

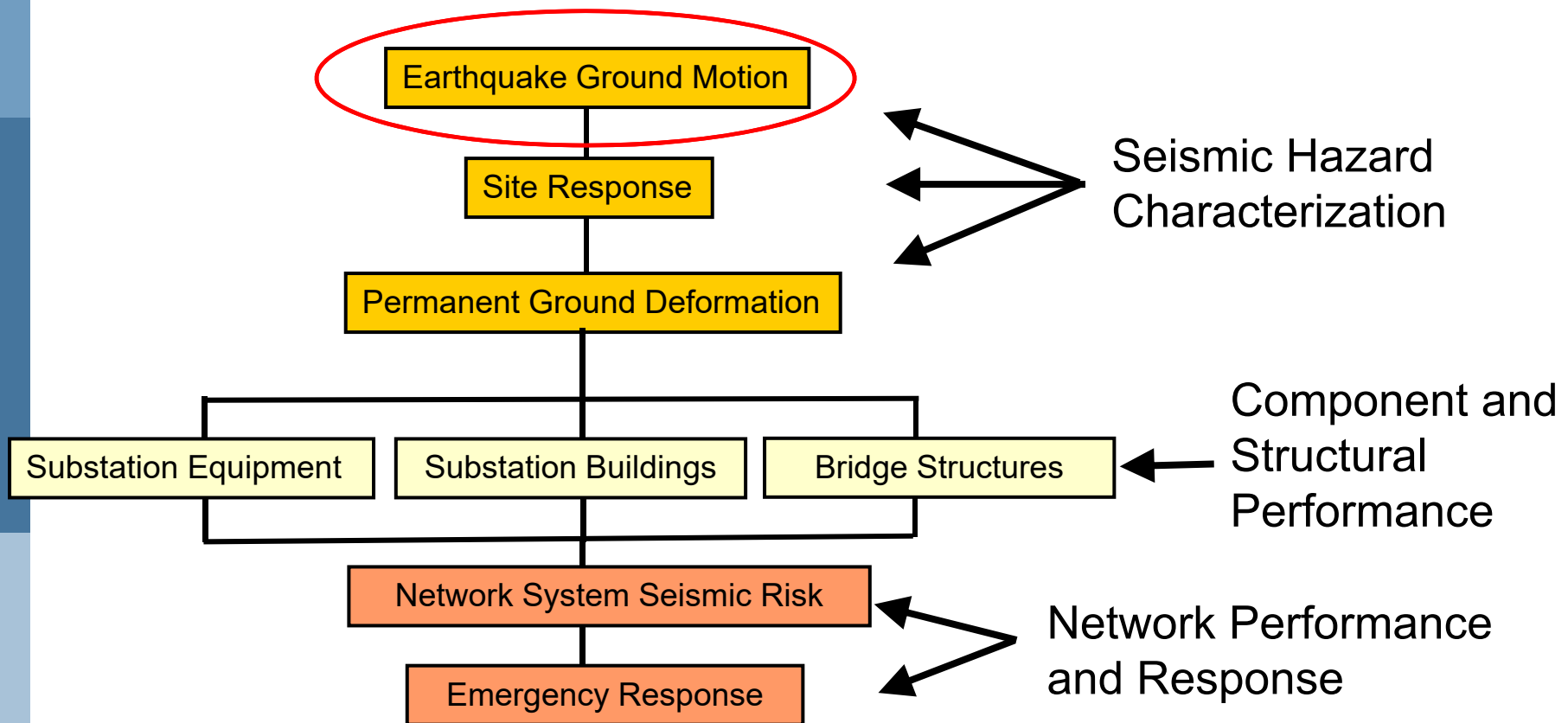
NGA Projects



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University of California, Berkeley

PEER Lifelines Program



Long-term partners: PG&E and Caltrans

Other partners: NRC, DOE, EPRI, CEA, CEC, Southern Cal Edison, FM Global, Swissnuclear, BC Hydro, USGS,...

Ground Motion Hazard: Next Generation Attenuation Projects (NGAs)



NGA Models

- **Models to scale ground shaking** with respect to fundamental parameters such as earthquake **magnitude**, **site-to-source distance**, **local soil condition**,...
- For any seismic design or evaluation you need such scaling models
- They are heavily used in Probabilistic Seismic Hazard Analysis (PSHA)
- And in National Seismic Hazard maps that are basic data for seismic design

NGA projects

- Three separate NGA projects have been coordinated by Pacific Earthquake Engineering Research Center (**PEER**):
 - For **active crustal** EQs (like California, Japan, Turkey, Taiwan,...): **NGA-West**
 - **Stable continental** regions (like central & eastern US, a good portion of Europe, South Africa,...): **NGA-East**
 - For **subduction** EQs (like Pacific Northwest and northern California, Japan, Chile, Peru,...): **NGA-Sub**

NGA projects

- Three separate NGA projects coordinated by Pacific Earthquake Engineering Research Center (PEER):

- For **crustal** EQs (like California, Japan, Turkey, Taiwan,...): **NGA-West**

- **Stable continental** EQs (like central & eastern US, a portion of Europe, South Africa,...): **NGA-East**

- For **subduction** EQs (like Pacific Northwest and northern California, Japan, Chile, Peru,...): **NGA-Sub**

In all NGA projects...

