SCEC Statewide California Earthquake Center

U.S. National Science Foundation · USGS science for a changing world · NASA · FEMA · Cal OES Governor's Office of Emergency Services · PG&E · USC

SCEC's Earthquake Rupture and Ground Motion Forecasting Capabilities

Xiaofeng Meng (SCEC)

OpenSHA/UCERF3-ETAS: Ned Field, Kevin Milner, Akash Bhatthal

Quakeworx: Yehuda Ben-Zion, Ahmed Elbanna, Alice-Agnes Gabriel, Fabio Silva, Chunhui Zhao, Evan Marschall

PyCSEP: Fabio Silva

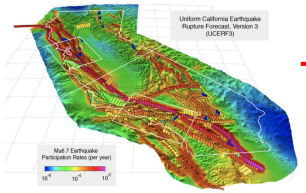
and many more collaborators

September 1, 2026

SCEC Annual Meeting, Palm Springs, California

SCEC Capabilities

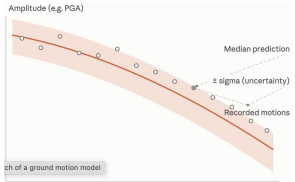
Earthquake Rupture Forecast (ERF)



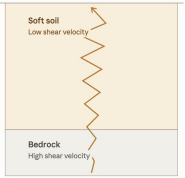
Estimates the probability, location, magnitude of future ruptures

Ground Motion Forecast

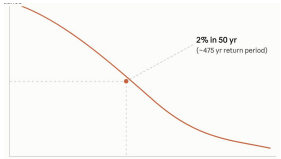
Ground Motion Model



Site response

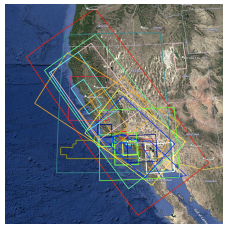


Hazard curve

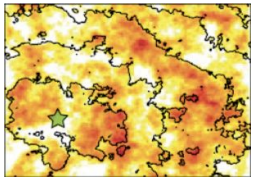


Physics-based Ground Motion Forecast

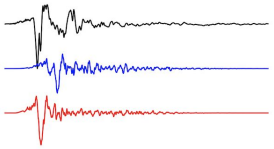
Velocity model



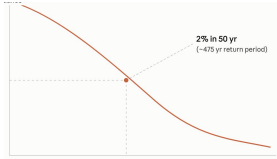
Kinematic/Dynamic rupture



Synthetic seismogram

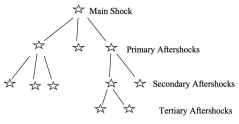


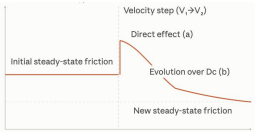
Hazard curve



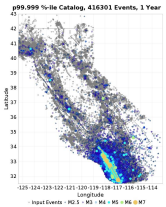
Seismicity / Earthquake Cycle Forecast

Statistical/Physics-based Model

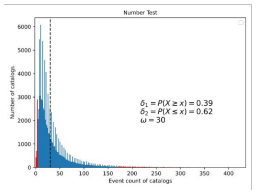




Synthetic catalogs



Statistical evaluation



OpenSHA

- A ***Open***-source platform for ***S***eismic ***H***azard ***A***nalysis
- It implements ERFs and combining them with ground motion models to compute hazard products
- It is used both on local workstations and in large-scale environments (e.g., HPC systems)
- A framework where any arbitrarily complex (e.g., physics based) SHA component can “plug in” for end-to-end SHA calculations

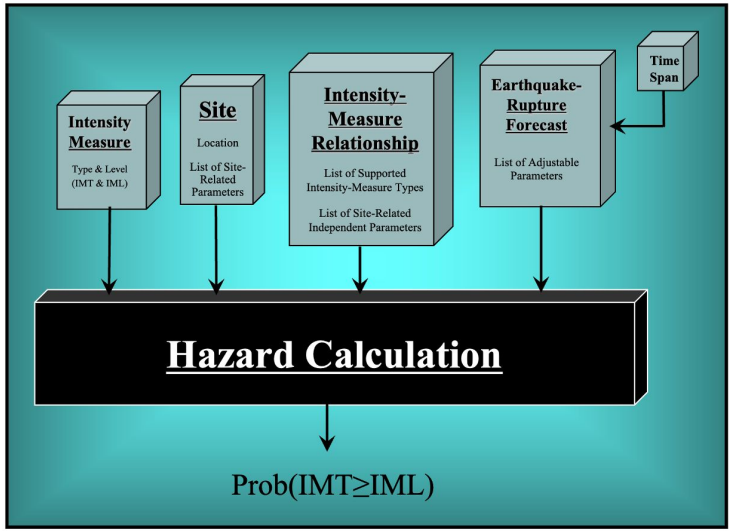
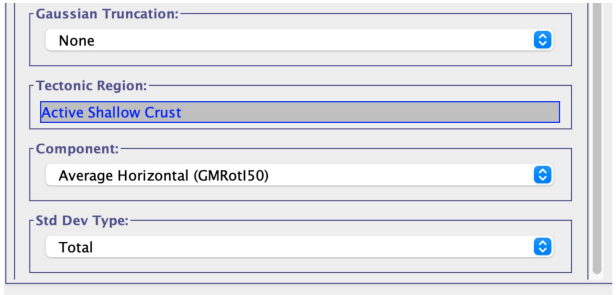
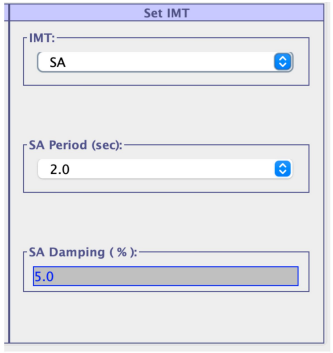


