SCEC Ground Motion Tools Supporting Engineering Applications

Edric Pauk (USC/SCEC)

CyberShake: Scott Callaghan, Xiaofeng Meng, Rob Graves, Kim Olsen, Mei-Hui Su, Fabio Silva, Akash Bhatthal, Morgan Moschetti, Albert Kottke, Kevin Milner, Yehuda Ben-Zion, Ahmed Elbanna, Phil Maechling

BBP & GMSV Toolkit: Fabio Silva, Rob Graves, Kim Olsen, Scott Callaghan, Ahmed Elbanna, Phil Maechling

UGMS: CB Crouse, Tom Jordan, Rob Graves, Kevin Milner, Phil Maechling

September 1, 2026 - SCEC2026, Palm Springs, CA

SIMULATIONS

Produce simulated ground motions

Broadband Platform (BBP)

Stochastic, broadband simulations

CyberShake

Physics-based, 3D wave propagation simulations

Simulated GMs: Improving Hazard Models

Characterization of basin effects on earthquake ground motions in empirical GMMs can be refined using ground motion simulations.

Moschetti et al. 2024 used **CyberShake simulated GMs to create basin-depth scaling models**.

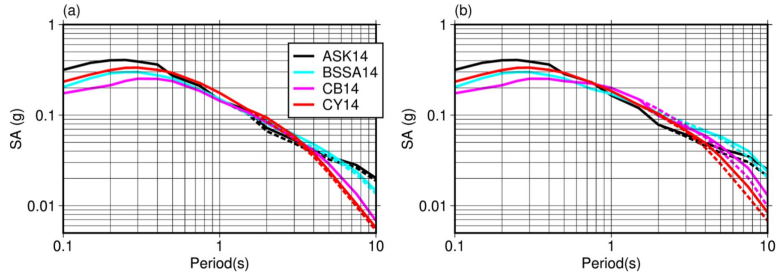


Figure 16. Comparison of median response spectra from the empirical GMMs (dashed lines) and CyberShake-adjusted GMMs (solid lines), for example, site conditions corresponding to (a) shallow basin depths, $Z_1 = 0.45$ km, $Z_{2.5} = 3$ km (i.e. $\delta Z_1 \approx 0$ km) and a (b) deeper basin site, $Z_1 = 0.8$ km, $Z_{2.5} = 5.5$ km. Scenario ground motions were computed for $M_W = 7.5$, $R_{RUP} = 50$ km, $R_{JB} = 50$ km, $R_X = 50$ km, width = 15 km, dip = 90°, $Z_{hyp} = 7.5$ km, $Z_{TOR} = 0$ km. Reference Z_1 values from NGA-West-2 GMMs are $Z_{1,ref}^{ASK14}(V_{S30} = 260\ \mathrm{m/s}) = 0.475$ km, $Z_{1,ref}^{BSSA14}(V_{S30} = 260\ \mathrm{m/s}) = 0.485$ km, and $Z_{1,ref}^{CY14}(V_{S30} = 260\ \mathrm{m/s}) = 0.485$ km.

⭐ Refining empirical GMMs already used in seismic hazard analysis is a pathway for bringing simulations into engineering applications.

Morgan P Moschetti, Eric M Thompson, Kyle Withers; Basin effects from 3D simulated ground motions in the Greater Los Angeles region for use in seismic hazard analyses. ***Earthquake Spectra*** *2024; 40 (2): 1042–1065. doi: https://doi.org/10.1177/87552930241232372*

Simulated GMs: Curated for Application

Simulated datasets are huge but curation makes them easier to adopt.

Baker et al. create a curated dataset of documented ground motions from CyberShake simulations for Response History Analysis (RHA) in the Los Angeles Region.

⭐ An engineer-ready dataset for structural design and assessment.

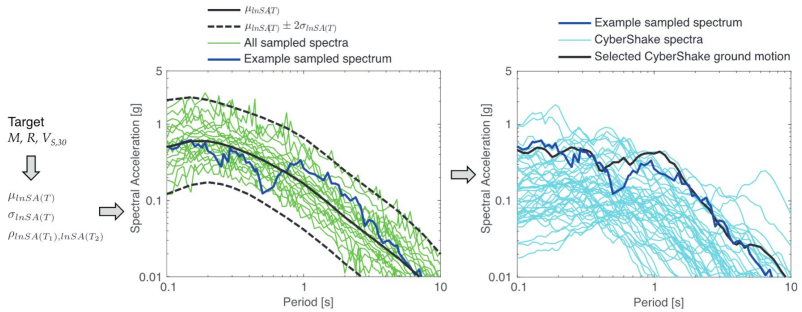


Figure 5. Schematic illustration of the ground-motion selection process. We first specify a target scenario and compute the means, standard deviations, and correlations of *lnSA* (left); we then sample response spectra from the resulting distribution (middle); finally, we compare each sampled response spectrum to the CyberShake spectra and select the closest match (right).