- We develop databases of **empirical and simulated** ground motion data
- Databases are public
 - Researchers and practitioners use databases continuously
- Highly **collaborative and teamwork** research among researchers and practitioners

NGA-Subduction



NGA-Subduction

- The focus so far has been on development of the database
- This is an international project in collaboration among:
 - US, Japan, Taiwan, Chile,...
- Funded by:
 - FM Global
 - USGS
 - Caltrans

NGA-Subduction database

Region	# of Recordings 3-comp each	# of Recordings M > 7	# of Events	# of Events, M > 7
Japan	31,699	10,564	96	28
Taiwan	10,713	409	74	1
South America	1,777	353	310	28
Pacific Northwest	1,645	17	20	2
Alaska	16,728	408	588	5
Total	96,018	11,751	1,088	64

Database includes 96,018 3-component recordings
288,054 records
By a factor of 4.5 larger than NGA-West2 database



NGA-Sub plan

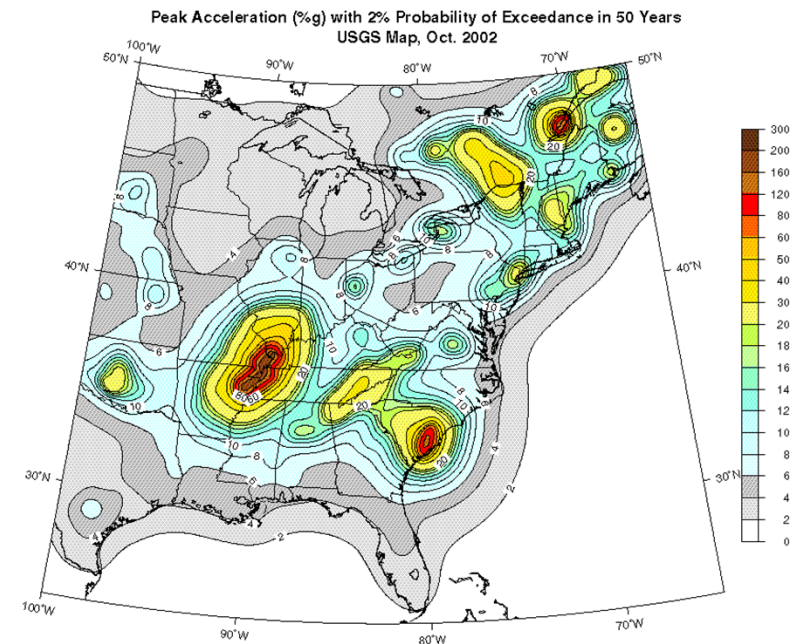
- To develop models for Japan and Taiwan
 - We have over 90,000 records from Japan
 - > 30,000 records from Taiwan
- Then generalize the models for other regions and worldwide
- NGA-Sub will be completed by mid 2017

NGA-East

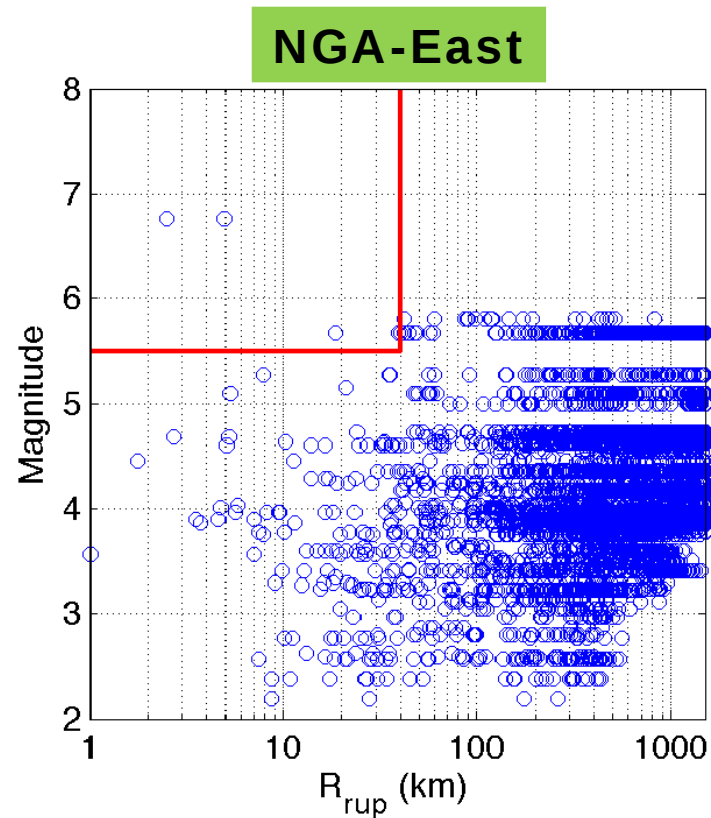


NGA-East

- Goal: To develop next generation Ground Motion Prediction Equations (GMMs) for Central & Eastern US
- Sponsors: **NRC, DOE, EPRI, USGS**
- Evaluation of 100 nuclear power plants in the US will be based on this project