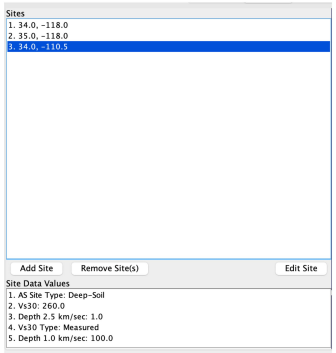
Figure from Ned Field

OpenSHA User Cases - Hazard Curves

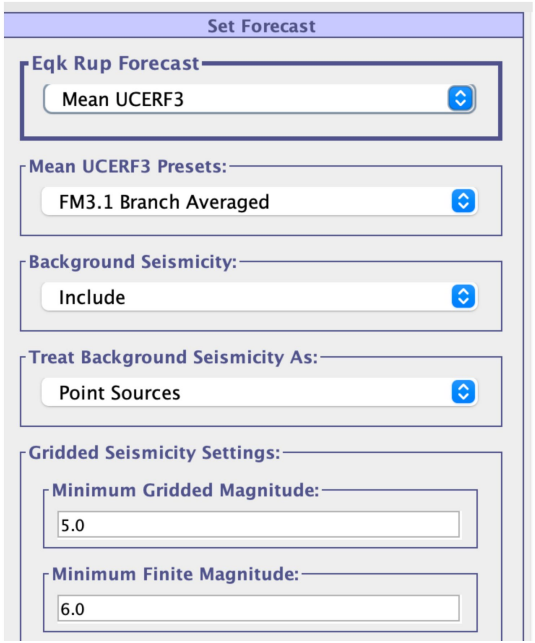
1. Select Ground motion model (GMM), Intensity Measure (IM) and site locations



