The Case for SCEC

Thomas H. Jordan

Former Director, Southern California Earthquake Center

SCEC Annual Meeting, 11 Sept 2017

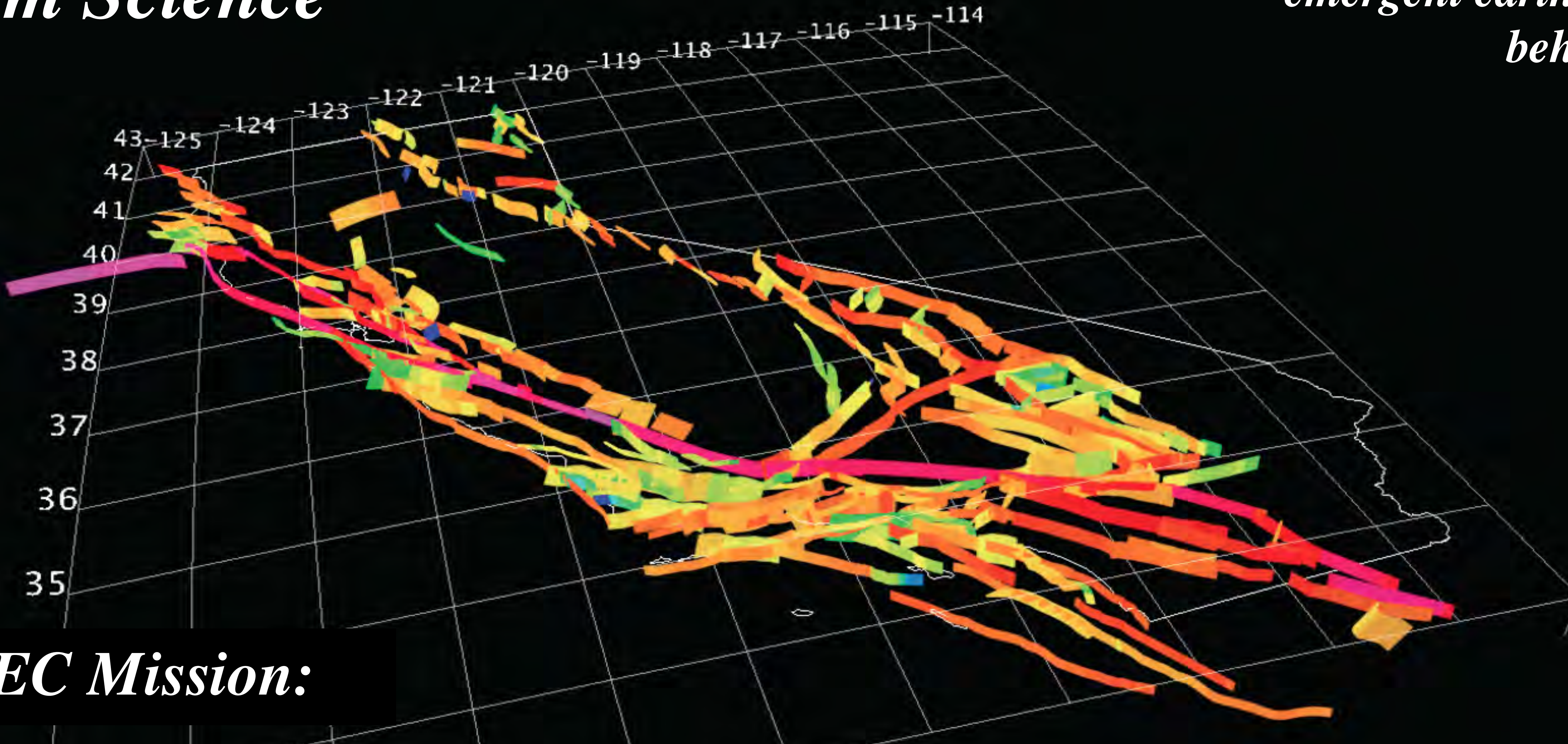
an NSF+USGS center

The Case for SCEC

1. **The SCEC community has created an interdisciplinary, multi-institutional "virtual organization" for coordinating earthquake research in Southern California**
   - Communicates useful knowledge for reducing earthquake risk and improving resilience
2. **SCEC sustains deep collaborations within an open, investigator-driven program of fundamental earthquake research**
   - Involves over 1000 earthquake experts at more than 70 research institutions
3. **SCEC partners with many organizations to develop and disseminate authoritative earthquake information and to educate the public about the earthquake threat**
   - Coordinates the Earthquake Country Alliance in California and ShakeOut drills worldwide
4. **SCEC collaboratories provide a unique cyberinfrastructure for system-level modeling of earthquake phenomena**
   - In 2017, SCEC was awarded 447 million CPU-hours on the nation's most powerful supercomputers
5. **Earthquake system science is revolutionizing seismic hazard analysis and earthquake forecasting**
   - A continuing program of coordinated interdisciplinary research will be necessary to refine and validate the new tools of physics-based PSHA and OEF

Earthquake System Science

Physical representations of active fault systems and emergent earthquake behaviors



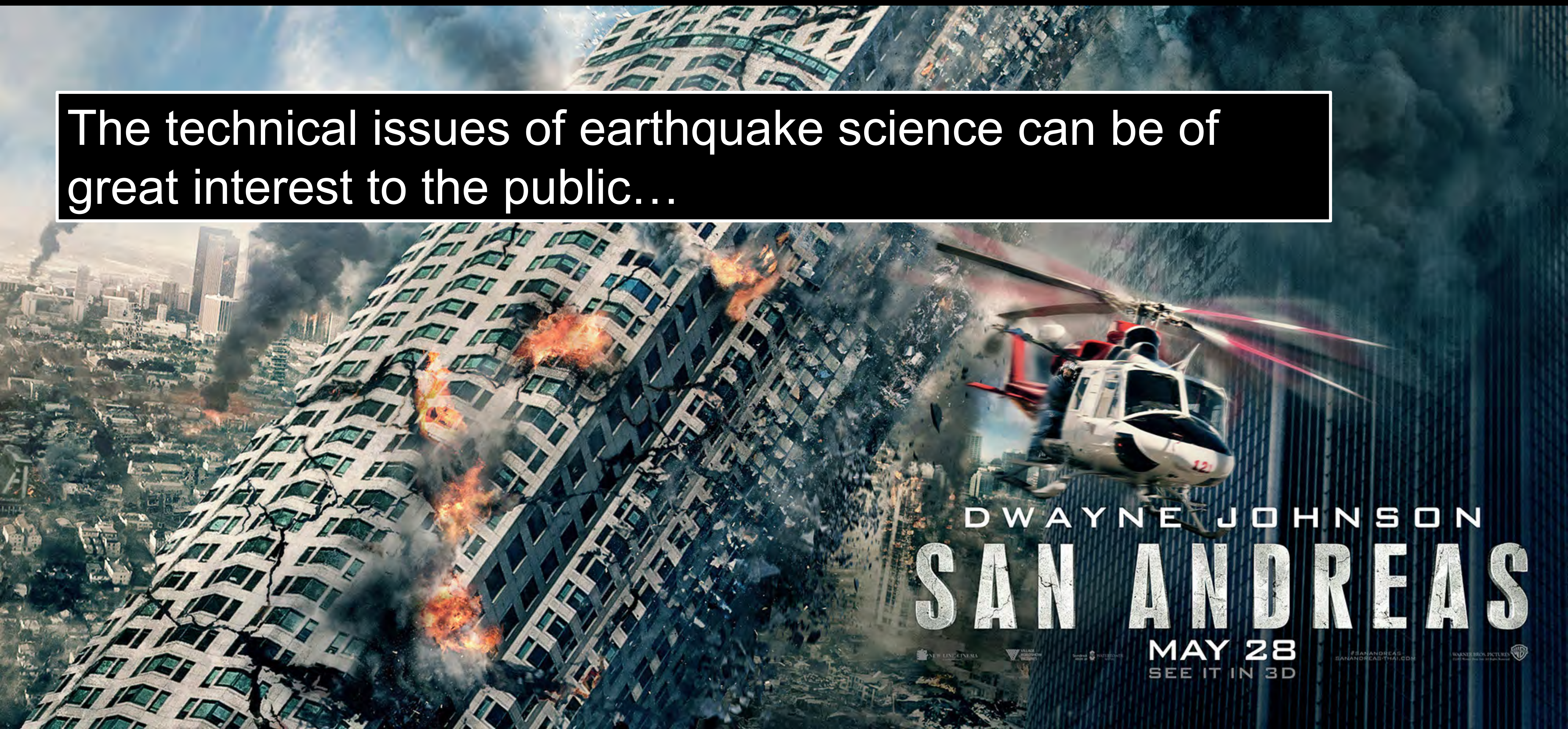
SCEC Mission:

1. Gather data on earthquakes in Southern California and elsewhere → **2. Integrate information into a comprehensive, physics-based understanding of earthquake phenomena** → **3. Communicate understanding as useful knowledge for reducing earthquake risk and improving community resilience**

Earthquake System Science

Physical representations of active fault systems and emergent earthquake behaviors

The technical issues of earthquake science can be of great interest to the public…



Dynamics of fault rupture

Nonlinear shallow crustal effects

Tsunami generation

Performance of tall buildings

Keiiti Aki

SCEC Founding Director

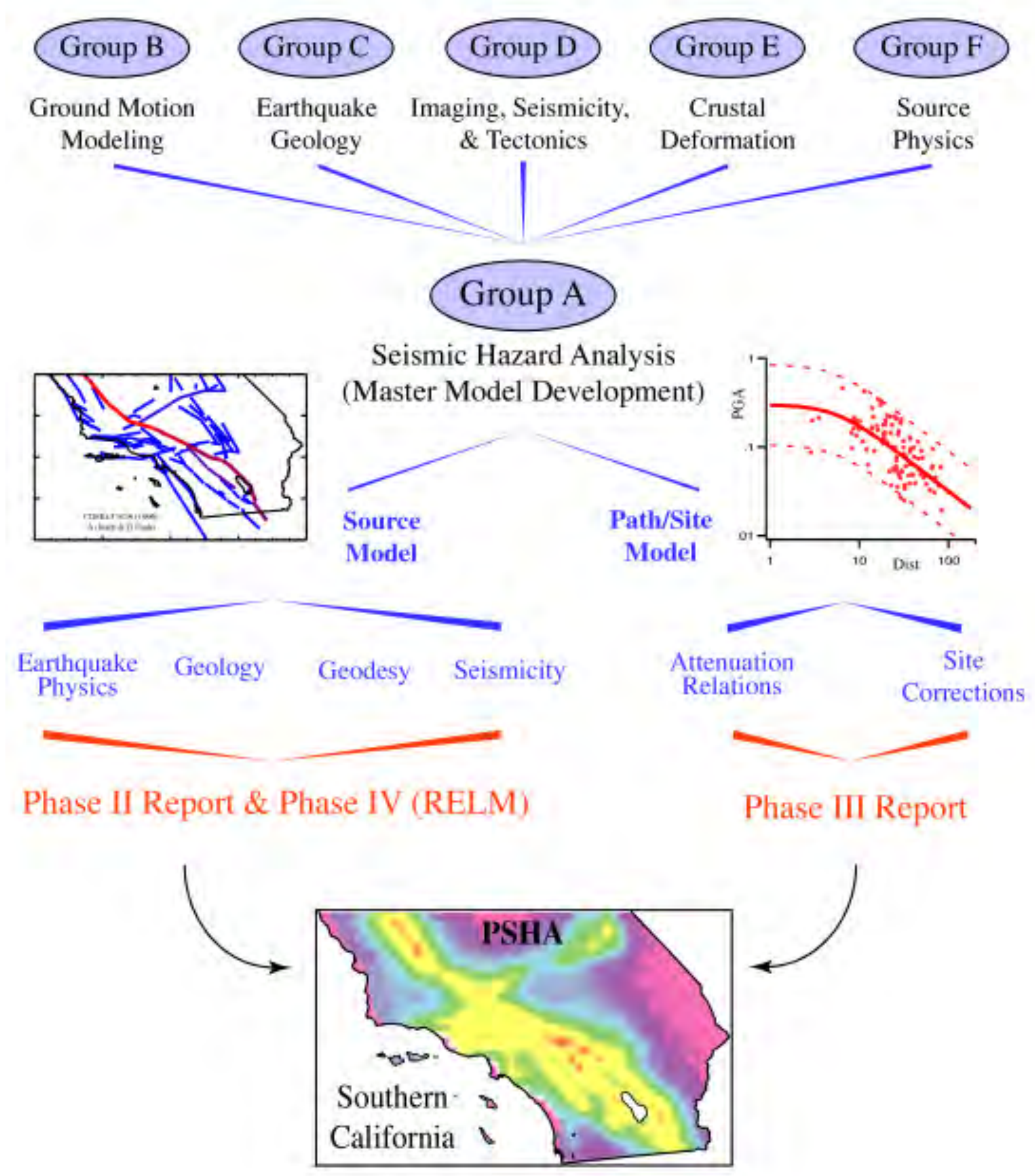
"… the goal of SCEC is to integrate research findings from various disciplines in earthquake-related science to develop a prototype probabilistic seismic hazard model (master model) for Southern California..."

Through appropriate interaction and feedback, the requirements of the master model will guide data acquisition and interpretation."

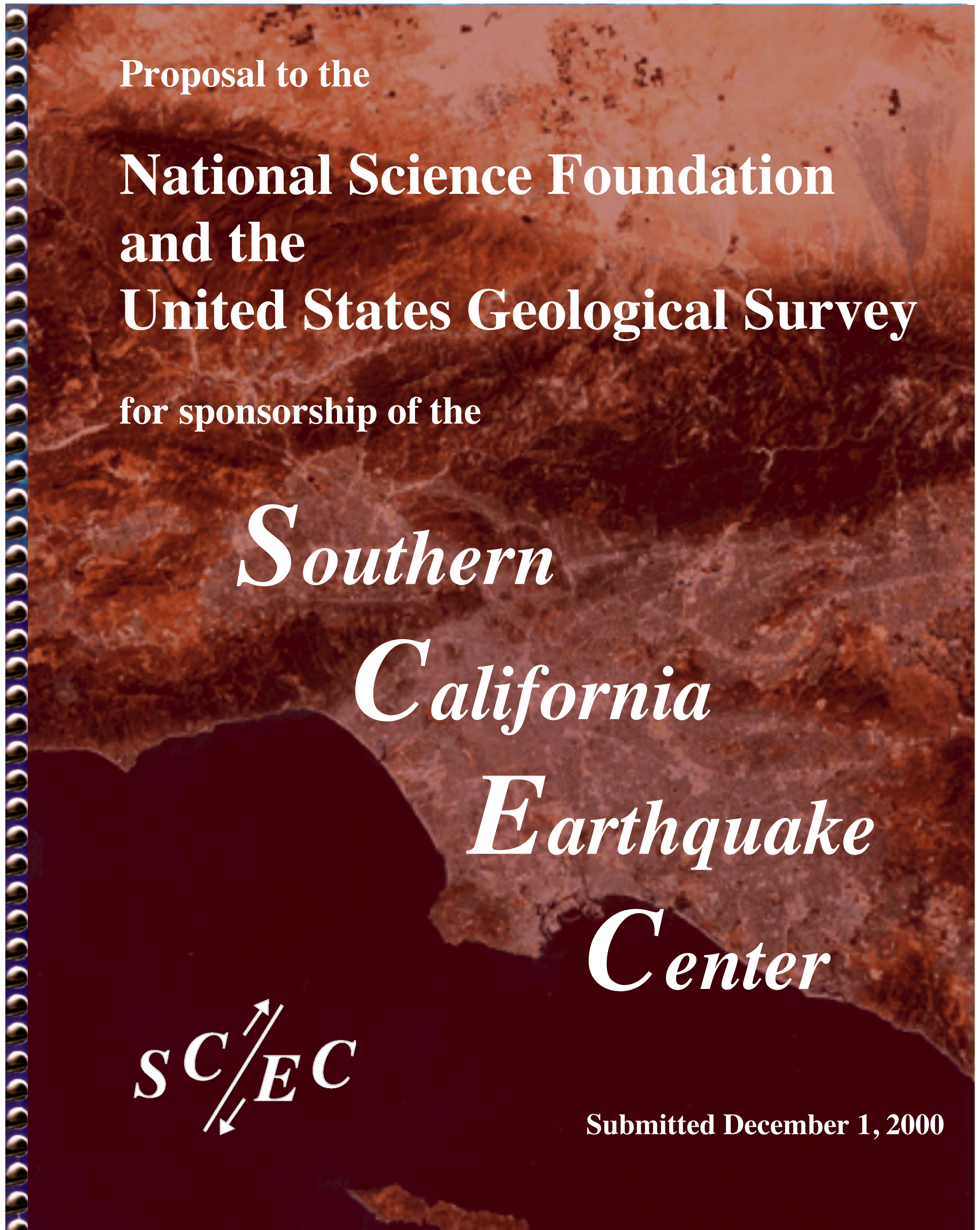
- Aki et al., SCEC proposal, 1989

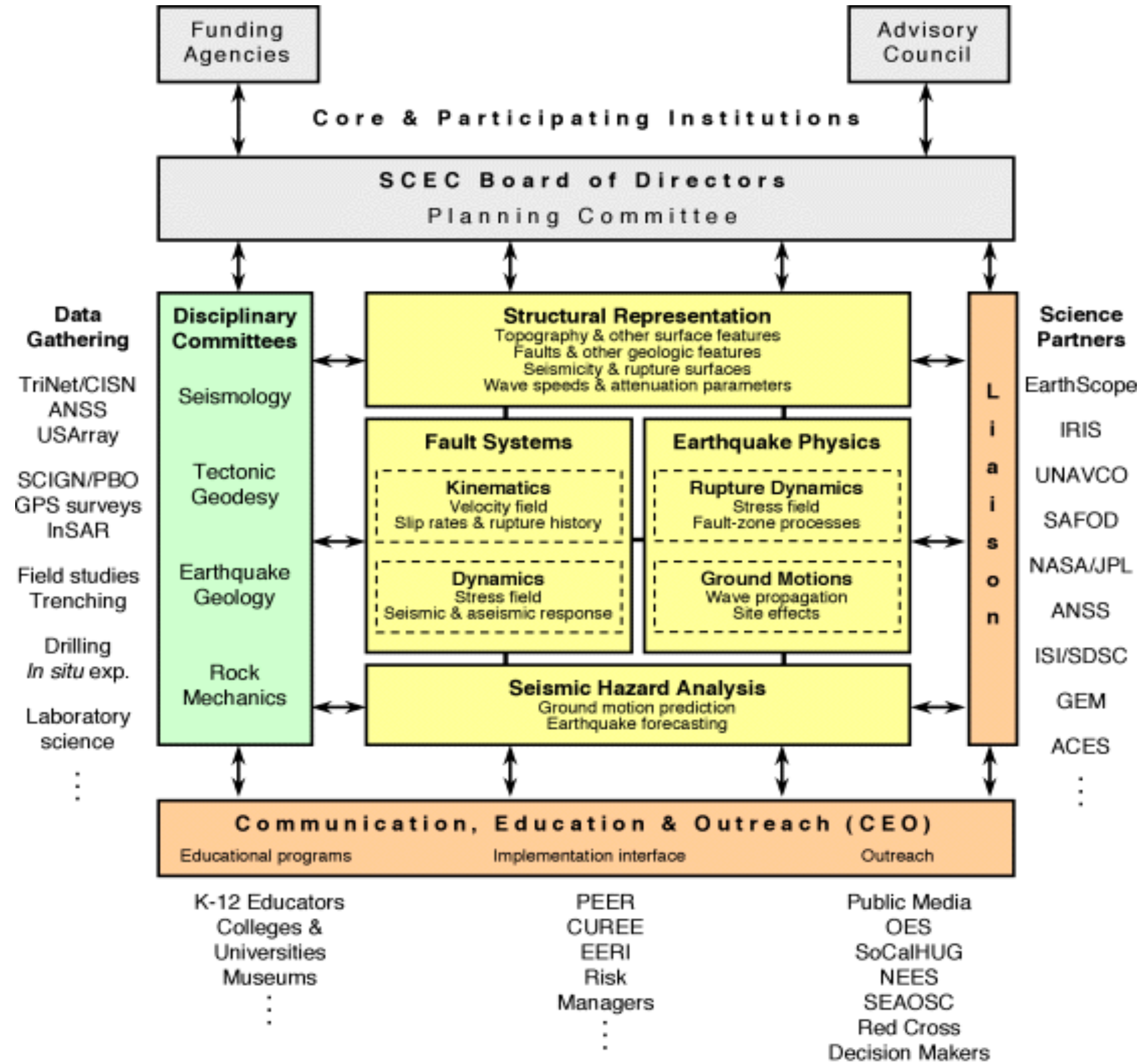
SCEC1 History

- **Founded in 1991 as NSF Science & Technology Center, jointly sponsored by the USGS**
  - **Motivation: lack of effort on Southern California earthquake problem**
  - **Goal: to develop a "master model" of earthquake hazards**
- **Organized through a series of focused studies**
  - ***Phase I:* *Future Seismic Hazards in Southern California, Implications of the 1992 Landers Earthquake Sequence***
  - ***Phase II:* *Seismic Hazards in Southern California: Probable Earthquakes, 1994 to 2024***
  - ***Phase III:* *Accounting for Site Effects in Probabilistic Seismic Hazard Analyses of Southern California***
  - ***Phase IV:* *Regional Earthquake Likelihood Models***
- **In 2002, "graduated" from STC Program and reconfigured as a free-standing center under a 5-year NSF/USGS collaborative agreement (SCEC2)**



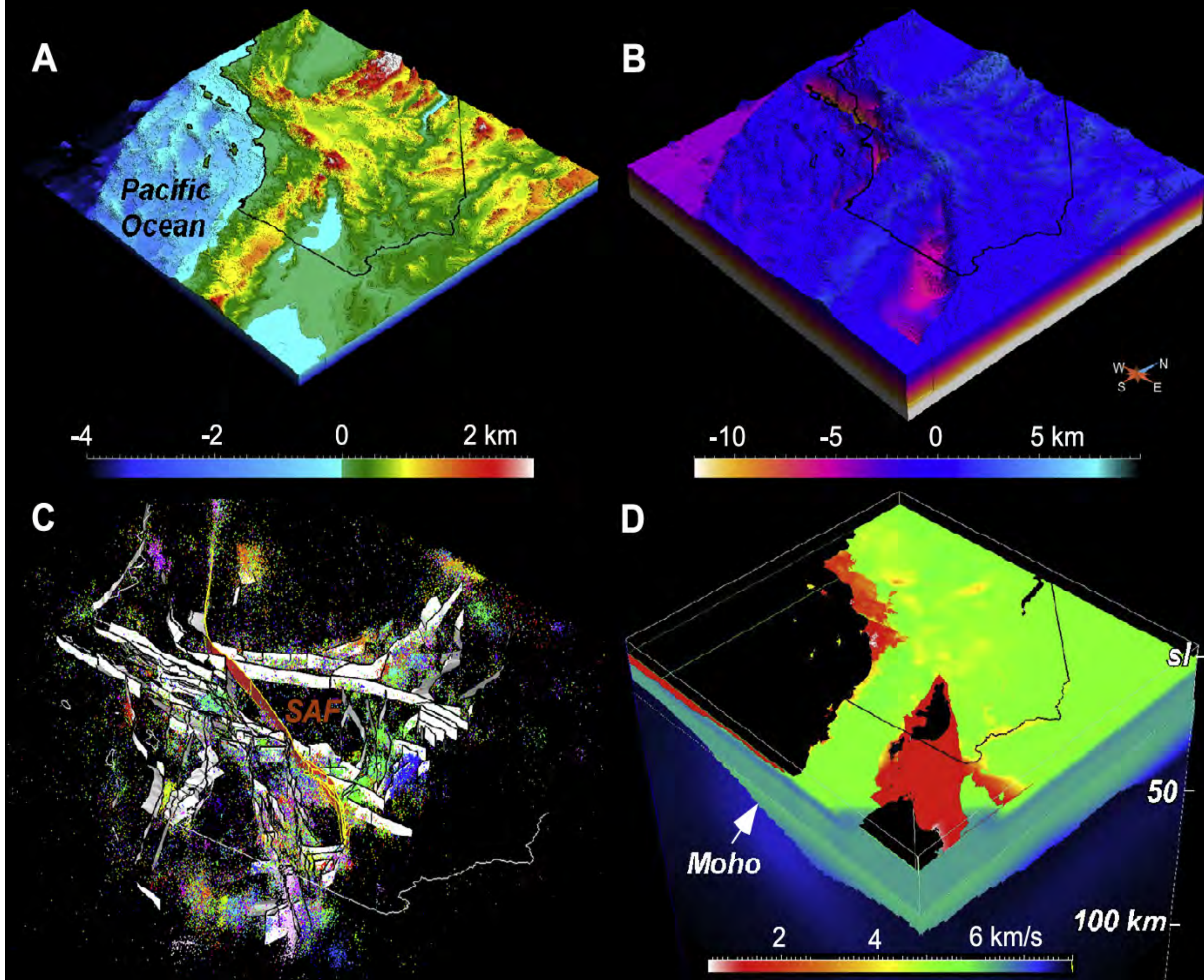
SCEC2 Proposal, Dec 1, 2000





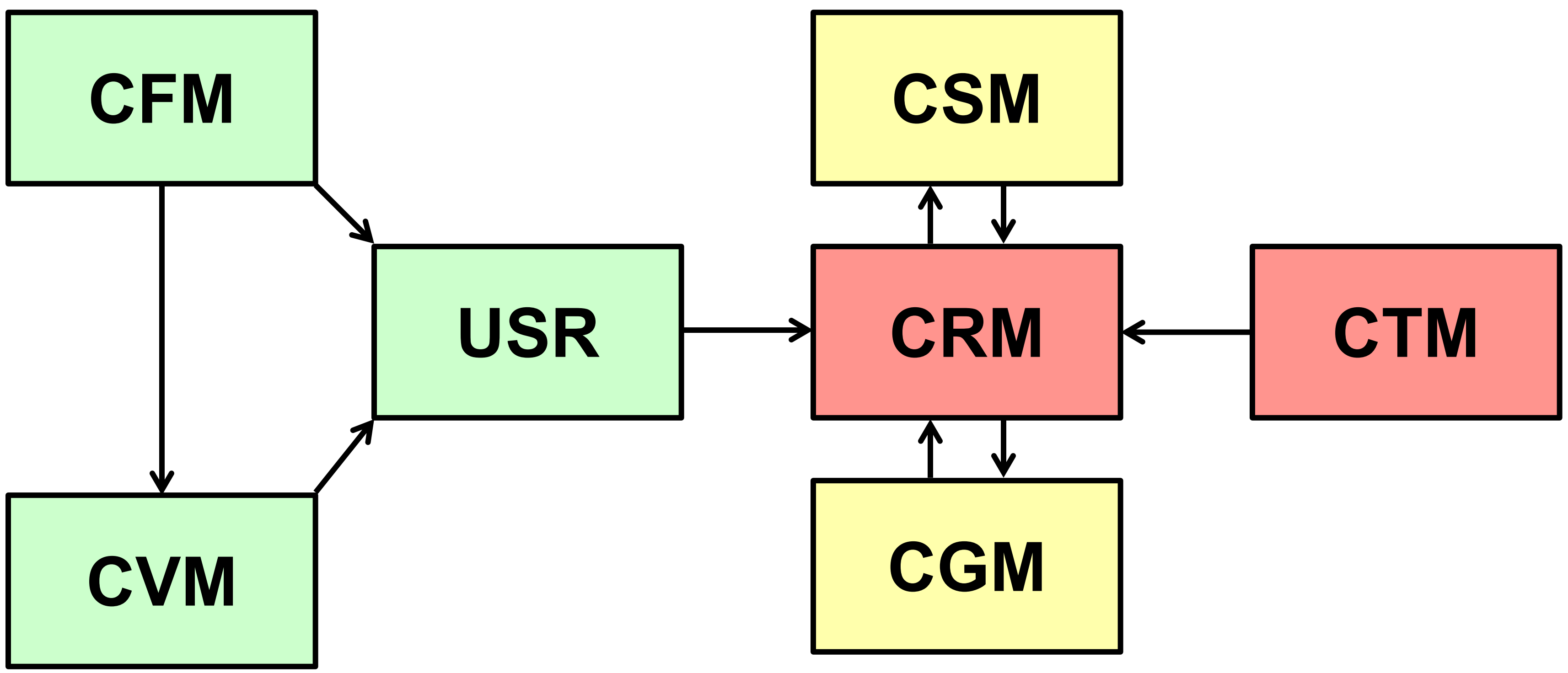
Southern California as a Natural Earthquake Laboratory

- **Tectonical diversity of faulting**
  - Well instrumented and mapped
  - Right scale for system-level earthquake research
- **High-risk environment with a population of over 23 million**
  - Comprises 40% of the national annualized earthquake risk
- **Proving ground for new risk-reduction technologies**
  - Fault-based earthquake forecasting
  - Physics-based hazard analysis
  - Performance-based design
  - Earthquake early warning



SCEC Unified Structural Representation (USR)
[Shaw et al., 2015]

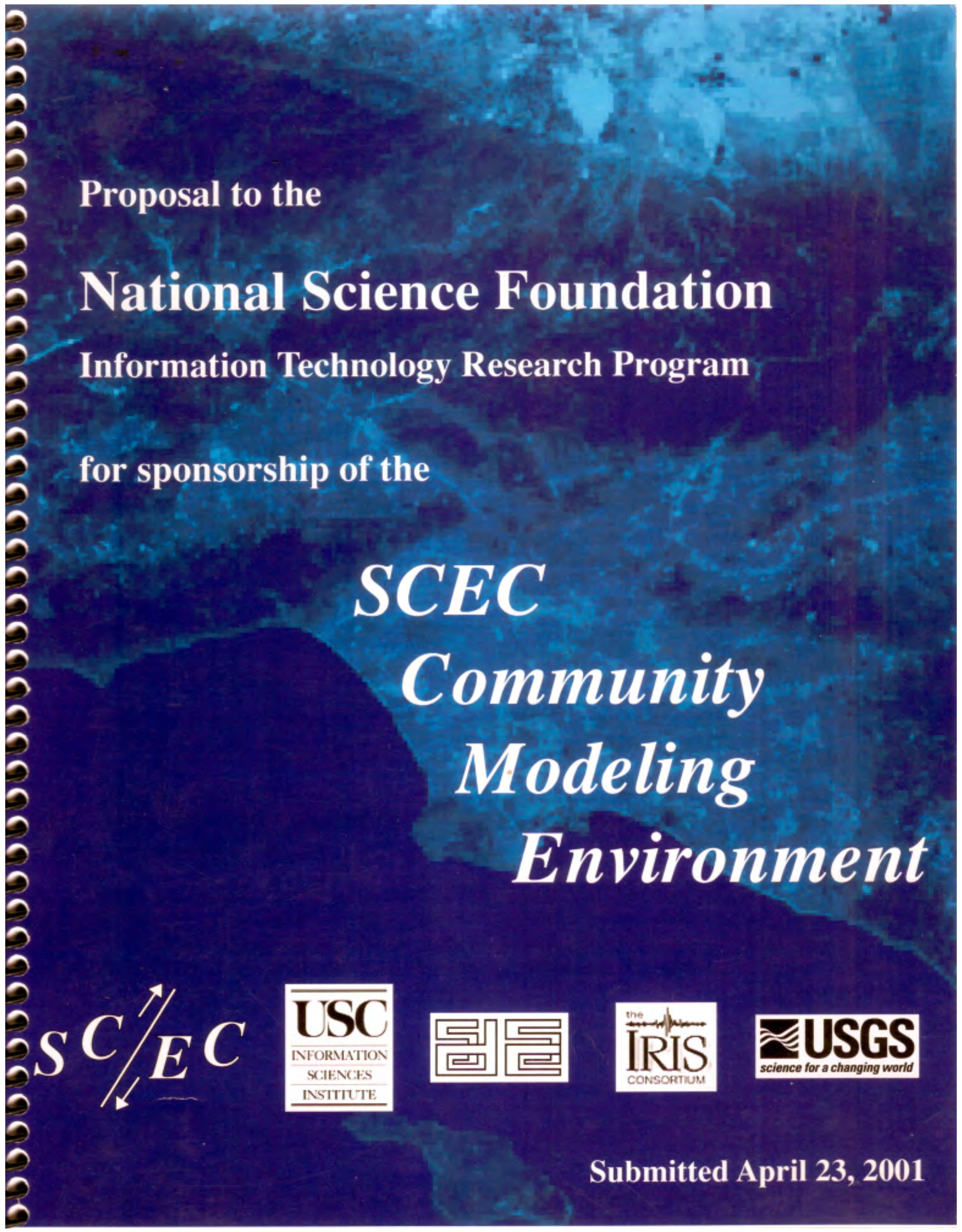
SCEC Community Models (CXMs)



Model key:
F = Fault S = Stress
G = Geodetic T = Thermal
R = Rheology V = Velocity
USR = Unified Structural Representation

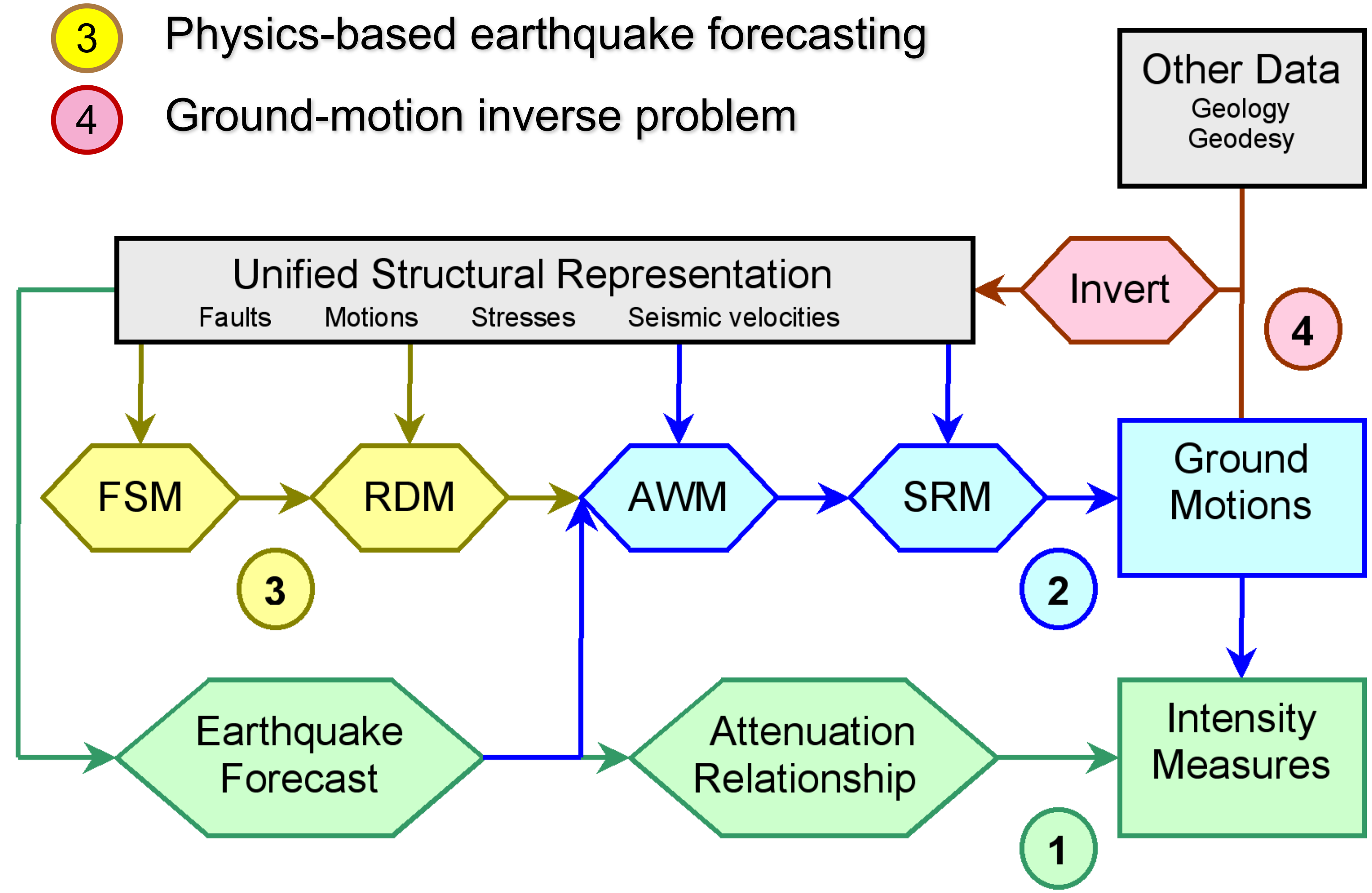
Schema of the SCEC Community Models, showing the main directions of information flow among the models. Box colors indicate the development status: mature (green), youthful (yellow), in utero (red).

