Insights into Seismic Site Response in San Fernando and San Gabriel Basin using Geomorphometric Parameters

Ana Sotelo Romero[1,2]; Rashid Shams[3]; Chukwuebuka C. Nweke[3]

[1]University of Wisconsin-Madison (sotelooromero@wisc.edu), [2]Statewide California Earthquake Center, [3]University of Southern California

1. Abstract

Seismic site response is a critical component of Ground Motion Models (GMMs). Recent studies have shown that sedimentary basins with complex subsurface geometries can significantly amplify ground shaking. However, many current GMMs represent site conditions using one-dimensional features, neglecting multidimensional components of seismic wave propagation effects due to complex subsurface geomorphological and geological variability. This study evaluates whether geospatial parameters can improve the characterization of site response variability in the San Fernando and San Gabriel Basins, two tectonically active basins with complex depositional histories shaped by strike-slip and thrust fault systems. These two settings exhibit substantial heterogeneity in crystalline basement depth and ground topography.

We examined the geologic structure of these basins using geologic cross sections and two Community Velocity Models (CVM-H 15.1 and CVM-S4.26.M01). GIS-based methods were applied to derive geomorphometric indices, including slope, curvature, aspect, and the Topographic Roughness Index (TRI) from high-resolution digital elevation models and basement depth maps. Seismic stations were classified into geomorphic categories (basin interior, basin edge, valley, and mnt/hills) based on topographic setting, enabling the spatial integration of earthquake recordings with geomorphic variables and refinement of basin outlines were refined.

Correlations between geomorphometric attributes and site response were assessed using mixed effects-based site residuals across multiple periods. Slope, TRI, and standard deviation of $z_{1.0}$ showed the strongest spatial trend with site response, with slope and TRI negatively correlating at longer periods, and standard deviation of $z_{1.0}$ showing reduced dispersion in residuals. Results indicate that specific geomorphic indicators capture systematic spatial trends in site response, reflecting both surface morphology and underlying basin geometry. This integrated approach advances the development of a non-ergodic site response modelling framework by incorporating both shallow geomorphic features and deep structural controls.

2. Introduction

Tectonic and Geologic Setting of the Study Basins

Sedimentary basins in Southern California strongly shape site response. Large ground-motion datasets (NGA-West2 and following updates) show long-period amplification reflects both shallow conditions and deep structure (e.g., basin depth), with basin interiors amplifying more and varying less than valleys or hills (Nweke et al., 2022).

