

# BSSA12 GMPEs

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# Model Description

- BA08 functional form for  $M$  and  $R_{jb}$  scaling
- Change from BA08:
  - Modified  $V_{s30}$ -scaling from NGA-West2 Task 8.

## The GMPE (same as used in BA08, except for $F_s$ )

$$\ln Y = F_M(\mathbf{M}) + F_D(R_{JB}, \mathbf{M}) + F_S(V_{S30}, R_{JB}, \mathbf{M}) + \varepsilon\sigma$$

$F_M$ ,  $F_D$ ,  $F_S$  are magnitude, distance, and site functions.  $\varepsilon$  is the fractional number of standard deviations of a single predicted value of away from the mean value of (*e.g.*, would be 1.5 standard deviations smaller than the mean value). All terms, including the coefficient  $\sigma$ , are period dependent.  $\sigma$  is computed using the equation

$$\sigma = \sqrt{\phi^2 + \tau^2}$$

where  $\phi$  is the intra-event aleatory uncertainty and  $\tau$  is the inter-event aleatory uncertainty.

# The Distance and Magnitude Functions

Distance dependence:

$$F_D(R_{JB}, \mathbf{M}) = [c_1 + c_2(\mathbf{M} - \mathbf{M}_{ref})] \ln(R / R_{ref}) + c_3(R - R_{ref})$$

where

$$R = \sqrt{R_{JB}^2 + h^2}$$

# The Magnitude Function

Magnitude Dependence (Primary):

For  $M \leq M_h$ :

$$F_M(\mathbf{M}) = e_1 SS + e_2 NS + e_3 RS + e_4(\mathbf{M} - \mathbf{M}_h) + e_5(\mathbf{M} - \mathbf{M}_h)^2$$

For  $M > M_h$ :

$$F_M(\mathbf{M}) = e_1 SS + e_2 NS + e_3 RS + e_6(\mathbf{M} - \mathbf{M}_h)$$

$$(e_6 \geq 0.0)$$

Mechanism	SS	NS	RS
strikeslip	1	0	0
normal	0	1	0
reverse	0	0	1

# The Site Amplification Function

$$F_S = F_{LIN} + F_{NL}$$

Linear Amplification:

$$F_{LIN} = b_{lin} \ln(V_{S30} / V_{ref})$$

$$(V_{ref} = 760 \text{ m/s})$$

The coefficient  $b_{lin}$  depends on period. We use the Stewart and Seyhan (2012) model.

# The Site Amplification Function

$$F_S = F_{LIN} + F_{NL}$$

Nonlinear Amplification:

$$F_{NL} = b_{nl} \ln \left( \frac{PGA_{760\text{m/s}} + 0.1g}{0.1g} \right)$$

The coefficient  $b_{nl}$  depends on period and  $V_{S30}$ . We use Stewart and Seyhan's (2012) model 2, where  $b_{nl}$  is called  $f_2$ .

# Not Included

- Directivity
- Basin depth
- Hanging wall (using  $R_{JB}$  accounts for this to some extent)
- Other possible predictor variables (e.g., dip, Ztor, etc.)



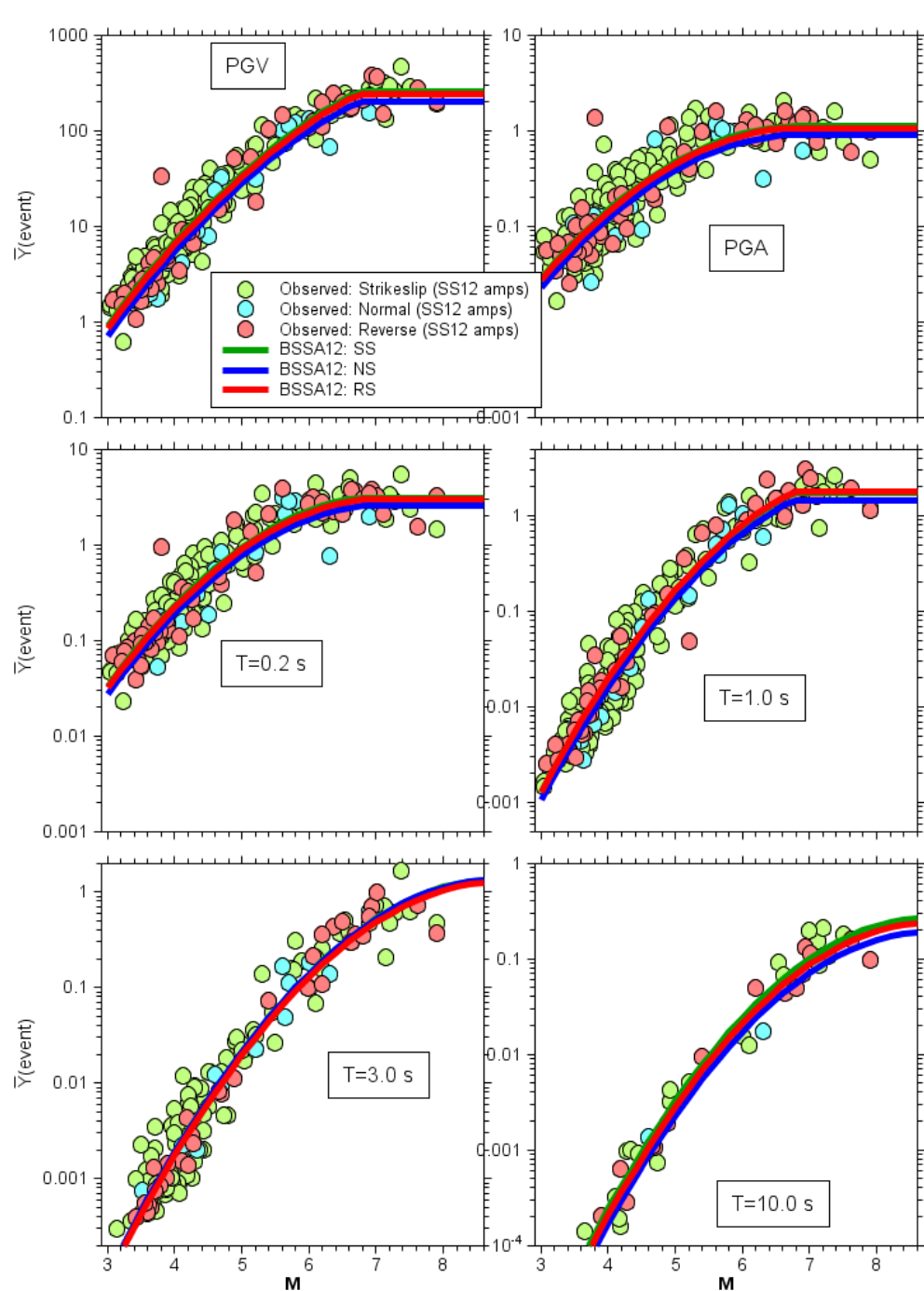
# Determination of Coefficients (2-stage regression)

- Select data:
  - no basement or large structure records, etc;
  - $R_{JB} < 80$  km
  - event class 1, as determined by  $CR_{JB}=10$  km
- Adjust observations to  $V_{s30}=760$  m/s using SS12 site amps
- Constrain  $c_3$  (anelastic term) to the BA08 values
- Regress for other coefficients, including pseudodepth  $h$

## Stage 2 regressions

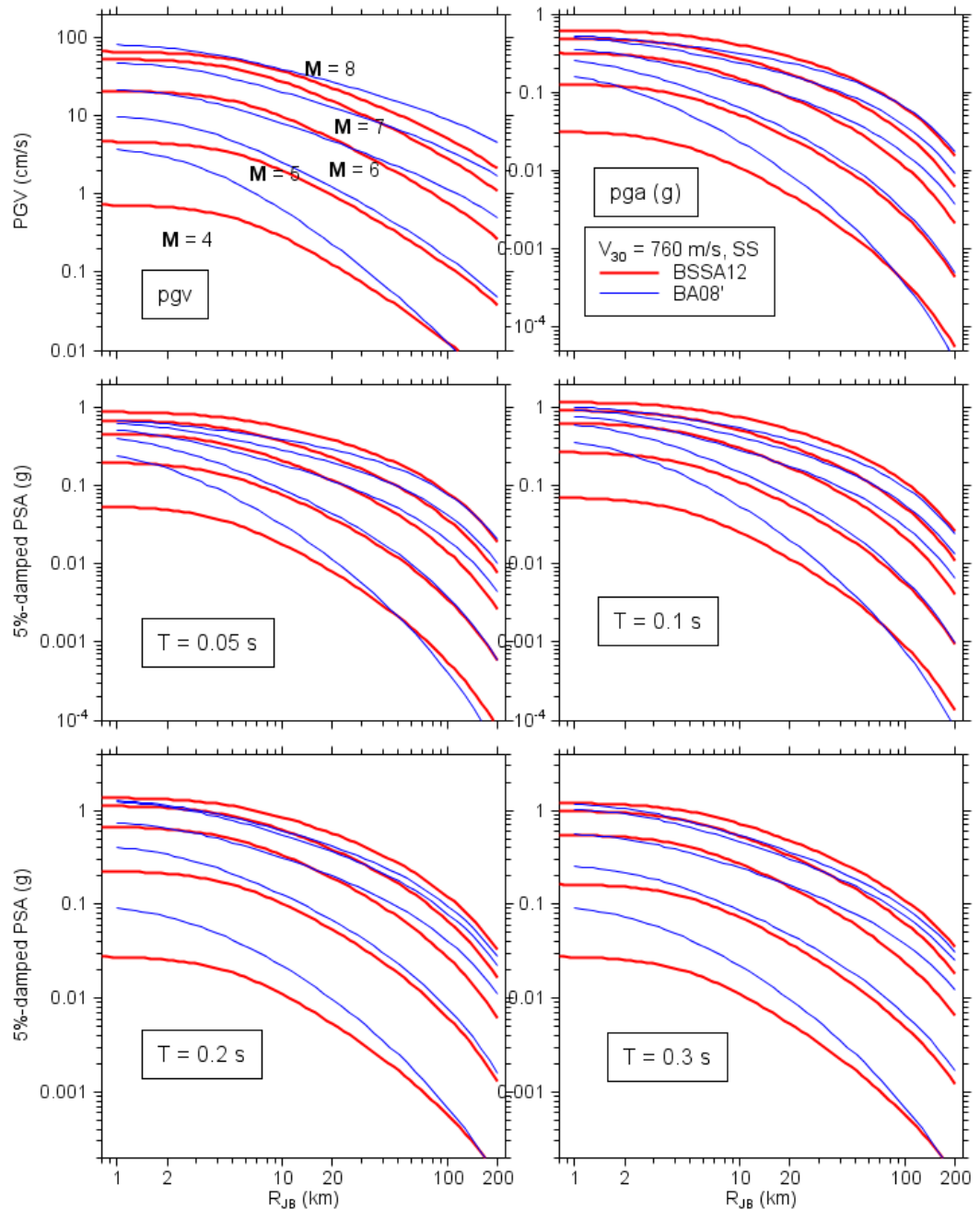
All but  $T=3.0, 10$  s: quadratic to 6.75; linear beyond, not allowed to go negative