NGA-East empirical database



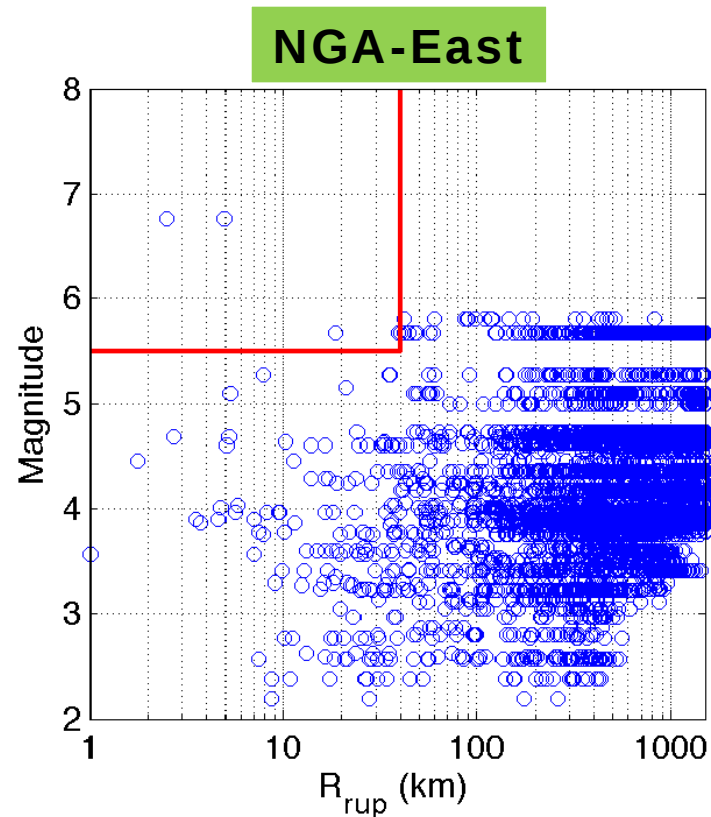
Central & Eastern North America

Courtesy: Goulet

NGA-East empirical database

Over 10,000 records

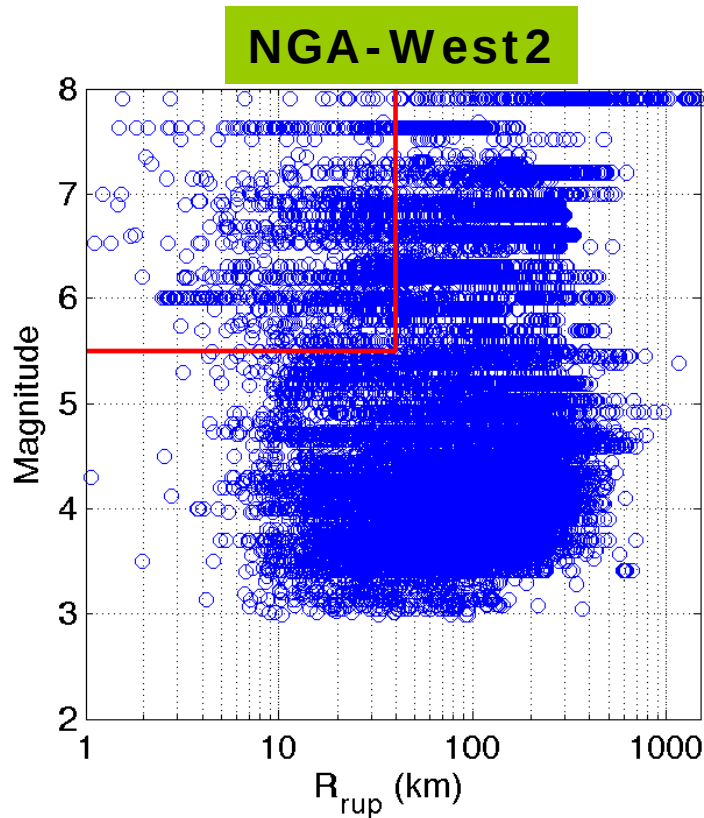
The database is available
online: both response
spectra and time series



