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

NGA West 2

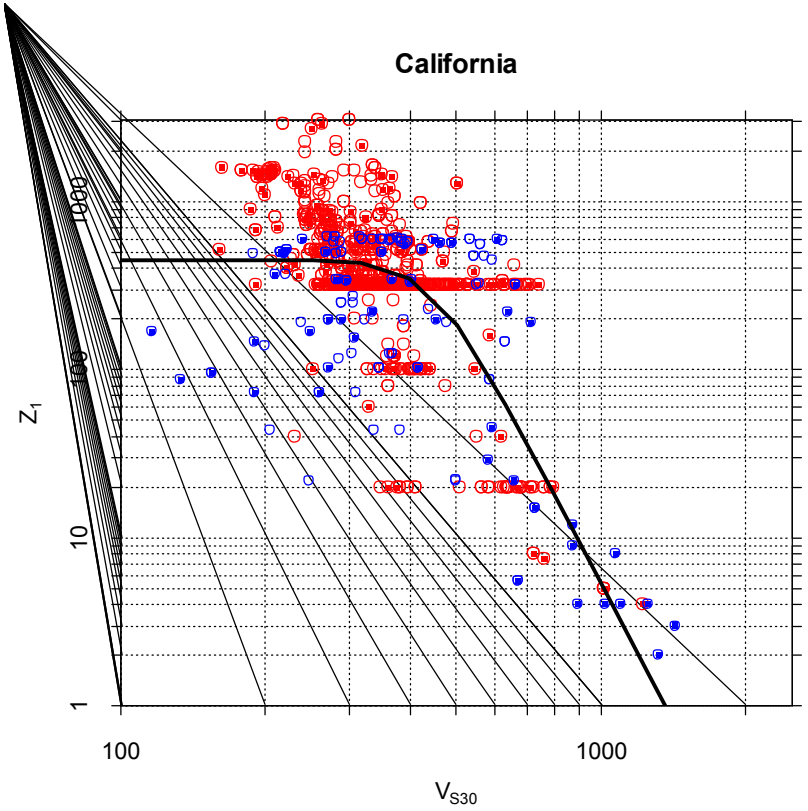
Public Workshop

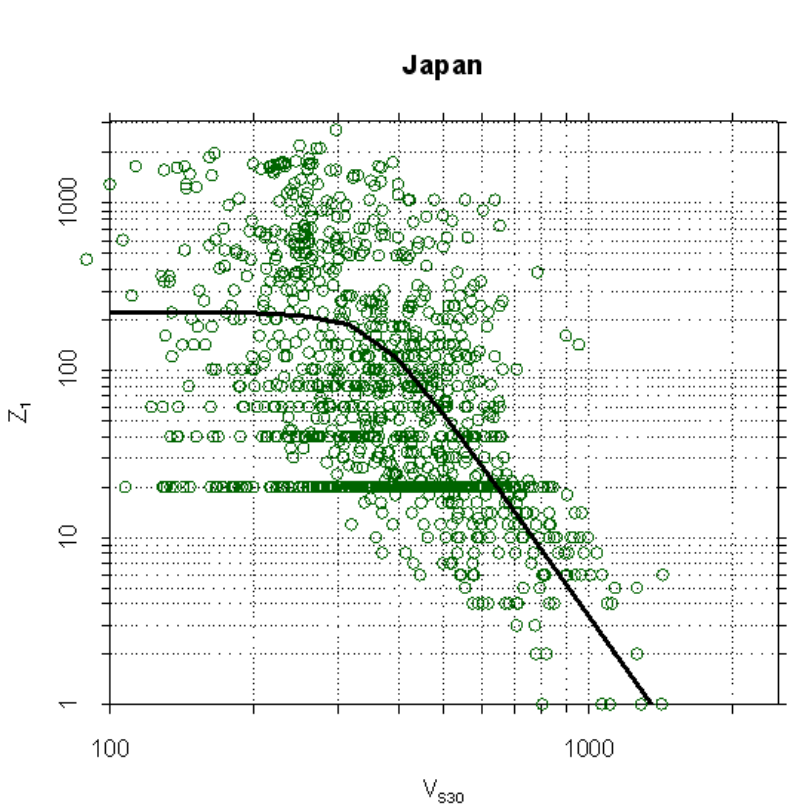
November 15, 2012

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





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

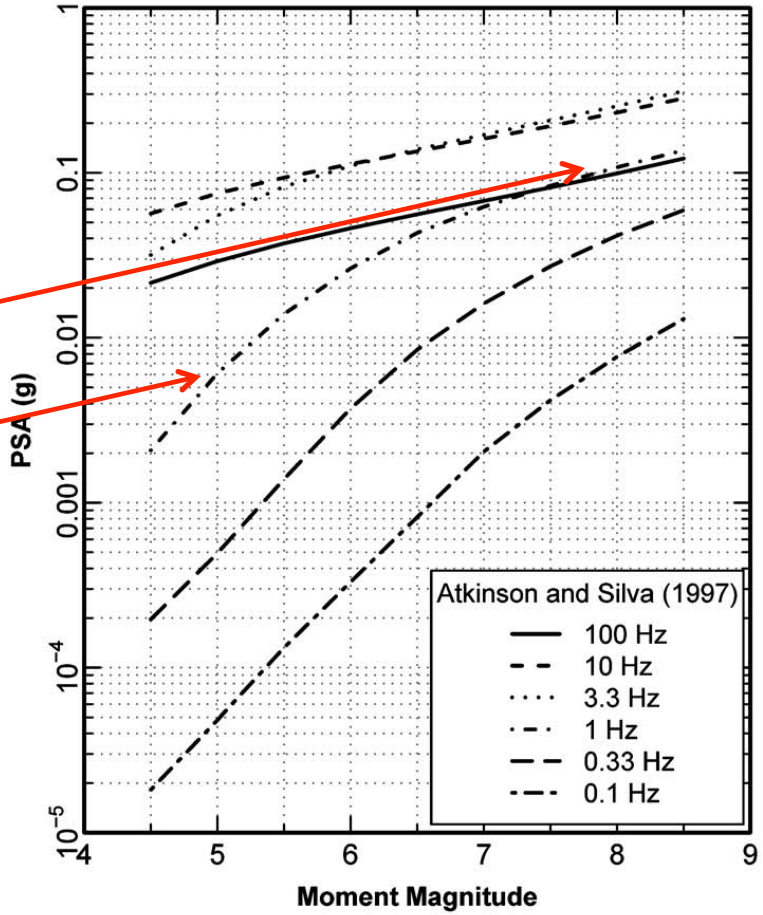
$$\ln(Z_{1.0}) = -\frac{4.018}{8}\ln\left(\frac{V_{S30}^{8} + 355.2^{8}}{1360^{8} + 355.2^{8}}\right)$$

Large Distance Magnitude Scaling Form

- Unchanged from CY2008

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

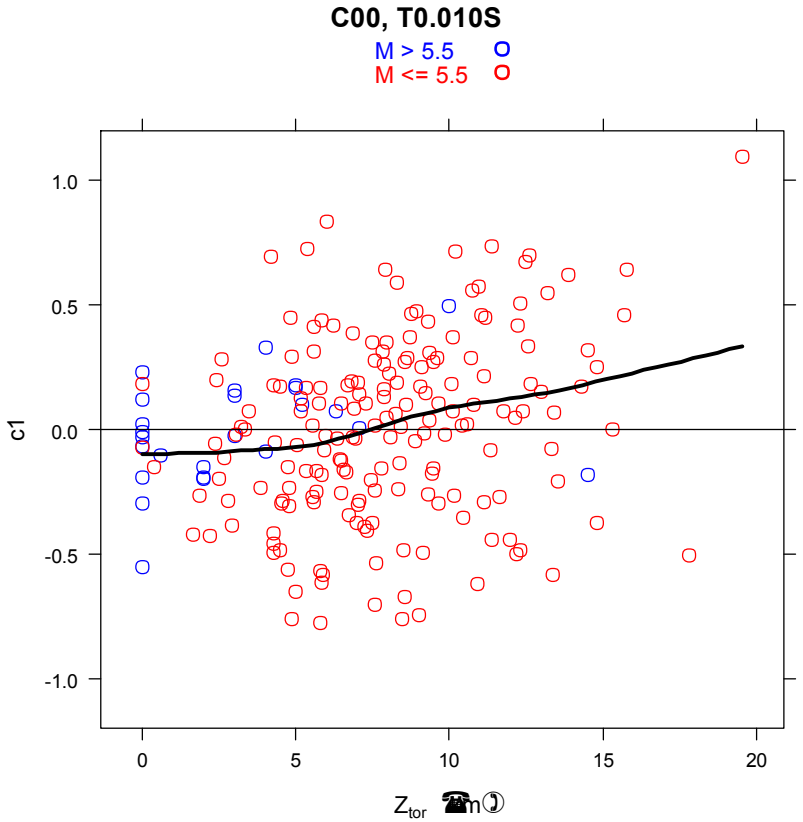
- At a given period, linear scaling at large magnitudes $\propto c_2$ and at small magnitudes $\propto c_3$
- Transition controlled by period dependent c_n and c_M
- Shown to work well over magnitude range 3 to 8 by Chiou et al (2010)

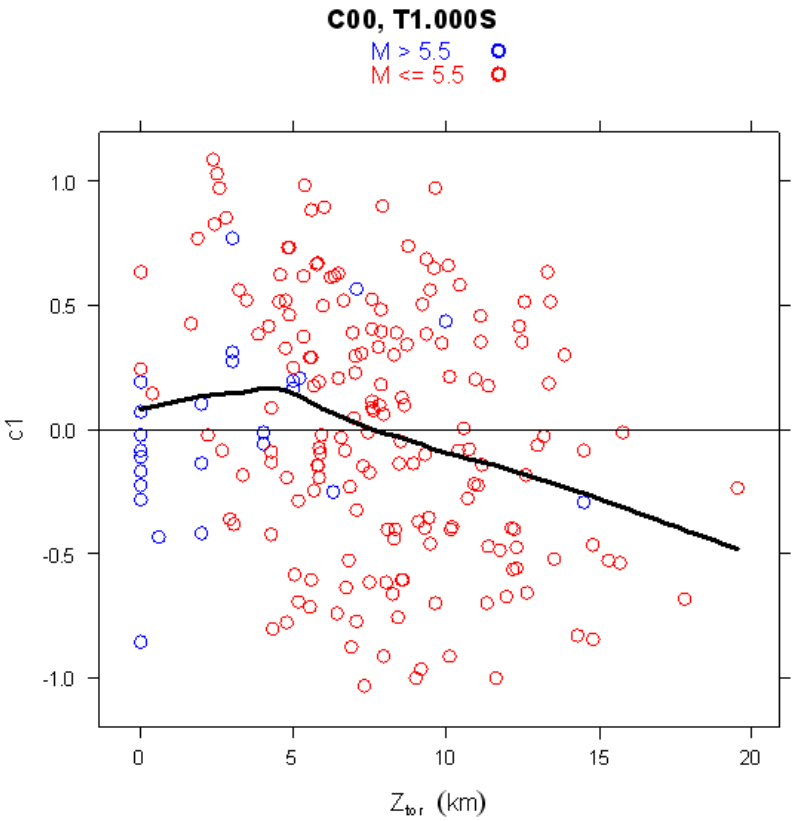


Scaling with Z_{TOR}

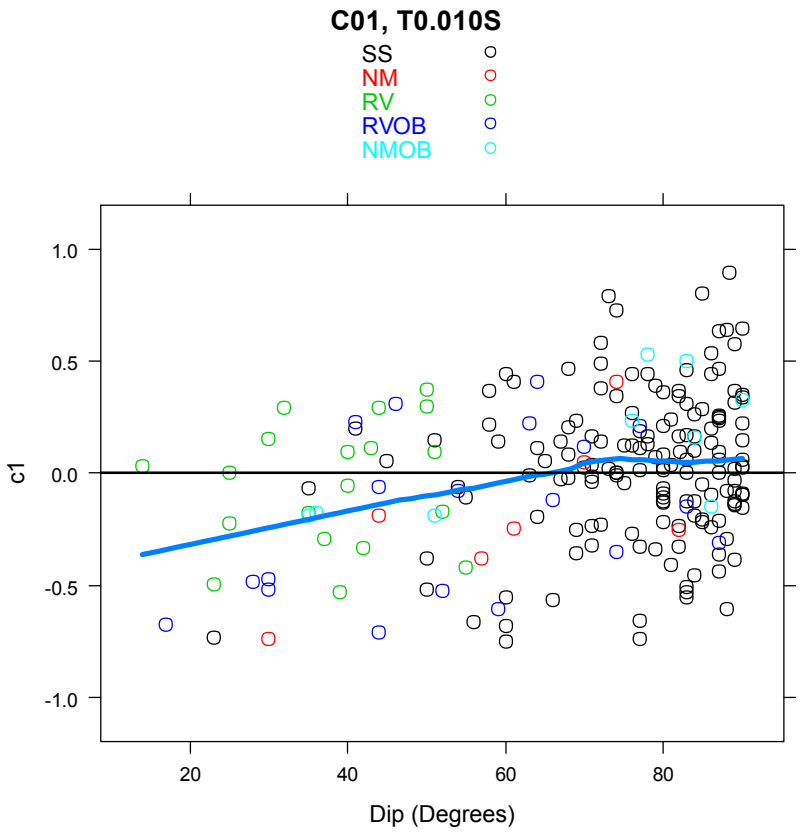
- Examined scaling compared with 2008 Z_{TOR} model
- Depth effect stronger that CY2008 model at high frequencies and weaker at low frequencies
- New effect found – correlation with dip angle for smaller magnitude earthquakes
- Need work out how depth, dip, and mechanism effects interact as they are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

