SCEC Statewide California Earthquake Center

2026 SCEC SHAKEOUT SCENARIO 2.0 WORKSHOP

Dynamic rupture model basis and results

Ahmed Elbanna & Chunhui Zhao

Oct 6th, 2026

It takes a COMMUNITY!

ShakeOut Scenario 2.0 Modeling: Led by SCEC HQ but It takes a COMMUNITY!

SCEC HQ	USGS	SeisSol
Chunhui Zhao	Rob Graves	Fabian Kutschera
Kristen Chiama	Kate Scharer	David Schneller
Xiaofeng Meng	Ruth Harris	Alice Agnes-Gabriel
Fabio Silva	Michael Barall	
Mei-Hui Su	Jeanne Hardebeck	
Scott Callaghan		
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Additional contributors — Andreas Plesch • Scott Marshall • Craig Nicholson • Karen Luttrell • Sylvain Barbot Alexis Ault • Caroline Syler • Kim Olsen • SCEC SURE Interns (Tomoka Yanao, Clare Ip, Ashley Seeman, Laura Garnet-Jones)

Special Thank You to: Lars Koesterke (Texas advanced computing center)

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Why now technically?

What has changed since the original ShakeOut?

The scientific ecosystem has significantly advanced.

COMPUTE

10^4 ×

more leading-edge capability

COMMUNITY EARTH MODELS

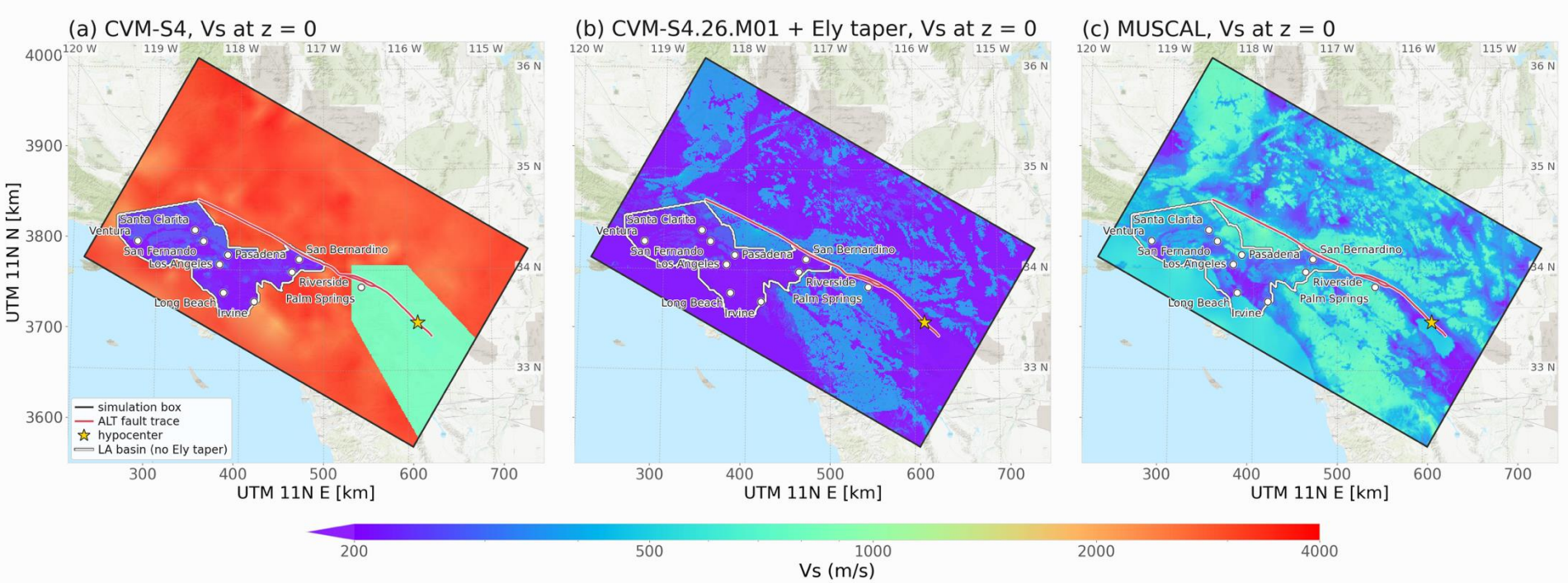
CEMs

Mature faults, rocks, stresses, thermal constraints

OBSERVATIONS

AI

continuous data revealing hidden structure at higher resolution

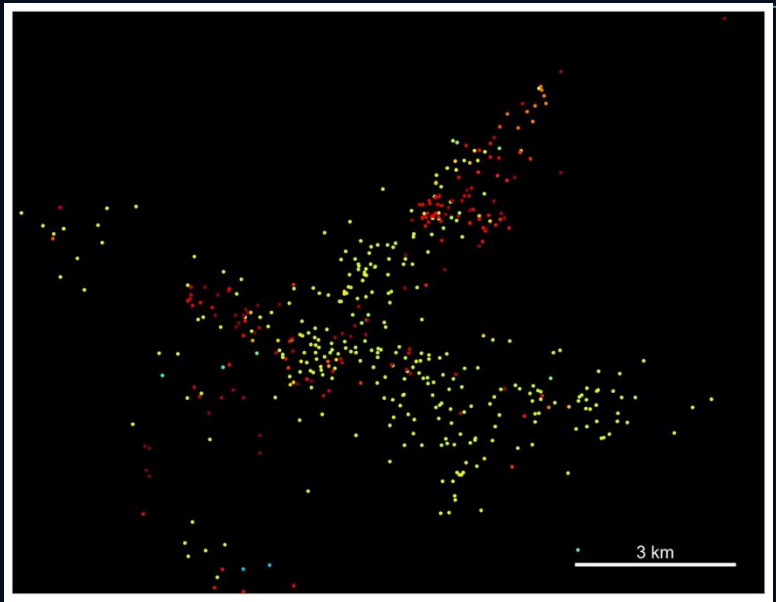


Magistrale et al., 2000; Kohler et al., 2003; Lee et al., 2014; Taborda et al., 2016; Yeh et al., 2026

AI Already Reveals Hidden Earthquake Structure

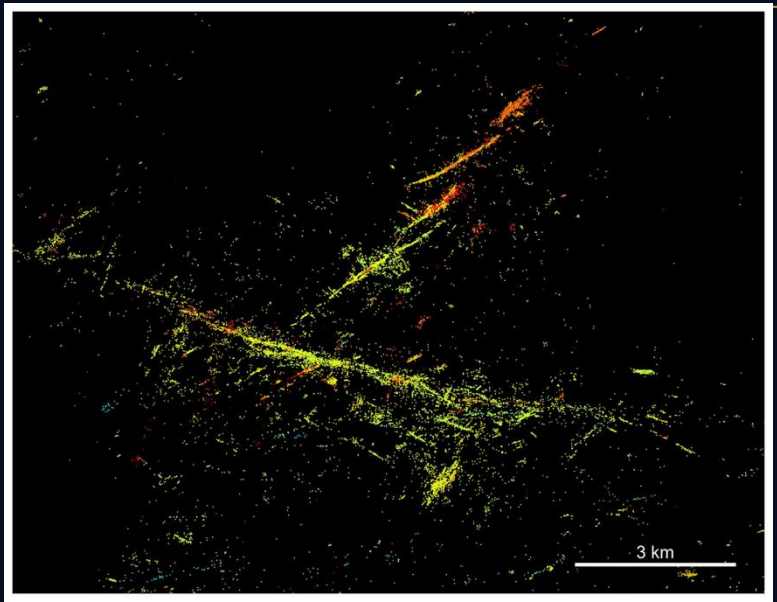
TRADITIONAL CATALOG

Known earthquakes detected by standard methods



AI-ENHANCED DETECTION

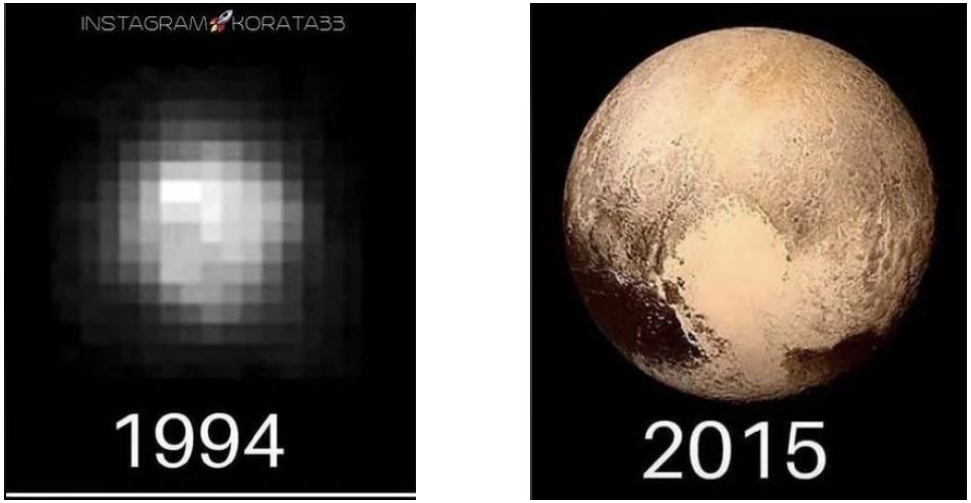
Earthquakes detected with AI from continuous data



