Reconsidering Basin Effects in Ergodic Site Response Models

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Acknowledgements

- Co-authors: Jonathan P. Stewart, Pengfei Wang, Scott J. Brandenberg
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- Thanks to Yousef Bozorgnia, Robert Graves, and staff at SCEC for access to basin models

Sedimentary Basin

Definition: A Depression in earth's surface filled by deep deposits of soft sediments that decrease in thickness towards their margins (Allen and Allen 2013)

Outline

- Introduction
- Database
- Basin classification
- Ground motion analysis
- Summary

Introduction

- Background
  - Physical processes contributing to site response in basins
  - Site response modeling
  - NGA-W2 basin response models
- Research motivation and scope

Site Response “Physics”

1D Ground Response

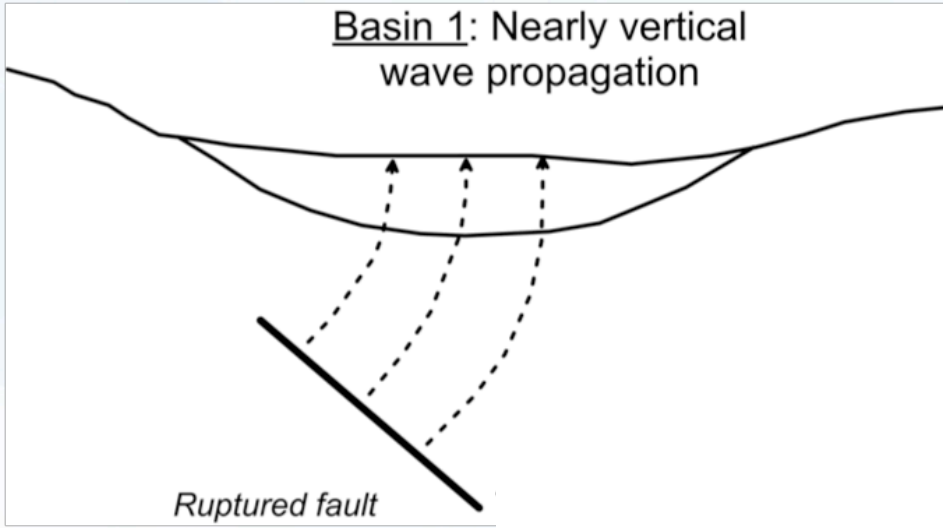
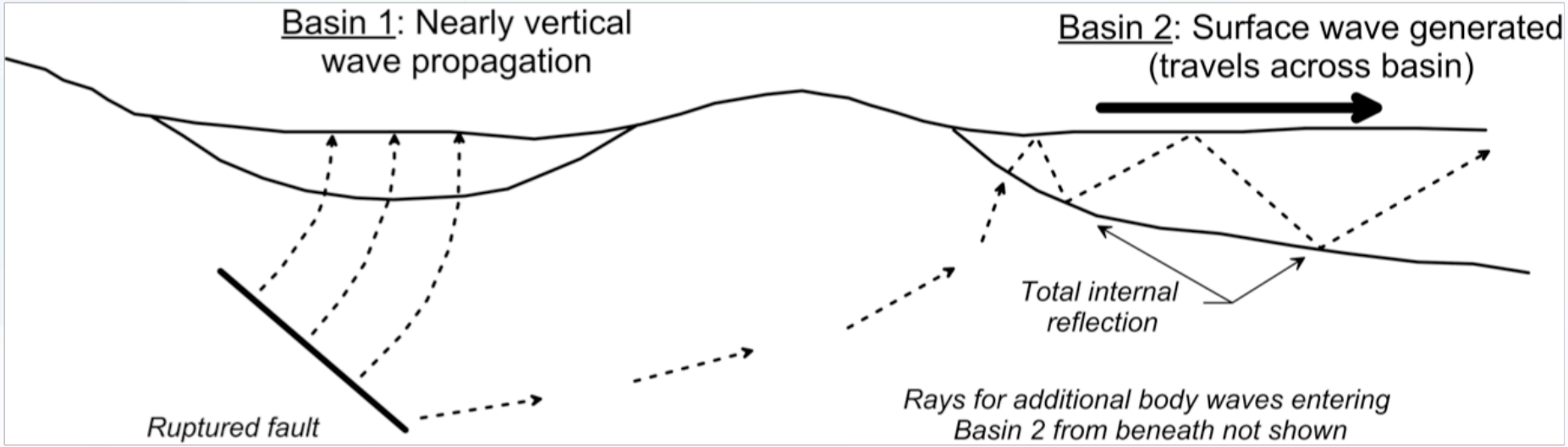


Illustration modified from Choi et al. 2005

Site Response “Physics”

1D Ground Response

Ground Response and Basin Effects



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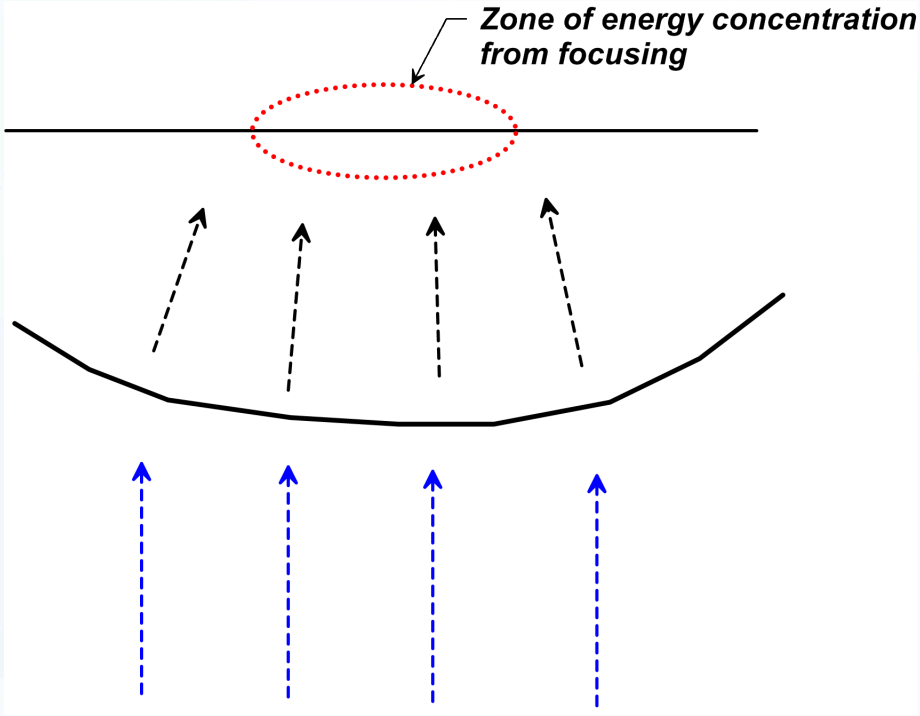
Site Response Physics

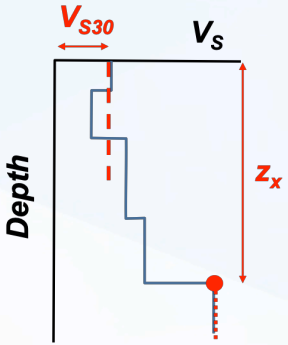


Site Response Modeling

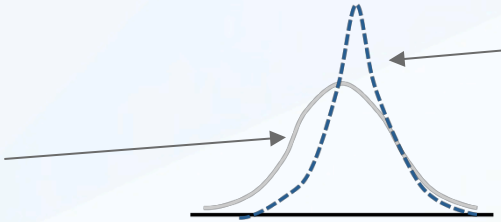
Ergodic approach

Non-ergodic approach

Regionally Adjusted Ergodic approach



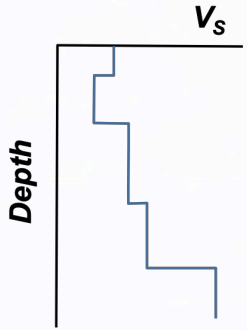
Global Models



Site Response

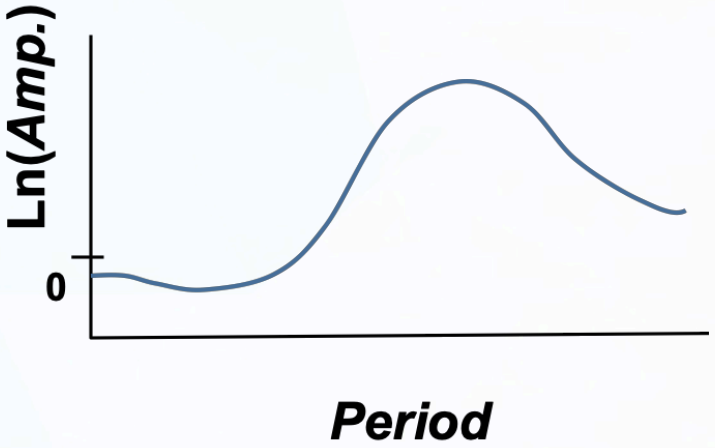
Ground Motion Analysis

1D Models



Basin Response Models

- First-order scaling effects from Vs30-scaling models



Basin Response Models

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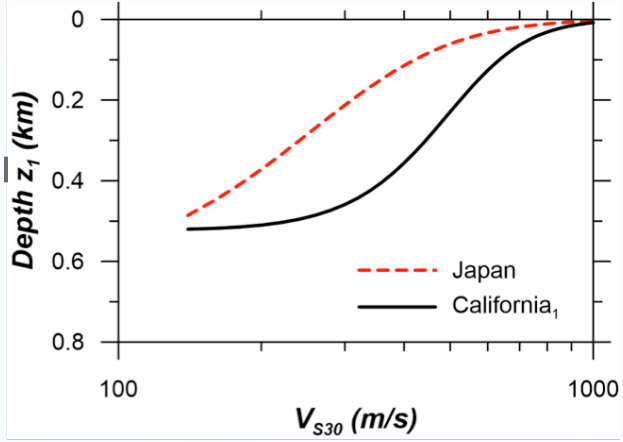
- Basin parameters are taken as differential depths



$$\delta z_x = z_x - \overline{z}_x$$

(new model for So. Cal.)

