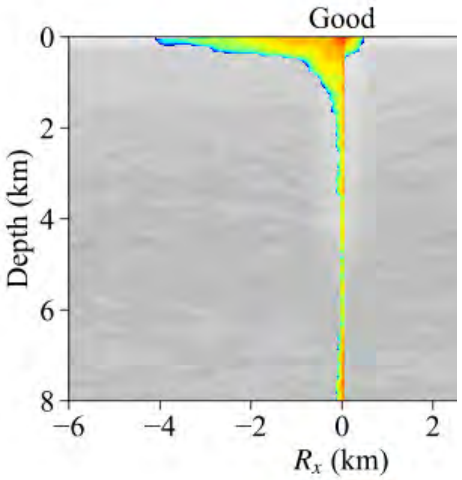
Special Projects as synergistic activities

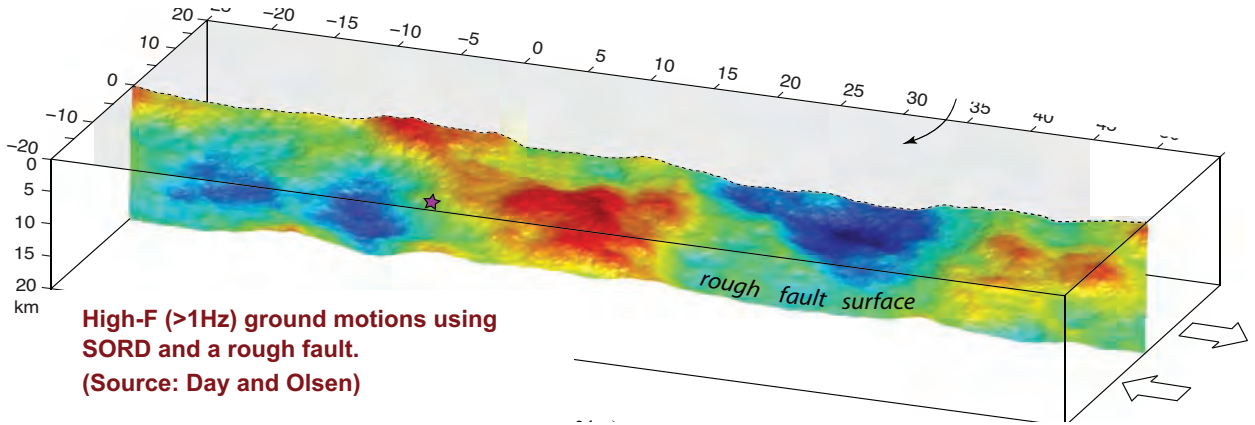
Christine A. Goulet
Executive Science Director for Special Projects

Slides and images from
Greg Beroza, Scott Callaghan, Yifeng Cui, Tom Jordan, Kevin Milner, Phil Maechling, Kim Olsen, Bruce Shaw, Daniel Roten, Fabio Silva, Ricardo Taborda, Many others...

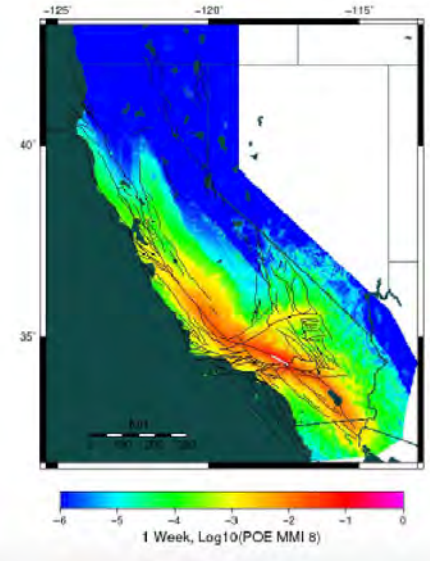
Special Projects: partnerships in targeted research

- Leverage and support Core Program goals and activities
- Provide additional resources
  - Funding
    - Support scientific research, applied research interface
    - Supports software programmers, IT specialists
  - HPC allocations
    - Support complex and large computations (large regions, 3D modeling, complex physics and rupture dynamics, plasticity, visualization, data management, validation,...)





High-F (>1Hz) ground motions using SORD and a rough fault.
(Source: Day and Olsen)



Funded Special Projects

Funded Special Projects	Funding Source	Software Involved	Amount	Duration
CISM (Collaboratory for Interseismic Simulation and Modeling)	Keck	RSQSim, OpenSHA/UCERF, CSEP, CyberShake	$2,000,000	3 yrs
MSW (Mining Seismic Wavefields)	NSF Geoinformatics	FAST, QTMatch, and GT-TM-GPU	$1,180,000	2 yrs
CCSP (Central CA Seismic Project) and Simulations	PG&E	CyberShake, Tomography, BBP, Dynamic Ruptures, URS, UCVM	$1,080,000	1 yr at-a-time
SEISM2 (Community Software for Extreme-Scale Computing in Earthquake System Science)	NSF SI2-SSI	High-F platform, Hercules, AWP, GP sims	$2,200,000	4 yrs

Pacific Gas and Electric Company®

Collaborations and Pending

Collaboration	Funding Source	Software Involved
NHERI CI (Natural Hazard Engineering Research Infrastructure)	NHERI NSF UT	BBP, Web
UGMS (Committee for Utilization of Ground Motion Simulations)	Core	CyberShake, OpenSHA, UCVM, Web
GMSV (Ground Motion Simulation Validation)	Core, PG&E	BBP, CyberShake

Pending

UCERF	CEA	OpenSHA

Collaboratory for Interseismic Simulation and Modeling (CISM)

(W. M. Keck Foundation)

Jordan, Dieterich, Field, Richards-Dinger, Maechling, Beroza, Cui, Gilchrist, Milner, Jackson, Werner, Goulet

- Develop a **collaboratory** for **interdisciplinary** teams to create **system-specific** models for **time-dependent** earthquake **forecasting** that are comprehensive, physics-based, data calibrated, and prospectively testable
- Develop a high-performance, workflow-oriented **cyberinfrastructure** that facilitates model verification, simulation, validation, and data assimilation

