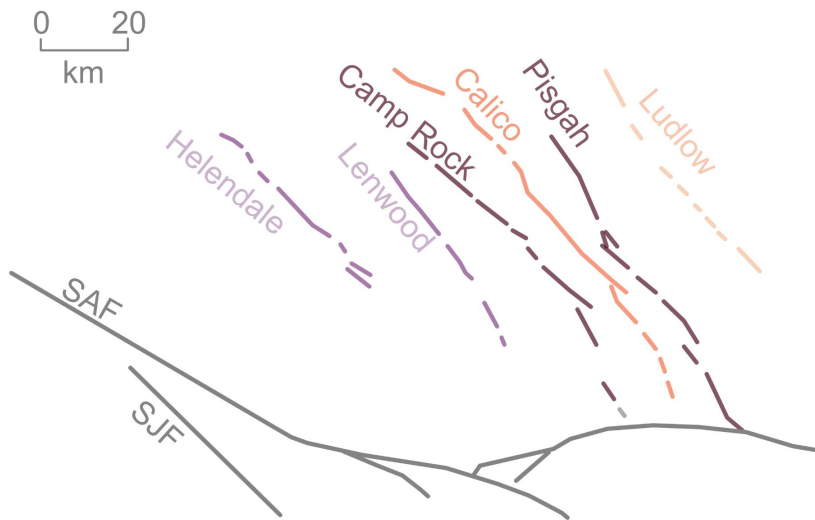


Earthquake sequence synchronization and alternation driven by quasistatic elastic interactions across faults

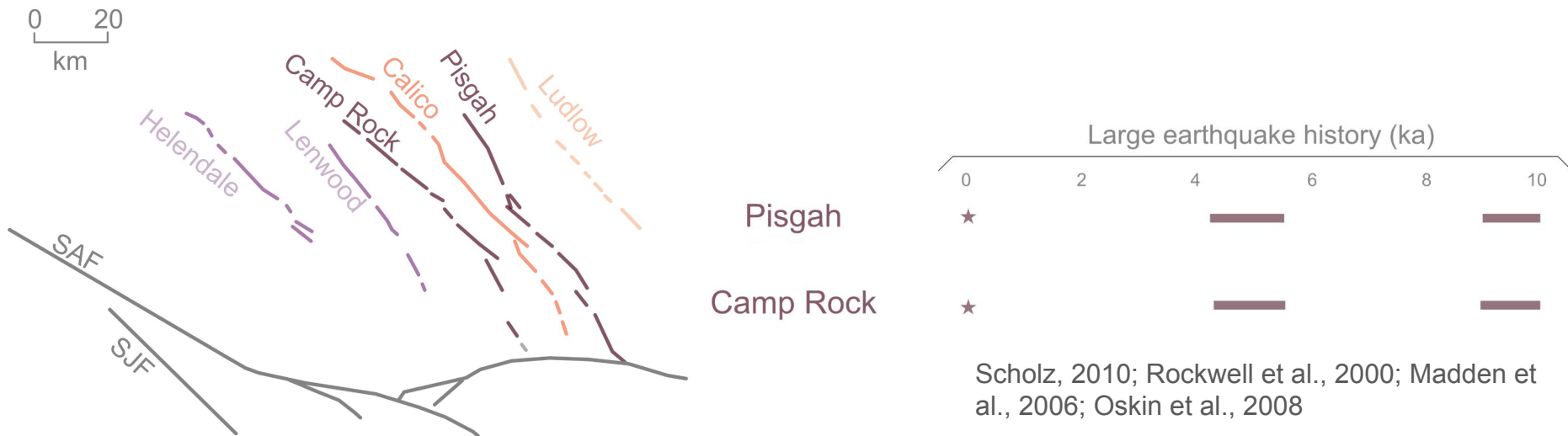
Alba M. Rodriguez Padilla, Alexis Saez, Jean-Philippe Avouac



Fault interactions in the geologic record: **synchronization**

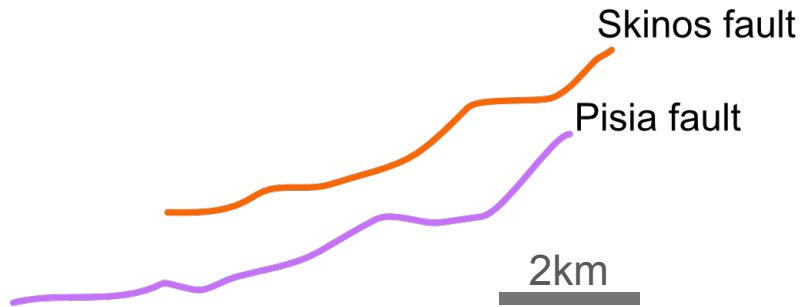


Fault interactions in the geologic record: **synchronization**

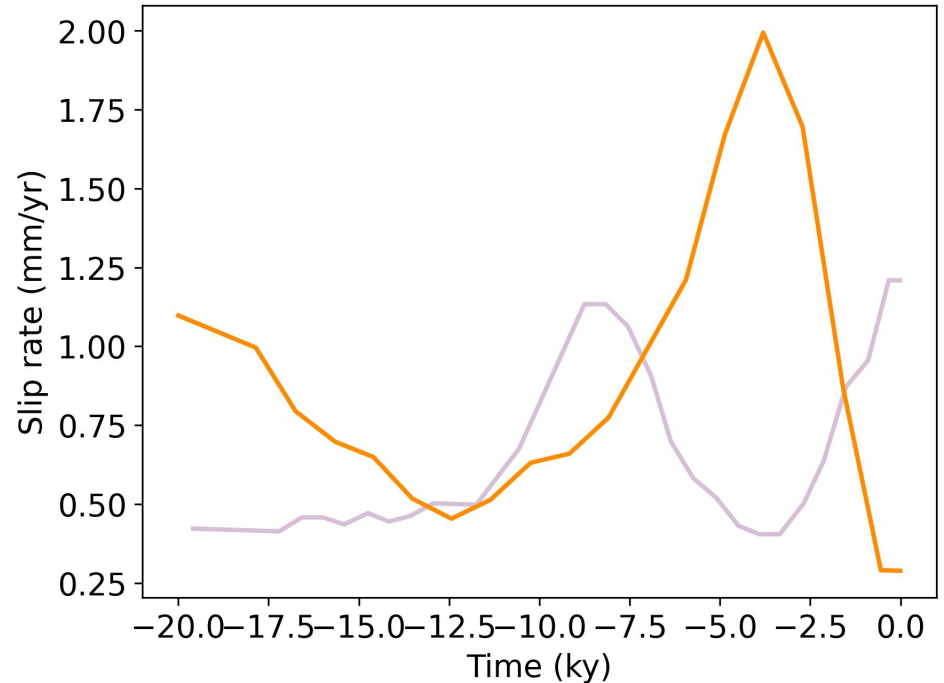


There is **paleoseismic evidence for synchronization** of the Pisgah and Camp Rock faults.

Fault interactions in the geologic record: **alternation**

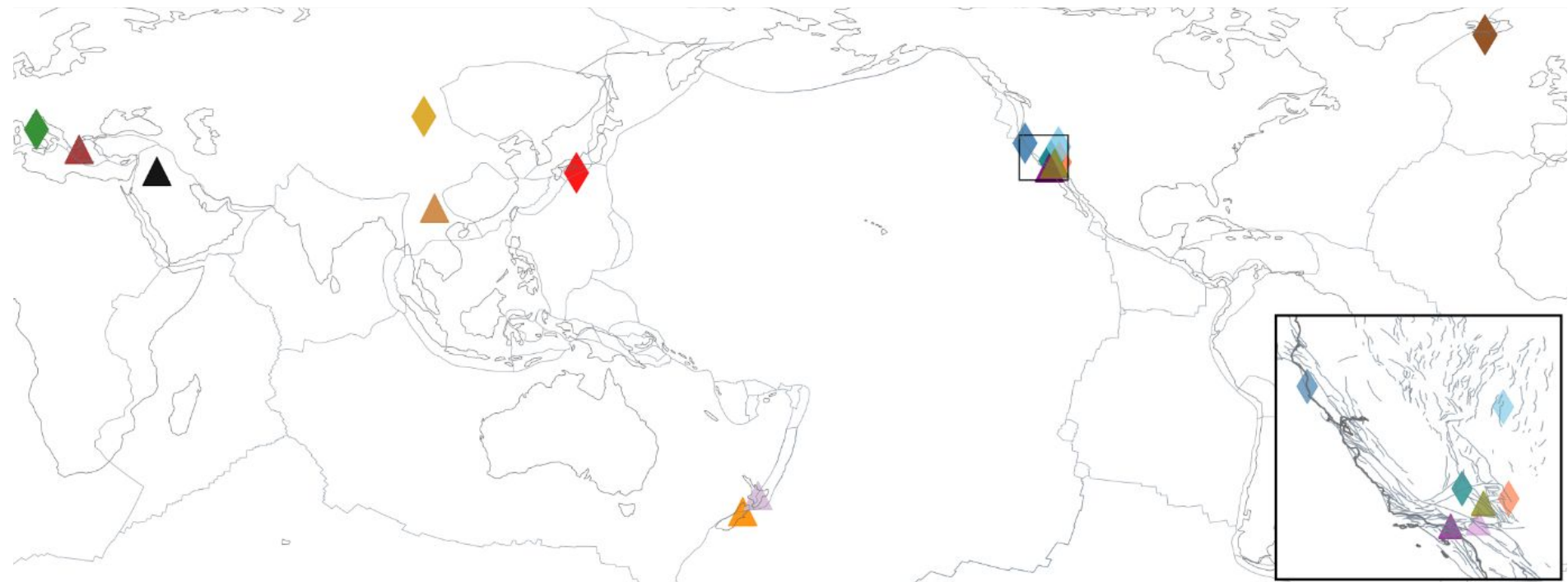


Mitchell et al., 2025



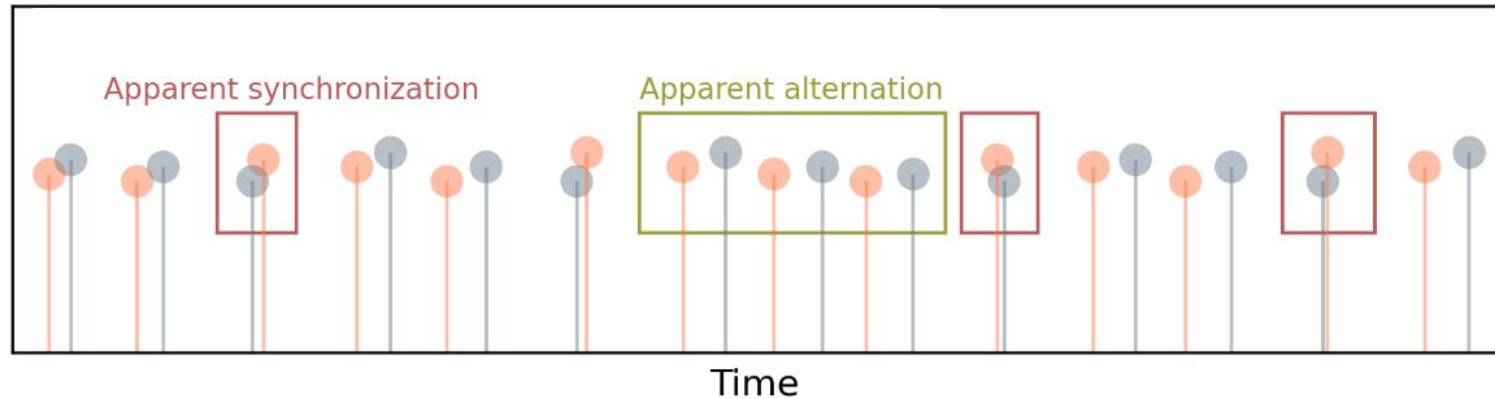
Periods of **accelerated slip** on Pisia fault roughly **correlate with periods of slower slip rate** on Skinos fault

How do we explain this behavior?





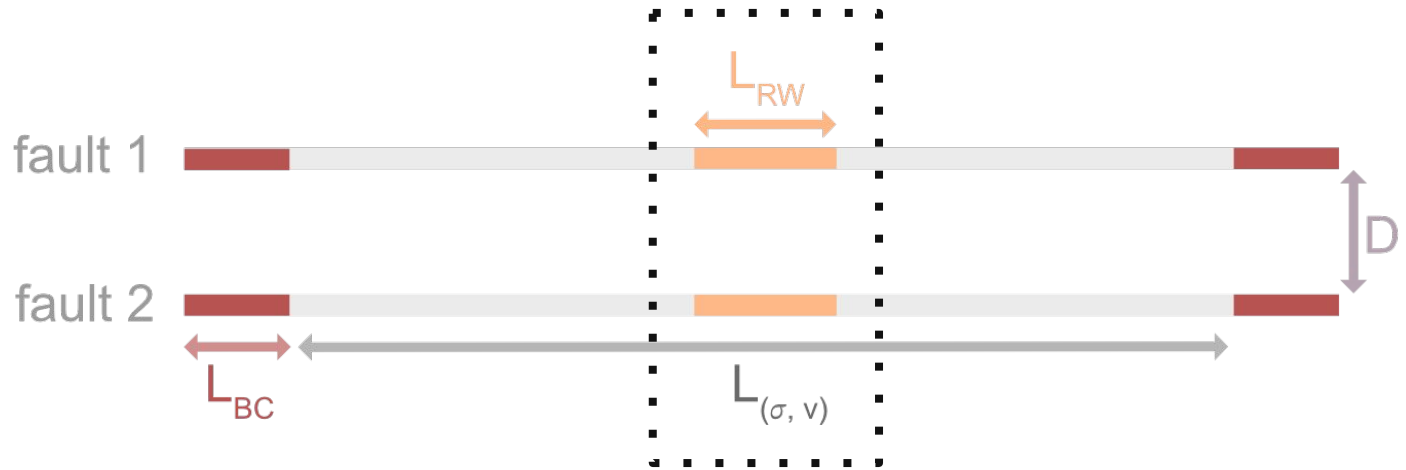
- ◇ Synchronization
- △ Alternation

How do elastic interactions contribute to establishing **alternation** and **synchronization**?