SCEC Community Modeling Environment, April 24, 2001



Funded for 2001-2006 by a $10M NSF/ITR grant

1. Standard seismic hazard analysis
2. Ground motion simulation
3. Physics-based earthquake forecasting
4. Ground-motion inverse problem



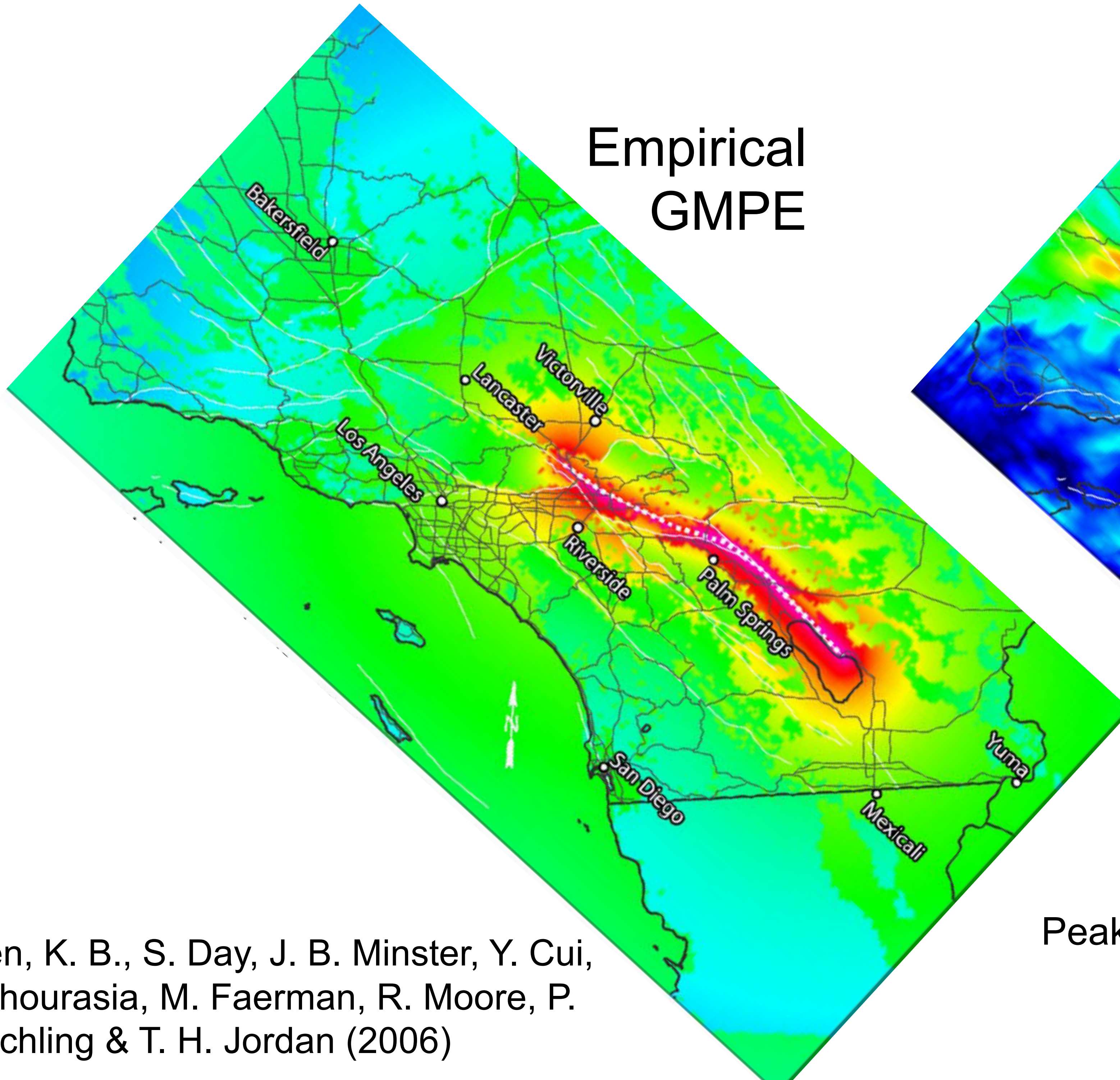
FSM = Fault System Model

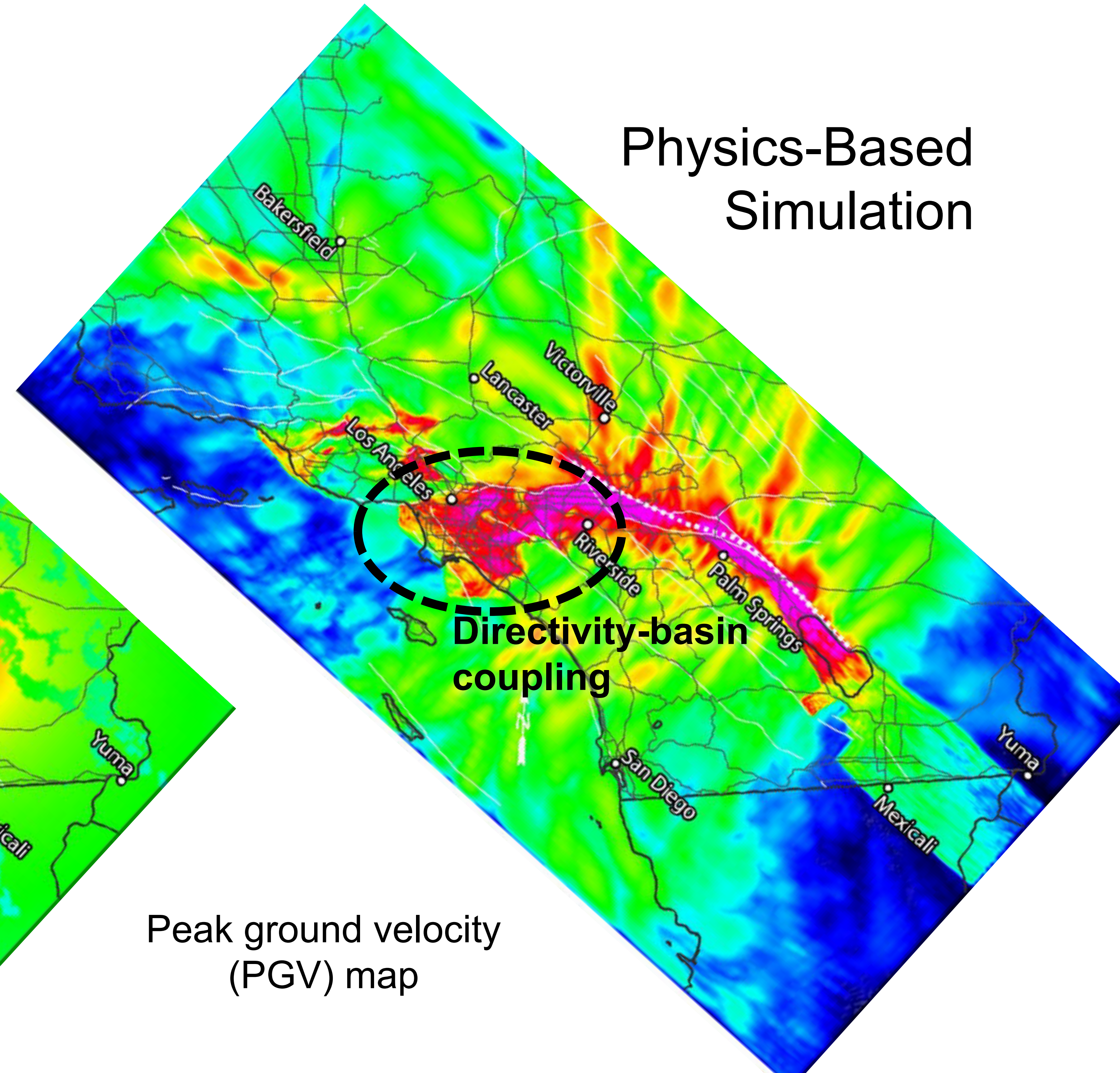
RDM = Rupture Dynamics Model

AWP = Anelastic Wave Model

SRM = Site Response Model

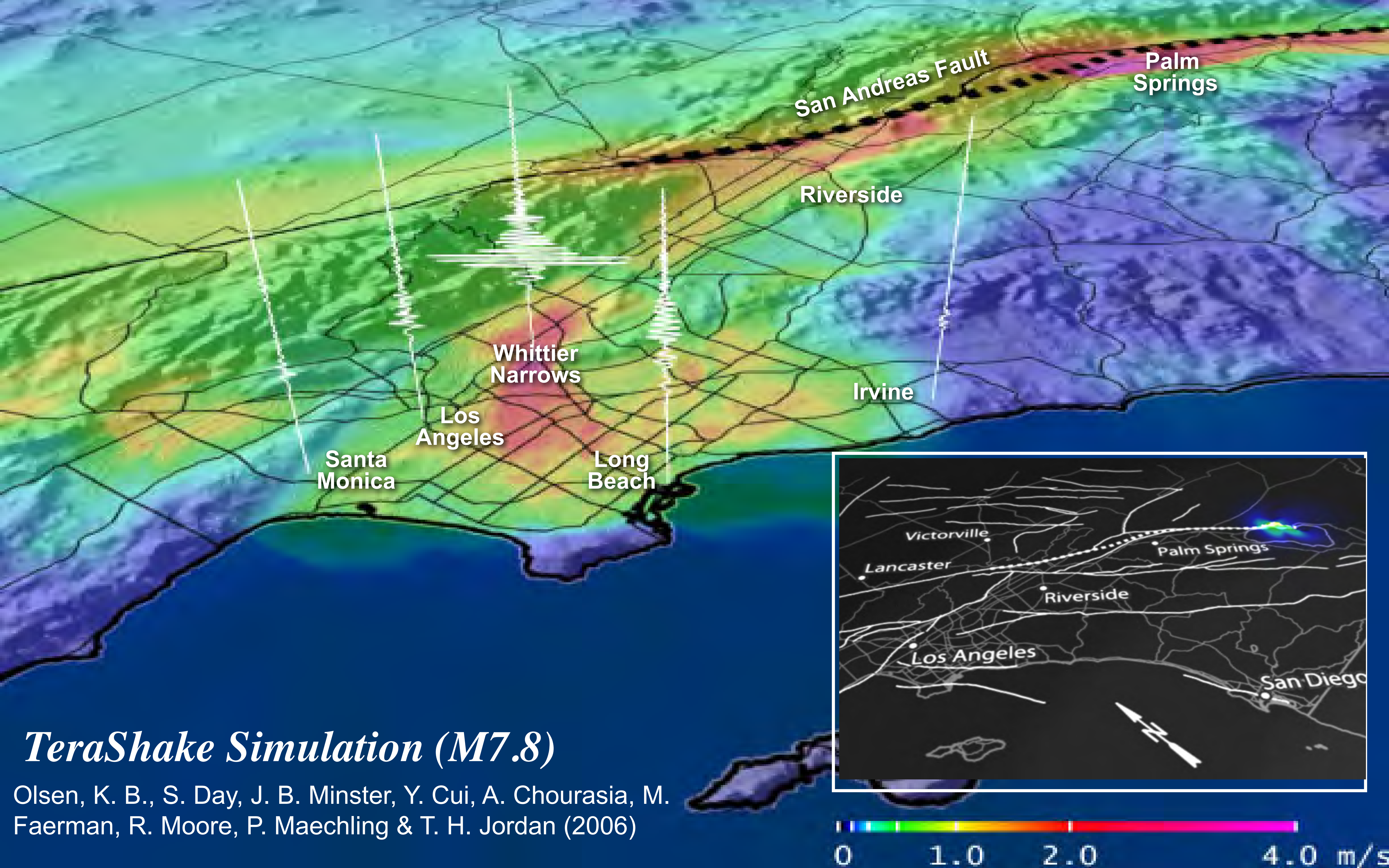
TeraShake Simulations of M7.7 Earthquake on the San Andreas Fault





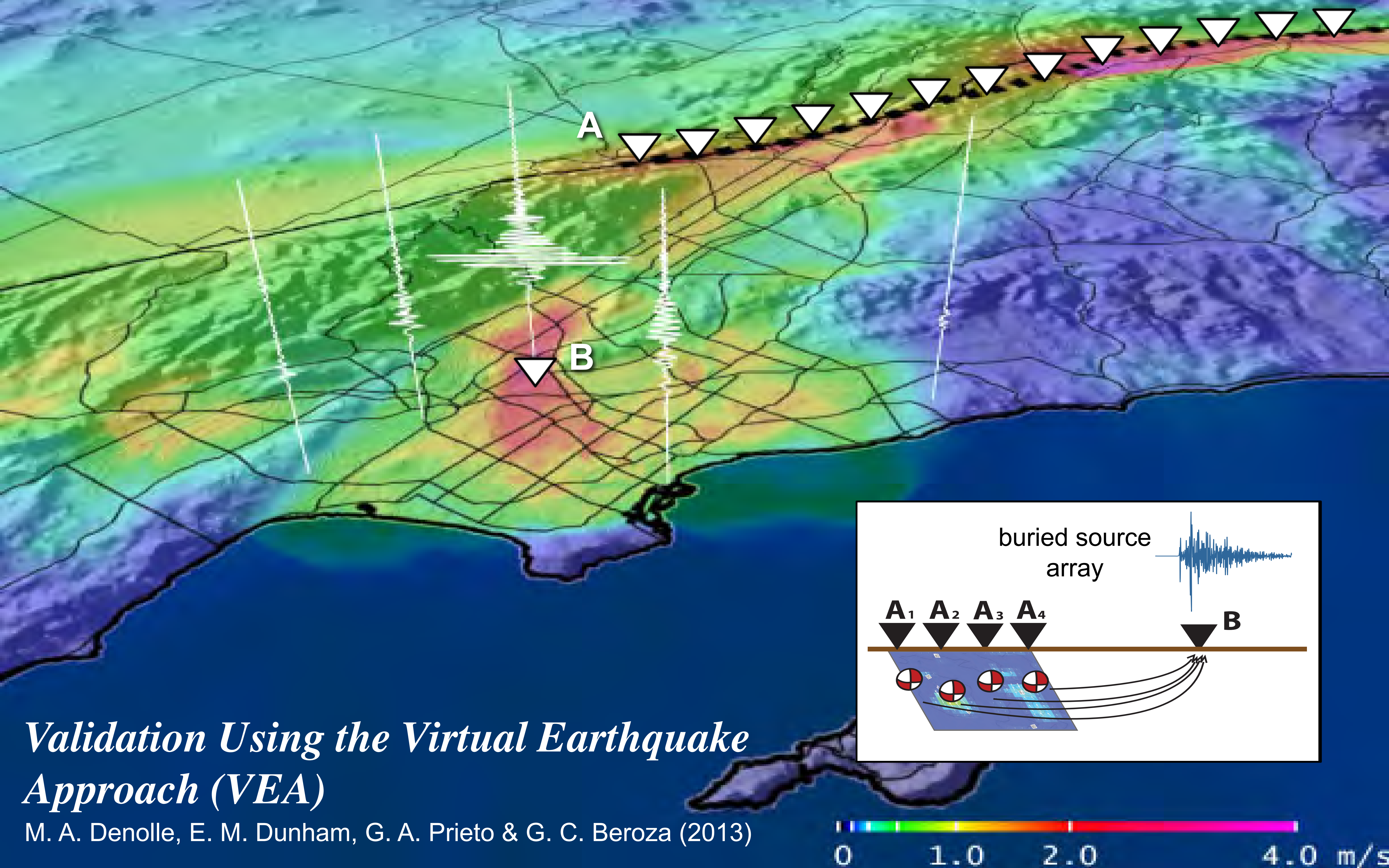
Peak ground velocity
(PGV) map

Olsen, K. B., S. Day, J. B. Minster, Y. Cui, A. Chourasia, M. Faerman, R. Moore, P. Maechling & T. H. Jordan (2006)



TeraShake Simulation (M7.8)

Olsen, K. B., S. Day, J. B. Minster, Y. Cui, A. Chourasia, M. Faerman, R. Moore, P. Maechling & T. H. Jordan (2006)

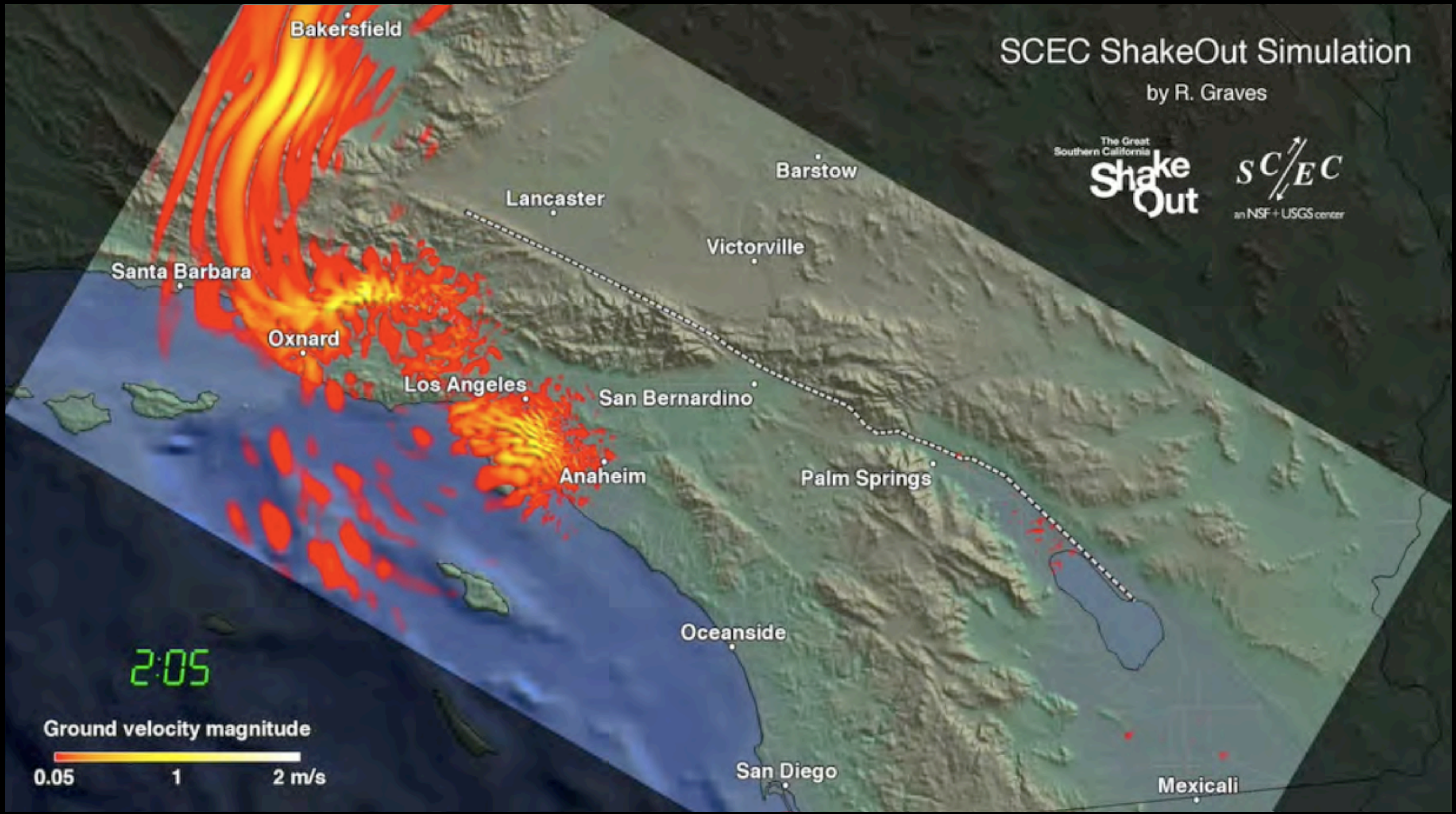


Validation Using the Virtual Earthquake Approach (VEA)

M. A. Denolle, E. M. Dunham, G. A. Prieto & G. C. Beroza (2013)

ShakeOut Scenario

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



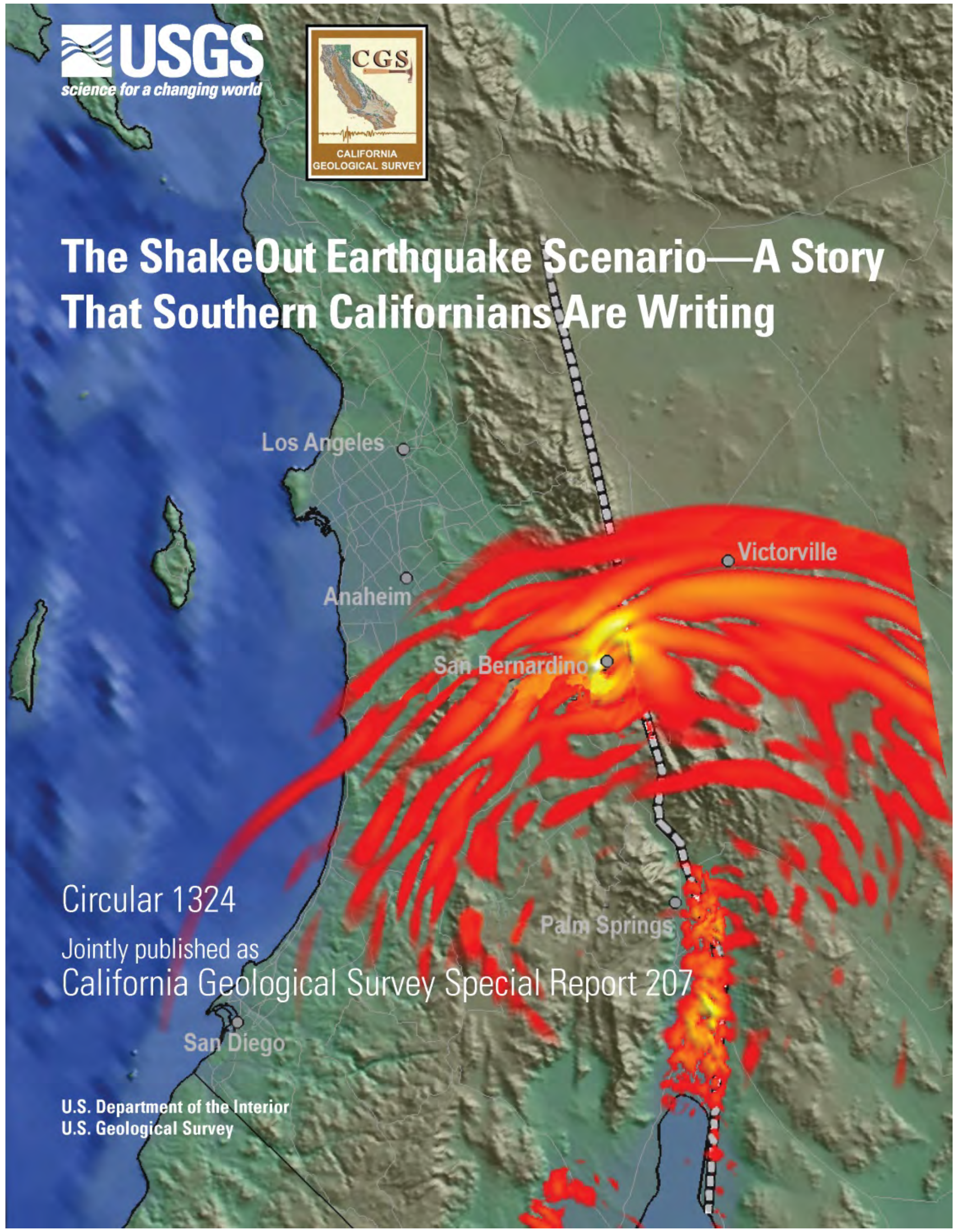
R. Graves, B. Aagaard, K. Hudnut, L. Star, J. Stewart & T. H. Jordan (2008)

The Great Southern California ShakeOut

November 13, 2008

Scenario Results

- M7.8 mainshock
  - Broadband ground motion simulation (0-10 Hz)
- Large aftershocks
  M7.2, M7.0, M6.0, M5.7…
- 10,000-100,000 landslides
- 1,600 fire ignitions
- $213 billion in direct economic losses
  - 300,000 buildings significantly damaged
  - Widespread infrastructure damage
  - 270,000 displaced persons
  - 50,000 injuries
  - 1,800 deaths
- Long recovery time



Exercise Results

- Largest emergency response exercise in US history
  - Golden Guardian exercise
  - Public events involving 5.3 million registered participants
- Demonstrated that existing disaster plans were inadequate for an event of this scale
  - Motivated reformulation of system preparedness and emergency response
  - Scientific basis for the LA Seismic Safety Task Force report, *Resilience by Design*

Resilience by Design

Report of the Los Angeles Mayoral Seismic Task Force (Lucy Jones, chair)

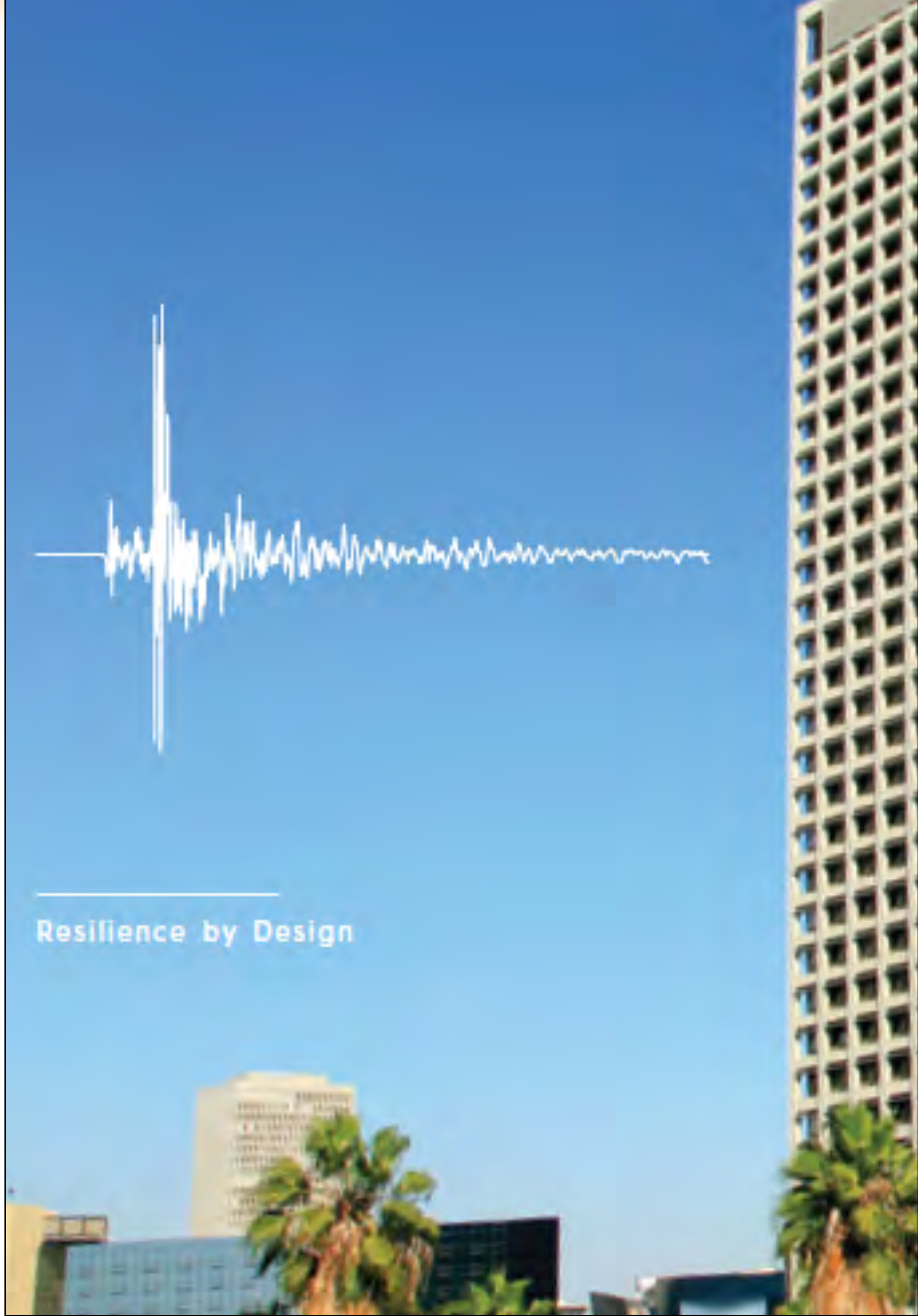
Released Dec 8, 2014

An ambitious plan to

- strengthen buildings
- fortify water supply and distribution system
- enhance reliable telecommunications

Team included USGS, CGS, FEMA, SCEC, and nearly 200 other partners in government, academia, emergency response, and industry.

http://www.lamayor.org/earthquake



SC/EC

Resilience by Design

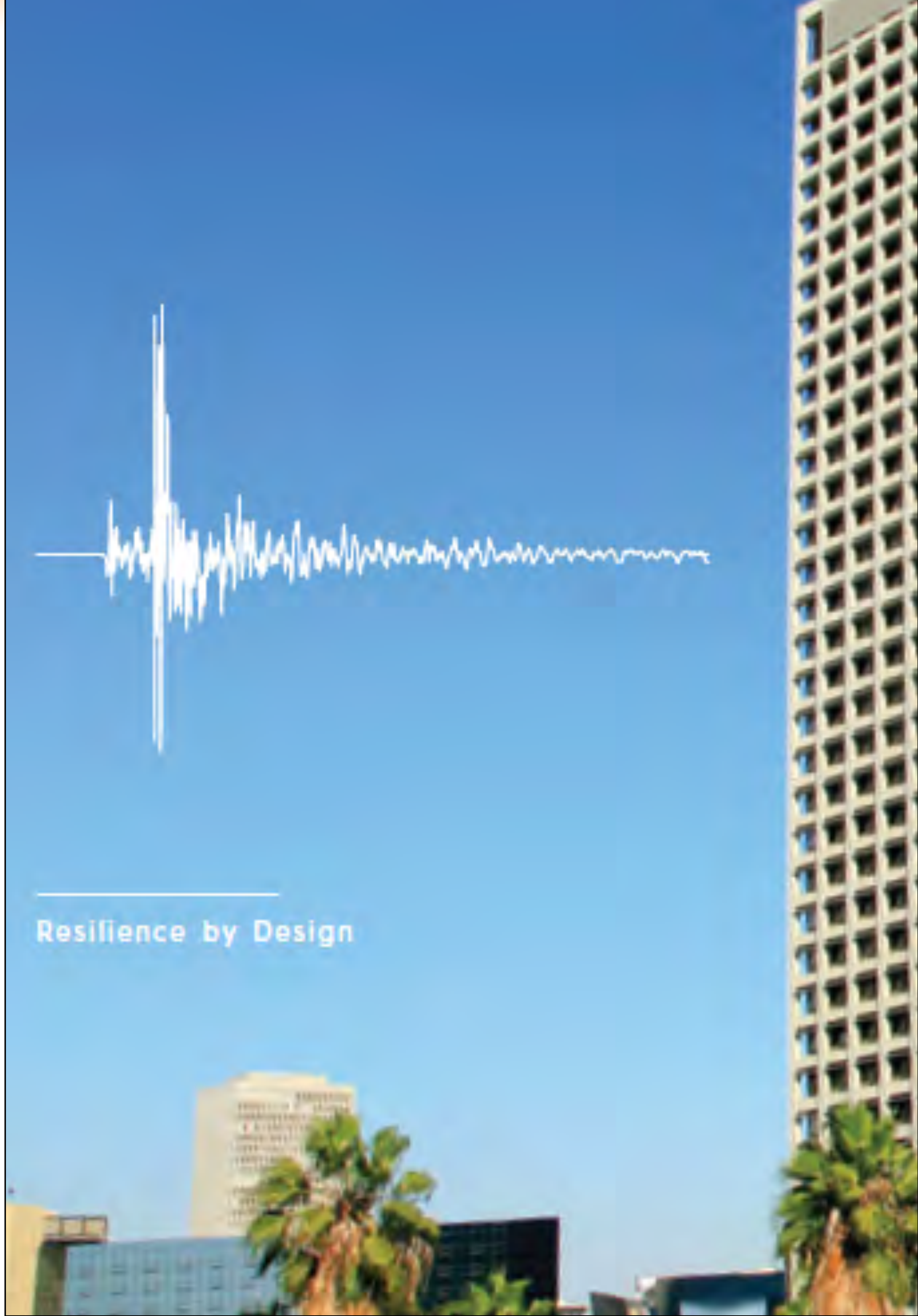
Report of the Los Angeles Mayoral Seismic Task Force (Lucy Jones, chair)

Released Dec 8, 2014

*"This Report's approach to evaluating the severity of the risk relies on the **ShakeOut Scenario**… created by a multidisciplinary team convened by the Multi-Hazards Demonstration Project of the USGS…"*

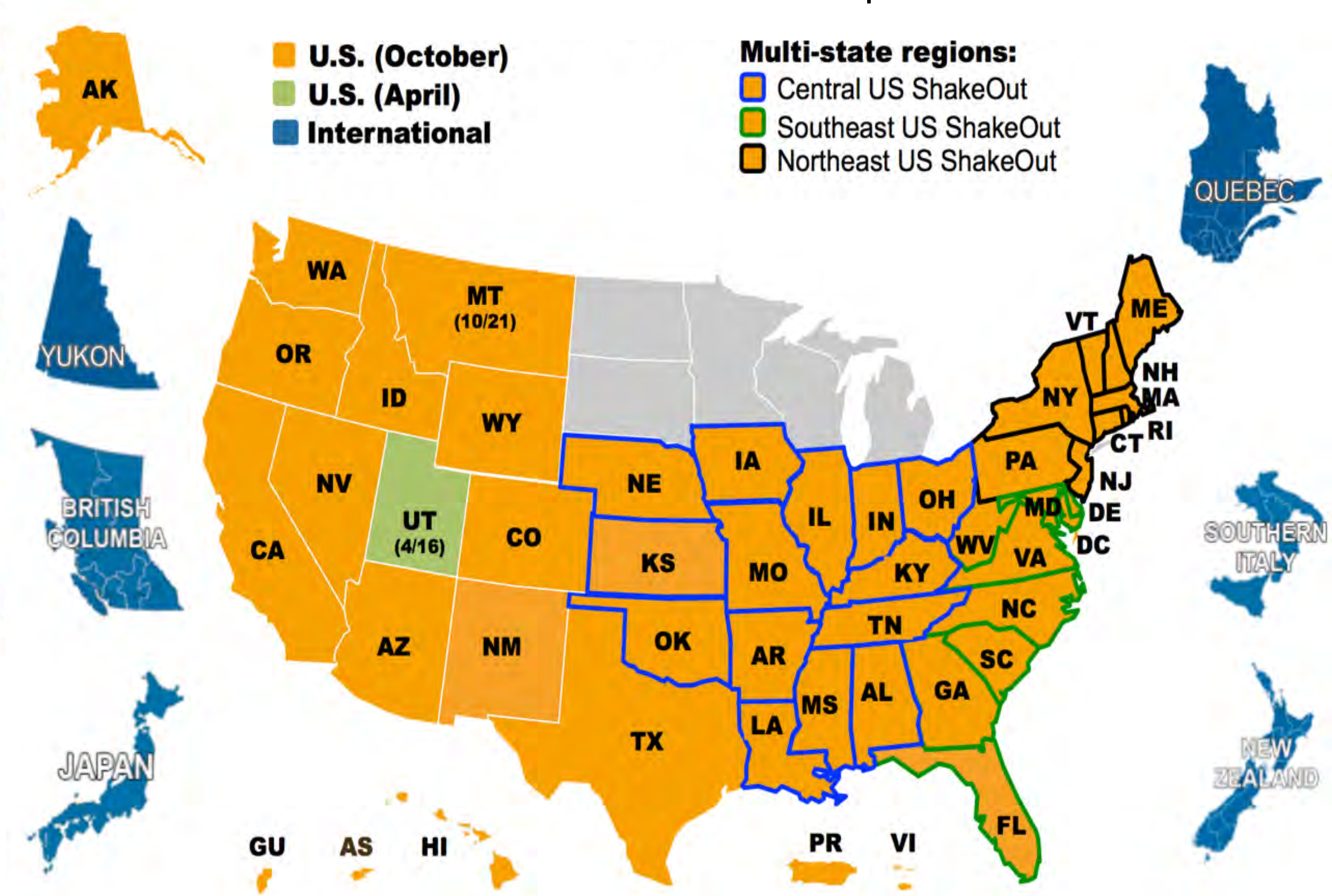
The Jones report demonstrated how the chain of scientific inference from hazard characterization to loss estimation can lead to implementation of effective mitigation options with well-defined costs and benefits

http://www.lamayor.org/earthquake



2016 ShakeOut Earthquake Drills

States, Territories, Provinces & Countries Participating in the 2015 Great ShakeOut Earthquake Drills



2016 Official ShakeOut Regions

28 Regions worldwide
22 U.S. regions spanning 51 states & territories
70 additional countries with independent registrations (individuals, schools, etc.)

