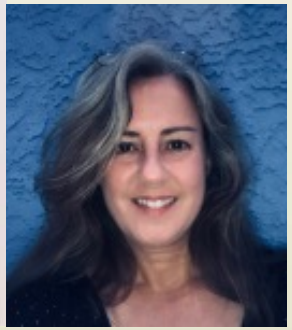
Probabilistic Fault Displacement project update

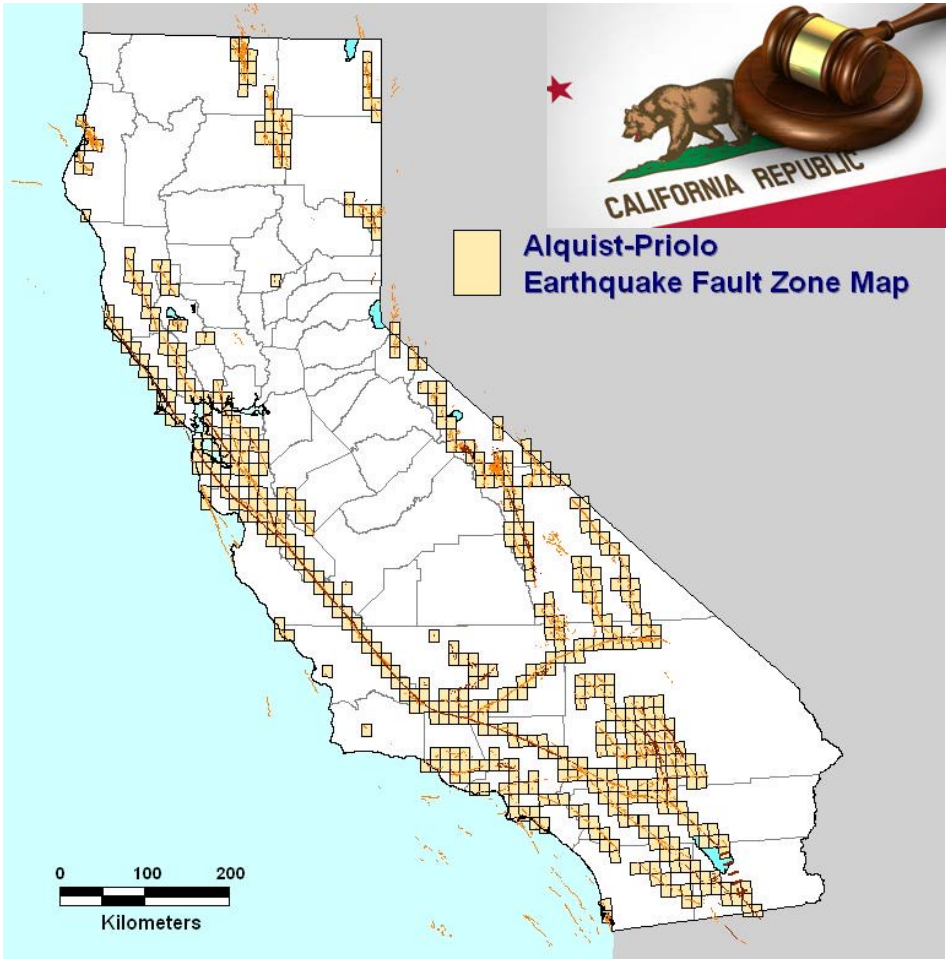
Yongfei Wang (yongfeiw@usc.edu)
Christine Goulet

Southern California Earthquake Center (SCEC)
University of Southern California

SCEC Dynamic rupture workshop, online, Jan 12th, 2023

Driver: risk to distributed infrastructure (SCEC5 theme)



Fault displacement hazard = fault surface rupture hazard

The Alquist-Priolo (AP) Act (California State Law) is to prohibit locating structures for **human occupancy** across an active fault, thus avoiding the hazard of surface fault rupture

Probabilistic fault displacement hazard analysis (PFDHA) critical for non-habitat distributed infrastructures:

- Buried gas lines
- Roads and bridges
- Electric distribution systems
- Water pipes, tunnels, aqueducts

