A Comparison of Site-Specific and Empirical Methods for Site Response Evaluation

Jonathan P. Stewart
University of California, Los Angeles

Mehmet B. Baturay
Geosyntec Consultants, Oakland, CA

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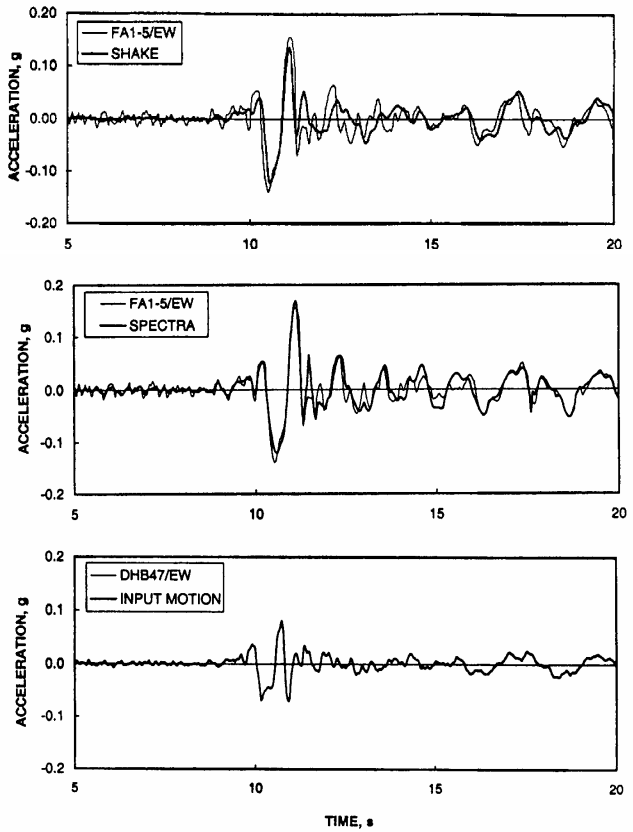
Outline

- Can we model site effects? Two views:
  - Geotechnical studies
  - Lee and Anderson (2000)
- Two procedures for site response evaluation
  - Empirical: amplification factors
  - Site specific: 1D wave propagation analyses
- Application of procedures for calibration sites
- Analysis of residuals
- Summary and recommendations

Can we model site effects?

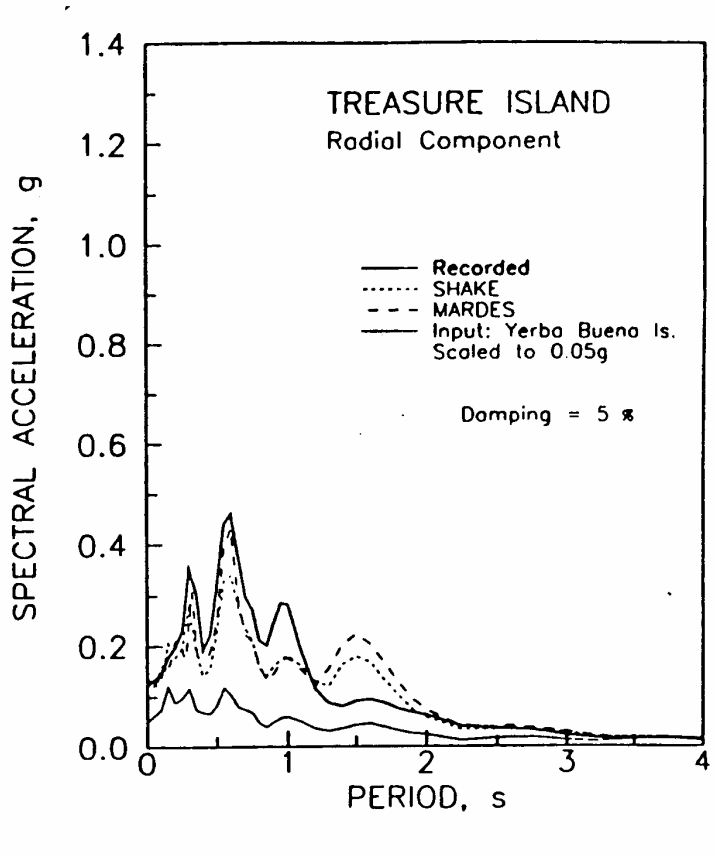
- Geotechnical perspective
  - Vertical array studies



Ref: Borja et al., 1999

Can we model site effects?

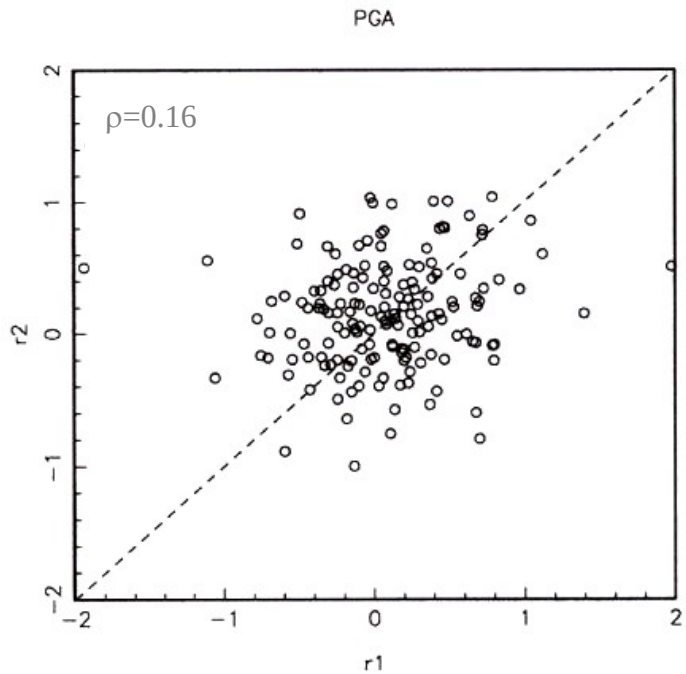
- Geotechnical perspective
  - Vertical array studies
  - Nearby soil-rock recordings



Ref: Dickenson, 1994

Can we model site effects?

- Lee and Anderson (2000)
  - Sites with multiple recordings
  - Evaluated residuals from soil attenuation relation
  - If site effect relative to attenuation site factor is significant…
  - Conclusion: site-specific effects not repeatable