Participation History (worldwide)

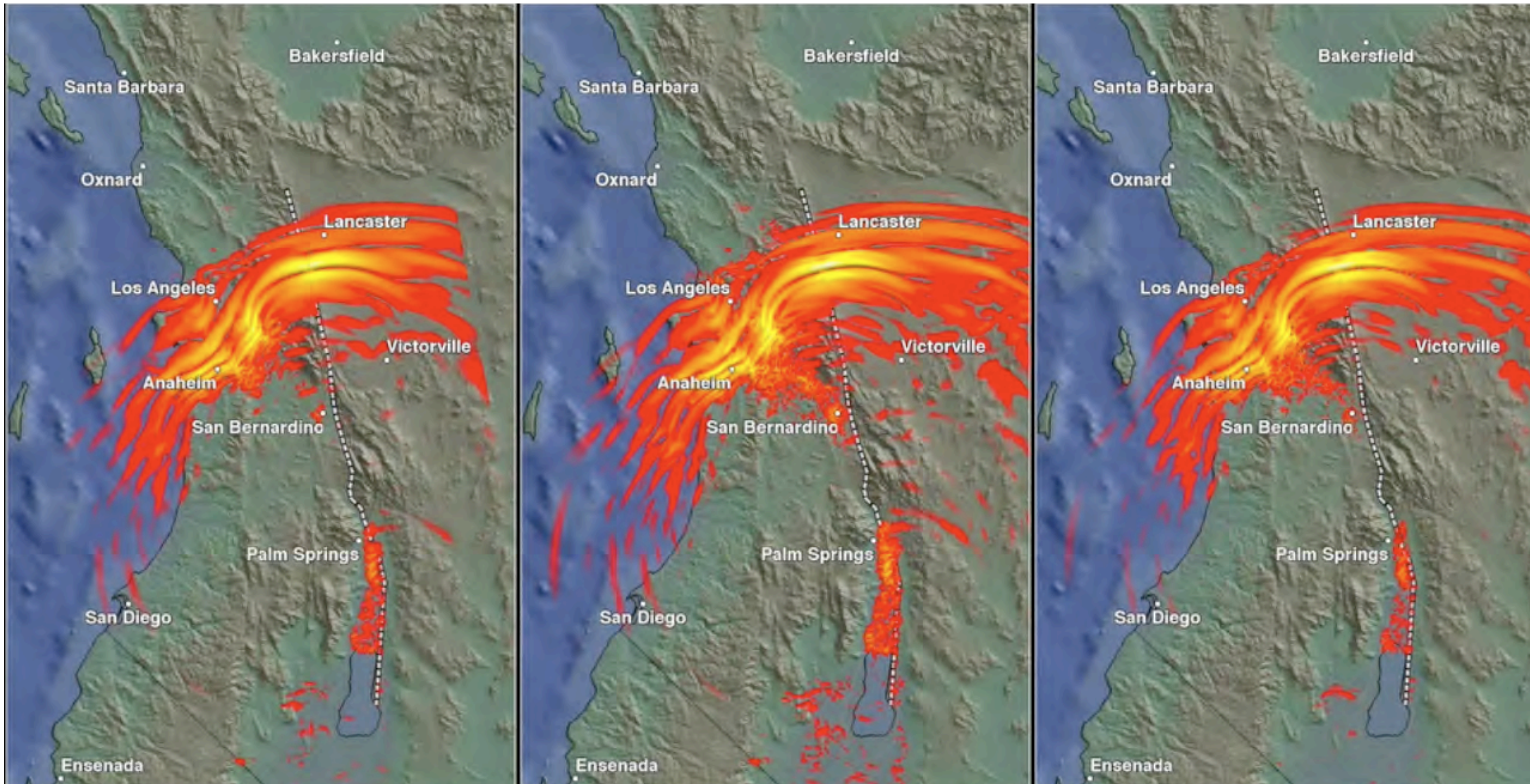
2016: 55.9 million (+ major drills in MX, PH, etc.)
2015: 43.8 million (+ TX, IA, LA, NE, global growth)
2014: 26.5 million (+ NM, KS, FL, Quebec, Yukon, more)
2013: 25.0 million (+ Southeast, Northeast, MT, WY, CO)
2012: 19.5 million (+ Japan, New Zealand, UT, WA, AZ)
2011: 12.5 million (+ Central US, BC, OR)
2010: 8.0 million (+ Nevada and Guam)
2009: 6.9 million (+ Northern California)
2008 5.4 million (Southern California)

Key Facts

- Participants practice "Drop, Cover, and Hold On" and other aspects of their emergency plans.
- Register at www.ShakeOut.org

In 2016, more than 55 million people were registered to participate in ShakeOut drills

Cross-Verification of ShakeOut Simulations



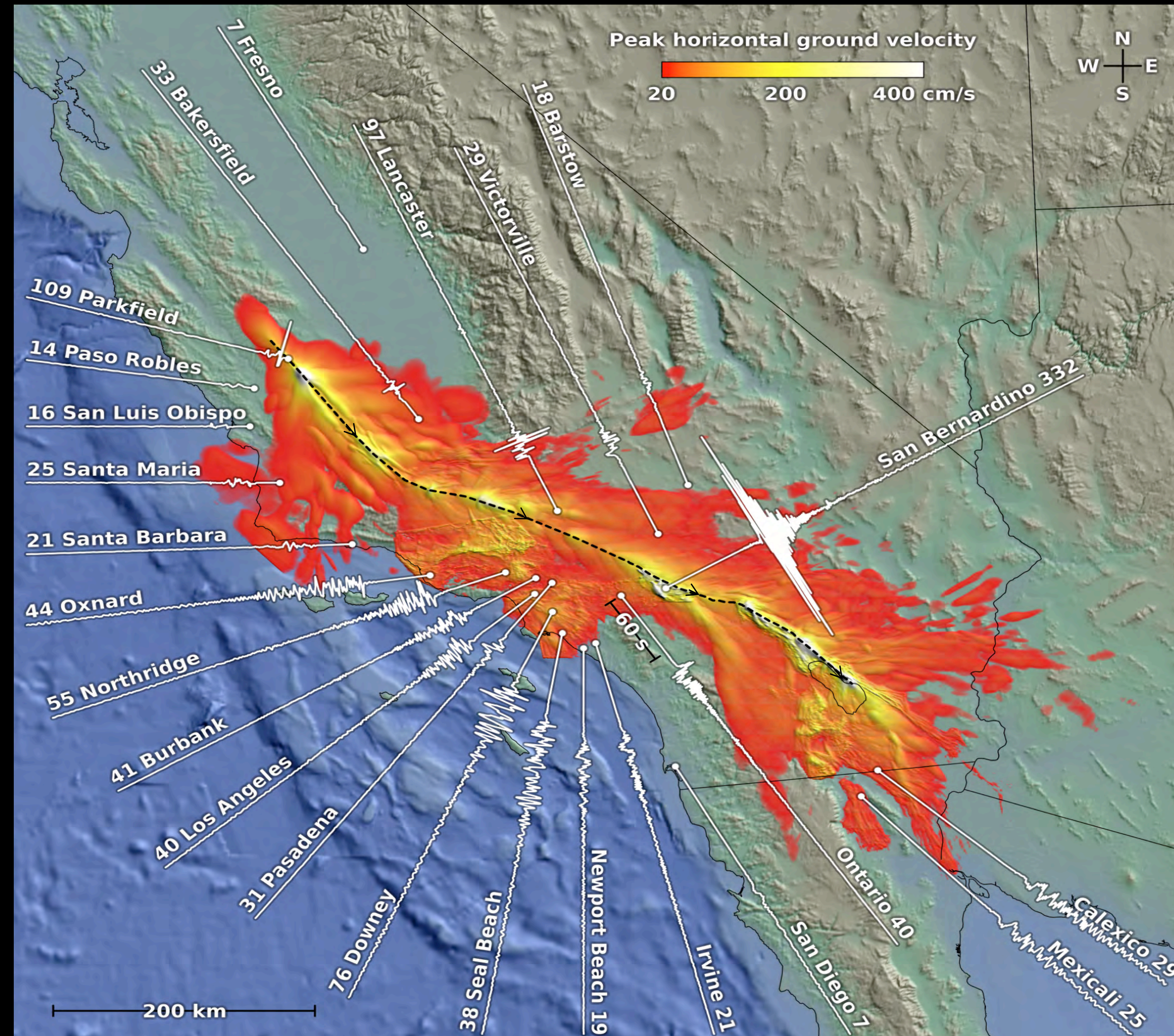
URS/USC SDSU/SDSC CMU/PSC

J. Bielak, R. Graves, K. Olsen, R. Taborda, L. Ramirez-Guzman, S. Day, G. Ely, D. Roten, T. H. Jordan, P. Maechling, J. Urbanic, Y. Cui, and G. Juve (2010)

M8 Simulation – 2010

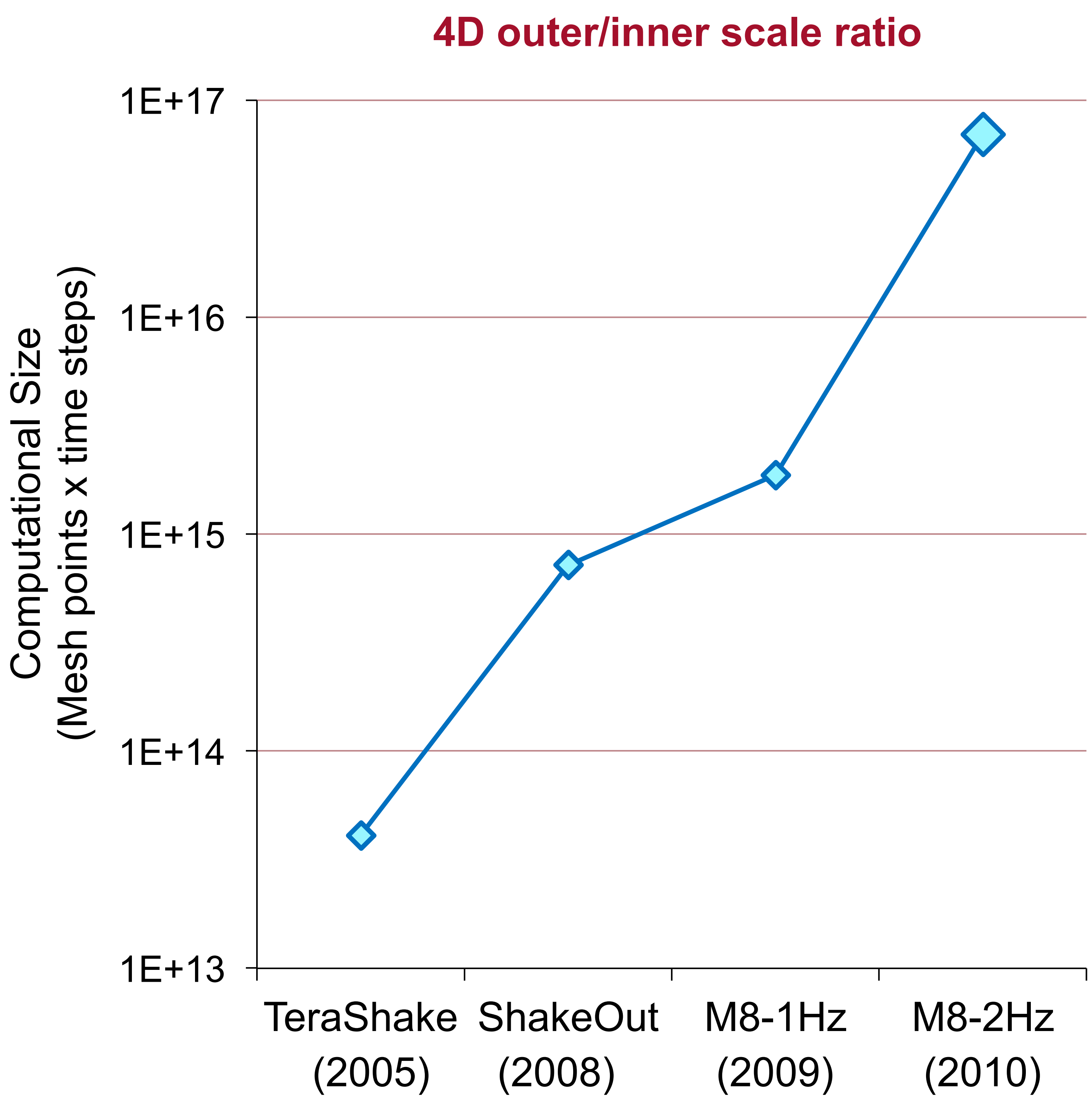
- **Magnitude 8.0 "wall-to-wall" scenario on southern San Andreas Fault**
  - **Fault length: 545 km**
  - **Minimum wavelength: 200 m**
- **Dynamic rupture simulation on *Kraken*, 7.5 hours using 2160 cores**
  - **881,475 subfaults, 250 sec of rupture**
  - **2.1 TB tensor time series output**
- **Wave propagation simulation performed on *Jaguar*, 24 hours using 223,074 cores (220 Tflop/s sustained).**
  - **436 billion grid points representing geologic model of dimension 810 x 405 x 85 km (40-m sampling)**
  - **368 s of ground motions (160,000 steps of 0.0023 s)**

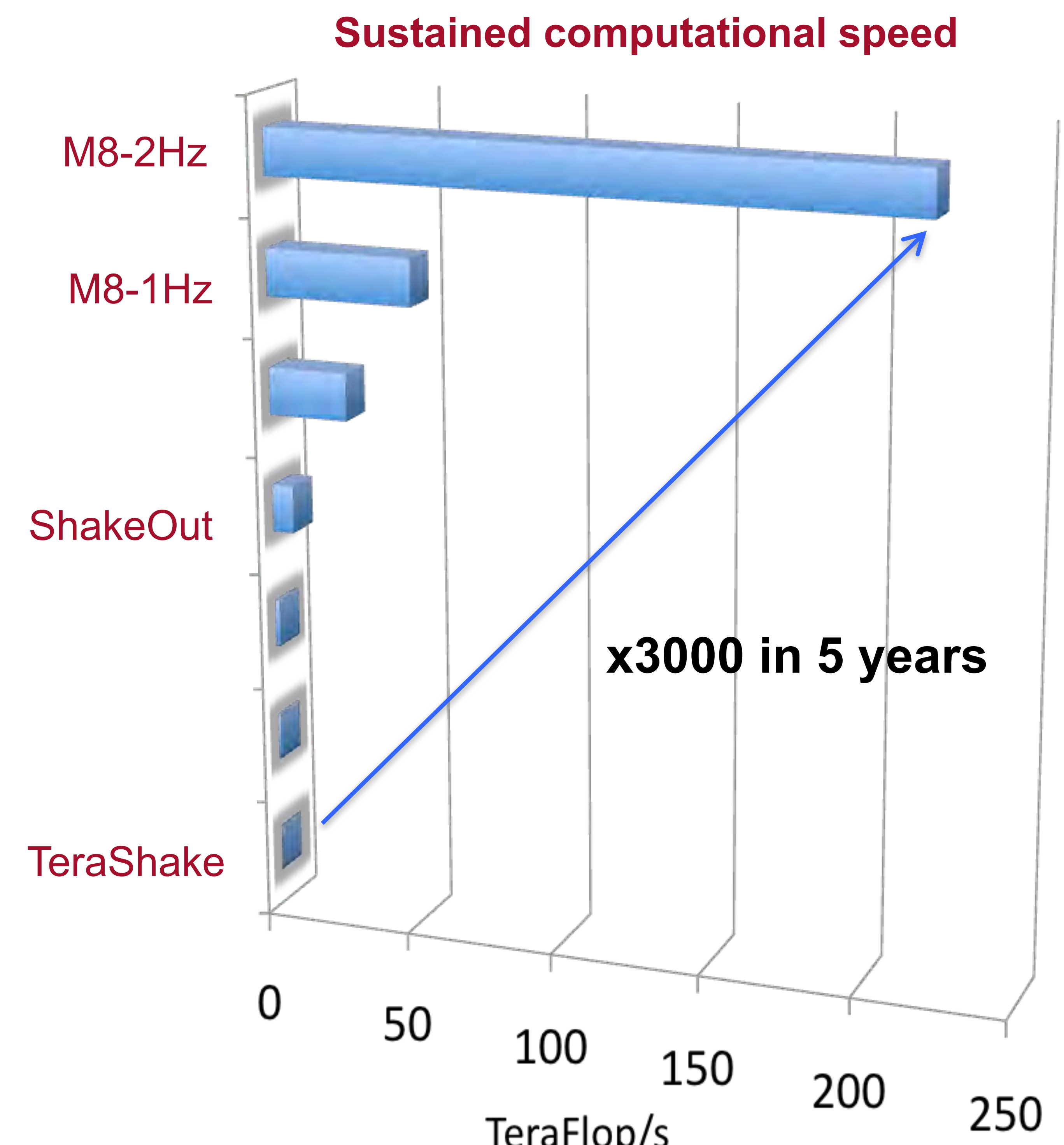
Ground motions of outer-scale event (M8) computed deterministically up to 2 Hz



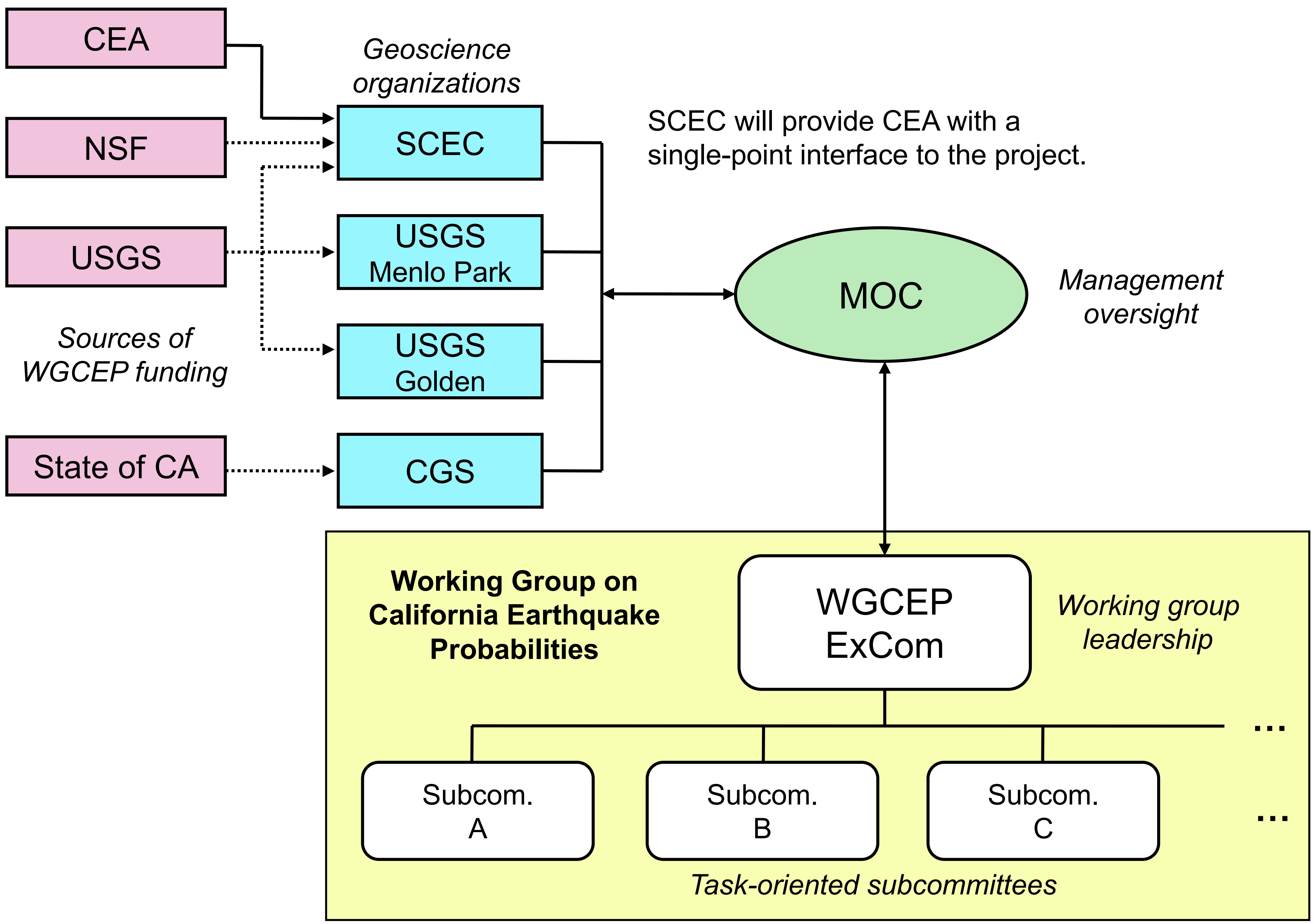
Cui, Y., K. B. Olsen, T. H. Jordan, K. Lee, J. Zhou, P. Small, D. Roten, G. Ely, D. K. Panda, A. Chourasia, J. Levesque, S. M. Day & P. Maechling (2010)

Performance of SCEC Large-Scale Simulations





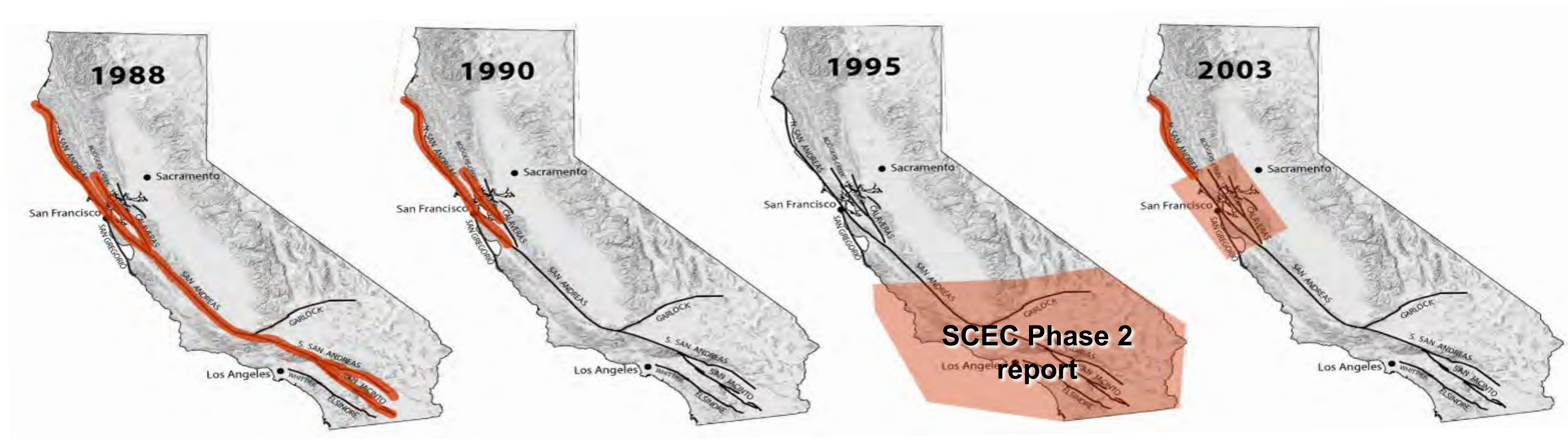
Uniform California Earthquake Rupture Forecast



- **Preproposal submitted to CEA Dec 3, 2003**
- **UCERF2 proposal submitted Feb 14, 2005**
  - **Approved Mar 20, 2005**
  - **Started Jun 1, 2005**
  - **UCERF1 submitted Feb 1, 2006**
  - **UCERF2 submitted Sep 30, 2007**
- **UCERF3 proposal submitted Dec 15, 2008**
  - **Approved Jun 25, 2009**
  - **Started Jan 1, 2010**

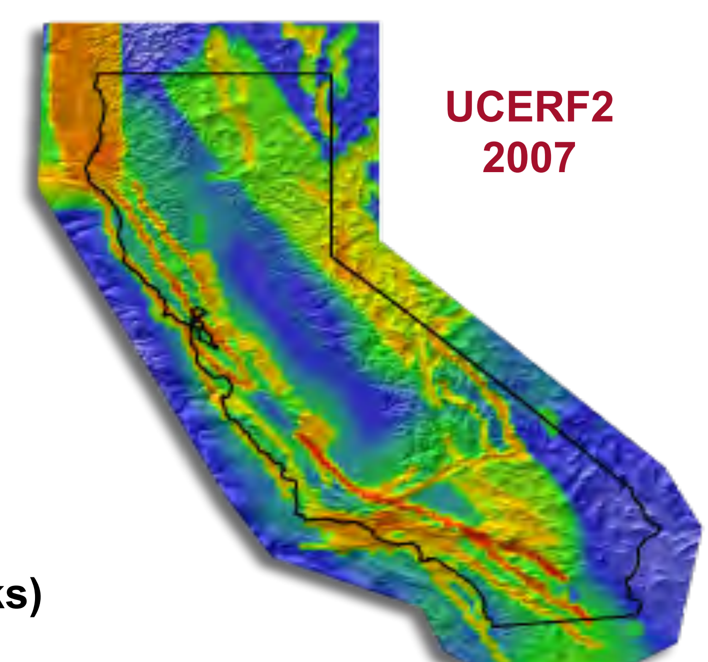
Working Group on California Earthquake Probabilities (WGCEP)

Began the development of time-dependent, fault-based earthquake forecasts in 1988

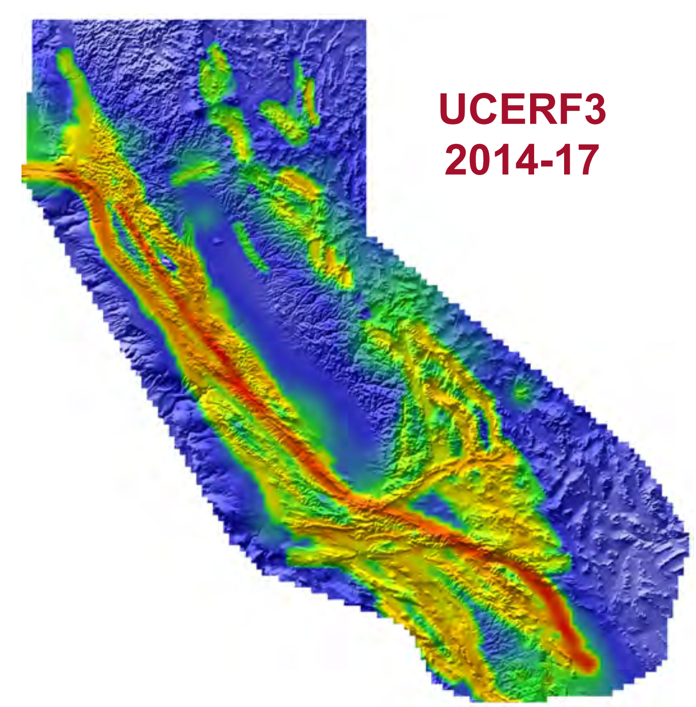


Released first Uniform California Earthquake Rupture Forecast (UCERF2) in 2007

- Assumes fault segmentation
- Excludes multi-fault ruptures
- Over-predicts M ~6.7 events
- Inconsistent elastic rebound
- No clustering (e.g., aftershocks)



UCERF2
2007



UCERF3
2014-17

UCERF3-TI

- Time-independent, incorporated into 2014 National Seismic Hazard Maps

UCERF3-TD

- Long-term time-dependent, based on a Reid renewal statistics

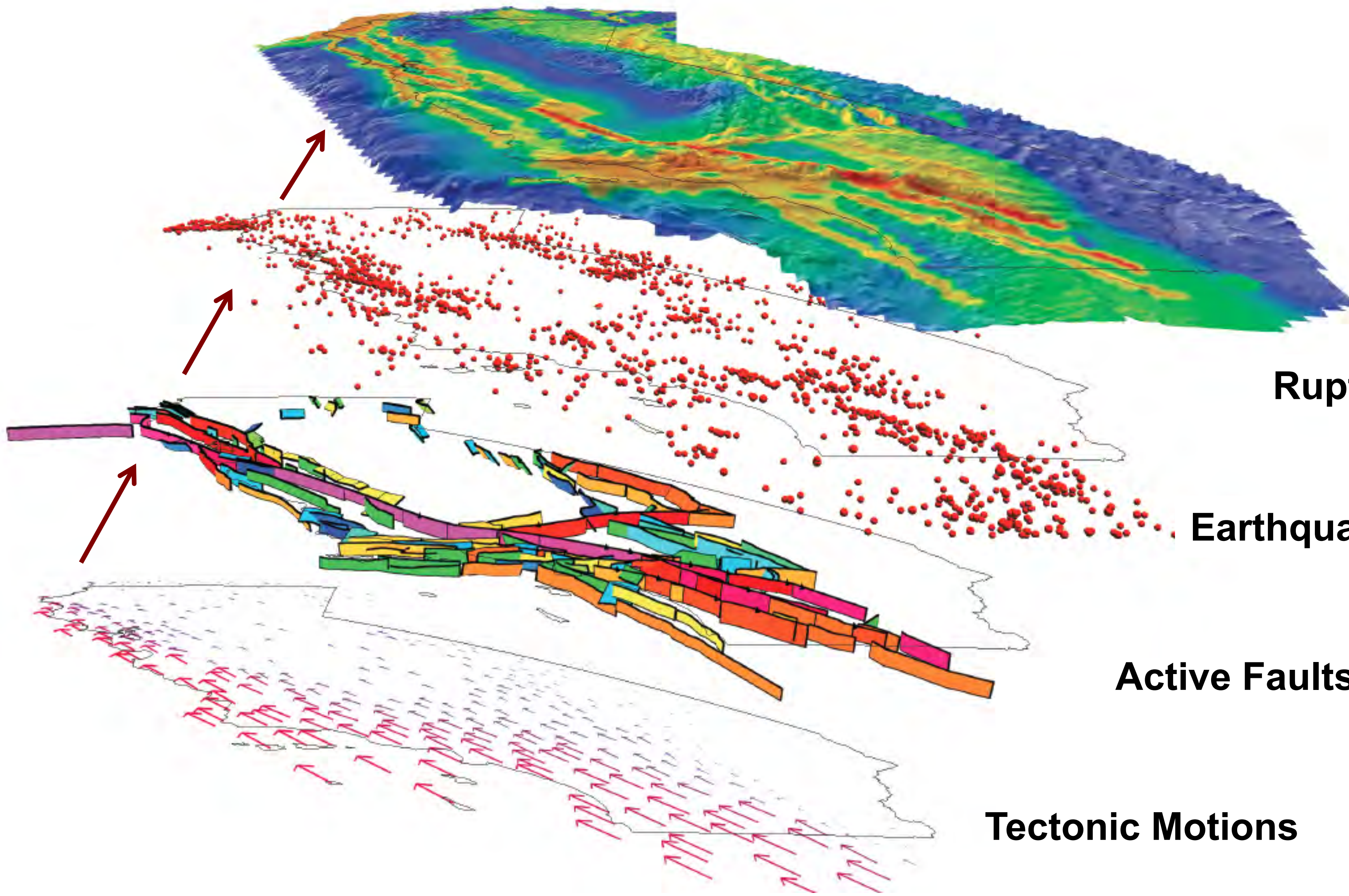
UCERF3-ETAS

- Short-term time-dependent, based on Omori-Utsu statistics (ETAS model)

Southern California Earthquake Center

Working Group on California Earthquake Probabilities

Uniform California Earthquake Rupture Forecast



The UCERF projects have been major drivers of SCEC research

Field et al. (2007)

Fault Models — Specifies the spatial geometry of larger, more active faults.

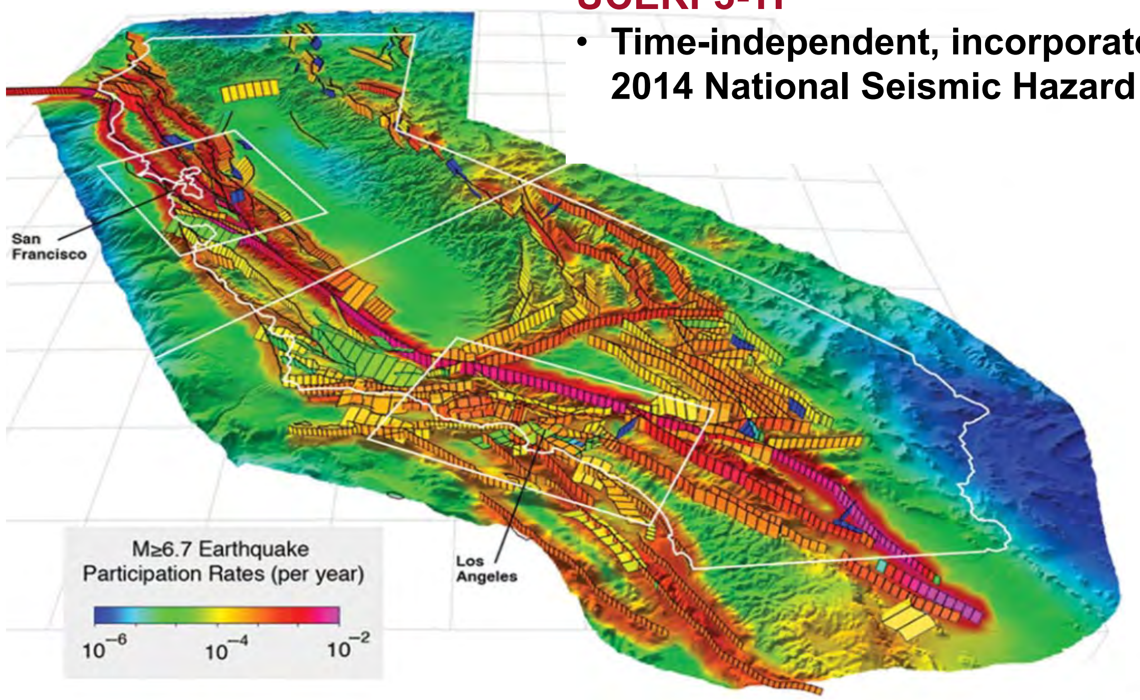
→ **Deformation Models** — Provides fault slip rates used to calculate seismic moment release.

→ ***Eathquake-Rate Models*** — Gives the long-term rate of all possible damaging earthquakes throughout a region.

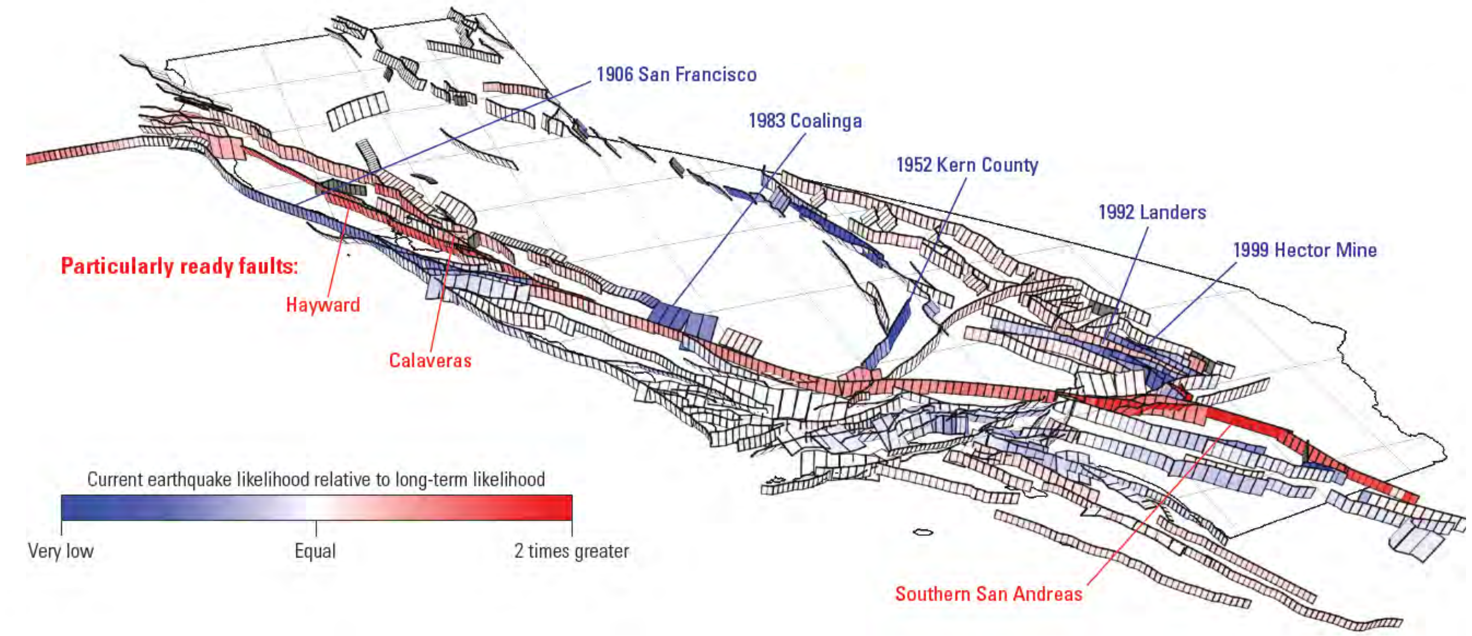
→ **Probability Models** — Gives the probability that each earthquake in the given Earthquake Rate Model will occur during a specified time span.

