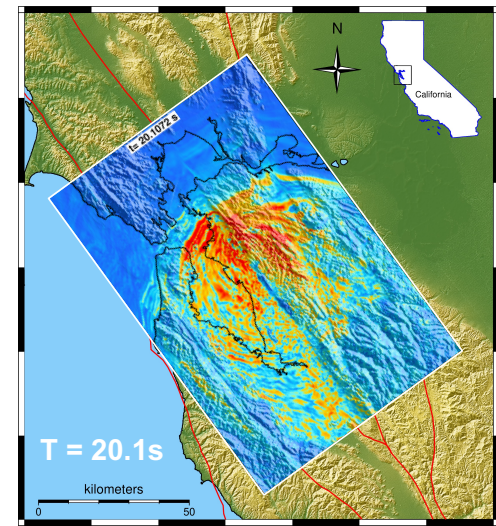
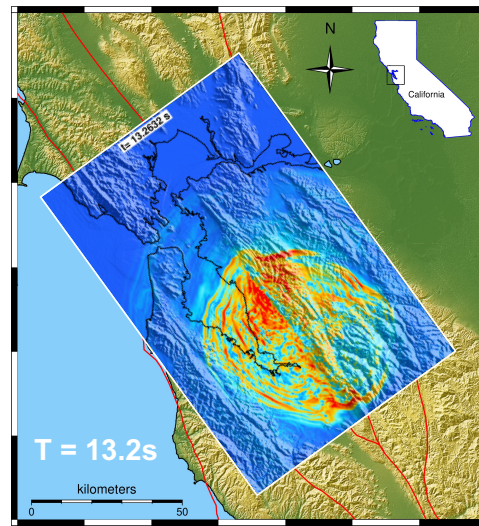
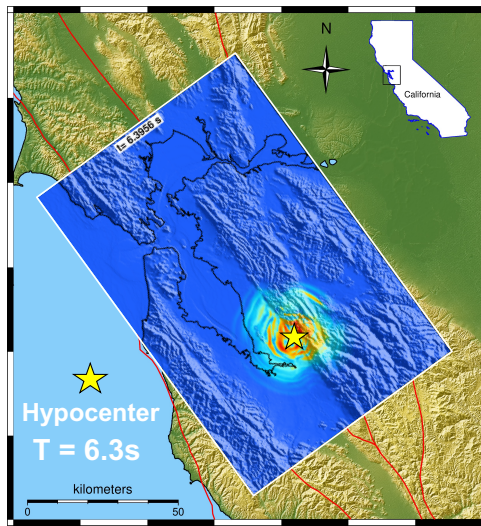




Development of the PEER Simulated Ground-Motion Database (PEER-SGD)

PEER Researchers Workshop
September 2022

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



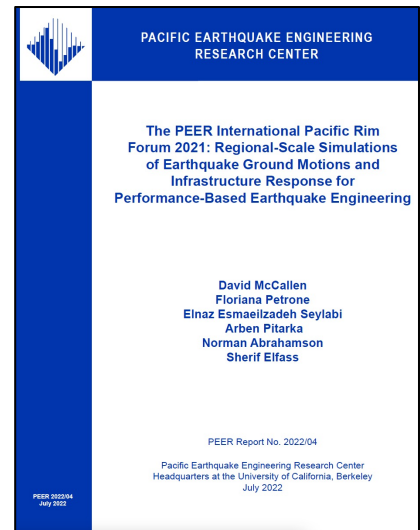
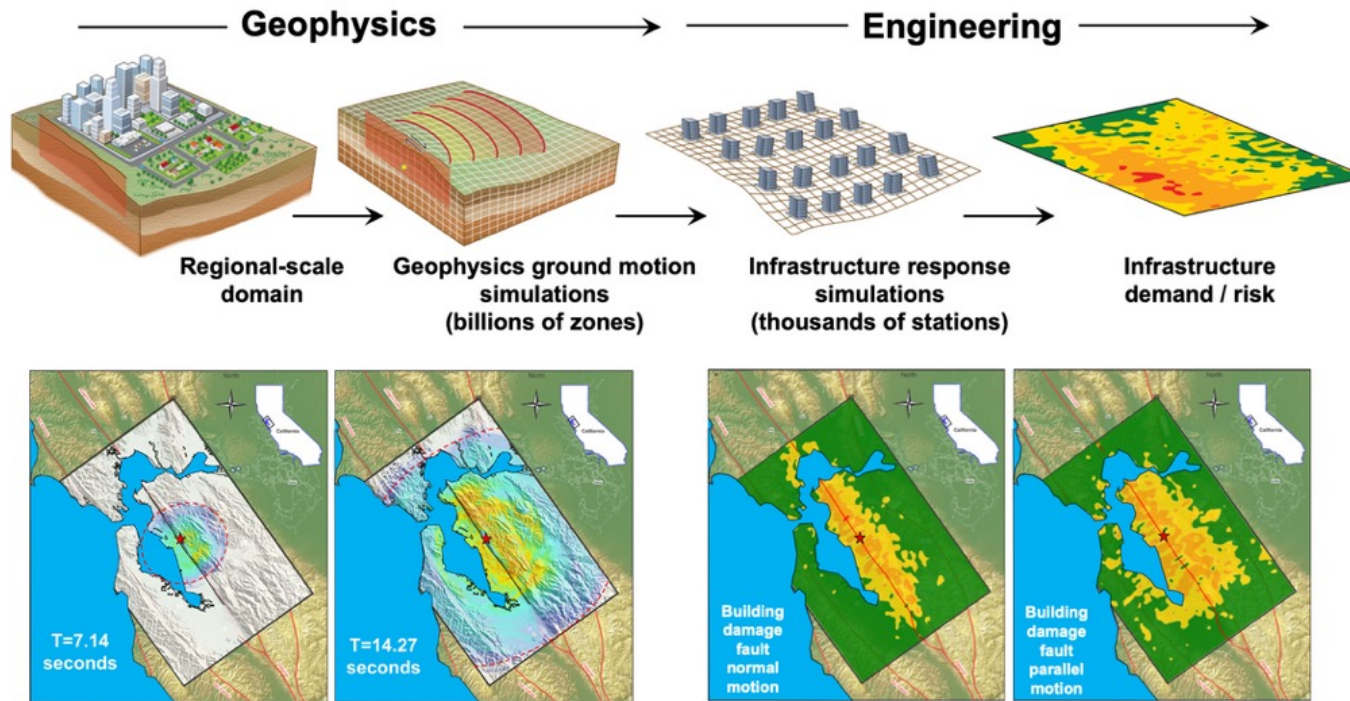
PEER



The PEER June 2021 Pacific Rim Forum on Regional-Scale Earthquake Simulations

PEER International Pacific Rim Forum
June 16-17, 2021

241 participants
41 presenters



★ Identified a priority need to create an open-access database of simulated ground motions for both research and practitioner communities

As a follow-on to the Forum, PEER created a Simulated Ground Motions Database Committee



Pedro Arduino
UW



David McCallen
UNR/LBNL



Morgan Moschetti
USGS



Floriana Petrone (Chair)
UNR/LBNL



Arben Pitarka
LLNL



Ertugrul Taciroglu
UCLA

SMGD Committee's long-view mission flowing out of the Pacific Rim Forum discussions

