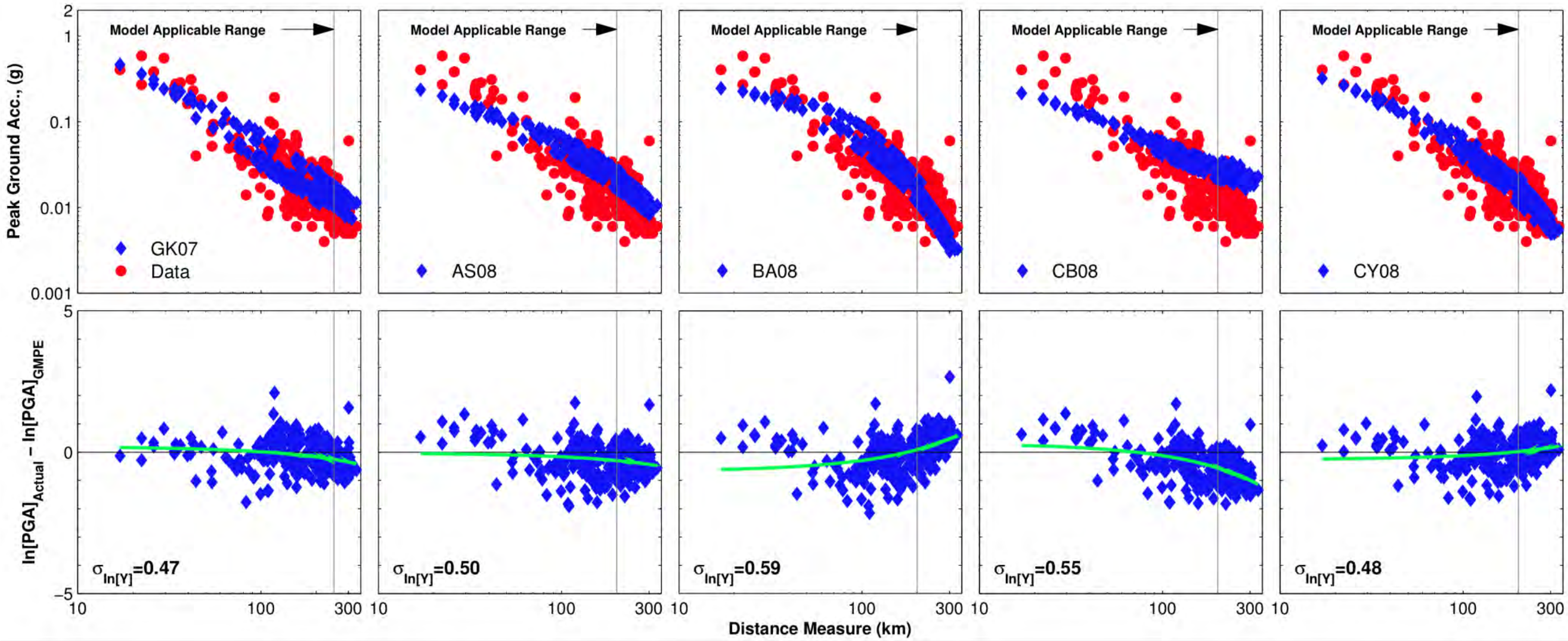
$$SA_{norm}(T/M,R,V_{S30}) = I(M,R)e^{-\frac{1}{2}\left(\frac{\ln(T)+\mu(M,R,V_{S30})}{S(M,R)}\right)^2} + \left[\left(1-\left(\frac{T}{T_{sp,0}}\right)^{\zeta}\right)^2 + 4D_{sp}^{\ 2}\left(\frac{T}{T_{sp,0}}\right)^{\zeta}\right]^{-1/2}$$



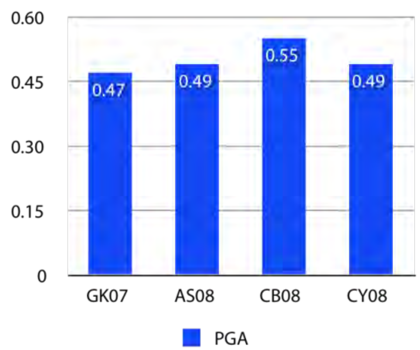
COMPARISON OF THE AVERAGE SA OBSERVED AT THE DISTANCE OF ~190 KM FOR M7.1-7.2 EARTHQUAKES

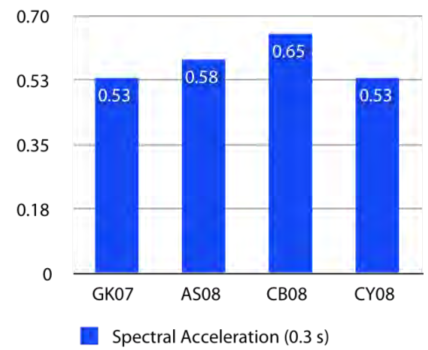


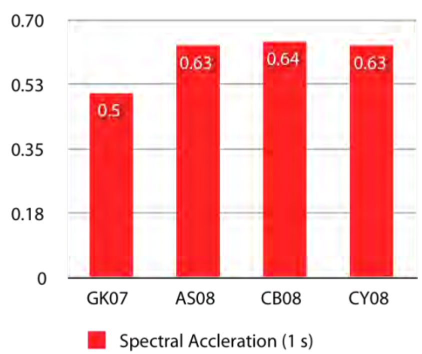
M7.2 El-Mayor Cucapah Eq.

