The Long and the Short of It: Duration in Earthquake Hazard Analysis

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1. Abstract

Traditional seismic hazard models emphasize amplitude-based metrics such as peak ground acceleration or response spectral acceleration, but often neglect an equally critical factor: ground motion duration. Duration strongly influences structural damage potential, collapse risk, and recovery time; particularly for long-period structures and soft-soil sites. However, duration continues to remain underrepresented in hazard frameworks. This project uses CyberShake, a physics-based ground motion simulation platform developed by the Southern California Earthquake Center, to analyze earthquake duration using the D5–75 metric (the time interval between 5% and 75% cumulative Arias Intensity). We retrieved and organized supporting site metadata, including basin depth (Z1.0, Z2.5) and rupture distance, from CyberShake's database to enable future correlation studies. To contextualize results, we compared CyberShake synthetic data to empirical records from the NGA-West2 database. Our results show clear duration trends with magnitude and rupture distance, and demonstrate CyberShake's ability to produce denser and broader coverage than recorded datasets; capturing rare, high-magnitude events often missing from empirical archives. By adding duration to hazard assessment, this work lays the foundation for next-generation seismic hazard models that integrate both intensity and time-domain effects, ultimately improving resilience planning and engineering applications. Future directions include expanding site coverage, developing predictive models, and exploring period-dependent duration metrics.

2. Introduction

Ground motion duration is an important yet underutilized metric in earthquake hazard assessment, influencing structural performance, infrastructure resilience, and safety. Longer shaking can increase cumulative damage and disrupt lifeline systems.

This study computes period-independent D5–75% durations from CyberShake, a physics-based seismic hazard model that uses 3D earth models and rupture simulations, and compares them with records from the NGA-West2 database. The D5–75% metric measures the time for Arias Intensity to grow from 5% to 75% of its total value. Arias intensity, or the cumulative energy released from seismic waves into the ground is calculated by the following equation: $I(t)=\dfrac{\pi}{2g}\int_0 a^2(\tau)\,d\tau$

This range captures the portion of shaking energy most relevant to structural damage while reducing the influence of low-amplitude coda waves, providing a robust basis for comparing synthetic and empirical datasets.

