NGA-West2 Site Database

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NGA-West2 Public Workshop
CITRIS Auditorium, UC Berkeley
November 15, 2012

Outline

- Role and principal contents of site database
- V_{s30} terms
- Data overview

Role and Contents

- Repository of information for recording stations contributing data to flatfile

Role and Contents

- Repository of information for recording stations contributing data to flatfile
- Basic station information

Identifying numbers

Name (descriptive)

Geodetic coordinates

Station housing (GMX first letter)

Role and Contents

- Repository of information for recording stations contributing data to flatfile
- Basic station information
- V_{s30} from measurements

Profile depth, z

V_{sz} (when z < 30 m)

V_{s30} (extrap. when necessary)

Data source

Role and Contents

- Repository of information for recording stations contributing data to flatfile
- Basic station information
- V_{s30} from measurements
- Site proxies

Geotechnical categories (GMX 3rd letter A-E)

Surface geology & 10 arc-sec slope (mostly CA)

30 arc-sec slope

Terrain-type proxy

Elevation (Taiwan)

Role and Contents

- Repository of information for recording stations contributing data to flatfile
- Basic station information
- V_{s30} from measurements
- Site proxies
- Depth parameters

SFBA model, USGS/Aagaard: $z_{1.0}$, $z_{1.5}$, $z_{2.5}$

Two So. Cal. Models (CVM-S4 & CVM-H11.1.0: $z_{1.0}$, $z_{2.5}$

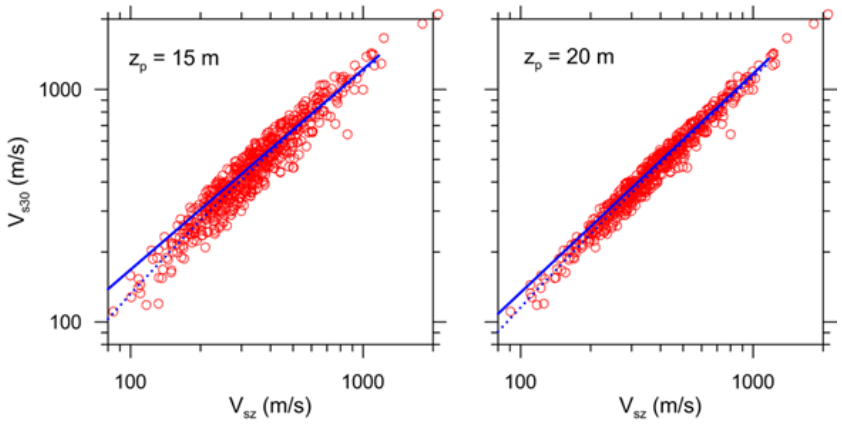
Japan model, NIED: $z_{1.0}$, $z_{1.5}$, $z_{2.5}$

V_{s30} Terms

- V_{s30} from data

Alternate extrapolation models when z < 30 m (CA, Japan – Kiknet, China)

Assigned uncertainty of σ_{lnV}=0.1 when z ≥ 30 m, increases for lower z



V_{s30} Terms

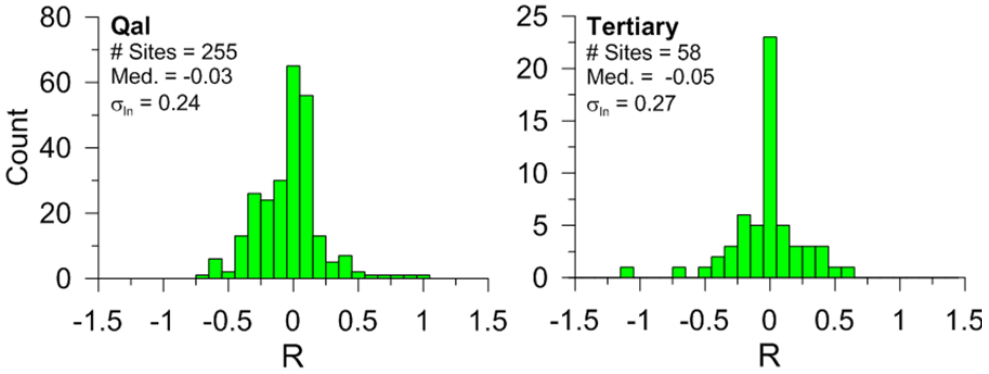
- V_{s30} from data
- V_{s30} from proxy

Used only when no measurements available

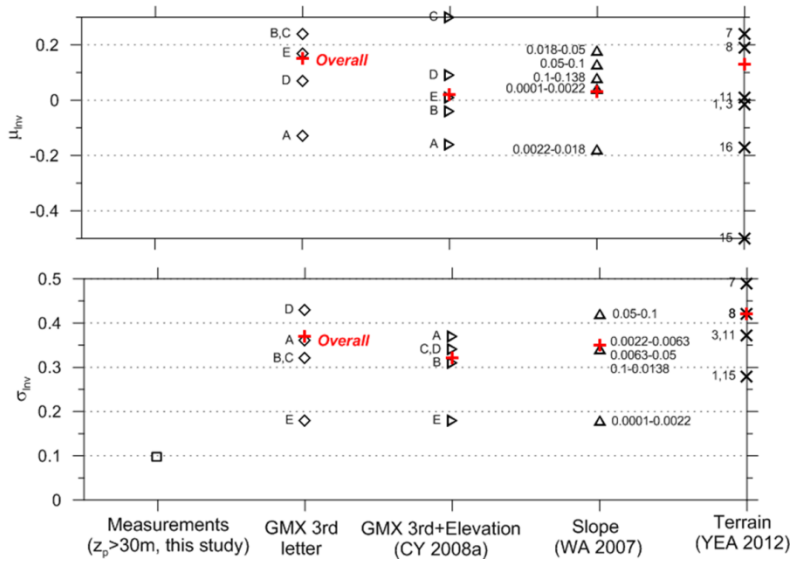
Proxies analyzed by region for bias and dispersion

Weighted estimates and σ_{lnV} provided. Applicable proxies indicated for each site in database.

California example



$$R = \ln(V_{s30})_{meas} - \ln(V_{s30})_{proxy}$$



Data Overview

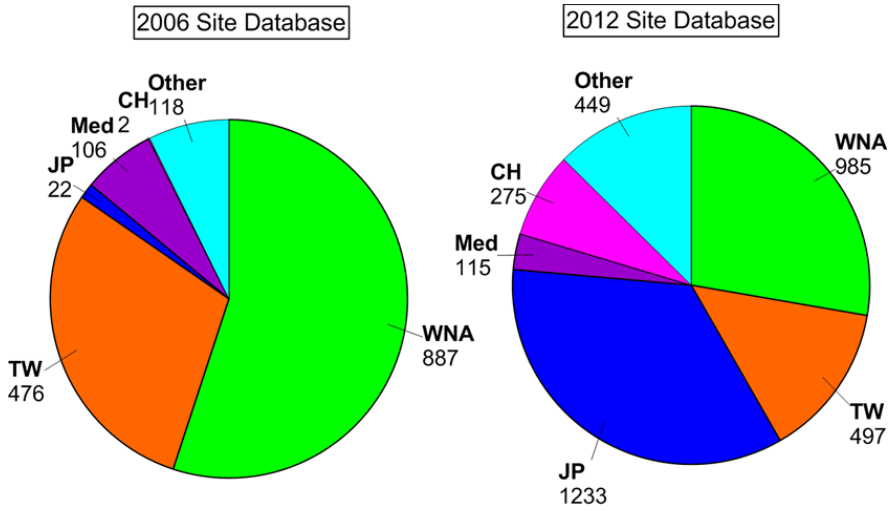
NGA-West2

- 4160 sites (1611 in NGA)

Data Overview

NGA-West2

- 4160 sites (1611 in NGA)
- Geographic distribution



Data Overview

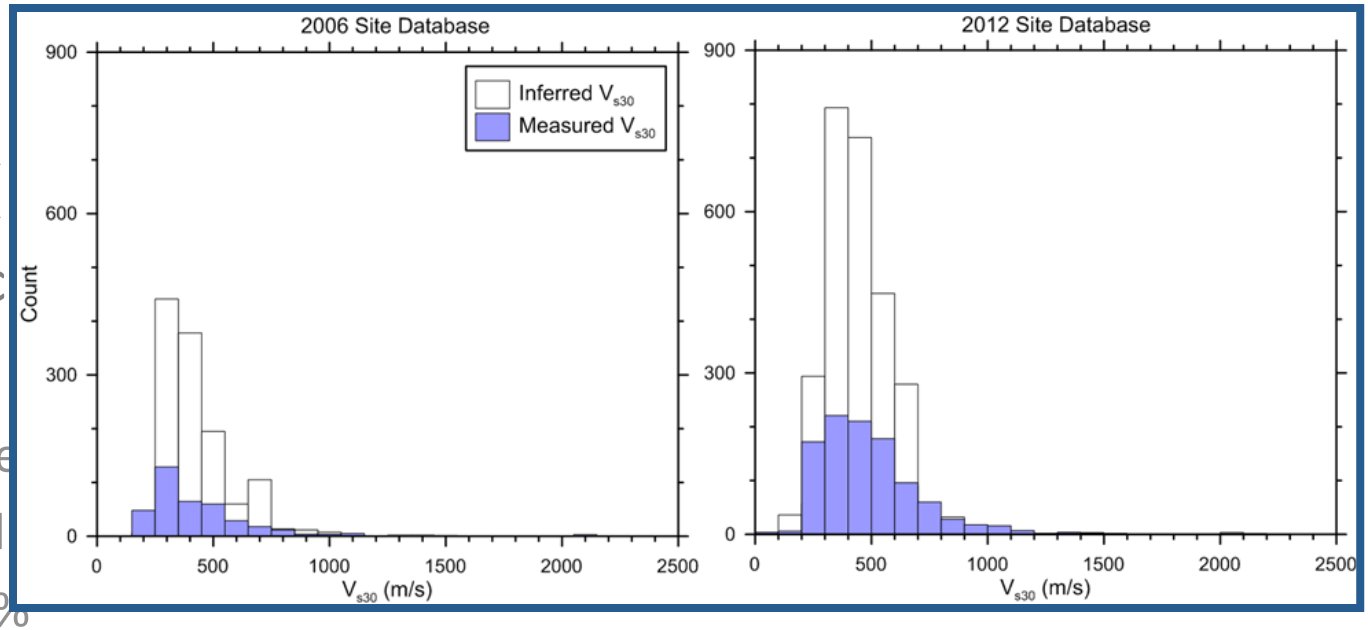
NGA-West2

- 4160 sites (1611 in NGA)
- Geographic distribution
- Availability of proxies:
  - GMX 3rd letter: 80%
  - Surf. Geol.: 35% (CA)
  - Slope: 99%

Data Overview

NGA-West2

- 4160 sites (
- Geographic
- Availability
  - GMX 3rd le
  - Surf. Geol
  - Slope: 99%
- V_{s30} from measurements vs proxy



Questions?

Nonlinear Site Response & Revisions to NEHRP/ASCE Site Factors

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Contributors

NGA-West 2, Task 8

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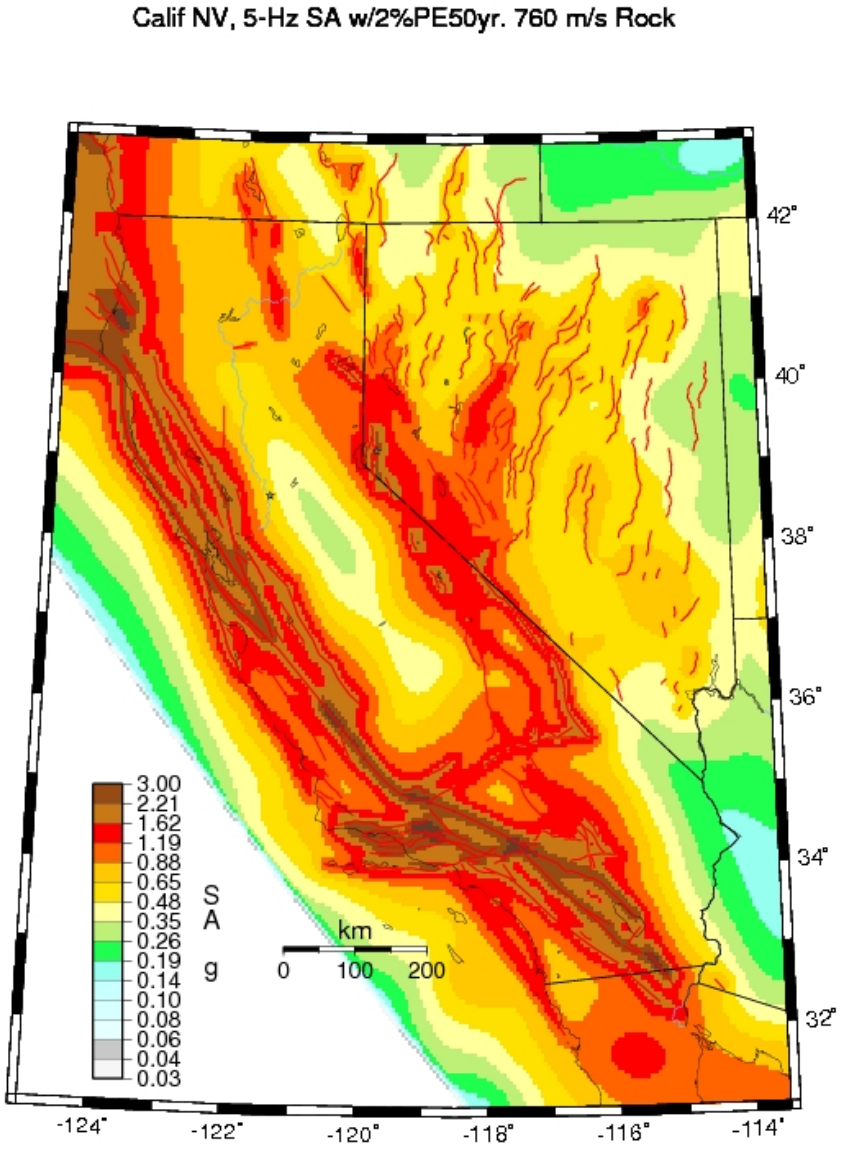
Outline