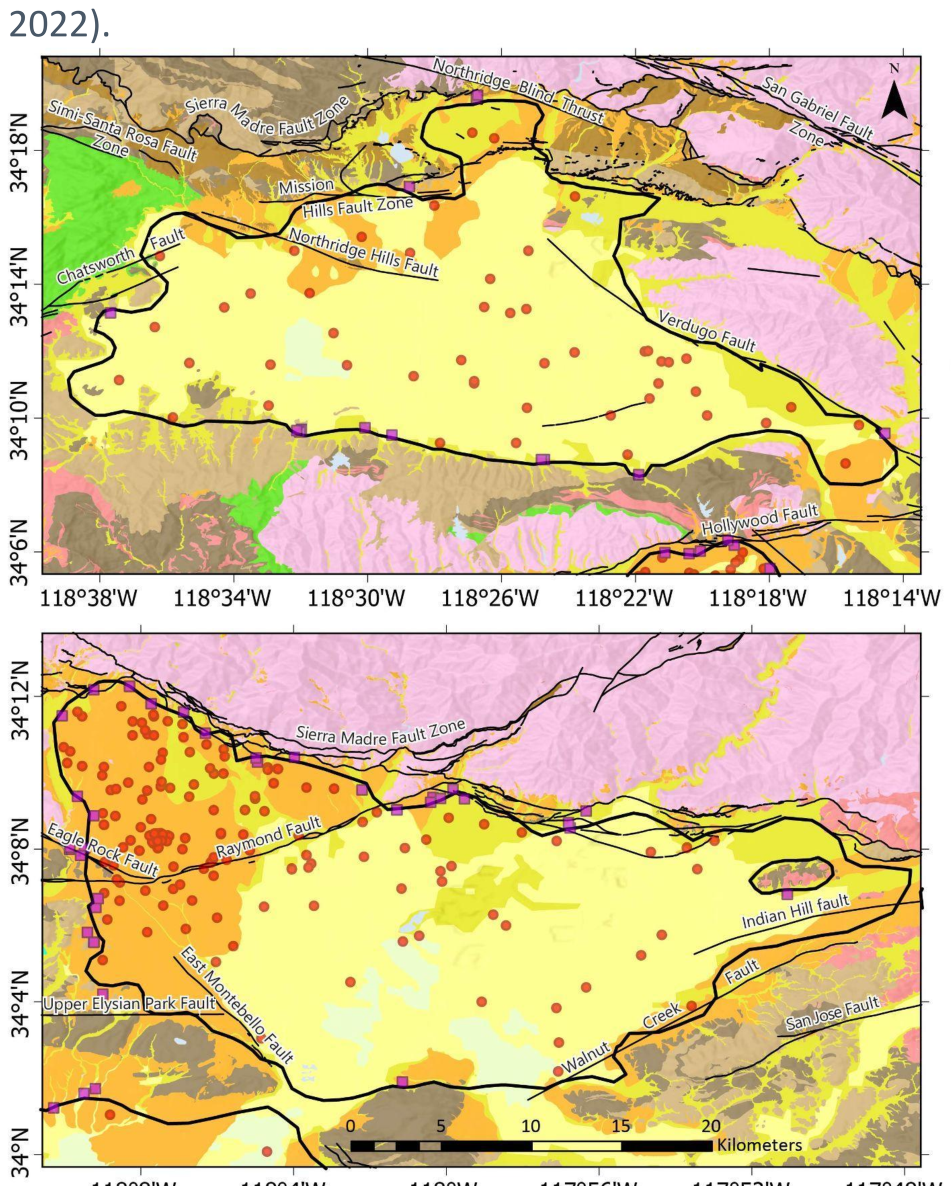


Figure 1: Geologic maps of the San Fernando Basin (SFB, top) and San Gabriel Basin (SGB, bottom). Basin outlines (black; refined in this study), geologic units, and mapped faults are shown.

Quaternary alluvial deposits (Qal1–Qal3, Qoa) dominate basin floors, while older sedimentary, volcanic, and crystalline rocks crop out along the margins. Major fault systems bound and shape both basins, controlling basin geometry and sediment accumulation.

