An Overview of the SCEC CyberShake Project

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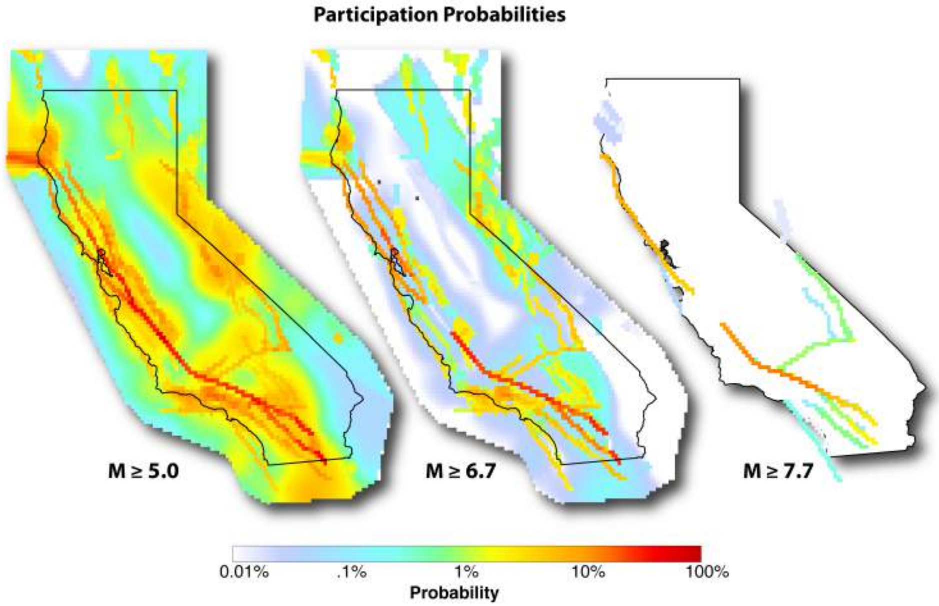
Meeting of the SCEC Committee for the Utilization of Ground Motion Simulations

4 May 2015

Probabilistic Seismic Hazard Model



Working Group on California Earthquake Probabilities (2007)

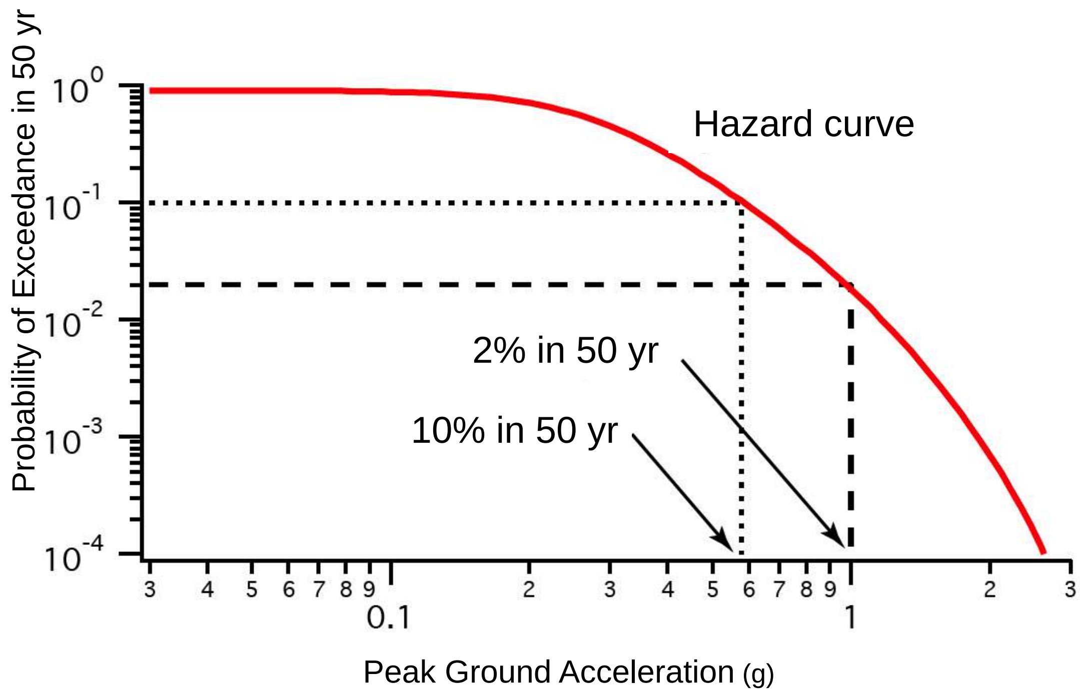
Uniform California Earthquake Rupture Forecast (UCERF2)

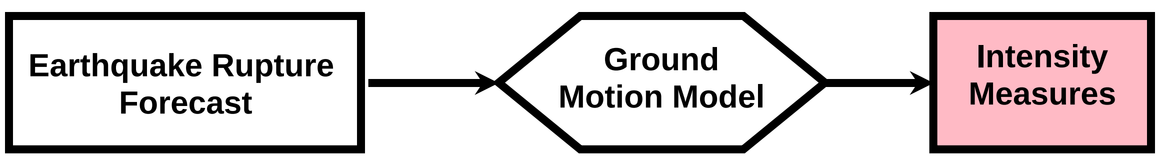
Earthquake Rupture Forecast → **Ground Motion Model** → **Intensity Measures**

$P(S_k)$ $P(Y_n \mid S_k)$ $P(Y_n)$

Probabilistic Seismic Hazard Model

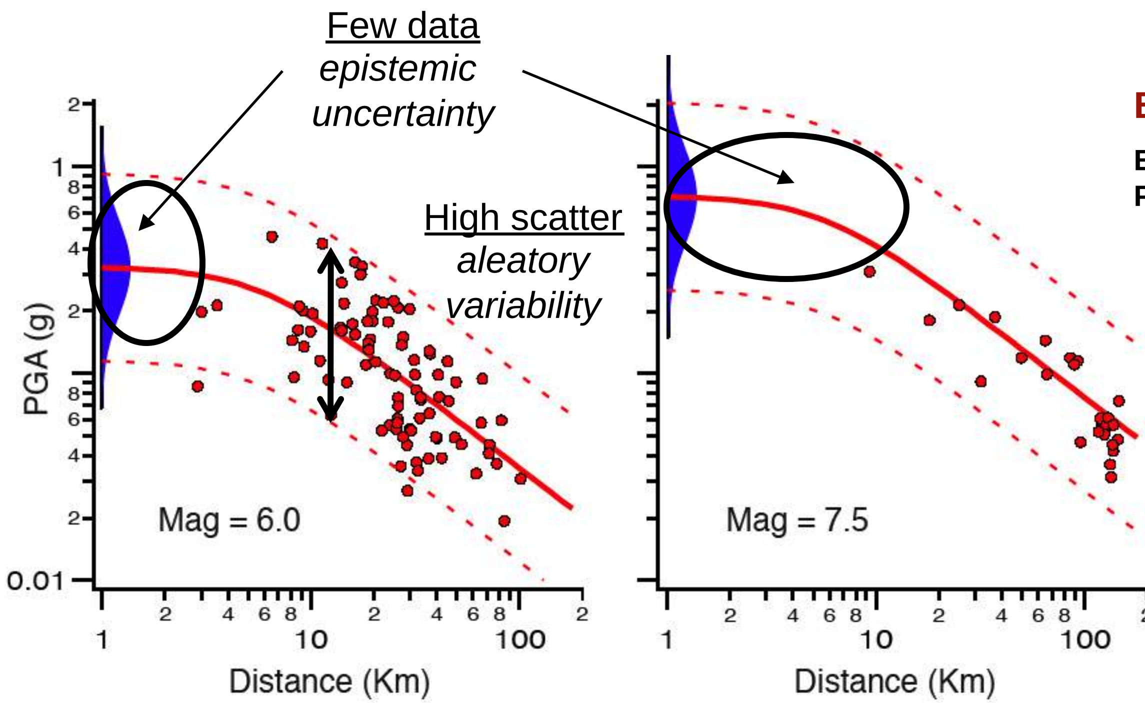
Hazard Curve:
- **Shaking intensity:** **Peak Ground Acceleration (PGA)**
- **Interval:** **50 years**
- **Site:** **Downtown LA**





