

Preliminary Results of Update to the Chiou and Youngs (2008) NGA GMPE

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USGS National Seismic Hazard Map (NSHMp) Workshop on
Ground Motion Prediction Equations (GMPEs)

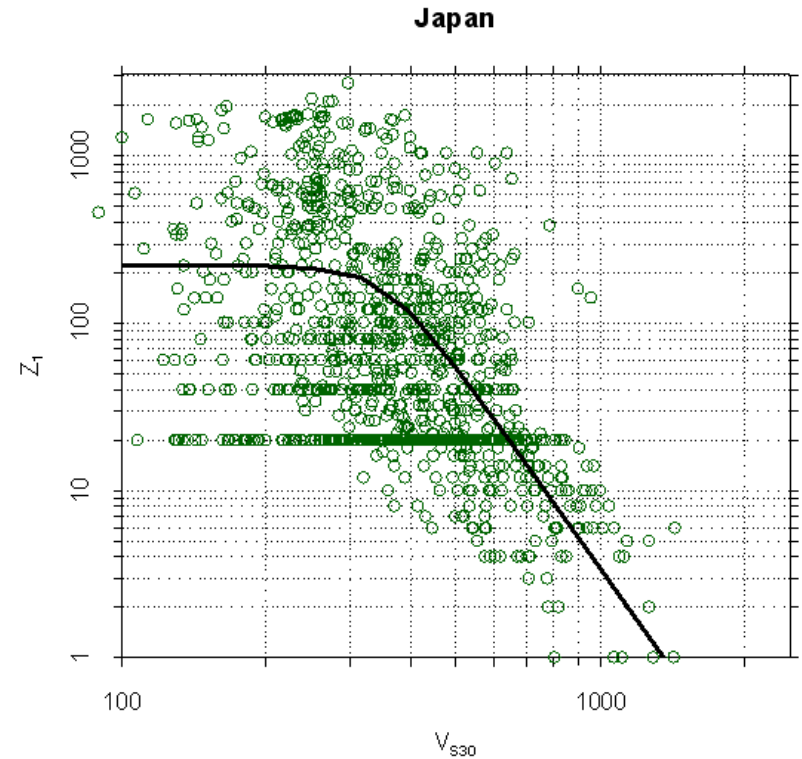
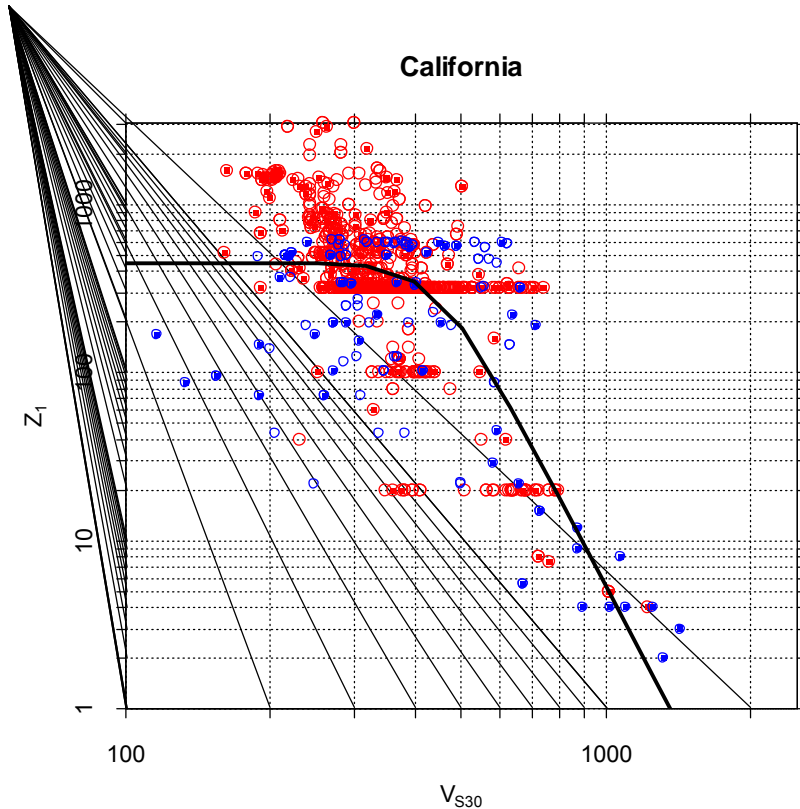
for the 2014 Update

December 13, 2012

Data Used

- PEER NGA West 2 Database
- Removed earthquakes flagged as not shallow crustal from active tectonic regions (same list as CY2008)
- Used the same acceptable site classifications as CY2008
- Used only data from earthquakes with ≥ 5 recordings (new in 2012)
- Used only main shocks used for preliminary updated model

Estimation of $Z_{1.0}$ for Sites without Values in NGA West 2 Data Base



$$\ln(Z_{1.0}) = -\frac{5.439}{8} \ln\left(\frac{V_{S30}^8 + 442.4^8}{1360^8 + 442.4^8}\right)$$