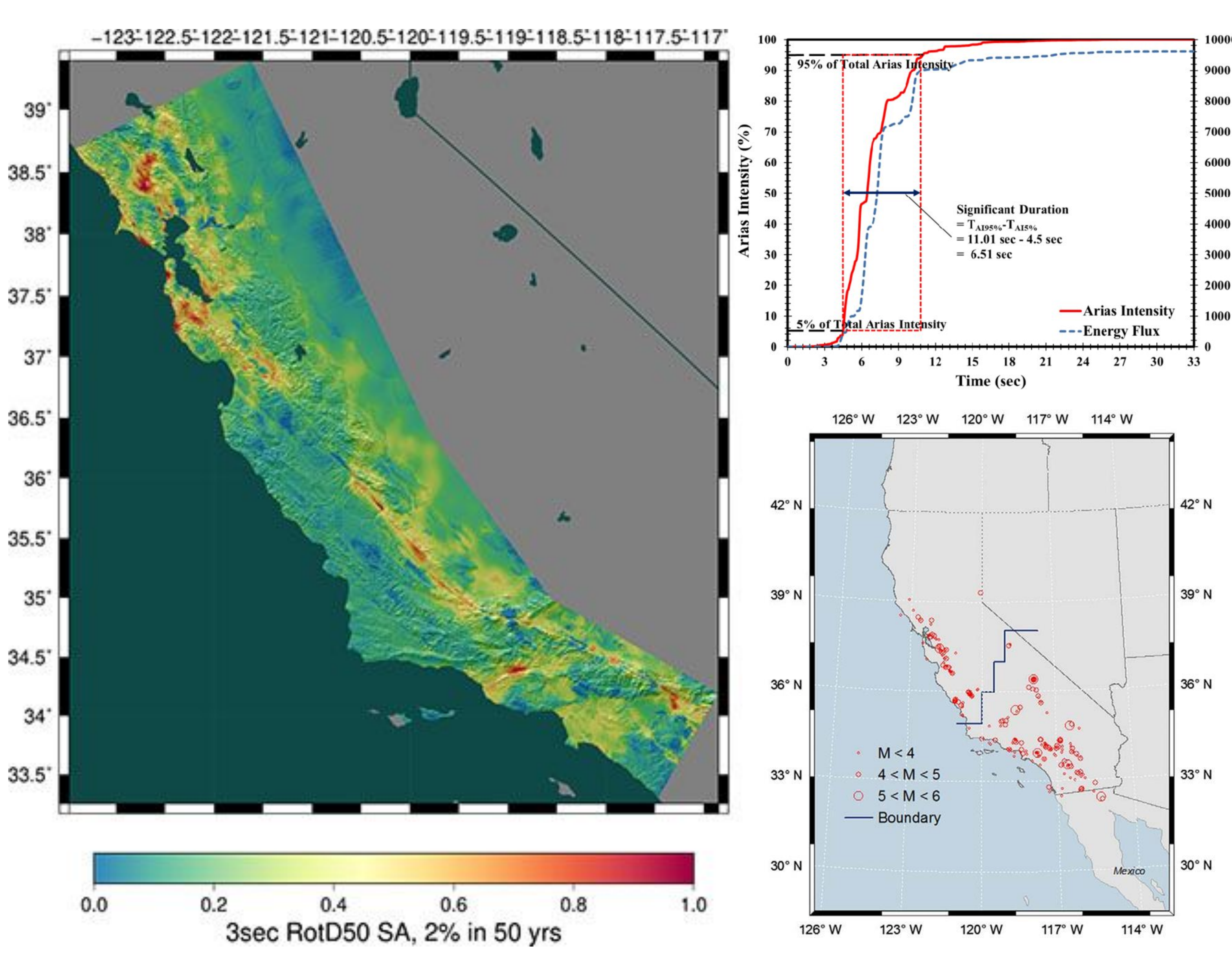


Figure 1: CyberShake study area (map), example Arias Intensity duration curve (5% to 75%), and NGA-West2 coverage area (map)

3. Methodology

To address the research question, I extracted synthetic ground motion data from CyberShake and empirical records from the NGA-West2 database. For CyberShake, I computed period-independent D5–75% durations from acceleration time series, and also retrieved site metadata; including geotechnical parameters (e.g., Vs30), rupture distances, and fault geometry; using Globus and OpenSHA tools. I identified comparable sites across datasets by matching location proximity and naming, focusing on CyberShake and NGA-West2's USC station. For the overall dataset comparison, I generated scatterplots, boxplots, and summary tables to evaluate duration patterns between CyberShake and NGA-West2. For the individual station analysis, I created log-scale heatmaps, correlation matrices, and boxplots to examine relationships between magnitude, rupture distance, and D5–75% durations. Results from both levels of analysis were compared to evaluate agreement and highlight discrepancies between simulated and observed shaking durations.