Objectives

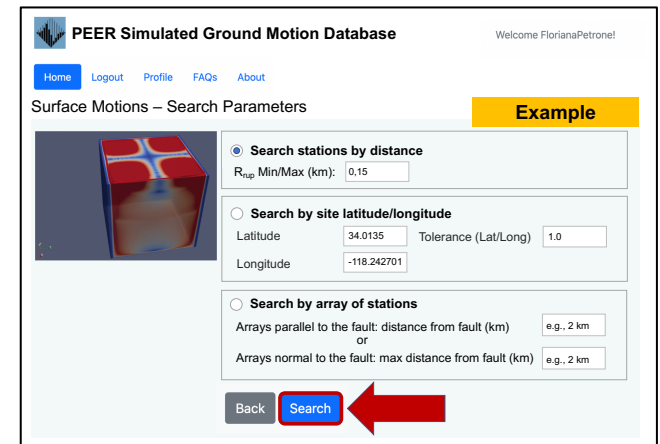
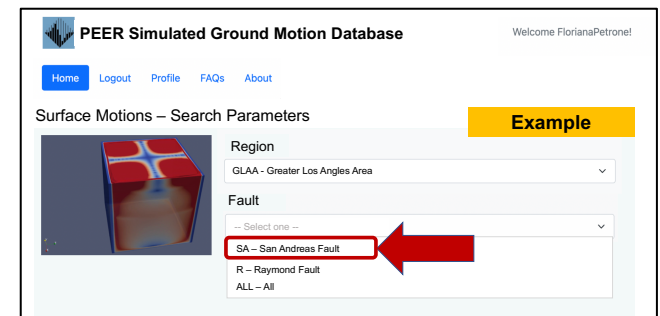
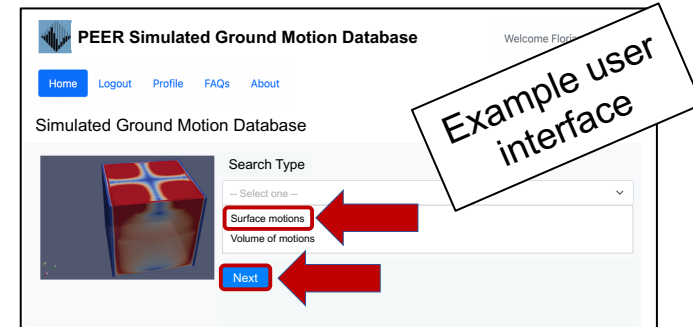
Metadata
User interface
etc.

DEFINE the path forward for the progressive inclusion of simulated ground motions in a PEER database

DEVELOP a plan for the characterization of uncertainties

IDENTIFY compelling use cases to evaluate utility and early success of simulated ground motions use

PROVIDE guidance on the appropriate use of simulated ground motions in PBEE

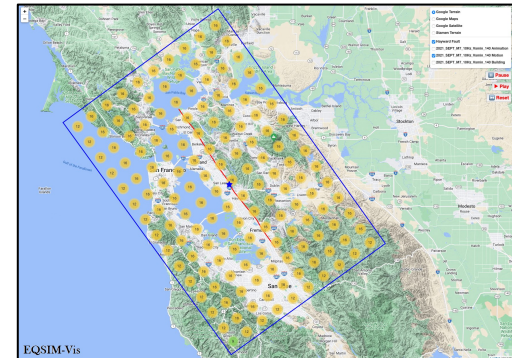
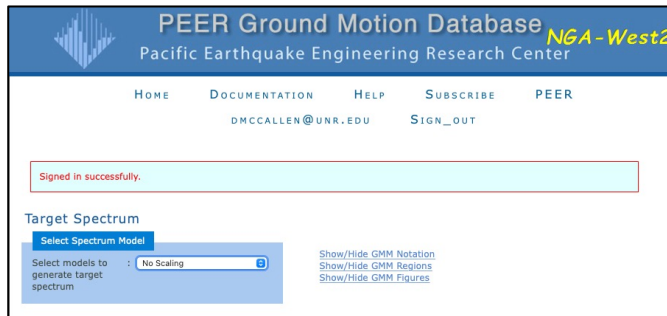


Two concurrent projects on regional-scale earthquake simulations are underway

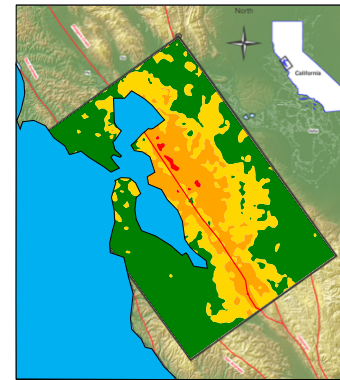
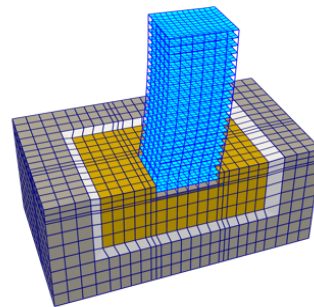
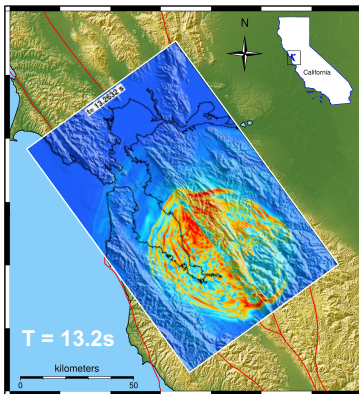
PEER SGD - A framework for efficient data storage and fetching for Performance Based Earthquake Engineering (PBEE) applications

Old - Spatially sparse measured motions

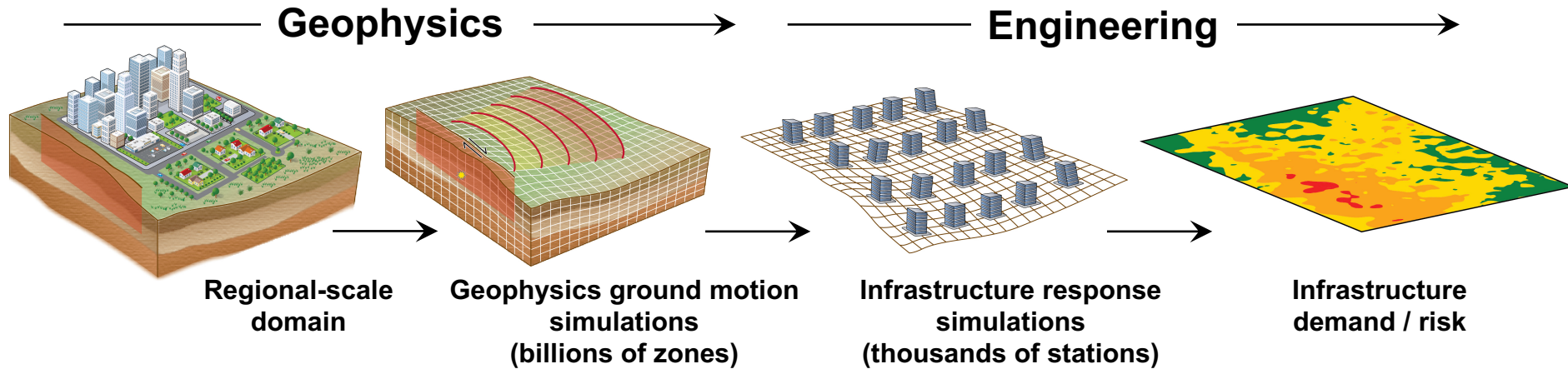
New - Spatially dense simulated motions



EQSIM - Advanced workflow and GPU-based platforms for regional-scale simulations of ground motions, infrastructure response and data display

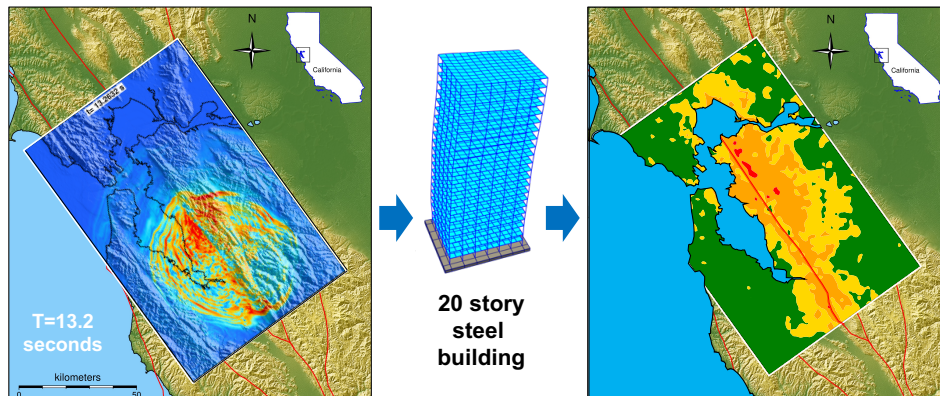


The EarthQuake SIMulation (EQSIM) application was purpose-built for exaflop systems

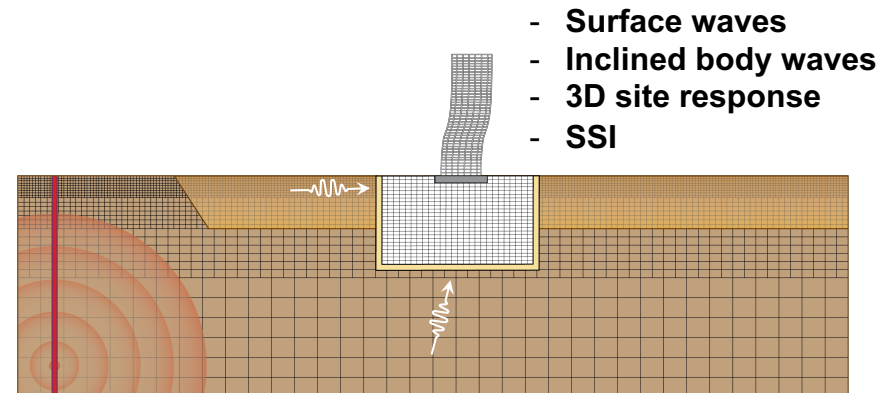


Key questions to be addressed...