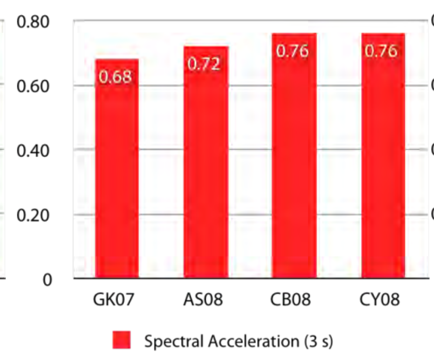


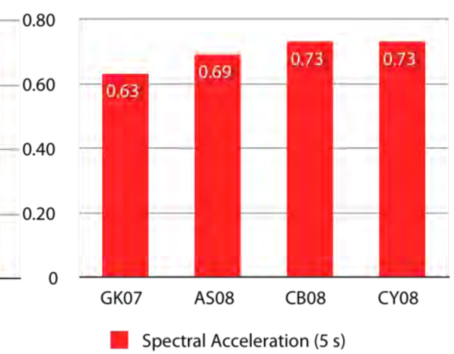
M7.2 El-Mayor Cucapah Eq.

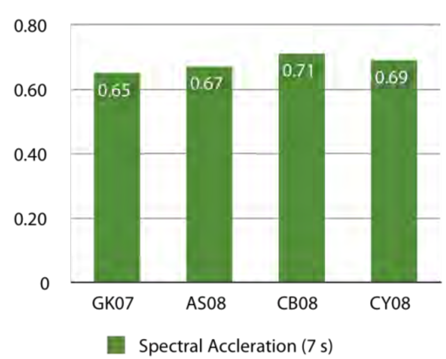


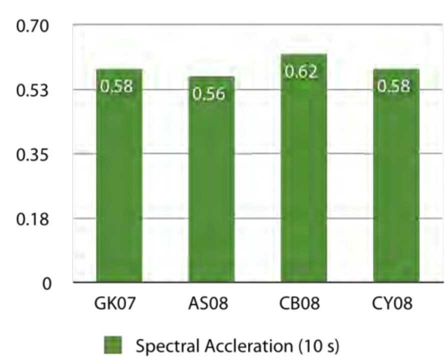




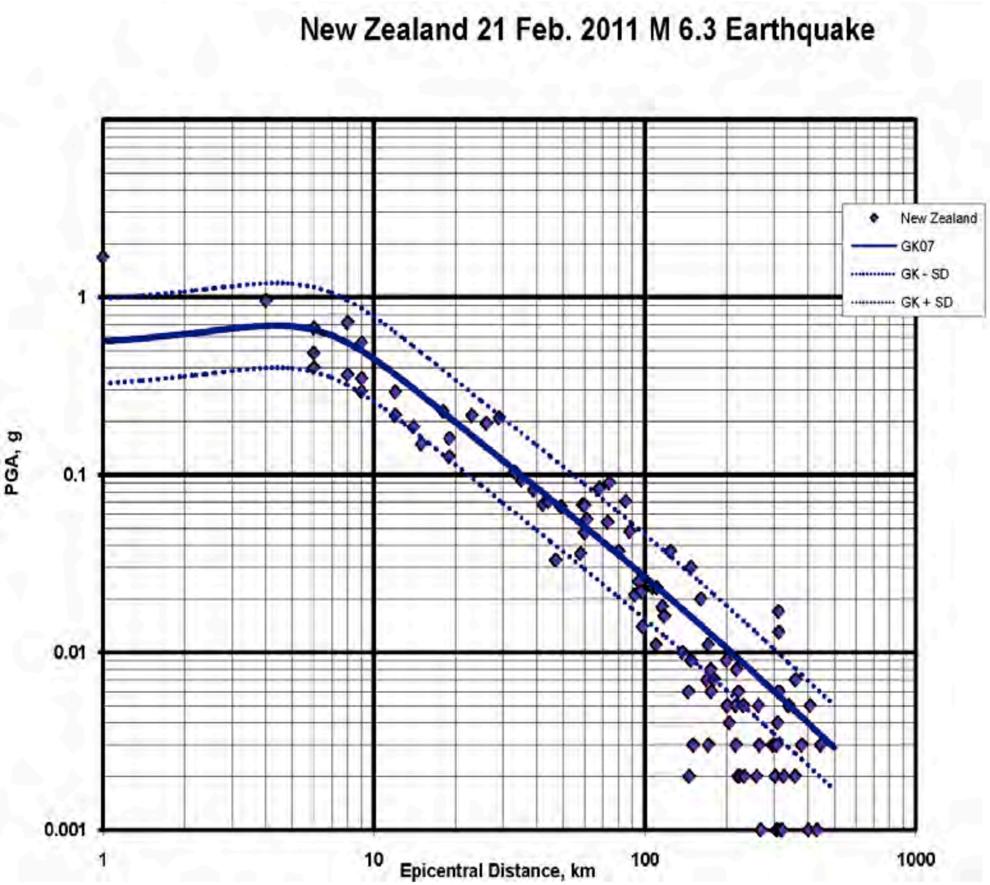