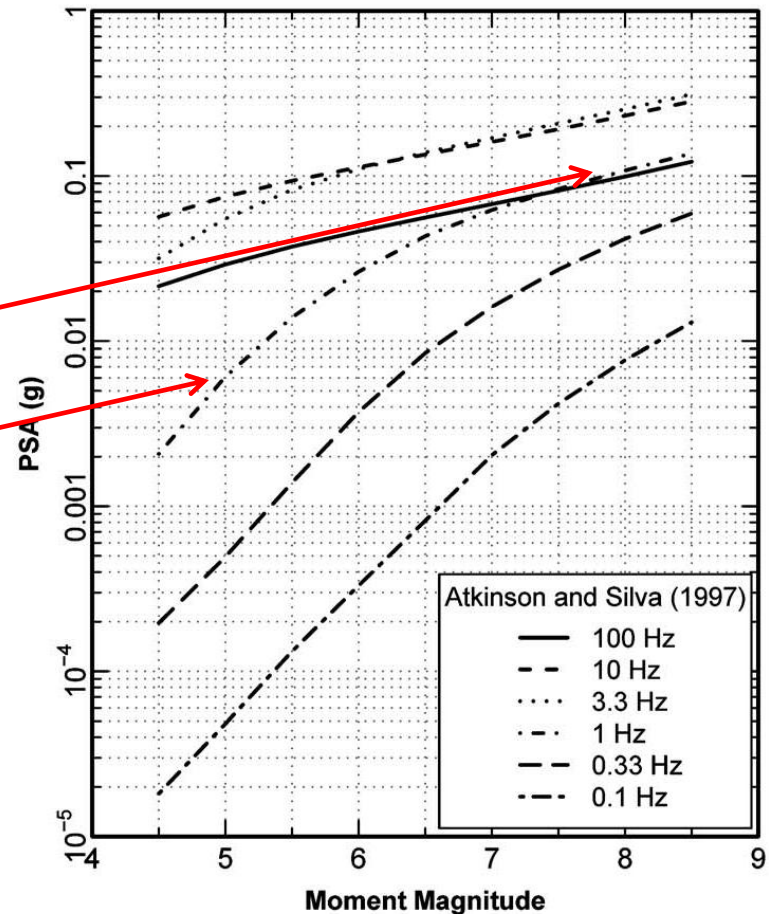
$$\ln(Z_{1.0}) = -\frac{4.018}{8} \ln\left(\frac{V_{S30}^8 + 355.2^8}{1360^8 + 355.2^8}\right)$$

Large Distance Magnitude Scaling Form

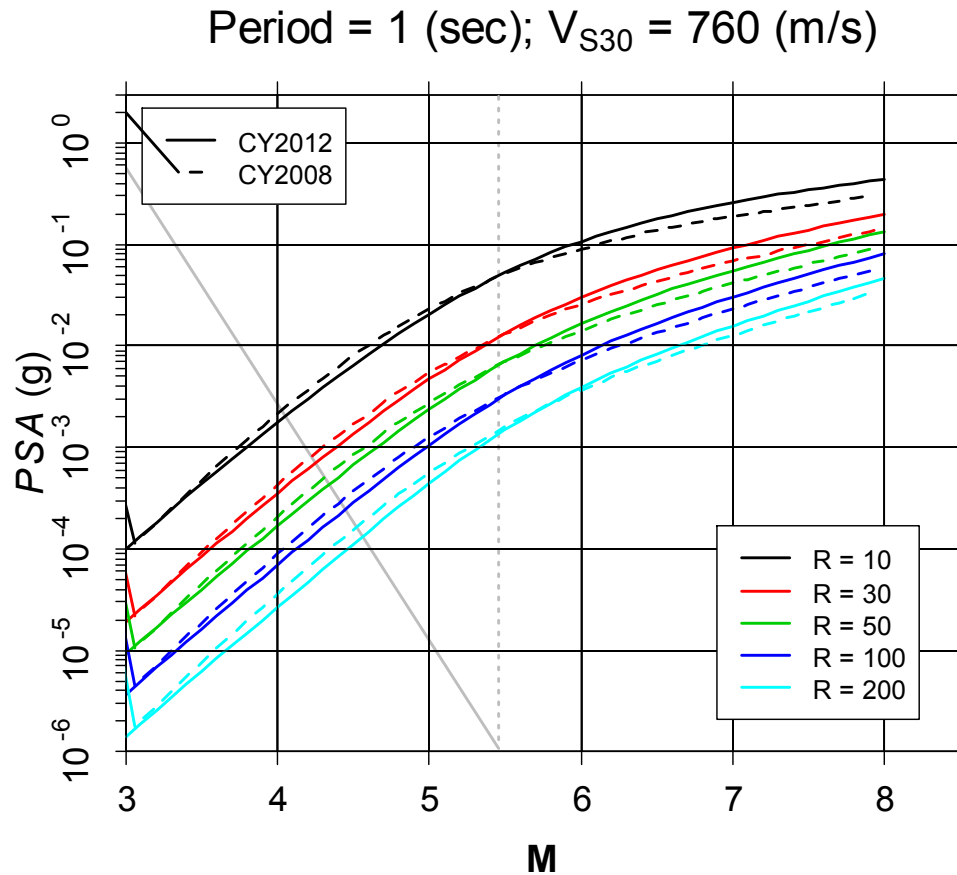
- Unchanged from CY2008

$$\ln(y) \propto c_2(\mathbf{M} - 6) + \frac{c_2 - c_3}{c_n} \ln[1 + \exp\{c_n(c_M - \mathbf{M})\}]$$