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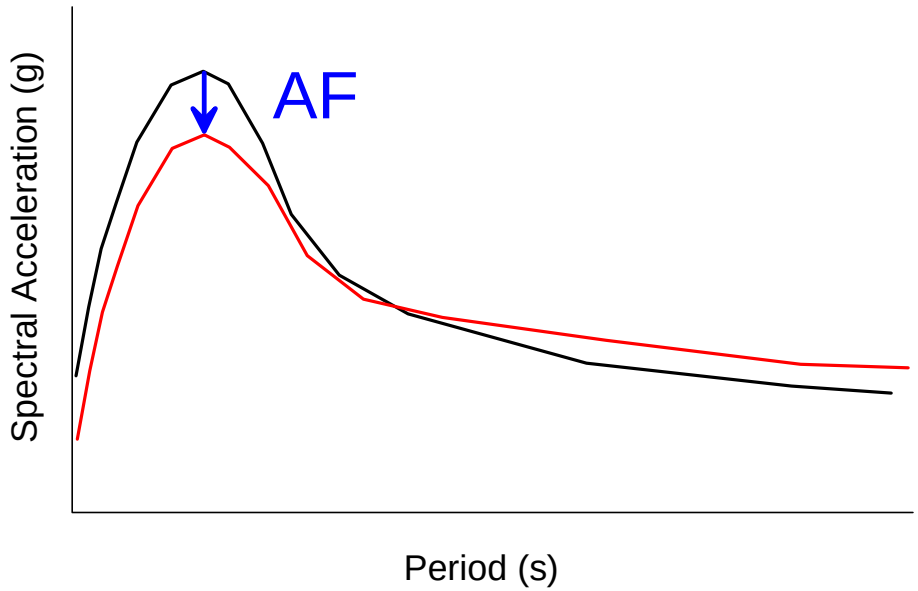
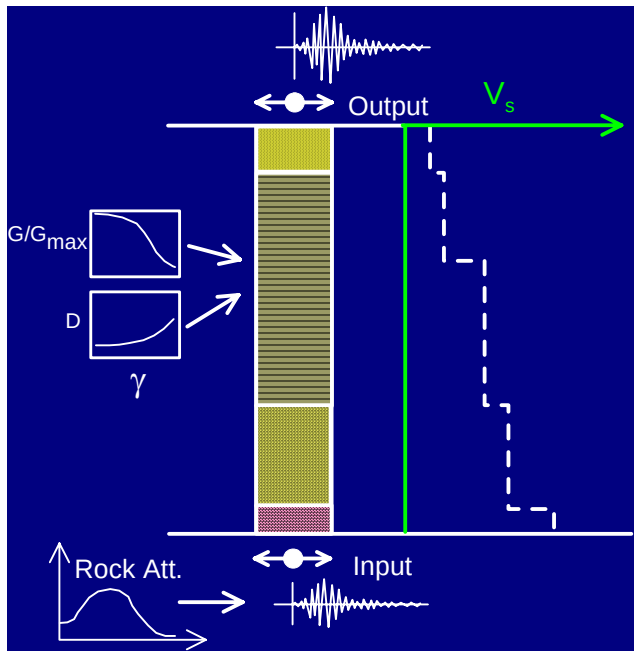
Methods of Site Response Evaluation: Empirical

- Reference motion:
  - Rock attenuation
- Apply amplification factor
  - Classify site
  - Adjust median
  - Modify standard deviation



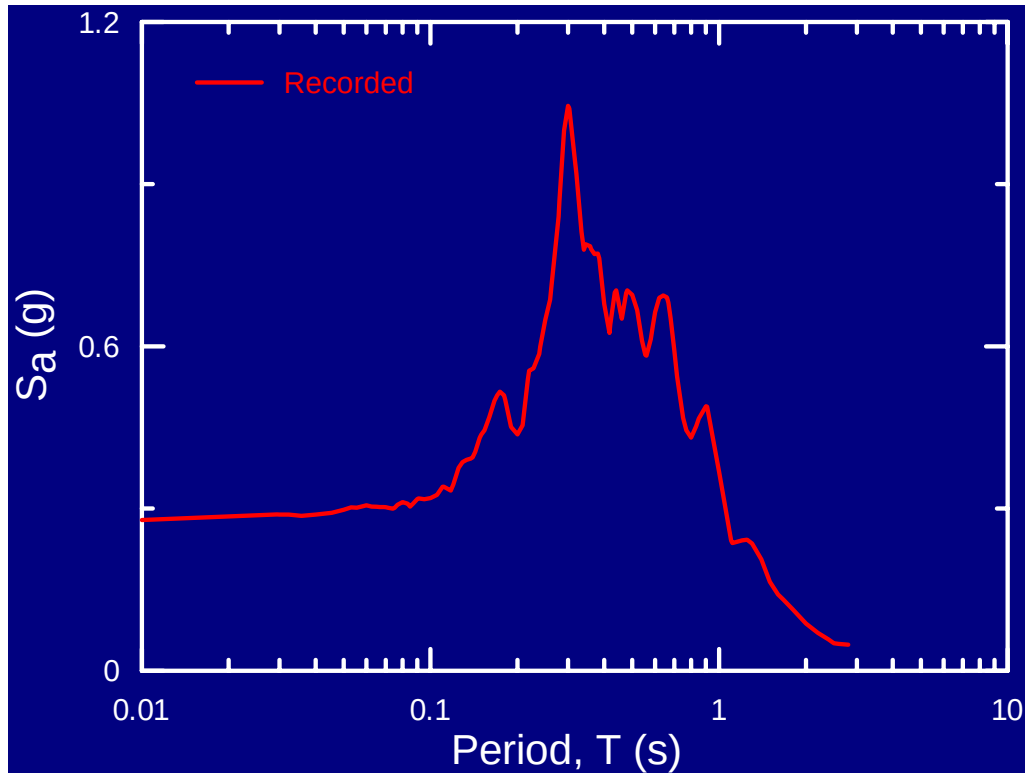
Methods of Site Response Evaluation: Site Specific

- Input data:
  - Site soil profile
  - Time history suite
- 1D analysis routine



Methods of Site Response Evaluation: Example

- Interpretation of output



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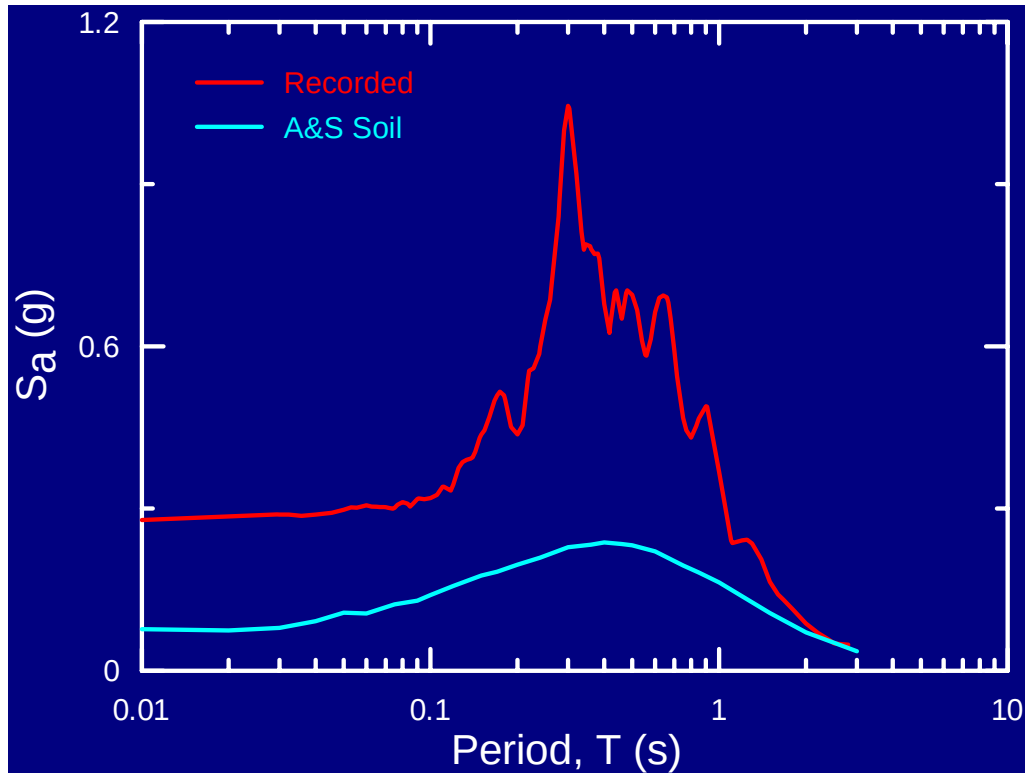

