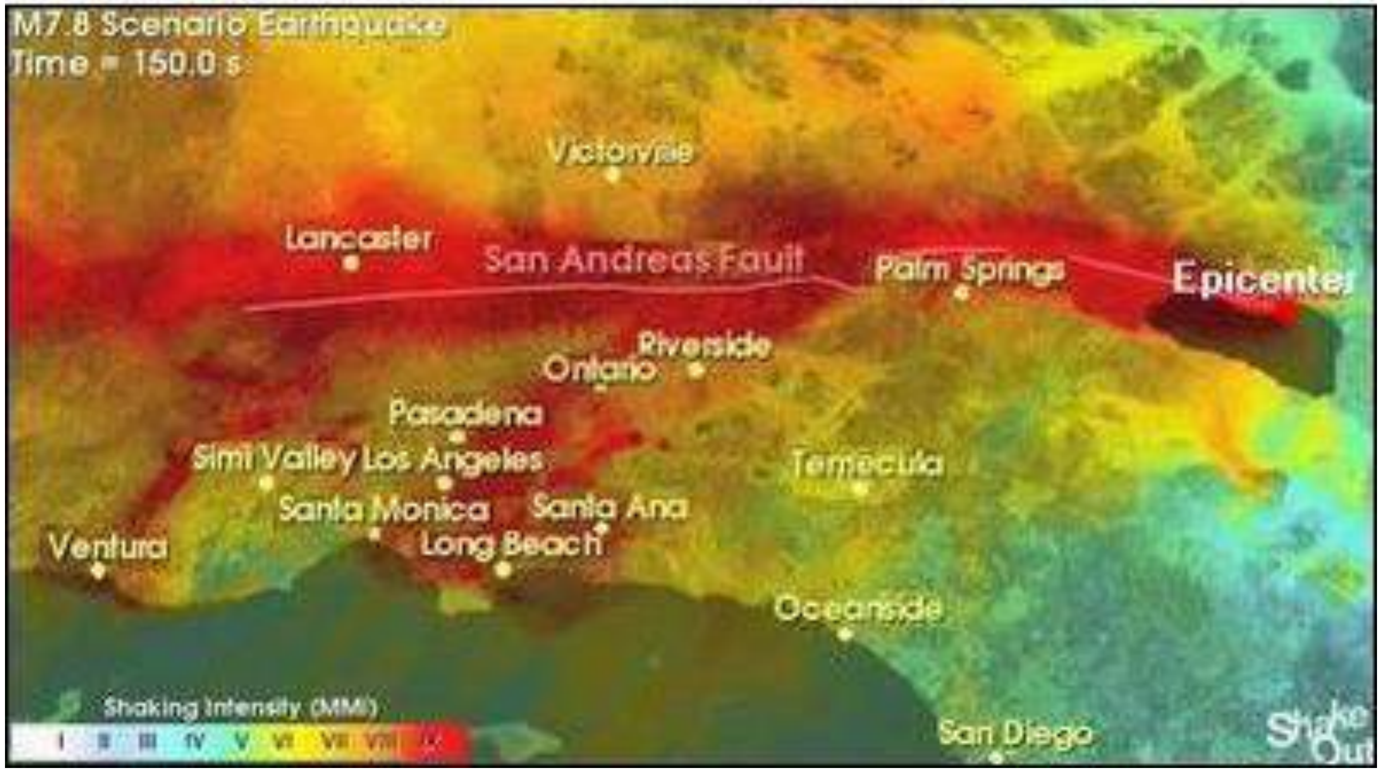
Considering fault interaction in estimates of stress in the San Gorgonio Pass region, southern California

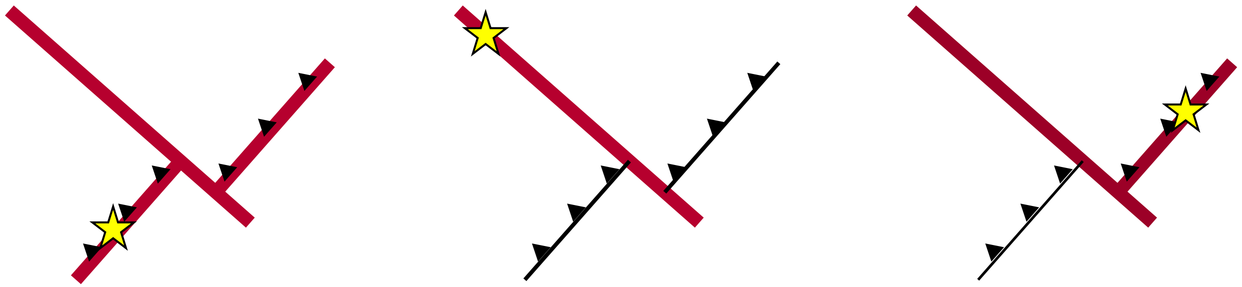
Jenn Hatch & Michele Cooke
SCEC CSM Workshop
January 15, 2019



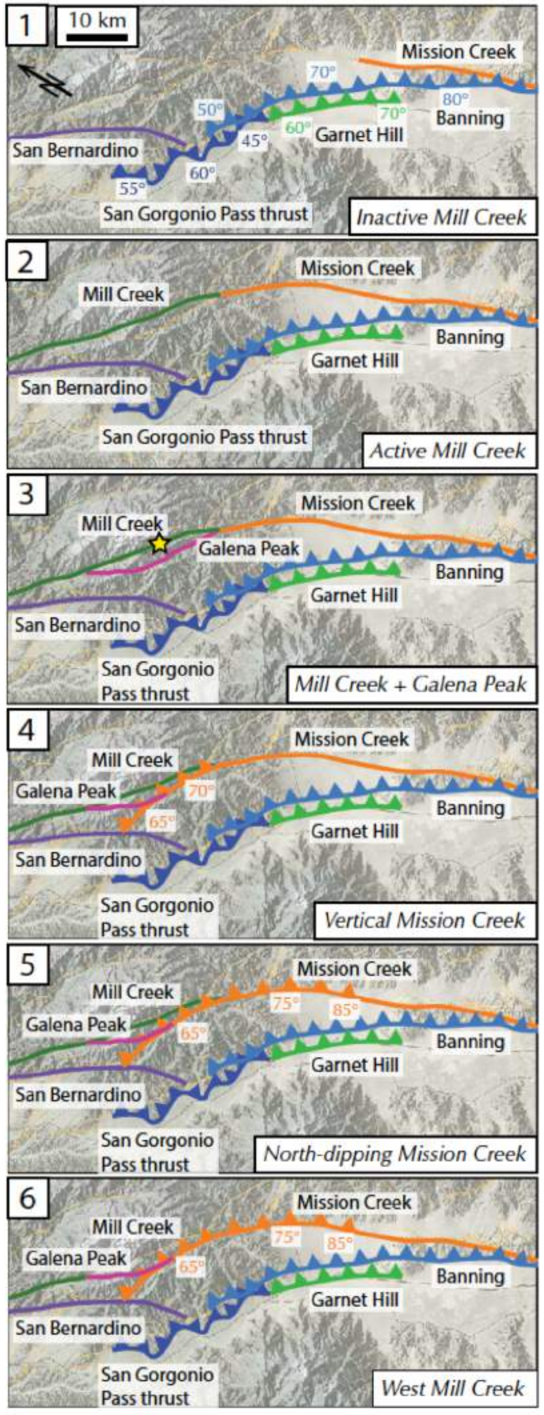
USGS

Ruptures - physical dependence

- Active fault geometry
  - Do we know which strands of the San Andreas are active?
  - Do we know the subsurface geometry?
- Rupture initiation
  - Where will the rupture start?
  - How will the rupture propagate at fault intersections?



