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# Characterization of Ground Motion Hazard

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Yousef Bozorgnia

*PEER Associate Director*

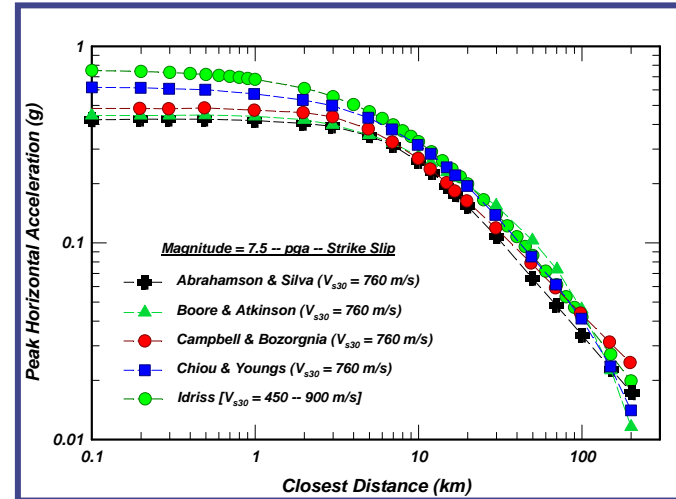


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**PEER Summative Meeting - June 13, 2007**

# Numerous Research Projects on Characterization of Ground Motion Hazard

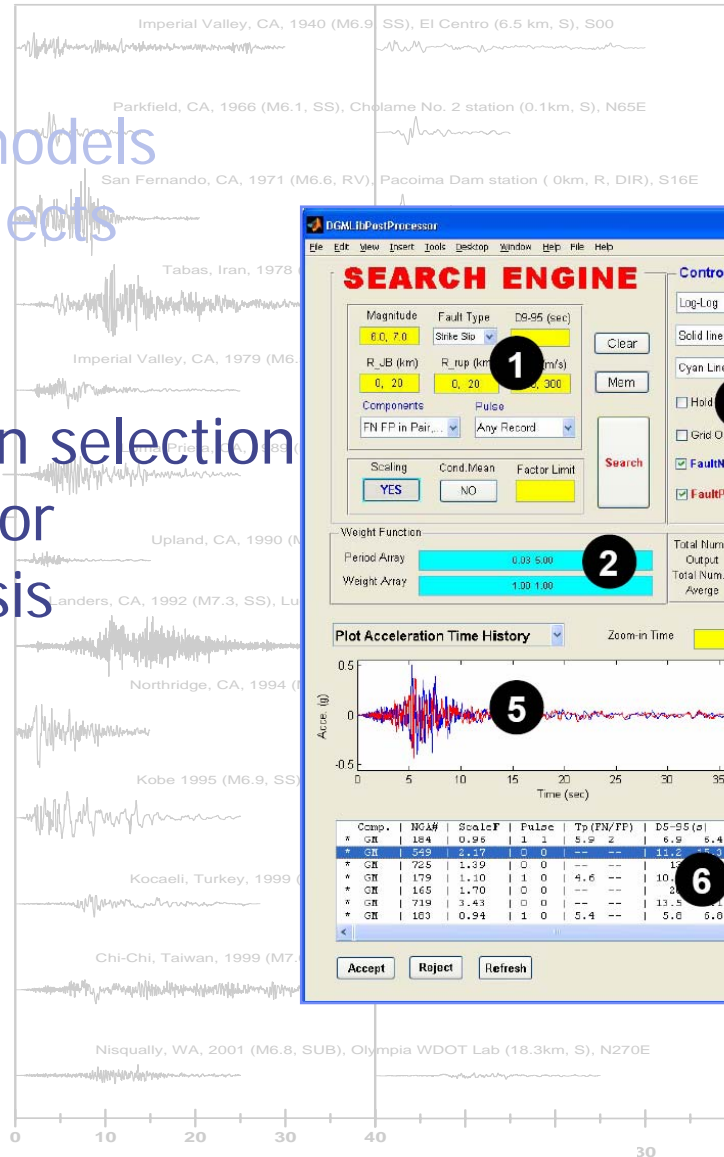
❖ Attenuation models and related projects



# Numerous Research Projects on Characterization of Ground Motion Hazard

❖ Attenuation models and related projects

❖ Ground motion selection & modification for nonlinear analysis



**DGM.HPostProcessor**

**SEARCH ENGINE**

Magnitude: 6.0, 7.0 | Fault Type: D5-95 (sec) | Site Slo: **1**

R<sub>uB</sub> (km): 0, 20 | R<sub>rup</sub> (km): 0, 20 | M<sub>max</sub>: 9.000

Components: Pulse | FN FP in Pair: Any Record

Scaling: YES | Cond. Mean: NO | Factor Limit: **2**

Weight Function: Period Array: 0.03 5.00 | Weight Array: 1.00 1.00

Control: Log-Log | Solid Line | Cyan Line | Hold | Grid On | **7**

FaultNormal |  FaultParallel

Total Num. Output: 30 | Total Num. Averages: 7

Plot Acceleration Time History | Zoom-in Time: **5**

**DGML Design Spectrum**

Spectral Response Acceleration, S<sub>a</sub>(g) vs. Period, T (sec)

Legend: Target Spectrum (black), Fault Normal (red), Fault Parallel (cyan)

Weight vs. Period, T (sec) | **4**

Comp.	NGA#	ScaleF	FuLoc	Tp (FN/FP)	D5-95 (σ)	Event	Year	Station	Mag
* GN	184	0.95	1 1	5.9 2	6.9 5.4	Imperial Valley-05	1979	El Centro Differential Array	6.5
* GN	555	2.17	0 0	-- --	11.2 7.0	Imperial Valley-06	1906	Dinwiddie #100 South St	6.5
* GN	725	1.39	1 0	-- --	10.7 7.0	Superstition Hills-02	1987	Poe Resa (Comp)	6.5
* GN	179	1.10	1 0	4.6 --	10.7 7.0	Imperial Valley-06	1979	El Centro Array #4	6.5
* GN	165	1.70	0 0	-- --	10.7 7.0	Imperial Valley-06	1979	Chihuahua	6.5
* GN	739	3.43	0 0	-- --	13.5 7.0	Superstition Hills-02	1987	Bradley Airport	6.5
* GN	103	0.94	1 0	5.4 --	5.6 5.0	Imperial Valley-05	1979	El Centro Array #0	6.5