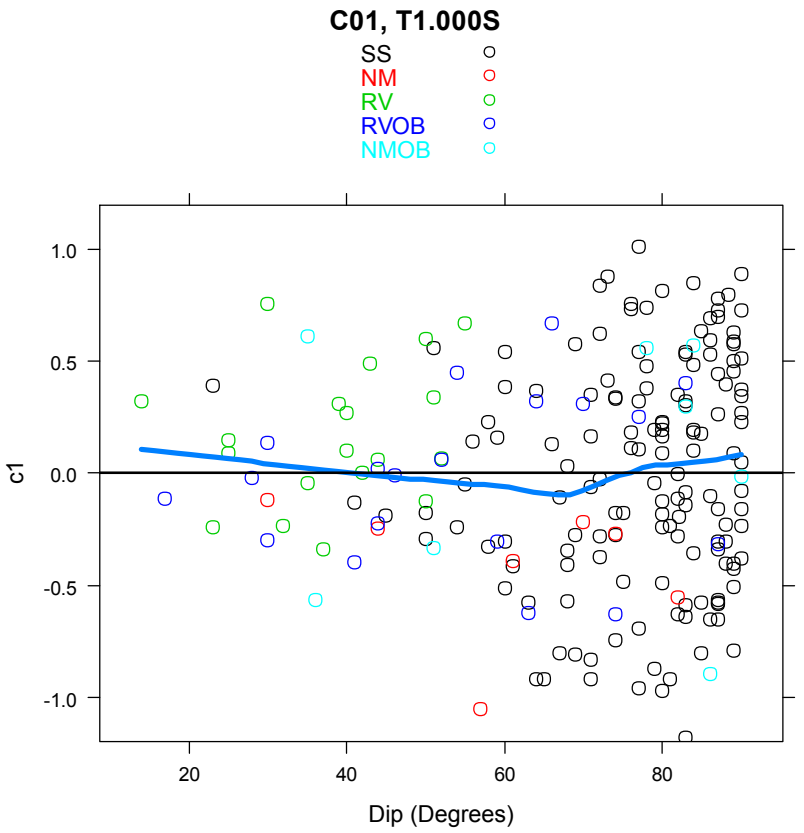
Plot of Event Terms Computed Using C&Y (2008) Depth Scaling Coefficients





Plot of Event Terms Computed Using Updated Depth Scaling Coefficients





Updated Event Scaling Model

$$\ln(y_{ref}) \propto +c_{1a}F_{RV} + c_{1b}F_{NM} + c_7(Z_{TOR} - 4)$$

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

$$+ ifelse\{\mathbf{M} \geq 6, 0, c_{11}\min(\delta - 70, 0)\}$$

Form of Distance Scaling Unchanged from CY2008

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

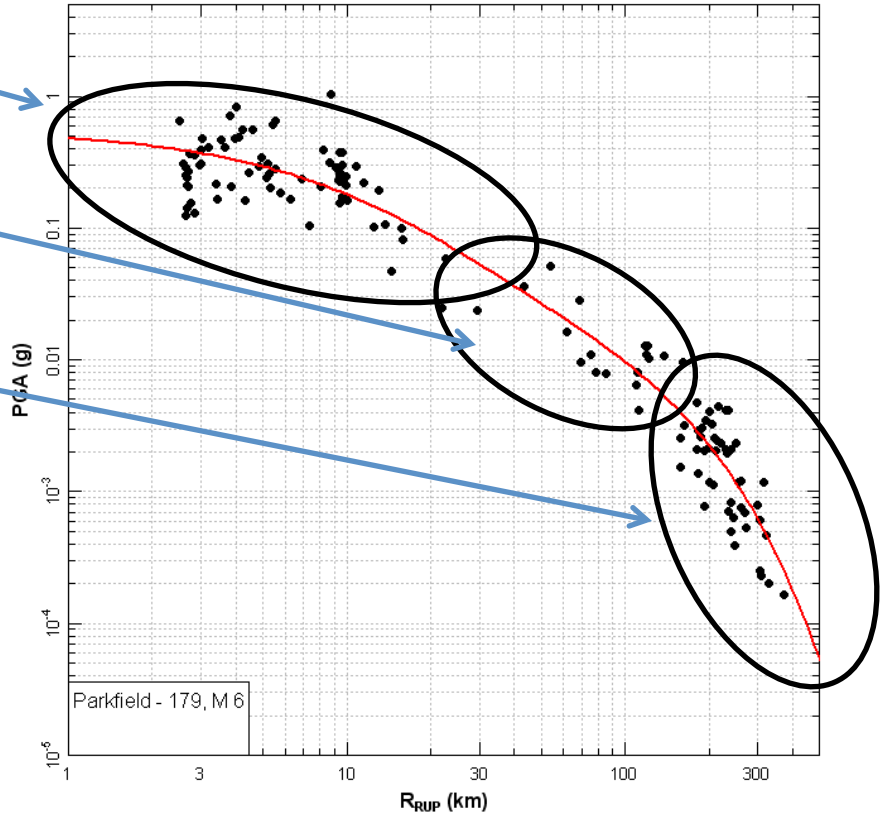
$$+ (c_{4a} - c_4) \ln\left(\sqrt{R_{RUP}^2 + c_{RB}^2}\right)$$

$$+ \gamma\, R_{RUP}$$

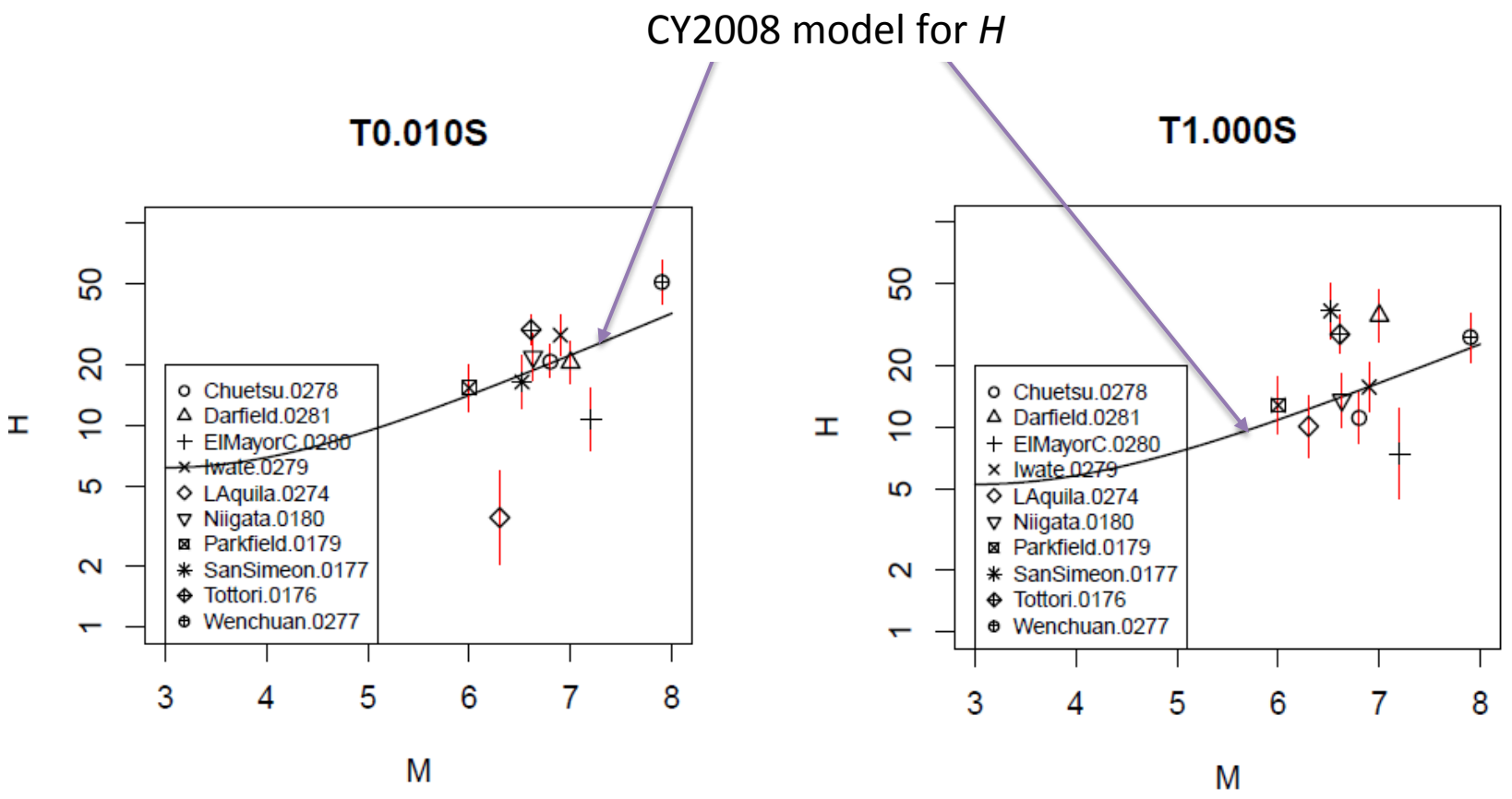
$$c_4 = -2.1, \quad c_{4a} = -0.5, \quad c_{RB} = 50$$