3. Methods

Seismic Site Classification by Geomorphic Setting

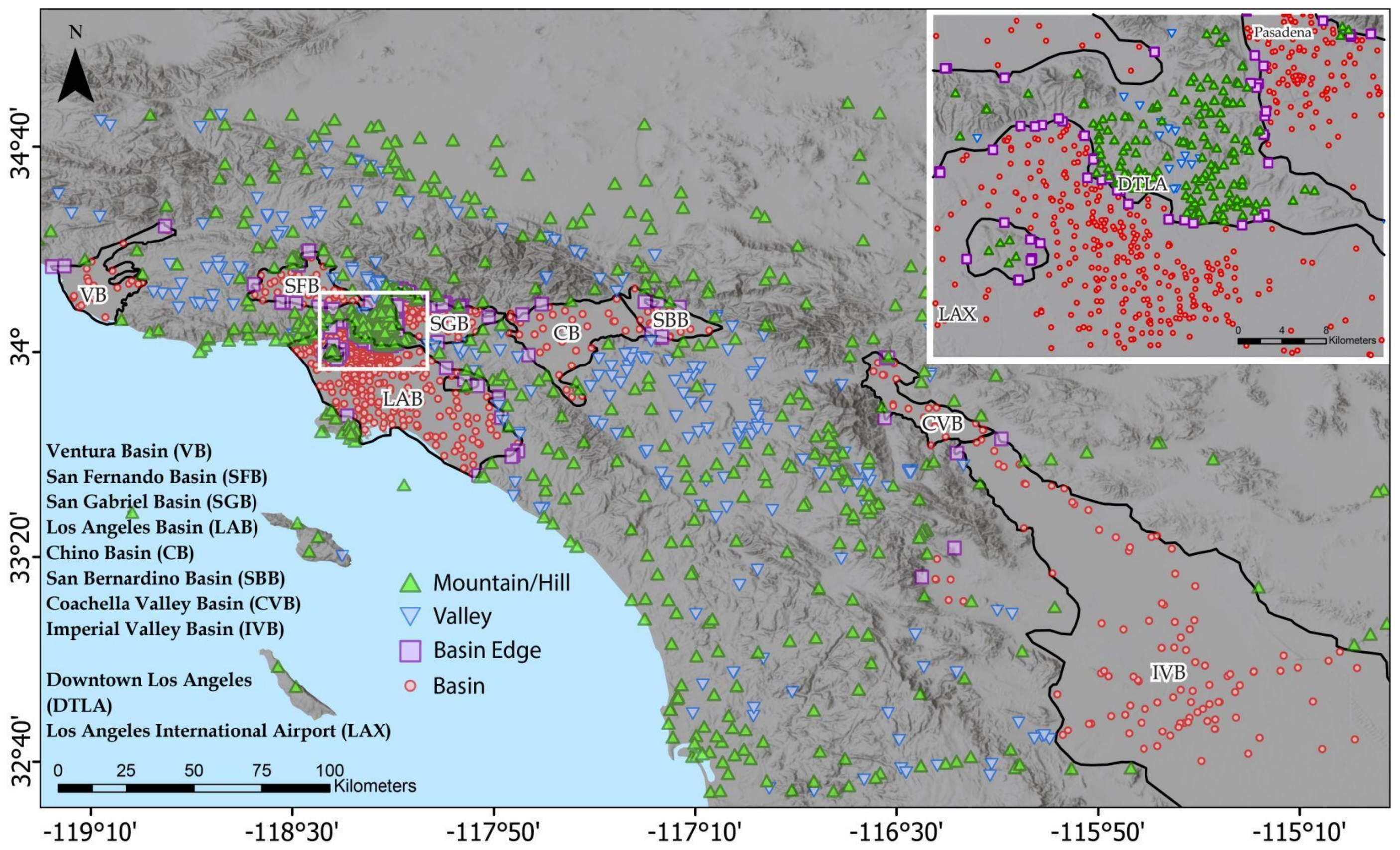
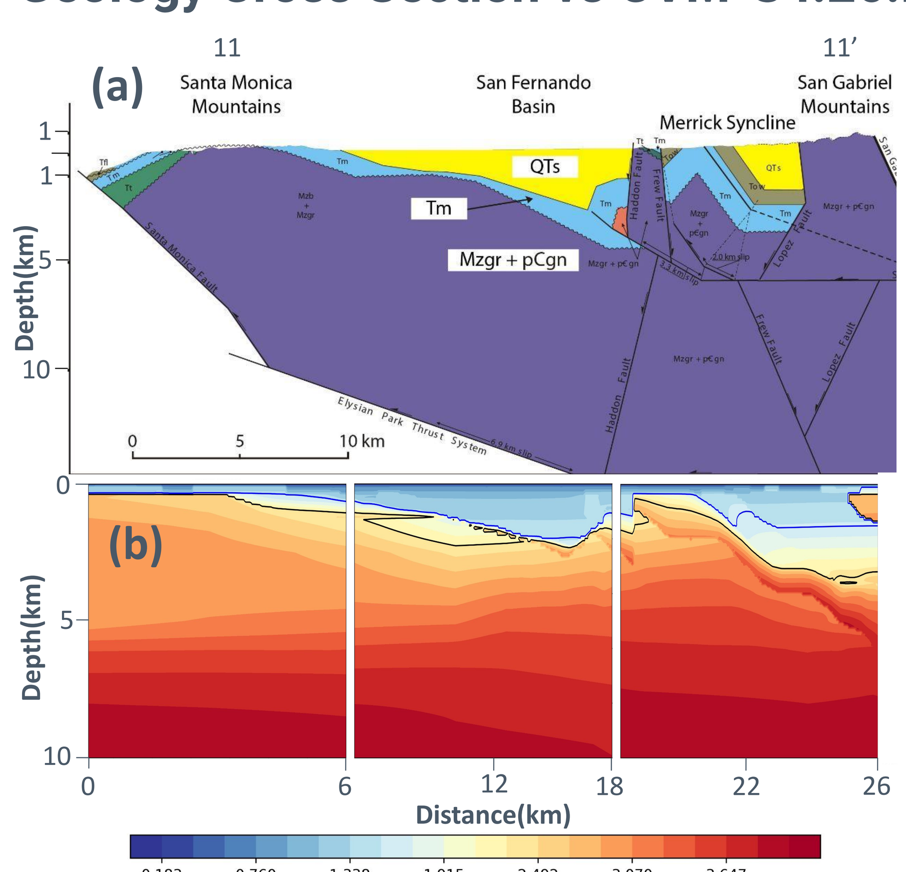