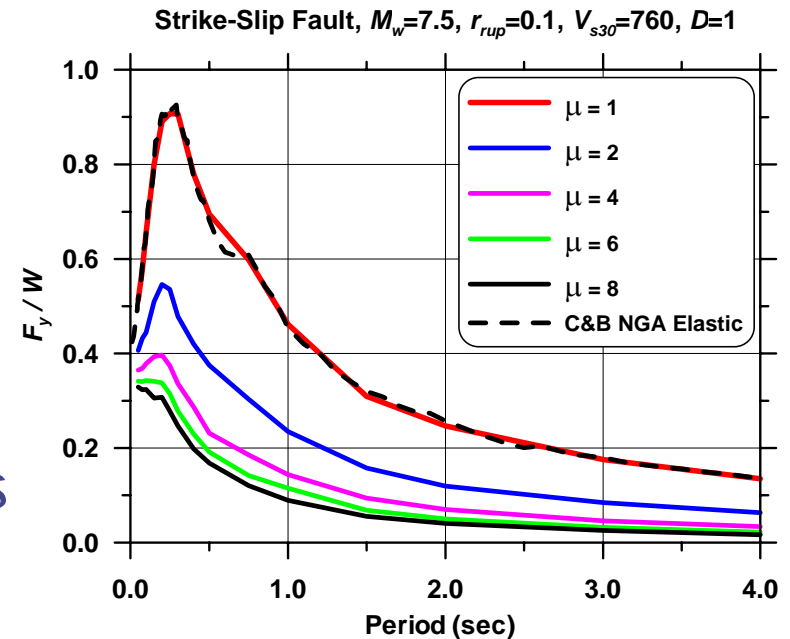
Buttons: Accept, Reject, Refresh, BACK, EXIT

# Numerous Research Projects on Characterization of Ground Motion Hazard

❖ Attenuation models and related projects

❖ Ground motion selection & modification for nonlinear analysis

❖ Investigation of various IMs



Inelastic Spectra

# Numerous Research Projects on Characterization of Ground Motion Hazard

- ❖ Attenuation models and related projects
- ❖ Ground motion selection & modification for nonlinear analysis
- ❖ Investigation of various IMs
- ❖ Input motion for tall buildings with large embedded structures