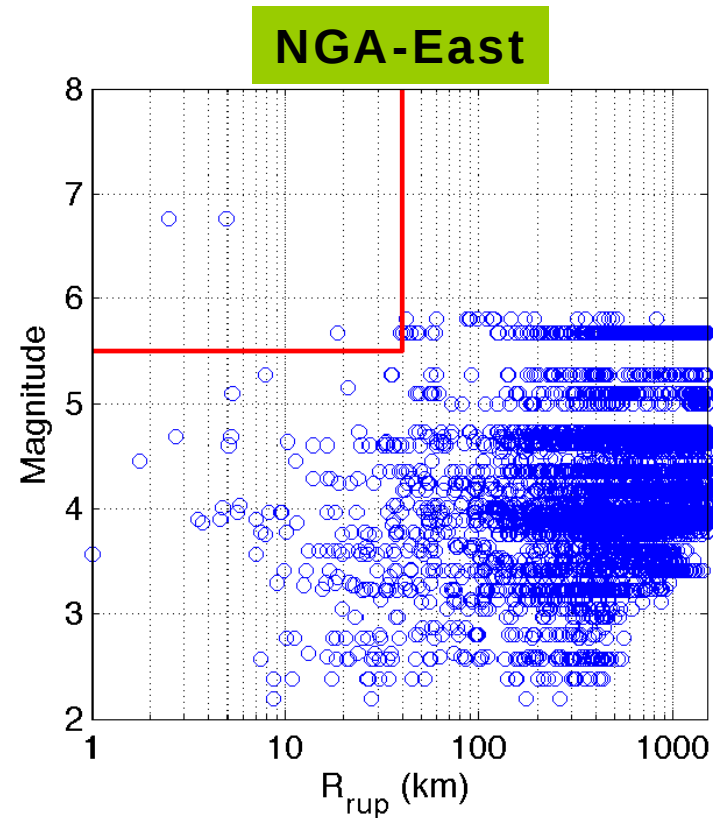
Central & Eastern North America

Courtesy: Goulet

NGA-East empirical database



Crustal EQs in
Active Tectonic Regions



Central & Eastern North America

Courtesy: Goulet

NGA-East ground motion models

- Empirical data are not sufficient to develop ground motion models
- Most models are heavily based on simulations
 - Point-source simulations
 - Finite-source simulations for magnitude scaling

NGA-East ground motion models

- 18 new models were developed by various teams
- These models were used as “**seed**” models to general a “**model space**”
- 29 models were then selected from the model space

Approach	Constraints	Extrapolation	Chapter Number, Title (Authorship)
Traditional Point-Source (PS) Stochastic (FAS-based)	PS model, published sets of empirical attenuation models, NGA-East database	PS model	2. Point-Source Stochastic-Method Simulations of Ground Motions for the PEER NGA-East Project (D.M. Boore)
	PS model, broadband inversion of NGA-East database	PS model	3. Development of Hard Rock Ground-Motion Models for Region 2 of Central and Eastern North America (R.B. Darragh, N.A. Abrahamson, W.J. Silva, and N. Gregor)
Regionally-Adjustable Generic GMM based on Point-Source model (PS Referenced Empirical)	PS model used to develop generic GMM, parameters defined from data-rich host region, adjustments using NGA-East database	Generic GMM adjusted to CENA data	4. Regionally-Adjustable Generic Ground-Motion Prediction Equation based on Equivalent Point-Source Simulations: Application to Central and Eastern North America (E. Yener and G.M. Atkinson)
Hybrid Empirical (FAS- and PSA-based)	Published sets of CENA and WUS PS models	GMM host region (WUS)	5. Ground-Motion Prediction Equations for Eastern North America using a Hybrid Empirical Method (S. Pezeshk, A. Zandieh, K.W. Campbell, and B. Tavakoli)
Finite-Fault (FF) Simulations (PSA-based)	FF model, NGA-East database	FF model	6. Ground-Motion Predictions for Eastern North American Earthquakes Using Hybrid Broadband Seismograms from Finite-Fault Simulations with Constant Stress-Drop Scaling (A. Frankel)
			7. Hybrid Empirical Ground-Motion Model for Central and Eastern North America using Hybrid Broadband Simulations and NGA-West2 GMPEs (A. Shahjouei and S. Pezeshk)
Traditional Empirical (PSA-based)	NGA-East database	Intensity	8. Empirical Ground Motion Prediction Equations for Eastern North America (M.N. Al Noman and C.H. Cramer)
		Imposed spectral shape	9. Ground-Motion Prediction Equations for the Central and Eastern United States (V. Graizer)
Referenced Empirical (PSA-based)	NGA-East database	GMM host region (WUS)	10. Referenced Empirical Ground-Motion Model for Eastern North America (B. Hassani and G.M. Atkinson)
FAS-RVT-PSA Empirical (require FAS and duration models)	NGA-East database	PS and FF models for scaling, Global GMs for extrapolation of duration model	11. PEER NGA-East Median Ground-Motion Models (J. Hollenbeck, N. Kuehn, C.A. Goulet and N.A. Abrahamson)

Several PEER reports have already been published



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Reference-Rock Site Conditions for Central and Eastern North America:

Part I – Velocity Definition

Developed by

NGA-East Geotechnical Working Group

Youssef M.A. Hashash, Albert R. Kottke, Jonathan P. Stewart,
Kenneth W. Campbell, Byungmin Kim, Ellen M. Rathje,
and Walter J. Silva

In Collaboration with:

Sissy Nikolau and Cheryl Moss

PEER 2014/11
AUGUST 2014



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Reference-Rock Site Conditions for Central and Eastern North America:

Part II – Attenuation (Kappa) Definition

Developed by

NGA-East Geotechnical Working Group

Kenneth W. Campbell
and

Youssef M.A. Hashash, Byungmin Kim, Albert R. Kottke,
Ellen M. Rathje, Walter J. Silva, and Jonathan P. Stewart