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

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



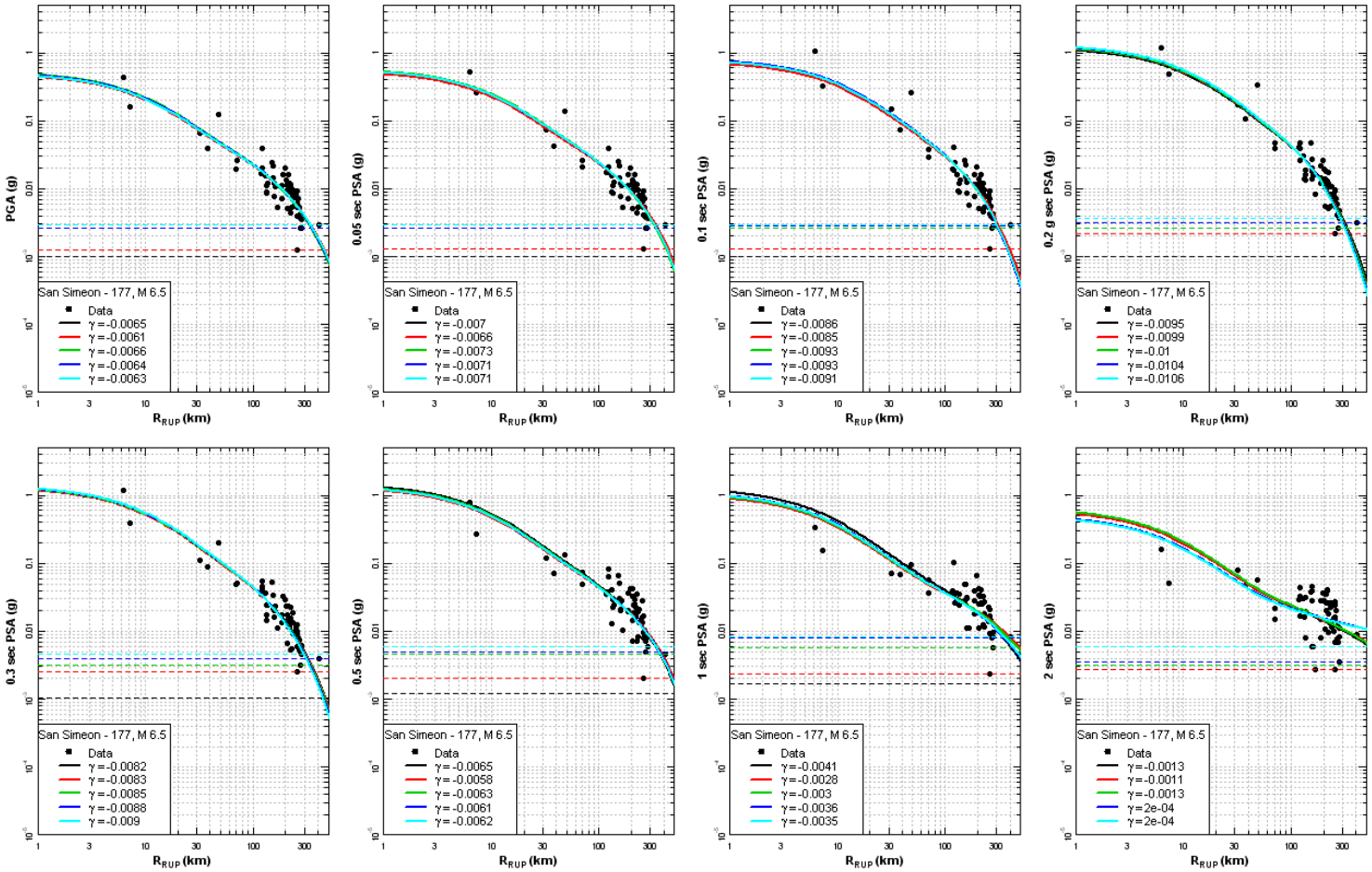
Near-source Saturation Term *H*



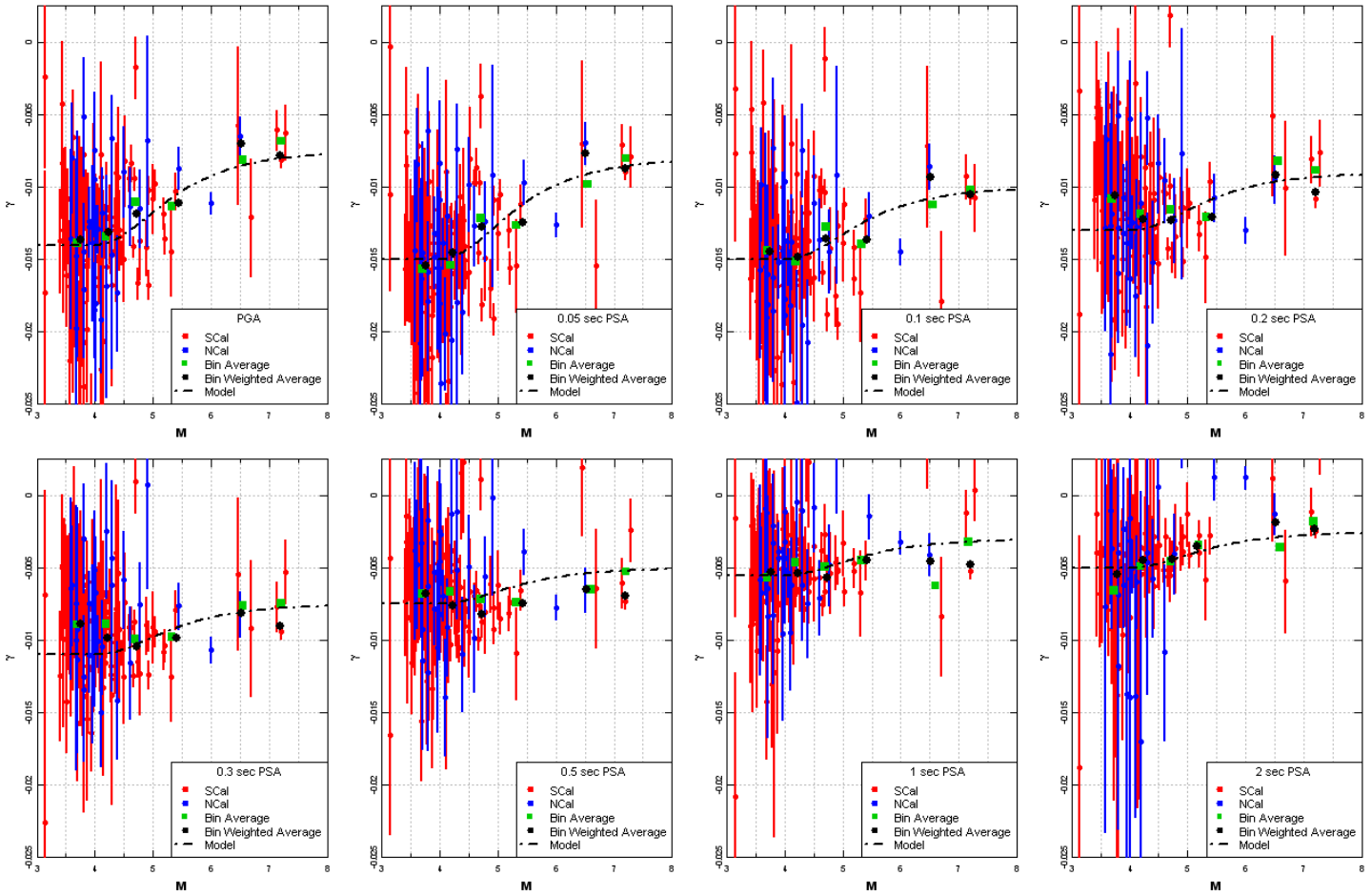
Regionalization of γ

- 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

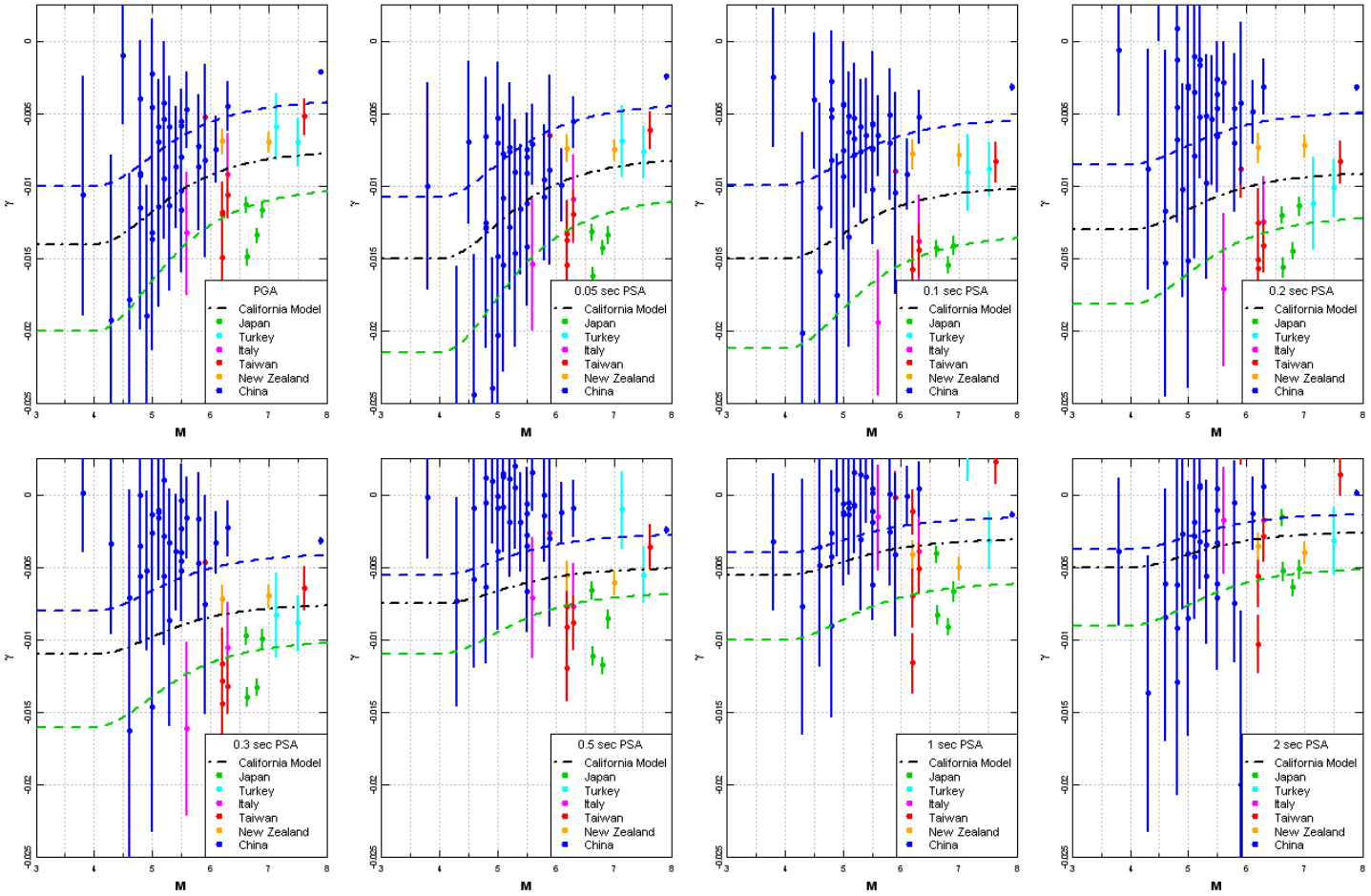
Example for San Simeon



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

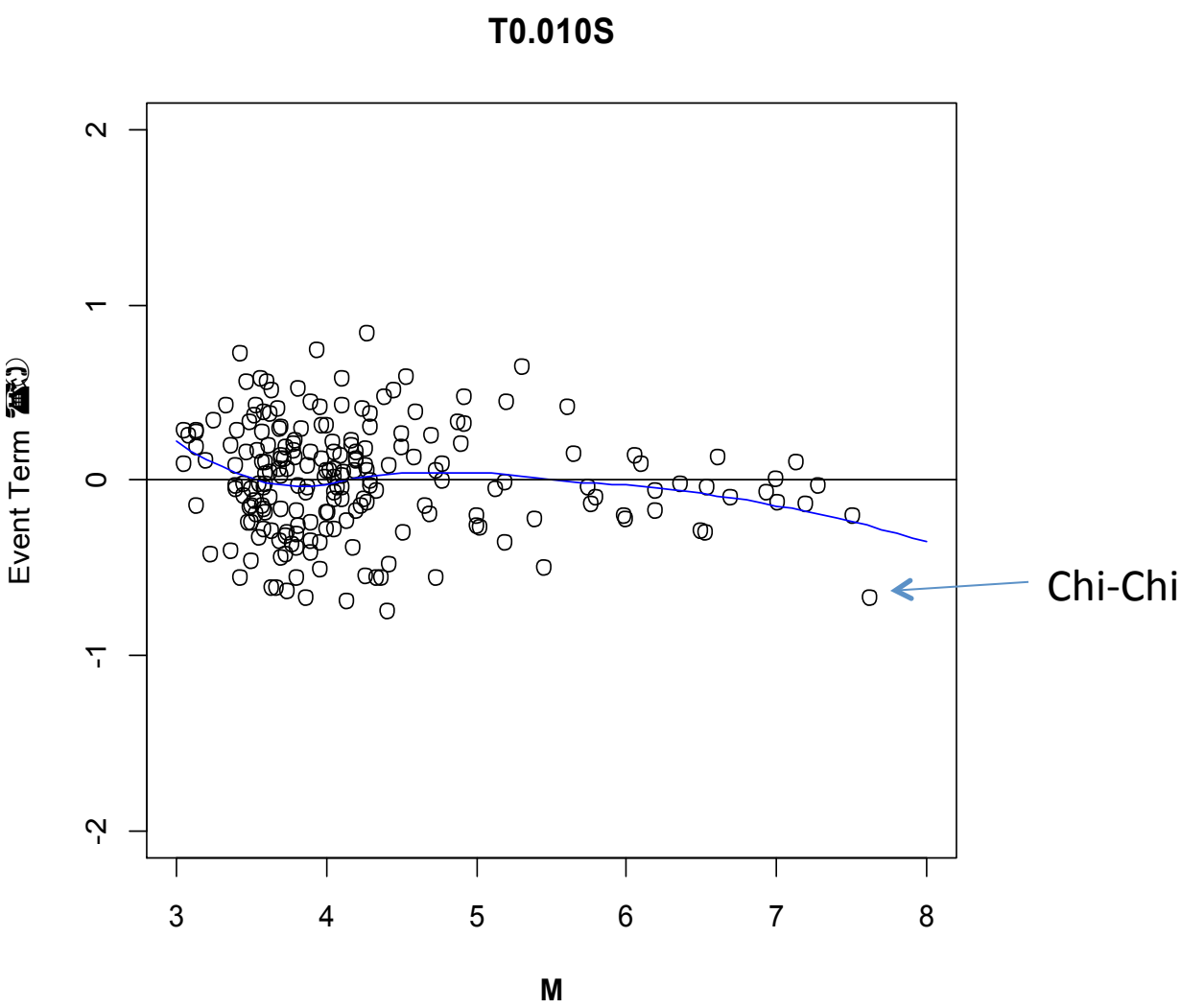
- Unchanged from CY2008
- Empirically based linear and non-linear V_{S30} scaling
- Empirically based $Z_{1.0}$ scaling

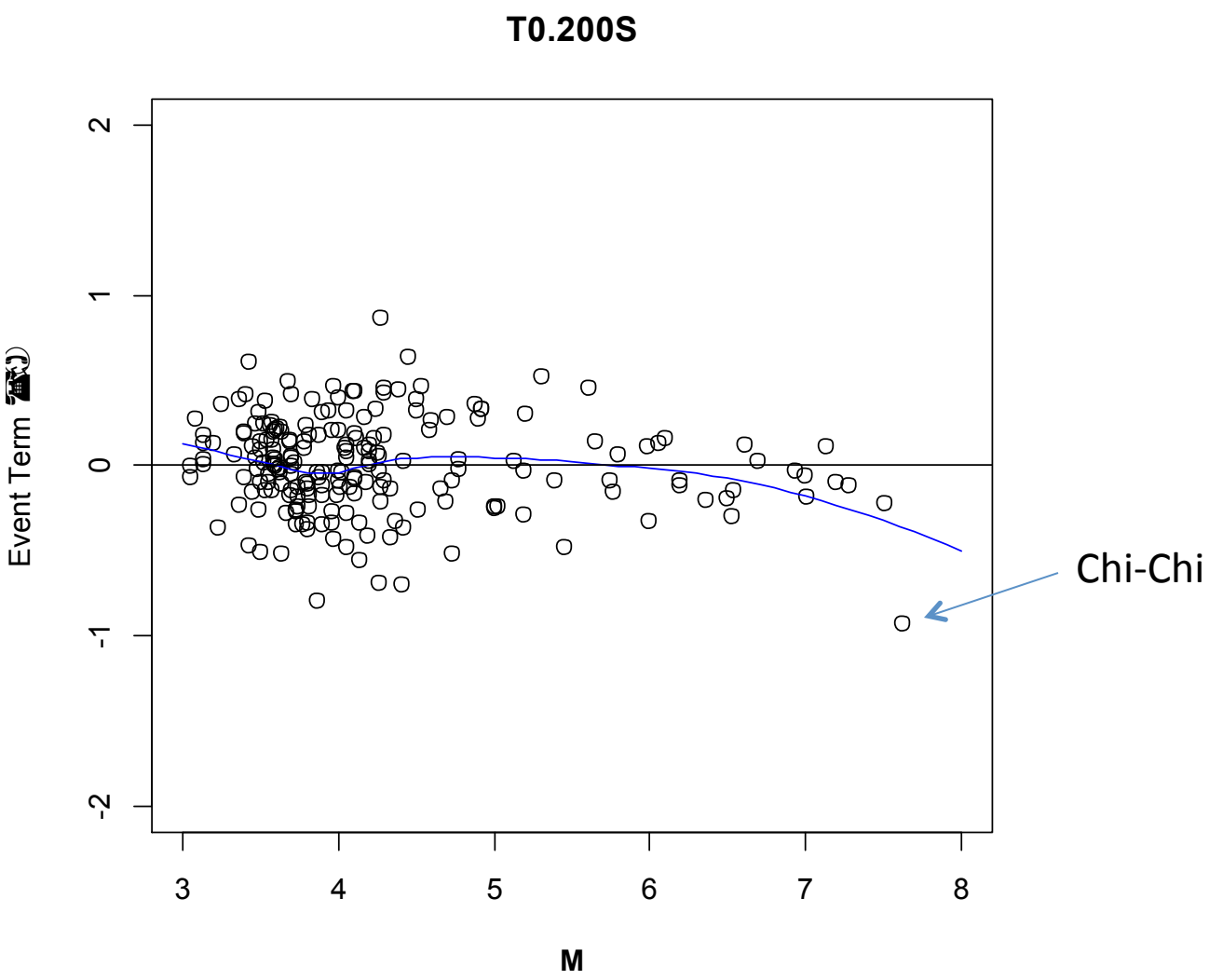
$$\ln(y) = \ln(y_{ref}) + \phi_1 \min\left[\ln\left(\frac{V_{S30}}{1130}\right), 0\right]$$