$T=3.0, 10$  s: quadratic



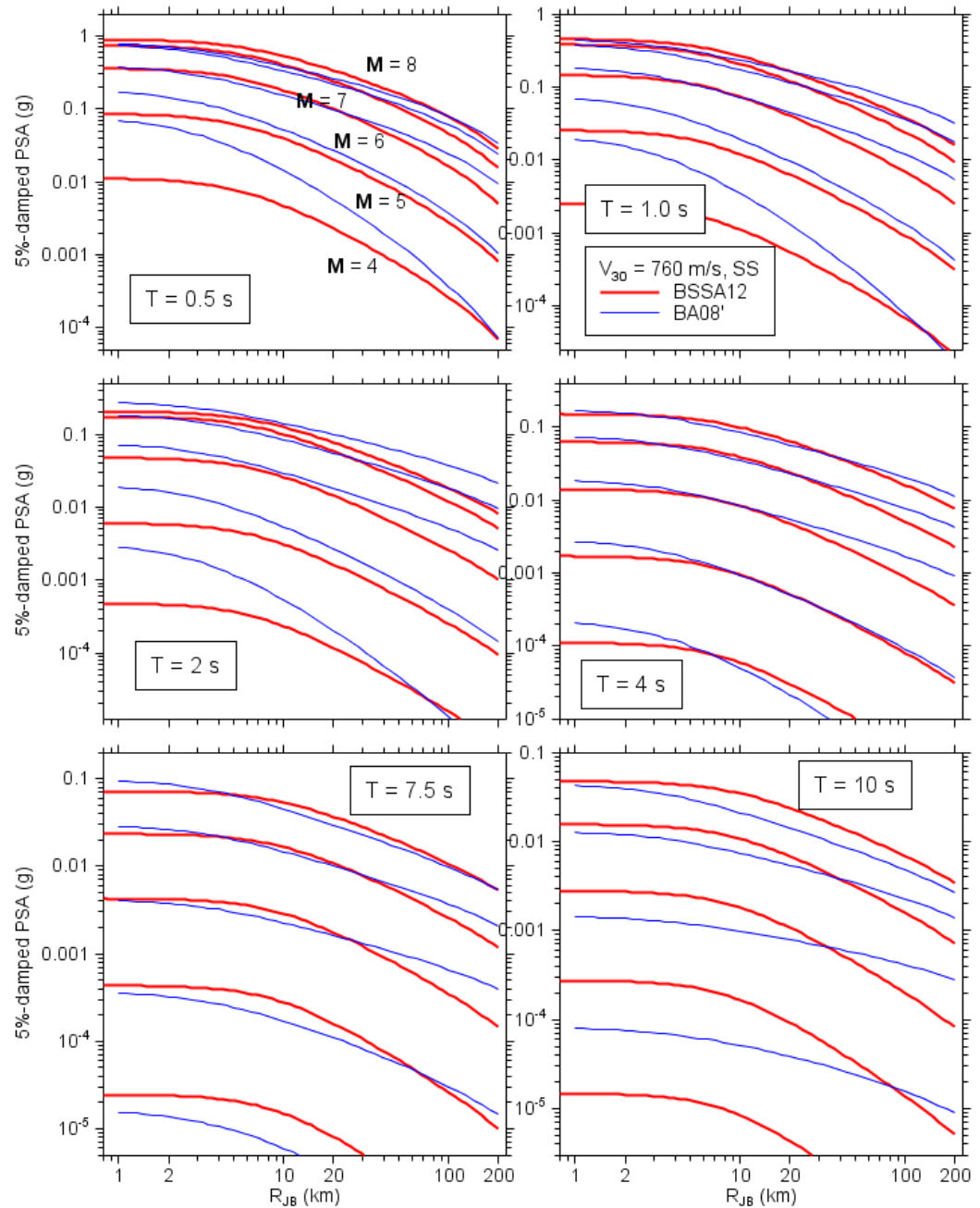
IM vs R, shorter periods  
(except PGV)

Compare BSSA12 and  
BA08' (for BA08' almost no  
data were available for  
 $M < 4.2$ )



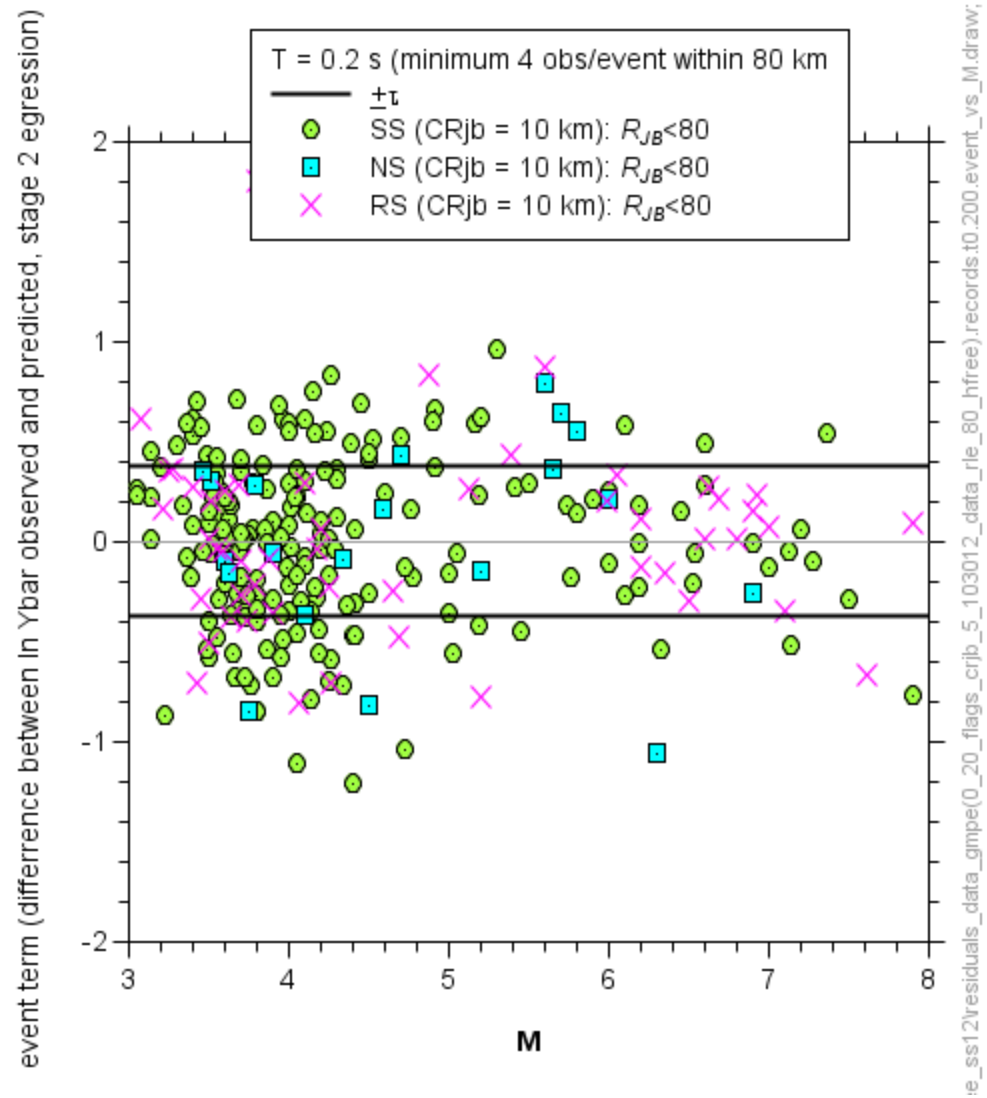
IM vs R, longer periods

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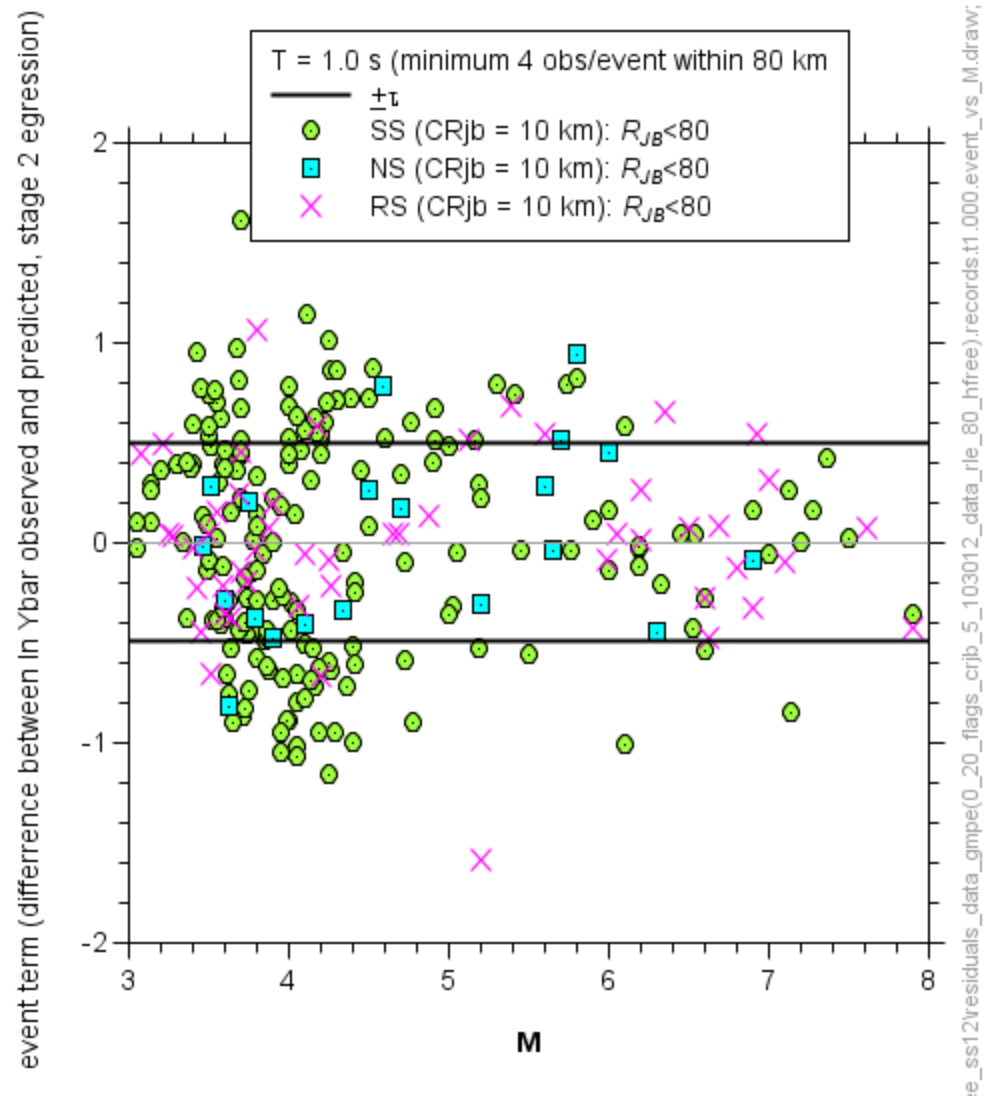
Interevent residuals vs  $M$  ( $T=0.2s$ )