Under the Auspices of the
Pacific Earthquake Engineering Research Center

PEER 2014/12
AUGUST 2014



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Scaling Relations between Seismic Moment and Rupture Area of Earthquakes in Stable Continental Regions

Paul Somerville
URS Corporation

Report to the Pacific Earthquake Engineering Research Center

NGA-East Project

PEER 2014/14
AUGUST 2014



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

NGA-East Regionalization Report: Comparison of Four Crustal Regions within Central and Eastern North America using Waveform Modeling and 5%-Damped Pseudo-Spectral Acceleration Response

Jennifer Drelling
Marius P. Iakei
Walter D. Mooney

U.S. Geological Survey
Menlo Park, California

Martin C. Chapman
Richard W. Godbee

Department of Geosciences
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

PEER 2014/15
OCTOBER 2014



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

PEER NGA-East Database

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AMEC Environment and Infrastructure
Oakland, California

PEER 2014/17
OCTOBER 2014



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

NGA-East: Median Ground-Motion Models for the Central and Eastern North America Region

PEER Report No. 2015/04
Pacific Earthquake Engineering Research Center
Headquarters at the University of California, Berkeley

April 2015

PEER 2015/04
APRIL 2015



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

NGA-East: Ground-Motion Standard Deviation Models for Central and Eastern North America

Linda Al Atik
Linda Alatik Consulting
San Francisco, California

PEER Report No. 2015/07
Pacific Earthquake Engineering Research Center
Headquarters at the University of California, Berkeley

June 2015

PEER 2015/07
JUNE 2015



PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

NGA-East: Adjustments to Median Ground-Motion Models for Central and North America

NGA-East status

- Technical tasks have all been completed
- Documentation and regulatory reviews are on-going
- Expected to finish by April 2016
- The PEER final (synthesis) report will be published by NRC as a NUREG report
- Overall, about 55 people have worked on various pieces of this project