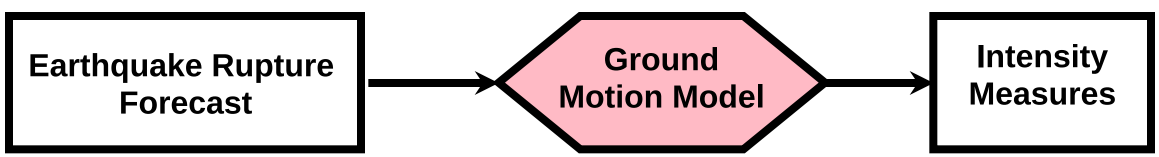
$P(S_k)$ $\quad$ $P(Y_n \mid S_k)$ $\quad$ $P(Y_n)$

Probabilistic Seismic Hazard Model



Boore et al. (1997)

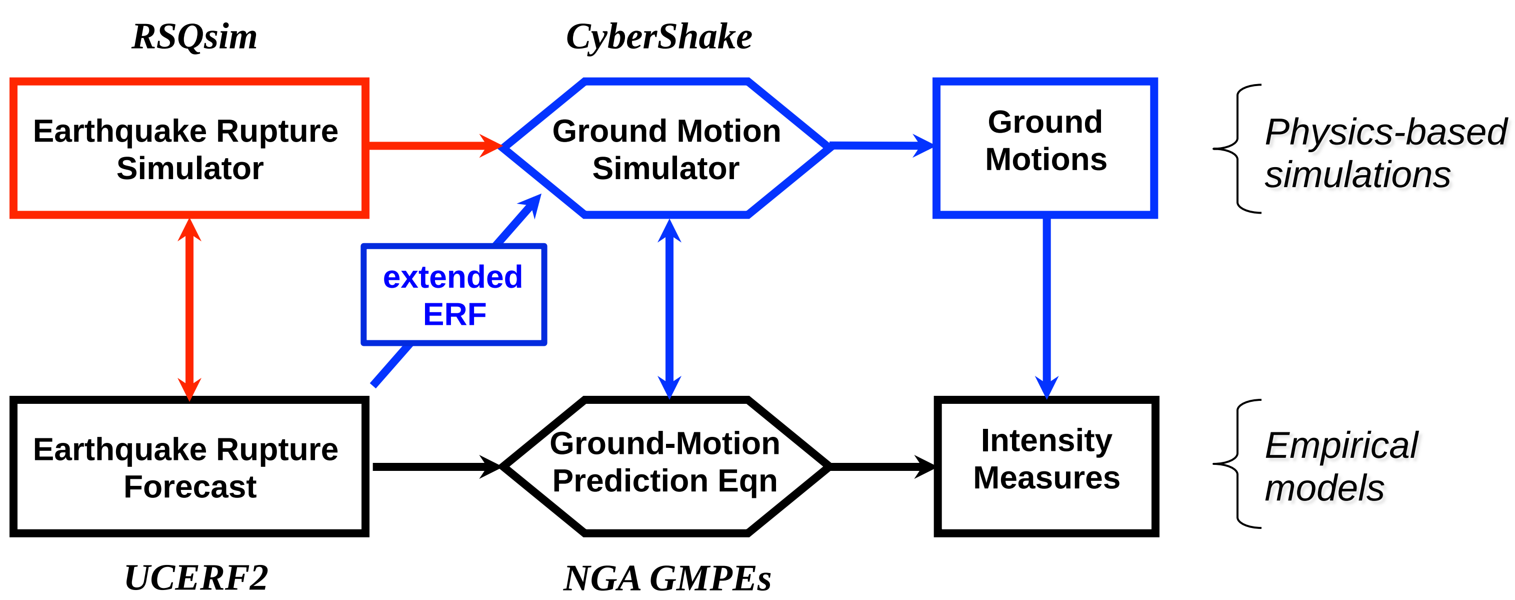
Empirical Ground Motion Prediction Equations (GMPEs)



$P(S_k)$ $P(Y_n \mid S_k)$ $P(Y_n)$

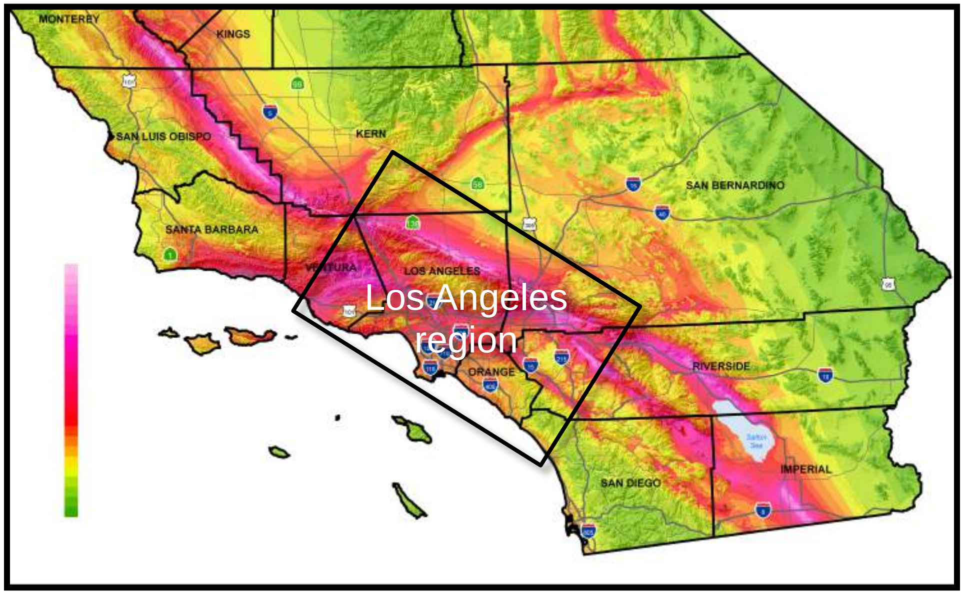
Probabilistic Seismic Hazard Analysis

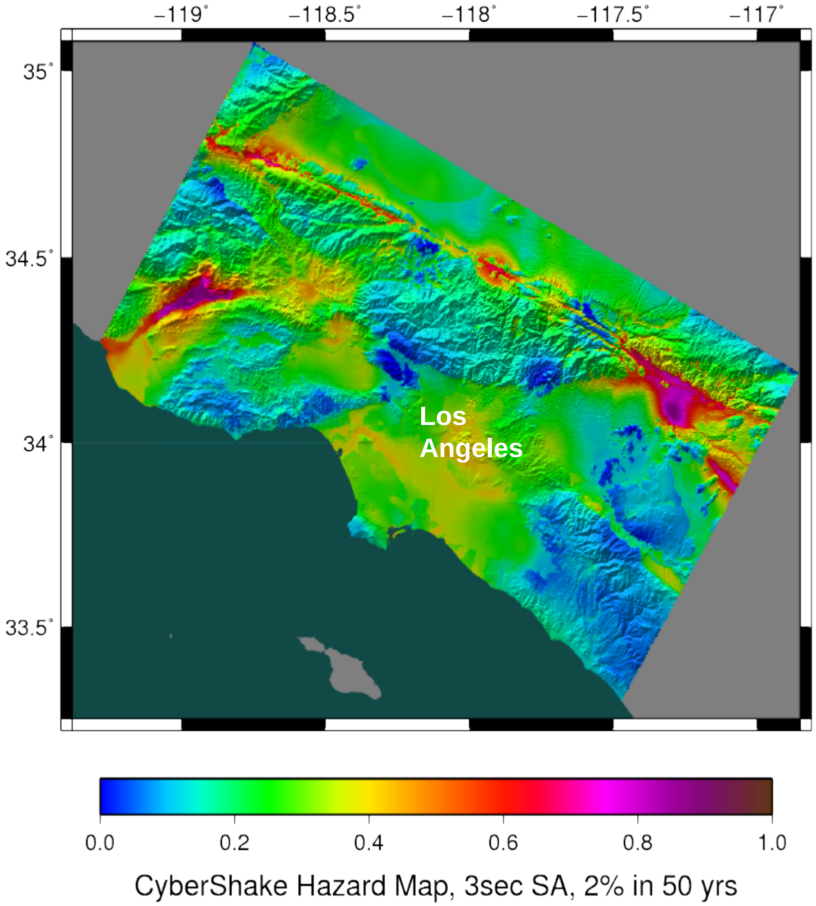
- **PSHA, as currently practiced, is based on empirical statistical models**
- **We seek to improve earthquake forecasting by incorporating more physics through numerical simulations**