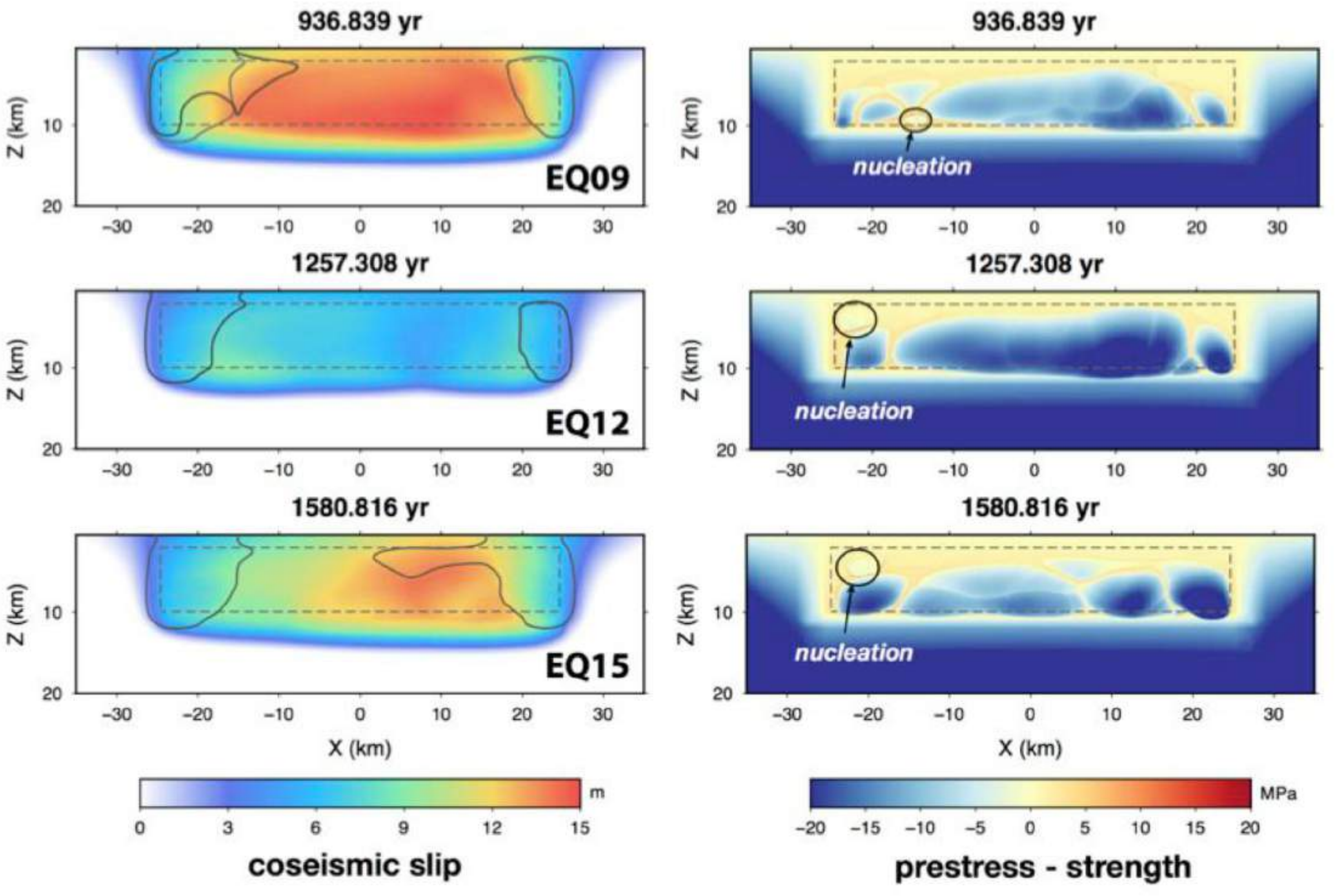
Tarnowski, 2017



Beyer et al., 2018

Ruptures - time dependence

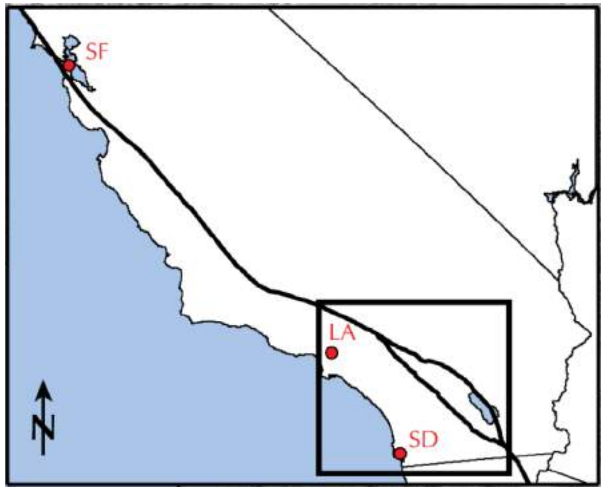
- Initial stress conditions
  - Time since last rupture event
  - Recent earthquakes – Landers (1992), 1812, 1726

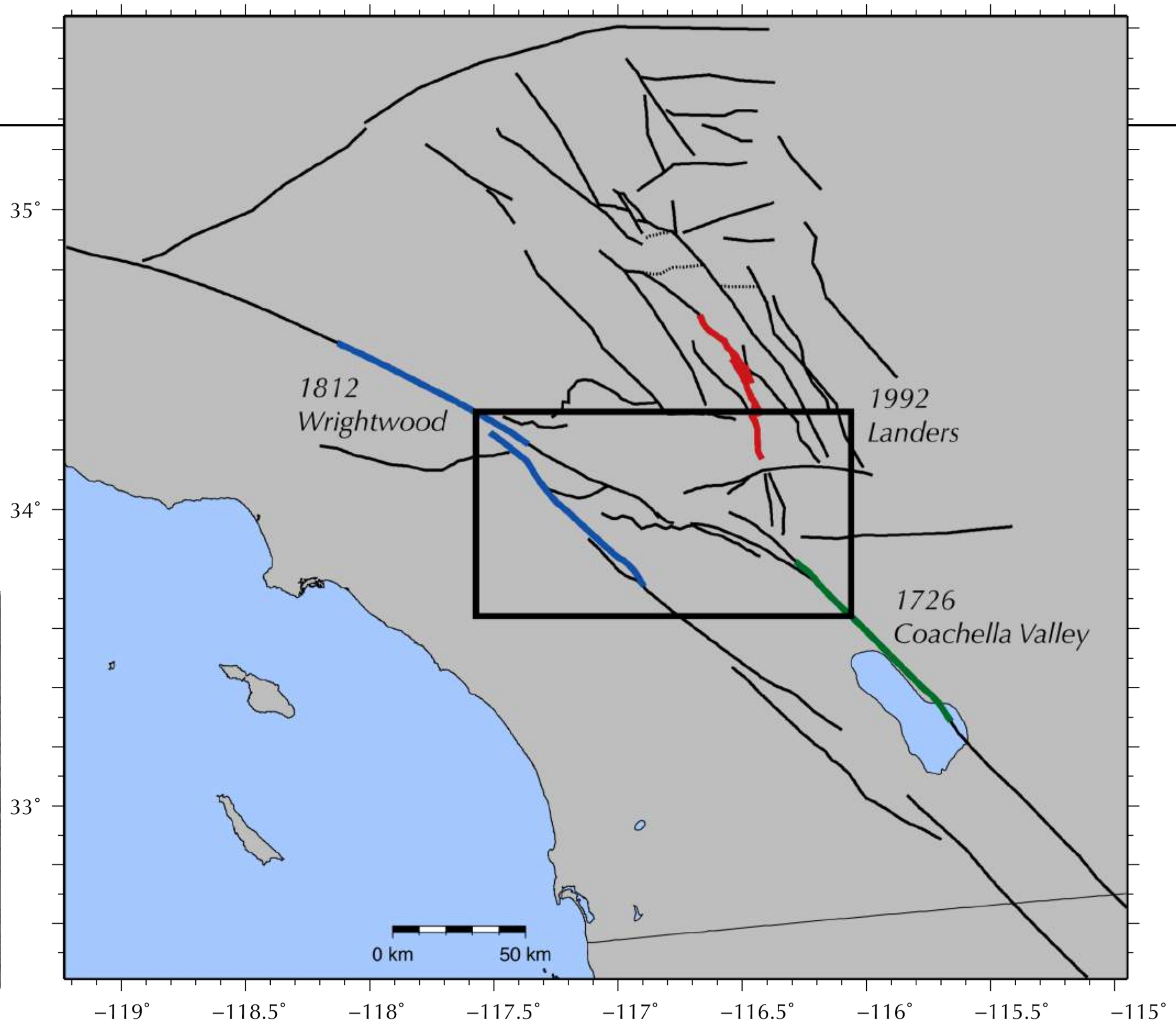


Jiang and Lapusta, 2015

The San Gorgonio Pass

- Restraining bend along the southern San Andreas.
- ‘Earthquake gate’
- Strands inside the pass have not ruptured since ~1400
- Other nearby earthquakes may impact stresses within the SGP