Working Group on California Earthquake Probabilities

Uniform California Earthquake Rupture Forecast

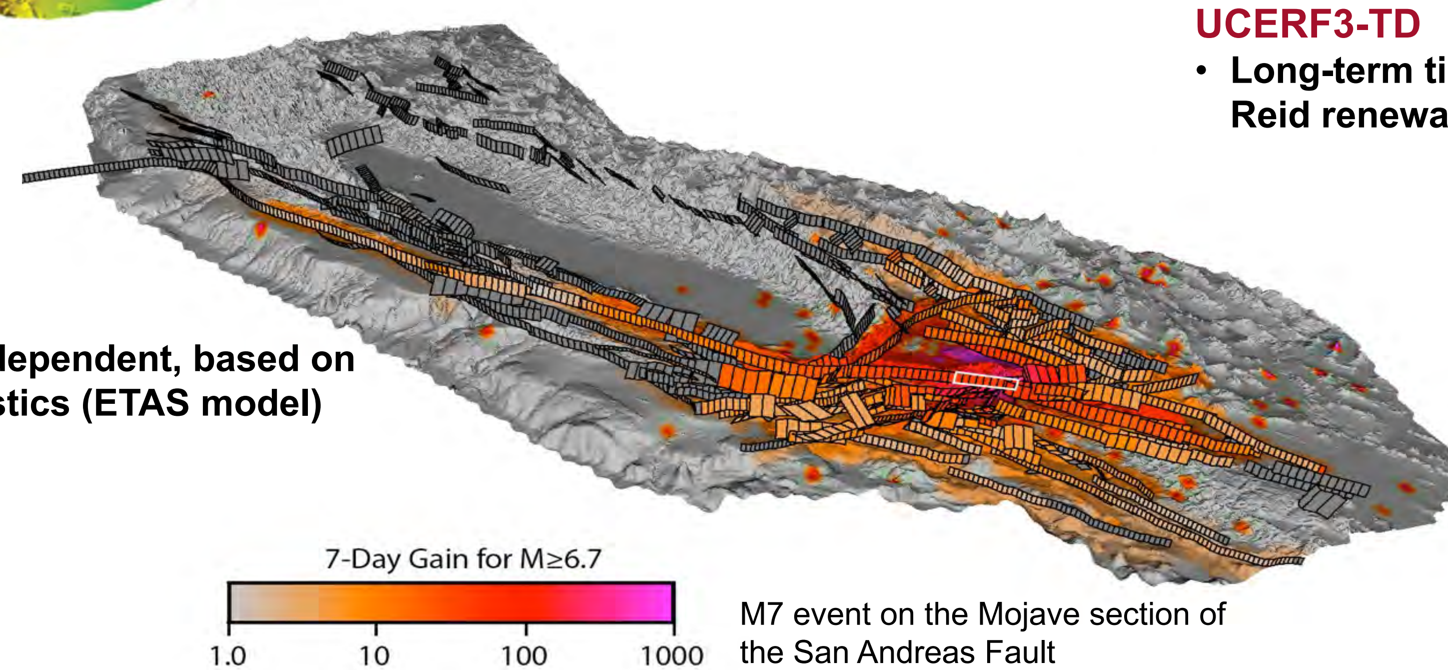


UCERF3-TI
- **Time-independent, incorporated into 2014 National Seismic Hazard Map**



UCERF3-TD
- **Long-term time-dependent, based on a Reid renewal statistics**

UCERF3-ETAS
- **Short-term time-dependent, based on Omori-Utsu statistics (ETAS model)**



M7 event on the Mojave section of the San Andreas Fault

Field et al. (2014, 2015, 2017)

UCERF3 Combines Two Scales of Seismic Hazard Change

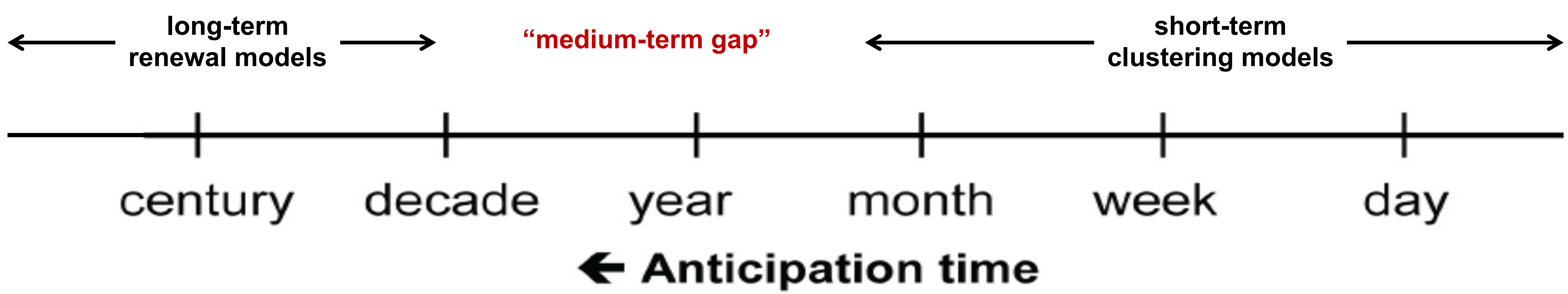
- **Faults accumulate stress over centuries during quasi-static tectonic loading**
  - **stress cycle represented by Reid *renewal* models**
- **Faults redistribute stress in seconds during dynamic ruptures**
  - **earthquake sequences represented by Omori-Utsu *clustering* models**

Probabilistic Seismic Hazard Analysis (PSHA)

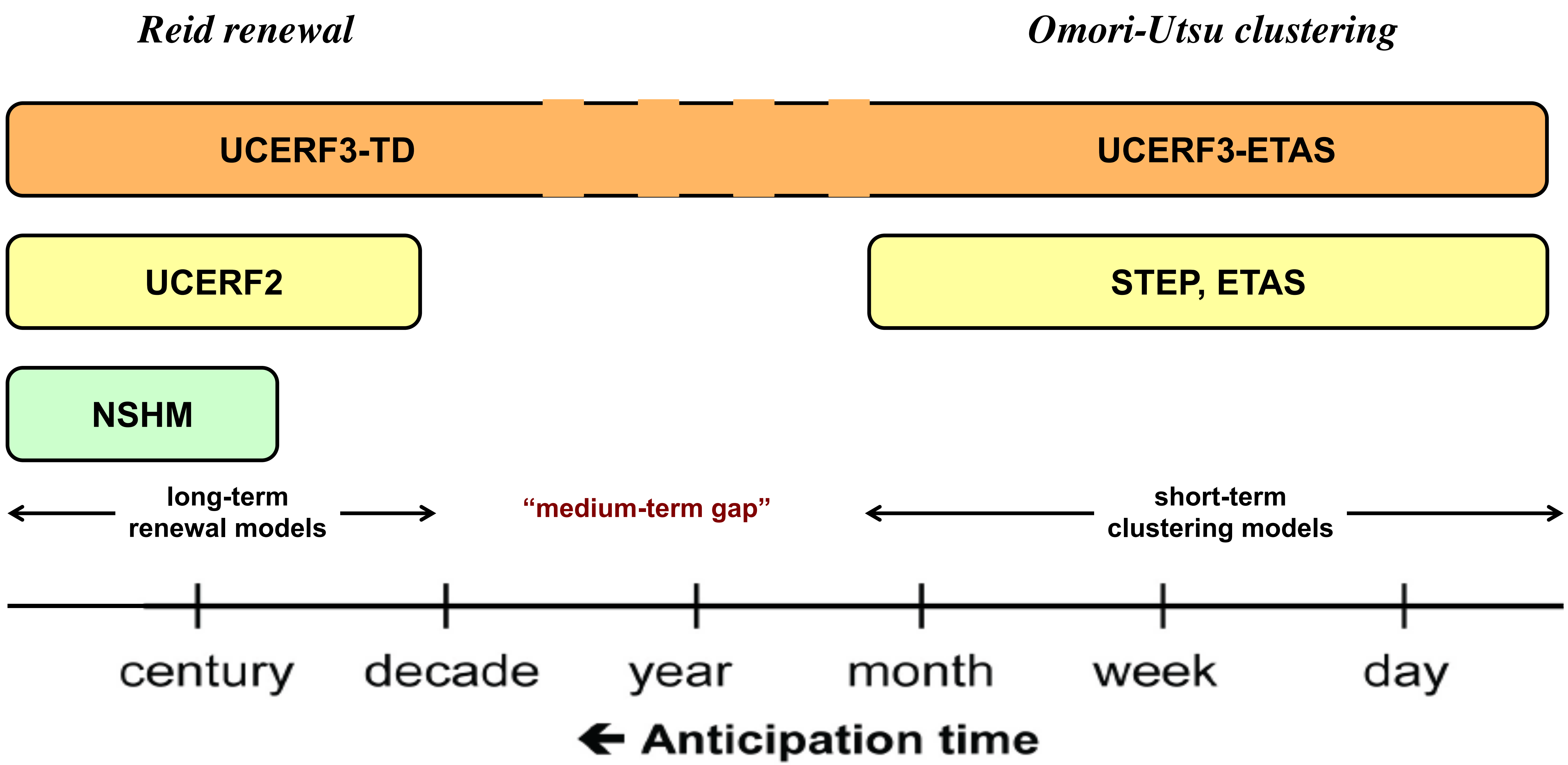
"Seismic Climate Forecasting"

Operational Earthquake Forecasting (OEF)

"Seismic Weather Forecasting"

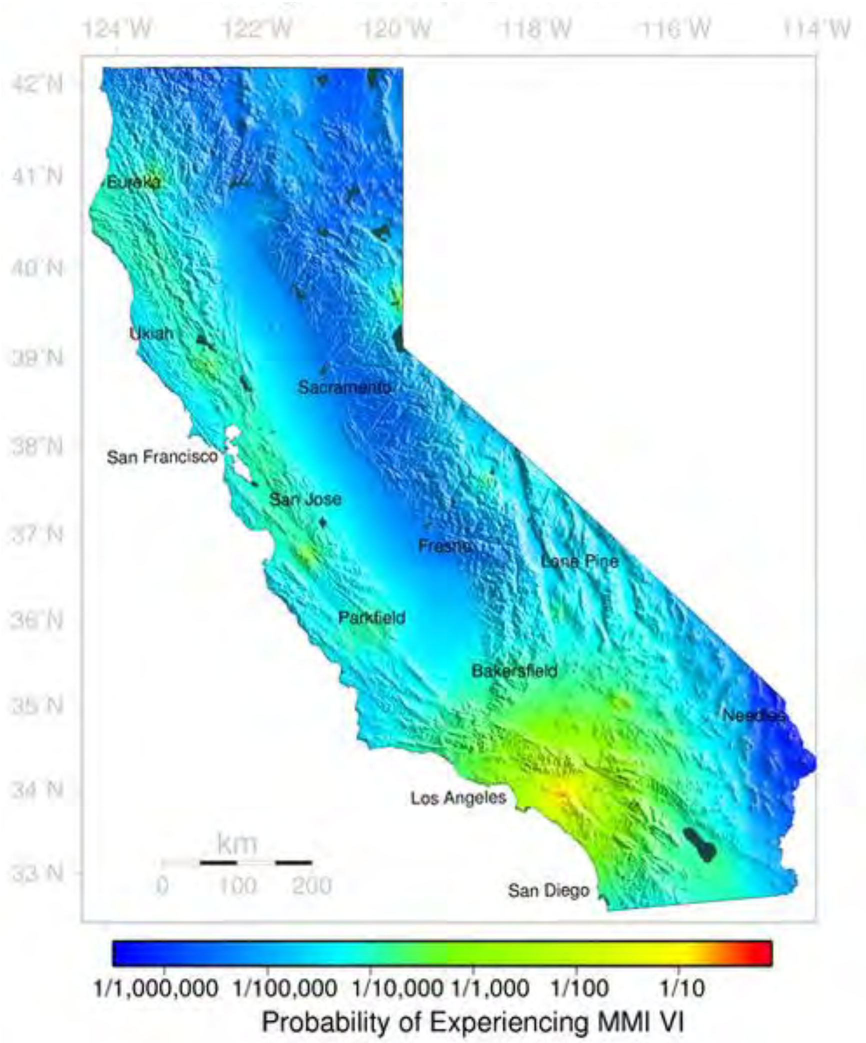


California Earthquake Forecasting Models

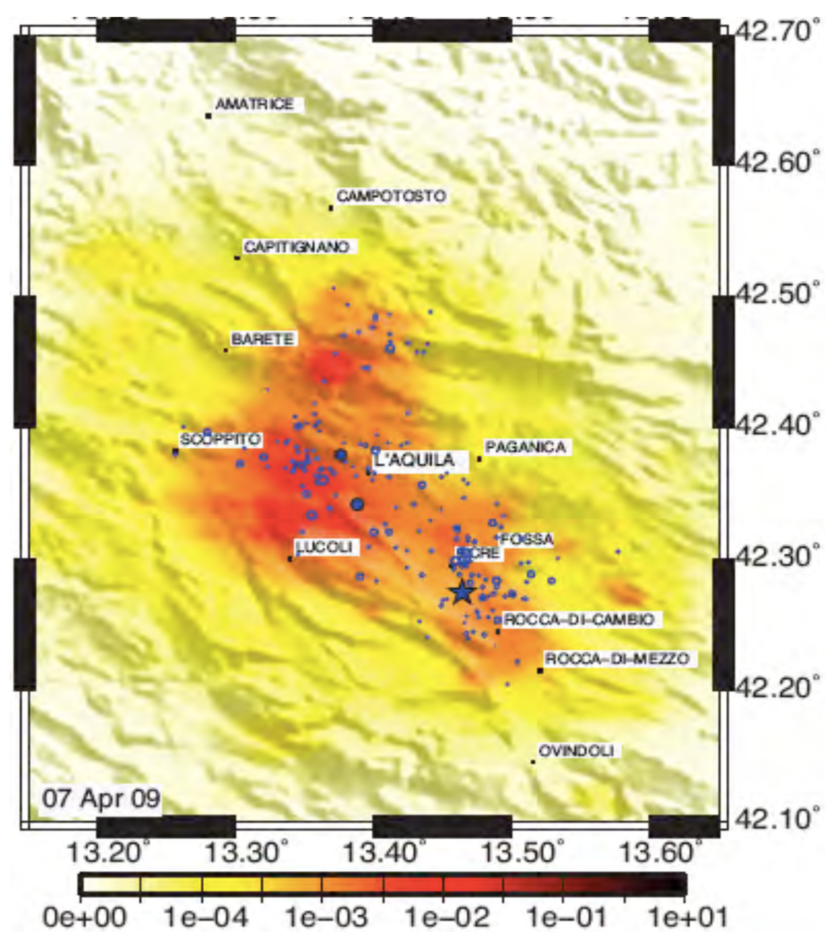


Short-term Forecasting Models

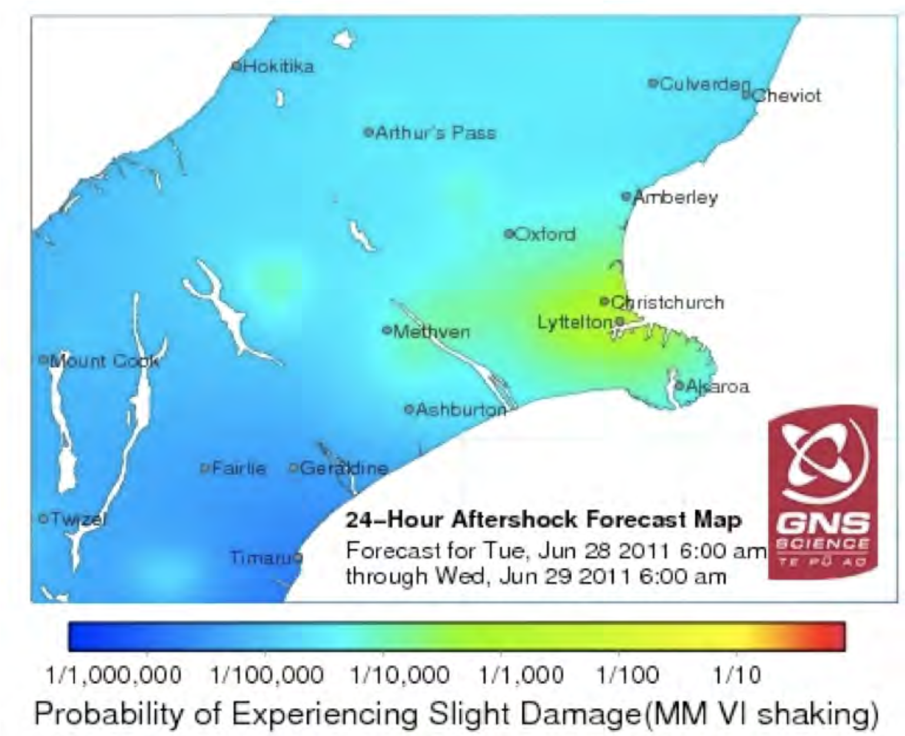
Statistical models based on the Gutenberg-Richter (magnitude-frequency) and Omori-Utsu (aftershock productivity) scaling relations



California STEP model
29 July 2008
(Gerstenberger et al., 2005)



Italy ETAS model
7 April 2009
(Marzocchi & Lombardi, 2009)

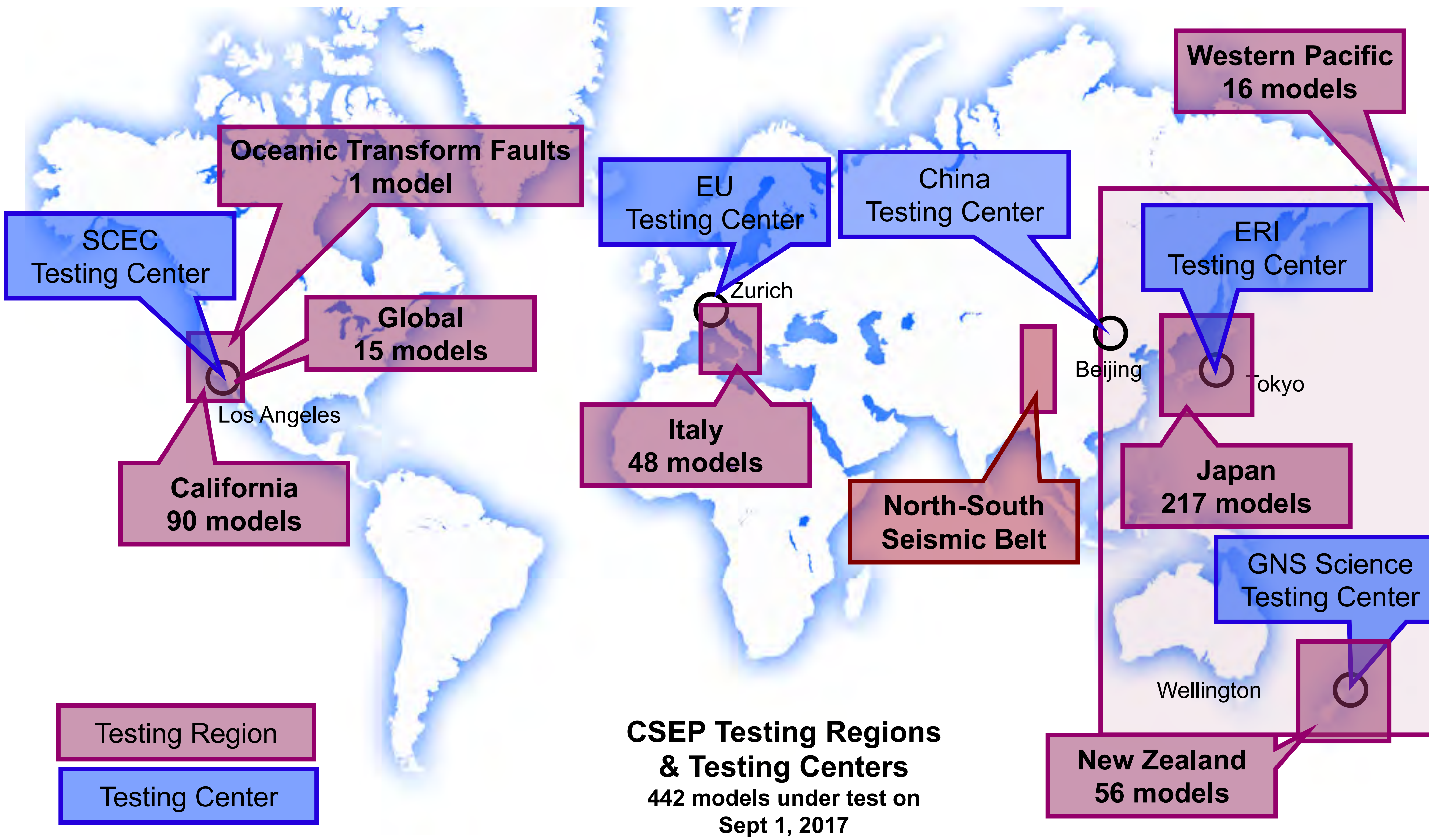


New Zealand STEP model
28 June 2011
(Gerstenberger, 2011)

Collaboratory for the Study of Earthquake Predictability (CSEP)

Cyberinfrastructure for automated, blind, prospective testing of forecasting models in a variety of tectonic environments and on a global scale

Established under a $1.2M grant by the W. M. Keck Foundation, awarded Jan 1, 2006



CSEP Testing Regions & Testing Centers
442 models under test on Sept 1, 2017

International Commission on Earthquake Forecasting for Civil Protection (ICEF)

- **Charged on 11 May 2009 by Dipartimento della Protezione Civile (DPC) to:**
  1. **Report on the current state of knowledge of short-term prediction and forecasting of tectonic earthquakes**
  2. **Indicate guidelines for utilization of possible forerunners of large earthquakes to drive civil protection actions**
- **ICEF report:** ***"Operational Earthquake Forecasting: State of Knowledge and Guidelines for Utilization"***
  - **Findings & recommendations released by DPC (Oct 2009)**
  - **Final peer-reviewed report published in *Annals of Geophysics* (Aug 2011)**

Members (9 countries):

T. H. Jordan, Chair, USA

Y.-T. Chen, China

P. Gasparini, Secretary, Italy

R. Madariaga, France

I. Main, United Kingdom

W. Marzocchi, Italy

G. Papadopoulos, Greece

G. Sobolev, Russia

K. Yamaoka, Japan

J. Zschau, Germany

http://www.annalsofgeophysics.eu/index.php/annals/article/view/5350

Operational Earthquake Forecasting

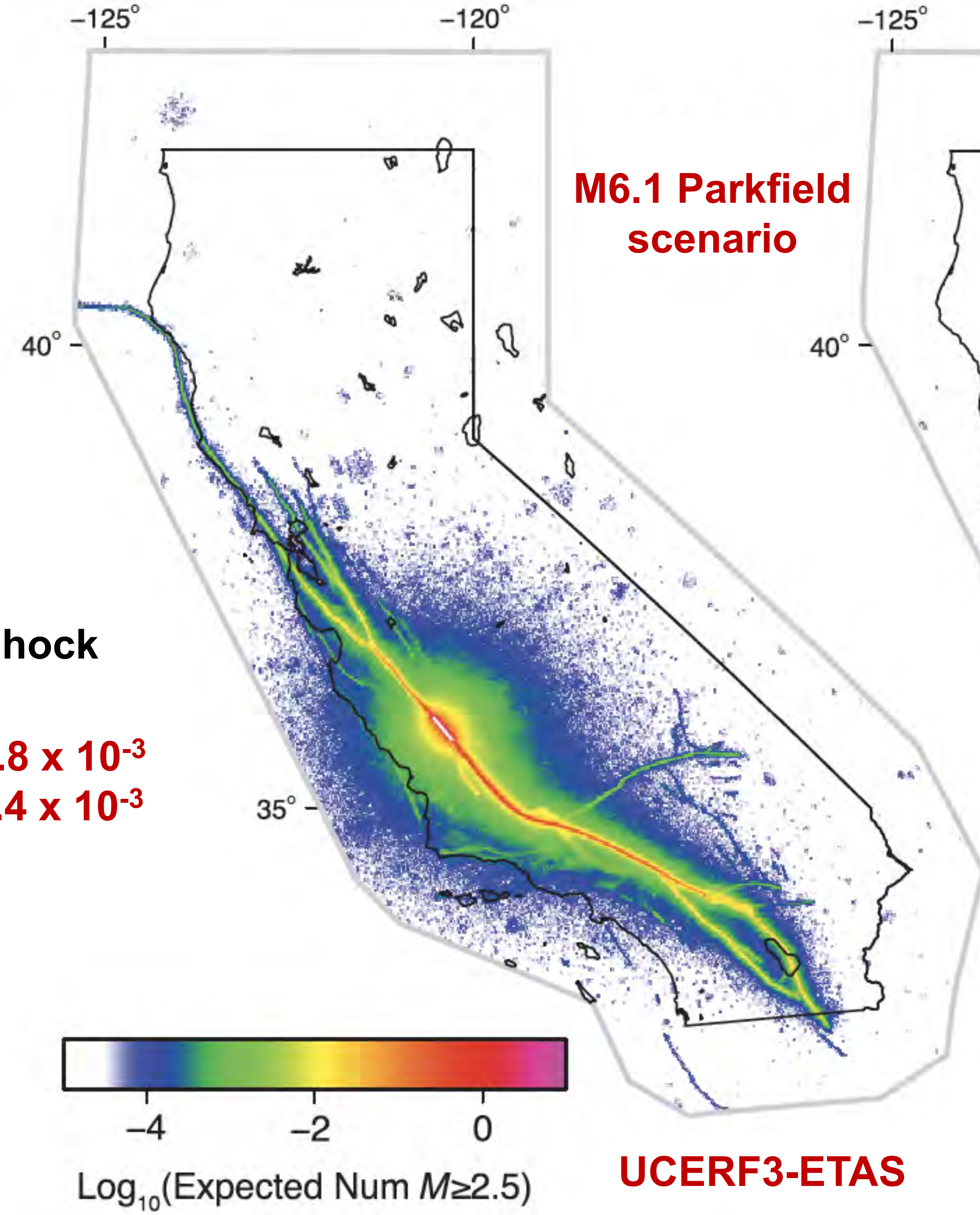
Timely dissemination of authoritative information about the future occurrence of potentially damaging earthquakes to reduce risk and enhance earthquake preparedness in threatened communities

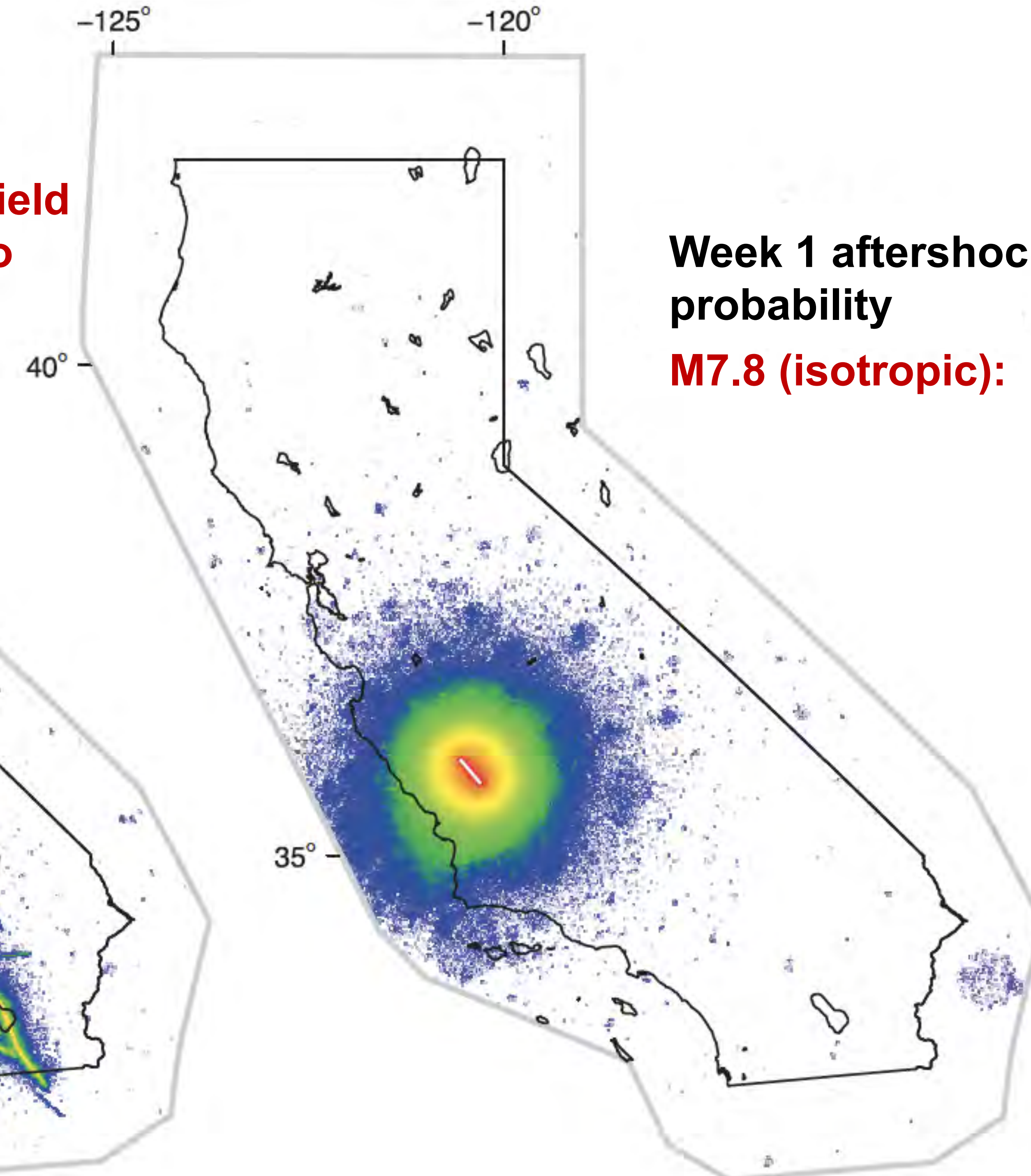
Subset of ICEF Recommendations:

- **Authoritative forecasts should be made available at regular intervals, during periods of normal seismicity as well as during seismic crises**
  - The public expects scientists to be transparent in forecasting natural disasters using the best information and most accurate methods
  - Information vacuums spawn bogus predictions and misinformation
- **Advisories should be rigorously reviewed and updated by experts in the creation, delivery, and utility of earthquake information**
  - Earthquake forecasts should be consistent across spatial and temporal scales (UCERF3)
  - Operational models should be evaluated by continuous prospective testing against alternative time-dependent models (CSEP)

Bottom line: Deployment of OEF is now a requirement, not an option

Uniform California Earthquake Rupture Forecast





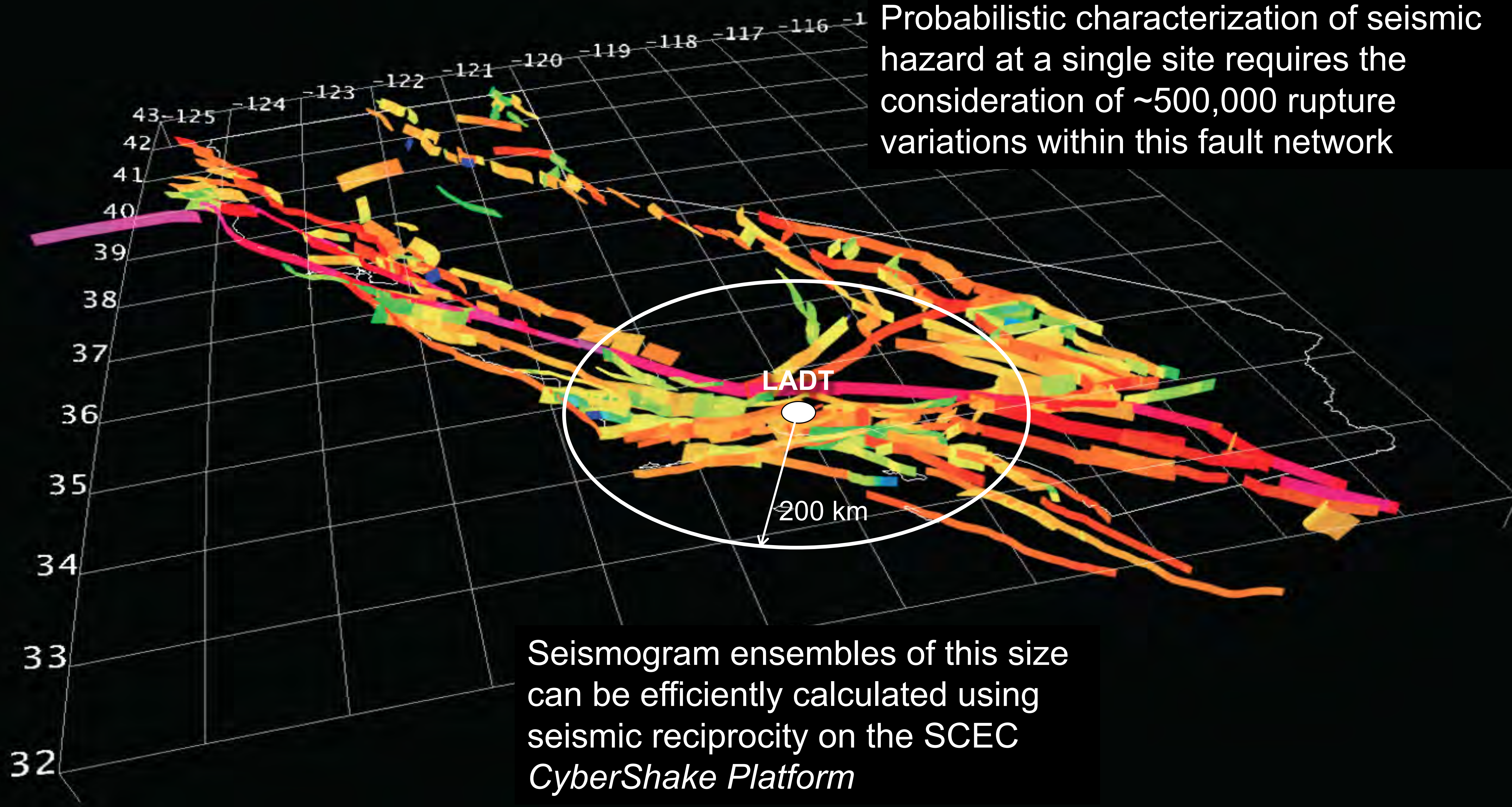
Week 1 aftershock probability

M7.8 (NW): 5.8 x 10^{-3}
M7.8 (SE): 0.4 x 10^{-3}

Week 1 aftershock probability

M7.8 (isotropic): 1.2 x 10^{-3}

CyberShake Project



Probabilistic characterization of seismic hazard at a single site requires the consideration of ~500,000 rupture variations within this fault network