time series, metadata, spectra, documentation
https://doi.org/10.5281/zenodo.3922295

Jack W Baker, Sanaz Rezaeian, Christine A Goulet, Nicolas Luco, Ganyu Teng; A subset of CyberShake ground-motion time series for response-history analysis. Earthquake Spectra 2021; 37 (2): 1162–1176. doi: https://doi.org/10.1177/8755293020981970

Simulated GMs: Beyond California

SCEC Broadband Platform (BBP) simulated ground motions used to constrain a new GMM for Australia, including magnitude scaling, depth scaling, near-source saturation, and distance scaling

⭐ Simulations constraining a new GMM, supporting seismic hazard analysis and engineering design ground motions.

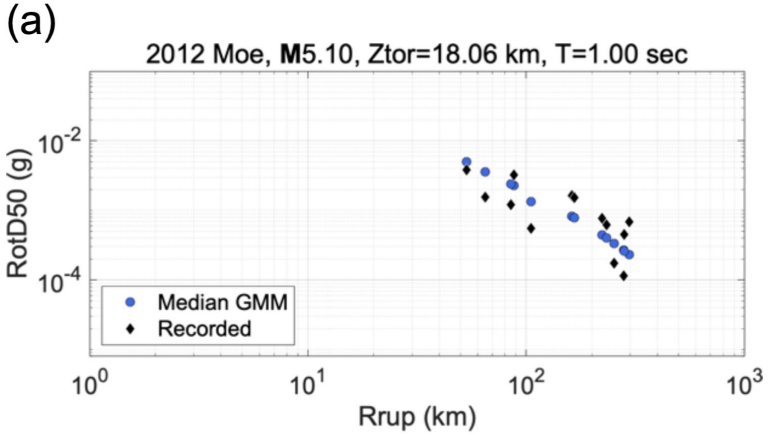


Figure 6. (a) Comparison between the model and data recorded in the 2012 Moe earthquake.

Bayless J. and P. Somerville (2024). An Updated Ground Motion Model for Australia Developed Using Broadband Ground Motion Simulations. Proc. of the 2024 Australian Earthquake Engineering Society National Conference. 21-23 November 2024, Adelaide, South Australia. https://www.jeff-bayless.com/wp-content/uploads/2024/10/2024-AEES-Paper.pdf

Simulated GMs Advancing Engineering Research

Moschetti 2024: GM simulations → **refine GMMs** → improve hazard assessment

Baker 2021: GM simulations → **curated GMs** → structural RHA

Bayless 2024: GM simulations → **constrain new GMM** → hazard & engineering app.

Simulation Benefits

- Large, near-fault earthquakes scenarios poorly represented in recordings
- Rupture directivity
- Basin effects

Different pathways to engineering adoption, same simulation benefits.

VALIDATION

Assess and use with confidence

GMSV Toolkit

Validation tools and metrics for simulations

SCEC GMSV Group Formed in 2011

Ground Motion Simulation Validation (GMSV) group established by SCEC in 2011 to:

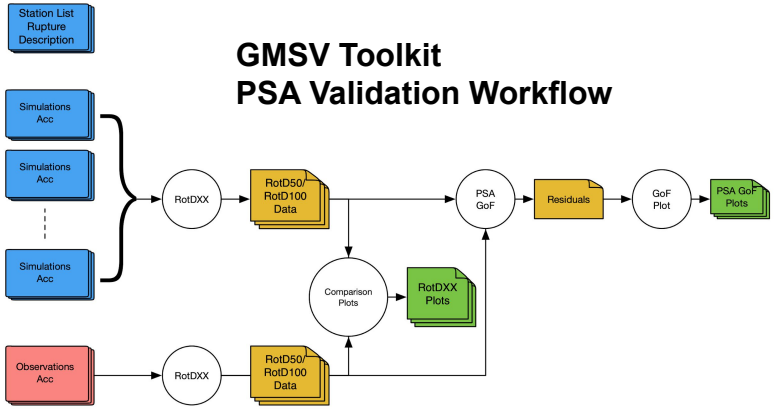
"develop and implement testing/rating methodologies via **collaboration between ground motion modelers and engineering users**."

