# Probabilistic Fault Displacement project update

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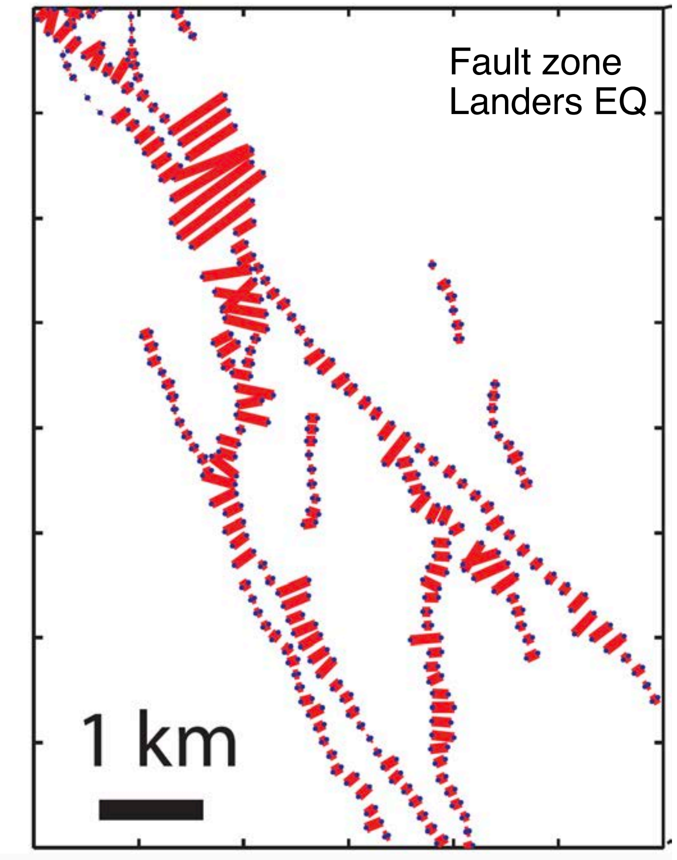
*Dynamic Rupture Group Workshop*
*Jan. 8, 2020*
*Pomona, CA*

# *Driver: risk to distributed infrastructure (SCEC5 theme)*




Probabilistic fault displacement critical for

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

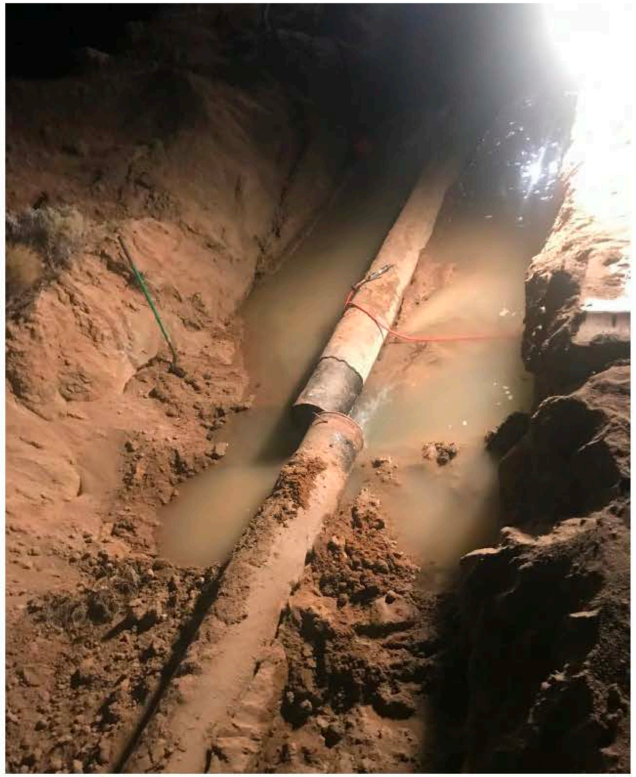
Complex problem with limited empirical dataset.