2019 Ridgecrest M7.1 event

Pictures from Matt Hartman; Ben Brooks / U.S. Geological Survey

Fault Displacement Hazard Initiative (FDHI)

- A community-based research project
  - Led by UCLA and involving over 25 researchers and practitioners
  - Analogous to NGA project for ground motion
- With the goals to:
  - Develop a more comprehensive **database** measured worldwide and
  - Develop new fault displacement **models** to be used for PFDHA
- Our SCEC physics-based simulation within FDHI supported by:


Cal Poly
Caltech
SCEC AN NSF+USGS CENTER
UC Irvine
UCLA
UC Santa Barbara
USC

Fault Displacement Hazard Initiative Database

Alexandra Sarmiento, P.E., C.E.G.
Danielle Madugo
Yousef Bozorgnia, Ph.D, P.E.
Andi Shen
Silvia Mazzoni, Ph.D.
University of California, Los Angeles

Grigorios Lavrentiadis, Ph.D.
University of California, Berkeley and Los Angeles

Timothy Dawson, C.E.G.
California Geological Survey Los Angeles

Christopher Madugo, Ph.D.
Albert Kottke, Ph.D., P.E.
Pacific Gas & Electric Company

Stephen Thompson, Ph.D., C.E.G.
Lettis Consultants International

Stéphane Baize, Ph.D.
Institut de Radioprotection et de Sûreté Nucléaire

Christopher Milliner, Ph.D.
California Institute of Technology

Fiia Nurminen
Paolo Boncio, Ph.D.
Università G. d'Annunzio di Chieti-Pescara

Francesco Visini, Ph.D.
Istituto Nazionale di Geofisica e Vulcanologia

A report on research supported by Pacific Gas & Electric Company, High-Speed Rail Authority, California Department of Transportation, Southern California Gas Company, Los Angeles Department of Water and Power, and California Energy Commission.

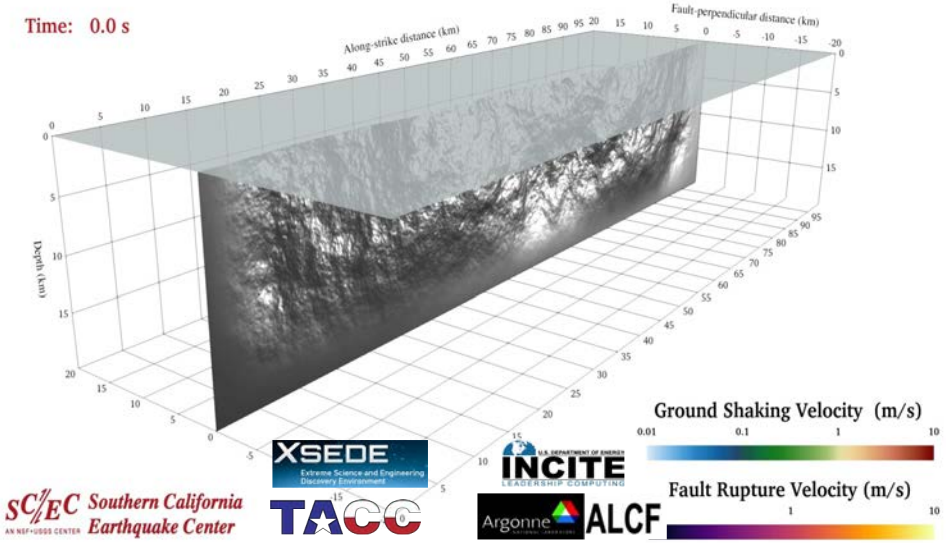
Report Report GIRS-2021-08
DOI: 10.34948/N36P48

University of California, Los Angeles (headquarters)