Basin Response Models

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- Basin amplification occurs for $\delta z_x \neq 0$

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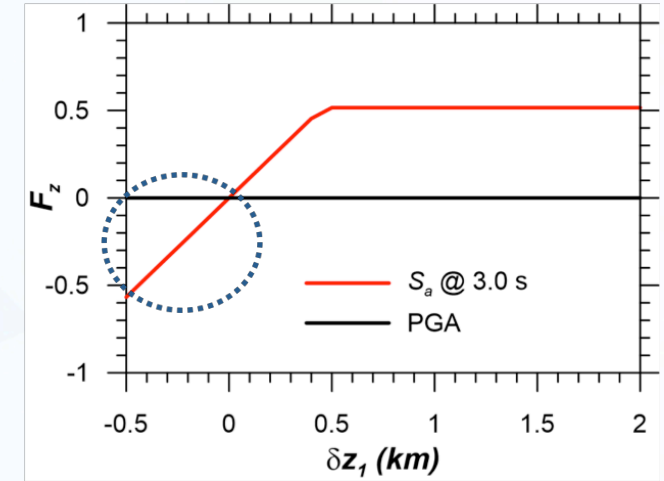

Decreasing Basin Thickness

Increasing Basin Thickness

Basin Response Models

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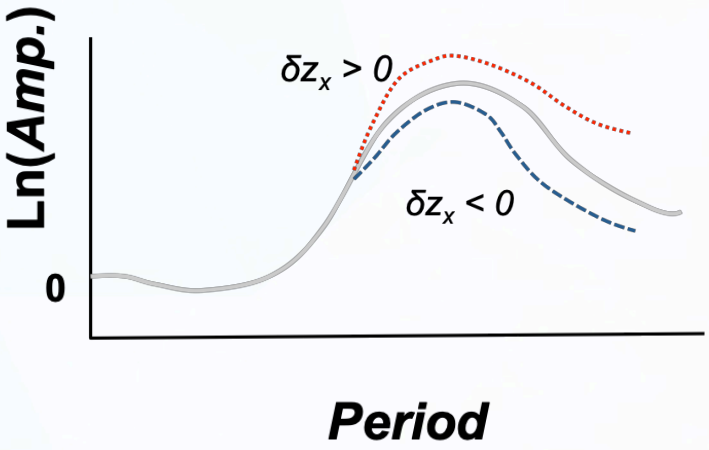

Objective and Scope

- Evaluate non-ergodic site response for many California sites
- Is basin information beyond z_x useful?
  - Site categories (basin, others)
  - Different basin structures
- Impact on:
  - Mean site response
  - Dispersion

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Database

Start with NGA-West 2 data from So. Cal.

- Time interval: 1938 to 2010
- 191 events
- 898 stations
- > 8200 recordings

Transformed to relational database – accessed via python scripts within Jupyter notebooks on DesignSafe

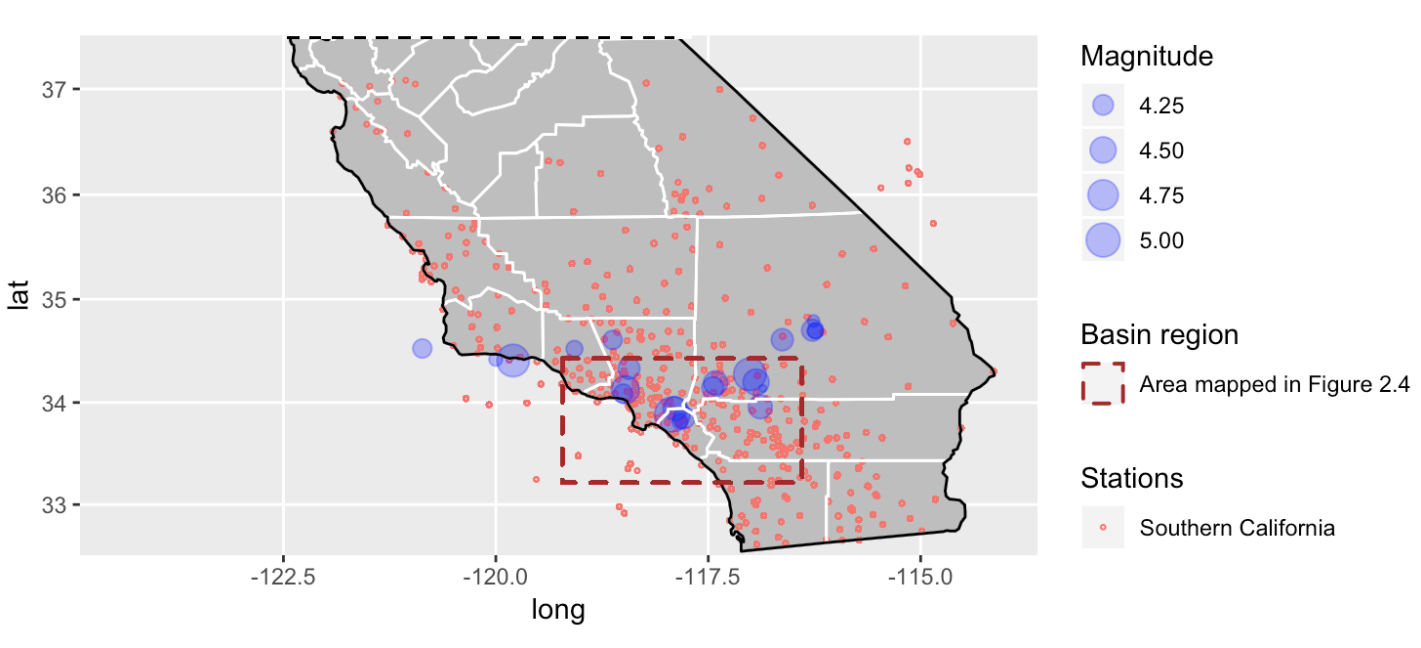
DESIGNSAFE-CI

NHERI: A NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

Database

Data supplemented with events since 2011

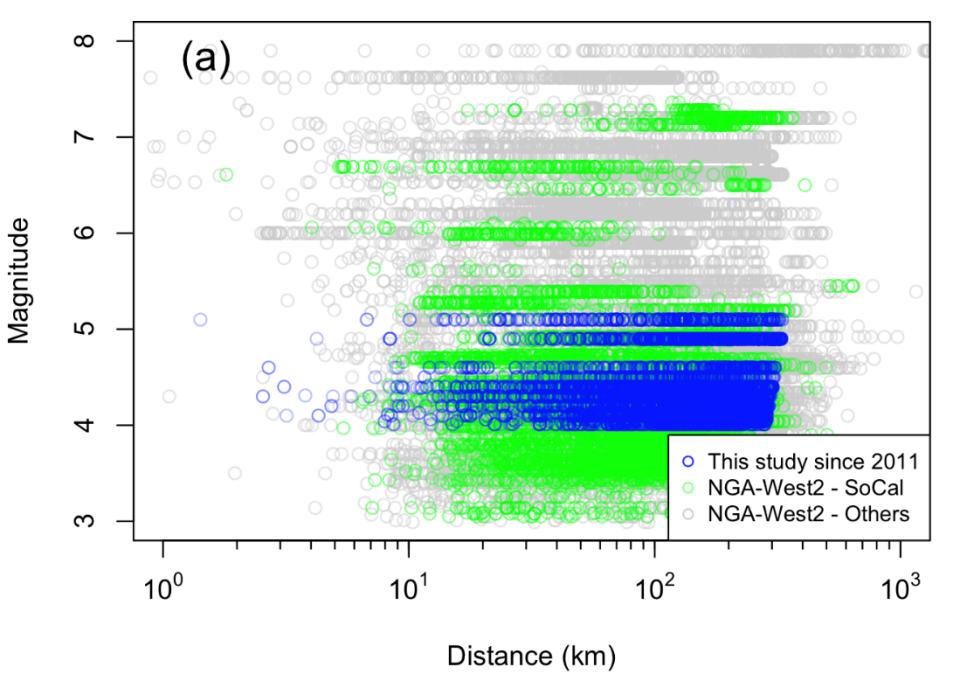
22 events, **M** > 4; 4260 recordings (3-comp); 362 sites

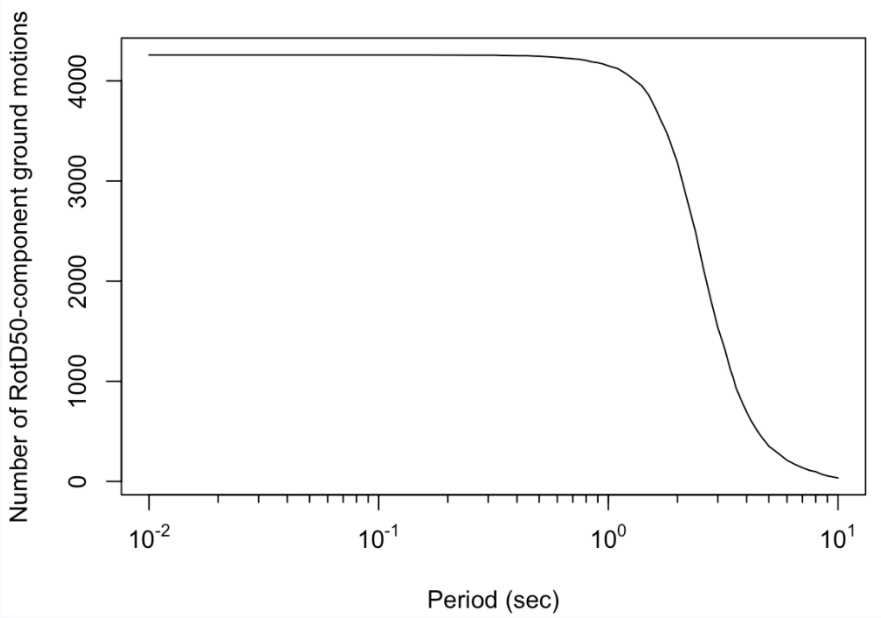


Database

Previously: 110 sites with ≥ 10 recordings

Now: 174 such sites





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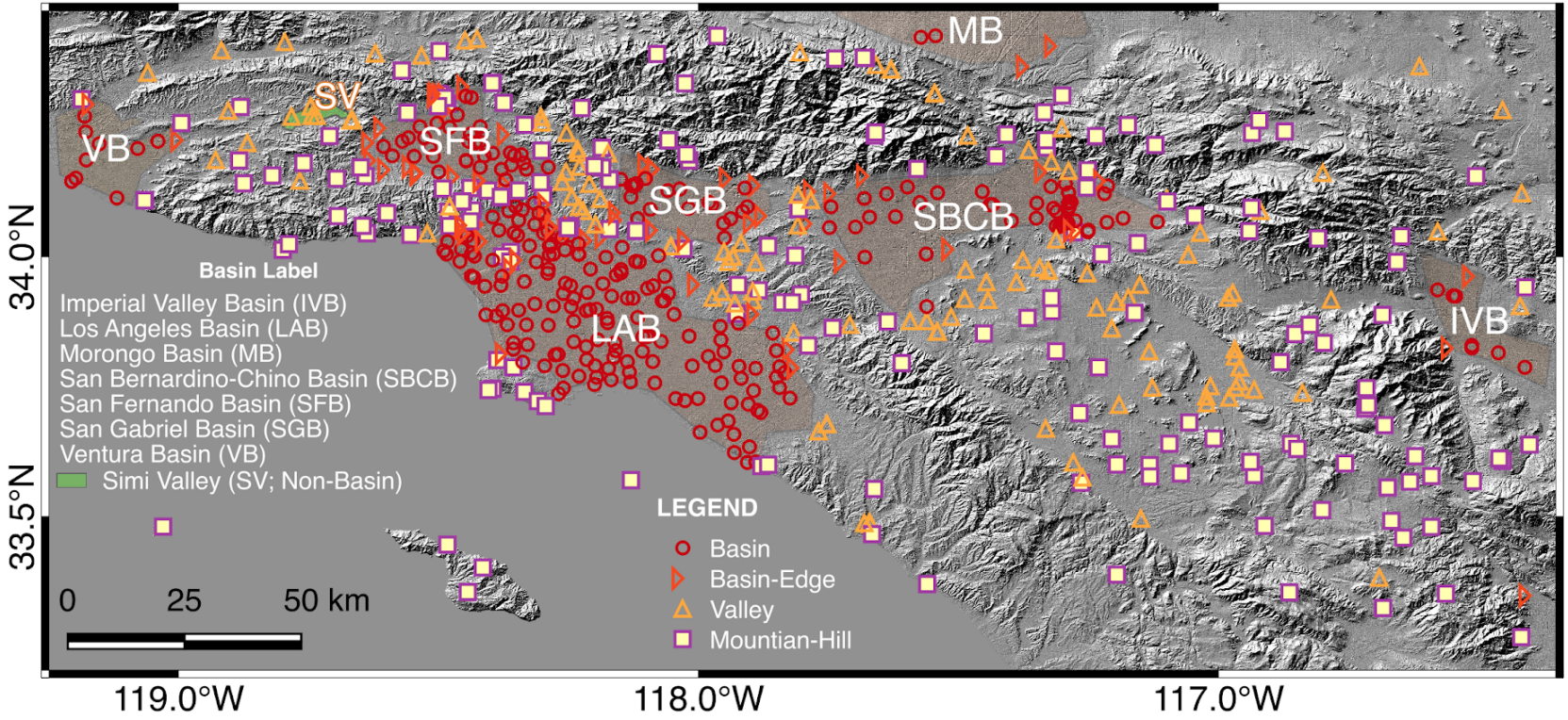
Southern California Basin Category Map