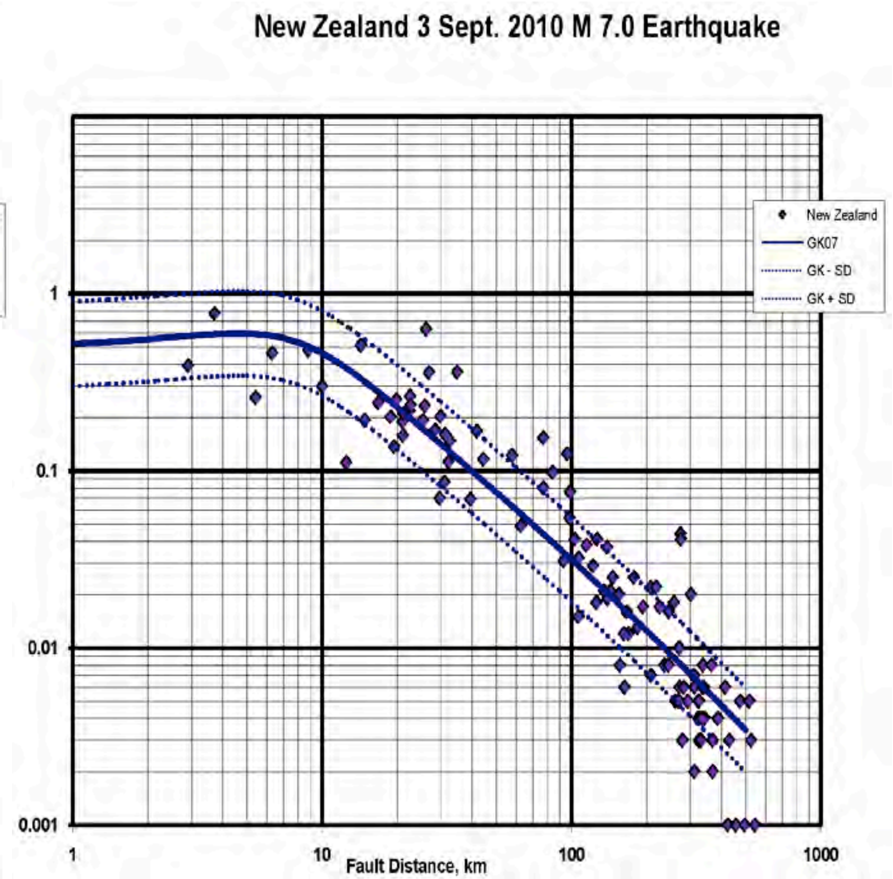




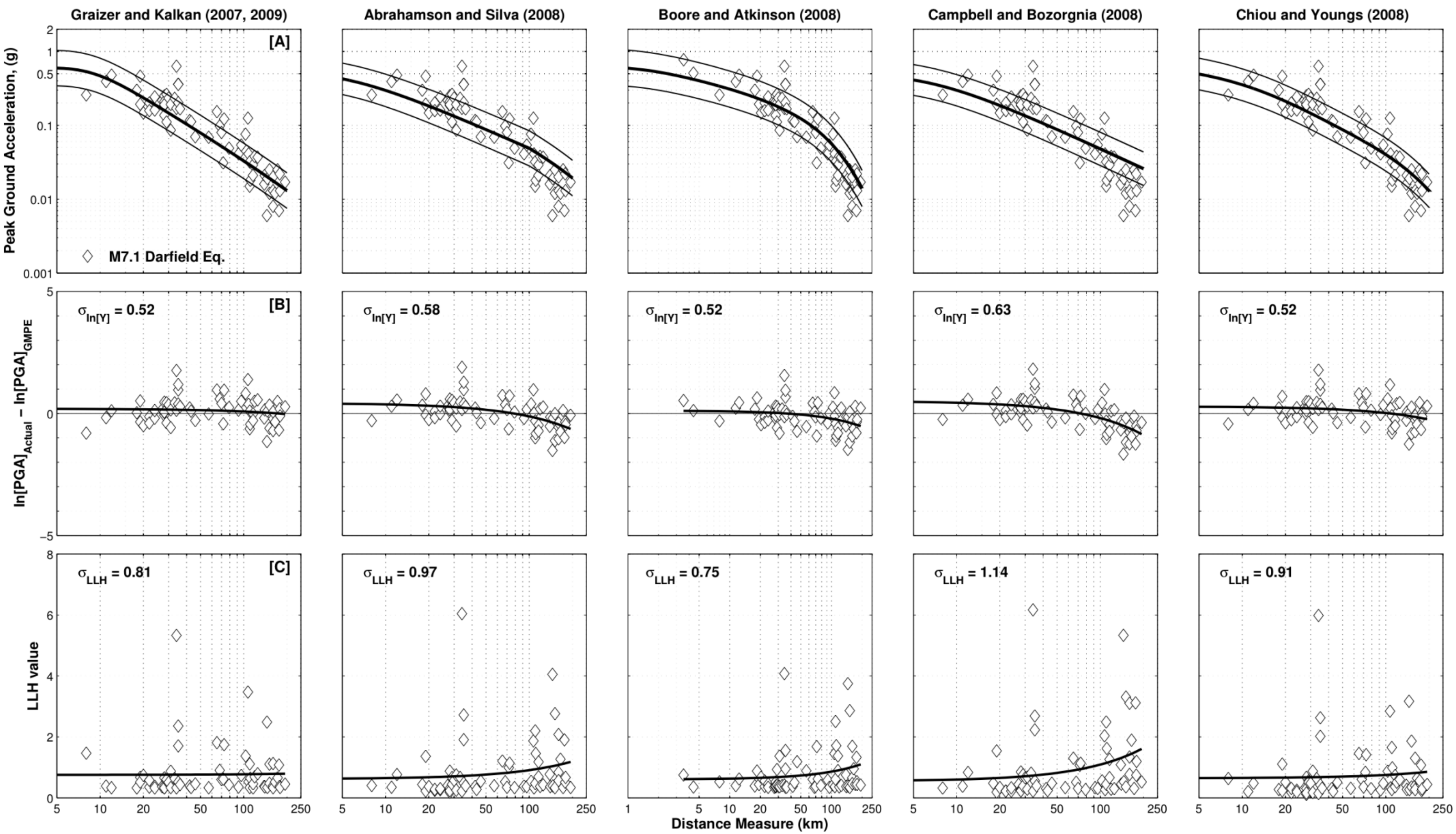


2010 DARFIELD AND 2011 CHIRSTCHURCH (NEW ZEALAND) EARTHQUAKES





M7.0 Darfield (New Zealand) Eq.



Higher sigma and higher log-likelihood (LLH) values indicate poorer performance.