The B. John Garrick Institute for the Risk Sciences
UCLA ENGINEERING

Role of physics-based simulation in PFDHA

Damage to buried pips in 2019 M7.1 Ridgecrest event



Development of PFDHA hindered by **limited empirical dataset**

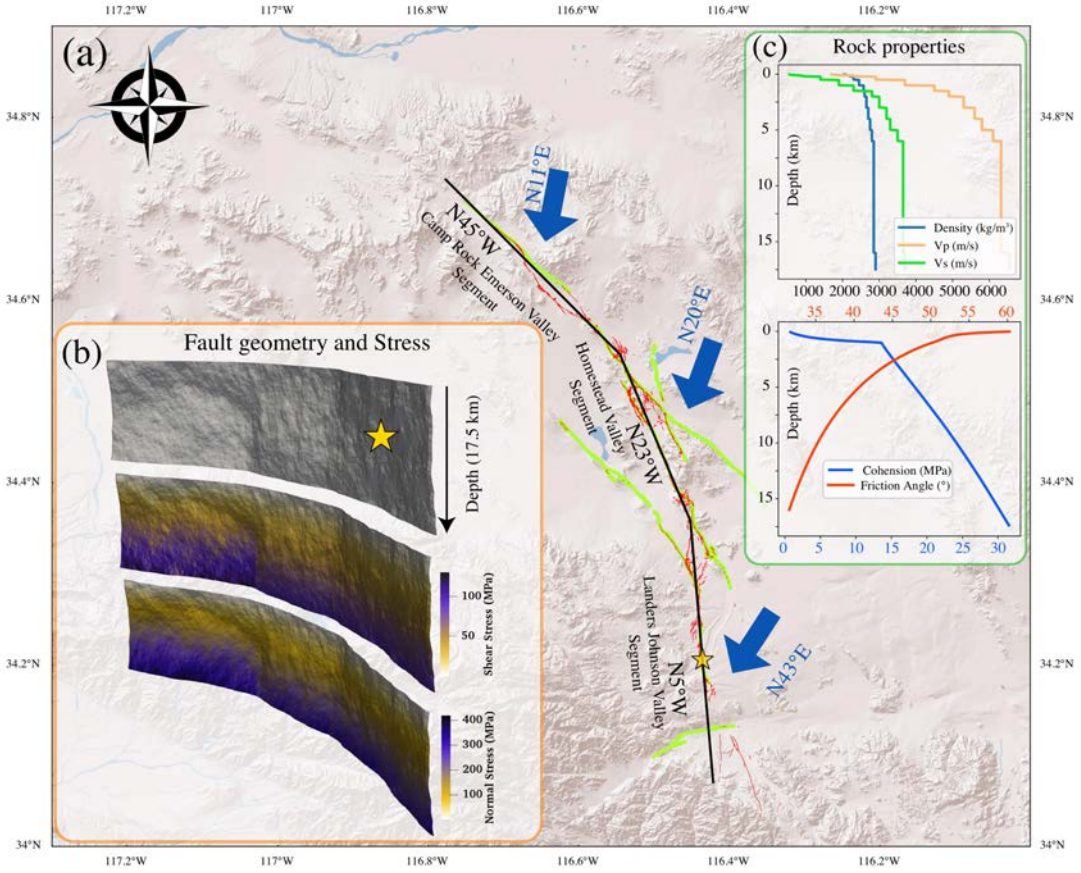
- Still sparse fault displacement dataset (FDHI project to remedy this issue)
- Especially limited data for small events (hard to break the surface)