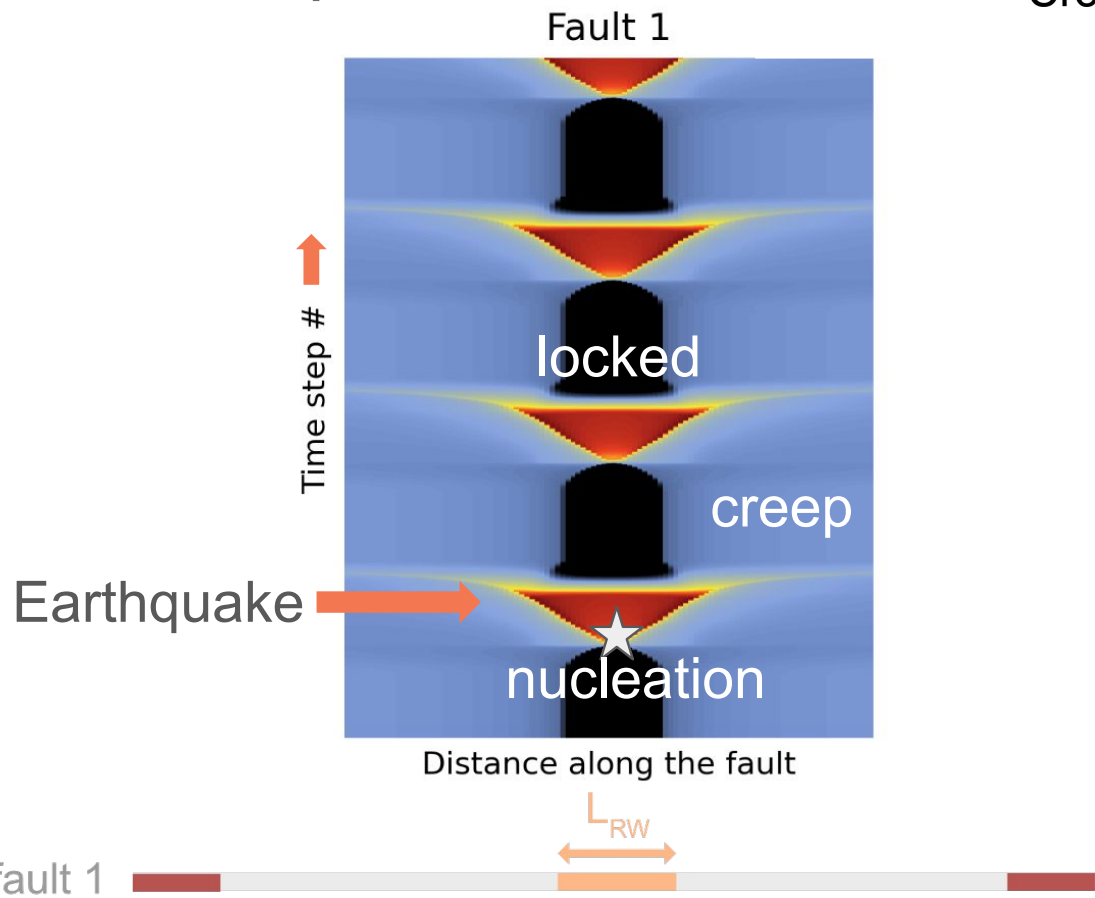
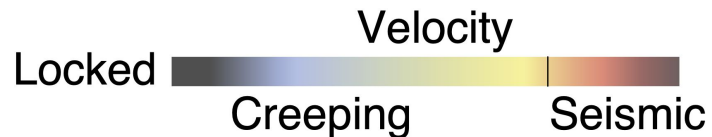
Why models? Observational record limited to only a few cycles, **hard to distinguish long-term interactions from apparent transients** and probe the physics of the system.

Model set-up: 1D faults governed by rate and state friction in a 2D elastic full space in **antiplane**  and **in-plane** 

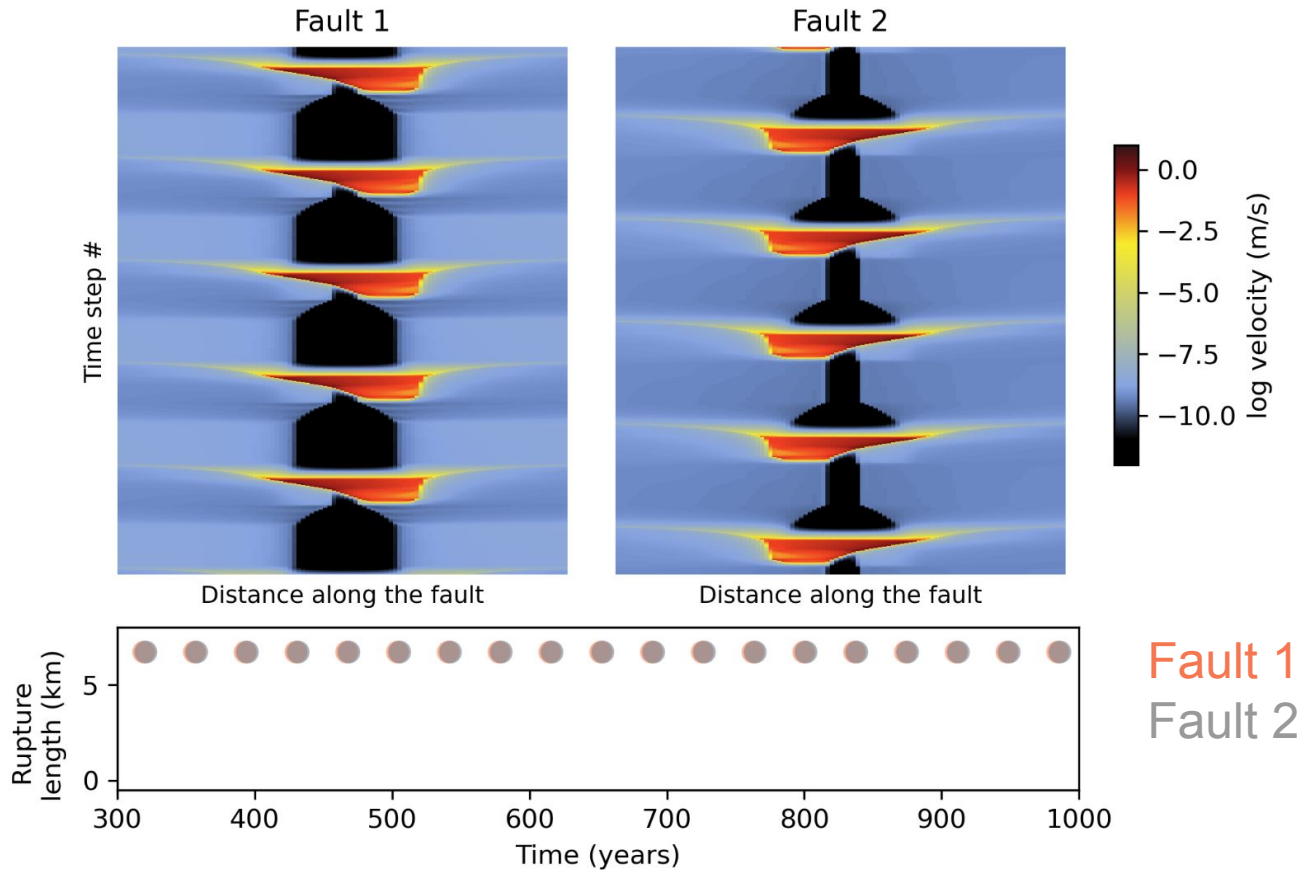


We explore the effect of... **the Instability ratio ($Ru = L_{RW}/h^*$)**
the spacing between the faults (D/L_{RW})
 in-plane and antiplane conditions