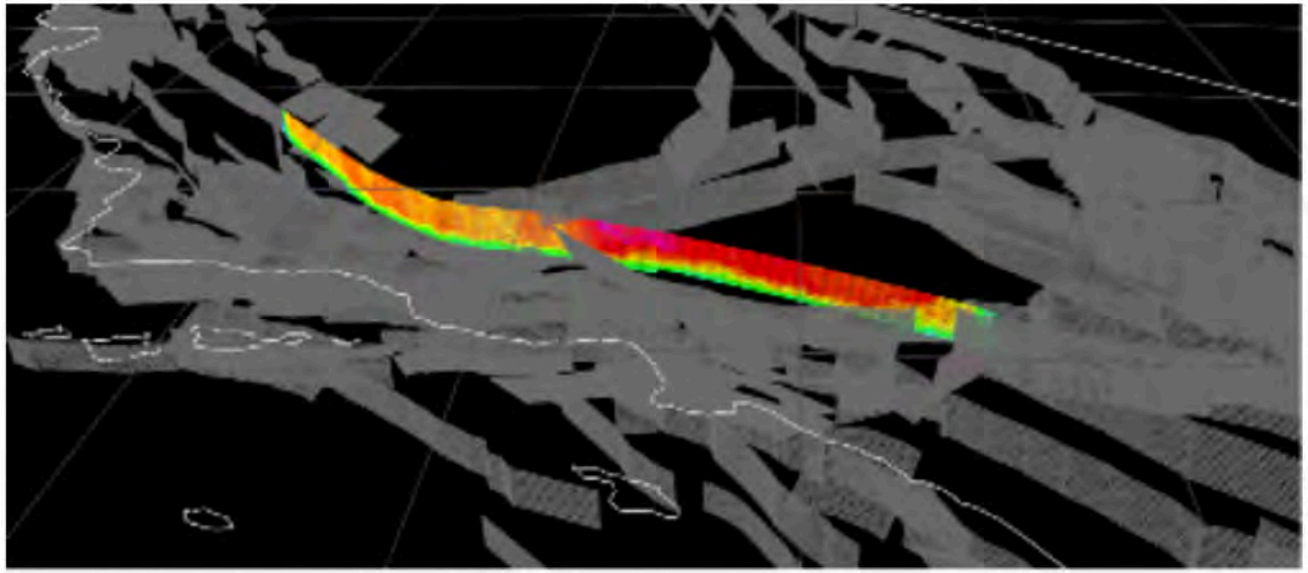
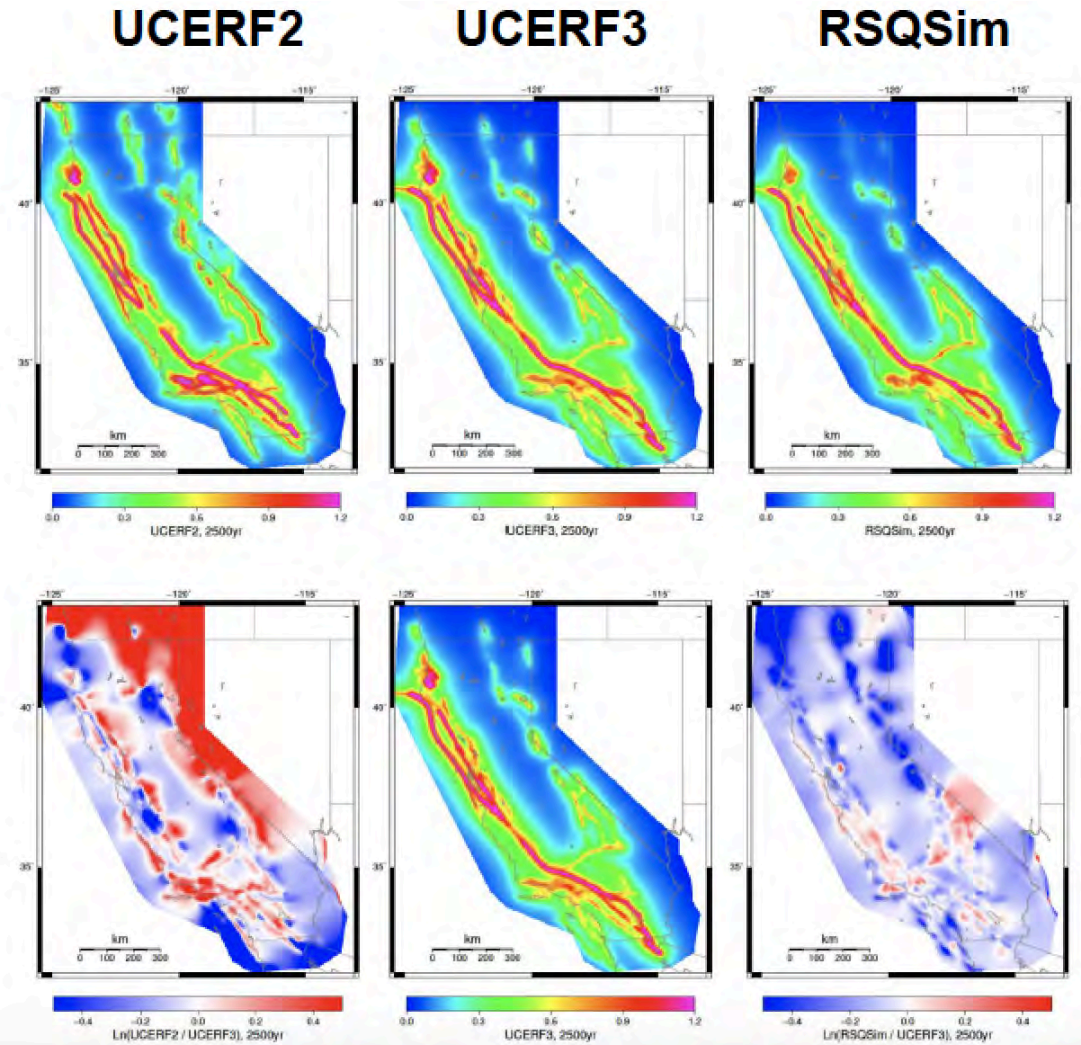


Figure 15.2. Visualization of a **M** 7.9 simulated RSQSim earthquake on the Southern San Andreas Fault in SCEC-VDO. The entire California fault model is shown in gray, with patches that slipped in this particular event colored from blue through purple according to their total displacement. A link to an example video spanning the earthquake simulation is also available (see link in the text).

CISM
(W. M. Keck Foundation)

- Hazard comparisons with UCERF3 show strong agreement, even with only global calibration
- RSQSim/UCERF3 differences often smaller than UCERF3/UCERF2
- Agreement between the empirical and physics-based models provides substantial support for the PSHA methodology



CISM
(W. M. Keck Foundation)

End-to-end physics-based PSHA: RSQSim as ERF into CyberShake

- Complex multi-fault ruptures slip/time series
- Will require retooling of CyberShake input and workflows

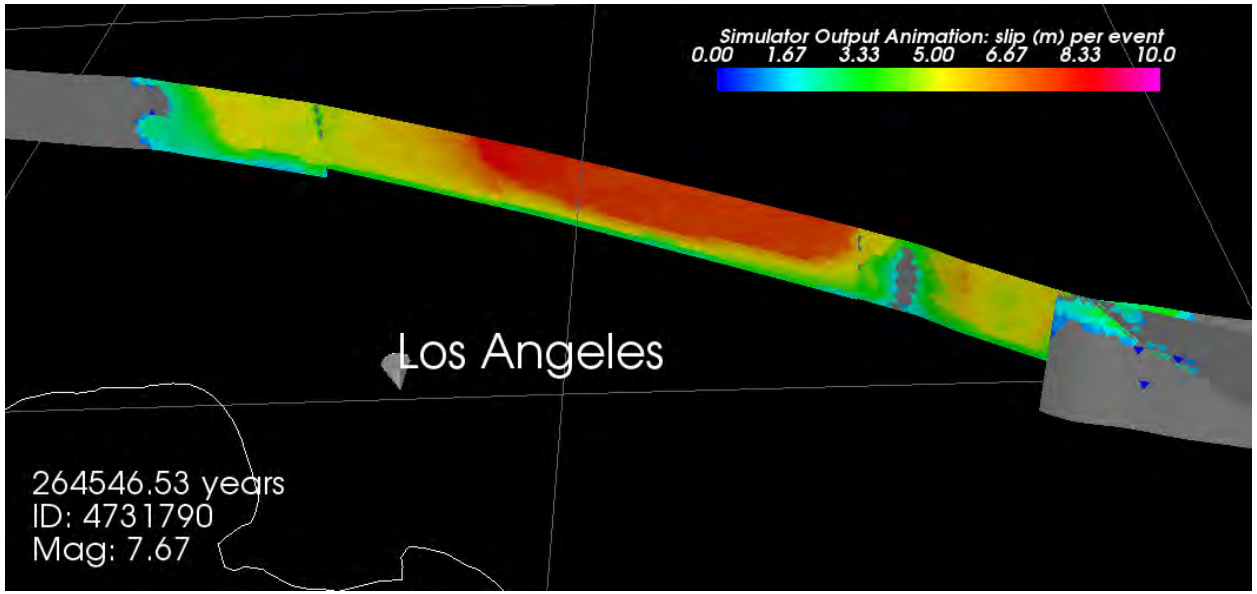
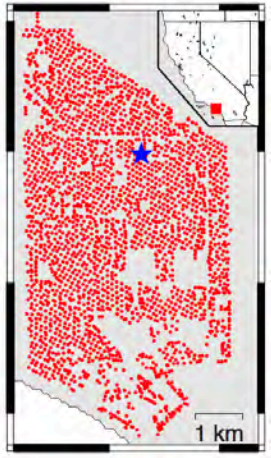


Figure 4: SCEC-VDO visualization of a M7.7 event on the San Andreas Fault from an RSQSim simulation. Colors represent slip on each patch involved in the event, with areas in red slipping more than areas in green.