Dynamic rupture modeling is an attractive alternative

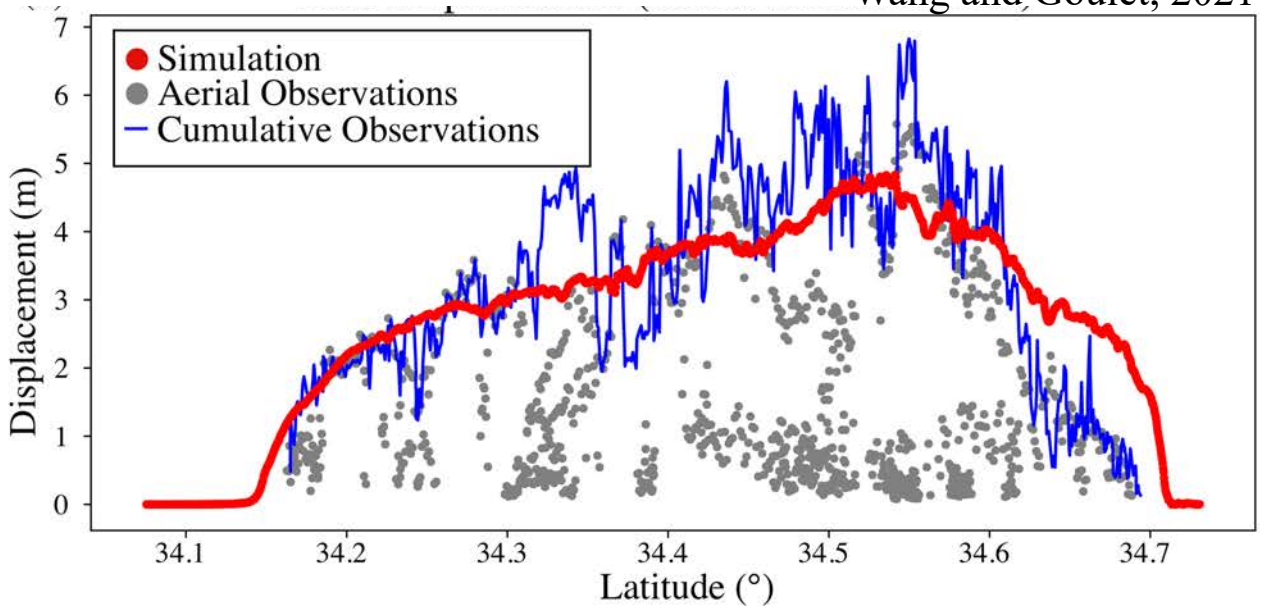
- **Supplement available observed data** (FDHI) to be included in PFDHA codes
- It doesn't prescribe the rupture/slip on fault

Before extrapolating, dynamic rupture needs to be validated against observed fault displacements

First validation case: 1992 Landers earthquake



Wang and Goulet, 2021



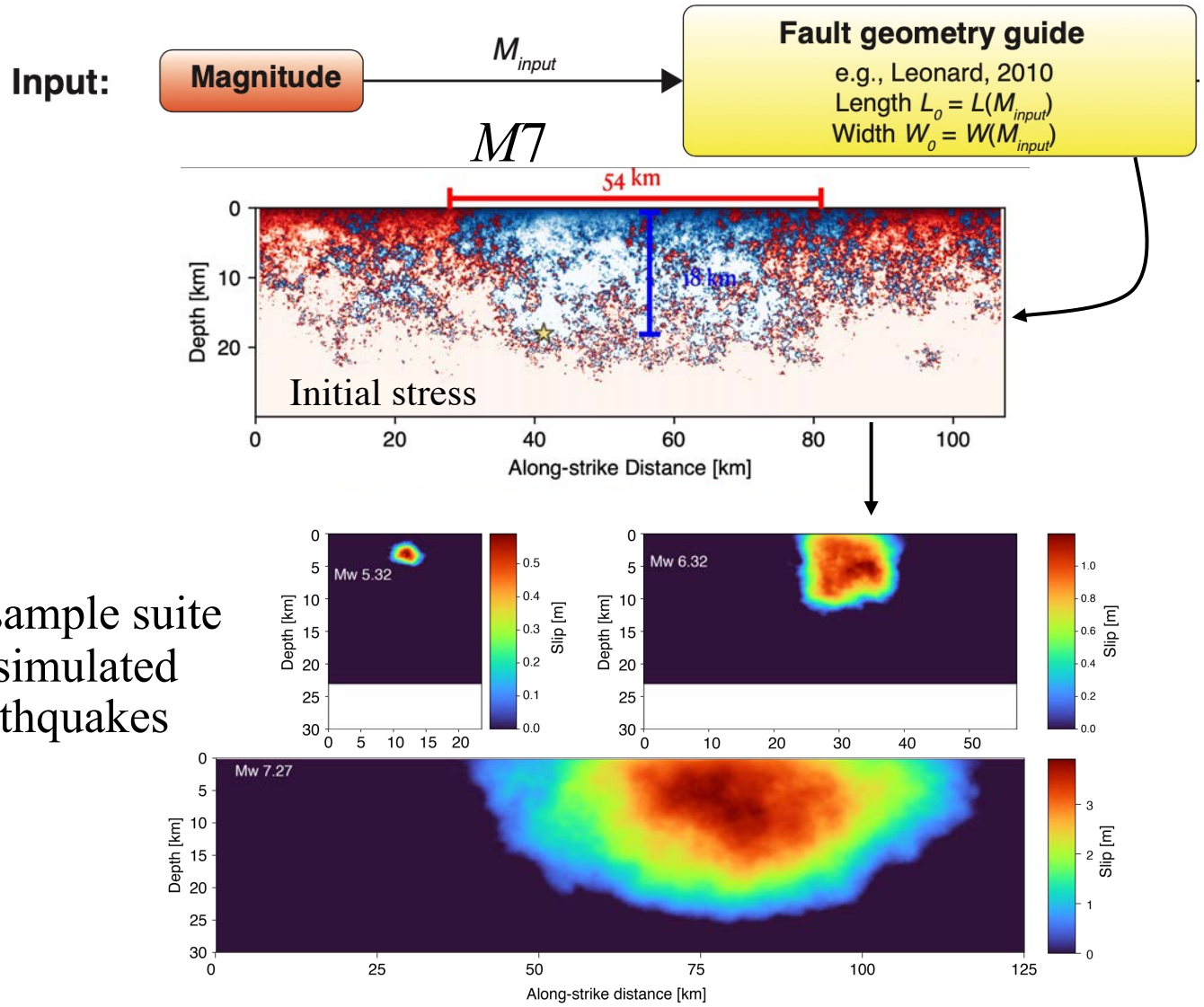
Dynamic rupture ingredients (event- and fault-specific and generic setups):