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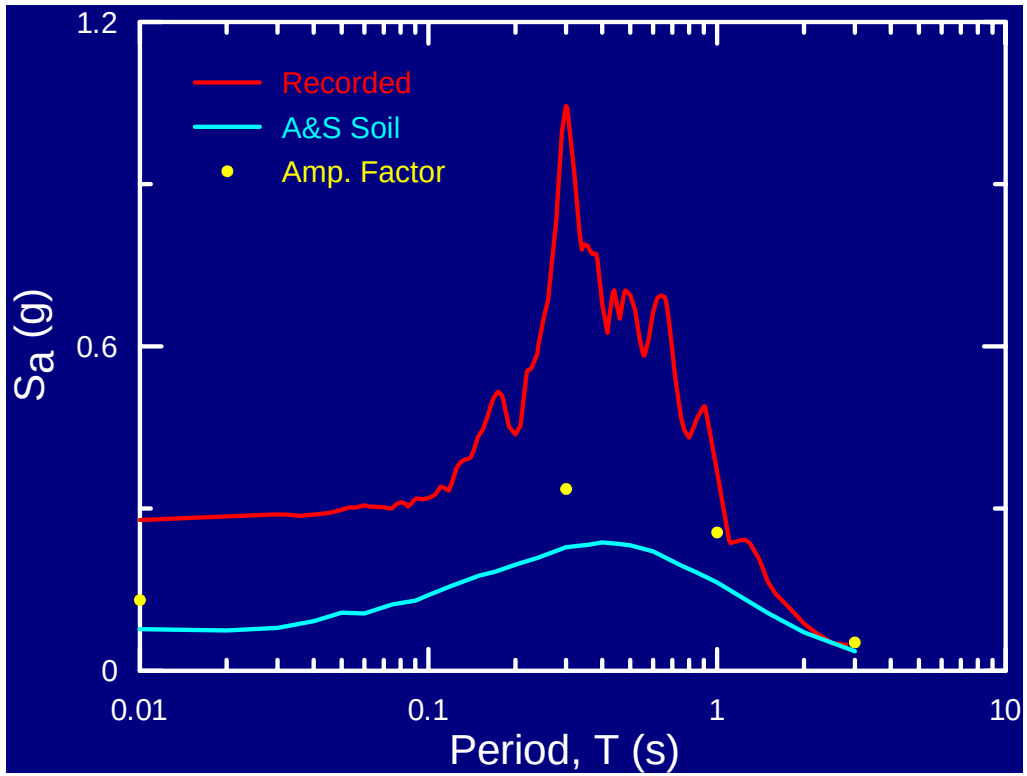
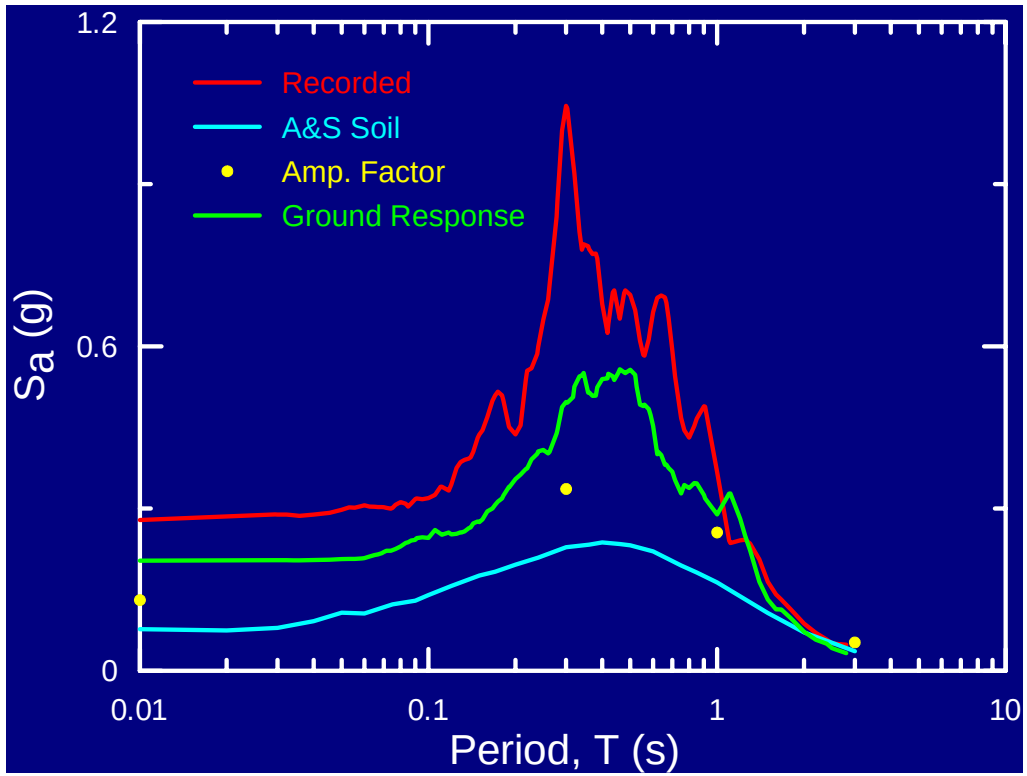


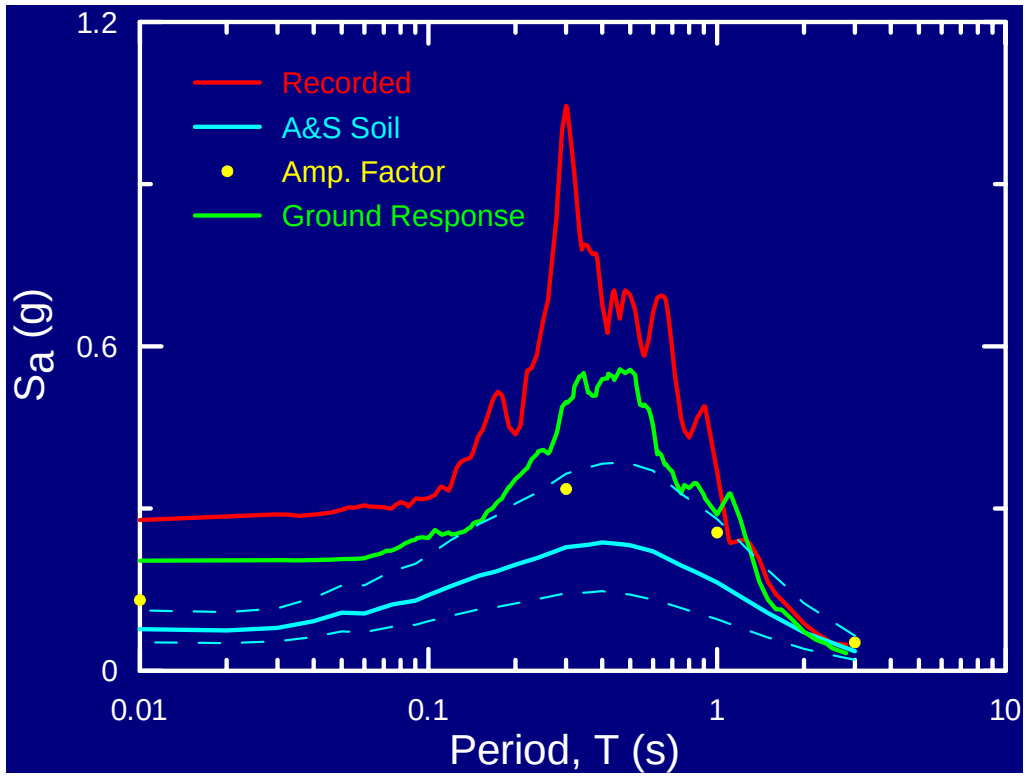
Methods of Site Response Evaluation: Example

- Interpretation of output
  - Bias of median?