Mining Seismic Wavefields

(NSF Geoinformatics)

Beroza, Hauksson, Peng, Jordan, Ben-Zion, Maechling, Gill



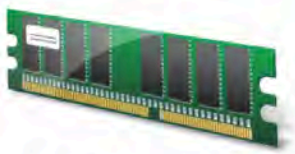
Large-N: dense seismic networks (1000's of stations)

Seismology has big data

Large-T: continuous seismic data over long time periods (>10 years)

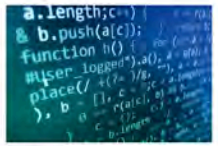
Seismology needs new scalable methods to extract information from massive data volumes

Computing power, parallel processing



Memory

Disk space

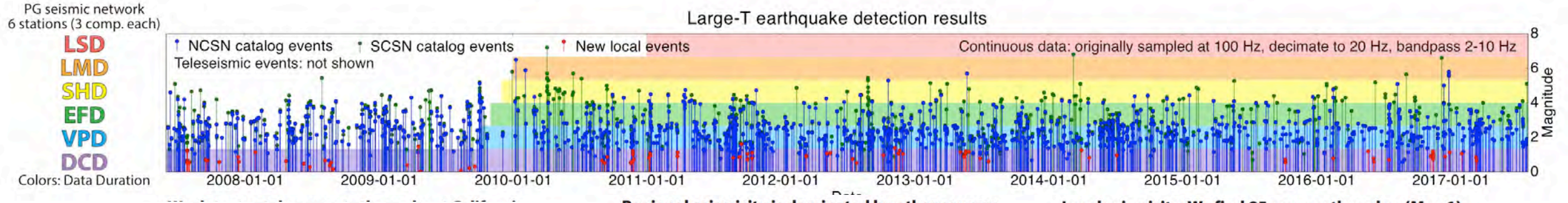


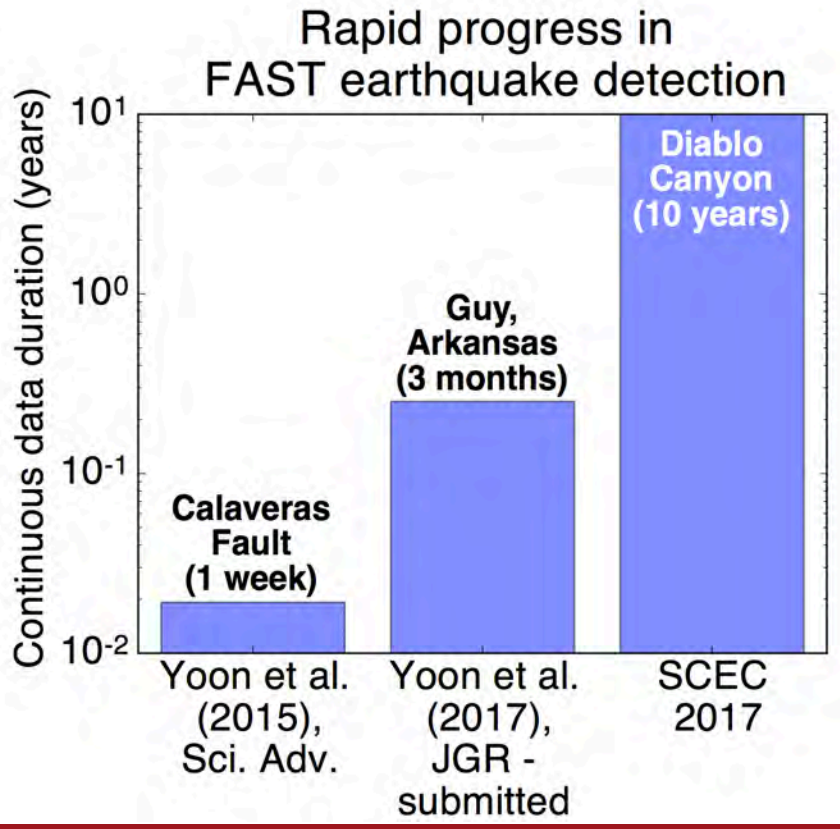
Algorithms

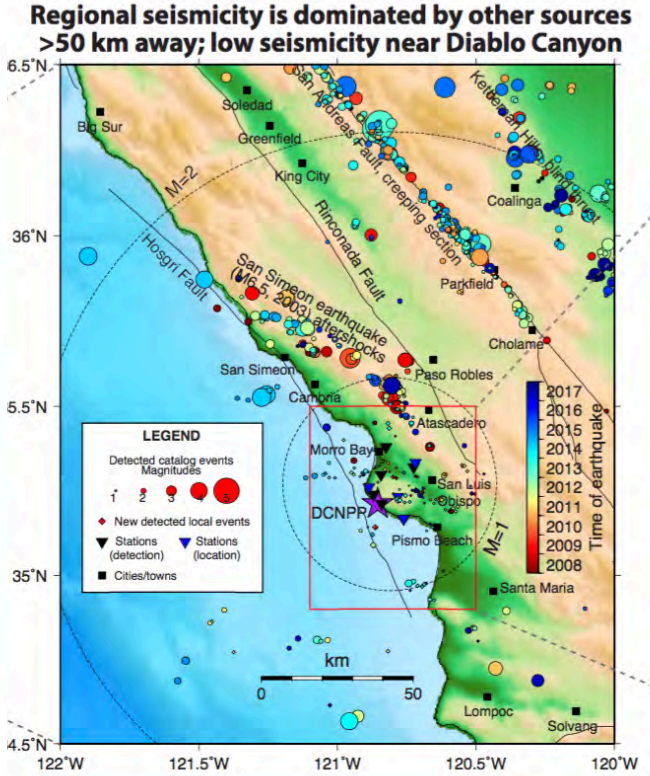
Sample Accomplishment

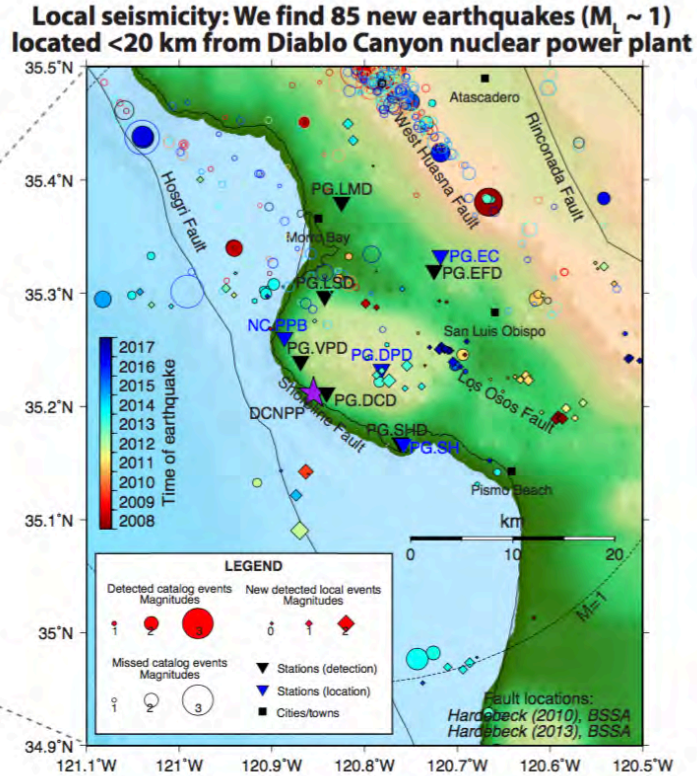
MSW: FAST for Earthquake Detection (Large-T)

(NSF Geoinformatics)





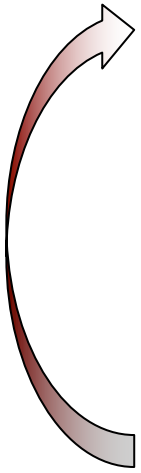




Yoon et al. #24

Central California Seismic Project (CCSP)
(Pacific Gas & Electric)