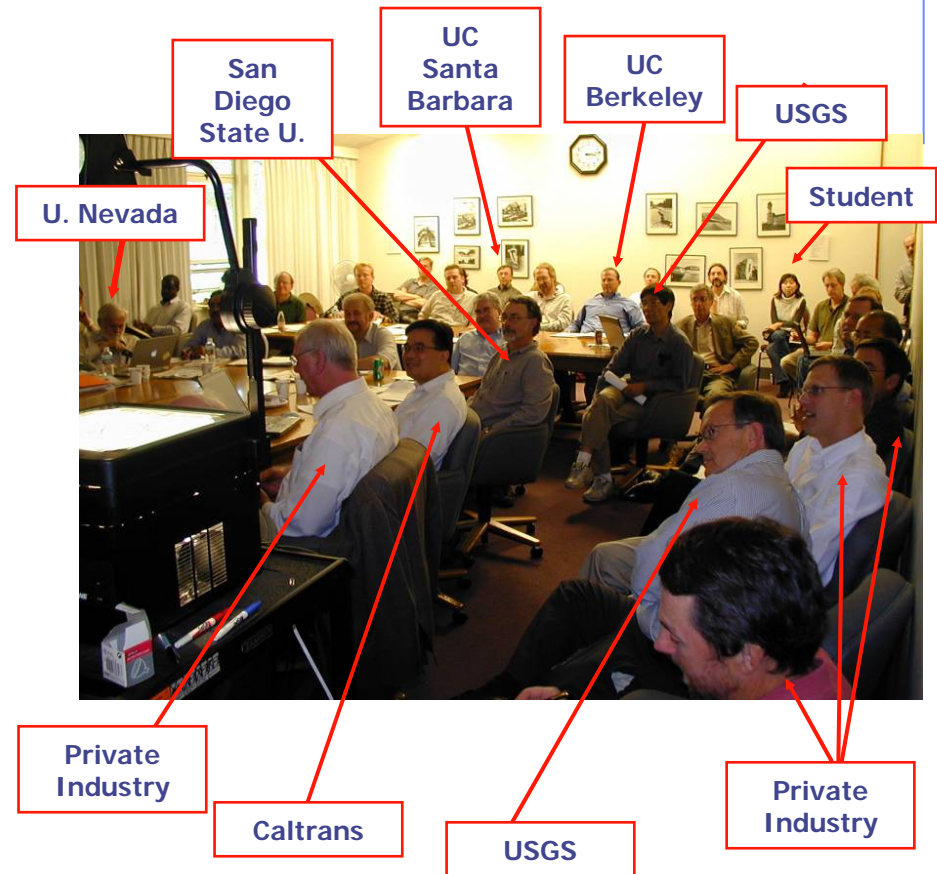


# Next Generation Attenuation (**NGA**) Models



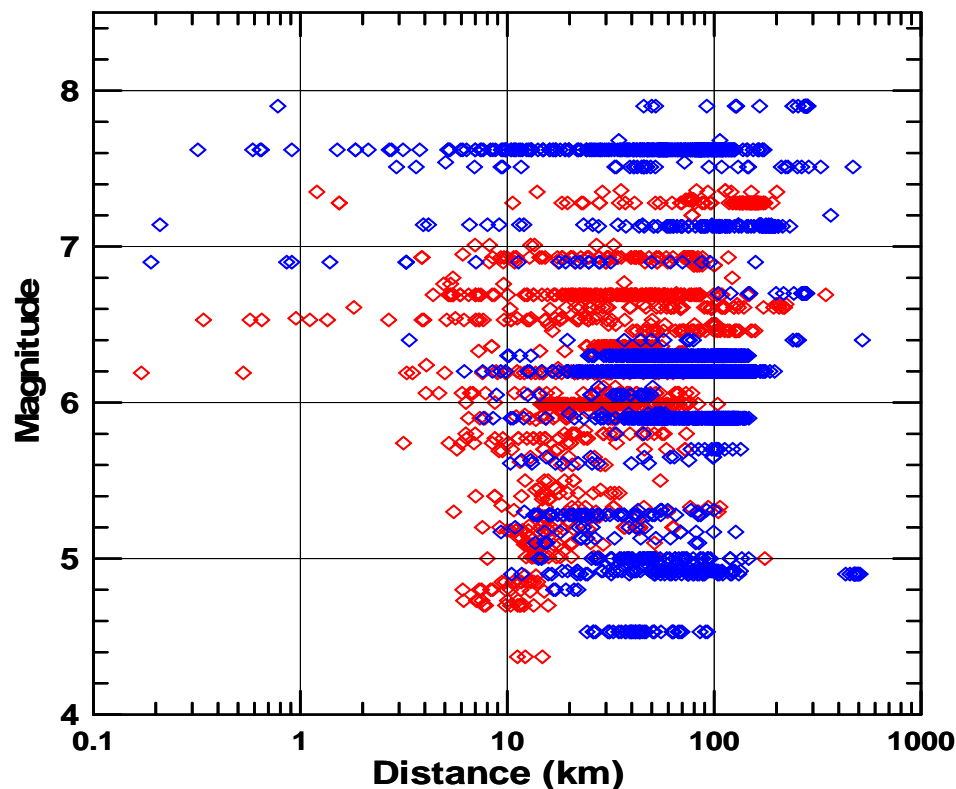
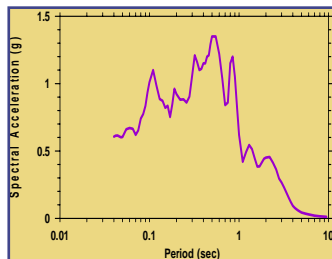
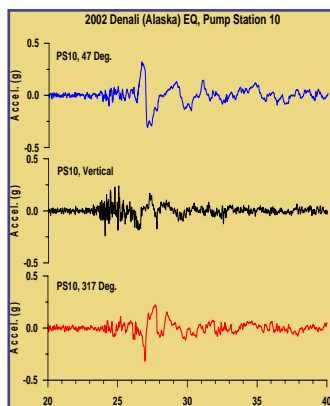
# Next Generation "Attenuation" (NGA) Is a Multidisciplinary "Program"

- ◆ Coordinated by PEER over the last four years
- ◆ Bringing together:  
*geologists,*  
*seismologists,*  
*geotechnical engineers,*  
*structural engineers,* and  
*users* of ground motion models
- ◆ And Researchers, practitioners



# PEER Compiled One of the Largest Uniformly-Processed Strong-Motion Databases in the World

- ◆ 173 worldwide earthquakes
- ◆ > 10,500 uniformly processed records



**Previous Data** **New Data**



# PEER Strong-Motion Database

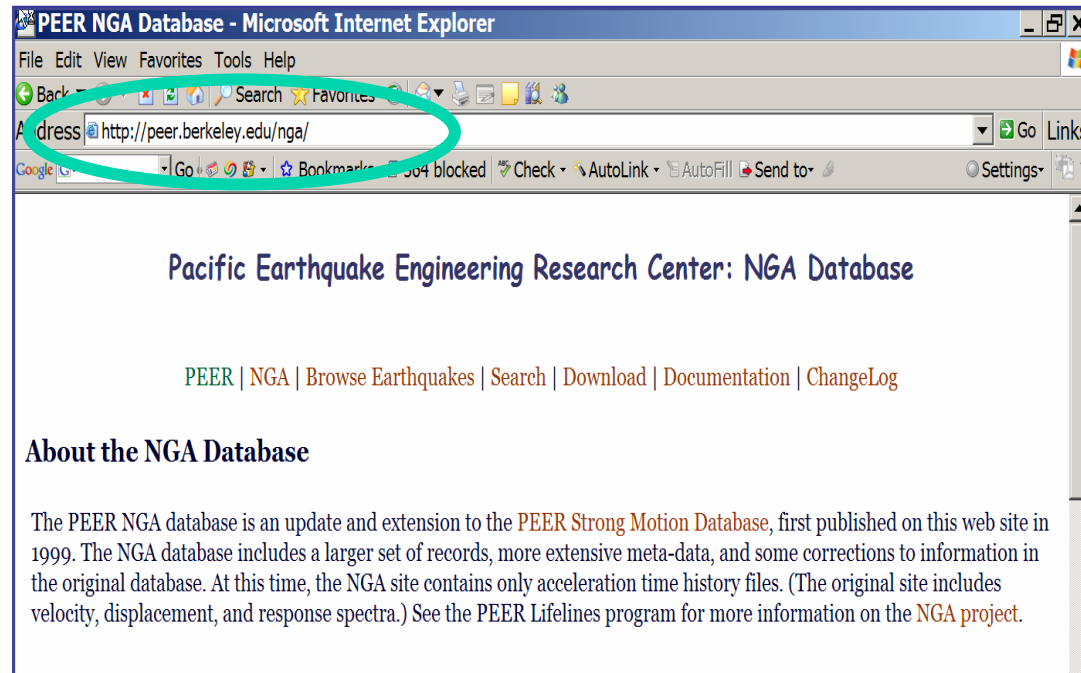
◆ There are more than 100 variables describing source/path/site conditions of a record:

✓ *6 types of distance measures*

✓ *4 site classification schemes*

✓ *Estimated  $V_{S30}$  for most of recording sites*

✓ *HW/FW classes*



**The database is fully available to the public**

# NGA Model Developer Teams

- ◆ NGA empirical ground motion model developers
  - **Abrahamson & Silva** (updating their 1997 model)
  - **Boore & Atkinson** (updating Boore et al., 1997 model)
  - **Campbell & Bozorgnia** (updating their 1997, 2003 models)
  - **Chiou & Youngs** (updating Sadigh et al., 1997 model)
  - **Idriss** (updating his 1993 & 1996 models)
  
- ◆ All model developers started with a common database

# NGA Attenuation Models

## ◆ Ground motion parameters:

- Horizontal components
- PGA, PGV, PGD
- Pseudo spectral acceleration at 5% damping
- Period: 0 - 10 sec