AI has already revealed an order of magnitude more earthquake activity than traditional detection.

Figure courtesy of Yongsoo Park

Earthquake Science is Having its Pluto Moment!



Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

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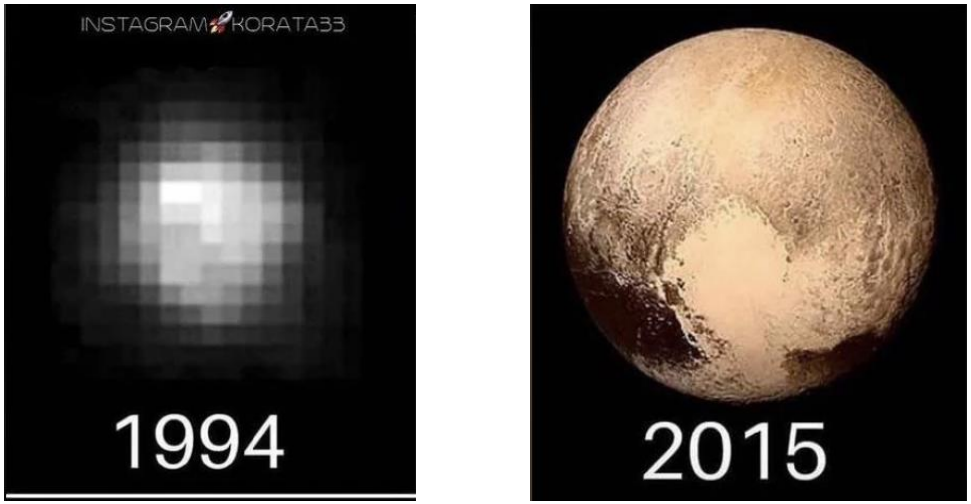

Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Southwest Research Institute

SOS2.0 capitalizes on this moment!

The Foundations of SOS2.0

Validated SCEC Community Earth Models

faults • velocity • stress • thermal constraints

+

Laws of Physics

dynamic rupture • wave propagation • nonlinear material response

+

State-of-the-Art HPC

scalable simulation • rapid iteration

=

SOS2.0

a physics-based scenario for the Southern San Andreas to inform hazard, engineering, and resilience applications

Leverages 20 years of SCEC Dynamic Rupture Verification and two decades of Southern San Andreas rupture science*

*Bazán Flores et al., 2024; Douilly et al., 2020; Ely et al., 2010; Kyriakopoulos & Oglesby, 2024; Kyriakopoulos et al., 2019, 2021; Liu et al., 2022; Lozos, 2016; Meng et al., 2025; Olsen et al., 2008, 2009; Roten et al., 2017, 2023; Tarnowski et al., 2022

Overview

MODEL BASIS

01	02	03	04	05
Geometry	Velocity	Rheology	Stress	Friction

SIMULATION

06 Model setup

07 Preliminary results

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Geometry

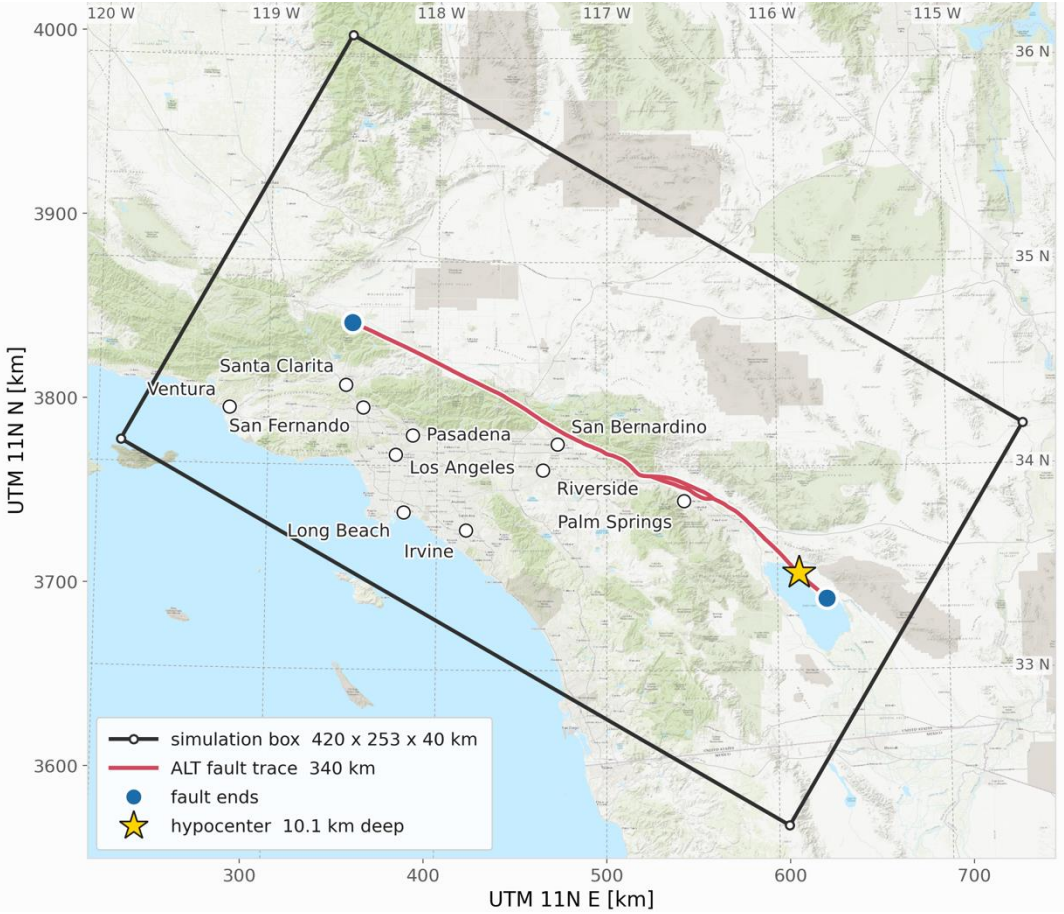
- **SIMULATION DOMAIN**
- FAULT GEOMETRY