- Context
- Site factors in NEHRP provisions
- Site factors from NGA-West2 project
- Conclusions & recommendations

Context

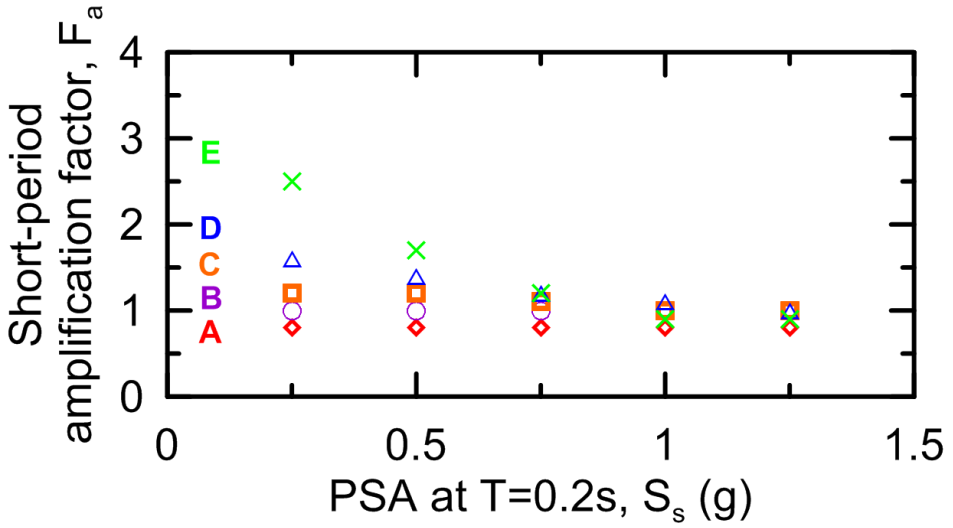
- Code-based ground motions
  - Ground motion parameters evaluated for rock conditions

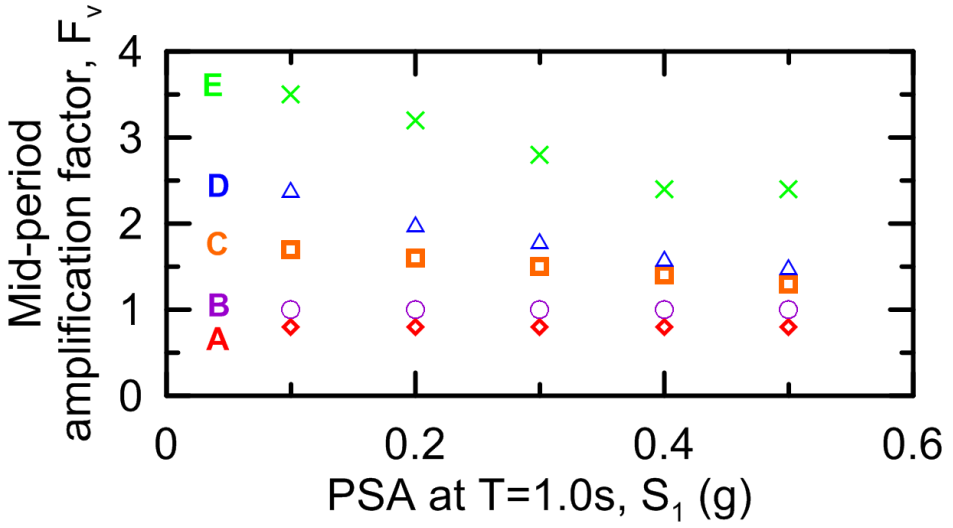
S_s, S_1



Context

- Code-based ground motions
  - Ground motion parameters evaluated for rock conditions
  - Site factors by site class

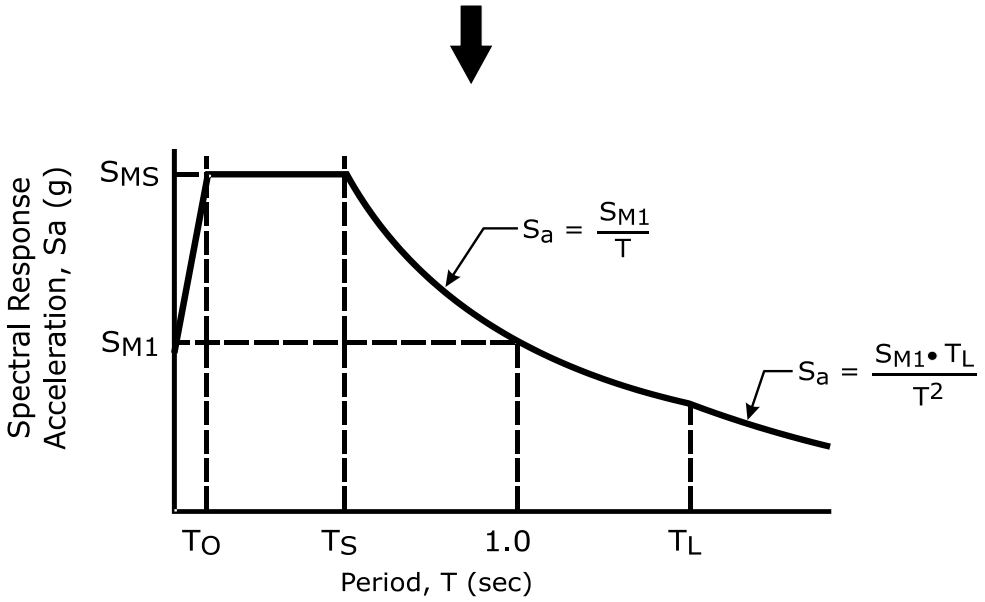




Context

- Code-based ground motions
  - Ground motion parameters evaluated for rock conditions
  - Site factors by site class
  - Combined to form MCE response spectrum

$$S_s \times F_a = S_{MS} \qquad S_1 \times F_v = S_{M1}$$



Outline

- Context
- **Site factors in NEHRP provisions**
- Site factors from NGA-West2 project
- Conclusions & recommendations

NEHRP Site Factors

- Role of NEHRP Provisions

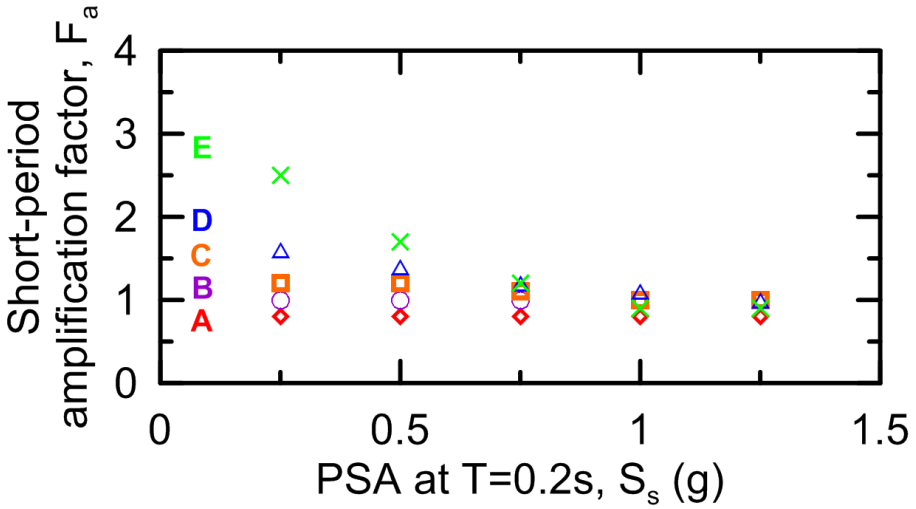
NEHRP Site Factors

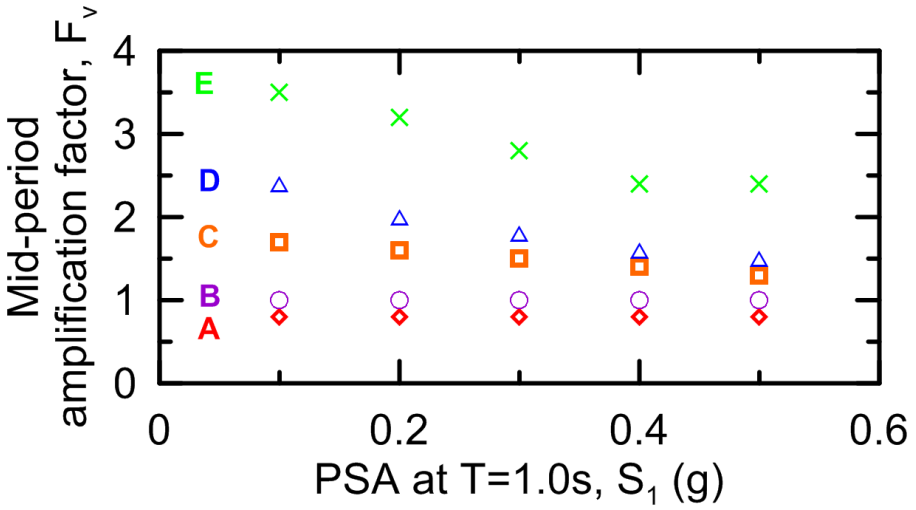
- Role of NEHRP Provisions
- Factors F_a and F_v

Derived for V_{s30}-based site categories A-E

NEHRP Site Factors

- Role of NEHRP Provisions
- Factors F_a and F_v



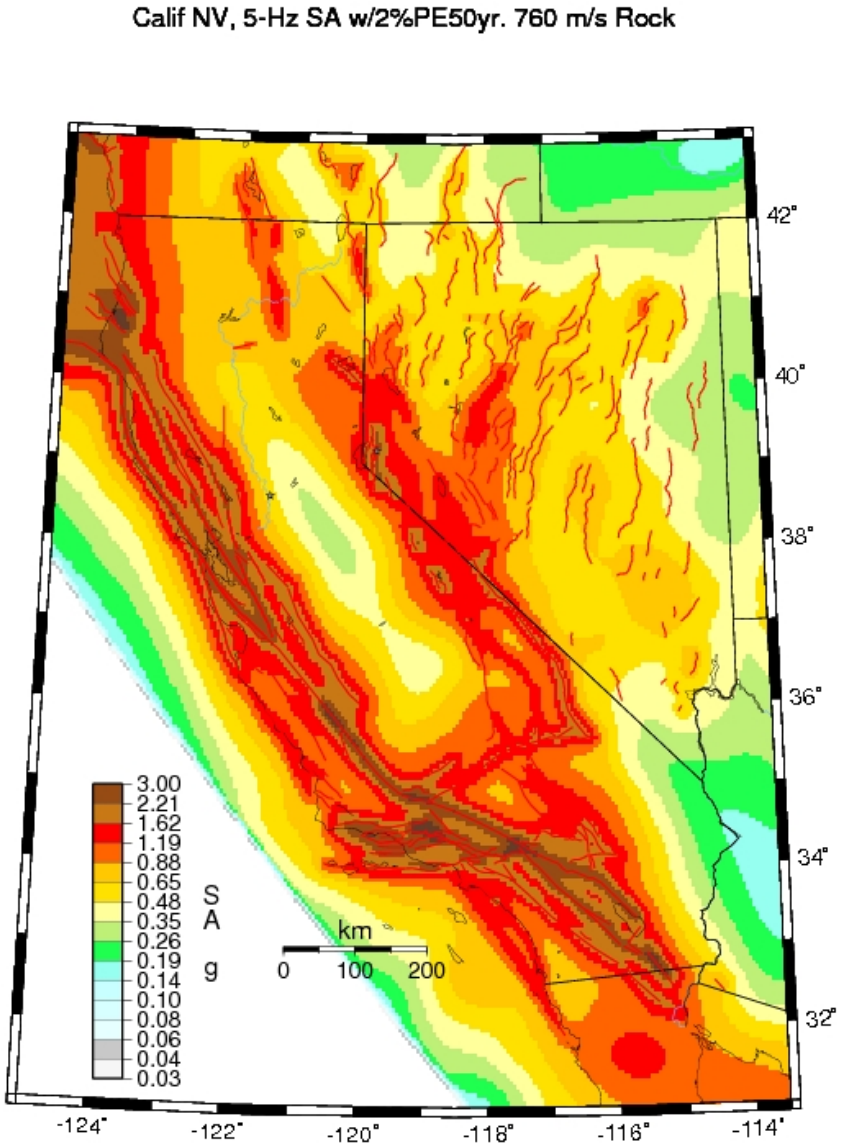


Intuitive trends

NEHRP Site Factors

- Role of NEHRP Provisions
- Factors F_a and F_v

Applied in combination with national maps. S_S and S_1 @ V_{s30} = 760 m/s



NEHRP Site Factors

- Role of NEHRP Provisions
- Factors F_a and F_v
- Background

Developed in 1992 workshop (used in 1994 NEHRP Provisions)

Contemporaneous national maps: Algermissen et al., 1990

GMPE: Schnabel & Seed, 1973

Bulletin of the Seismological Society of America. Vol. 63, No. 2, pp. 501–516. April 1973