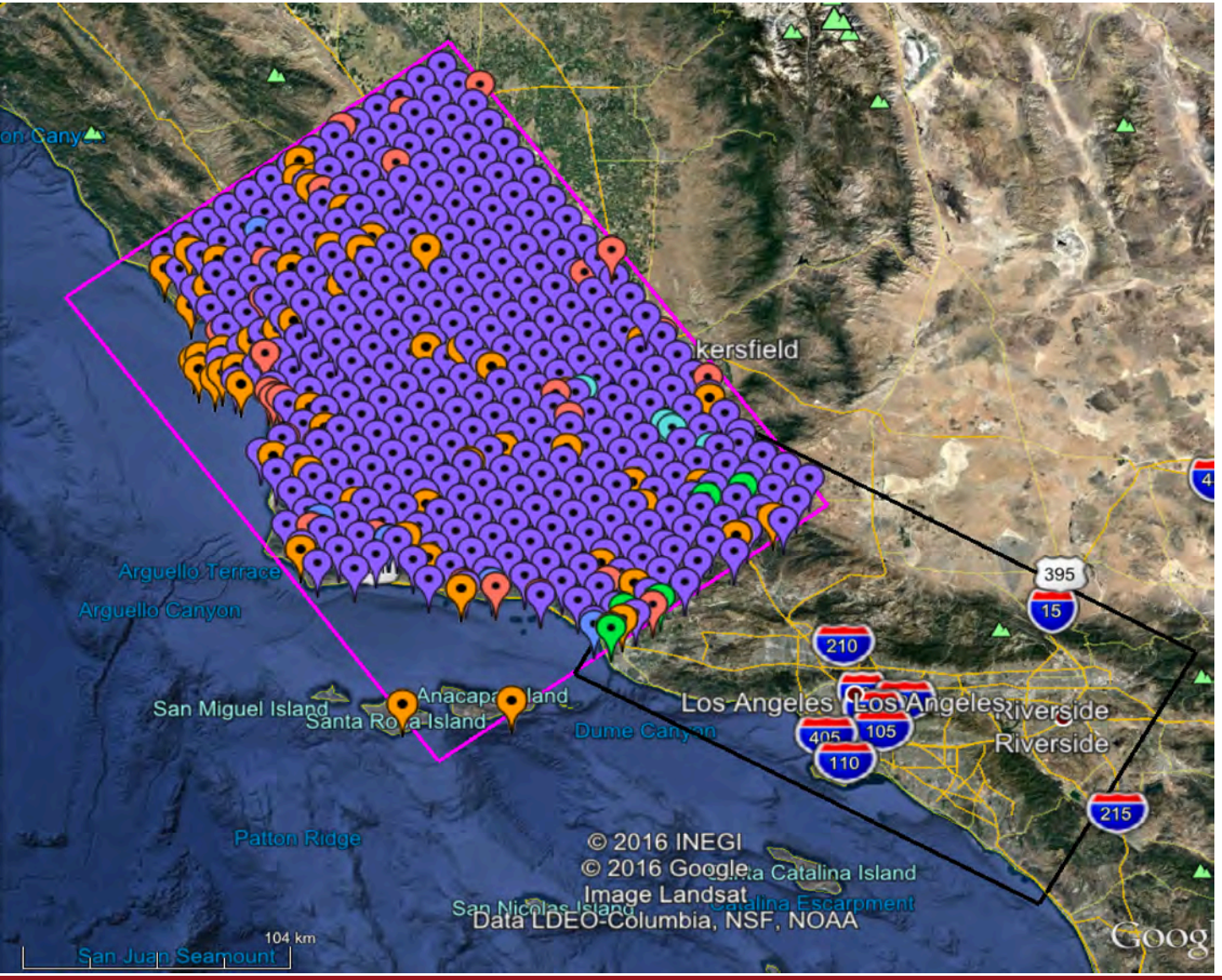
- Scientific Goal:
  - Assess effectiveness of physics-based seismic wavefield modeling in reducing the epistemic uncertainties in path effects and other hazard-estimation components at low exceedance probabilities, using Central California as a natural laboratory.
- Objectives and Tasks:



1. Gather data
2. Analyze data
3. Assimilate data into models and forecasts
4. Estimate reduction of epistemic uncertainties
5. Evaluate impact
6. Provide physics understanding of results

CCSP: CyberShake Study 17.3

(Pacific Gas & Electric)



- Proof-of-concept for expanding CyberShake to new regions
- Twice the size of CyberShake Southern California
- 438 locations
  - CISN stations
  - Water pumping sites
  - Cities from USGS Gazetteer
  - Historic missions
  - Regular grid for interpolation

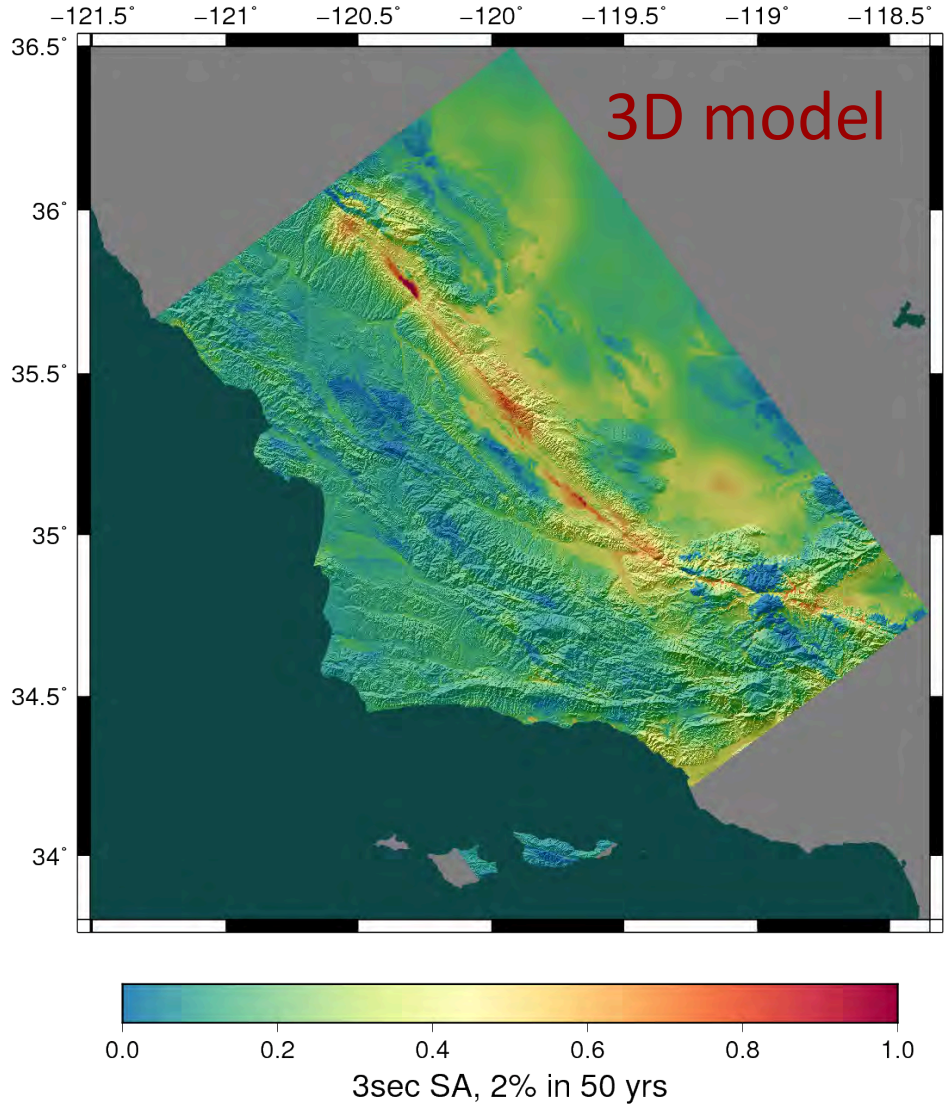
Sample Accomplishment

CCSP: CyberShake Study 17.3

(Pacific Gas & Electric)

- Calculations for 2 velocity models for each of 438 sites, 1 Hz simulations, 40,000+ earthquakes

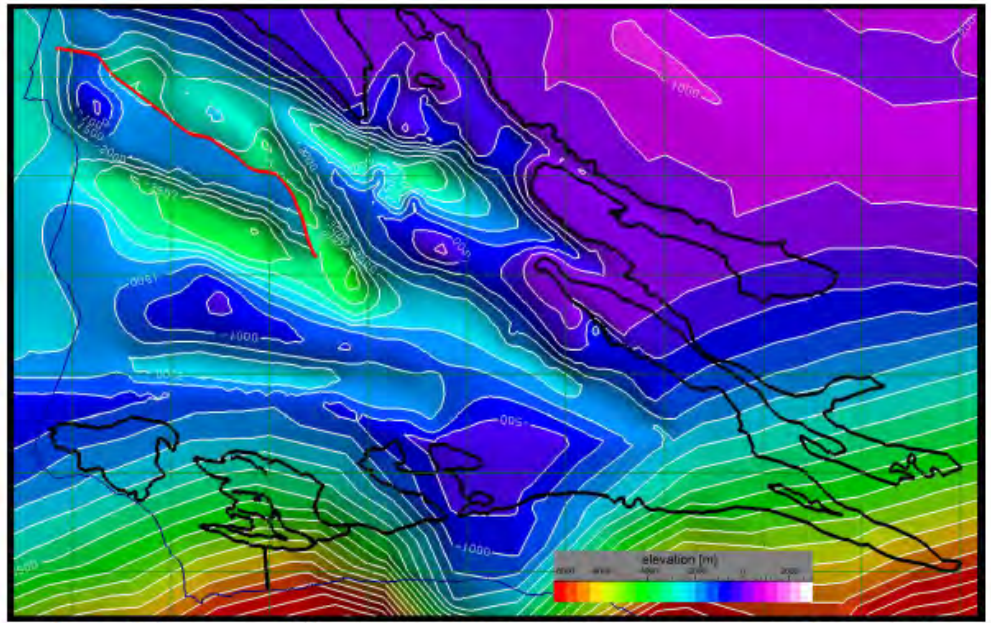
- Used OLCF Titan and NCSA Blue Waters
  - Averaged 1295 nodes (CPU + GPU) for 31 days, maximum of 5374
  - 900,000 node-hours consumed (21.6M core-hours)
  - Pegasus, HTCondor, Globus used for workflows
  - Workflow tools scheduled 15,581 jobs to both systems
  - Transferred 308 TB of intermediate data between the two systems
- Generated 285 million two-component seismograms
  - 43 billion intensity measures
- Workflow tools managed 777 TB of data
  - 10.7 TB of output data automatically staged back for archival storage