## ◆ Magnitude range:

- 5.0 - 8.0+

## ◆ Distance range:

- 0 – 200 km

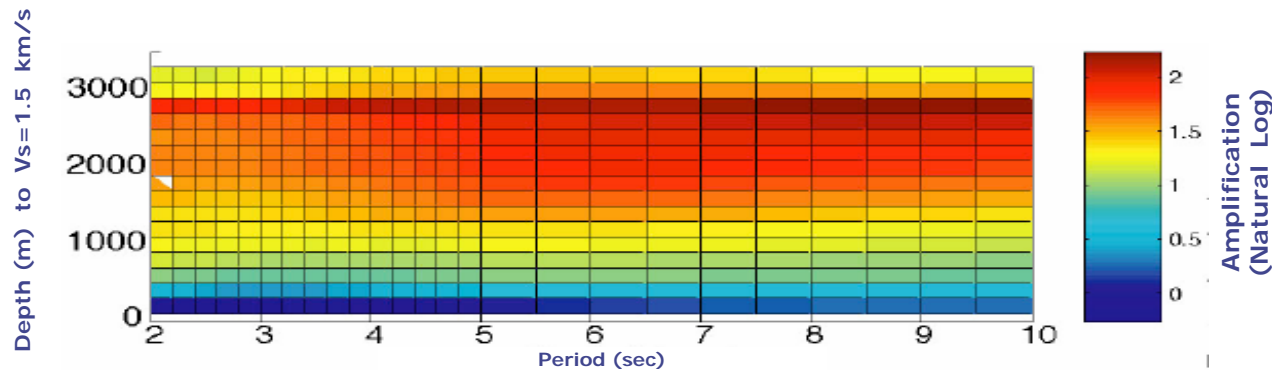
## ◆ Fault Mechanism:

- Strike-Slip
- Reverse
- Normal

## ◆ Site Effects

- $V_{s30}$

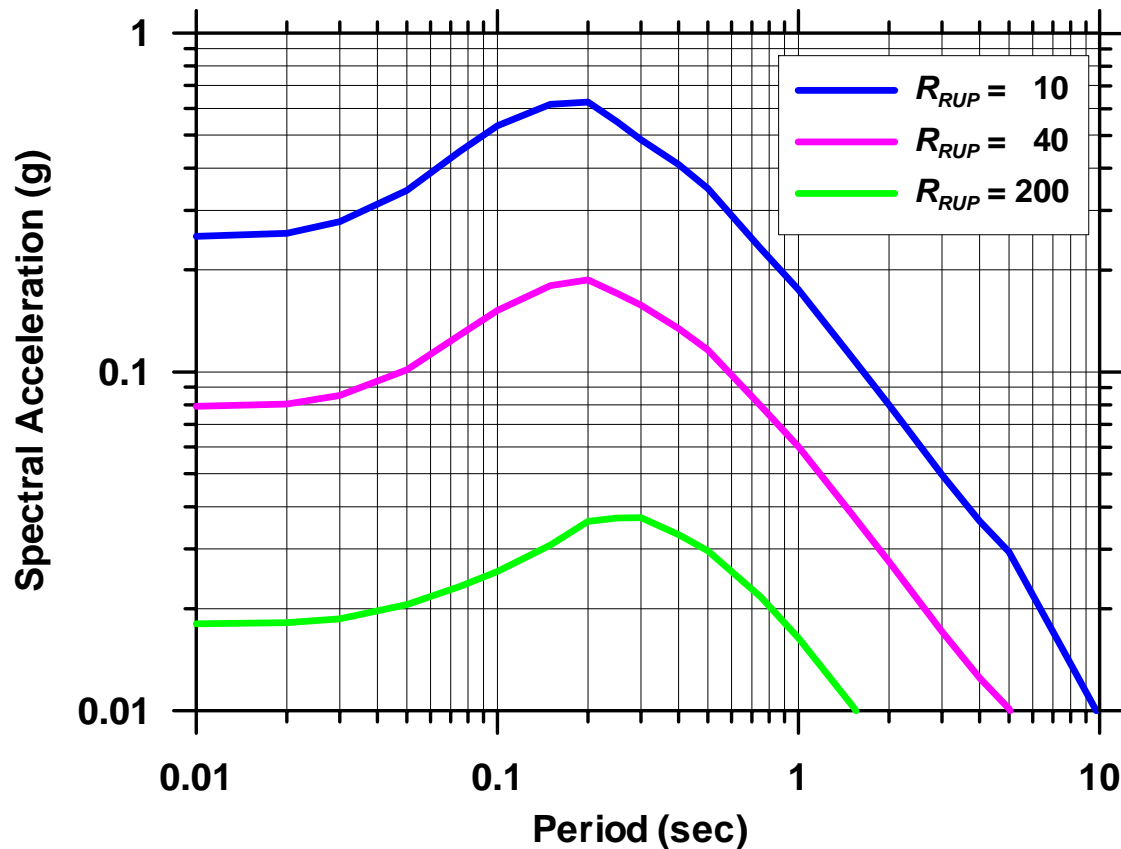
# NGA Models Were Constrained by Simulation



- *To fill the gaps in data*
- *Simulations of 3-D basin and 1-D rock motions*
  - ❖ *To model amplification due to sediment-depth*
  - ❖ *To constrain attenuation models*
- *Nonlinear soil response analysis*
  - ❖ *Amplification factors for different soil profiles subjected to a wide range of input motions*