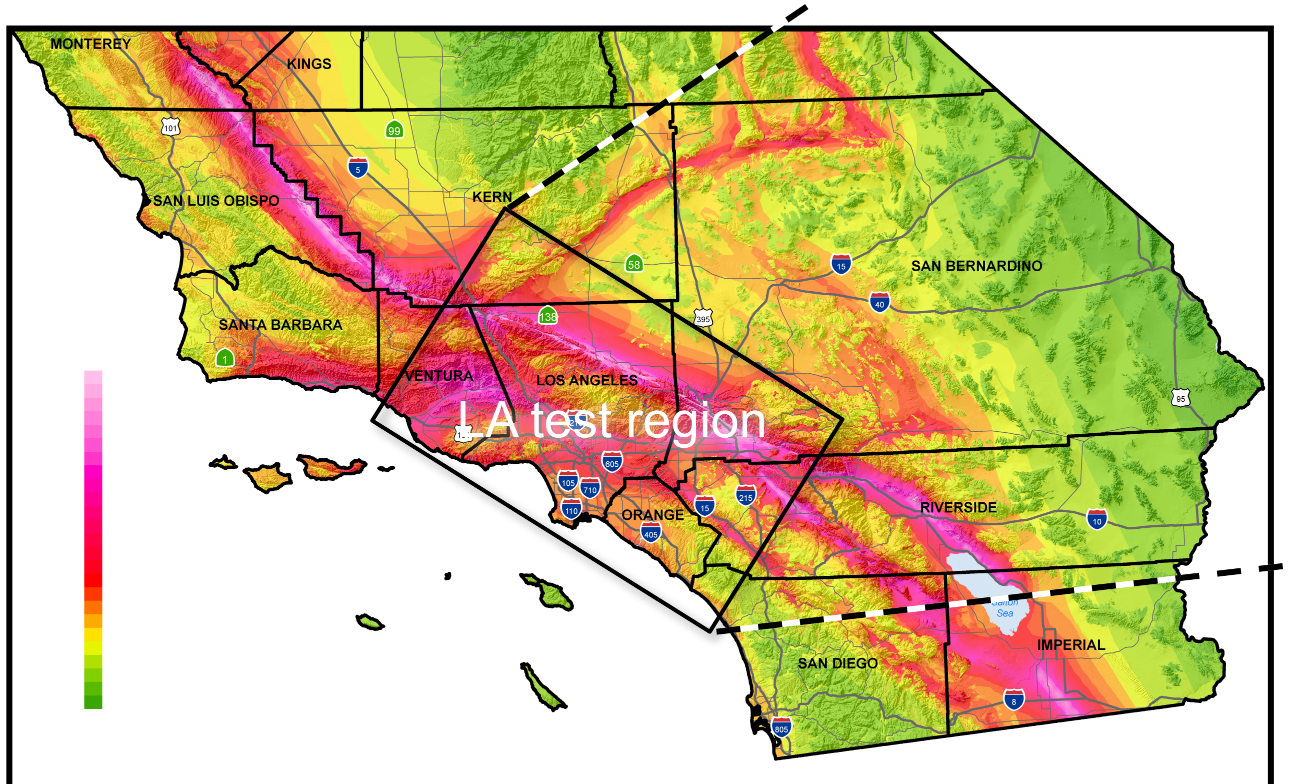
Seismogram ensembles of this size can be efficiently calculated using seismic reciprocity on the SCEC *CyberShake Platform*

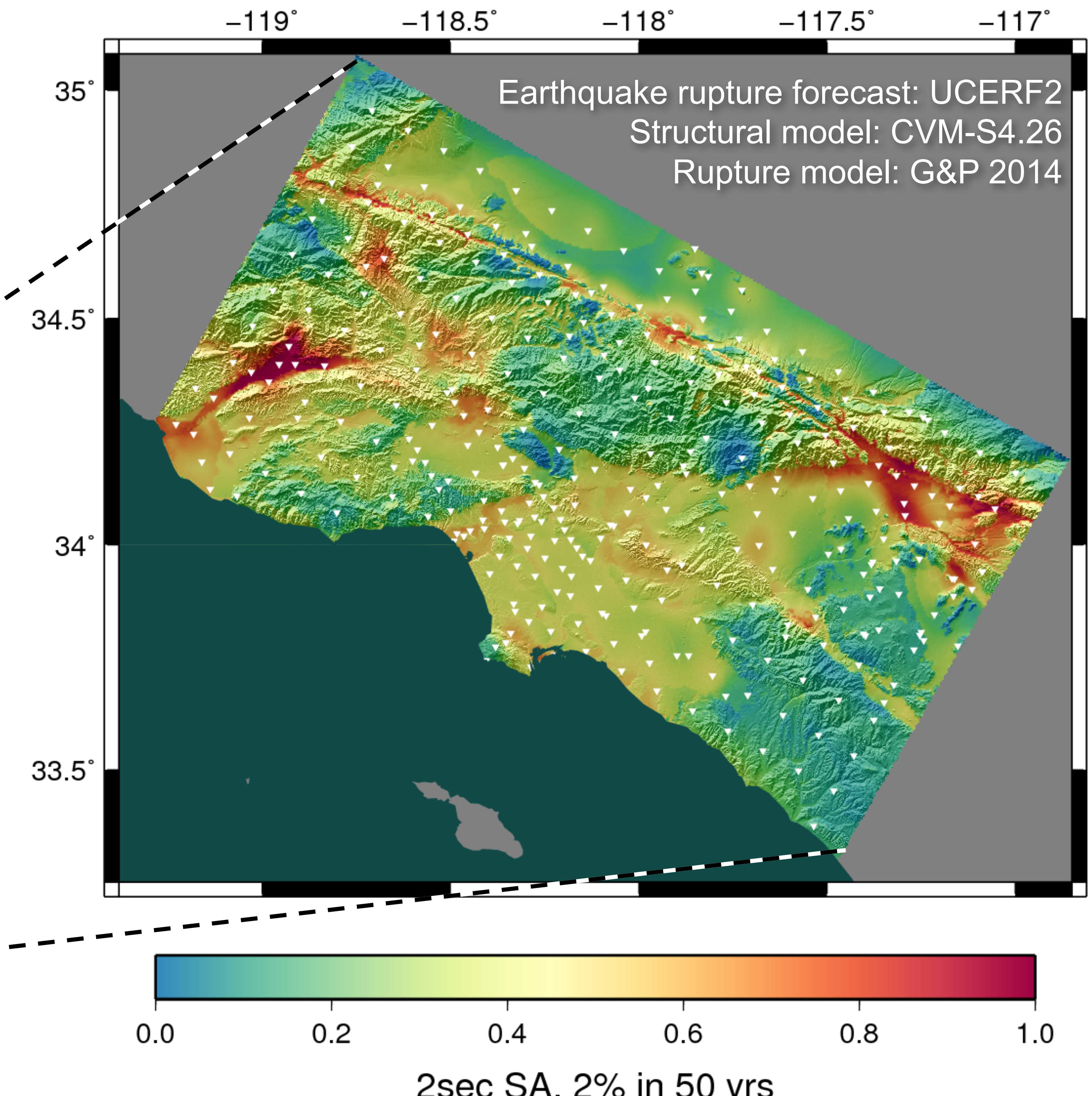
CyberShake Platform

Generates probabilistic seismic hazard models from large ensembles (> 10^8) of synthetic seismograms

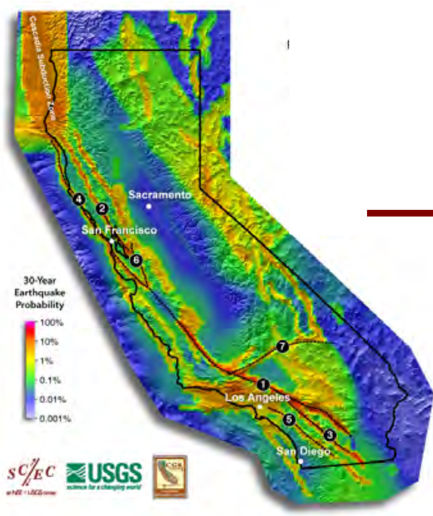
- **UCERF2 fault-based event set**
- **Graves & Pitarka rupture models**
- **SCEC 3D seismic velocity models**

(Graves et al., 2011; Wang & Jordan, 2014)



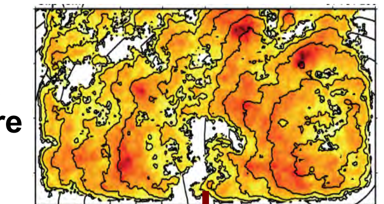


Coupling of Models in the CyberShake Workflow



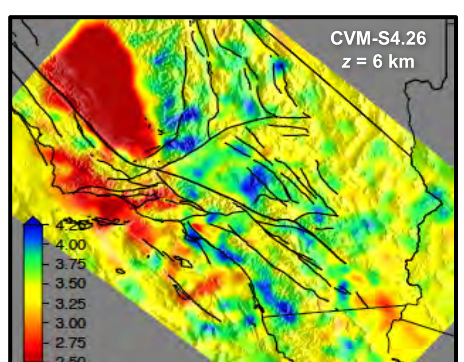
Uniform California Earthquake Rupture Forecast

Graves-Pitarka kinematic rupture simulator



UCVM

Mesh generation
1 job per site
MPI, 1500-4000 cores



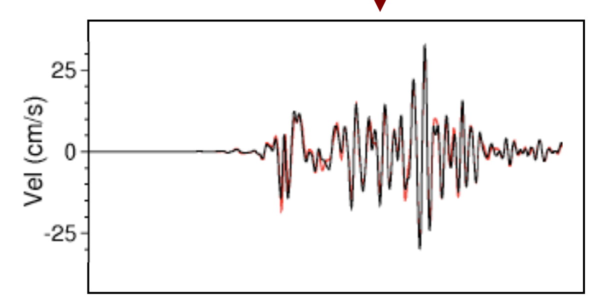
Community Velocity Model

AWP-ODC

SGT computation
2 jobs per site
MPI, 200-800 GPUs
NCSA *Blue Waters*
OLCF *Titan*

Seismogram Synthesis

Post-processing
~500,000 jobs per site
MPI master/worker, 3712 cores
NCSA *Blue Waters*
OLCF *Titan*

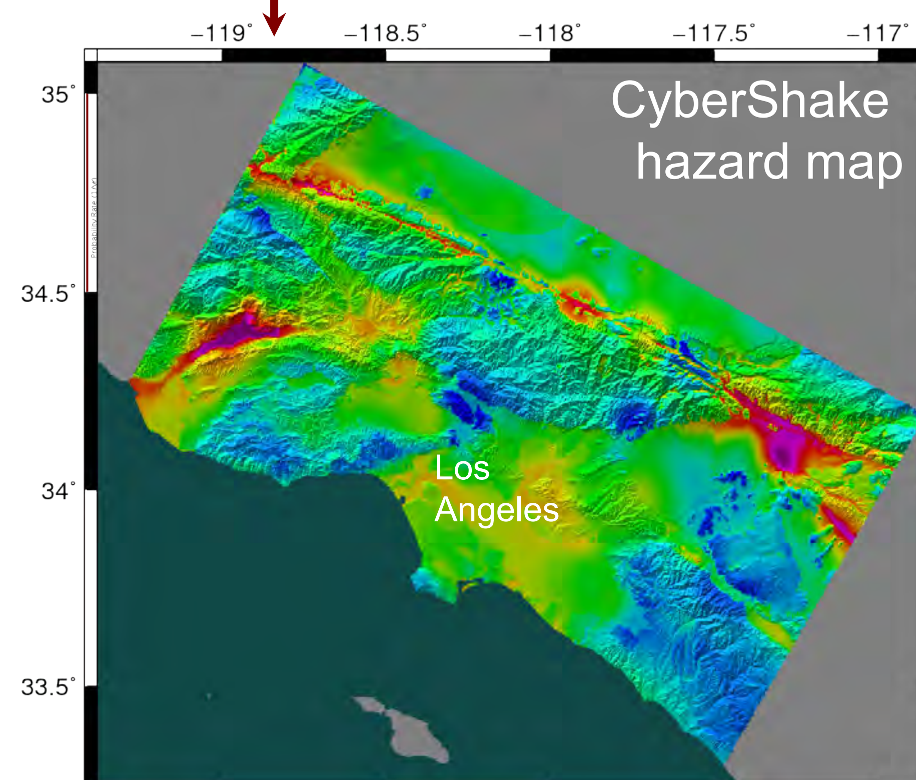


500,000 Seismograms
75M intensity measures

12 TB data transfer

Data Product Generation

Populate DB, construct queries
6 jobs per site

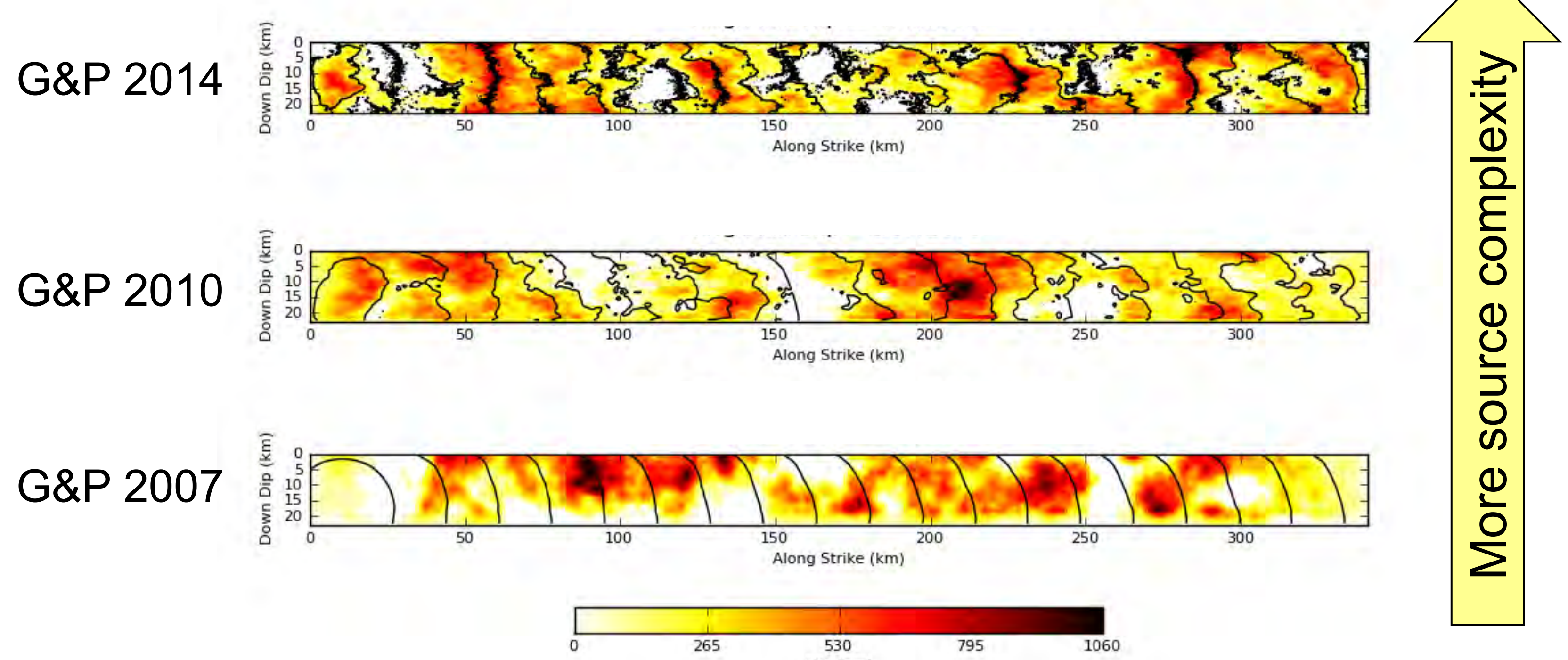


A complete CyberShake model for the Los Angeles region comprises ~300 million synthetic seismograms

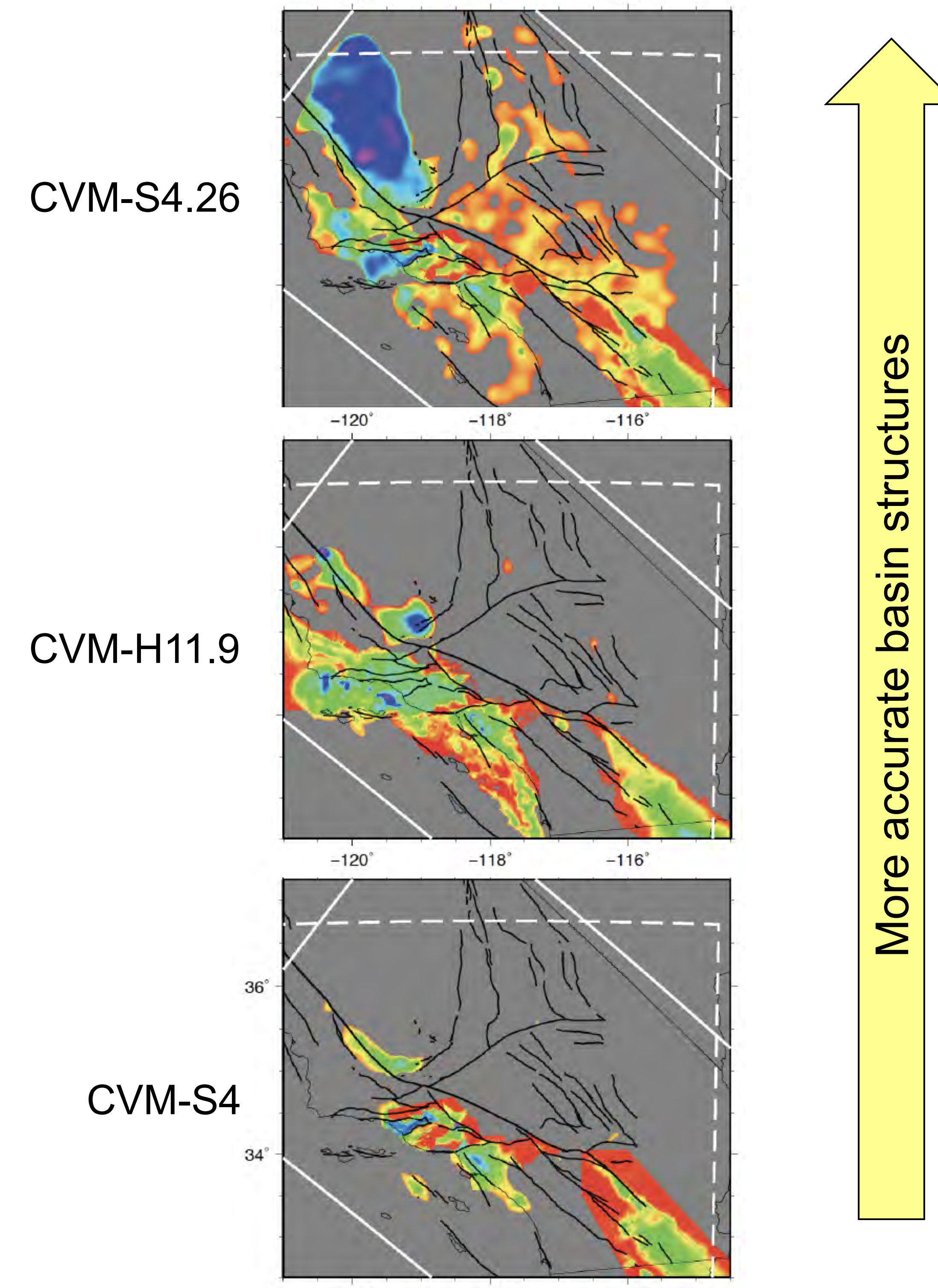
CyberShake Studies

Study ID	Model ID	Fmax (Hz)	Rupture Generator	Velocity Model	SGT Code	# Sites
17.3	CS-CCA17.3a	1.0	G&P 2014	CCA06-3D	AWP-SGT-GPU	438
	CS-CCA17.3b	1.0	G&P 2014	CCA06-1D	AWP-SGT-GPU	438
15.4	CS-LA15.4	1.0	G&P 2014	CVM-S4.26	AWP-SGT-GPU	336
14.2	CS-LA14.2.a	0.5	G&P 2010	CVM-S4.26	AWP-SGT-GPU	286
	CS-LA14.2.b	0.5	G&P 2010	CVM-H11.9	AWP-SGT-CPU	286
	CS-LA14.2.c	0.5	G&P 2010	BBP-1D	AWP-SGT-GPU	286
	CS-LA14.2.d	0.5	G&P 2010	CVM-S4.26	AWP-SGT-CPU	286
13.4	CS-LA13.4.a	0.5	G&P 2010	CVM-S4.0	RWG v3.0.3	283
	CS-LA13.4.b	0.5	G&P 2010	CVM-H11.9-GTL	RWG v3.0.3	283
	CS-LA13.4.c	0.5	G&P 2010	CVM-S4.0	AWP-SGT-CPU	283
	CS-LA13.4.d	0.5	G&P 2010	CVM-H11.9	AWP-SGT-CPU	283
1.0	CS-LA1.0	0.5	G&P 2007	CVM-S4.0	RWG v1.16.3	223

Graves & Pitarka Pseudo-Dynamic Rupture Models



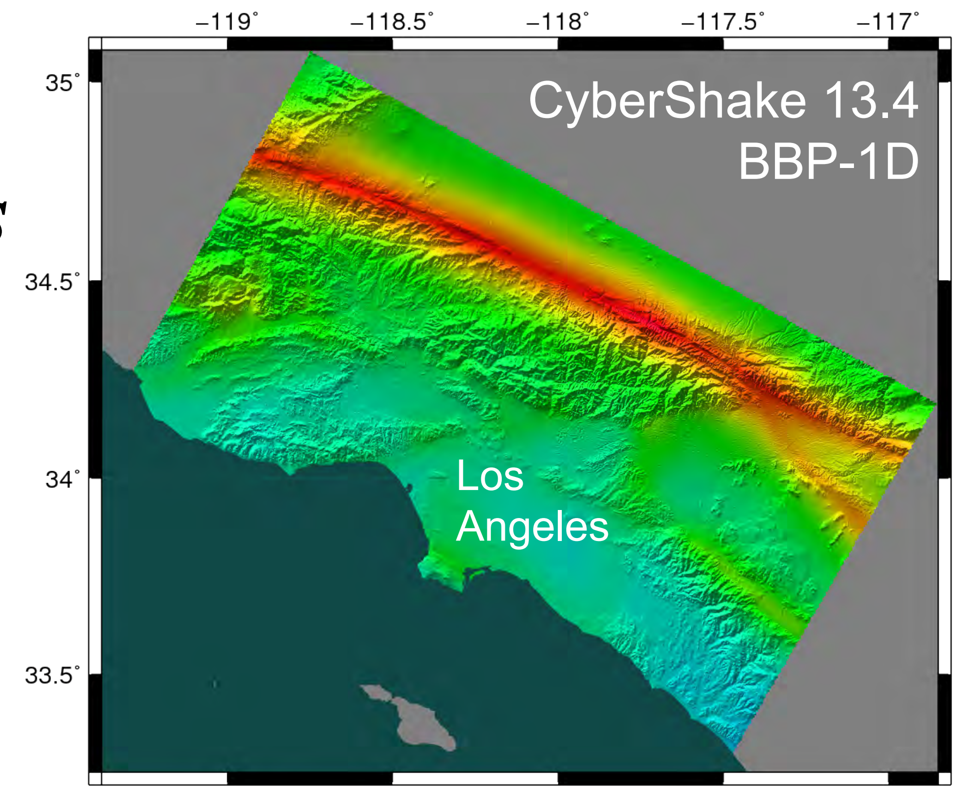
SCEC Community Velocity Models



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

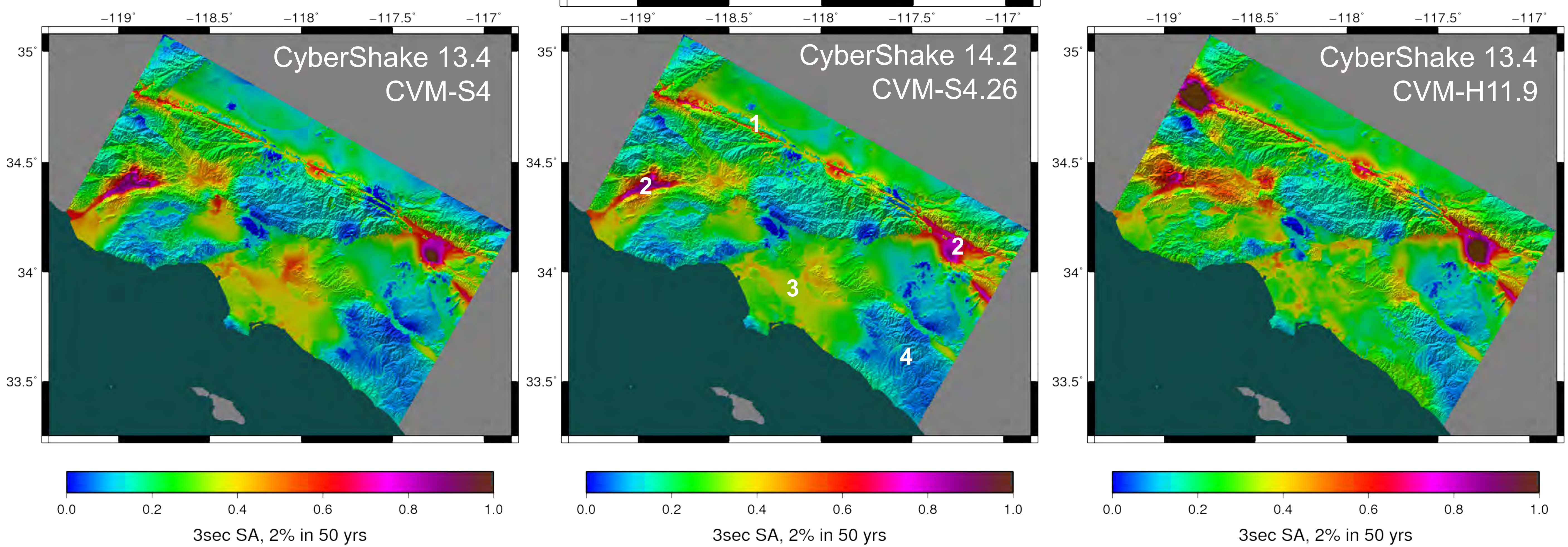
Comparison of 1D and 3D CyberShake Models for the LA Region

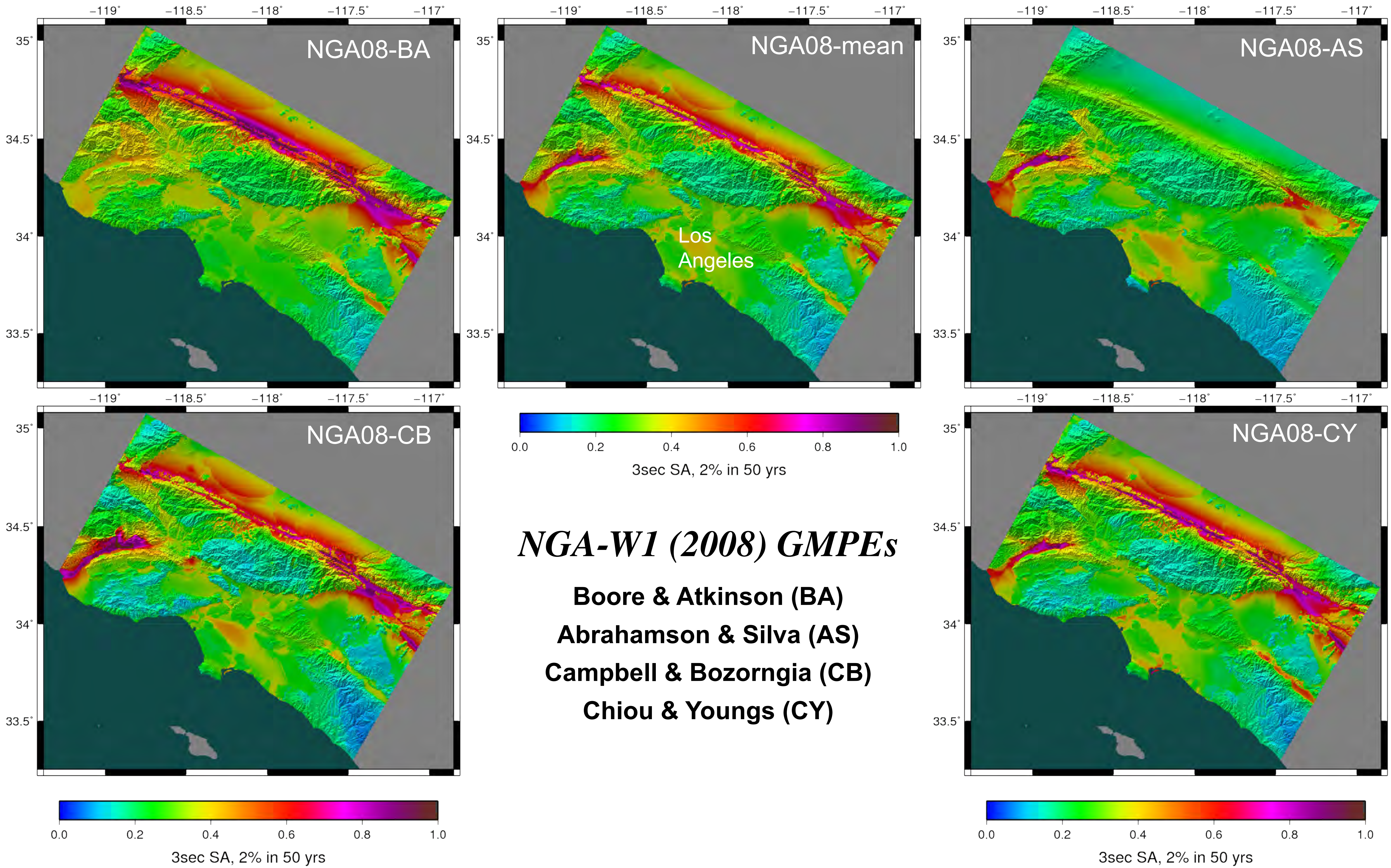
IM: 3s-SA (g) at 2% in 50 yrs
Rupture generator: GP2010



3D-1D Differences

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

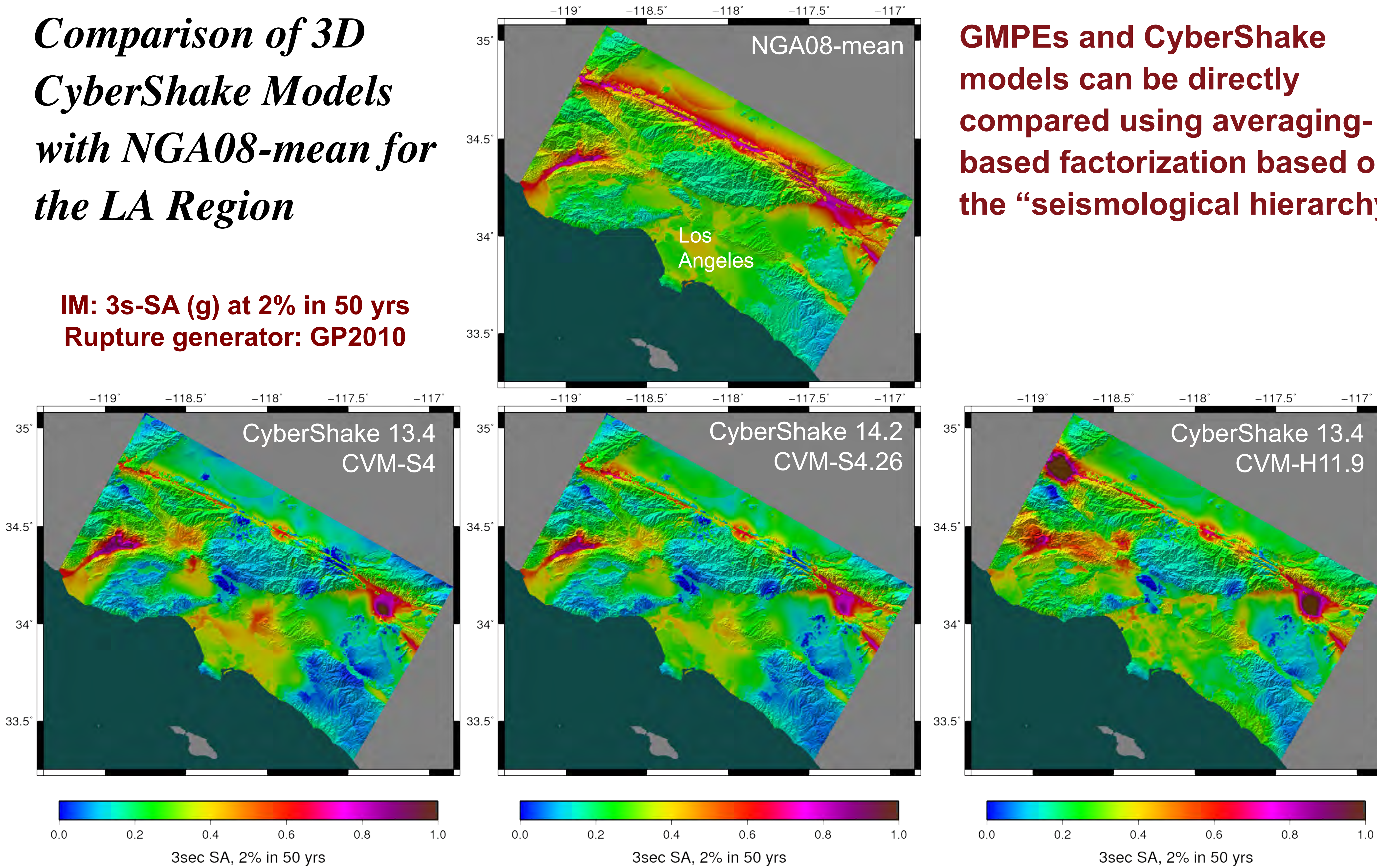



NGA08-BA
NGA08-mean
NGA08-AS
NGA08-CB
NGA08-CY
Los Angeles
–119°
–118.5°
–118°
–117.5°
–117°
35°
34.5°
34°
33.5°
0.0
0.2
0.4
0.6
0.8
1.0
3sec SA, 2% in 50 yrs
NGA-W1 (2008) GMPEs
Boore & Atkinson (BA)
Abrahamson & Silva (AS)
Campbell & Bozorngia (CB)
Chiou & Youngs (CY)

Comparison of 3D CyberShake Models with NGA08-mean for the LA Region

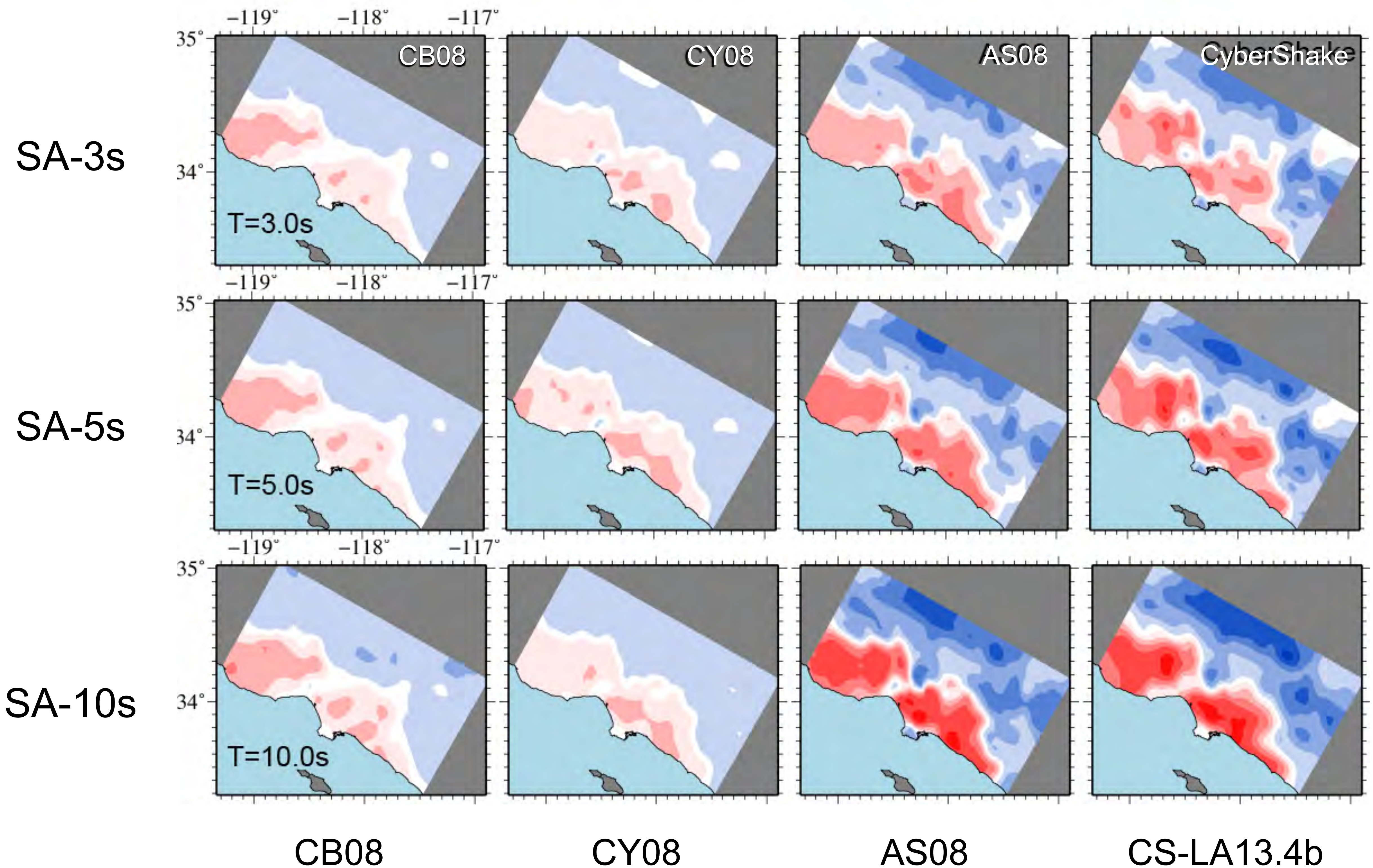
GMPEs and CyberShake models can be directly compared using averaging-based factorization based on the "seismological hierarchy"

