NGA-Subduction Regional Ground Motion Models for Interface and Intraslab Events

Grace Parker, Jonathan Stewart, Behzad Hassani, Gail Atkinson and David Boore

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NGA-Subduction

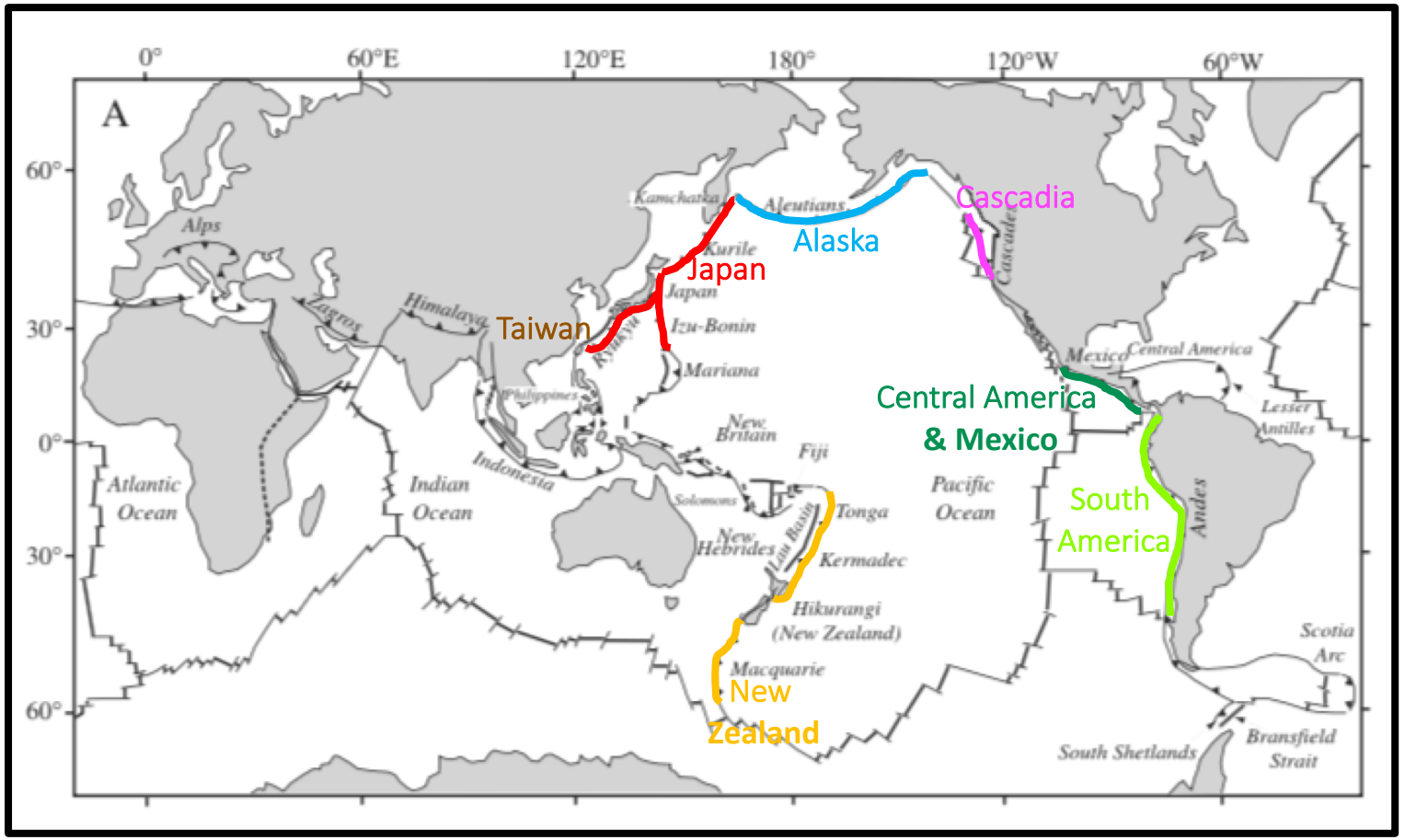

Figure 1a from Stern (2002) showing a map of global plate boundaries, with a focus on convergent locations

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Subduction Zone Terminology

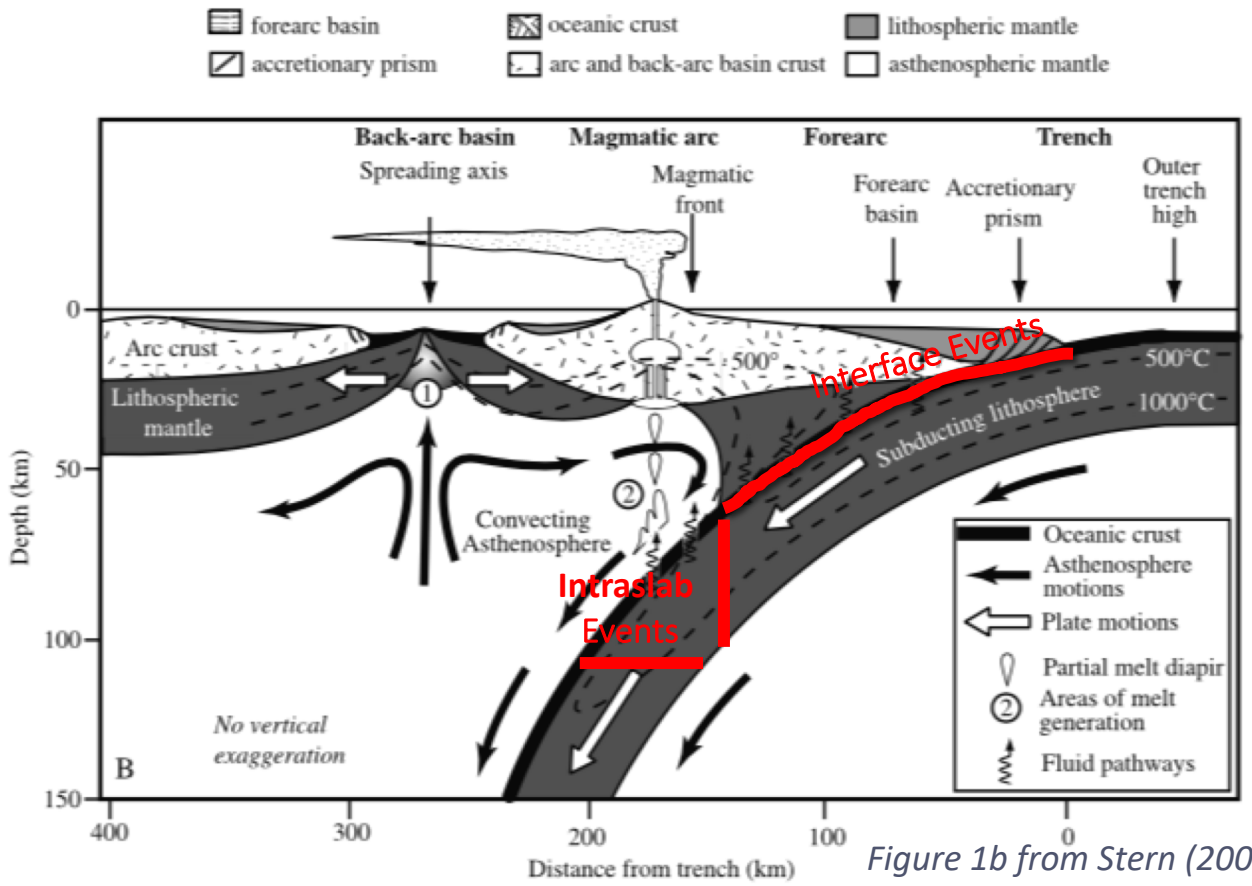

Figure 1b from Stern (2002) showing a schematic section through the upper 150km of a subduction zone