NGA-West Projects

Shallow Crustal Earthquakes

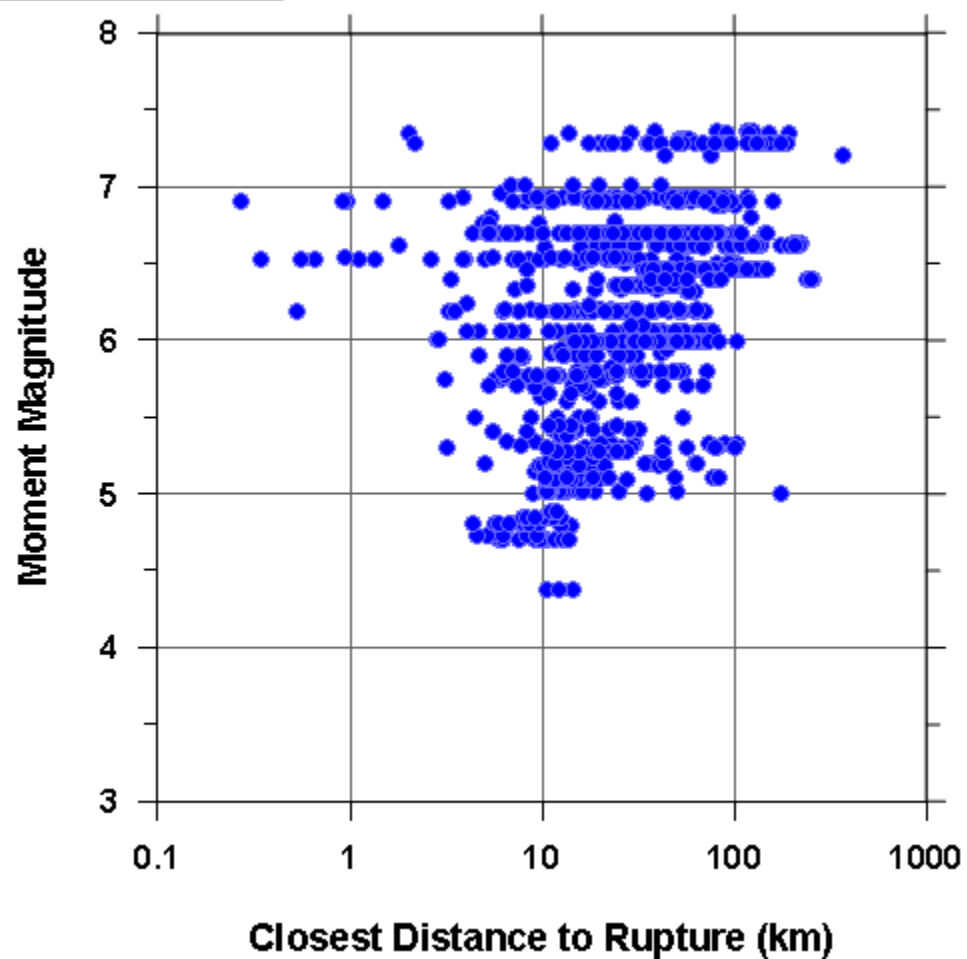


NGA-West1

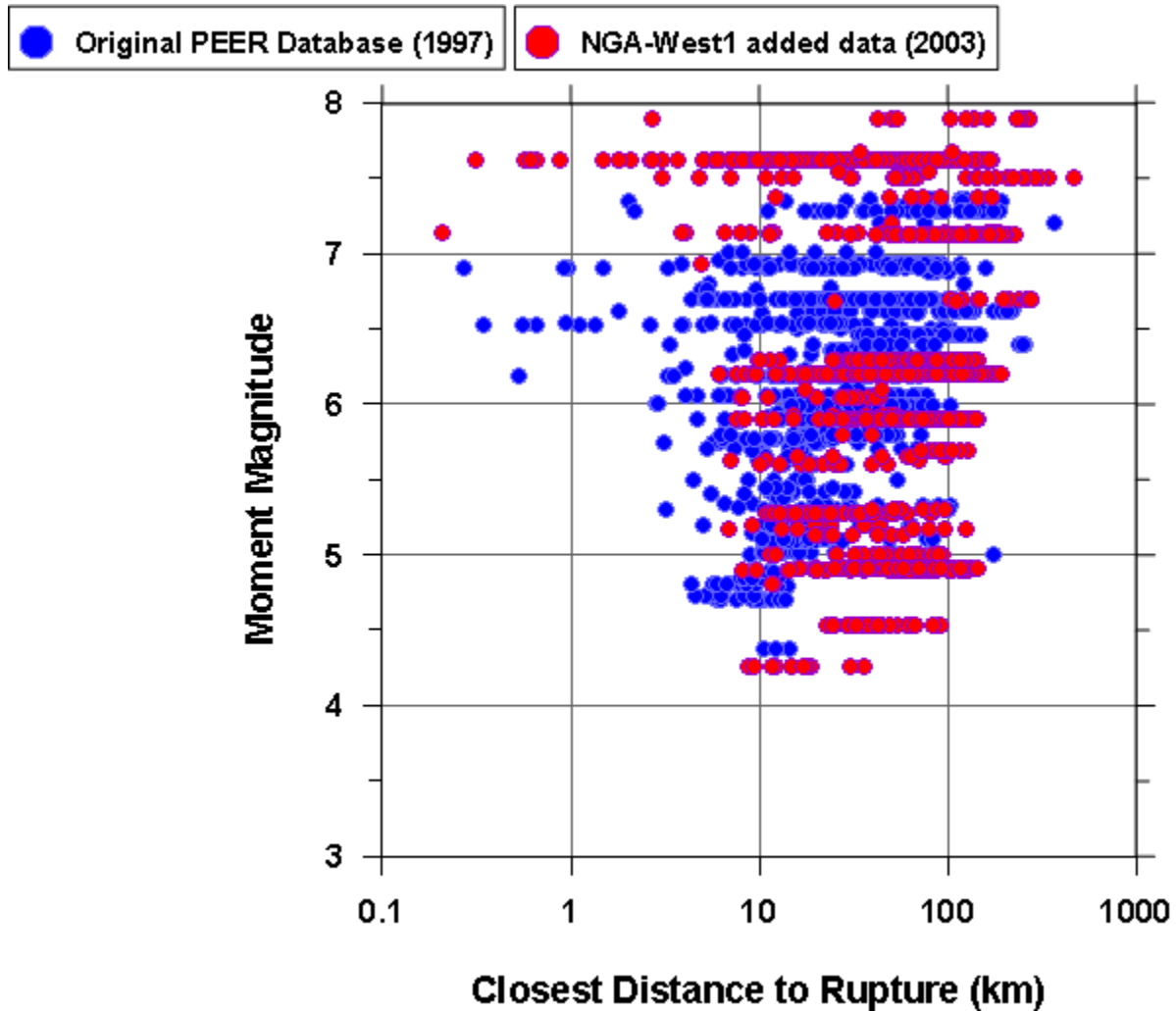
- Initiated October 2003
- In 2008, NGA ground motion models (**GMMs**) were finalized
- USGS adopted the NGA-West1 GMMs for the US National Seismic Hazard Maps
- **NGA-West2 was a follow-up of NGA-West1**
- Funded by Caltrans, PG&E, and CEA