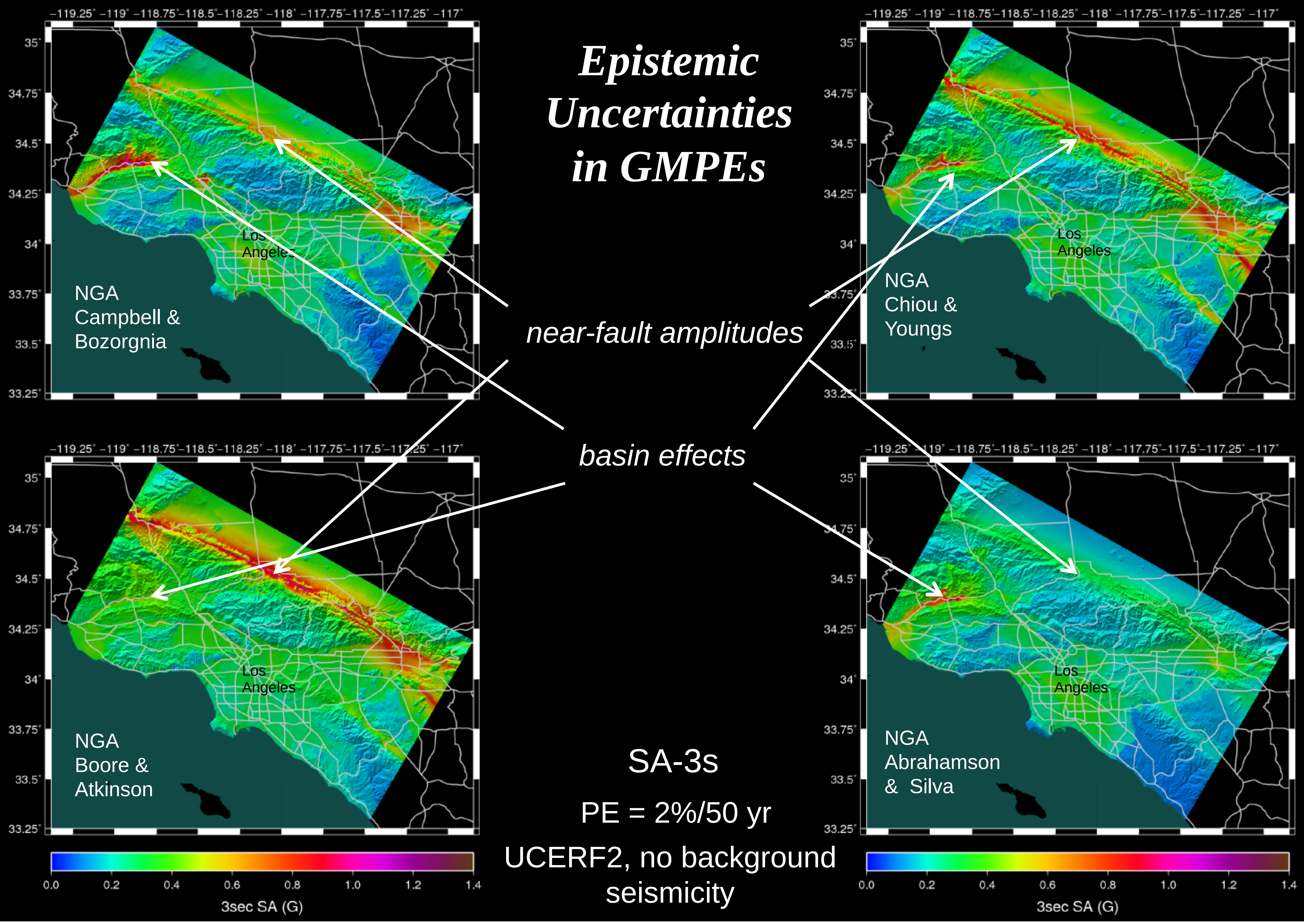
CyberShake Hazard Model 14.2

- **Sites:**
  - **289 sites in the greater Los Angeles region**
- **Ruptures:**
  - **All UCERF2 ruptures within 200 km of site (~14,900)**
- **Rupture variations:**
  - **415,000 per site using Graves-Pitarka pseudo-dynamic rupture model**
- **Seismograms:**
  - **240 million per model**