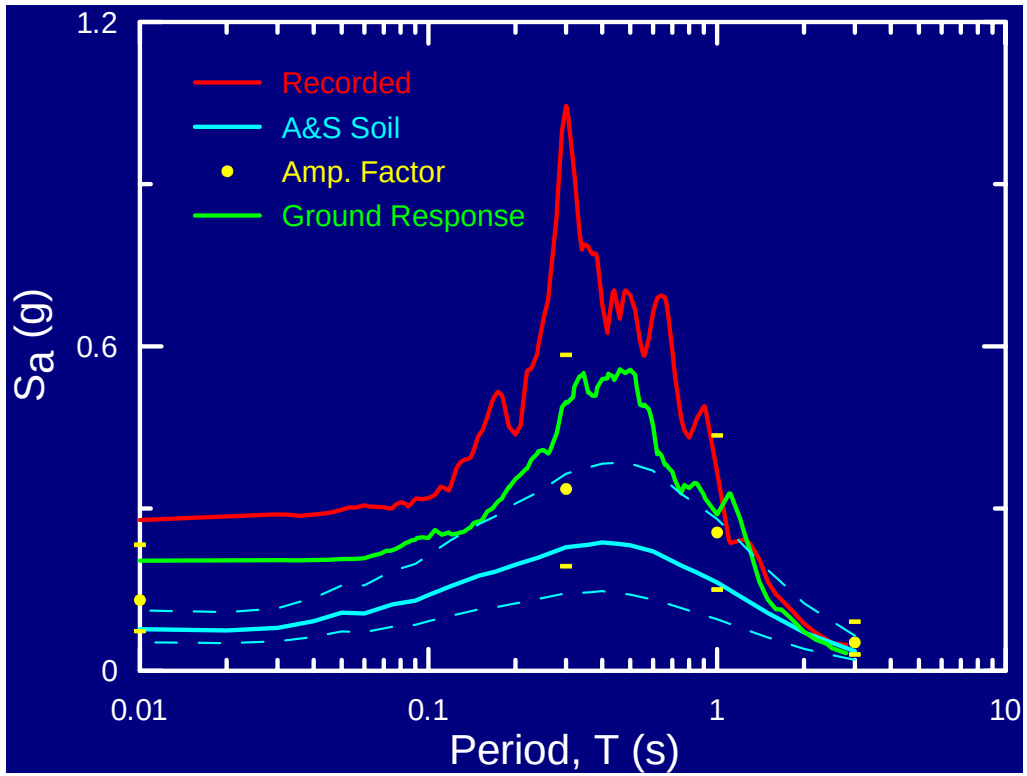
Methods of Site Response Evaluation: Example

- Interpretation of output



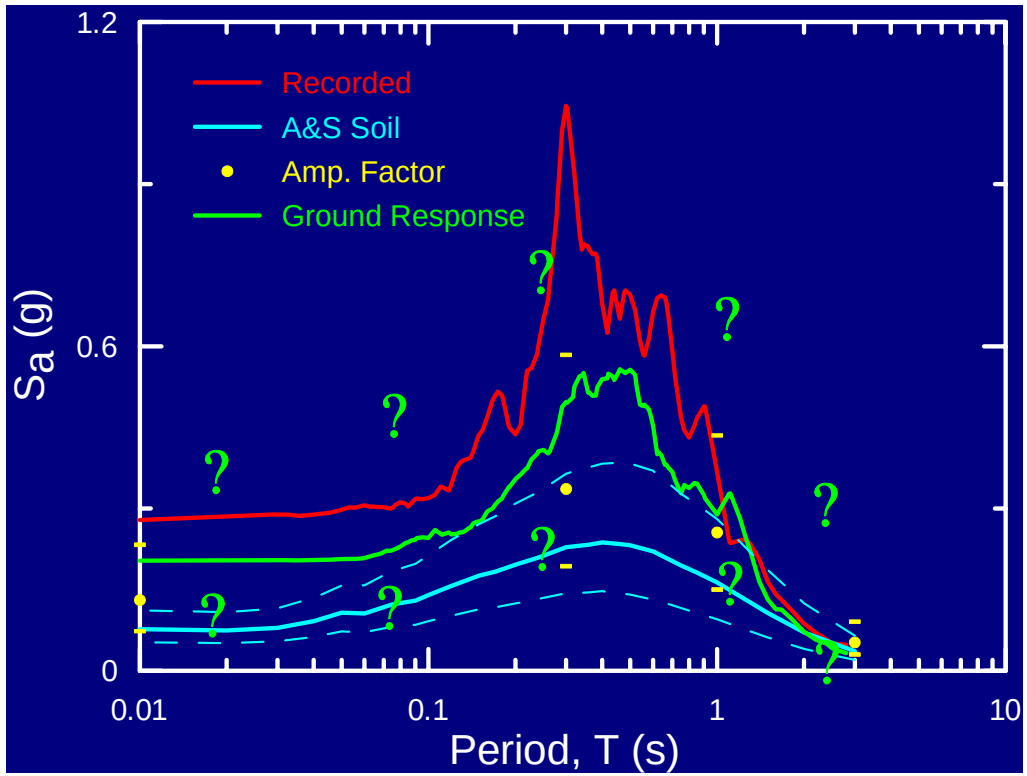
Methods of Site Response Evaluation: Example

- Interpretation of output



Methods of Site Response Evaluation: Example

- Interpretation of output
  - GR standard deviation?



Outline

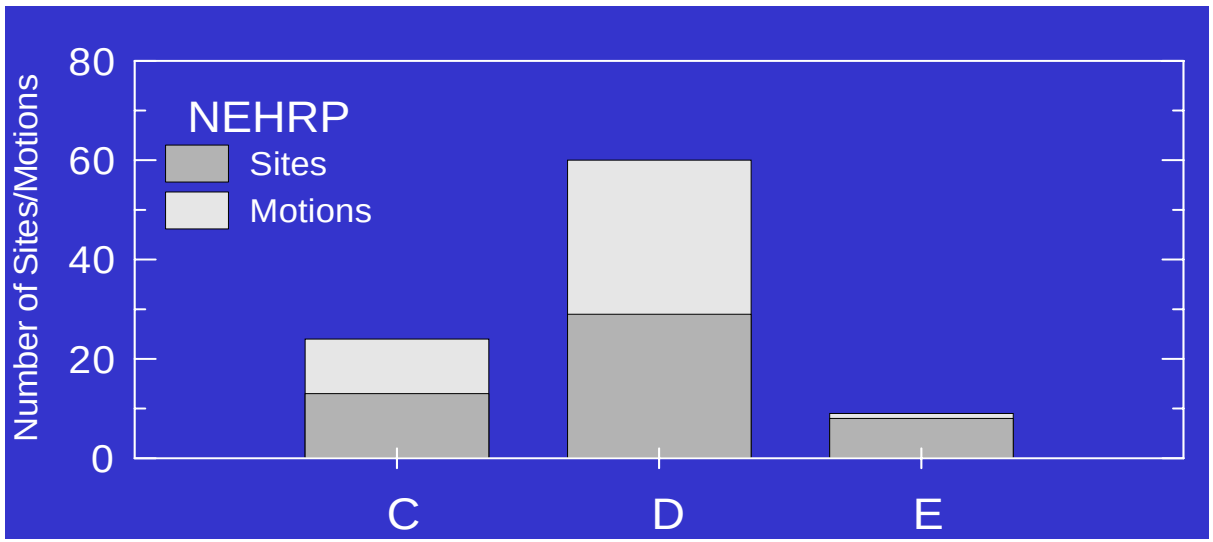
- Can we model site effects? Two views:
- Two procedures for site response evaluation
- Application of procedures for calibration sites
- Analysis of residuals
- Summary and recommendations