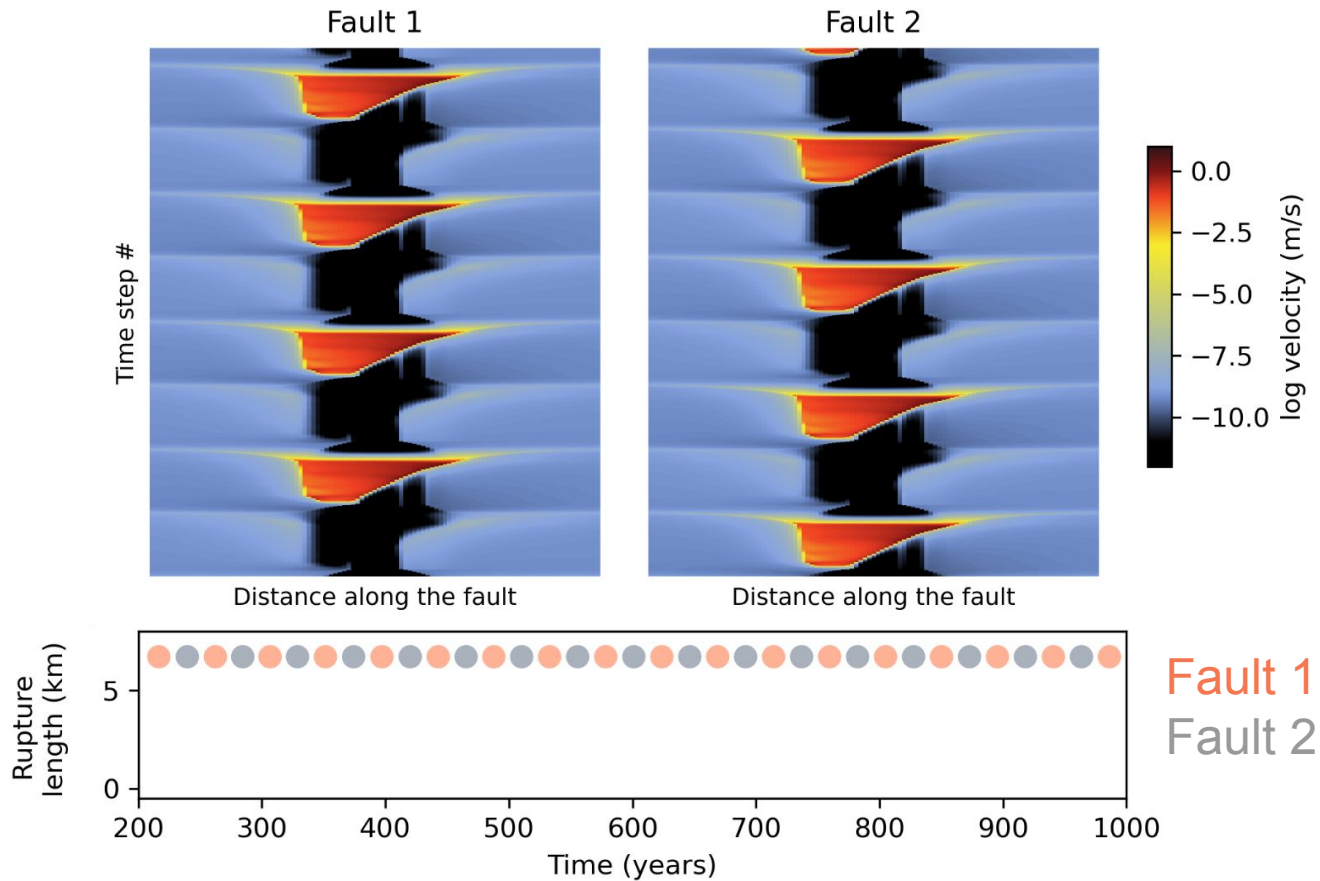
Reading model outputs



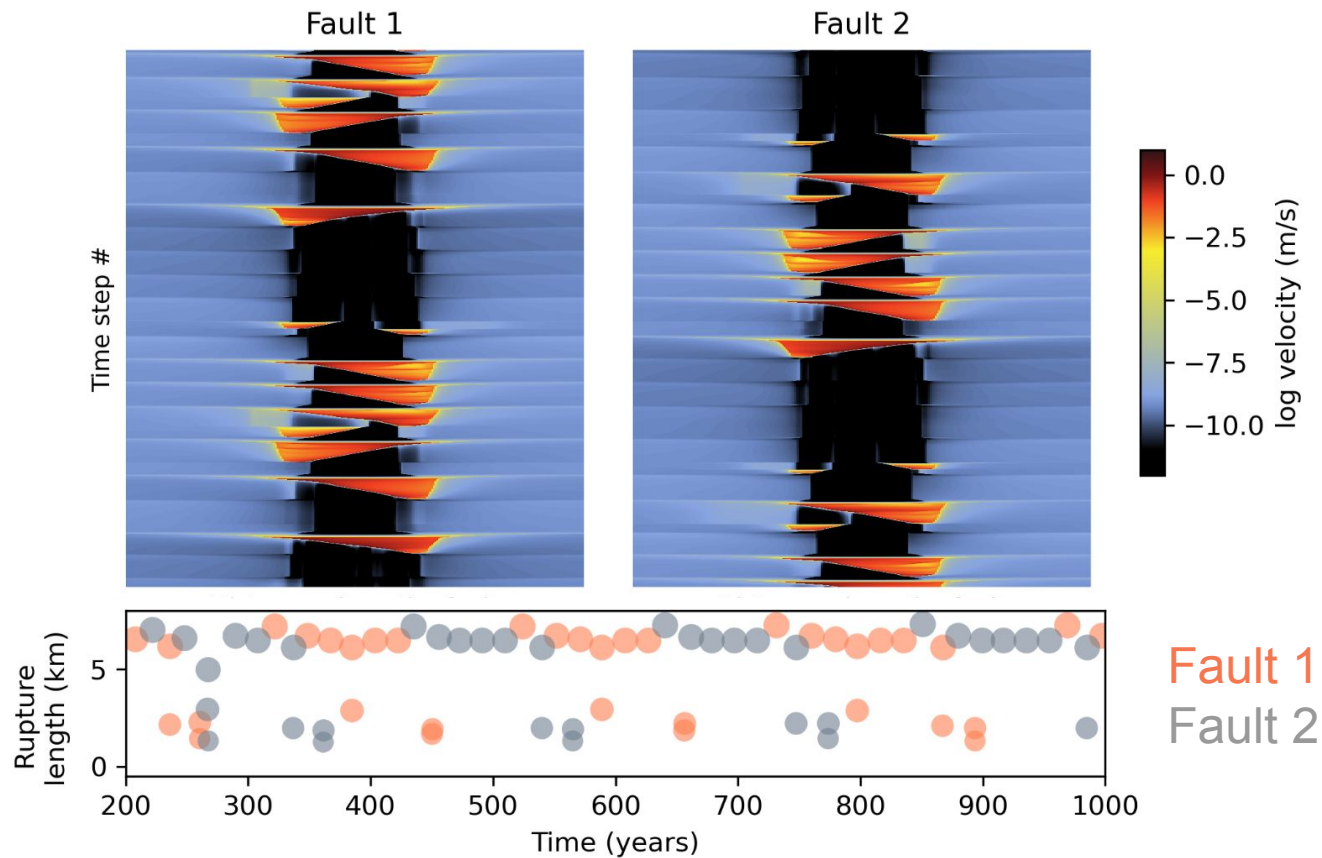
Synchronization



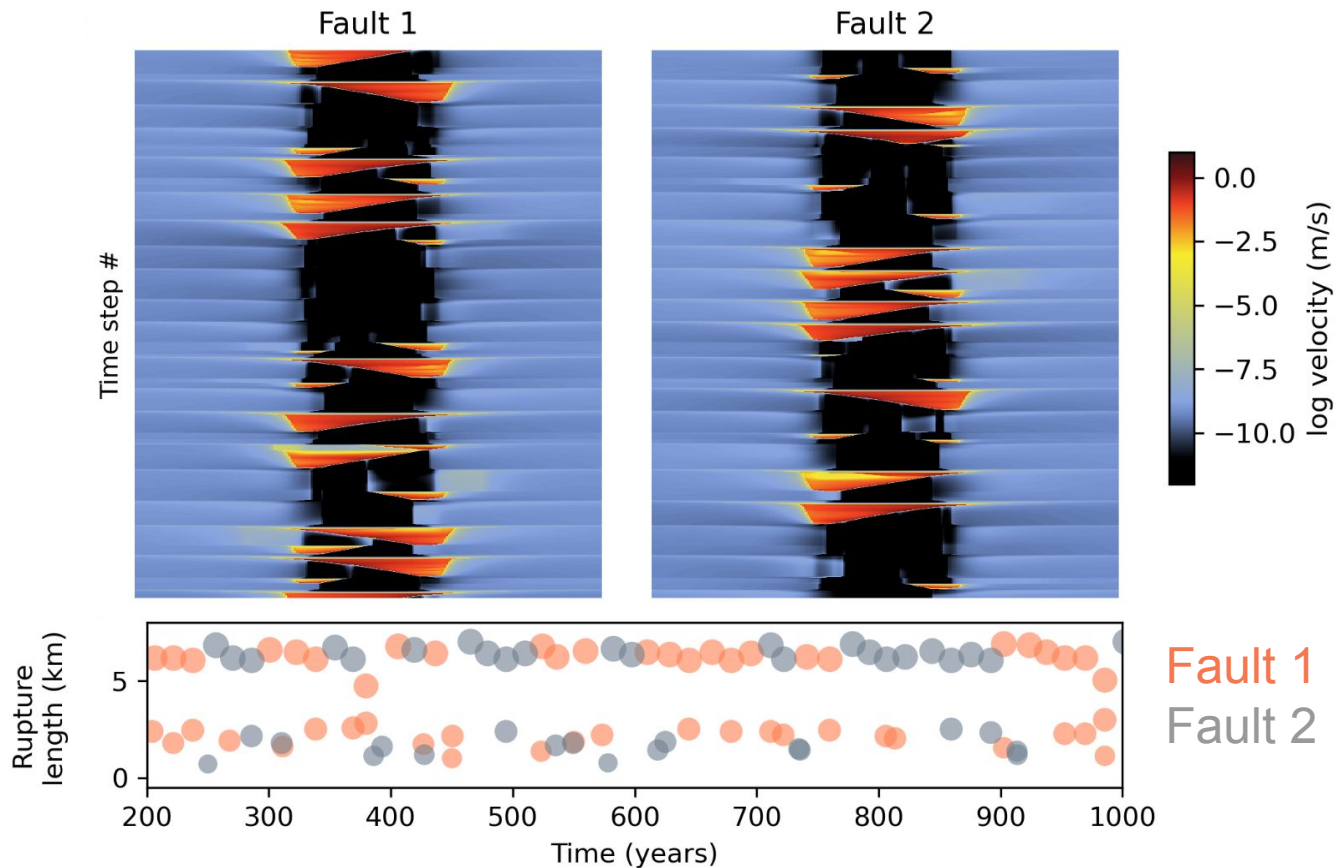
Alternation



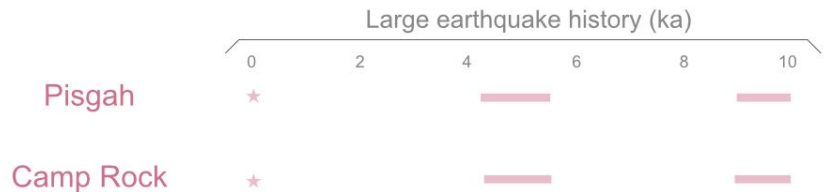
Alternating supercycles



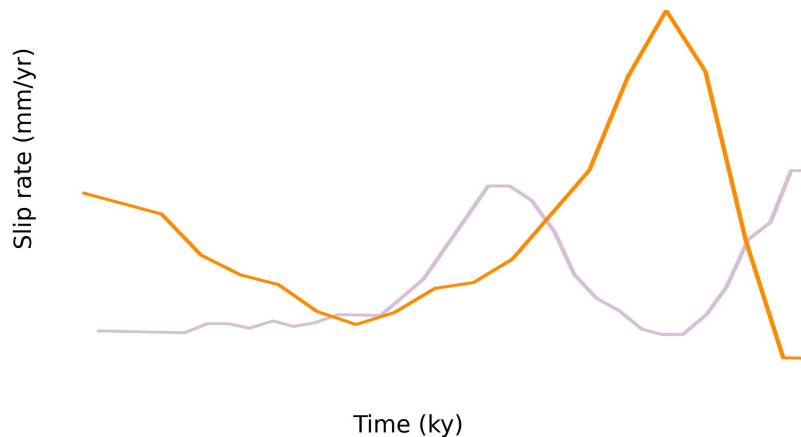
Alternating supercycles



Fault interactions in the geologic record: **characterization**

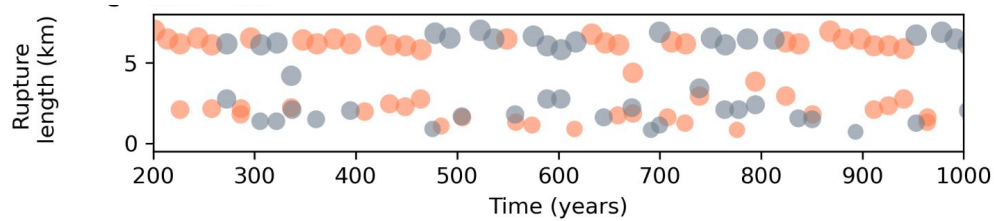


Earthquake chronology:
timing of discrete events

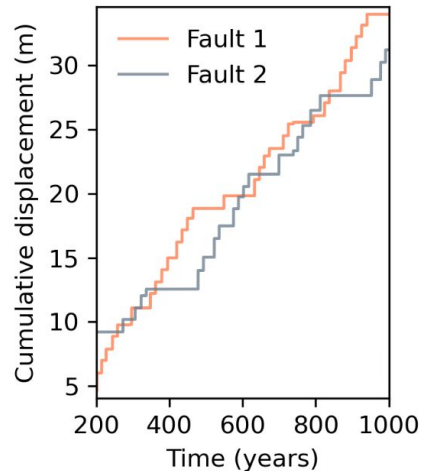


Incremental slip rate:
**measurements of slip
spanning different time
windows**

Fault interactions in the models: **characterization**

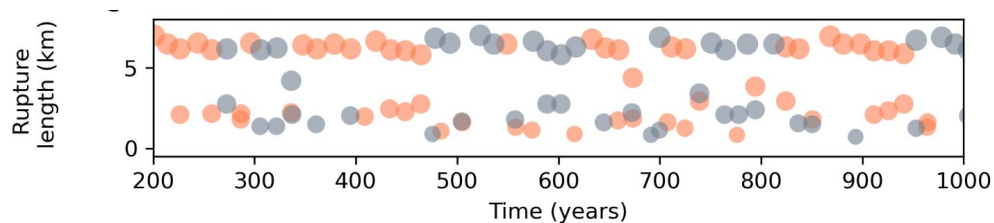


Earthquake chronology:
timing of discrete events

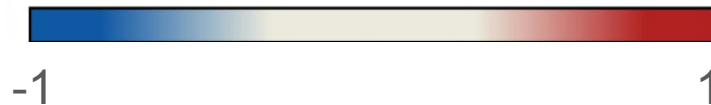
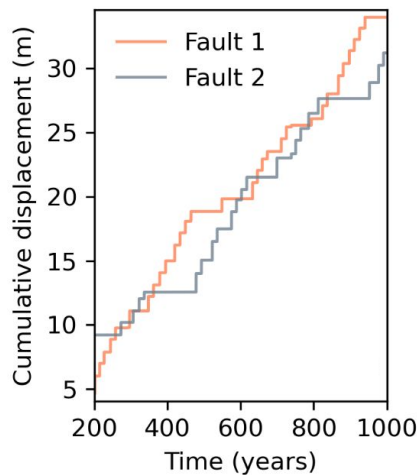


Incremental slip rate:
**measurements of slip
spanning different time
windows**

Metrics for quantifying interaction in models and data

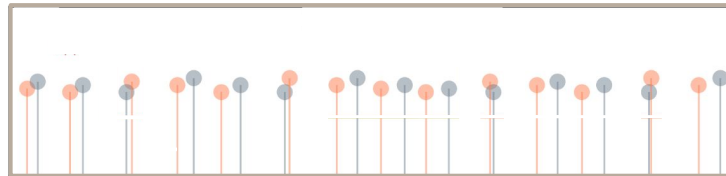
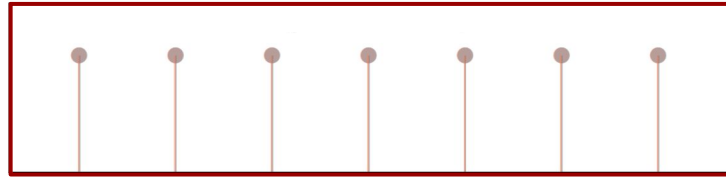


Alignment coefficient

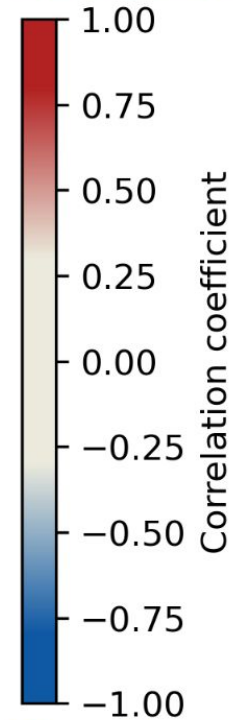


Correlation coefficient

Correlation and alignment coefficient → simple metrics to characterize interactions in model outputs and geologic data