CONCLUDING REMARKS ON GK09

- **Ground motion prediction equation (GMPE) based on representation of attenuation function as a series of filters has been developed using expanded NGA database. In this GMPE, each filter represents a certain physical phenomenon on seismic radiation.**

- **New approach to modeling response spectra as a continuous function is developed.**

- **Extensive testing and comparison with newly recorded data demonstrates good performance of the developed GMPE.**

- **Based on formal statistical comparisons GK09 GMPE performs at least as well as others NGA-West GMPE models**

PAPERS PUBLISHED IN REVIWED JORNALS

- Graizer V. and Kalkan E., 2007. Ground Motion Attenuation Model for Peak Horizontal Acceleration from Shallow Crustal Earthquakes, *Earthquake Spectra*, **23**(3): 585-613.
- Graizer V. and Kalkan E., 2009. Prediction of Response Spectral Acceleration Ordinates Based on PGA Attenuation, *Earthquake Spectra*, **25**(1): 39-69.
- Graizer V. and Kalkan E., 2011. Modular Filter-based Approach to Ground Motion Attenuation Modeling, *Seism. Res. Letters*, **82**(1): 22-31.
- Segou, M. and Kalkan, E., 2011. Ground Motion Attenuation during M7.1 Darfield and M6.3 Christchurch (New Zealand) Earthquakes and Performance of Global Predictive Models", *Seism. Res. Letters*, **82** (6), 866-874.
- Graizer V., 2011. Comment on “On the Selection of Ground-Motion Prediction Equations for Seismic Hazard Analysis” by Julian J. Bommer, John Douglas, Frank Scherbaum, Fabrice Cotton, Hilmar Bungum, and Donat Fäh. *Seism. Res. Letters*, **82**(2): 233-2361.

COMPUTER CODES

Our attenuation models are available in EXCEL, FORTRAN, and MATLAB from the authors upon request.

DISCLAIMER

Any opinions, findings and conclusions expressed in this article are those of the authors and do not necessarily reflect the views of the United States Nuclear Regulatory Commission.

Updated Model GK12

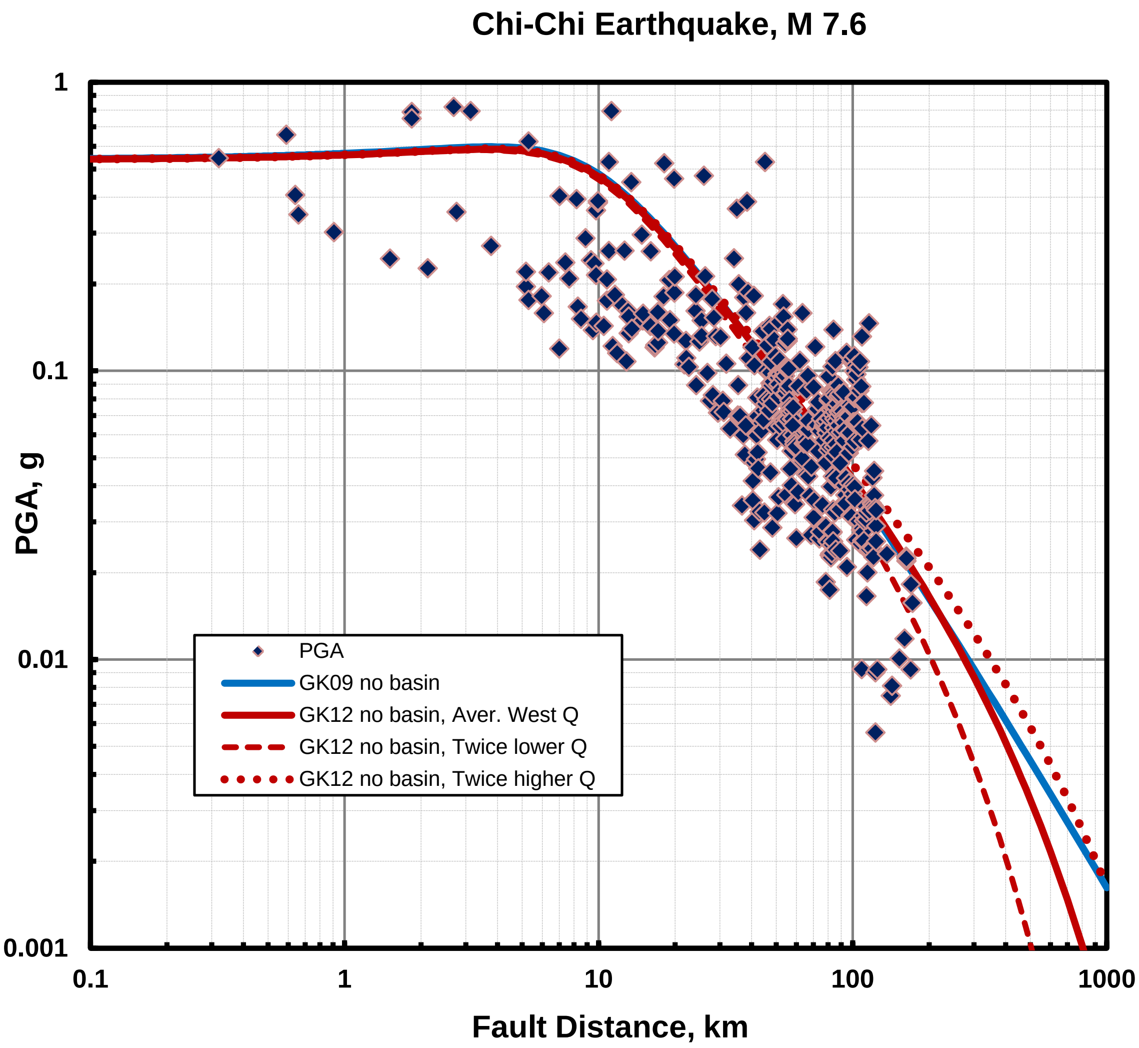
- Based on GK09

- Replaces G3 filter with two: anelastic attenuation and basin effect.