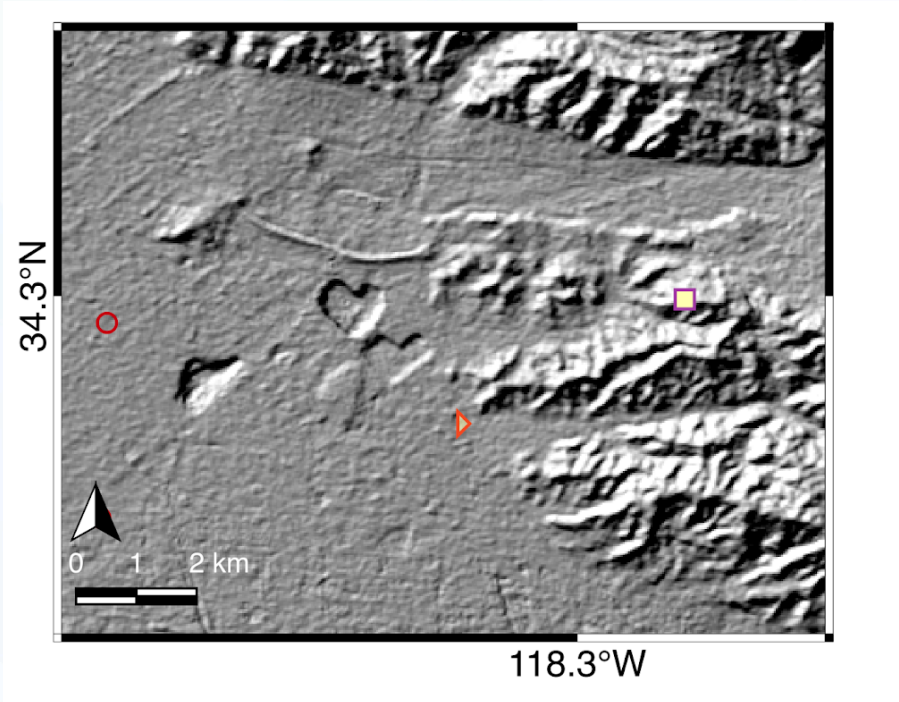
Objective of basin categories: Distinguish sedimentary structure for which wave propagation mechanisms that produce basin effects on ground motions may differ

Basin Categories

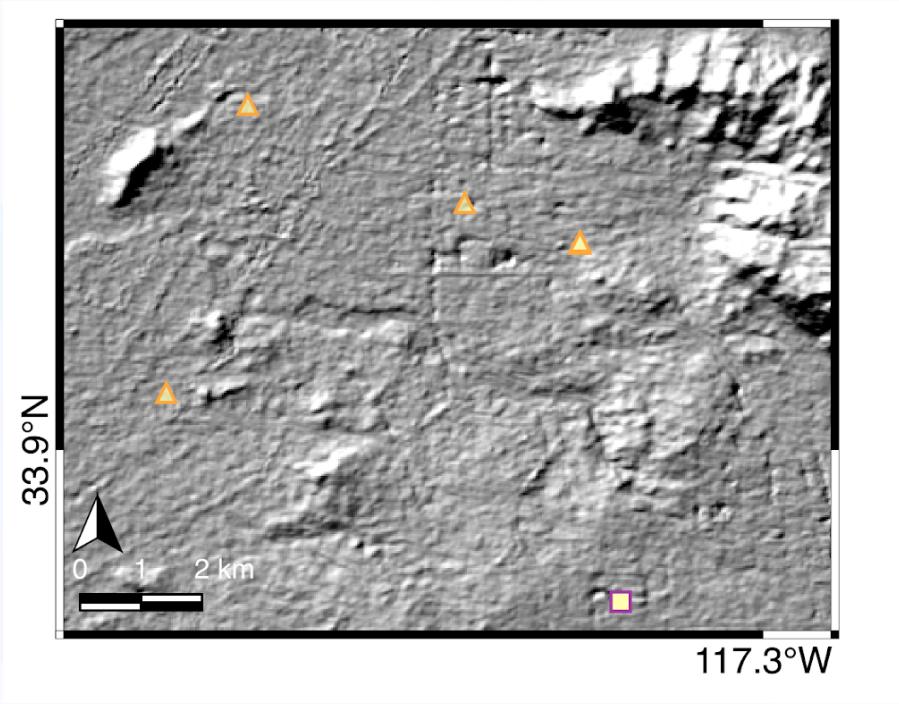
Category	Description	Criteria	Category ID	# of Sites
Basin	Site location in basin interior	Basin width in short direction > 3 km	3	288
Basin Edge	Along basin margin	Within 300m of basin edge*	2	72
Valley	“Small” sedimentary structure	Valley width in the short direction < 3 km	1	134
Mountain-Hill	Sites without significant sediments, generally having topographic relief	Generally identified on basis of appreciable gradients and/or irregular morphology	0	225

* Basin edge defined visually from break in slope (topographic feature)

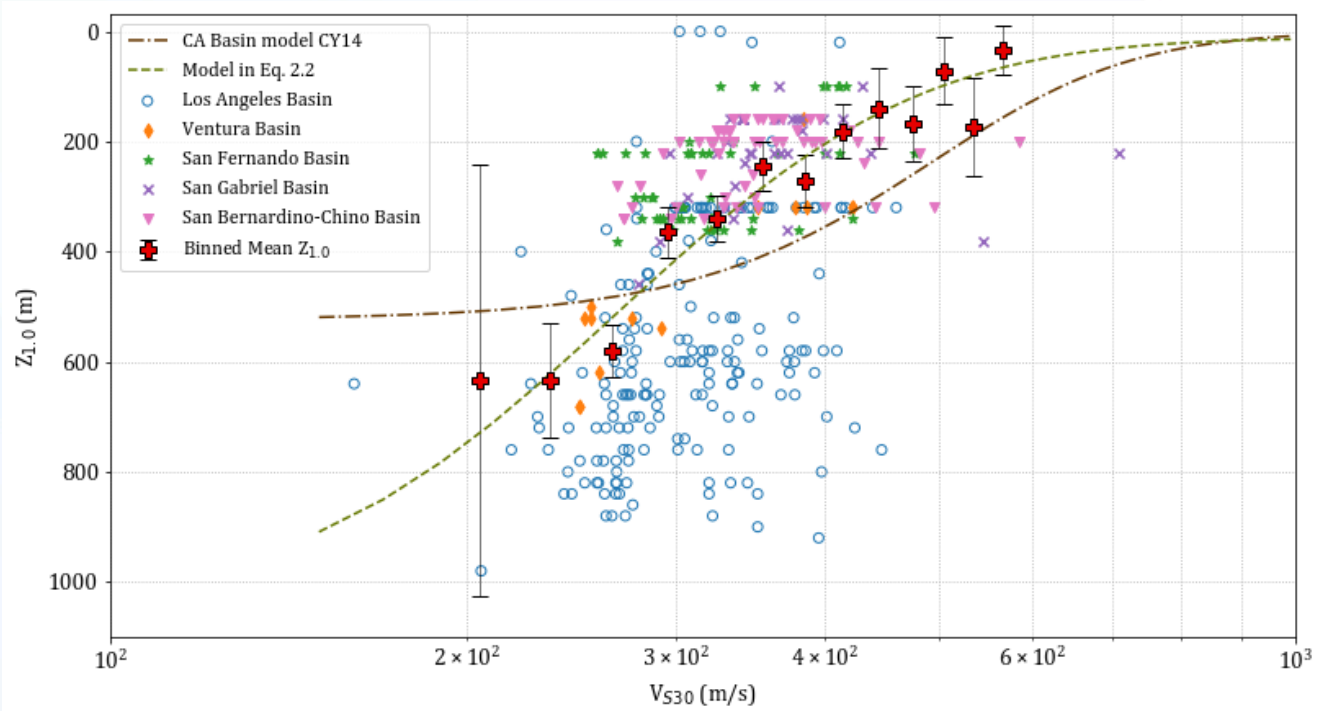
Basin Categories: Straightforward assignment example - Panorama City/Sun Valley



Basin Categories: Challenging assignment example - UC Riverside



Mean Basin Depths



$$\overline{z_1} = c_1 \left[1 + erf\left(\frac{\log\left(V_{S30}\right) - \log\left(v_\mu\right)}{v_\sigma \sqrt{2}} \right) \right] + c_0$$

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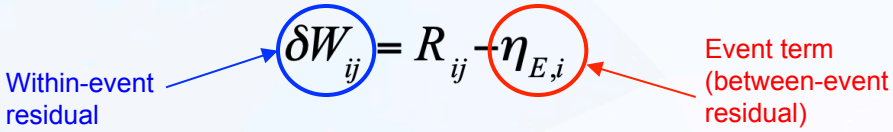
Ground Motion Analysis Approach (Mean)