What is the regional distribution of ground motions and associated infrastructure response?

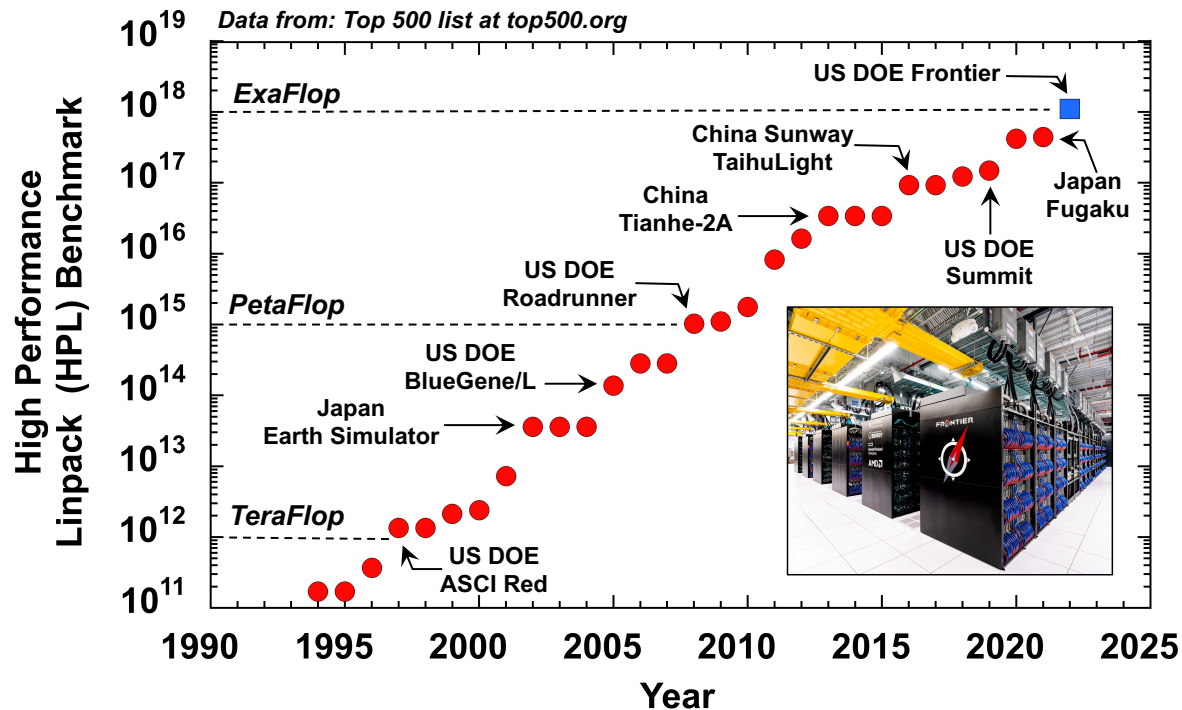


How do complex (realistic) incident seismic waves interact with infrastructure?



DOE's new exaflop platforms are here!

Frontier is in final stages of acceptance testing



Perlmutter, GPU-accelerated
71 Pflop/s Top500 #7
Lawrence Berkeley National Lab



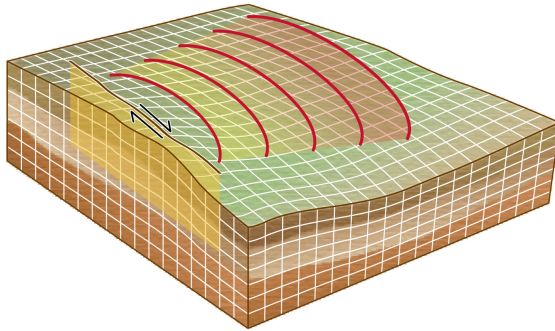
Summit, GPU-accelerated
148 Pflop/s Top500 #4
Oak Ridge National Lab



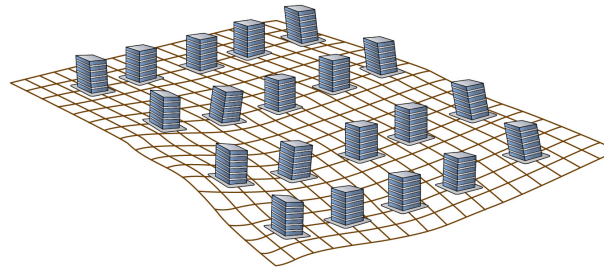
Frontier, 2022, GPU-accelerated
1,102 Pflop/s Top500 #1
Oak Ridge National Lab

Three distinct components of workflow have been advanced for fault-to-structure simulations

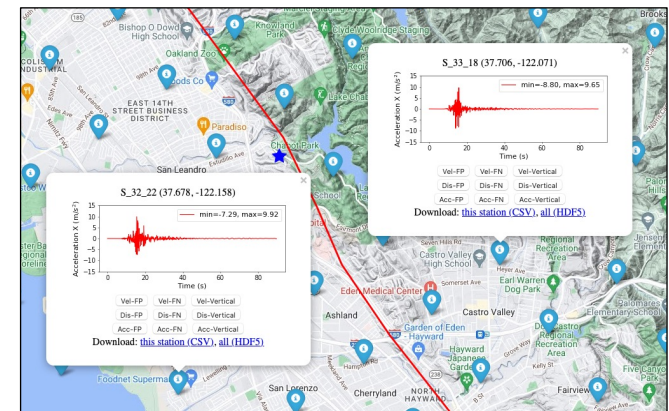
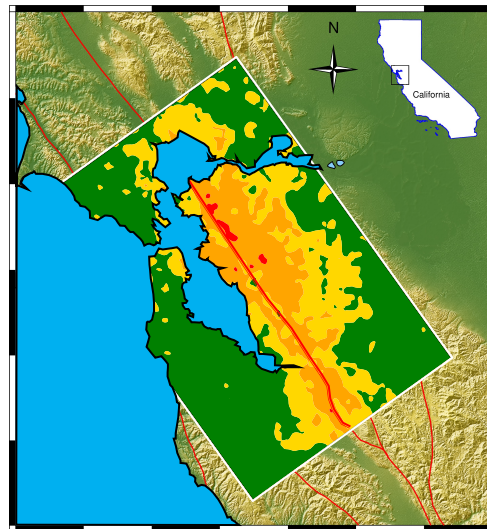
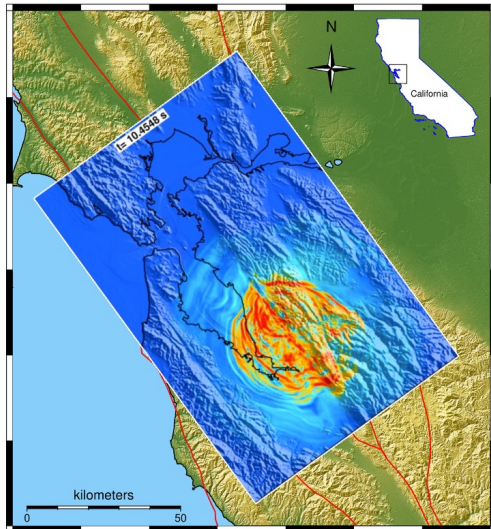
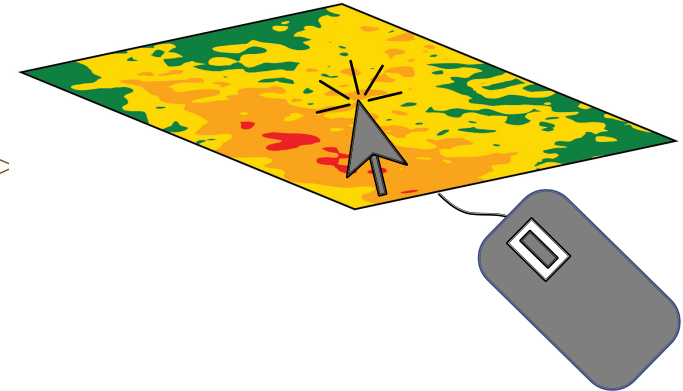
Component 1
Regional simulation of
ground motion