Application

- Site selection
- Generation of input motions
- Protocols for performing wave propagation analyses
- Form of results

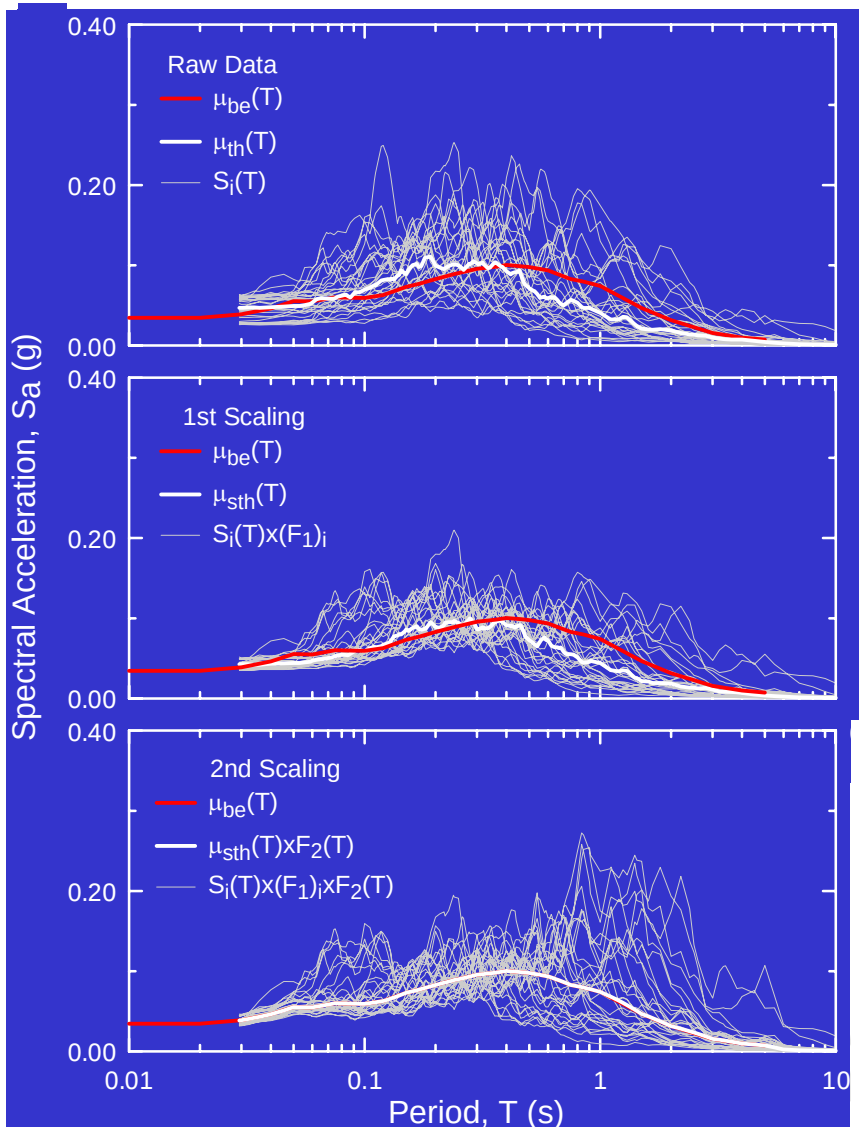
Application: Site Selection

- Well characterized sites (soil types, V_s measurements)
- Strong motion recordings
- Results: 50 sites with 93 recordings



Application: Input motions

- Target spectrum
  - Rock attenuation
  - Event term, directivity correction
- Select rock time histories
- Scale time histories
  - Each record match target for T=0-1s (avg. sense)
  - Median match target for T=0-3 s



Application: Performing analyses

- Equivalent-linear modeling (SHAKE91)
- Site-specific V_s profile
- Modulus reduction and damping

Soil Type	Condition[1]	Curve
Sand and silty sand	Z < 100 m	Seed et al. (1986) upper bound sand G/G_{max} and lower bound β
	Z > 100 m	EPRI (1993): Z = 76 - 153 m
Clays, silty clays, loams	PI = 15 & Z < 100m	Vucetic and Dobry (1991): PI = 15[2]
	PI = 15 & Z > 100m	Stokoe et al. (1999), CL curve, Z > 100 m
	PI >= 30	Vucetic and Dobry (1991): PI >= 30
	Bay Mud	Sun et al. (1988)
	Old Bay Clay	Vucetic and Dobry (1991): PI = 30[3]
Bedrock	Vs < 900 m/s	Soil curves for appropriate material type and condition
	Vs > 900 m/s	Schnabel (1973)

