Introduction to SCEC CyberShake

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for

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SCEC
an NSF+USGS center

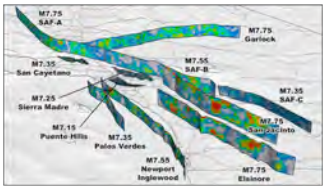
Contributions to Ground Motions

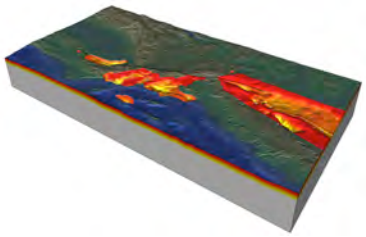
- Source effects
  - Detailed fault geometry
  - Fault magnitude distribution
  - Recurrence models (over time)

  Earthquake Rupture Forecasts
- Path/wave propagation effects
  - Distance effects, damping
  - Effect of basin structures and heterogeneities

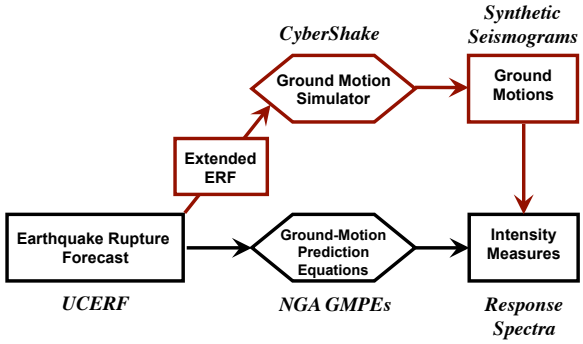
  Crustal models and wave propagation codes or simple attenuation rules
- Site effects
  - Wave propagation to the surface

  Nonlinear site response models
- Other relevant site-source effects
  - Hanging wall effects
  - Rupture directivity

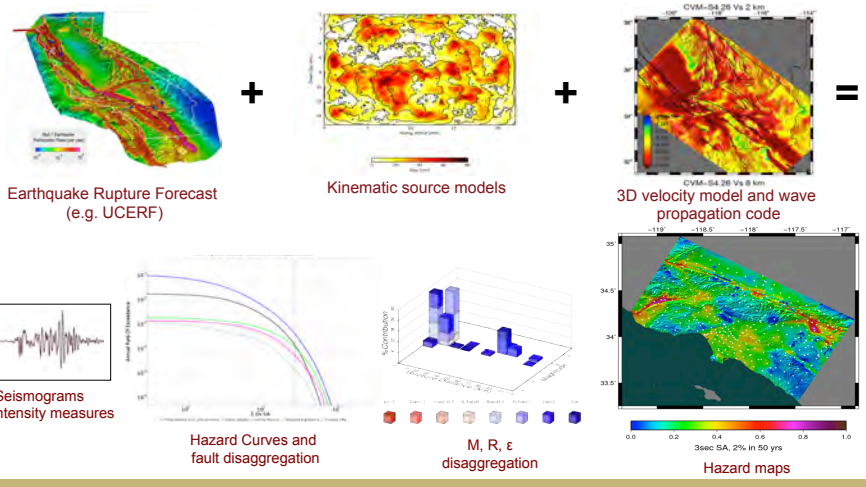




PSHA – Traditional and CyberShake



CyberShake: PSHA from Physics-Based Simulations



ShakeOut Scenario – 2008

M7.8 earthquake simulation on Southern San Andreas Fault
(deterministic band *f* = 0-1 Hz; stochastic band *f* = 1-10 Hz)

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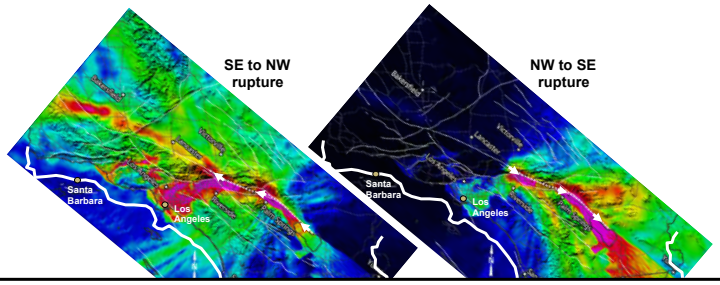
TeraShake Simulations of M7.7 Earthquake on the San Andreas Fault



Simulations indicated strong 3D focusing of ground motions

- **Quantified the importance of source directivity and basin excitation effects in earthquake forecasting and PSHA**

Olsen, K. B., S[illegible], A. Chourasia, M. Faerman, R. Moore, P. Maechling & T. H. Jordan (2006)