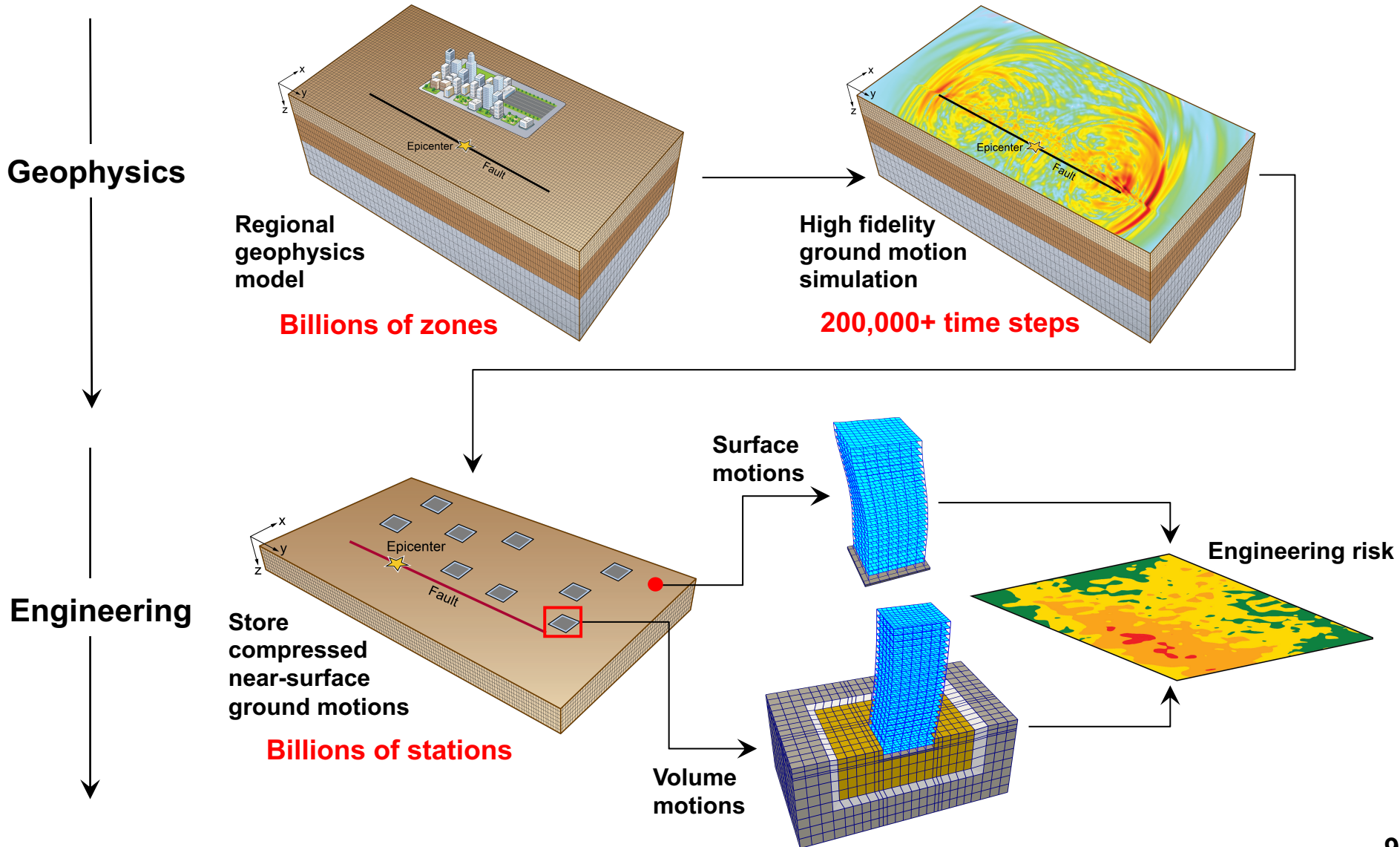
Component 2
Regional simulation of
infrastructure response



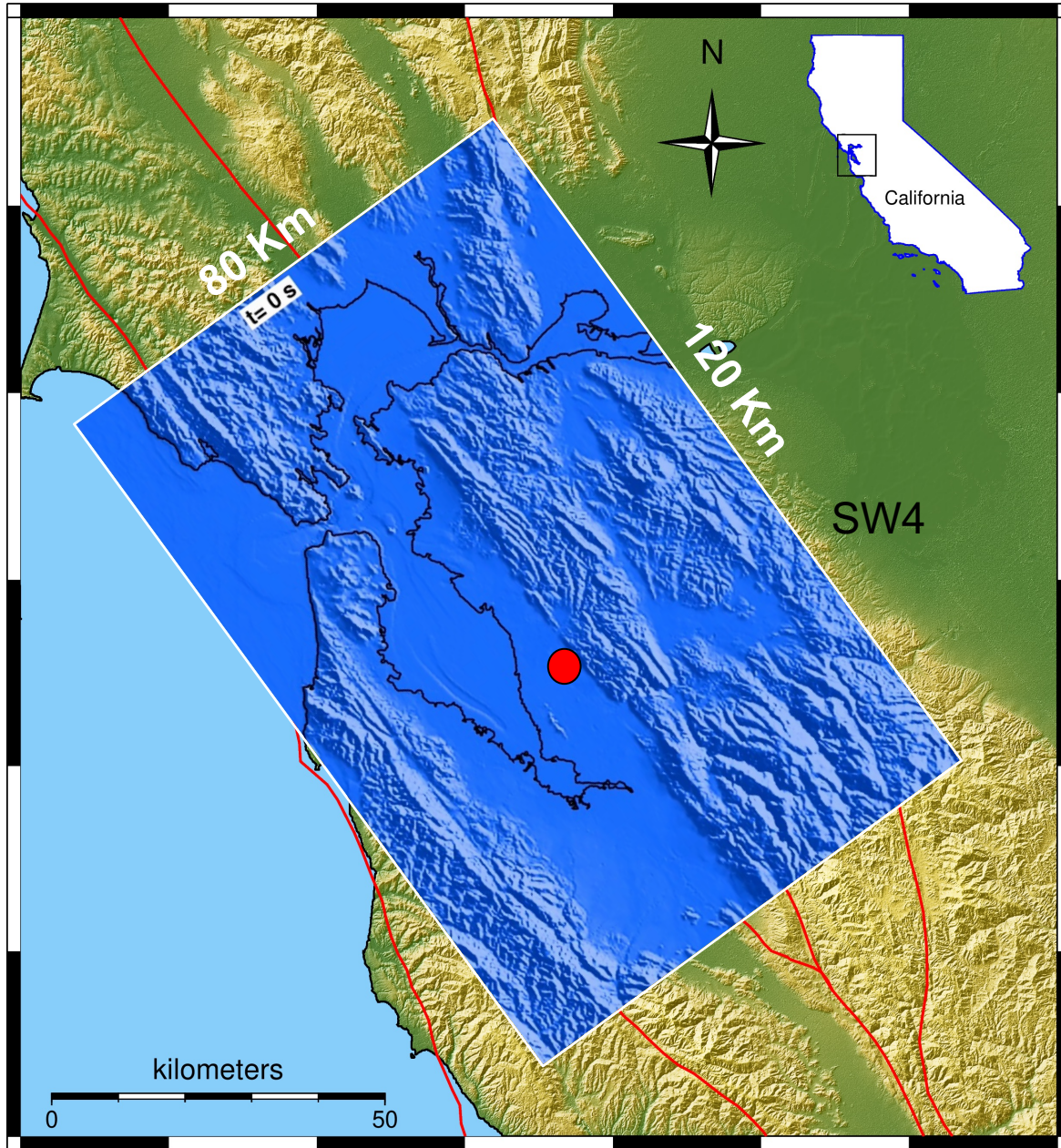
Component 3
Interactive display and
interrogation of large
datasets