Note that  $\tau$  seems to be overestimated for larger  $M$



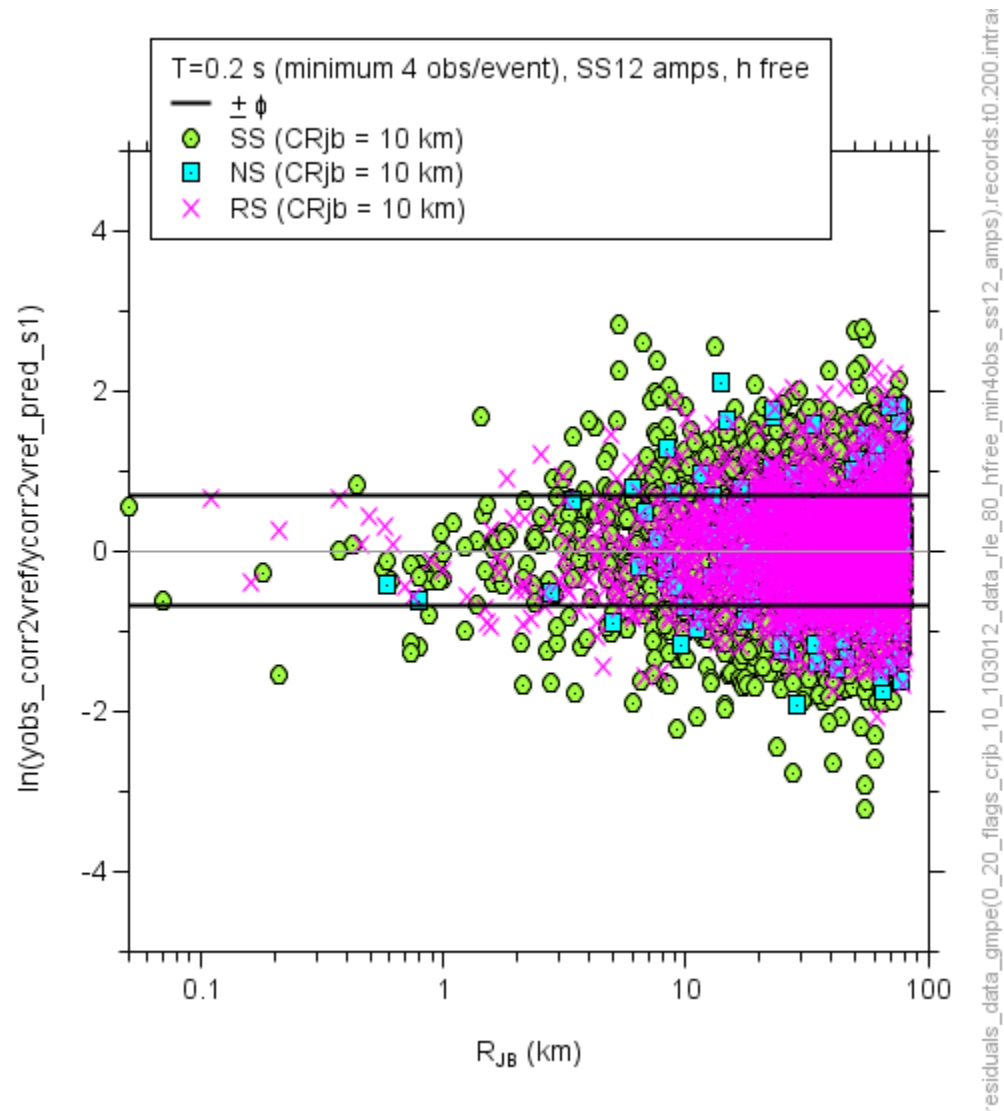
Interevent residuals vs  $M$  ( $T=1.0s$ )

Note that  $\tau$  seems to be overestimated for larger  $M$



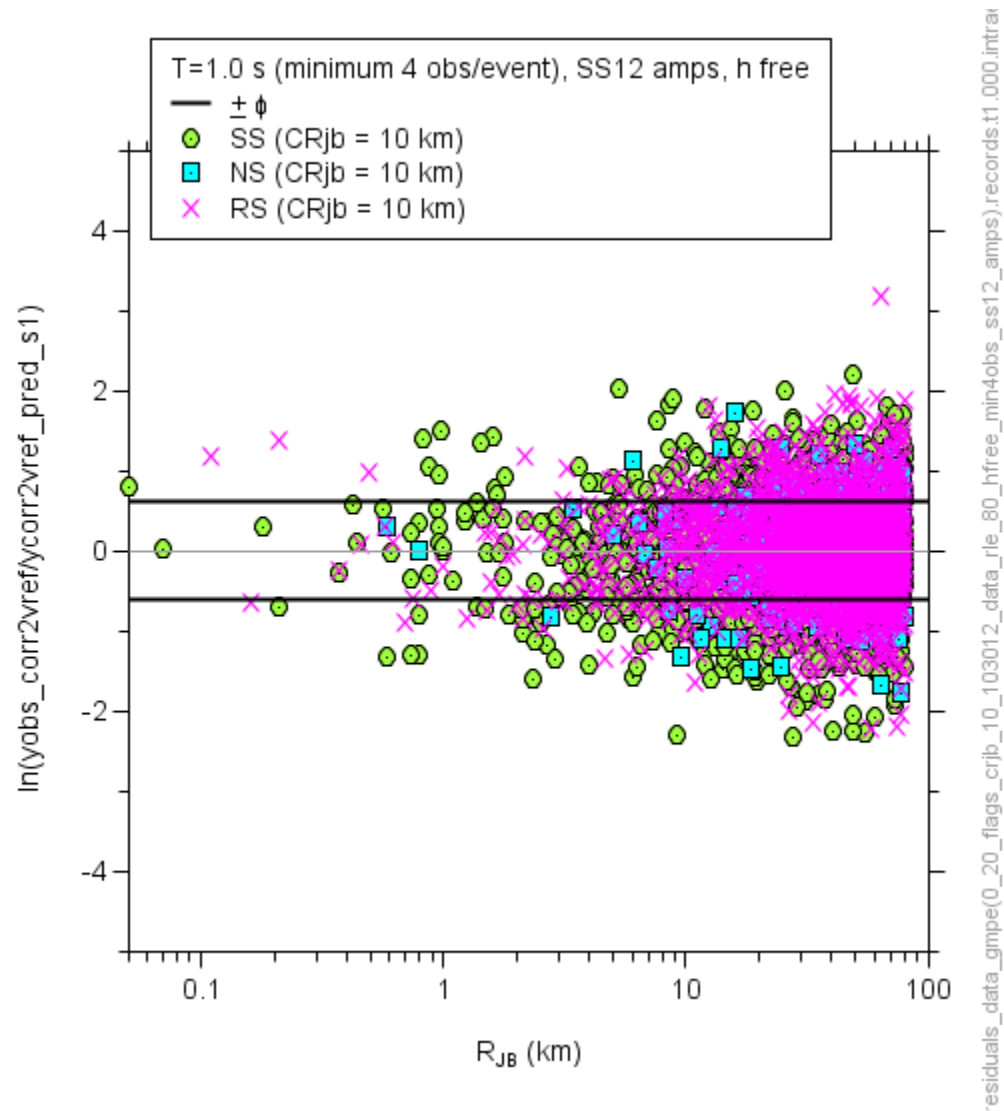
Intraevent residuals vs  $R_{JB}$  ( $T=0.2s$ )

Note that  $\phi$  seems to be overestimated for small  $R_{JB}$



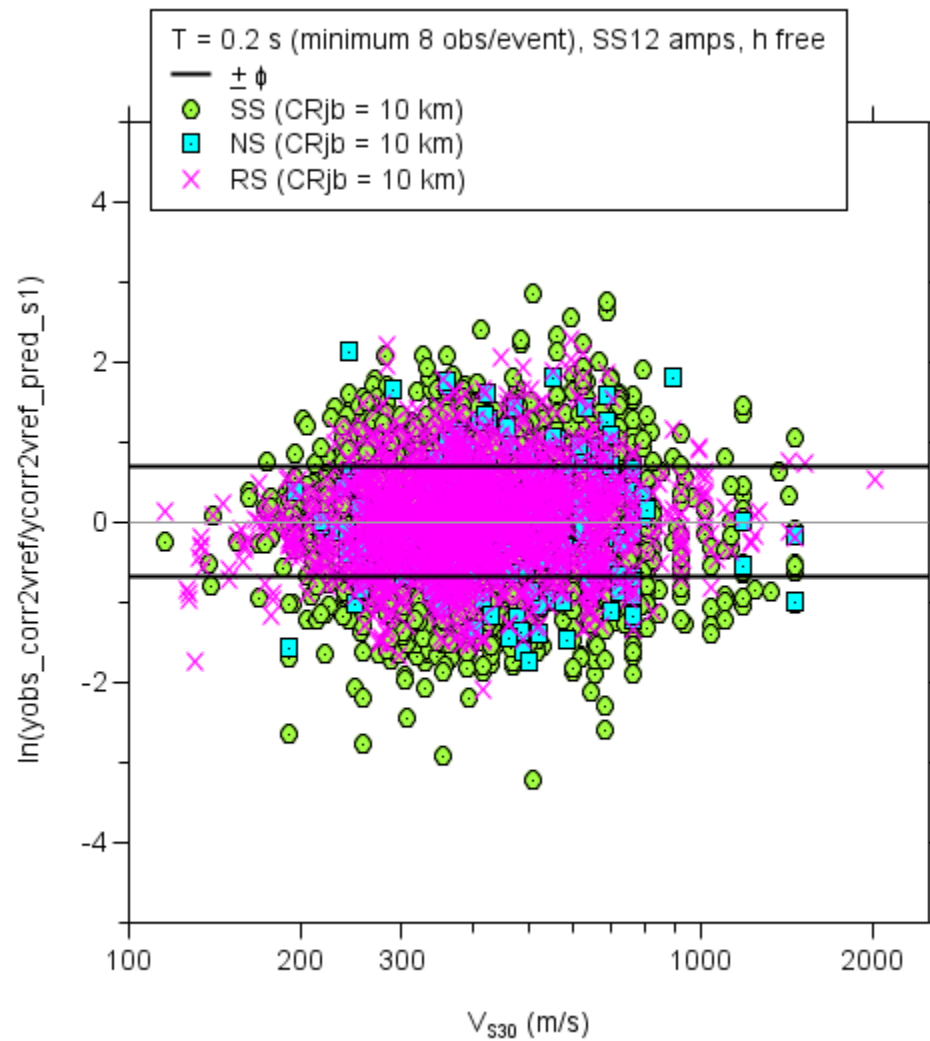
Intraevent residuals vs  $R_{JB}$  ( $T=1.0s$ )