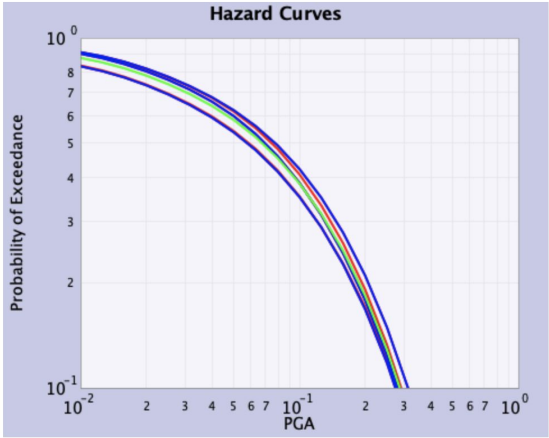




2. Select ERF



3. Results (plots and csv files)



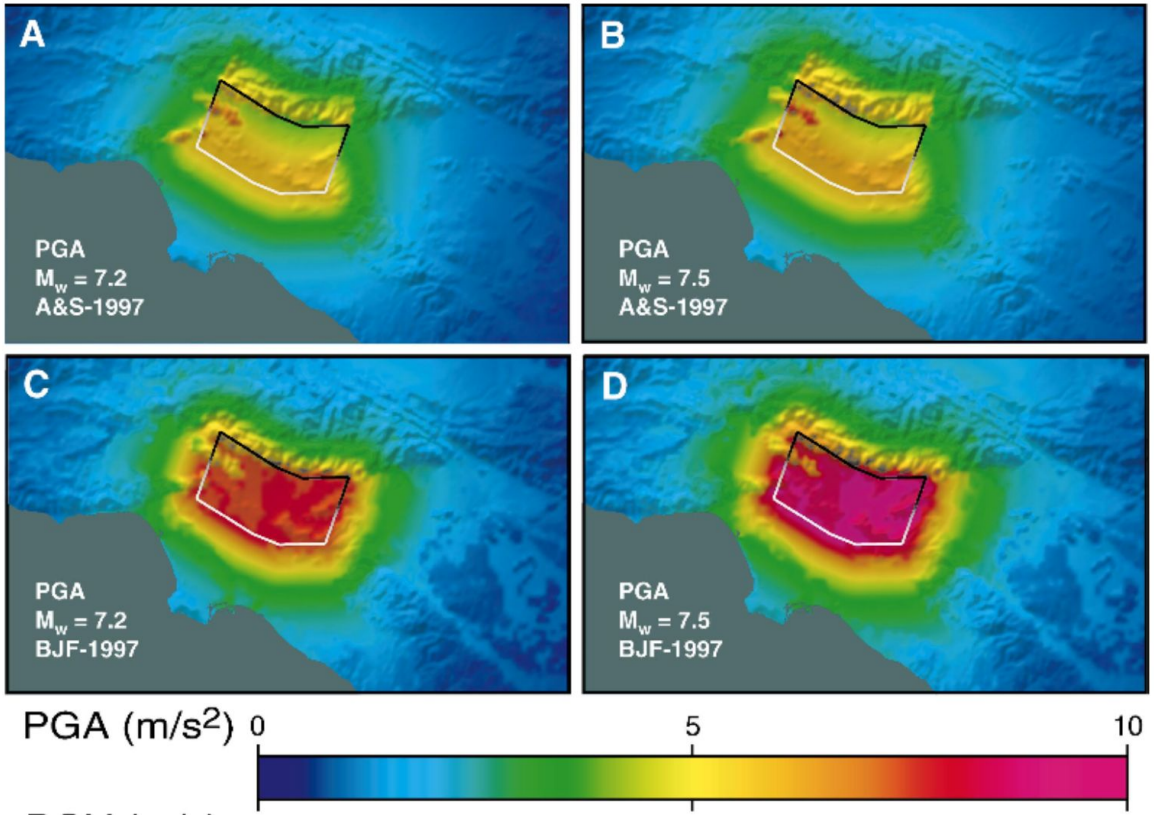
Figures from OpenSHA tutorials

OpenSHA User Cases - Scenario Shakemap

1. Select GMM and IM

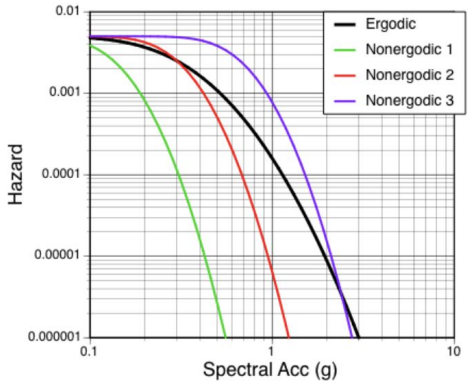
2. Define an earthquake rupture (create a custom one or choose one from ERF)

3. Define a geographic region and site conditions



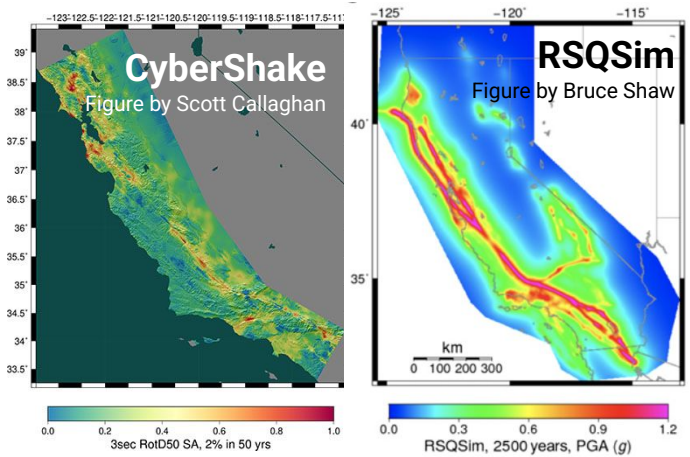
Figures from OpenSHA tutorials

OpenSHA Future Improvements

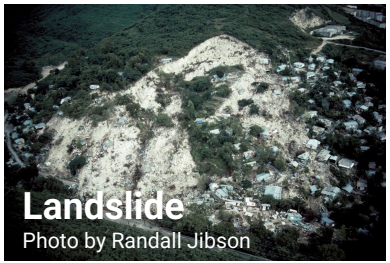


Non-ergodic seismic hazard analysis

Integration of physics-based models

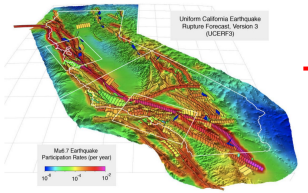


Support hazard computations for



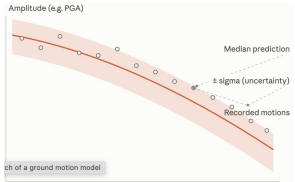
SCEC Capabilities

Earthquake Rupture Forecast (ERF)