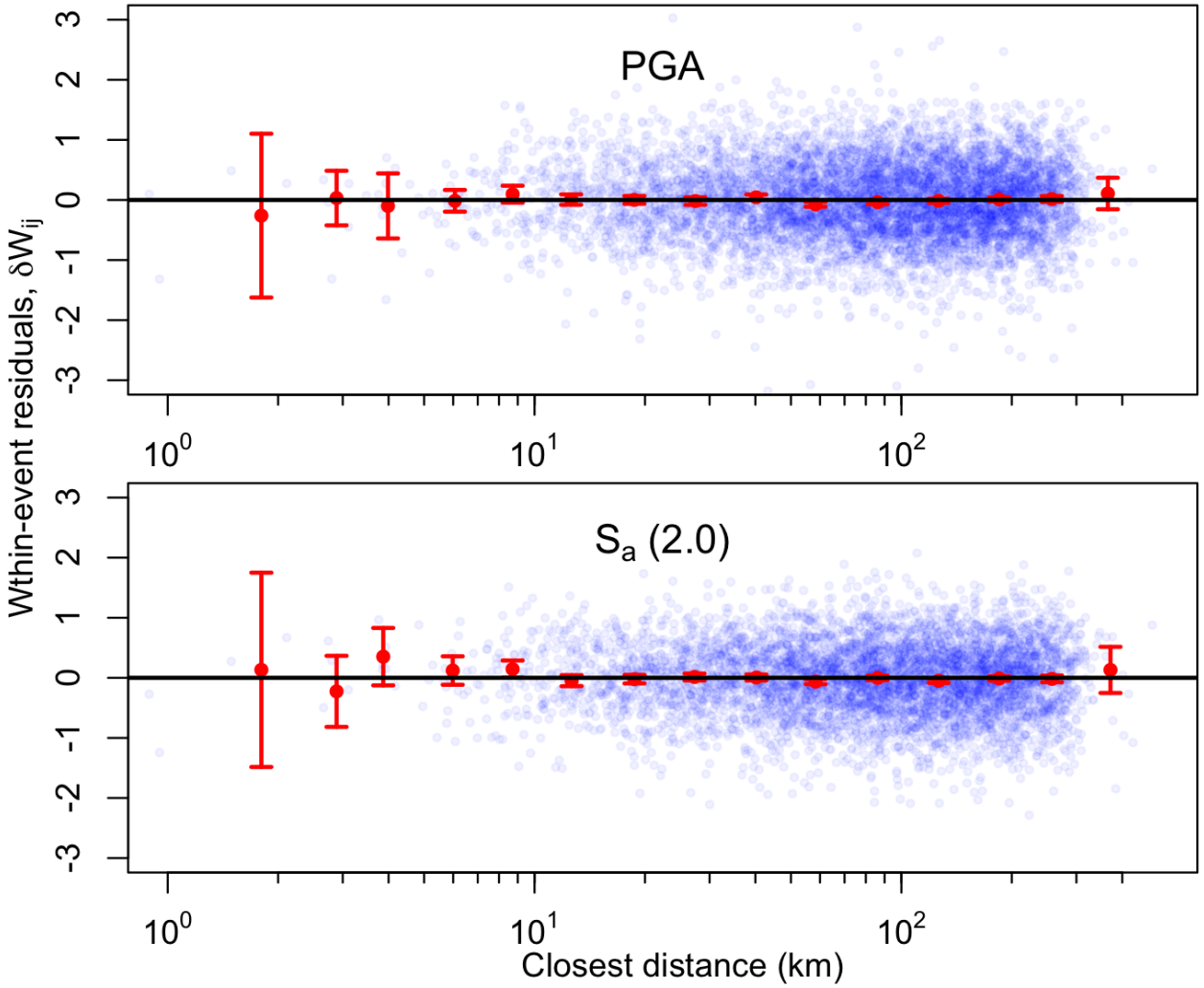
- Compute residuals using Ground Motion Models (GMMs) that include ergodic site response/basin models

$$R_{ij} = \ln(Z_{ij}) - \mu_{\ln}(M_i, F_i, R_{ij}, V_{S30}, z_{1.0})$$

- Remove effect of event-related bias



- $\delta W_{ij} \neq 0$ from path and site errors … so check for regional applicability of path model…


PGA
S_a (2.0)
Within-event residuals, δW_{ij}
3
2
1
0
-1
-2
-3
10^0
10^1
10^2
Closest distance (km)

Ground Motion Analysis Approach (Mean)

- Compute residuals using Ground Motion Models (GMMs) that include ergodic site response/basin models

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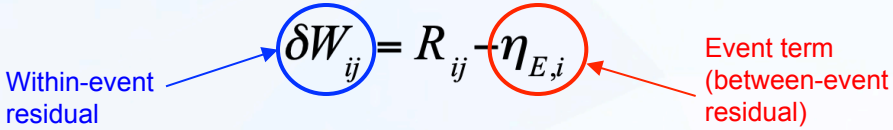
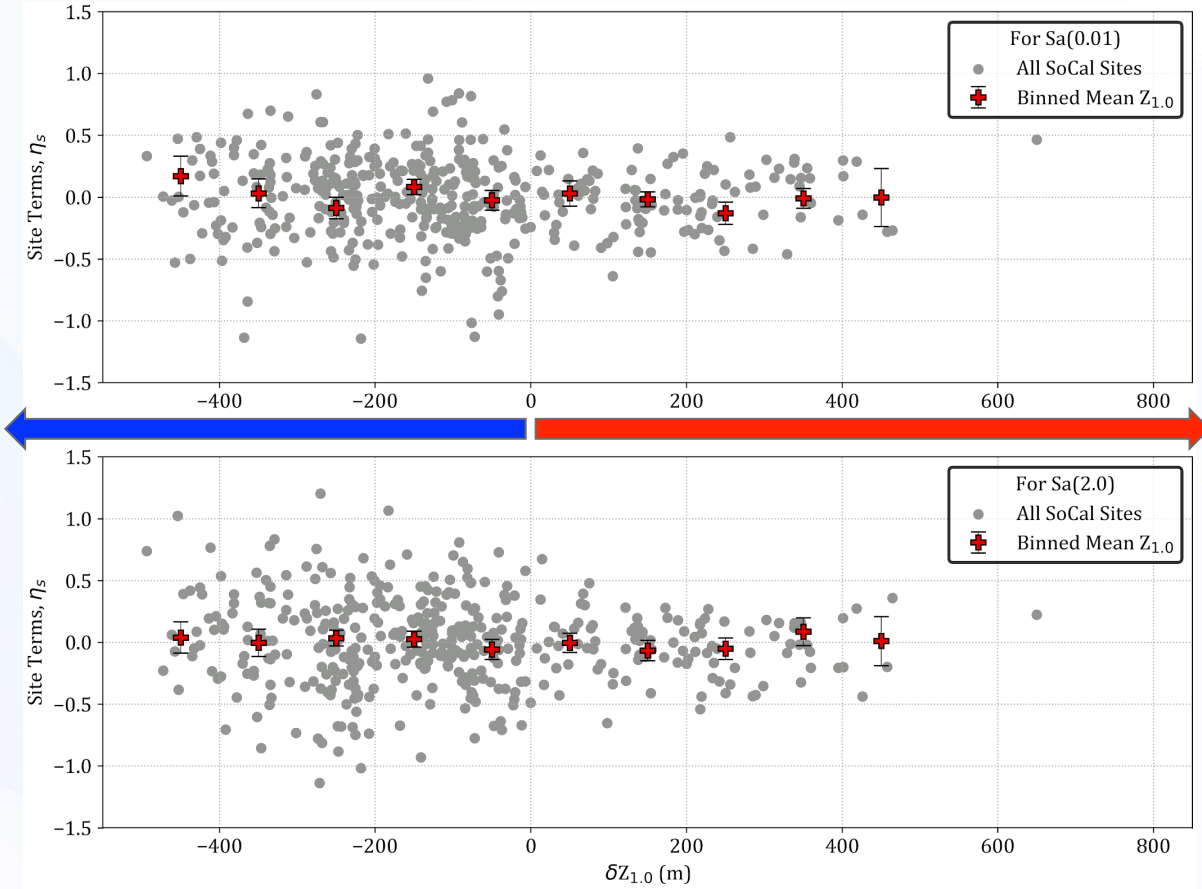
- Remove effect of event-related bias