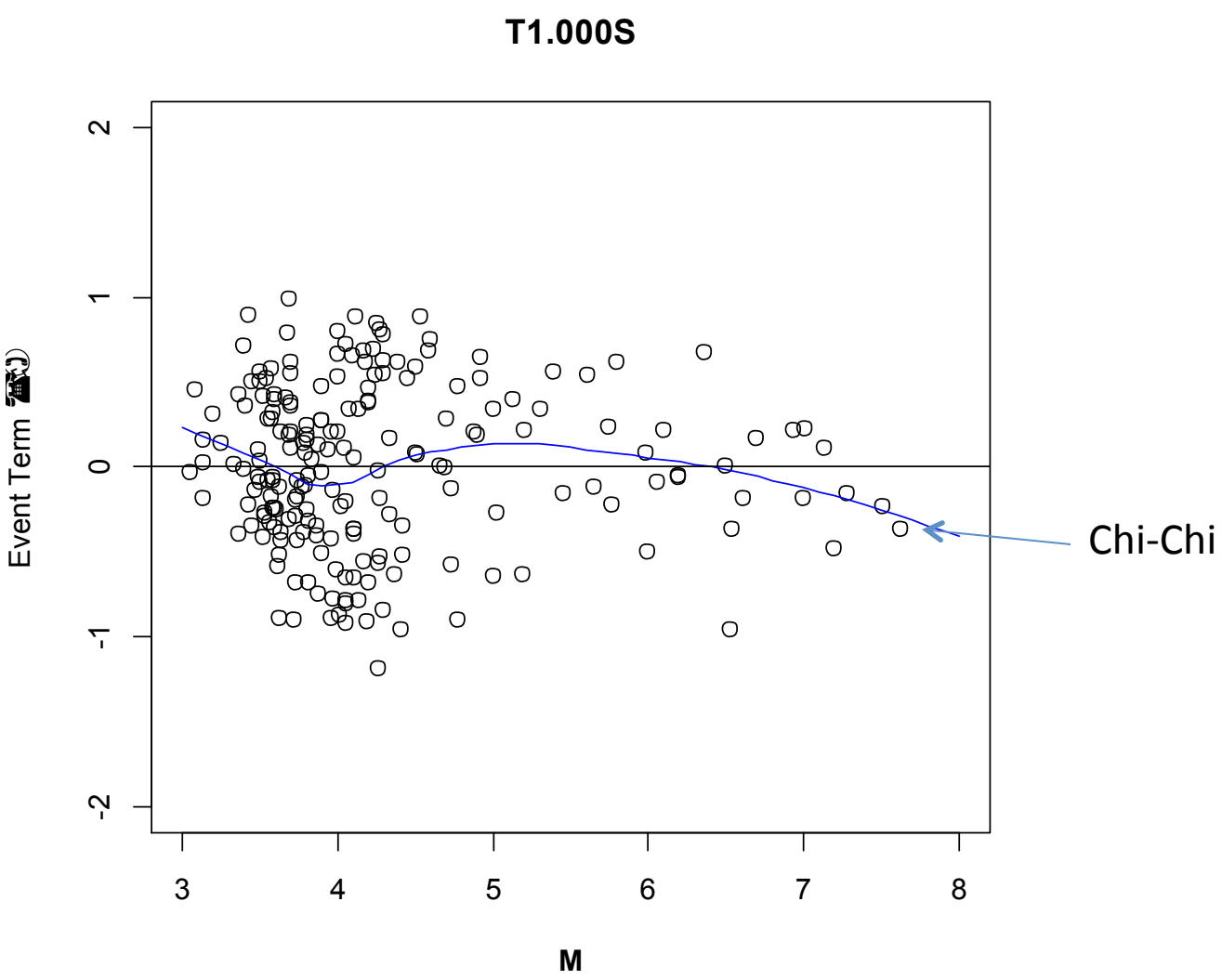
$$+ \phi_2\left[\exp\phi_3\{\min(V_{S30}, 1130) - 360\} - \exp\exp\phi_3\{1130 - 360\}\right]\ln\left(\frac{y_{ref} + \phi_4}{\phi_4}\right)$$

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

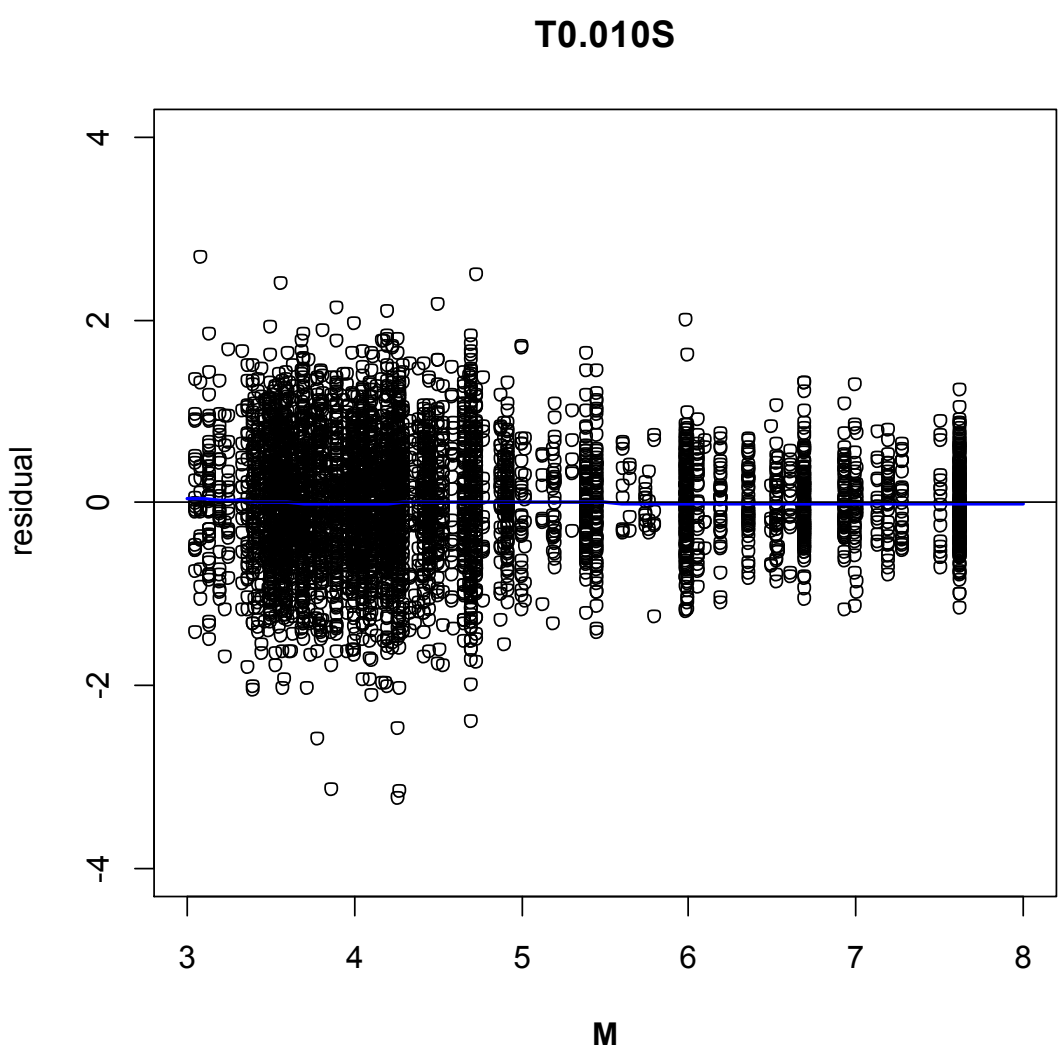
Preliminary Model
Event Terms Versus **M**

