Recent progress in seismic hazard analysis and ground motion selection

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Stanford University

PEER Annual Meeting – September 30, 2011

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Introduction

- PEER has produced a variety of tools to aid in seismic hazard analysis and ground motion selection

- Today I will highlight three recent efforts
  - PEER Ground Motion Database
  - PEER Transportation Systems Research Program ground motions
  - Engineering validation of ground motion simulation

PEER Ground Motion Database

http://peer.berkeley.edu/peer_ground_motion_database

PEER Ground Motion Database
Pacific Earthquake Engineering Research Center
BETA

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Welcome to the PEER Ground Motion Database

For Shallow Crustal Earthquakes in Active Tectonic Regimes

The Pacific Earthquake Engineering Research Center (PEER) ground motion database includes a very large set of ground motions recorded in worldwide shallow crustal earthquakes in active tectonic regimes. The database has one of the most comprehensive sets of meta-data, including different distance measure, various site characterizations, earthquake source data, etc. The current version of the database is similar to the NGA (Next Generation Attenuation) database, which was used to develop the 2008 NGA ground motion prediction equations.

The Beta version of the web-based PEER ground motion database provides tools for searching, selecting and downloading ground motion data. The database and web-site are periodically updated and expanded. Comments on the features of this web site are gratefully welcome; please send emails to: peer_center@berkeley.edu

Interactive web application based on DGML Ver. 2.0 software package

w/ funding from

PEER Caltrans CGS CALIFORNIA GEOLOGICAL SURVEY

w/ thanks to

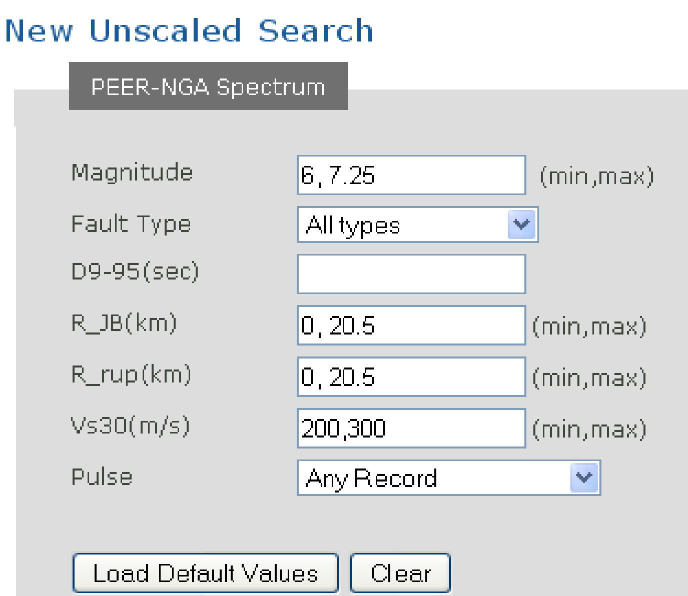
amec Geomatrix

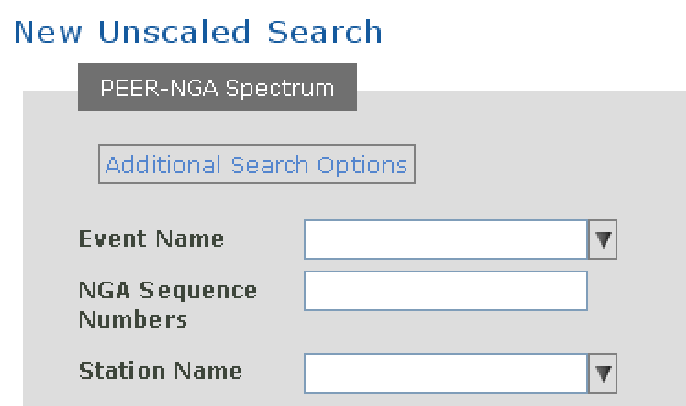
Slides courtesy Camila Coria and Carola Di Alessandro

Search for unscaled ground motions

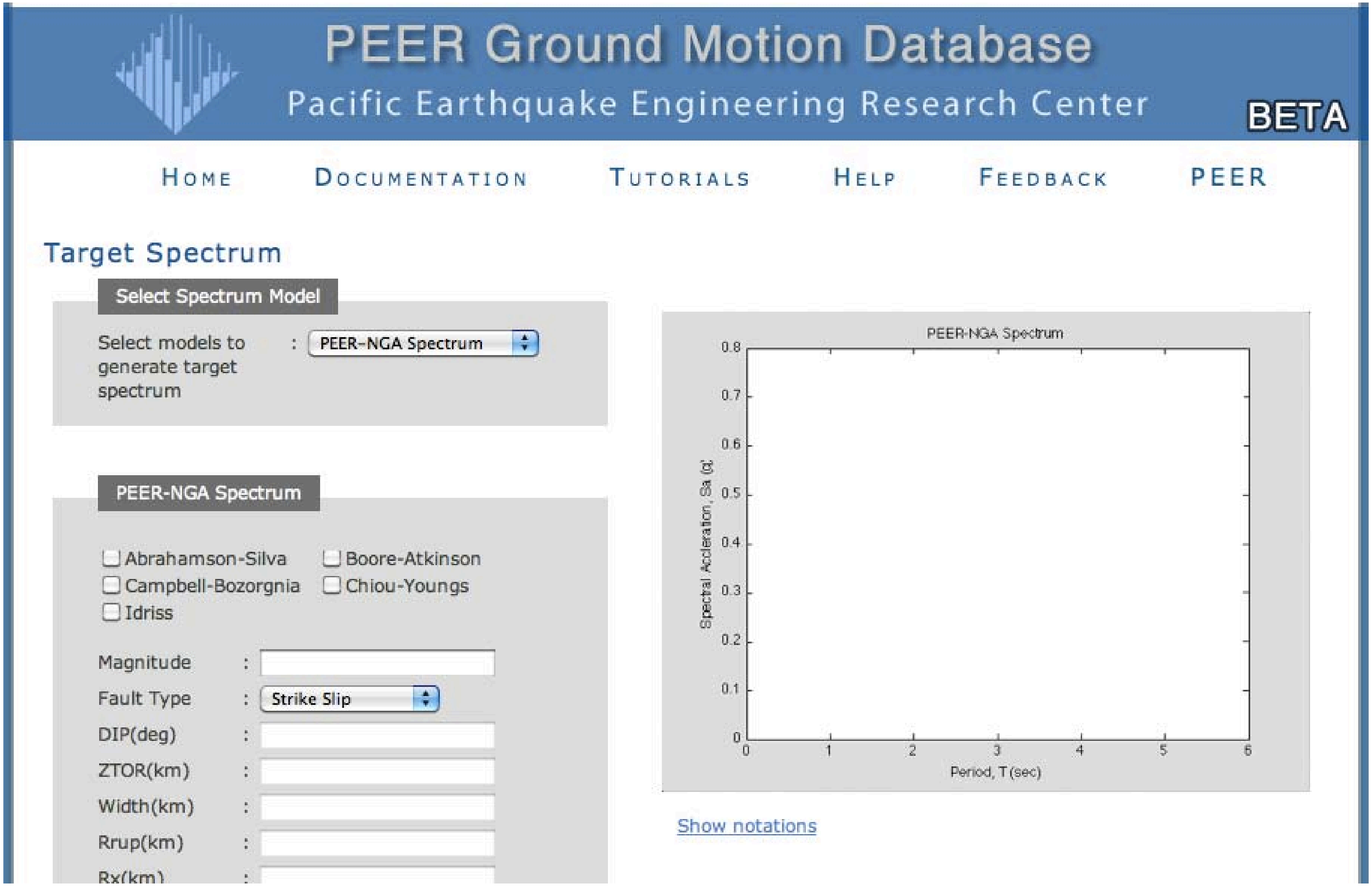
Search by

- Earthquake parameters
- Event name / Station Name / Ground Motion Number





Search for scaled ground motions



Slides courtesy Camila Coria and Carola Di Alessandro

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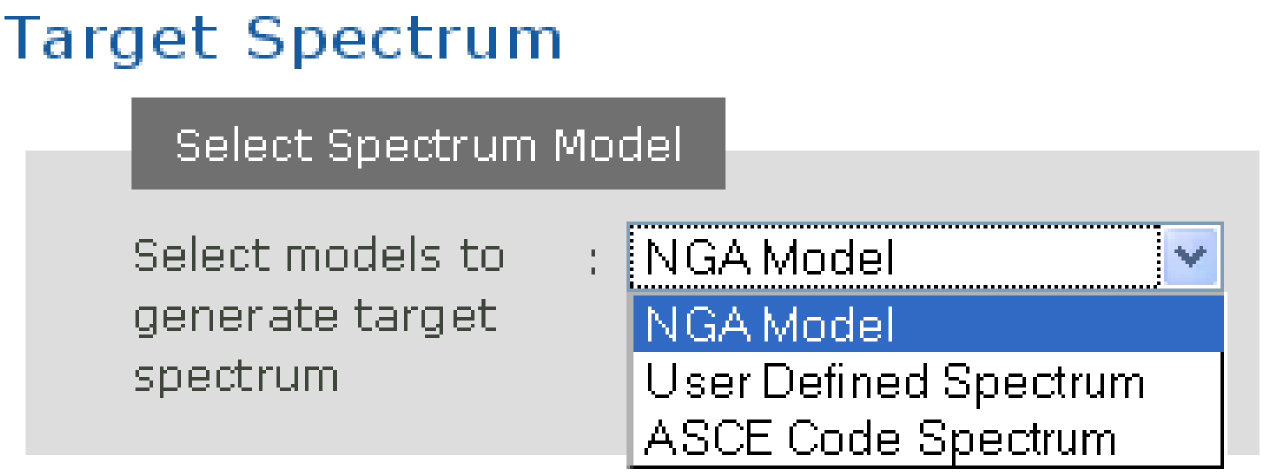
Search for scaled ground motions