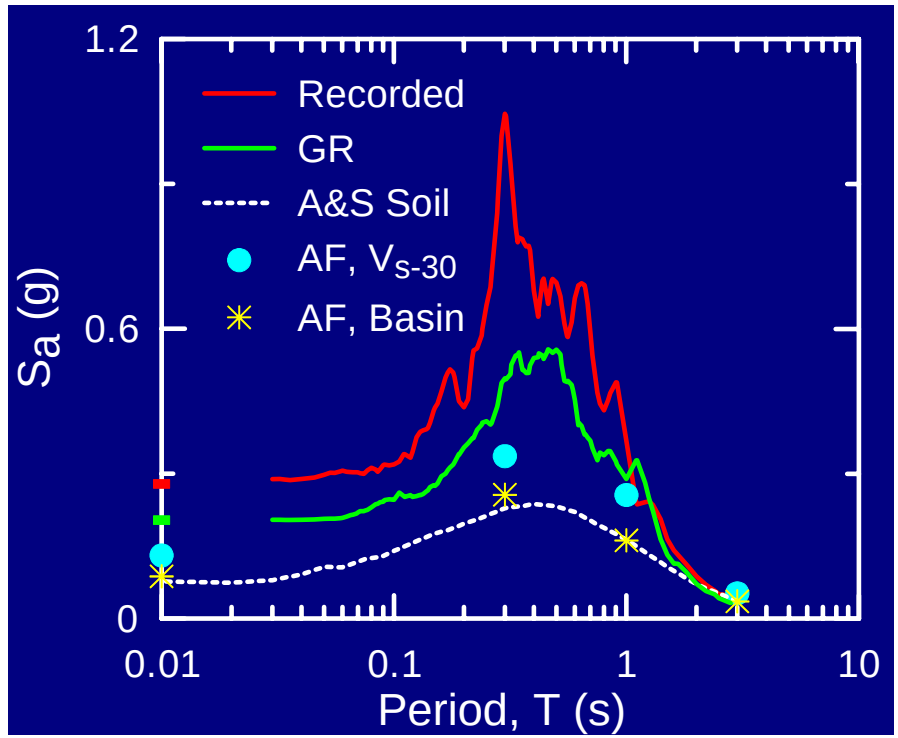
[1] Z = depth, PI = plasticity index

[2] Consistent with Stokoe et al. (1999), CL curve, Z < 100 m

[3] Consistent with Guha et al. (1993) material testing

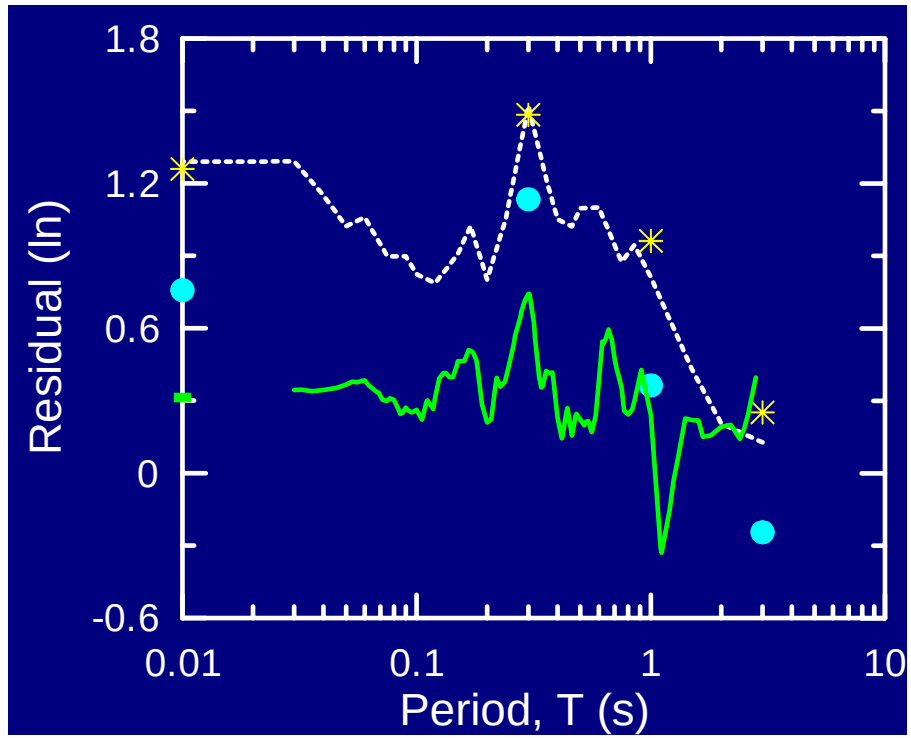
Application: Form of output

- Ground response:
  - Suite of spectra
  - Prediction taken as the median
- Amplification factors:
  - Prediction taken as $S_{a,r} \times AF$



Application: Form of output

- Ground response:
  - Suite of spectra
  - Prediction taken as the median
- Amplification factors:
  - Prediction taken as $S_{a,r} \times AF$
- Residual = data - model



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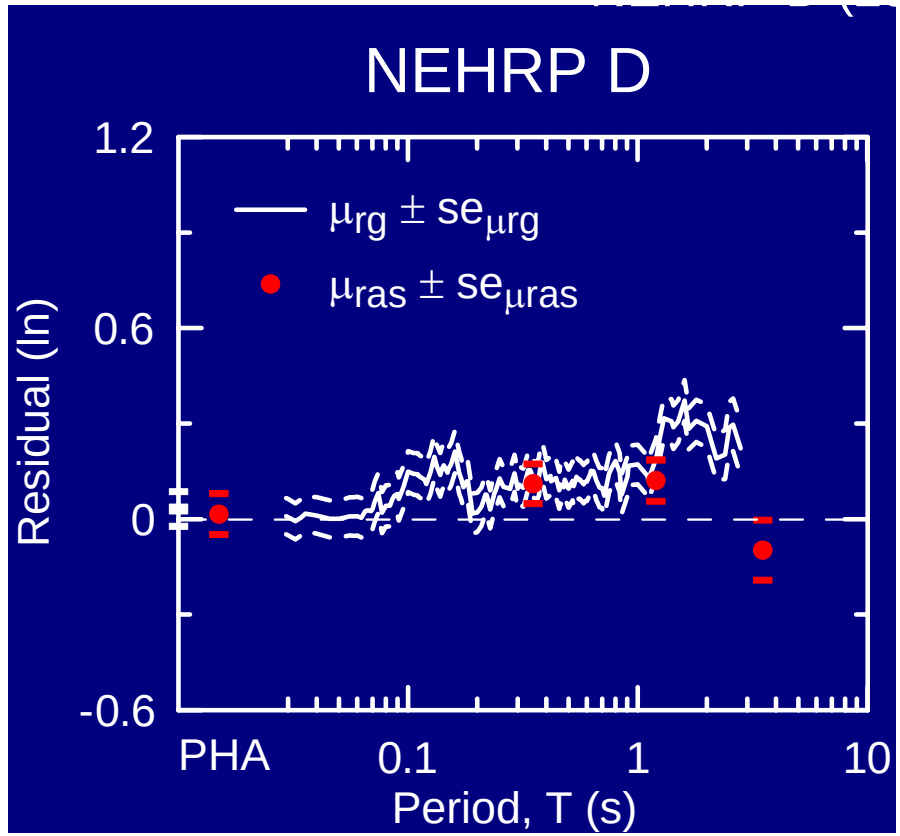
Analysis of Residuals

- Statistics of residuals within site categories
  - NEHRP C, D, Hlm
- Dependence of residuals on:
  - $V_{s\text{-}30}$
  - Depth to V_s = 1.0 km/s ≡ z_1
  - Shear strains

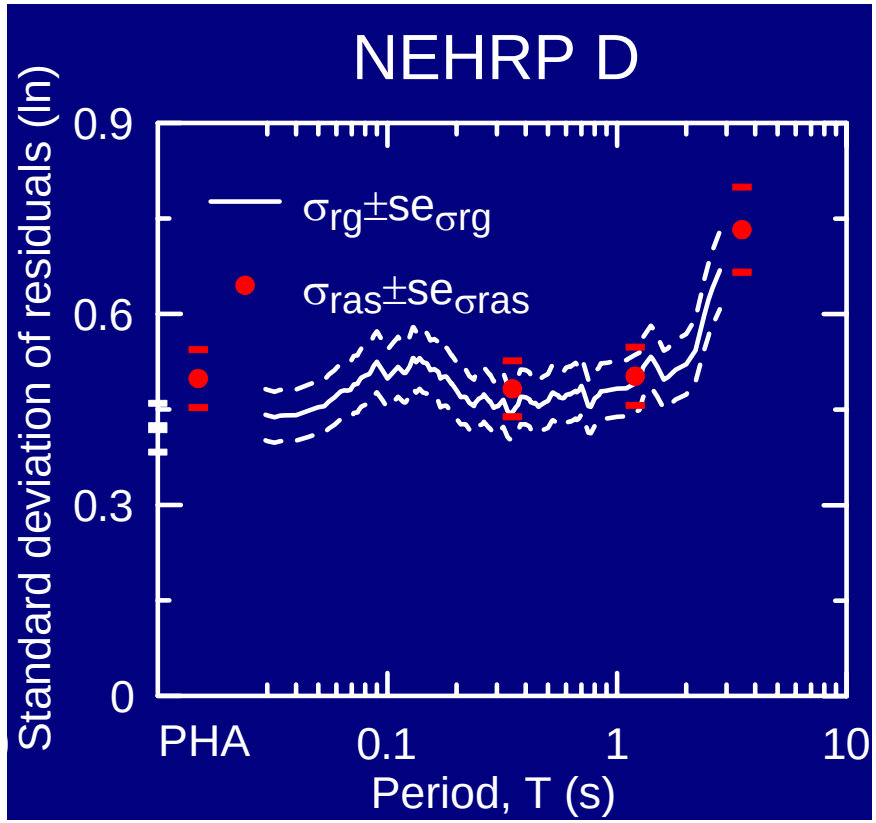
Analysis of Residuals: Categories

- Median residuals
  - AF provides baseline
  - Negligible bias for $T < 1$ s
  - Positive bias for $T > 1$ s: underprediction