- **Partition within-event residual to identify site component**

Site Terms: All Southern California Sites



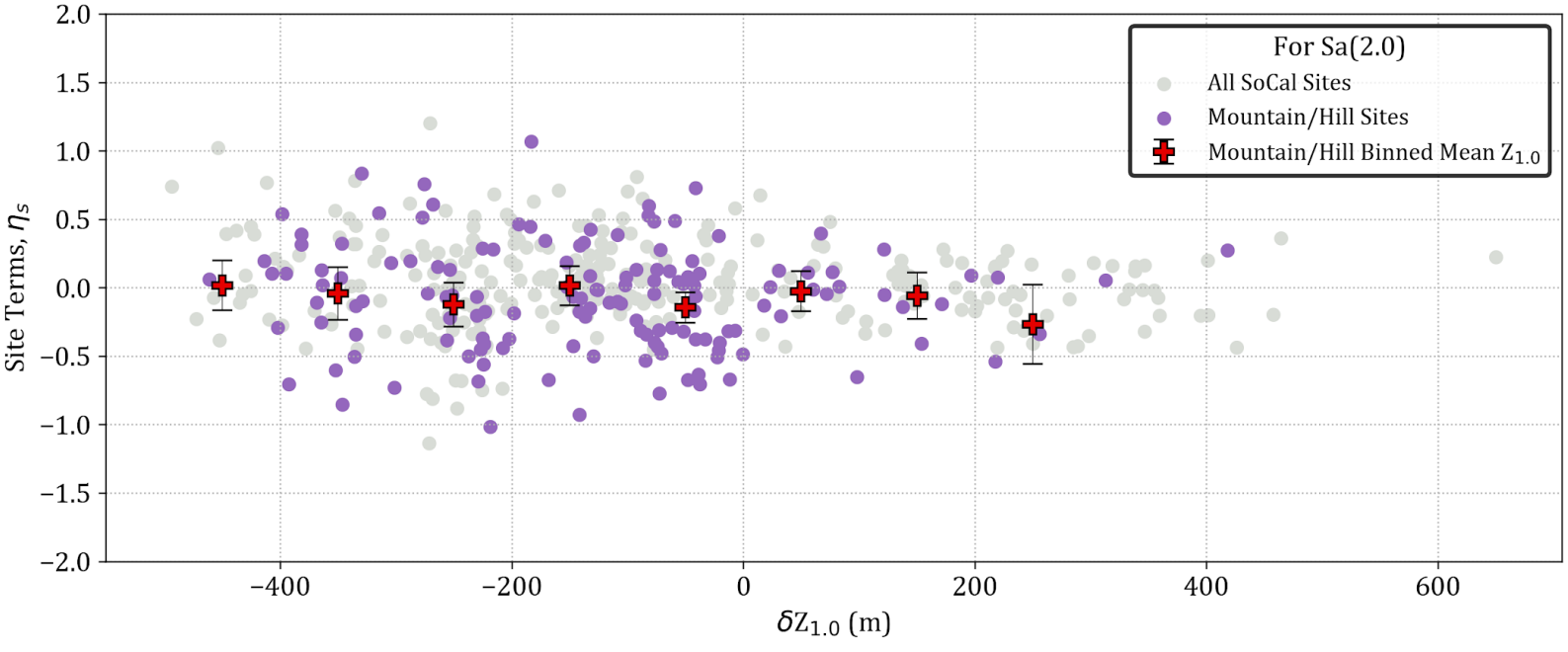
Underprediction

Overprediction

Decreasing Basin Thickness

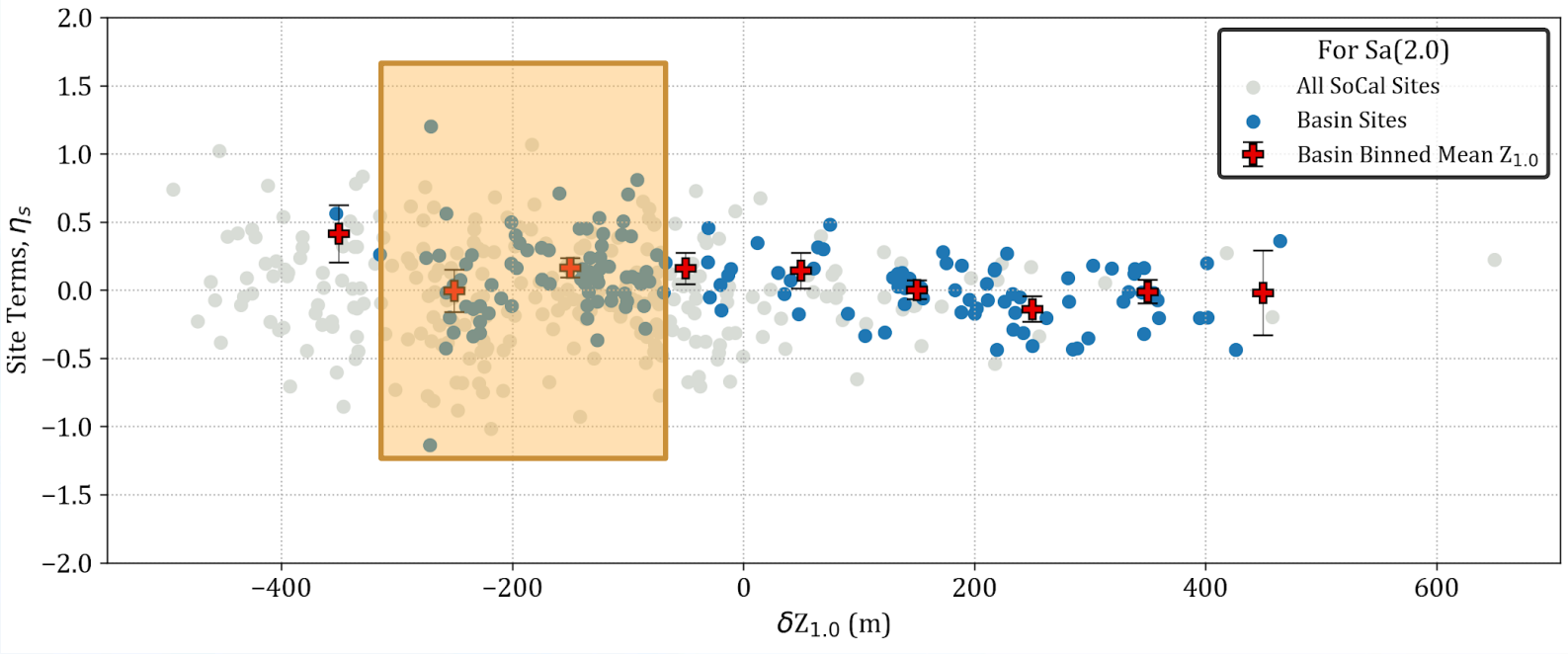
Increasing Basin Thickness

Site Terms: Mountain-Hill Category Sites



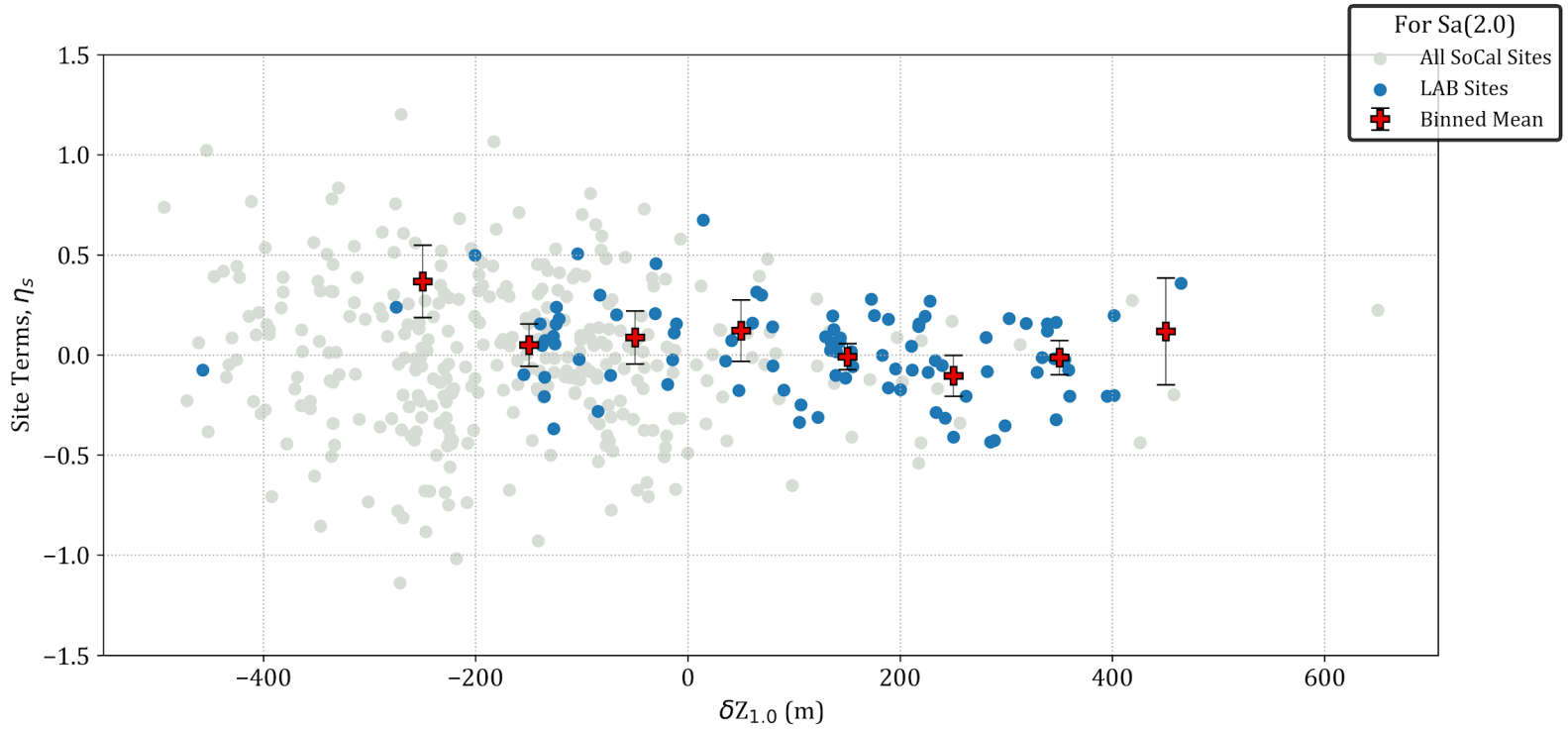
- Persistent negative bias (indicating overprediction) for δz_1
- No appreciable trend

Site Terms: Basin Category Sites

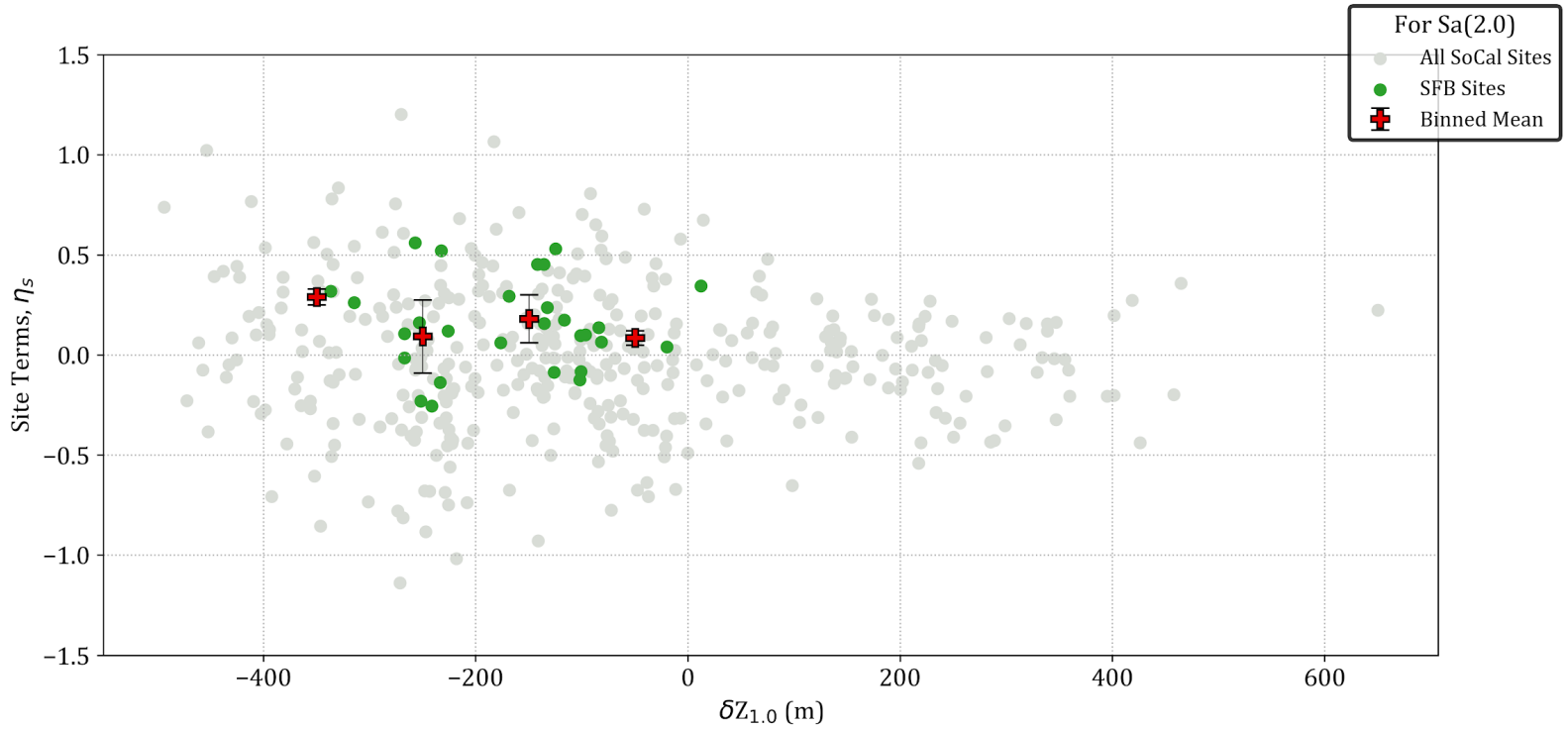


- Data wants steeper slope for $\delta z_1 < 0$ (mostly from SBCB)
- No trend for $\delta z_1 > 0$ (mostly from LAB)