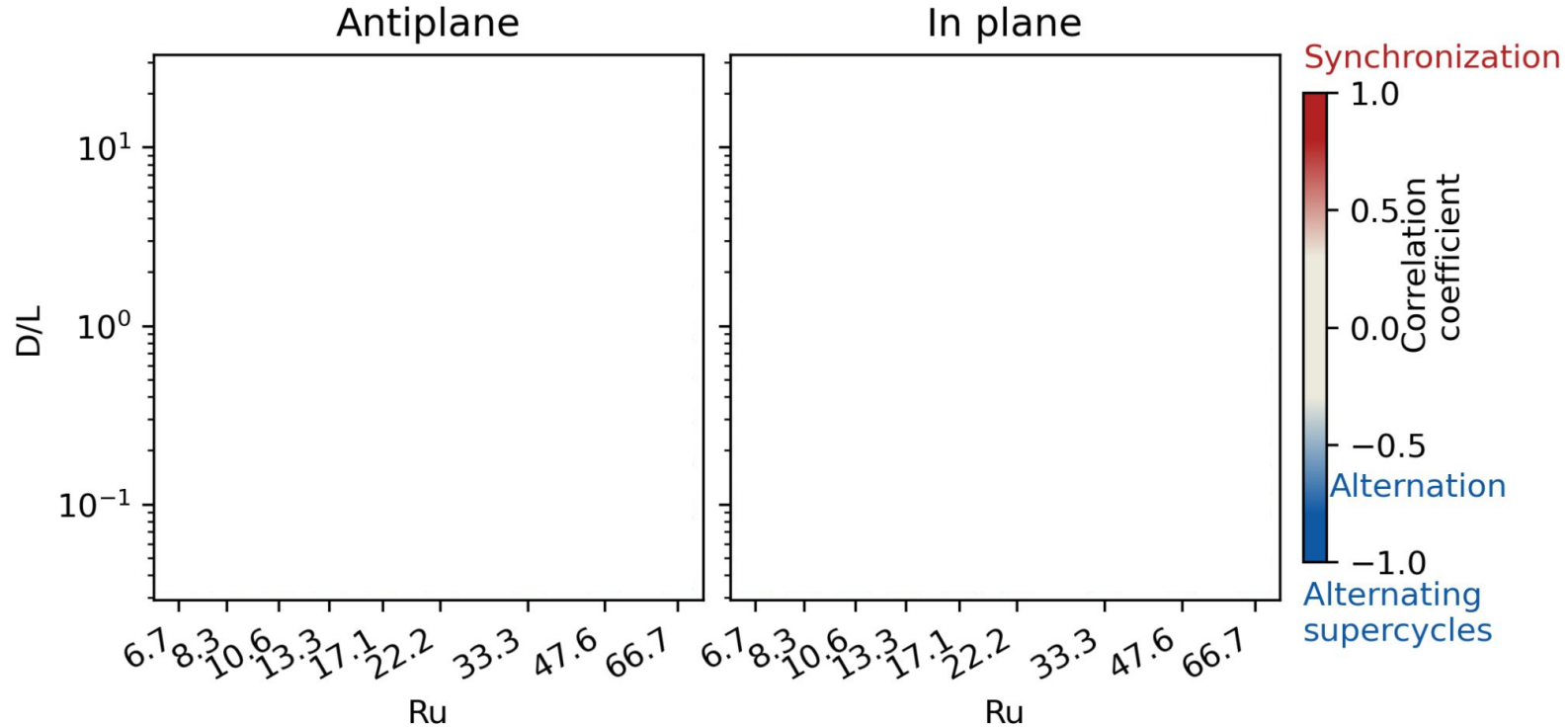
Synchronization



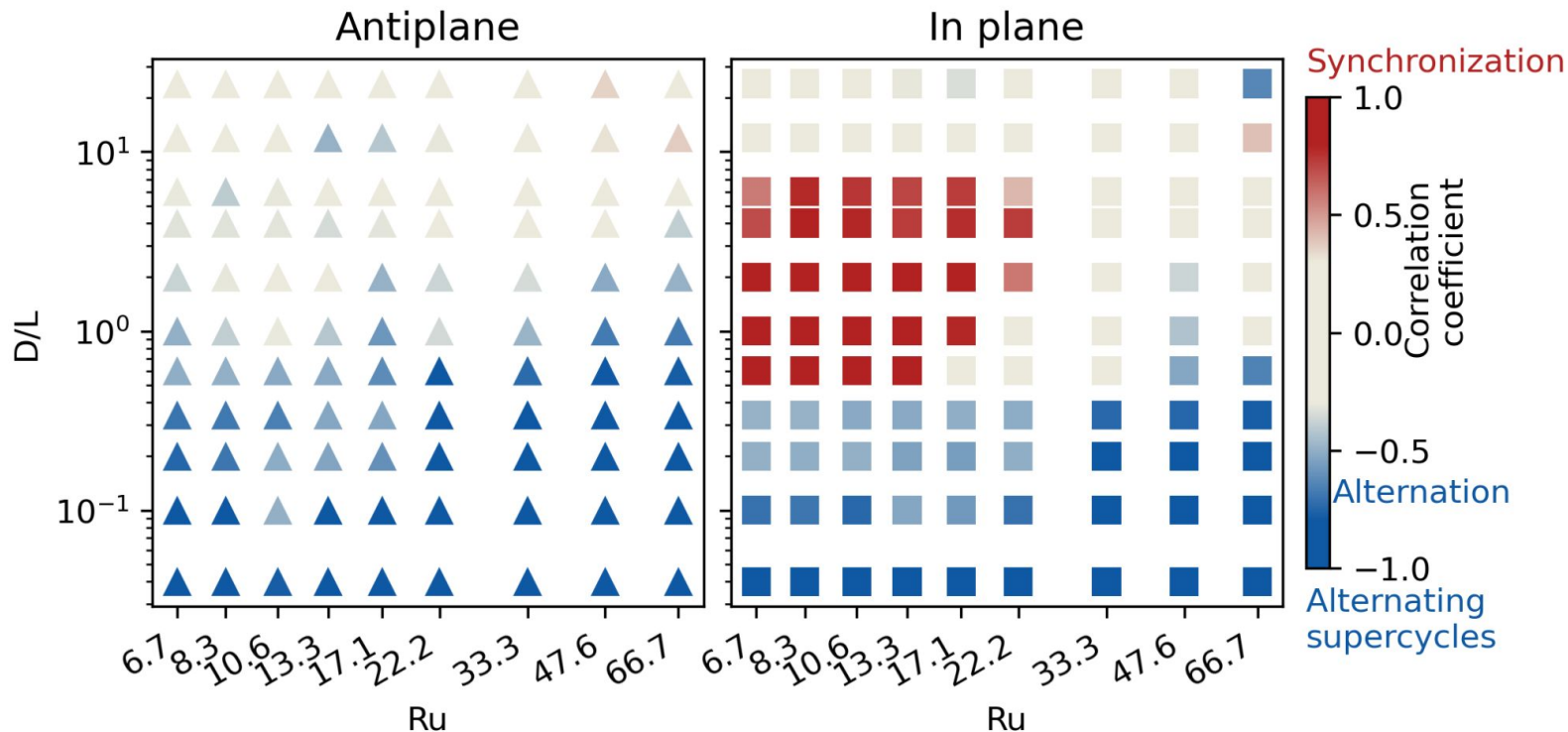
Correlation coefficient

Alternating supercycles

Alternating supercycles and **alternating ruptures** occur when the faults are close irrespective of the instability ratio and loading conditions.

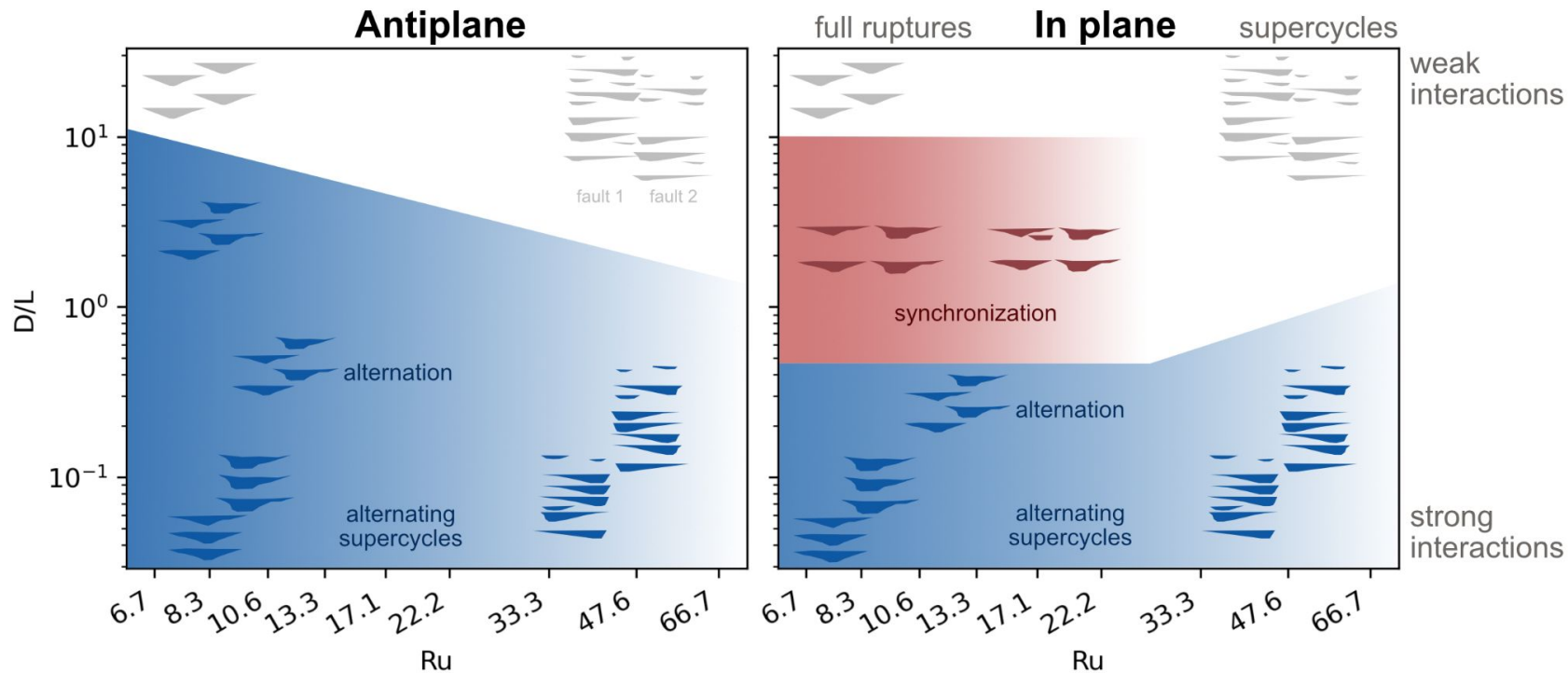


Alternating supercycles and **alternating ruptures** occur when the faults are close irrespective of the instability ratio and loading conditions.



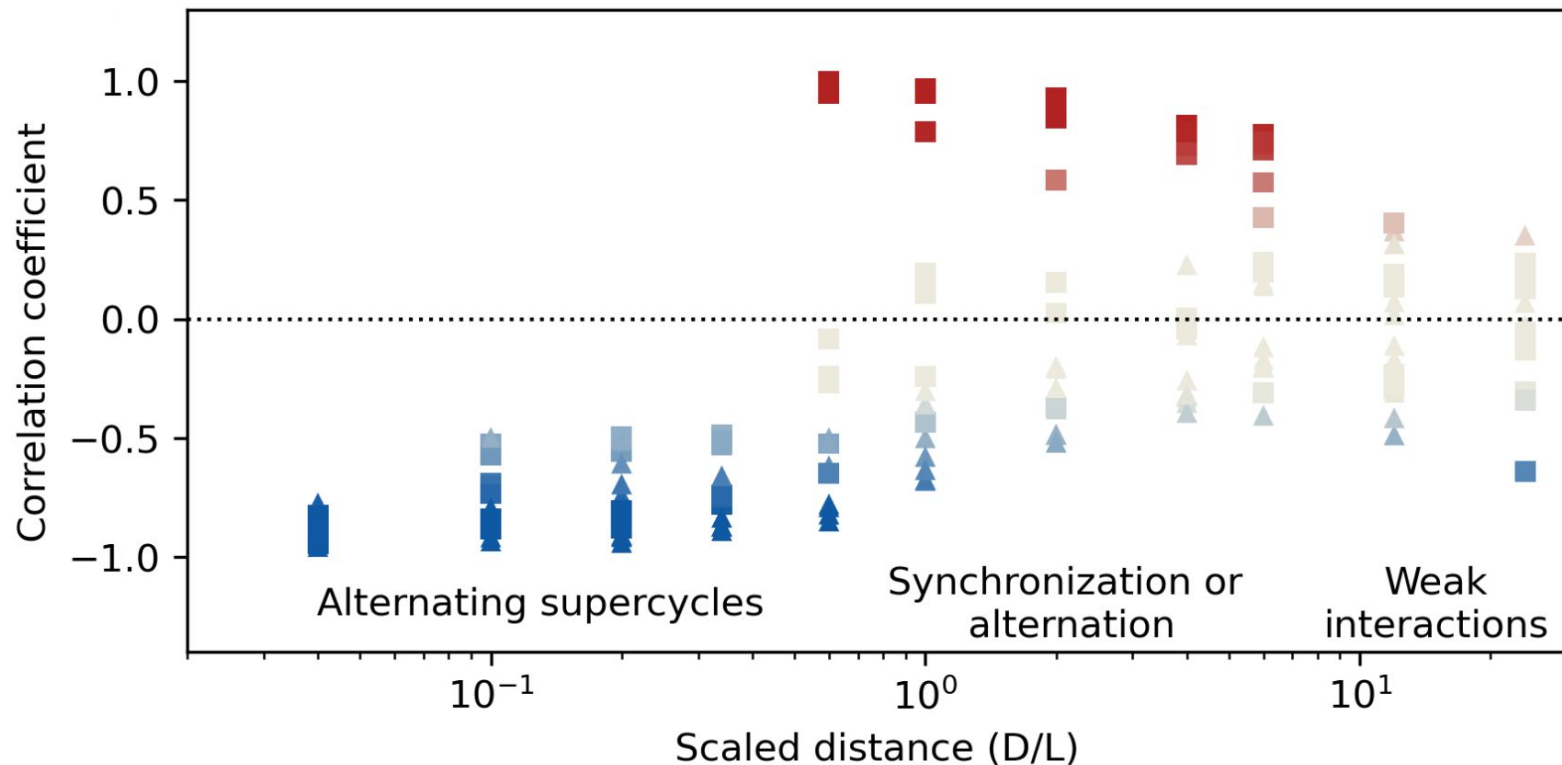
Synchronization occurs for $Ru < 23$ and $0.5 < D/L < 8$ under in plane conditions.