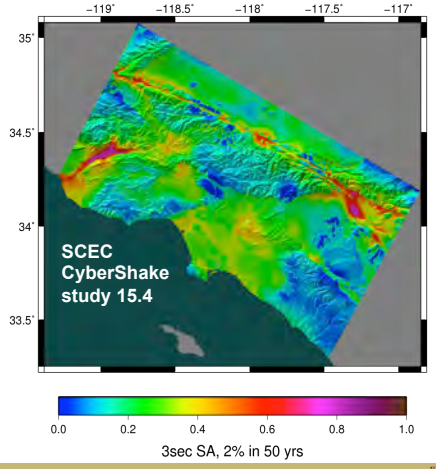
Peak ground velocity (PGV) maps

CyberShake: first complete PSHA model derived from simulations

CyberShake 15.4 Study

Los Angeles urban seismic hazard model

- **Seismic frequency limit f_{max} increased to 1 Hz**
- **Spatial sampling increased to 336 sites**
  - **> 330 million synthetic seismograms**
  - **> 22 billion shaking intensity measures**
- **Run on NCSA *Blue Waters* and OLCF *Titan***
- **Computational makespan of 38 days**
  - **795,000 GPU-hours, 19 million CPU-hours**
    - **956,000 node-hours on NCSA *Blue Waters***
    - **428,000 node-hours on OLCF *Titan***
  - **3.2x code efficiency gain**
  - **post-processing file I/O reduced by 99.9%**
  - **> 1 petabyte of data managed**
- **Fully automated using workflow tools**
  - **42 concurrent workflows running on average**



CyberShake: first complete PSHA model derived from simulations

CyberShake 15.4 Study

Los Angeles urban seismic hazard model

CyberShake is a transformative step towards physics-based PSHA

- **Used as database for machine-learning of California Earthquake Early Warning system**
- **Coupled to UCERF3-ETAS as prototype operational earthquake forecasting system**
- **Leading model in USGS Urban Seismic Hazard Mapping Project (Moschetti)**
- **Source of new UGMS model for long T structures (this group)**

- 428,000 node-hours on OLCF *Titan*
- 3.2x code efficiency gain
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- > 1 petabyte of data managed
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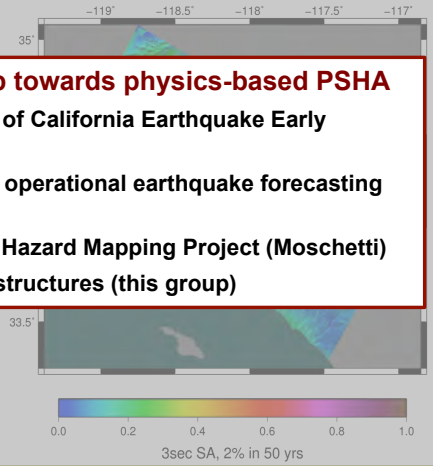
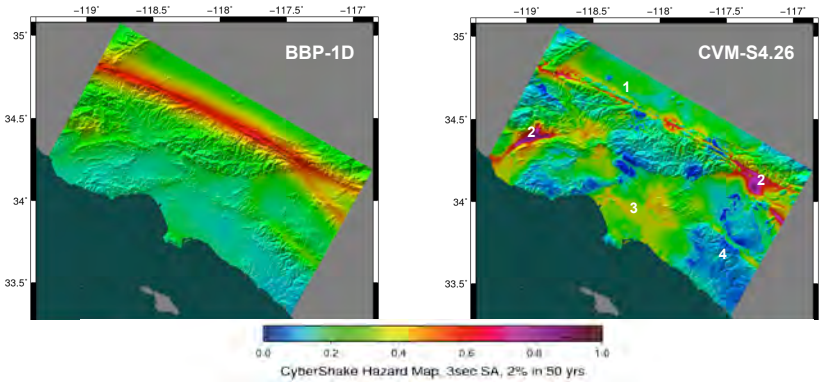


Comparison of 1D and 3D CyberShake Models for the Los Angeles Region



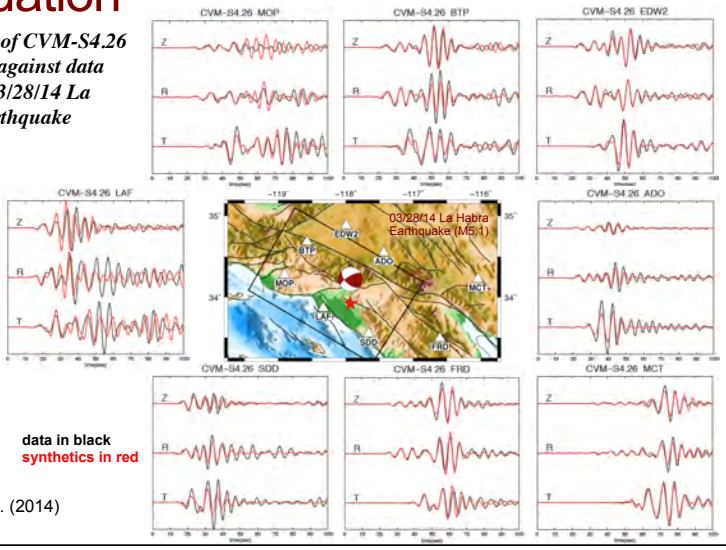
CyberShake Hazard Map, 3sec SA, 2% in 50 yrs