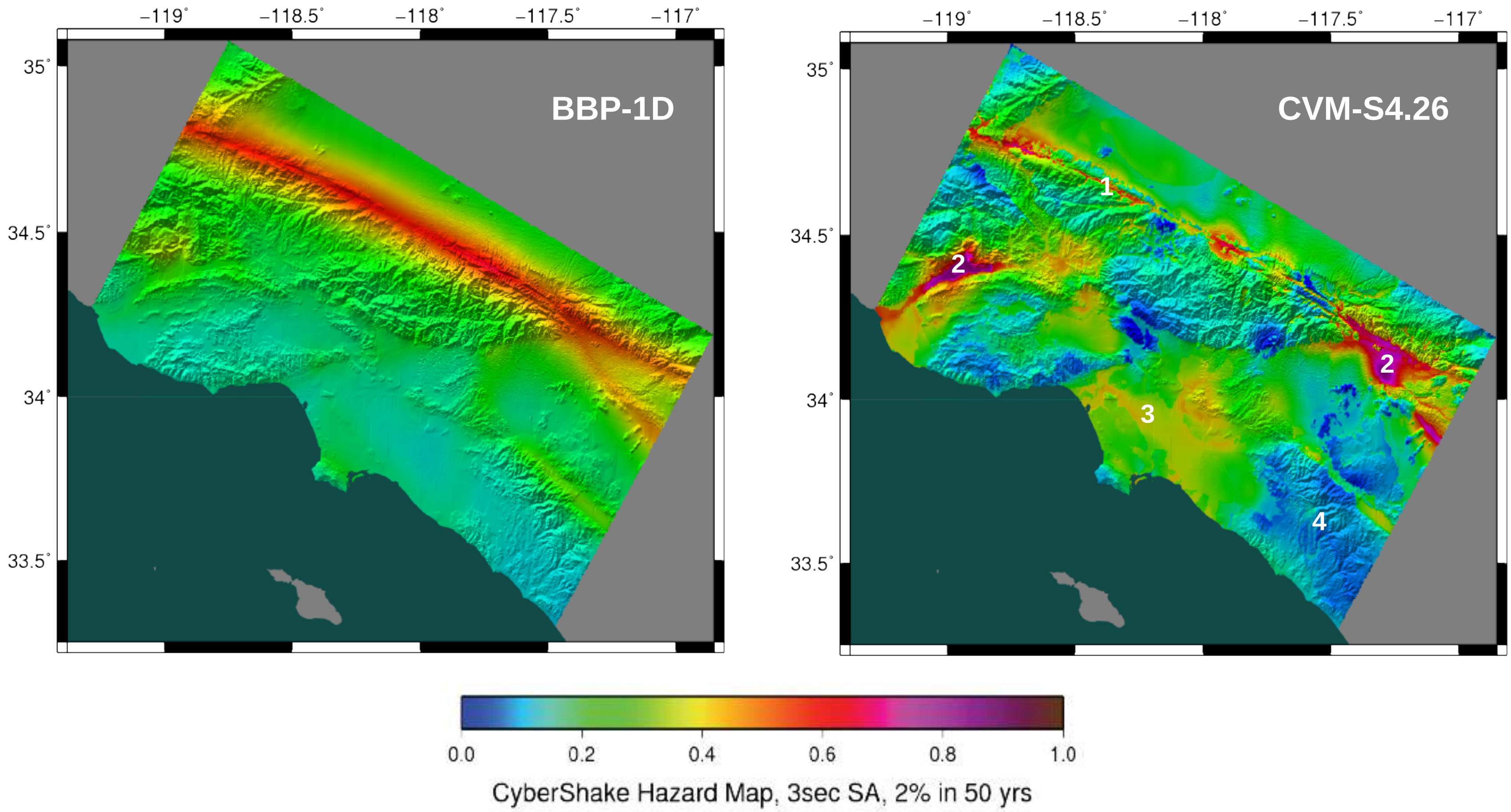


NGA (2008) GMPEs used in the National Seismic Hazard Maps



Southern California Earthquake Center

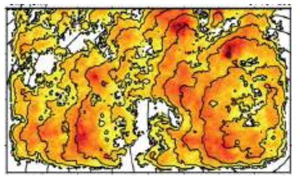
Comparison of 1D and 3D CyberShake Models for the Los Angeles Region

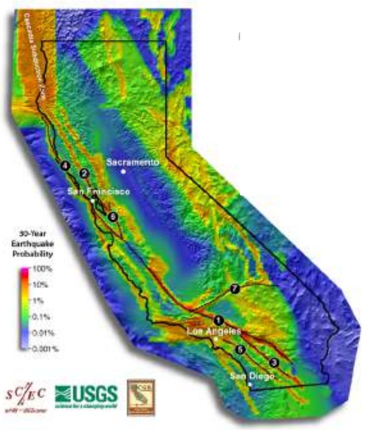


1. lower near-fault intensities due to 3D scattering
2. much higher intensities in near-fault basins
3. higher intensities in the Los Angeles basins
4. lower intensities in hard-rock areas

CyberShake Workflow

Kinematic rupture model

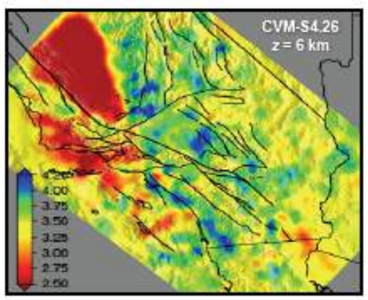




Uniform California Earthquake Rupture Forecast

UCVM

Mesh generation
1 job per site
MPI, 320 cores



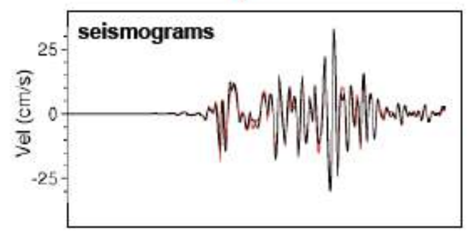
Full-3D tomographic model of S. California

AWP-ODC

SGT computation
2 jobs per site
MPI, 10k CPUs or 100 GPUs

SeisSynth

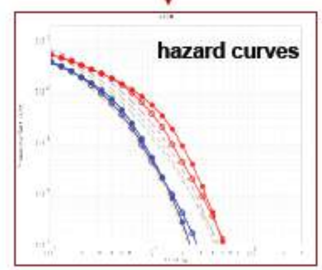
Post-processing
415,000 jobs per site
serial