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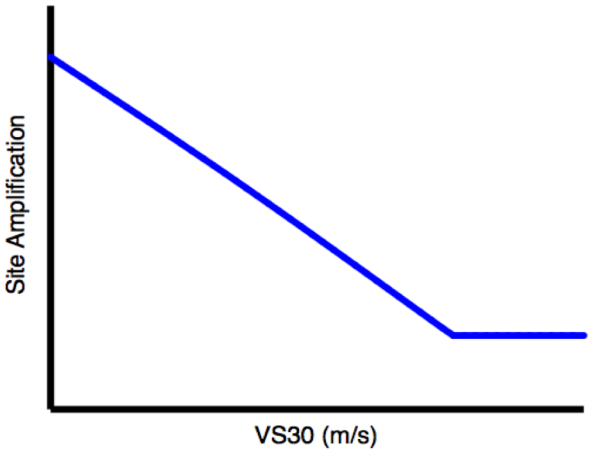
Model Development Approach

$$\mu_{ij} = F_{E,i} + F_{P,ij} + F_{S,j}$$

Use Seyhan and Stewart (2014) to correct to 760 m/s



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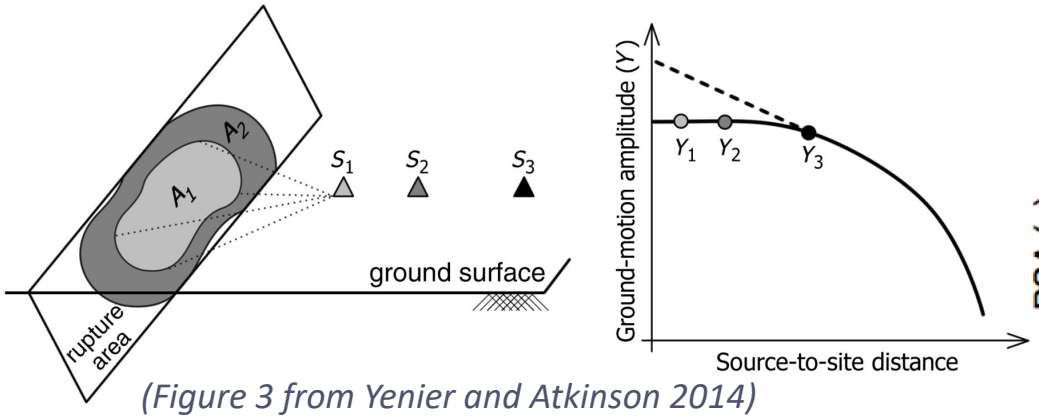
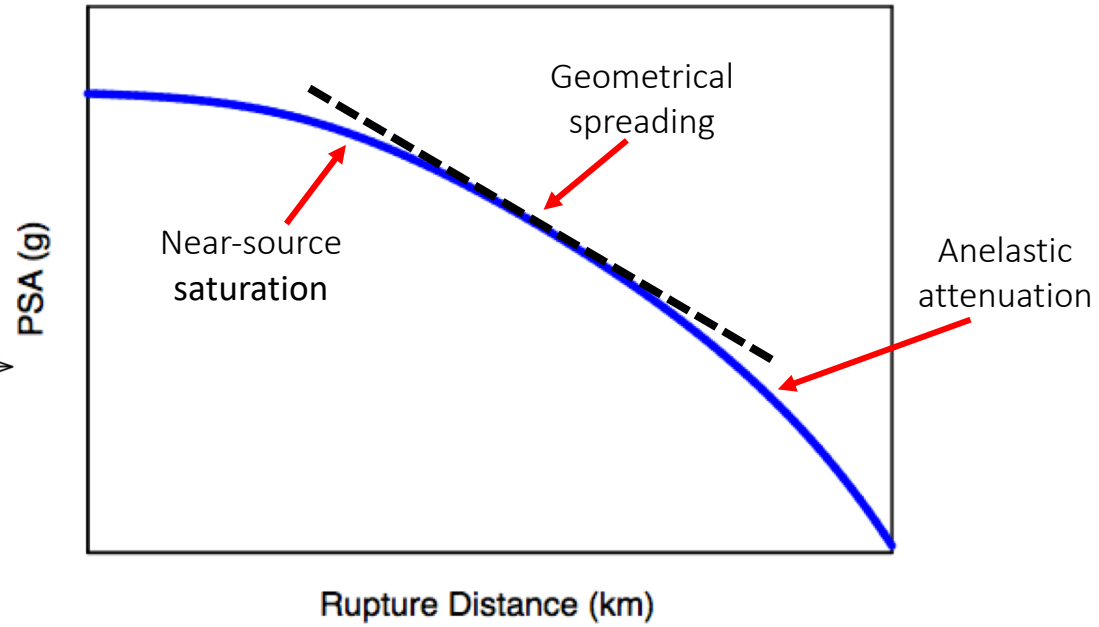
Model Development Approach

$$\mu_{ij} = F_{E,i} + F_{P,ij} + F_{S,j}$$



(Figure 3 from Yenier and Atkinson 2014)



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Model Development Approach

$$\mu_{ij} = F_{E,i} + F_{P,ij} + F_{S,j}$$

Use binning to deal with source term during path term development, then fit source model to residuals computed using completed path model. This term includes magnitude scaling and source depth scaling.

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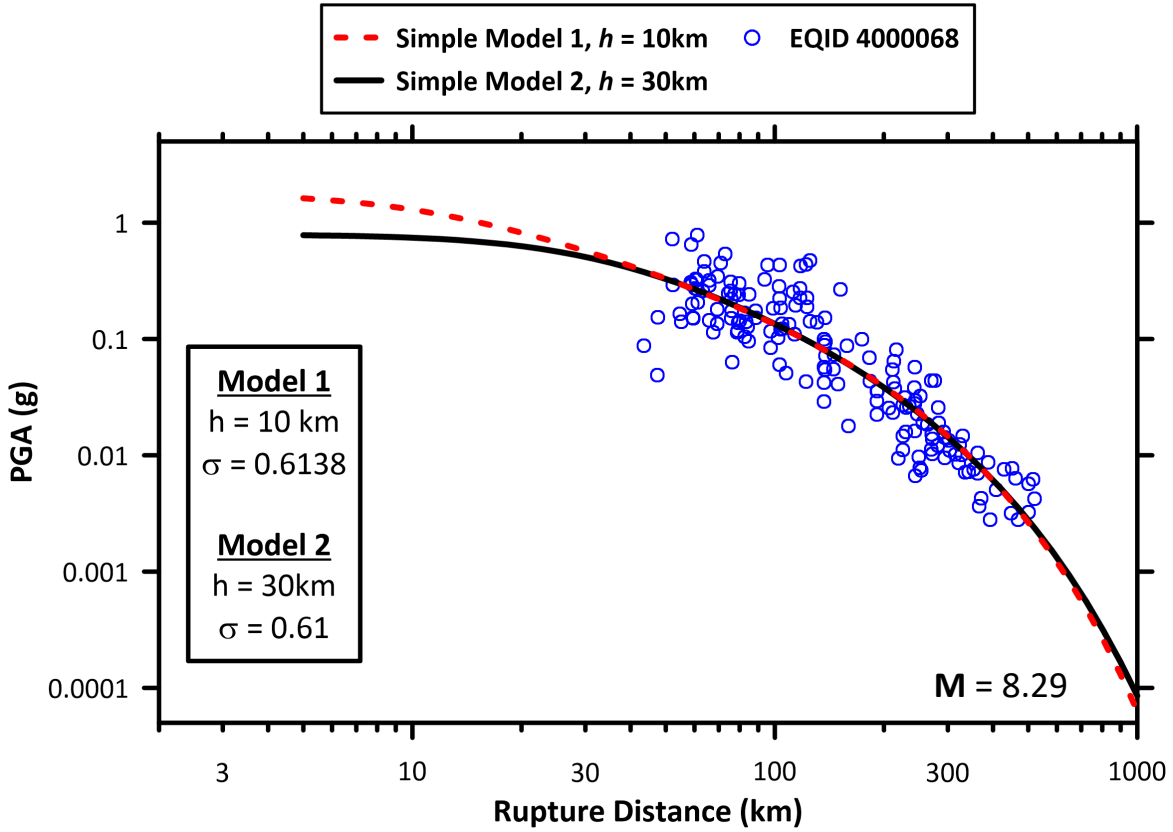
Near Source Saturation