The distance between the faults **controls interactions**.
The instability ratio (rupture complexity) plays a secondary role.

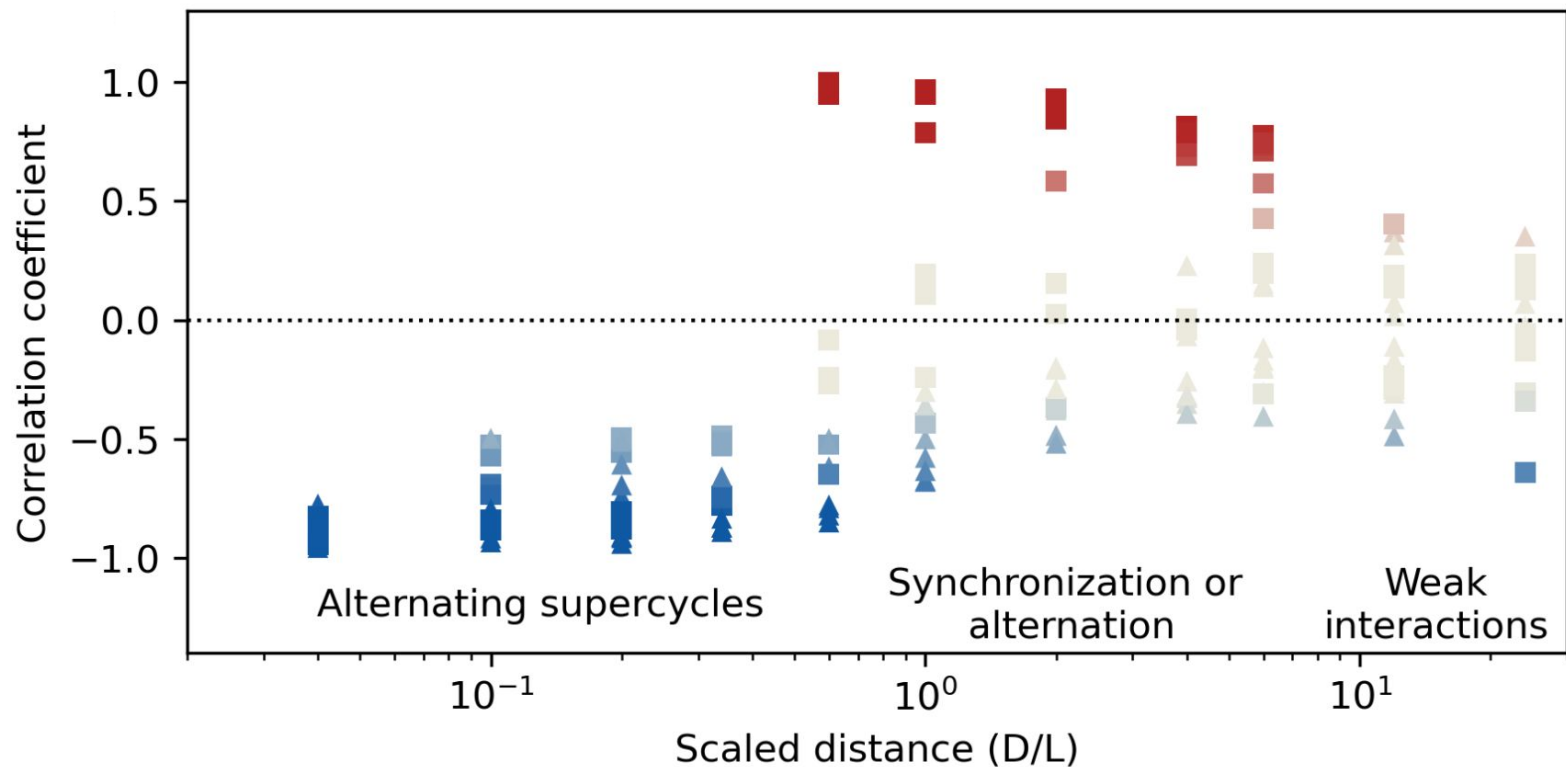


The distance between the faults **controls interactions**.

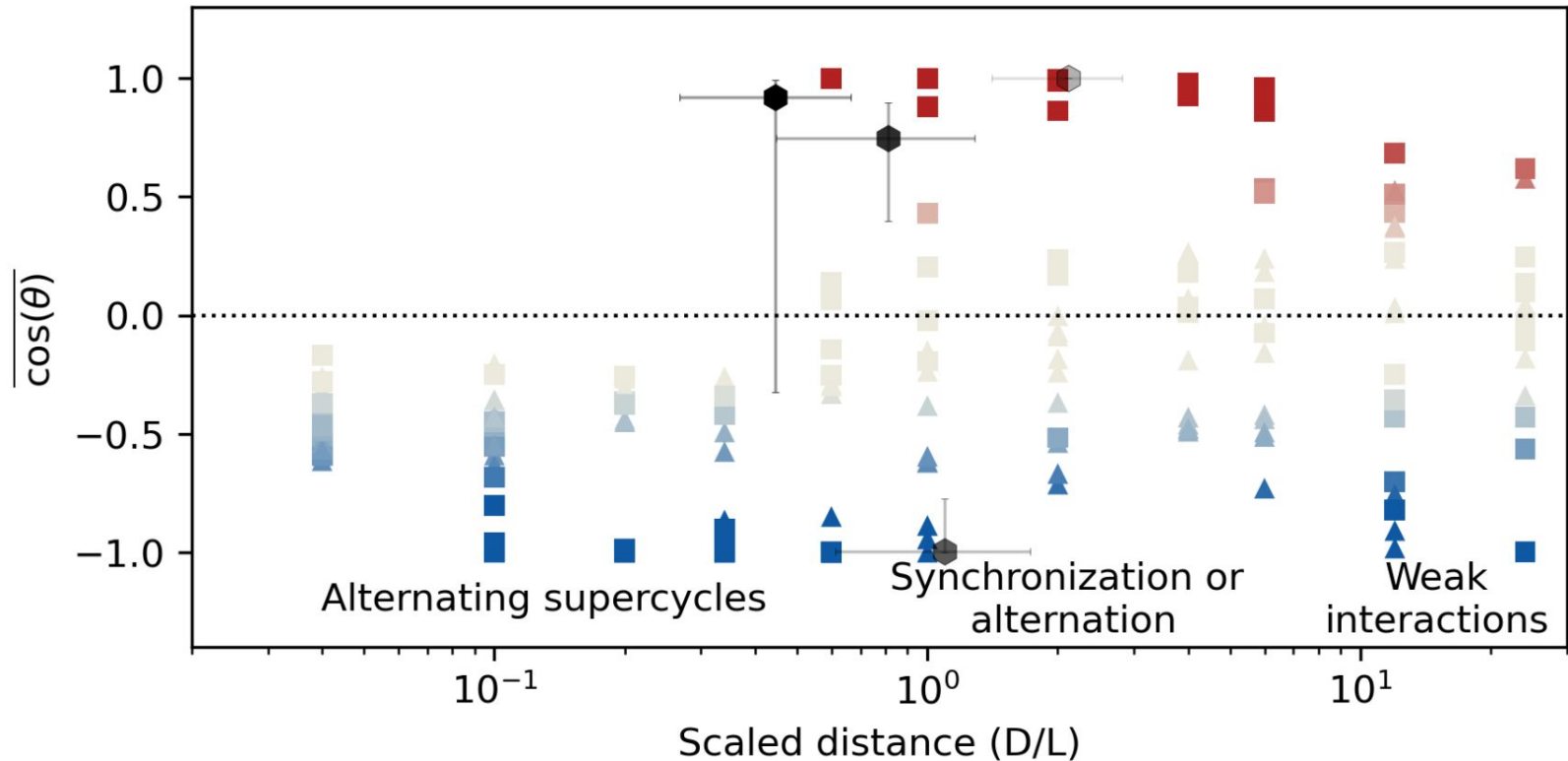
The instability ratio (rupture complexity) plays a secondary role.



We can place real faults in this phase space!

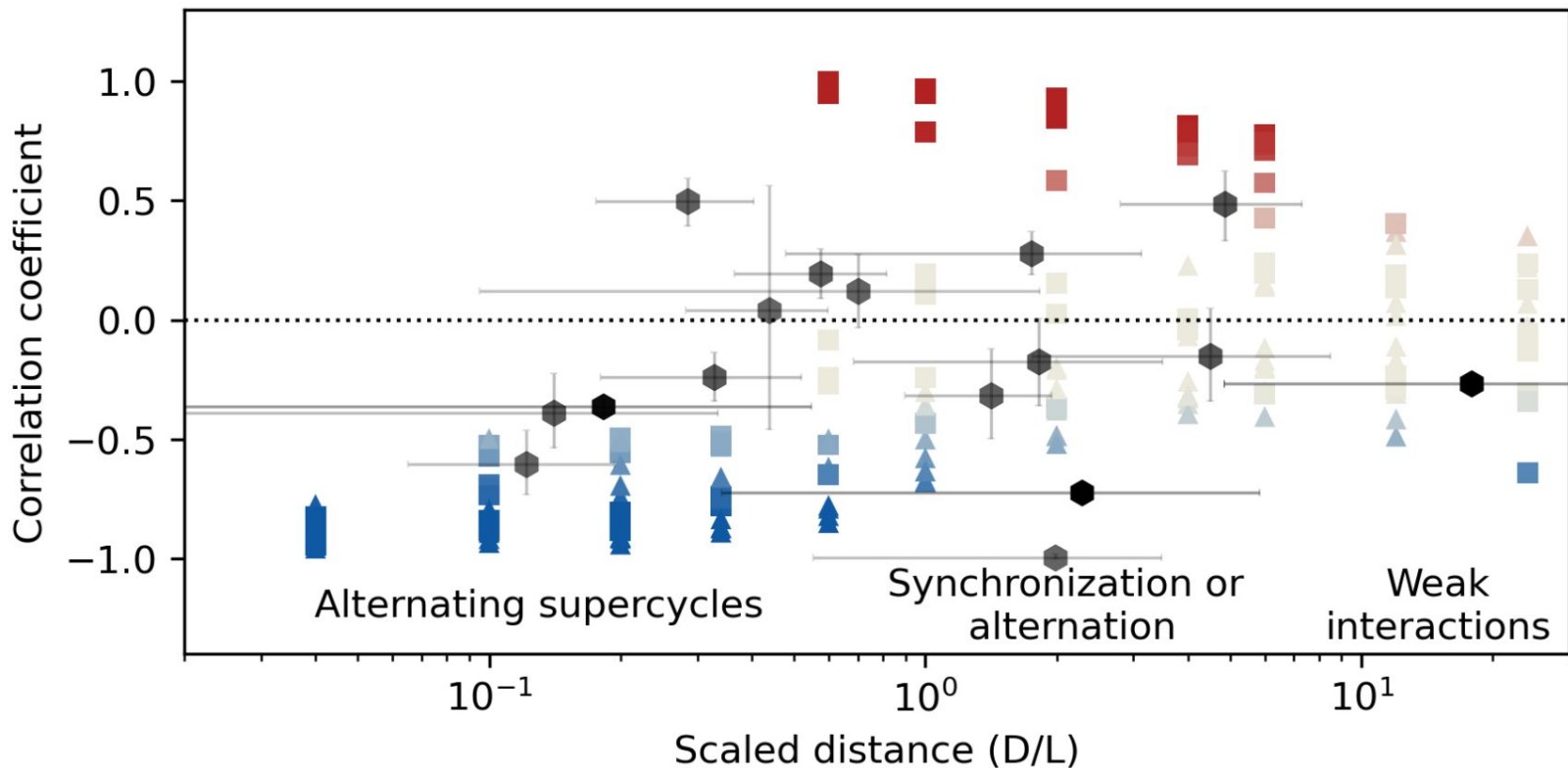


Data from earthquake chronologies fall within the space proposed by the models → **fault interplay resulting primarily from stress interactions**