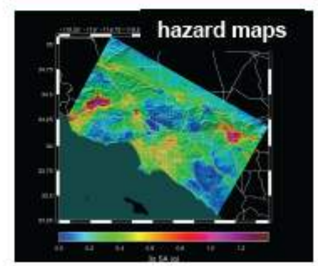


data transfer

Data Product Generation

Populate DB, construct queries
4 jobs per site

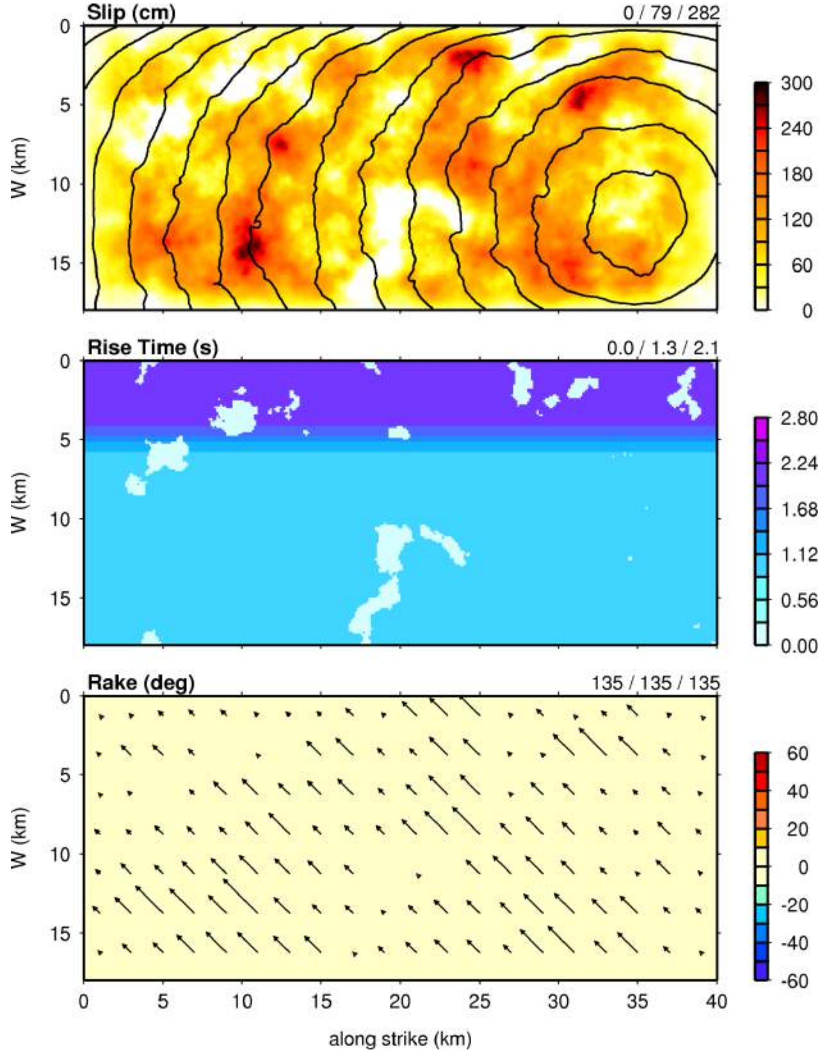




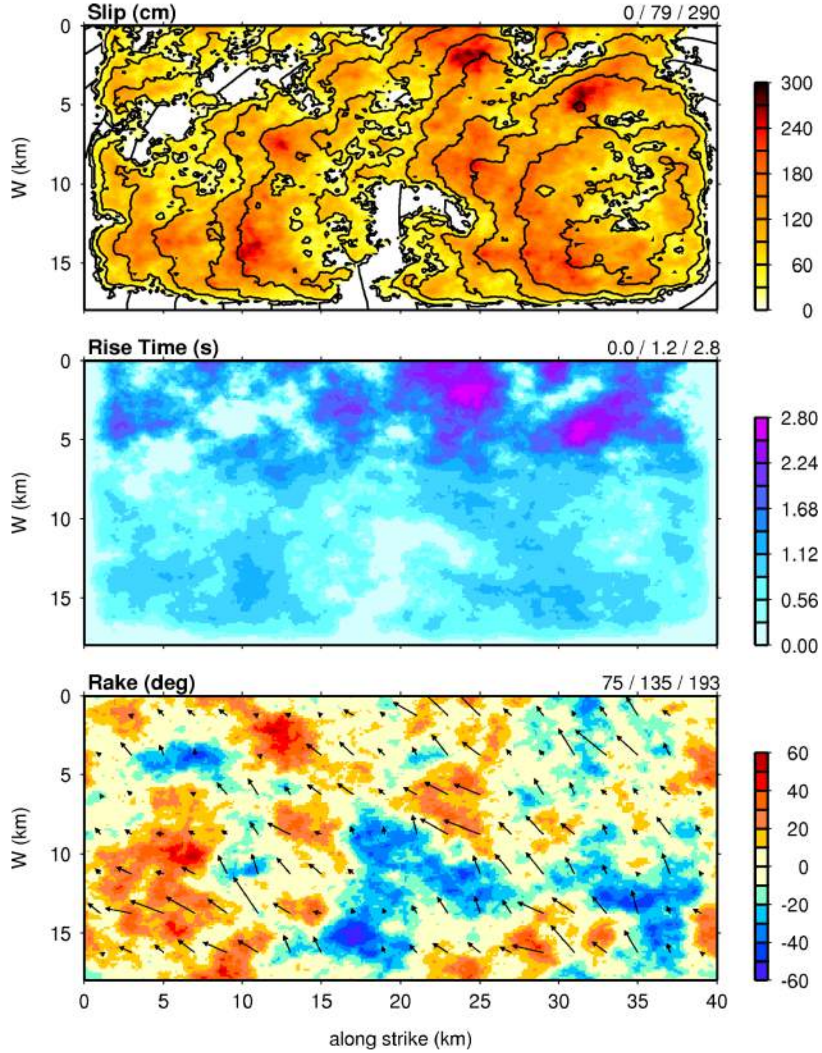
Conditional Slip Distribution

Graves-Pitarka Pseudo-Dynamic Rupture Models

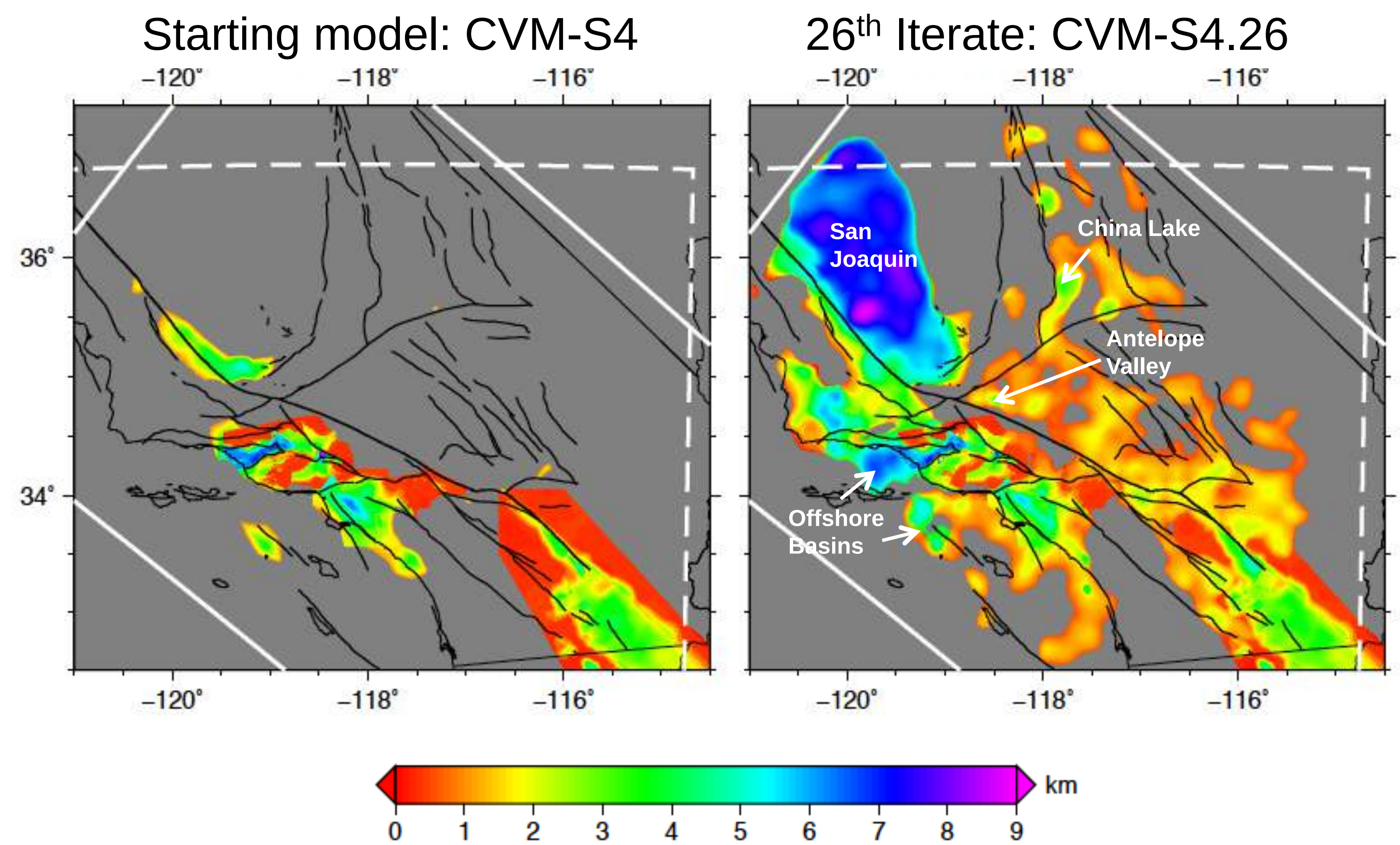
GP07