SCEC contributions

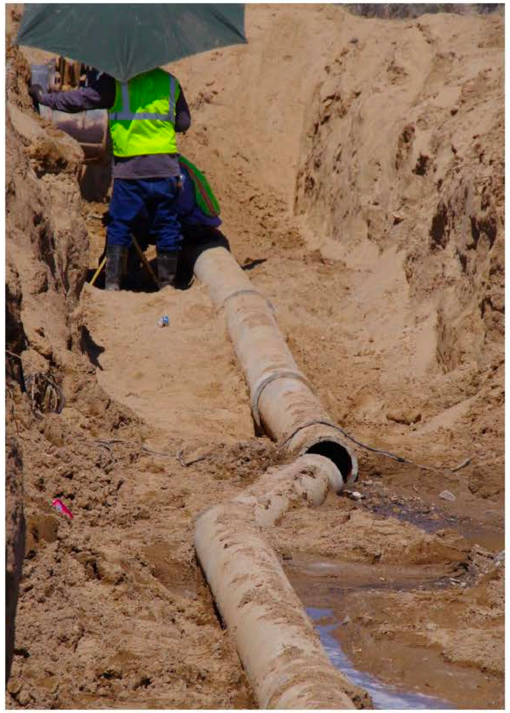
- Earthquake rupture forecasts (UCERF)
- Geologic knowledge
- Simulation-based displacement estimates

# *Ridgecrest Sequence, damage to buried pipes*

M6.4 trace



M7.1 trace



Pictures from GEER report rev. 2,
Stewart et al. 2019

# *Seismic Risk Assessment and Management of Natural Gas Storage and Pipeline Infrastructure in CA*

(funding from CEC, with UCLA-based NHR3)

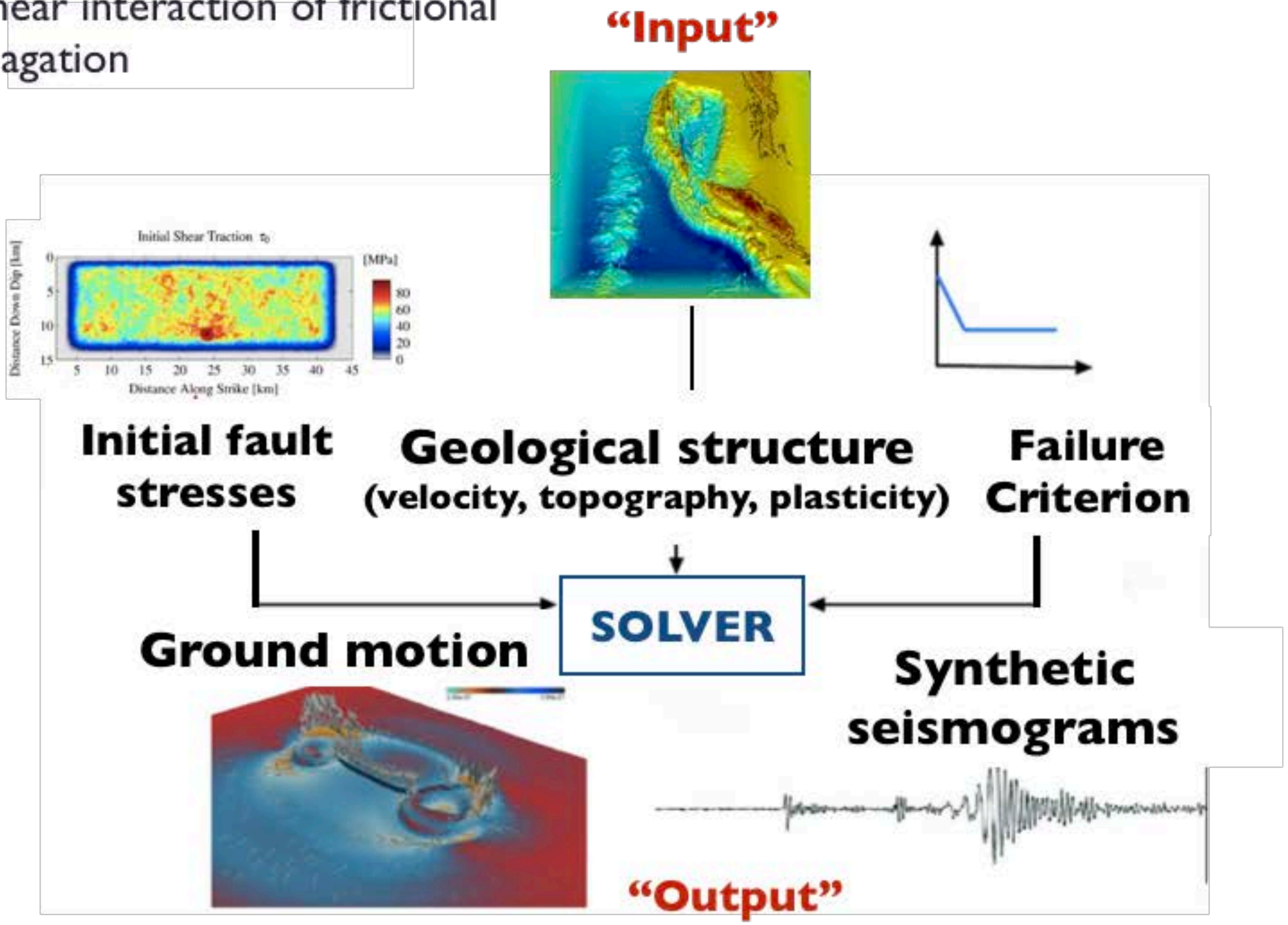
- Scientific Goal:
  - Quantifying near-fault displacements using simulations
  - Supplement available observed data on near fault displacements to be included in probabilistic fault displacement hazard analysis codes
  - Constrain
    - Main trace displacements
    - Secondary displacements
    - Strains at intermediate distance
    - After-slip
    - Uncertainty
  - Use dynamic rupture modeling