- Anelastic attenuation allows adjustment for differences in Q.

- Basin effect is depth and distance dependent.

Effect of Q on attenuation

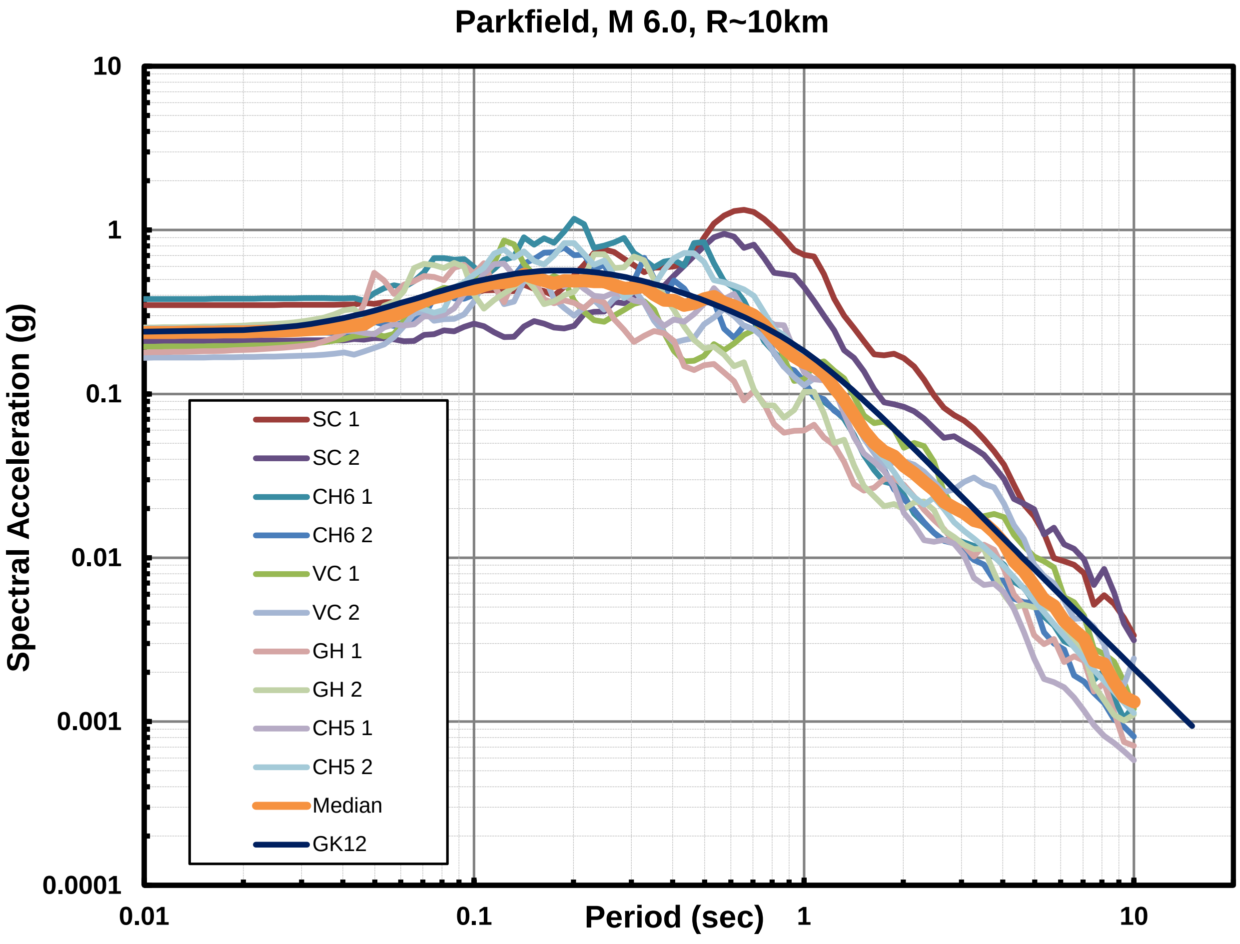


GK12 model allows tuning-up GMPE based on the variations in *Q*. It also allows for variable, e.g., distance dependent *Q(R)*.