used in CS11



GP10
used in CS13

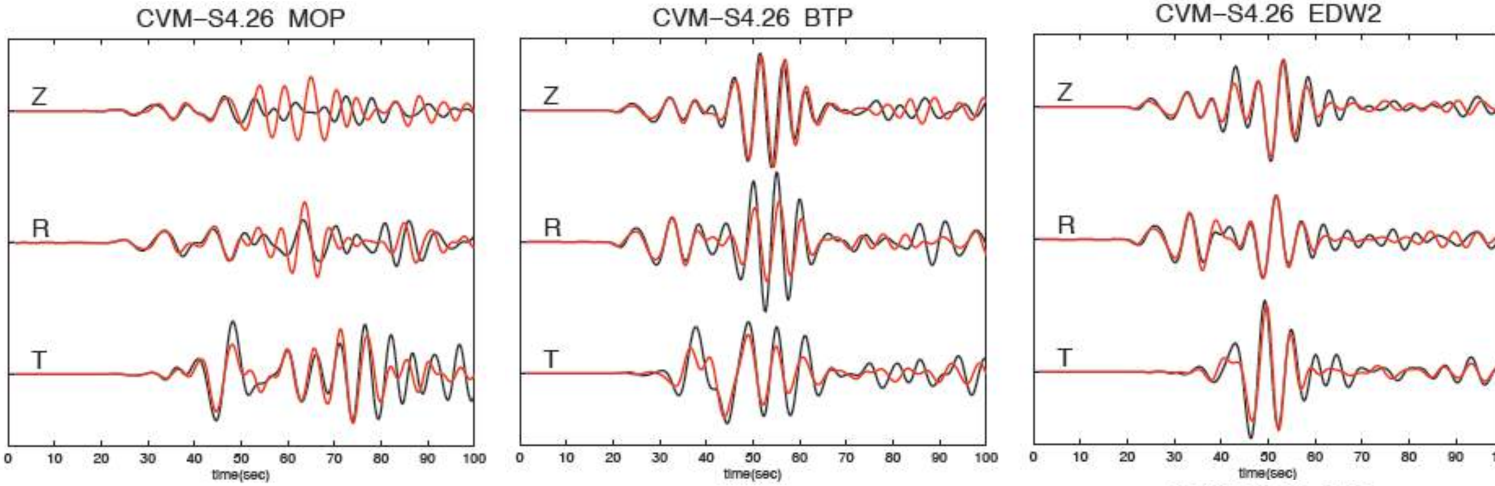


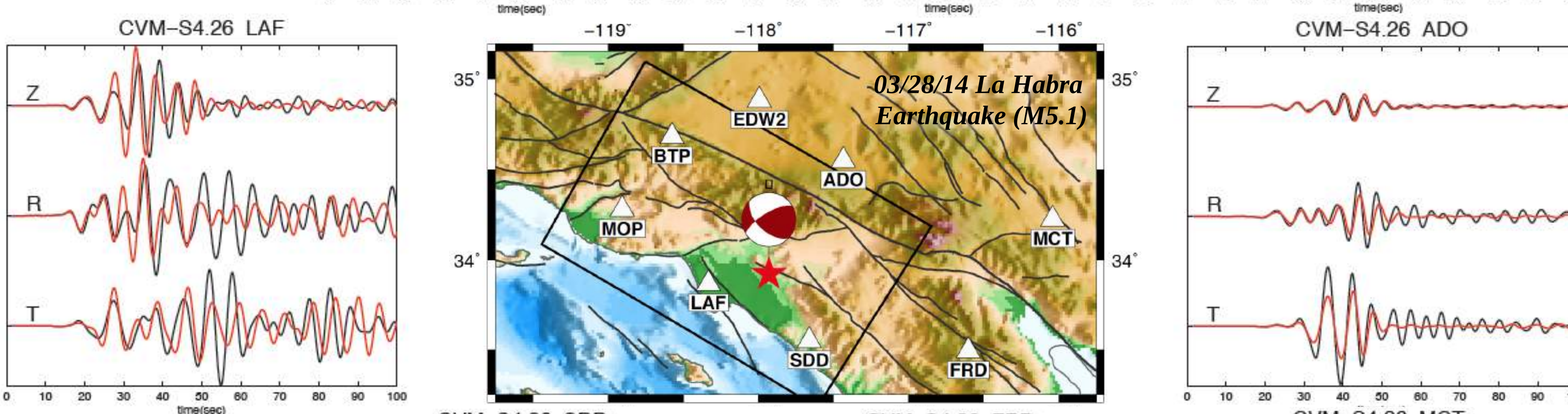
Comparison of Basin Structures

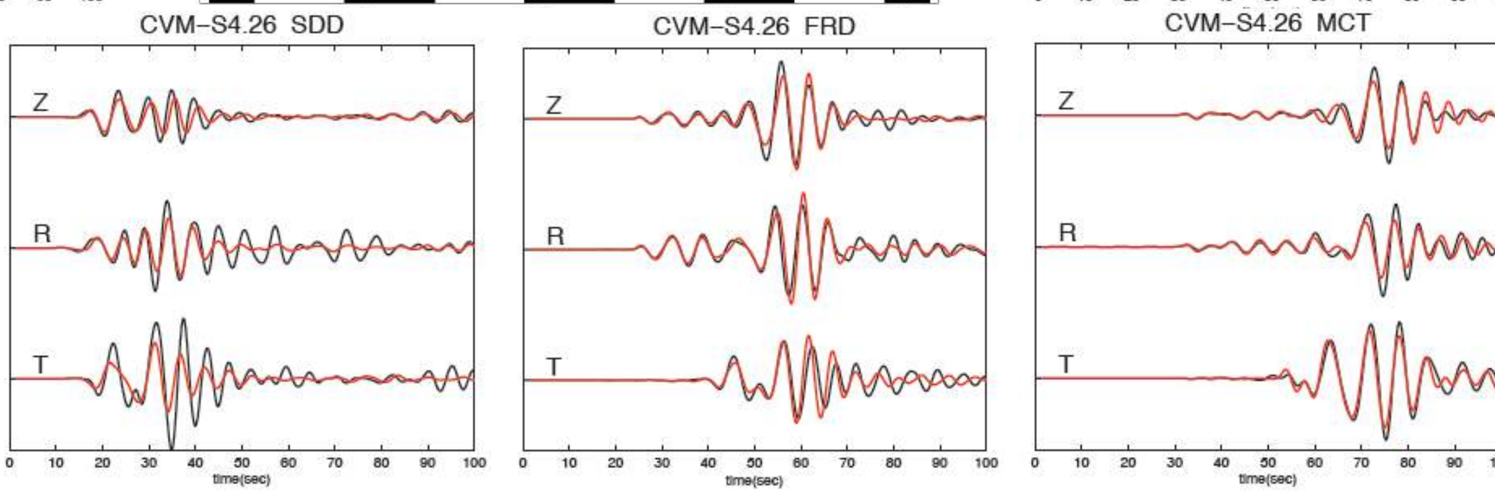


Z_{2500} : iso-velocity surfaces at $V_S = 2.5$ km/s

Test of CVM-S4.26 synthetics against data from the 03/28/14 La Habra Earthquake (M5.1)