IM: 3s-SA (g) at 2% in 50 yrs
Rupture generator: GP2010



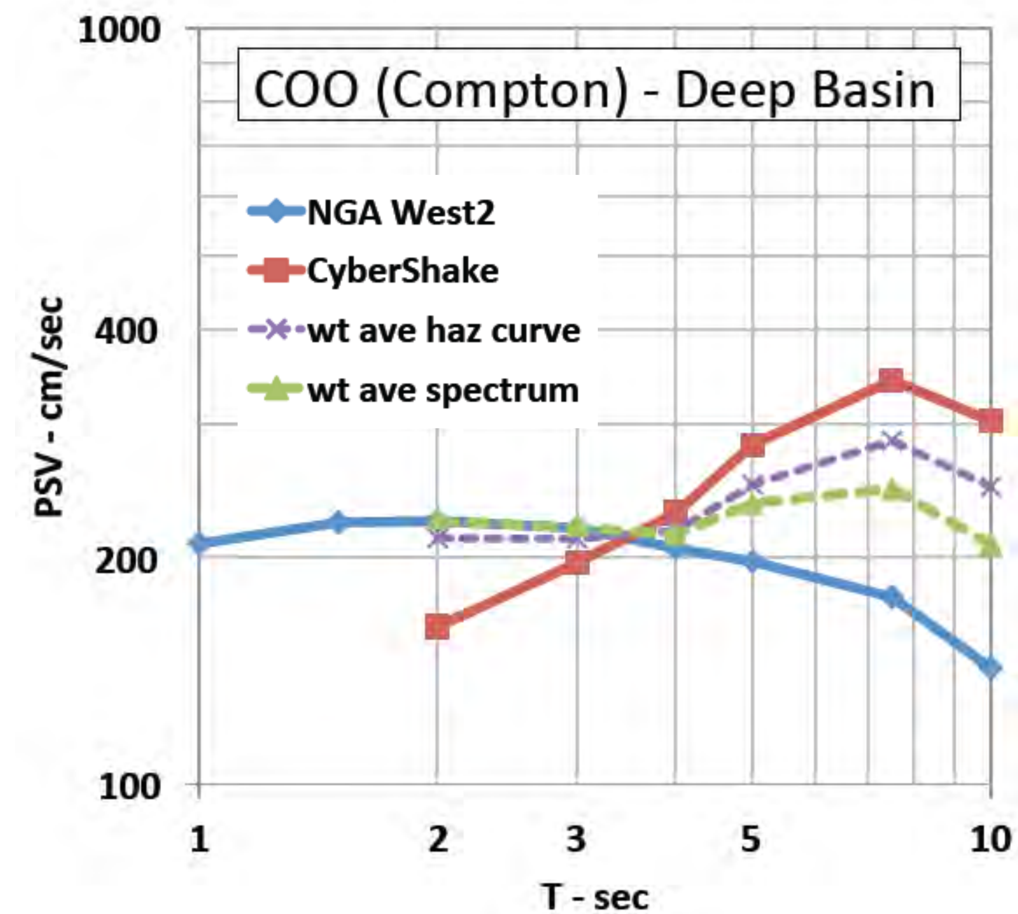
Basin Effect Maps

(SA *b*-maps corrected for V_{S30} using BA08)



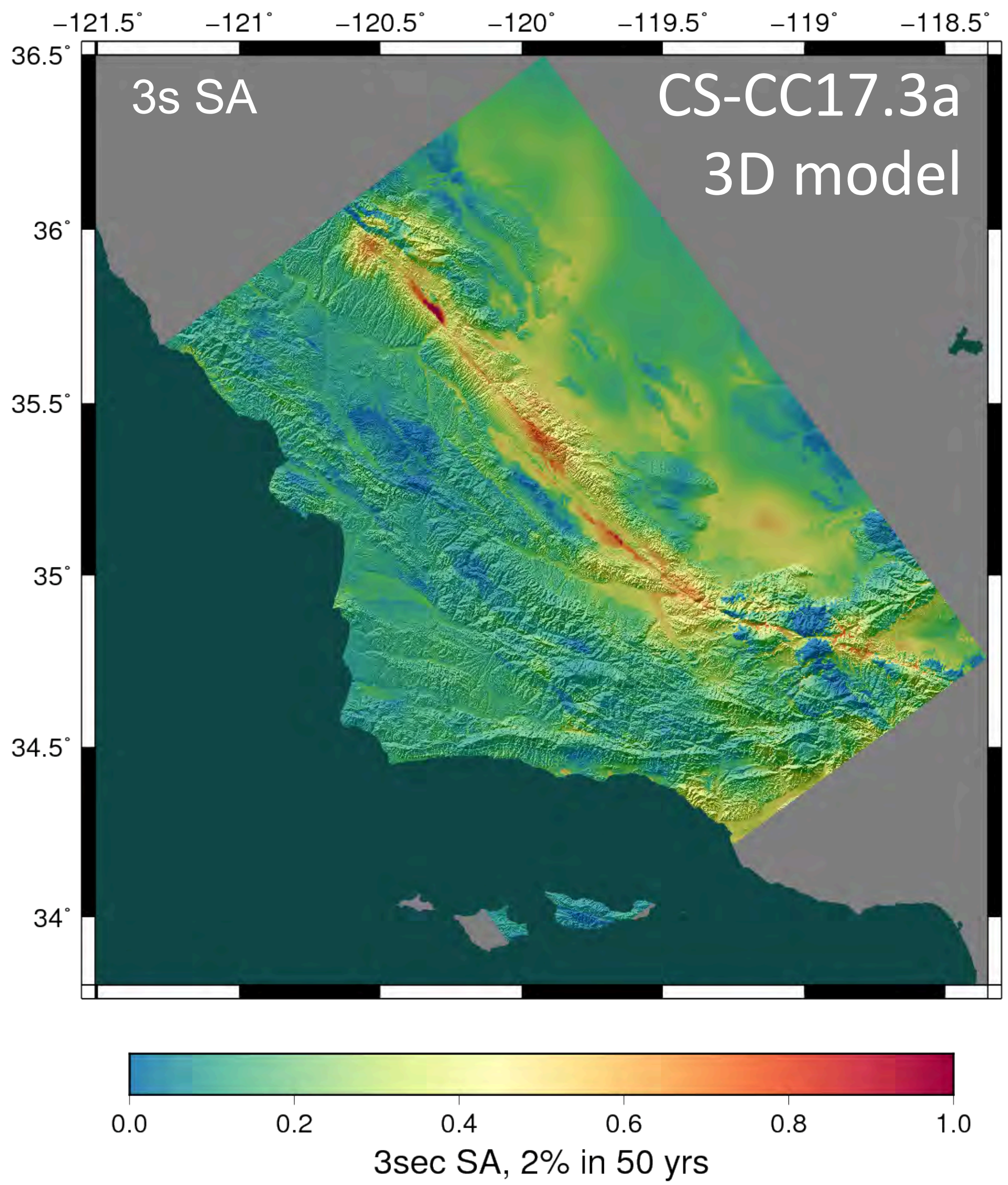
SCEC Committee on the Utilization of Ground Motion Simulations

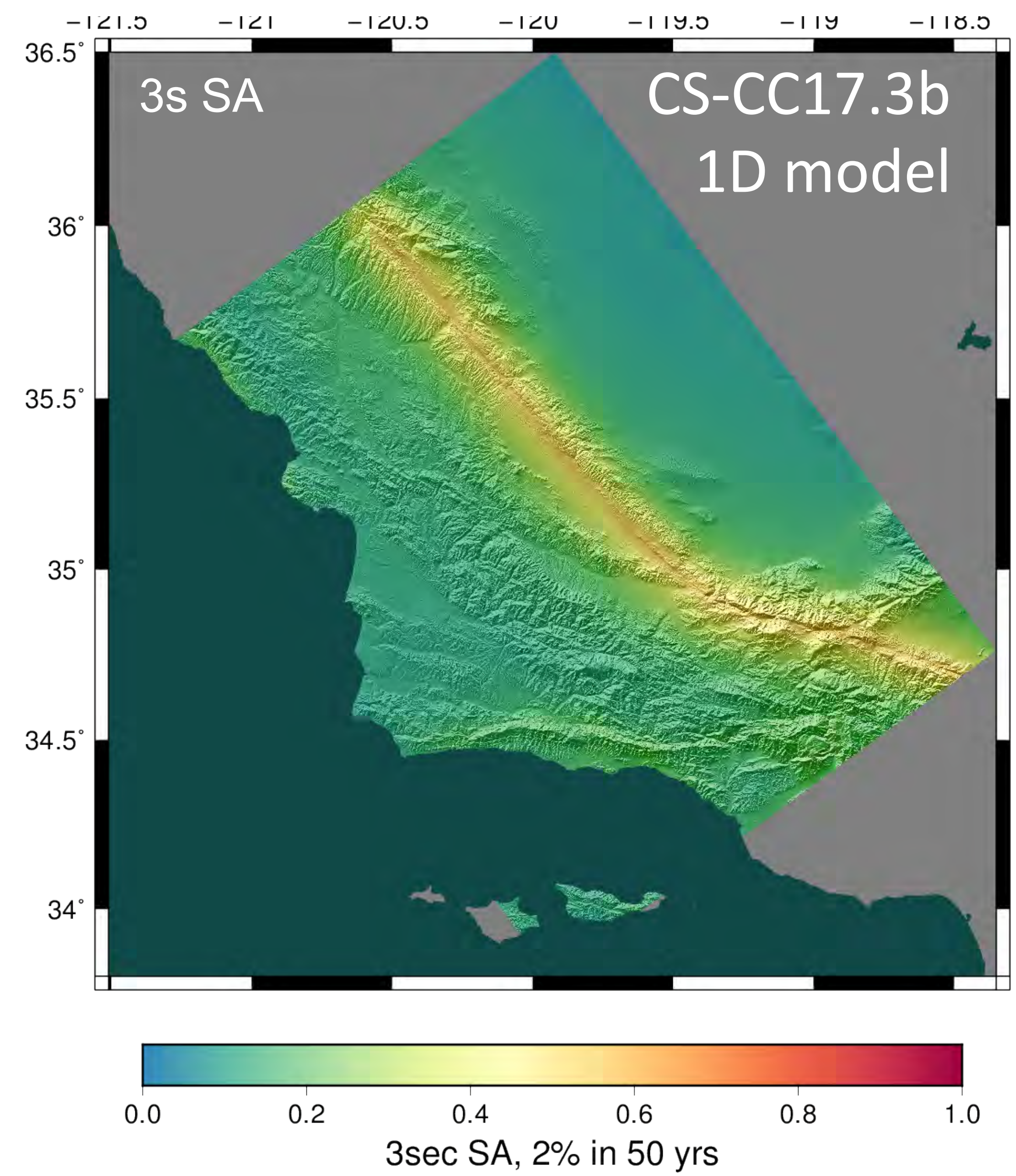
- **Formed in 2013, chaired by C. B. Crouse, and populated by 20 earthquake engineers and seismologists**
- **Using CyberShake results to develop long-period MCE_R response spectra maps for the Los Angeles region**
  - **To be proposed as a provision for ASCE 7-22 maps for Southern California**
  - **Resource to consultants and local jurisdictions (e.g. LA City DBS)**
  - **Look-up tool ~ USGS web app tool**
- **Conducting verification and validation studies**
- **Release planned for Fall 2017**



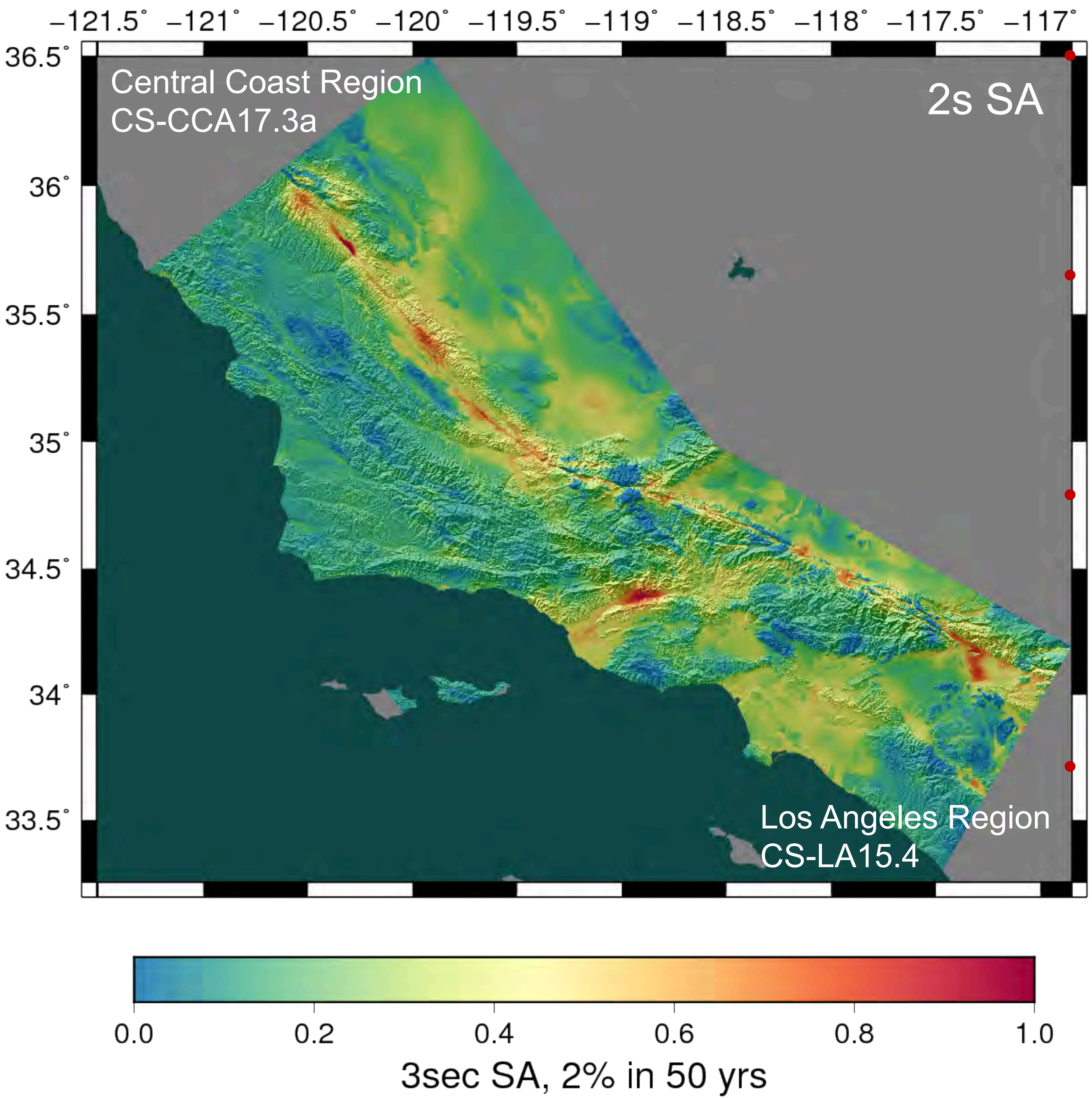
Southern California Earthquake Center

CyberShake Models for Central California





CyberShake Research Issues



Model improvements
- Verify Monte Carlo sampling schemes
- Incorporate a UCERF3 rupture set
- Improve CVMs at shallow depths

Validation
- GMPE comparisons
- Historical and new events
- Virtual earthquakes from ambient field

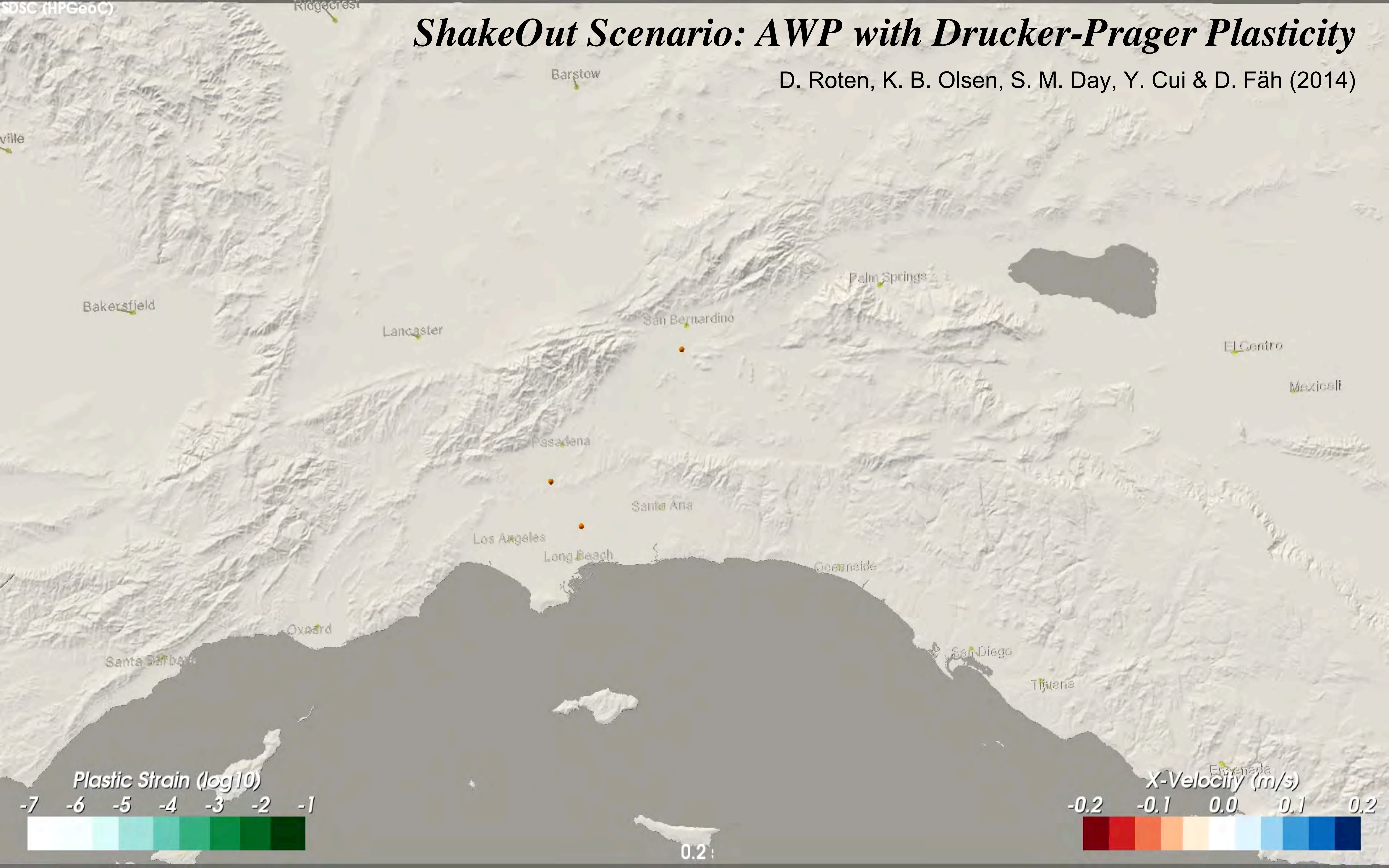
Characterization of epistemic uncertainties
- Earthquake rupture forecast
- Pseudo-dynamic rupture model
- 3D velocity structure
- Site effects

Push to higher frequencies
- Fault complexity
- F-dependent attenuation
- Near-fault nonlinearity
- Near-surface nonlinearity
- Small-scale heterogeneity

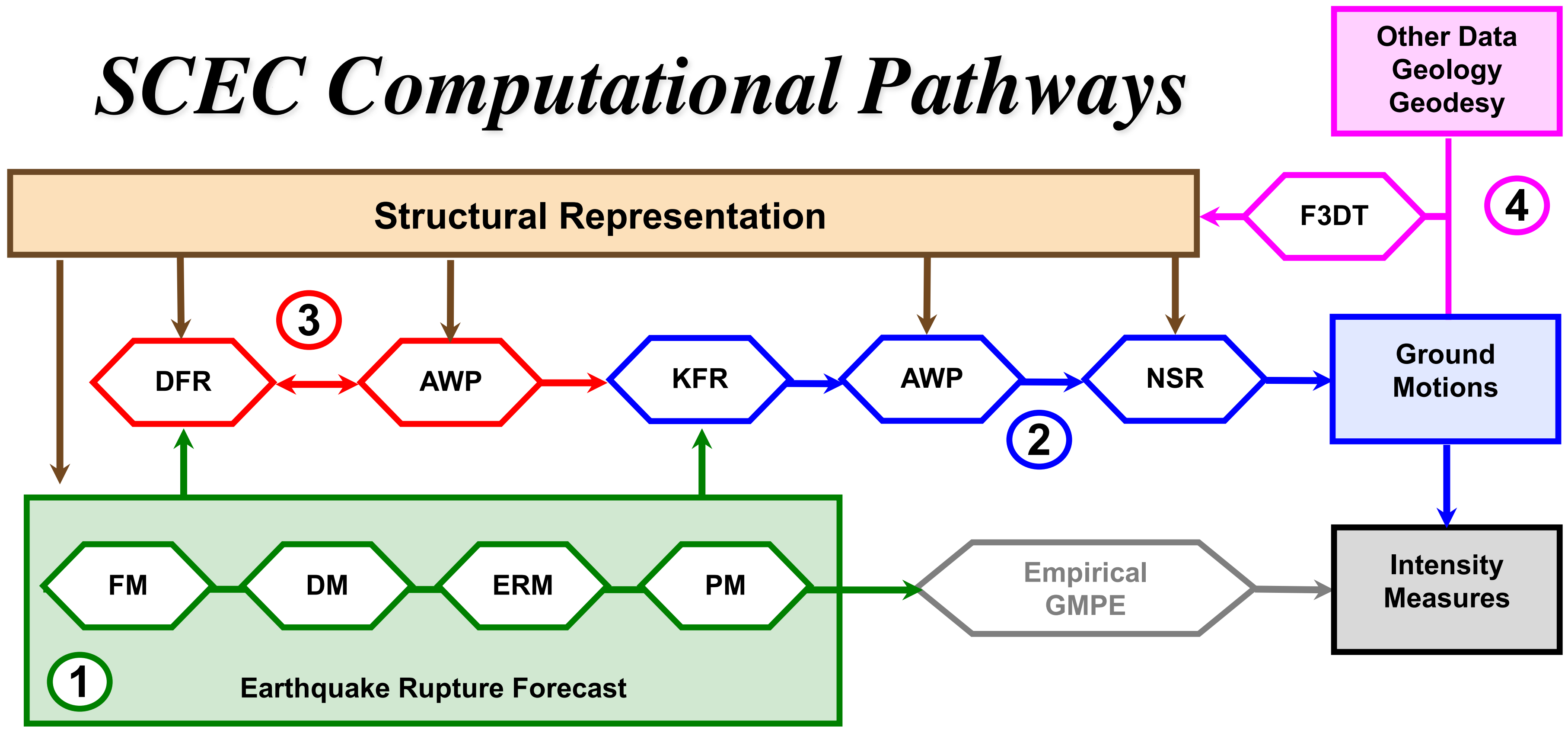
High-F Project

ShakeOut Scenario: AWP with Drucker-Prager Plasticity

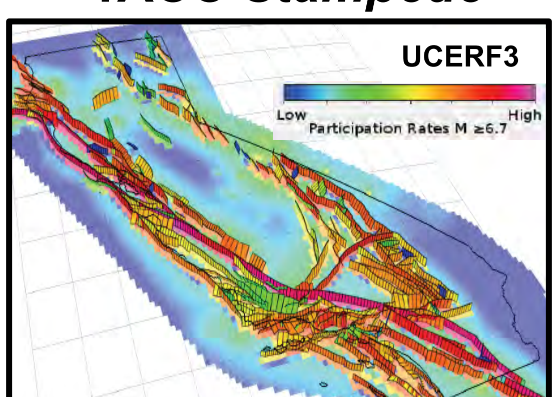
D. Roten, K. B. Olsen, S. M. Day, Y. Cui & D. Fäh (2014)



SCEC Computational Pathways

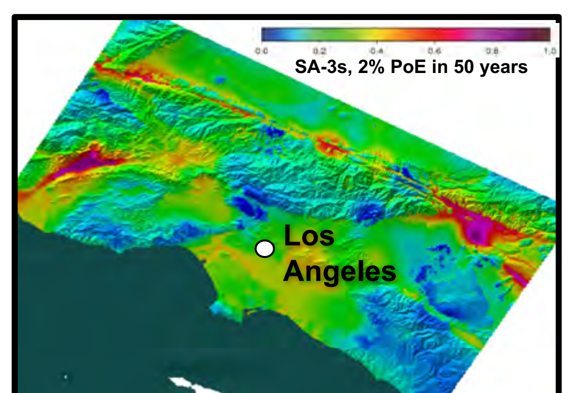


TACC *Stampede*



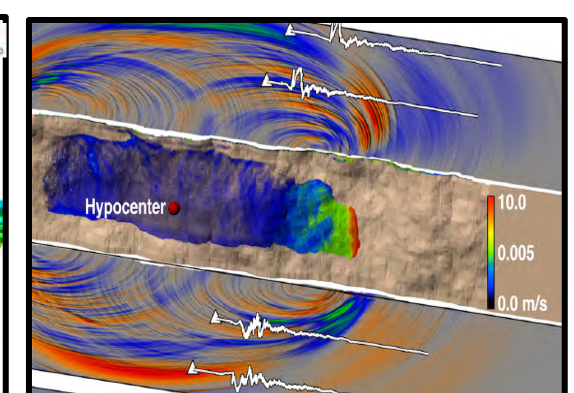
1 Uniform California Earthquake Rupture Forecast (UCERF3)

NCSA *Blue Waters*



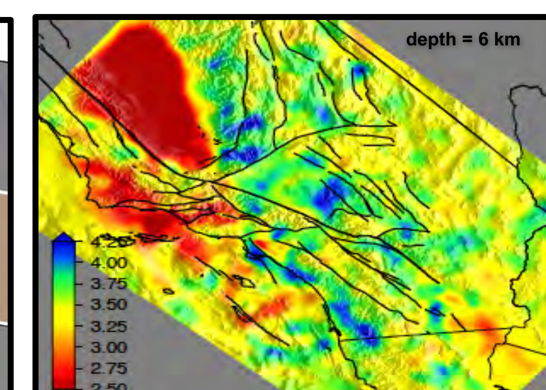
2 CyberShake 14.2 seismic hazard model for LA region

OLCF *Titan*



3 Dynamic rupture model of fractal roughness on SAF

ALCF *Mira*

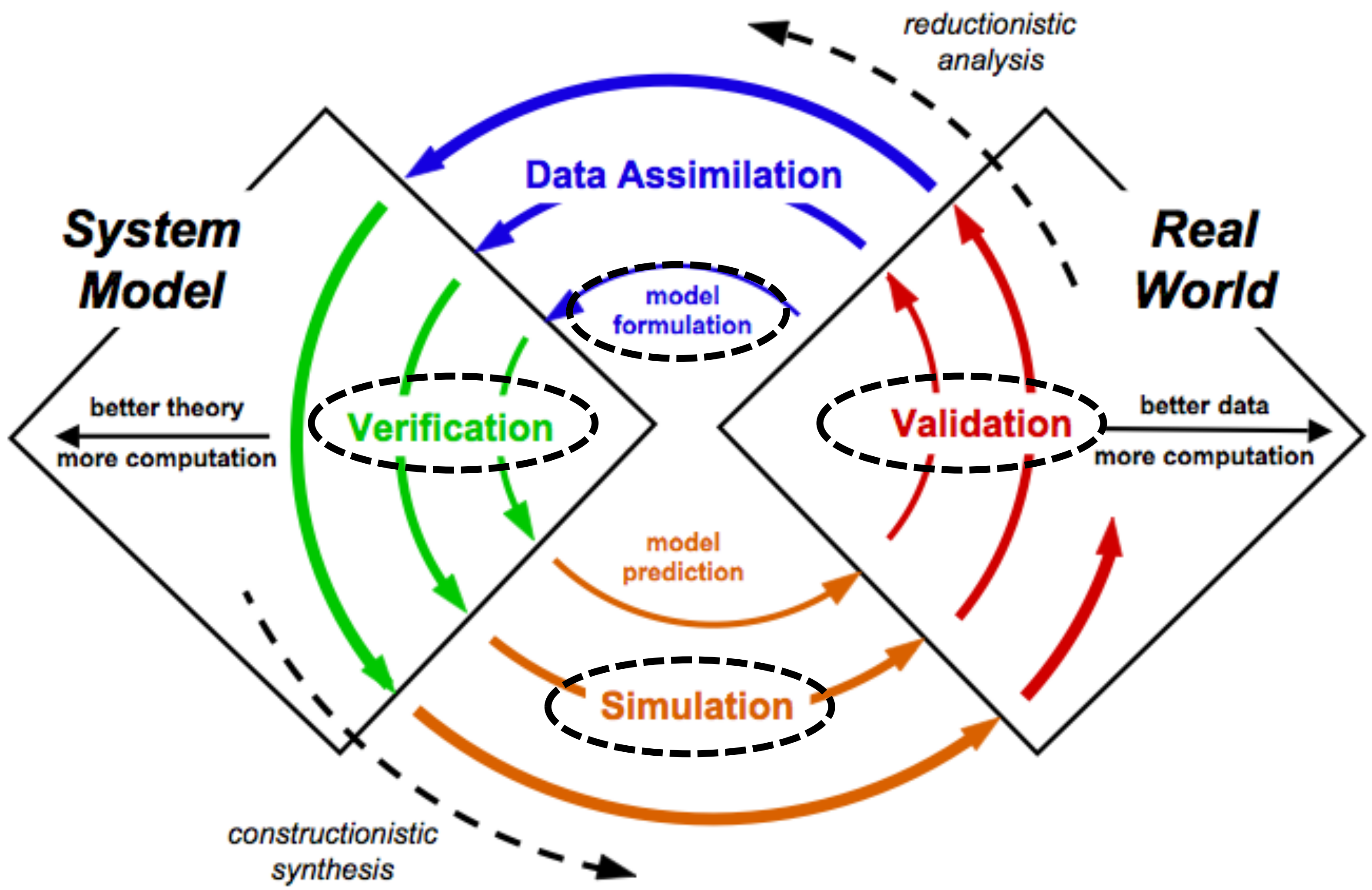


4 Full-3D tomographic model CVM-S4.26 of S. California

Inference Spiral of System Science

Verification: *Is the model correctly computed with a specified precision?*

Formulation: *Model designed to explain observed system-level behavior*



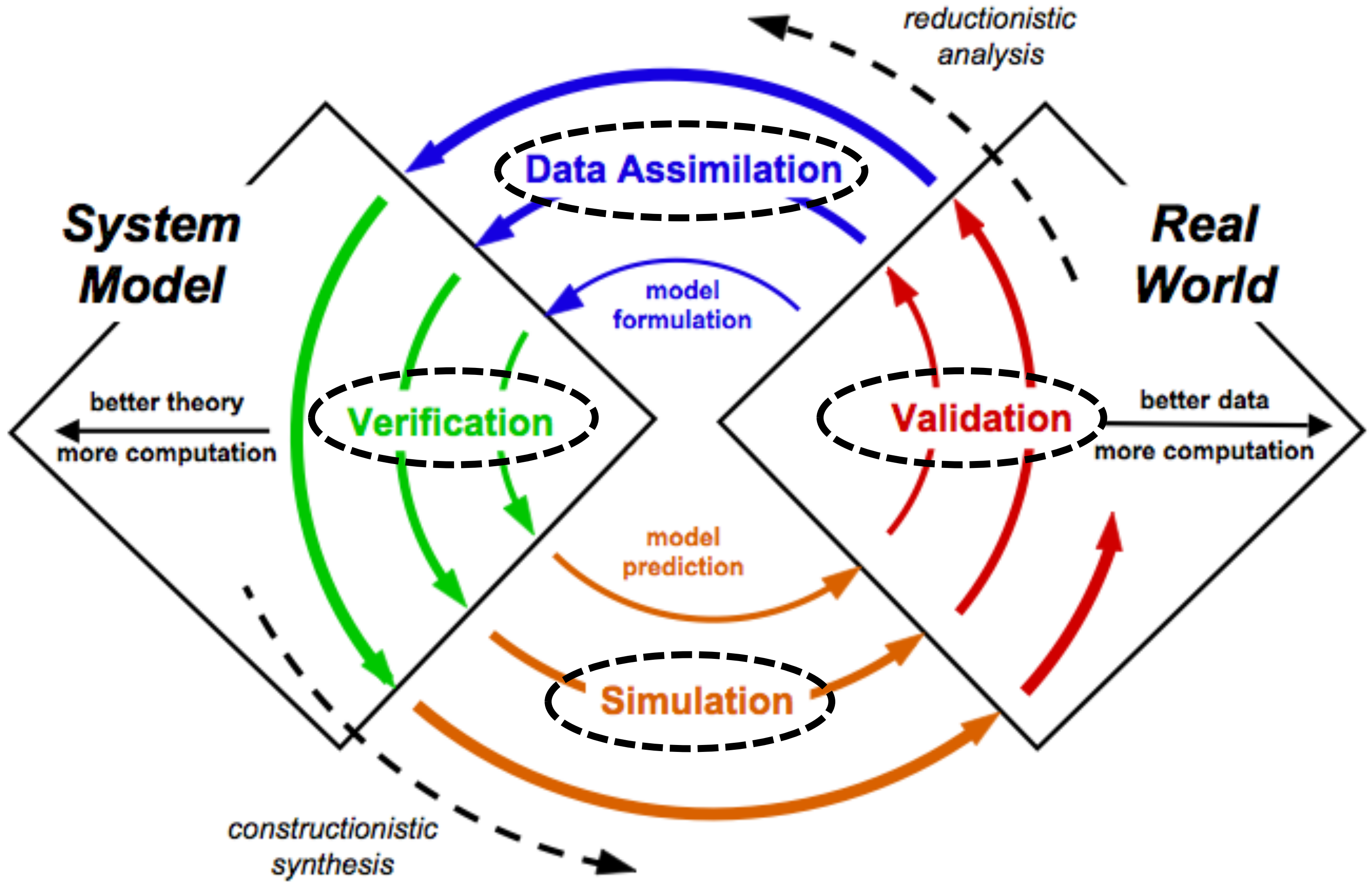
Simulation: *Model makes predictions for comparisons with observations*

Validation: *Can the model adequately predict the specified system behavior?*

Inference Spiral of System Science

Verification: *Is the model correctly computed with a specified precision?*

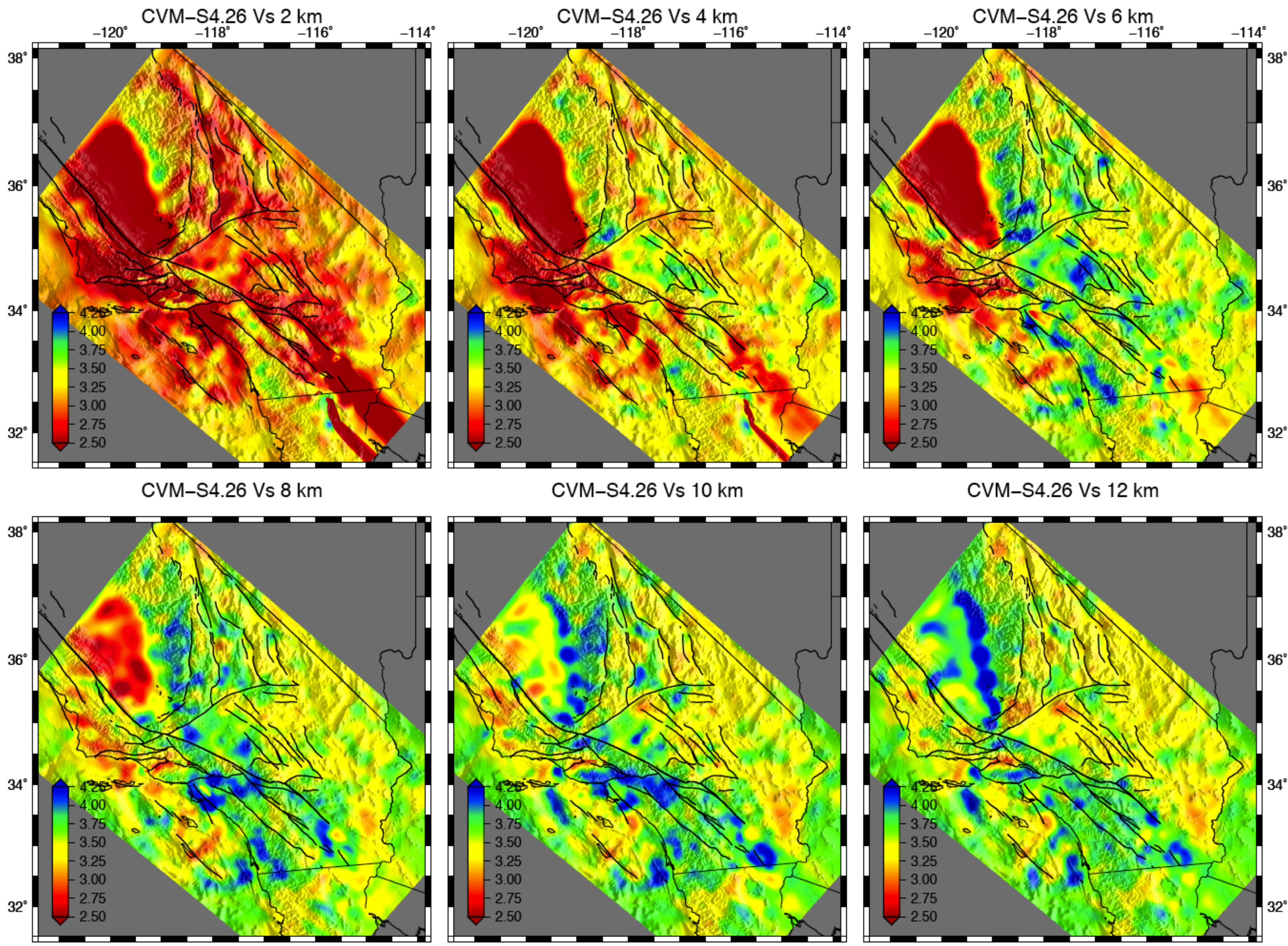
Data Assimilation: How should the model be adjusted to fit new empirical information?