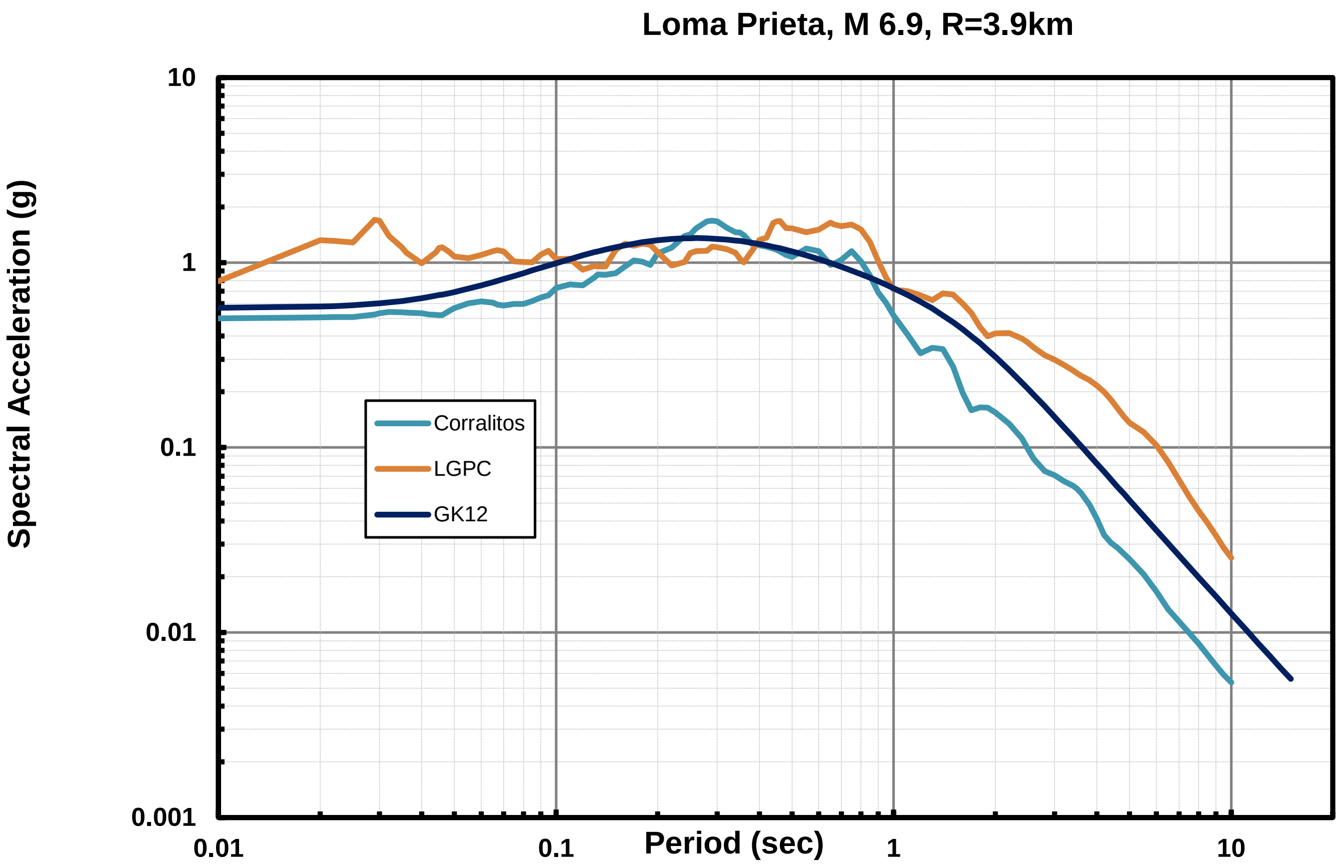
Modeling Basin Effect

- Basin depth is defined as depth to 1.5 km/sec isosurface (Z1.5).
- Basin effect is based on the work of Day et al., 2008.
- Basin effect is distance dependent with less effect in the near-field and full scale at distances of more than ~ 40 km