- At small magnitudes, can constrain saturation empirically, using results from Atkinson et al. (2016), Yenier and Atkinson (2014)
- At large magnitudes, used EXSIM simulations
  - Source inputs based on NGA-Sub interface events
  - 5 events for each magnitude 4 – 9.5 with 0.25 steps
  - Dips 15-28°
  - Sites with azimuthal angles of 45,60, and 90° out to 1000km



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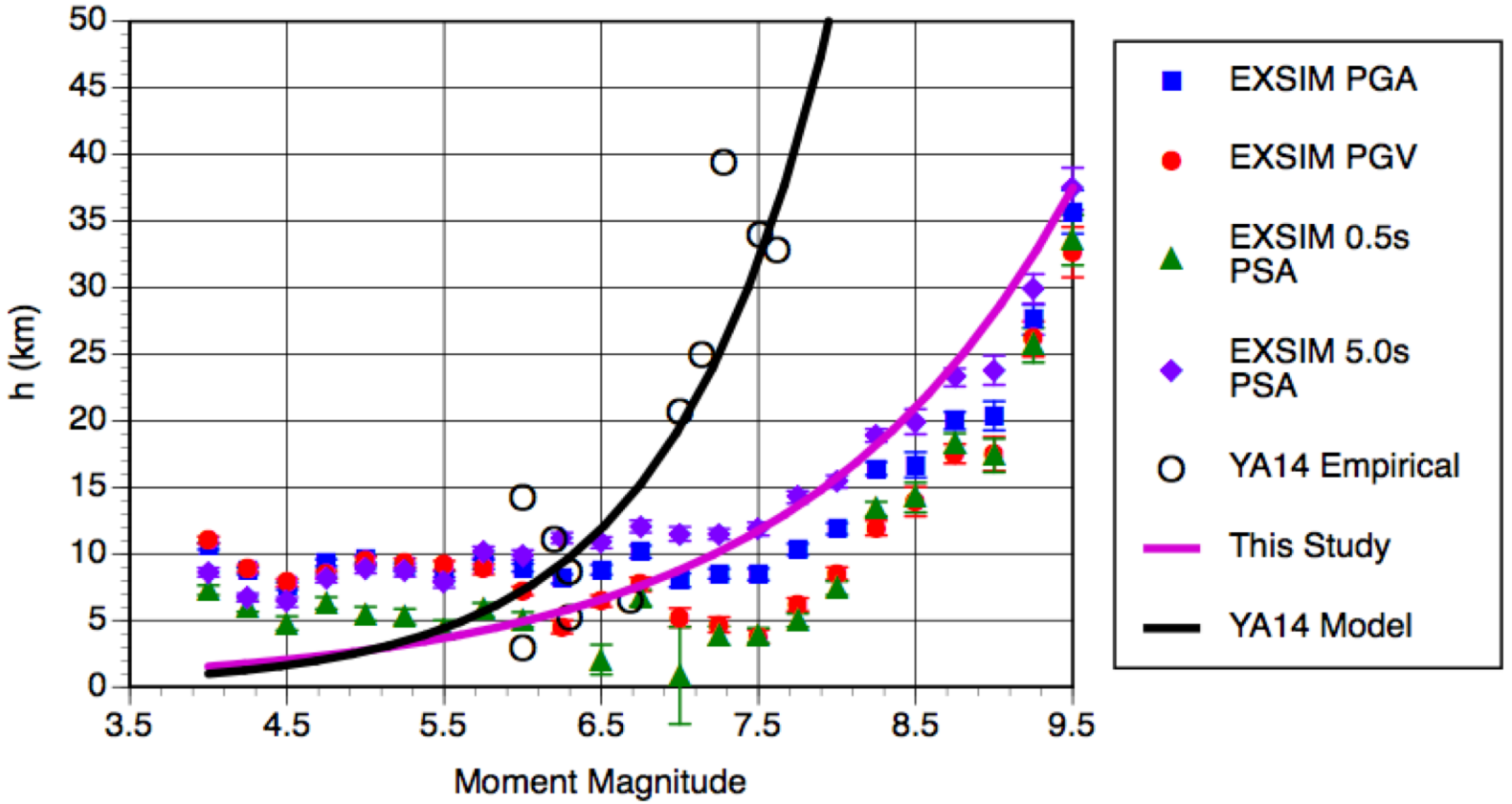
Near Source Saturation