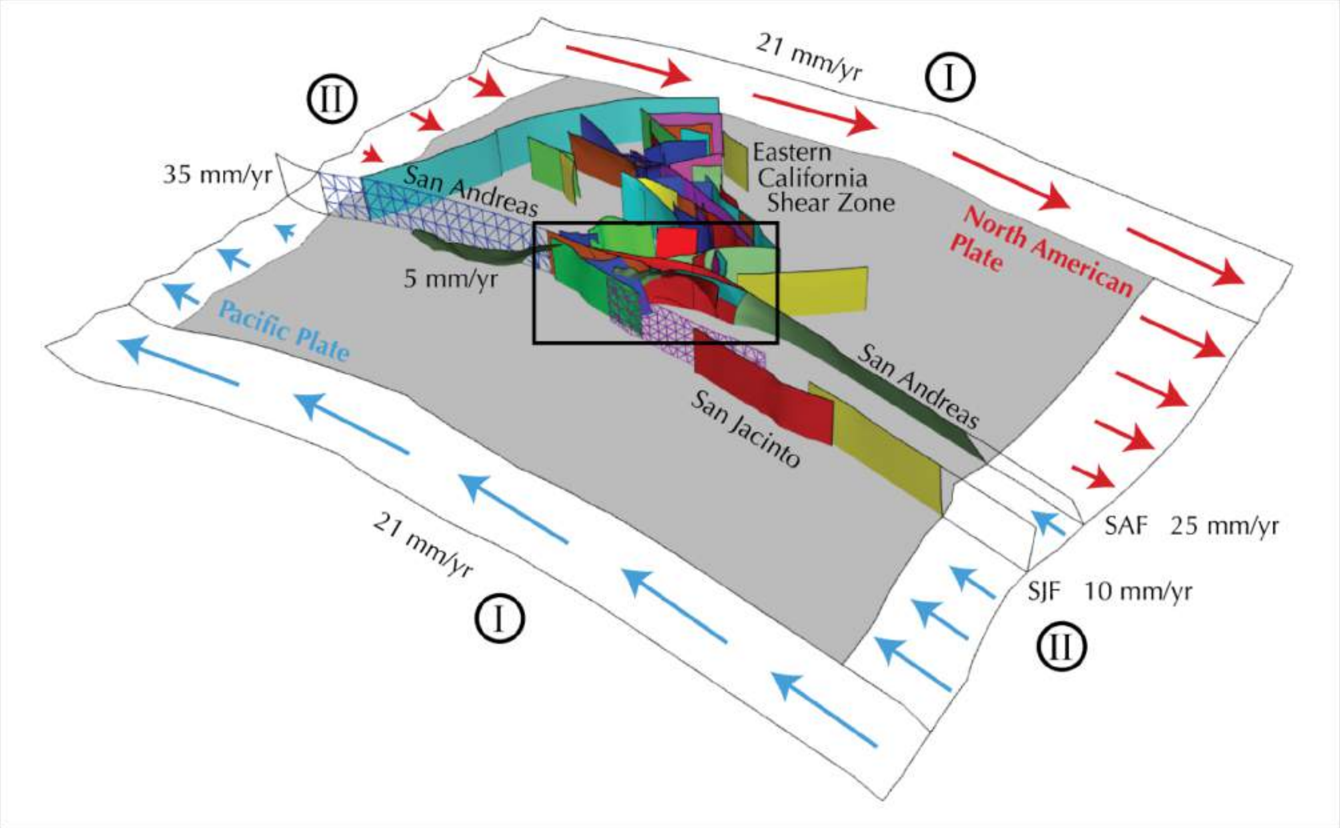


Methodology

- Poly3D: Three-dimensional Boundary Element Method code
  - Solves the equations of continuum mechanics
  - Discretizes boundaries and faults into linear triangular elements

- Faults from the SCEC Community Fault Model (Plesch et al, 2007)
- Plate motions applied at the edges of the model
- Faults are freely-slipping

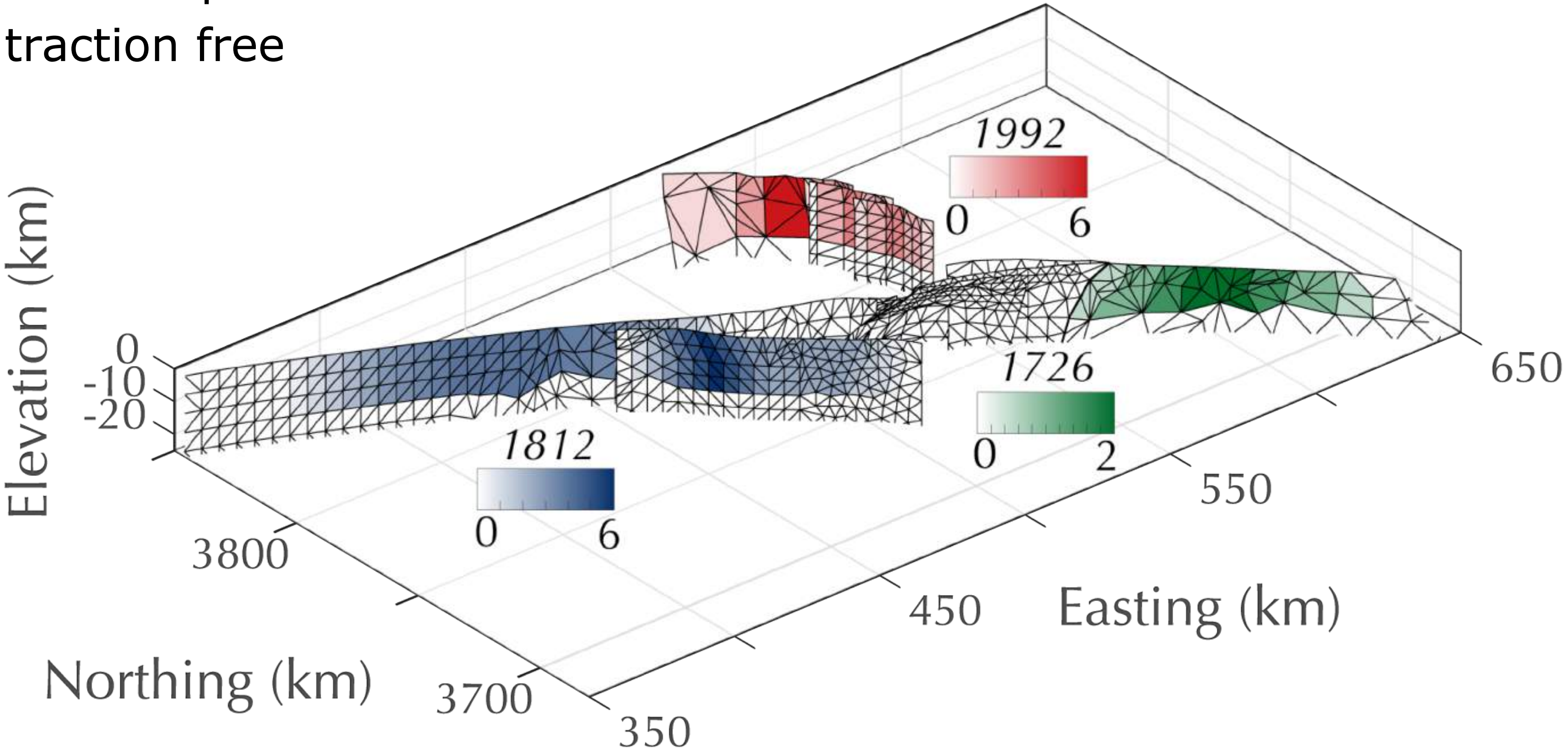
- Three step approach
  - Steady state models
  - Interseismic models
  - Coseismic models



