

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.

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

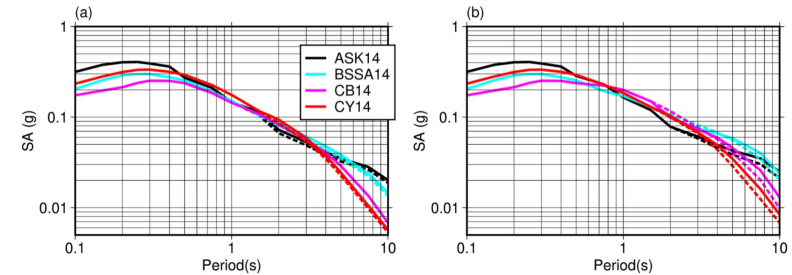


Figure 16. Comparison of median response spectra from the empirical GMMs (dashed lines) and CyberShake-adjusted GMMs (solid lines), for example, site conditions corresponding to (a) shallow basin depths, $Z_1 = 0.45$ km, $Z_{2.5} = 3$ km (i.e. $\delta Z_1 \approx 0$ km) and a (b) deeper basin site, $Z_1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

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.

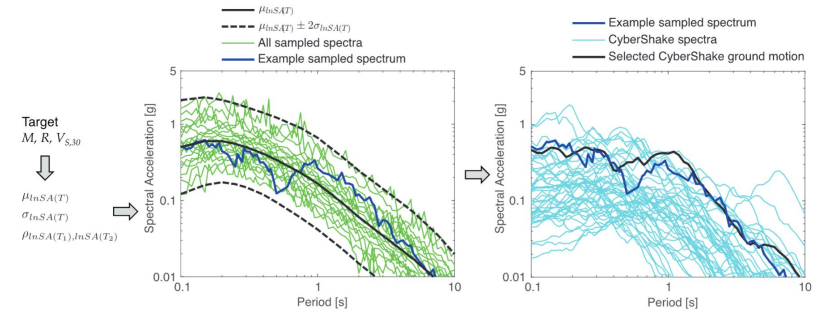


Figure 5. Schematic illustration of the ground-motion selection process. We first specify a target scenario and compute the means, standard deviations, and correlations of $\ln SA$ (left); we then sample response spectra from the resulting distribution (middle); finally, we compare each sampled response 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.

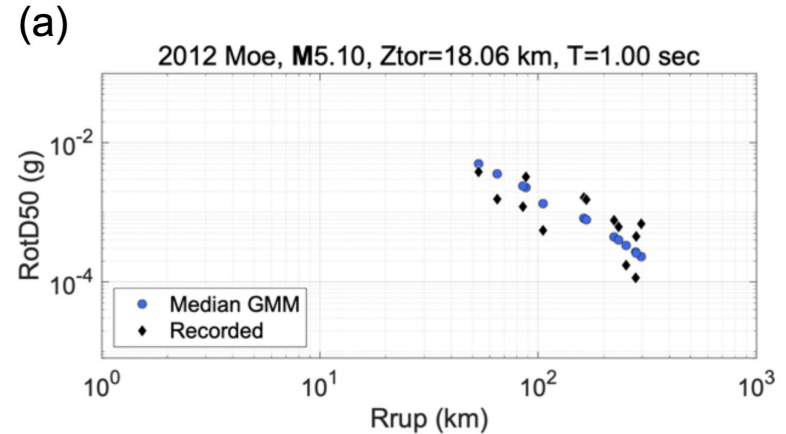


Figure 6. (a) Comparison between the model and data recorded in the 2012 Moe earthquake.

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.**

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 **Southern California Earthquake Center**
Studying earthquakes and their effects in California and beyond

AN NSF+USGS CENTER

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SCEC Community Workshop: SCEC Ground Motion Simulation Validation Workshop

Convener: Nico Luco, Paul Somerville
Dates: January 10, 2011 (10am-5:30pm)
Location: SCEC Boardroom, University of Southern California

SUMMARY: SCEC is establishing a Technical Activity Group (TAG) focused on Ground Motion Simulation Validation (GMSV) in order to develop and implement testing/rating methodologies via collaboration between ground motion modelers and engineering users. The main purpose of the planning workshop will be to enumerate and prioritize work that should be conducted within the GMSV TAG. SCEC will only be able to fund relatively few projects per year that contribute to the GMSV TAG, so prioritization is particularly important. General ideas for work that could be conducted within the GMSV TAG include:

- Research on important ground motion or structural (e.g., building) response parameters and statistics that should be used in comparing simulated versus recorded seismograms.
- Comparisons of simulated ground motions with empirical ground motion prediction equations, in terms of both median predictions and the variability about them. Note that simulations for the [CyberShake Project](#) aim to accurately represent both the median and variability of ground motions.
- Compilation of representative nonlinear structural models of different types for which the responses to simulated versus recorded seismograms can be compared.
- Comprehensive analysis and documentation of the sensitivity of simulated ground motions to model input parameters and their interactions and uncertainties.
- Development of testing and/or rating metrics for simulated ground motions, perhaps considering testing concepts from the [Collaboratory for the Study of](#)