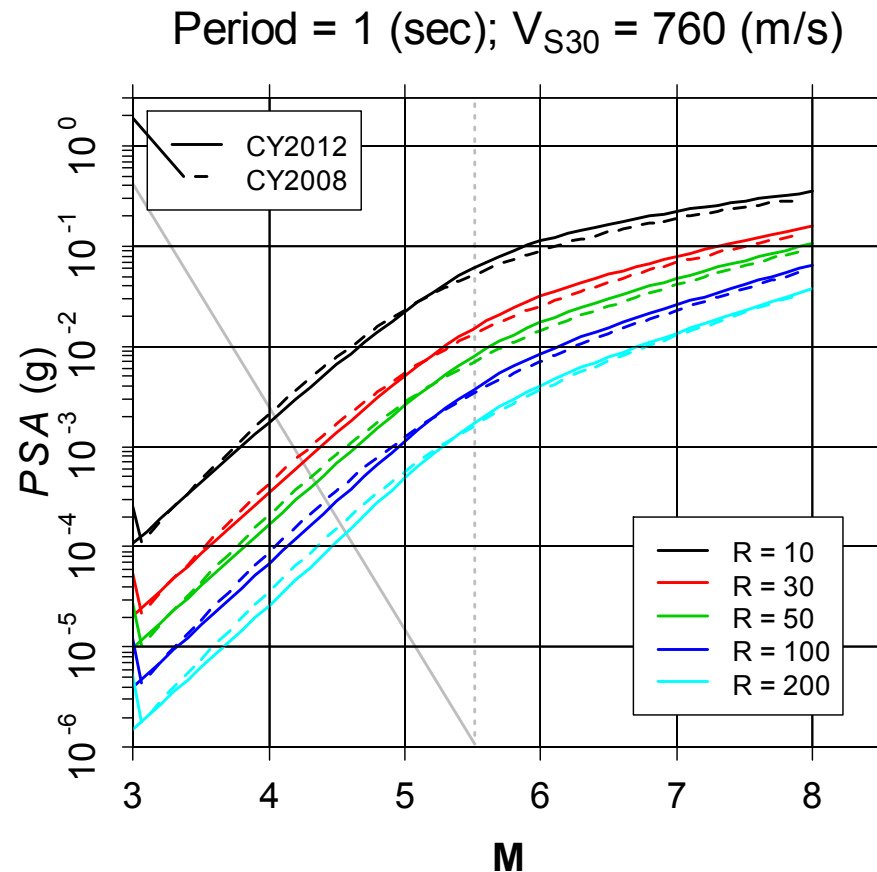
- At a given period, linear scaling at large magnitudes $\propto c_2$ and at small magnitudes $\propto c_3$
- Transition controlled by period dependent c_n and c_M
- Shown to work well over magnitude range 3 to 8 by Chiou et al (2010)