Parkfield, 2004



Loma Prieta, 1989



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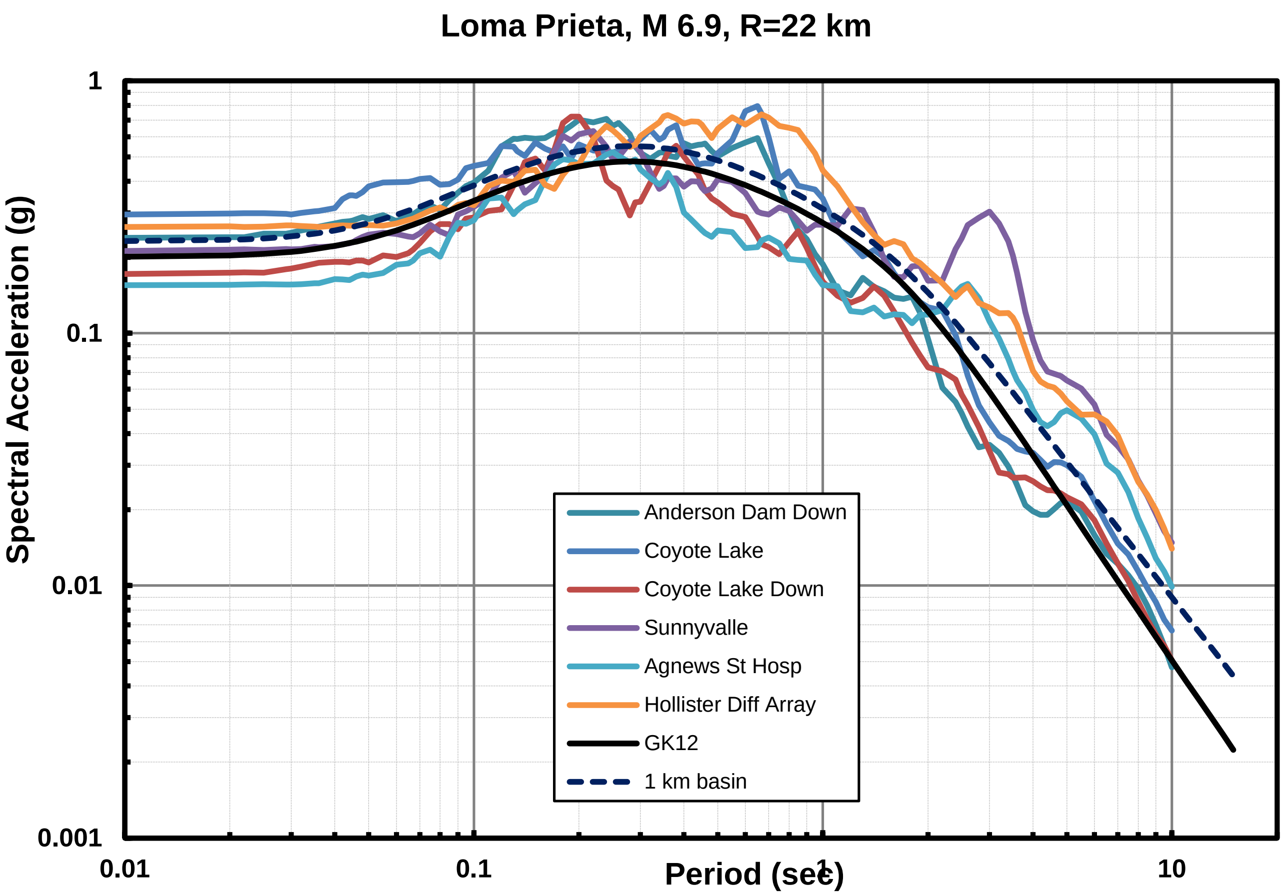
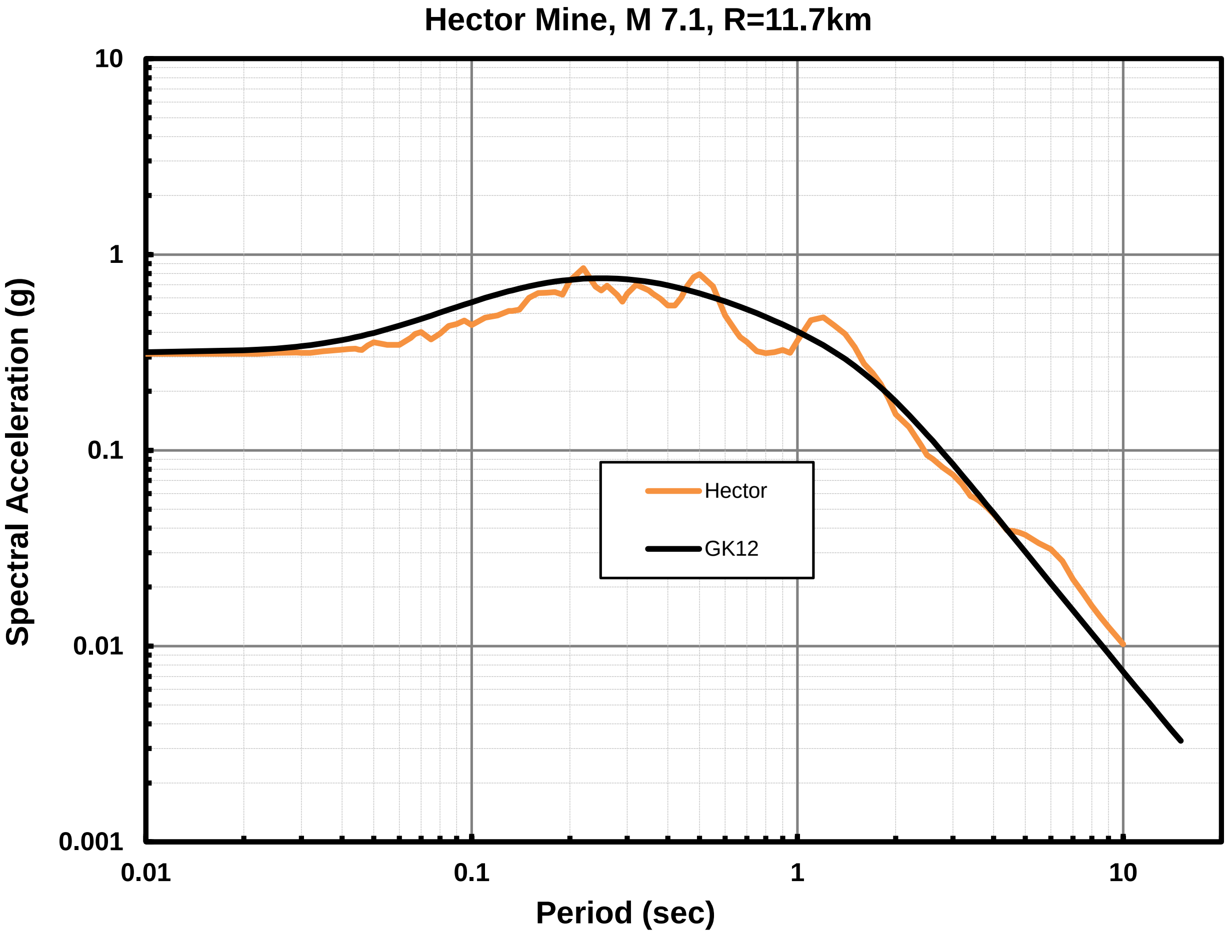