FAULT ENDS

NW end
34.698495 N, 118.508948 W
SE end
33.350090 N, 115.711920 W

HYPOCENTER

Location
33.47557 N, 115.87587 W
Depth
10.068 km



Geometry

SIMULATION DOMAIN

FAULT GEOMETRY

FAULT MODEL

Source

SCEC Community Fault Model ALT 7.0

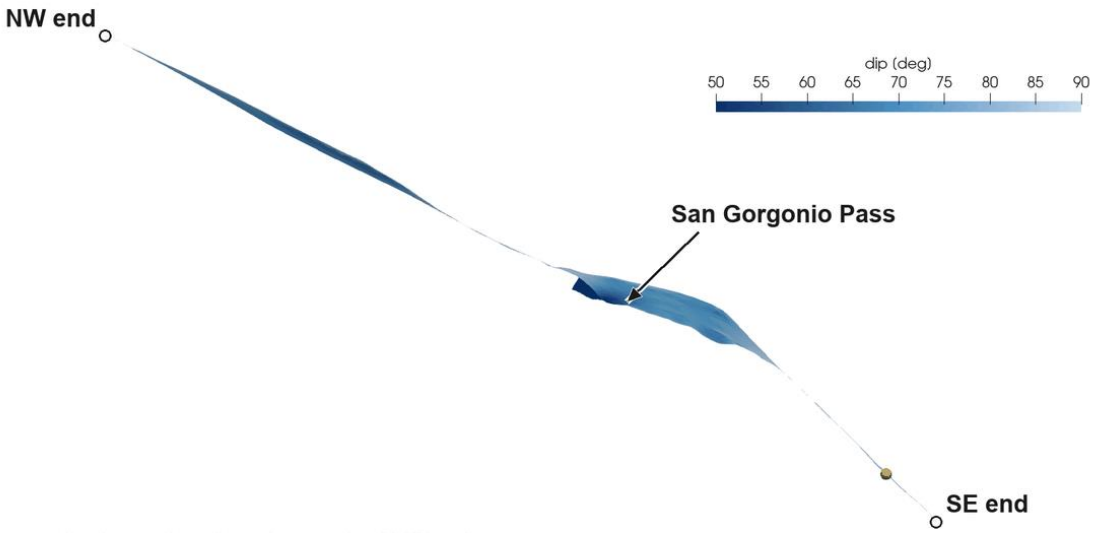
Depth

20 km (full depth)

Geometry

Mostly vertical, with dip-slip expected around San Gorgonio Pass.

Plesch et al., 2007; Plesch et al., 2024



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01 **Geometry**

02 Velocity

03 Rheology

04 Stress

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Velocity

VELOCITY MODEL

Source

SCEC Community Velocity Model

Model

CVMS4.26-M01 + Ely taper

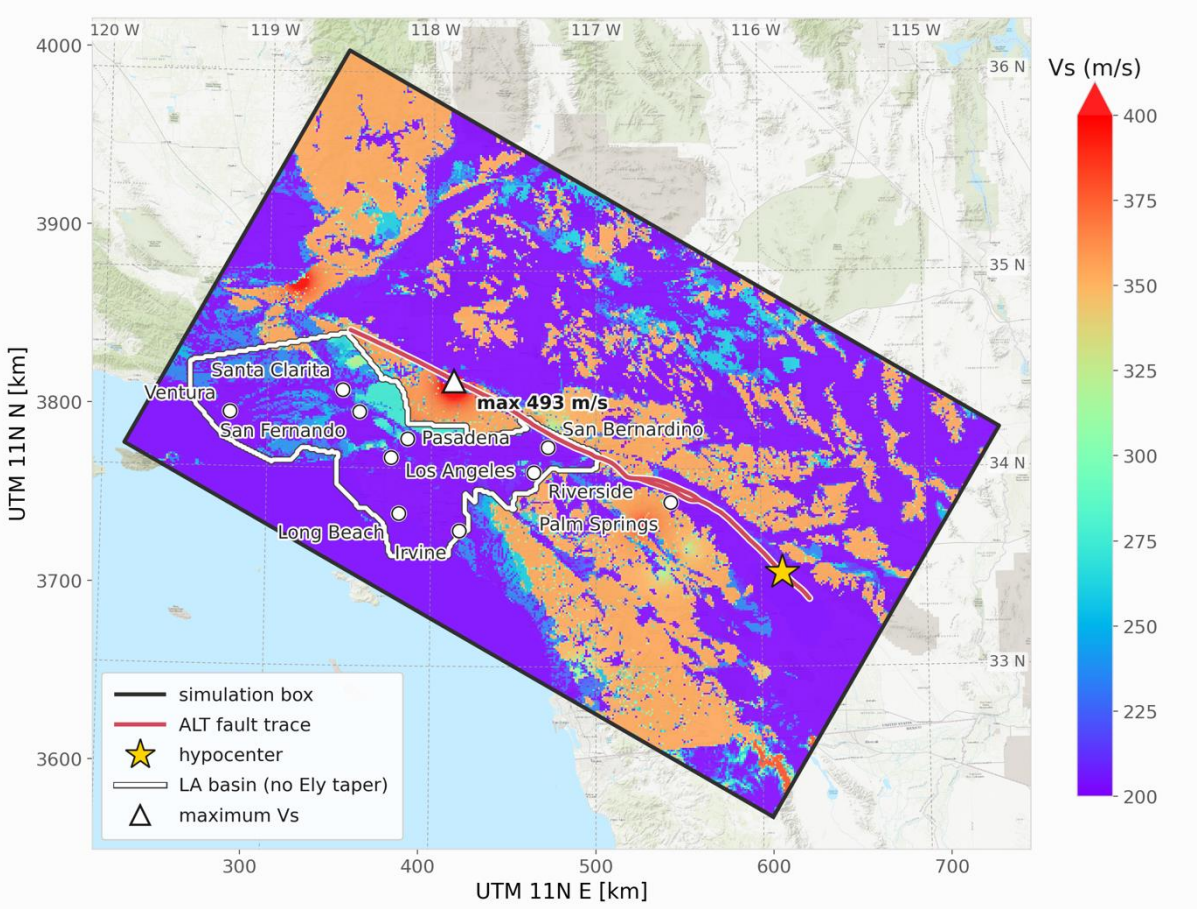
Ely taper

Applied outside the LA basin only, up to 700 m

Minimum Vs

200 m/s (capped)

Lee et al., 2014; Taborda et al., 2016



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Rheology

PLASTICITY

Rheology

Drucker-Prager visco-plastic

Cohesion

$c = 10^{-4}\ \mu$

Friction angle (spatially distributed)