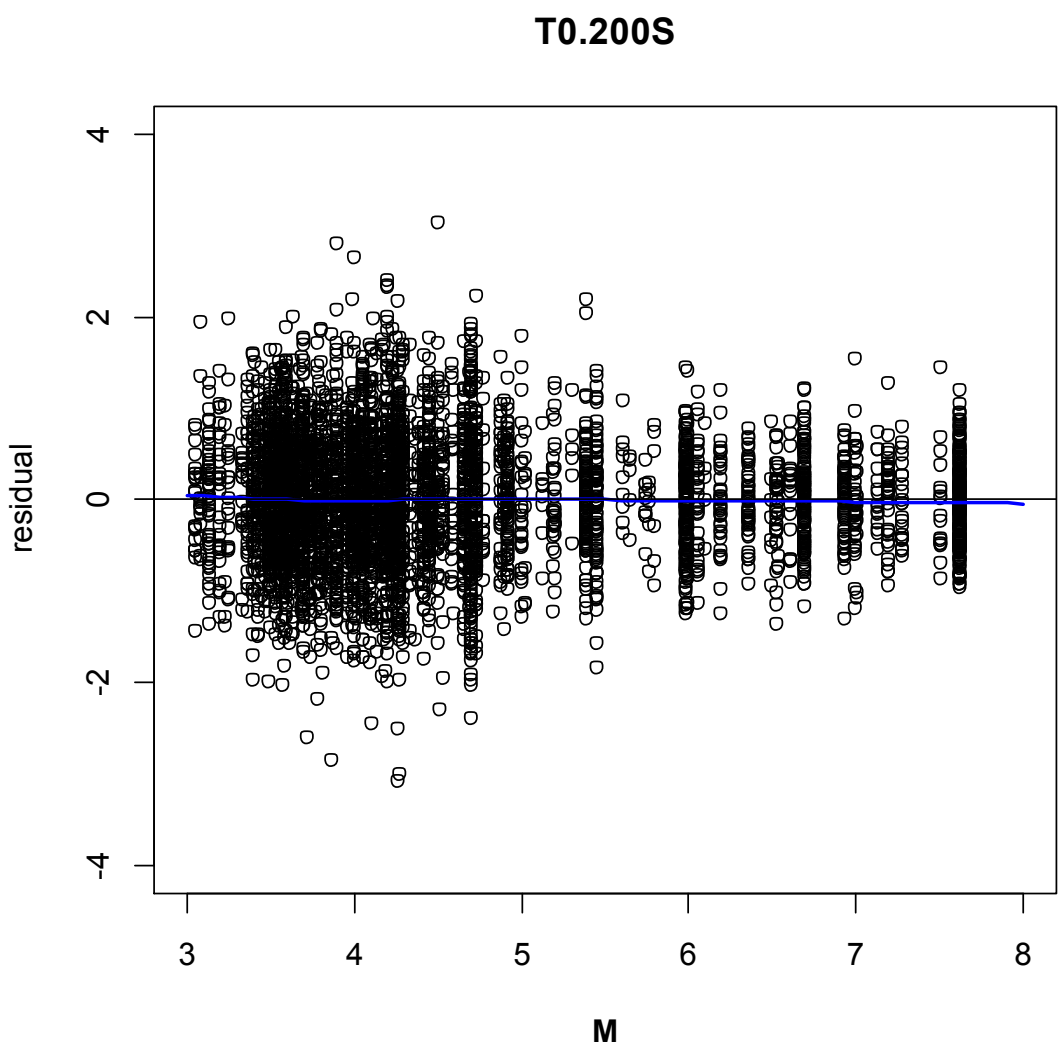

T0.010S
Event Term
2
1
0
-1
-2
3
4
5
6
7
8
M
Chi-Chi

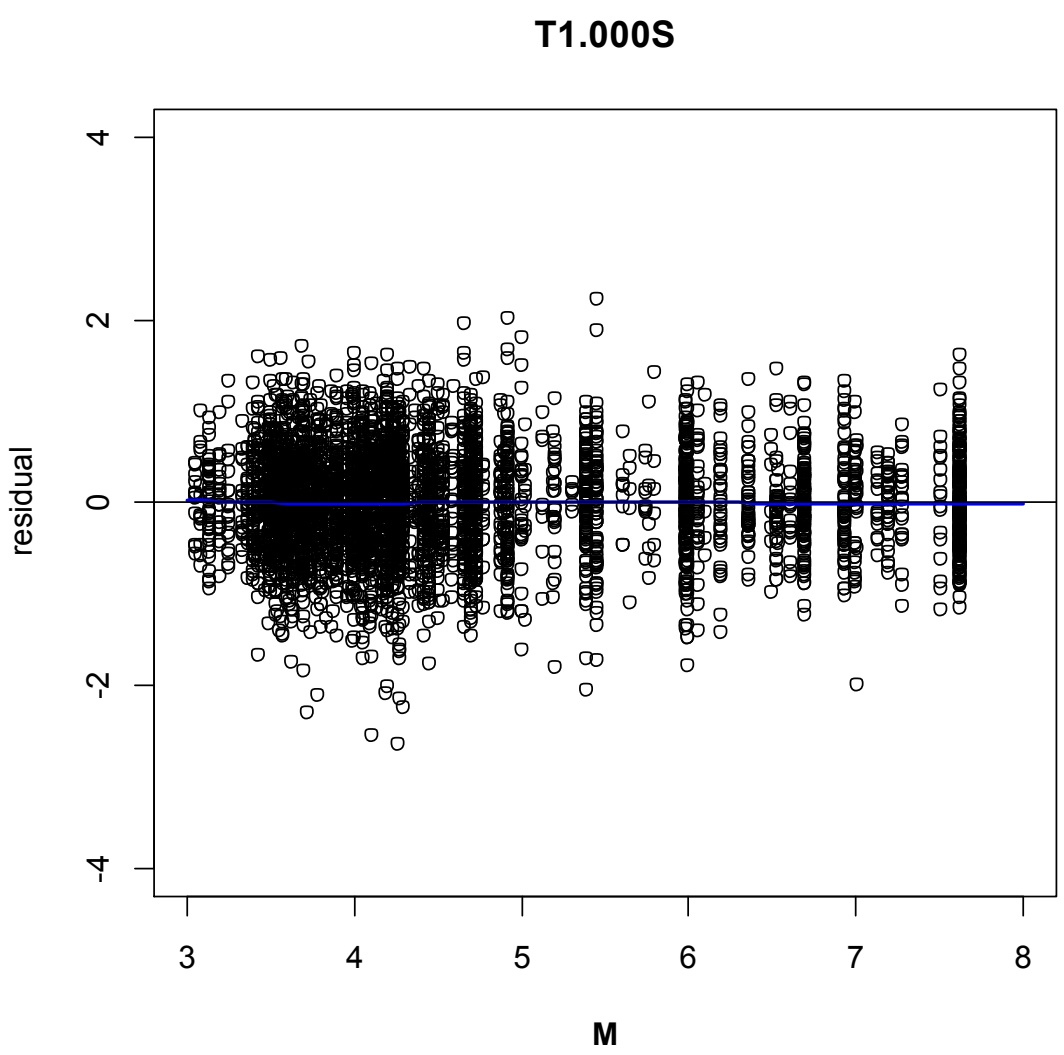

T0.200S
Event Term
M
2
1
0
-1
-2
3
4
5
6
7
8
Chi-Chi


T1.000S
Event Term
2
1
0
-1
-2
3
4
5
6
7
8
M
Chi-Chi

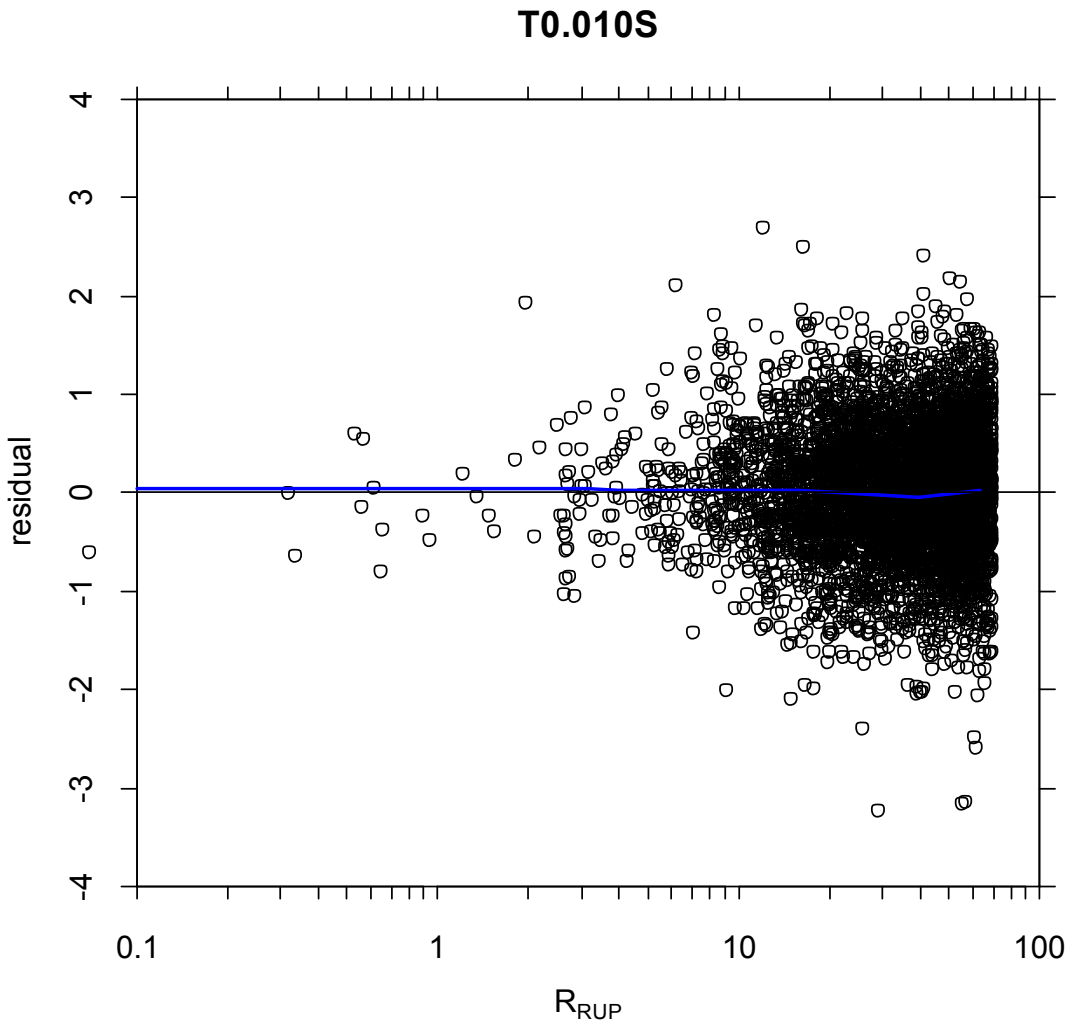
Preliminary Model
Intra-event Residuals Versus **M**

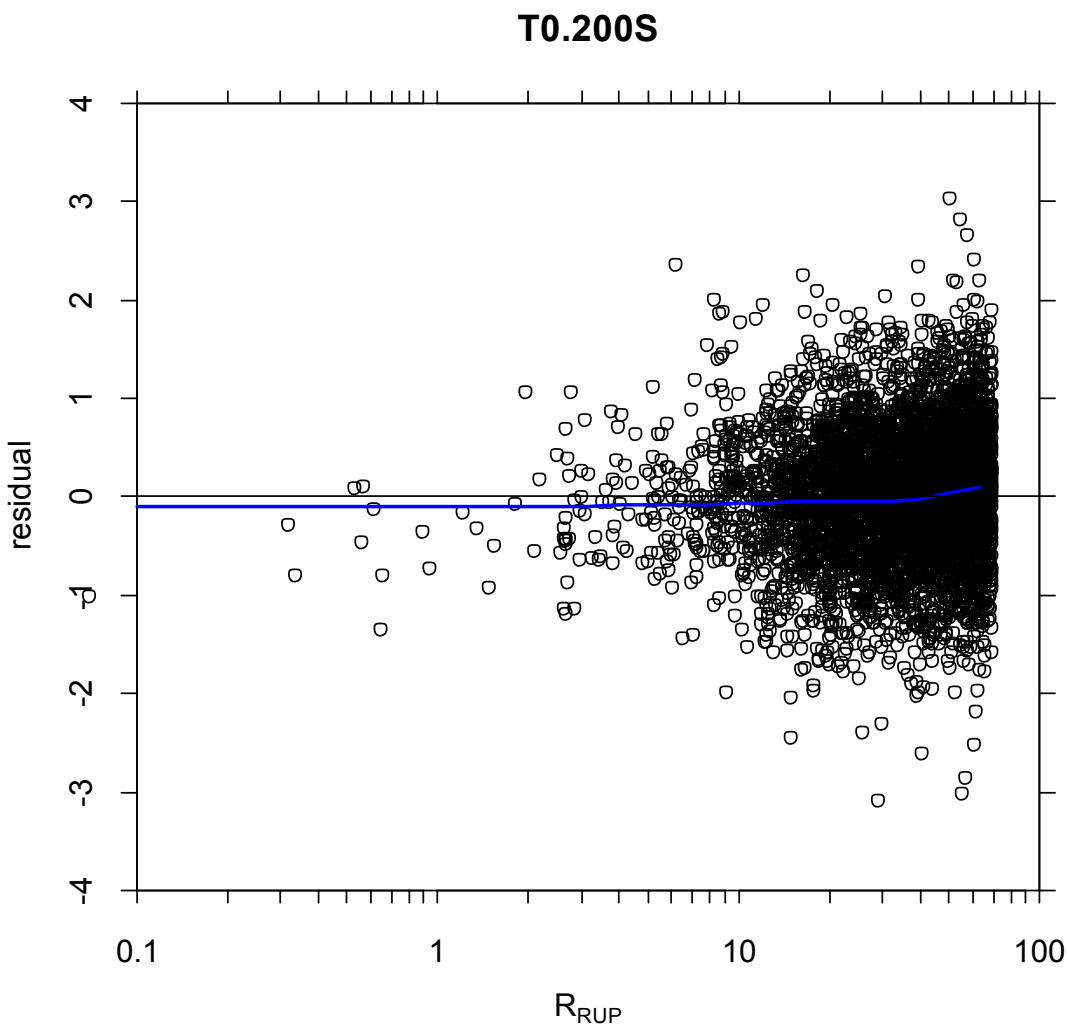

T0.010S
residual
4
2
0
-2
-4
3
4
5
6
7
8
M

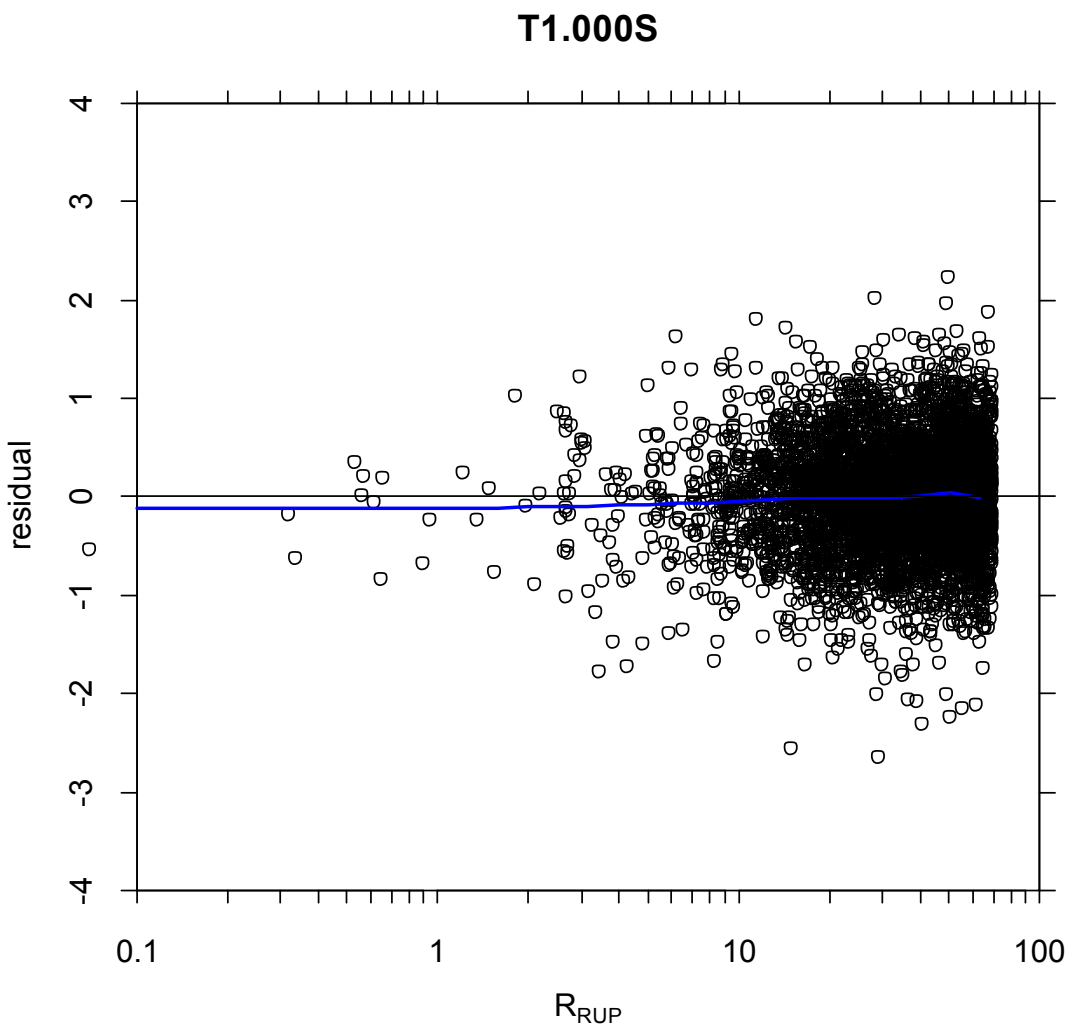

T0.200S
residual
4
2
0
-2
-4
3
4
5
6
7
8
M


T1.000S
residual
4
2
0
-2
-4
3
4
5
6
7
8
M

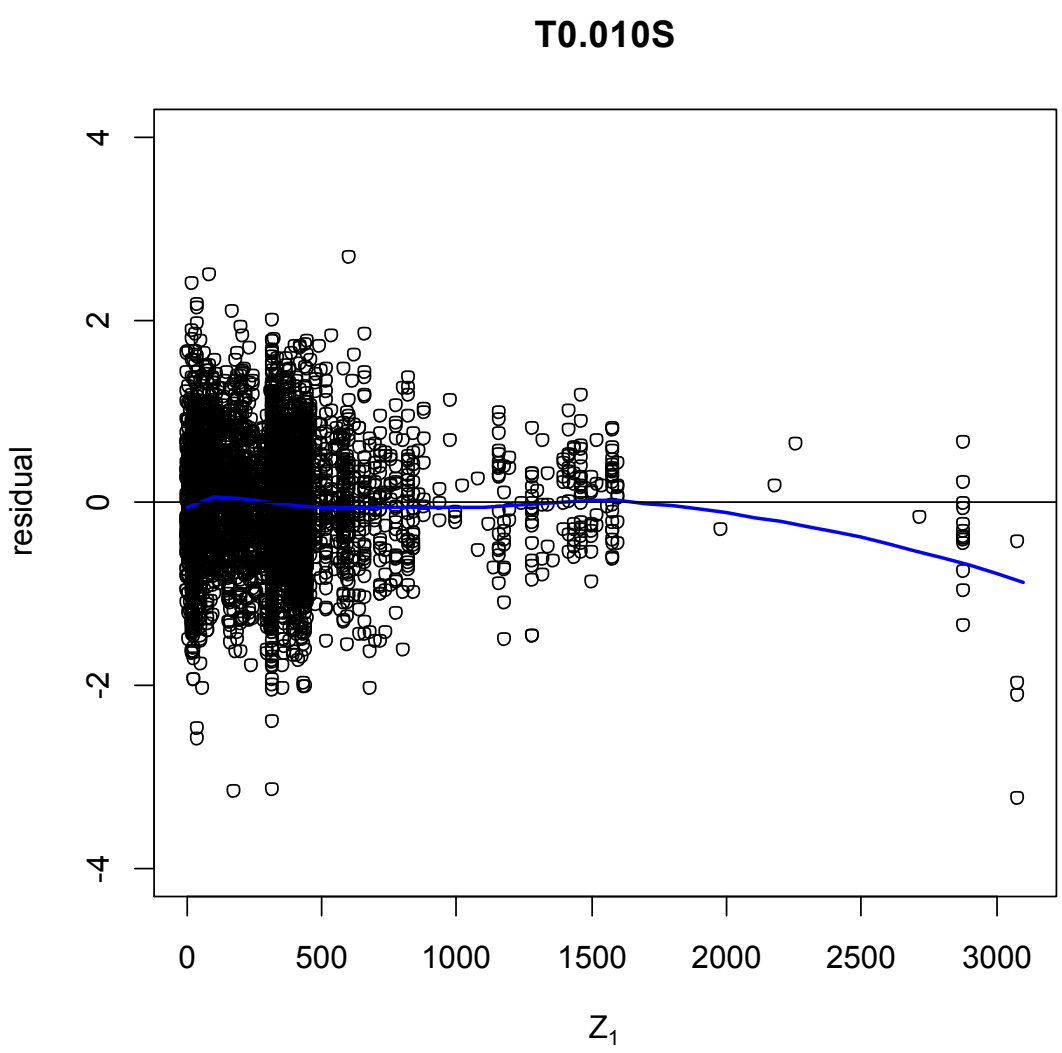
Preliminary Model
Intra-event Residuals Versus R_{RUP}