Update worldwide database

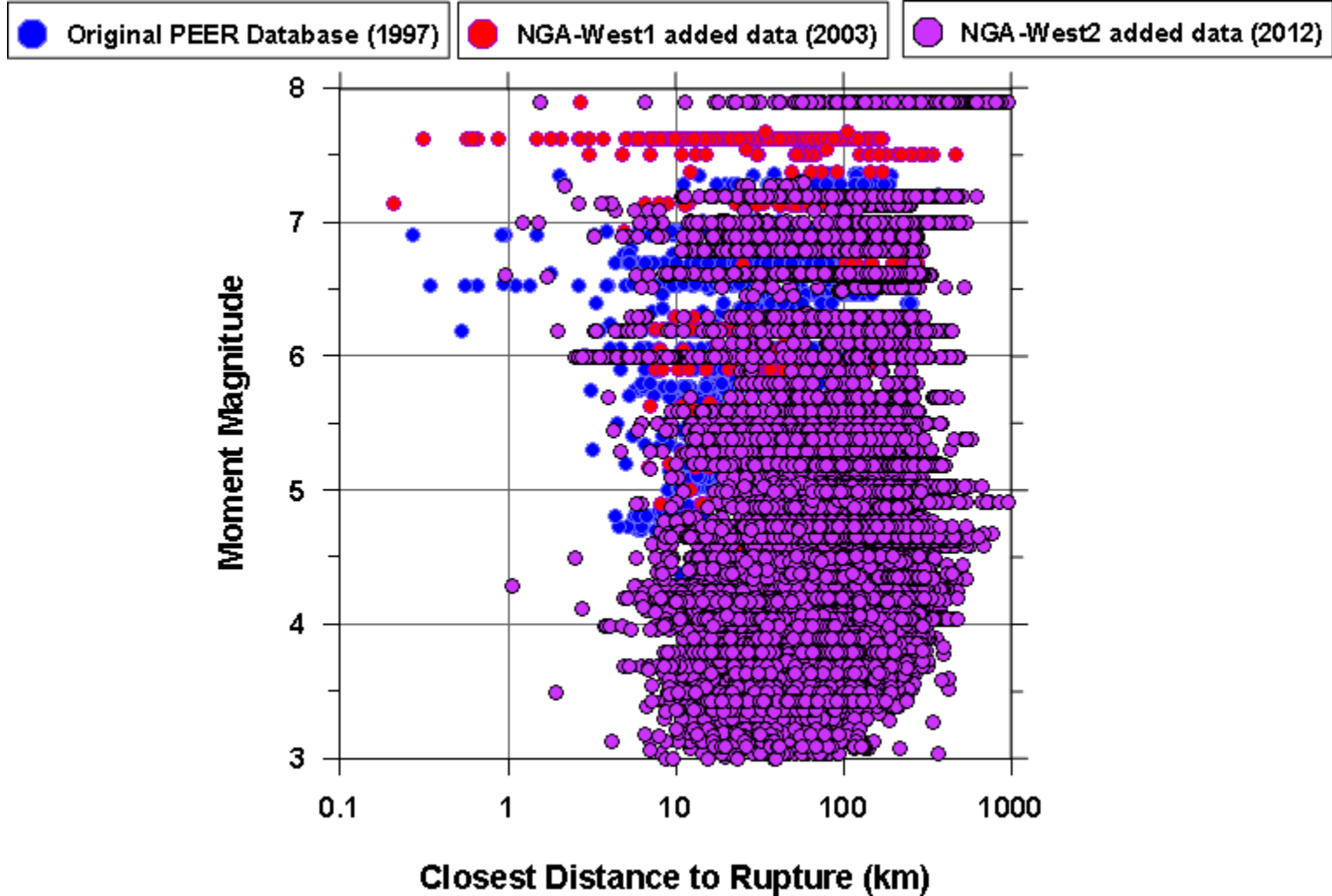
● Original PEER Database (1997)