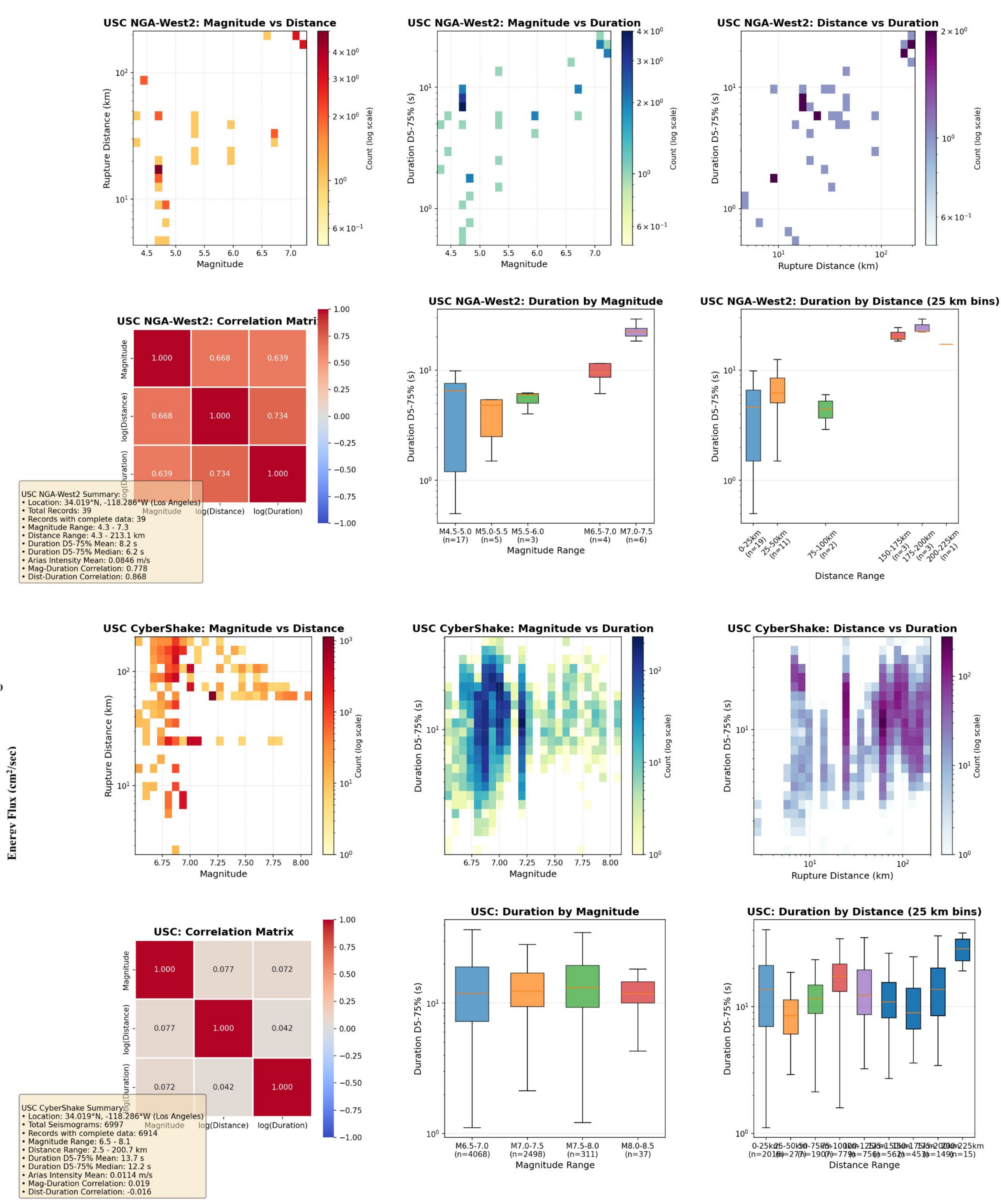
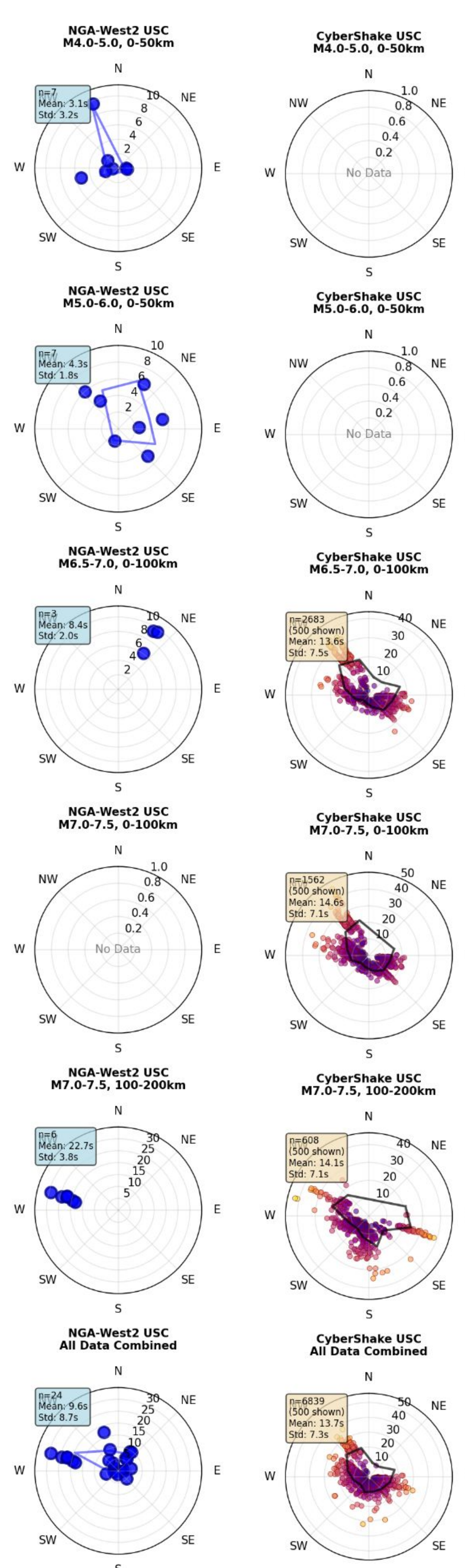


Figure 2: Magnitude–distance–duration relationships for Cybershake. Heatmaps show magnitude vs. rupture distance, magnitude vs. D5–75 duration, and rupture distance vs. D5–75 duration. Correlation matrices quantify relationships between log-transformed variables. Boxplots illustrate D5–75 duration trends by magnitude and distance bins. NGA-West2 data are empirical recordings at USC; CyberShake data represent simulated scenarios for USC.

4. Results

CyberShake produces systematically longer durations and a wider spread than NGA-West2, particularly for M6.0–7.5 events. This scatter grows with increasing distance, highlighting the influence of 3D wave propagation and basin complexity. In contrast, NGA-West2 remains shorter and more uniform, reflecting its empirical, smoothed regression basis. The polar plots show directional dependence in CyberShake (durations vary with azimuth) whereas NGA-West2 appears isotropic. Overall, CyberShake emphasizes source–site interactions and path effects that empirical models tend to average out.