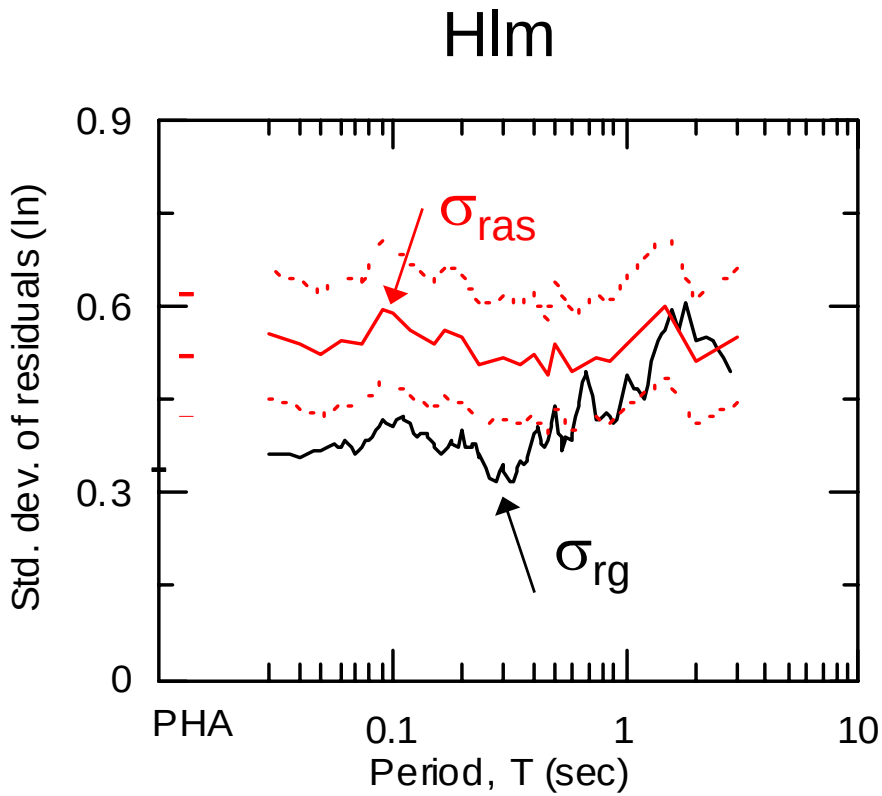
Analysis of Residuals: Categories

- Standard deviation of residuals
  - C-D: Small difference
  - Suggests 1D analysis is not removing site-to-site variations in ground motion



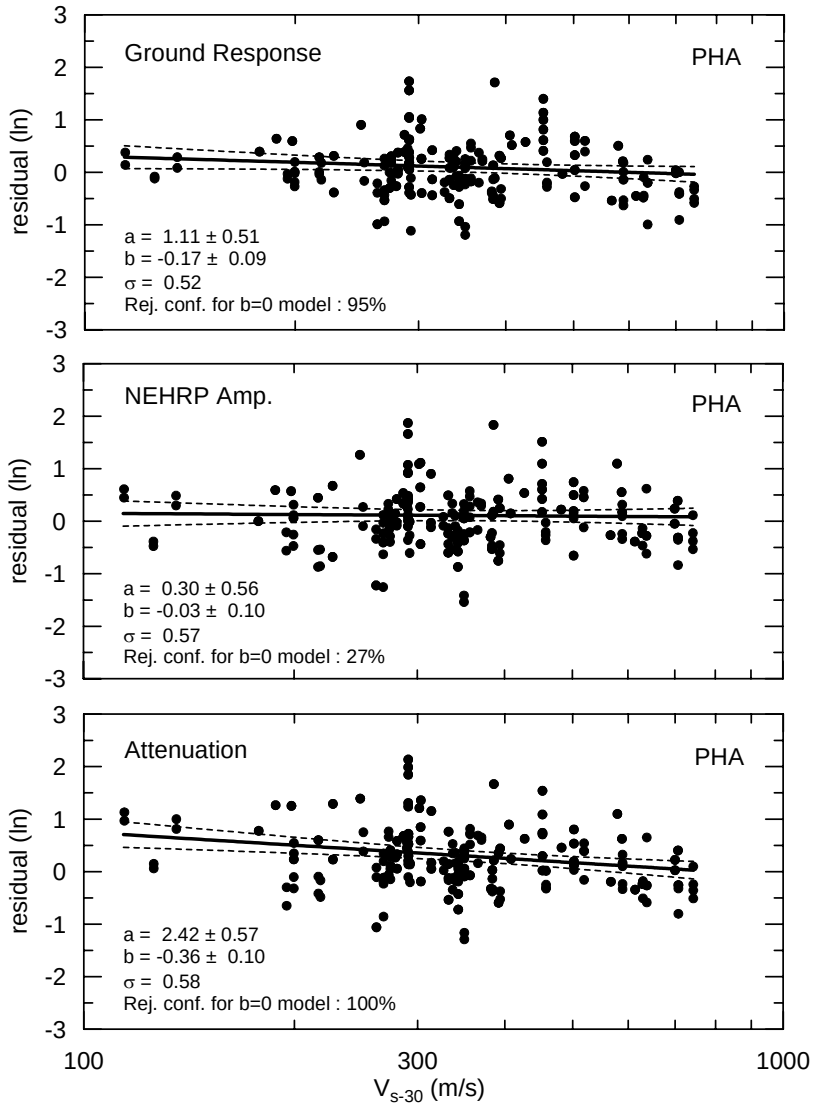
Analysis of Residuals: Categories

- Standard deviation of residuals
  - Hlm: Statistically significant difference for $T < 1$ s



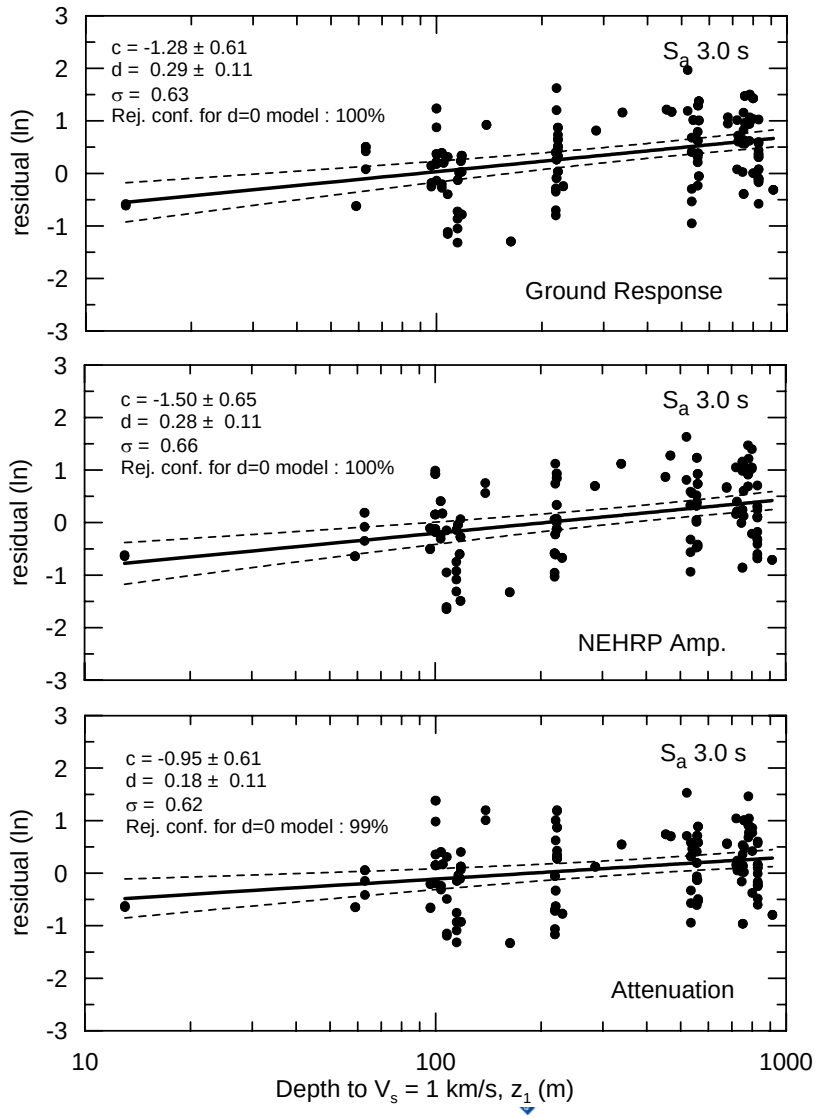
Analysis of Residuals: Parameter-Dependence