$$F_P = f(R)$$

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

$$h = 10^{-0.82+0.252*M}$$



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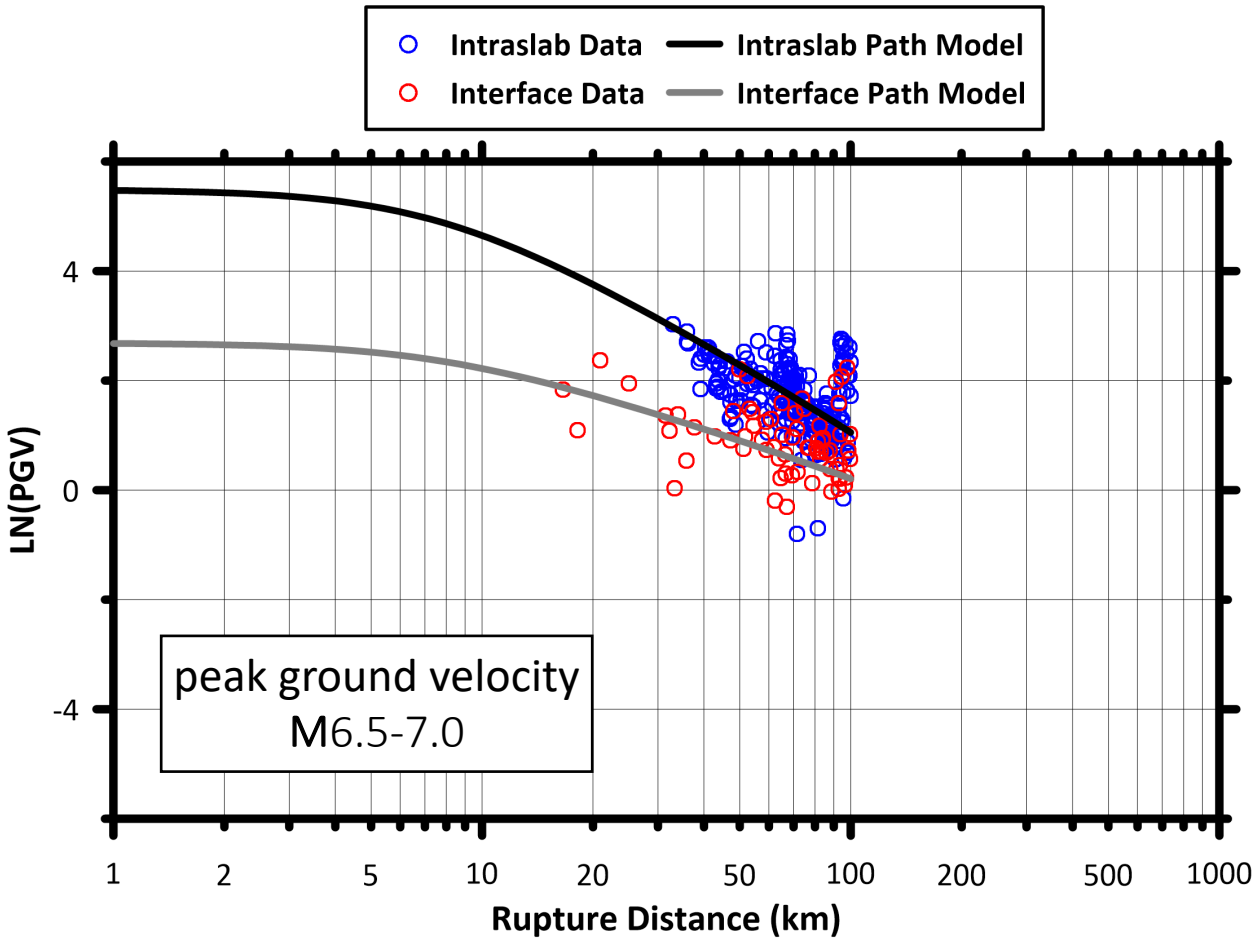
Semi-Empirical Geometric Spreading

$$F_{GS} = c_1 lnR + (b_3 + b_4 \boldsymbol{M}) lnR$$

- Coefficient c_1 is set using data at $R_{rup} \leq 100$km, and is different for intraslab and interface events
- Magnitude dependence (b_4) set by Hassani and Atkinson (2018) simulations
- Earlier models assume same slope on R between event types (BC Hydro), or don't have M-dependence (Zea06, Atkinson and Macias 2009)



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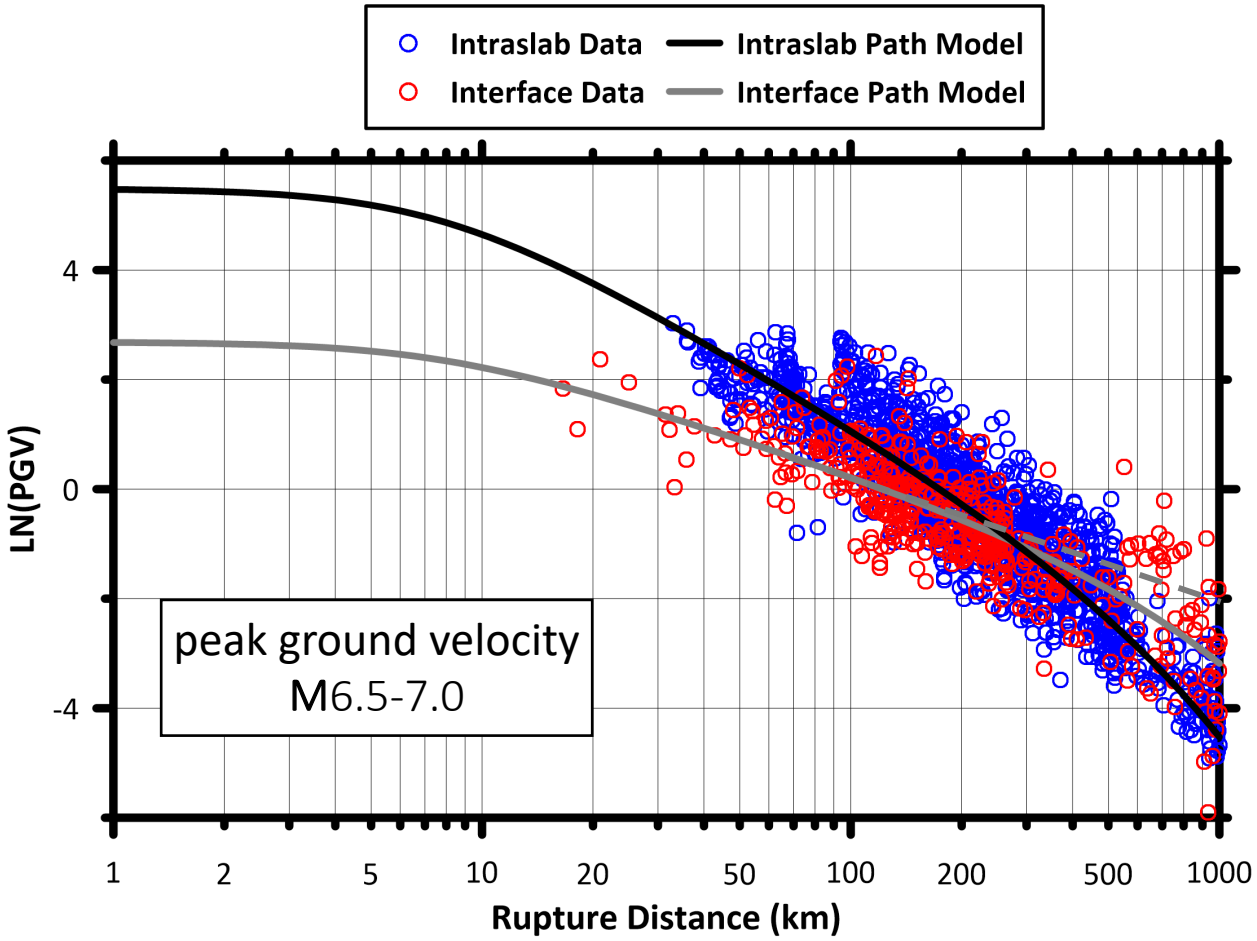
Global and Regional Anelastic

$$F_{AN} = a_0 R$$

- Coefficient a_0 is determined empirically after GS term is set
- Interface and intraslab coefficients are different
- Coefficient a_0 is regionalized
- Global and regional values are regressed using mixed effects methods