Define a target spectrum:

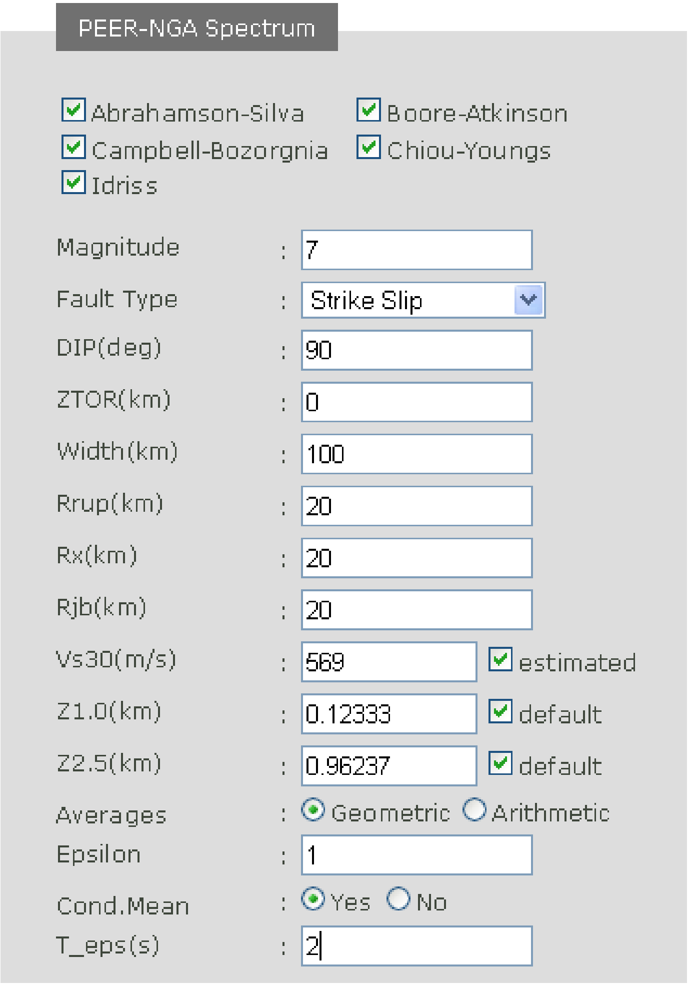


NGA model spectrum

Which model(s)?

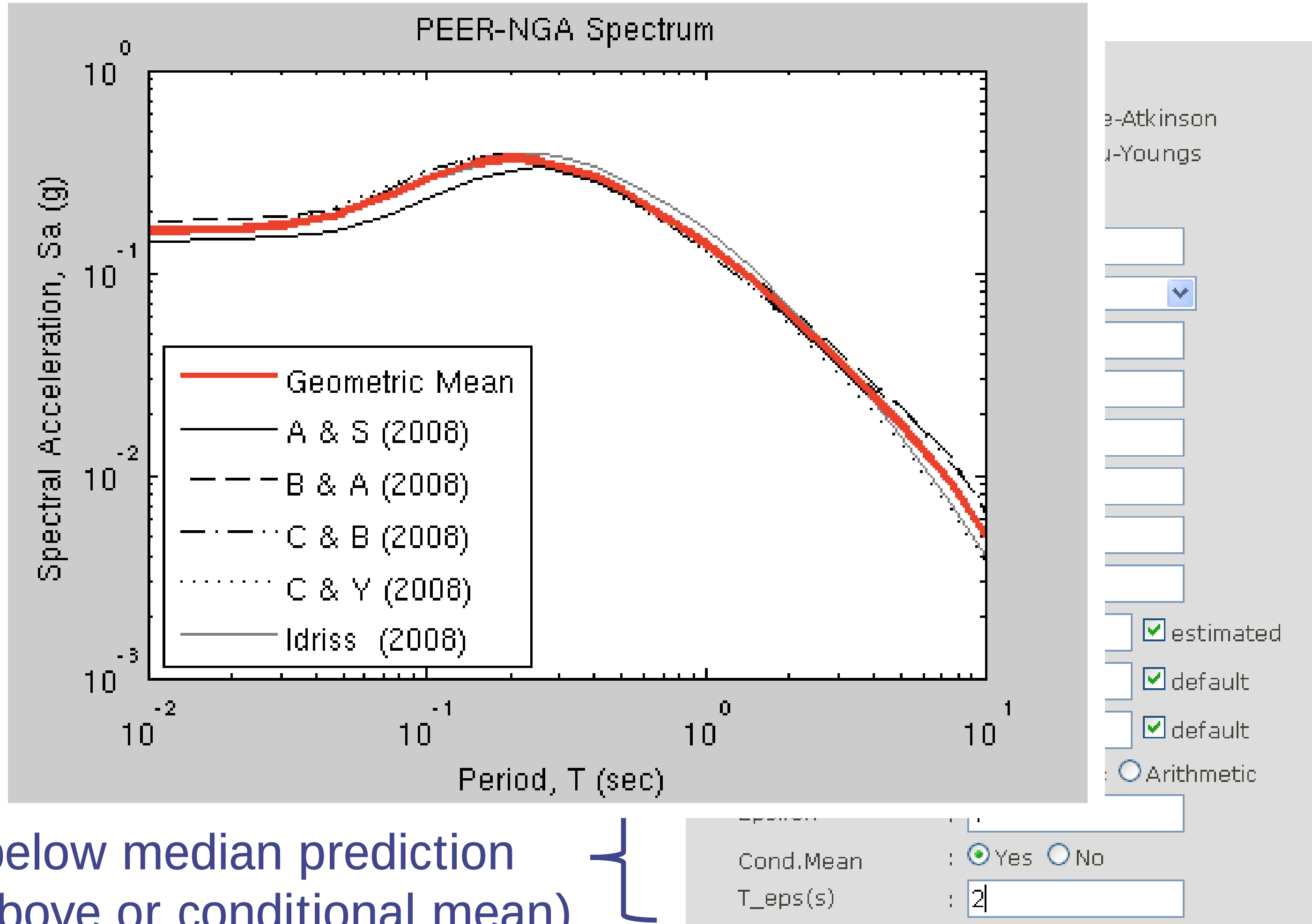
Model parameters

Amount/below median prediction
(uniformly above or conditional mean)



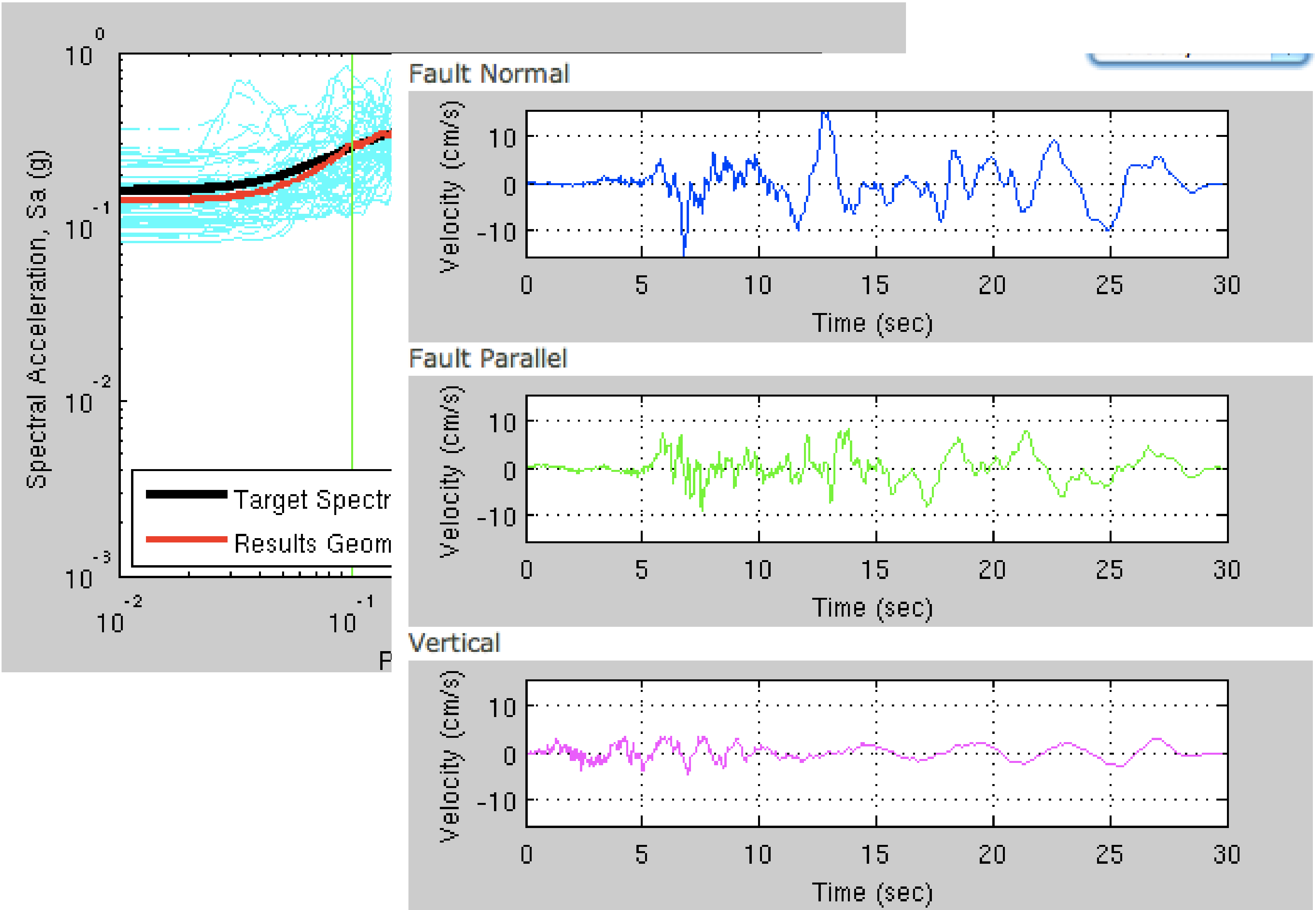
Slides courtesy Camila Coria and Carola Di Alessandro