$\phi = 30^o\ (V_s < 2.5\text{km/s})$

$\phi = 40^o\ (V_s \geq 2.5\text{km/s})$

Roten et al., 2014; Wollherr et al., 2018

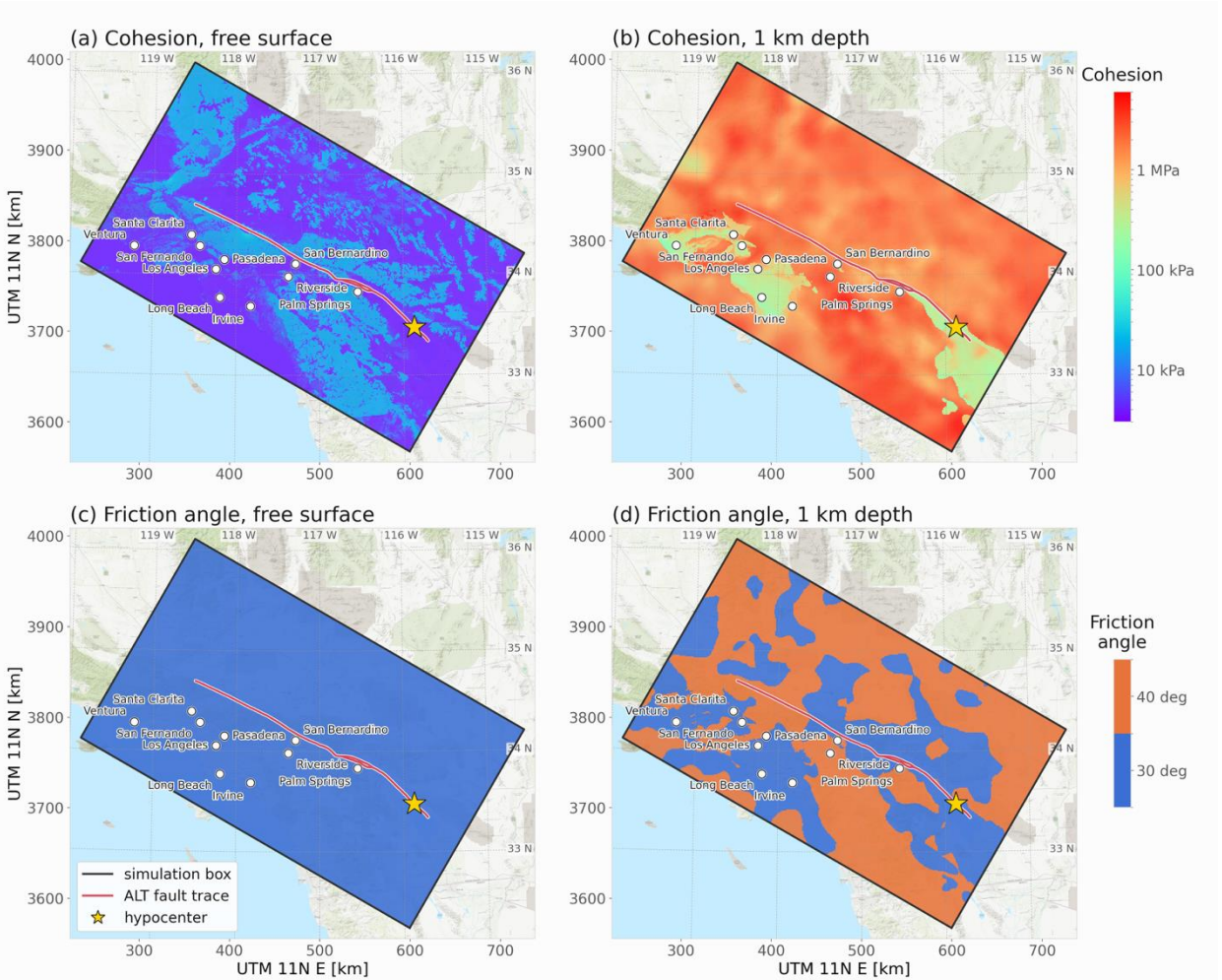
VISCOELASTIC ATTENUATION

Q relations

$Q_s = 0.5\ Q_p$

$Q_s = 0.05\ V_s\ [\frac{m}{s}]$

Olsen et al., 2009; Käser et al., 2007



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Stress

STRESS MODEL

Community Stress Model

Parameters

SHmax azimuth angle θ

Shape ratio $R = (\sigma_1 - \sigma_2)/(\sigma_1 - \sigma_3)$

Fault parameter A_ϕ (rank of S_v)

Yang and Hauksson, 2013

ASSUMPTIONS

Stress ratio

Assume uniform $k = \sigma_1/\sigma_3$

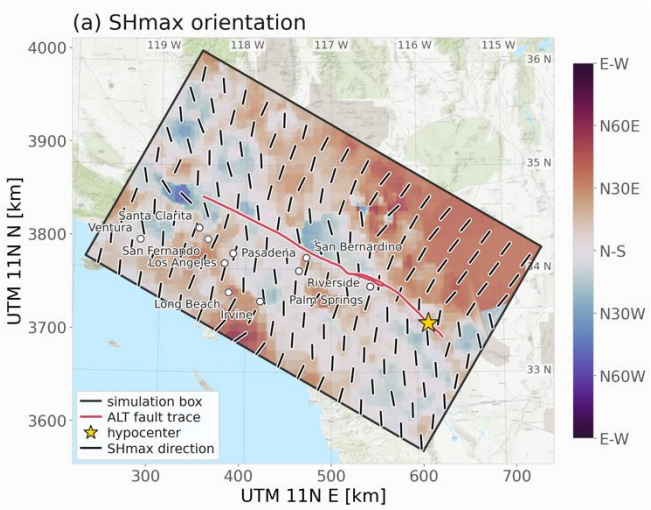
Andersonian stress state

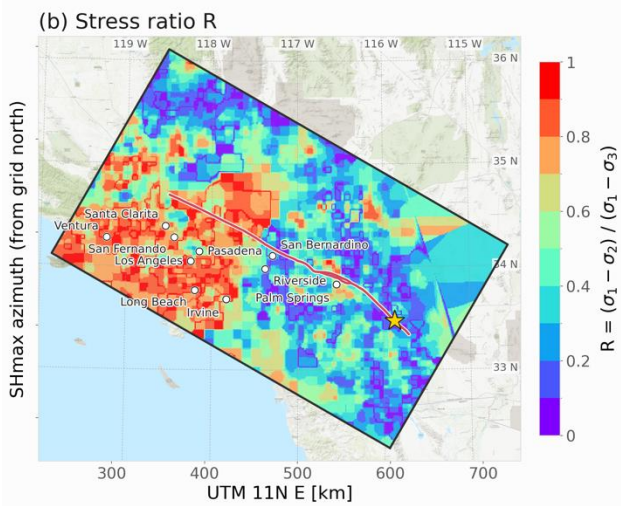
Sv vertical; SHmax, Shmin horizontal

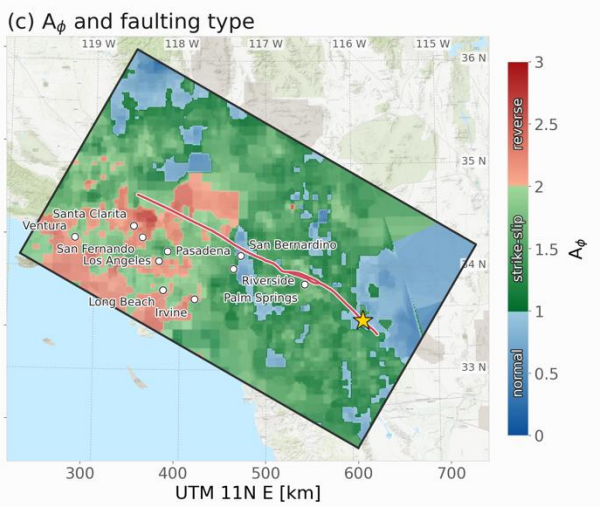
OUTPUTS

Full-field stress tensor

On-fault tractions after projection







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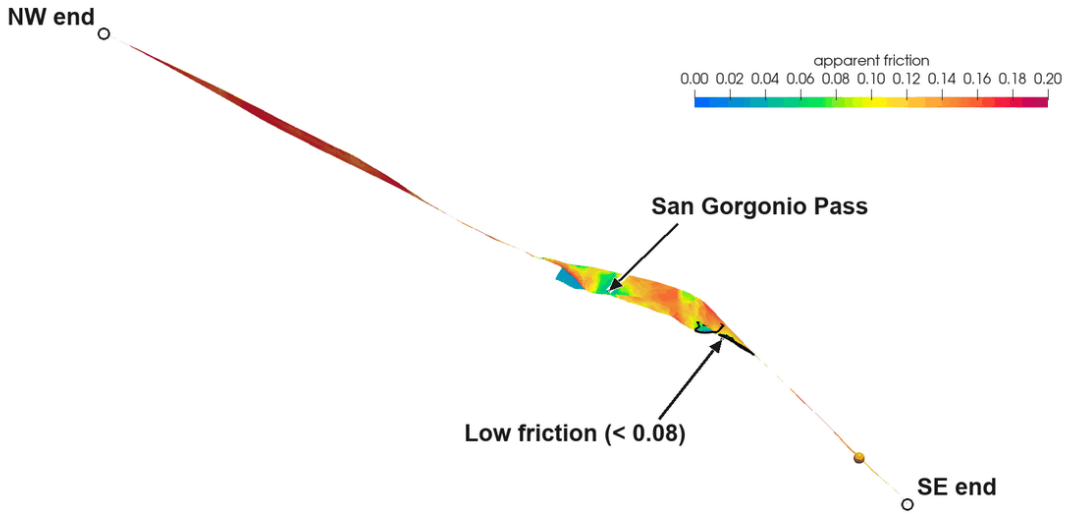