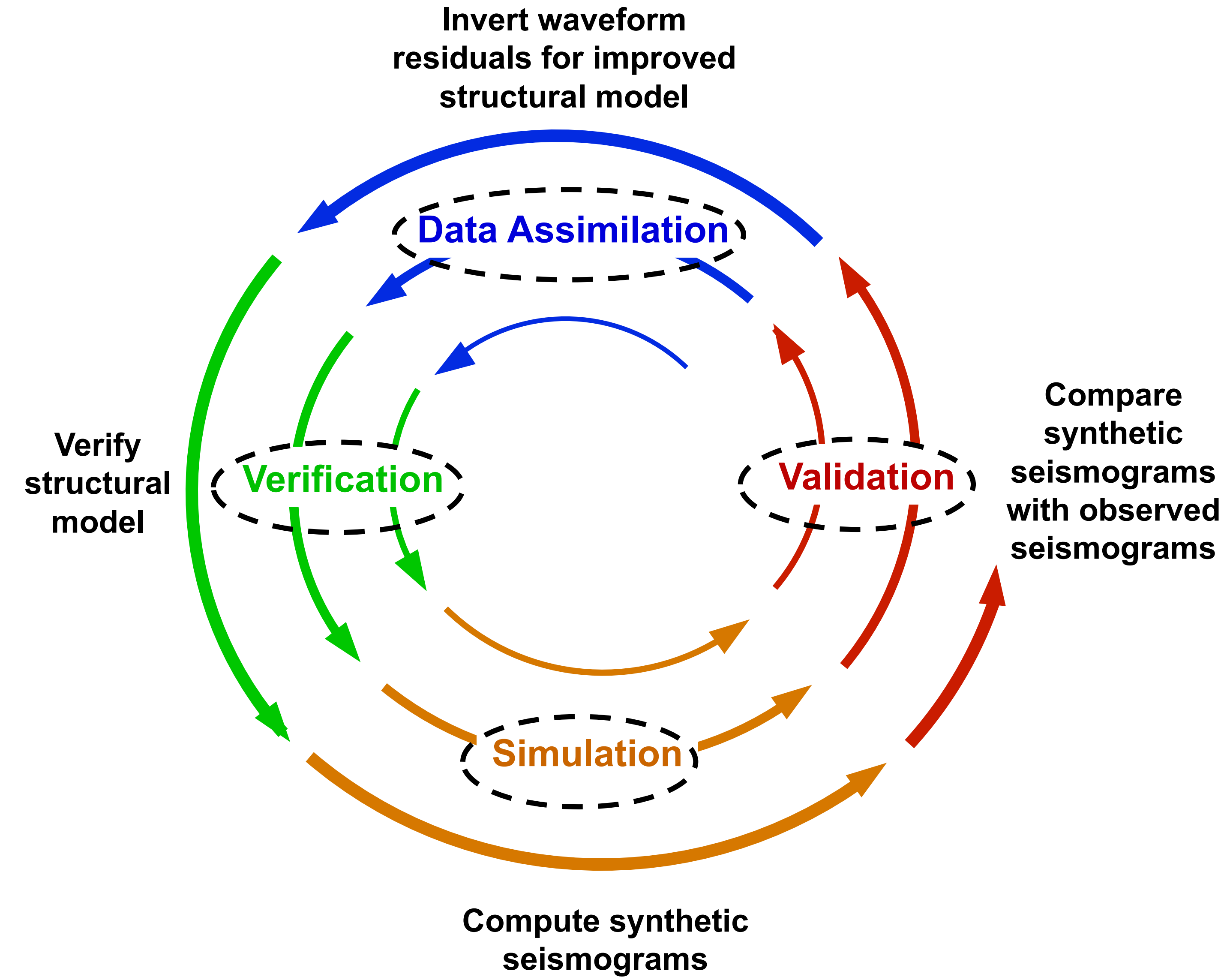


Simulation: *Model makes predictions for comparisons with observations*

Validation: *Can the model adequately predict the specified system behavior?*

Inference Spiral of Full-3D Tomography





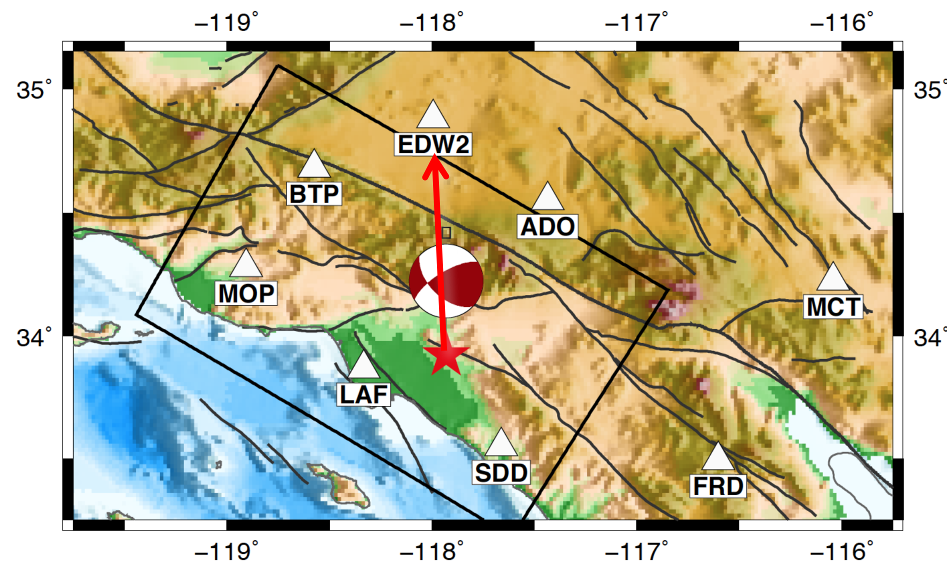
CVM-S4.26 (Lee et al, 2014)

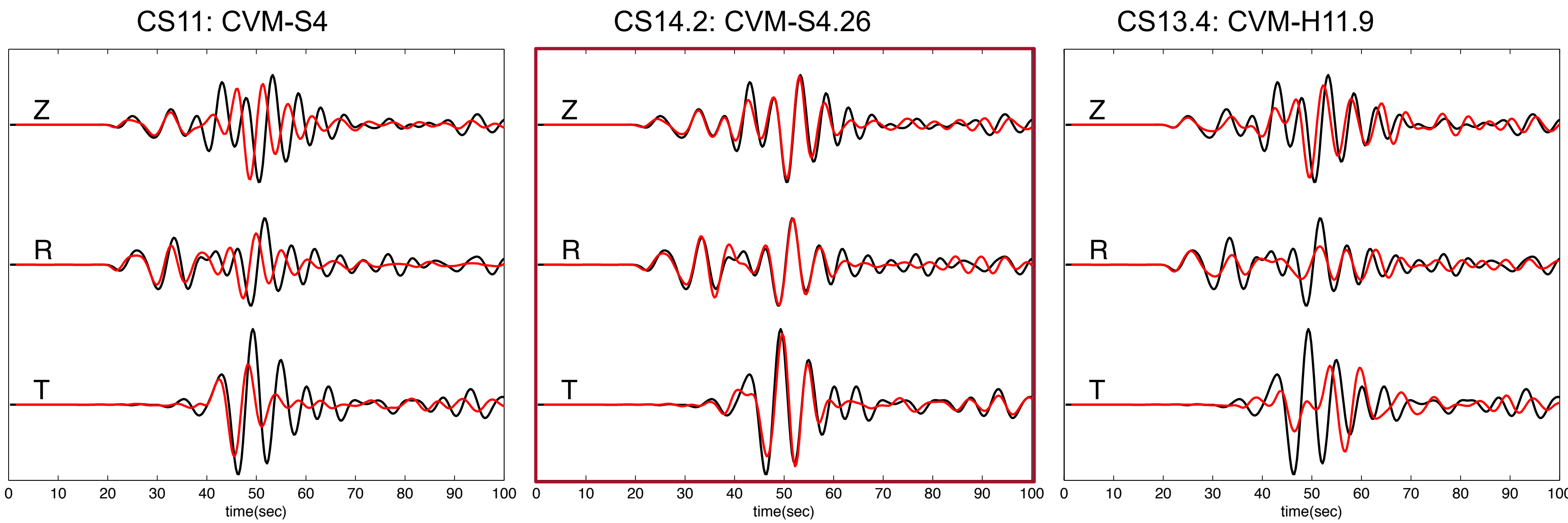
- **CVM-S4 starting model**
- **26th iterate of a full-3D tomographic (F3DT) inversion procedure using 550,000 differential waveform measurements at *f* ≤ 0.2 Hz**
  - **38,000 earthquake seismograms**
  - **12,000 ambient-noise Green functions**

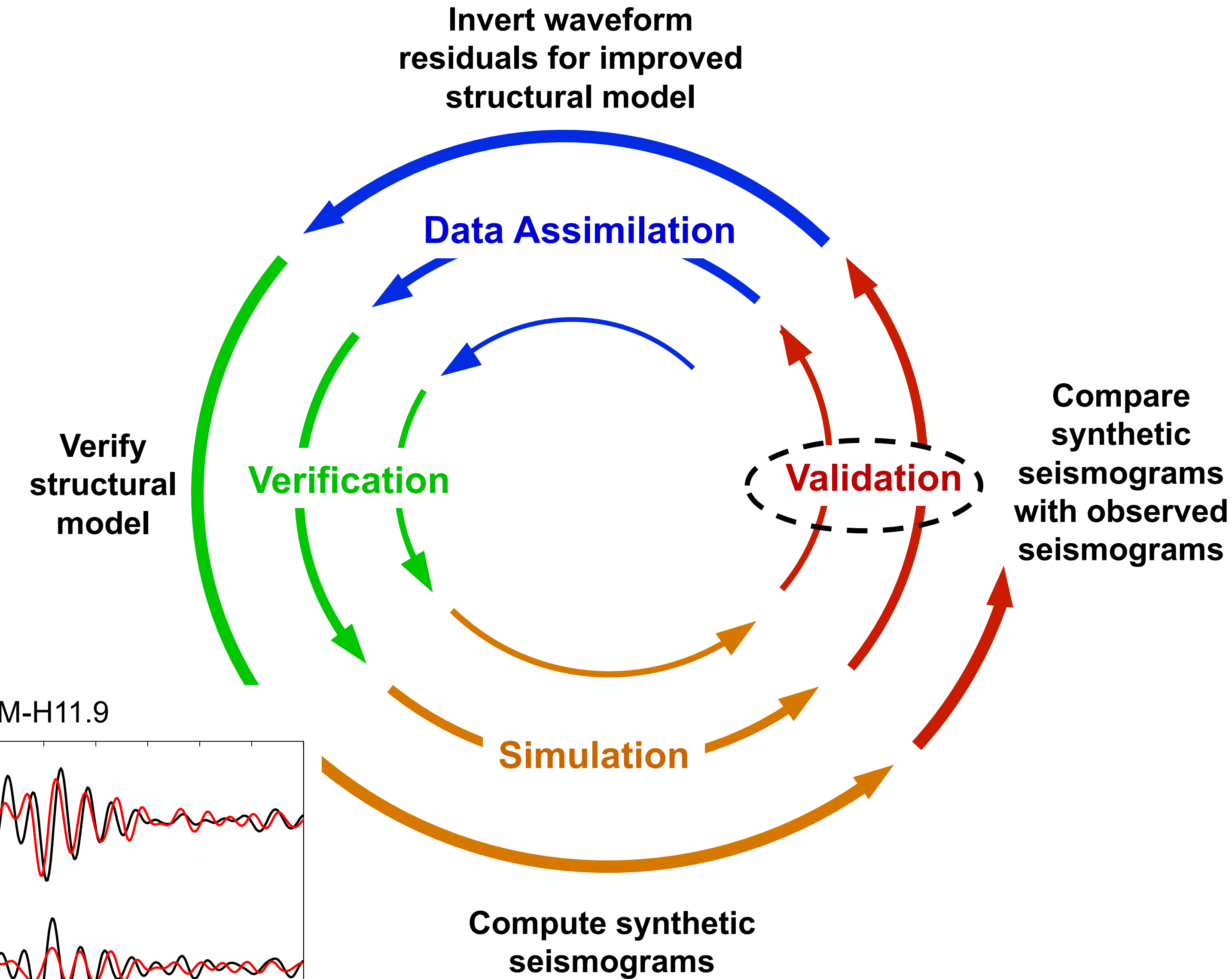
Inference Spiral of Full-3D Tomography

03/28/14 La Habra Earthquake (M5.1)

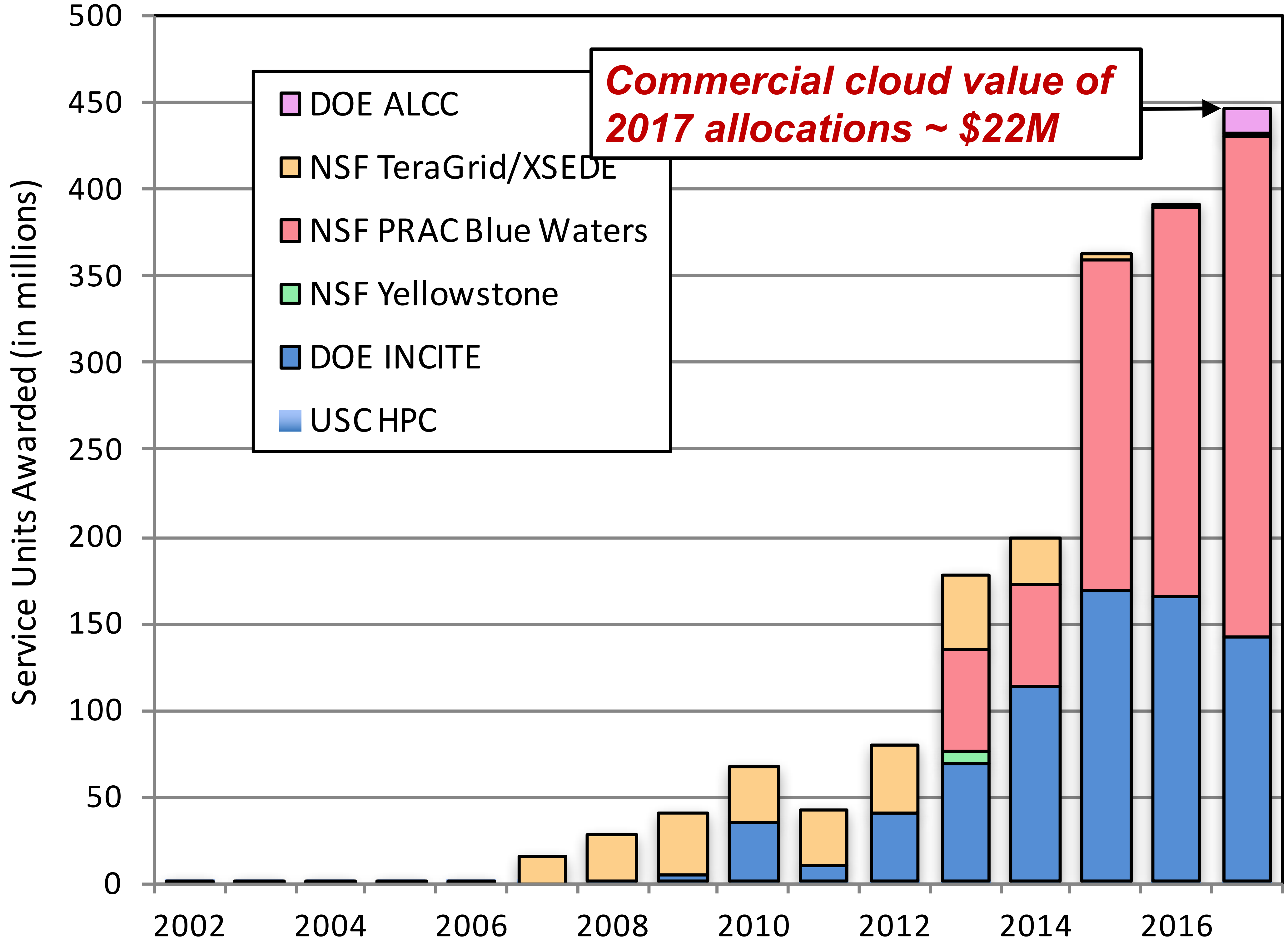
Station EDW2
Observed in black
Synthetic in red



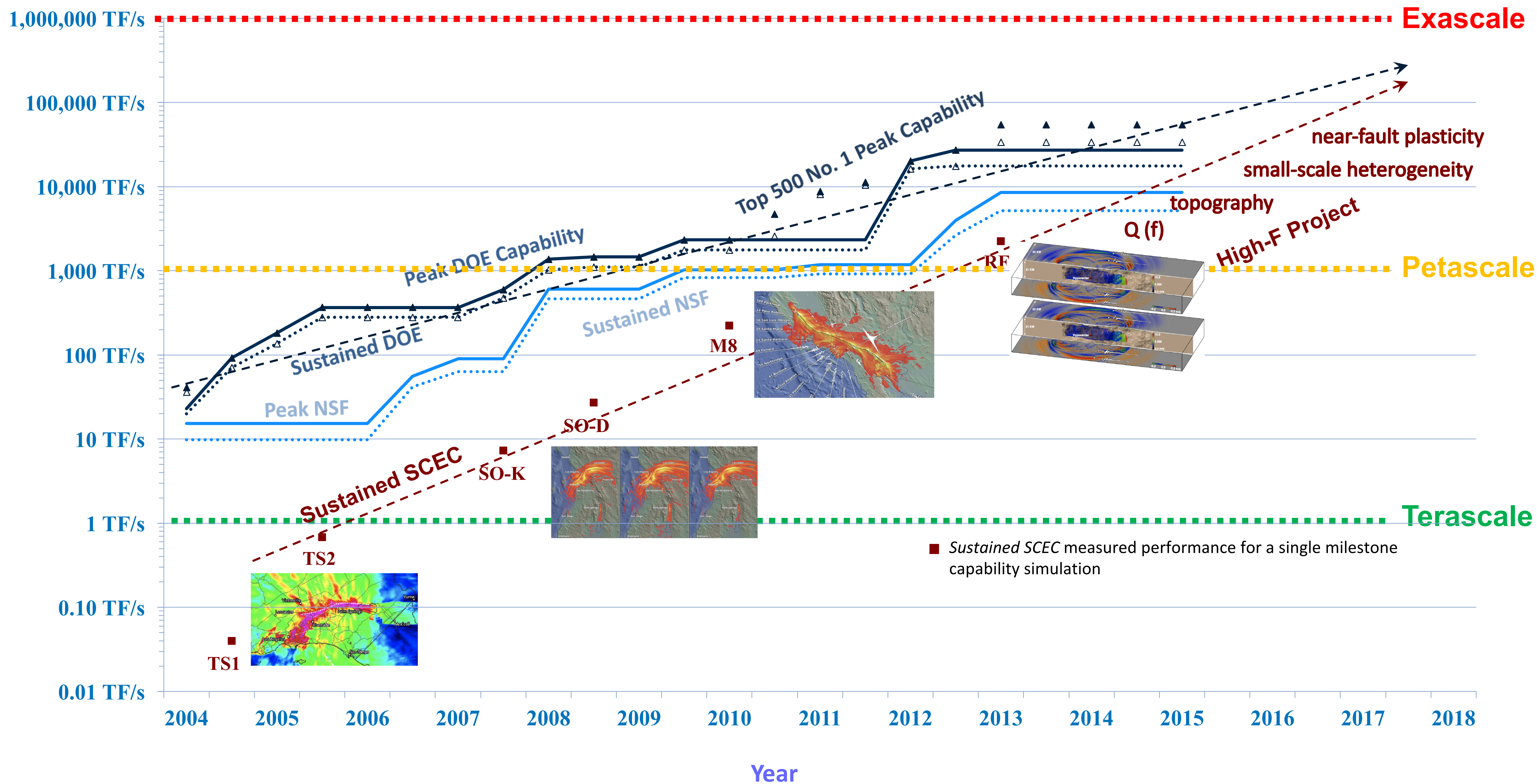




SCEC HPC Allocations



SCEC Extreme-Scale Earthquake Simulations



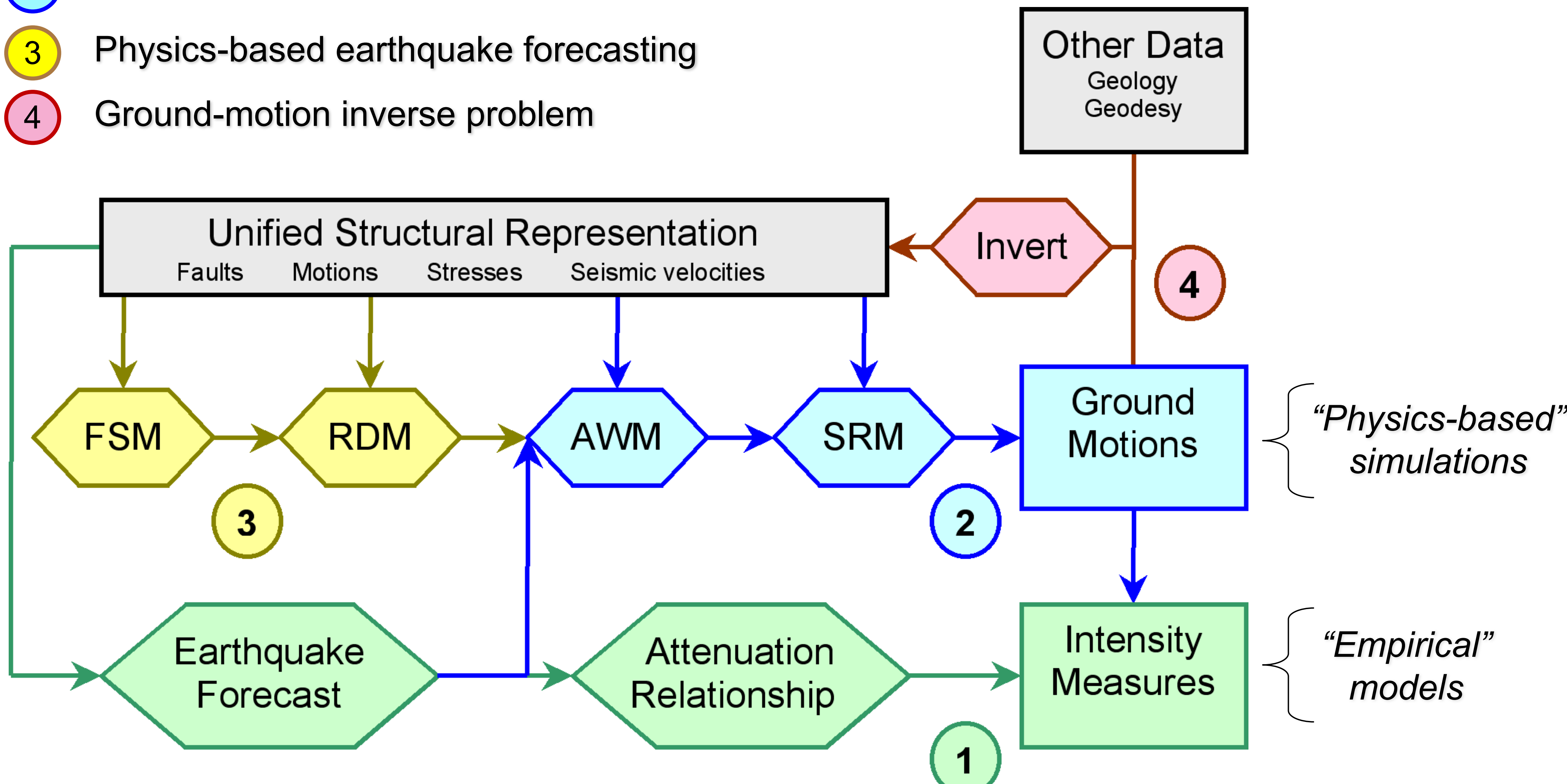
SCEC Computational Pathways (2001)

1 Standard seismic hazard analysis

2 Ground motion simulation

3 Physics-based earthquake forecasting

4 Ground-motion inverse problem



FSM = Fault System Model

RDM = Rupture Dynamics Model

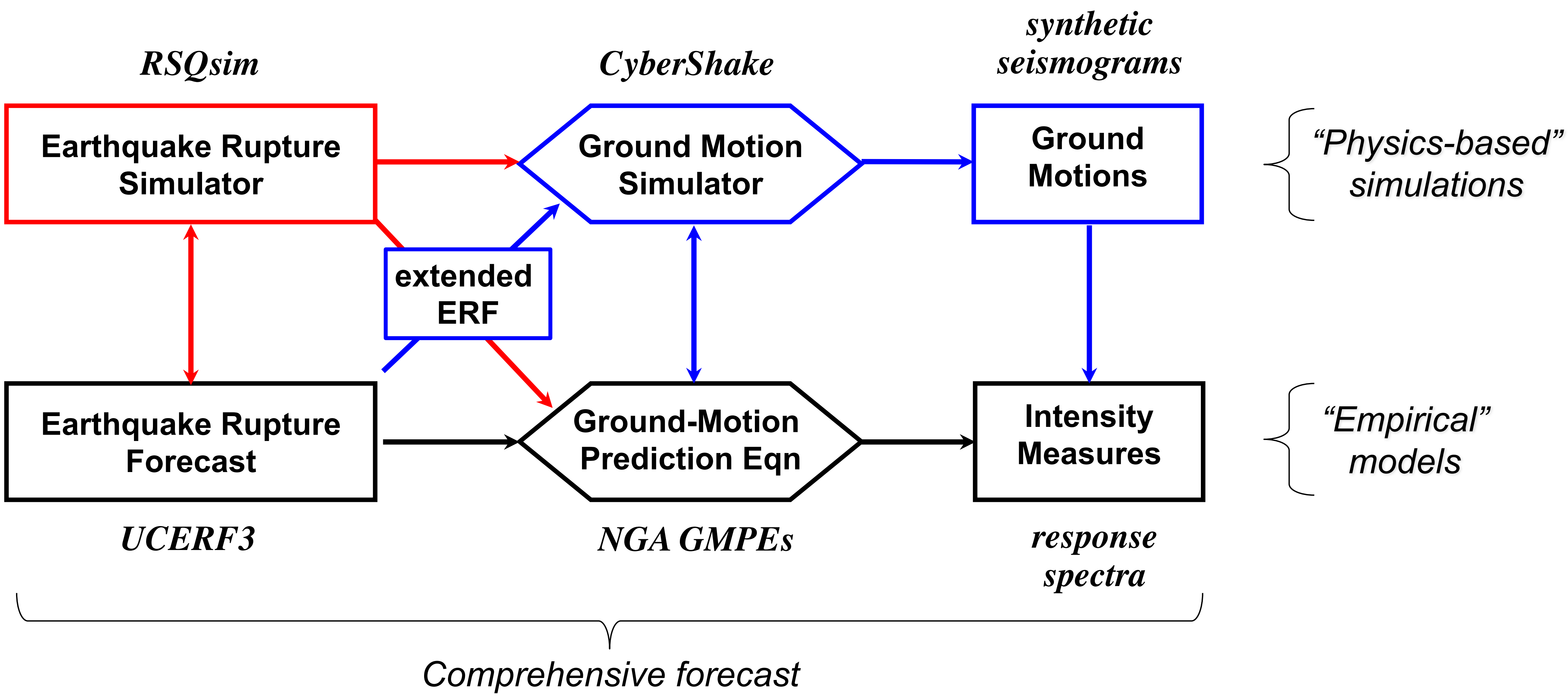
AWP = Anelastic Wave Model

SRM = Site Response Model

Collaboratory for Interseismic Simulation and Modeling (CISM)

Cyberinfrastructure for developing system-specific, time-dependent earthquake forecasting models that are comprehensive, physics-based, data-calibrated, and prospectively testable

Established under a $2M grant from the W. M. Keck Foundation, awarded on July 1, 2015

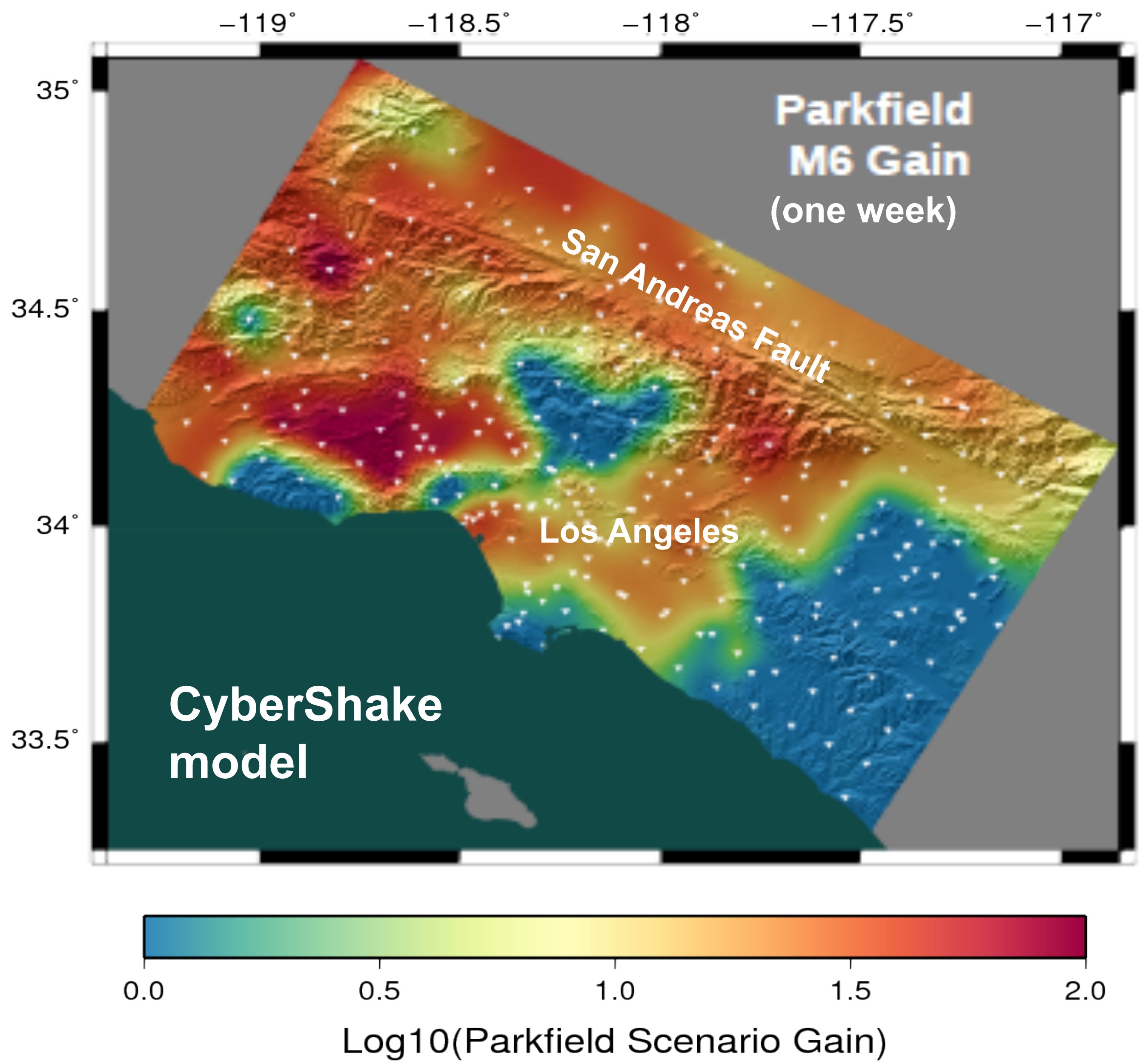


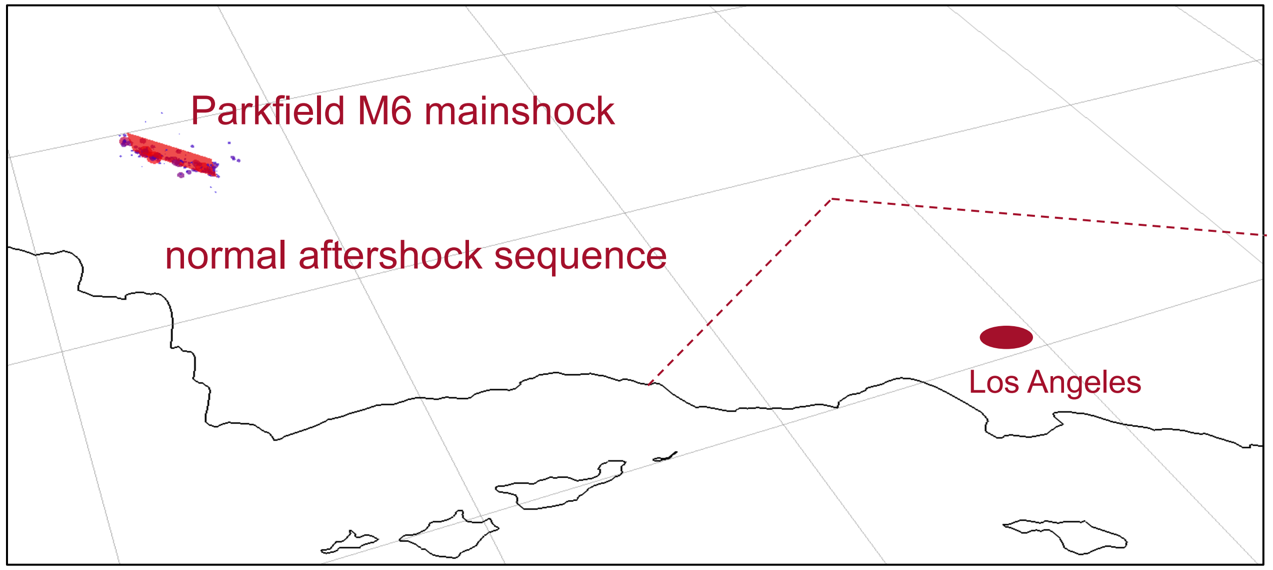
SC/EC

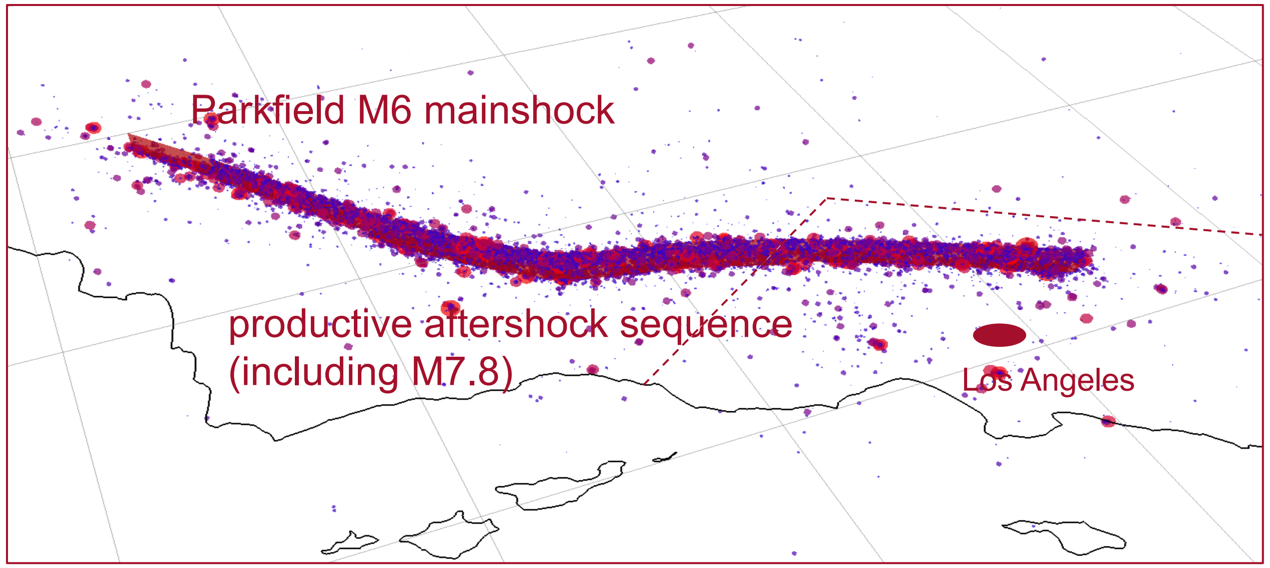
Southern California Earthquake Center

Coupling of UCERF-ETAS to CyberShake

Because it may be a foreshock of a large San Andreas rupture, a Parkfield earthquake significantly amplifies the shaking hazard in Los Angeles