NGA model spectrum



Amount/below median prediction
(uniformly above or conditional mean)

Find time histories with matching spectra



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Slides courtesy Camila Coria and Carola Di Alessandro

PEER Transportation Systems Research Program standardized sets of ground motions

http://peer.berkeley.edu/transportation/projects/

Transportation Systems Research Program

Pacific Earthquake Engineering Research Center

TSRP

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Ground Motion Studies for Transportation Systems

Sample Project Title

Home » Projects » Ground Motion Studies for Transportation Systems

Ground Motion Studies for Transportation Systems

Project # NCTRJB

Research Team

- Jack Baker, Professor of Structural Engineering, Stanford University (PI)
- Nirmal Jayaram, Graduate Student, Stanford University
- Shrey Shahi, Graduate Student, Stanford University

Research Abstract

This project contains three subsets of objectives related to ground motion selection and scaling for transportation projects.

Objective 1, Ground Motion Selection, will consist of selecting a versatile set of ground motions for the TSRP program, to enable researchers to perform a variety of studies while still using a standardized set of ground motions.

To maximize the value of the ground motions selected, Objective 2, Guidance for Use of Ground Motions, will be conducted. These activities focus on enabling users to perform useful analyses with this ground motion set, which contains several new features that researchers will not be experienced in utilizing. The techniques will be demonstrated using example analyses of simple bilinear SDOF's, to transparently illustrate the procedures in a situation where the audience can intuitively predict resulting responses.

Incremental Dynamic Analysis (IDA) has become a popular tool for use in Performance Based Earthquake Engineering (PBEE), to quantify the relationship between ground motion intensity measure (IM) and structural response. A notable shortcoming of this approach, however, is that the input ground motions are considered to be identical at all IM levels, while probabilistic seismic hazard analysis (PSHA) clearly show that ground motion properties (such as causal magnitude and spectral shape) change as the IM changes. Objective 3 of this project, Demonstration of Adaptive Incremental Dynamic Analysis, will improve current IDA methods, to account for the fact that these grounmotion properties change with the IM.

Research Outcomes

The following files document selected ground motions for use in the PEER transportation systems research program.

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

New Ground Motion Selection Procedures and Selected Motions for the PEER Transportation Research Program

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Ting Lin
Shrey K. Shahi
Department of Civil and Environmental Engineering
Stanford University

Nirmal Jayaram
Risk Management Solutions, Inc.

PEER 2011/03
MARCH 2011

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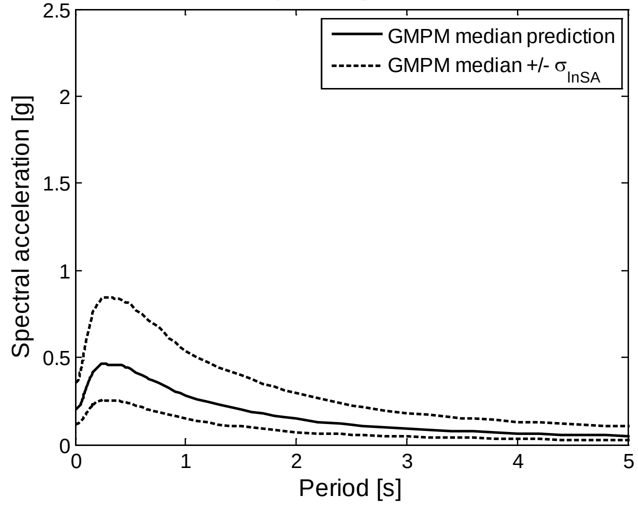
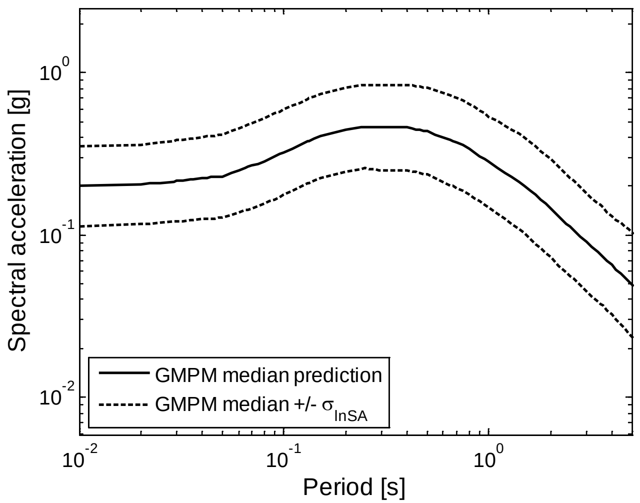
Broadband ground motions

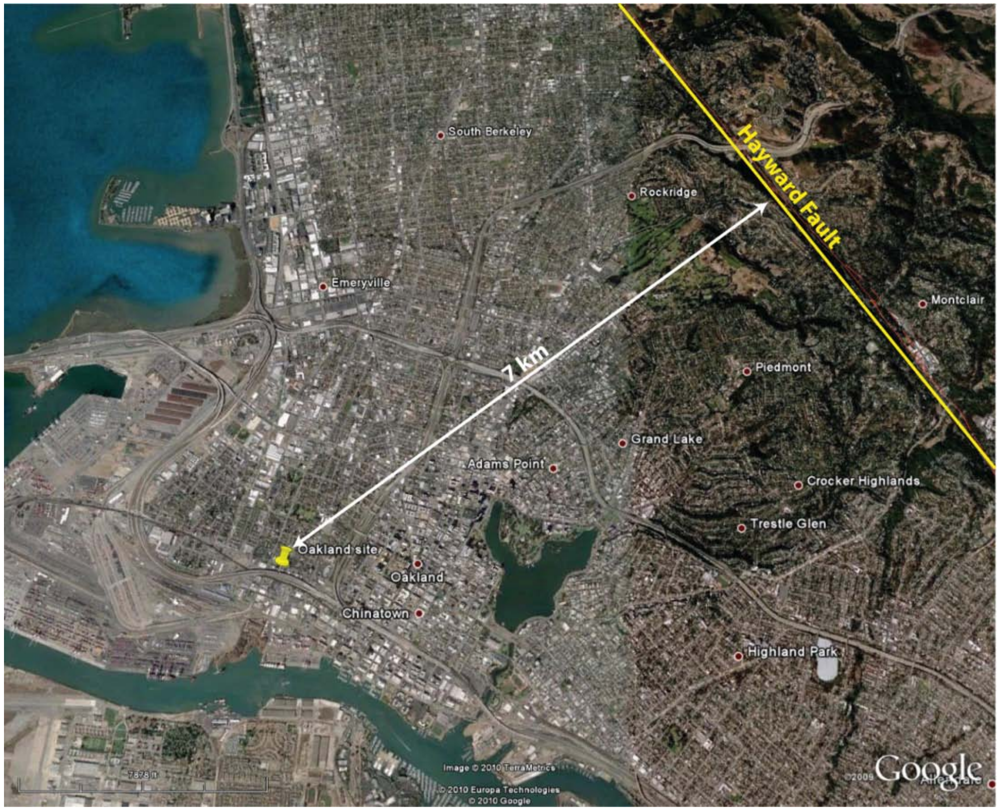
- 40 unscaled 3-component motions
- Selected to match the median *and variability* in response spectra associated with an M = 7, R = 10 km strike slip earthquake
- Separate sets are provided for soil and rock conditions (V_{s30} = 250m/s and 760m/s)
  - Recordings from appropriate sites
  - Target spectra account for site conditions
- A third set is provided for lower-amplitude shaking (M = 6, R = 25 km V_{s30} = 250m/s)

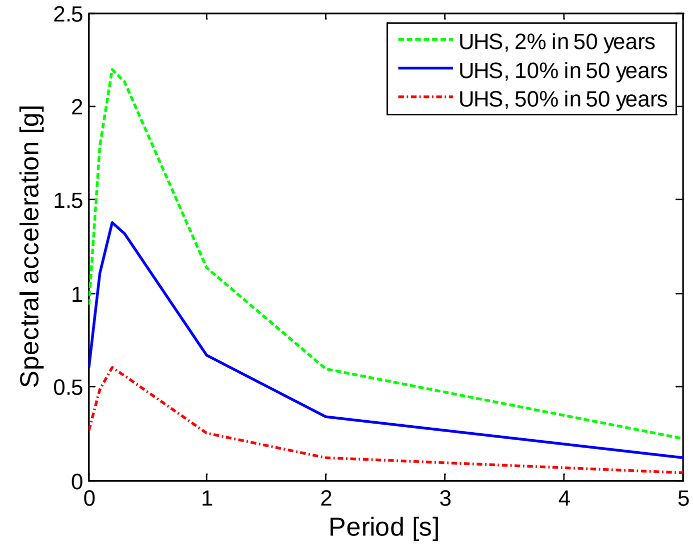
Target spectrum:

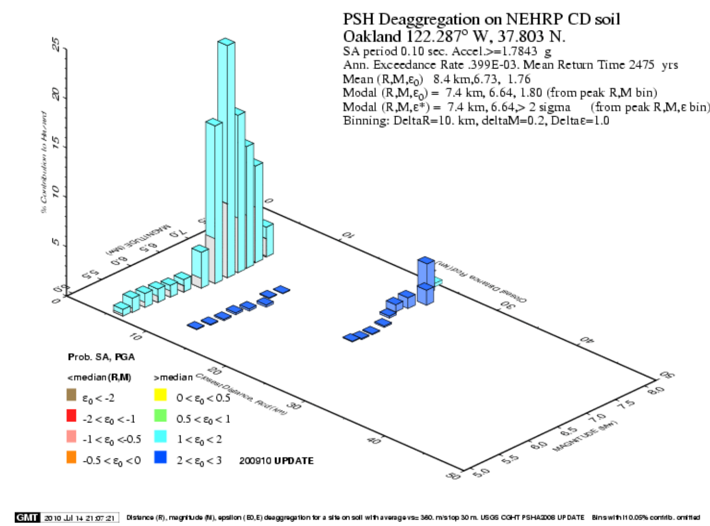




Site-specific ground motions for Oakland I-880 Viaduct





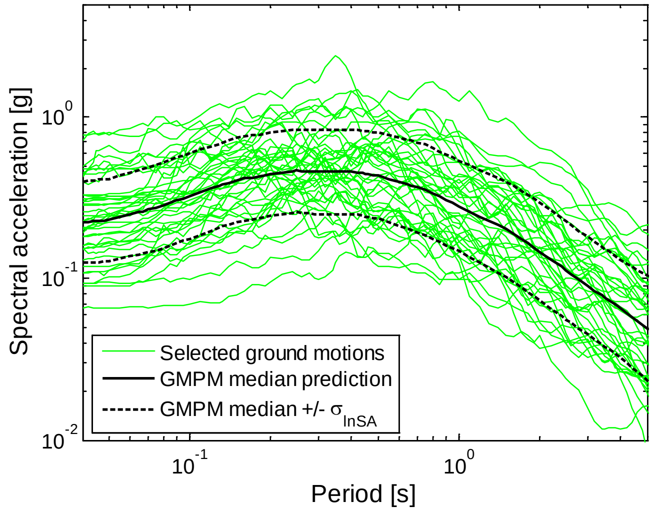


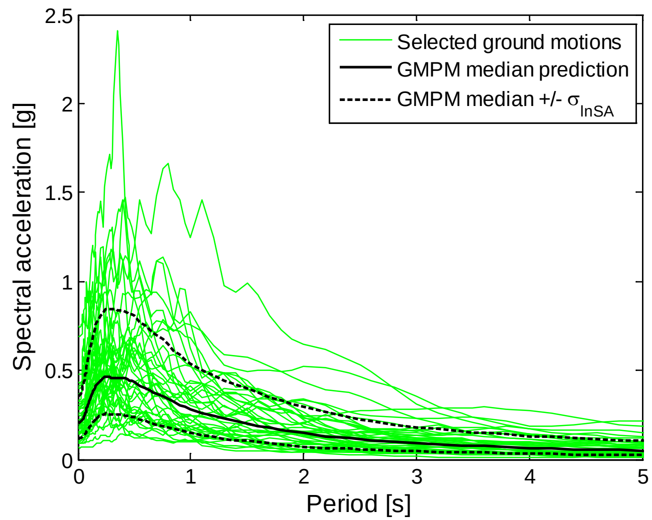
- Same location as the PEER I880 testbed

- Ground motions selected to *closely* match USGS Uniform Hazard Spectra and Deaggregations