- 3-segmented fault plane + small-scale roughness [*informed by AP Act zone*]
- Depth-variable tectonic stress [*local stress model*]
- 1D velocity model [*informed by local structure*]
- Hoek-Brown plasticity [*generic*]
- Slip-weakening friction [*generic*]

Our dynamic rupture model generally reproduces fault displacement observed in the Landers event

- Location of peak displacement
- Fault displacement profile and amplitude

Extension to generic strike-slip events



A sample suite of simulated earthquakes

1. For broader use, model parameters are generalized for a wide range of magnitudes (M5-M8) and ~~all event-specific setups~~ are dropped (e.g., in Landers)

2. Our overarching goal: to capture first-order fault displacement trend as a whole instead of comparing detailed displacements

3. A target magnitude (**Only input**) -> Fault geometry guide -> Randomized pre-stress field

4. Run dynamic rupture model: earthquakes spontaneously propagate. Fault geometry and magnitude are unknown before simulations end (**not prescribed, input M7->M6.5-7.5**)

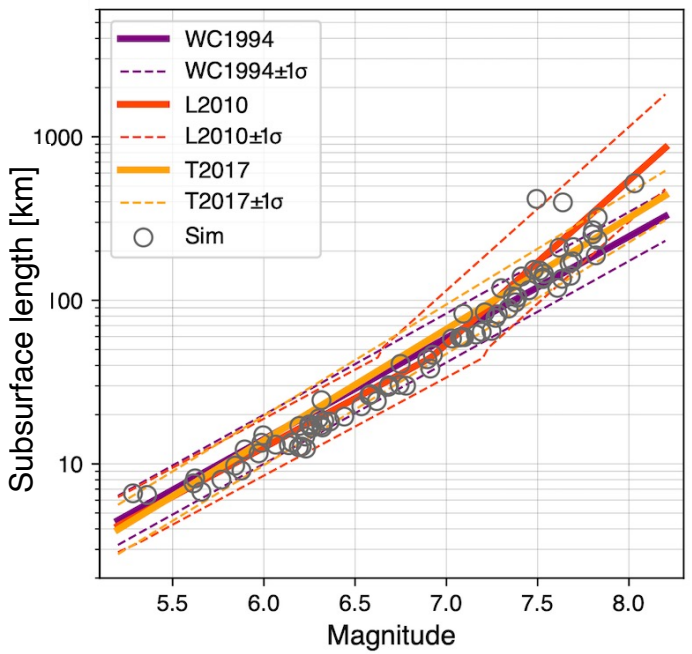
5. An ensemble of dynamic rupture models generated and slips at top layer exported as fault displacements (**First dynamic rupture ensemble M5-8**)