⭐ **Validation is critical to adoption of ground motion simulations.**

https://southern.scec.org/workshops/2011/gmsv

GMSV Toolkit: Validation to Build Confidence

- standardized and verified tools for a "**broad seismological and engineering community** of researchers interested in ground motion simulations and their validation."
- See Poster 214 (Group B), Fabio Silva, et al. to learn more
- Validation provides **confidence for adoption and application**



Metrics Provided Include

- Arias Intensity and Arias Intensity Duration RotD50 PSA
- Fourier Amplitude Spectra (FAS)
- RZZ 2015 metrics
- GMM computations for RotD50 PSA (NGA-West 1 and NGA-West 2)

Silva, F., Goulet, C. A., Maechling, P. J., & Ben-Zion, Y. (2023, 09). The SCEC GMSV Toolkit: Open-Source Tools for Ground Motion Simulation Processing and Validation. Poster Presentation at 2023 SCEC Annual Meeting.

Hazard application → response spectra, M/R scaling, attenuation

RHA → spectral shape, duration, pulses, engineering-relevant metrics

Distributed risk → spatial correlation

Etc...

Validation Isn't Just One Thing

Validations should reflect the **characteristics that matter to the use case.**

GMSV: Lessons for Adoption of GM Simulations

Research Paper

EARTHQUAKE SPECTRA

Findings from a decade of ground motion simulation validation research and a path forward

Earthquake Spectra
2024, Vol. 40(1) 346–378

DOI: 10.1177/87552930231212475
journals.sagepub.com/home/eqs
Sage

Sanaz Rezaeian[1], Jonathan P Stewart, M.EERI[2],
Nicolas Luco, M.EERI[1], and Christine A Goulet, M.EERI[3]

User Needs

- Specific use cases
- Application-specific validation
- Easy access to datasets
- Guidance & documentation

Poster #239 (Group A)

SCEC GM-SVU TAG Co-PIs @ SCEC2026

Sanaz Rezaeian (USGS)

Buka Nweke (USC)

Scott Callaghan (USC)

Paths to Utilization

Moschetti et al. (2024) addressed a **specific hazard application** and translated simulation results into an existing GMM framework.

Baker et al. (2024) addressed **accessibility, curation and documentation**.

Bayless & Somerville (2024) addressed **validation tied to a specific application**.

User Needs

- Specific use cases
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CASE STUDY

Translate to engineering implementation

UGMS MCER Tool

From simulations to site-specific design spectra for the Los Angeles region

The Committee for the Utilization of Ground Motion Simulations

Use CyberShake ground motions to "develop long-period response spectral acceleration maps for inclusion in NEHRP and ASCE 7 Seismic Provisions and in Los Angeles City Building Code."

Convened by SCEC in 2013

UGMS Members

C. B. Crouse (Chair)
Norm Abrahamson
John Anderson
Bob Bachman
Jack Baker
Jacobo Bielak
Art Frankel
Josh Gebelein
Christine Goulet
Rob Graves
Ron Hamburger
Curt Haselton
John Hooper
Marty Hudson
Tom Jordan
Charlie Kircher
Marshall Lew
Nico Luco
Farzad Naeim
Paul Somerville

Structural Engineers
Ground Motion Modelers
Engineering Seismologists
Geotechnical Engineers
Seismologists
City & State Bldg Officials