Figure 2: Map of the Southern California study area showing seismic site categorized by topographic setting.

This classification allows for targeted analysis of site response patterns across distinct geomorphic environments by aligning seismic data and site residuals with calculated geomorphic indices.

Geology Cross Section vs CVM-S4.26.M01 Velocity Model



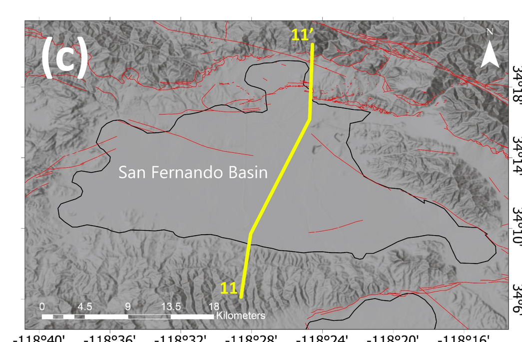
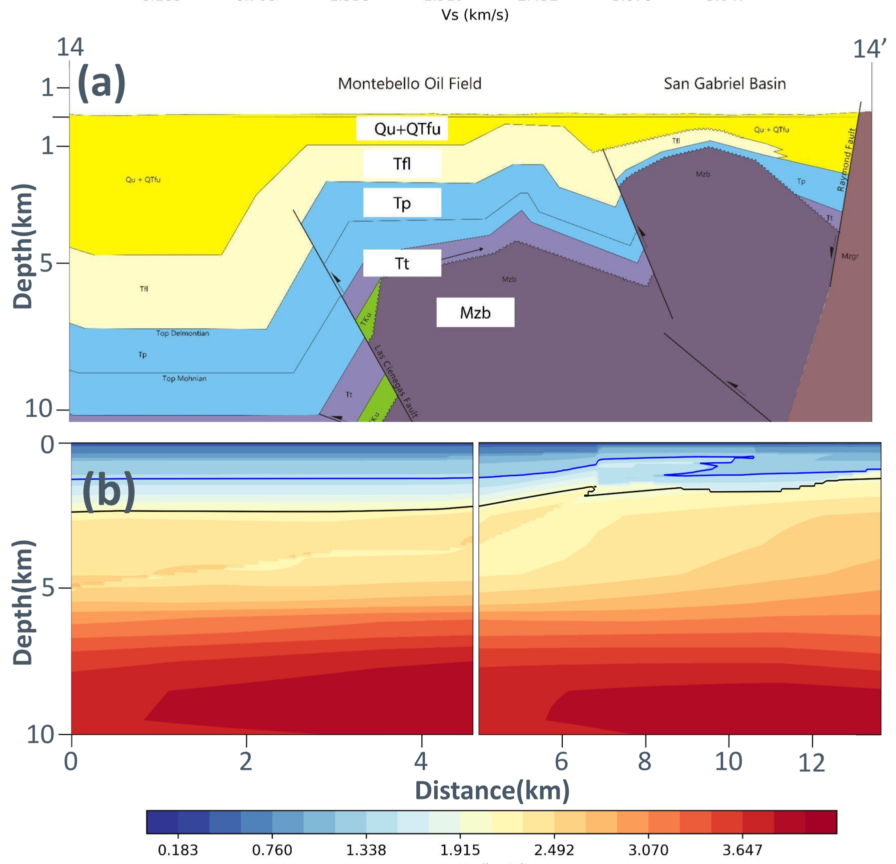