# *Oct. 2019 workshop: critical issues, data needs, interface plans*

- SCEC researchers: geology, geodesy, kinematic and dynamic rupture modelers, ground motion modelers (academic, CGS and USGS)
- Broad community of stakeholders: gas and electric utilities, CalTrans, CA high-speed rail, geologists, research engineers, hazard modelers, consultants
- Presentations and group discussions
  - industry applications and needs,
  - database development,
  - currently available and proposed new models,
  - fault rupture simulations (kinematic and dynamic),
  - fundamental and applied research needs
    - short term (2020 SCEC Collaboration plan)
    - long term

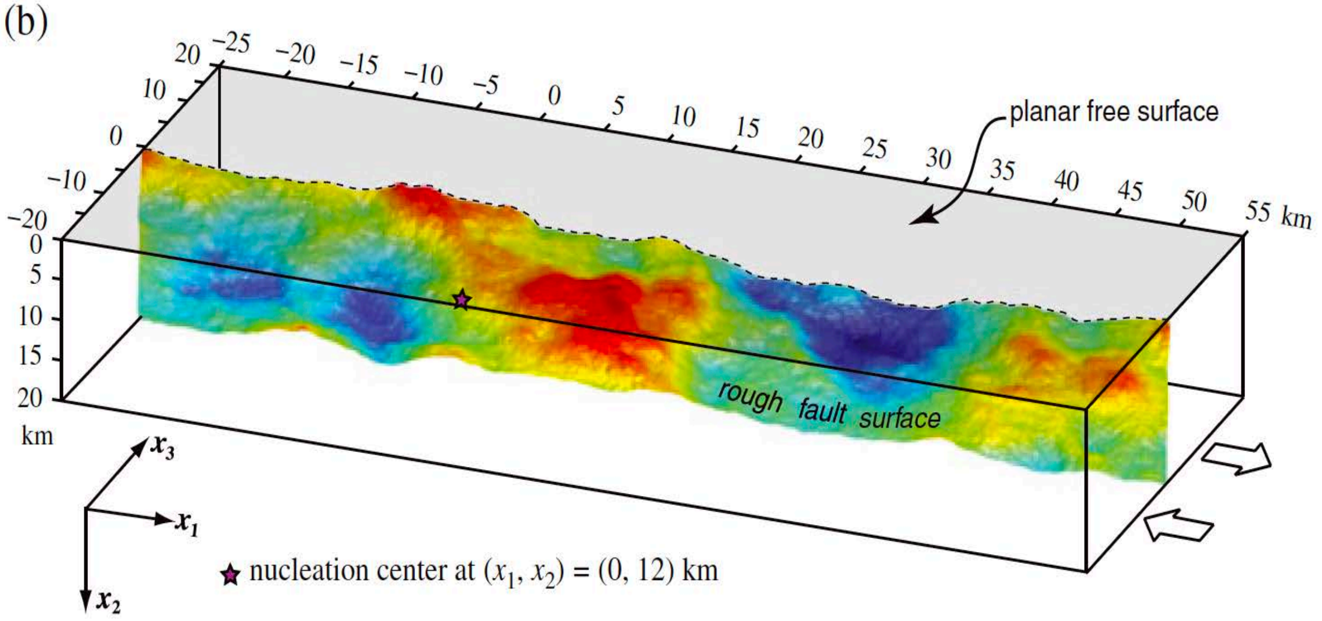
# *Framework of dynamic rupture simulation*

- **Physics-based approach:** Solving for spontaneous dynamic earthquake rupture as non-linear interaction of frictional failure and seismic wave propagation