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Friction

FRICTION LAW

Rate-and-state friction
with strong rate weakening

Rice, J. R., 2006; Noda, Dunham & Rice, 2009

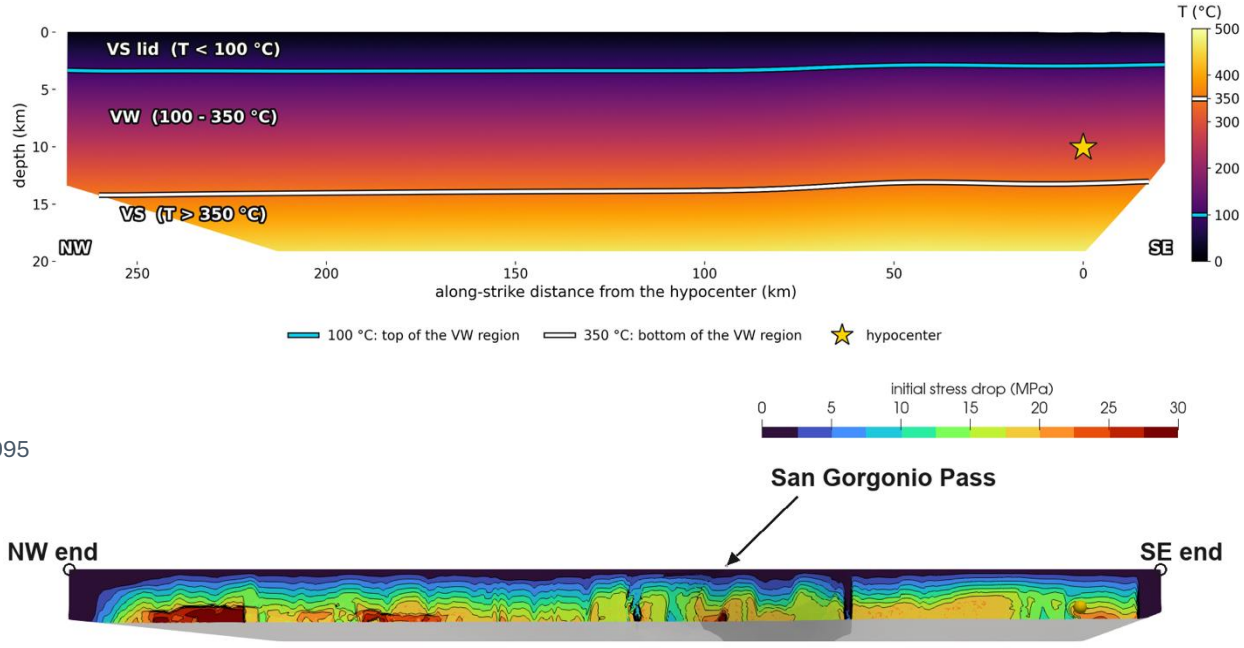
VELOCITY-WEAKENING REGION

Community Thermal Model determines boundaries of velocity weakening/strengthening region

Thatcher et al., 2020; Tse & Rice, 1986; Blanpied et al., 1995

CALIBRATION

Adjust stress drop (perturb residual friction) to ensure *full length propagation* and *target earthquake magnitude* *(Mw ~ 7.8)*



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RUPTURE SIMULATOR

SeisSol

master v1.3.1-2778-ge908ec54a

POLYNOMIAL ORDER

p5

O6 accuracy

MESH

~200M

tetrahedral elements

RESOLVED FREQUENCY

1 Hz

minimum

COMPUTATION

2,048 nodes · 110,592 threads (Frontera TACC) Dan et al., 2020

~80 hours wall-clock, 160k node-hour

Ulrich et al., 2019; Pelties et al., 2014; Breuer et al., 2016; Uphoff et al., 2017; Uphoff & Bader, 2020; Gabriel et al., 2025

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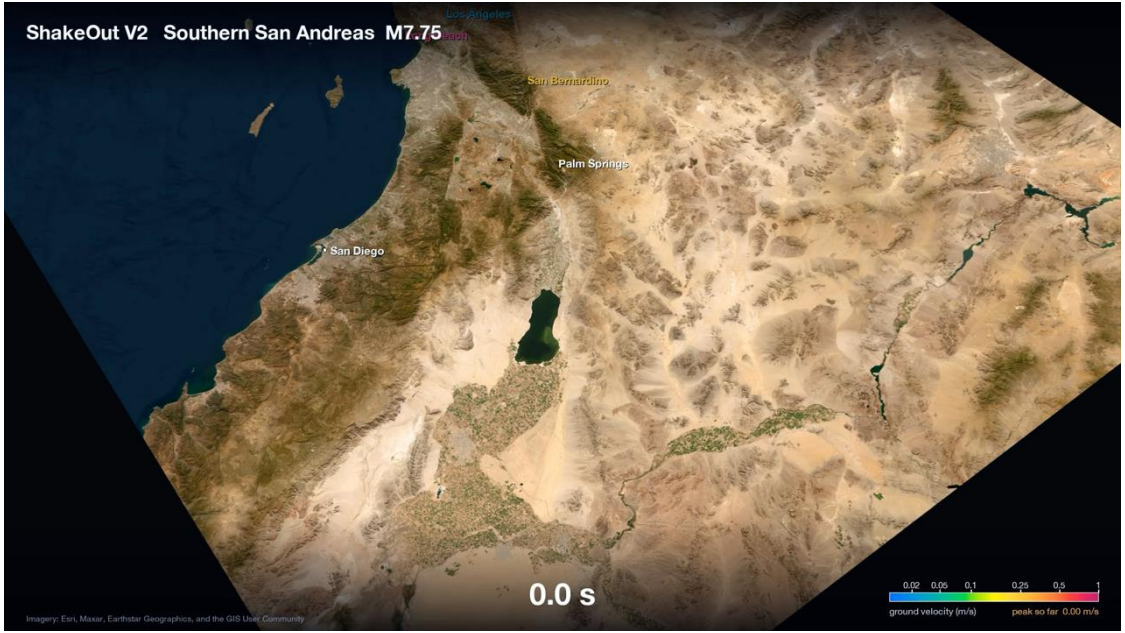
- ATTENUATION
- ON-FAULT QUANTITIES



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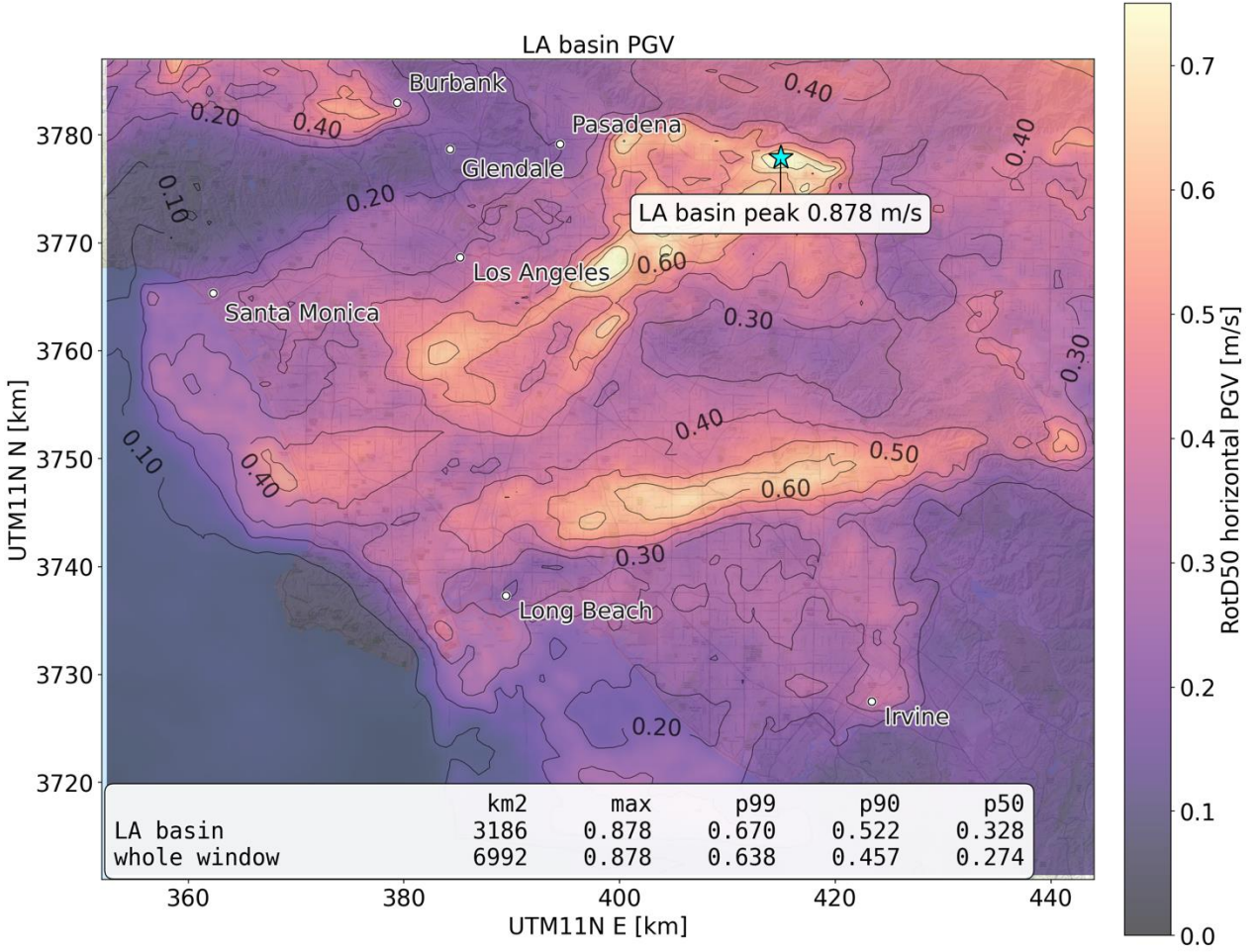