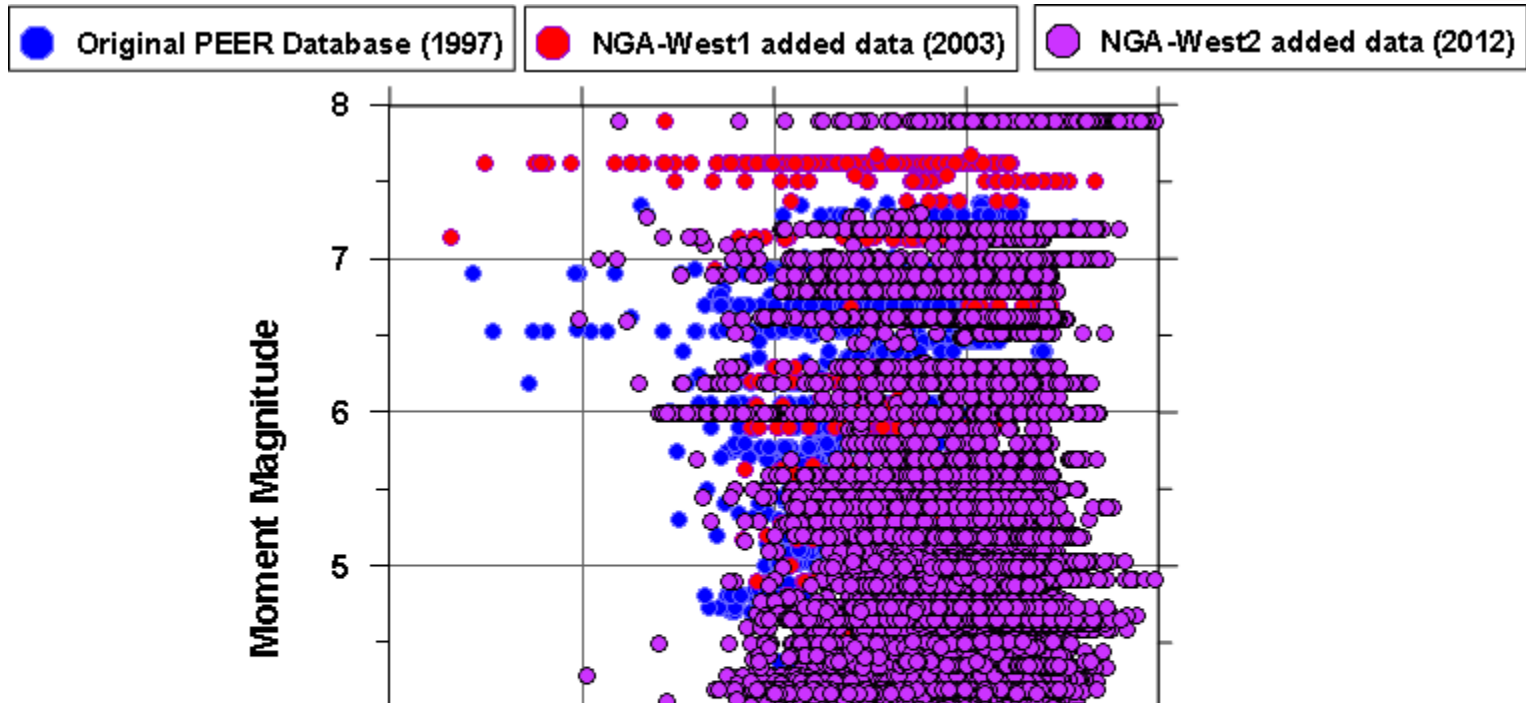
Update worldwide database



Update worldwide database



Update worldwide database



NGA-West2 database includes over 21,000 three-component recordings... (over 63,000 records)

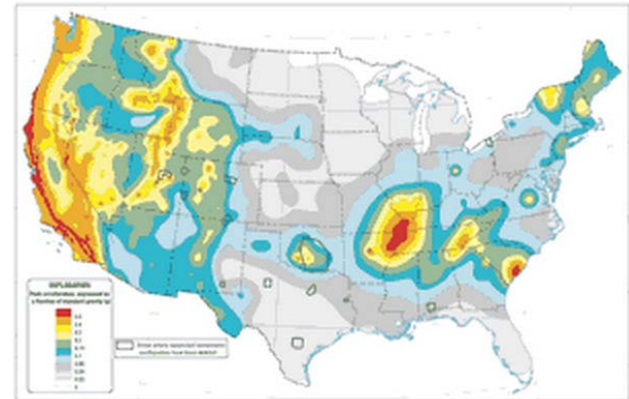
From NGA-West1 to NGA-West2 the size of database was increased by a factor of 6

Public availability of NGA-West2 database

- All spectra have already been posted for the public
- Actual time series (“time-histories”) are available for download through PEER on-line ground motion database:
 - <http://ngawest2.berkeley.edu/>
- The web site tool has been in service for more than a year now
- To date, the site has **14,239 users**
- With a total of **1,565,824 downloads**

Status of NGA-West2 models for horizontal motions

- Completed in 2014
- USGS adopted the five models for development of the US National Seismic Hazard Maps



- Seismic design and evaluation of all civil engineering facilities in the western US are affected by this project, like its 2008 version

NGA-West2 other research projects have also been successful

- Ground motion models for vertical component have been developed
- NEHRP soil classifications in the building code are being redefined by NGA-West2 site response study
- Definition of “aftershocks” has been updated since decades ago for the purpose of hazard analysis
- ...

Intellectual impact of NGA-West project

- NGA publications have been heavily cited
- For example, some NGA papers have been cited over 700 times since 2008

NGA ground motion model for the geometric mean horizontal component of PGA, PGV, PGD and 5% damped linear elastic response spectra for periods ranging from ...

KW Campbell, Y **Bozorgnia** - Earthquake Spectra, 2008 - earthquakespectra.org

Abstract We present a new empirical ground motion model for PGA, PGV, PGD and 5% damped linear elastic response spectra for periods ranging from 0.01–10 s. The model was developed as part of the PEER Next Generation Attenuation (NGA) project. We used a ...

Cited by 723 Related articles All 18 versions Cite Save

Ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods between 0.01 s and 10.0 s

DM **Boore**, GM Atkinson - Earthquake Spectra, 2008 - earthquakespectra.org

Abstract This paper contains ground-motion prediction equations (GMPEs) for average horizontal-component ground motions as a function of earthquake magnitude, distance from source to site, local average shear-wave velocity, and fault type. Our equations are for ...

Cited by 934 Related articles All 11 versions Cite Save

Plan for the future of **NGAs**

- **NGA-Sub** is on-going (until May 2017)
- **NGA-East** is being completed
 - Numerous publications will be prepared
 - A set of national seminars will be organized to present final findings
- **NGA-West3** is being planned
 - For 2018-2019 update of ground motions
 - Database will be updated
 - New methodology to characterize ground motion hazard is being developed
 - Effects of “hard rock”, “soft soil”, topographic, aftershocks, inelastic response,...will be investigated
 - ...

Thank You!



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