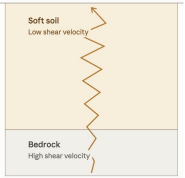


Hazard Forecast

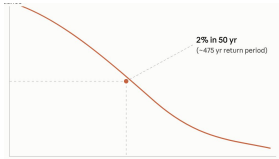
Ground Motion Model



Site response

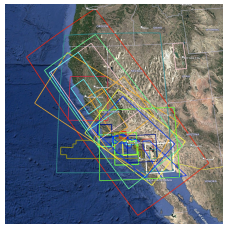


Hazard curve

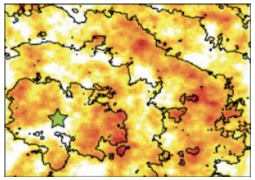


Physics-based Hazard Forecast

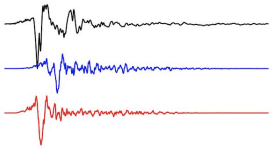
Velocity model



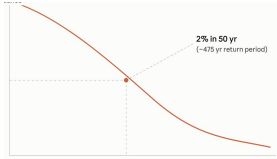
Kinematic/Dynamic rupture



Synthetic seismogram

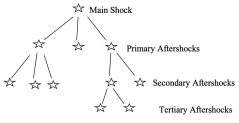


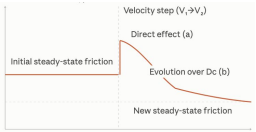
Hazard curve



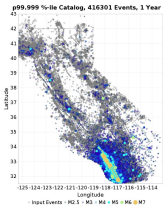
Seismicity / Earthquake Cycle Forecast

Statistical/Physics-based Model

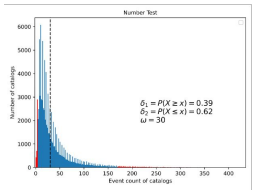




Synthetic catalogs

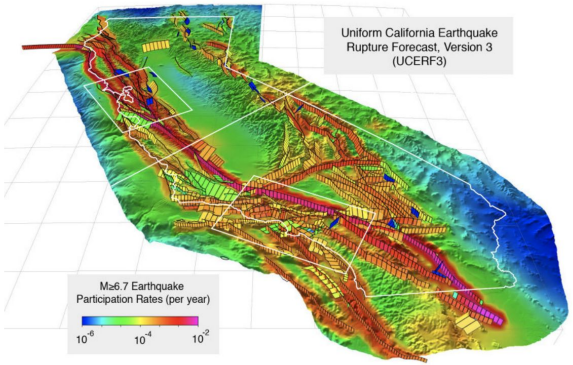


Statistical evaluation

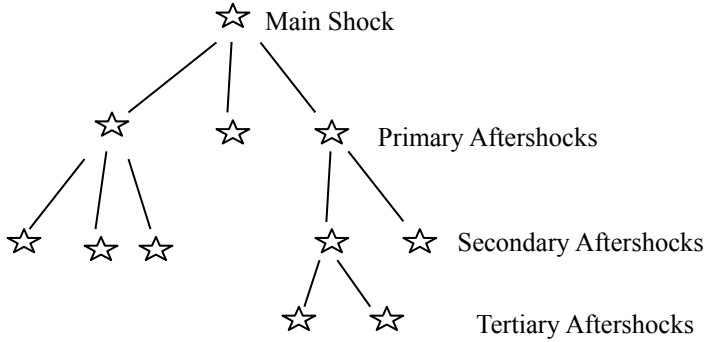


UCERF3-ETAS

Uniform California Earthquake Rupture Forecast, Version 3 (UCERF3)



Epidemic Type Aftershock Sequence (ETAS)



UCERF3-ETAS simulates time-dependent clustered seismicity from days to hundreds of years