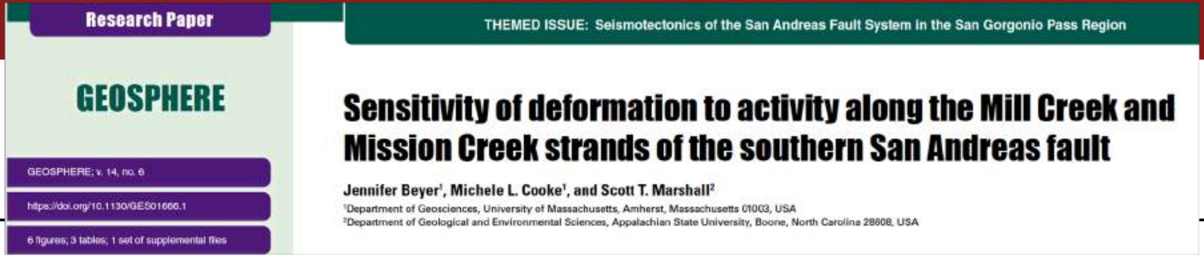
Effect of nearby earthquakes

- Slip is applied to the upper portion of faults involved in each rupture
- All other faults are traction free

Applied slip distributions (m)



Model Validation – slip rates


Research Paper

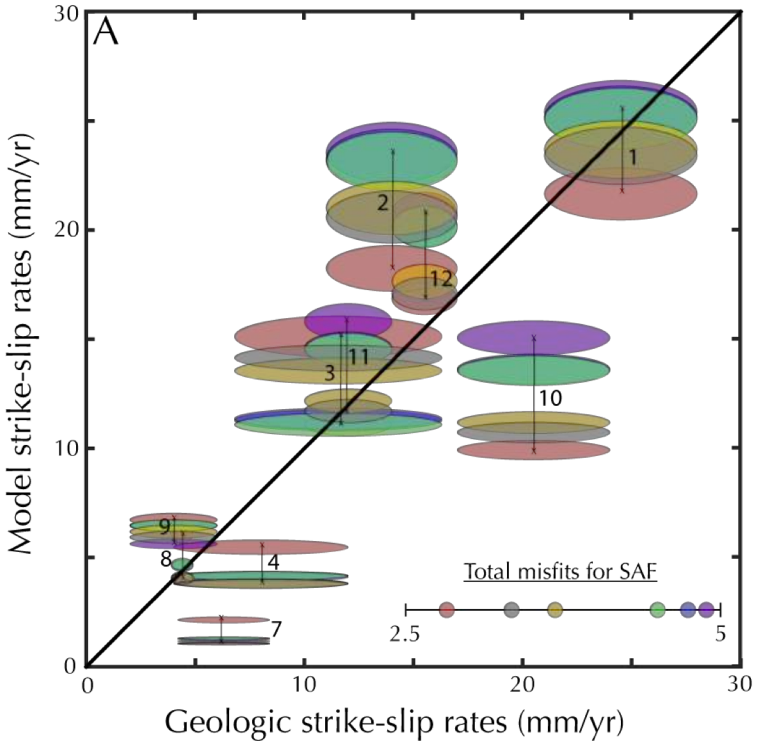
GEOSPHERE

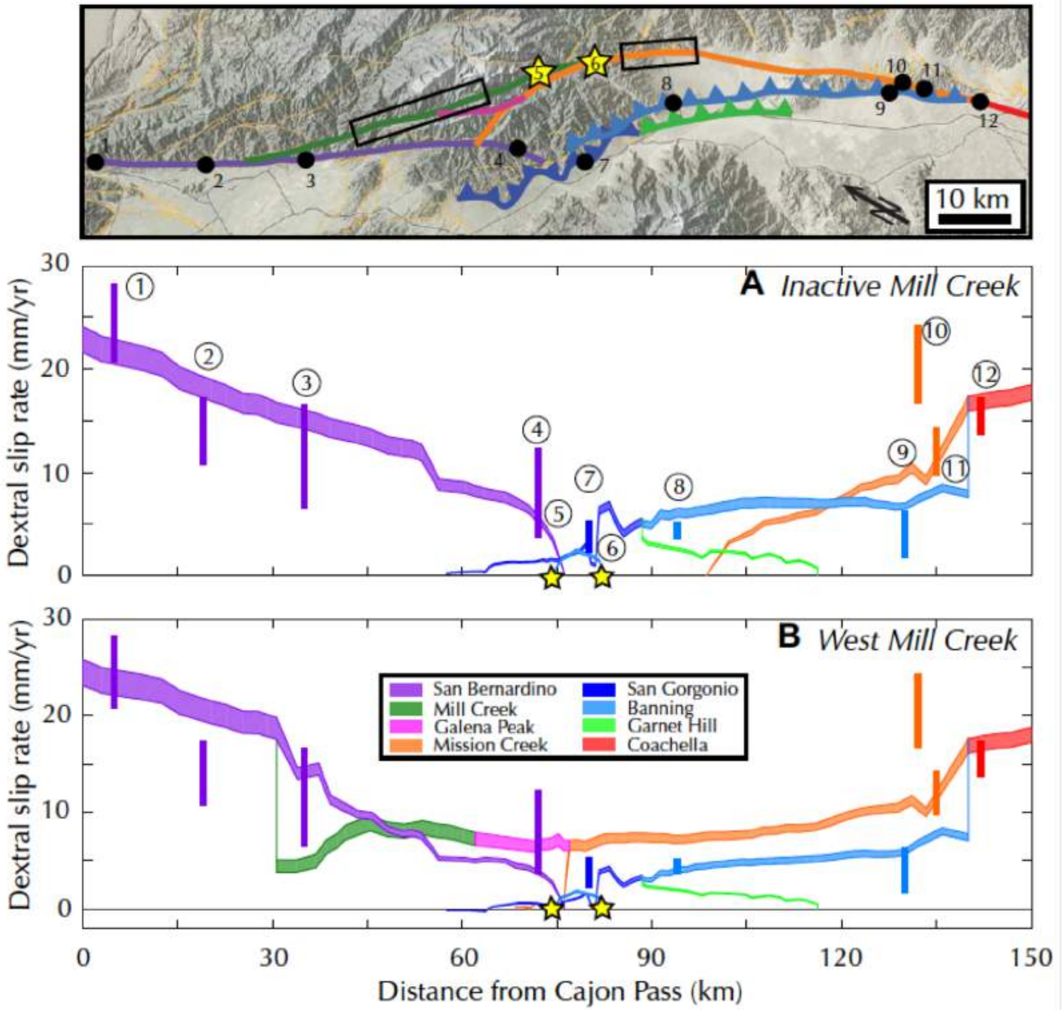
GEOSPHERE; v. 14, no. 6
https://doi.org/10.1130/GES01666.1
6 figures; 3 tables; 1 set of supplemental files
THEMED ISSUE: Seismotectonics of the San Andreas Fault System in the San Gorgonio Pass Region

Sensitivity of deformation to activity along the Mill Creek and Mission Creek strands of the southern San Andreas fault