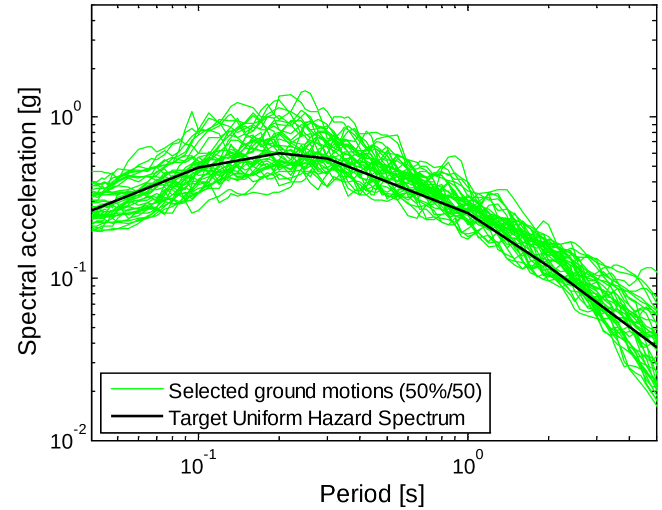
Comparison of ground motion spectra

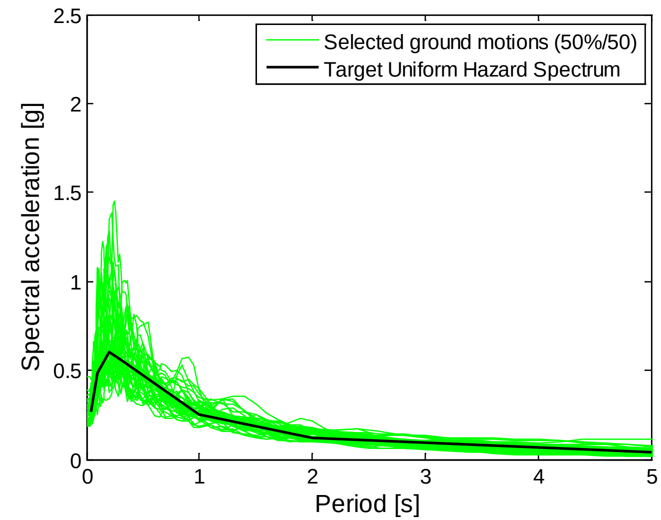
Broadband soil ground motions





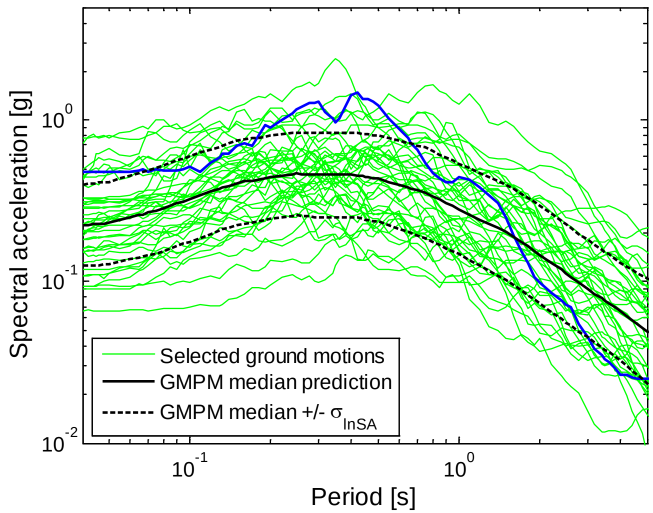
50%/50 yrs site-specific ground motions

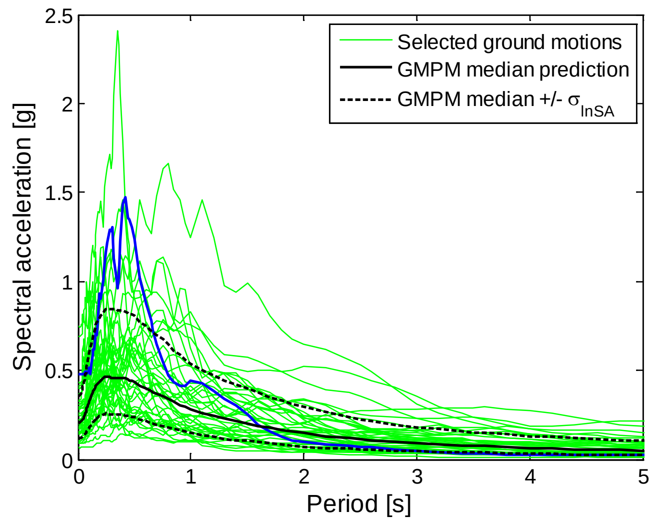




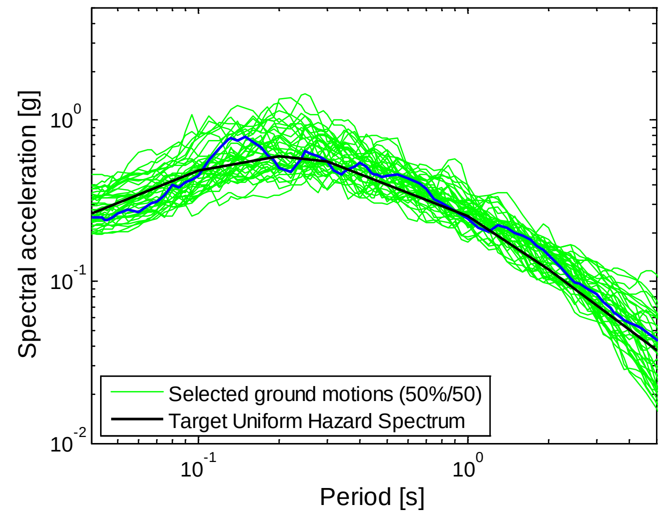
Comparison of ground motion spectra

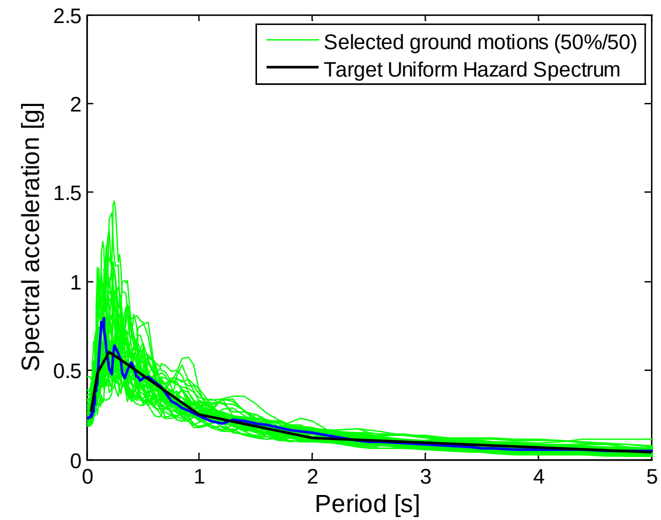
Broadband soil ground motions





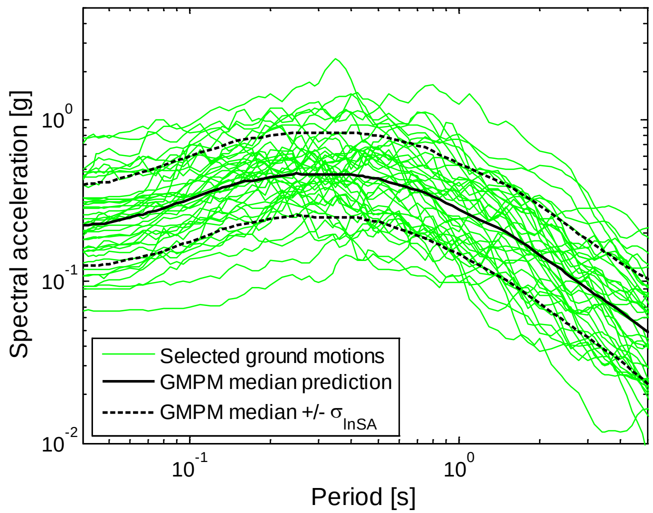
50%/50 yrs site-specific ground motions

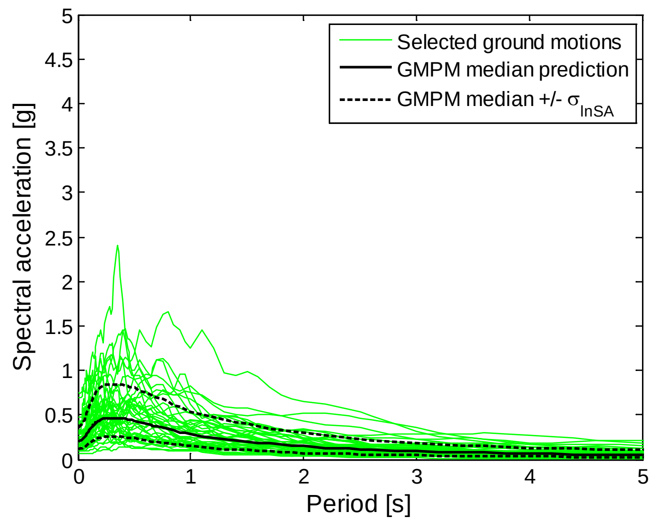




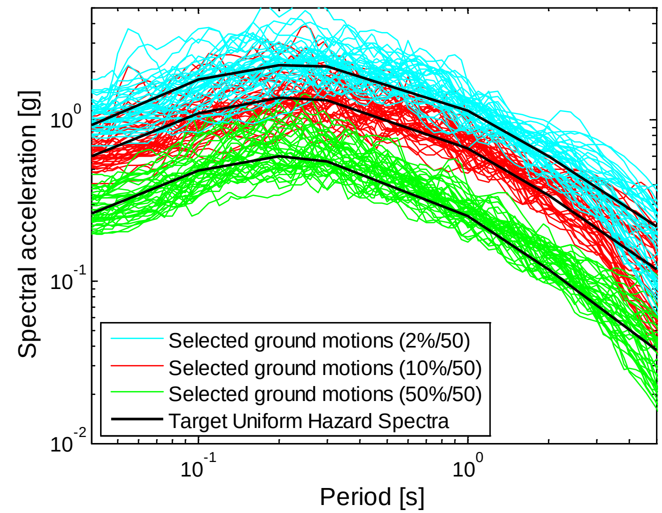
Comparison of ground motion spectra

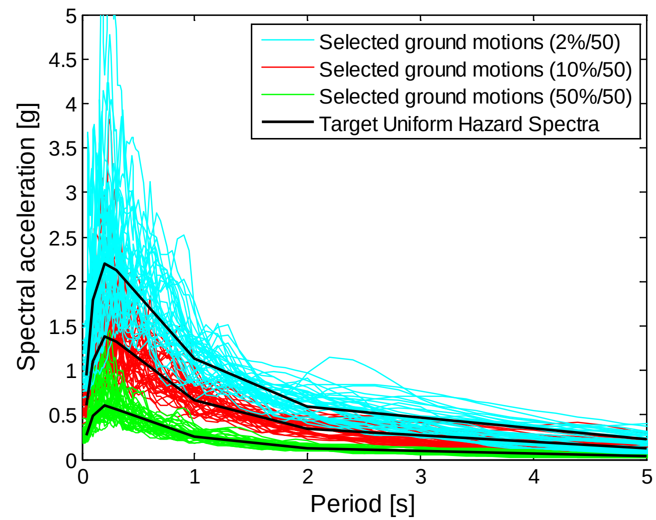
Broadband soil ground motions





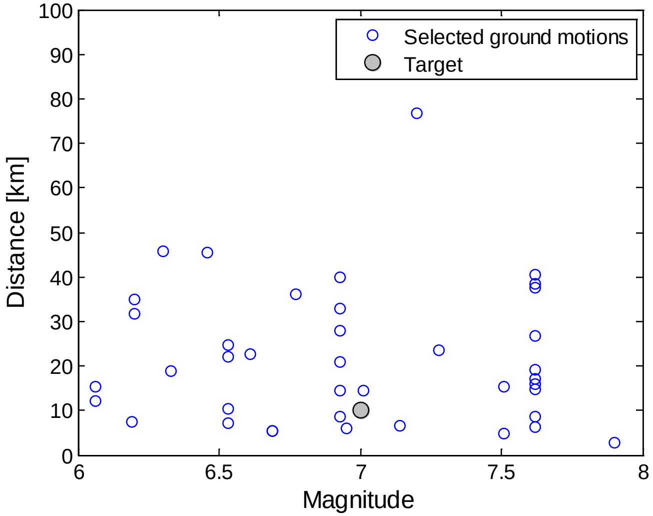
Site-specific ground motions





Comparison of other ground motion properties

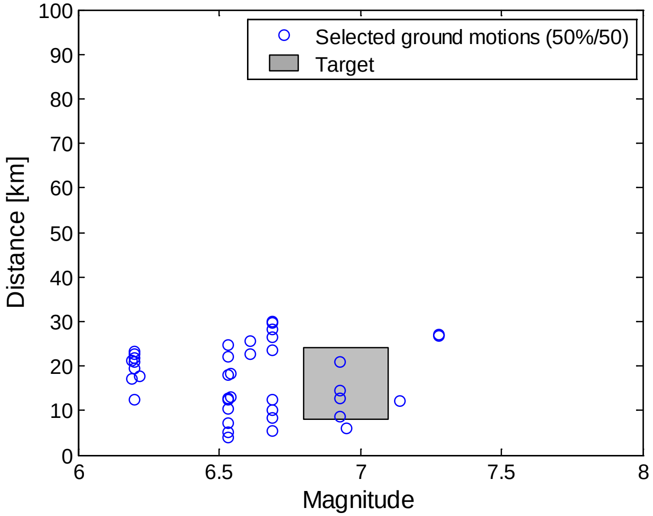
Broadband soil ground motions



Other properties

- Variability included
- No scaling
- Velocity pulses not specifically included or excluded