The EQSIM workflow stitches these together for regional-scale, fault-to-structure simulations

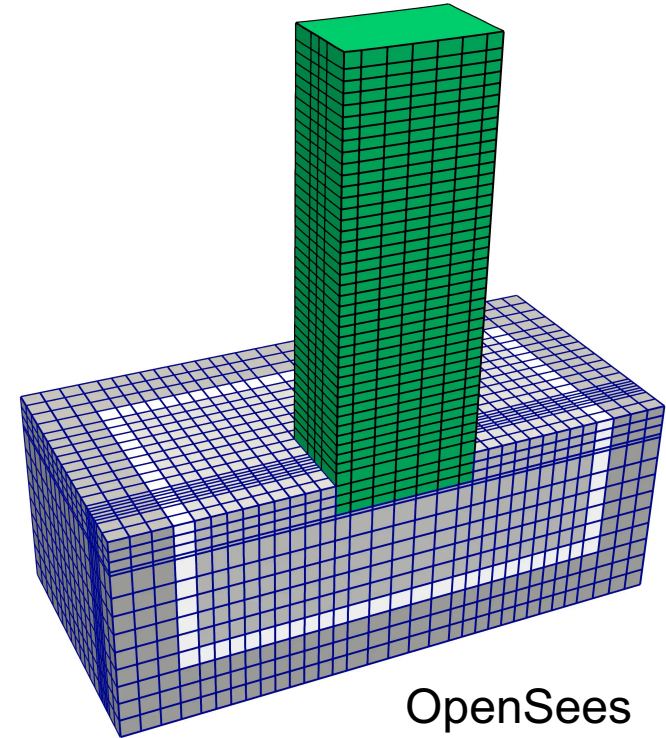


Regional Geophysics Model **Fmax 10 Hz Vsmín 140 m/s**
(M7 Hayward fault earthquake) **391 Billion grid points**

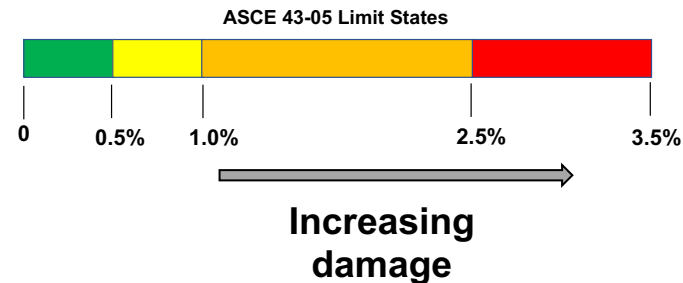


Local Soil / Building Model

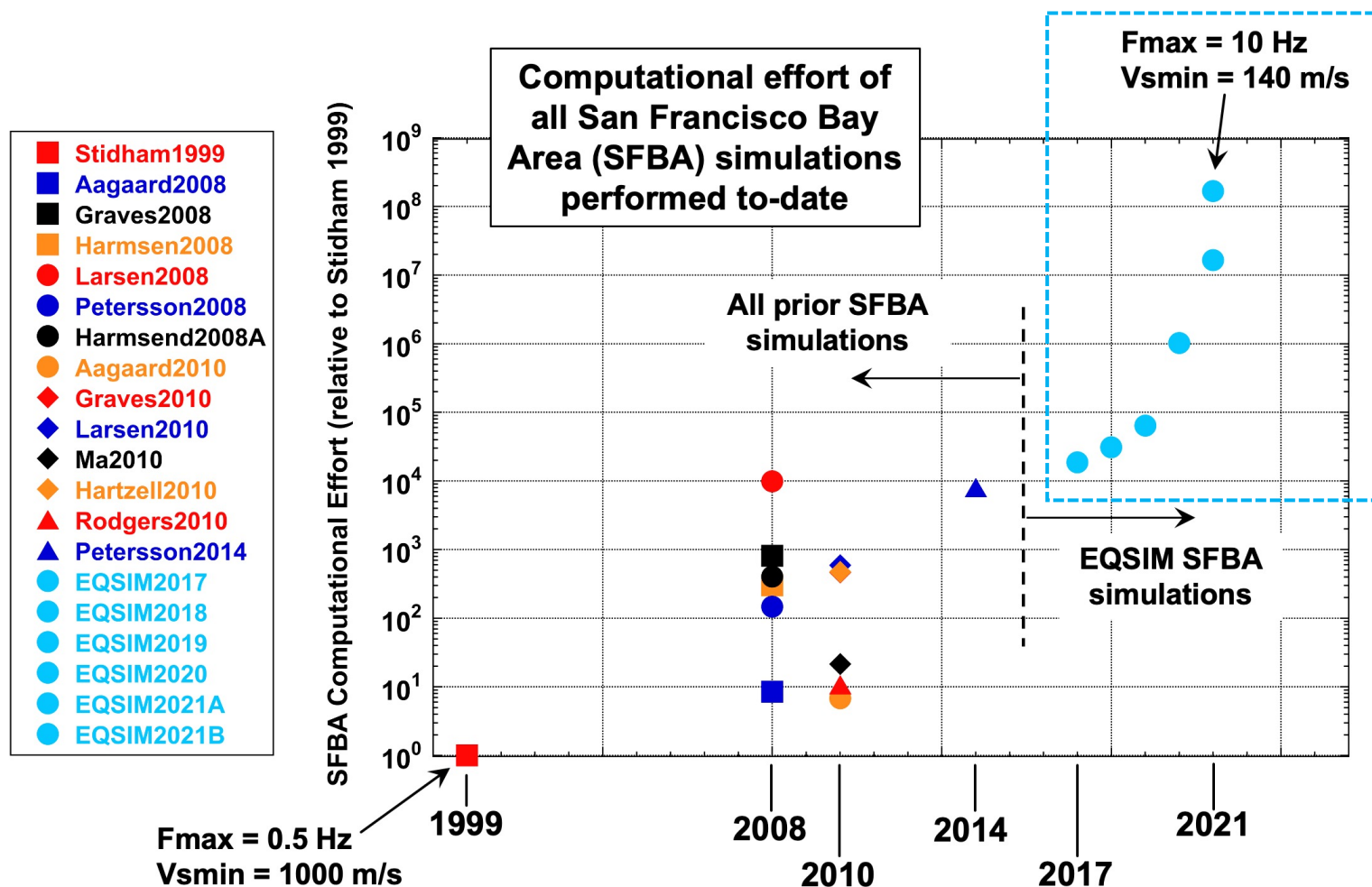
- Soil-structure interaction
- Complex 3D waves



 **Building location**



GPU-accelerator platforms have expanded the higher fidelity regional simulations

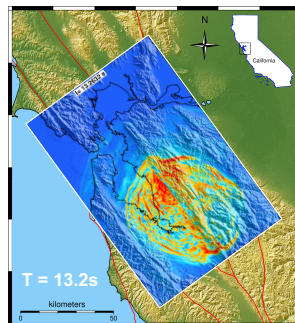


Computational Effort $\propto$ (Model Volume) x (Earthquake Duration) x (Freqmax / Vsmin)⁴

GPU-accelerator platforms provide faster turn-round for multiple regional simulations



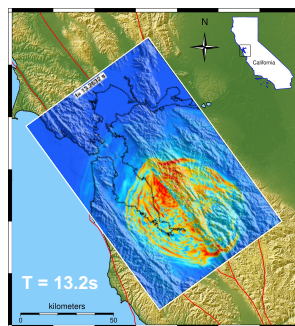
1536 nodes
4 GPU / node



One realization
Fmax = 5Hz
V_{min} = 250m/s
29.6 billion grid points
Wall clock time = 9 hrs