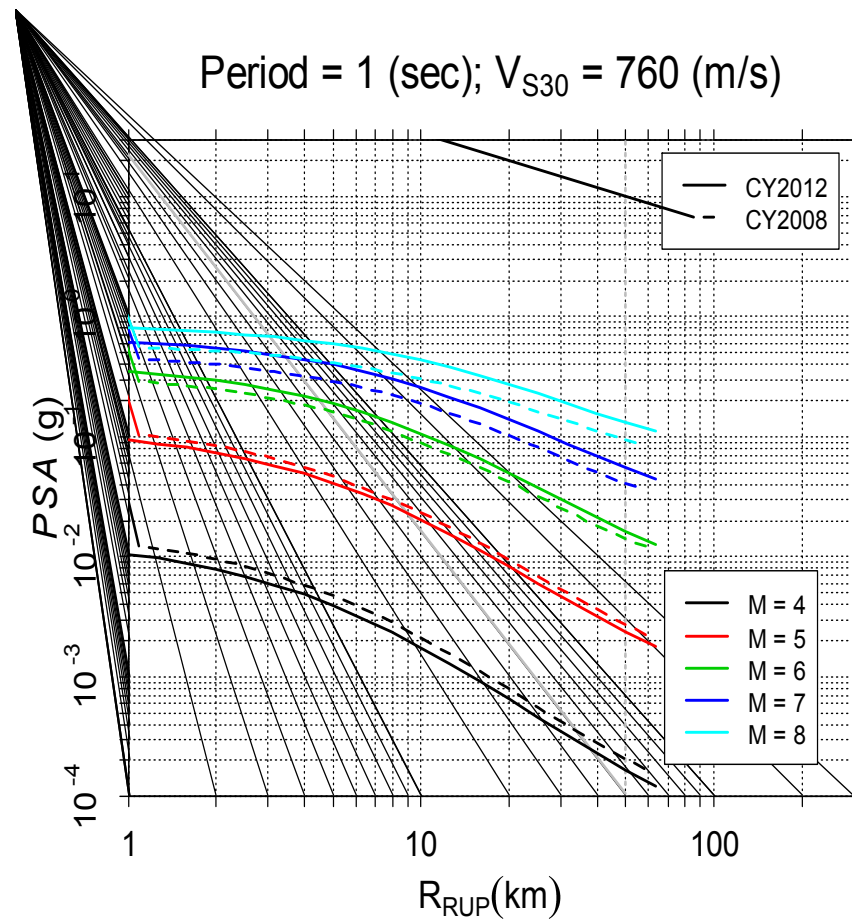
Scaling in October Preliminary Model



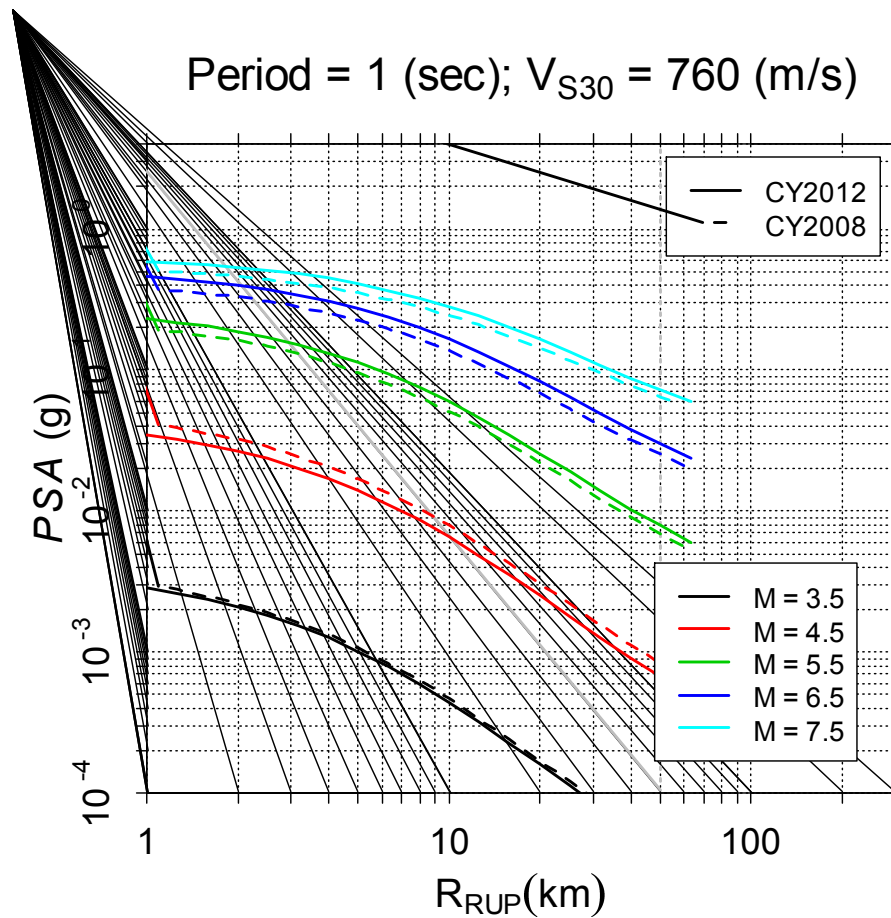
December Revised Scaling



Preliminary Model in October



December Revision



Scaling with Z_{TOR}

- Examined scaling compared with 2008 Z_{TOR} model
- Depth effect stronger than CY2008 model at high frequencies and weaker at low frequencies
- New effect found – correlation with dip angle for smaller magnitude earthquakes
- Need work out how depth, dip, and mechanism effects interact as they are correlated parameters

Form of Distance Scaling Unchanged from CY2008

$$\ln(y) \propto c_4 \ln[R_{RUP} + H]$$

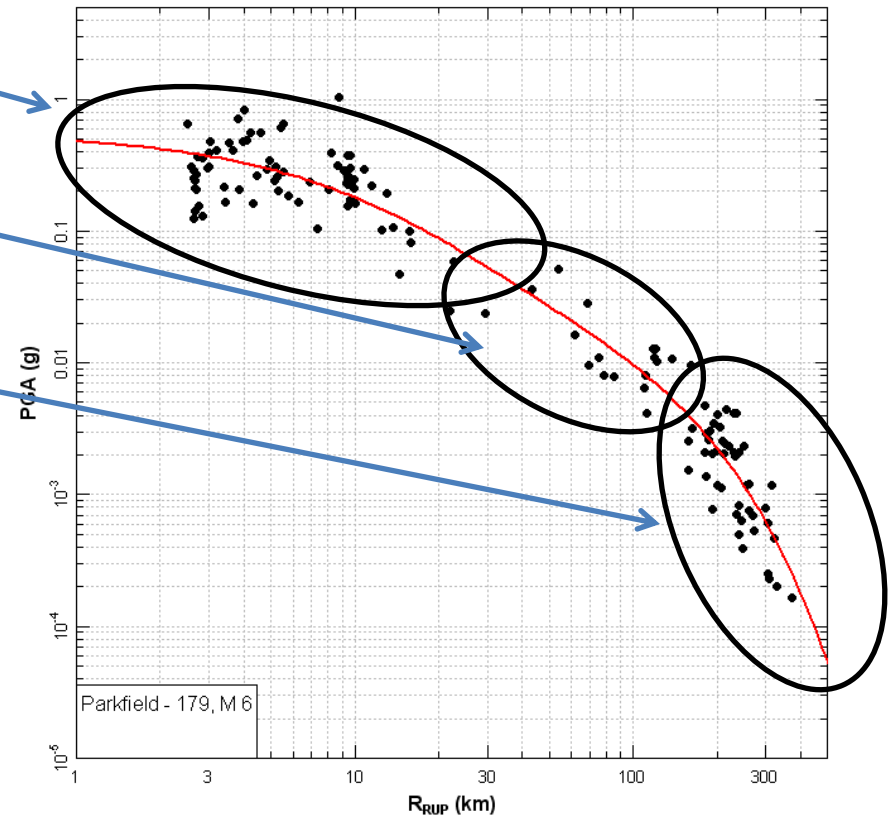
$$+ (c_{4a} - c_4) \ln\left(\sqrt{R_{RUP}^2 + c_{RB}^2}\right)$$