Jennifer Beyer[1], Michele L. Cooke[1], and Scott T. Marshall[2]
[1]Department of Geosciences, University of Massachusetts, Amherst, Massachusetts 01003, USA
[2]Department of Geological and Environmental Sciences, Appalachian State University, Boone, North Carolina 28608, USA

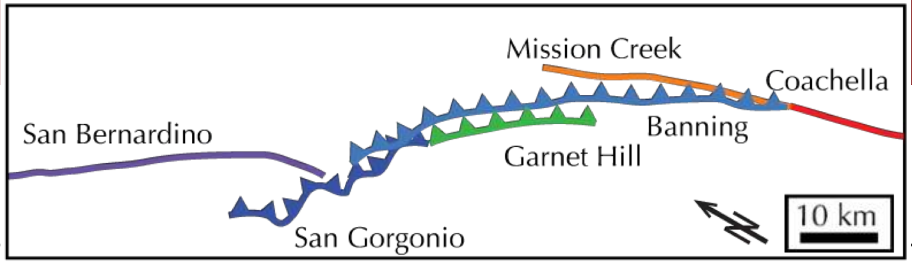
- Model slip rates from steady state models.
- Our models provide a good match to geologic slip rates
- 6 fault configurations tested
- 2 best-fit fault geometries

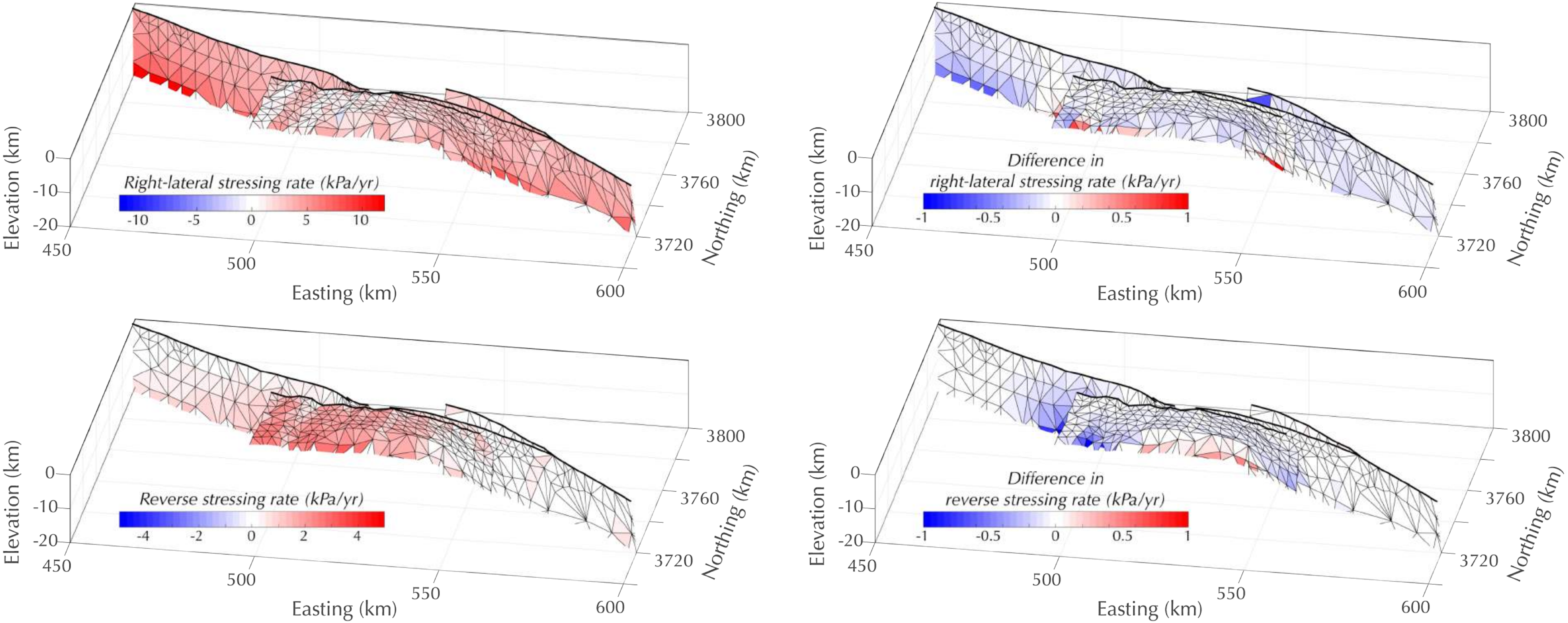




Beyer et al., 2018

Fault stressing rates

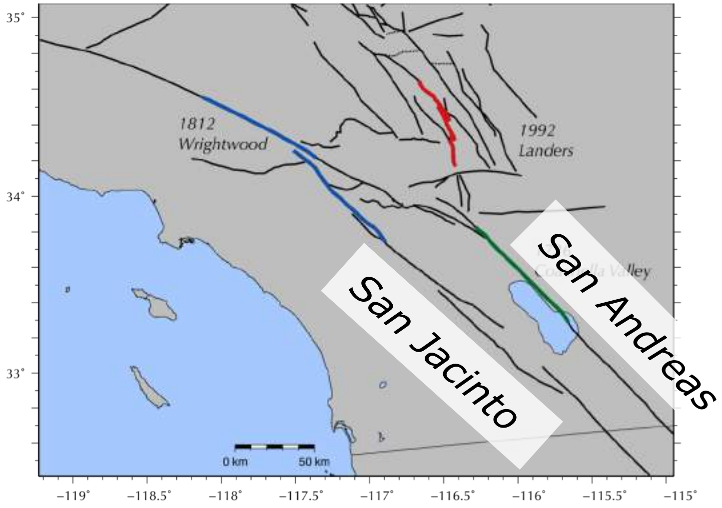


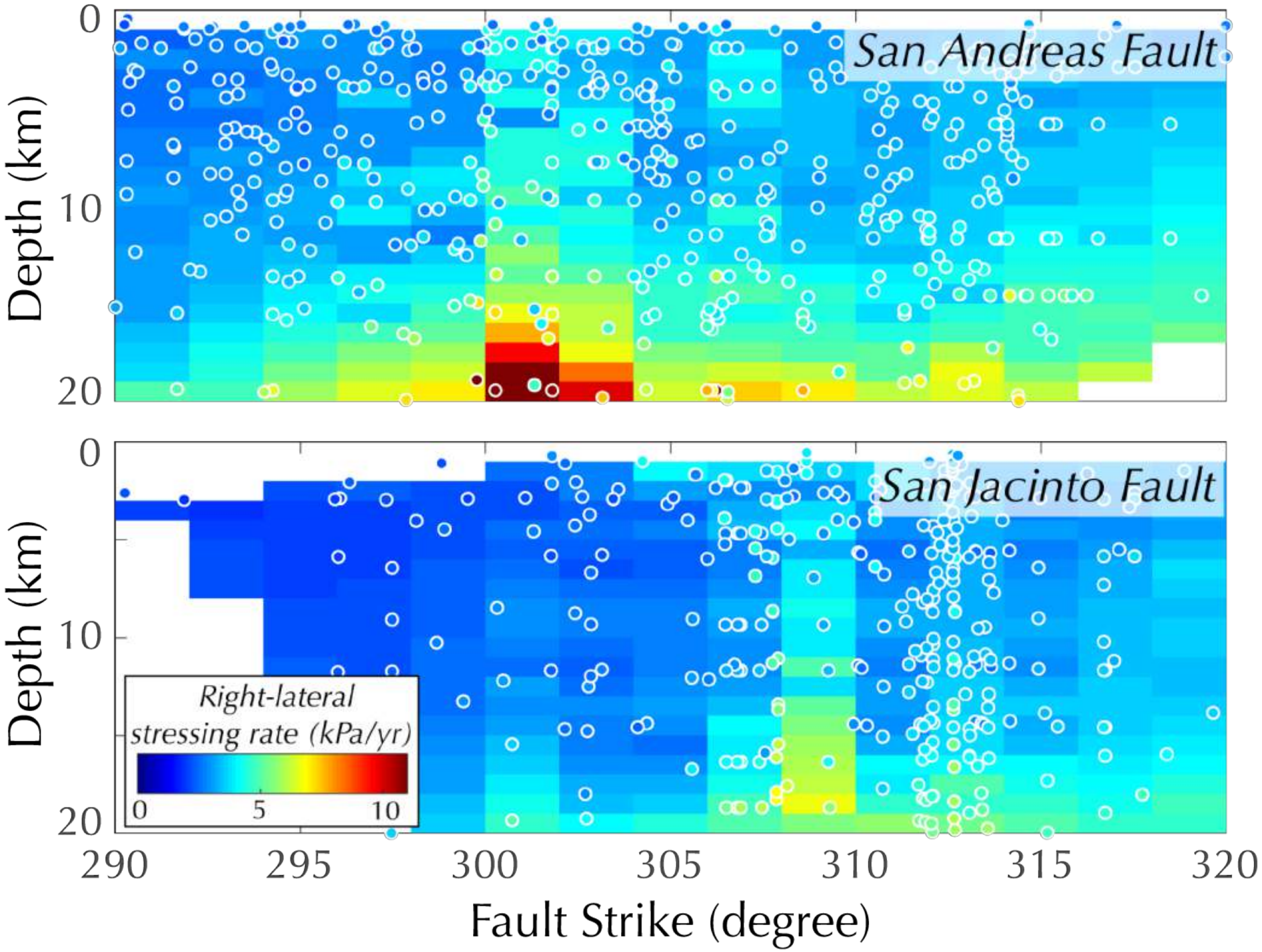


Stresses are impacted by fault interaction