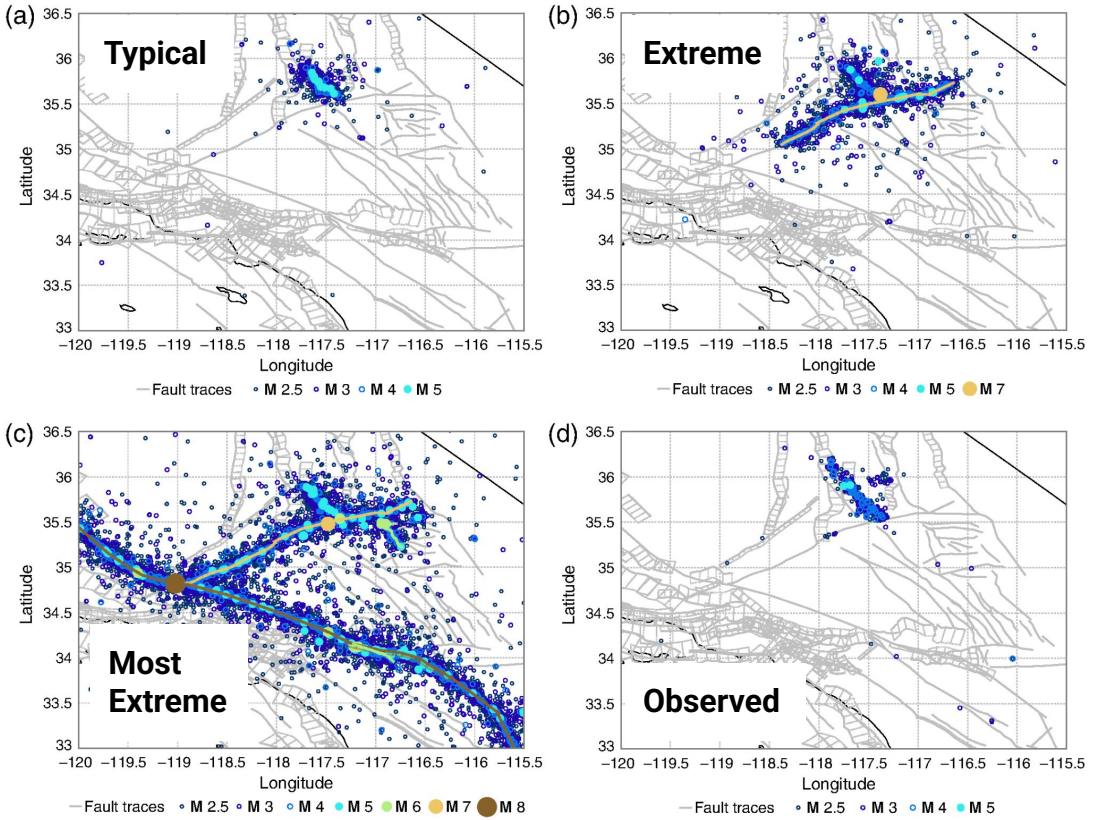
- Inputs can include:
  - Historical catalog
  - Scenario events
  - Trigger ruptures, either on or between UCERF3 faults
- Outputs are suites of synthetic seismicity catalogs

Figures from Kevin Milner

UCERF3-ETAS Aftershock Calculations

Aftershock Sequence Forecasting

2019 M7.1 Ridgecrest sequence example



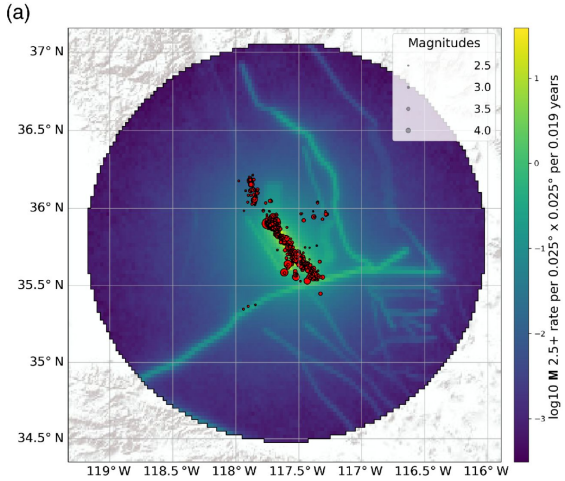
Figures from Kevin Milner

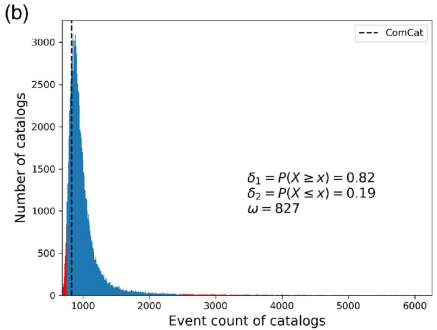
pyCSEP

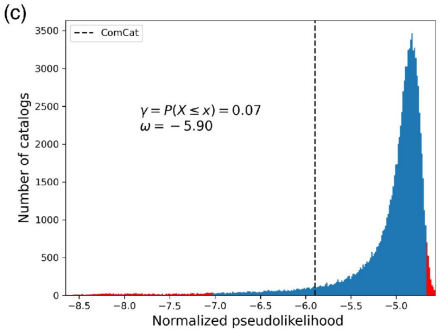
The Collaboratory for the Study of Earthquake Predictability (CSEP)

pyCSEP provides open-source implementations of useful tools for evaluating earthquake forecasts with real data