Note that  $\phi$  may be overestimated for small  $R_{JB}$



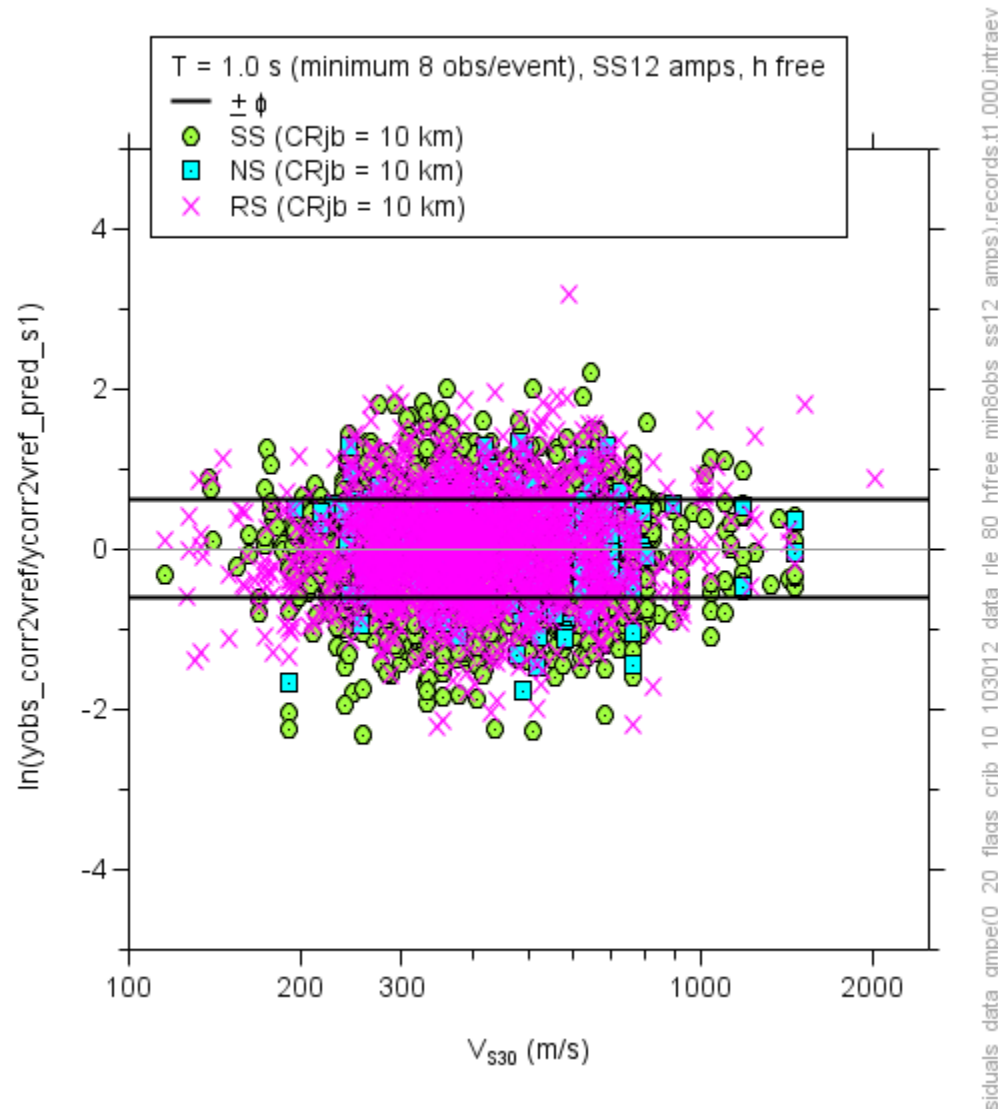


Intraevent residuals vs  $V_{S30}$  (T=0.2s)



siduals\_data\_gmpe(0\_20\_flags\_crijb\_10\_103012\_data\_rle\_80\_hfree\_min8obs\_ss12\_amps).records.t0.200.intraev

Intraevent residuals vs  $V_{S30}$  (T=1.0 s)



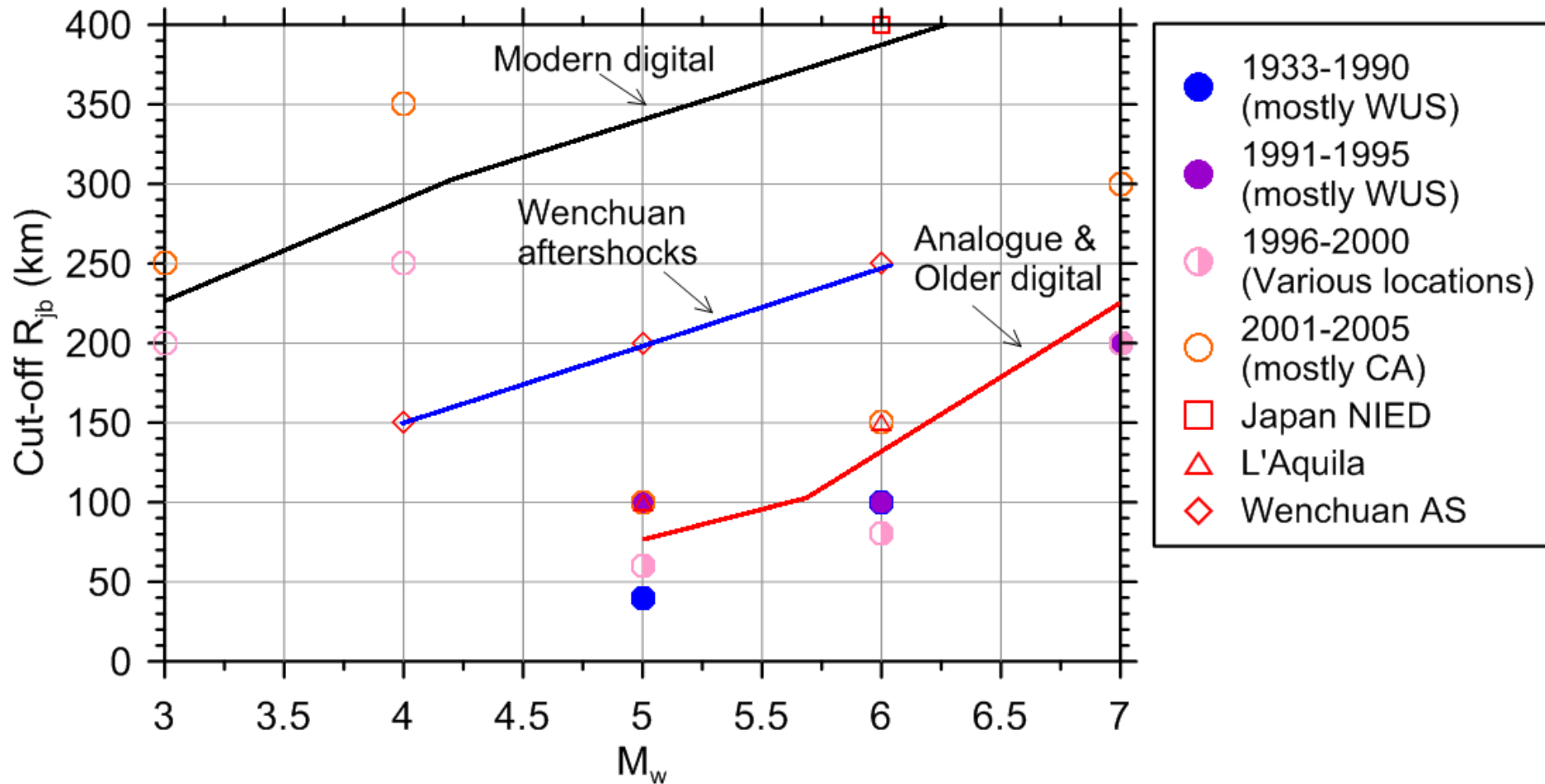
# RE Residuals Analysis

- Purpose: evaluate model performance using broader data set (> 80 km considered, C1 & C2 events, 15600 recordings)
- Procedure: compute  $c$  and  $\eta_i$  from following RE regression ( $i$  is event index,  $j$  is record index):

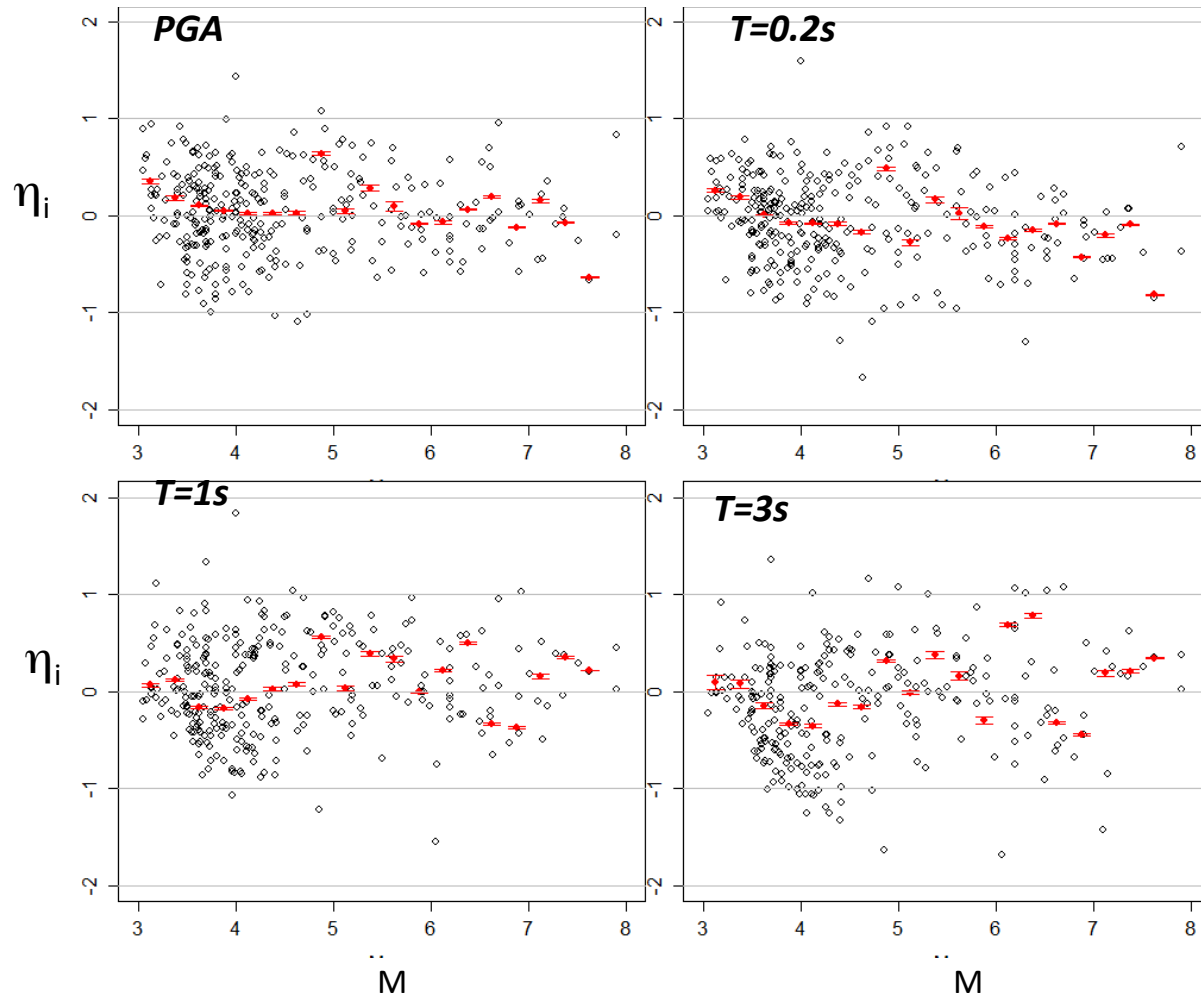
$$R_{i,j} = c + \eta_i + \varepsilon_{i,j}$$

- $\eta_i$  examined relative to source parameters
- $\varepsilon_{ij}$  examined relative to  $R_{jb}$  and  $V_{s30}$
- For evaluation of site effects, also look at rock residuals,  $\varepsilon_{ij}^r$  (computed setting  $V_{s30} = 760$  m/s).