$$+ \gamma R_{RUP}$$

$$c_4 = -2.1, \quad c_{4a} = -0.5, \quad c_{RB} = 50$$

$$H = c_5 \cosh\{c_6 \max(\mathbf{M} - c_{HM}, 0)\}$$

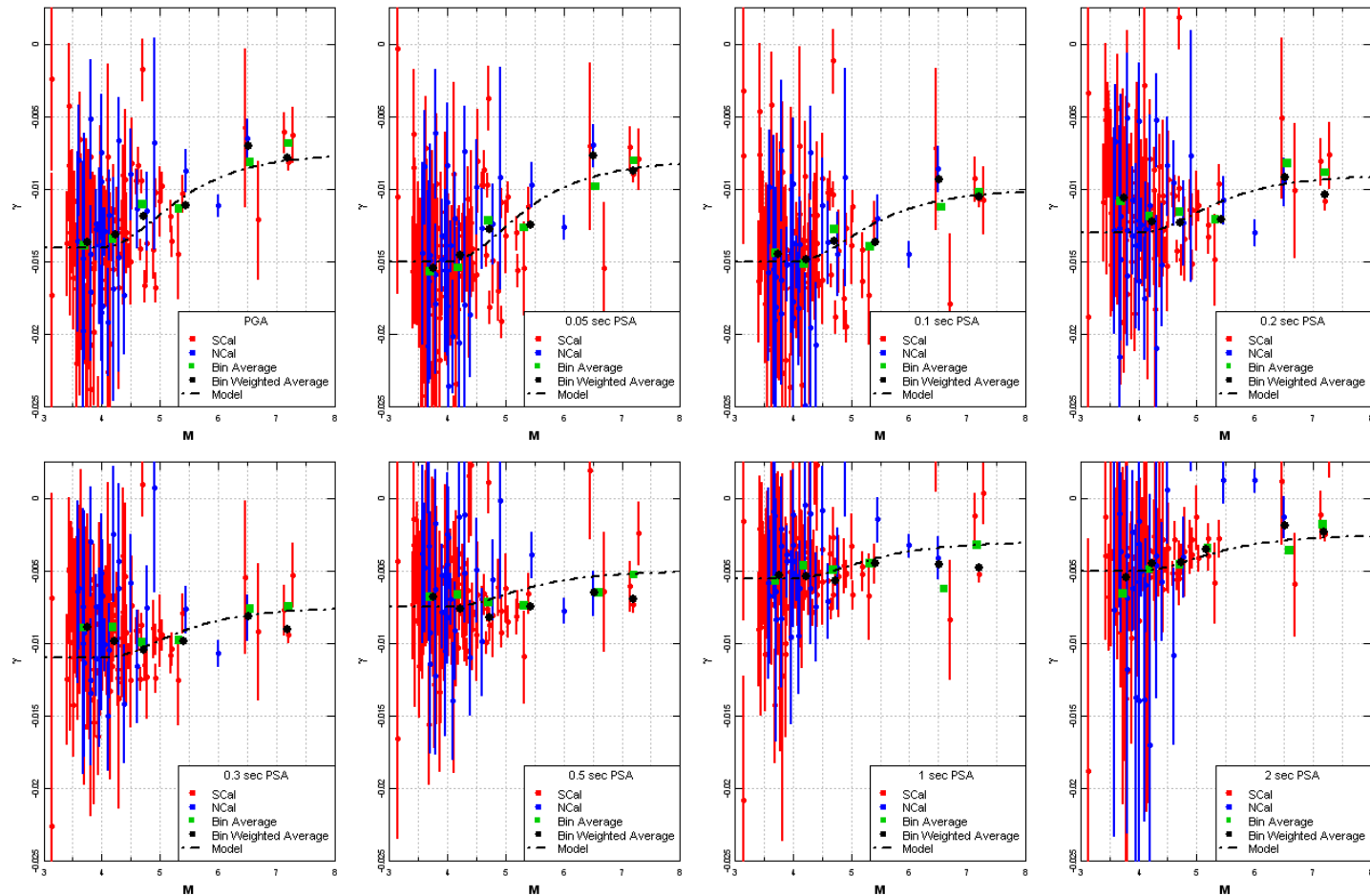
$$\gamma = c_{\gamma 1} + \frac{c_{\gamma 2}}{\cosh[\max(\mathbf{M} - 4, 0)]}$$