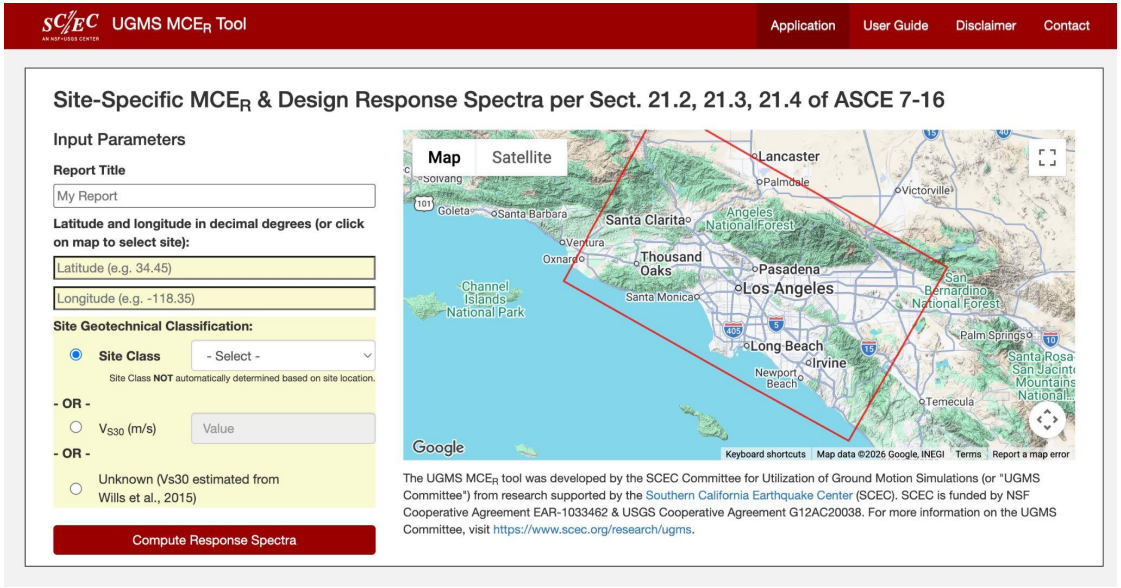
WORKING WITH

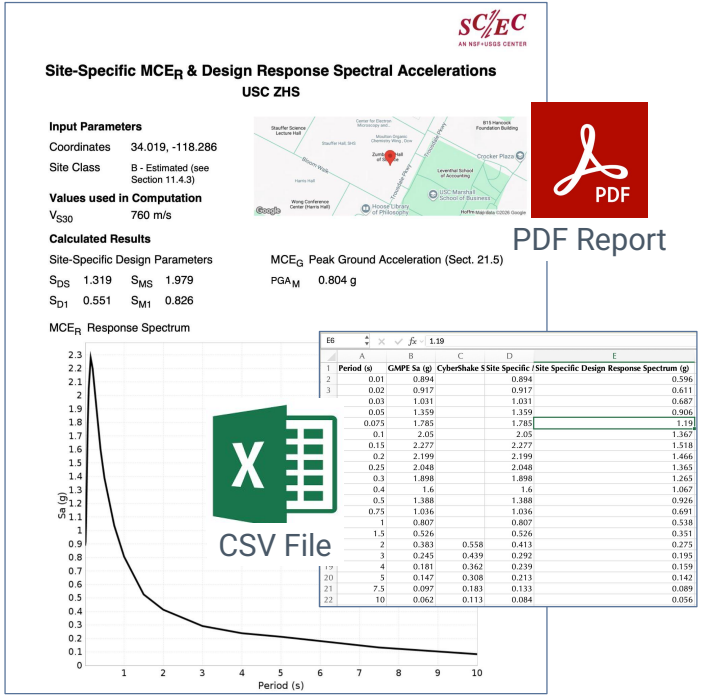
SCEC Researchers, Computer Scientists, & Software Engineers

SCEC Team

Scott Callaghan
David Gill
Phil Maechling
Xiaofeng Meng
Kevin Milner
Edric Pauk

UGMS Direct-to-Practice Tool



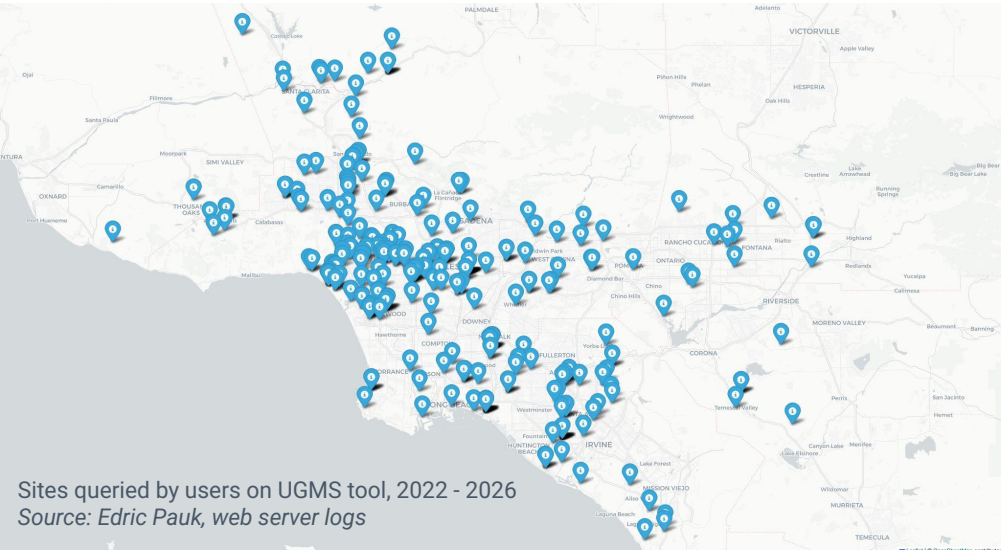


Released in 2018, the UGMS data access tool was designed with and for structural engineers.