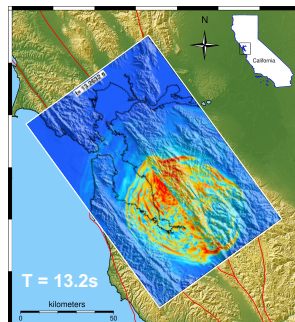
4608 nodes
6 GPU / node



One realization
Fmax = 10Hz
V_{min} = 140m/s
391 billion grid points
Wall clock time = 42 hrs



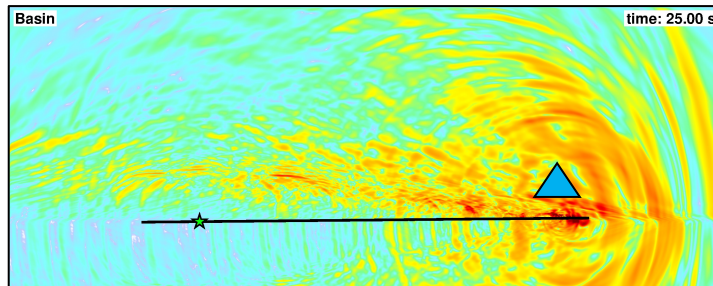
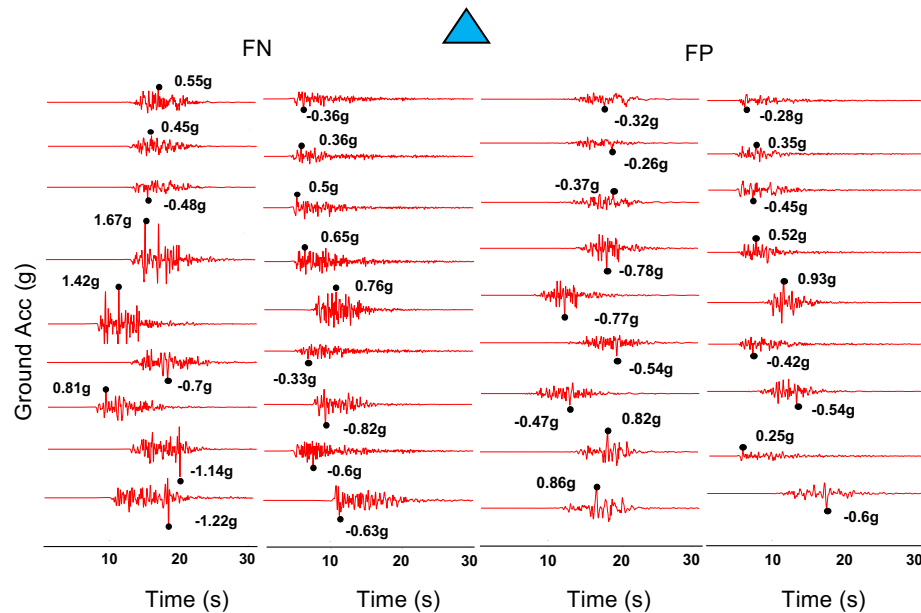
9000 nodes
8 GPU / node



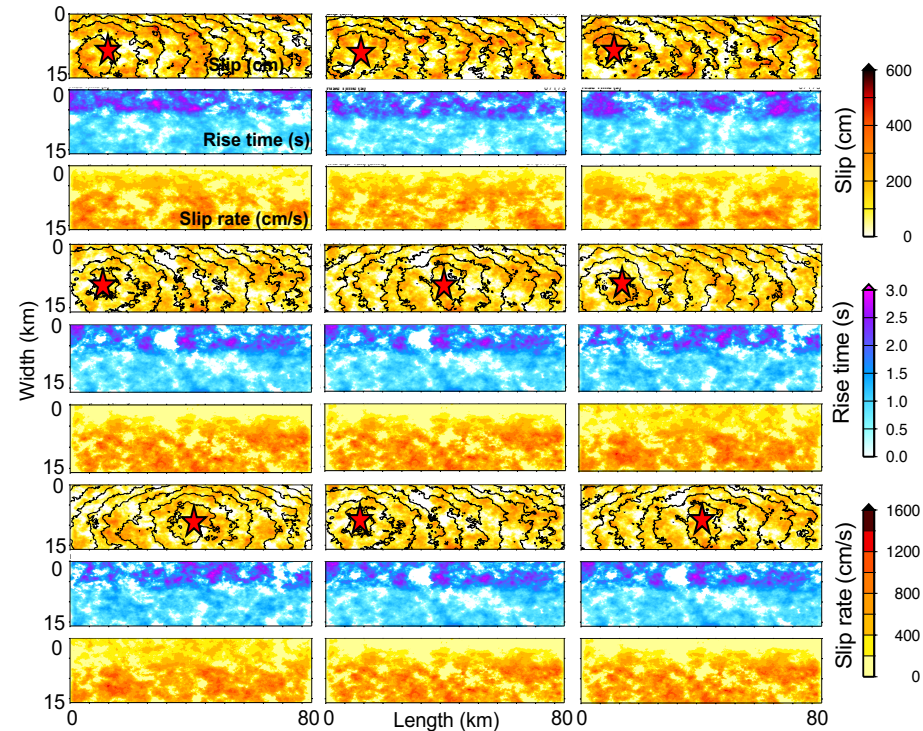
One realization
Fmax = 10Hz
V_{min} = 140m/s
391 billion grid points
Wall clock time = TBD

For the PEER SGD, we will use GPU platforms for 10 realizations of a M7 Hayward fault event

We observe substantial inter - event variability

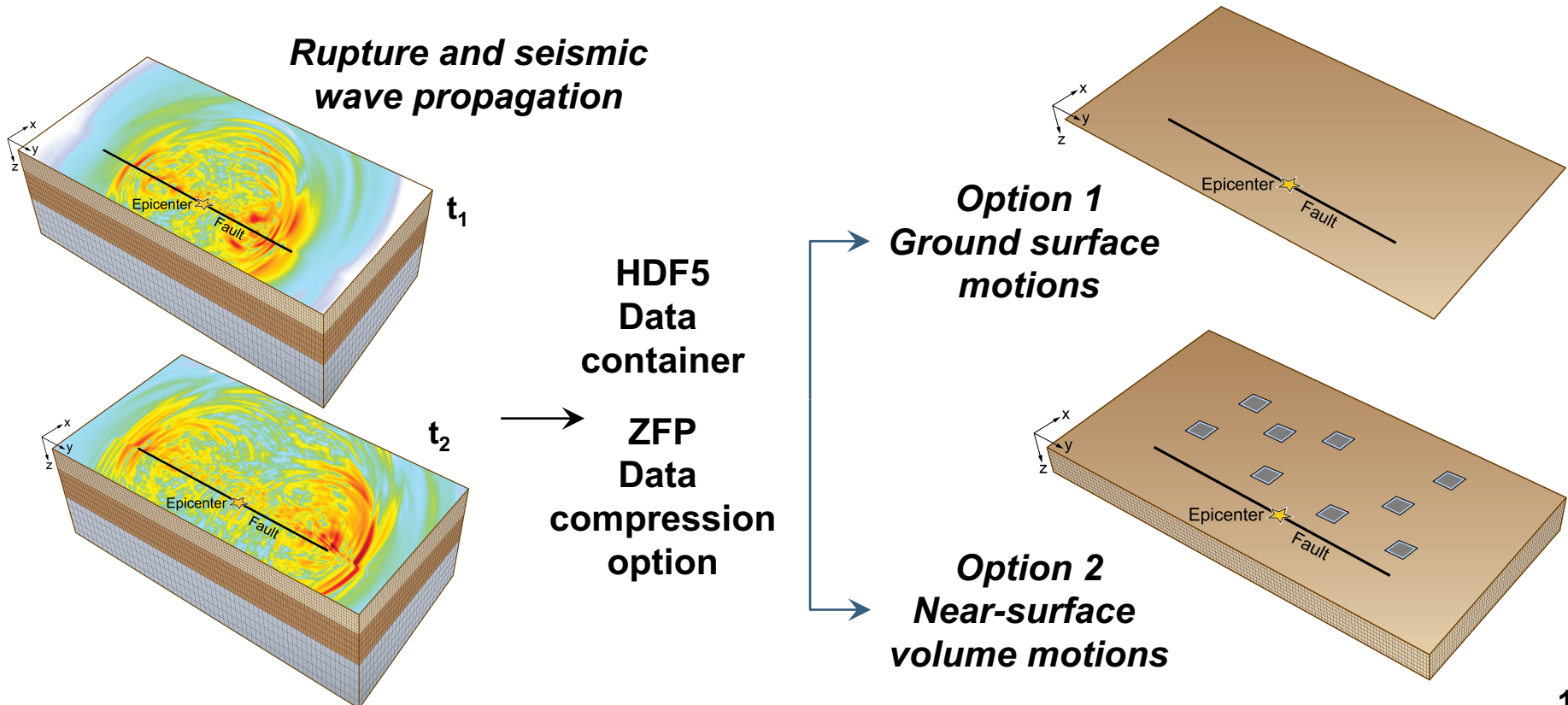


Ten Hayward fault M7 realizations
(Graves-Pitarka rupture model)
Initially 5Hz 250m/s