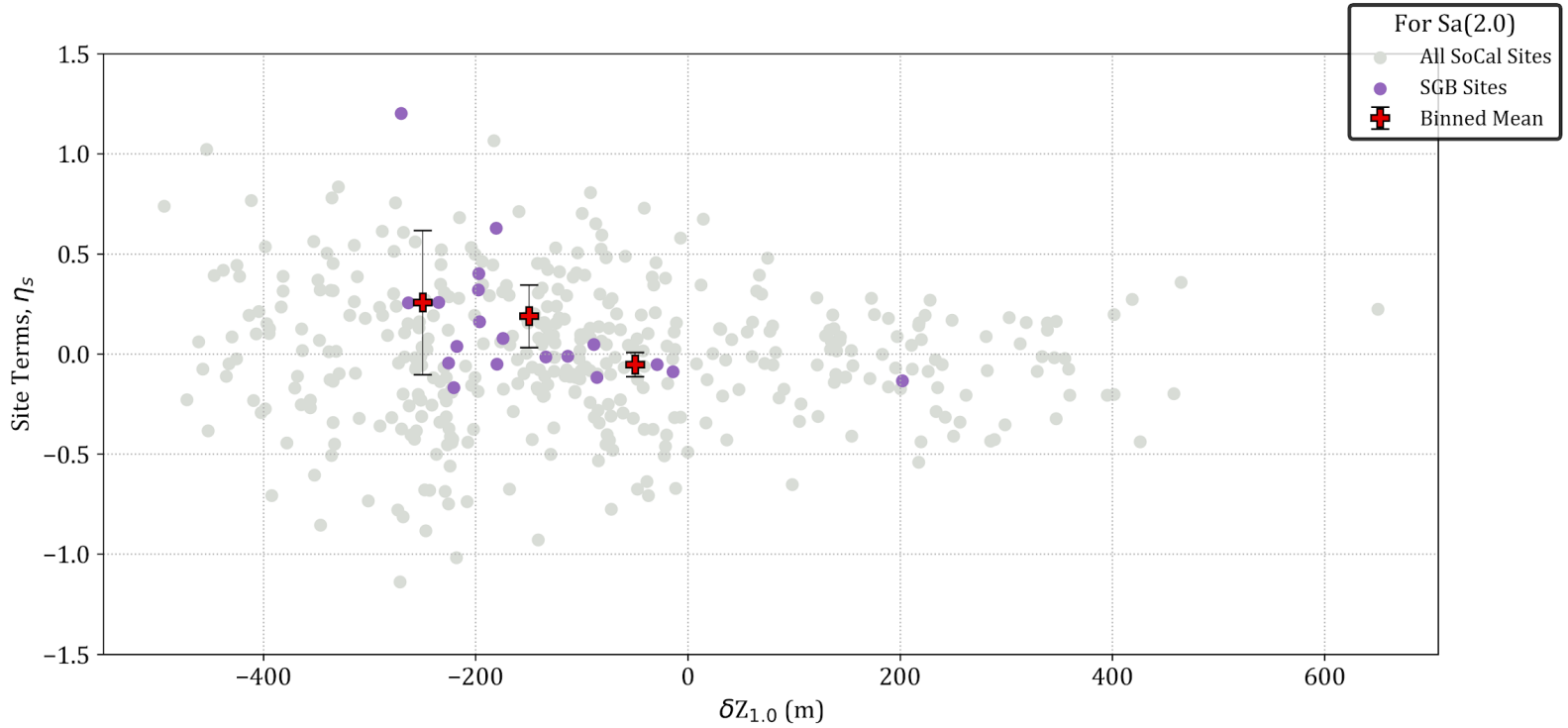
Site Terms: Los Angeles Basin (LAB)



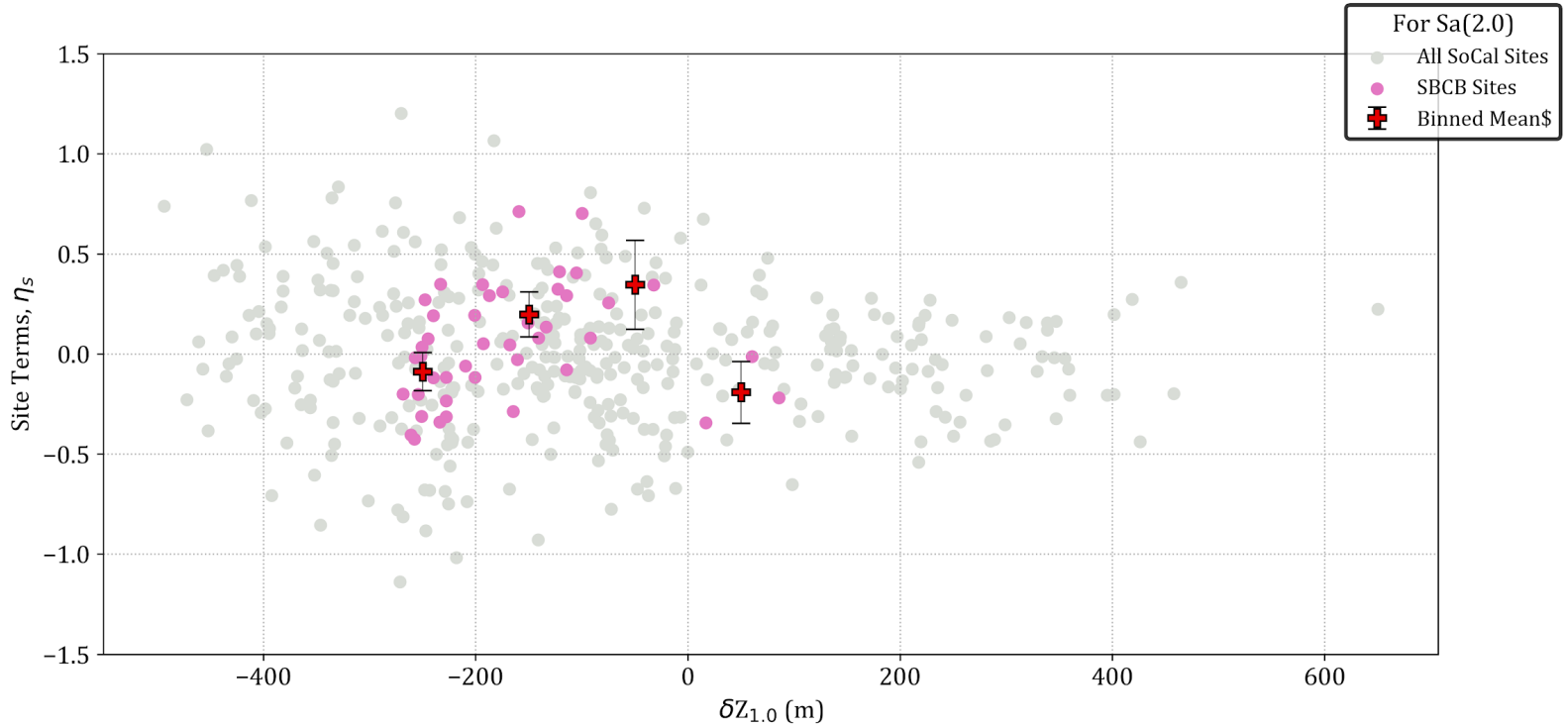
Site Terms: San Fernando Valley Basin (SFB)



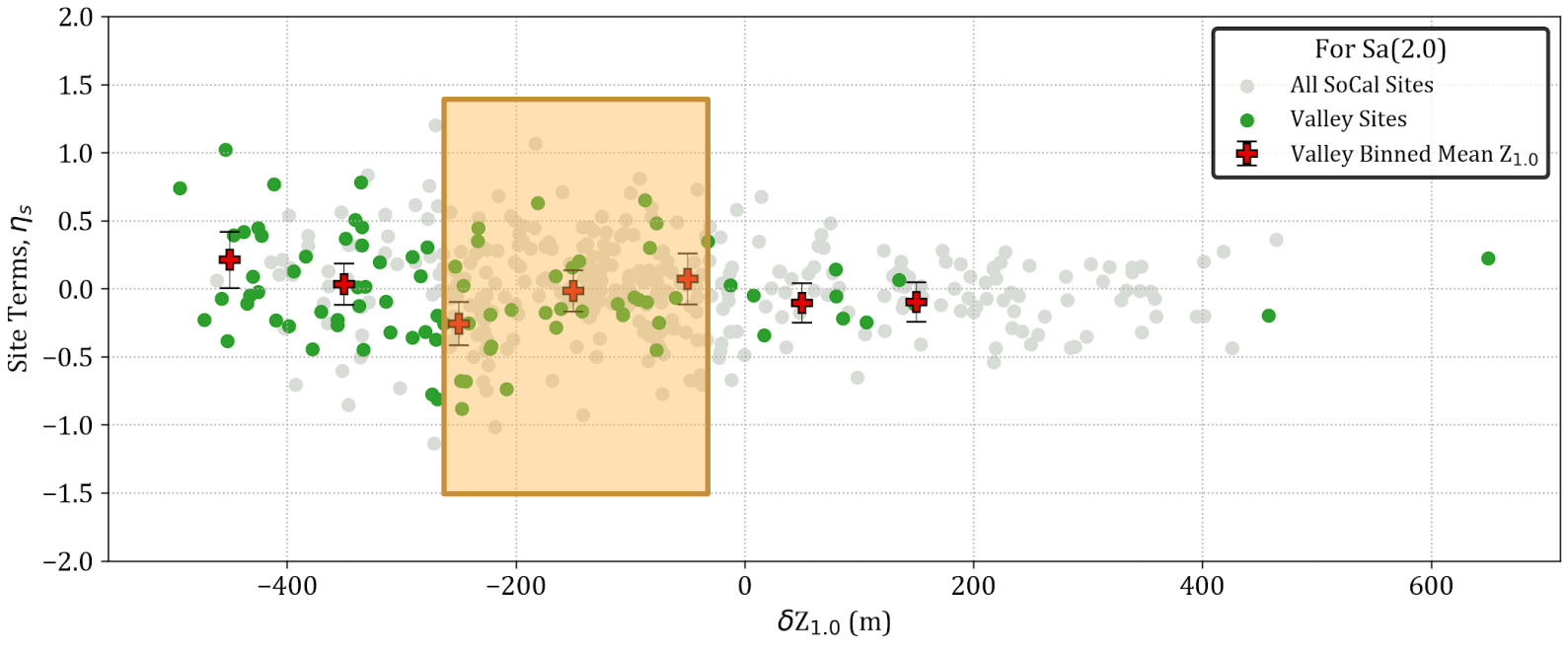
Site Terms: San Gabriel Basin (SGB)



Site Terms: San Bernardino-Chino Basin (SBCB)