- Resolving remote stress field results in the same on-fault stress for faults of similar orientation

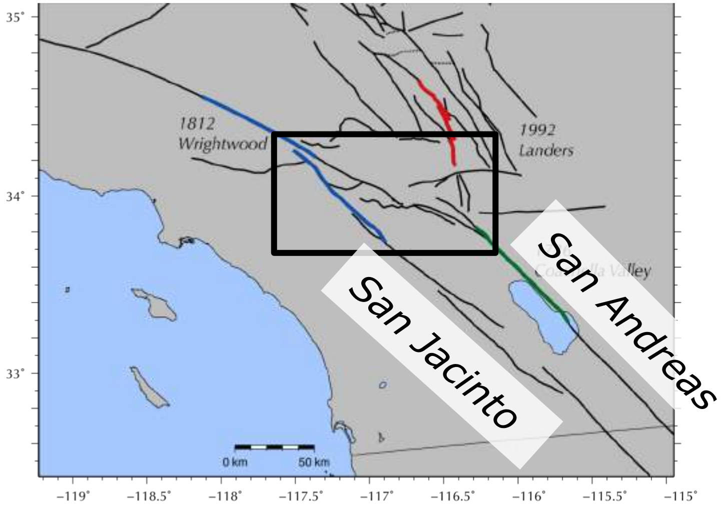
- Near proximity of the San Andreas and San Jacinto faults allows for fault interaction

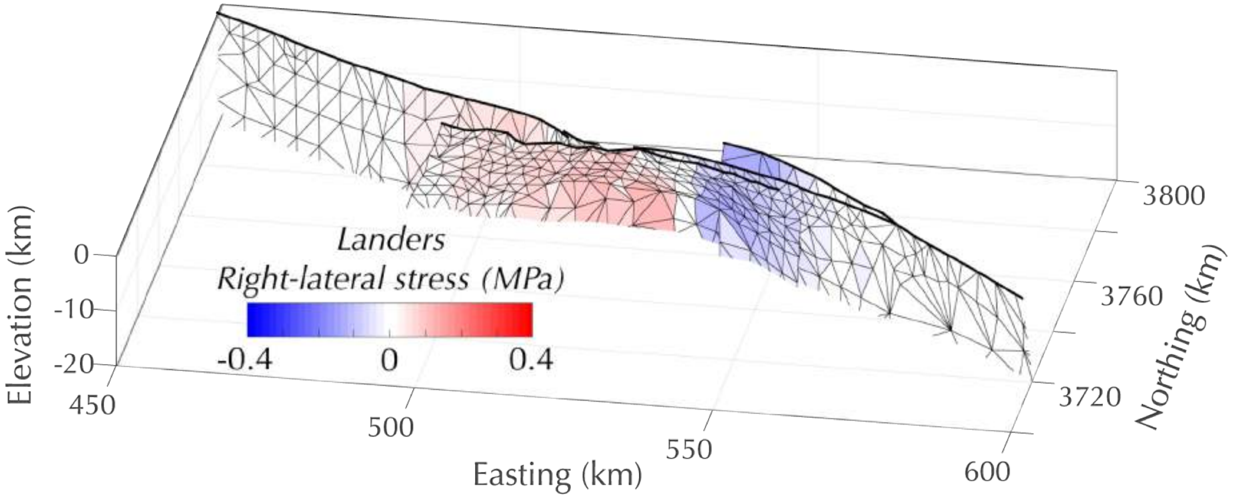


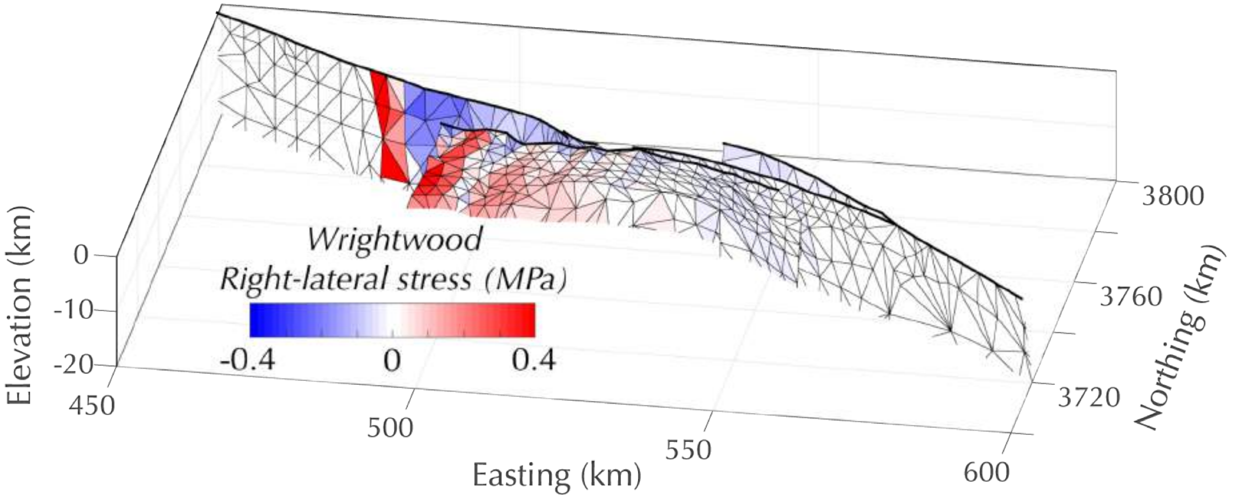


Impact of recent nearby earthquakes

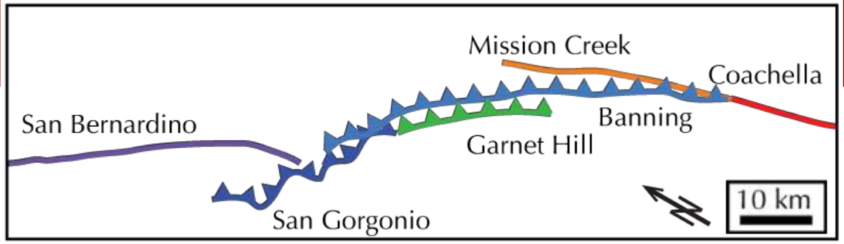
- Landers (1992)
  - right-lateral loading of the northern portion of the pass
  - left-lateral loading in the south
- Wrightwood (1812)
  - right-lateral loading of SGP thrust and just in front of rupture extent on San Bernardino strand
  - rest of SGP feels slight left-lateral loading