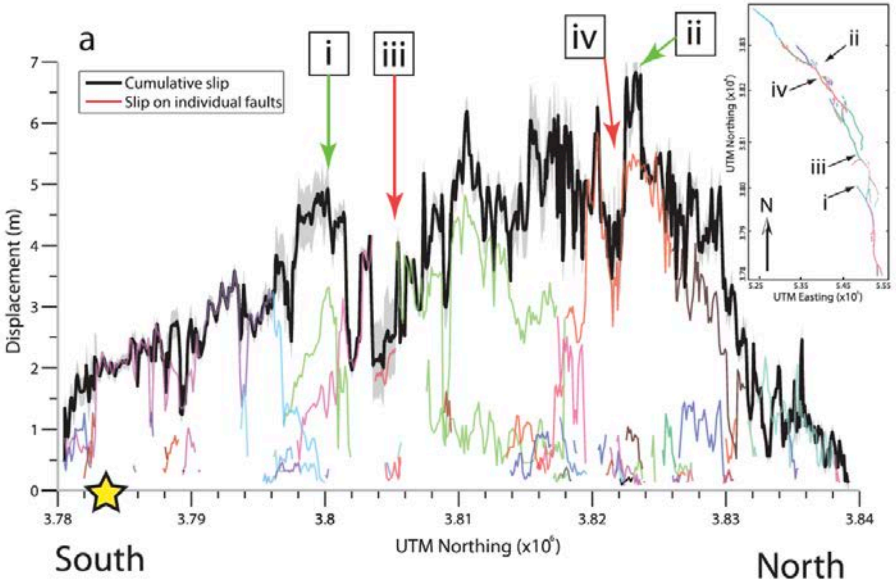



Simulation results from dynamic ruptures

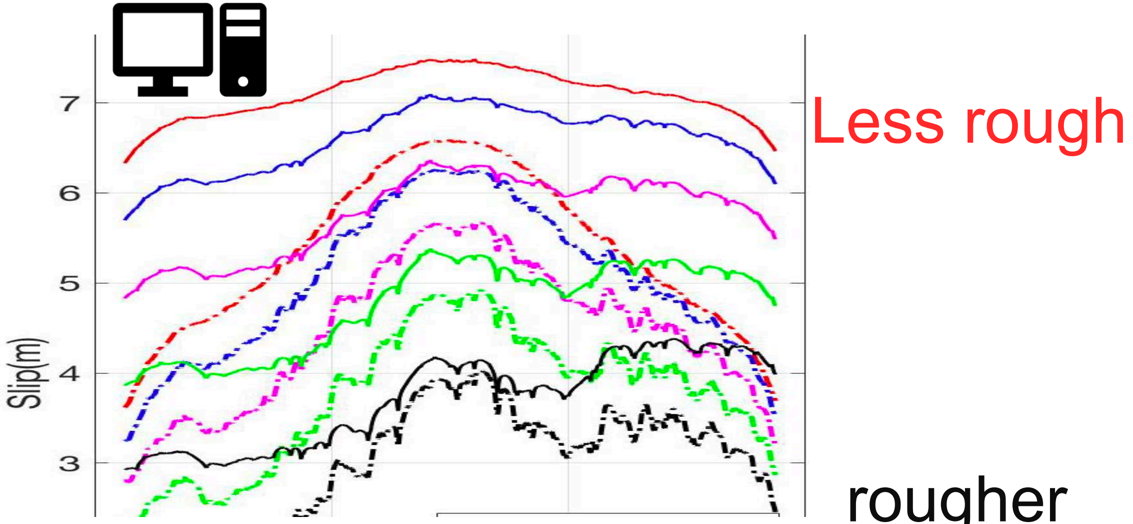
# *Fault geometry (roughness and nonplanar faults)*




Shi and Day, 2013




Milliner et al., 2015



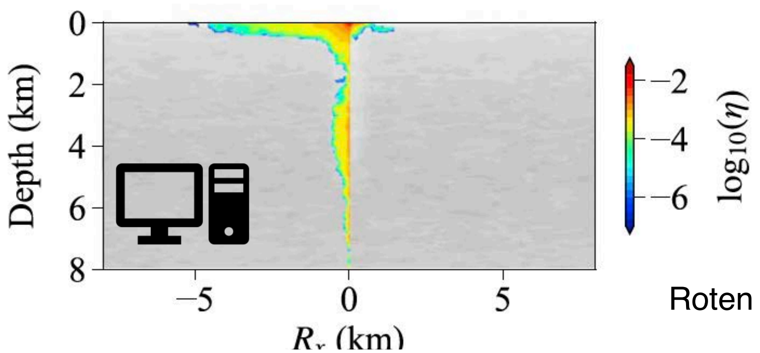

Yao, 2017

Fault roughness can reproduce broad-band fault displacements

# *Off-fault nonlinearity-plasticity*

Accumulated plastic strain:
approximate microfracture

(c)