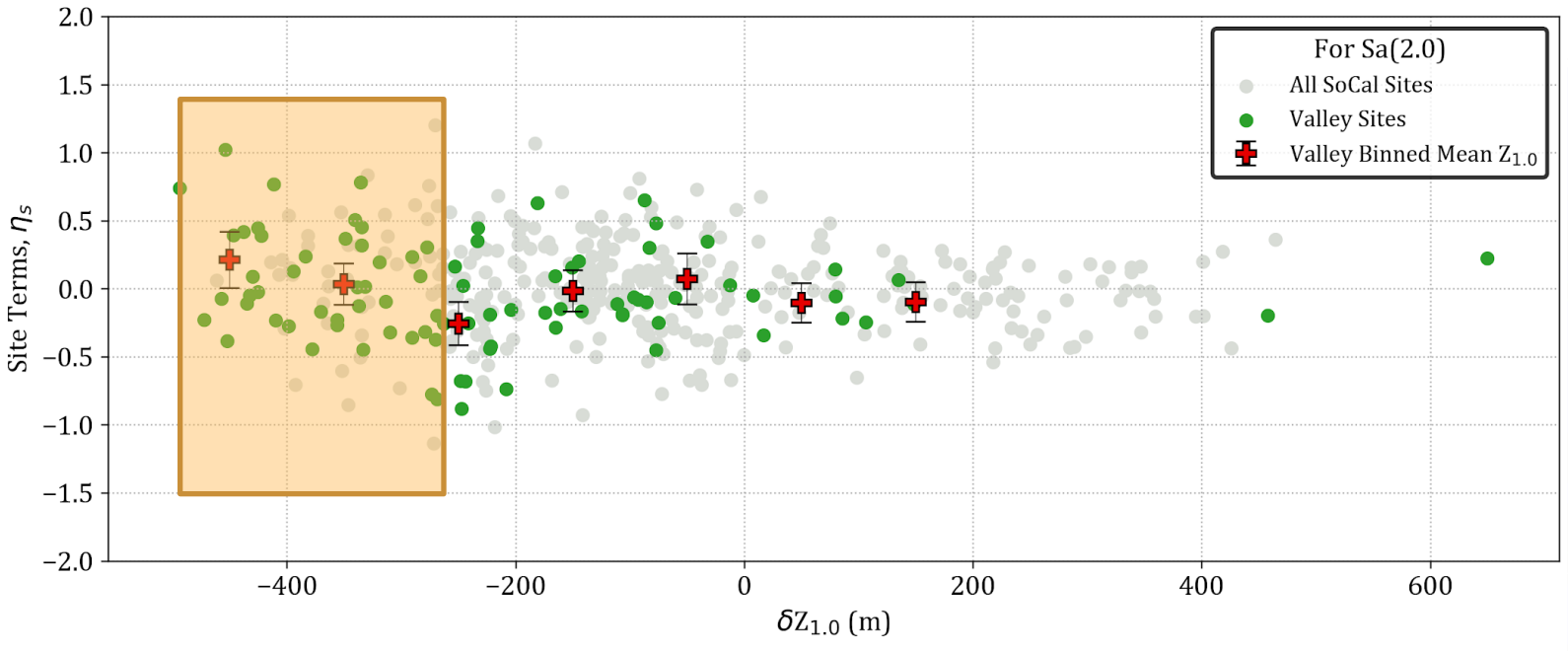


Site Terms: Valley Category Sites



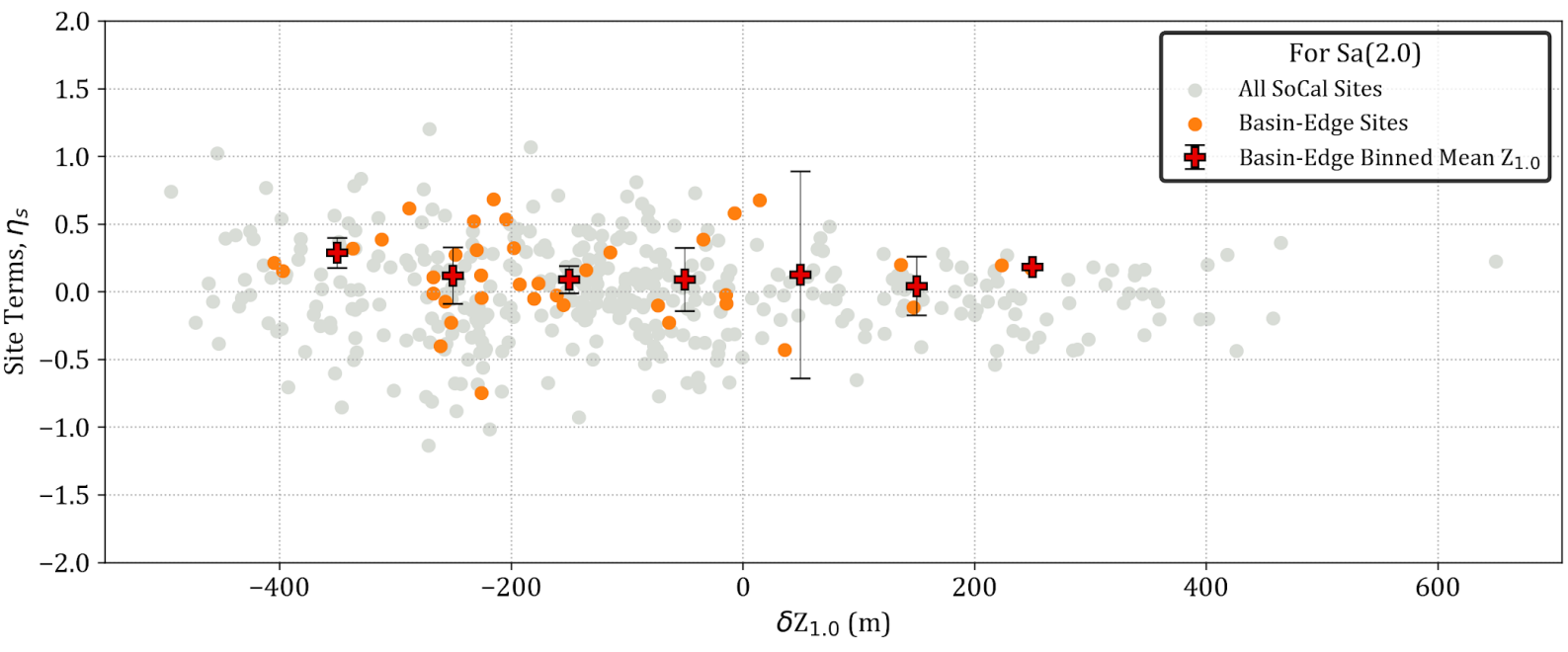
- Variable trends over different depth ranges:
  - Upward trend for -250m to 0m
- Suggest amplification ramp should possibly be steepened

Site Terms: Valley Category Sites



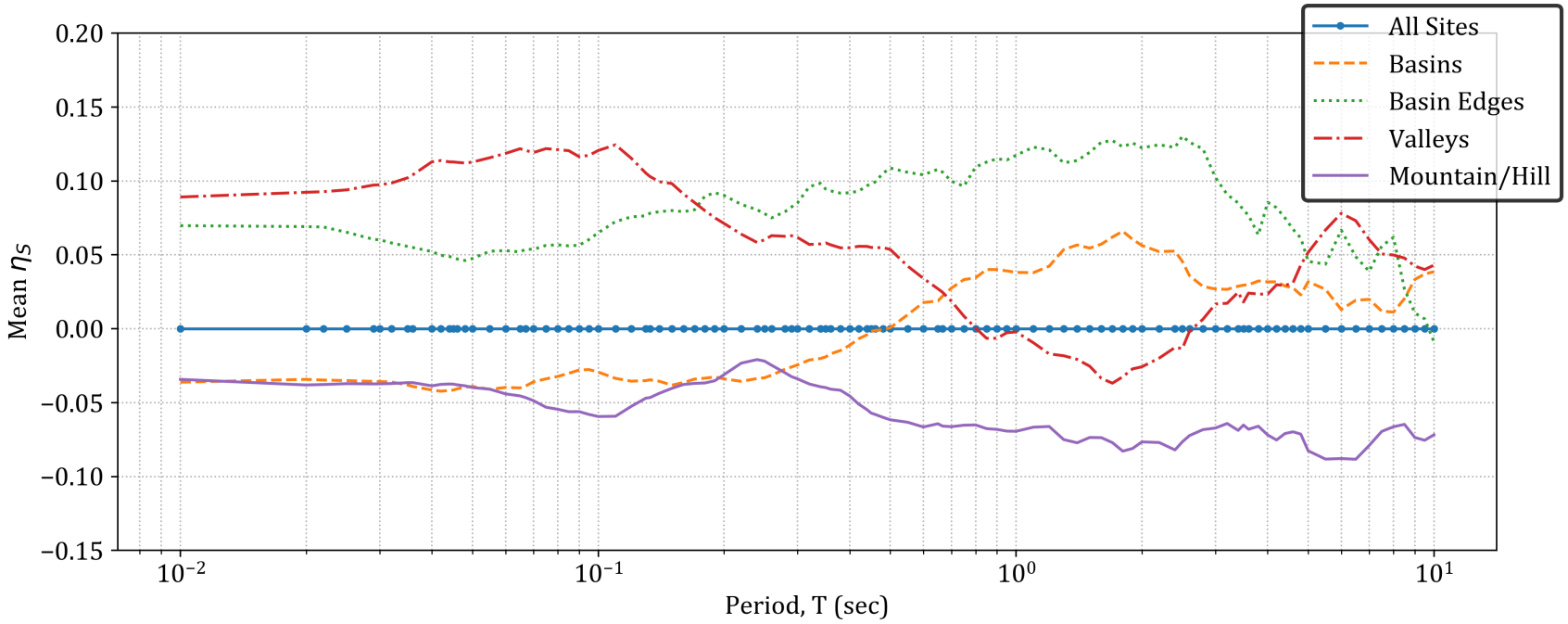
- Variable trends over different depth ranges:
  - Downward trend for -400m to -250m
- Suggest amplification ramp should be truncated

Site Terms: Basin Edge Category Sites



- Positive bias (indicating underprediction) and a slight downward trend for $\delta z_1 < 250m$
- This observable under-prediction for $\delta z_1 < 0$ suggests the current basin models de-amplification feature in this range is not controlled by basin edge sites