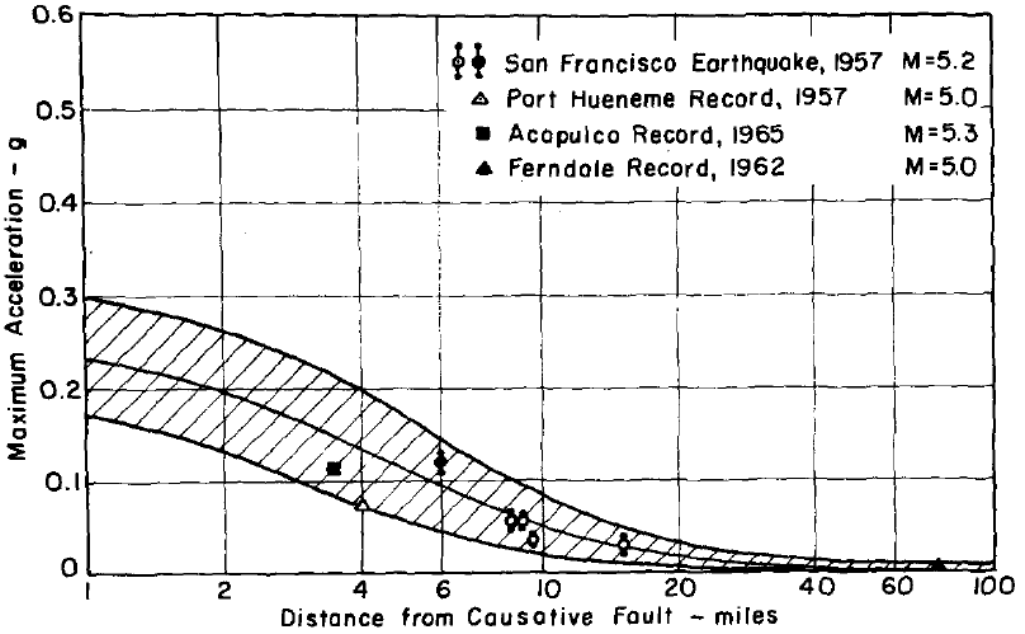
ACCELERATIONS IN ROCK FOR EARTHQUAKES IN THE WESTERN UNITED STATES

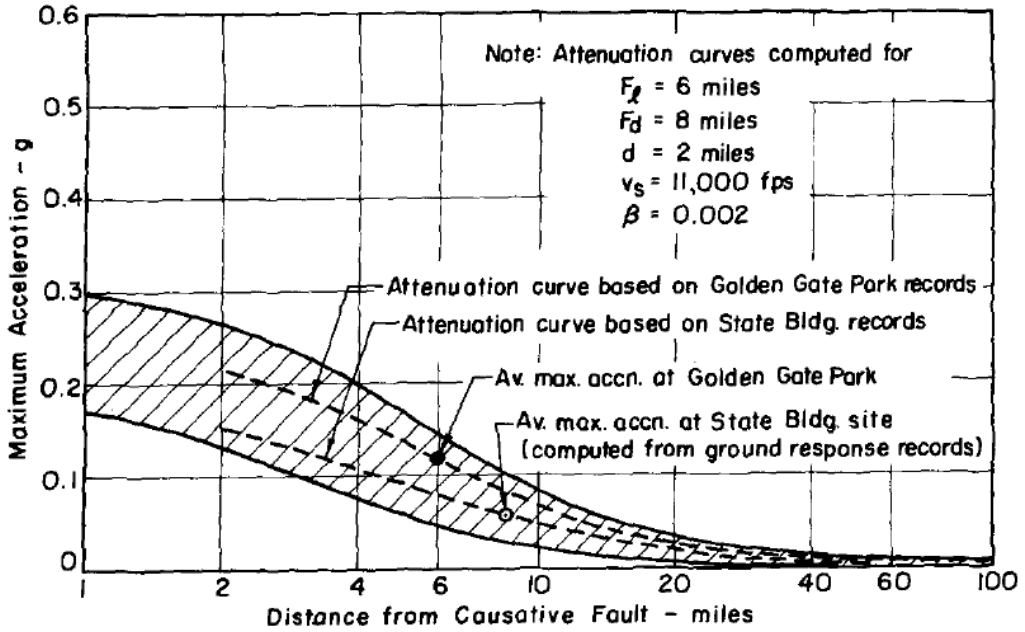
BY PER B. SCHNABEL AND H. BOLTON SEED

Schnabel & Seed, 1973

Combination of rock recordings (likely $V_{s30} \approx$ 600 m/s) & deconvoled soil recordings (V_s = 2400 m/s)

Reported to apply for 11000 ft/s = 3400 m/s



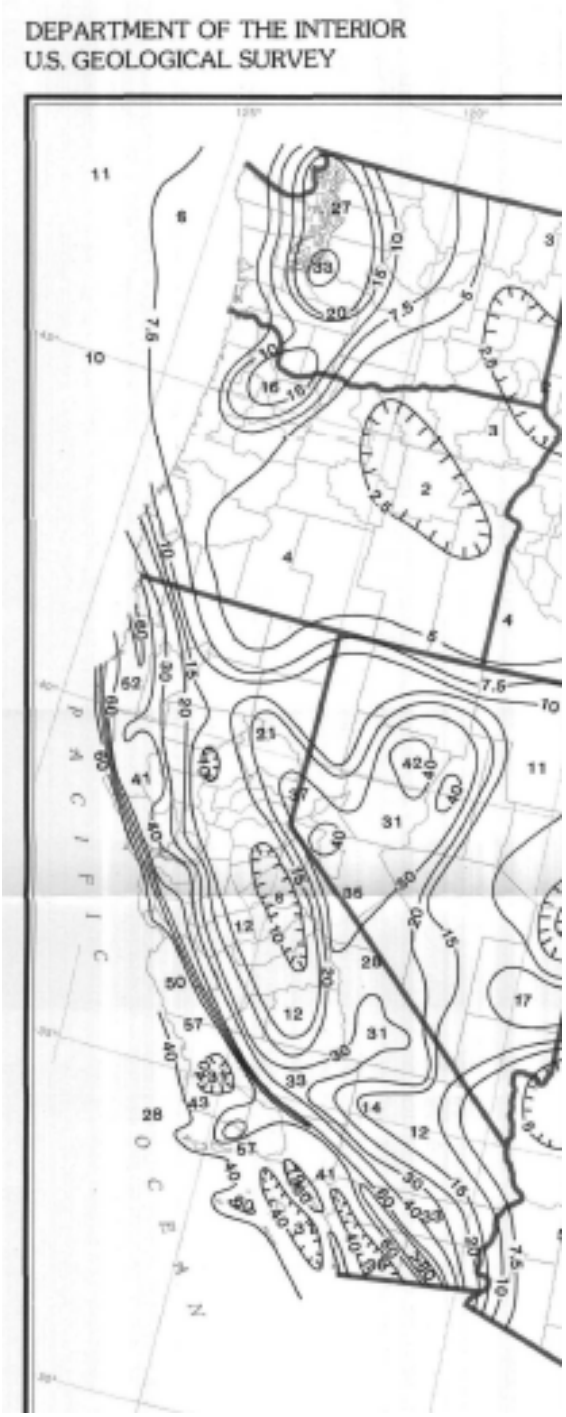


Algermissen et al., 1990 (MF 2120)

Indicates V_s = 750-900 m/s

Contradicts the utilized GMPE

Regardless, applies for hard rock site conditions

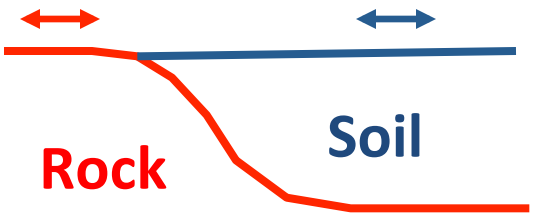


NEHRP Site Factors

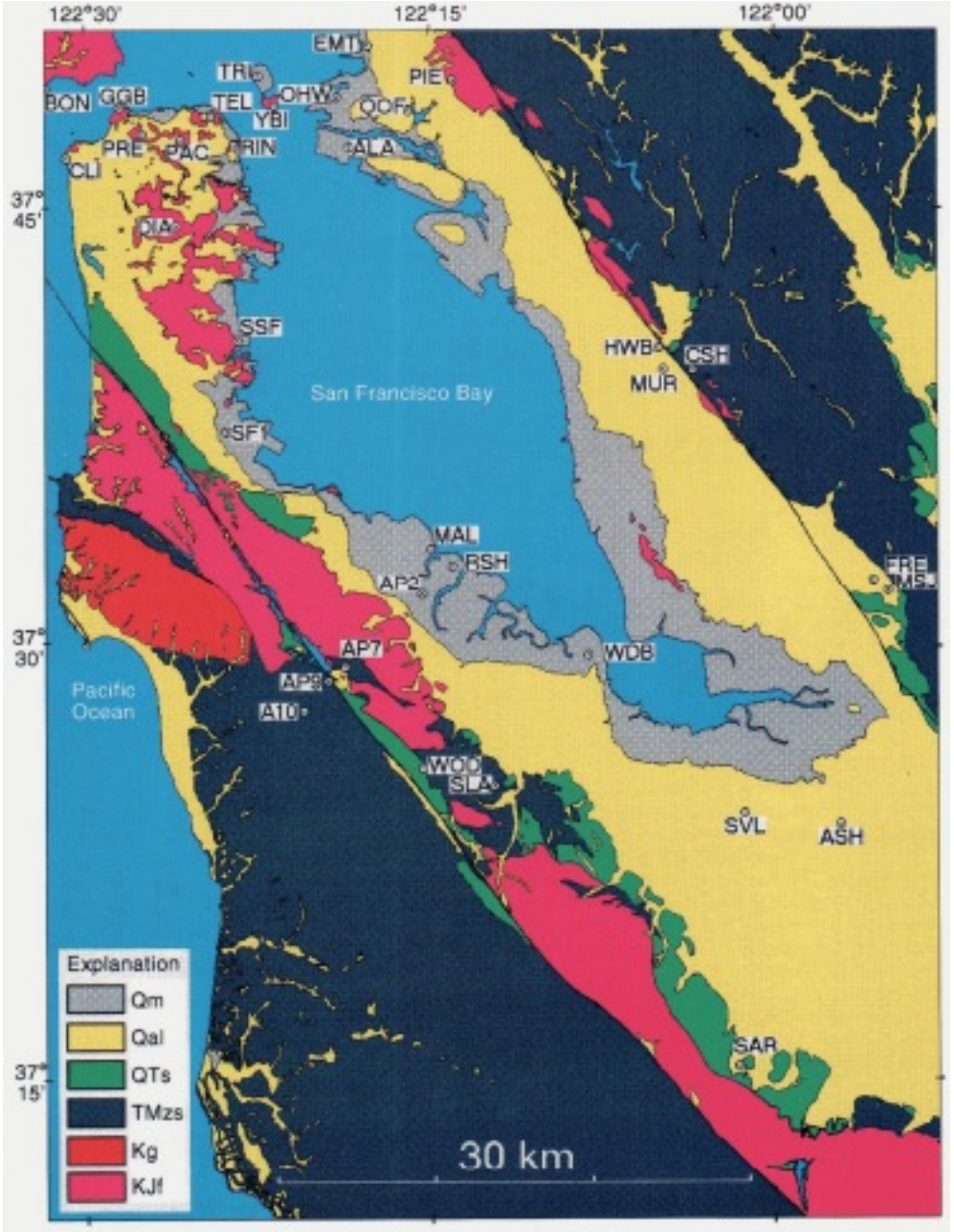
- Role of NEHRP Provisions
- Factors F_a and F_v
- Background
- Development

Empirical weak motion amplification ($PGA_r \approx 0.1$ g)

SFBA Station pairs, 1989 Loma Prieta Eq. (35 pairs)



$$F(T) = \frac{FA_{Vs30}(T)}{FA_{ref}(T)}$$



Ref: Borcherdt and Glassmoyer, 1994

Linear site amplification:

$$F_{lin} = \left(\frac{V_{s30}}{V_{ref}} \right)^{c}$$

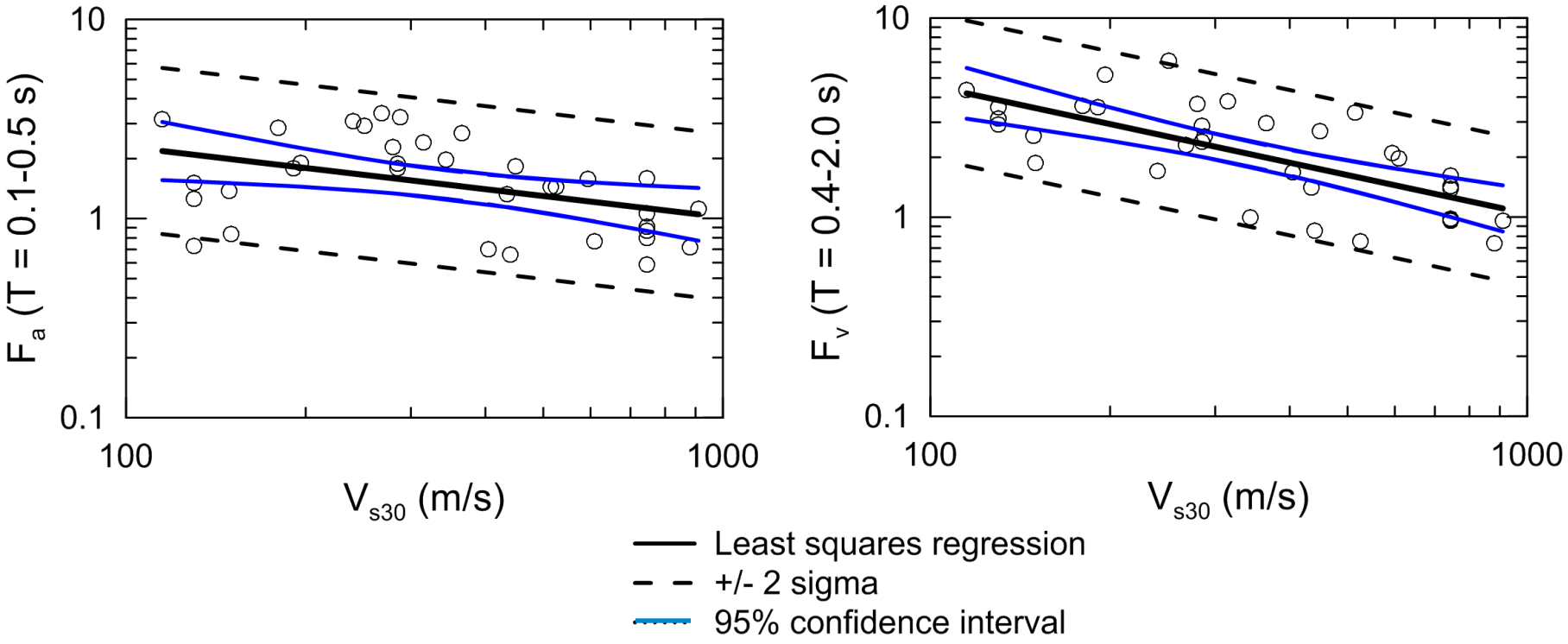
F_{lin} = linear site amplification

V_{ref} = reference velocity

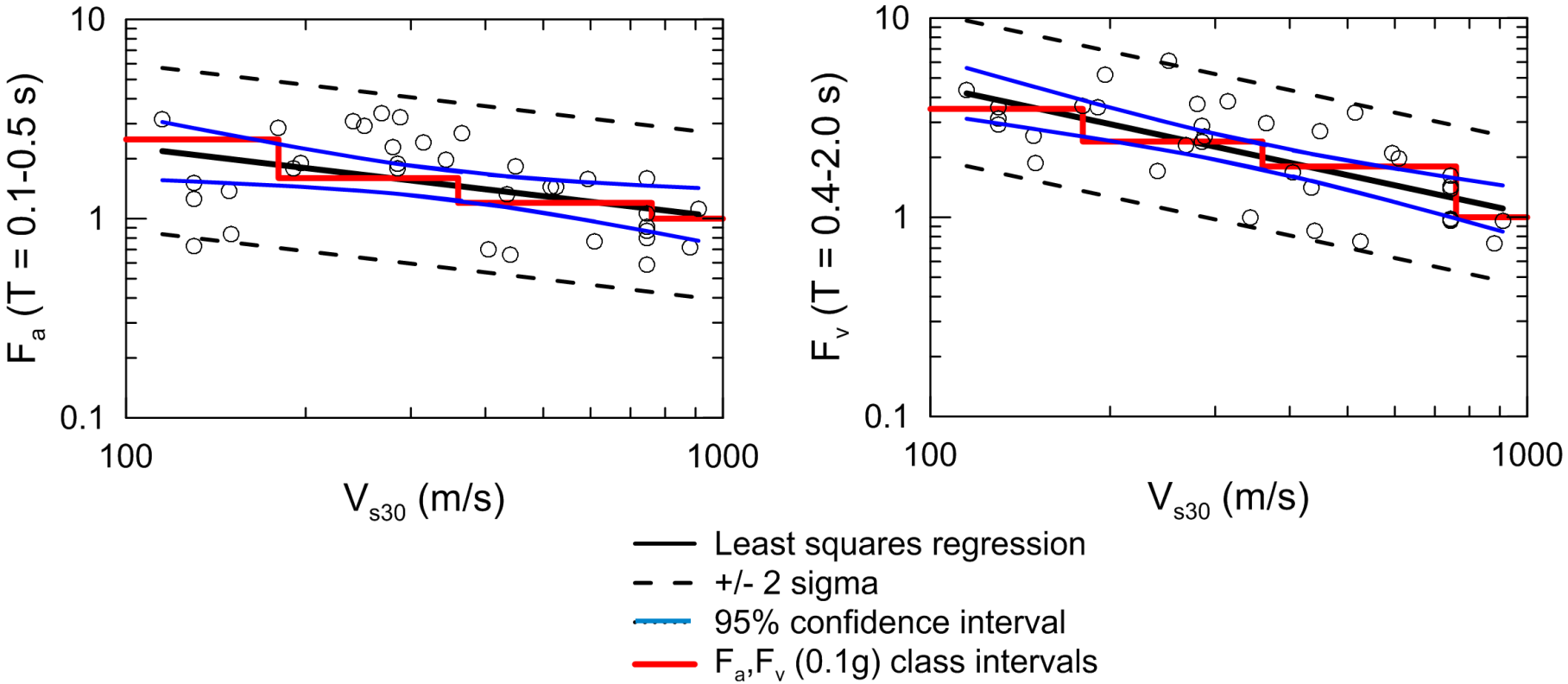
c = slope parameter

V_{ref} ≈1050 m/s

Borcherdt, 1994



Category boundaries and amplification levels set by committee consensus



NEHRP Site Factors

- Role of NEHRP Provisions
- Factors F_a and F_v
- Background
- Development

Empirical weak motion amplification ($PGA_r \approx 0.1$ g)

Simulation-based nonlinearity

1-D Ground Response simulations

Representative V_s profiles

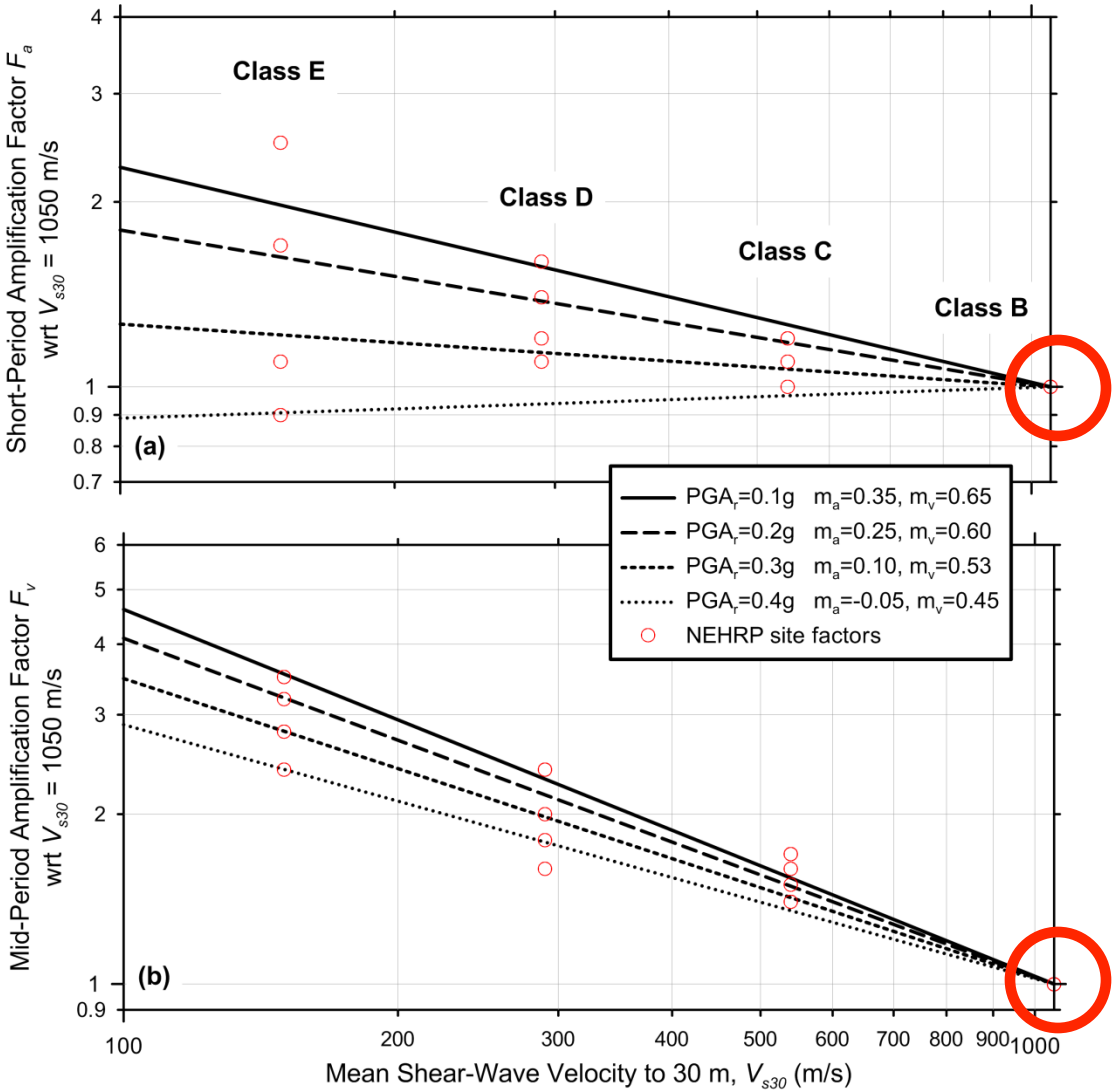
MRD curves from Vucetic & Dobry 1991; Seed et al. 1984

Results synthesized as:

$$F_a = \left(V_{s30}/V_{ref}\right)^{-m_a}$$

$$F_v = \left(V_{s30}/V_{ref}\right)^{-m_v}$$

by Borcherdt, 1994; Dobry et al., 2000



V_{ref} =1050 m/s

NEHRP Site Factors

- Role of NEHRP Provisions
- Factors F_a and F_v
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Empirical weak motion amplification ($PGA_r \approx 0.1$ g)

Simulation-based nonlinearity

General compatibility between Algermissen PSHA maps & site factors

NEHRP Site Factors

- Role of NEHRP Provisions
- Factors F_a and F_v
- Background
- Development
- Subsequent use (since 1994)

Change of national maps:

1996: Set to B-C boundary (V_{s30} = 760 m/s); Frankel et al., 1996

Mix of category-based and V_{s30}-based GMPEs

2008: NGA GMPEs for WUS with V_{s30}=760 m/s

Outline

- Context
- Site factors in NEHRP provisions
- **Site factors from NGA-West2 project**
- Conclusions & recommendations

NGA-West2 Site Factors

- Task 8 committee found discrepancies between NEHRP and original NGA site factors
- Site amplification model developed to guide evaluation of new factors
- Proposal developed based on model (tabulated factors & equations)
- Alternate proposal by dissenting committee member

Data Selection Criteria

- July 2012 flatfile. 8611 records. 346 events
- Minimum of 10 records / event
- Data with $R_{jb} < 100$ km only
- Records omitted having unknown ground motions, **M**, R, or V_{s30}

Site Model

- Consider GMPE for rock site conditions (V_{s30}=760 m/s)
- Misfits expected for recording on soil
- Compute residuals between data and rock GMPE

$$R_{ij} = \ln\left(IM_{obs}\right)_{ij} - \left[\left(\mu_r\right)_{ij} + \eta_i\right]$$

- Construct a site amplification model to remove trends with site parameters

Model Summary

- ***Combined model***

$$\ln(F) = \ln(F_{lin}) + \ln(F_{nl})$$

- ***Linear term***

$$\ln(F_{lin}) = (c + \Delta c)\ln\left(\frac{V_{s30}}{V_{ref}}\right)$$

V_{ref} = 760 m/s
c = slope term for V_{s30}-scaling
Δc = regional correction

- ***Nonlinear term***

$$\ln(F_{nl}) = f_1 + f_2 \ln\left(\frac{PGA_r + f_3}{f_3}\right)$$

f_2 = f(V_{s30}, PGA_r)
f_3 = 0.1 g, f_1 = 0

Steps in Model Development

- Evaluation of nonlinearity. Guided by data trends and simulation results
- Evaluation of V_{s30}-scaling, including regional effects
- Analysis of residuals to check performance

Nonlinearity

- Data analysis

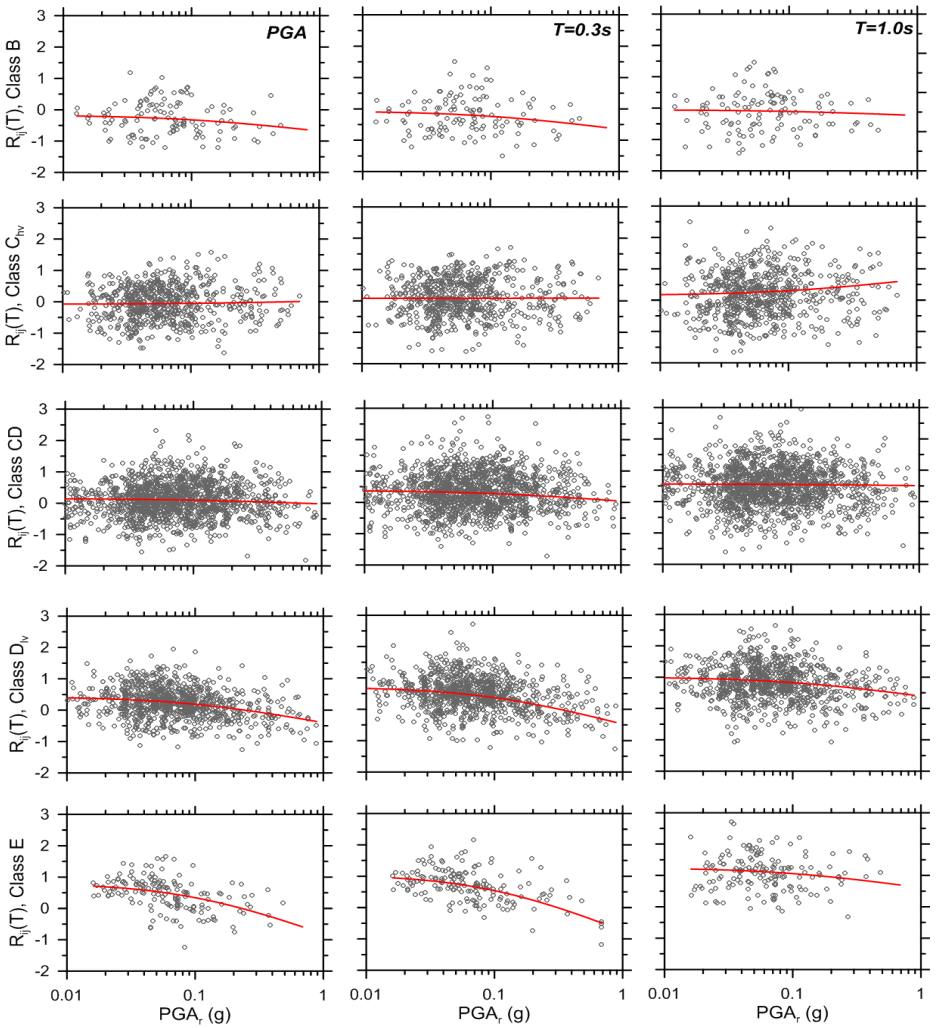
Bin residuals (R_{ij}) by V_{s30}:

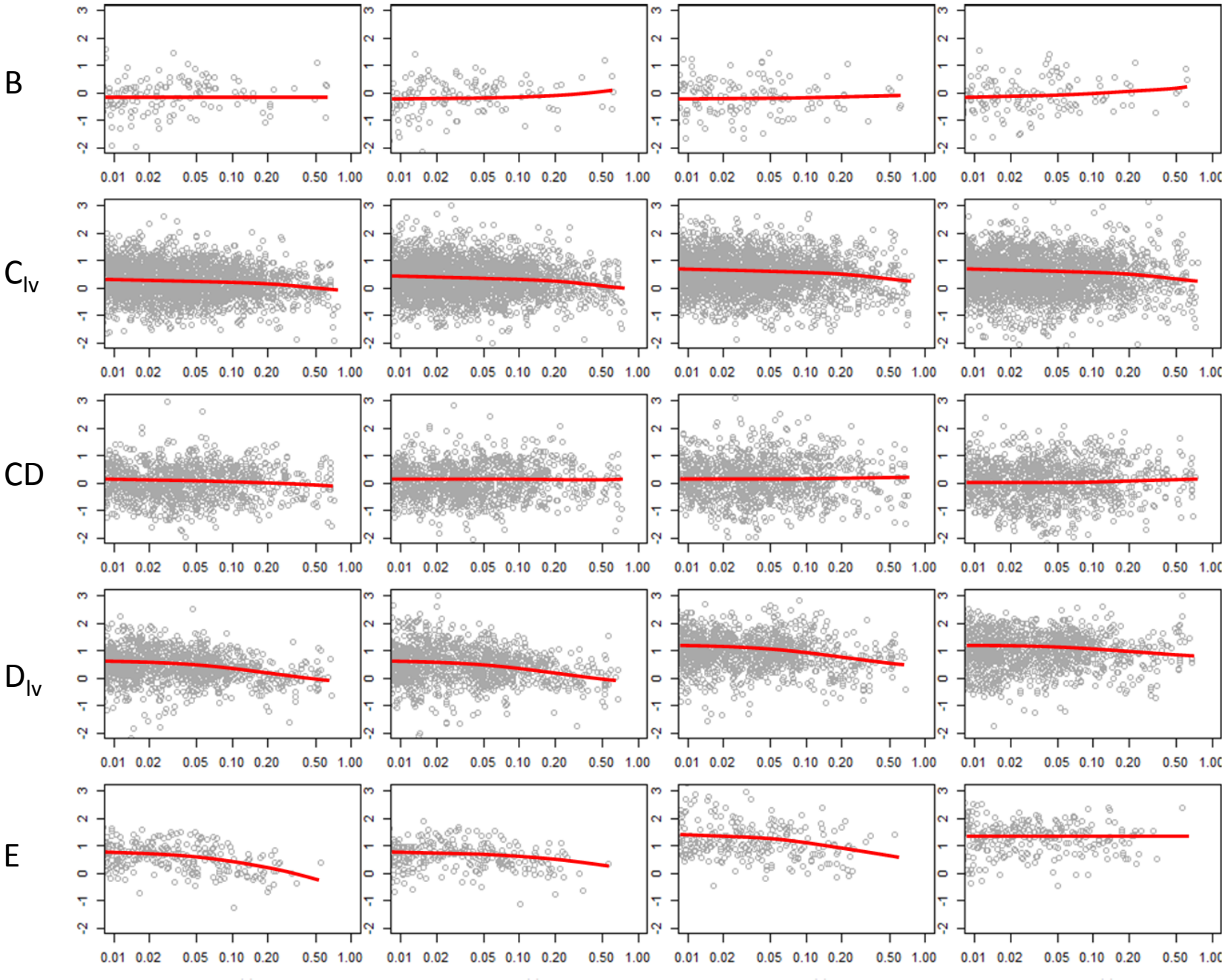
$$Class\ B \quad : 760 < V_{s30} < 1500\ m/s$$
$$Class\ C_{hv} : 520 < V_{s30} < 760\ m/s$$
$$Class\ CD : 310 < V_{s30} < 520\ m/s$$
$$Class\ D_{lv} : 200 < V_{s30} < 310\ m/s$$
$$Class\ E \quad : 200 \geq V_{s30}\ m/s$$

Plot against PGA_r

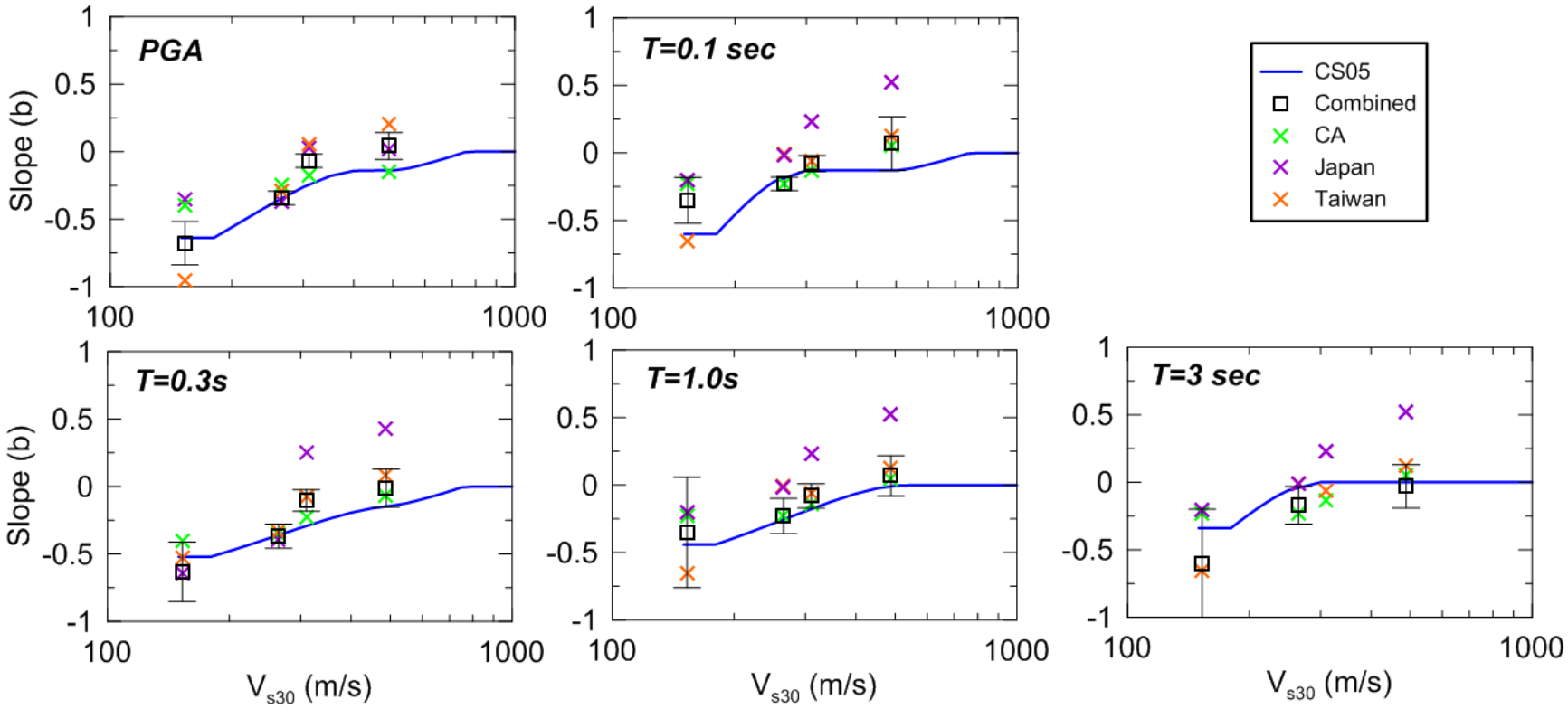
Nonlinear regression

$$R_i = a + b\ln\left(PGA_r + d\right) + \varepsilon_i$$




B
C_{lv}
CD
D_{lv}
E
-2 -1 0 1 2 3
0.01 0.02 0.05 0.10 0.20 0.50 1.00

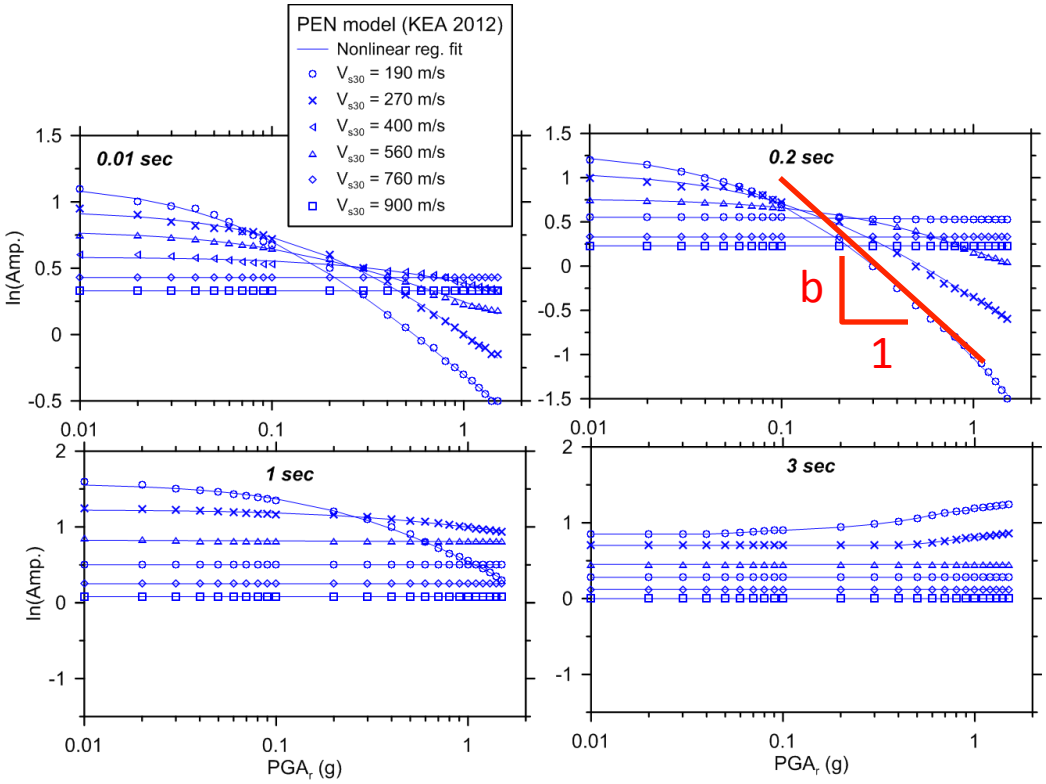
Nonlinearity



Nonlinearity

- Data analysis
- Interpretation of simulation results (Kamei et al., 2012)

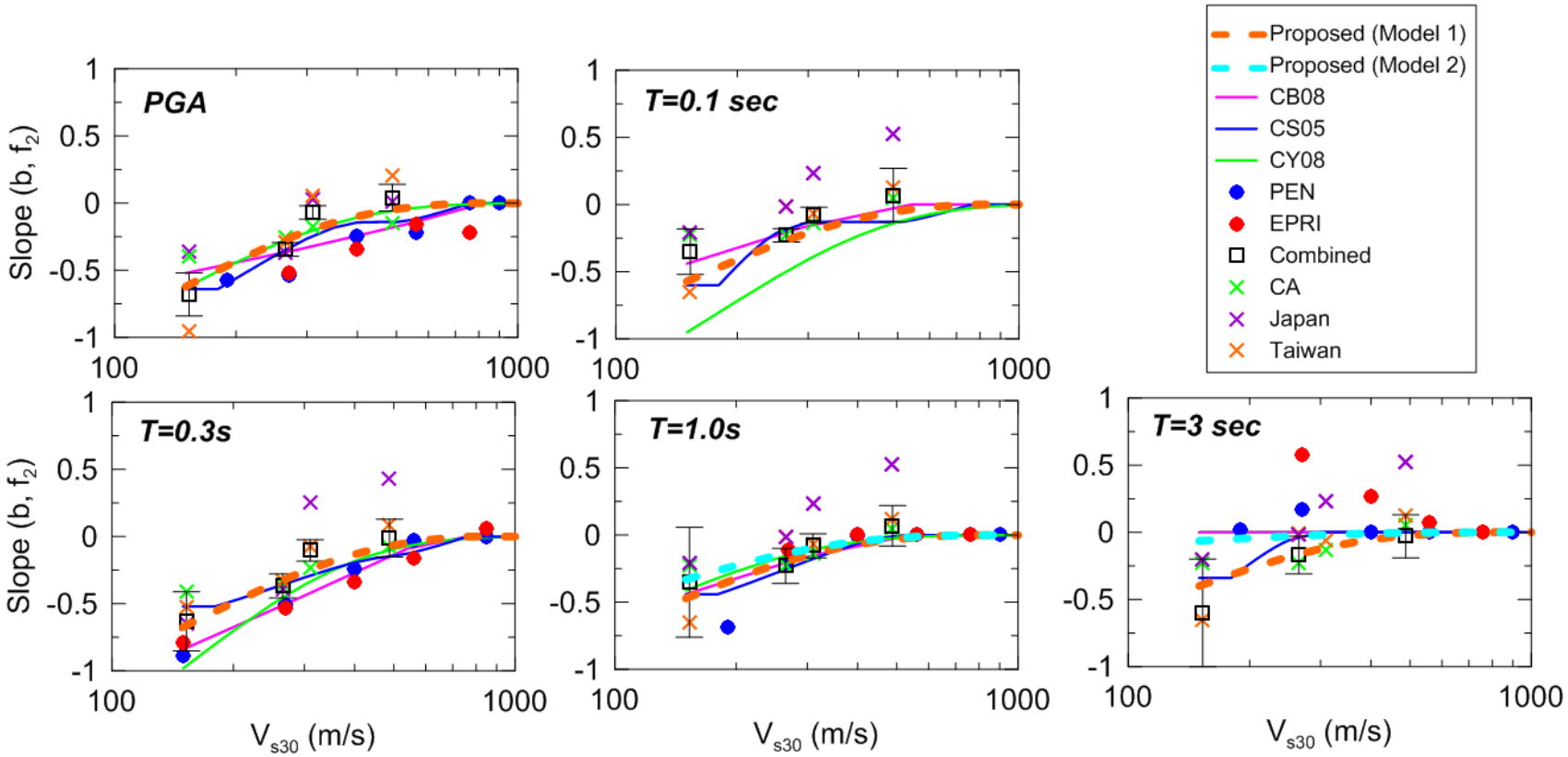
Fit slope parameter to simulation results