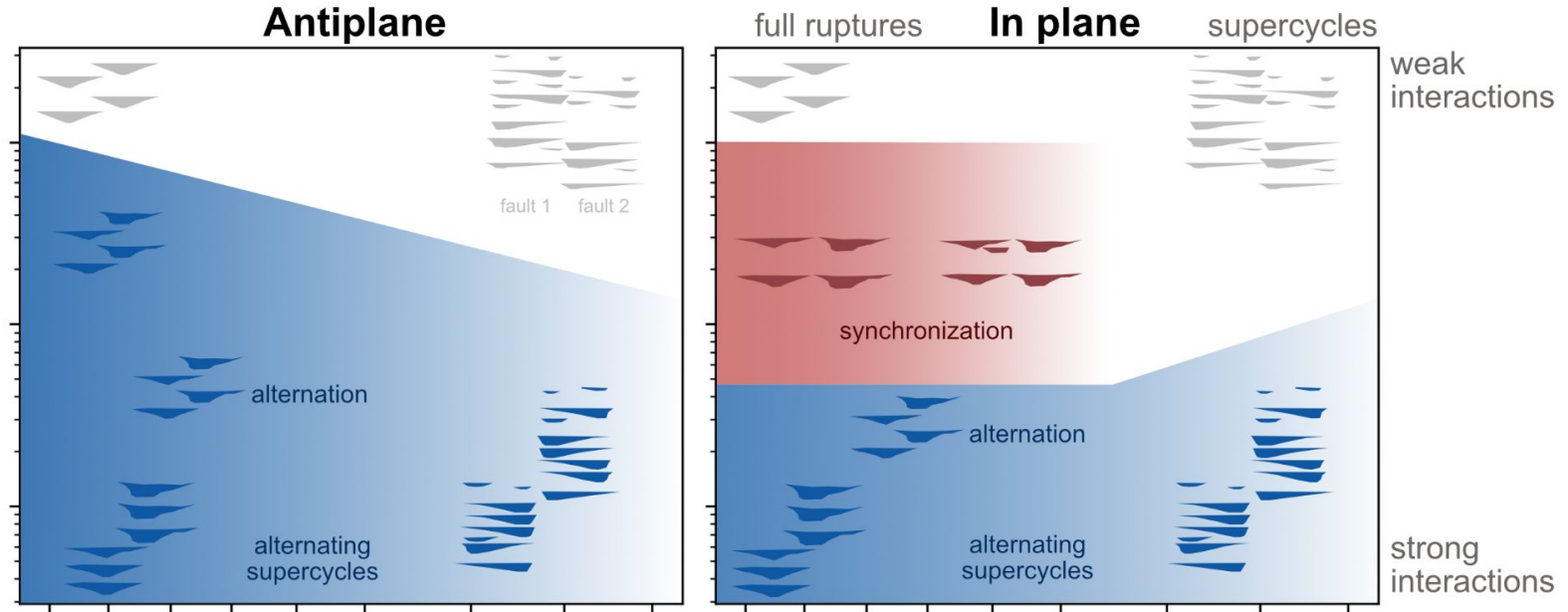
Measurements include nearest neighbors in fault network only.

Data from **incremental slip rate records** show reasonable agreement with the space proposed by the models

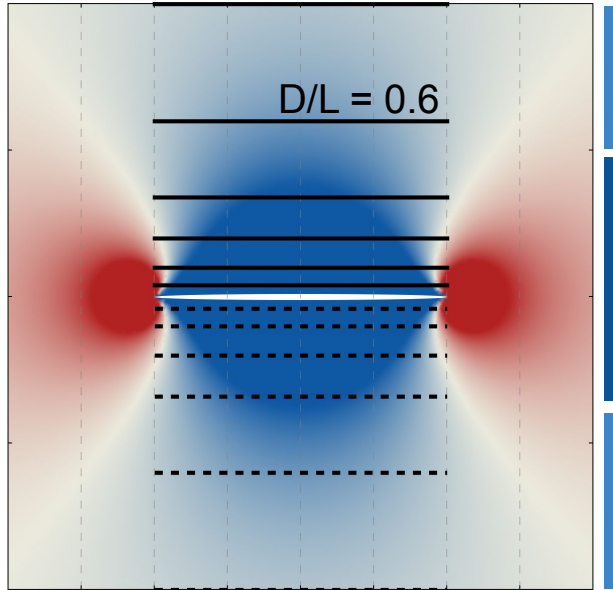


Measurements include nearest neighbors in fault network only. Plotting incremental slip rates from datasets proposed to alternate and some that don't.

Why do **antiplane** and **in-plane** simulations have different phase spaces?



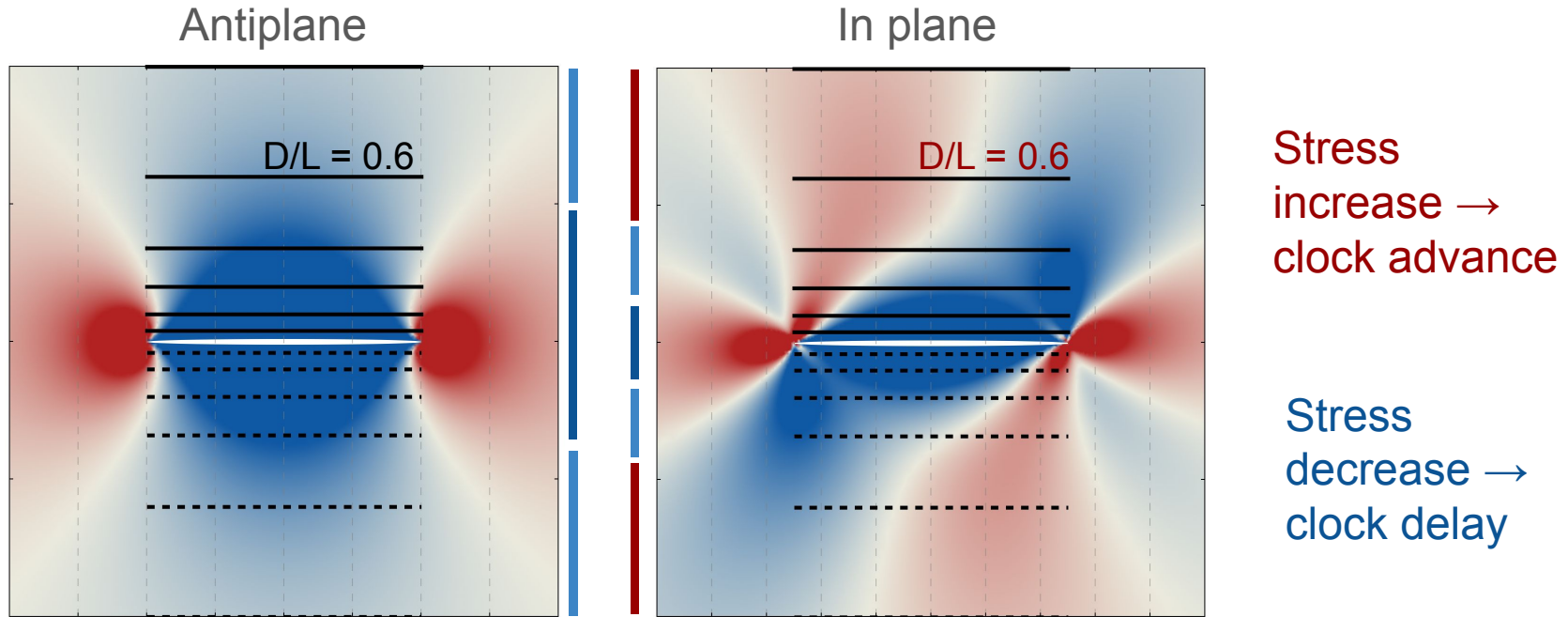
Antiplane → every rupture **delays** the next earthquake on its neighbor,
fosters **alternation**



Stress
increase →
clock advance

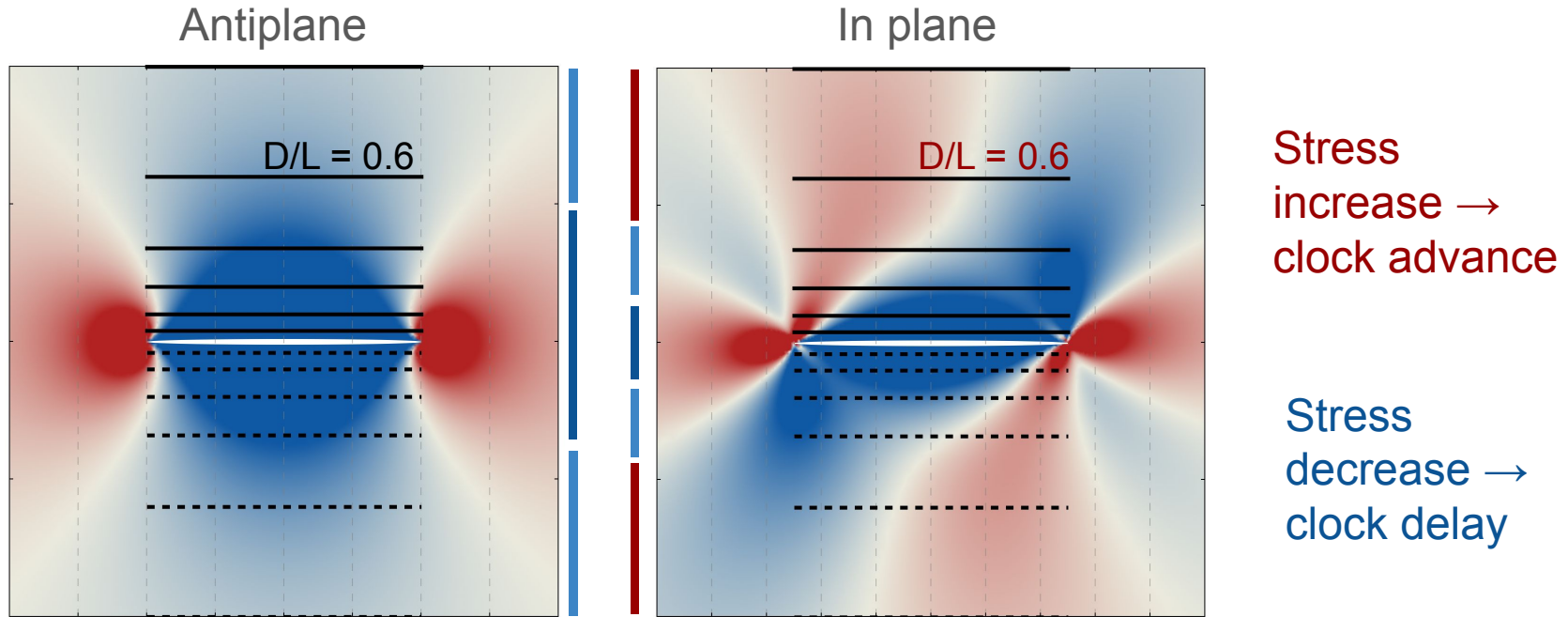
Stress
decrease →
clock delay

Antiplane → every rupture **delays** the next earthquake on its neighbor, fosters **alternation**



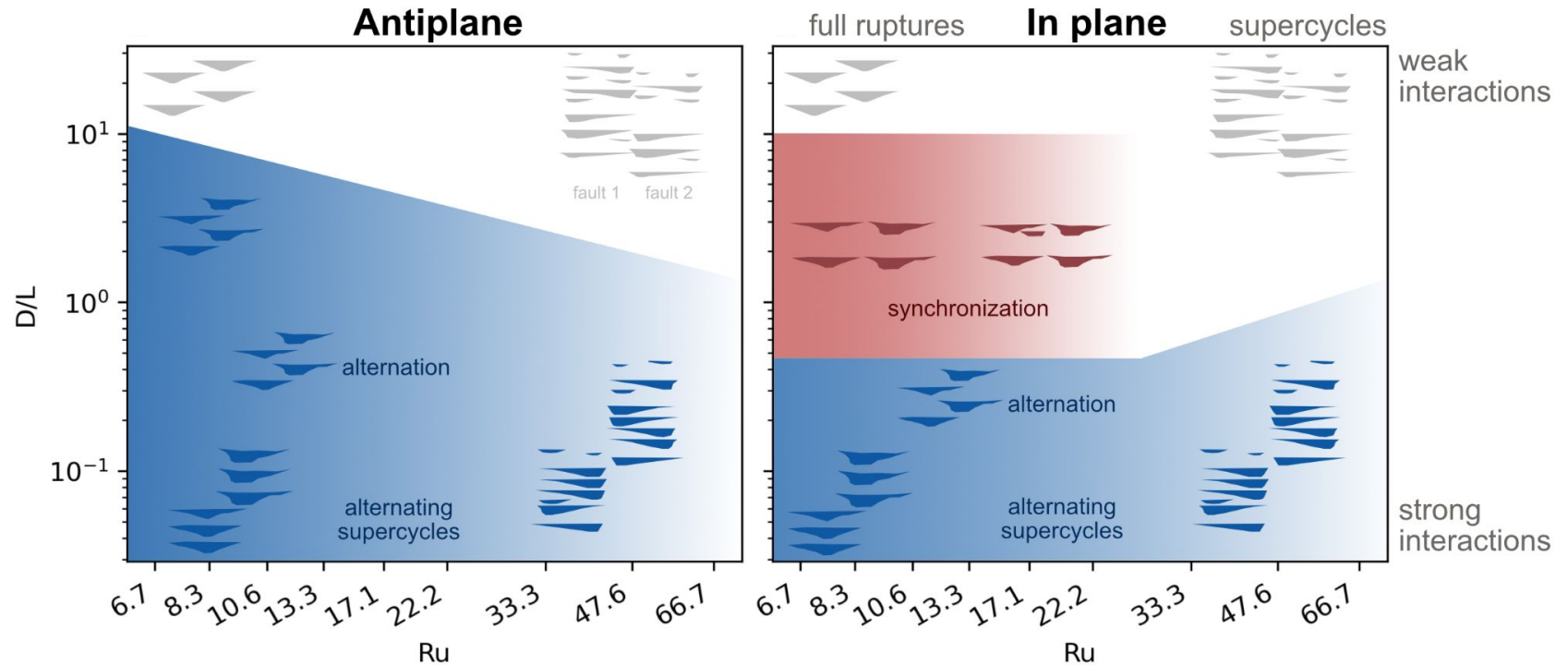
In plane → when $D/L > 0.5$ most to all of the receiver fault experiences a **clock advance** from the stress increase, fostering **synchronization**

We test parallel faults but stress kernels are easy to compute for any geometry



Because interactions are encompassed in D/L , they can be captured for natural faults via this proxy

Phase space of fault interactions emerges (and can be explained by) the stress interactions between neighboring parallel faults



Questions?