Figure 3: Geologic–seismic transect across the San Fernando Basin: (a) geologic cross section with major faults and units; (b) CVM-S4.26.M01 shear-wave velocity (Vs) along the same line to 10-km depth; and (c) map showing the transect location within the basin.



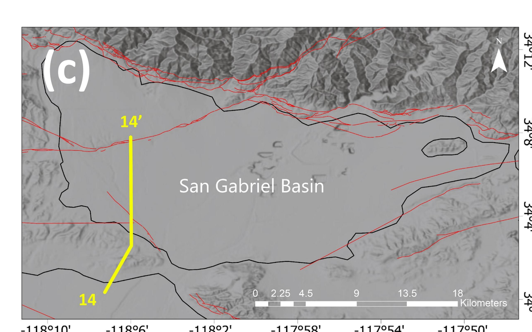
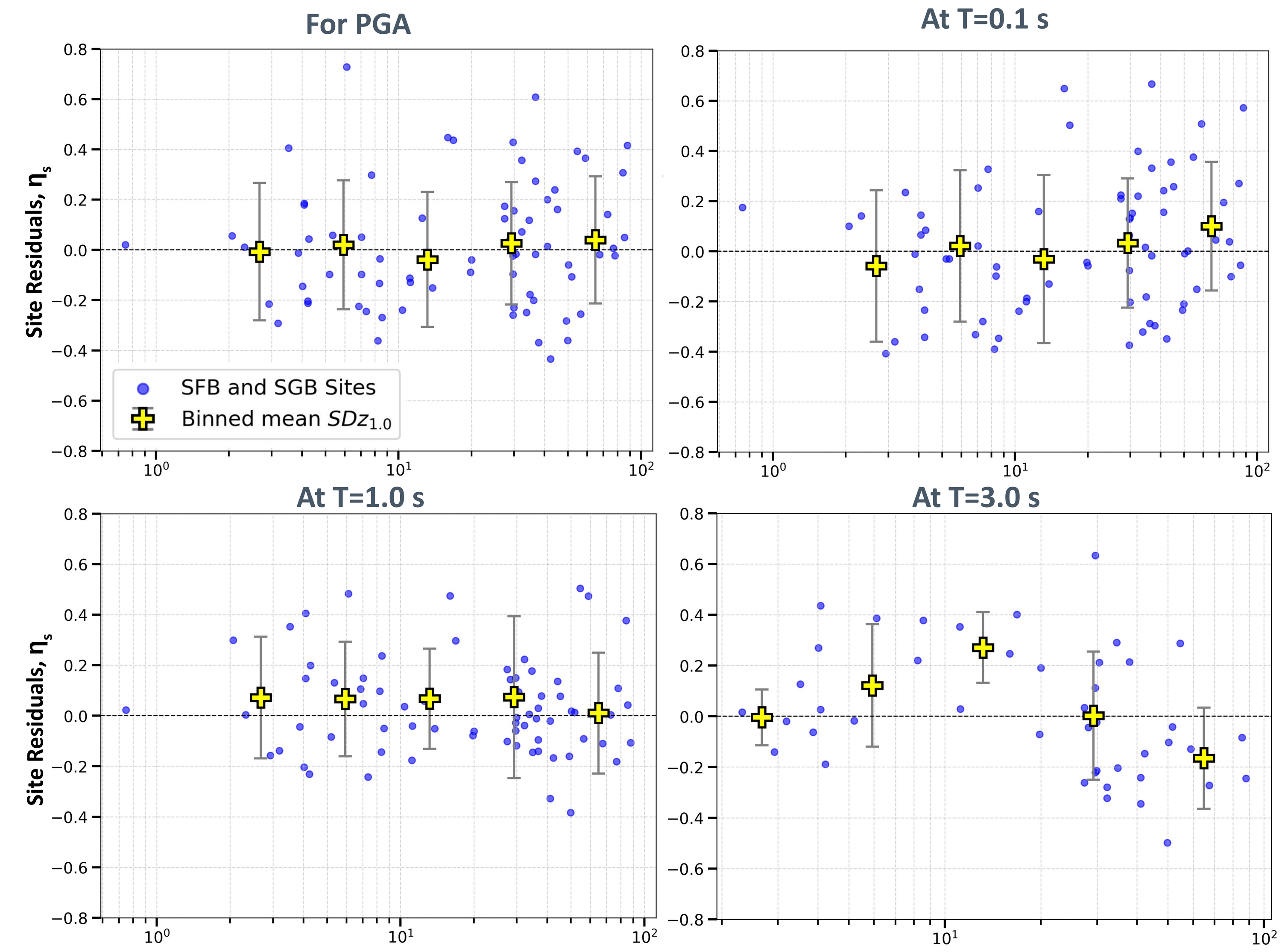