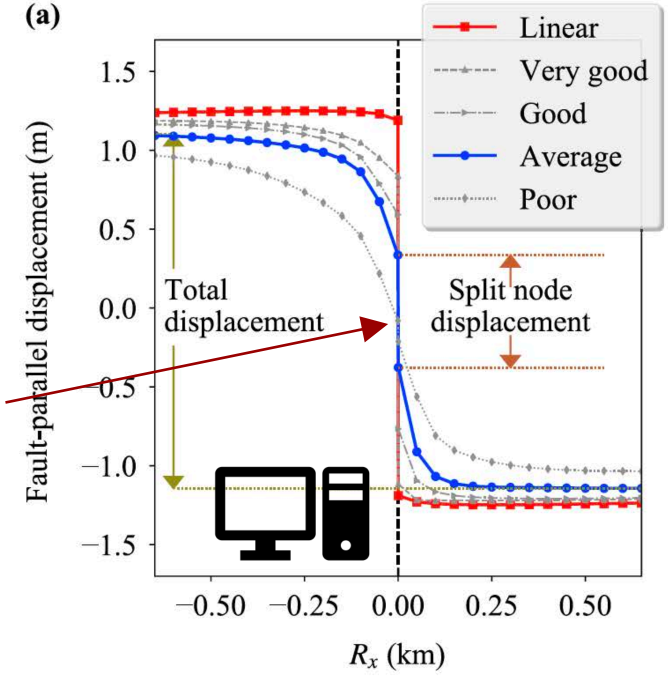

Plasticity can mimic off-fault strains

Roten et al., 2017

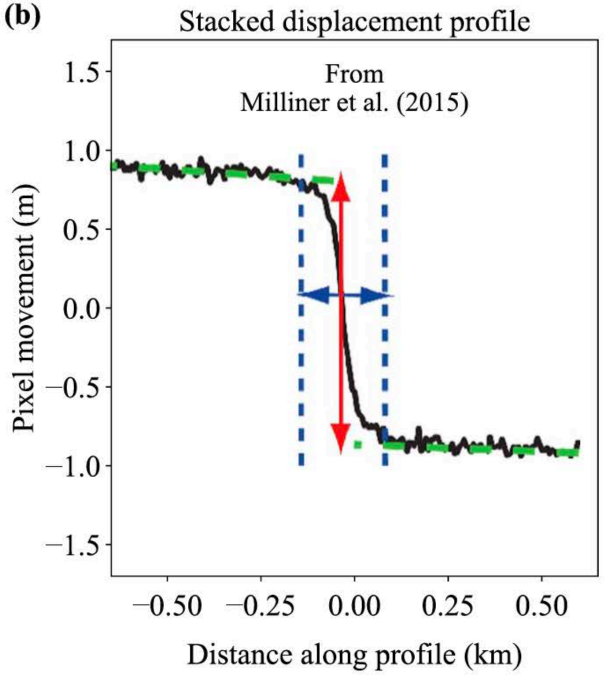
**Off-fault displacement**

**On-fault displacement**

(a)