# M and $R_{jb}$ Data Screening

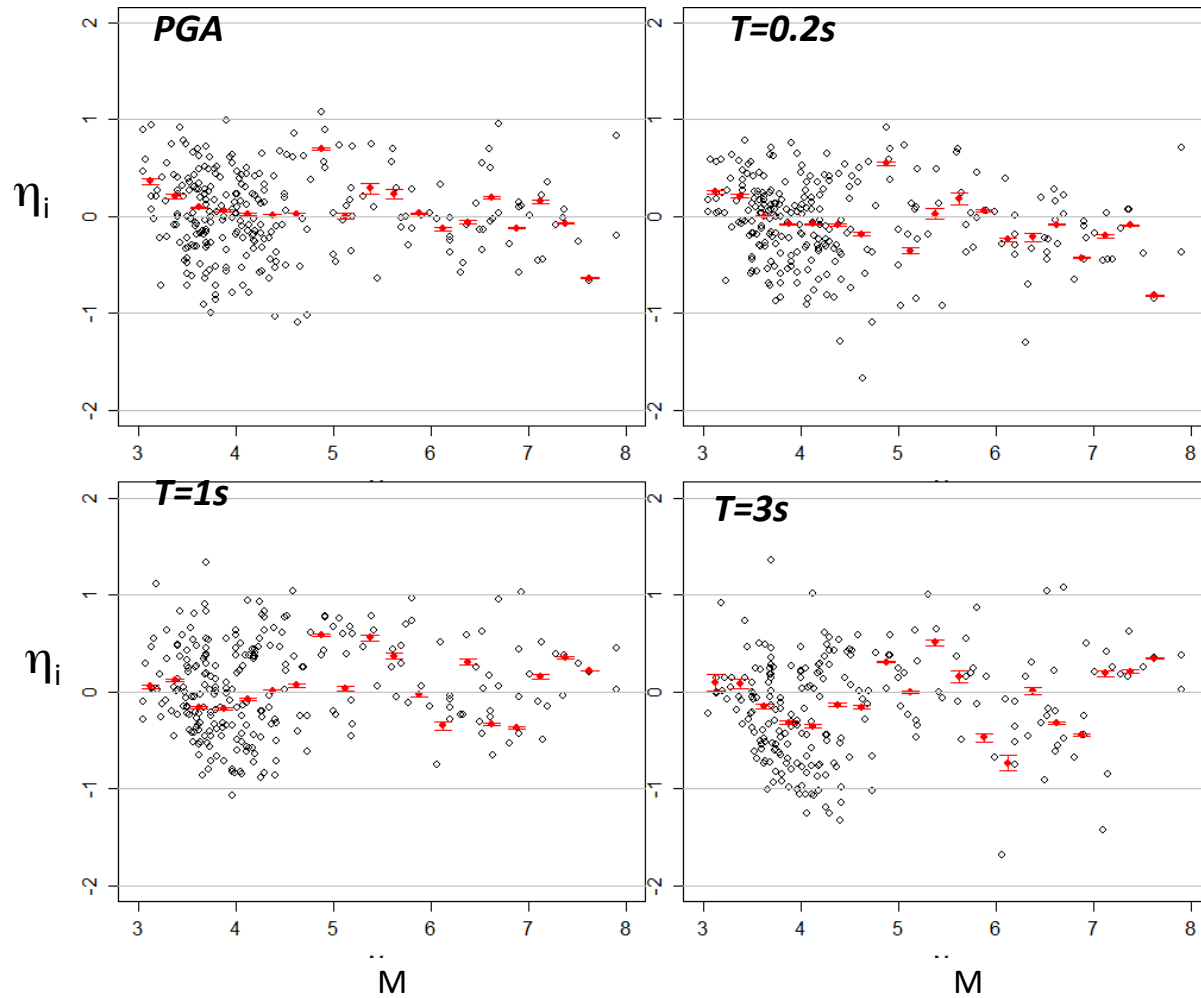


# Event Term Trends



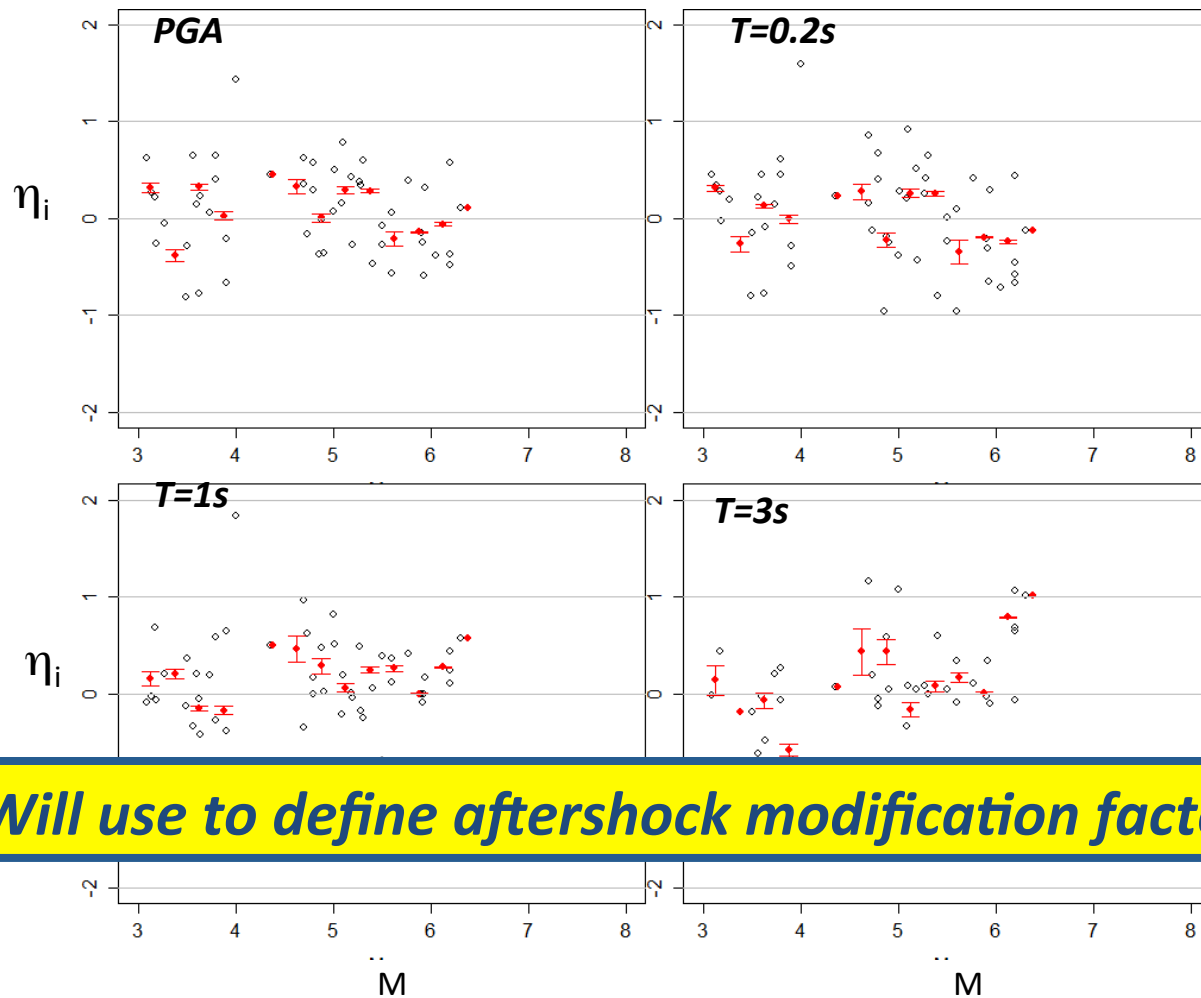
**C1 & C2**  
**CR<sub>jb</sub> 10 km**

# Event Term Trends



**C1**  
**CR<sub>jb</sub> 10 km**

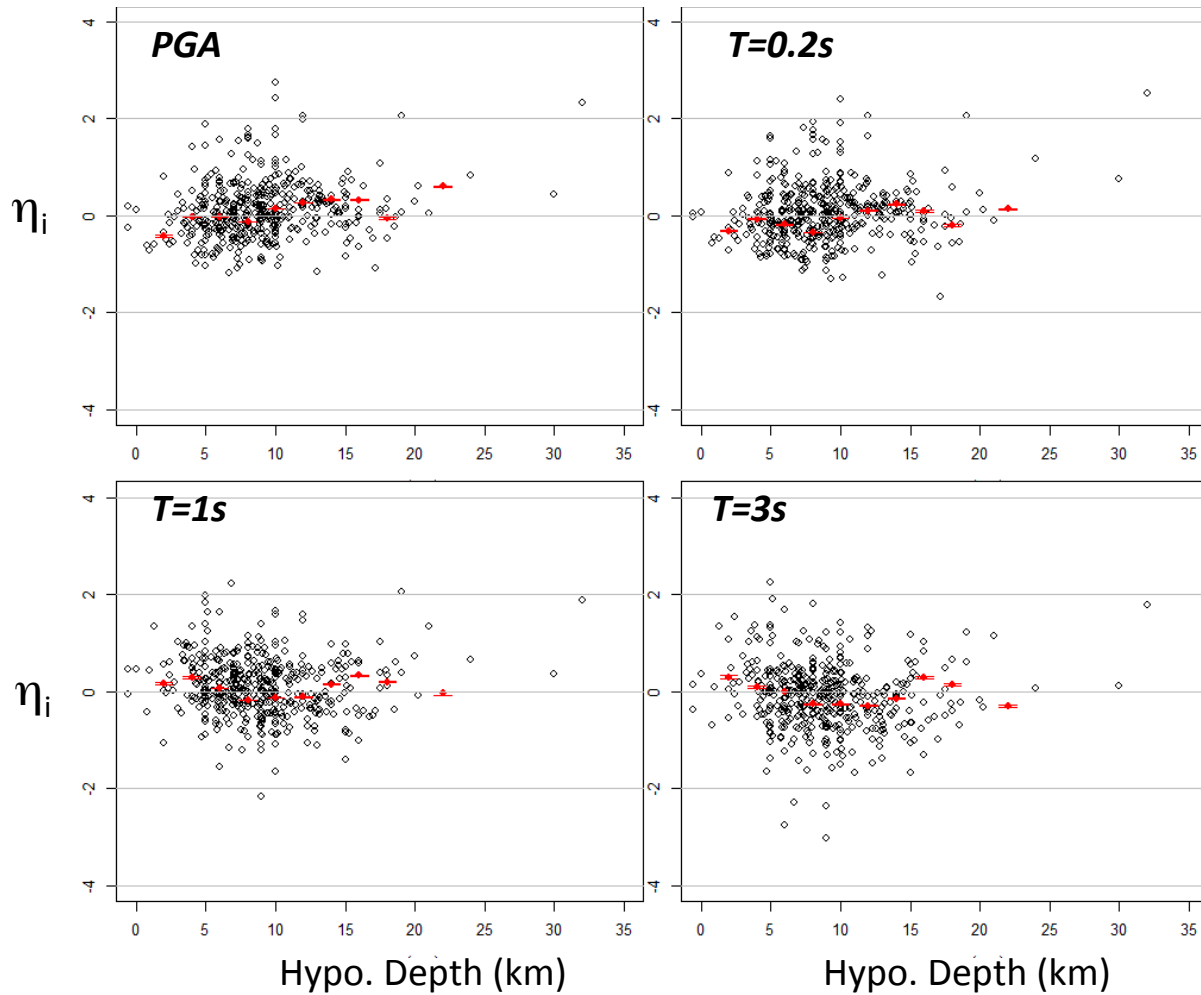
# Event Term Trends



C2  
CR<sub>jb</sub> 10 km

**Will use to define aftershock modification factors**

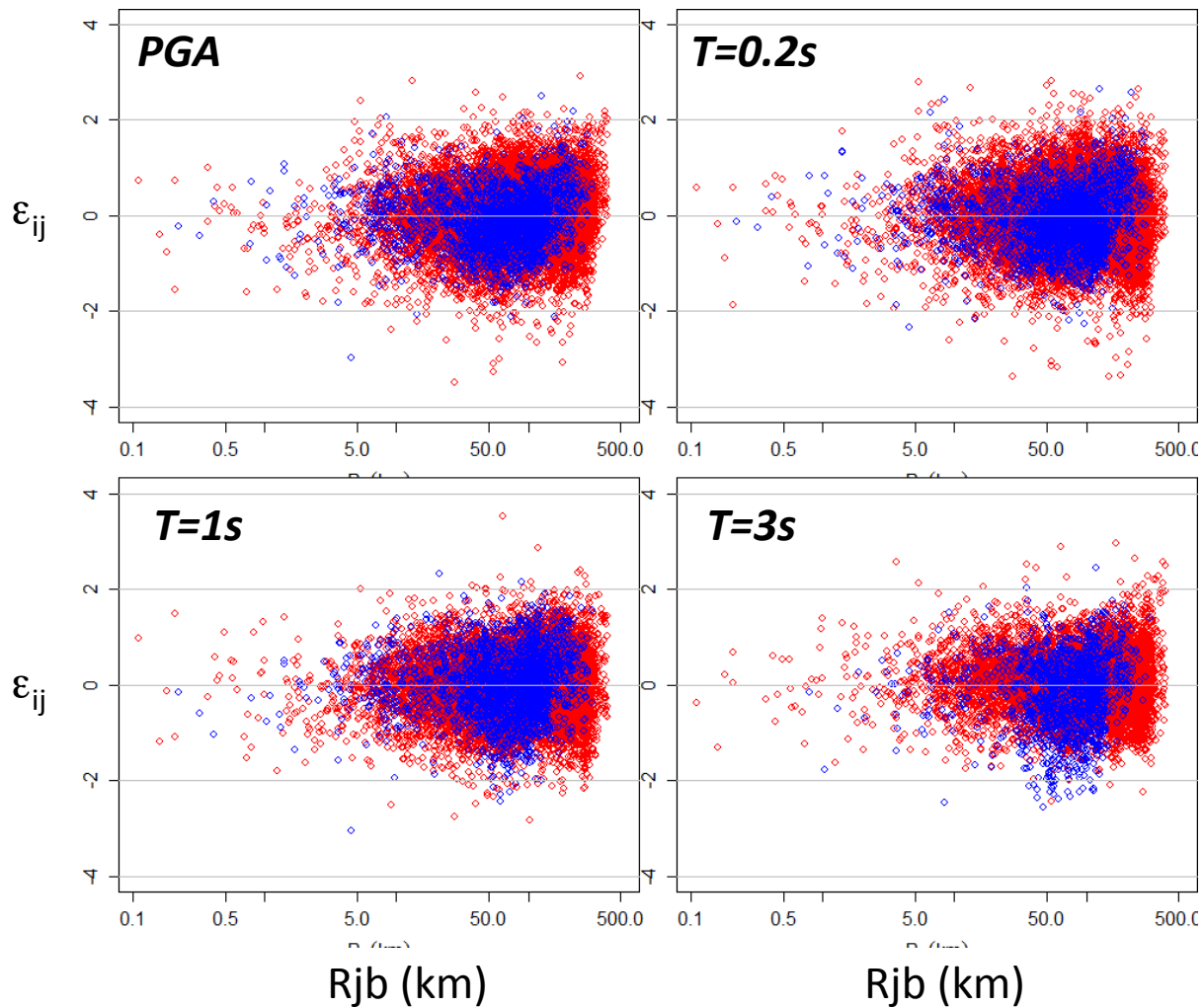