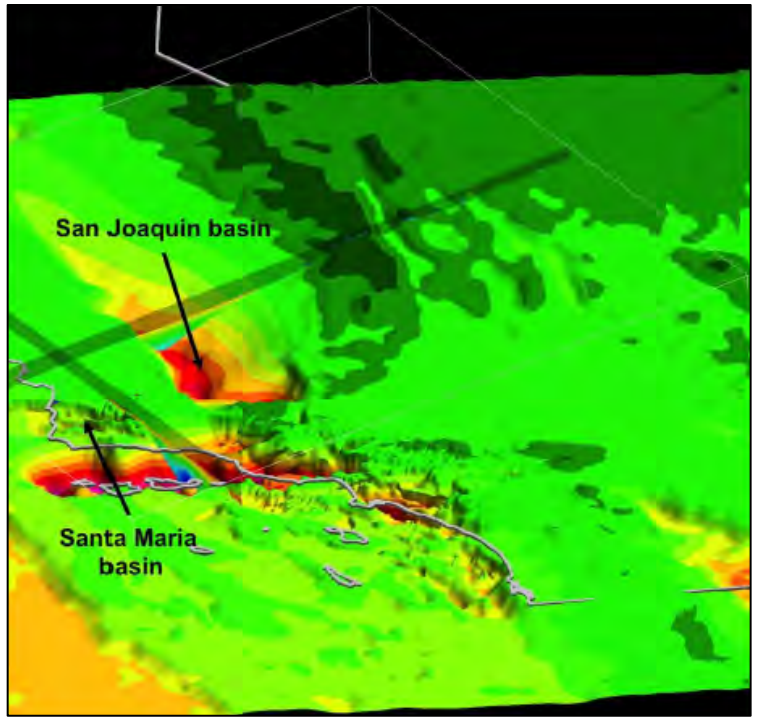
CCSP: New CVMs

(Pacific Gas & Electric)

- Integrate geology-constrained basins into CCA-06
- Rerun CyberShake



Improved velocity model of the Santa Maria basin from the southern California USR using industry seismic reflection and well data.



New velocity (Vp, Vs, density) model of the San Joaquin basin, which incorporates major geologic horizons (base Quaternary; base Tertiary; top basement) and faults from the SCEC Community Fault Model (CFM).

Software Environment for Integrated Seismic Modeling (SEISM) (NSF SI-2)

Jordan, Cui, Olsen, Taborda, Graves, Bielak, Maechling, Silva, Goulet, Gill, Mosalam,

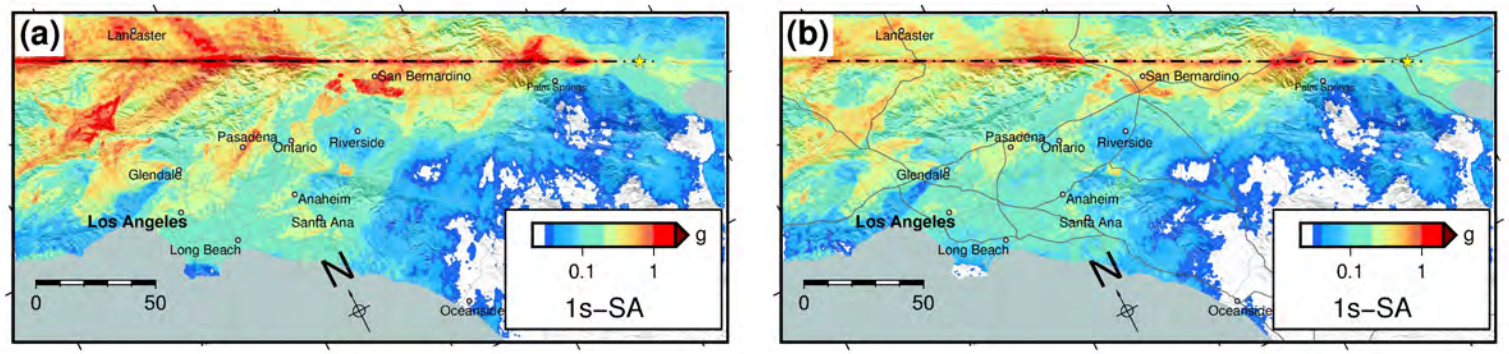
High-F project

Pushing deterministic ground-motion simulations to higher frequencies (~10Hz) while

- **Improving computational efficiency**
- **Adding more realistic physics:**
  - **near-fault plasticity**
  - **fault roughness**
  - **small-scale near-surface heterogeneity**
  - **frequency-dependent attenuation, Q(f)**
  - **topography**
  - **near-surface nonlinearity**

Spectral Acceleration at 1s, PSA(1s): Linear

PSA(1s): Nonlinear, Good-Average Rock Quality



Roten et al. 2017

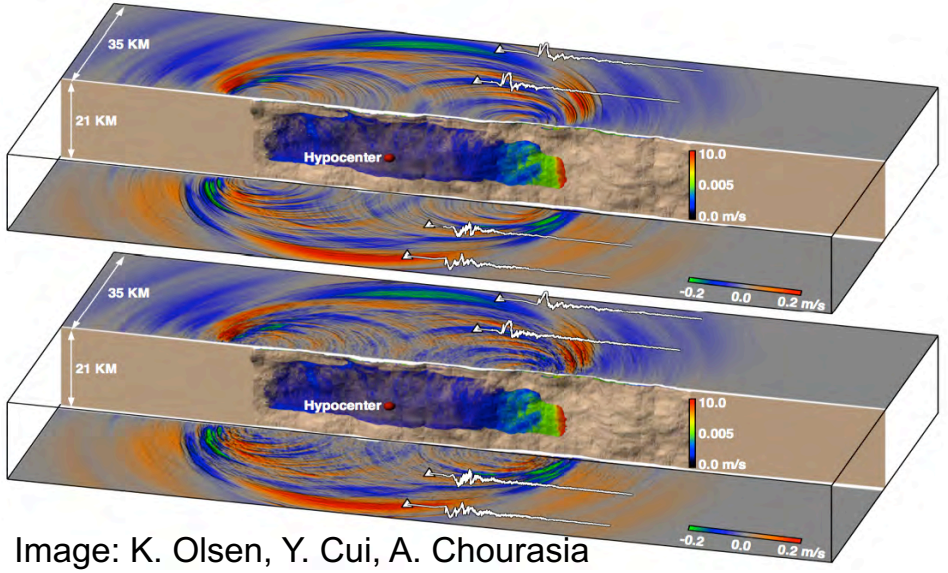


Image: K. Olsen, Y. Cui, A. Chourasia

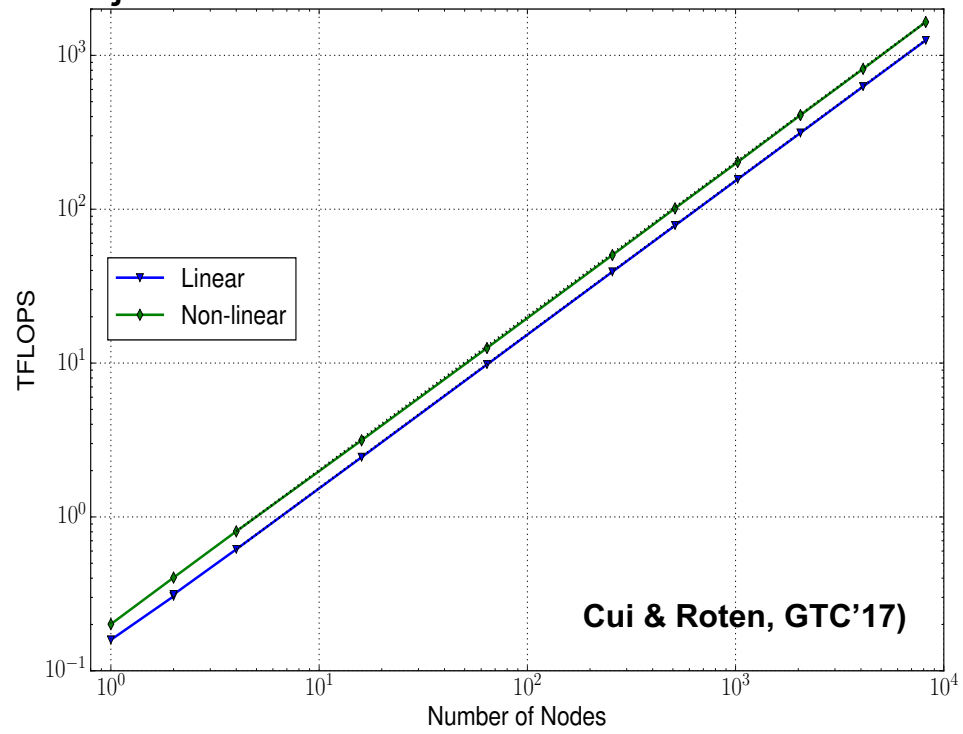
SEISM2 Software Development (NSF SI-2)

(Posters #011, #278, #279, #280)

SDSC team working closely with CME

- Open-source software sustainability
- Performance improvements (RSQSim, AWP-ODC)
- New EDGE (DG FEM) code development
- Co-development for current and future HPC architecture

AWP-ODC on Blue Waters and PAID Project



SDSC team: Yifeng Cui, Alex Breuer, Amit Chourasia, Rajdeep Konwar, David Lenz, Dawei Mu, Dmitry Pekurovsky and Josh Tobin

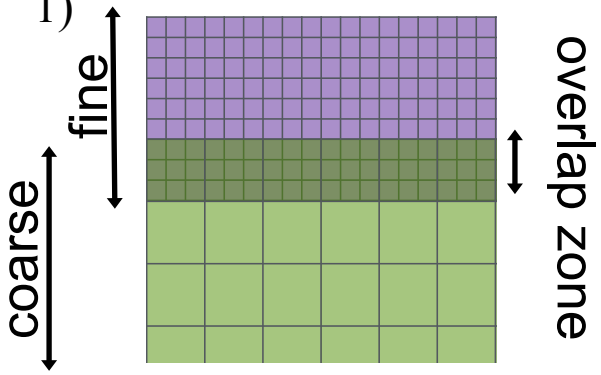
SEISM2, High-F (NSF SI-2)

WEDMI - Wavefield Estimation using a Discontinuous Mesh Interface (AWP-DM)

Motivation: Uniform-grid methods inefficient for large contrasts in seismic wave speeds, such as basin models.
Approach: Factor-of-three contrast in grid spacing along all three dimensions.

Poster #249

1)



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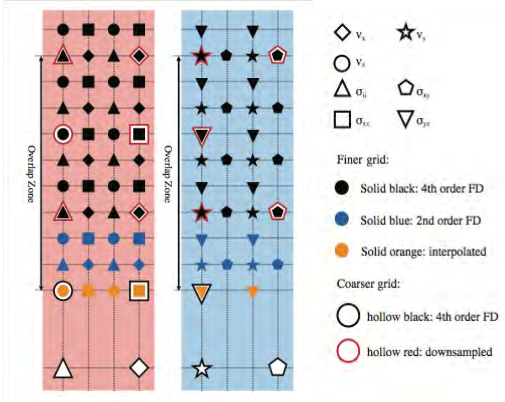

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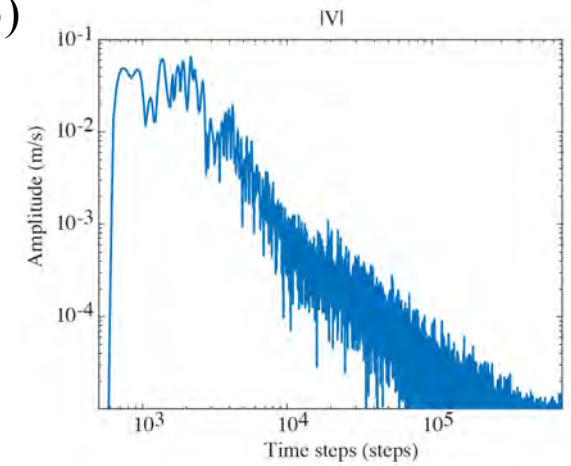

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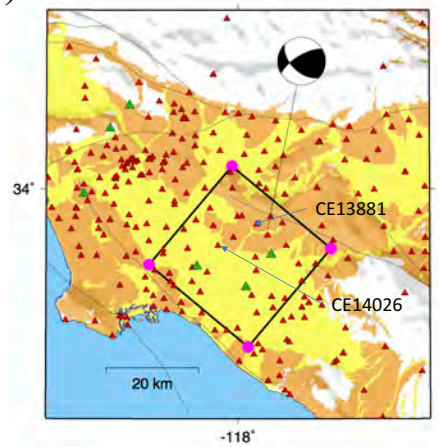

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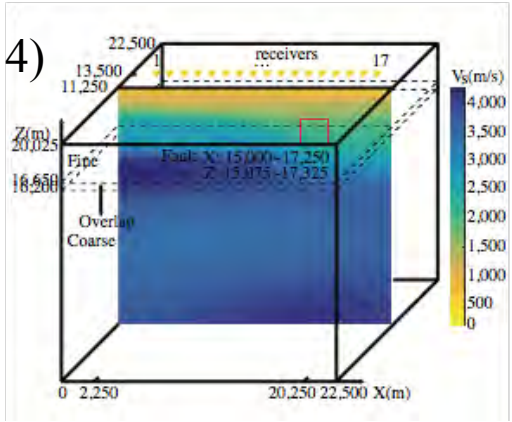

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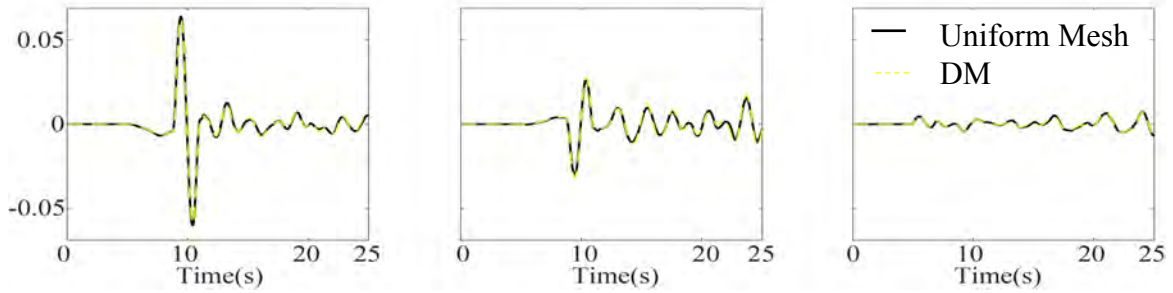

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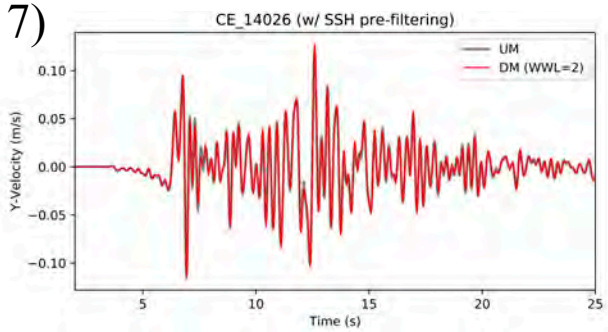


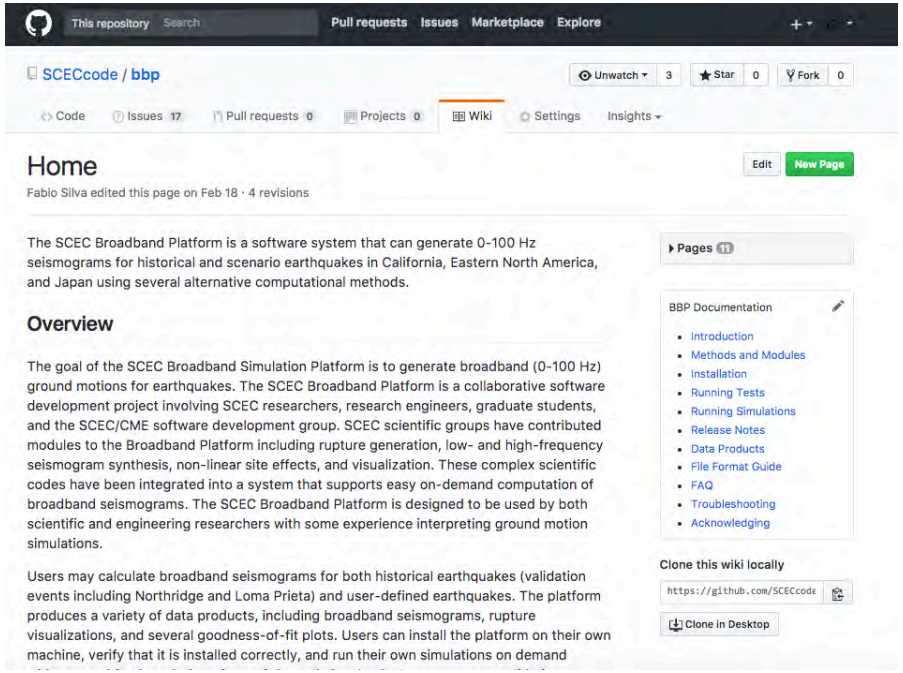
Slide: modified from K. Olsen

Sample Accomplishment

Broadband Platform Release 17.3

(Pacific Gas & Electric/SEISM2)

On github repository with new features including:

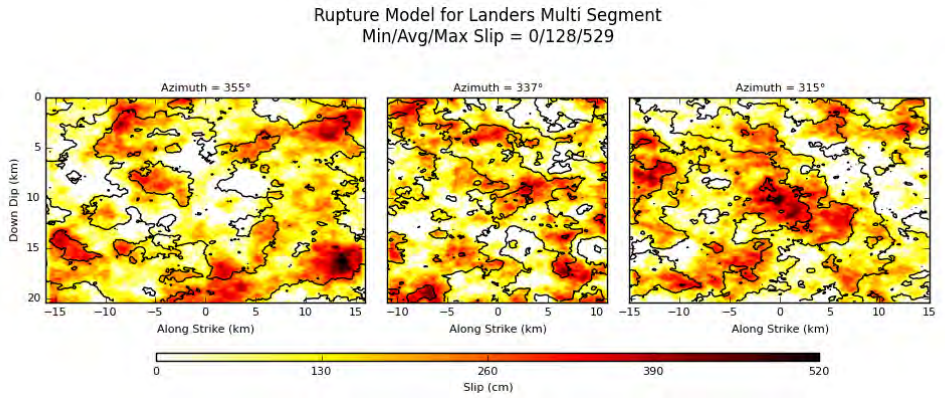


Method Updates

- NEW Irikura Recipe Method 1
- UPDATED GP rupture generator code to model multi-segment ruptures
- UPDATED GP match.py module to improve the merging of low- and high-frequency seismograms.

General Improvements

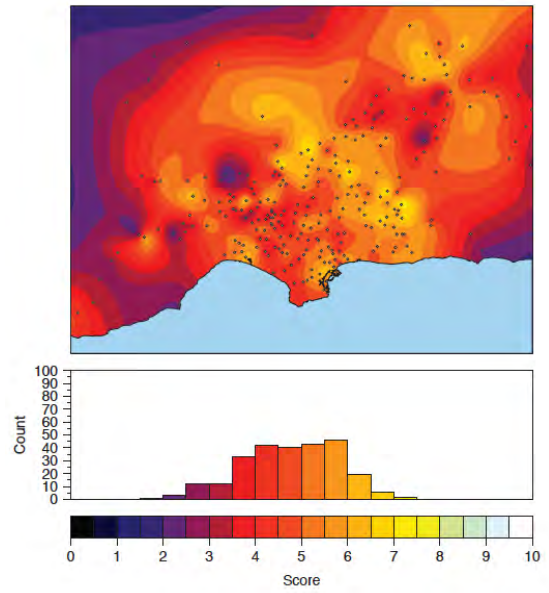
- NEW FAS calculation module
- NEW Central United States simulation region (Hosseini and Somerville)
- NEW scripts to combine time series from a number of separately-calculated segments, allowing for a multi-segment rupture to be simulated.
- IMPROVEMENTS for running ensembles calculation using cluster computers.

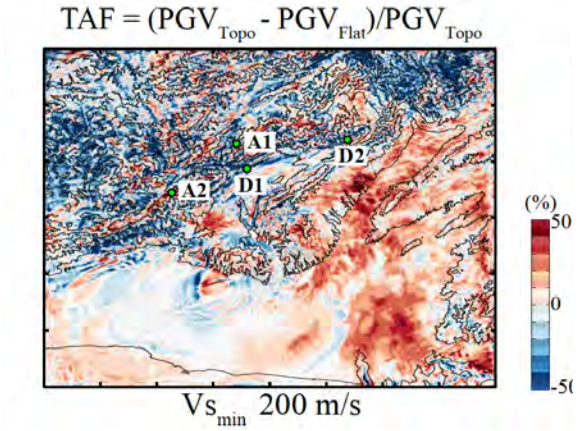


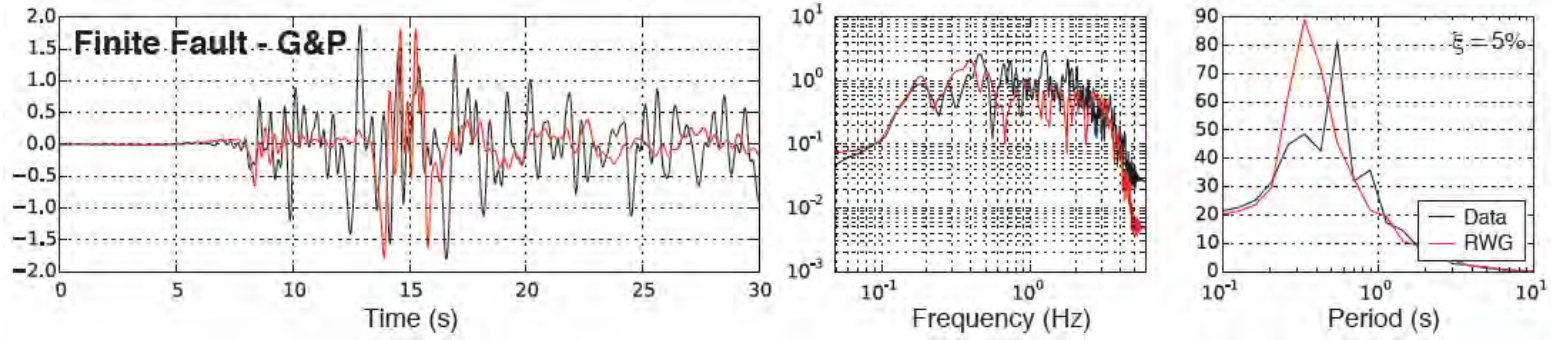
Full waveform modeling up to 10 Hz

Reach 10 Hz realistic 3D full waveform ground motions.

- We have most of the different components needed to reach the high frequencies (Q(f), SSH, topo, plasticity,..), but need to map the trade-off between parameters.
- Requires starting with small events, isolating parameters, building-up with frequency
- Involves simultaneous validation using several events
- Ongoing work...



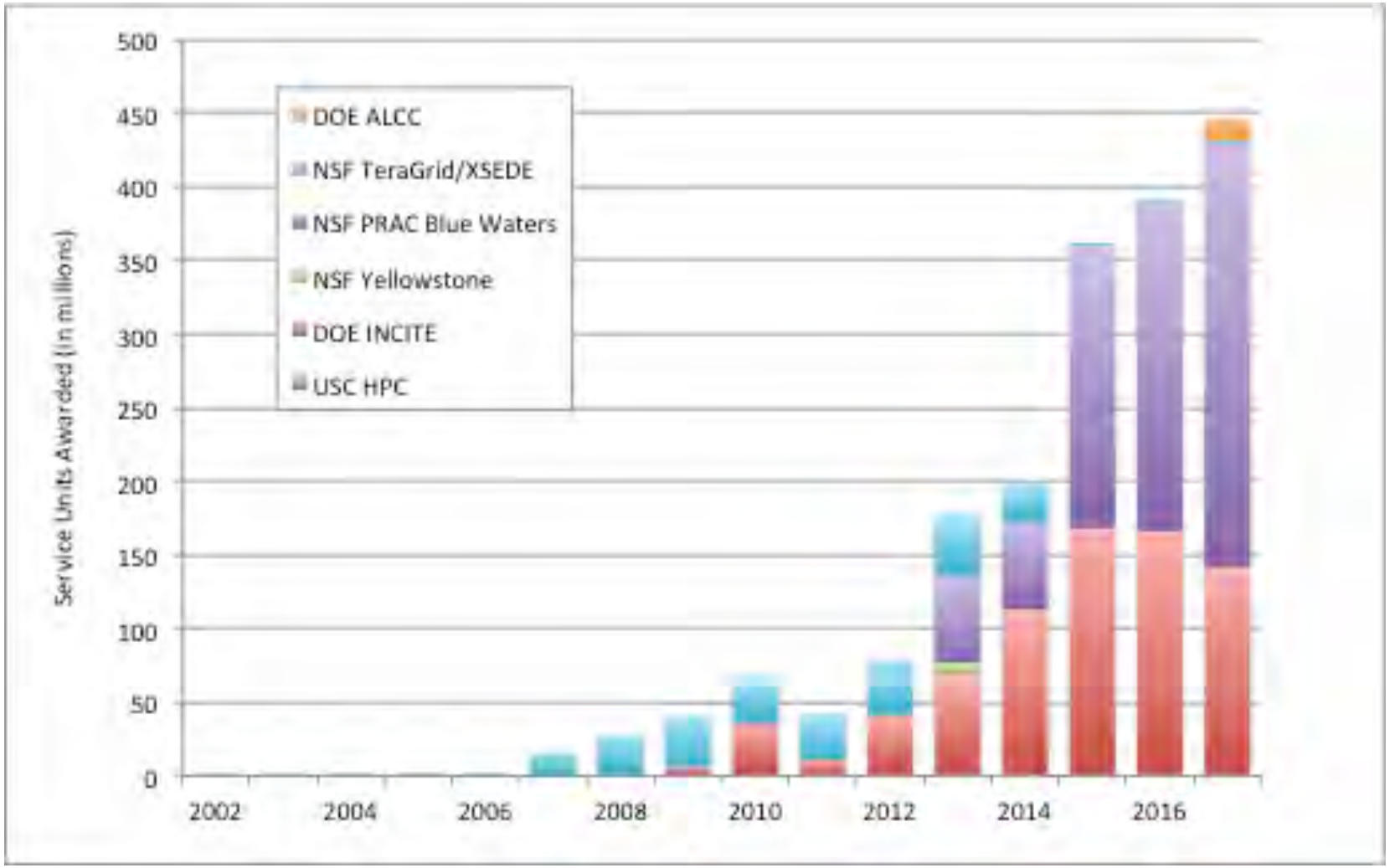




HPC Allocations

Allocations

- PRAC: Blue Waters
- INCITE: Titan, Mira
- XSEDE: Stampede, Stampede2, Jetstream, Comet, Bridges
- ALCC: Cori2
- USC HPCC



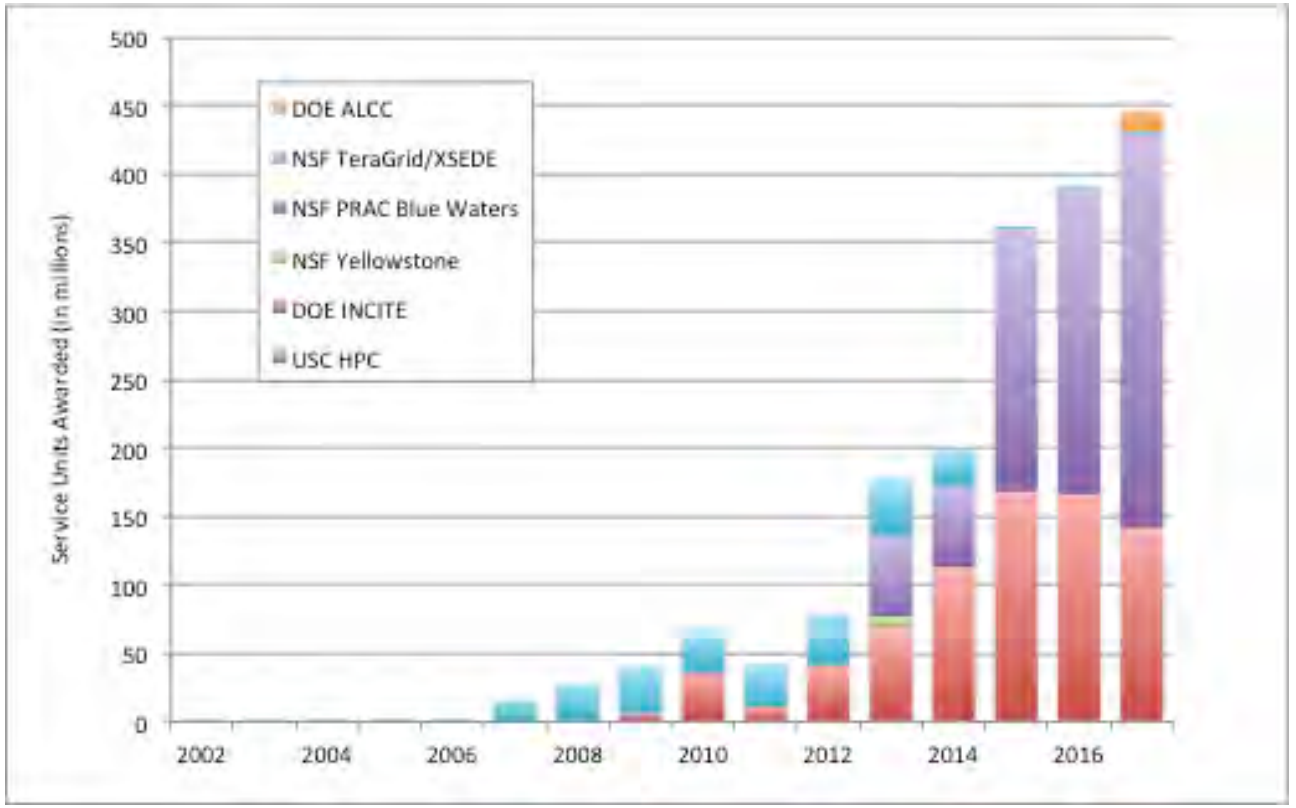
What's next?

Diversify our funding sources

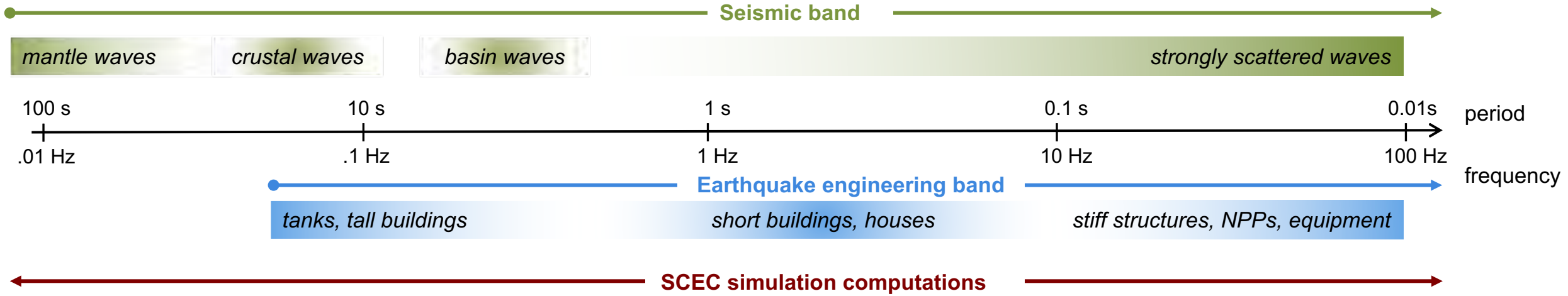
Potential special projects

- Nonlinear end-to-end shallow crustal modeling of site effects
- UCERF4
- Resilience of water supply infrastructure
- Other ideas?

Photo: Michael Collier, "A land in motion"


Service Units Awarded (in millions)
500
450
400
350
300
250
200
150
100
50
0
2002
2004
2006
2008
2010
2012
2014
2016
DOE ALCC
NSF TeraGrid/XSEDE
NSF PRAC Blue Waters
NSF Yellowstone
DOE INCITE
USC HPC

SCEC ground-motion simulation platforms



SCEC simulation computations

BroadBand Platform	1D Deterministic	Stochastic	**Development and production software (runs on clusters and PCs)**
CyberShake	3D Deterministic		**Complete physics-based PSHA (runs on HPC)**
BroadBand CyberShake	3D Deterministic CyberShake	Stochastic BroadBand Platform	
High-F	3D Deterministic		**Physics-based development for new physics (runs on HPC and clusters)**