CyberShake Hazard Map, 3sec SA, 2% in 50 yrs

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**

Validation

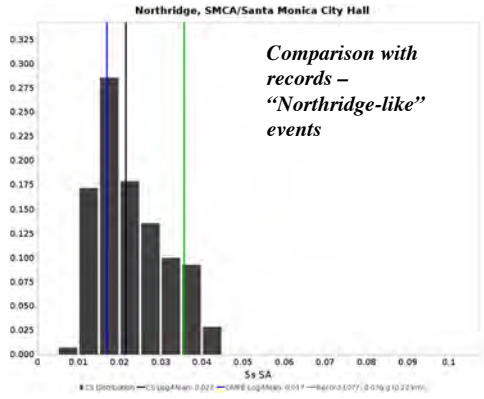
Validation of CVM-S4.26 synthetics against data from the 03/28/14 La Habra Earthquake (M5.1) f≤0.2 Hz



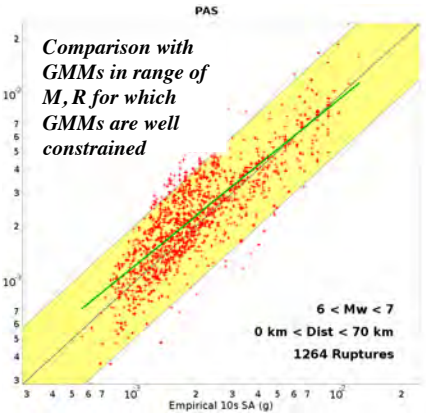
data in black
synthetics in red

Lee et al. (2014)

Validation

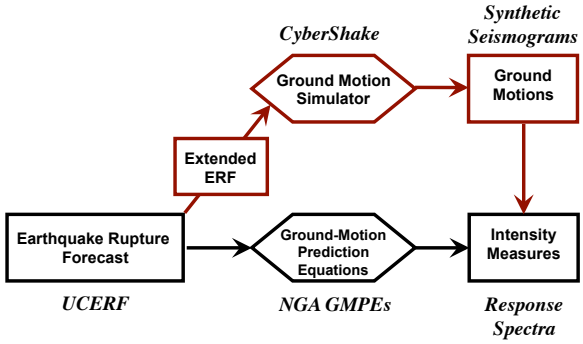


Comparison with records – "Northridge-like" events

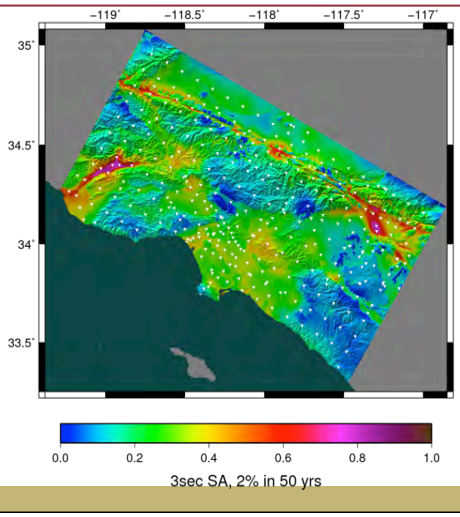


Comparison with GMMs in range of M, R for which GMMs are well constrained

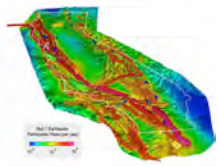
PSHA – Traditional and CyberShake



CyberShake Map 15.4 for UGMS



Thank you!



Earthquake Rupture Forecast
(e.g. UCERF)

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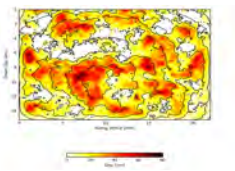

Kinematic source models

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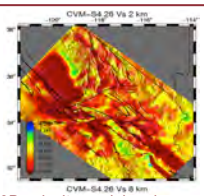

3D velocity model and wave
propagation code

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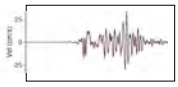
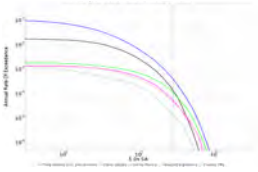
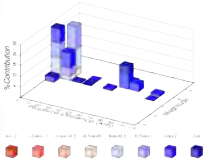


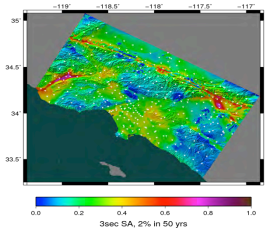
Seismograms
and intensity measures



Hazard Curves and
fault disaggregation



M, R, ε
disaggregation



Hazard maps

SCEC