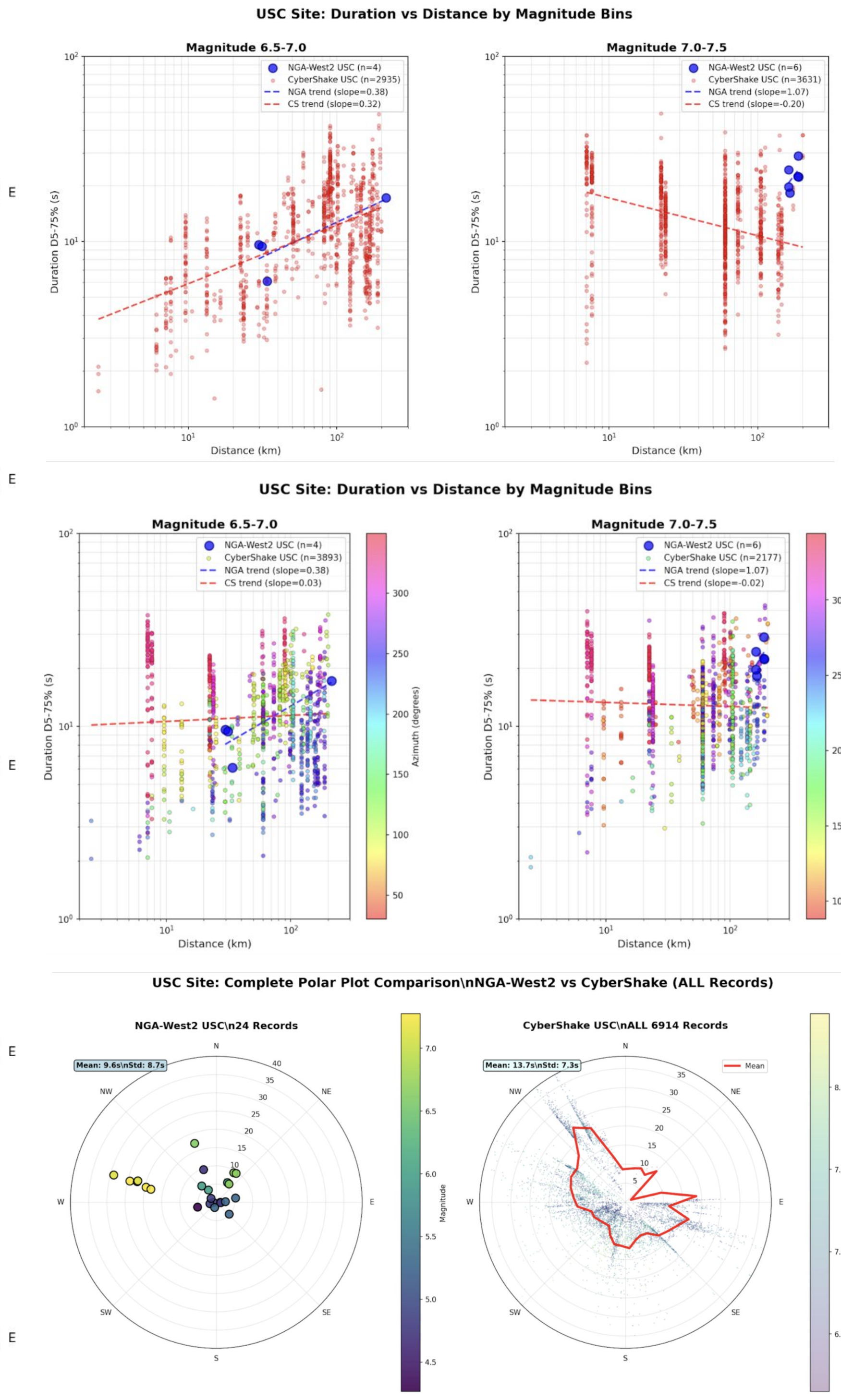


Figure 3: USC site comparison of NGA-West2 and CyberShake durations. CyberShake shows consistently longer and more variable durations than NGA-West2, especially at higher magnitudes and distances. Azimuthal patterns in CyberShake indicate source–site and basin effects not captured by the empirical NGA-West2 data.

5. Discussion

These results highlight that CyberShake and NGA-West2 produce differing duration trends, with variations in magnitude and distance dependence suggesting model-specific sensitivities. By directly comparing empirical and physics-based datasets, this work addresses a gap in understanding how simulated durations align with real-world observations;critical for improving seismic hazard models. Expanding this research would require analysis across a broader set of sites, additional rupture scenarios, and integration of more empirical datasets to validate patterns. Future studies could also explore predictive modeling of durations, incorporate site-specific geologic parameters, and assess implications for engineering design and risk mitigation.

6. References Cited

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SCEC U.S. National Science Foundation Verisk Cal elac HUSKIES Cal Poly Pomona

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