# Example Result: C&B NGA Predicted Acceleration Spectra

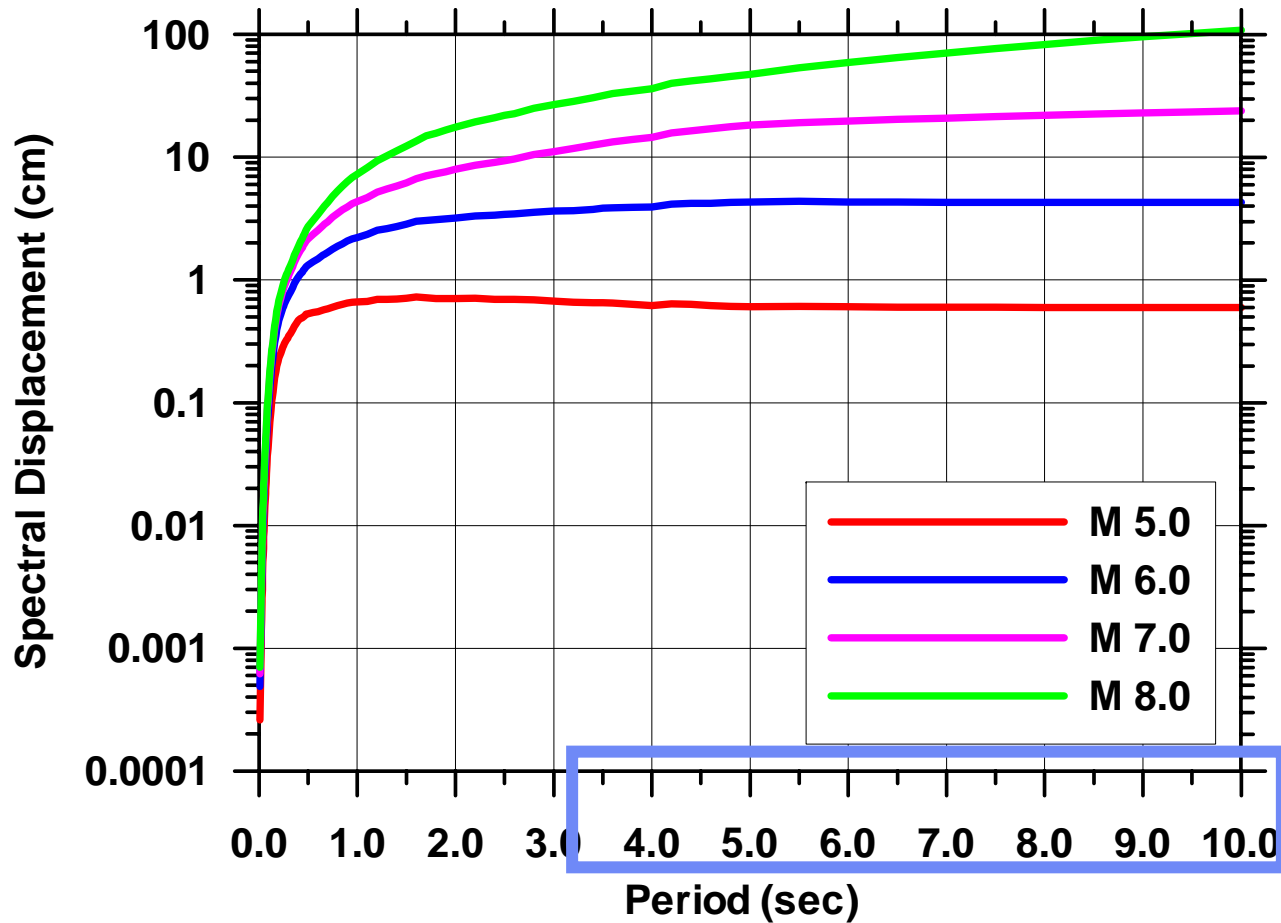
Strike Slip,  $M = 7.0$ ,  $V_{S30} = 760$  m/s



# Behavior at Long Periods

## C&B NGA Predicted Spectral Displacement

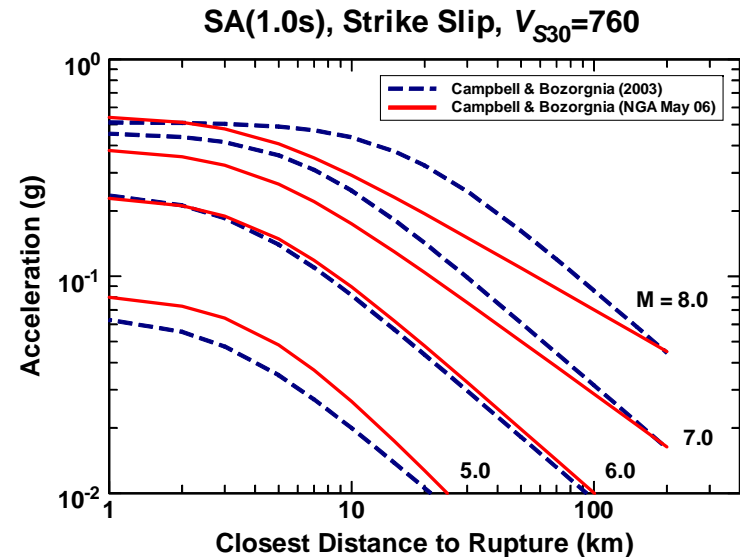
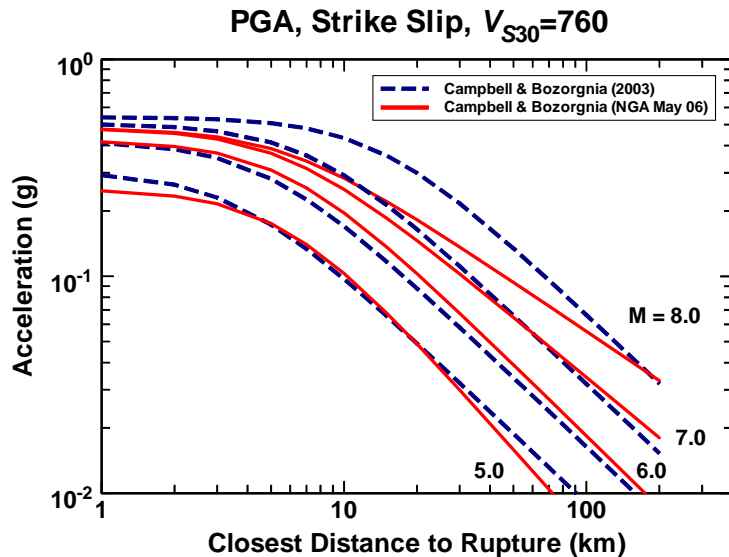
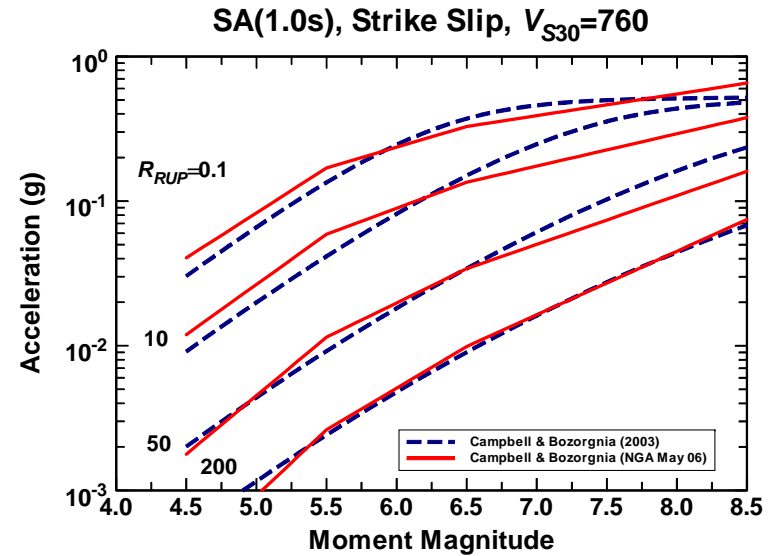
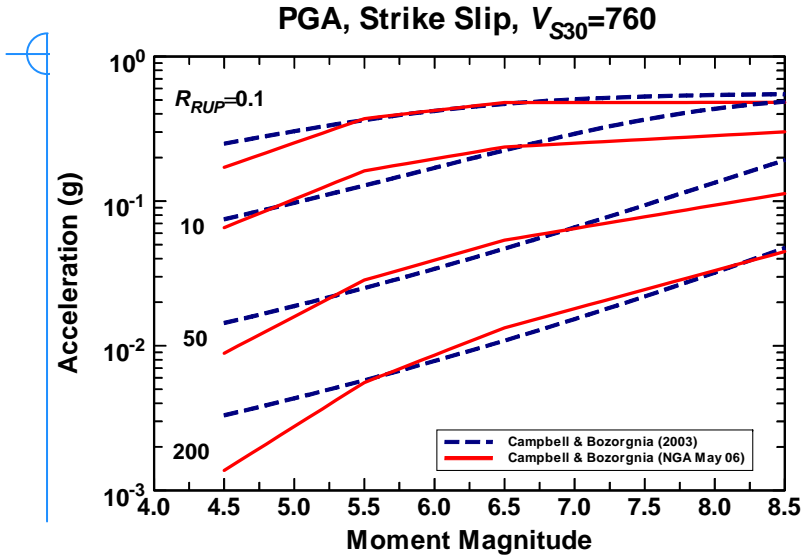
Strike Slip,  $R_{RUP} = 10$  km,  $V_{S30} = 760$  m/s