Category Means



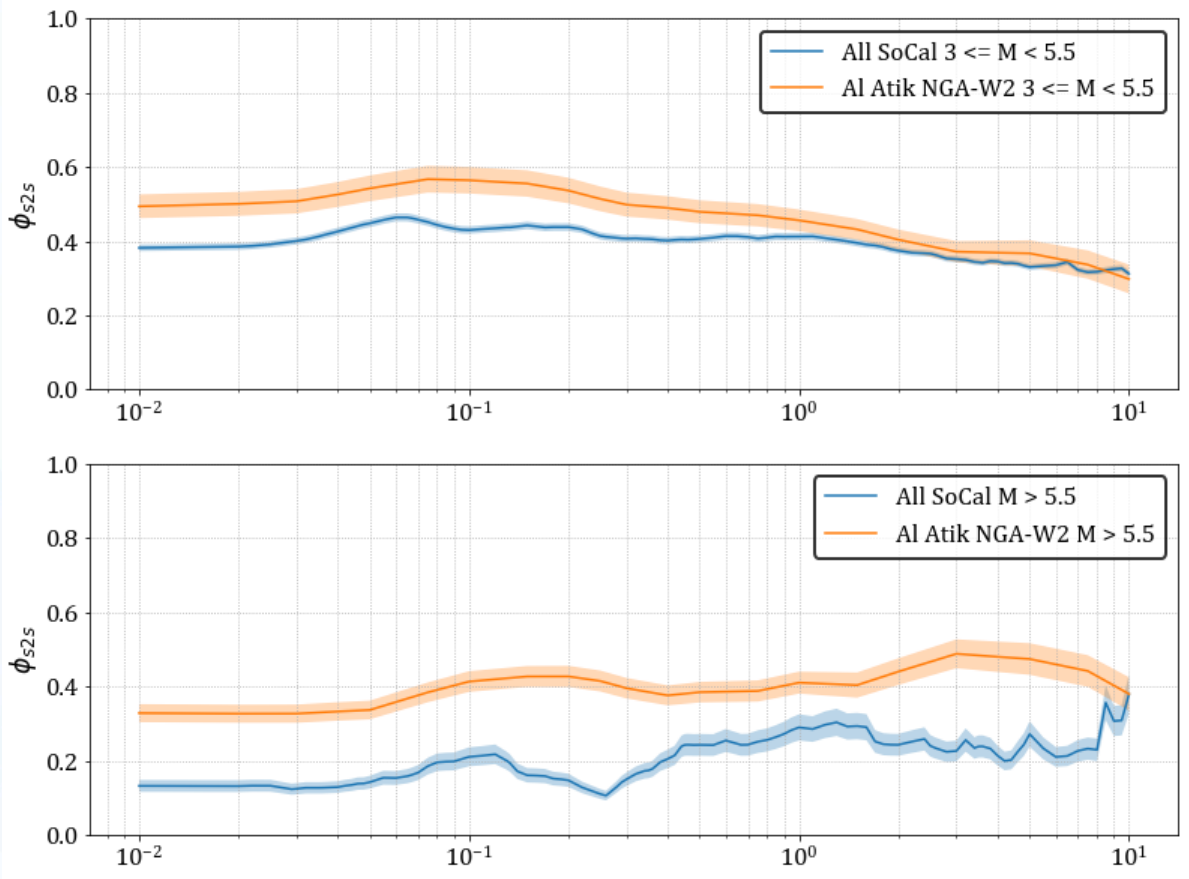
Ground Motion Analysis (Site-to-site Variability)

- Standard deviation of η_s is an approximation of ϕ_{s2s}
- Large contributor to within-event variability ϕ_{ln}

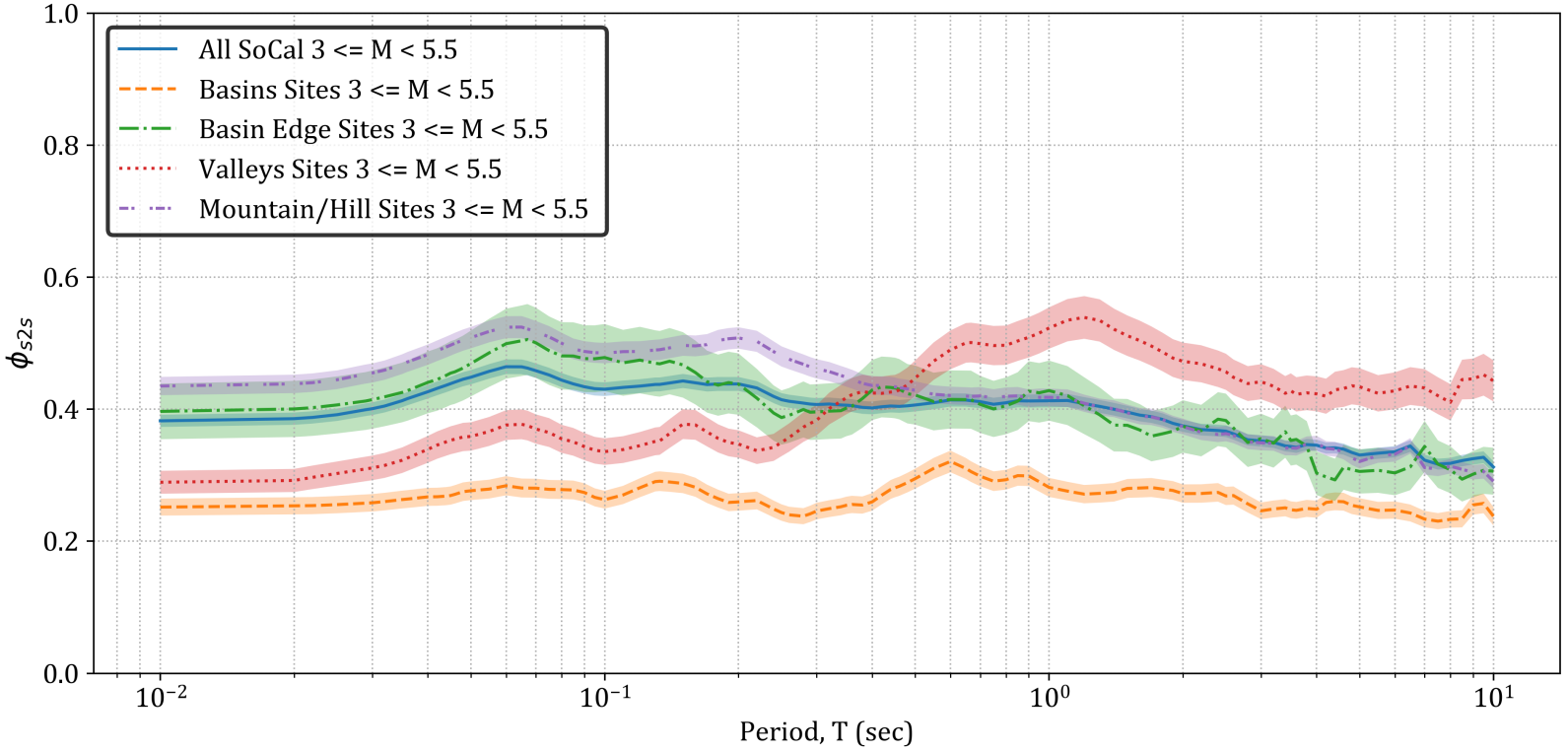
$$\phi_{\ln} = \sqrt{\phi_{P2P}^2 + \phi_{S2S}^2 + \phi_{\ln Y}^2}$$

- Can knowledge of basin categories affect ϕ_{s2s}?

Site-to-site Variability: All Sites



Site-to-site Variability: Basin Site Categories



Contributions and Findings

- Amplification portion of basin model driven by basin sites (i.e., LA Basin); *slightly underpredicts*

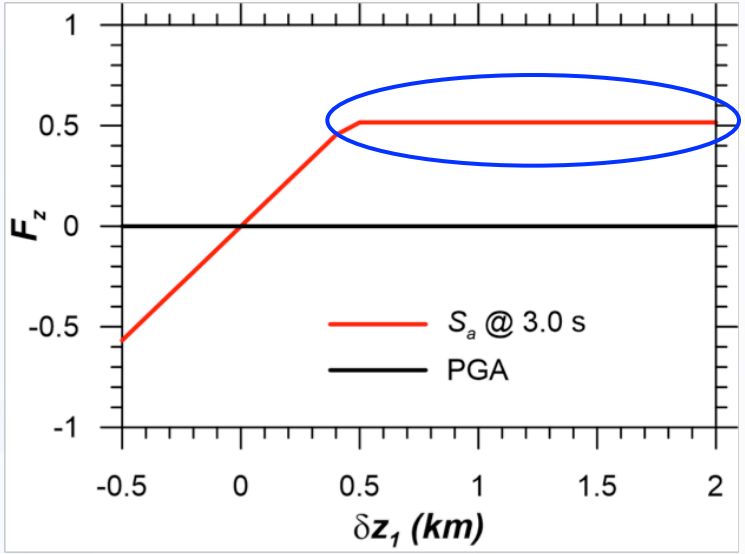


Illustration modified from J. Stewart

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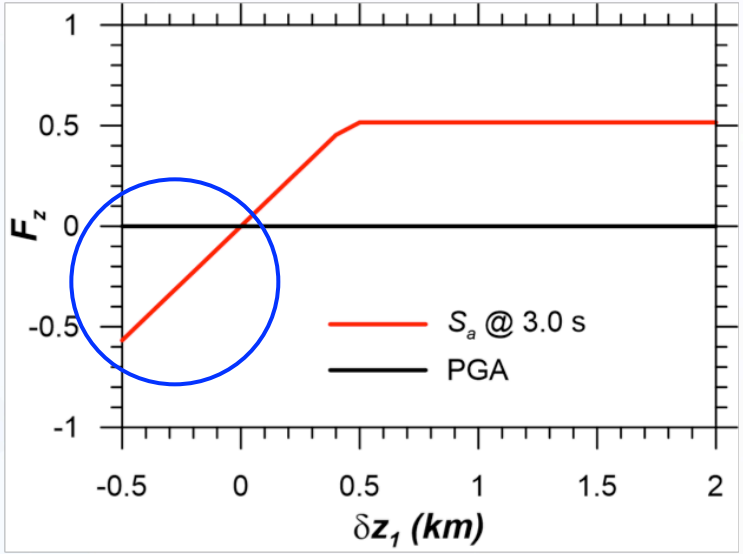

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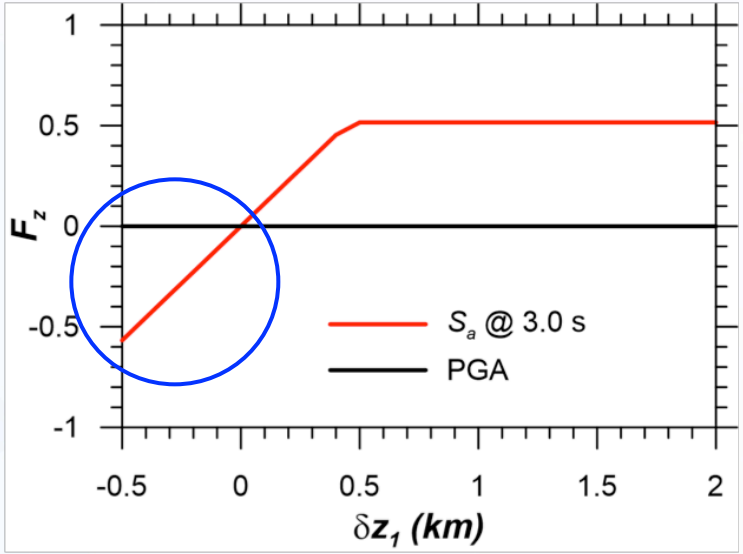

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- Models coming…

THANK YOU