- Grid-based probabilistic earthquake forecast
- Catalog-based probabilistic earthquake forecast (e.g., UCERF3-ETAS)
- Number test
- Spatial test
- Magnitude test
- Pseudolikelihood test







Savran et al., (2020)

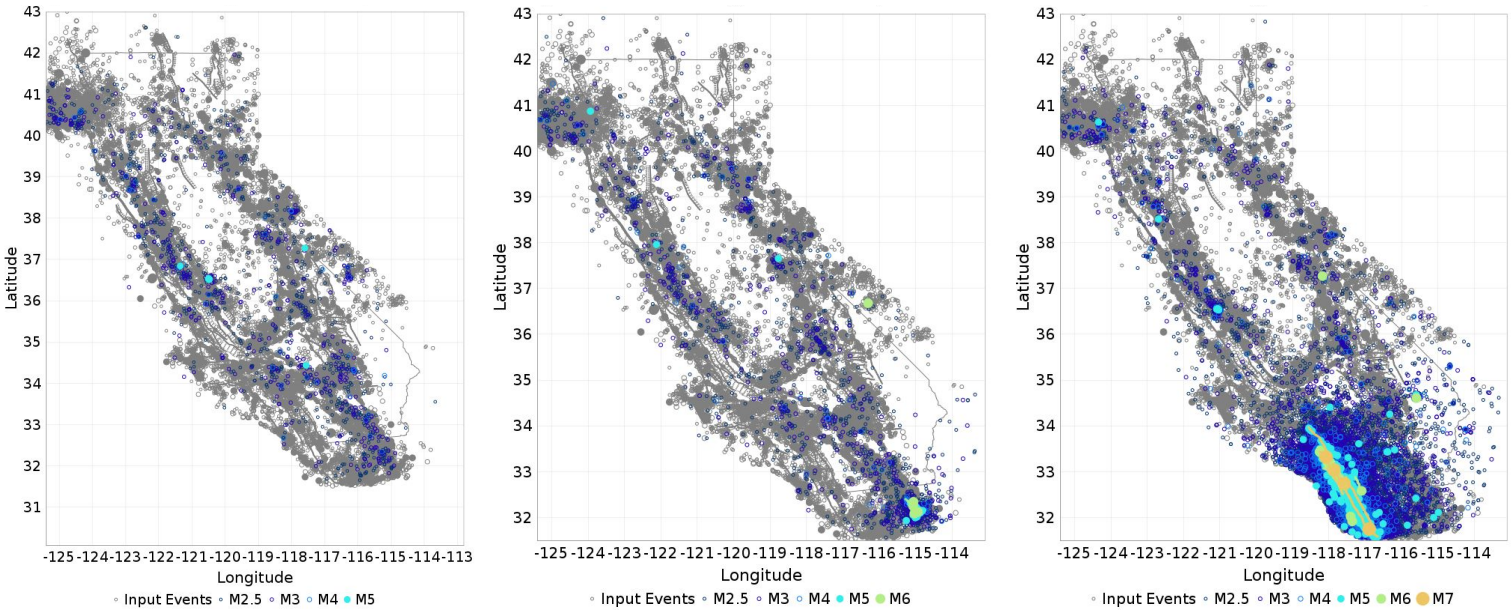
UCERF3-ETAS Spontaneous Calculations

Used to create realistic statewide synthetic catalogs

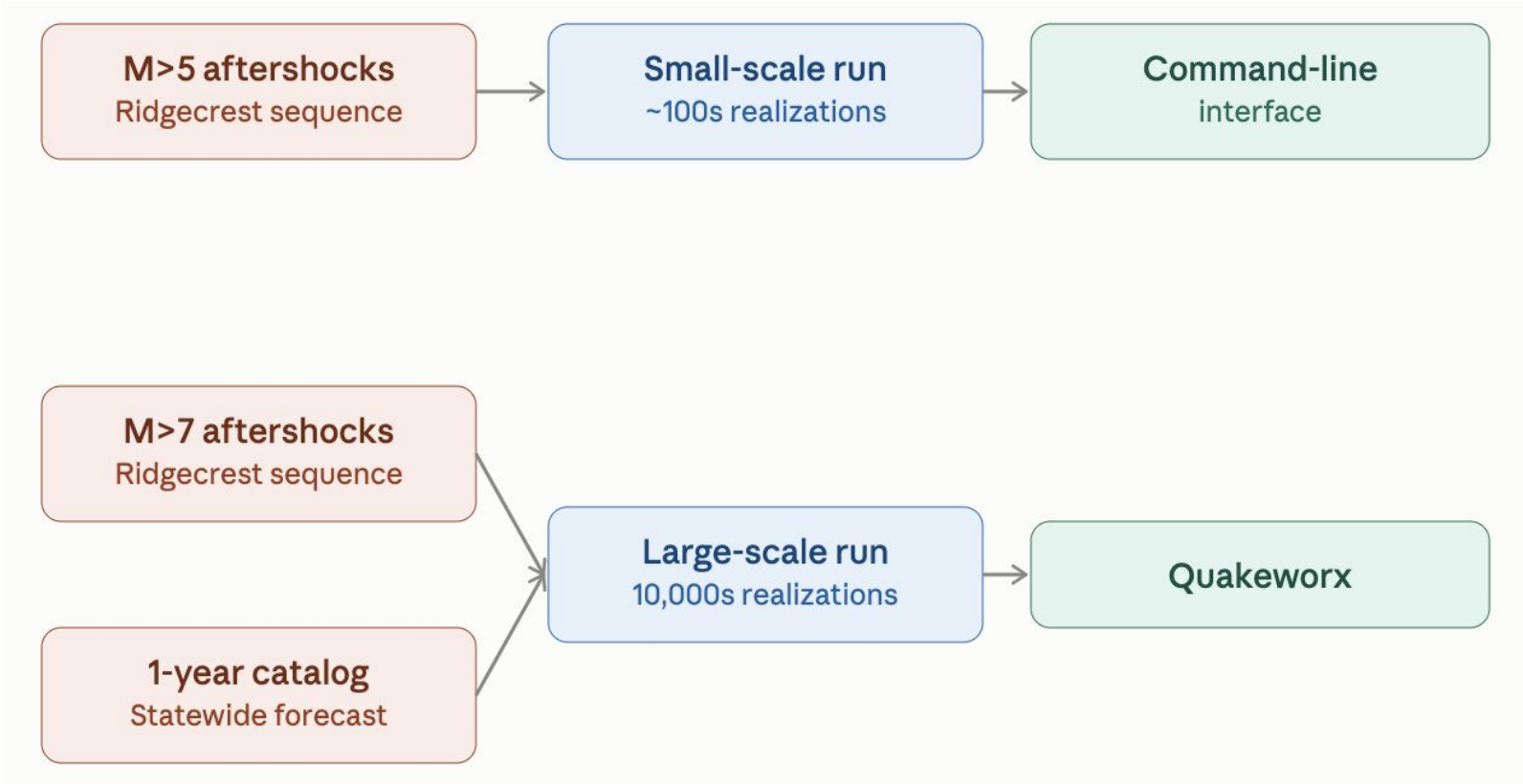
Figures from Kevin Milner