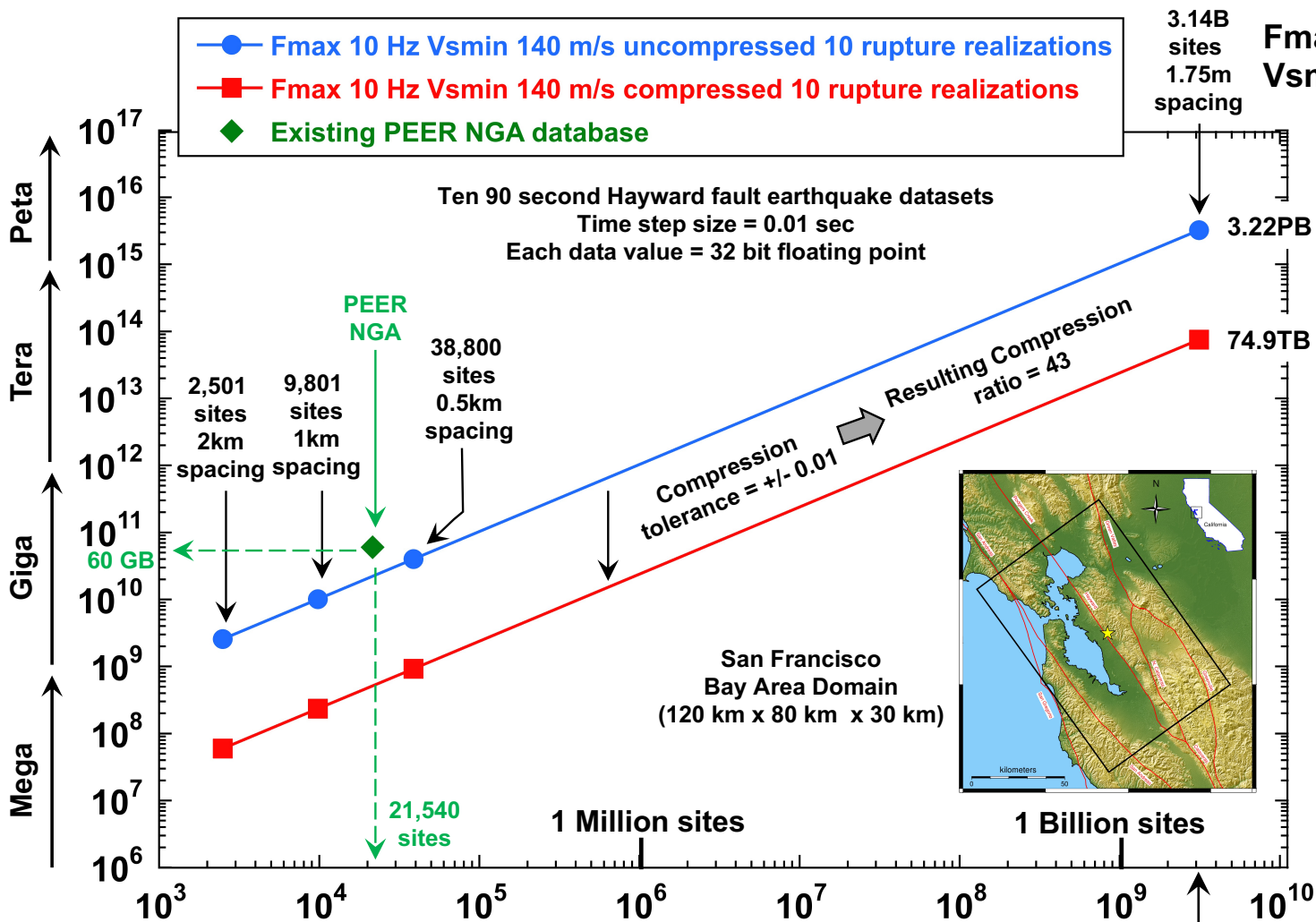


This dataset will help frame the elements of simulated ground motion data management

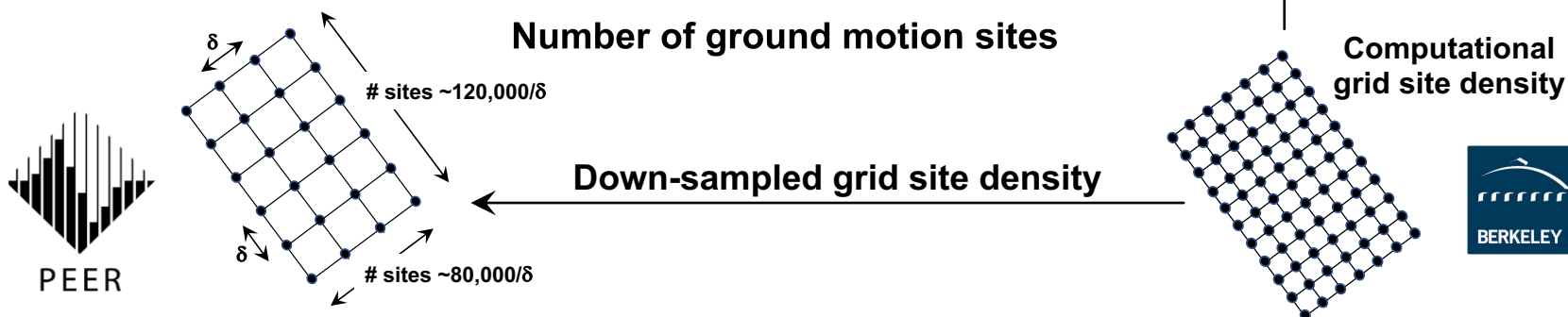
- Spatially dense grid of ground motions from high fidelity simulations
- Need to include multiple rupture realizations for a given earthquake scenario
- Users must have a down-sampling capability from a baseline dataset
- Database design should proceed with **future scalability** in mind



Storage requirements (Bytes)