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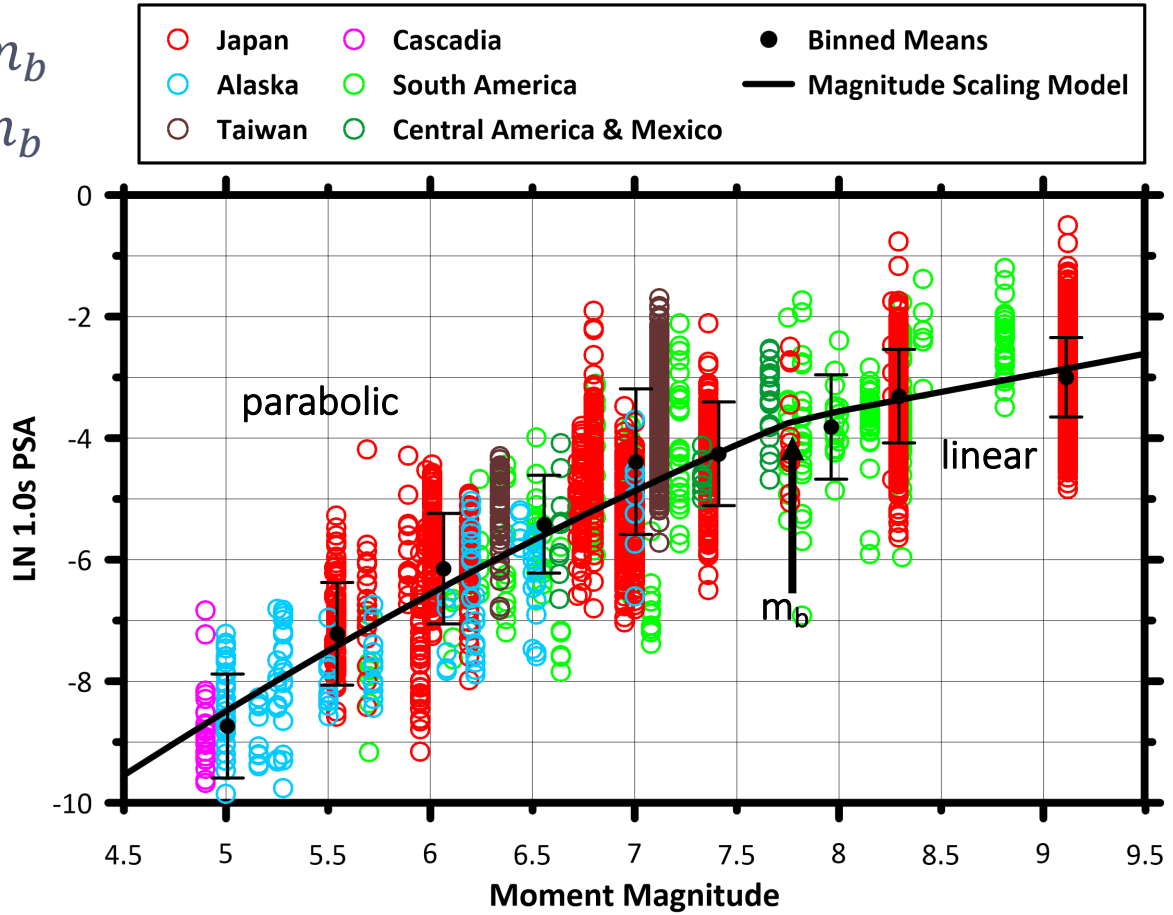
Magnitude Scaling Model

$$F_M = \begin{cases} c_0 + c_4(\boldsymbol{M} - m_b) + c_5(\boldsymbol{M} - m_b)^2 & for\ \boldsymbol{M} \le m_b \\ c_0 + c_6(\boldsymbol{M} - m_b) & for\ \boldsymbol{M} > m_b \end{cases}$$

- Fit **M**-scaling to residuals computed using completed path model
- Coefficients on **M** empirical, with m_b from geometrical constraints (Archuleta and Ji 2018; Campbell 201x)
- m_b is regionalized



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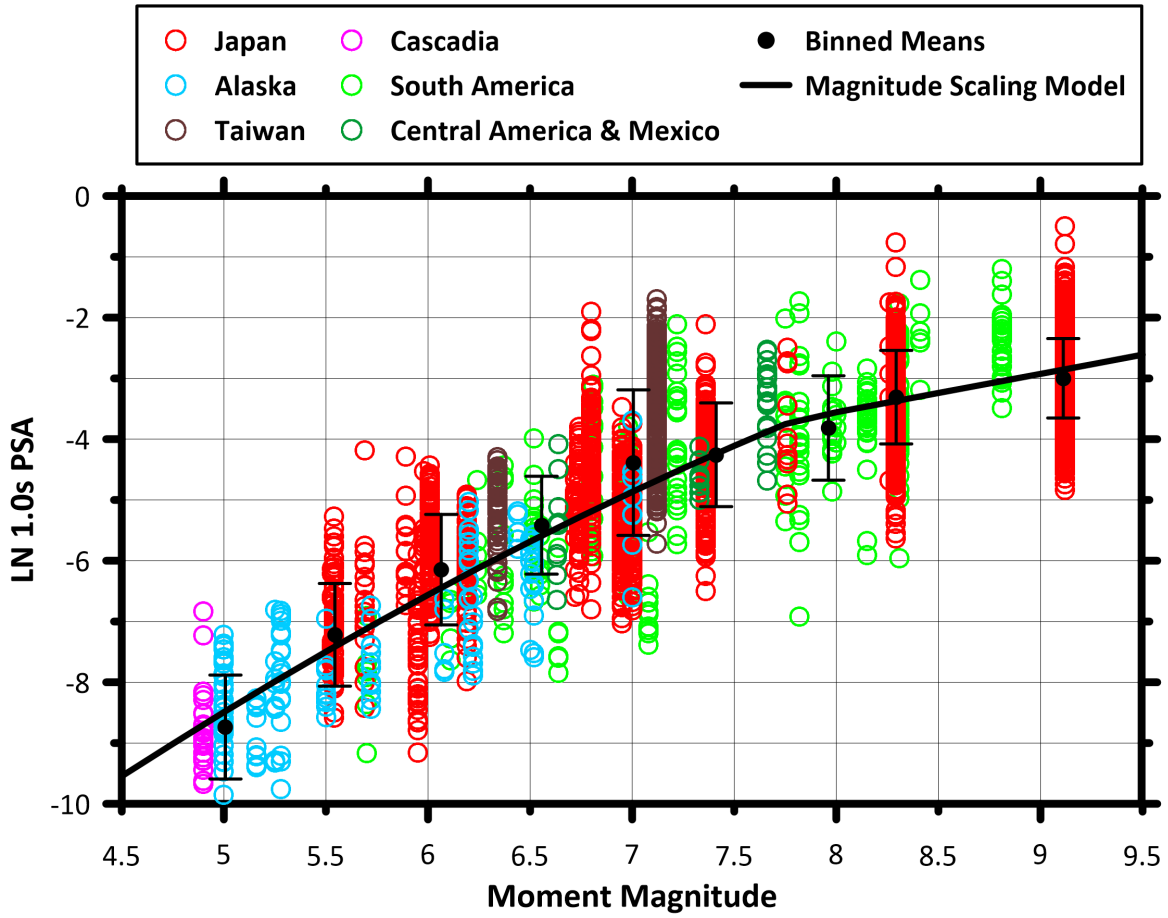
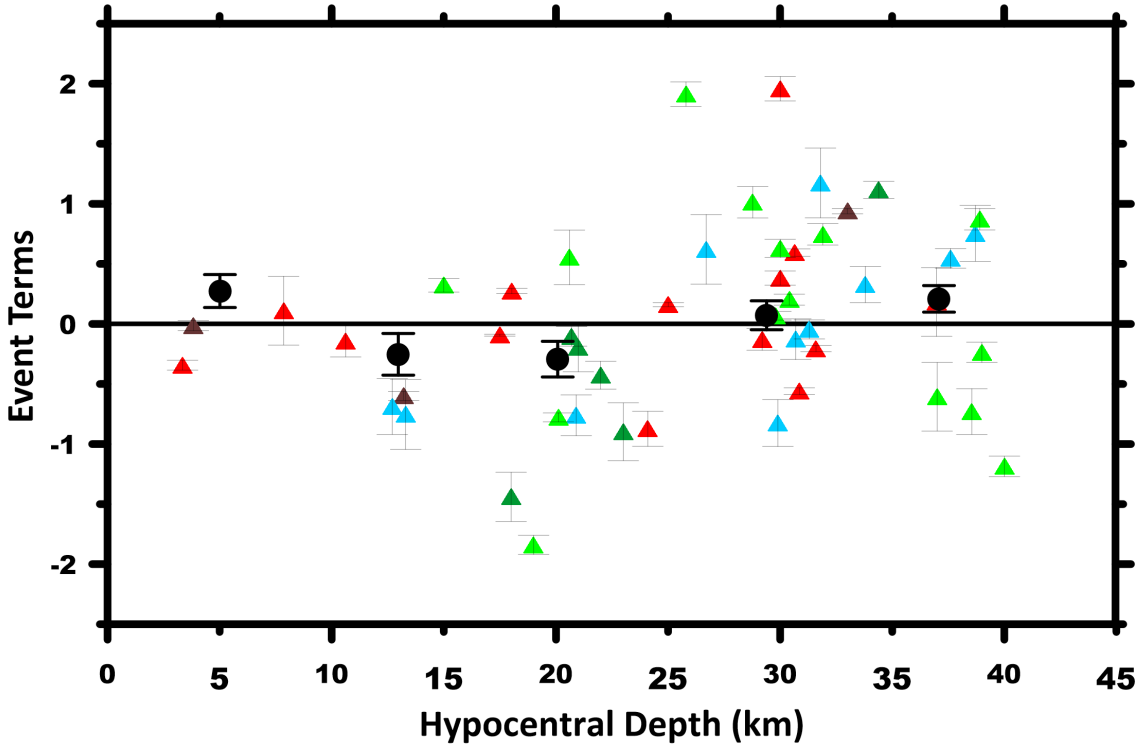
Source Depth Scaling