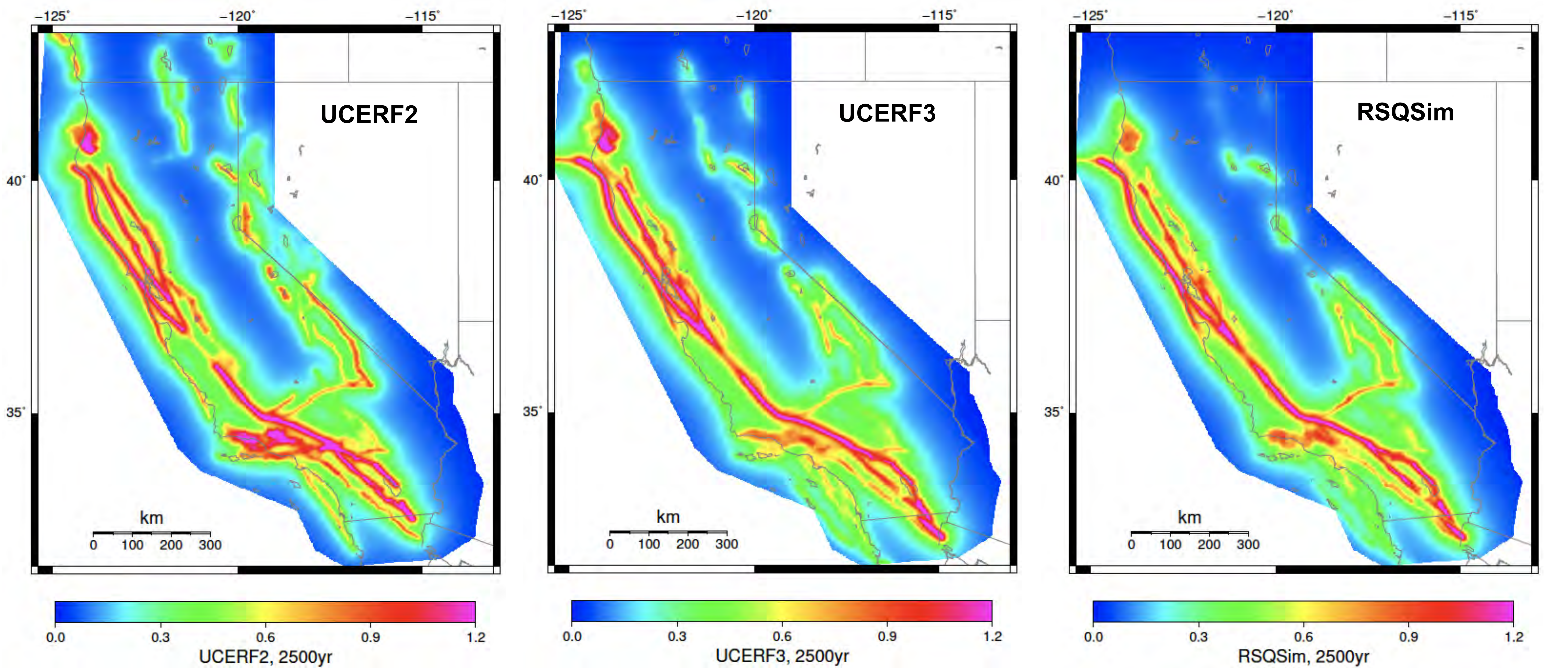






Calculation combines UCERF2-ETAS with the CyberShake ground motion prediction model

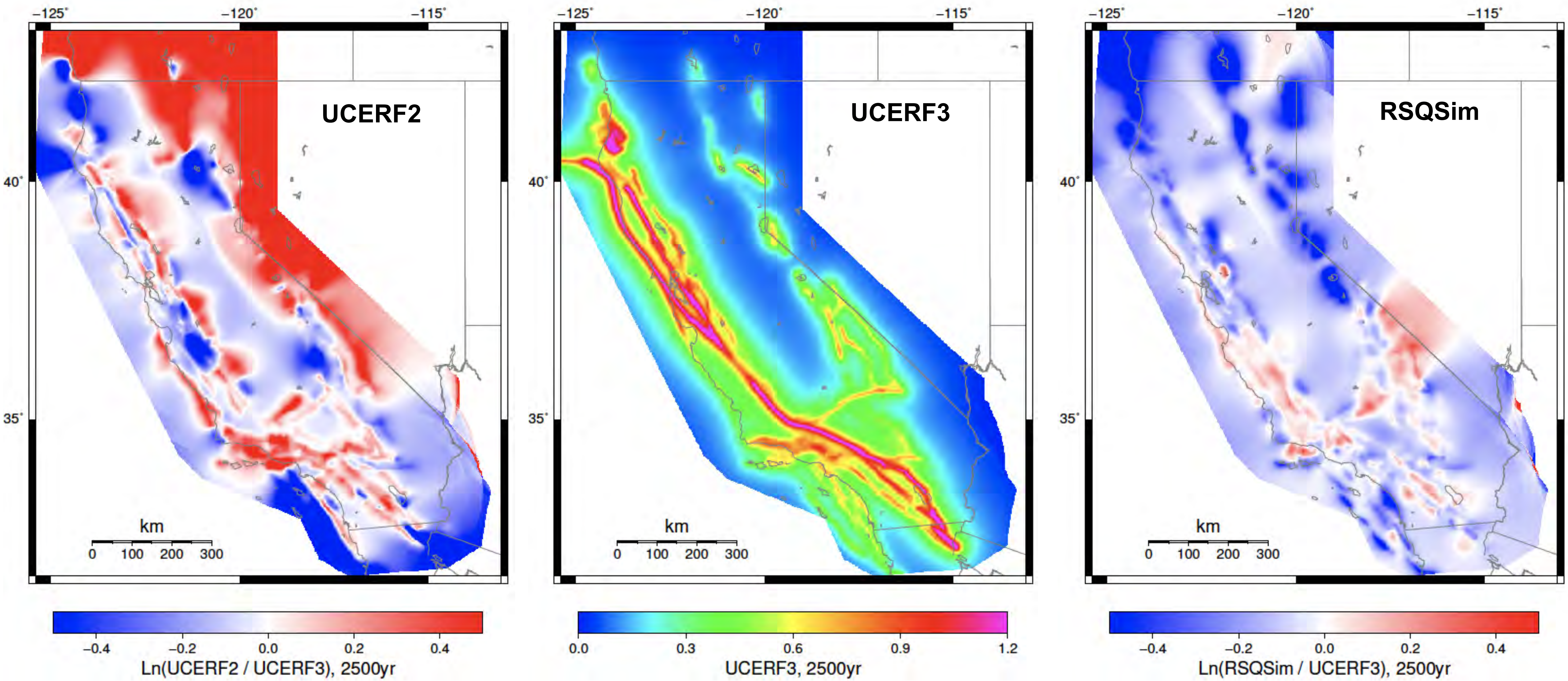
Hazard Map Comparison



Peak Ground Acceleration (g) at 2% PoE in 50 yrs

B. Shaw et al. (2017)

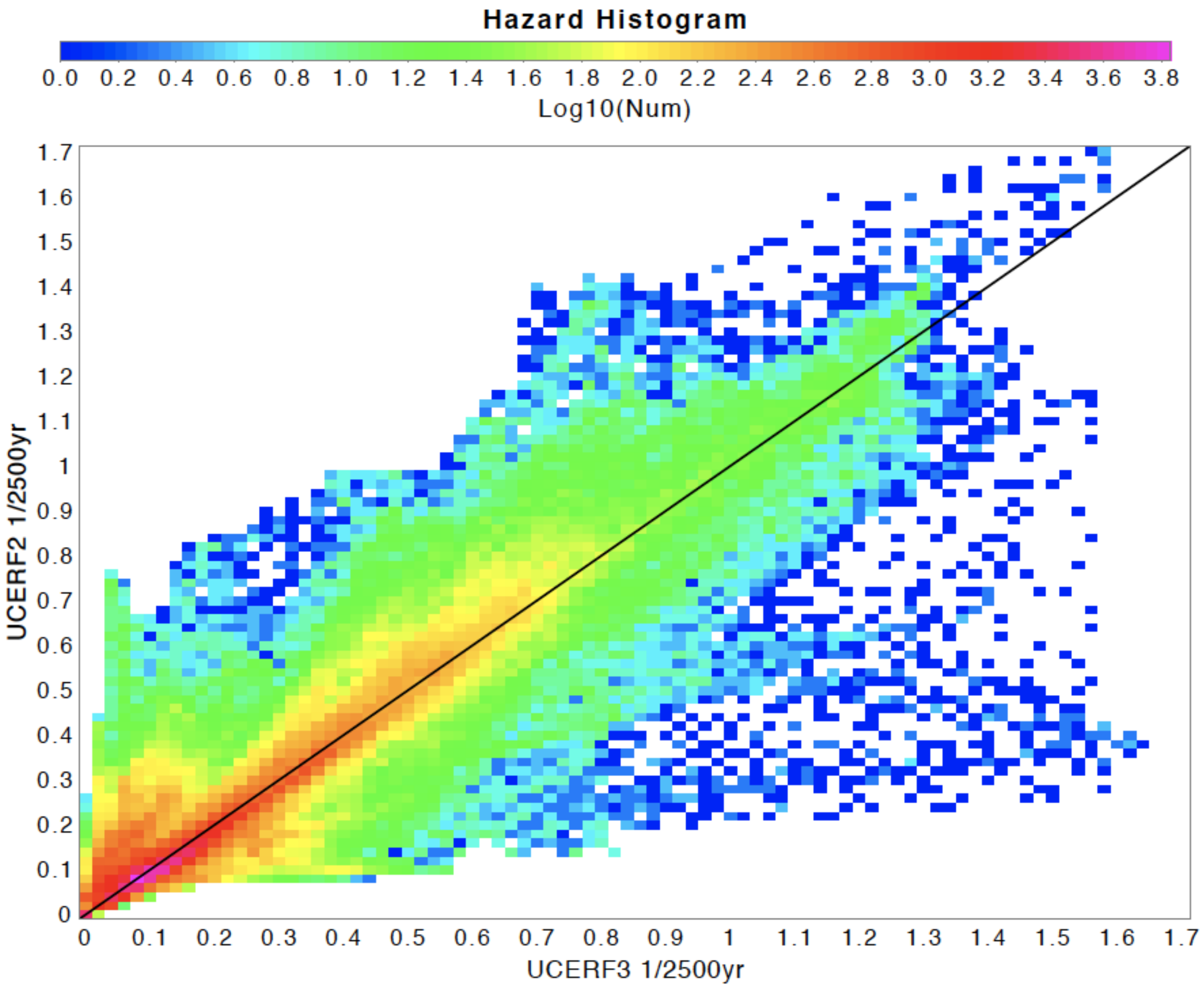
Hazard Map Comparison

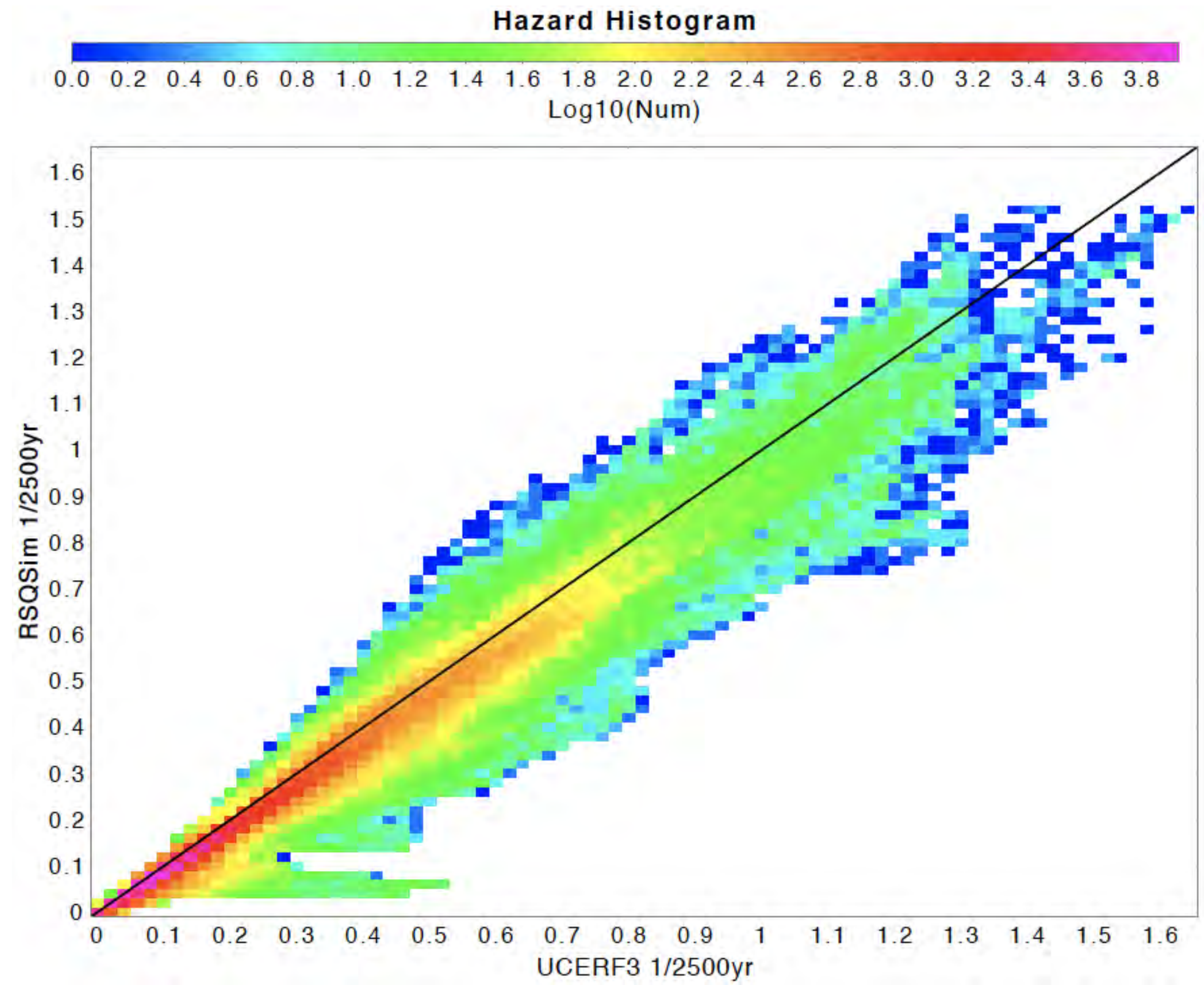


Peak Ground Acceleration (g) at 2% PoE in 50 yrs

B. Shaw et al. (2017)

Hazard Histogram Comparison

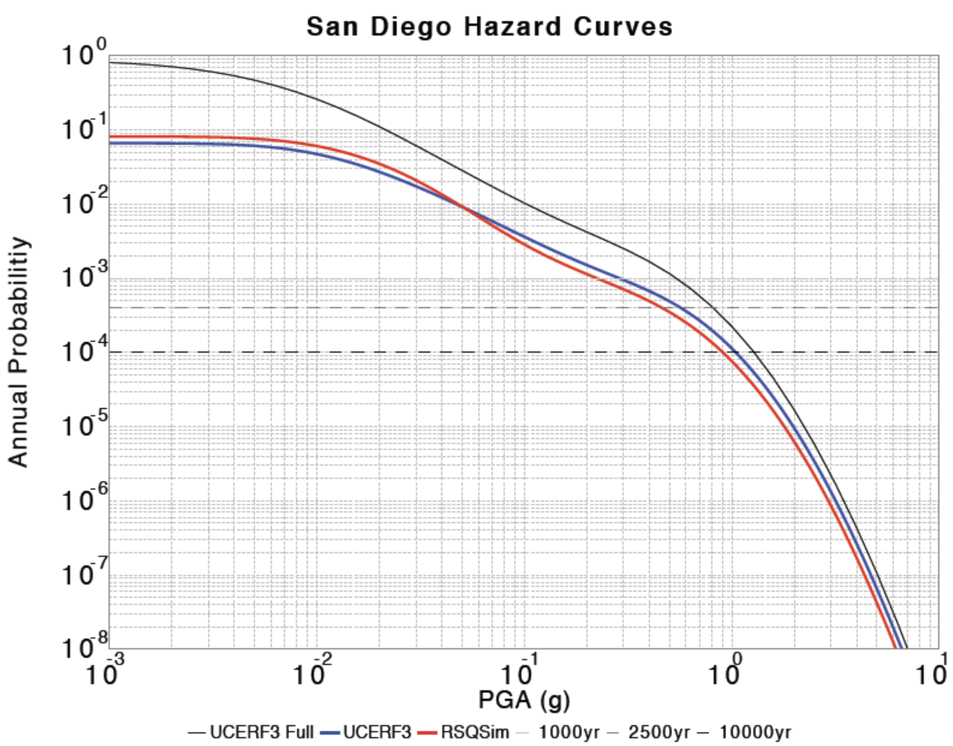


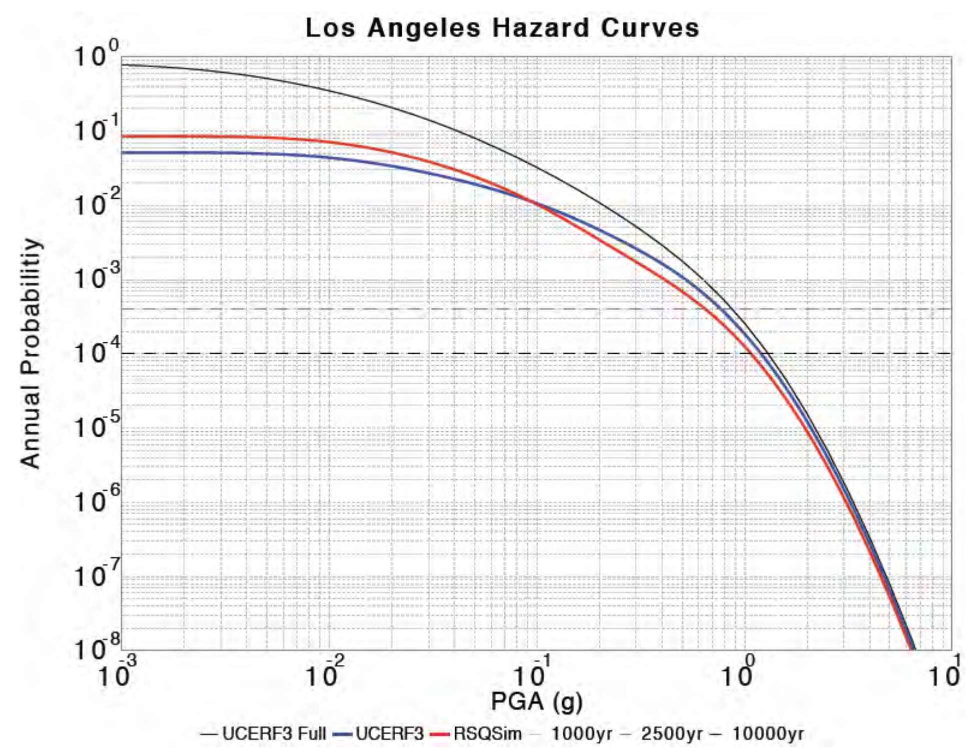


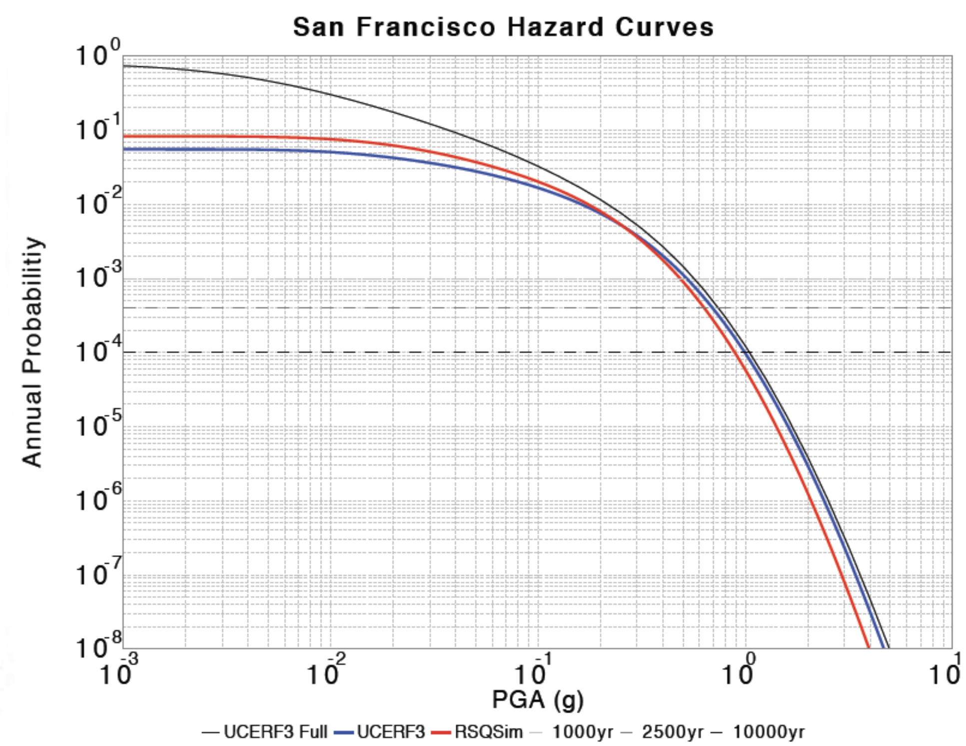
Peak Ground Acceleration (g) at 2% PoE in 50 yrs

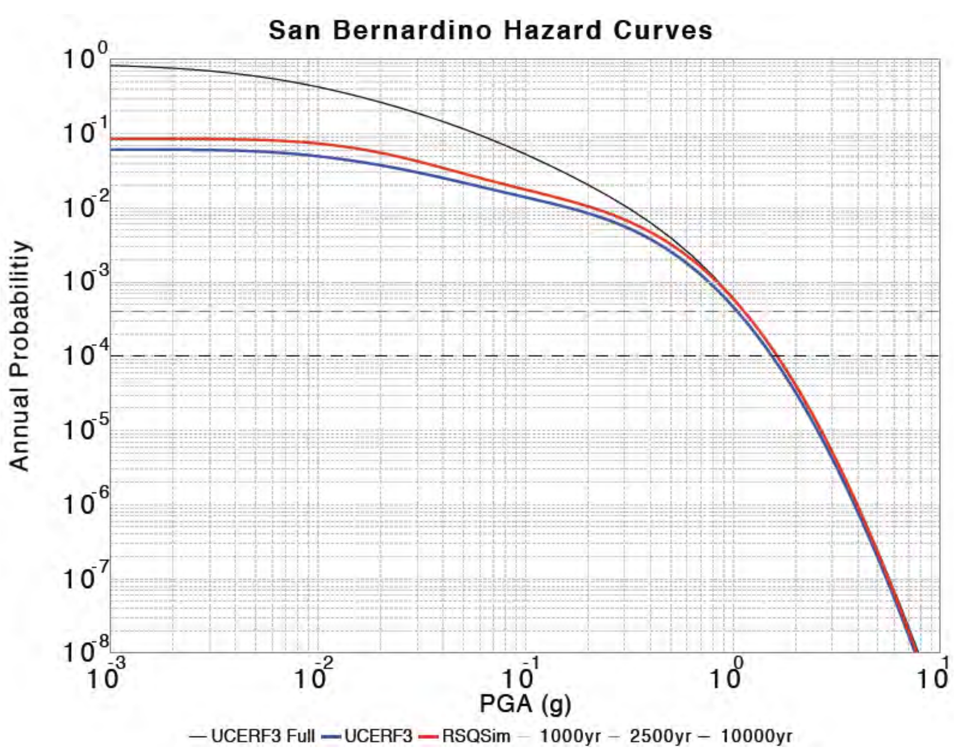
B. Shaw et al. (2017)

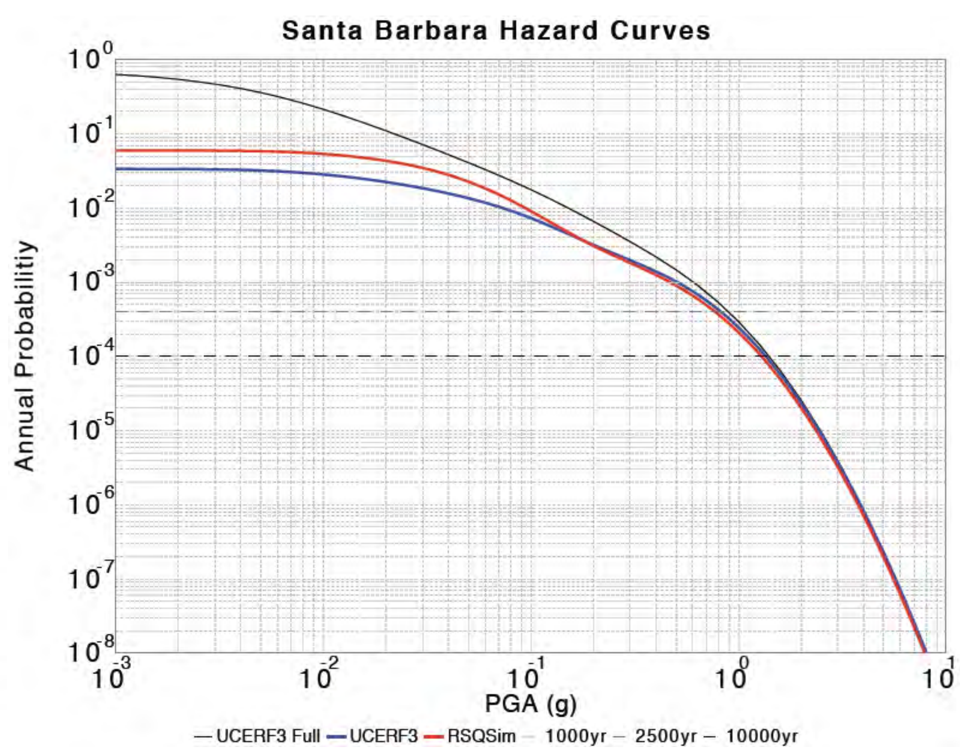
Hazard Curve Comparison

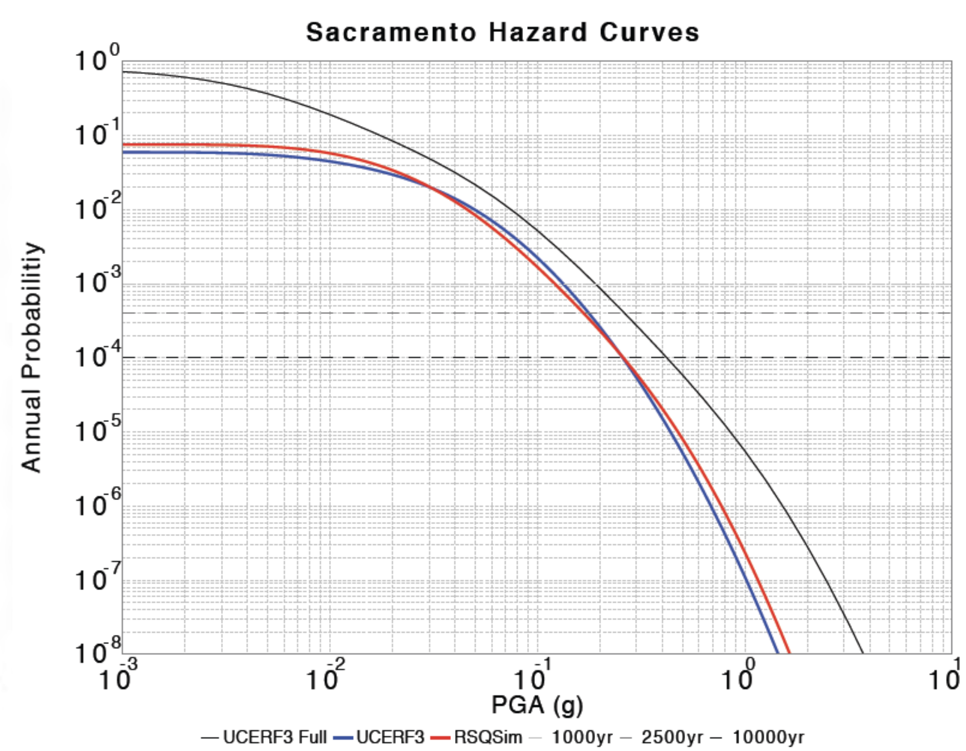




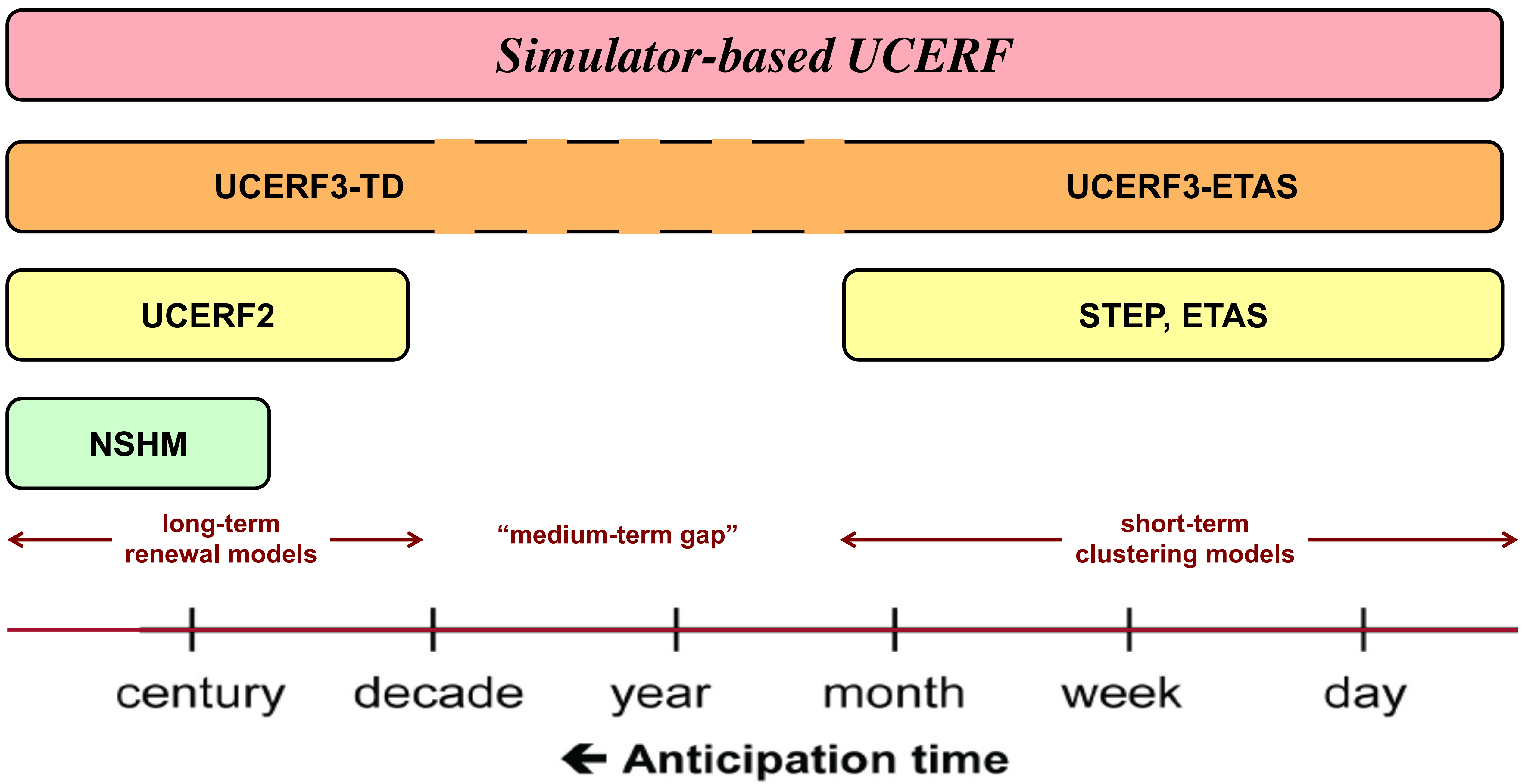








California Earthquake Forecasting Models



The Case for SCEC

1. The SCEC community has created an interdisciplinary, multi-institutional "virtual organization" for coordinating earthquake research in Southern California
   - Communicates useful knowledge for reducing earthquake risk and improving resilience
2. SCEC sustains deep collaborations within an open, investigator-driven program of fundamental earthquake research
   - Involves over 1000 earthquake experts at more than 70 research institutions
3. SCEC partners with many organizations to develop and disseminate authoritative earthquake information and to educate the public about the earthquake threat
   - Coordinates the Earthquake Country Alliance in California and ShakeOut drills worldwide
4. SCEC collaboratories provide a unique cyberinfrastructure for system-level modeling of earthquake phenomena
   - In 2017, SCEC was awarded 447 million CPU-hours on the nation's most powerful supercomputers
5. Earthquake system science is revolutionizing seismic hazard analysis and earthquake forecasting
   - A continuing program of coordinated interdisciplinary research will be necessary to refine and validate the new tools of physics-based PSHA and OEF

Thank you!

*"But my heart is not weary, it's light and it's free
I've got nothing but affection for all those who've sailed with me."*

- B. Dylan