Earthquake sequence synchronization and alternation driven by quasistatic elastic interactions across faults

Authors: [Dr. Alba Mar Rodriguez Padilla](#)  , [Dr. Alexis Saez](#)  , and [Prof. Jean-Philippe Avouac](#)  

[Authors Info & Affiliations](#)

<https://doi.org/10.22541/essoar.15004063/v1>



N/A



N/A



Primary Abstract

Footnote

Supplementary Material

30 May 2026

Earthquake sequence synchronization and alternation driven by quasistatic elastic interactions across faults

Alba Mar Rodriguez Padilla¹, Alexis Saez², Jean-Philippe Avouac³

1. California Institute of Technology
2. Caltech
3. California Institute of Technology



USU Rock Deformation and Earthquake Mechanics Lab

PI Srisharan Shreedharan



Srisharan
Shreedharan

Assistant Professor



Kelian Dascher-
Cousineau

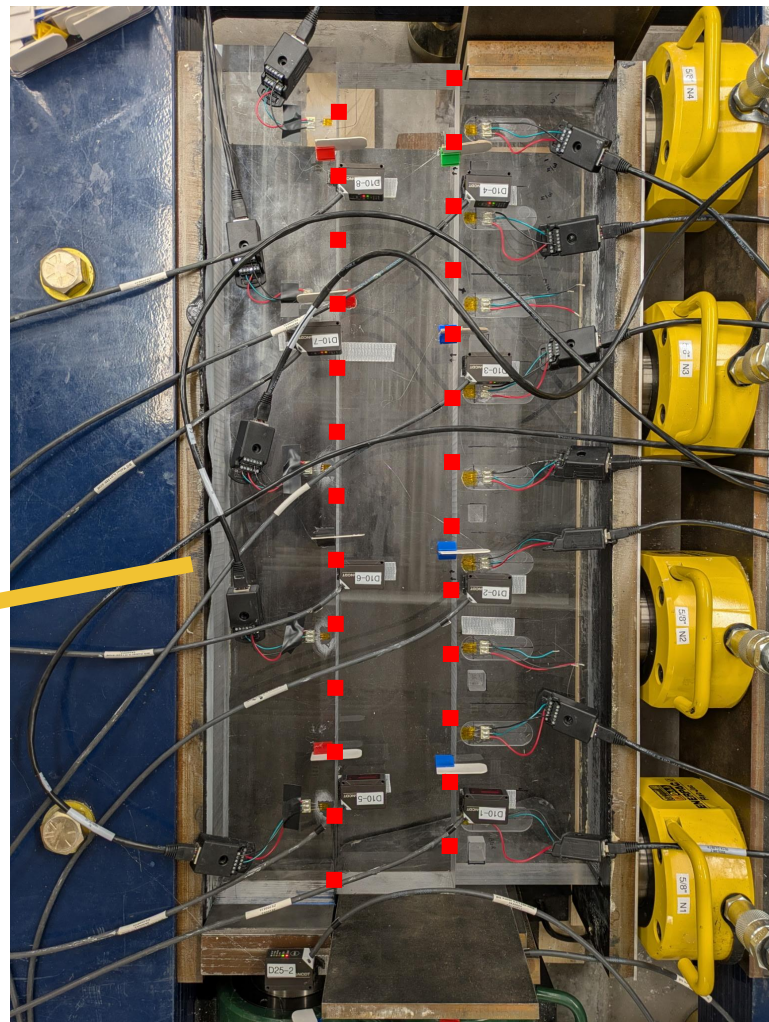
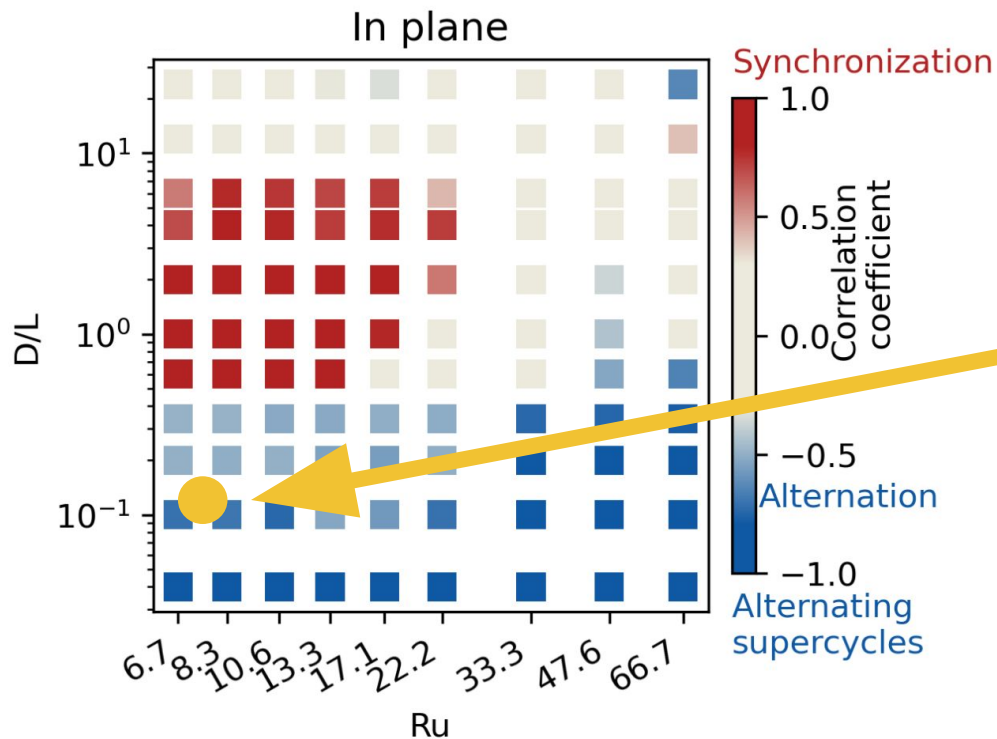
Assistant Professor



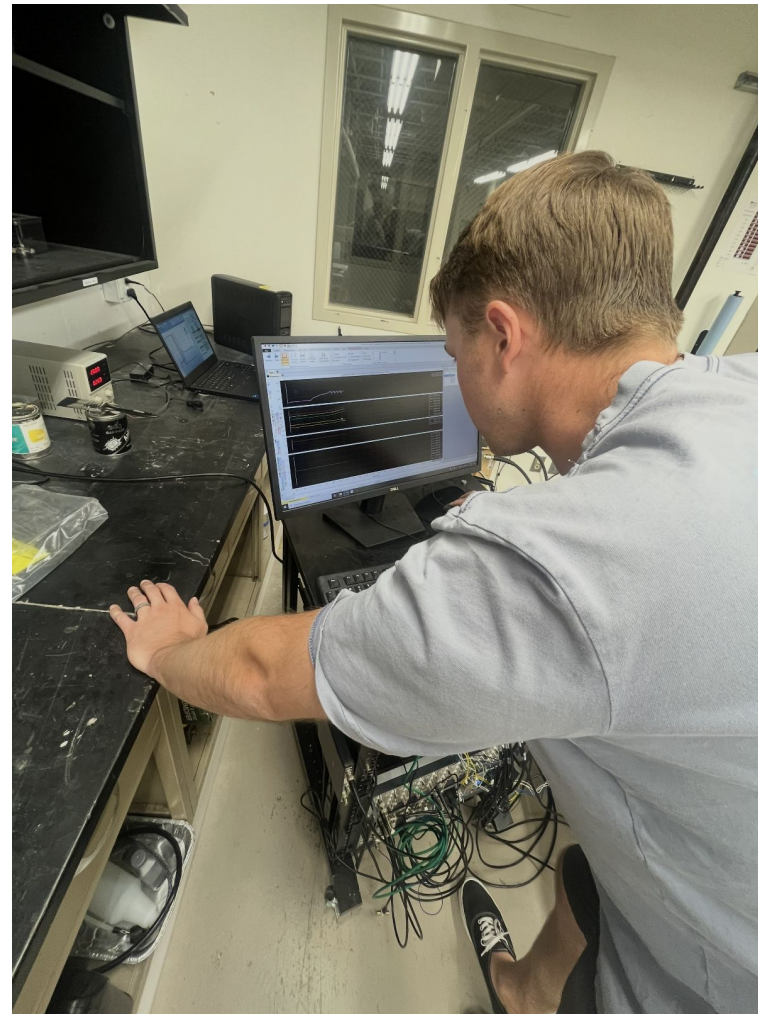
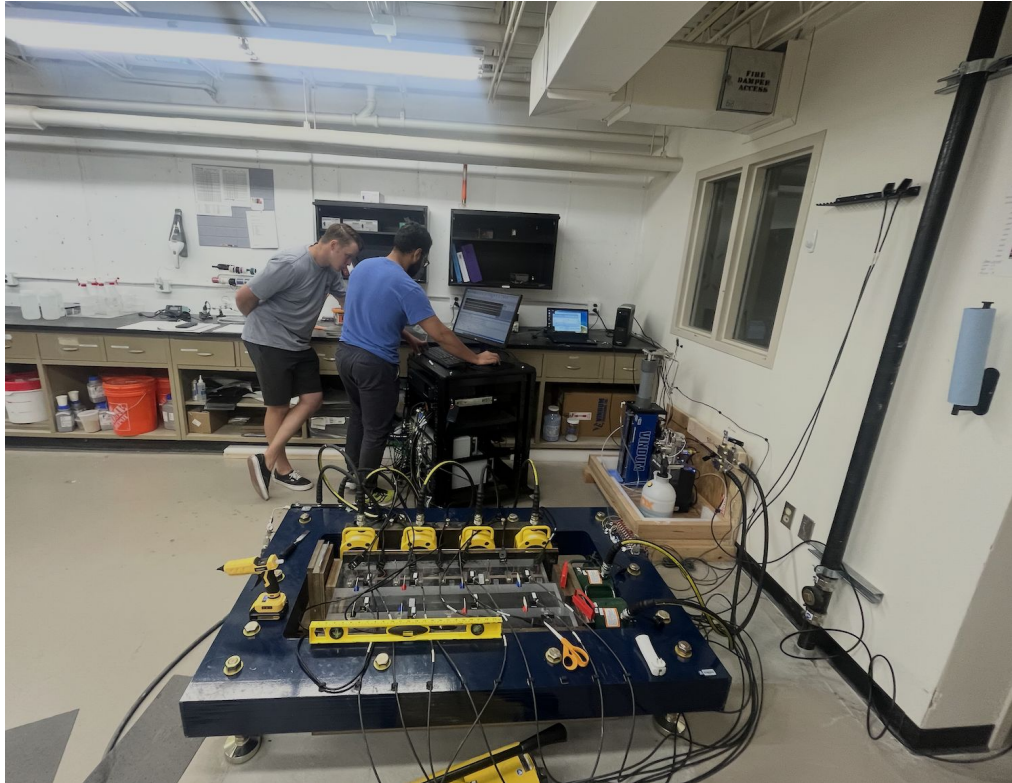
Chas Bolton

Assistant Research
Professor (UT
Austin)

1 m biaxial shear apparatus with two faults (bi-biax)

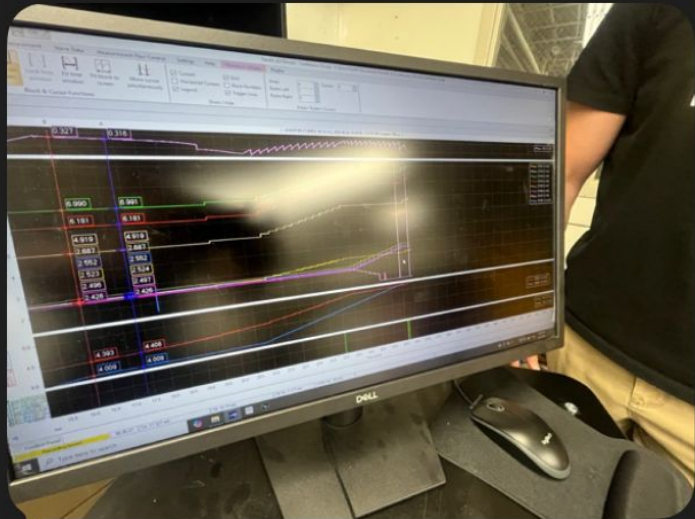


Experiments running yesterday afternoon...