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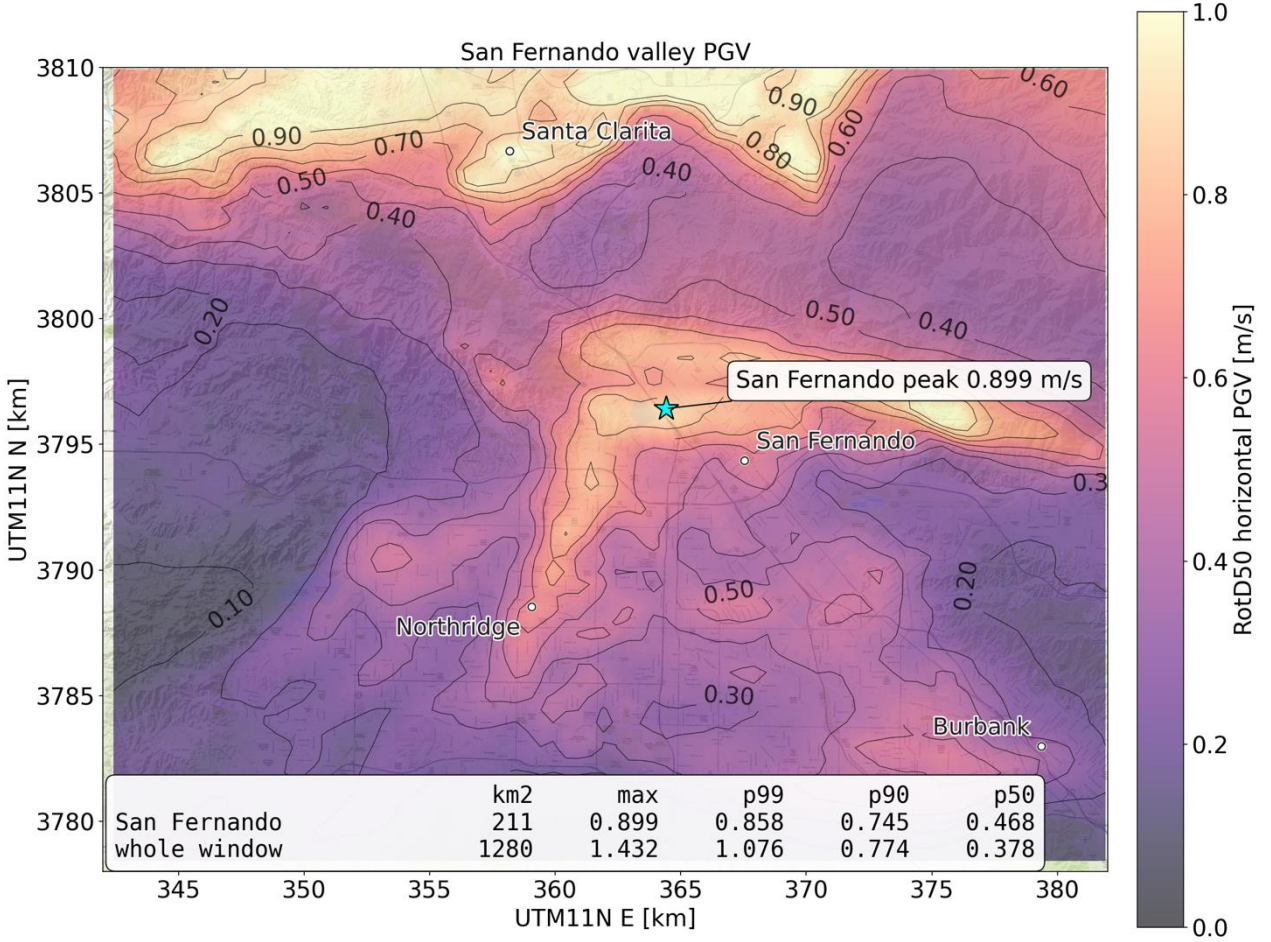

	km2	max	p99	p90	p50
San Fernando	211	0.899	0.858	0.745	0.468
whole window	1280	1.432	1.076	0.774	0.378

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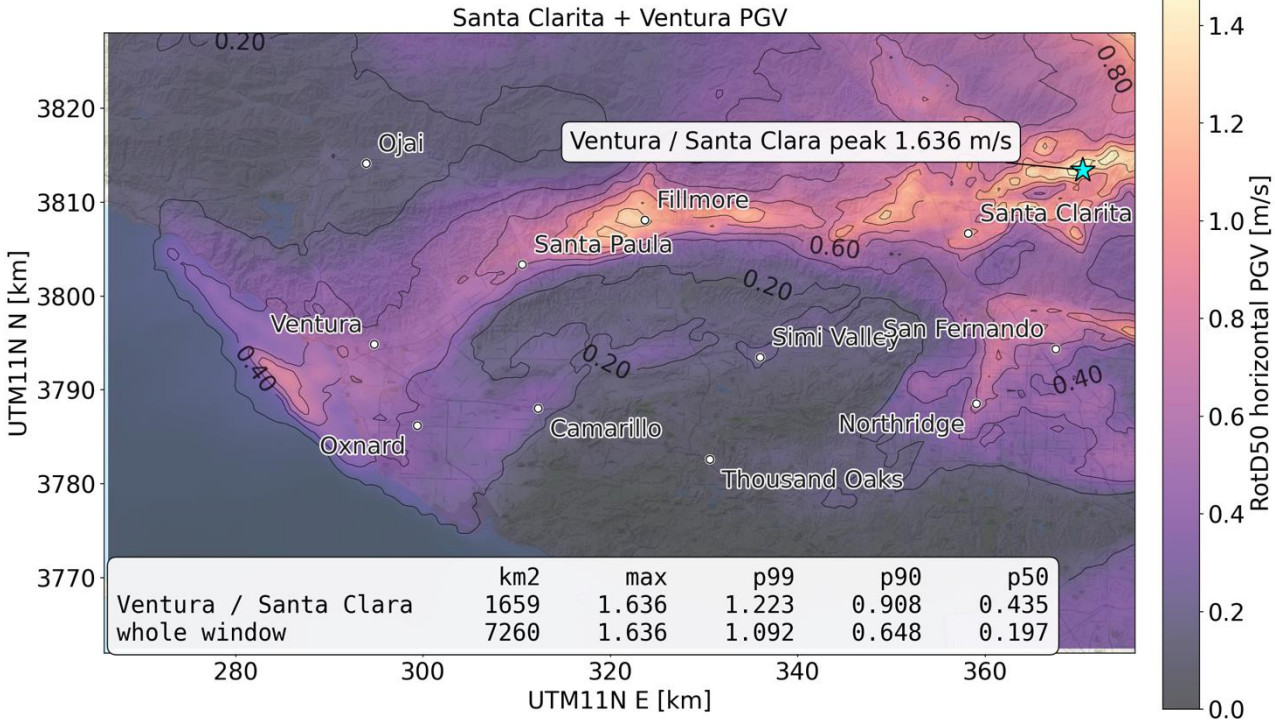