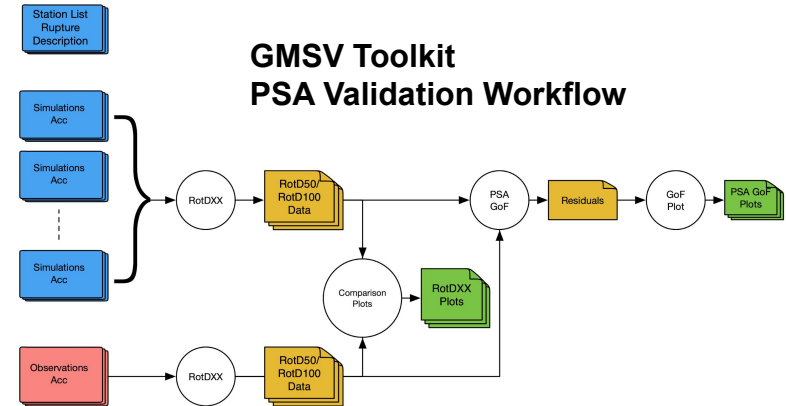
<https://southern.scec.org/workshops/2011/gmsv>



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**

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.



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)

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

EE **EARTHQUAKE**
RI **SPECTRA**

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

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

Sanaz Rezaeian¹ , Jonathan P Stewart, M.EERI² ,
Nicolas Luco, M.EERI¹, and Christine A Goulet, M.EERI³

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

Application-specific validation

Easy access to datasets

Guidance & documentation

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
Jacob 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



Site-Specific MCE_R & Design Response Spectral Accelerations

USC ZHS

Input Parameters

Coordinates 34.019, -118.286

Site Class B - Estimated (see Section 11.4.3)

Values used in Computation

V_{S30} 760 m/s

Calculated Results

Site-Specific Design Parameters

S_{DS} 1.319 S_{MS} 1.979

S_{D1} 0.551 S_{M1} 0.826

MCE_R Response Spectrum



MCE_R Peak Ground Acceleration (Sect. 21.5)

PGA_M 0.804 g



PDF Report



CSV File

		A	B	C	D	E
		f _r : 1.19				
1	Period (s)	GMPE Sa (g)	CyberShake Site Specific	Site Specific Design Response Spectrum (g)		
2	0.01	0.894		0.894		0.596
3	0.02	0.917		0.917		0.611
	0.03	1.031		1.031		0.687
	0.05	1.359		1.359		0.906
	0.075	1.765		1.765		1.150
	0.1	2.05		2.05		1.367
	0.15	2.277		2.277		1.518
	0.2	2.199		2.199		1.466
	0.25	2.048		2.048		1.365
	0.3	1.898		1.898		1.265
	0.4	1.6		1.6		1.067
	0.5	1.388		1.388		0.926
	0.75	1.036		1.036		0.691
	1	0.807		0.807		0.538
	1.5	0.526		0.526		0.351
	2	0.383	0.558	0.413		0.275
	3	0.245	0.439	0.292		0.195
	4	0.181	0.362	0.239		0.139
	5	0.147	0.308	0.213		0.142
	7.5	0.097	0.183	0.133		0.089
	10	0.062	0.113	0.084		0.056

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



Case Study: UGMS Project

User Needs

Specific use case



Application-specific validation



Easy access to datasets



Guidance & documentation



UGMS MCER Tool

Site-Specific MCER, design parameters per ASCE 7-16 for seismic design of tall buildings in LA

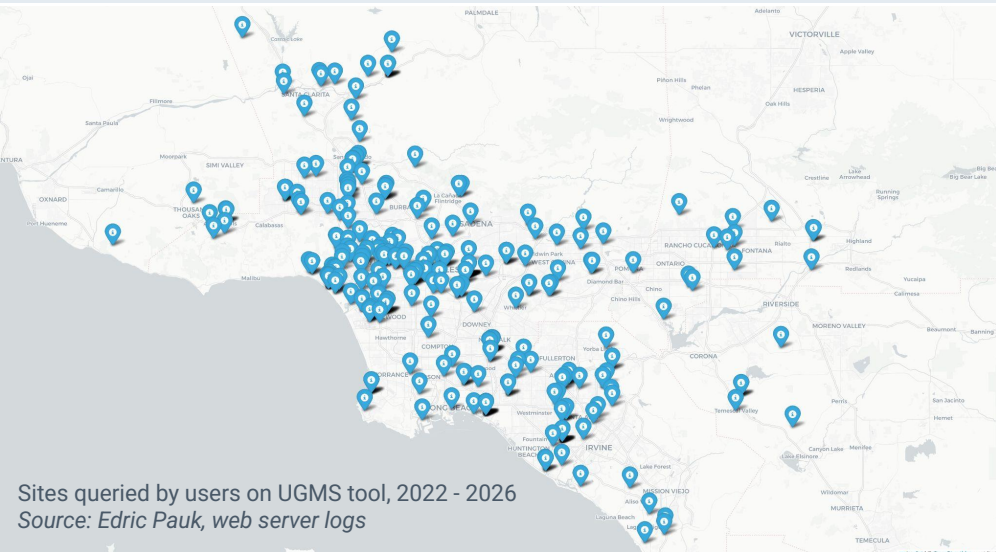
Collaborative stakeholder meetings created consensus methodology, curated dataset