# Event Term Trends



**C1 & C2**  
**CR<sub>jb</sub> 10 km**

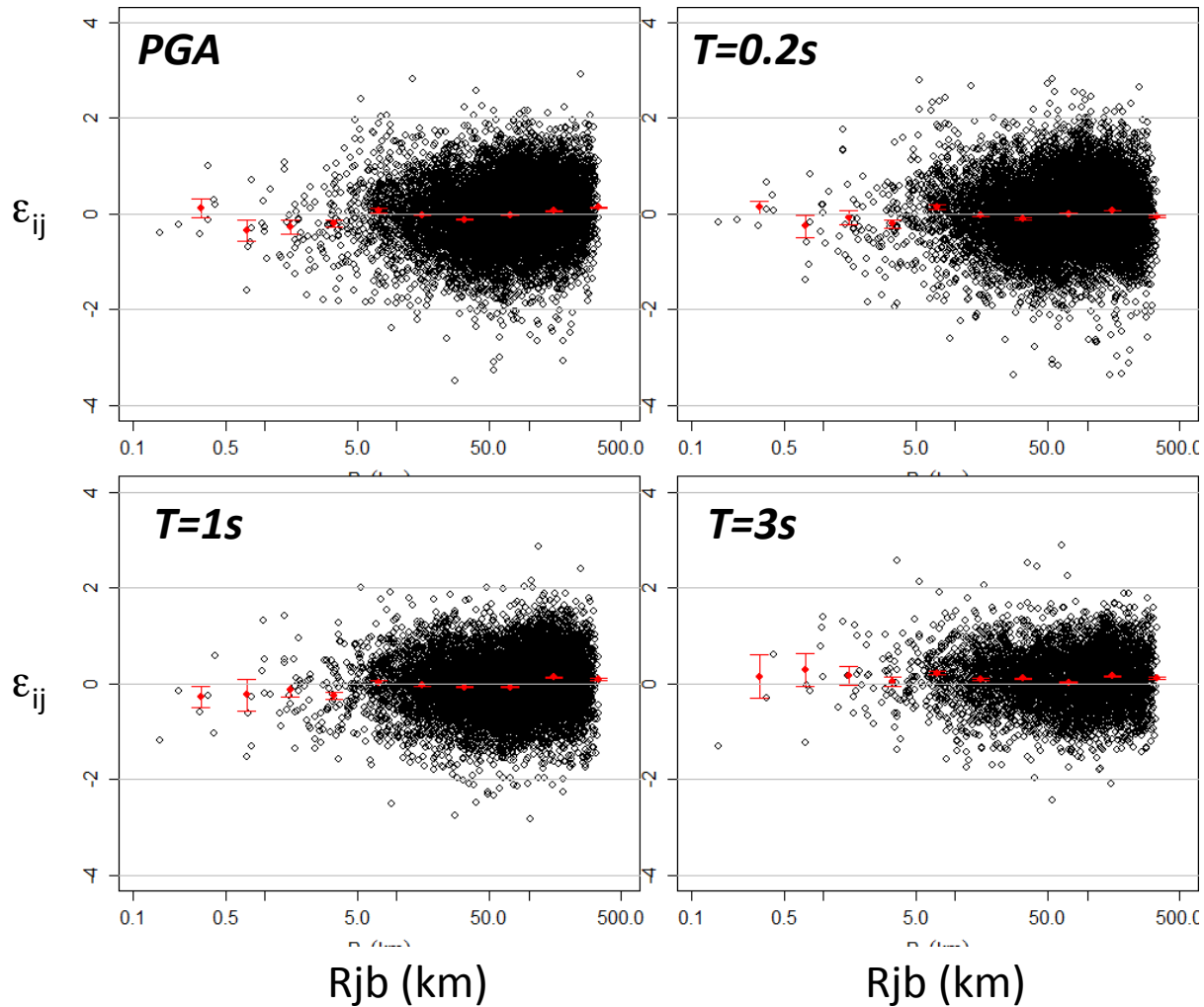


# Within-Event Residuals



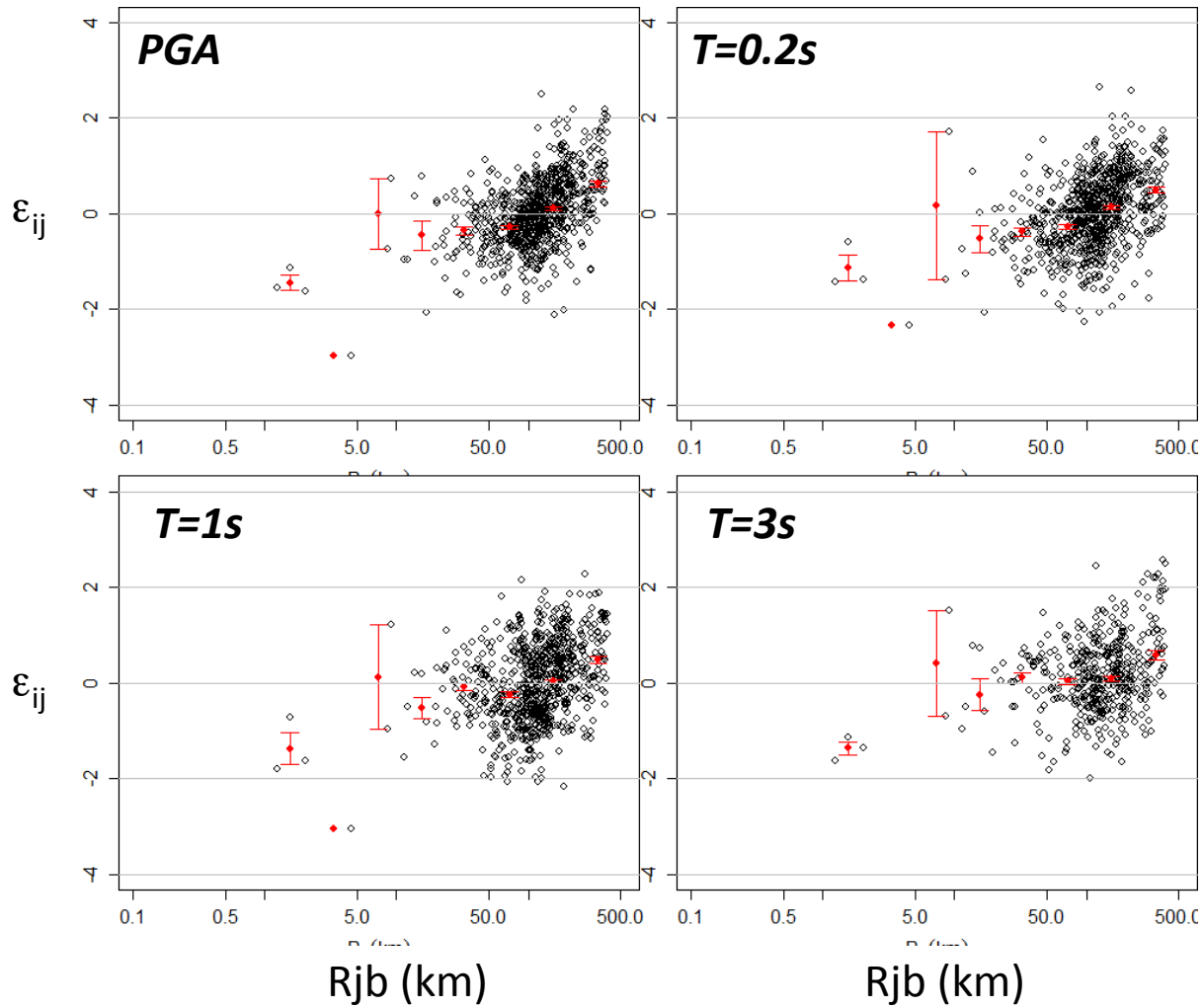
All data  
C1 & C2  
 $CR_{jb}$  10 km

# Within-Event Residuals

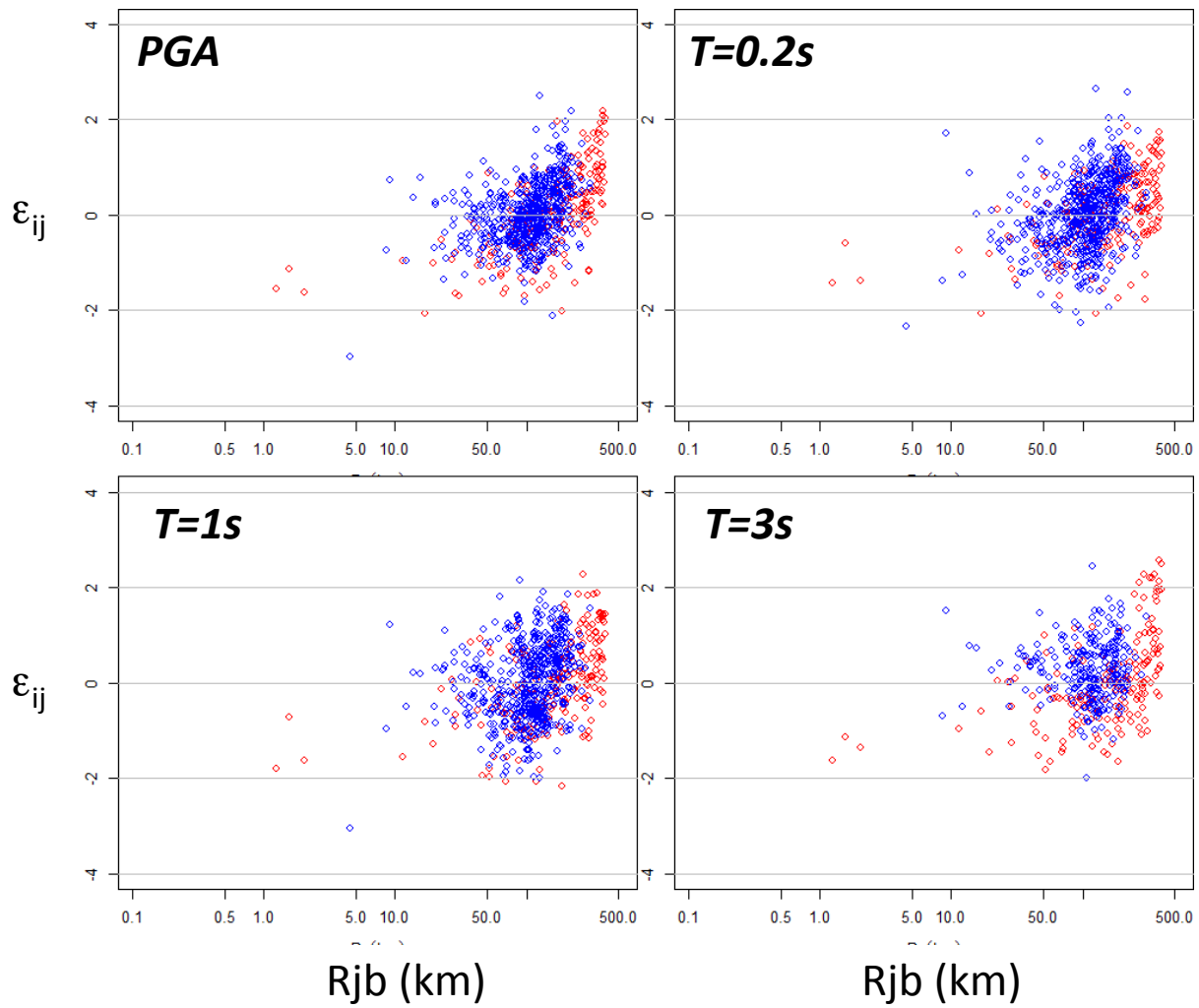


California  
C1 & C2  
CR<sub>jb</sub> 10 km

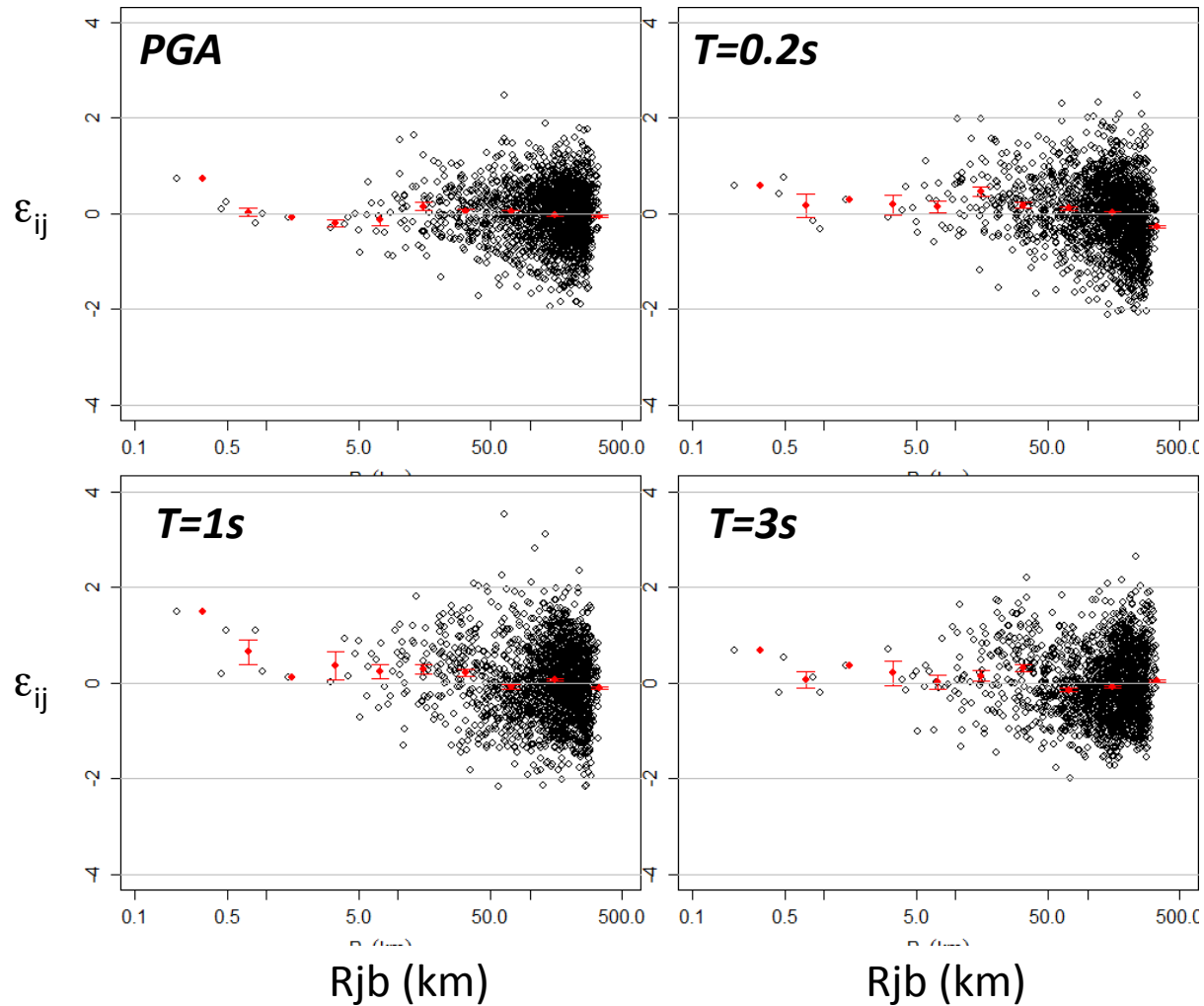
# Within-Event Residuals



China  
C1 & C2  
 $CR_{jb}$  10 km

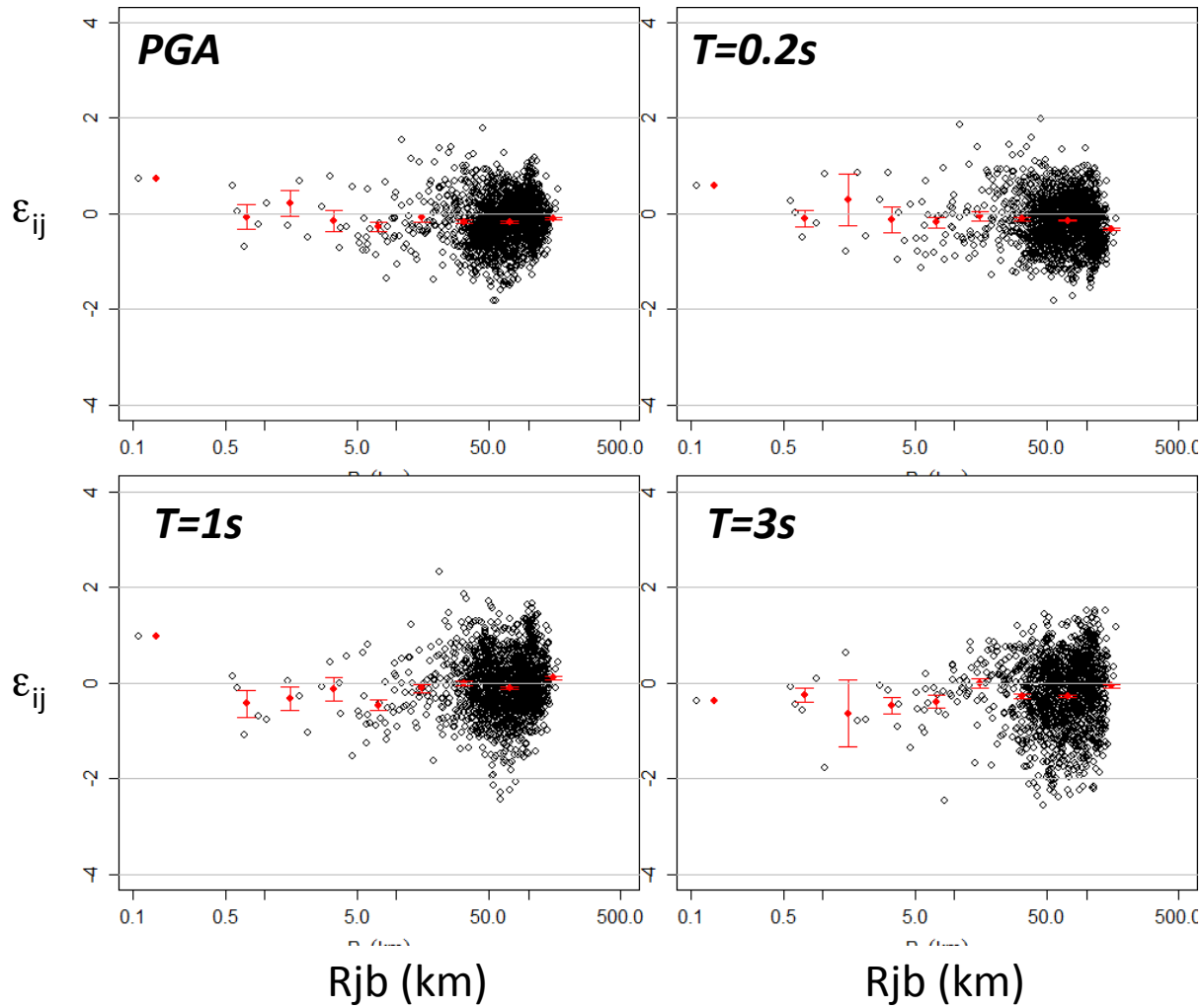