50%/50 yrs site-specific ground motions

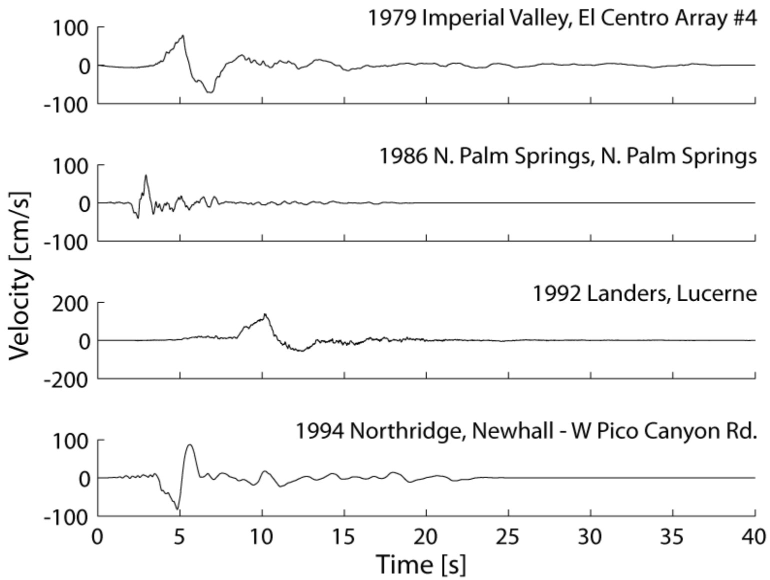


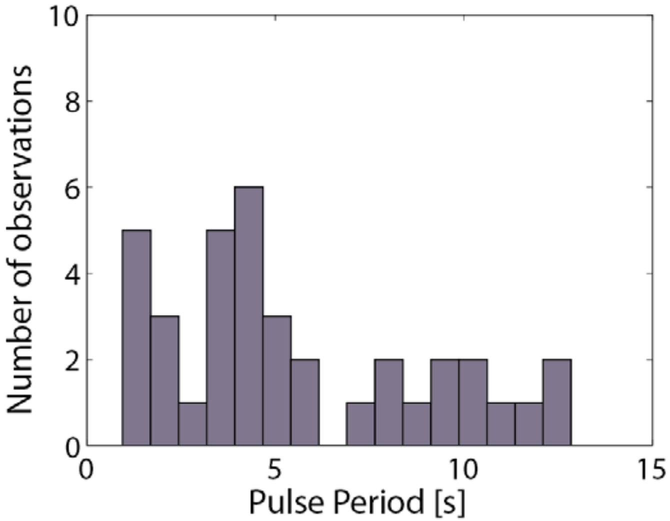
Other properties

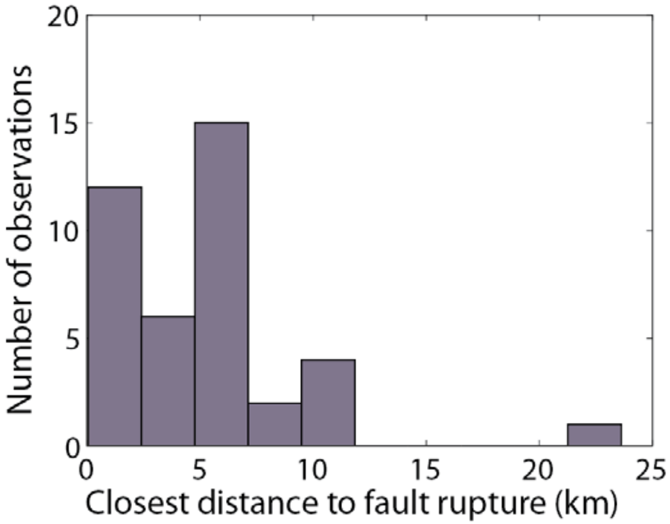
- No variability desired in spectra or other properties
- Scaled to match target spectra
- Velocity pulses included in proportion to expected occurrence at the site of interest

Another set of ground motions: near-fault motions with pulses

- 40 three-component motions, all high intensity and recorded close to faults
- They have a variety of pulse periods, in recognition of the variety of structures that they might be used to analyze







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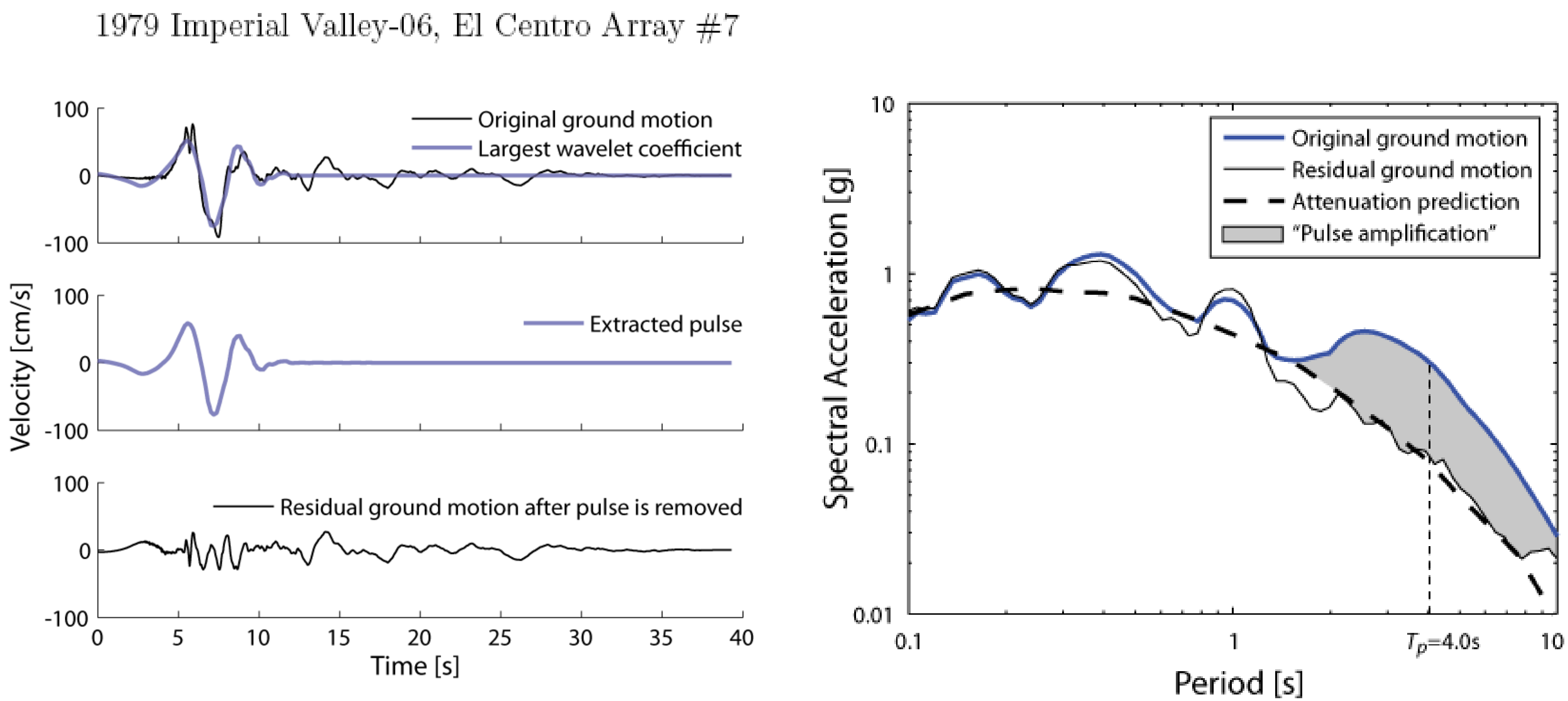
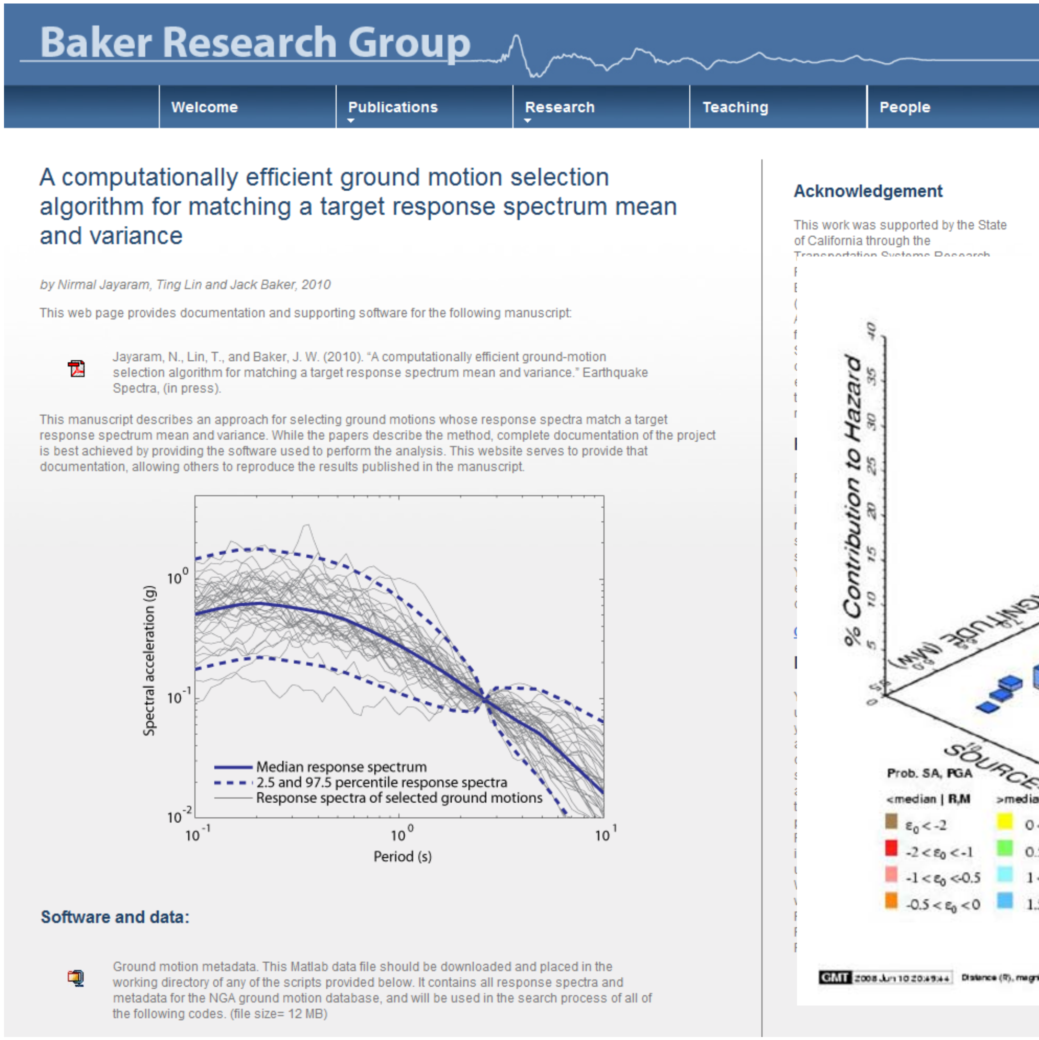
Additional data for the near-fault motions with pulses



Time histories and response spectra for all three "parts" of the ground motions are available

Source code for selection of these ground motion sets

http://www.stanford.edu/~bakerjw/gm_selection.html


Baker Research Group

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A computationally efficient ground motion selection algorithm for matching a target response spectrum mean and variance

by Nirmal Jayaram, Ting Lin and Jack Baker, 2010

This web page provides documentation and supporting software for the following manuscript:

Jayaram, N., Lin, T., and Baker, J. W. (2010). "A computationally efficient ground-motion selection algorithm for matching a target response spectrum mean and variance." Earthquake Spectra, (in press).