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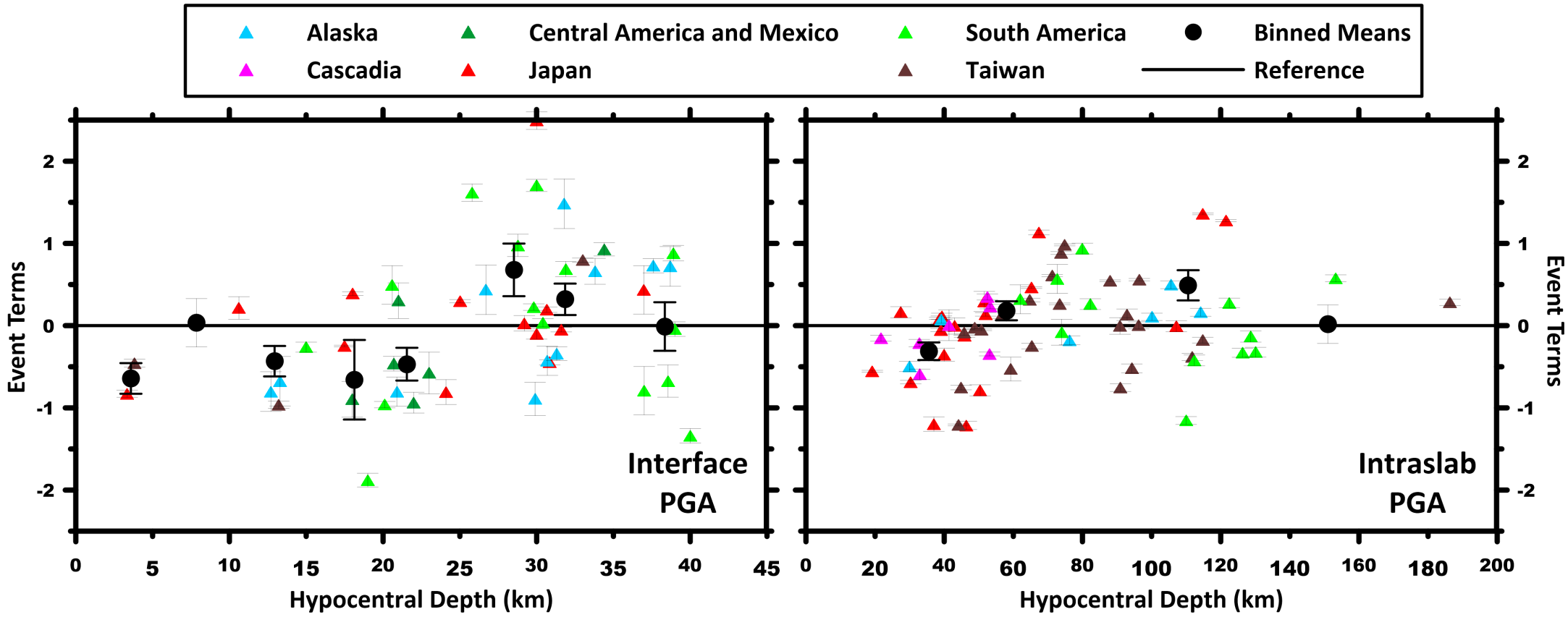
Source Depth Scaling



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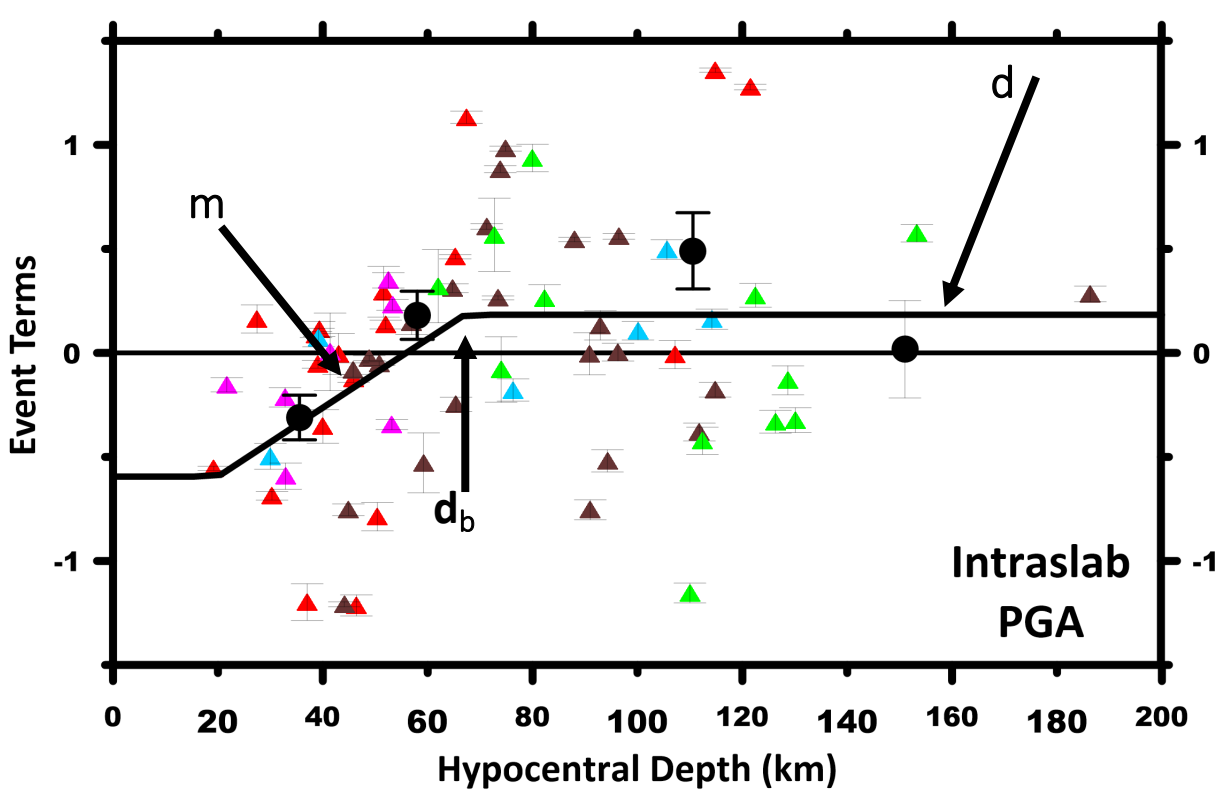
Source Depth Scaling