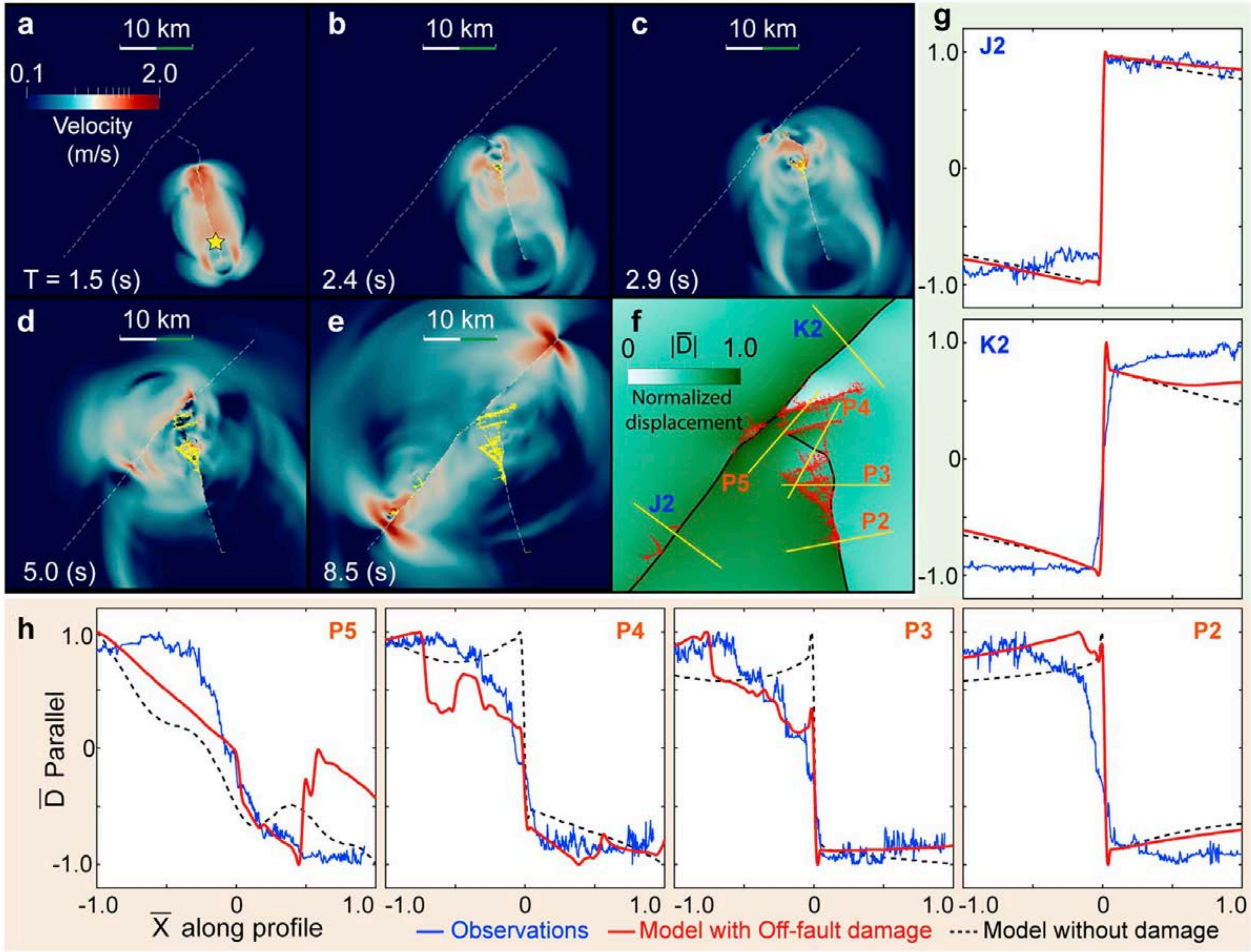



(b)




One possible metric: fault-zone size, slope(off-fault displacement/fault-zone size)