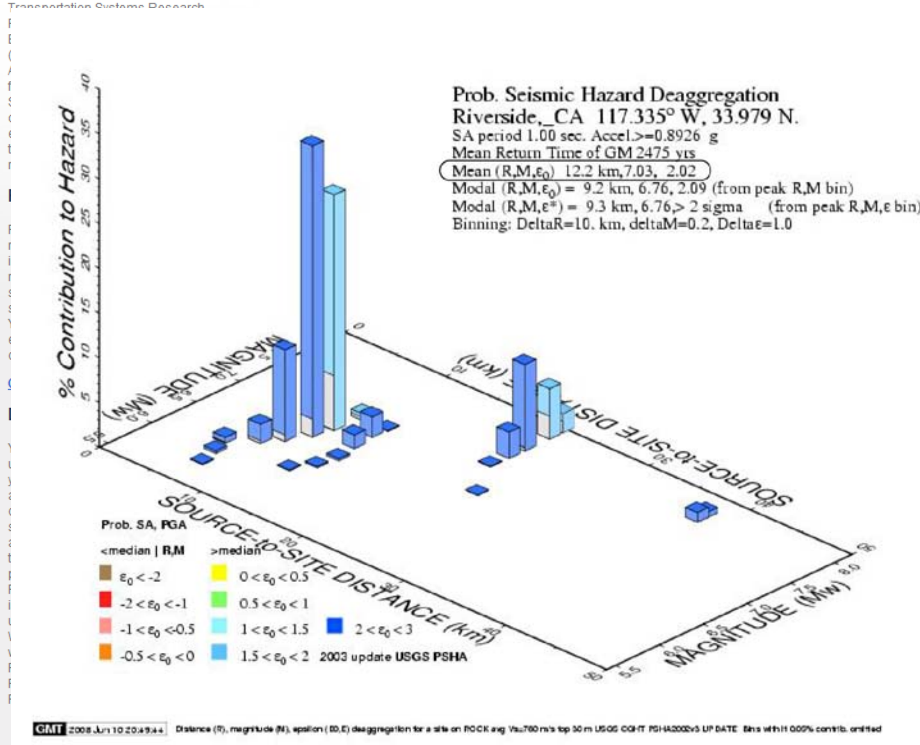
This manuscript describes an approach for selecting ground motions whose response spectra match a target response spectrum mean and variance. While the papers describe the method, complete documentation of the project is best achieved by providing the software used to perform the analysis. This website serves to provide that documentation, allowing others to reproduce the results published in the manuscript.

Software and data:

Ground motion metadata. This Matlab data file should be downloaded and placed in the working directory of any of the scripts provided below. It contains all response spectra and metadata for the NGA ground motion database, and will be used in the search process of all of the following codes. (file size= 12 MB)

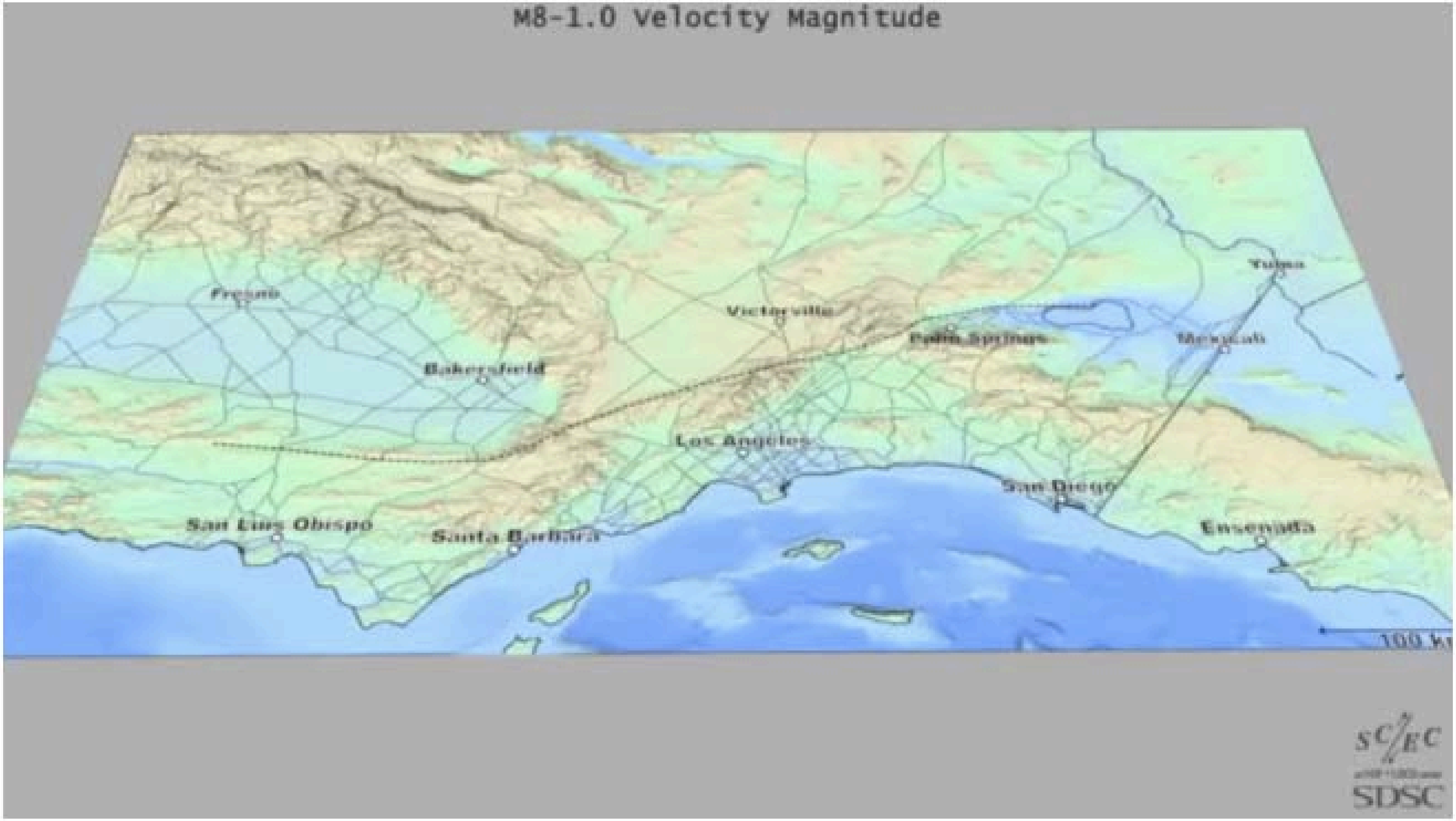
Acknowledgement

This work was supported by the State of California through the



Jayaram, N., Lin, T., and Baker, J. W. (2011). "A computationally efficient ground-motion selection algorithm for matching a target response spectrum mean and variance." Earthquake Spectra, 27(3), 797-815.

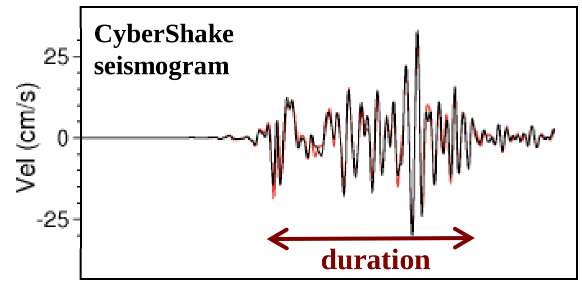
Looking forward: M8 Southern San Andreas rupture simulation

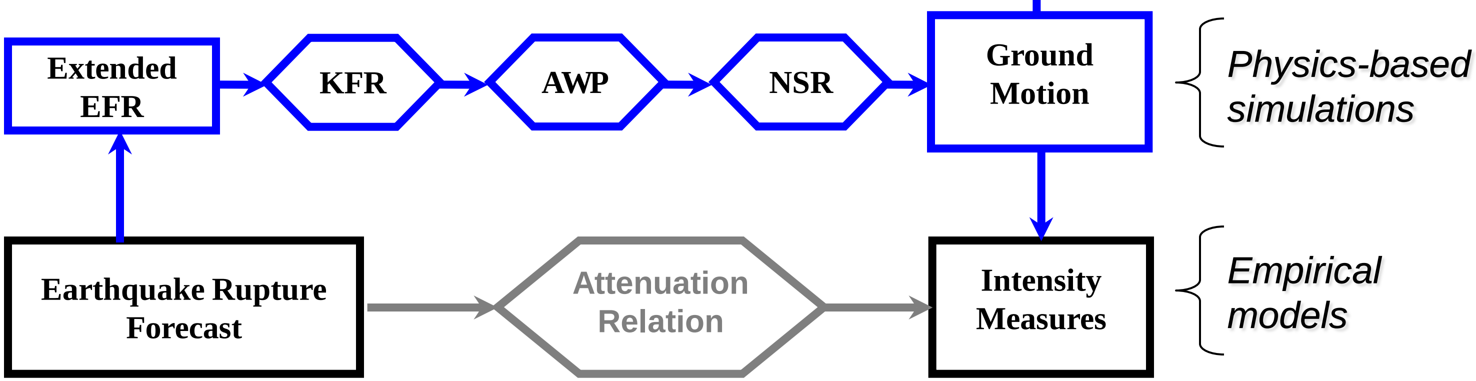


Video courtesy Kim Olsen and SCEC

Ground motions and PSHA using CyberShake

- **Uses an *extended* earthquake rupture forecast**
  - **Source area probabilities from UCERF2**
  - **Hypocenter distributions**
  - **Slip variations from psuedo-dynamic model**
- **Calculates *seismograms* efficiently using "reciprocity"**
  - **Kinematic fault ruptures**
  - **3D anelastic model of wave propagation**
  - **Nonlinear site response**

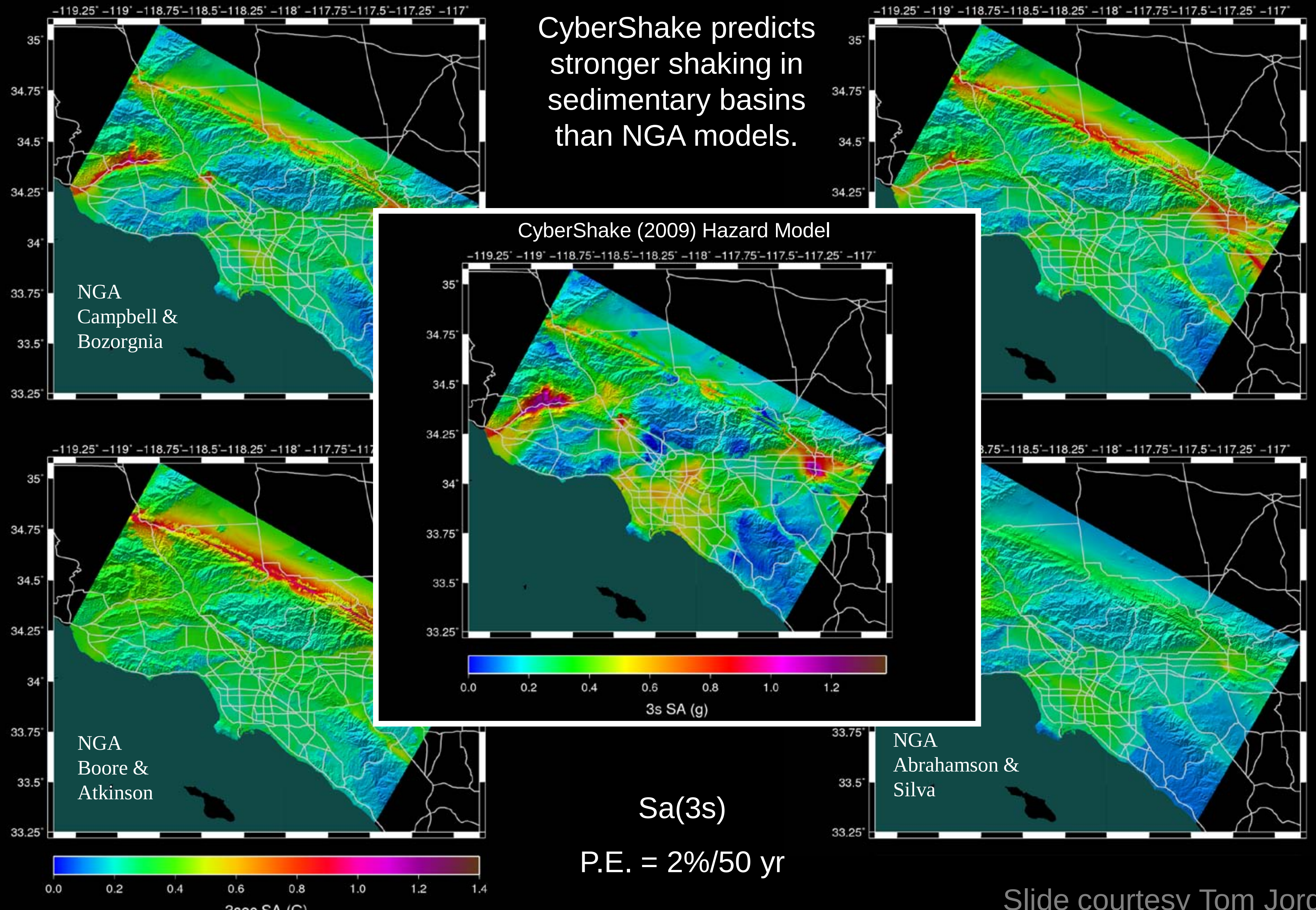




KFR = kinematic fault rupture model
AWP = anelastic wave propagation model
NSR = nonlinear site response

Hazard maps from 2008 NGA GMPMs versus simulations

CyberShake predicts stronger shaking in sedimentary basins than NGA models.



Sa(3s)

P.E. = 2%/50 yr

Slide courtesy Tom Jorda

Example simulation validation

- Motions procedu
- Analysis

Observatio

- Too-fast attenuat
- Too-low standard short pe

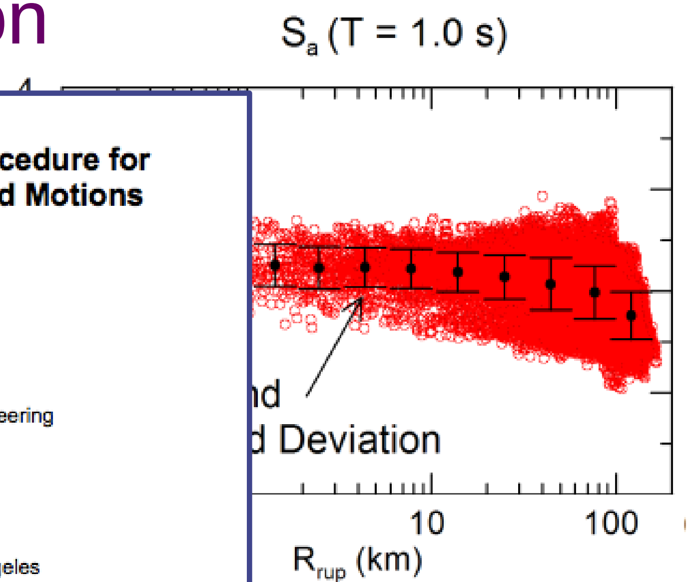
Calibration of Semi-Stochastic Procedure for Simulating High Frequency Ground Motions

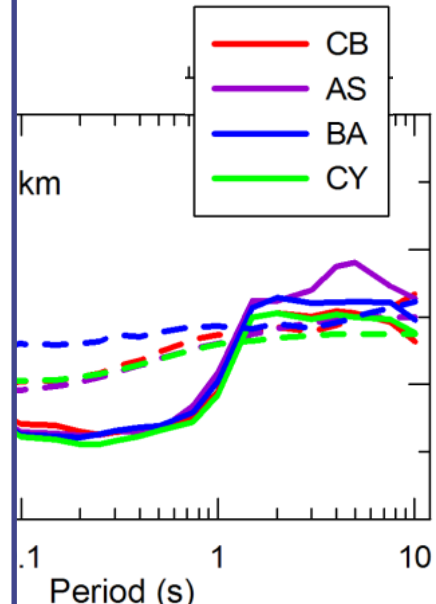
Jonathan P. Stewart, PhD, PE
Emel Seyhan
Department of Civil and Environmental Engineering
University of California, Los Angeles

and

Robert W. Graves, PhD
U.S. Geological Survey, Pasadena, Los Angeles

PEER Report 2011/xx
Pacific Earthquake Engineering Research Center
College of Engineering
University of California, Berkeley
September 2011





Slide courtesy Jon Stewart, Emel Seyhan, Lisa Star, Rob Graves

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Ground Motion Simulation Validation Technical Activity Group

- SCEC-sponsored effort to develop and implement simulation testing/rating methodologies via collaboration between ground motion modelers and engineering users

- 25 participants at first workshop in January 2011

- Currently coordinating with the PEER Ground Motion Selection and Modification Working Group (a PEER-hosted joint meeting is being scheduled)

Conclusions

- Ground motion and hazard analysis tools ready today:
  - **PEER Ground Motion Database**
  - **Standardized ground motion sets**
  - Tall Buildings Initiative ground motion guidelines
  - Ground Motion Selection and Modification working group report
  - Models for spatial ground motion coherence and correlation
  - Stochastic ground motion simulation models

- Tools under development
  - **Engineering validation of numerically simulated ground motions**
  - NGA West 2 ground motion prediction models
  - NGA East ground motion models
  - Global Earthquake Model, Ground Motion Prediction Equations Program

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Future research opportunities

How does ground motion selection relate to structural/geotechnical analysis objectives and acceptance criteria?

How can we use numerically simulated motions?

Do we fully understand the risk and impact of:

- Incoherent motions?
- Long duration motions?
- Near-fault fling-step effects?