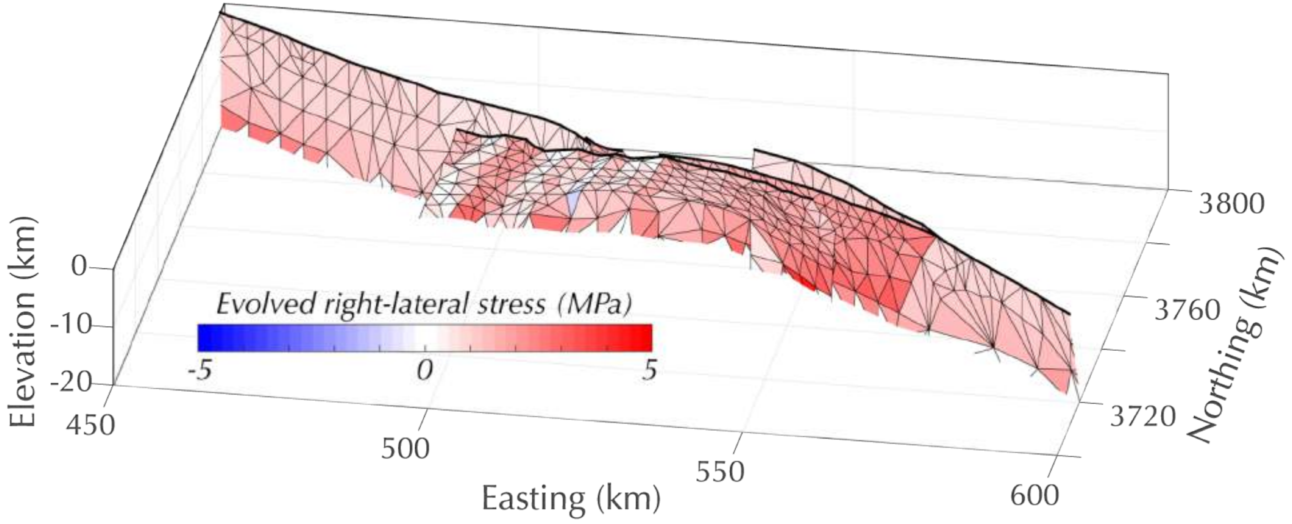


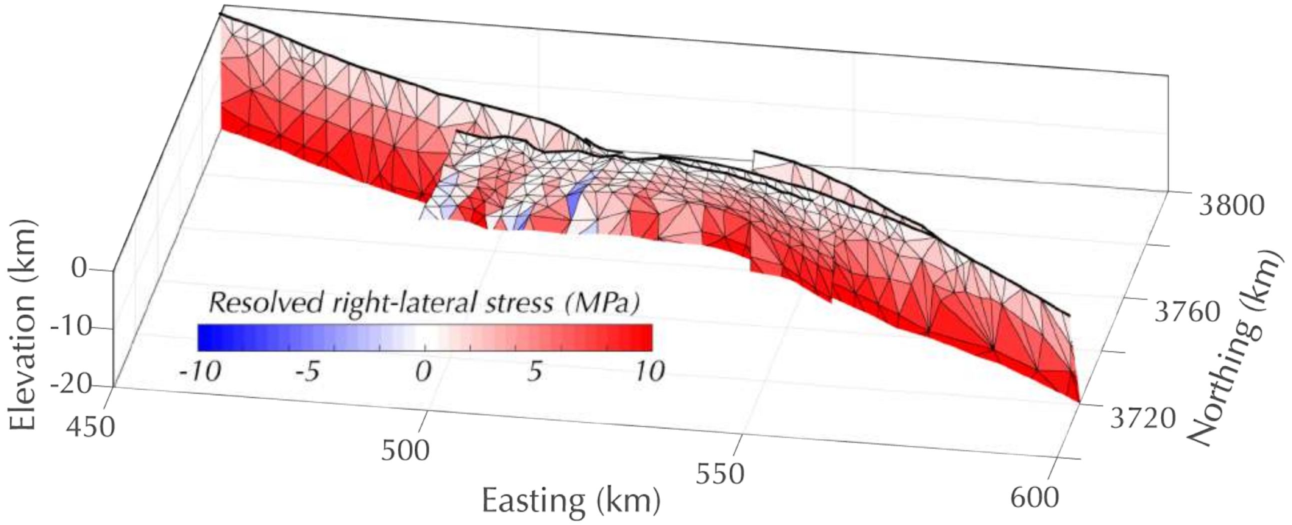
Total evolved fault stress



- Total evolved fault stress
- Includes effects of:
  - fault interaction
  - nearby earthquakes
  - *assumes complete stress drop*

Don't resolve 'em…
EVOLVE 'em!



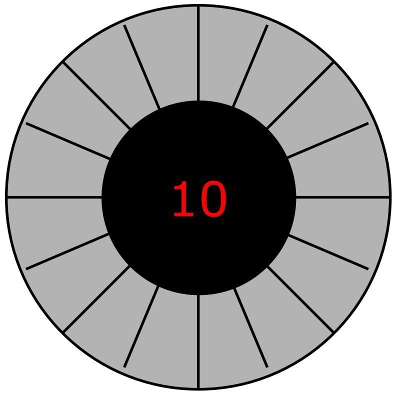


Stresses for dynamic rupture modelers

2019 Evolved stresses

Loading on the faults up until present day – includes fault interaction and impact of recent earthquakes

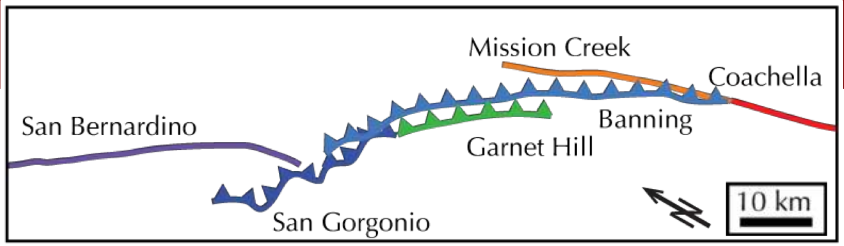
Stressing Rates x



Years into the future

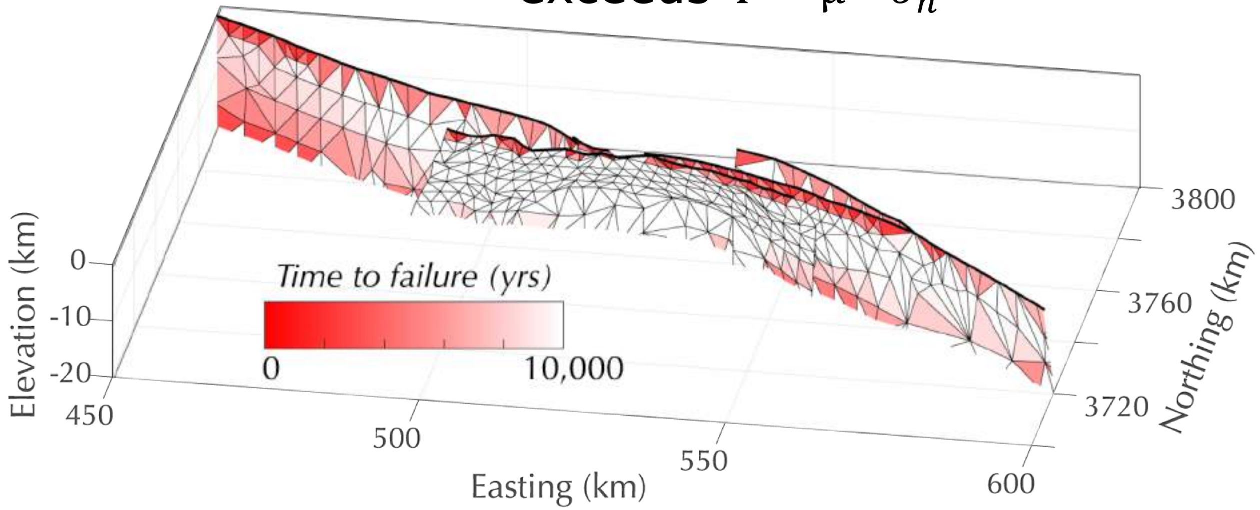
Allows dynamic rupture modelers to bring faults to rupture