Nonlinearity

- Data analysis
- Interpretation of simulation results (Kamei et al., 2012)
- Plot b vs V_{s30} and select model that captures trends

Nonlinearity



V_{s30}-Scaling

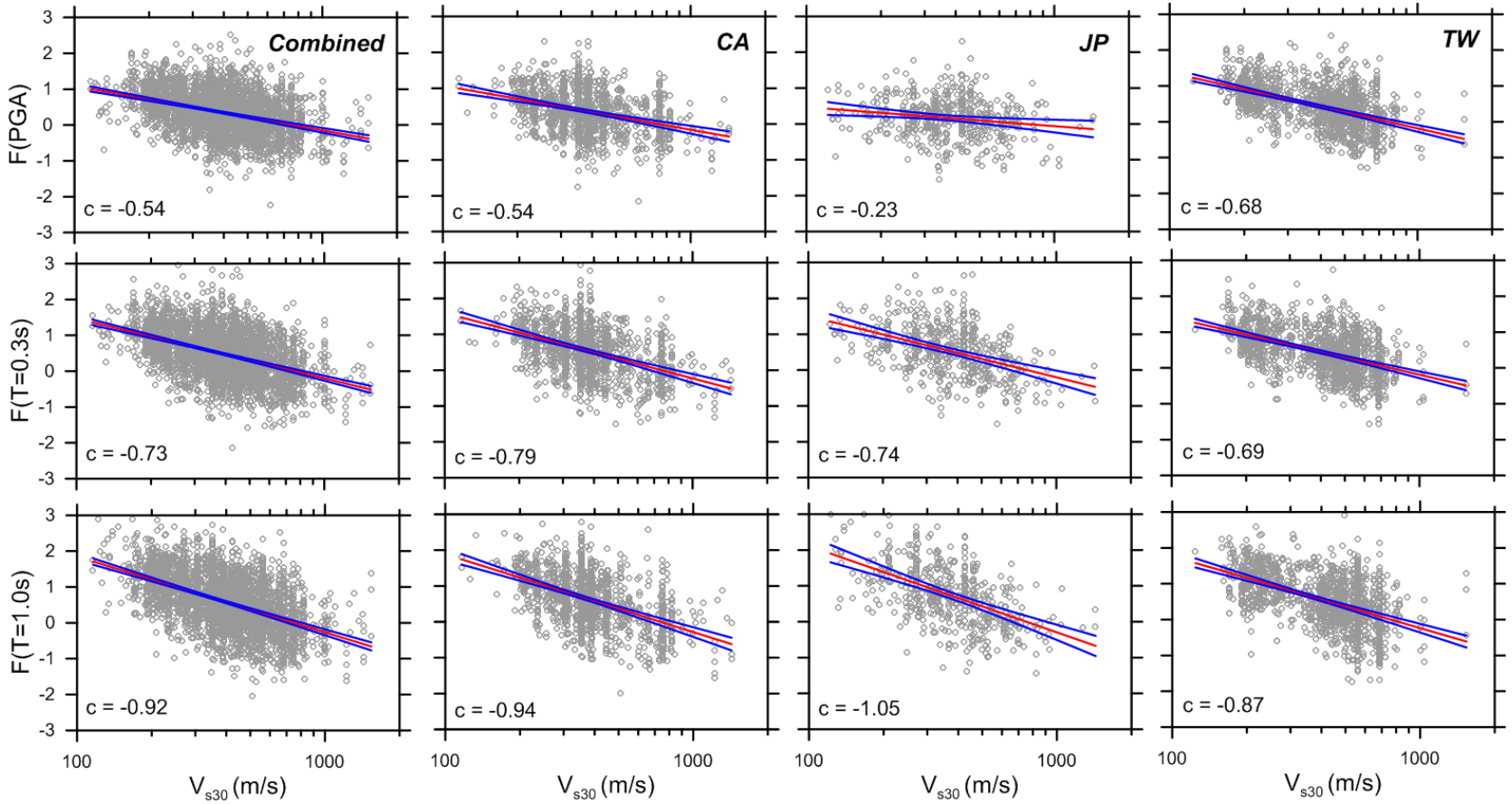
- Remove nonlinearity from residuals

$$R_k^{lin} = R_{i,j} - \ln\left(F_{nl}\right)$$

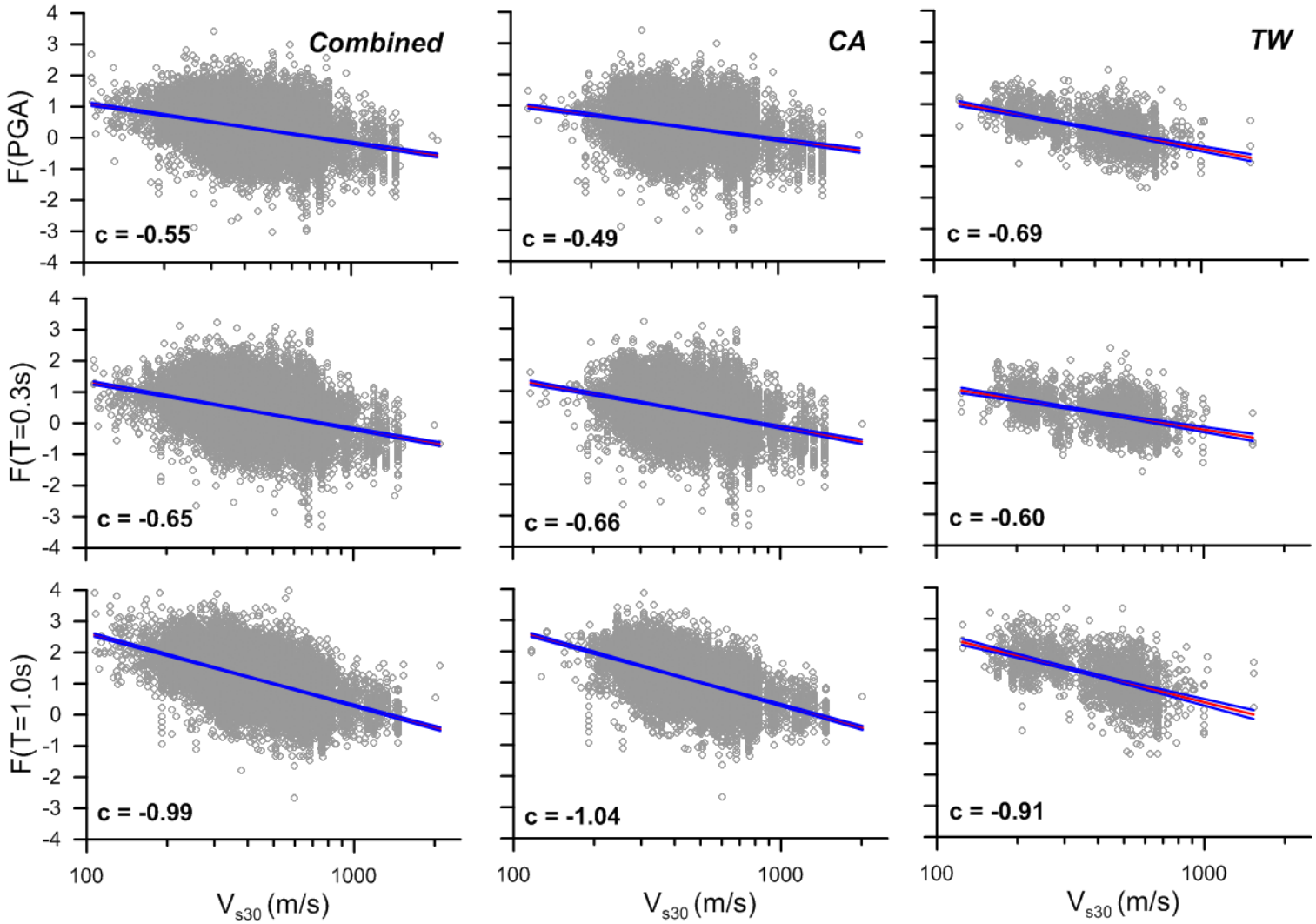
V_{s30}-Scaling

- Remove nonlinearity from residuals
- Plot adjusted residuals against V_{s30}, compute slope

V_{s30}-Scaling

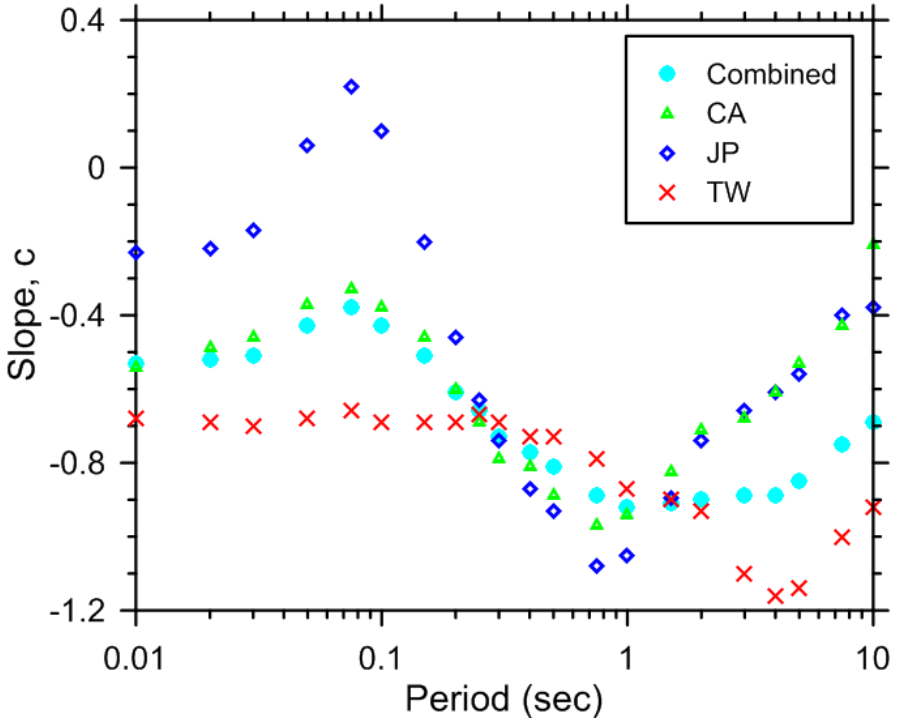


V_{s30}-Scaling



V_{s30}-Scaling

- Remove nonlinearity from residuals
- Plot adjusted residuals against V_{s30}, compute slope
- Regional variations in slope observed



V_{s30}-Scaling

- Remove nonlinearity from residuals
- Plot against V_{s30}, compute slope
- Regional variations in slope observed
- Parameter *c* set from combined data set, Δc from regional results