data in black,
synthetics in red,
low-passed at 0.2 Hz

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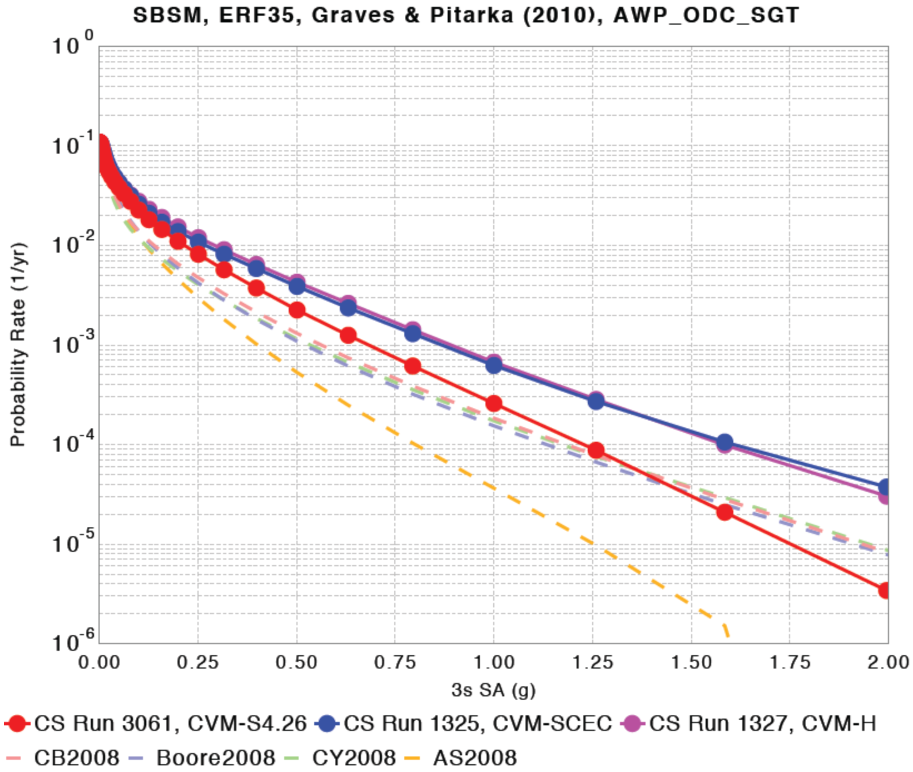
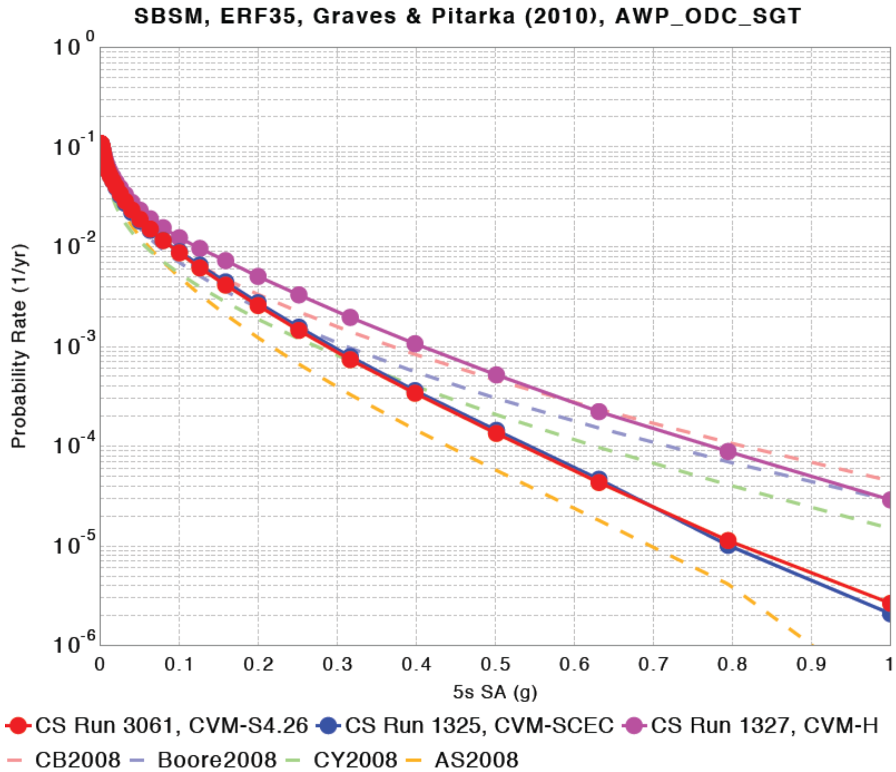
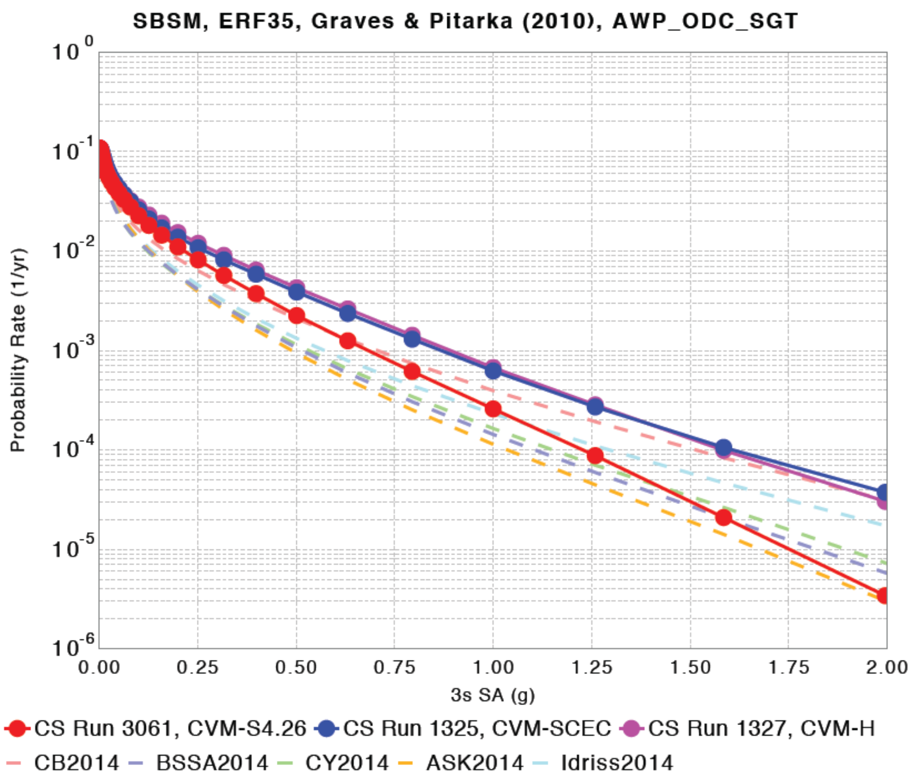
NGA08-CyberShake Comparisons

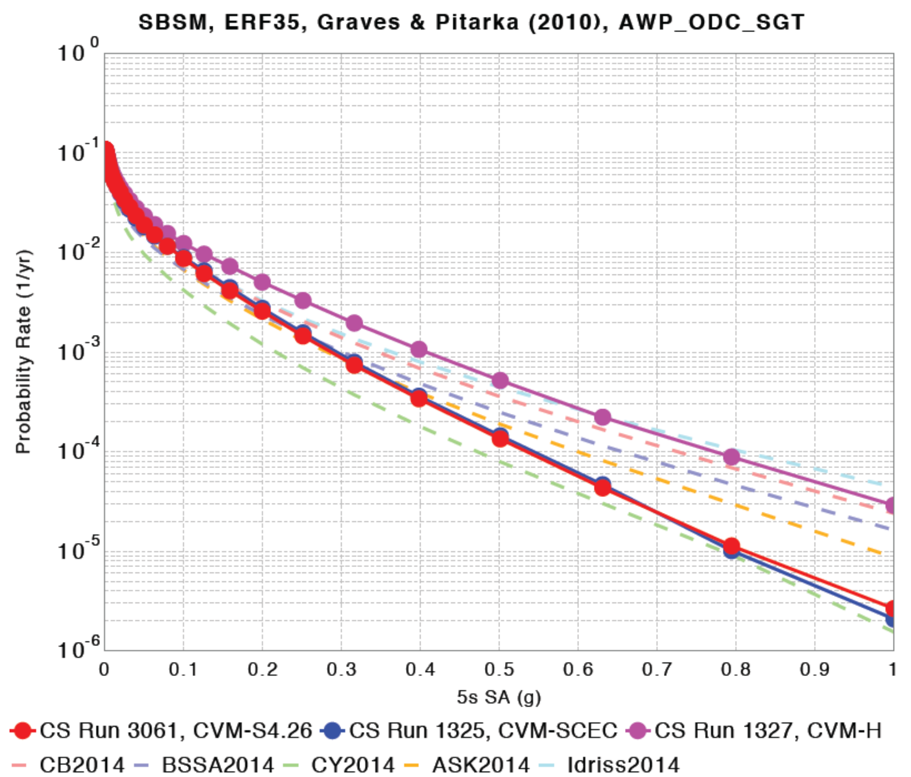




Site SBSM

NGA14-CyberShake Comparisons





Site SBSM

CyberShake Research Issues

- Validation of long-period results
  - GMPE comparisons
  - Historical and new events
  - Virtual earthquakes synthesized from ambient noise
- Characterization of epistemic uncertainties
  - Earthquake rupture forecast
  - Pseudo-dynamic rupture model
  - 3D velocity structure
  - Site effects
- Push to shorter periods
  - Fault complexity
  - Near-fault plasticity
  - Frequency-dependent attenuation
  - Near-surface nonlinearity and small-scale heterogeneity

Averaging-Based Factorization

(Wang & Jordan, *BSSA*, 2014)

- **Representation of excitation functionals**

Expected shaking intensities constructed by averaging over slip variations (s), hypocenters (x), sources (k), and sites (r)

$$G(r,k,x,s) = A + B(r) + C(r,k) + D(r,k,x) + E(r,k,x,s)$$

$G(r,k,x,s)$	A	$B(r)$	$C(r,k)$	$D(r,k,x)$	$E(r,k,x,s)$
ln (Y)	level	site effect	path effect	directivity effect	slip complexity effect