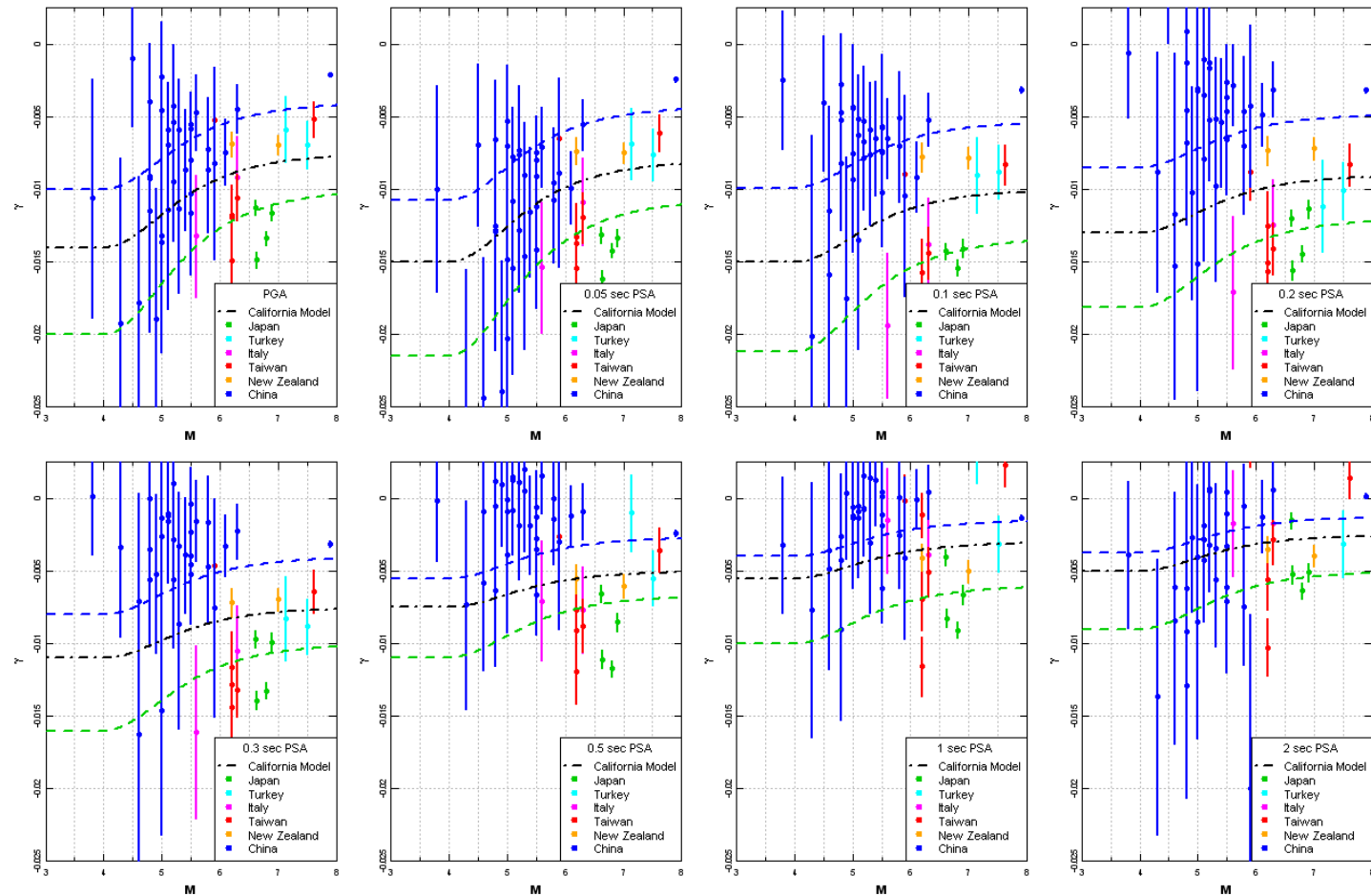
Regionalization of γ

- Following approach of CY2008, analyzed individual earthquakes in NGA West 2 data base
- Used truncated regression allowing for data truncation at specified ground motion levels
- Included effect of basin depth using CY2008 $Z_{1.0}$ scaling model
- Use earthquakes with a minimum of 5 recordings $R_{RUP} < 100$ km **and** 5 with $R_{RUP} > 100$ km
- Examined effect of selection of truncation point as n^{th} lowest value, with n 1 to 5

γ Model for California



γ Model for Other Regions



γ Regionalization Results

- Inclusion of $Z_{1.0}$ scaling results in no statistically significant difference between northern and southern California
- γ for New Zealand, Taiwan, and Turkey similar to California
- γ for Japan and Italy larger in absolute value (lower Q), γ for Wenchuan, China smaller in absolute value (higher Q)
- For preliminary model, use only data from regions with γ similar to California