# Examples of Comparison of NGA Models

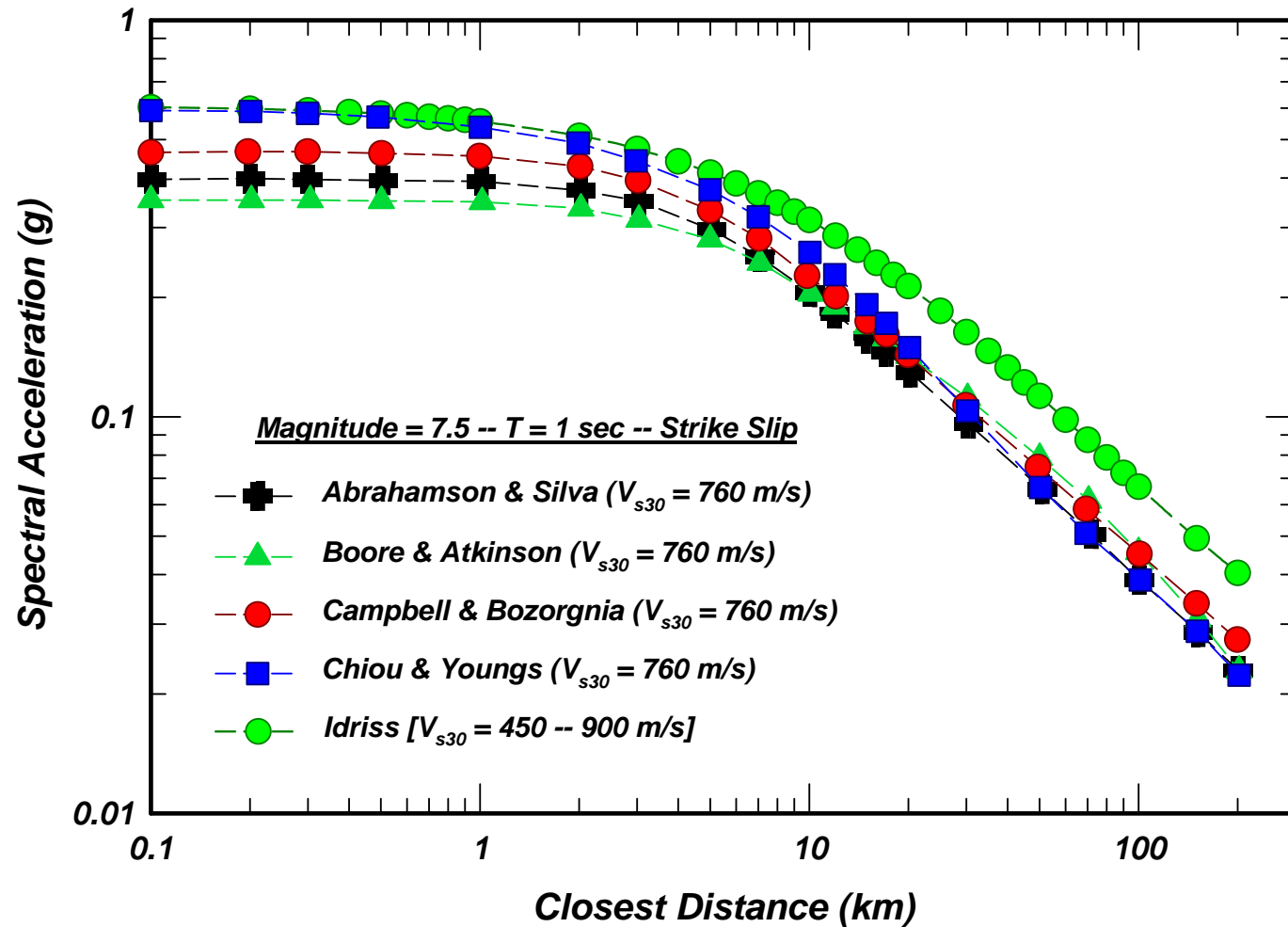


# Campbell & Bozorgnia (C&B) NGA vs. C&B 2003 Strike-Slip Fault, NEHRP B-C





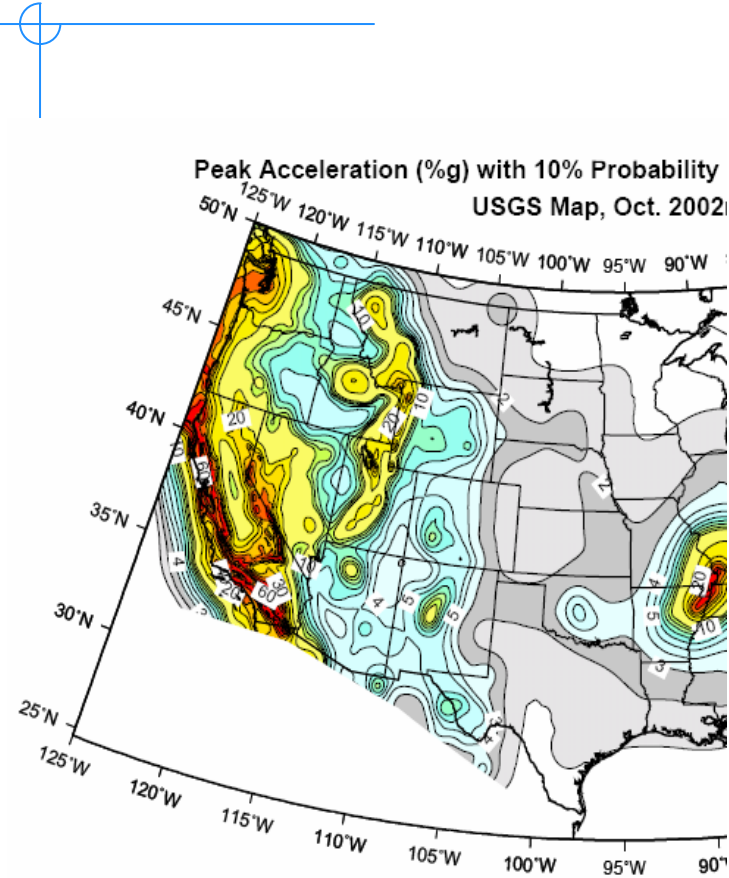
# $S_a(T=1.0s)$ – Strike-Slip, M 7.5, NEHRP B-C



NGA &  
US National Seismic Hazard Maps



# Impact of NGA Models on Seismic Design



- ◆ USGS has extensively reviewed NGA, and is adopting the NGA models for the US National Seismic Hazard Maps
- ◆ Design spectra based on either deterministic or probabilistic approach will be affected by NGA models

WUS 2007/2002 ratio 5-Hz SA w/2%PE50YR

**Period=0.2 sec Spectral Acceleration  
2% P.E. in 50 years**

## Ratio of New/Old:

Using 3 NGA relations

Versus:

2002 Hazard Maps

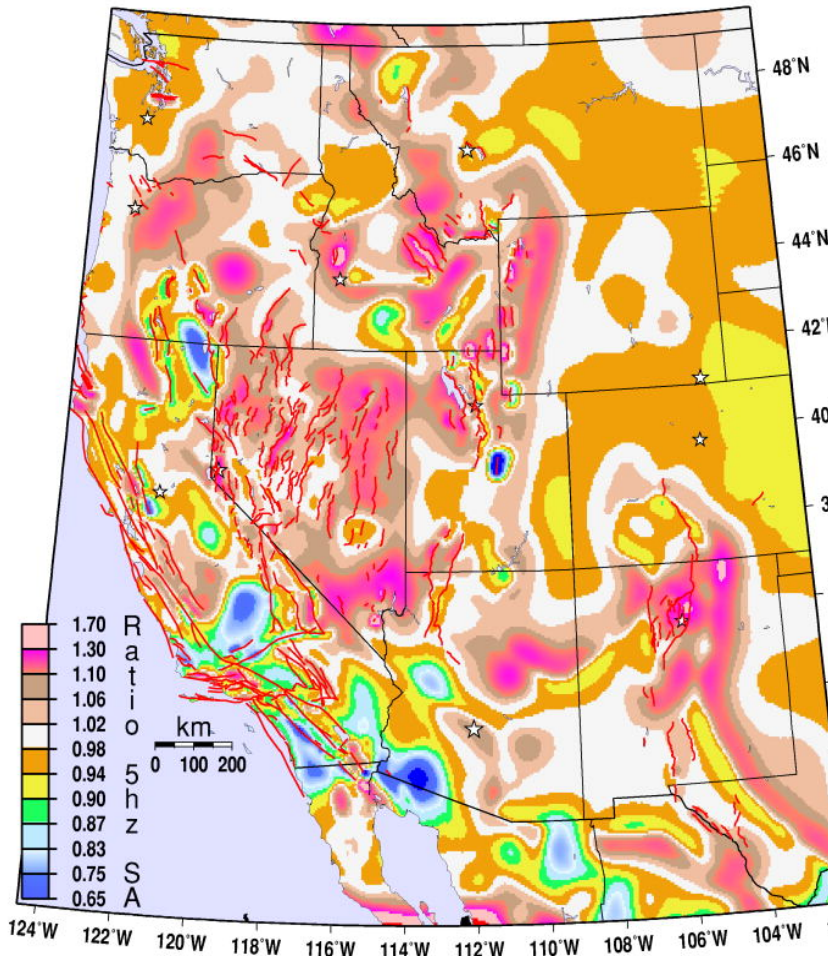
Abrahamson and Silva (1997),

Sadigh et al. (1997),

Boore et al. (1997),

Campbell and Bozorgnia (2003),

Spudich et al. (1999) for extensional areas



GMT Apr 4 08:17 SA, 2007 model over 2002 model. Site 760ms. 5 Hz 2%/50 yr PE. denom is 2002 official 5hz sa