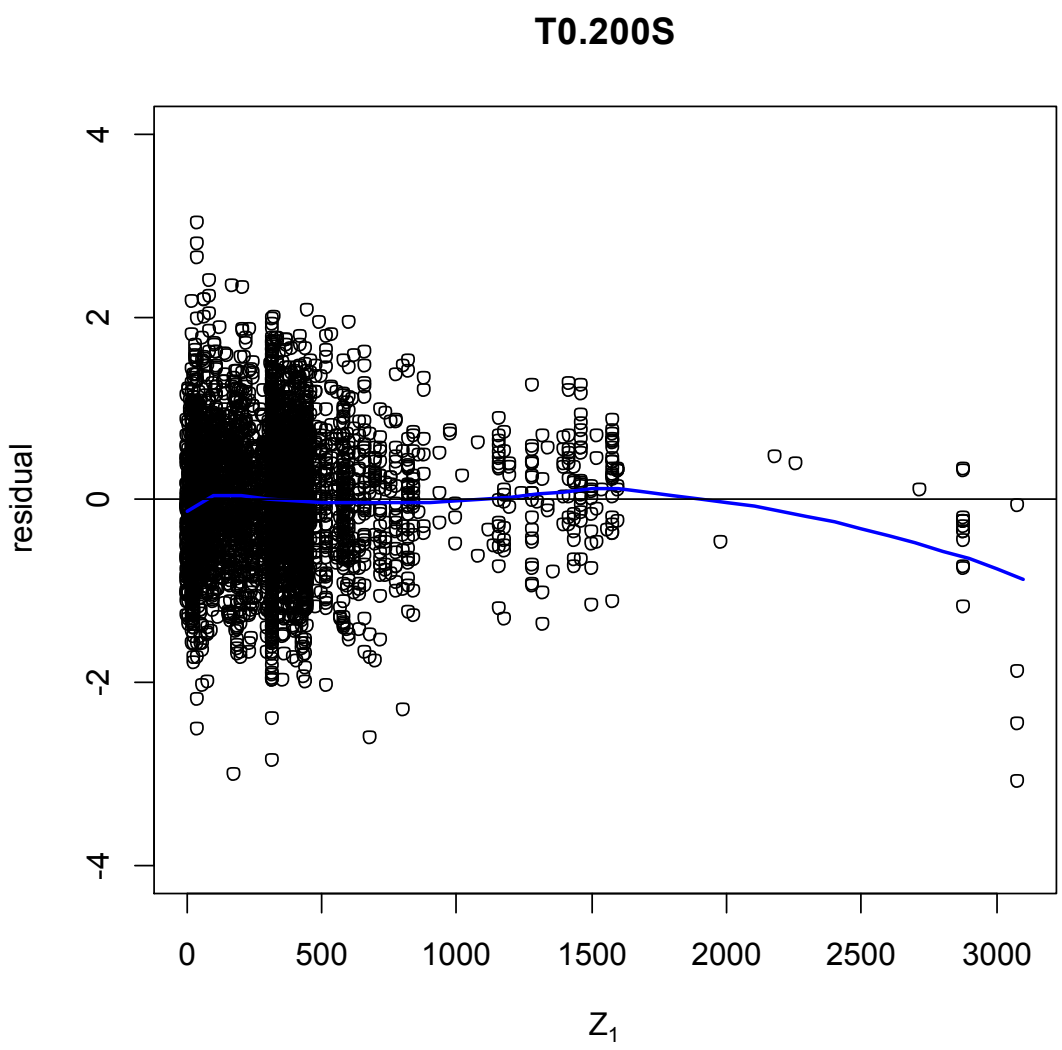

T0.010S
residual
4
3
2
1
0
-1
-2
-3
-4
0.1
1
10
100
R_{RUP}

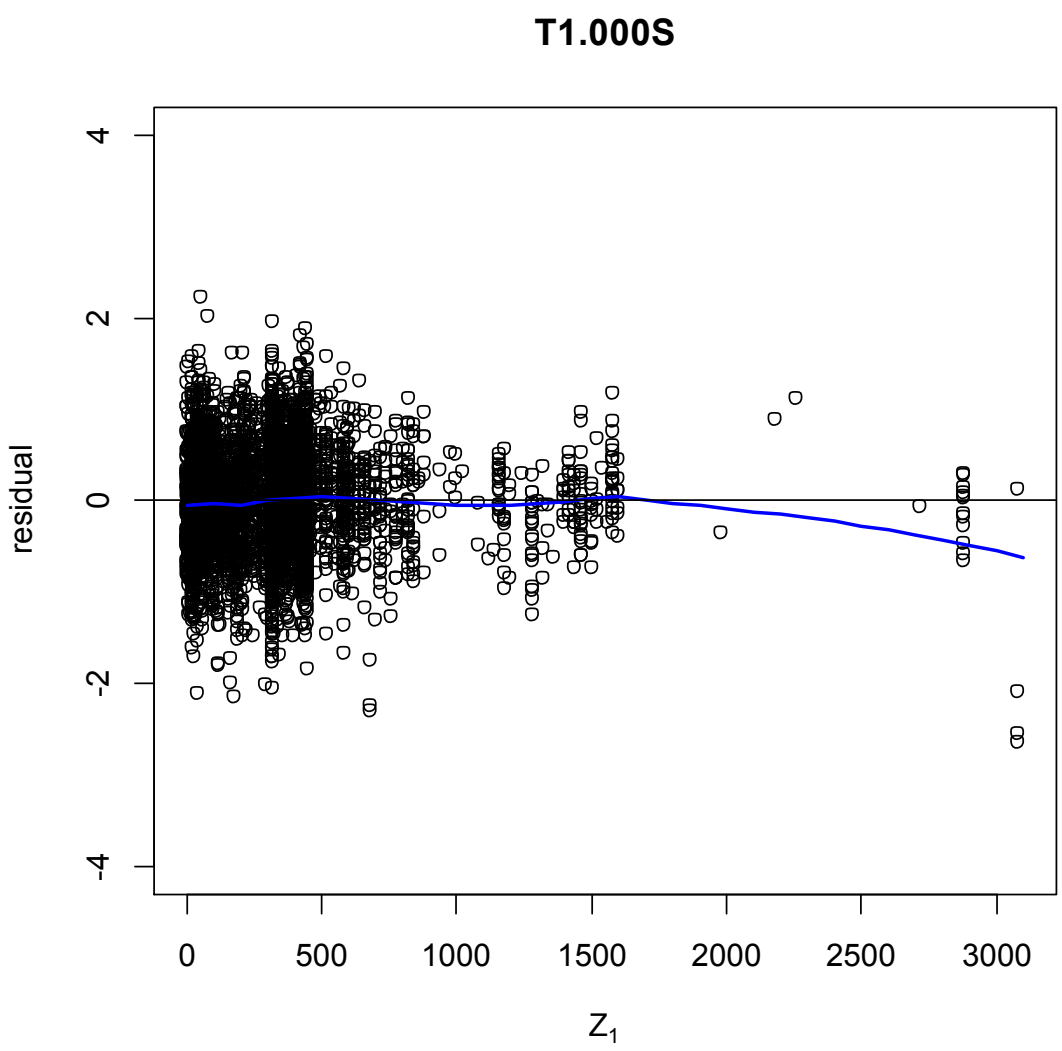

T0.200S
residual
4
3
2
1
0
-1
-2
-3
-4
0.1
1
10
100
R_RUP


T1.000S
residual
4
3
2
1
0
-1
-2
-3
-4
0.1
1
10
100
R_RUP

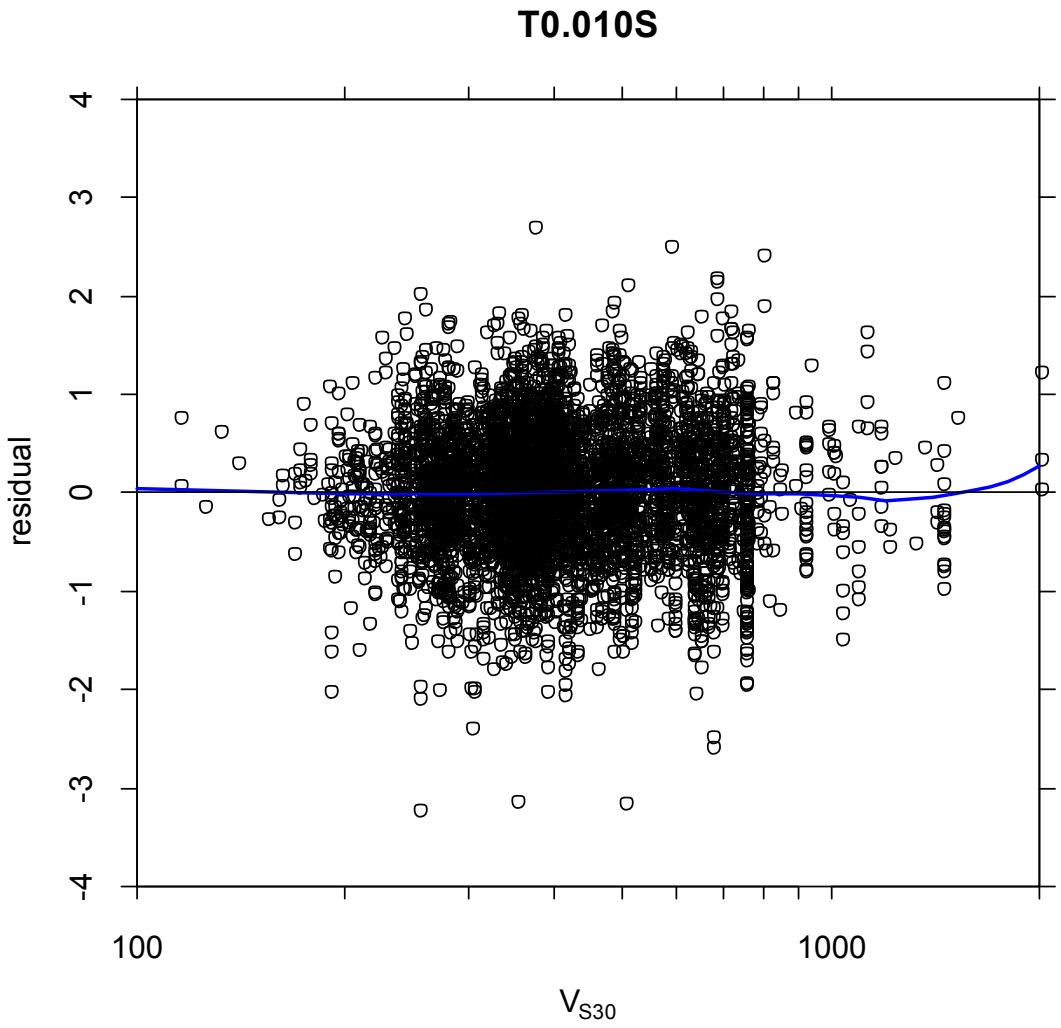
Preliminary Model Intra-event Residuals Versus $Z_{1.0}$ Using CY2008 $Z_{1.0}$ Scaling