Case Study: UGMS Project

User Needs	UGMS MCER Tool
Specific use case	Site-Specific MCER, design parameters per ASCE 7-16 for seismic design of tall buildings in LA
Application-specific validation	Collaborative stakeholder meetings created consensus methodology, curated dataset
Easy access to datasets	Site-specific data accessible via website, outputs plug into existing engineering workflows
Guidance & documentation	Documentation on website, including usage in practice guidelines

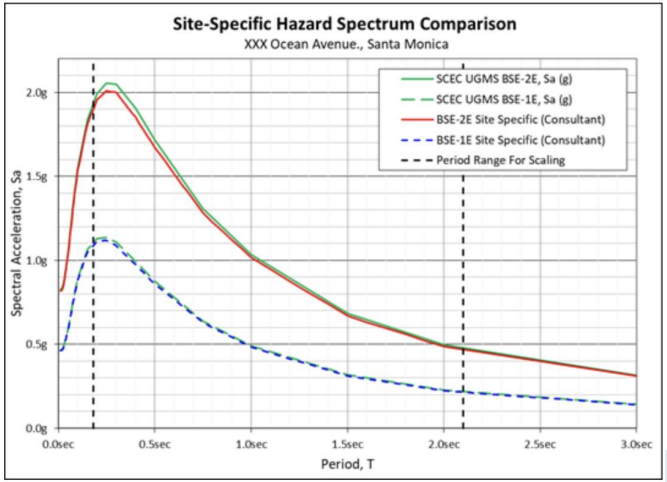
UGMS MCER Tool continues to support engineering practice.



Sites queried by users on UGMS tool, 2022 - 2026
Source: Edric Pauk, web server logs

1,000+ site reports generated (2022–2026).

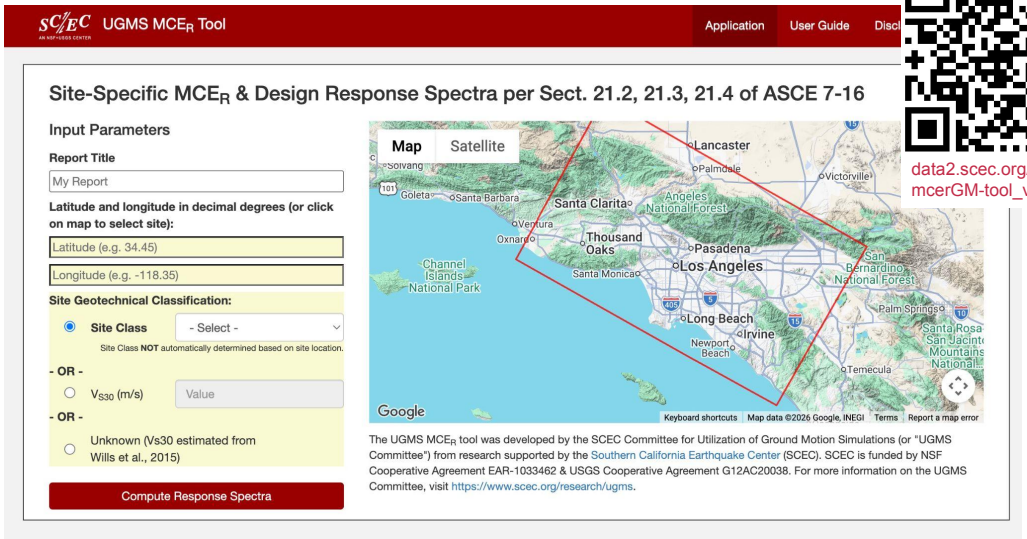
data2.scec.org/ugms-mcerGM-tool_v18.4



UGMS MCER tool outputs shown compared to site-specific hazard provided by a geotechnical consultant shows a consistent overlay.

Future Work

- Expanding geographical scope to northern California
- Support newer building standards
- Incorporate new data for RHA (Searchable 3D physics-based broadband ground motions)



data2.scec.org/ugms-mcerGM-tool_v18.4

Conclusion

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Produce simulated ground motions

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  Physics-based, 3D wave propagation simulations

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- **GMSV Toolkit**
  Validation tools and metrics for simulations

PRACTICE

Translate to engineering implementation

- **UGMS MCER Tool**
  From simulations to site-specific design spectra for the Los Angeles region

We need YOU, the SCEC community, to help build the capabilities and tools that accelerate adoption of ground motion simulations to bring **science to society**.