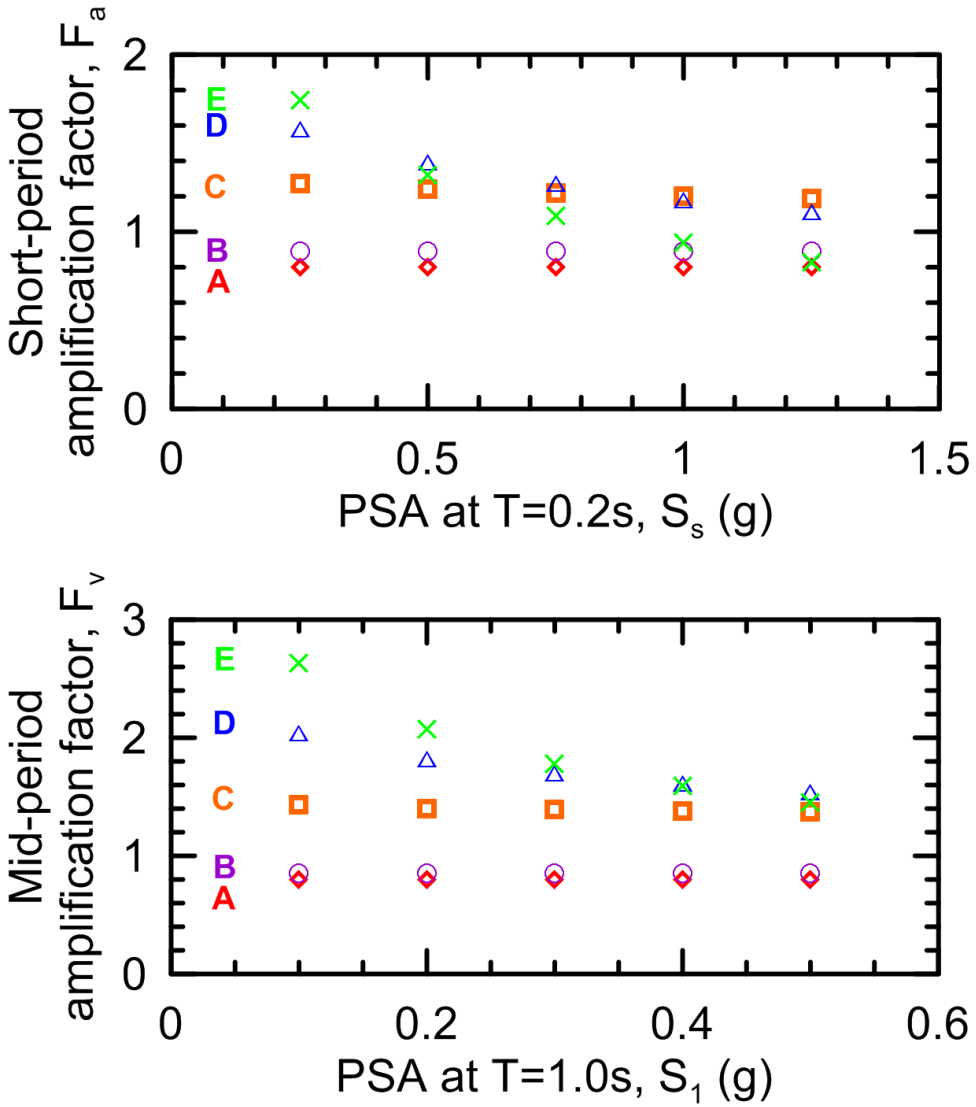
$$\ln(F_{lin}) = (c + \Delta c)\ln\left(\frac{V_{s30}}{V_{ref}}\right)$$

Period (sec)	c	Δ c (CA)	Δ c (JP)	Δ c (TW)
0.01	-0.53	-0.01	0.30	-0.15
0.02	-0.52	0.03	0.30	-0.17
0.03	-0.51	0.05	0.34	-0.19
0.05	-0.43	0.06	0.49	-0.25
0.075	-0.38	0.05	0.60	-0.28
0.1	-0.43	0.05	0.53	-0.26
0.15	-0.51	0.05	0.31	-0.18
0.2	-0.61	0.01	0.15	-0.08
0.25	-0.66	-0.03	0.03	-0.01
0.3	-0.73	-0.06	-0.01	0.04
0.4	-0.77	-0.04	-0.10	0.04
0.5	-0.81	-0.08	-0.12	0.08
0.75	-0.89	-0.08	-0.19	0.10
1	-0.92	-0.02	-0.13	0.05
1.5	-0.91	0.09	0.02	0.01
2	-0.90	0.19	0.16	-0.03
3	-0.89	0.21	0.23	-0.21
4	-0.89	0.28	0.28	-0.27
5	-0.85	0.32	0.29	-0.29
7.5	-0.75	0.32	0.35	-0.25
10	-0.69	0.48	0.31	-0.23

NEHRP / ASCE Factors

- Extensive deliberations over > 2 years.
- Use V_{ref} = 760 m/s
- Use $\Delta c = 0$
- Select representative V_{s30} within categories
- Use mean values of f_2 across period ranges for F_a and F_v for each V_{s30}
- Convert PGA_r to S_s and S_1: $S_s \approx 2.3 \times PGA_r$ $S_1 \approx 0.7 \times PGA_r$
- Use mean values of c across period ranges

NEHRP / ASCE Factors



NEHRP / ASCE Factors

F_a

Site Class	$S_s < 0.25$		$S_s = 0.5$		$S_s = 0.75$		$S_s = 1.0$		$S_s > 1.25$	
	PEER	ASCE	PEER	ASCE	PEER	ASCE	PEER	ASCE	PEER	ASCE
A	0.8	**0.8**	0.8	**0.8**	0.8	**0.8**	0.8	**0.8**	0.8	**0.8**
B	0.9	**1.0**	0.9	**1.0**	0.9	**1.0**	0.9	**1.0**	0.9	**1.0**
C	1.3	**1.2**	1.2	**1.2**	1.2	**1.1**	1.2	**1.0**	1.2	**1.0**
D	1.6	**1.6**	1.4	**1.4**	1.3	**1.2**	1.2	**1.1**	1.1	**1.0**
E	1.7	**2.5**	1.3	**1.7**	1.1	**1.2**	0.9	**0.9**	0.8	**0.9**

F_v

Site Class	$S_1 < 0.1$		$S_1 = 0.2$		$S_1 = 0.3$		$S_1 = 0.4$		$S_1 > 0.5$	
	PEER	ASCE	PEER	ASCE	PEER	ASCE	PEER	ASCE	PEER	ASCE
A	0.8	**0.8**	0.8	**0.8**	0.8	**0.8**	0.8	**0.8**	0.8	**0.8**
B	0.9	**1.0**	0.9	**1.0**	0.9	**1.0**	0.9	**1.0**	0.9	**1.0**
C	1.4	**1.7**	1.4	**1.6**	1.4	**1.5**	1.4	**1.4**	1.4	**1.3**
D	2.0	**2.4**	1.8	**2.0**	1.7	**1.8**	1.6	**1.6**	1.5	**1.5**
E	2.6	**3.5**	2.1	**3.2**	1.8	**2.8**	1.6	**2.4**	1.5	**2.4**

Favorable PUC response in Oct 2012 meeting

NEHRP / ASCE Factors

Alternate proposal

- Reference condition taken as Class B (not V_{s30} = 760 m/s). $V_{ref} \approx$ 1050 m/s per Borcherdt (1994)
- NEHRP coefficients compared to 2008 NGA site terms adjusted for V_{ref} = 1050 m/s
- NEHRP factors modified to remove misfits
- Both proposals currently out for balloting in Task 8 working group
- Proposal with most votes goes to PUC

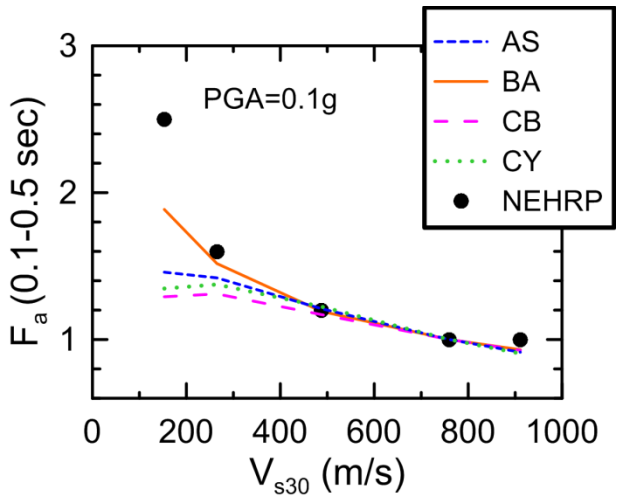
Conclusions & Recommendations

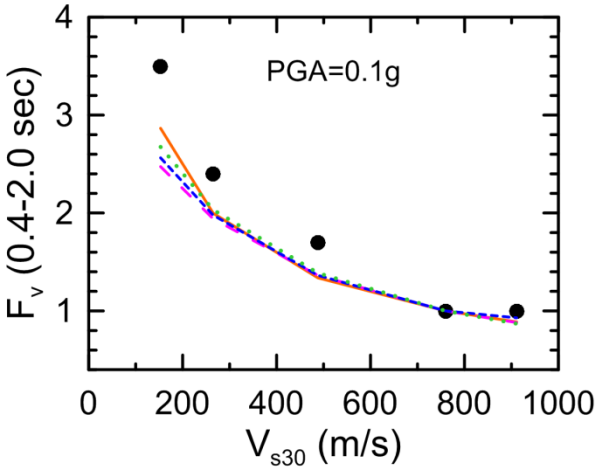
- V_{s30} remains the baseline site parameter
- NGA-West2 GMPEs will have nonlinear V_{s30}-based site terms
  - Nonlinearity from data and simulations
  - Regional V_{s30}-scaling. Why?
- Pending changes to NEHRP/ASCE site factors
  - Lack of consensus on V_{ref}
  - V_{s30}-scaling based on global data
  - Reduced levels of nonlinearity (esp. C & D)

Site Factors in GMPEs

- Utilization of V_{s30}
- Derivation of site factors
- NGA-NEHRP comparisons

Results indicate similar V_{s30} scaling (parameter c)

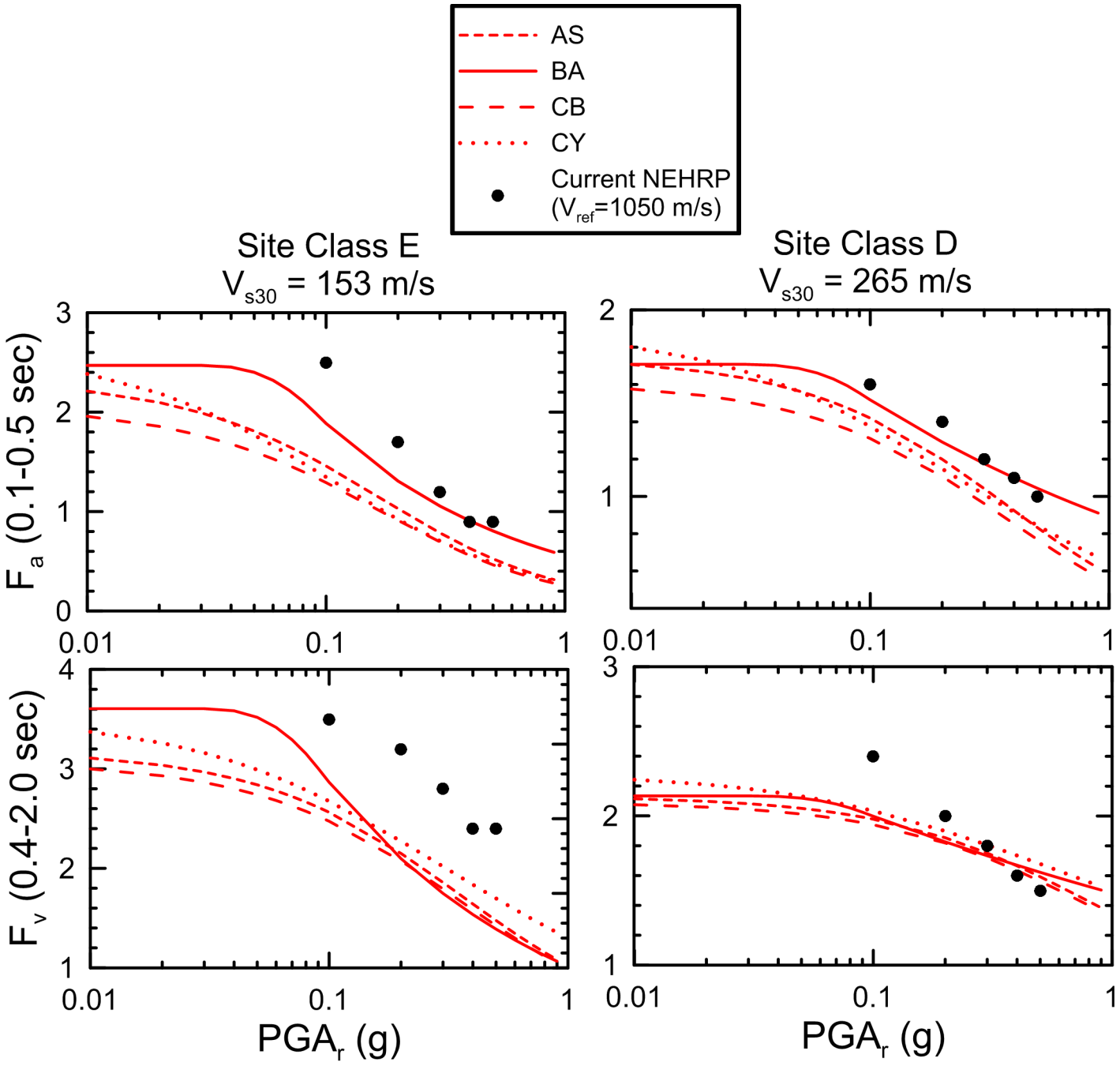




Large epistemic uncertainty for E

Misfits:

- **F_a (B, E)**
- **F_v (general)**
- **F_v slopes (C, D)**



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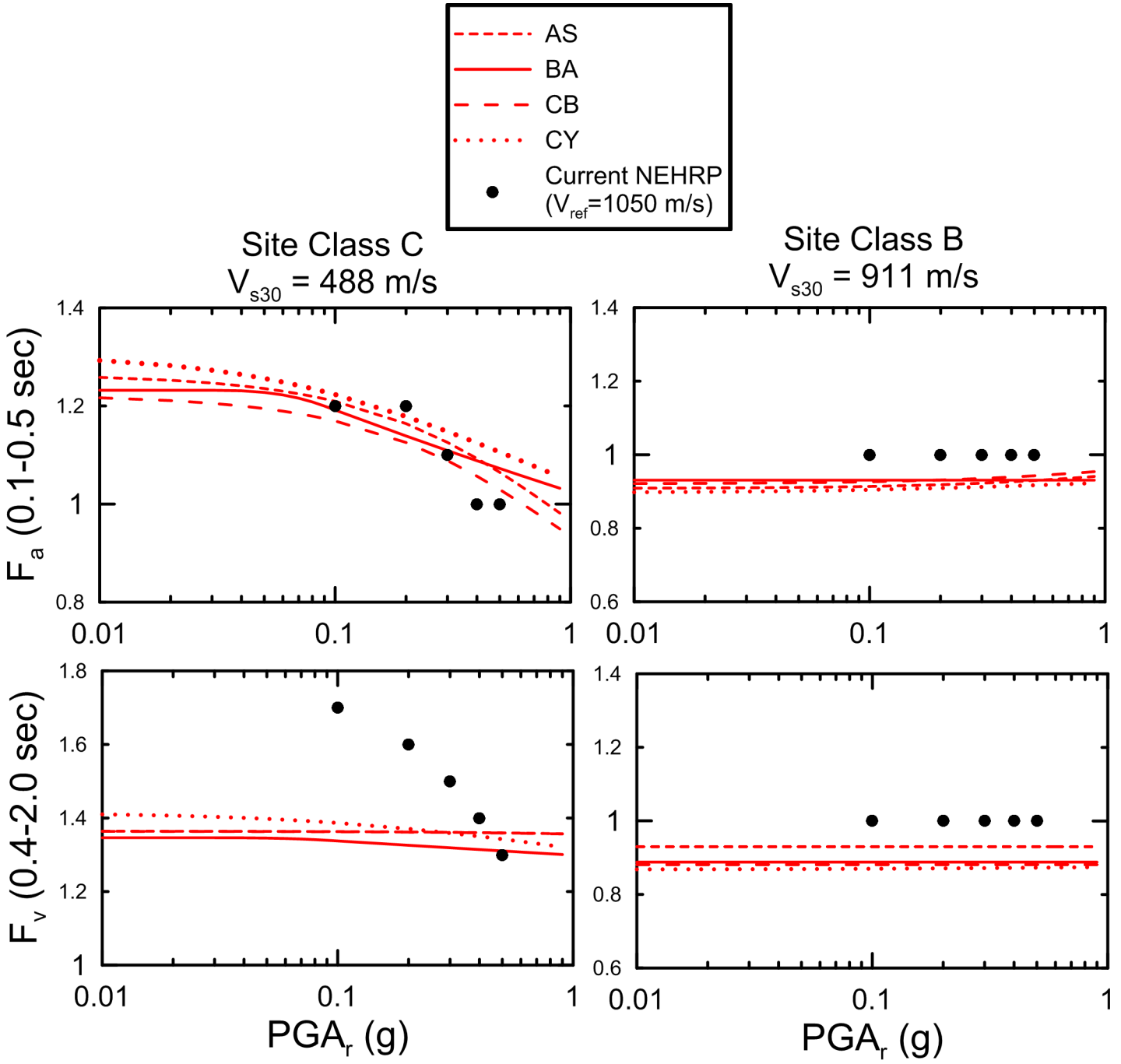
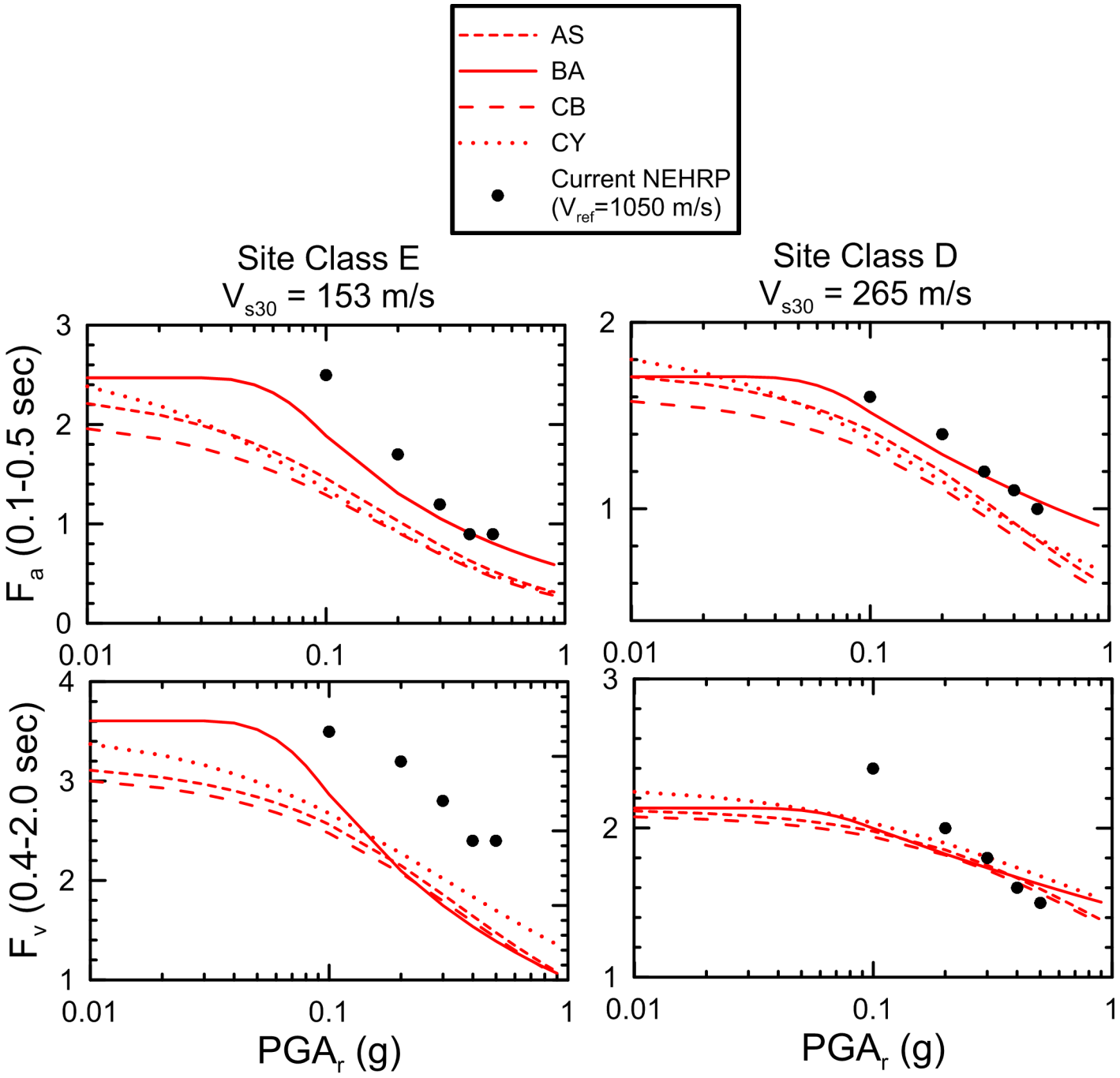


Effect of changing NEHRP V_{ref}=760 m/s



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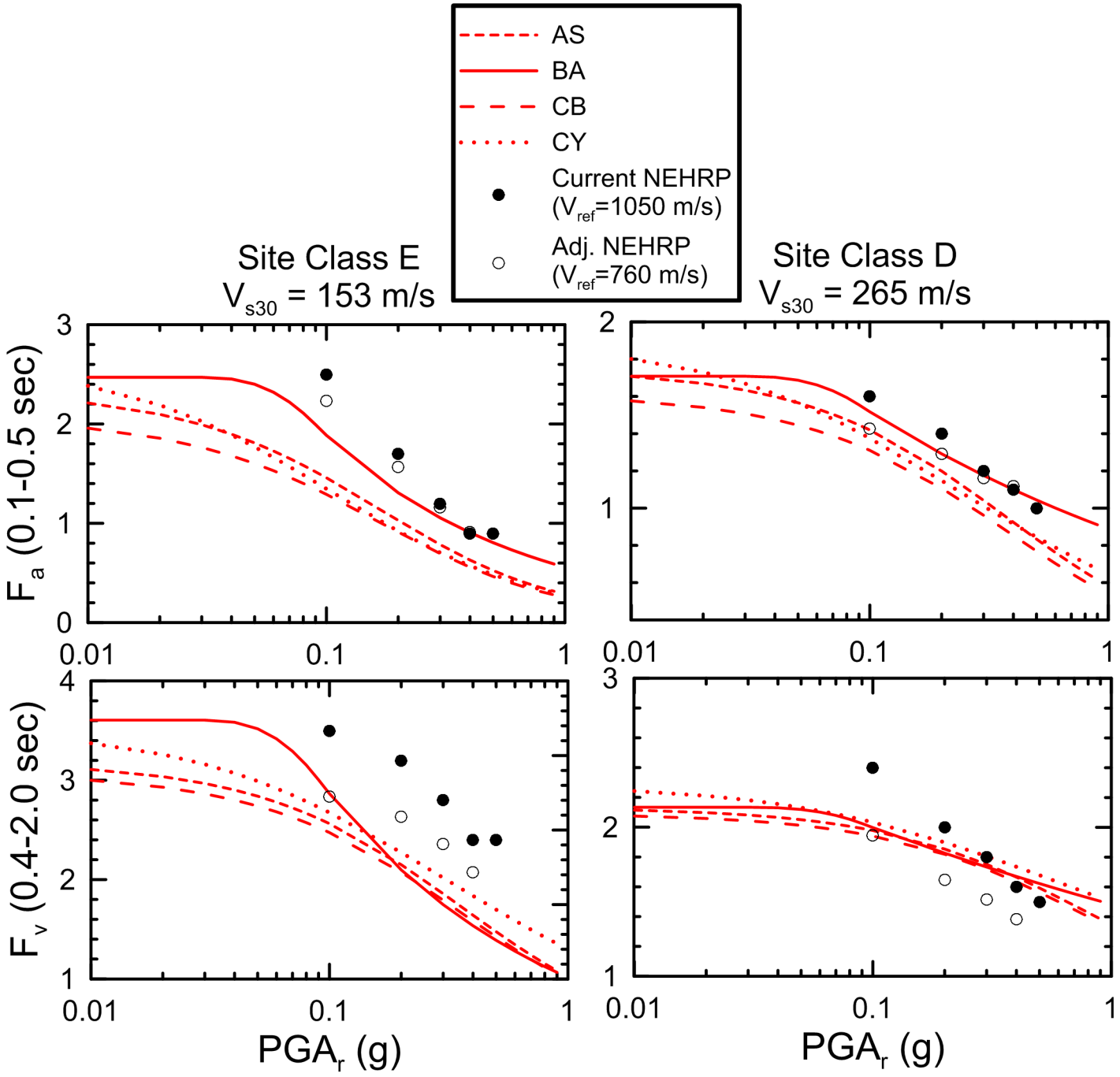

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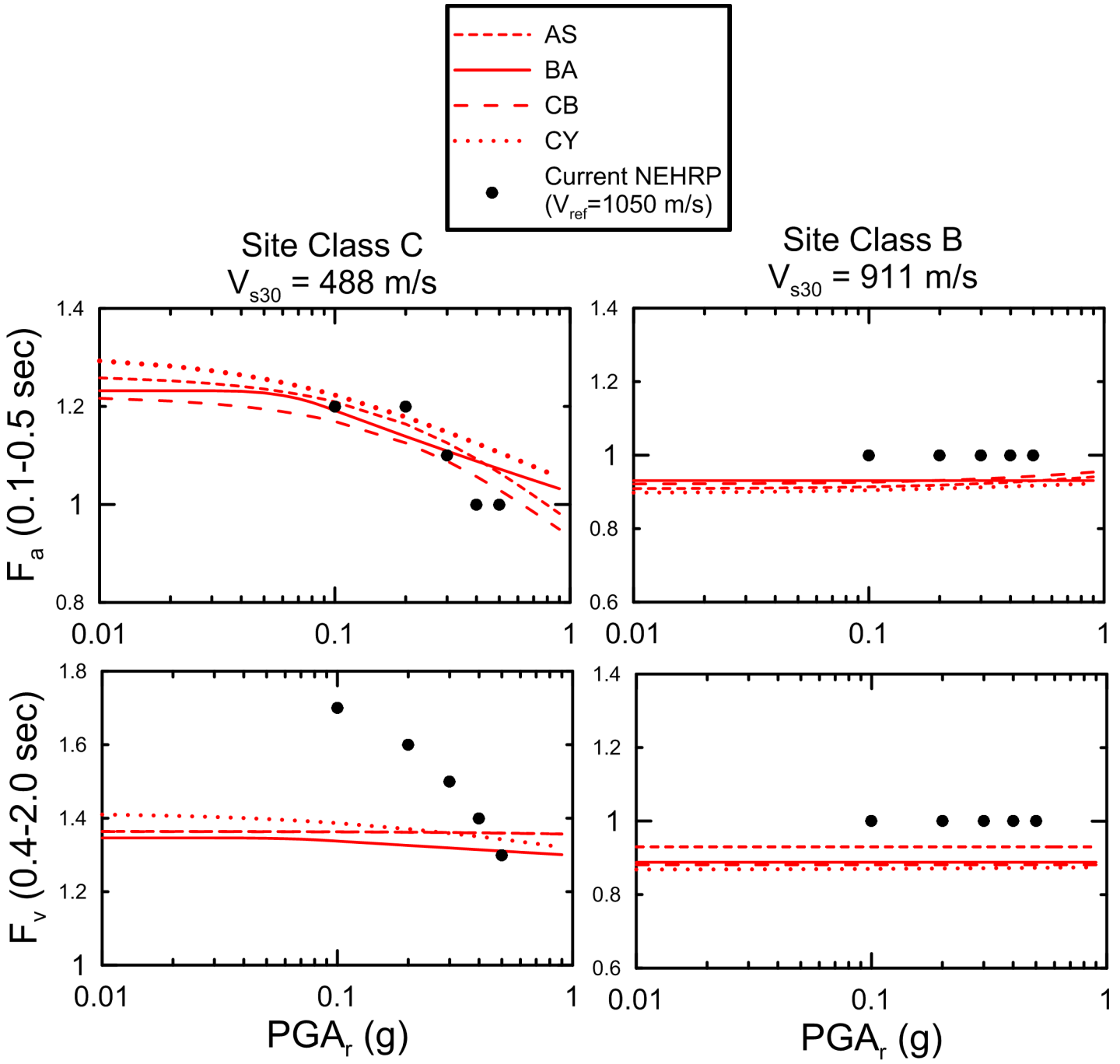

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