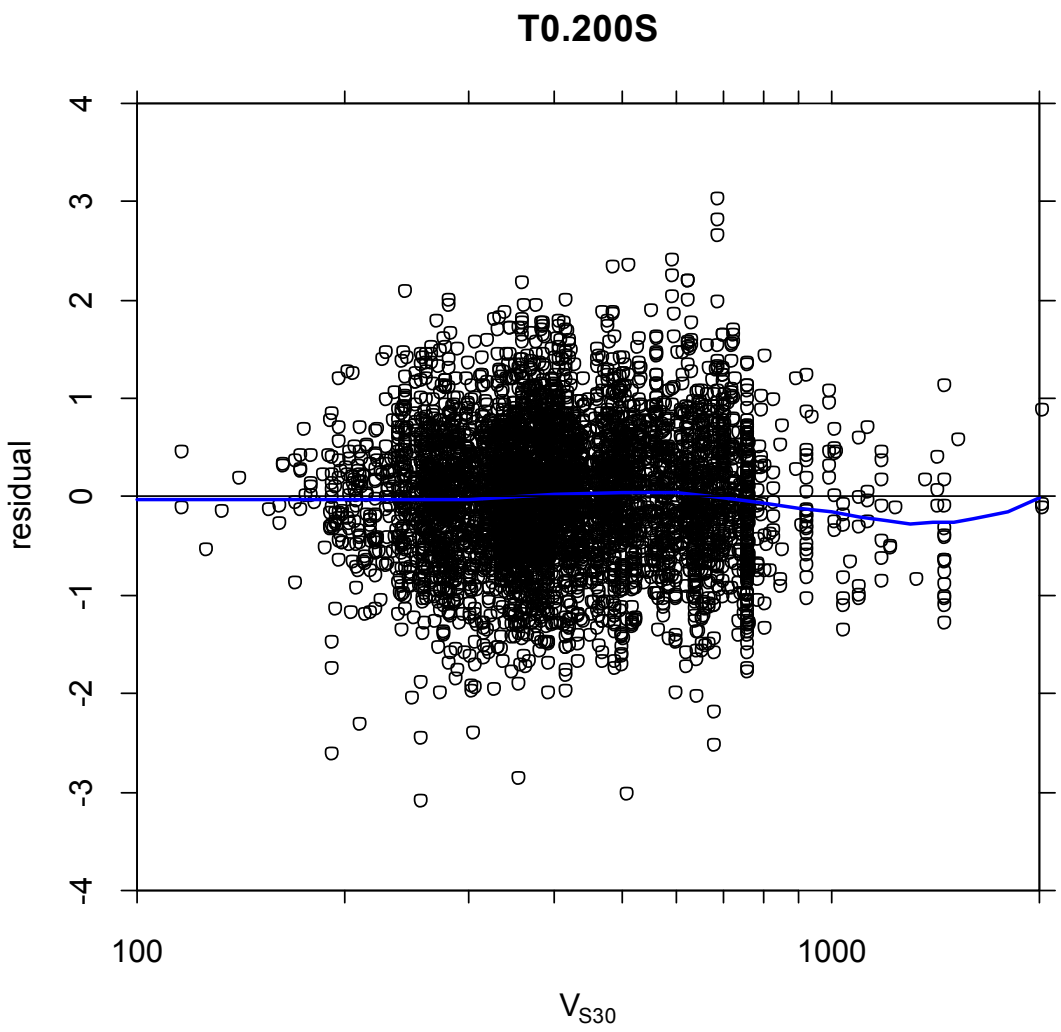

T0.010S
residual
4
2
0
-2
-4
0
500
1000
1500
2000
2500
3000
Z1

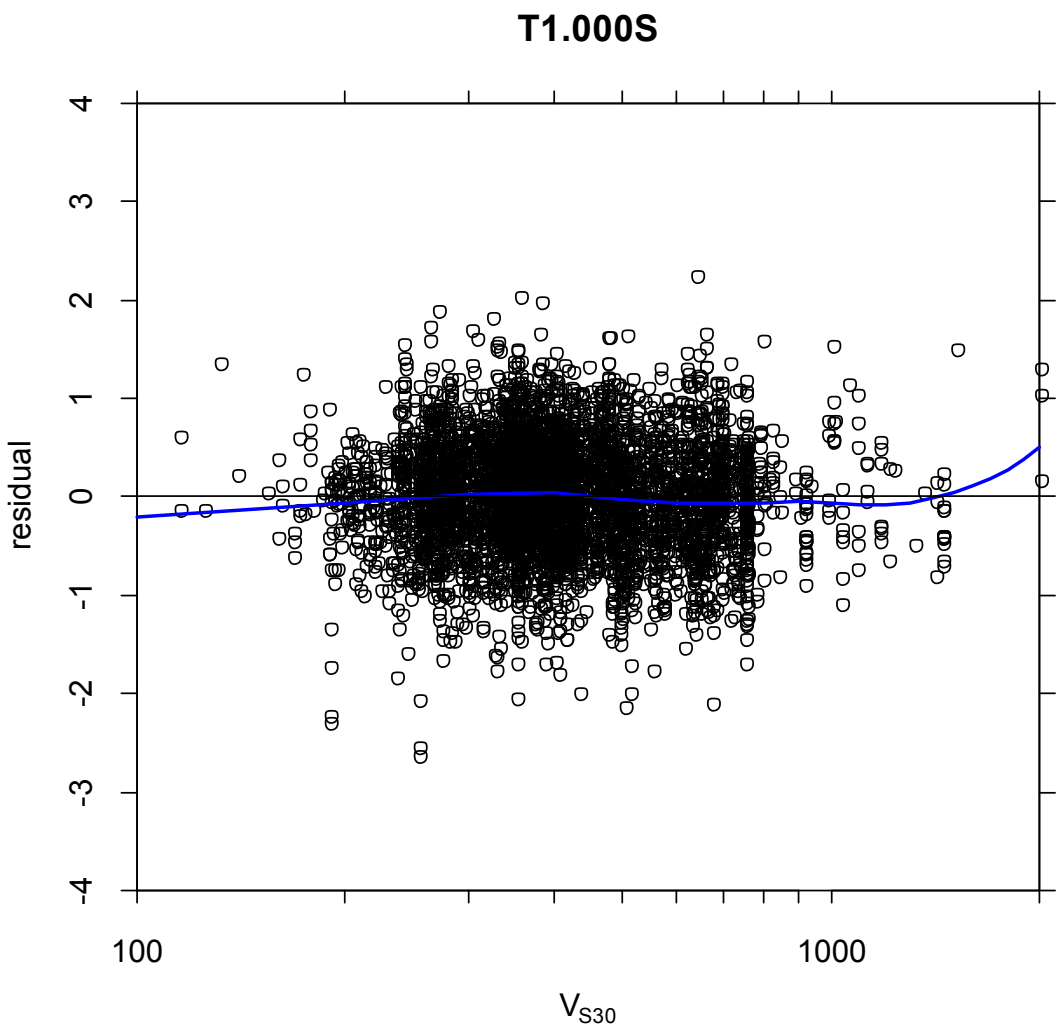

T0.200S
residual
4
2
0
-2
-4
0
500
1000
1500
2000
2500
3000
Z1

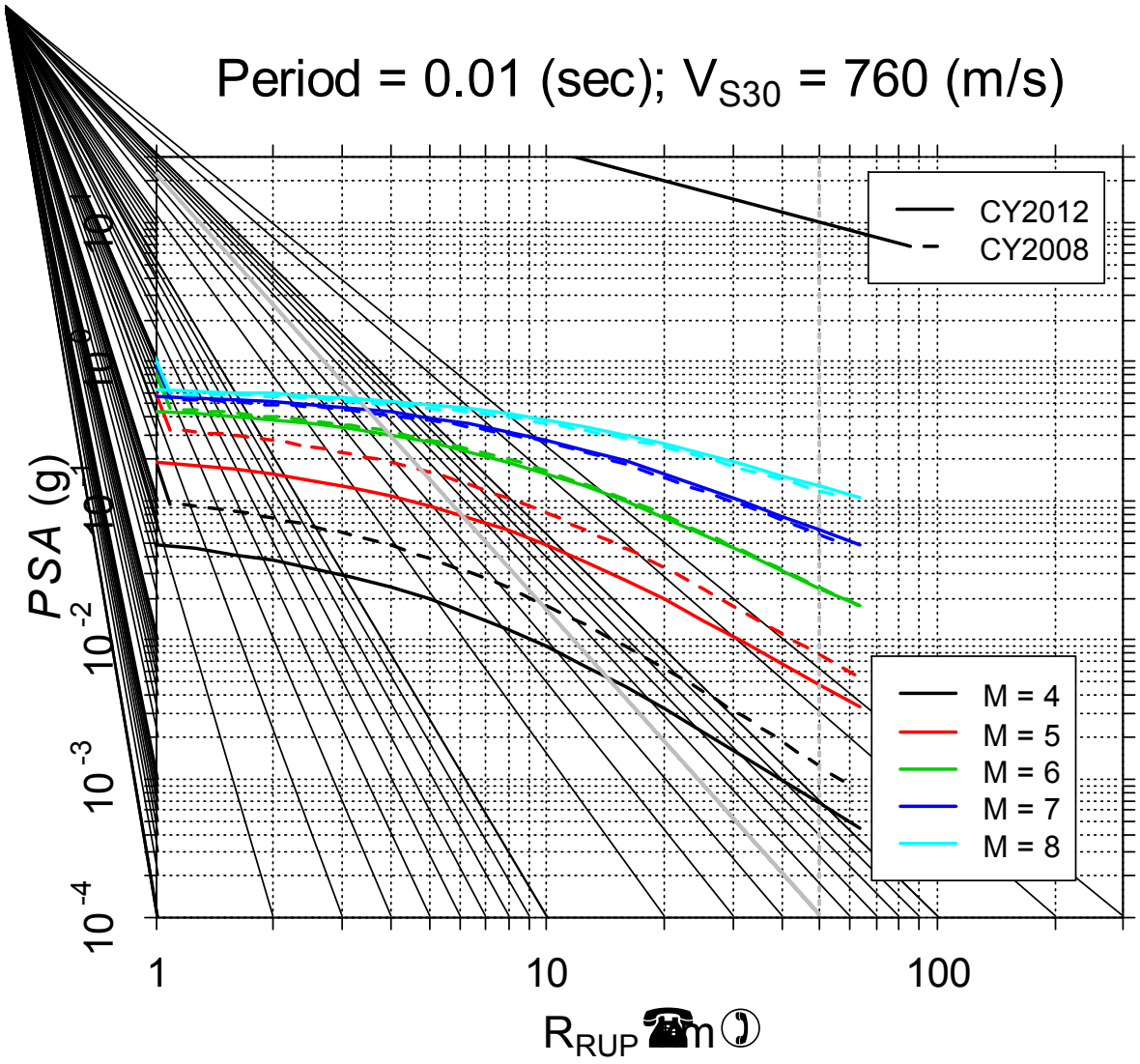

T1.000S
residual
4
2
0
-2
-4
0
500
1000
1500
2000
2500
3000
Z_1

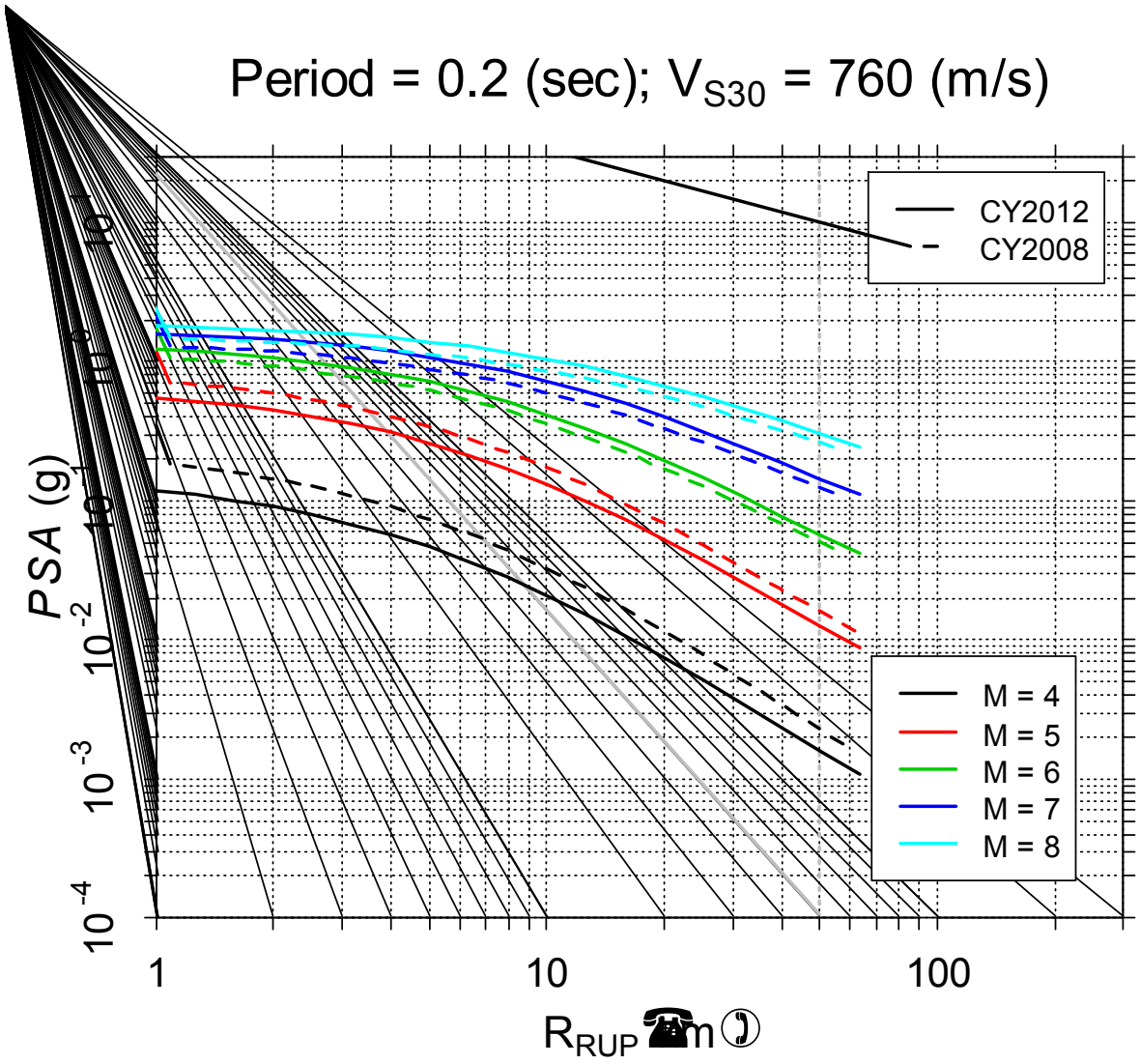
Preliminary Model Intra-event Residuals Versus V_{S30} Using CY2008 Model