$$F_D = \begin{cases} m(d_{hyp} - d_b) + d & for\ d_{hyp} < d_b \\ d & for\ d_{hyp} \geq d_b \end{cases}$$

- Bi-linear model as a function of hypocentral depth
- Corner depth is period independent
- Model coefficients *m*, *d*, go to 0 at 2.0s for both even types

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Linear Site Amplification

- Empirical site amplification computed using mixed effects analysis
- Within-event rock residuals computed utilizing the NGA-Sub GMM at 760m/s, associated event terms, and SS14 F_{nl} term
- Then use nonlinear least-squares to fit F_{lin} function

$$F_{lin} = \begin{cases} s_1 ln\left(\frac{V_{S30}}{V_1}\right) + s_2 ln\left(\frac{V_1}{V_{ref}}\right) & for\ V_{S30} \leq V_1 \\ s_2 ln\left(\frac{V_{S30}}{V_{ref}}\right) & for\ V_1 < V_{S30} \leq V_2 \\ s_2 ln\left(\frac{V_2}{V_{ref}}\right) & for\ V_{S30} > V_2 \end{cases}$$

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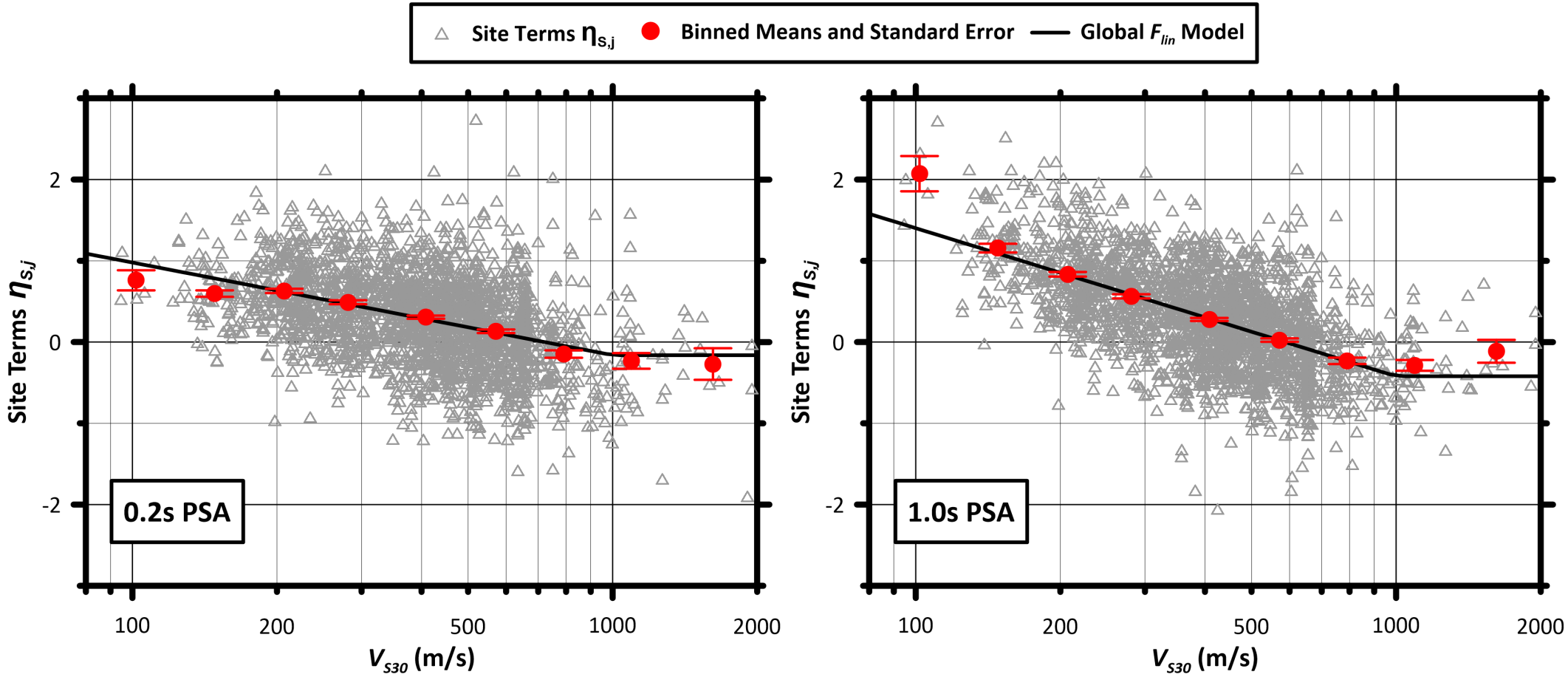
Global Linear Site Amplification