- 100k realizations of the next 1 year of seismicity
- 1k realizations of the next 500 years to look at behavior over multiple seismic cycles

Typical → **Extreme**

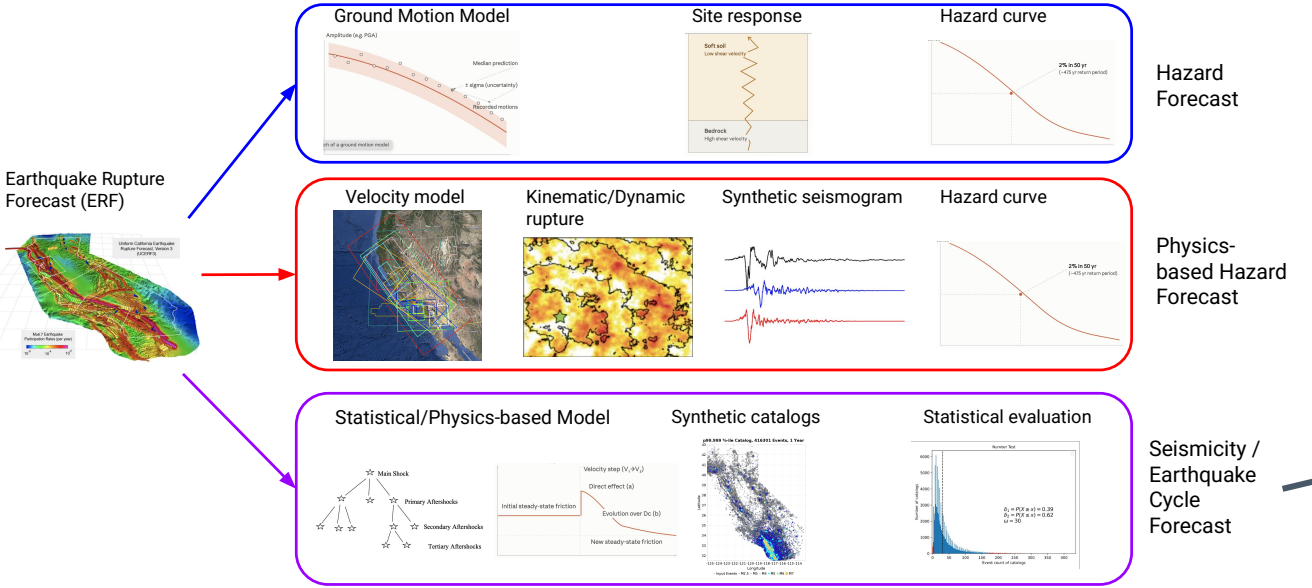


UCERF3-ETAS


M>5 aftershocks
Ridgecrest sequence
Small-scale run
~100s realizations
Command-line
interface
M>7 aftershocks
Ridgecrest sequence
1-year catalog
Statewide forecast
Large-scale run
10,000s realizations
Quakeworx