Site Amplification Model

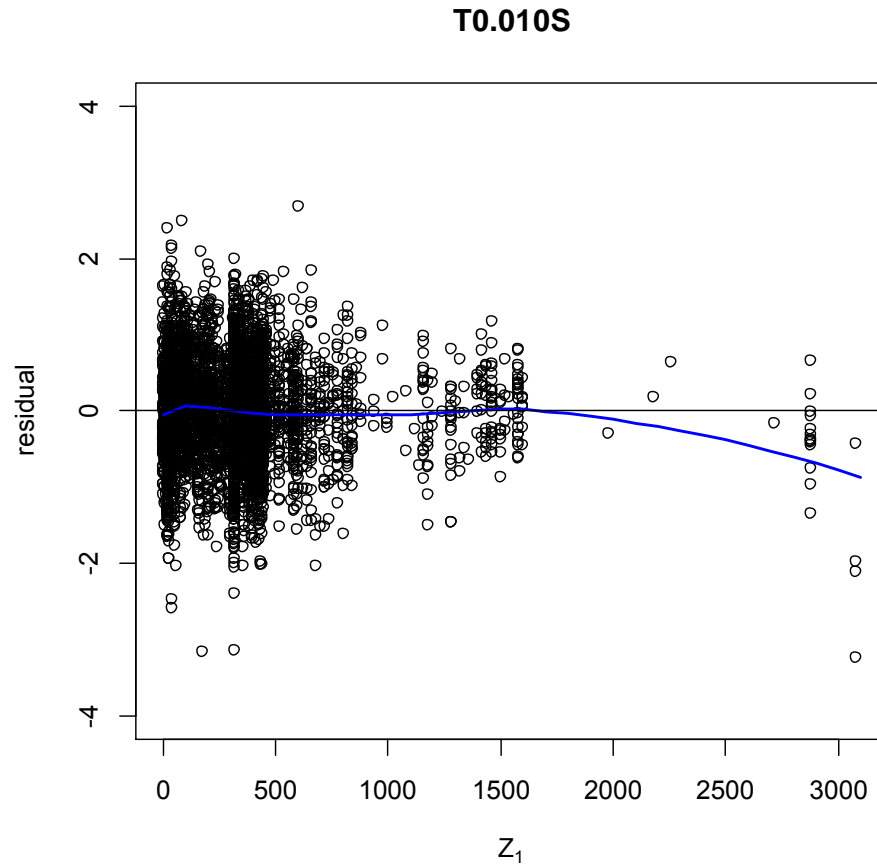
- Unchanged from CY2008
- Empirically based linear and non-linear V_{s30} scaling
- Empirically based $Z_{1.0}$ scaling

$$\ln(y) = \ln(y_{ref}) + \phi_1 \min \left[\ln \left(\frac{V_{s30}}{1130} \right), 0 \right]$$

$$+ \phi_2 \left[\exp \phi_3 \{ \min(V_{s30}, 1130) - 360 \} - \exp \phi_3 \{ 1130 - 360 \} \right] \ln \left(\frac{y_{ref} + \phi_4}{\phi_4} \right)$$

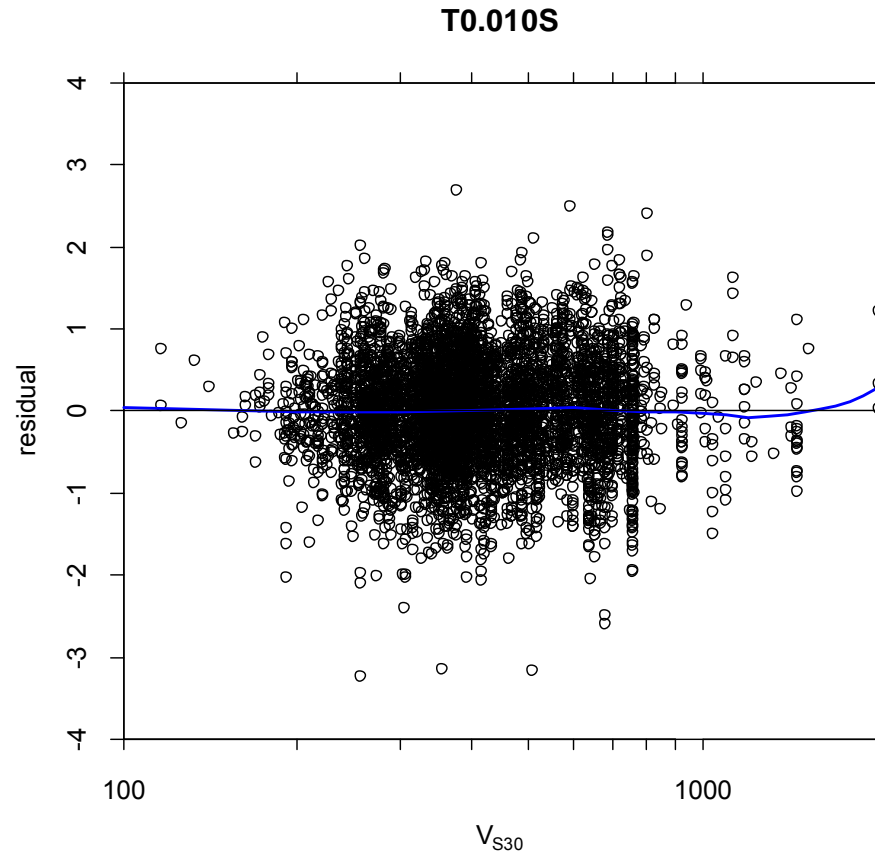
$$+ \phi_5 \left(1 - \frac{1}{\cosh[\phi_6 \max(0, Z_{1.0} - \phi_7)]} \right) + \frac{\phi_8}{\cosh[0.15 \max(0, Z_{1.0} - 15)]}$$