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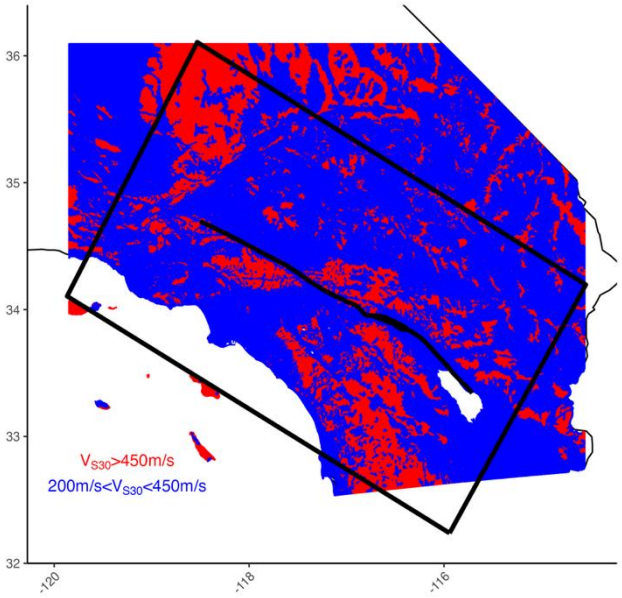

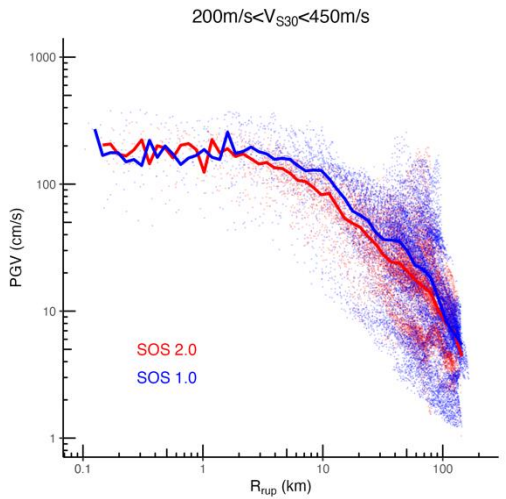

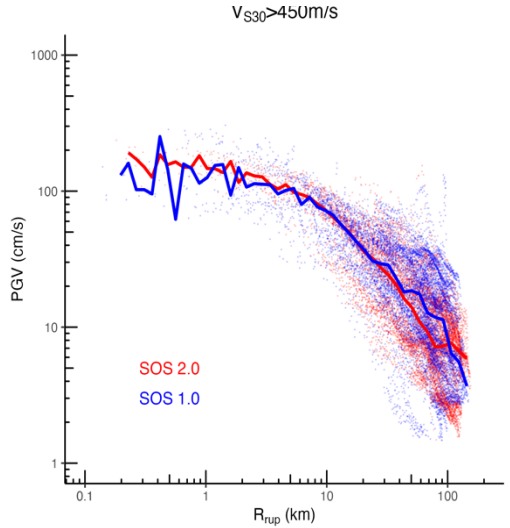

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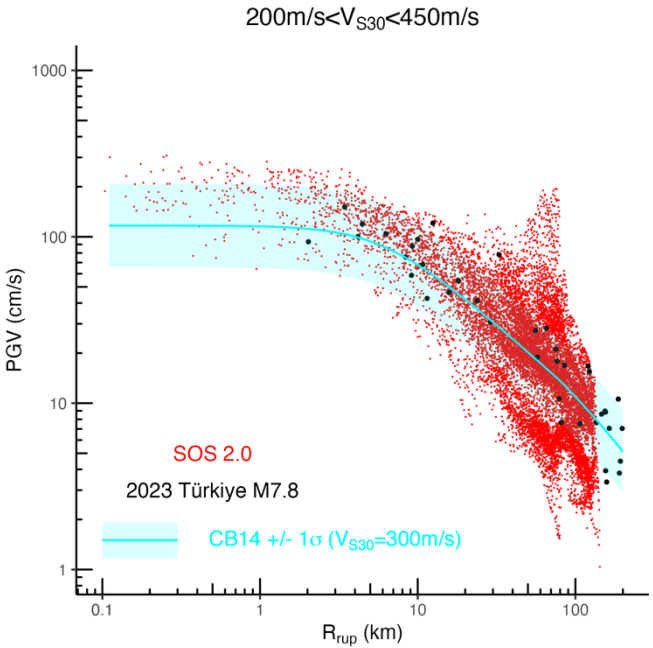

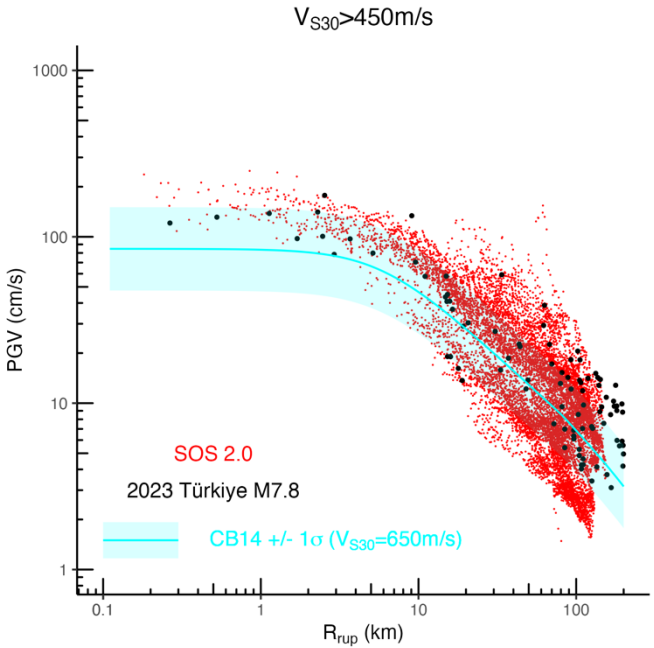

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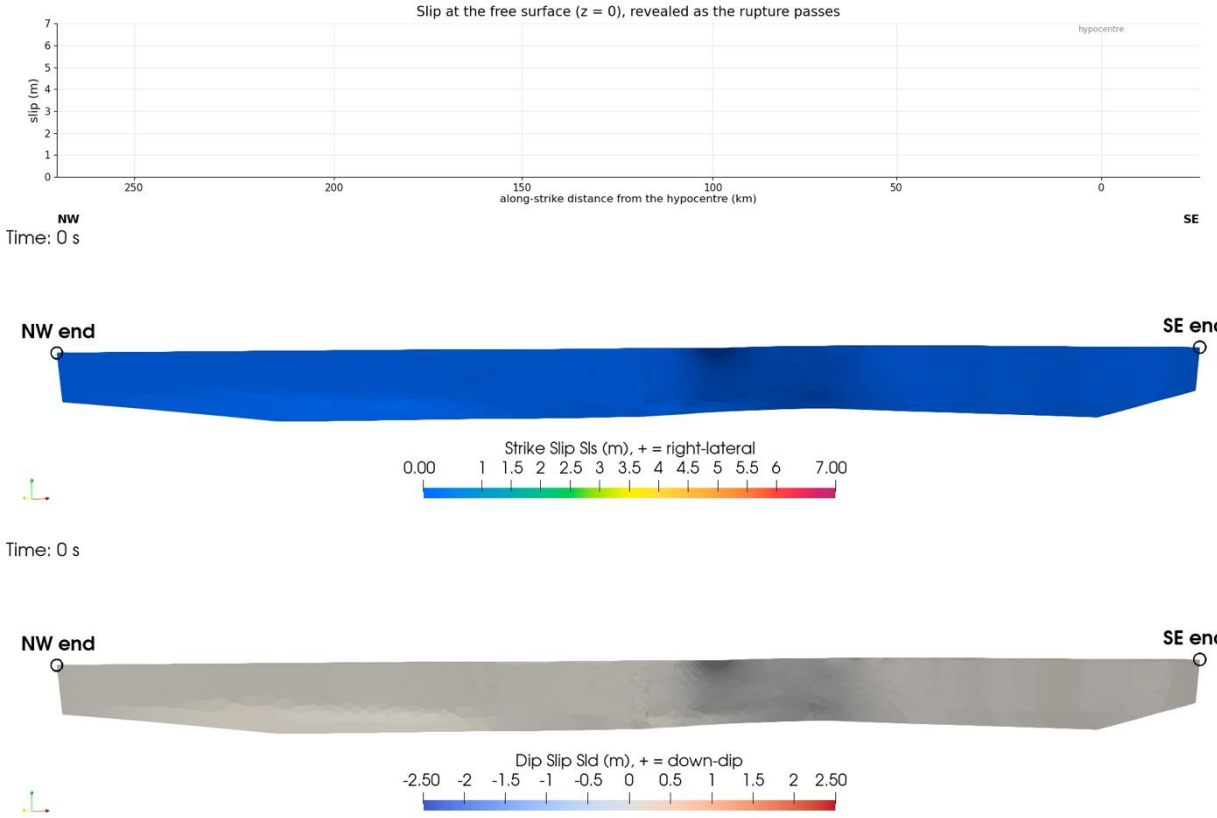