Future fault stresses

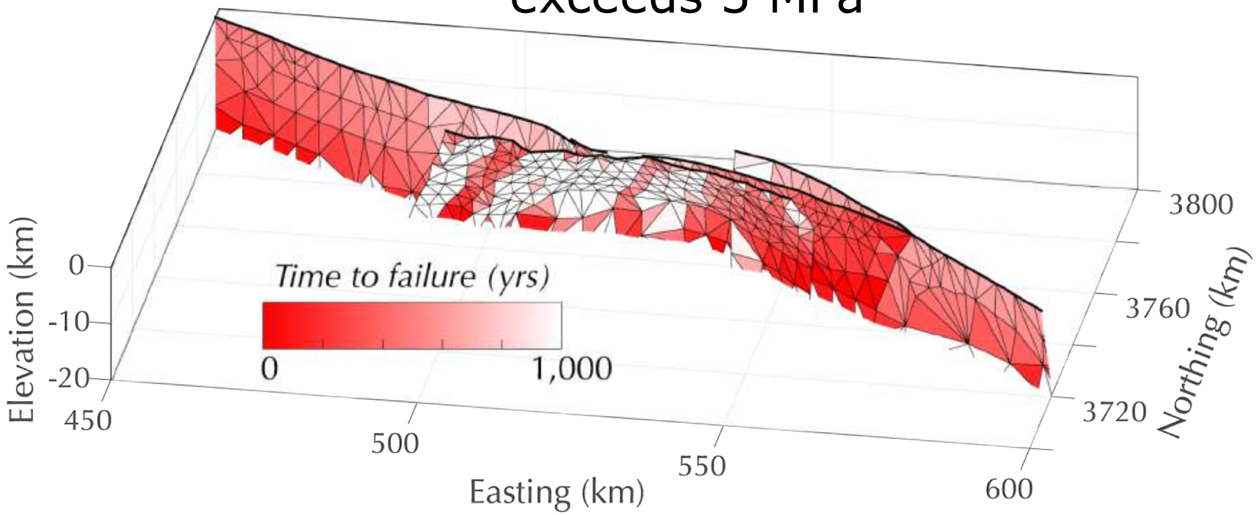


- Calculate fault stresses using stressing rates and time since last event on each fault

Failure when element exceeds $\tau = \mu * \sigma_n$



Failure when element exceeds 3 MPa



On-going stress projects in the SGP

- Investigation of off-fault stresses using focal mechanisms


AGU100 ADVANCING EARTH AND SPACE SCIENCE

Geophysical Research Letters

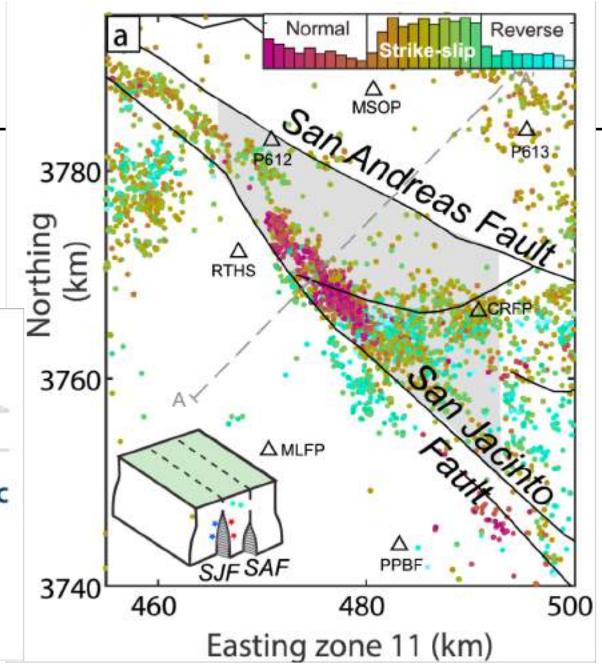
RESEARCH LETTER
10.1029/2018GL078932

Key Points:
- Crustal deformation models demonstrate the plausibility of deep creep along the northern San Jacinto fault to account for nearby enigmatic normal slip mechanisms

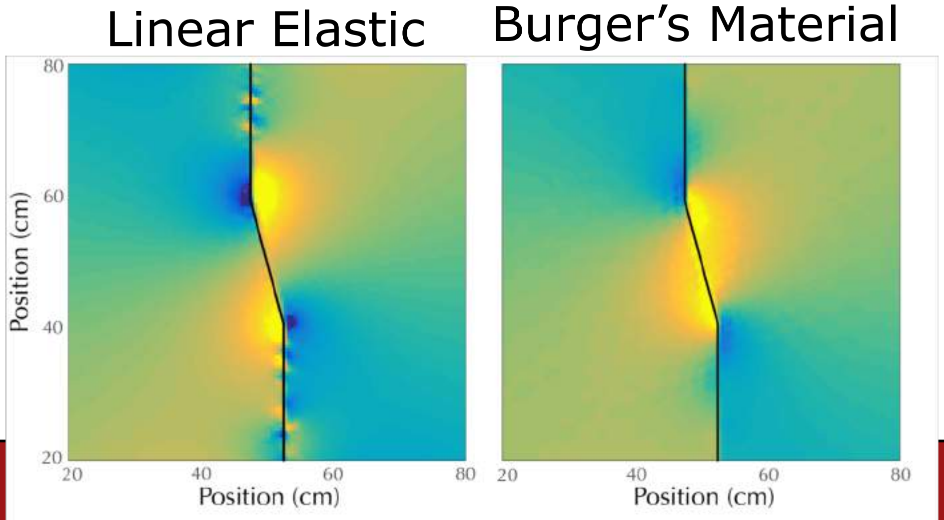
Off-Fault Focal Mechanisms Not Representative of Interseismic Fault Loading Suggest Deep Creep on the Northern San Jacinto Fault

M. L. Cooke[1] and J. L. Beyer[1]

[1]Geosciences Department, University of Massachusetts Amherst, Amherst, MA, USA

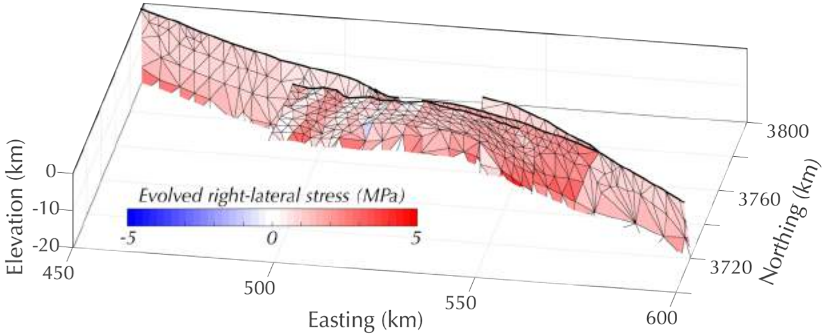


- New finite element models in COMSOL Multiphysics explore the effects of rheology



Summary

- 3D crustal deformation models provide interseismic stressing rates
- Faults of similar orientation have different fault stresses due to interaction with nearby faults
- Fault stresses are calculated using the TSLE of each fault
- Evolved fault stresses include:
  - effects of fault interaction and recent nearby earthquakes
  - a linear gradient with depth – consistent with being loaded at depth



- Implications:
  - Complete stress drop after rupture events may be unrealistic