# Within-Event Residuals



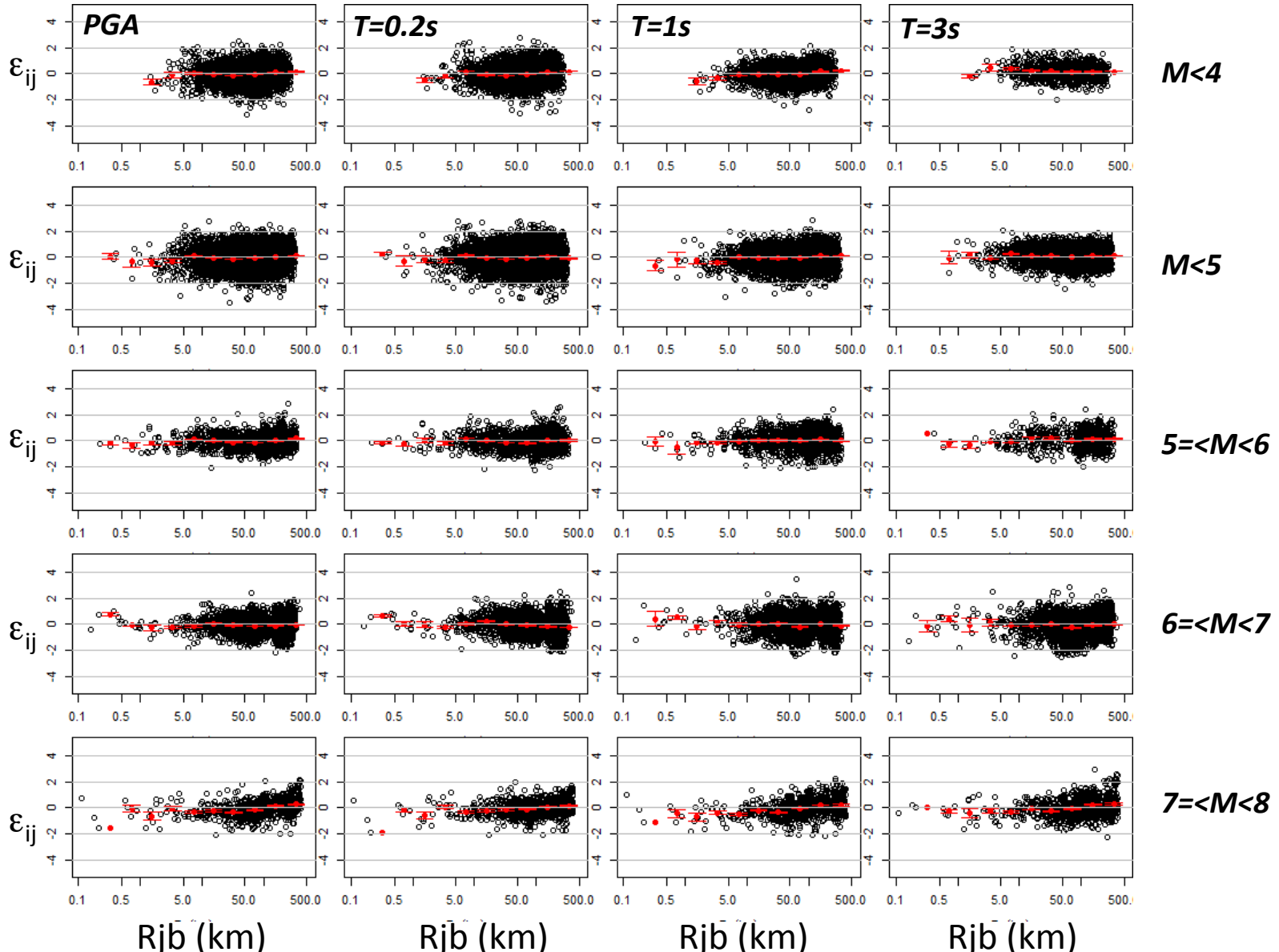
Japan  
C1 & C2  
CR<sub>jb</sub> 10 km

# Within-Event Residuals

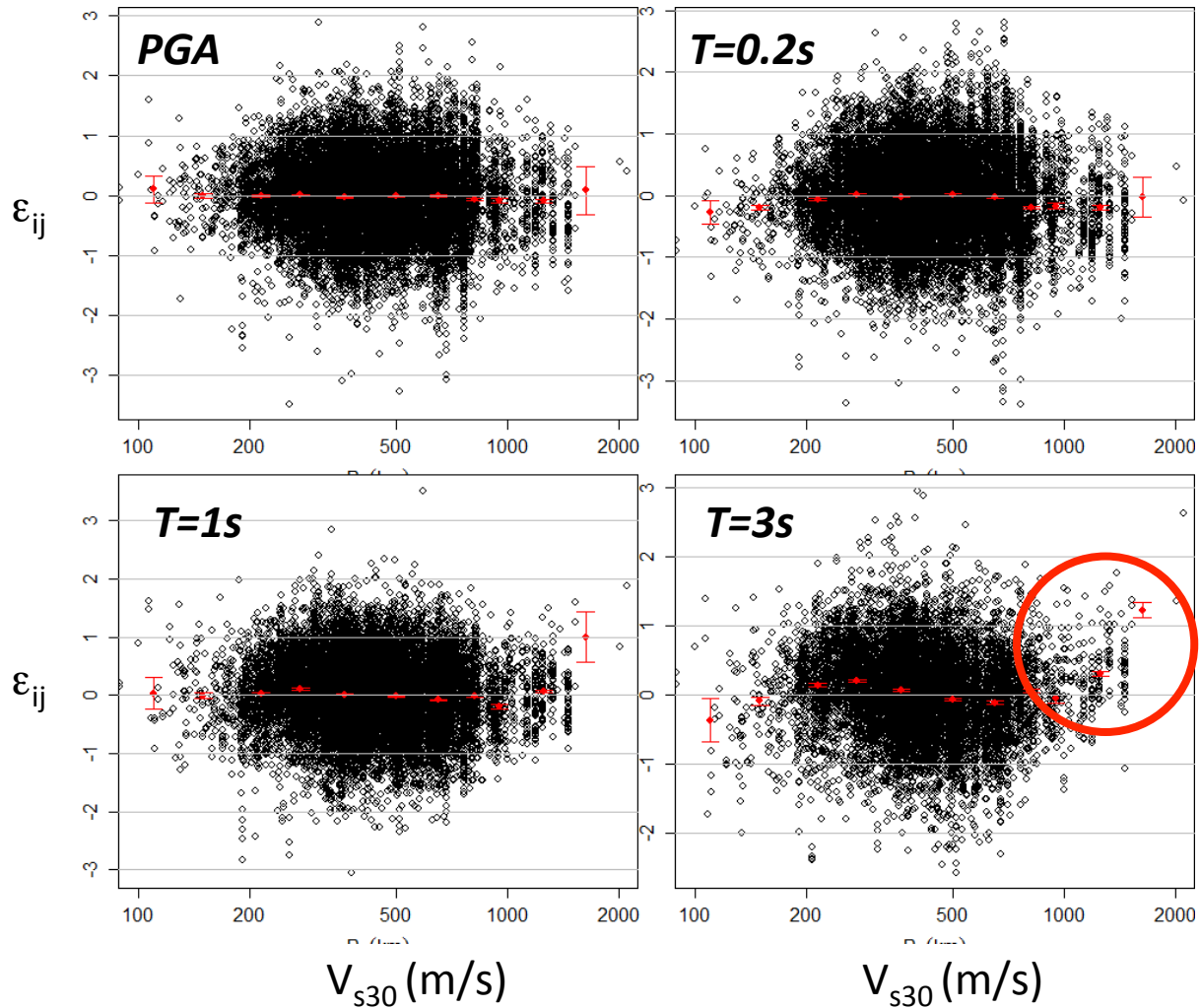


Taiwan  
C1 & C2  
CR<sub>jb</sub> 10 km

# Within-Event Residuals



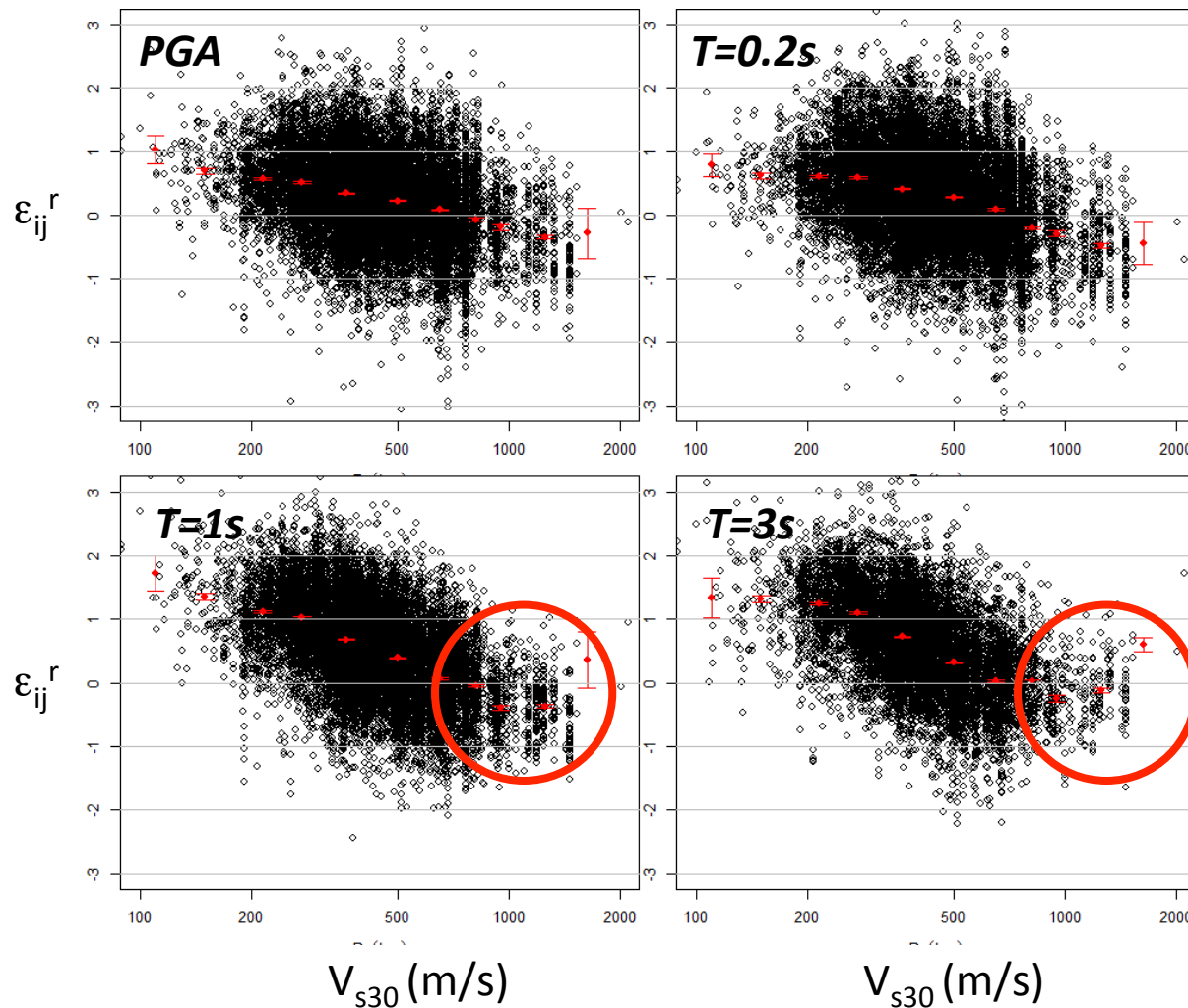
# Within-Event Residuals



All data  
C1 & C2  
CR<sub>jb</sub> 10 km



# Within-Event *Rock* Residuals



All data  
C1 & C2  
CR<sub>jb</sub> 10 km

# Summary and Next Steps

- Simple model, retains principal aspects of functional form from BA08
- What's the trade off for this simplicity?
  - Potentially higher sigma
  - Not applicable for certain conditions
- Anticipated future changes:
  - Final coefficients from RE regressions
  - Anelastic attenuation re-evaluated from SMM data
  - Aftershock (C2) correction
  - Regional corrections for anelastic attenuation &  $V_{s30}$ -scaling
  - Additional residuals analysis and adjust as needed