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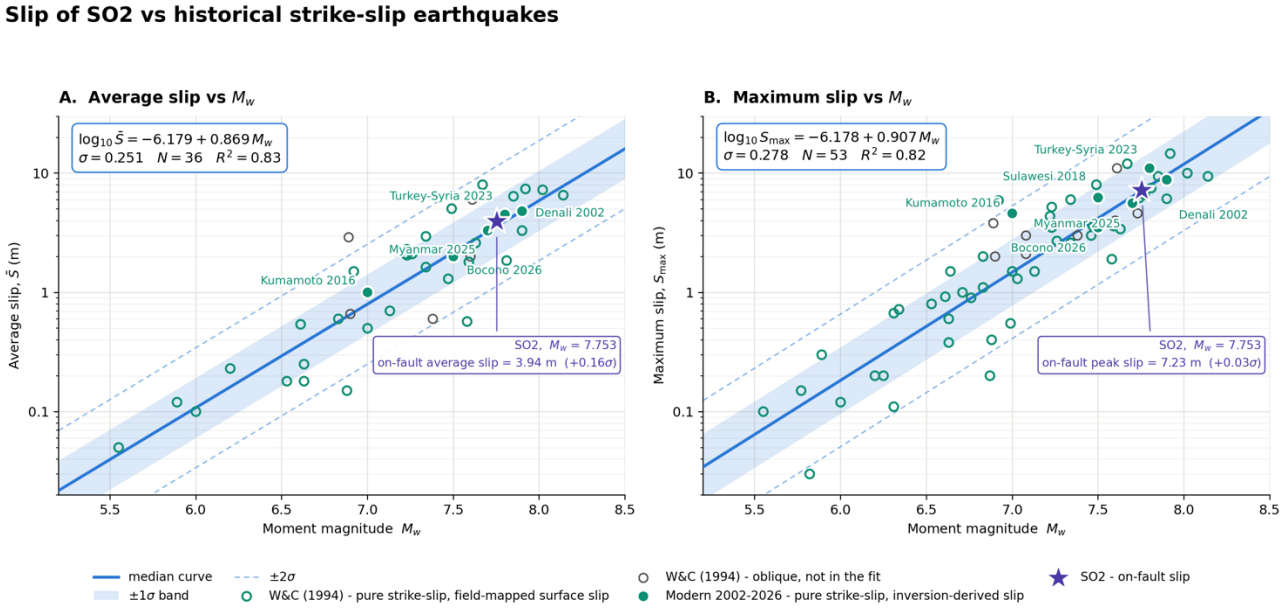

Wells & Coppersmith, 1994

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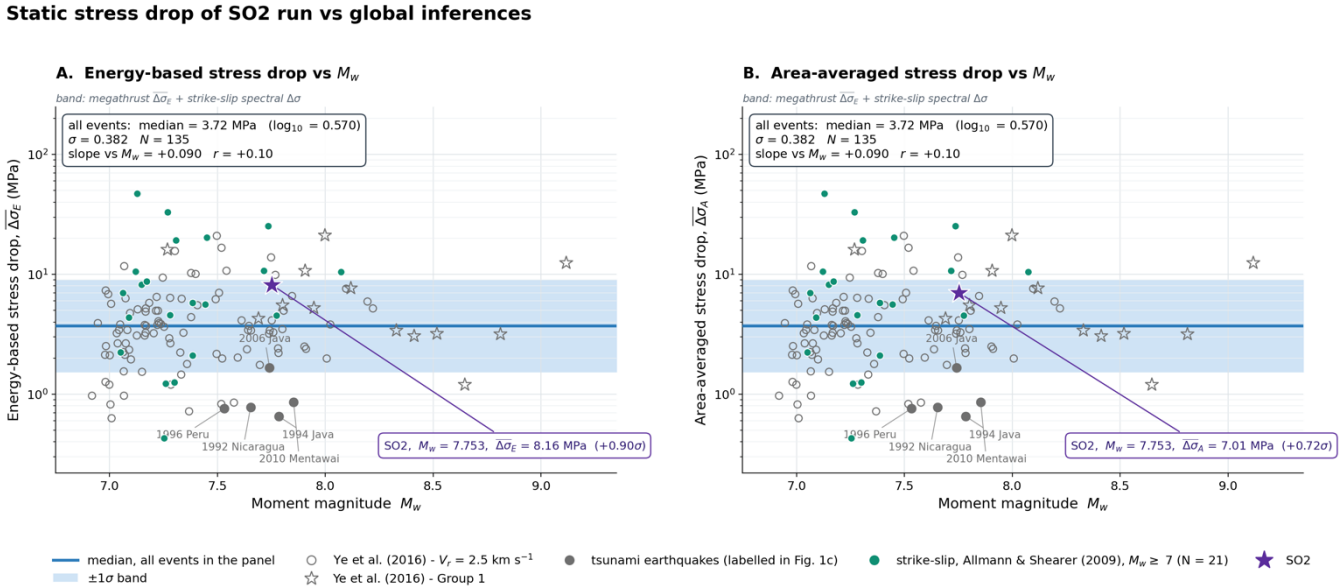
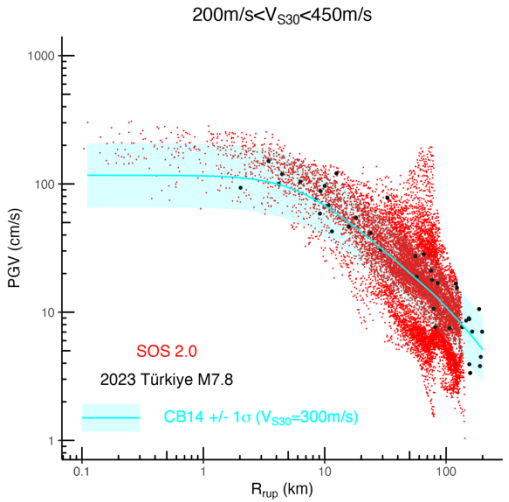
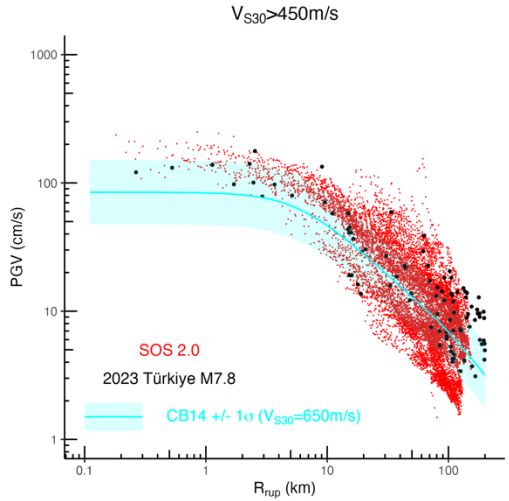


Lambert et al., 2021; Allmann & Shearer, 2009

Conclusions

- **A M7.8 southern San Andreas rupture is rare, but physically plausible.**
  The simulated rupture is compatible with regional fault geometry, stress, and crustal structure.
- **Los Angeles and the Santa Clarita basins experience prolonged strong shaking.**
  Significant shaking persists for **~1.5–2 minutes**, although shaking levels are slightly lower than in SOS1.0. Shaking intensity is also heterogeneous. This matters for building and distributed infrastructure.
- **The simulated PGV and attenuation are consistent with observations from the 2023 Türkiye earthquakes.**
  This provides an important reality check on the amplitude and spatial decay of the simulated motions.





Reference

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Thanks for your attention!

Question?