Figure 4: Geologic–seismic transect across the San Gabriel Basin: (a) geologic cross section with major faults and units; (b) CVM-S4.26.M01 shear-wave velocity (Vs) along the same line to 10-km depth; and (c) map showing the transect location within the basin.

4. Results

Relationships Between Site Residuals and Parameters



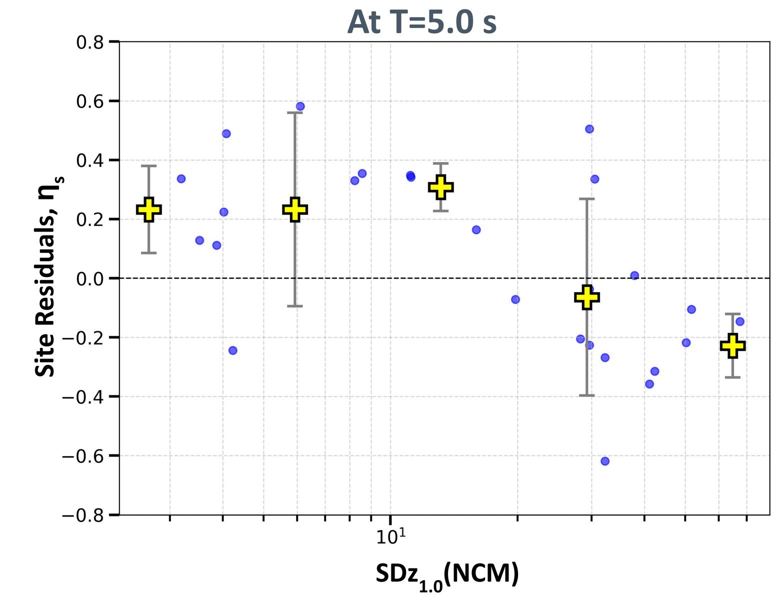


Figure 5: Site term residuals (η_s) plotted against the parameters standard deviation of $z_{1.0}$ ($SDz_{1.0}$) derived from the National Crustal Model (NCM), for spectral acceleration at multiple periods (PGA, 0.1s, 1.0s, 3.0s, and 5.0s). While residuals are generally centered around zero at shorter periods (PGA to 1.0s), a slight downward trend in the binned means becomes apparent at longer periods (3.0s and 5.0s).