# *Off-fault nonlinearity-microfracture*




Microfracture can also mimic observed off-fault deformation

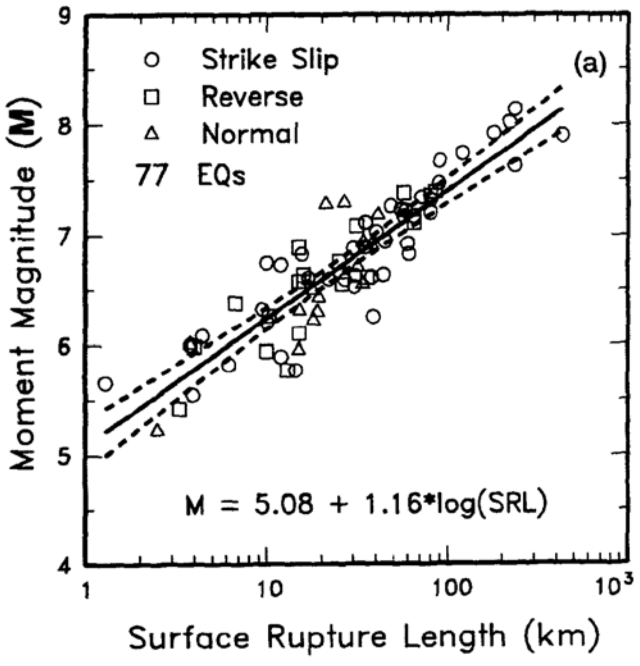
Klinger et al., 2018

# Validation metrics with rupture dynamics

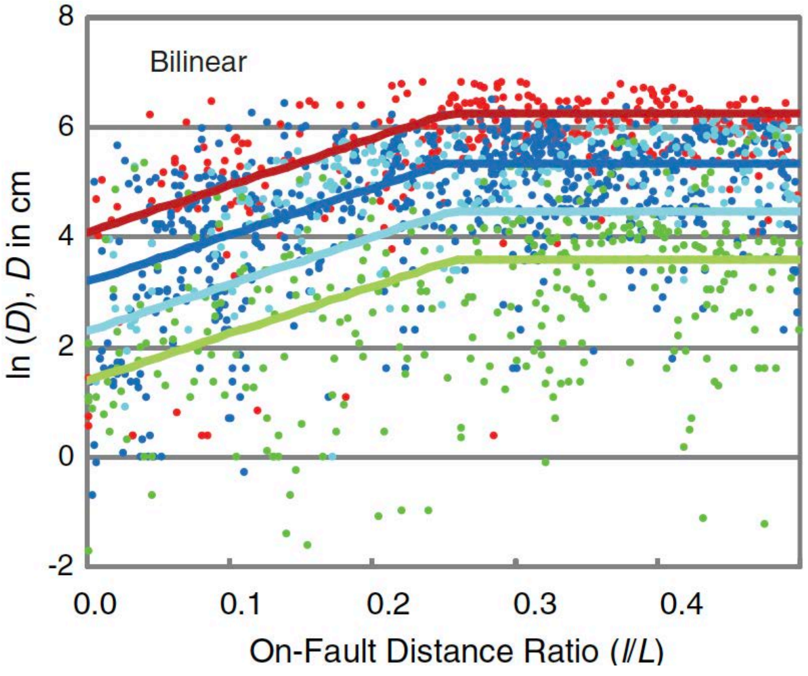
1. Scaling laws (e.g., magnitude, surface displacement, subsurface displacement, maximum/average surface displacement) (first-order validation with whole dataset)

2. Fault displacement vs on-fault distance ratio (first-order validation with whole dataset; subset for case-study validation)

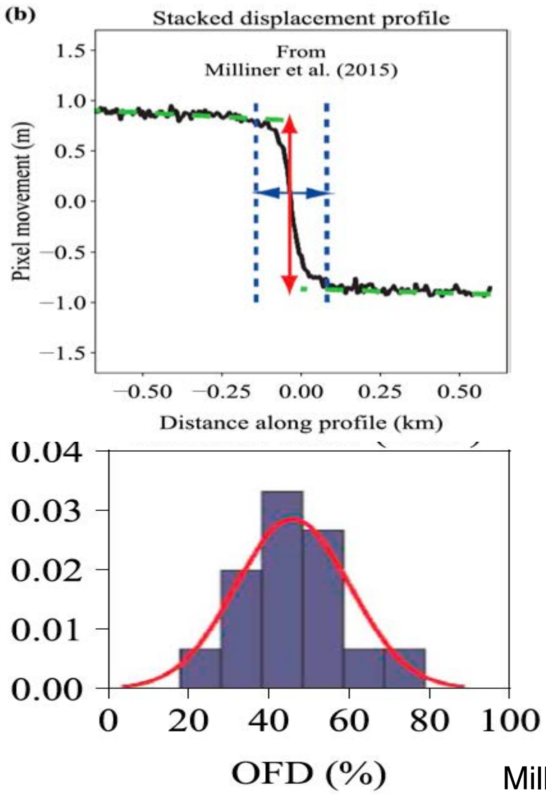
3. Off-fault deformation and off-fault deformation ratio (histogram) (whole dataset/ subset (case validation), e.g., Landers, Hector Mine, Ridgecrest)




Wells and Coppersmith, 1994




Petersen et al., 2011




Milliner et al., 2015

# *Research questions examples and interfaces*

Questions

- Can the current best science products replicate observations? How to define validation approach and metrics?
- How can we efficiently model the fault deformation zone? What complexity can we accommodate (short and long term)?
- What are the most appropriate and sufficient material mechanics to use?
  - Continuum mechanics and plasticity
  - Fracture mechanics
- How to develop constraints on input parameters (stress, geometry, friction, plasticity parameters, etc.)? This also requires seismology, geodesy, rock mechanics…
- How to quantify uncertainty of complex models (unconstrained parameter space)?
- How can we improve recon data collection to support research?

Interfaces (cross-pollination)

- Dynamic Rupture Group (Harris et al.),
- Stress and Deformation Over Time (SDOT),
- Dynamic ruptures validation group (Withers et al.),
- Sequences of Earthquakes and Aseismic Slip (SEAS TAG)
- ERFs (UCERF and EQ simulators), EEII, other validation groups, etc.