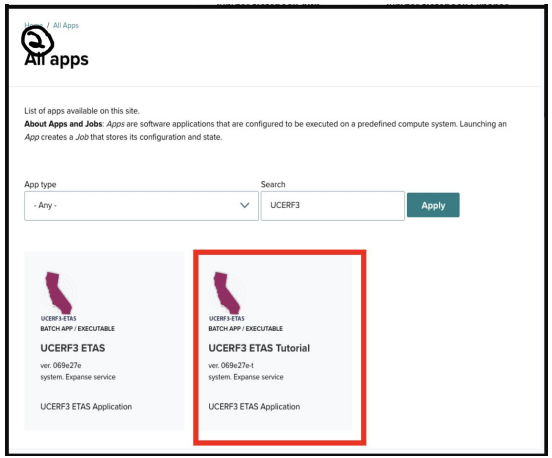
Quakeworx

- A web-based cyberinfrastructure for the community to run and contribute advanced computational tools
- It curates a suite of state-of-the-art earthquake modeling codes, runnable via a web browser or command line

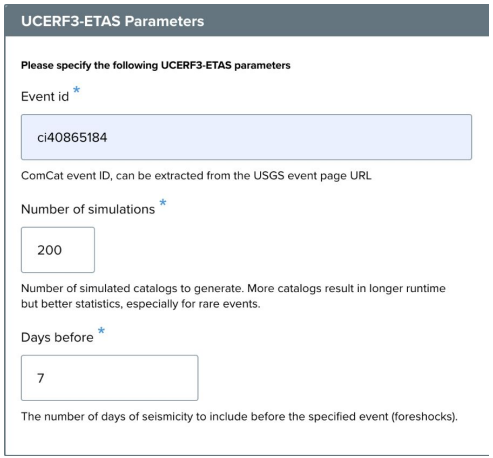


Quakeworx Web Portal

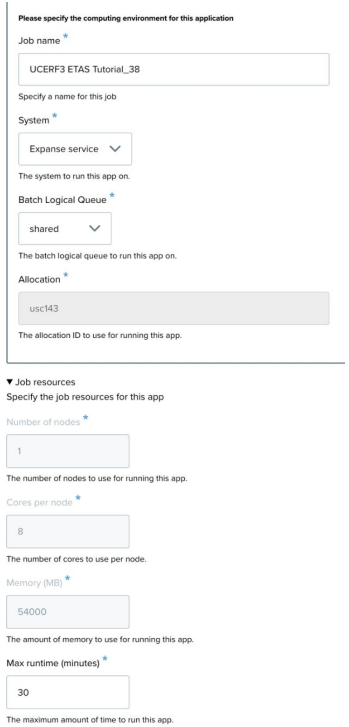
1. Select an app



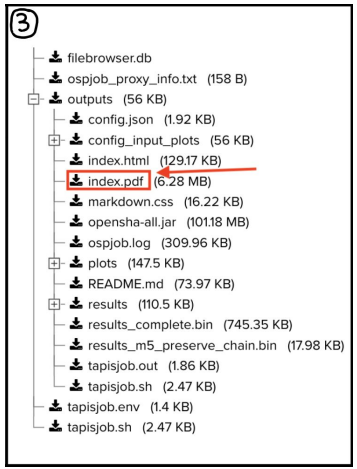
2. Define parameters



3. Set up computing environment



4. Outputs



Figures from Akash Batthal

Quakeworx Apps

Physics-based Ground Motion Forecast

Broadband Platform

SeisSol

Moose-FARMS

Reduced-Order Models (ROMs)

Seismicity / Earthquake Cycle Forecast

UCERF3-ETAS

TANDEM

RSQSim

HFQsim

Community Model

Unified Community Velocity Model (UCVM)

Earthquake Forecast Evaluation

pyCSEP

Guiding Principles

1. **Develop a range of open-source tools to forecast ruptures, aftershocks, and seismic hazard, based on best available science**

2. **Reduce technical barrier and accelerate scientific discovery**

3. **Support scientific research, operational aftershock forecasting during major sequences, engineering applications, and catastrophe risk models used in the insurance sector**