Intra-event Residuals Versus $Z_{1.0}$ Using CY2008 $Z_{1.0}$ Scaling

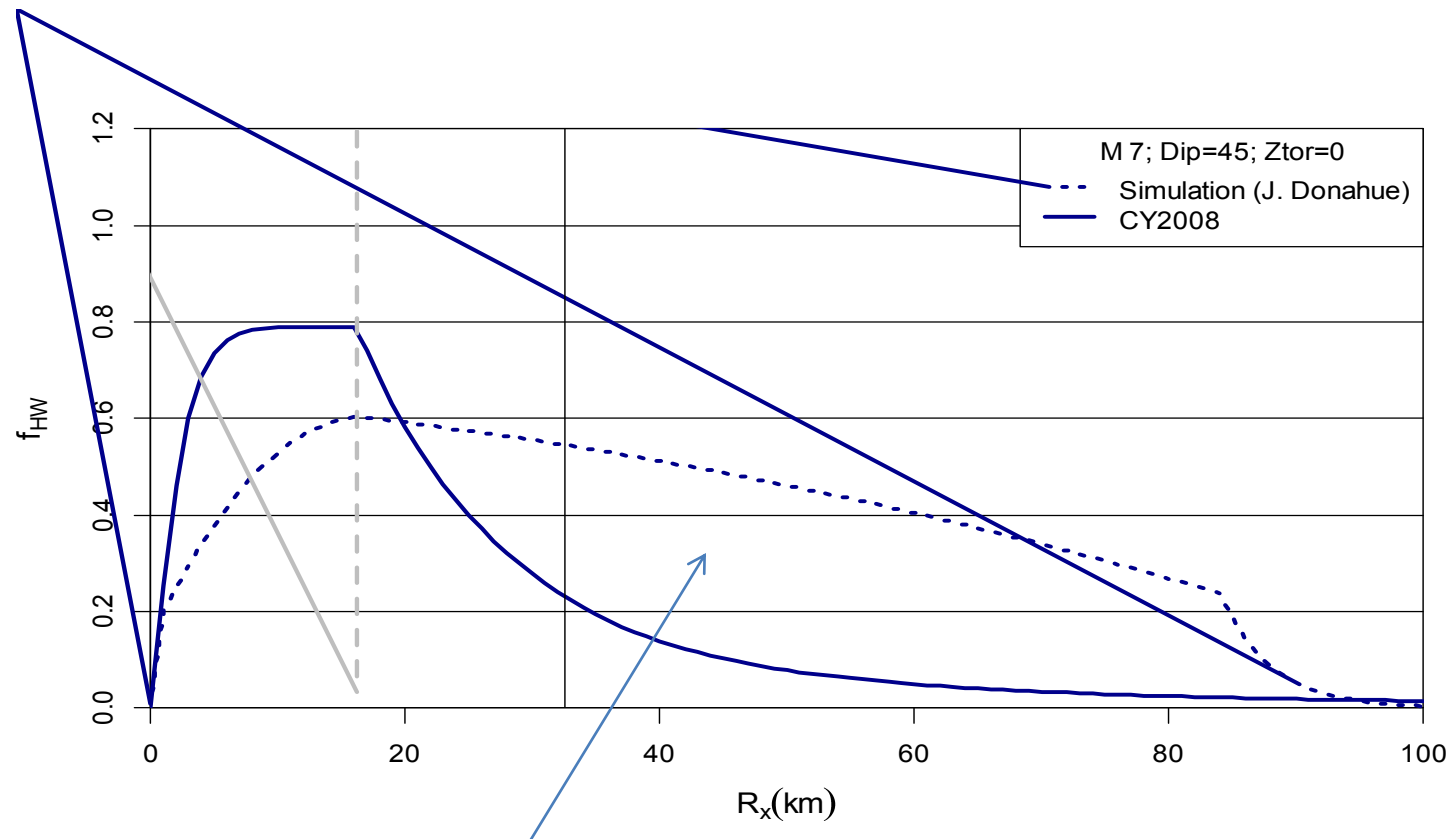


Intra-event residuals Based on CY2008

Scaling vs V_{S30}



Hanging Wall Scaling



Taper off of the hanging wall found by other developers to be stronger than shown by simulations

Work Left to Do to Finalize Horizontal Model

- Resolve model for dip/depth/mechanism interaction
- Incorporate data from other regions with different γ
 - Utilize small/moderate data sets from other regions
 - check for differences in V_{s30} scaling
- Update $Z_{1.0}$ scaling
- Refine hanging wall model using simulation results and data (currently unchanged from CY2008)
- Incorporate directivity model (Spudich and Chiou 2012 version likely choice)
- Include Class 2 (aftershock) data and examine Class 2 scaling
- Analyze aleatory variability
 - Initial results suggest similar values to CY2008 for $M > 5$
 - Greater variability for $M < 5$