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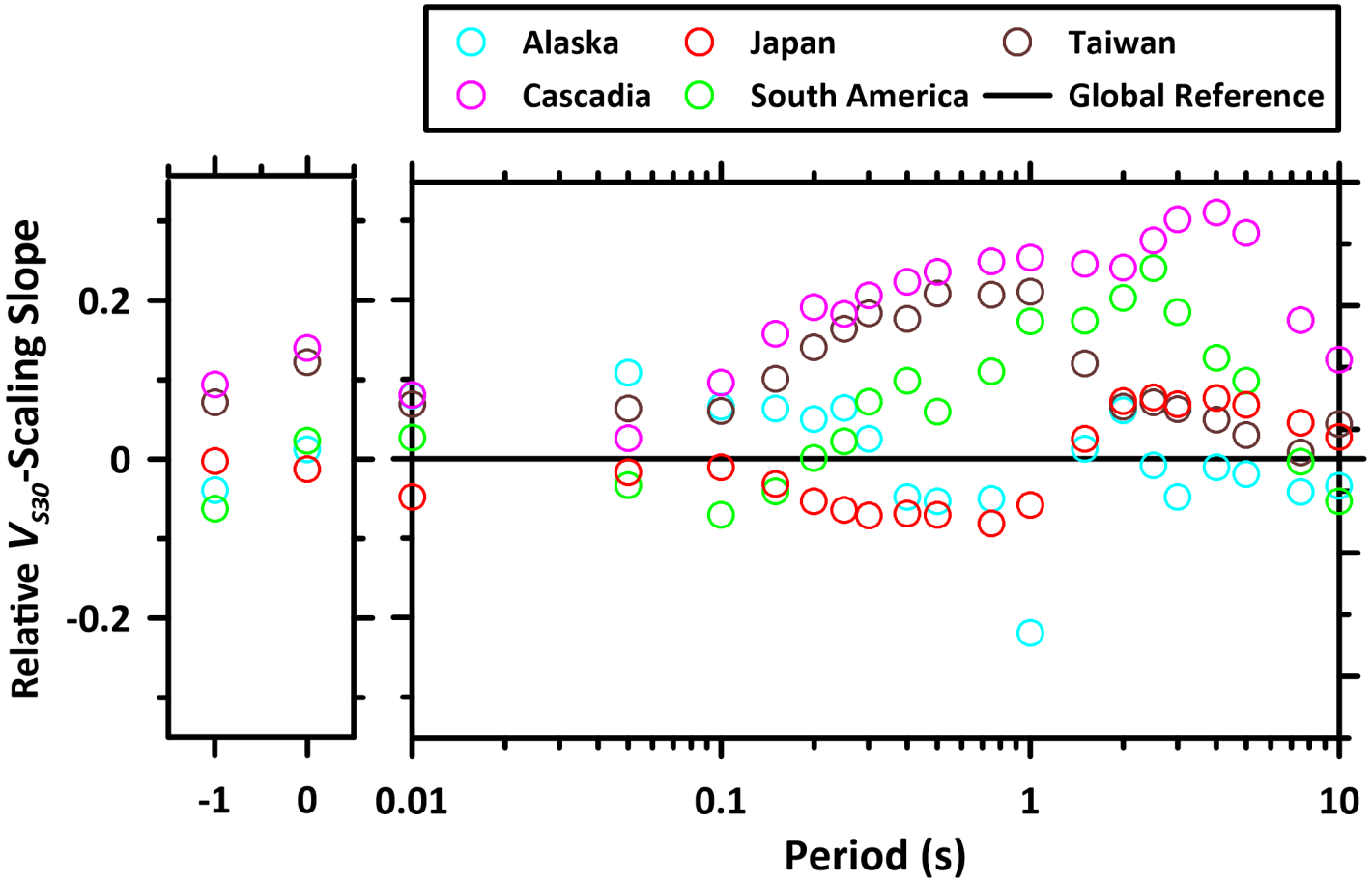
F_{lin} Slope Comparison



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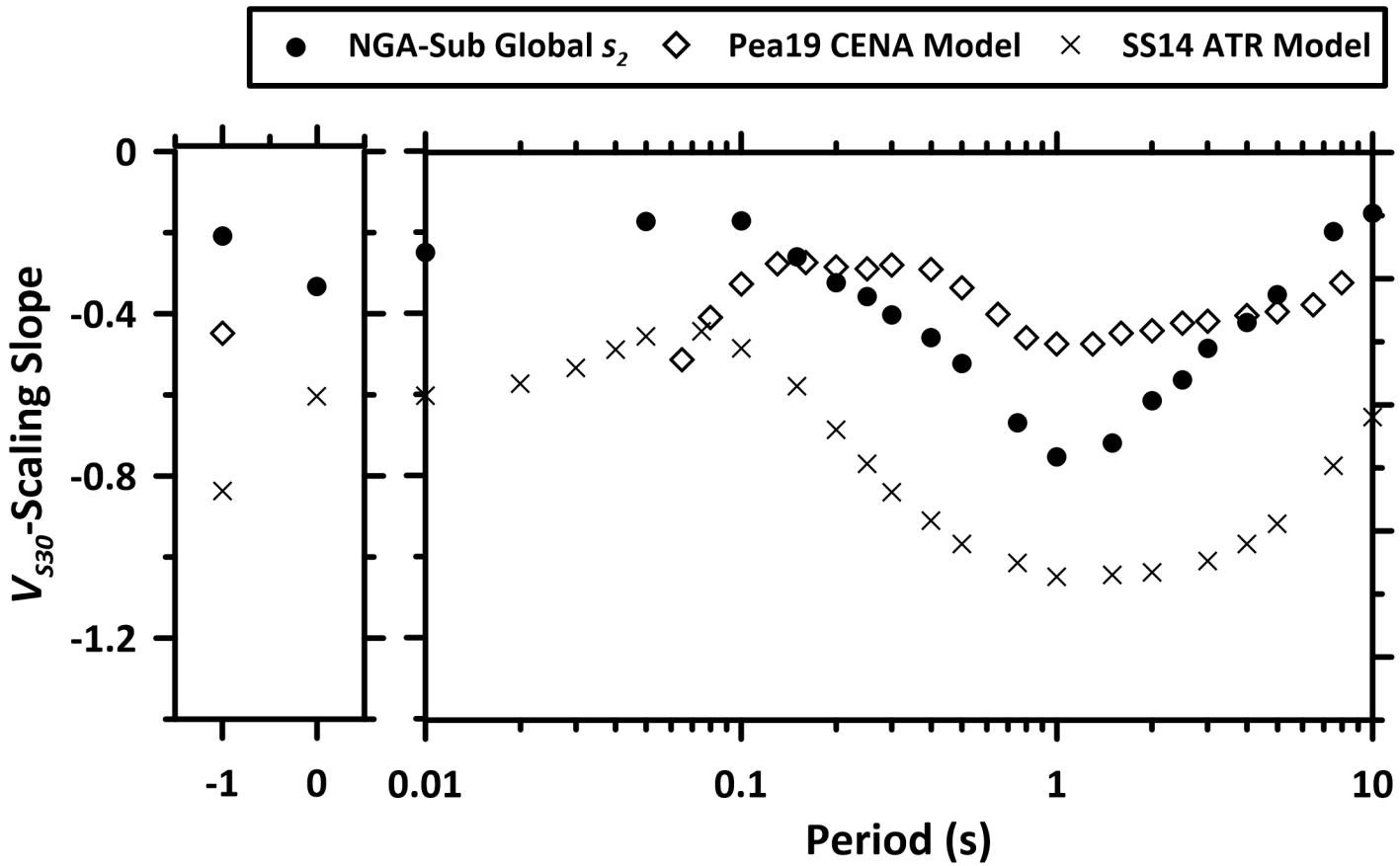
F_{lin} Slope Comparison



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Ongoing Work

1. NGA-Subduction basin terms
2. NGA-Subduction GMM uncertainty model
3. Model verification; comparison of model to other NGA-Subduction models, and models from literature (e.g. Abrahamson et al. 2012; Atkinson and Boore 2003; Zhao et al. 2006; Zhao et al. 2016a,b)
4. Model validation against NGA-Subduction data from New Zealand, and Frankel et al. (2018) simulations for **M**9 Cascadia interface events
5. Residuals analysis in regional back-arc regimes

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Main Conclusions

- Developing a GMM for both interface and slab events, with regional constant, anelastic attenuation term, magnitude break point, and linear site term
- Model is semi-empirical; multiple elements constrained by simulations and geometry
  - Near-source saturation at large magnitudes
  - Magnitude dependent geometrical spreading
  - Magnitude break-point, m_b
- Site response term is subduction-specific and regional:
  - Regional V_{S30} – scaling
  - NGA-Sub nonlinear site amplification model
  - Ongoing work is evaluating regional basin effects (Japan, Seattle, Taipei)

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