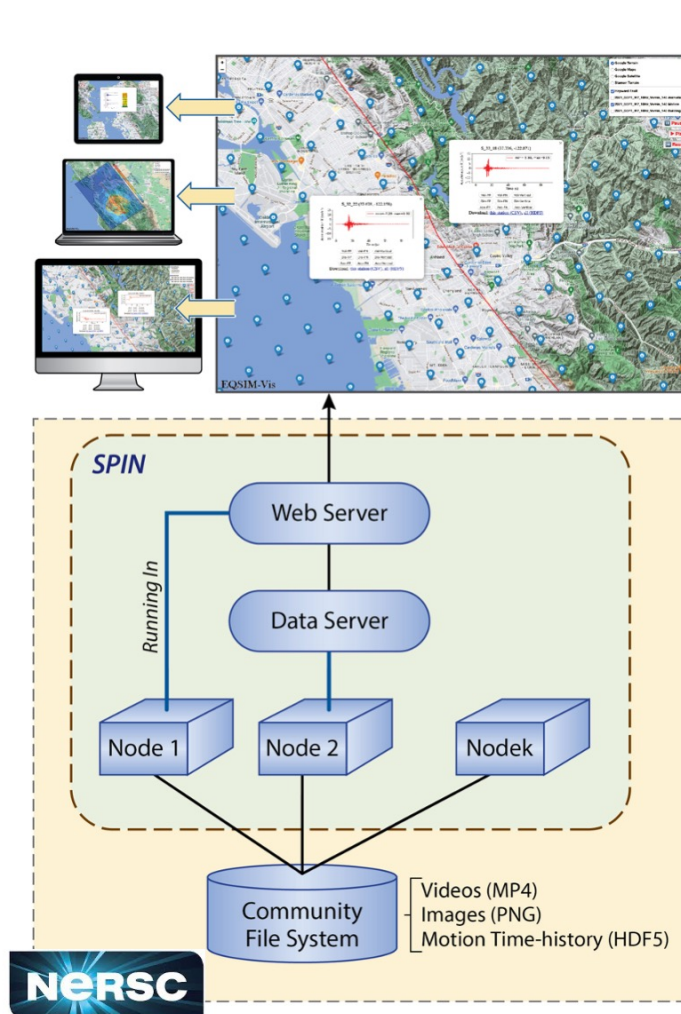


Surface Motions



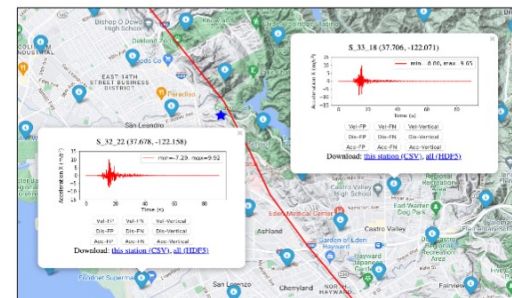
An LBNL interactive tool has been developed for data display and user download of data

Efficient handling of big data – 3.1347 billion surface sites



Data at 2Km spacing (2,300 surface sites)
x, y, z - disp., vel., acc. = 20,700 time series

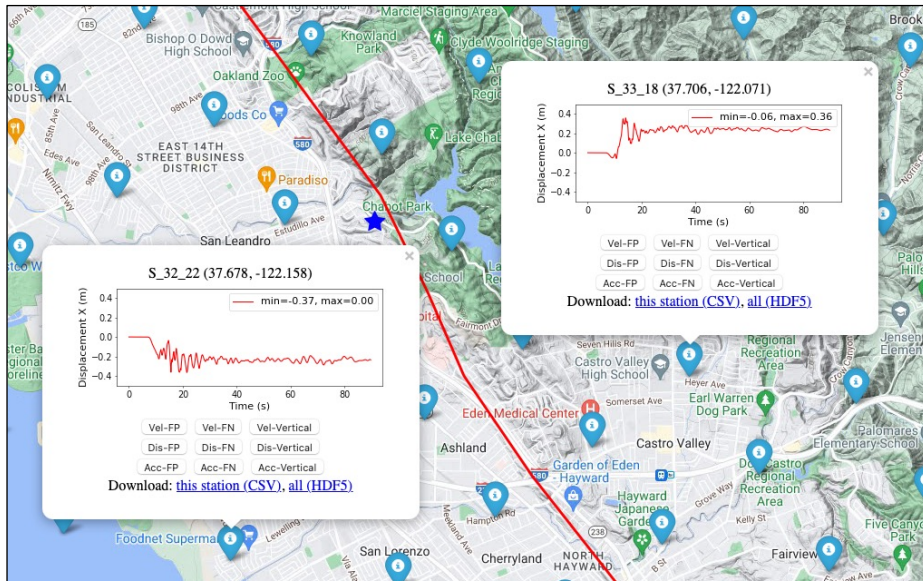
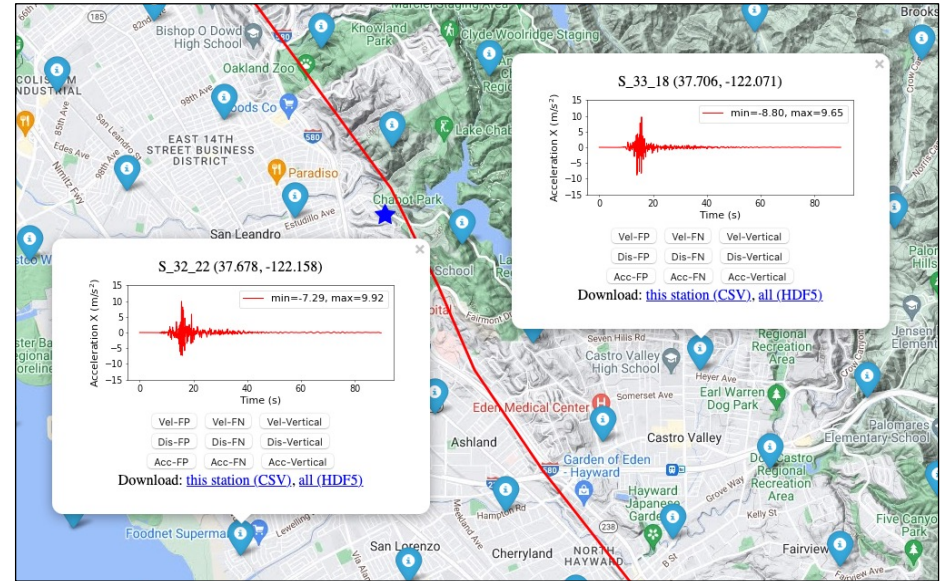
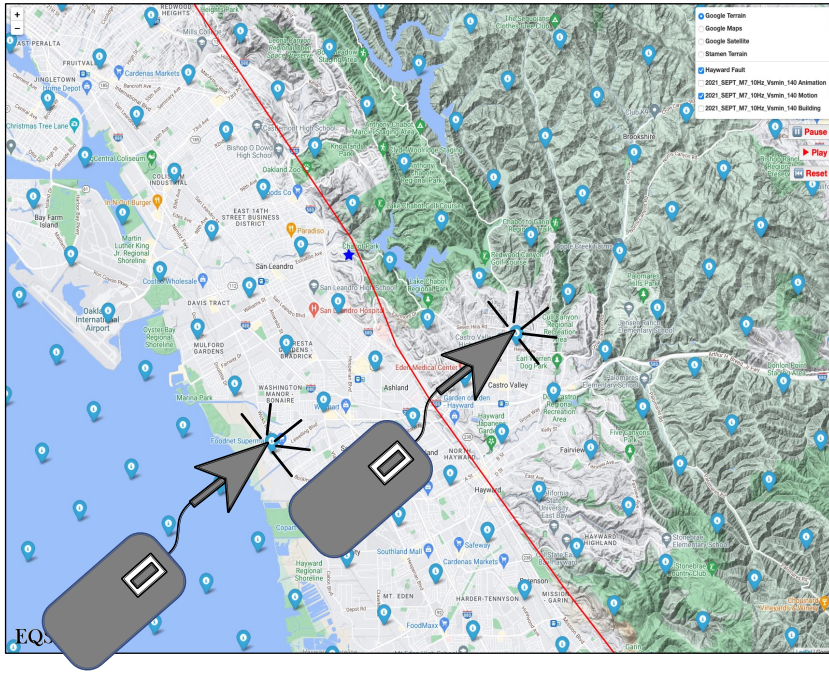
20,700 pre-created time series images (326 Mb)



Option 1 - Click for specific station data

Option 2 - Click for all surface data
in an HDF5 data container (1.3 GB)

Click to select sites, motion components and GMPE comparison



We are leveraging the expertise and work of many critical EQSIM contributors

Engineering Mechanics

**David
McCallen**



**Floriana
Petrone**



Applied Math / Numerical Methods

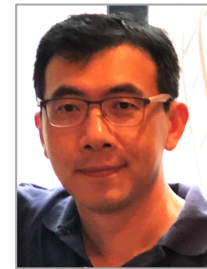
**Anders
Petersson**



**Bjorn
Sjogreen**

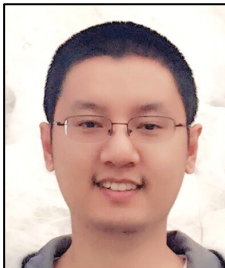


**Wei
Liu**



Computer Science

**Houjun
Tang**



**Ramesh
Pankajakshan**



Seismology / Geophysics

**Arben
Pitarka**



**Arthur
Rodgers**



**Rie
Nakata**