Site-specific data accessible via website, outputs plug into existing engineering workflows

Documentation on website, including usage in practice guidelines



UGMS MCER Tool continues to support engineering practice.



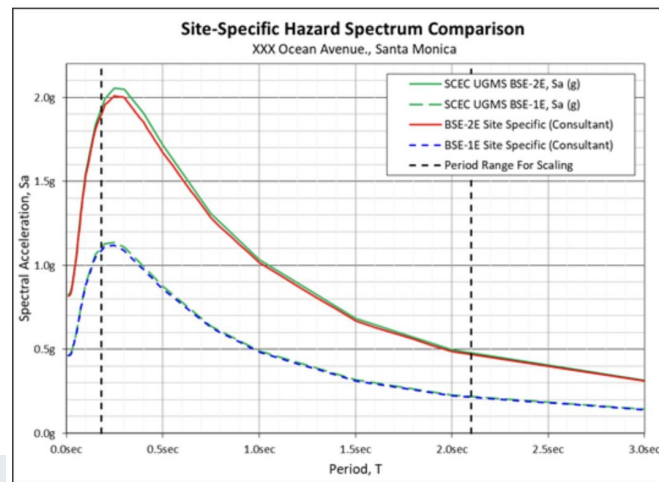
Sites queried by users on UGMS tool, 2022 - 2026
Source: Edric Pauk, web server logs

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

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

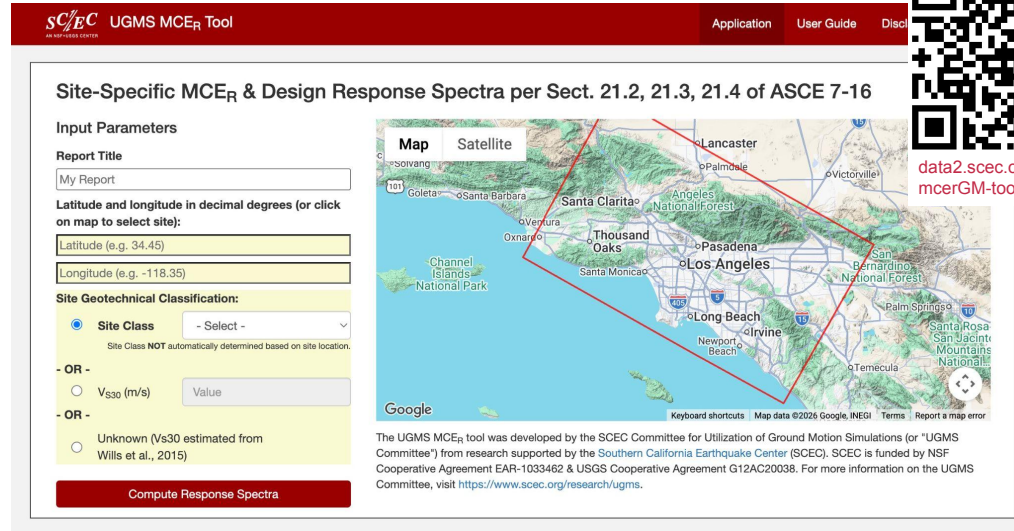


data2.scec.org/ugms-mcerGM-tool_v18.4



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

The UGMS MCE_R tool was developed by the SCEC Committee for Utilization of Ground Motion Simulations (or "UGMS Committee") from research supported by the Southern California Earthquake Center (SCEC). SCEC is funded by NSF Cooperative Agreement EAR-1033462 & USGS Cooperative Agreement G12AC20038. For more information on the UGMS Committee, visit <https://www.scec.org/research/ugms>.



Conclusion

SIMULATIONS

Produce simulated ground motions

Broadband Platform (BBP)

Stochastic, broadband simulations

CyberShake

Physics-based, 3D wave propagation simulations

VALIDATION

Assess and use with confidence

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PRACTICE

Translate to engineering implementation

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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.**