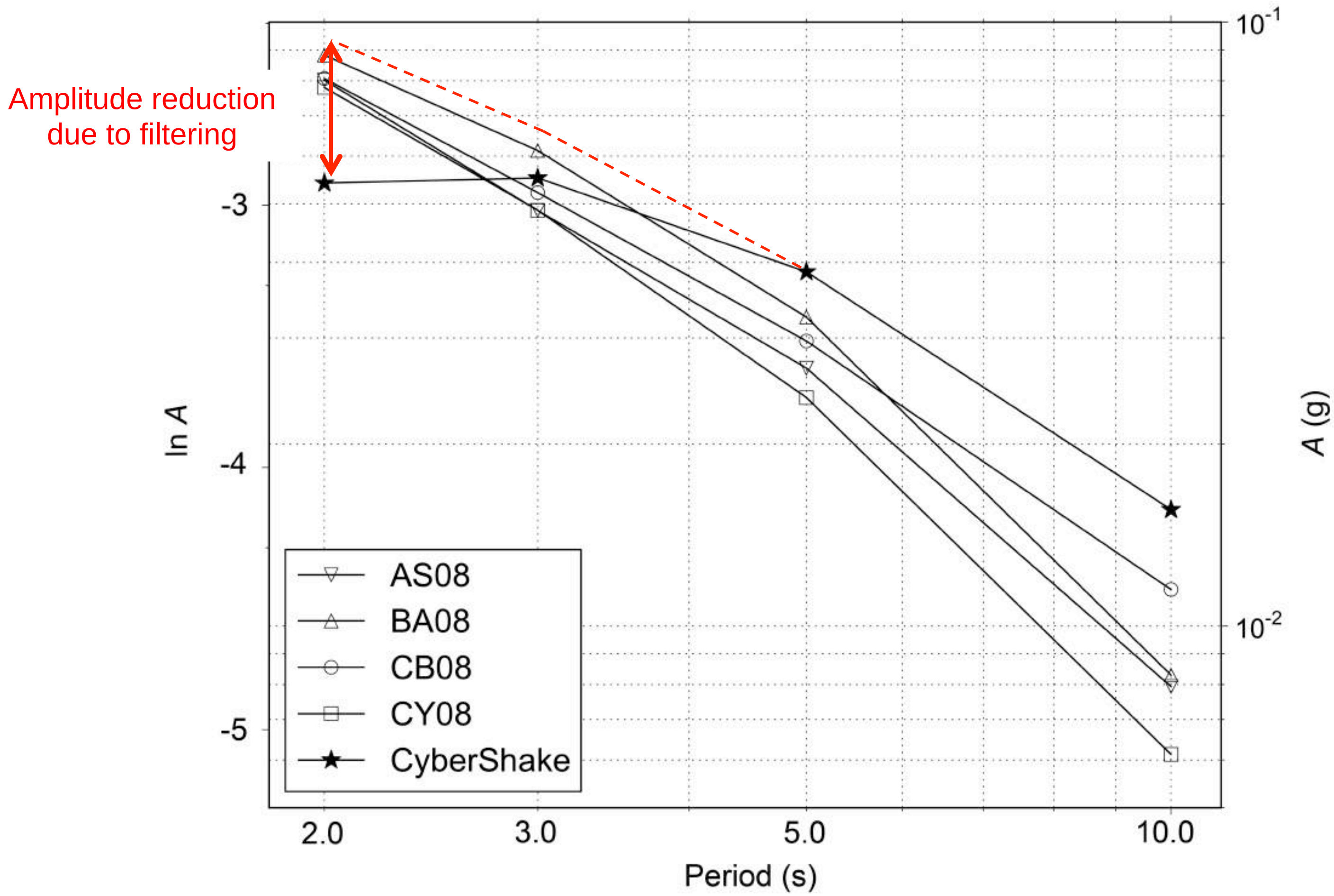
- **Representation of excitation variance**

$$\mathrm{Var}[G] = \bar{\sigma}_G^2 \equiv \left\langle [G(r,k,x,s) - A]^2 \right\rangle_{S,X,K,R}$$

$$= \sigma_B^2 + \left\langle \sigma_C^2(r) \right\rangle_R + \left\langle \sigma_D^2(r,k) \right\rangle_{K,R} + \left\langle \sigma_E^2(r,k,x) \right\rangle_{X,K,R}$$

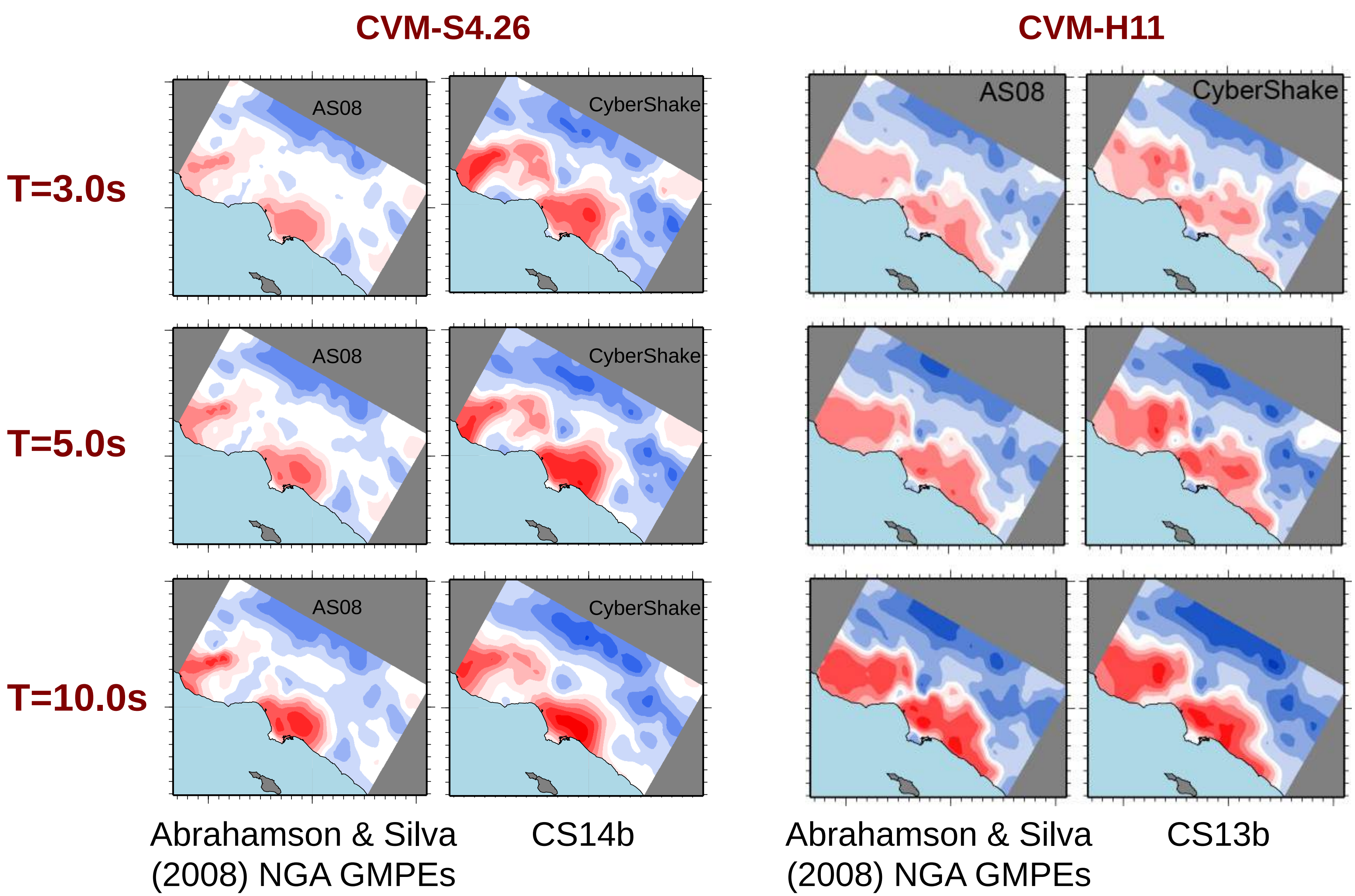
$$\equiv \sigma_B^2 + \bar{\sigma}_C^2 + \bar{\sigma}_D^2 + \bar{\sigma}_E^2$$

A-values of CyberShake models



Dependence of Basin Effects on Velocity Structures

(SA corrected for V_{S30} using BA08)



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