**Preliminary Map**

Using same set of fault sources as 2002 maps; Subduction zone and deep earthquakes are not included

Rock site condition

PSHA WUS 2007/2002 ratio 1-Hz SA w/2%PE50YR

**Period=1.0 sec Spectral Acceleration  
2% P.E. in 50 years**

**Ratio of New/Old:**

**Using 3 NGA relations**

**Versus:**

**2002 Hazard Maps**

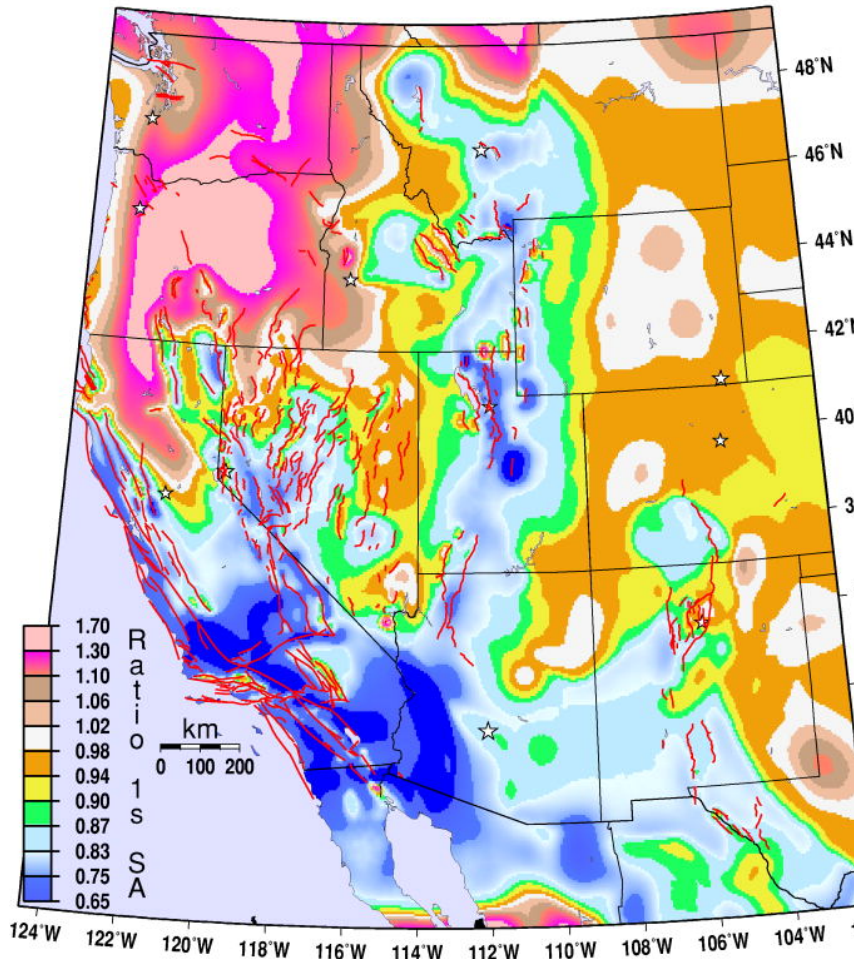
**Abrahamson and Silva (1997),**

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**Boore et al. (1997),**

**Campbell and Bozorgnia (2003),**

**Spudich et al. (1999) for extensional areas**



GMT Apr 4 08:15 Revised SA ratios for WUS using latest agrids & SoCal A. 2007 over 2002. Site 760ms. 1 Hz 2%/50 yr PE. denom is 2002 official

**Preliminary Map**

# Reasons...

- ❖ “Some of the decrease of 1 sec  $S_a$  from the 2002 maps is caused by:
  - ❖ Difference in the  $V_{s30}$  assigned for “rock” sites in the 2002 maps and the average  $V_{s30}$  for rock sites reported in NGA (shouldn’t be a factor in the Campbell-Bozorgnia and Boore-Atkinson NGA relations)”
- ❖ “Most of the decrease is from having additional data from moderate and large earthquakes and improved functional forms to fit the data”

# NGA Reports & Papers

- ◆ Draft final reports are available at PEER web site
- ◆ Including computer files of the models
- ◆ PEER reports are being printed
- ◆ Journal papers will be published in special issue of **EERI Spectra**, March 2008

PEER Website :: PEER Lifelines Program - Microsoft Internet Explorer

http://peer.berkeley.edu/lifelines/repngamodels.html

PEER LIFELINES PROGRAM

Updated Reports of Next Generation Attenuation (NGA) Models

Reports of NGA models are provided on the PEER web site (posted on 3, 2006) for review and trial use. Additional reports will be added to the site as they are completed.

authors and for any  
and not yet  
n be  
Email:

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Campbell-Bozorgnia NGA Ground Motion Relations for the Geometric Mean Horizontal Component and Spectral Ground Motion Parameters

Kenneth W. Campbell  
EQECAT, Inc.  
Beaverton, Oregon  
and  
Yousef Bozorgnia  
Pacific Earthquake Engineering Research Center  
University of California, Berkeley

PEER 2007/02  
MAY 2007

PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

Boore-Atkinson NGA Ground Motion Relations for the Geometric Mean Horizontal Component of Peak and Spectral Ground Motion Parameters

David M. Boore  
U.S. Geological Survey, Menlo Park, California  
and  
Gail M. Atkinson  
University of Western Ontario, Canada

PEER 2007/01  
MAY 2007

# NGA Models Are More Robust Than Old Models Because...

- ◆ **Quantity and quality of data**
- ◆ **Amount of time the developers spent on models**
- ◆ **Interactions among model developers**
- ◆ **Number of independent variables**
- ◆ **Availability of supporting ground motion simulations**
- ◆ **Public participation via workshops and conferences**
- ◆ **Formal peer review commissioned by USGS**



# Finally...It would have been much more difficult to accomplish NGA without a framework of a national earthquake engineering center

◆ Example: For NGA, PEER coordinated efforts, and has had research contracts with:

- USGS (different researchers)
- California Geological Survey
- SCEC (various contracts)
- Various universities
- Several firms and practitioners



# Special Thanks To:

