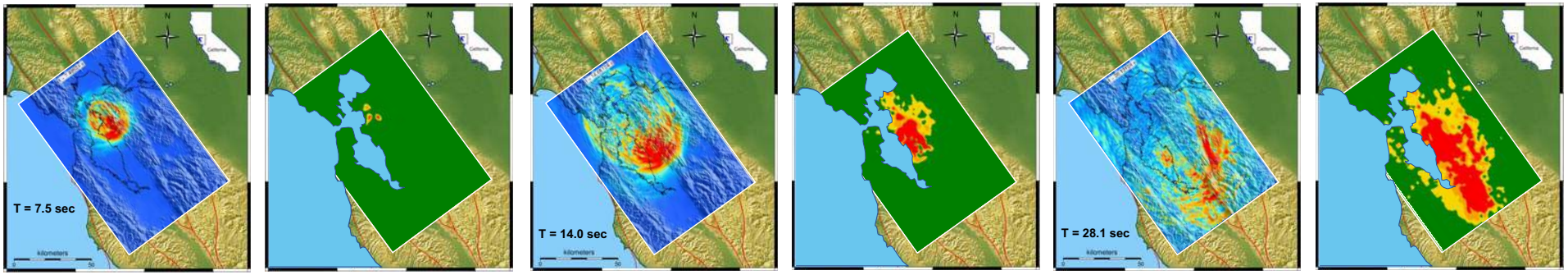


Development of the PEER - LBNL Simulated Earthquake Ground Motion Database for the San Francisco Bay Area

2023 PEER Annual Meeting
August 24 - 25, 2023

David McCallen PI
University of Nevada, Reno
& Lawrence Berkeley National Laboratory

Florina Petrone Co-PI
University of Nevada, Reno
& Lawrence Berkeley National Laboratory

Parmida Rahmani
PhD student
University of Nevada, Reno

Majid Nia
Postdoctoral scholar
University of Nevada, Reno

BERKELEY LAB

PEER

None of this would be possible without leveraging six years of DOE capability building

Engineering Mechanics

David McCallen

Floriana Petrone

Mamun Miah

Seismology / Geophysics

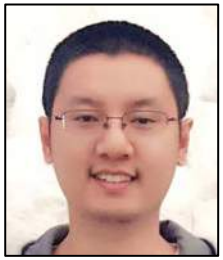
Arben Pitarka

Rie Nakata

Arthur Rodgers

Computer Science

Houjun Tang



Ramesh Pankajakshan

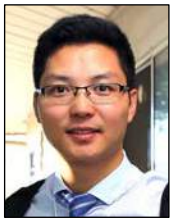
Applied Math Numerical Methods

Anders Petersson

Bjorn Sjogreen

Postdocs / early career

Kenawy



Wu

Panilla Ramos

Graduate students

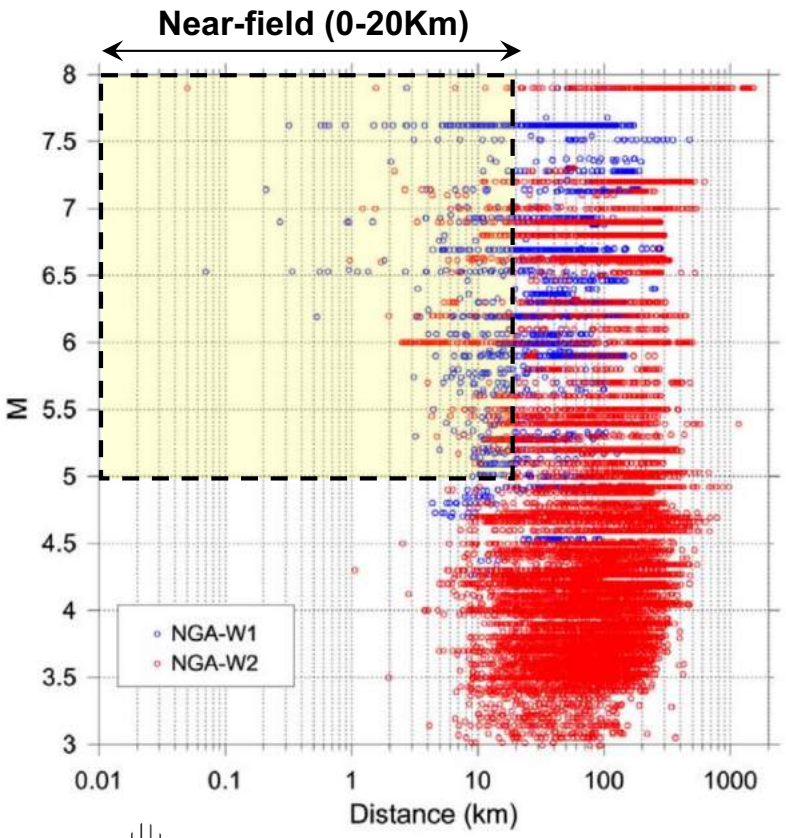
Huang

Rahmani

Aryal

Challenges associated with sparse data for empirical ground motion models persist

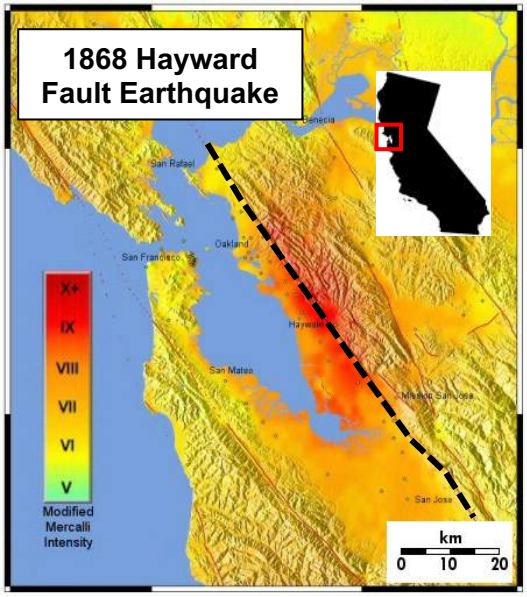
Observational ground motion data is very limited

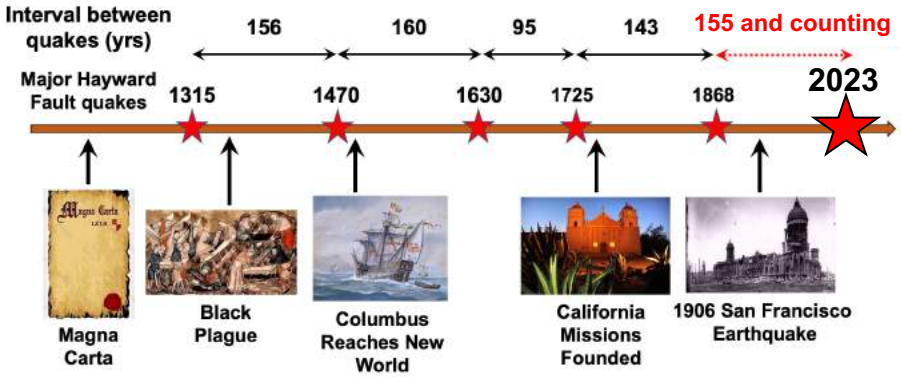


NGA Strong Motion Database

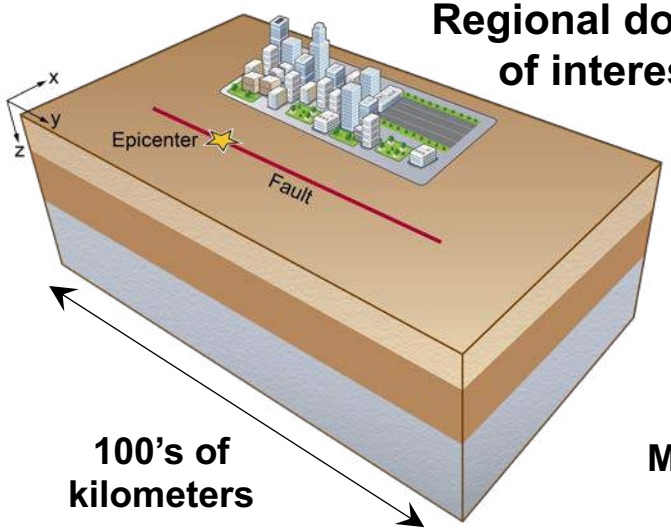
PEER

For many regions of interest, data for large historical events does not exist



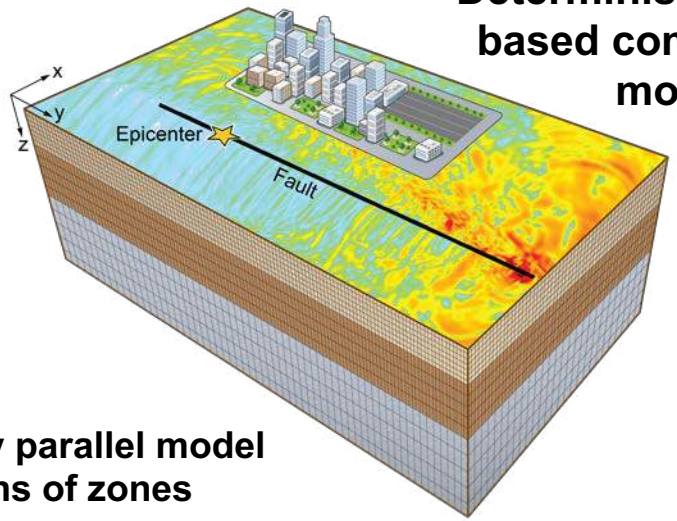


Interest (and research efforts) continue to grow in physics-based regional-scale EQ simulations



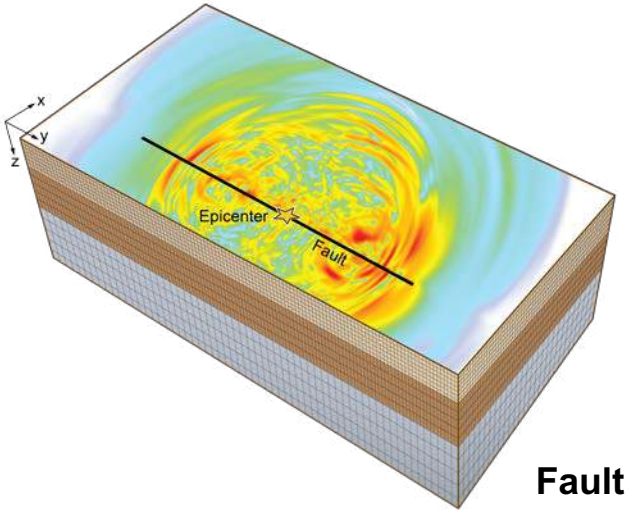
Regional domain of interest

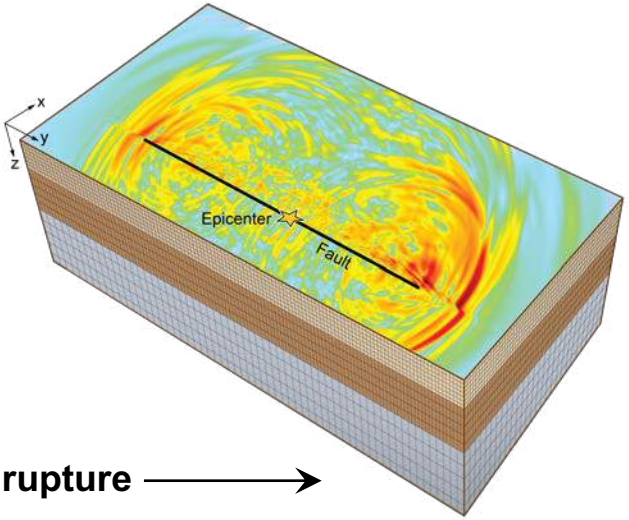
100's of kilometers

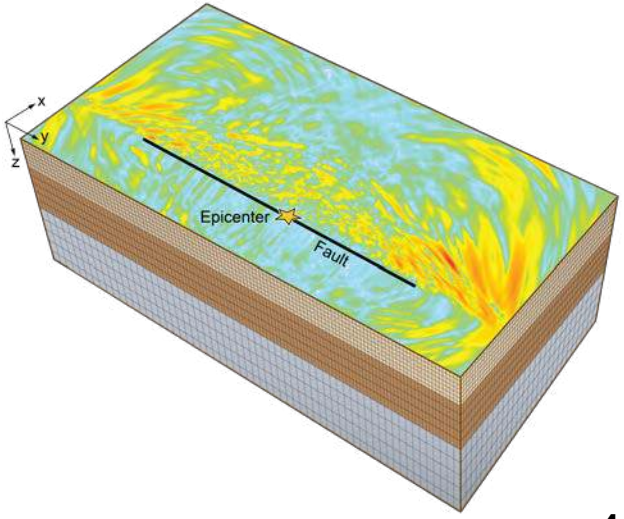


Deterministic, physics-based computational models

Massively parallel model billions of zones



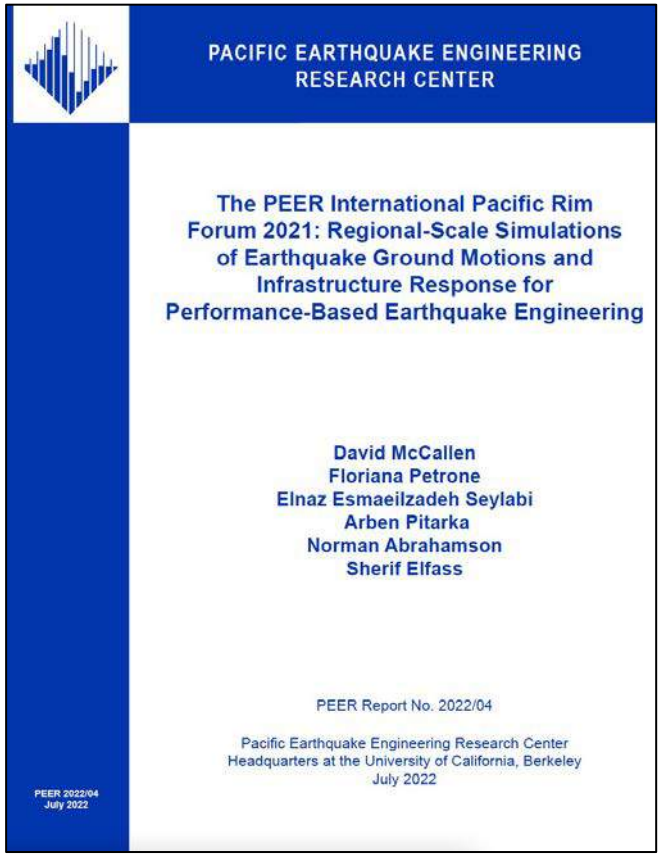




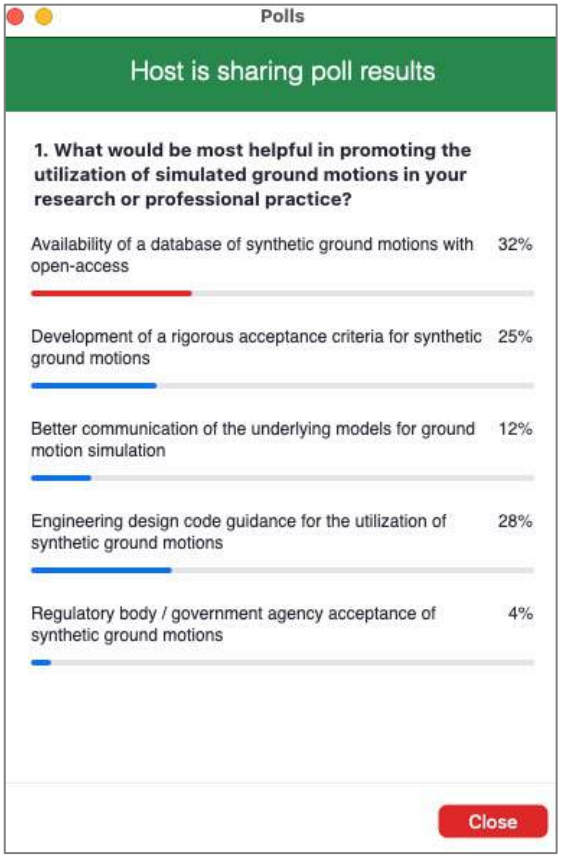
Fault rupture ⟶

The PEER 2021 Pacific Rim Forum helped frame a roadmap for utilization of simulated motions

PEER Pacific Rim Forum
June 2021



261 International Participants
41 International Speakers



Attendees voted on priorities

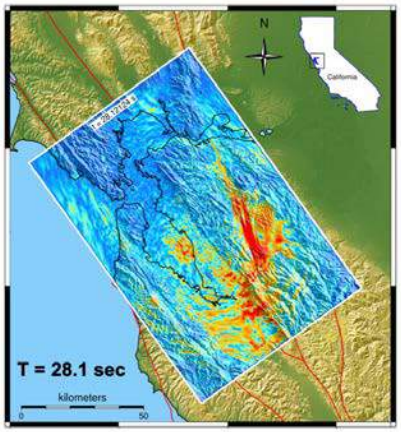
#1
Availability of a database of synthetic motions with open-access

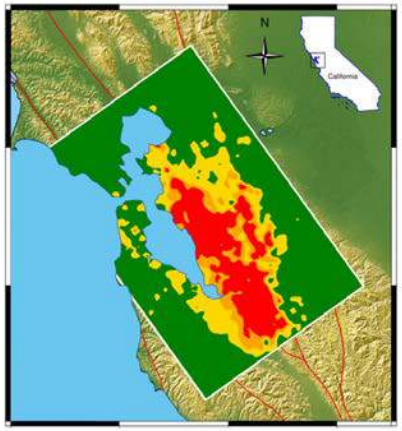
#2
Engineering design code guidance for synthetic motion utilization

#3
Development of rigorous acceptance criteria for synthetic motions

Two complementary projects on regional-scale simulations are contributing to this roadmap

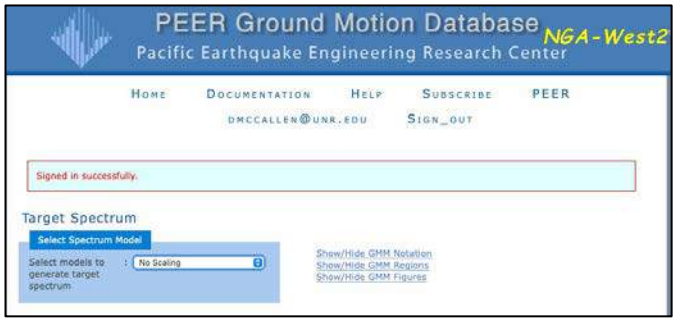
LBNL / LLNL EQSIM - Advanced workflow and GPU-based platforms for regional-scale simulations of ground motions and infrastructure response





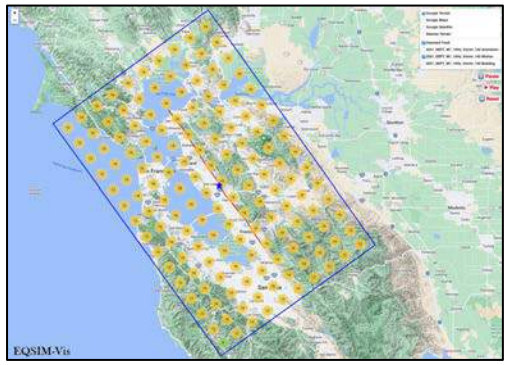
PEER / LBNL SGDB - A framework for efficient data storage and fetching for Performance Based Earthquake Engineering (PBEE) applications

Old - Spatially sparse measured motions

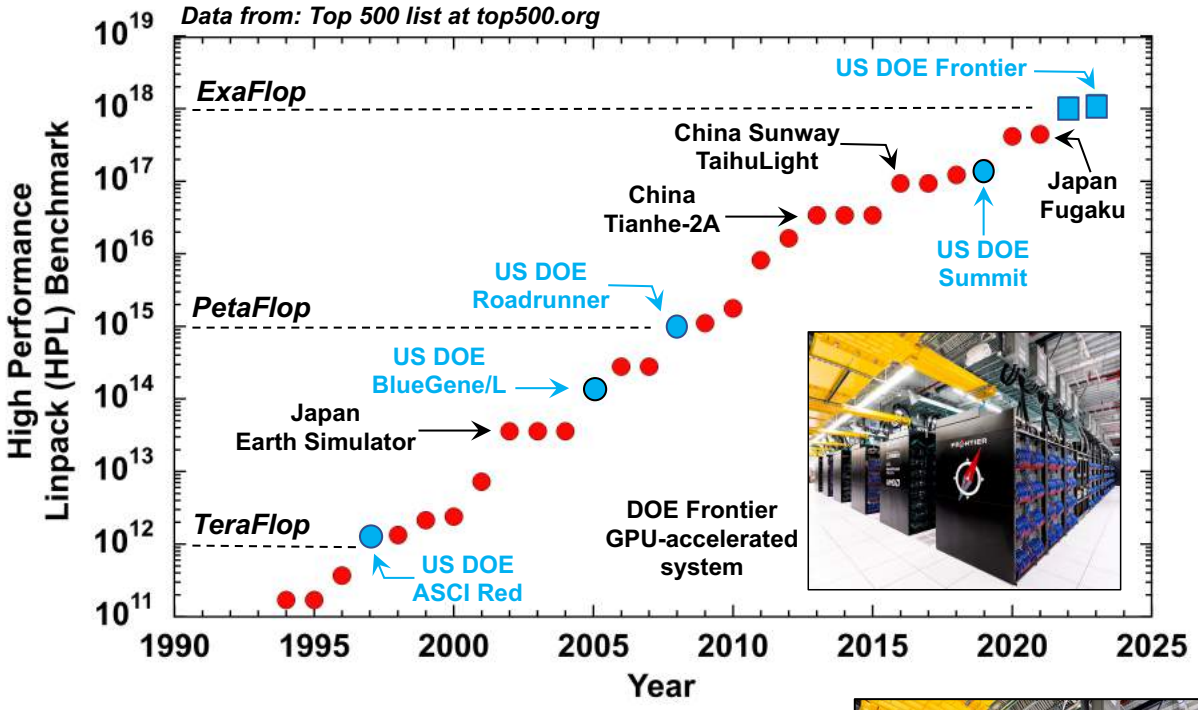


+

New - Spatially dense simulated motions



The DOE Exascale Computing Project is driving next generation GPU-accelerated computers

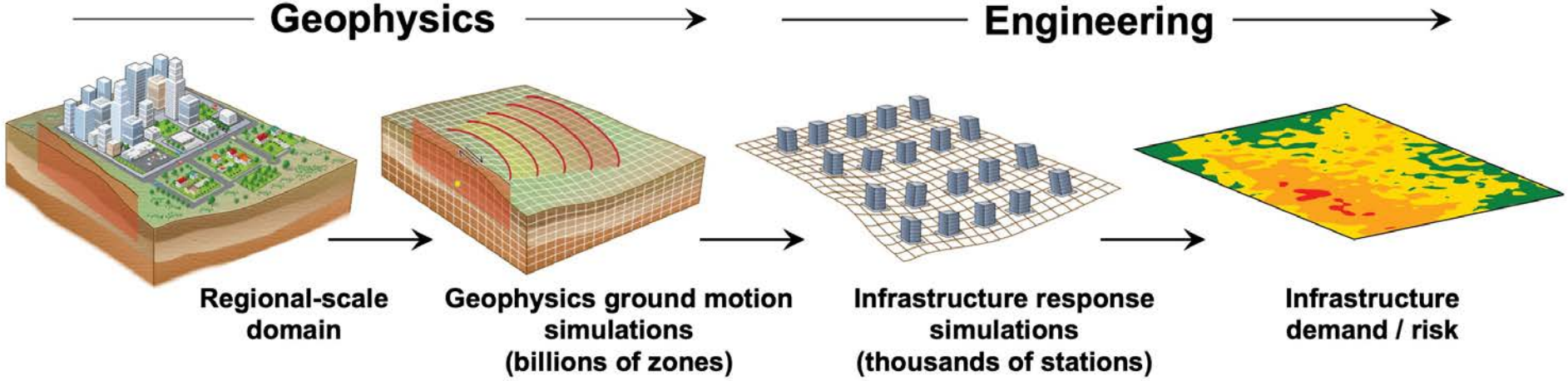


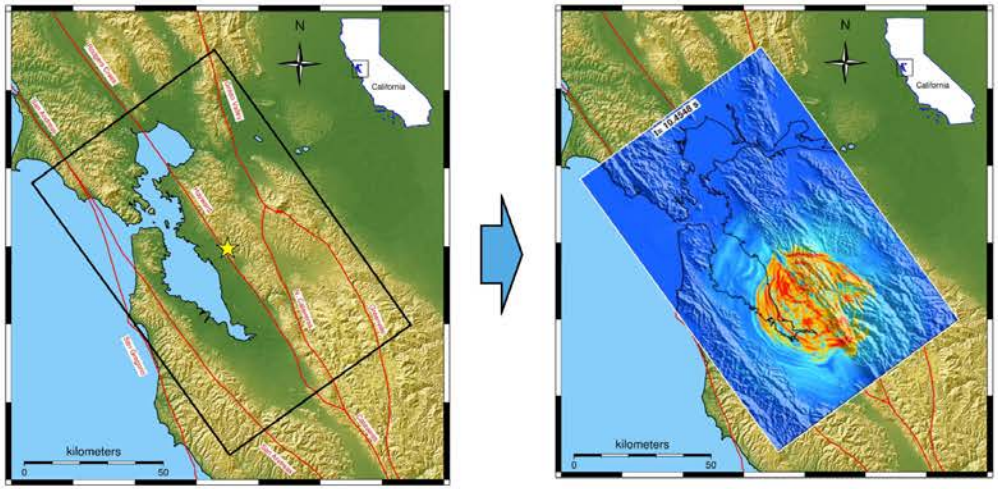
Perlmutter, GPU-accelerated
71 Pflop/s Top500 #8
Lawrence Berkeley National Lab

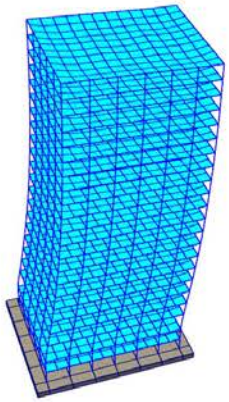
Summit, GPU-accelerated
148 Pflop/s Top500 #5
Oak Ridge National Lab

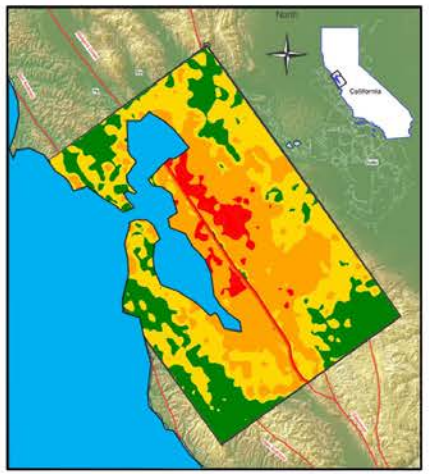
Frontier, 2022, GPU-accelerated
1,102 Pflop/s Top500 #1
Oak Ridge National Lab

The DOE's EarthQuake SIMulation (EQSIM) application is purpose-built for exaflop systems





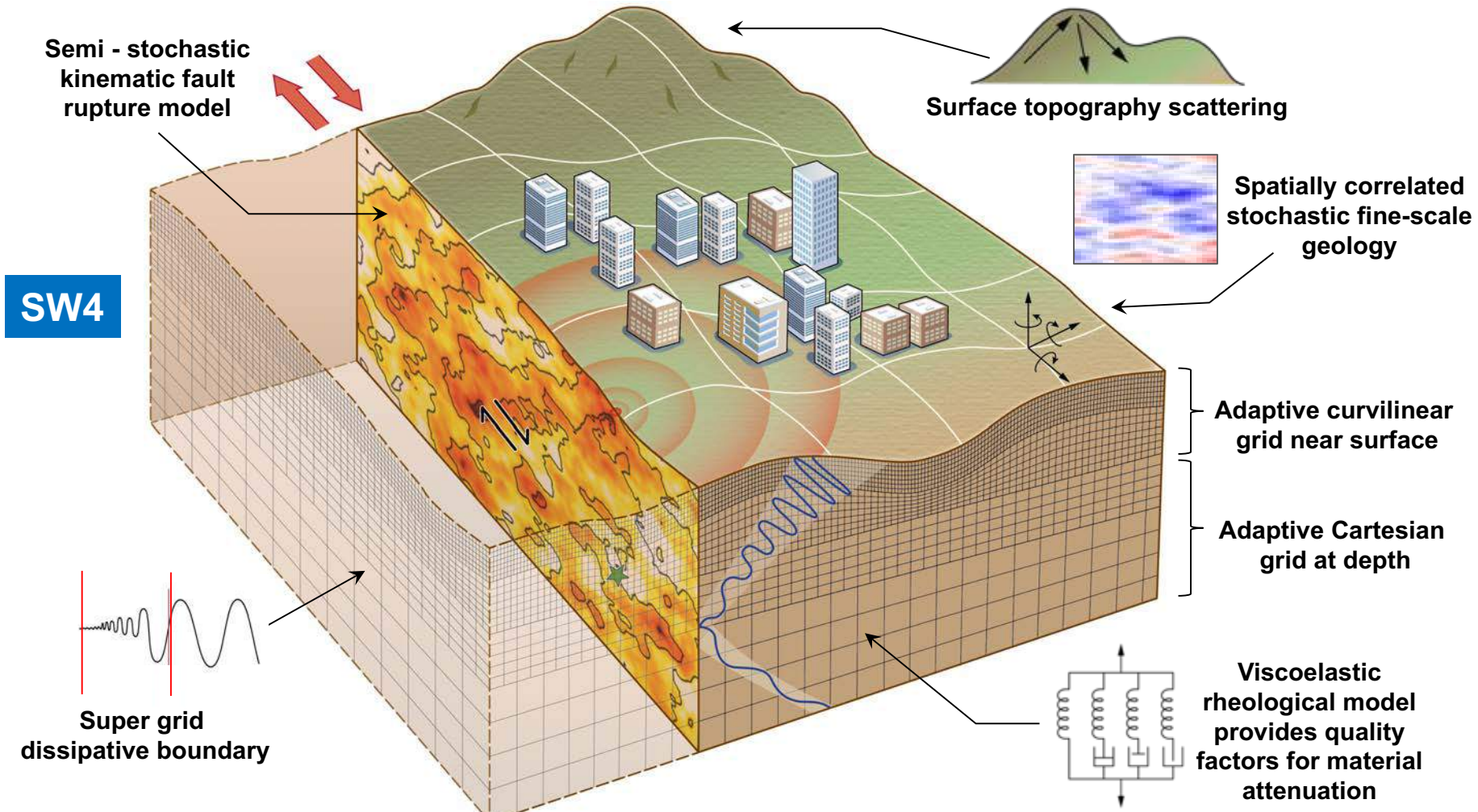




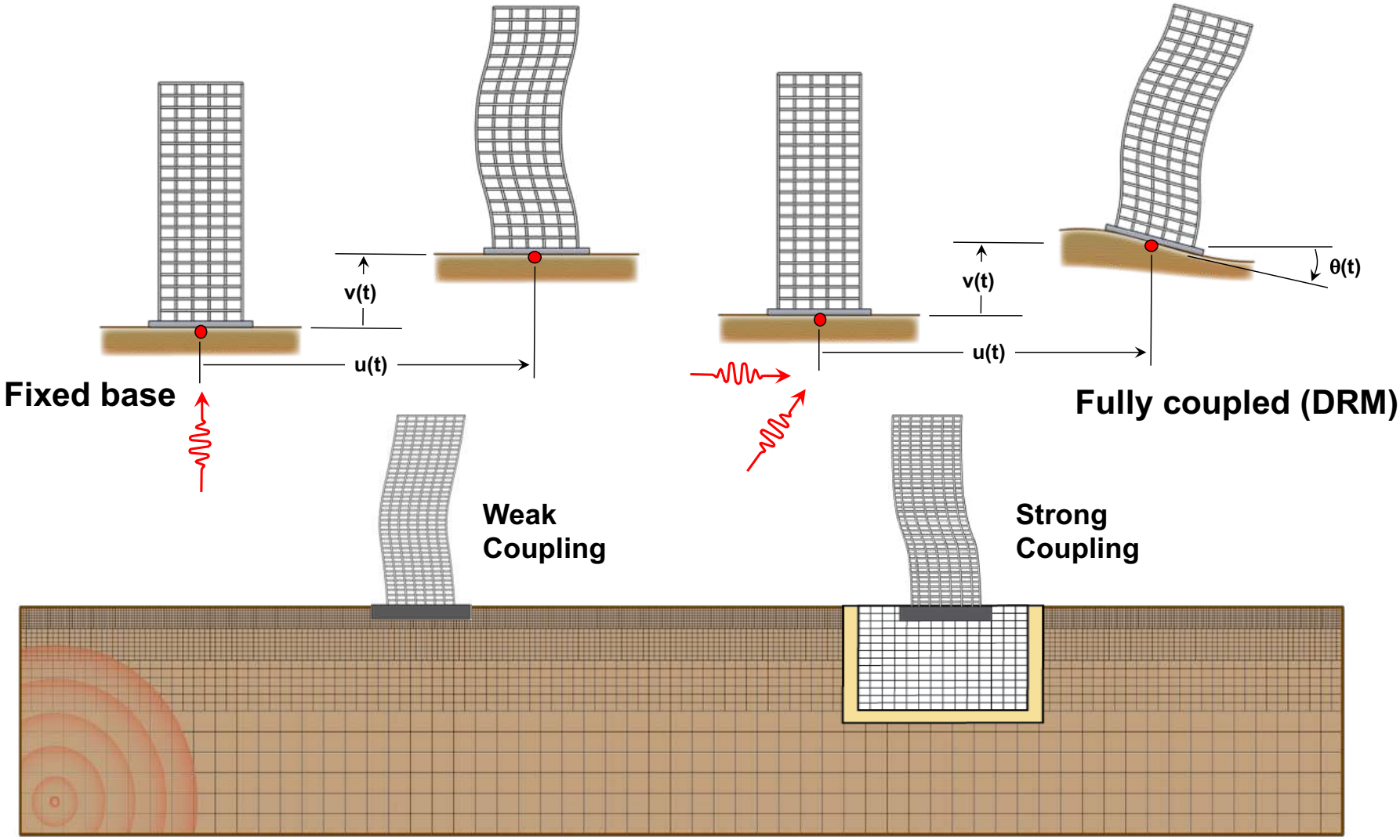
What's the distribution of ground motions? **What's the distribution of demand?**

Many advancements have been completed for the SW4 geophysics wave propagation code

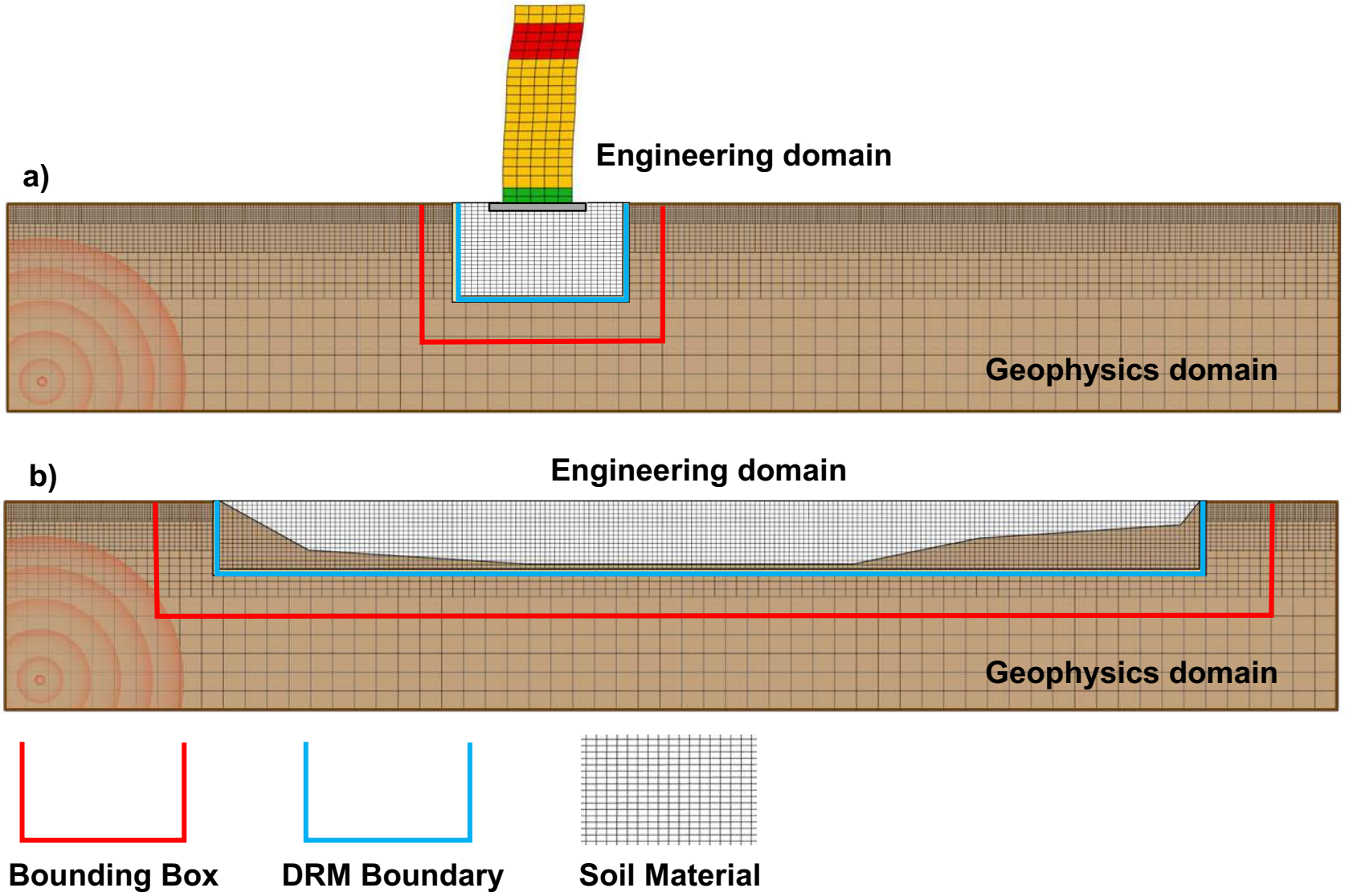
Improved physics, computational efficiency at 300 billion grid points



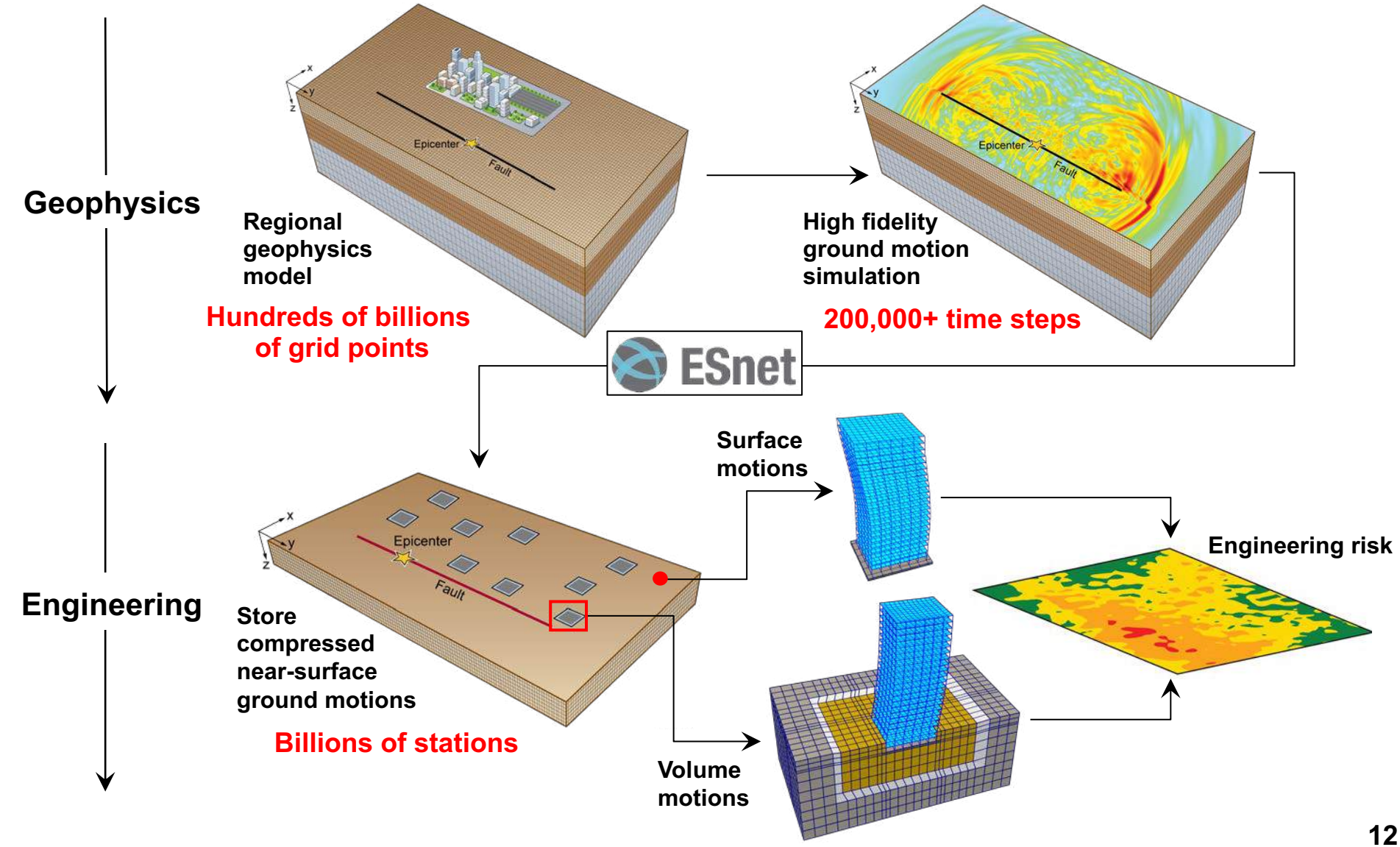
EQSIM has implemented two options for coupling geophysics and engineering models



DRM allows representation of SSI, inclined waves and nonlinear soft near-surface soils

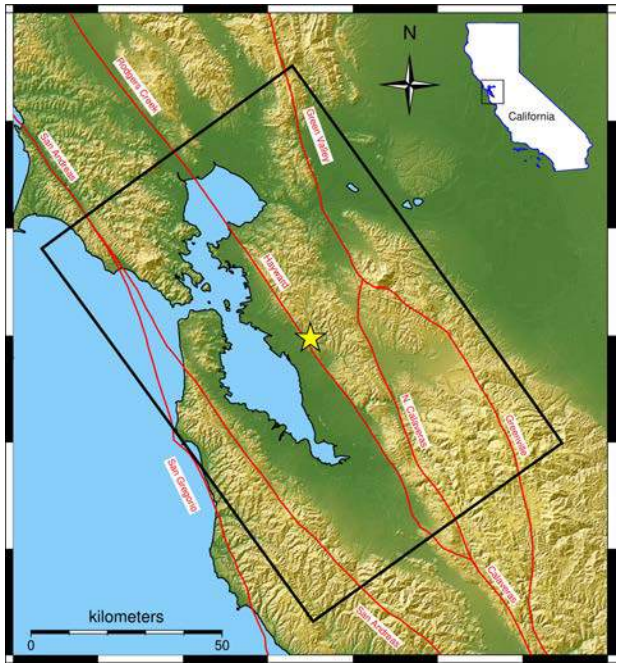


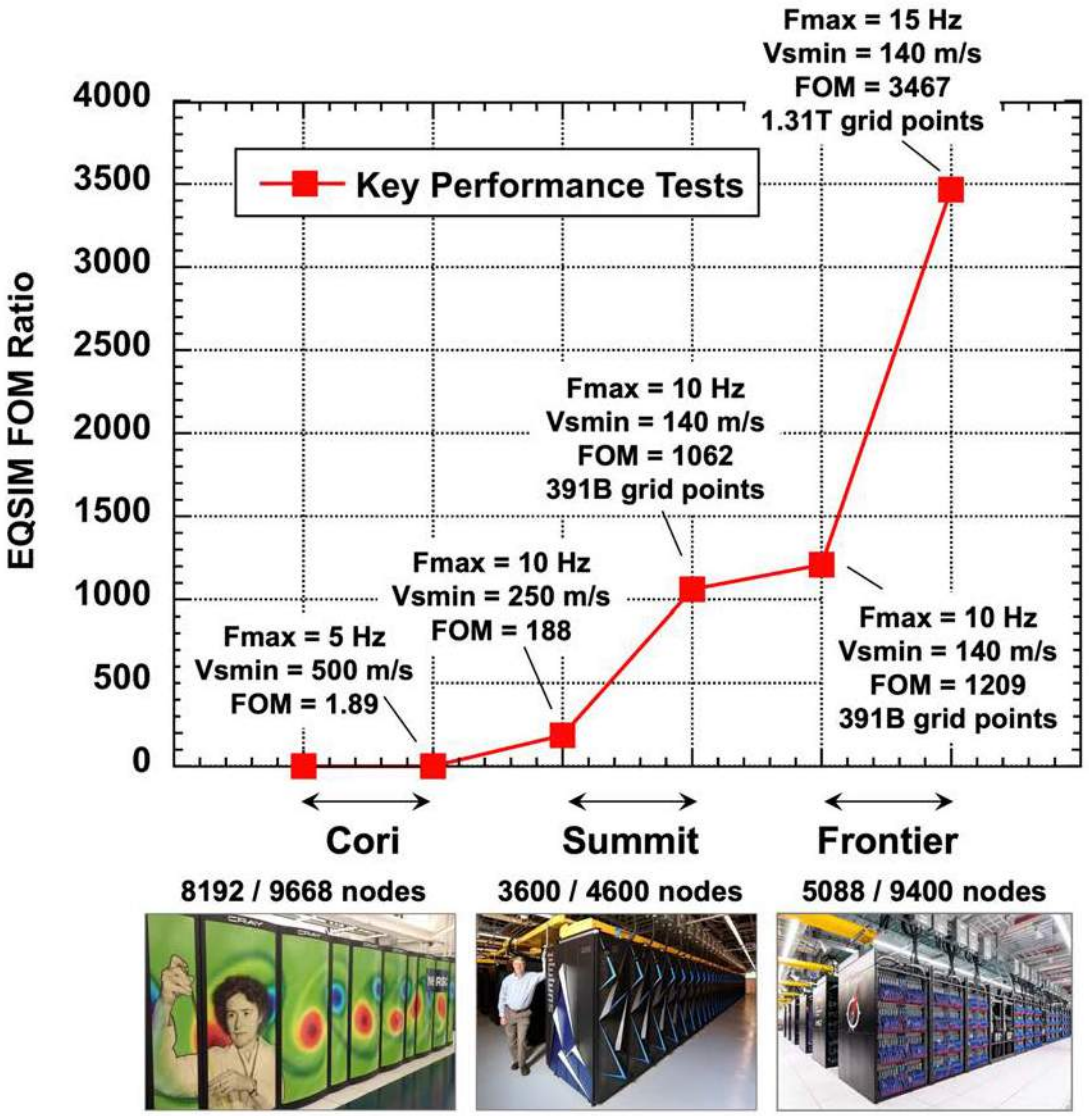
Six years of effort has gone into developing efficient fault-to-structure workflow



EQSIM has substantially pushed the envelope for regional simulation resolution and speed

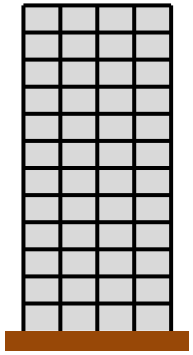
EQSIM SFBA performance test domain





Creating the database

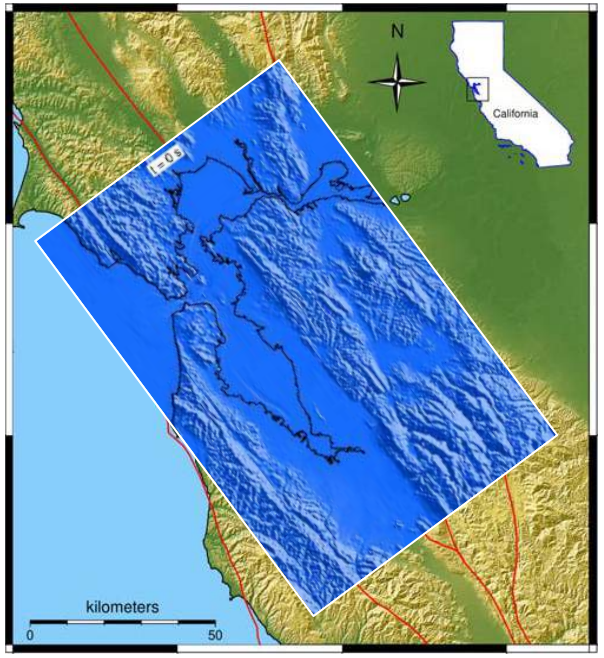
20 realizations of a M7 Hayward fault event have been generated (Inter-event variability example)

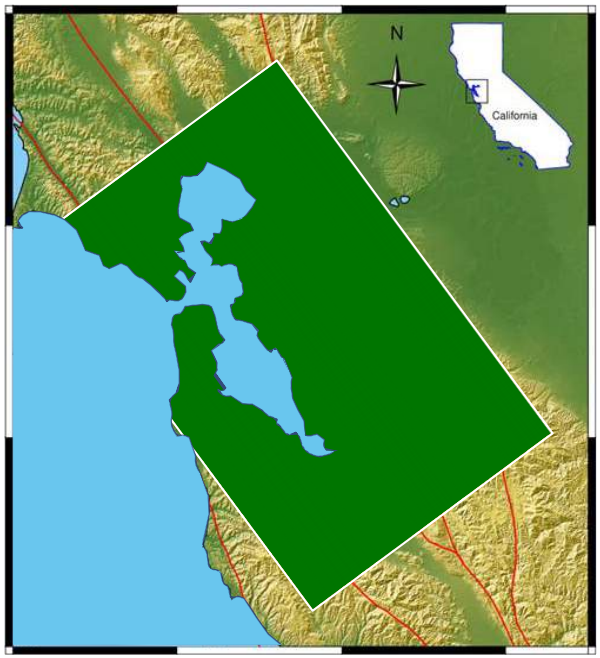


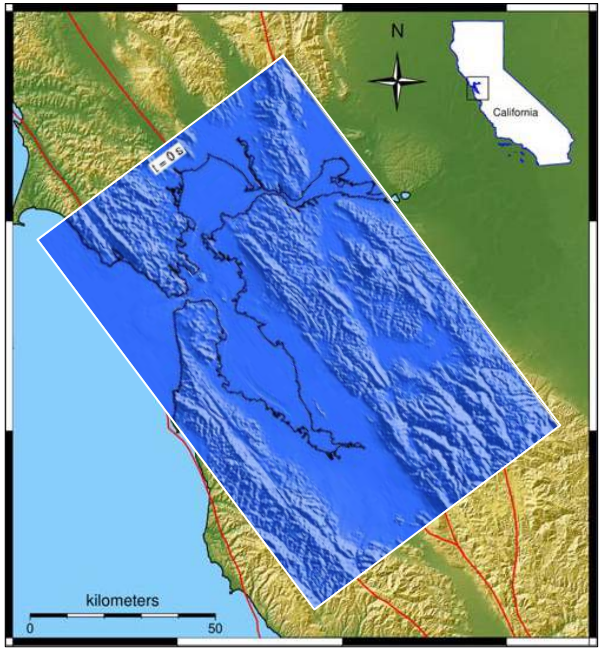
12 story RC frame OpenSees fiber model

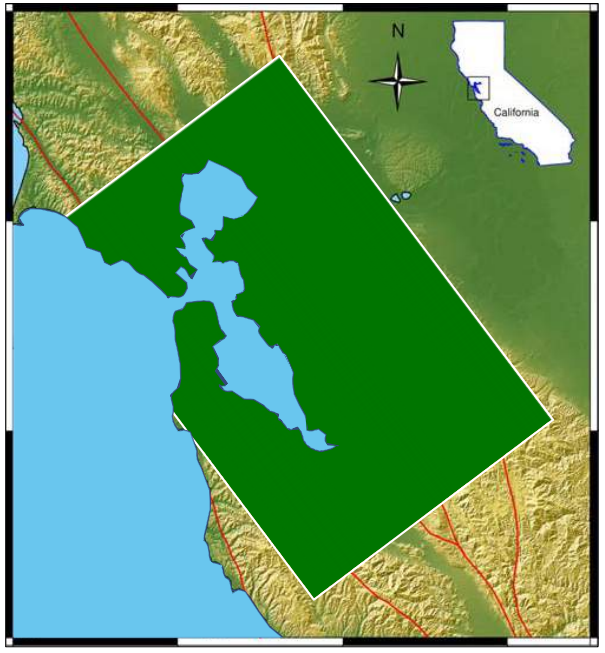
South hypocenter

North hypocenter



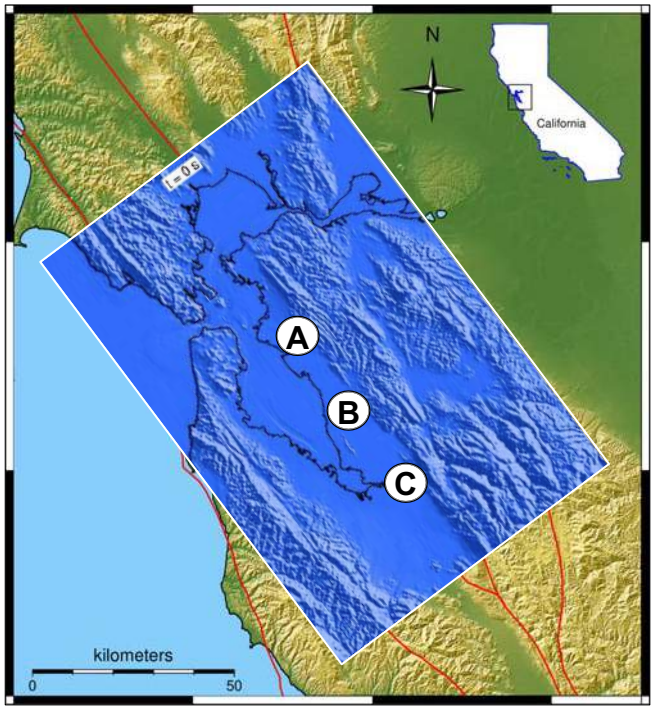




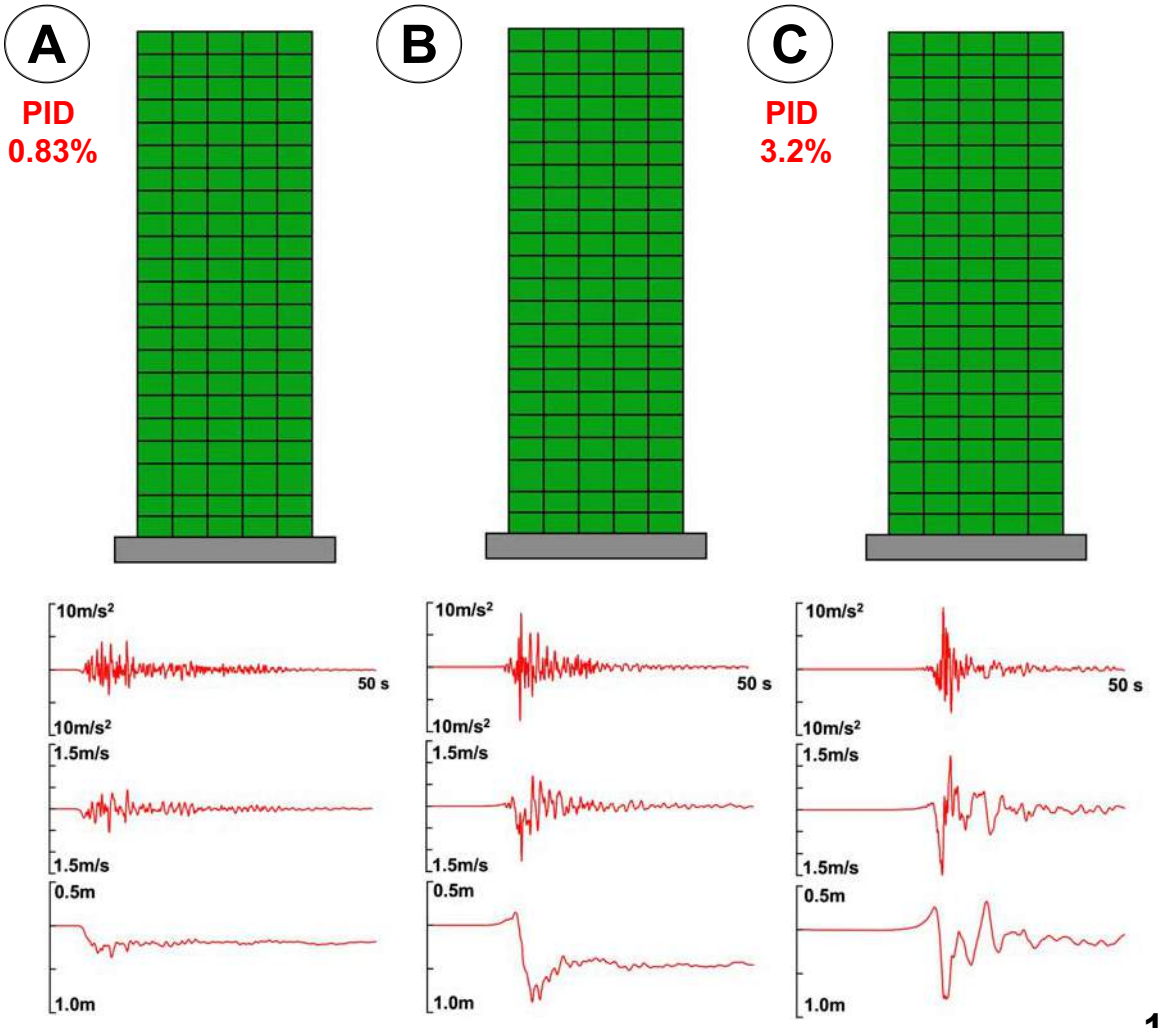


There is *LOTs* to explore - intra-event variability example showing site-specific building response

Magnitude 7
Hayward fault
northern hypocenter

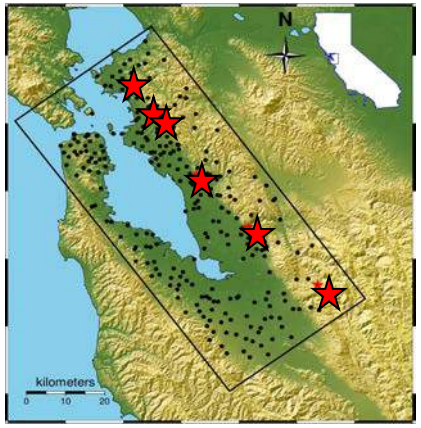


20 story streel frame Nevada fiber model
(fault-normal motions)

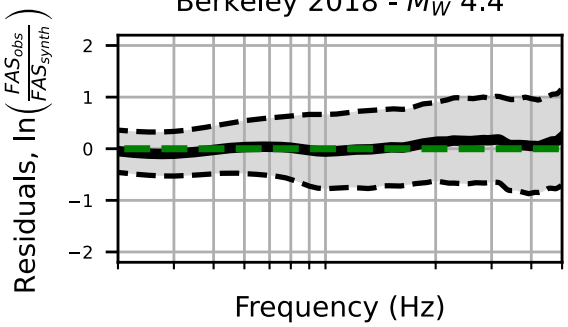


We are working on the acceptance of simulated motions for the 20 Hayward fault realizations

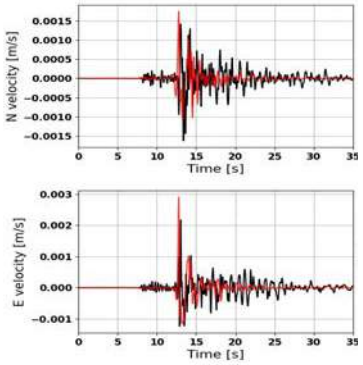
1) Stress testing the EQSIM model – 7 small Hayward fault event simulations



Spectral comparisons

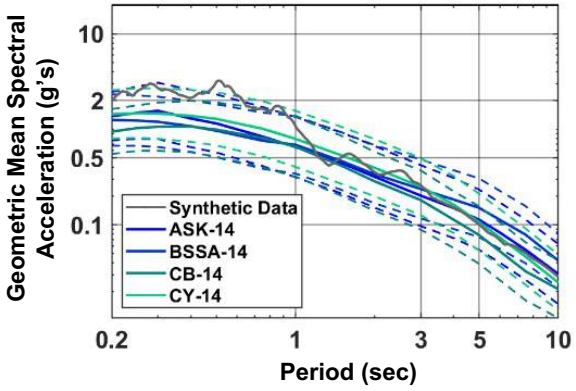


Comparison to measured ground motion waveforms

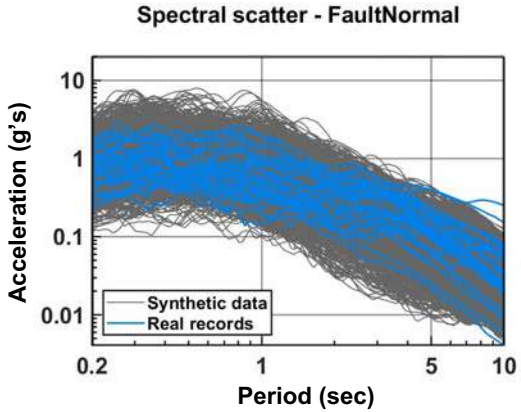


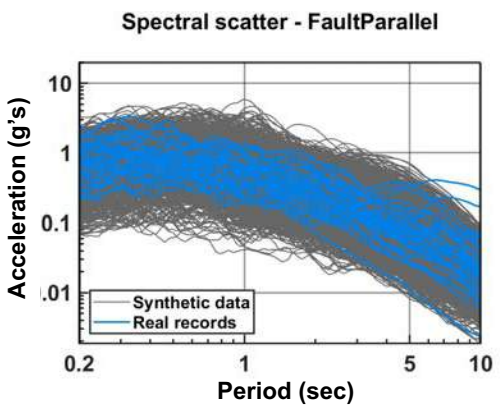
2) Evaluating the large events - 20 M7 Hayward fault realizations

Comparison to existing empirical GMP equations

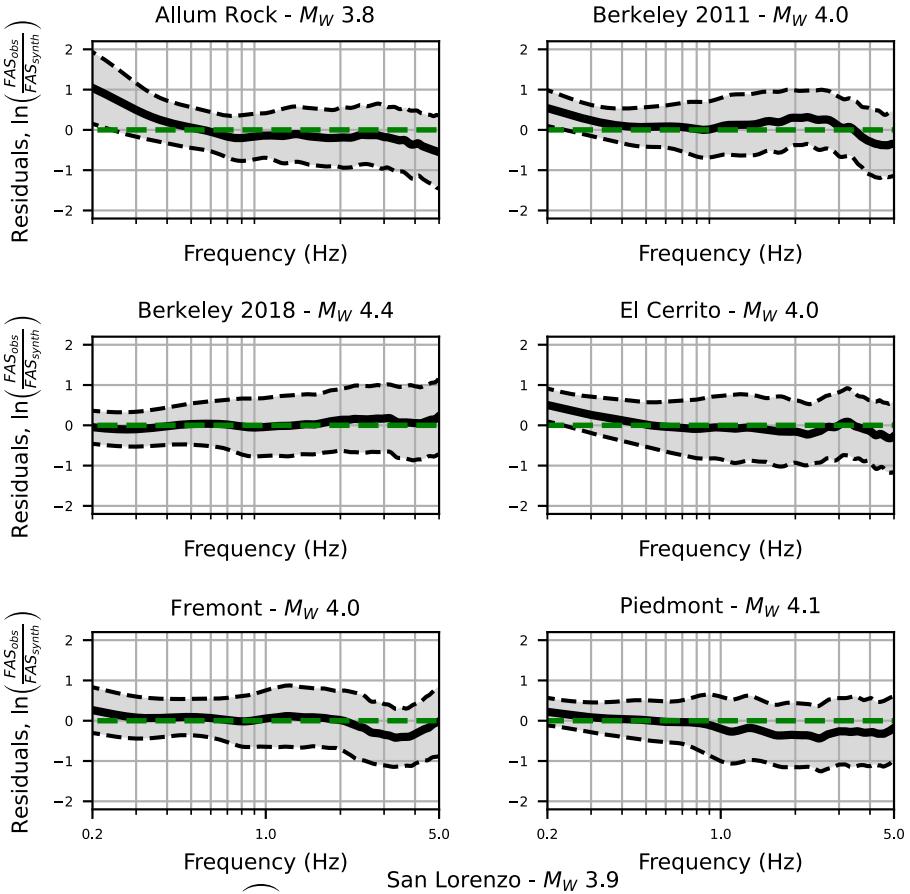


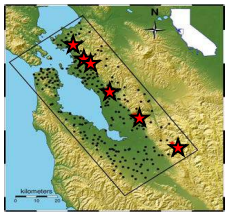
Comparison to existing commensurate ground motion data (near-fault sites < 10 km)

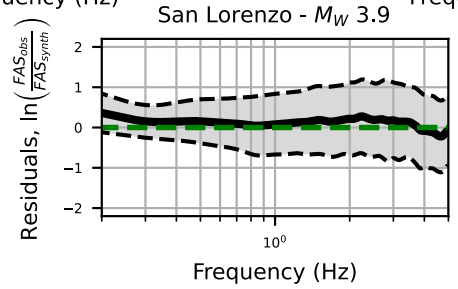


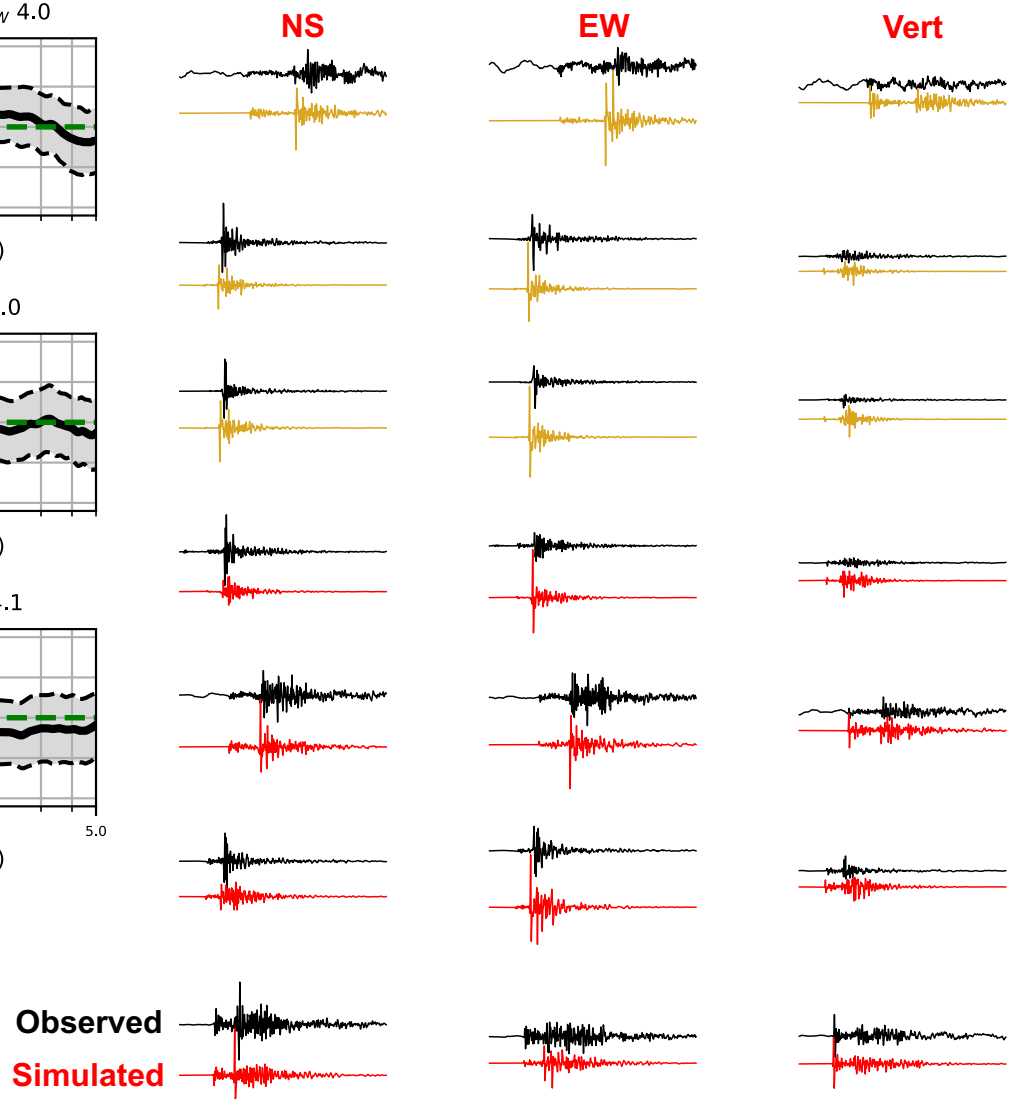


Simulation / data comparison based on the seven small Hayward fault events (0-5Hz)







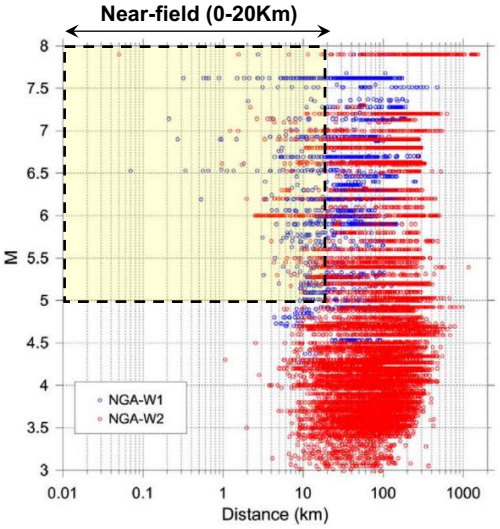


Ground velocity waveforms

We are striving to make the simulated ground motion database "familiar" to PEER users

Existing - Spatially sparse measured motions

Sparse ground motions from everywhere



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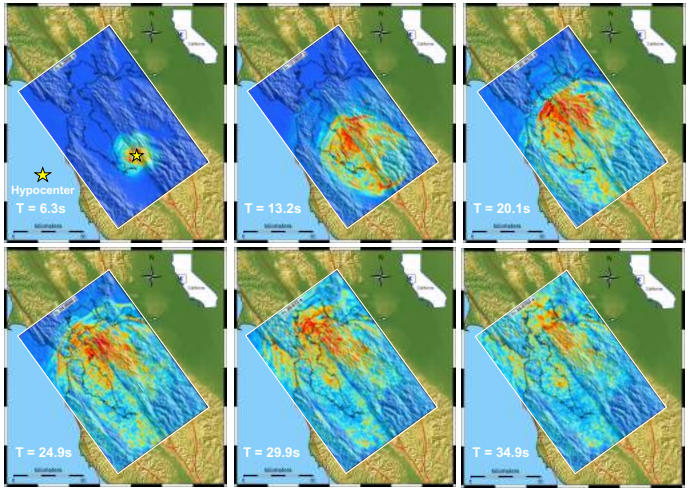
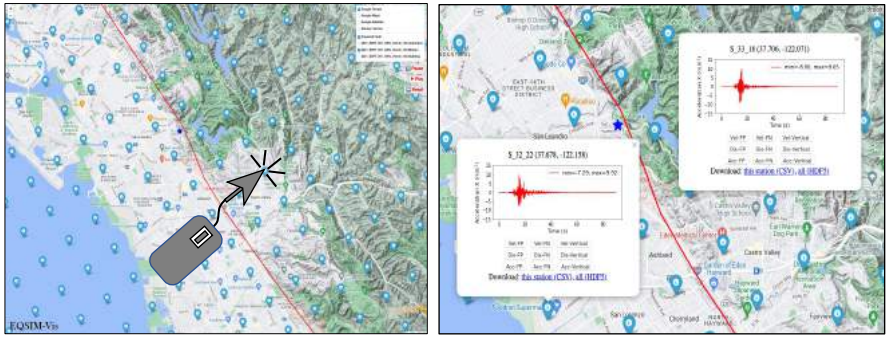
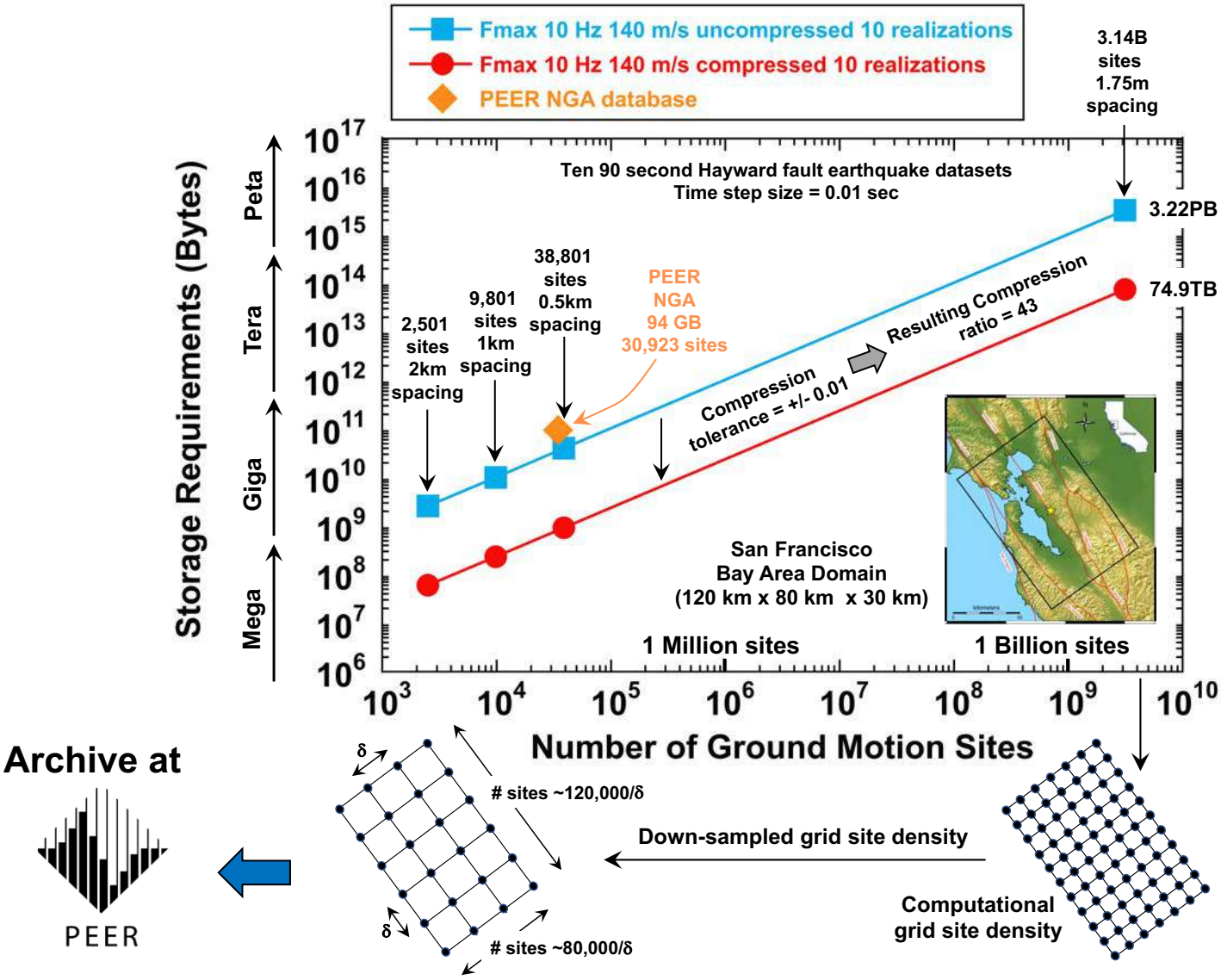
New - Spatially dense simulated motions for the San Francisco Bay Area



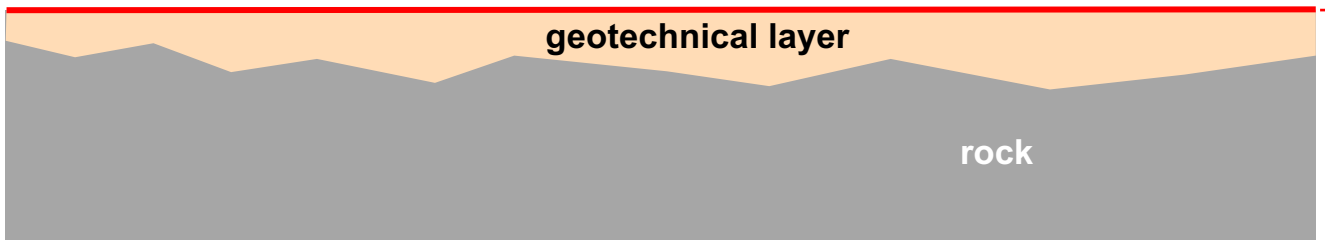
High-fidelity, spatially dense regional ground motions



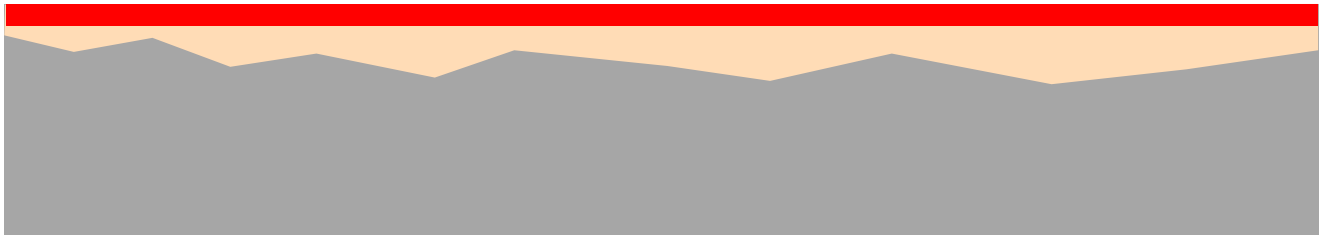
Key decisions - bifurcated (PEER / LBNL) storage and fetching of large data is essential



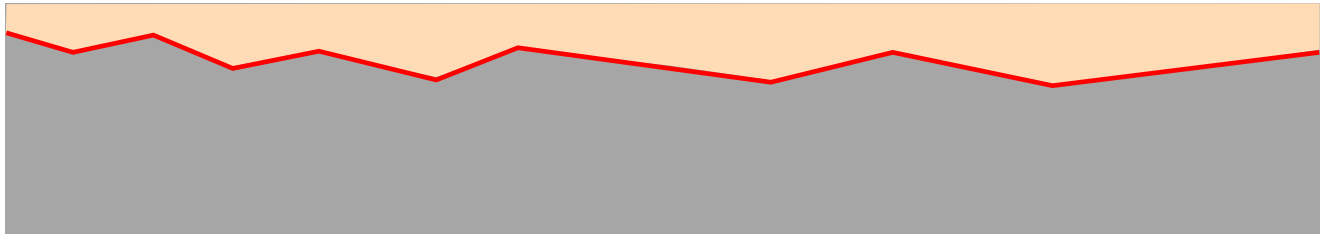
The design of the PEER - LBNL database can ultimately support many use cases



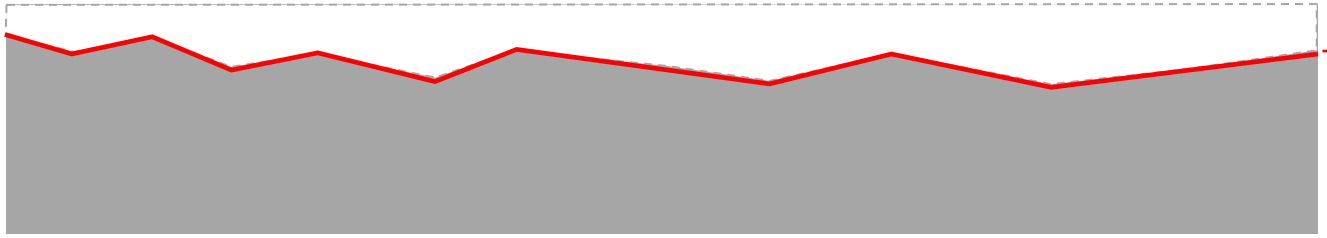
→ Ground surface motions (Fixed base analysis)



→ Near surface volume motions (DRM utilization for SSI and/or nonlinear soil response)



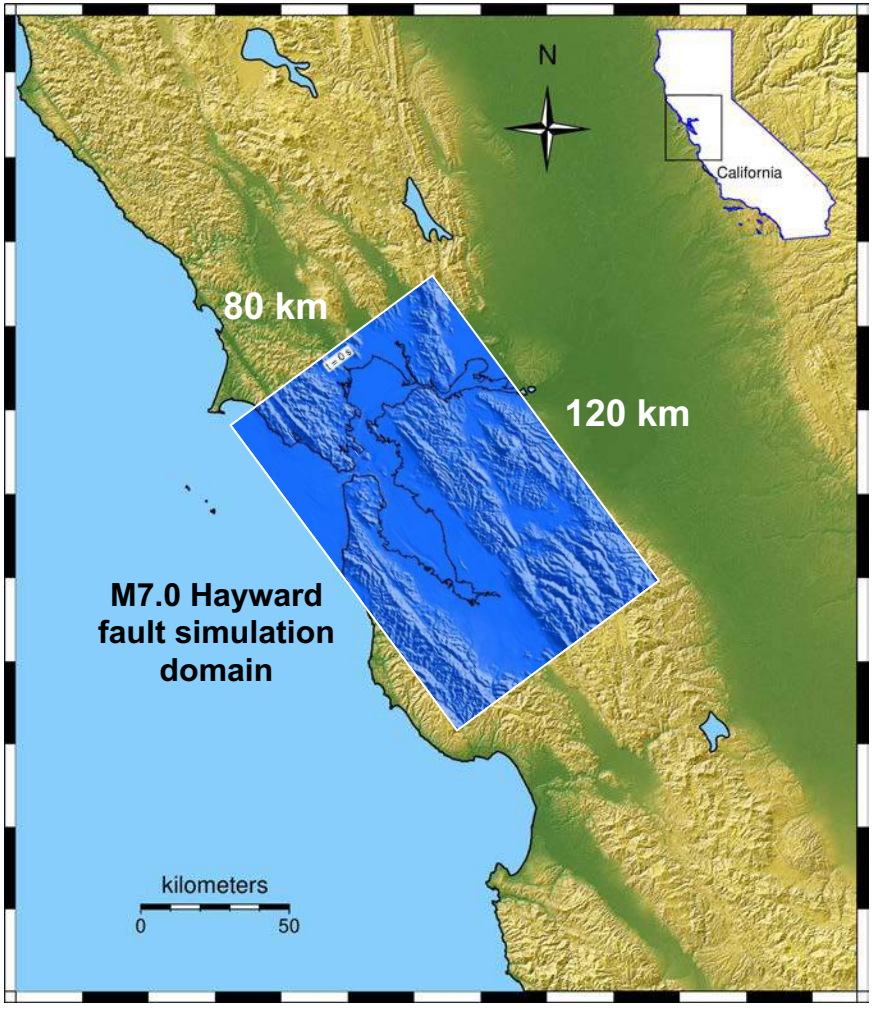
→ In-column motions (1D site response)



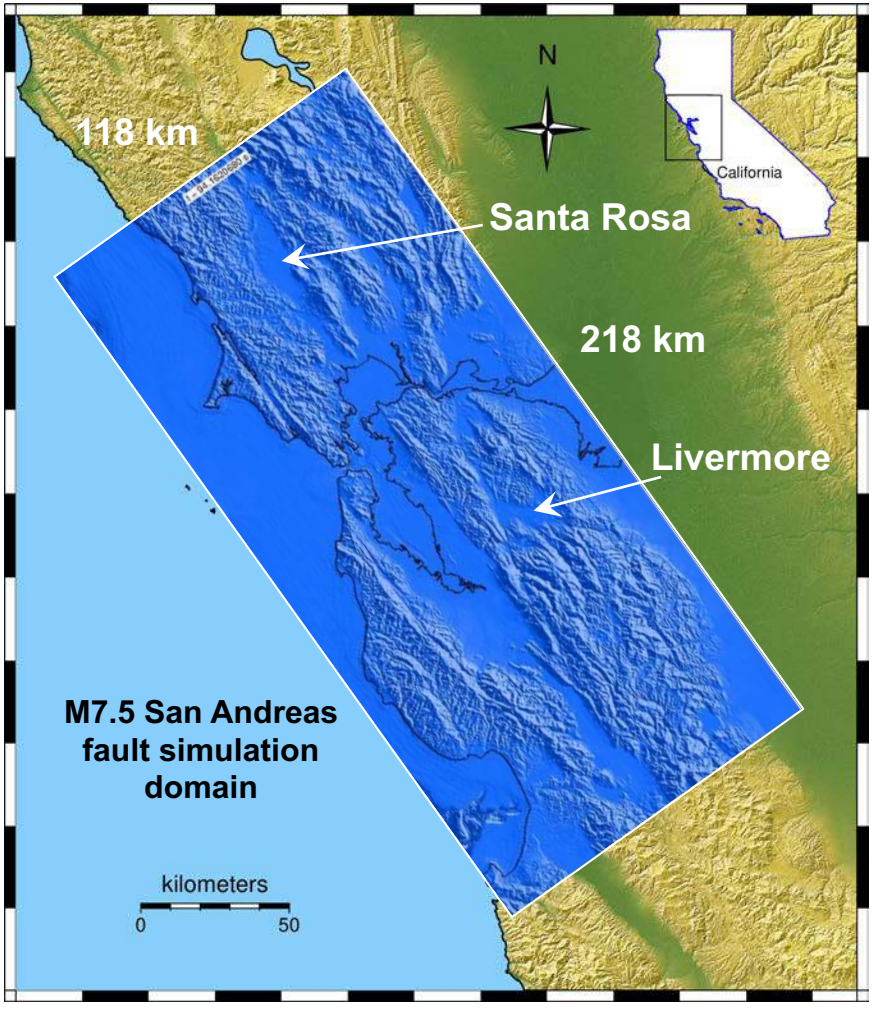
→ Outcrop motions (1D site response)

The database design schema must be scalable to allow many realizations and larger M events

M7 Hayward realizations



M7.5 San Andreas realizations



Looking ahead

- **DOE supported PEER / LBNL simulated ground motion workshop to discuss use cases, data structure and data access (January 2024)**
- **Completion of the assessment of the full suite of simulated SFBA motions (initially 20 events Fmax 5Hz, Vsmin 250m/s)**
- **Build-out the data server at PEER (DOE funding support for hardware and IT staff has just arrived)**
- **Selected set of early users to test system software**