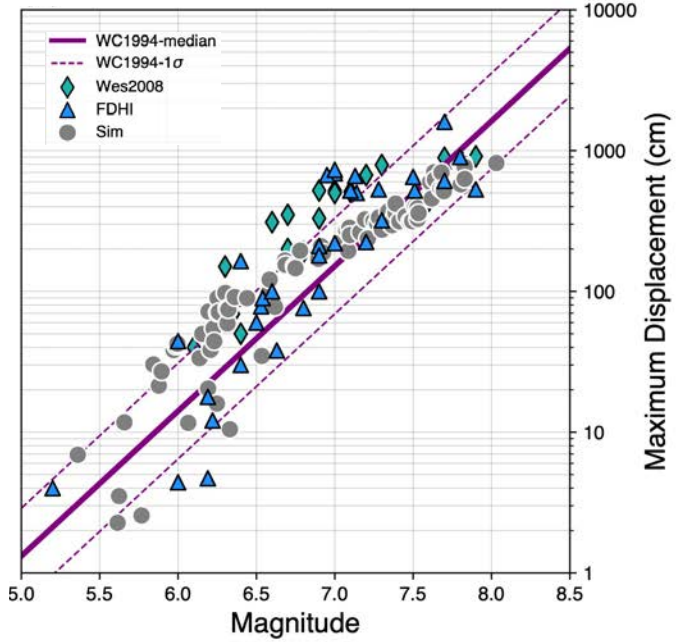
Various Validations of physics-based database

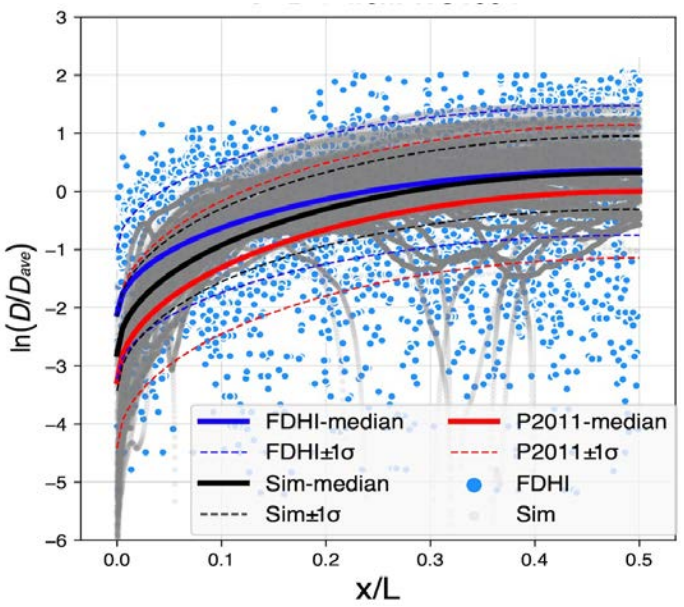
We perform validations of simulated database for:

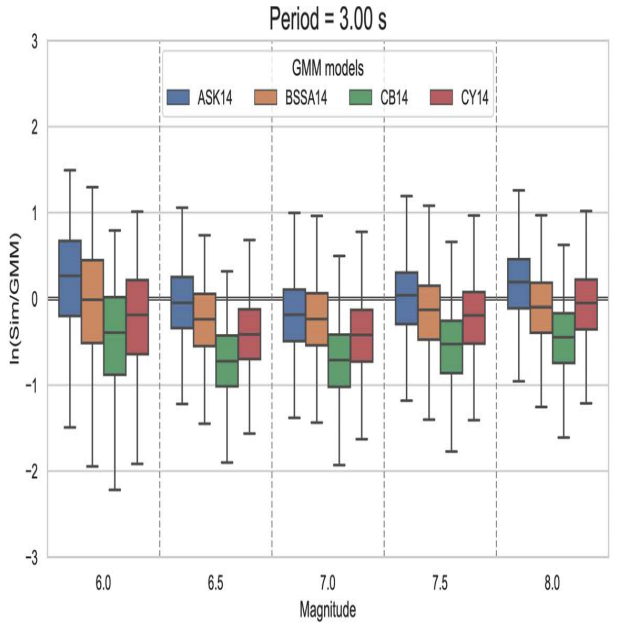
- On-fault quantities (subsurface length, width, area, average slip…)
- Surface quantities (surface rupture length, average and maximum fault displacement…)
- Along-strike distribution of fault displacement
- Near-fault ground motions (up to 3Hz)