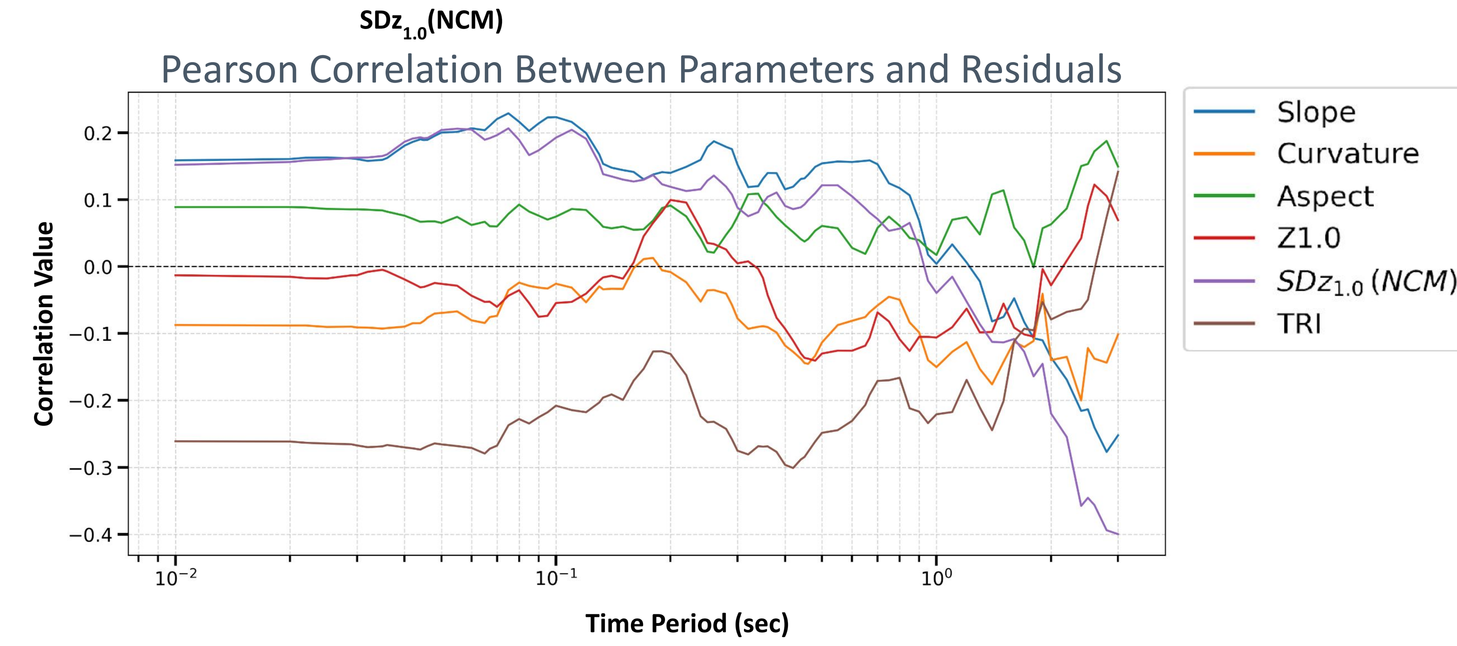


Figure 6: Correlation between site parameters and residuals across periods, showing values for each parameter at periods ranging from 0.1 to 3.0 seconds.

5. Conclusion

Negative correlations at longer periods suggest that terrain variability and basin geometry may play a stronger role in modifying long-period ground motions. These findings highlight the limitations of 1D site condition metrics used in many ground motion models (GMMs).

6. References Cited

Nweke C.C., Shams R., (2024). Geometric Parameterization of Sedimentary Basins in Southern California for Site Response Analysis and Modeling. The B. John Garrick Institute for the Risk Sciences at UCLA Engineering. 10.34948/N3988K

Davis T., Namson J., (1998). Southern California Cross Section Study Cross-Section 11-11', 14-14'. DAVIS NAMSON CONSULTING GEOLOGISTS

Acknowledgements

SCEC is funded by NSF Cooperative Agreement EAR-2225216 and USGS Cooperative Agreement G24AC00072.

SCEC NSF U.S. National Science Foundation USC