Hector Mine, 1999



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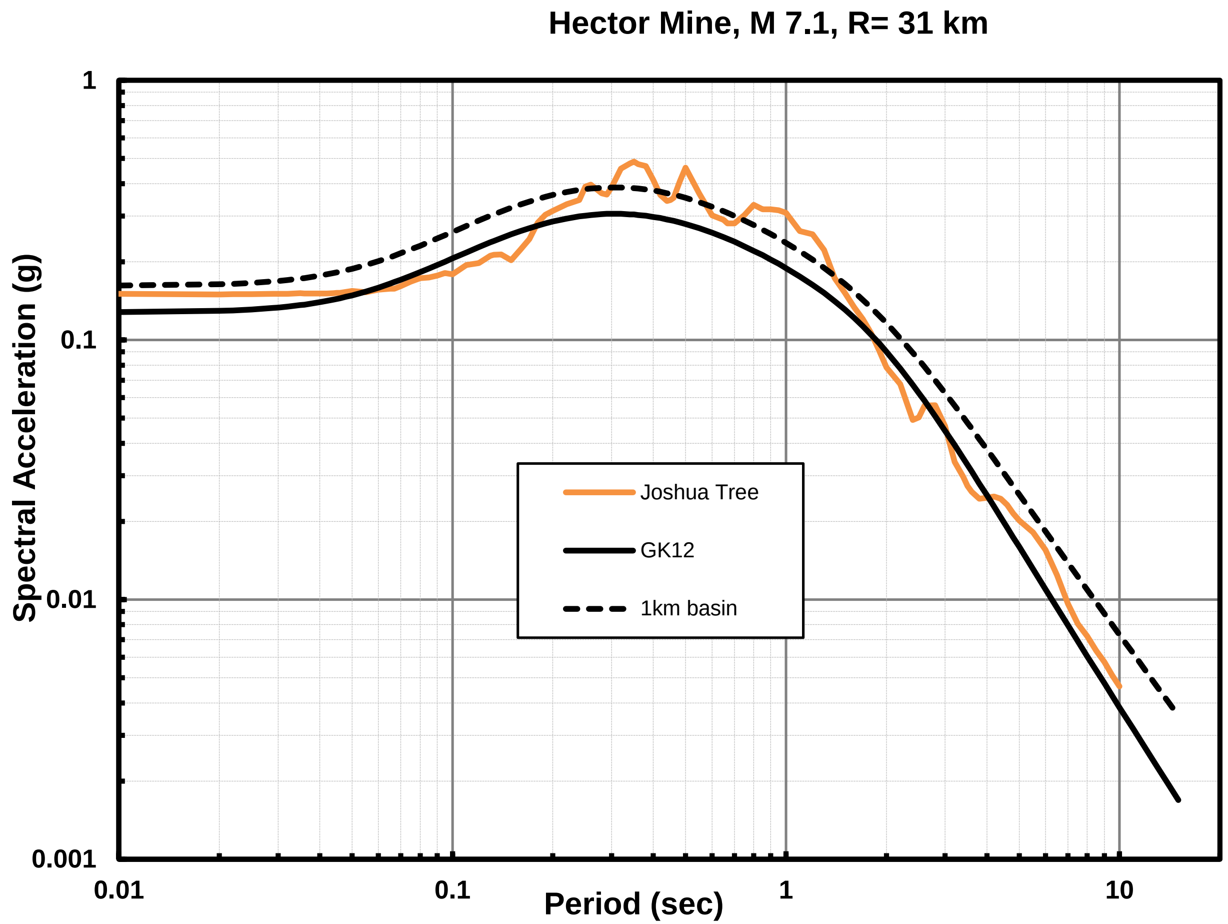

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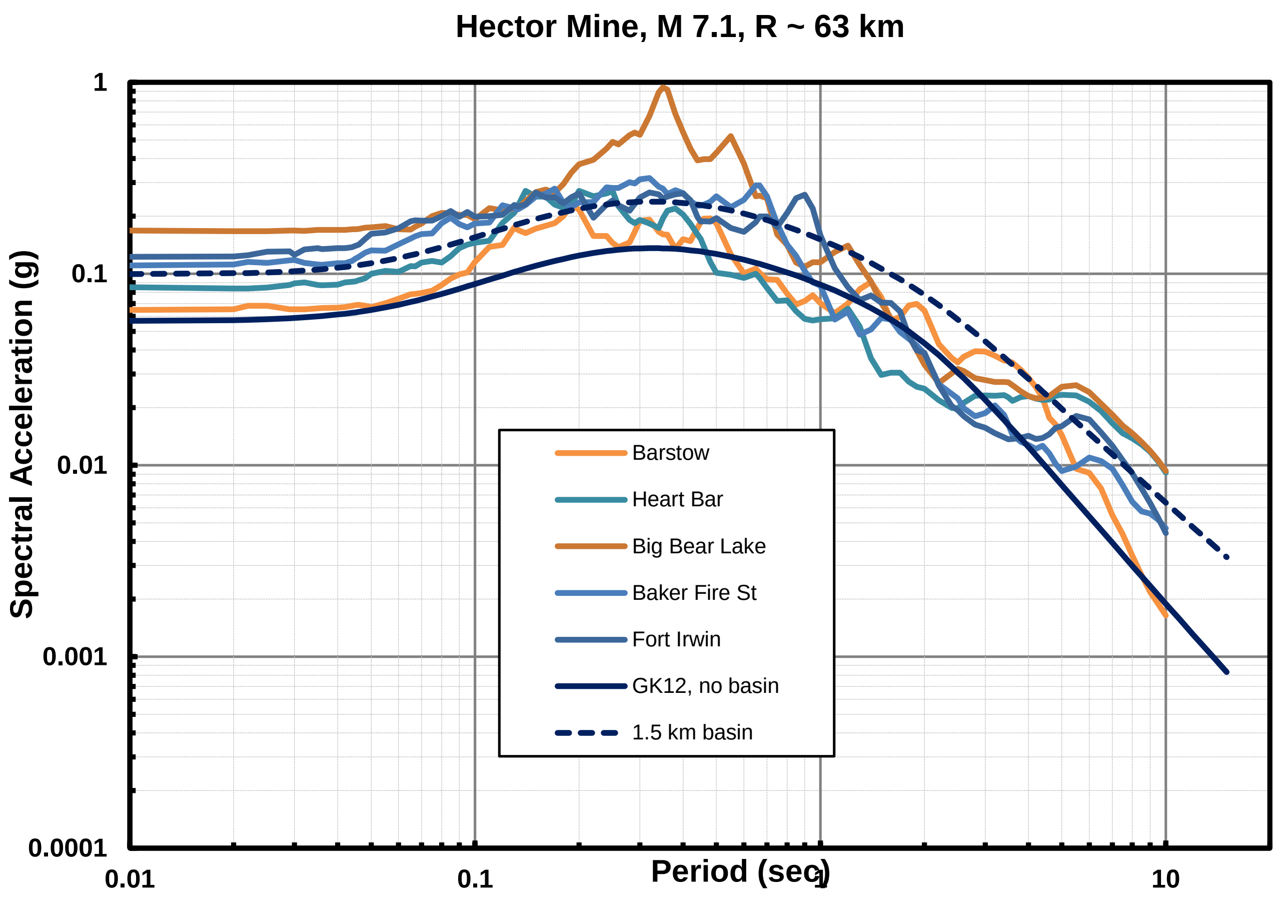

Sigma