All of them in general follow empirical data (FDHI) and models (Wells and Coppersmith, Petersen et al, GMMs…)

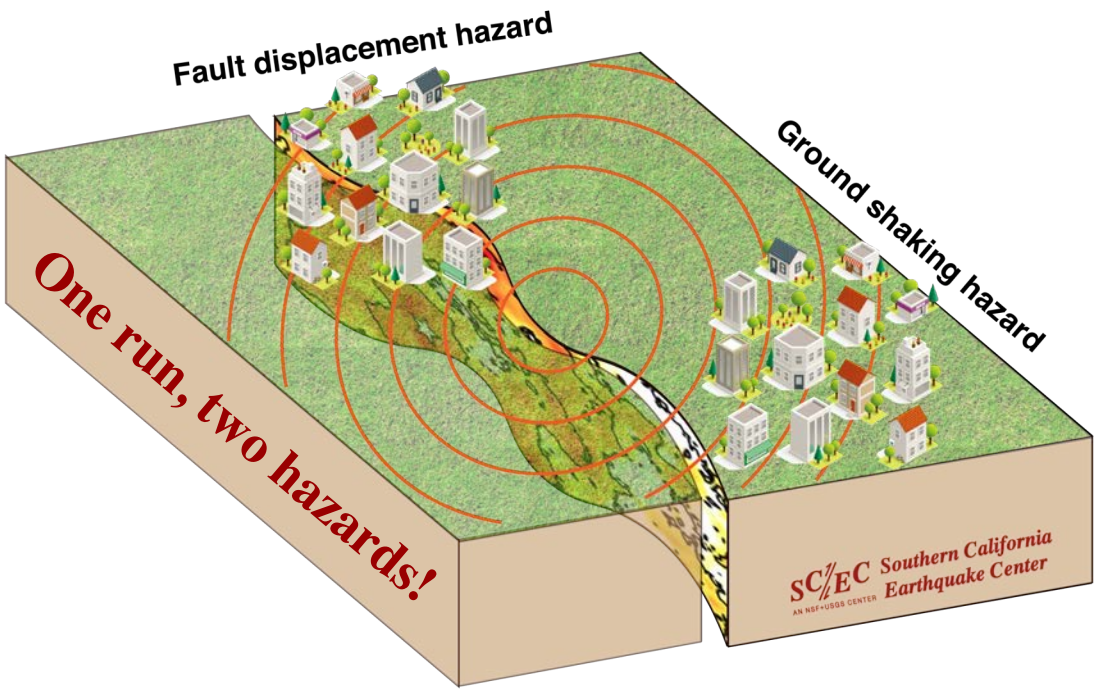








Take-home messages



- Provided it is appropriately validated, the dynamic rupture model can help support PFDHA model development
- It can reproduce fault displacements and ground motion observed in the Landers earthquake
- New simulated FD dataset captures similar trends of magnitude and fault distance ratio against empirical datasets (e.g., FDHI) and relations but provides a more **continuous and complete** dataset supporting scaling model development
- The dynamic rupture model is considered an effective model serving for both hazards of fault displacement and ground shaking (**One run, two hazards!**)

Wang, Y. and C. Goulet (2021). "Validation of Fault Displacements from Dynamic Rupture Simulations against the Observations from the 1992 Landers Earthquake." *Bulletin of the Seismological Society of America* **111**(5): 2574-2594.

Wang, Y. and C. Goulet (2022). "Validation of Simulated Fault Displacements for Strike-slip Events from Dynamic Ruptures." *Earthquake Spectra (in prep)*.

Thanks for your attention!

Q&A

yongfeiw@usc.edu