- $V_{s\text{-}30}$:
  - GR & AF: no dependence
  - Atten: significant dependence



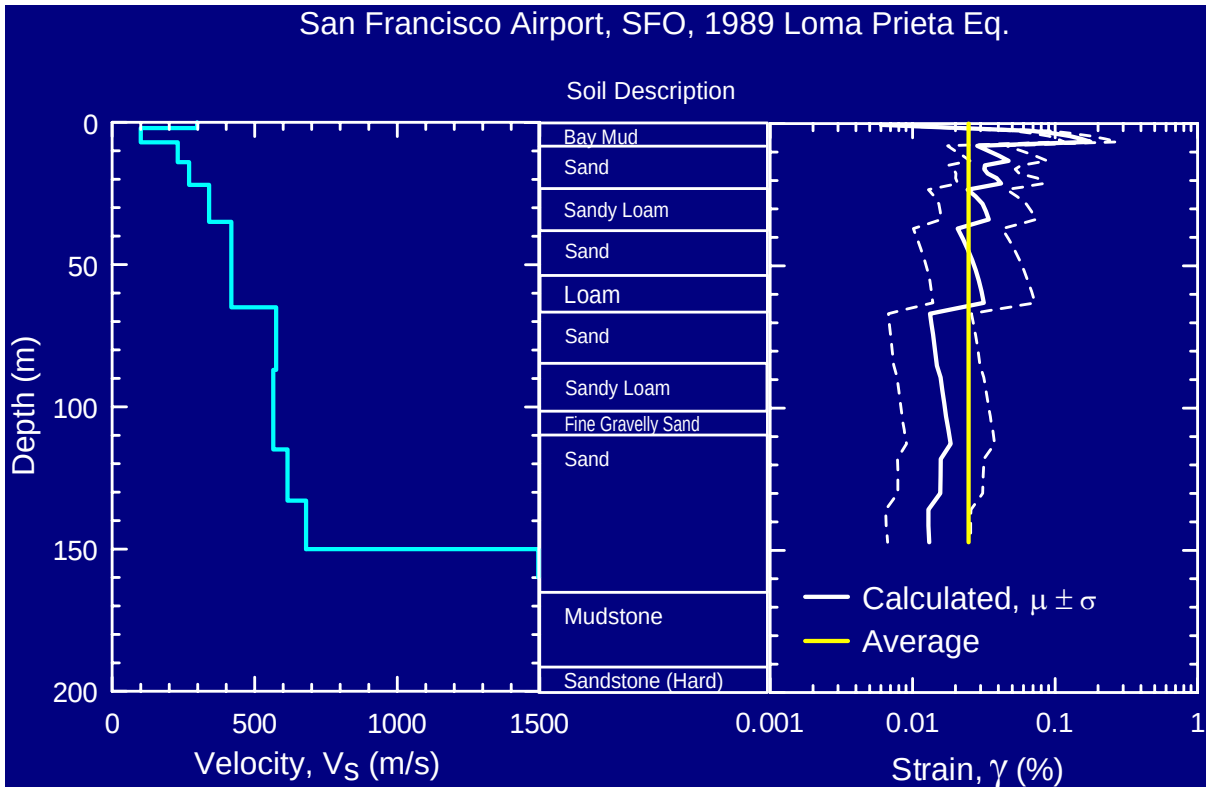
Analysis of Residuals: Parameter-Dependence

- $V_{s\text{-}30}$
- z_1:
  - Significant dependence at long period



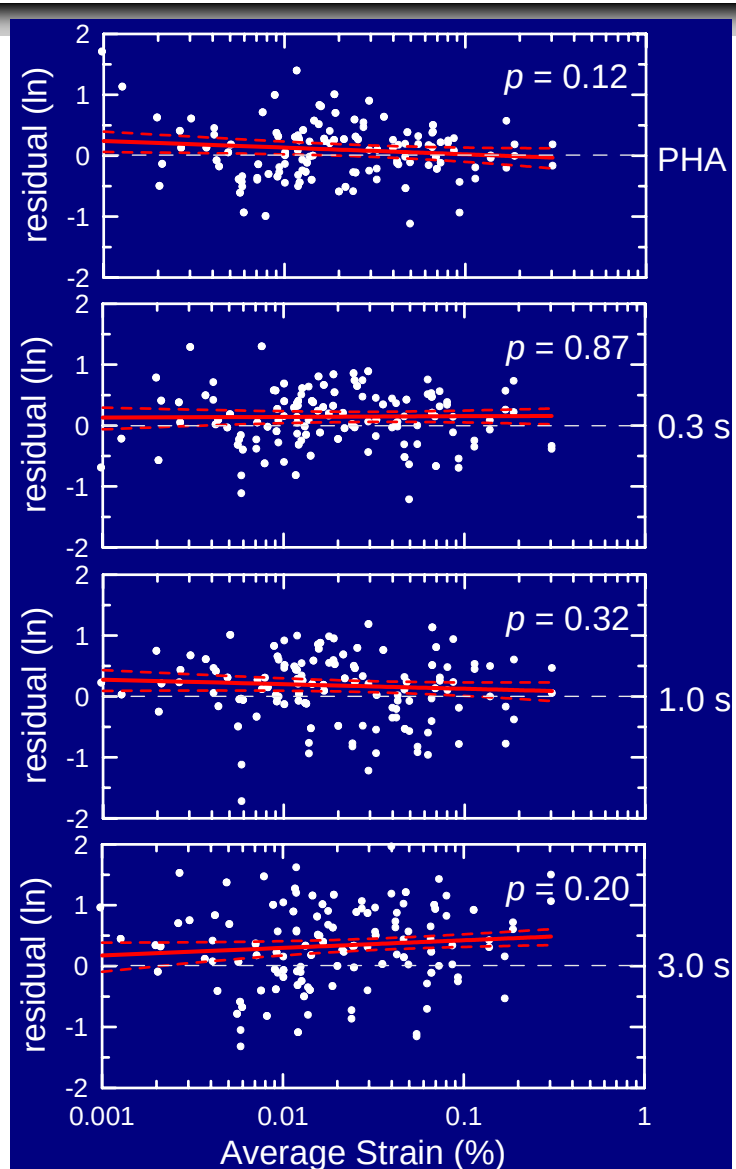
Analysis of Residuals: Parameter-Dependence

- $V_{s\text{-}30}$
- z_1
- Average shear strain:



Analysis of Residuals: Parameter-Dependence

- $V_{s\text{-}30}$
- z_1
- Average shear strain:
  - No significant dependence



Summary and Recommendations

- Site specific analyses:
  - Justified for sites with significant impedance contrast (soft soils)
  - Not justified for most stiff soil sites
- Median is unbiased
- Standard deviation
  - Aleatory from source, path, imperfect physics, etc.
  - "Known" variability in site-specific AF from input motion and soil property variability