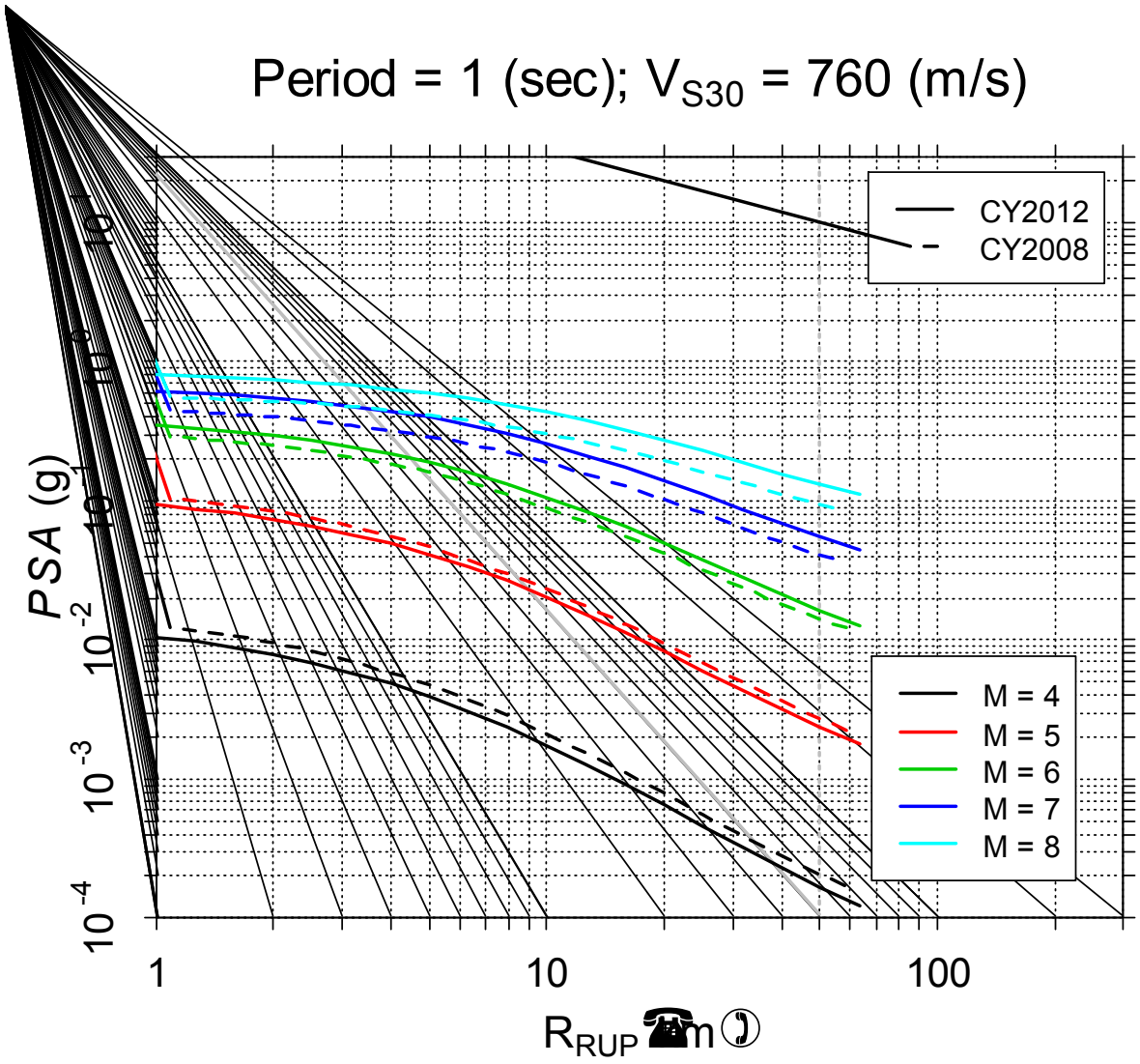

T0.010S
residual
4
3
2
1
0
-1
-2
-3
-4
100
1000
V_{S30}

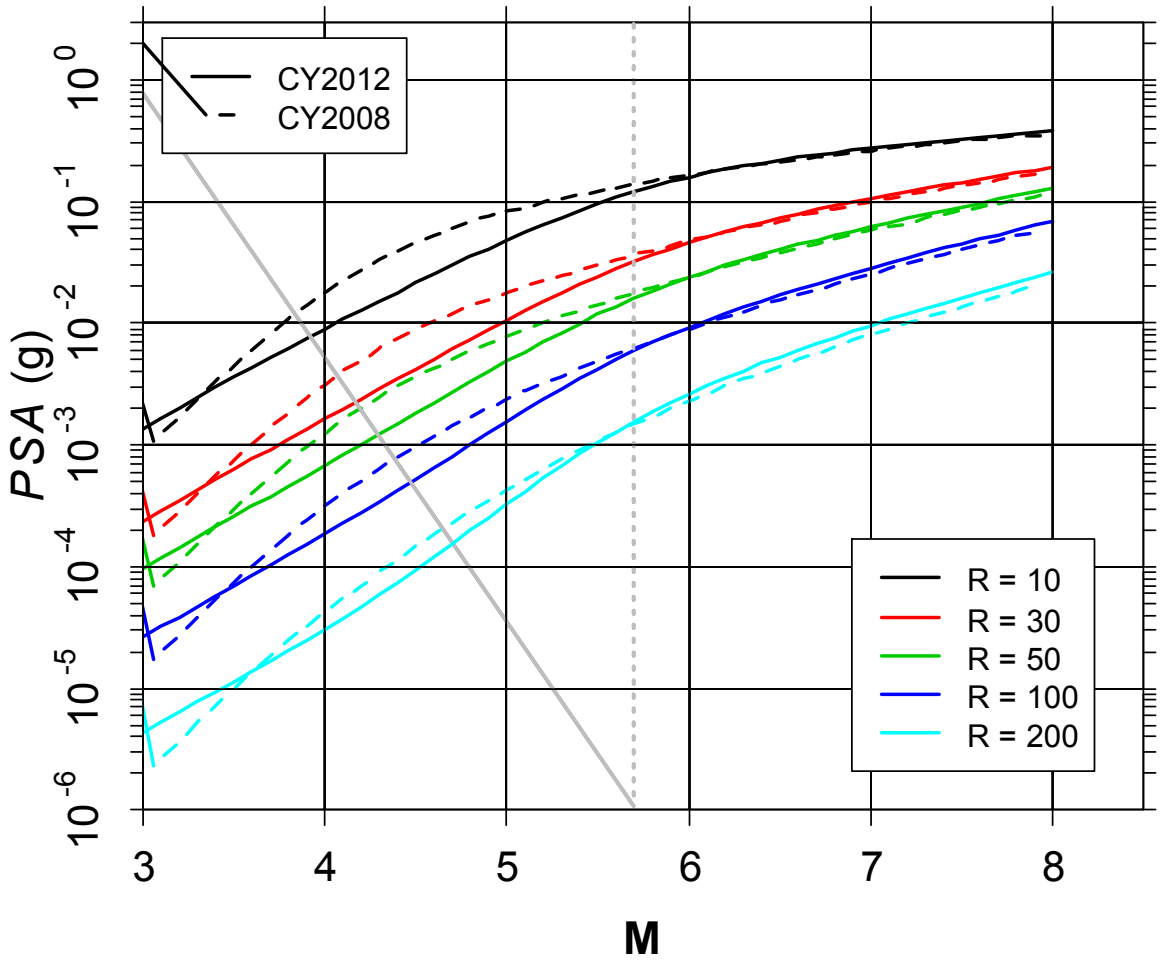

T0.200S
residual
4
3
2
1
0
-1
-2
-3
-4
100
1000
V_{S30}

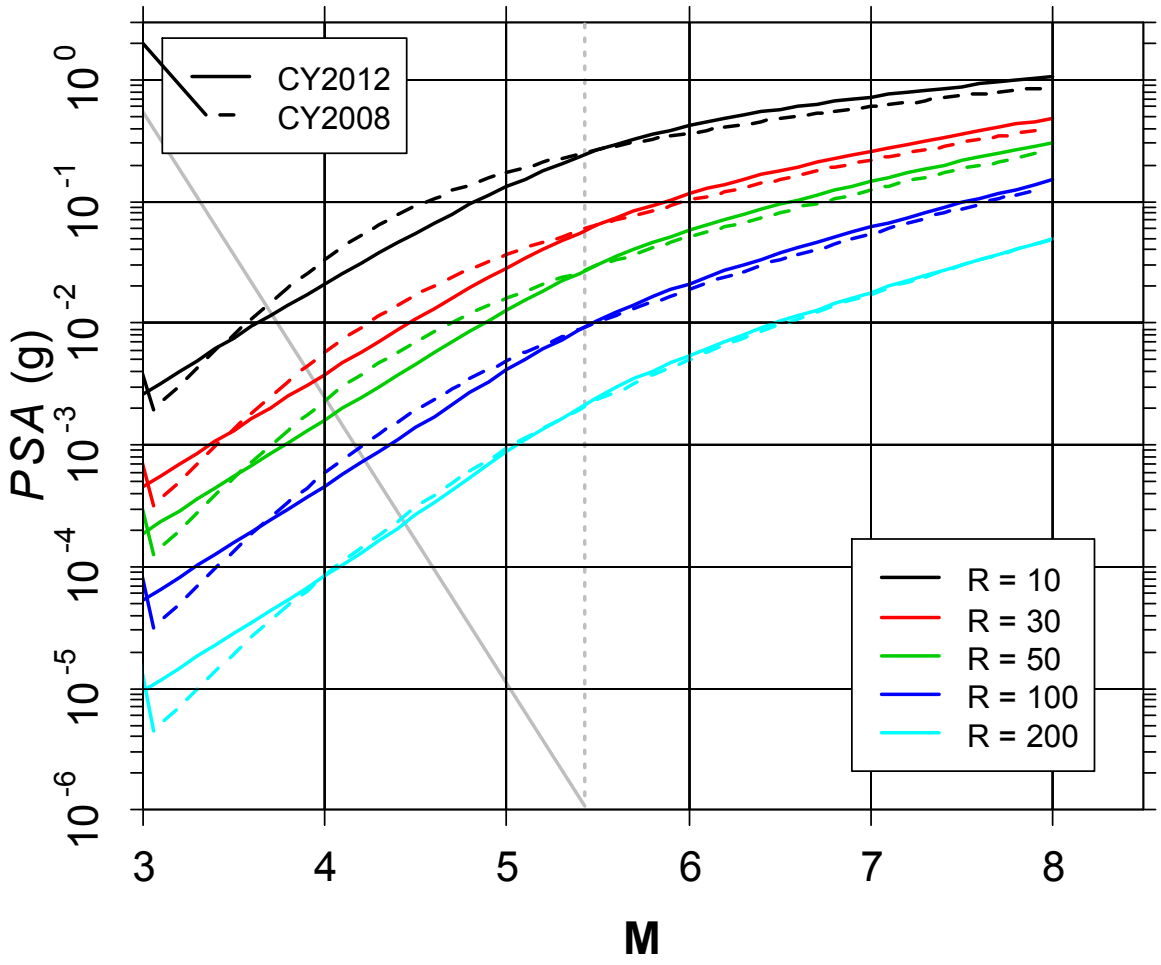

T1.000S
residual
4
3
2
1
0
-1
-2
-3
-4
100
1000
V_{S30}

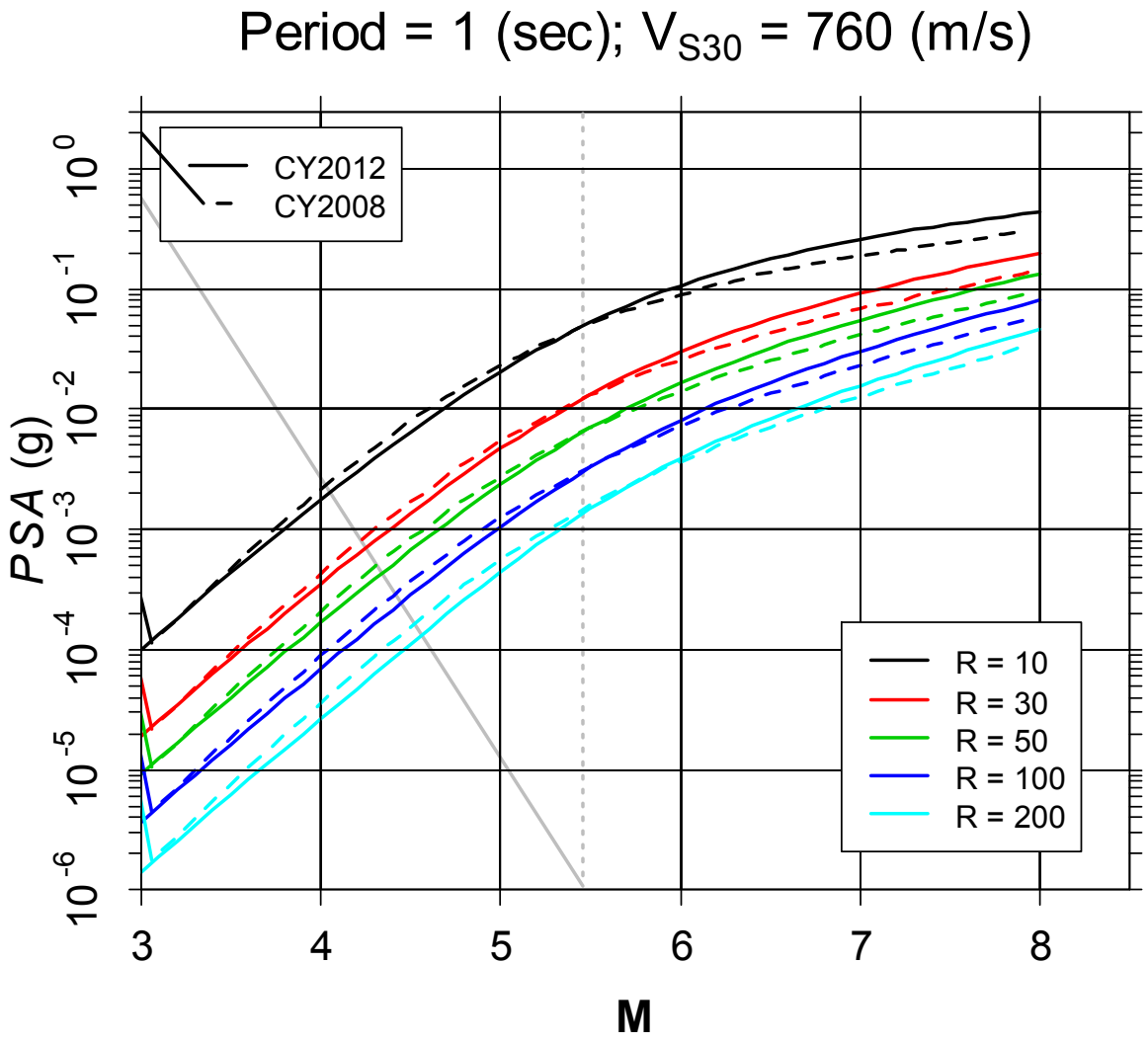

Period = 0.01 (sec); V_{S30} = 760 (m/s)
CY2012
CY2008
M = 4
M = 5
M = 6
M = 7
M = 8
PSA (g)
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
10
100
R_{RUP} ☎m✆


Period = 0.2 (sec); V_{S30} = 760 (m/s)
CY2012
CY2008
M = 4
M = 5
M = 6
M = 7
M = 8
PSA (g)
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
10
100
R_{RUP} ☎m✆


Period = 1 (sec); V_{S30} = 760 (m/s)
CY2012
CY2008
M = 4
M = 5
M = 6
M = 7
M = 8
PSA (g)
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
10
100
R_{RUP} ☎m◑


Period = 0.01 (sec); V_{S30} = 760 (m/s)
CY2012
CY2008
R = 10
R = 30
R = 50
R = 100
R = 200
PSA (g)
M
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
3
4
5
6
7
8


Period = 0.2 (sec); V_{S30} = 760 (m/s)
CY2012
CY2008
R = 10
R = 30
R = 50
R = 100
R = 200
PSA (g)
M
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
3
4
5
6
7
8


Period = 1 (sec); V_{S30} = 760 (m/s)
CY2012
CY2008
R = 10
R = 30
R = 50
R = 100
R = 200
PSA (g)
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
3
4
5
6
7
8
M

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 (currently unchanged from CY2008)
- Incorporate directivity model (Spudich and Chiou 2012 version likely choice)
- Examine Class 2 scaling
- Analyze aleatory variability
  - Initial results suggest similar values to CY2008 for **M** > 5
  - Greater variability for **M** < 5