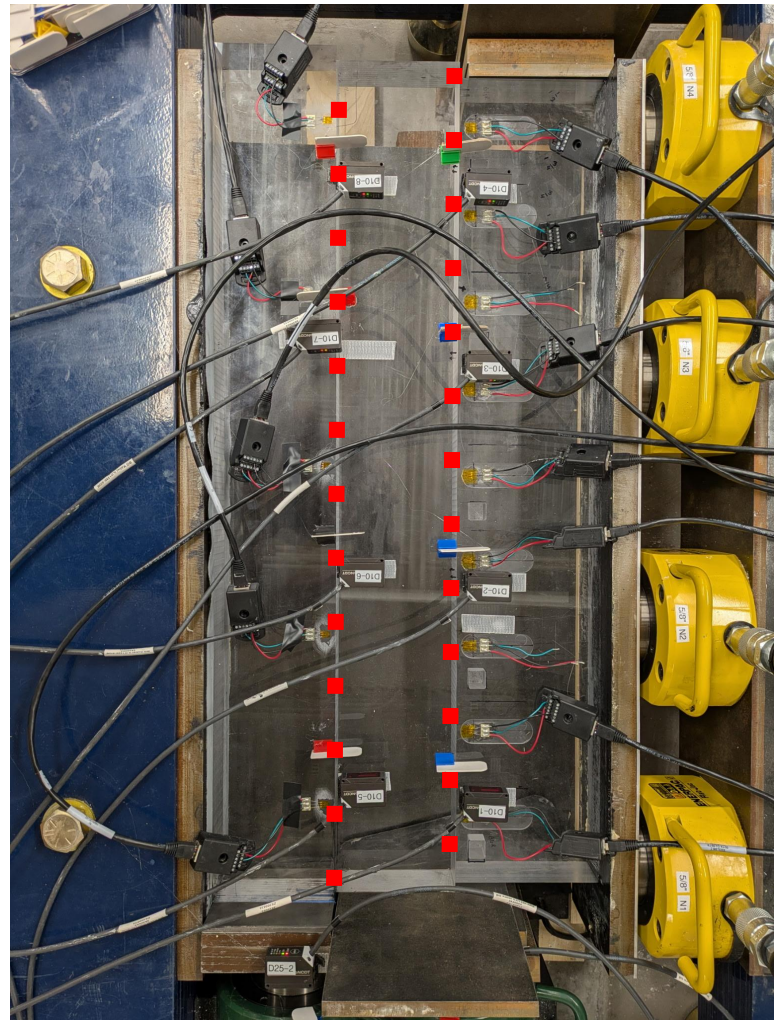


Today 4:33 PM

SUPERCYCLES!!

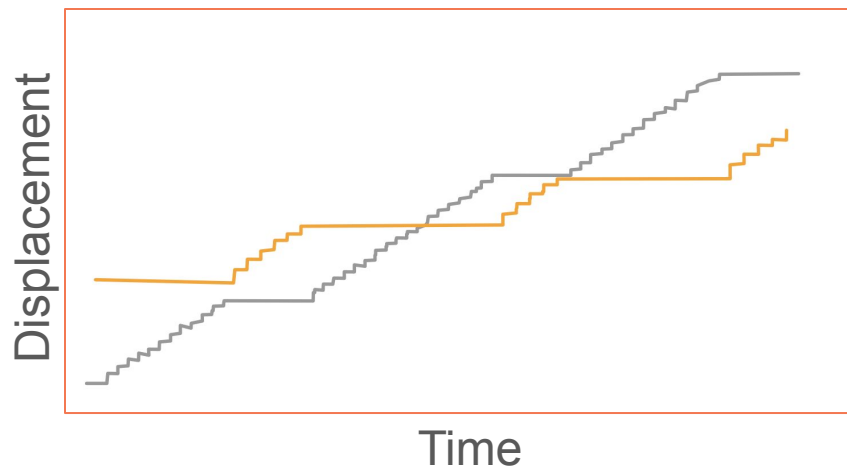
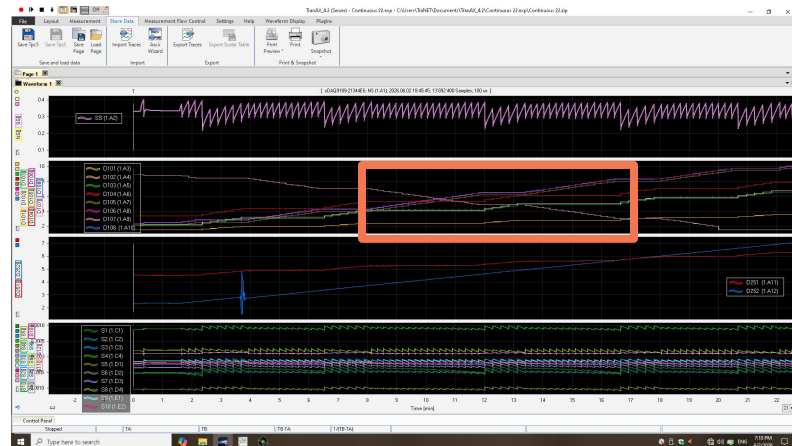
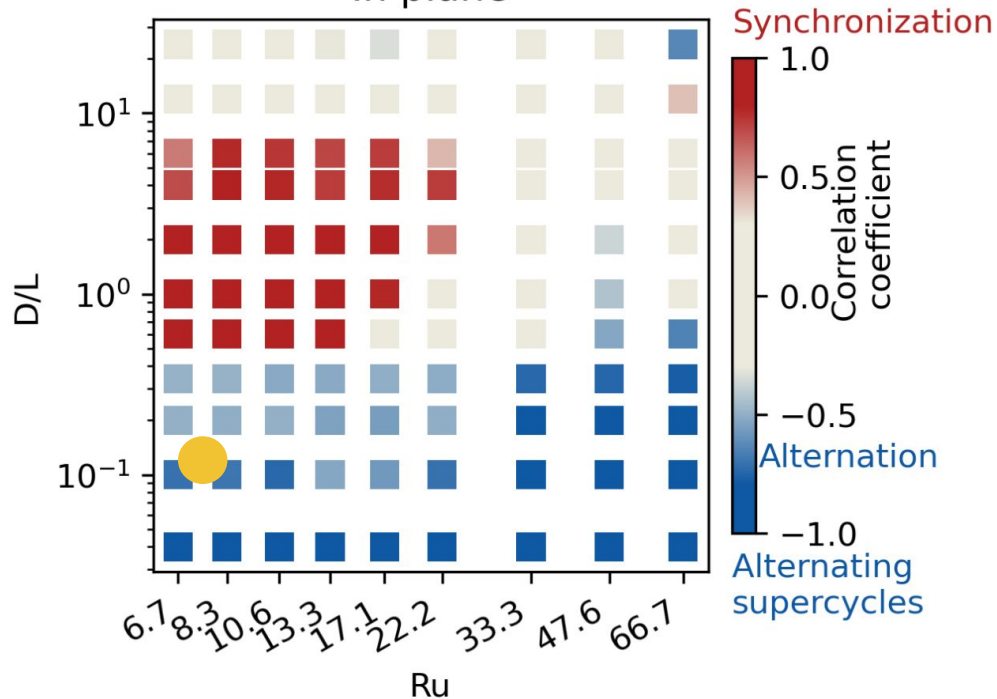


Saw it happen in real time!



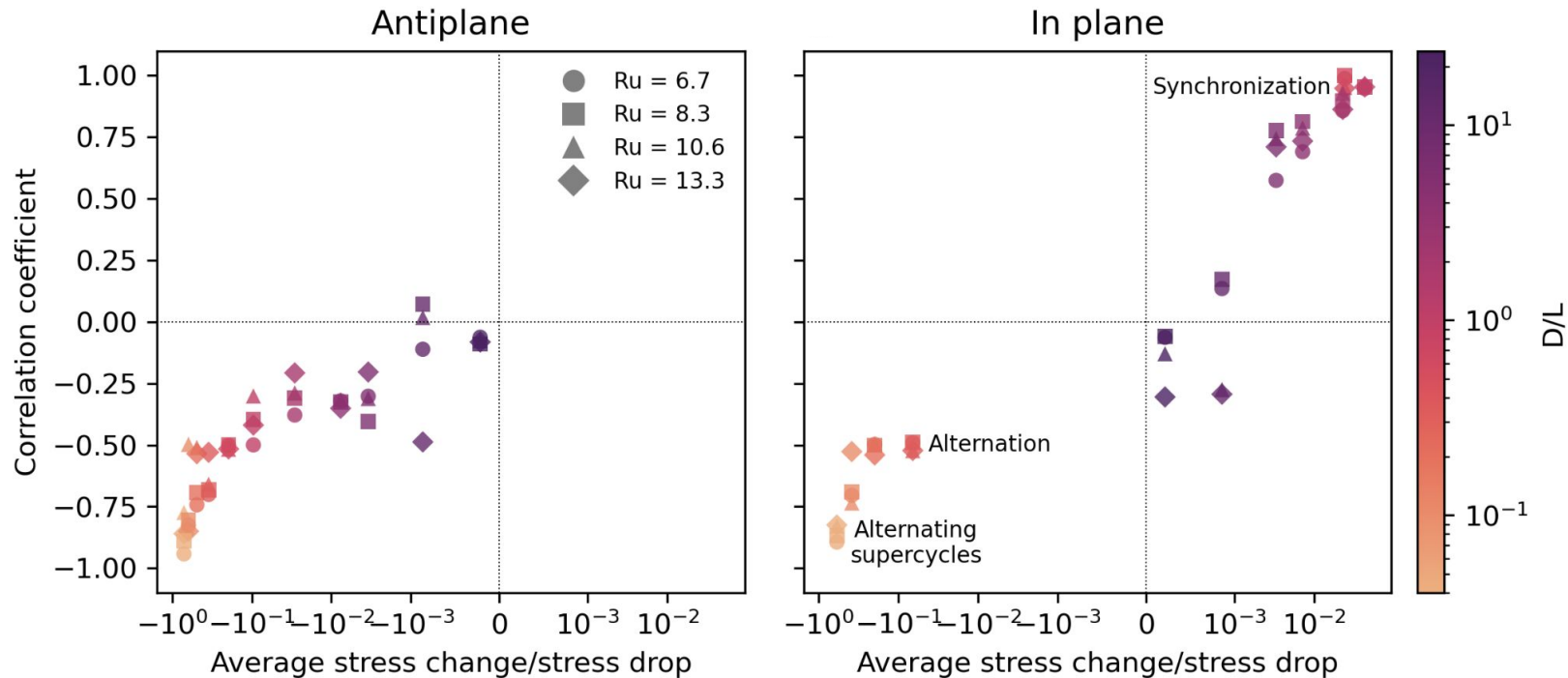
Alternating supercycles in the lab!!!!

In plane



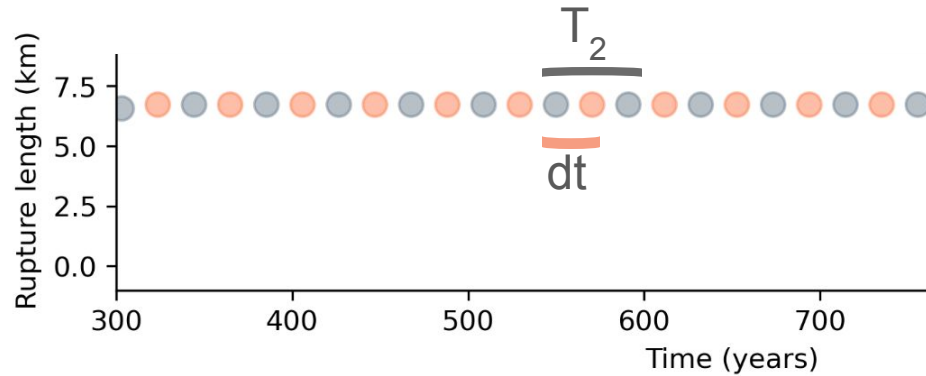
BONUS SLIDES

The sign and magnitude of Coulomb stress perturbations on the receiver fault control the interactions



Because these are encompassed in D/L, they can be captured for natural faults via this proxy

Alignment: a parameter to quantify the relationship of event times on a fault with respect to its neighbor

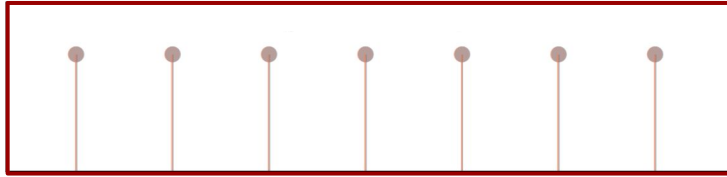


$$\theta = 2\pi \frac{dt}{T_2}$$

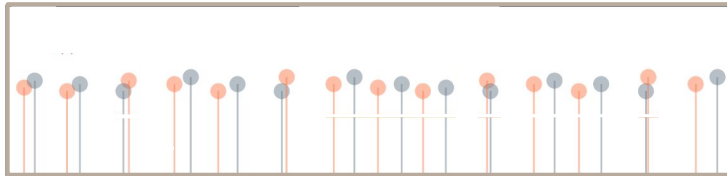
$$\text{Alignment} = \overline{\cos\theta}$$

We only consider full ruptures in the alignment metric calculation.

Alignment coefficient → metric to characterize interactions in earthquake catalogs



Synchronized faults have alignment coefficient close to 1



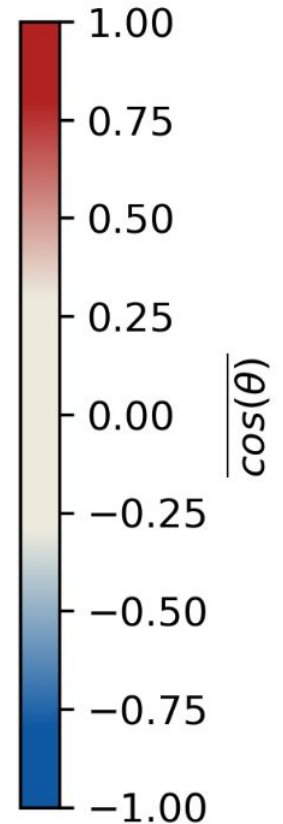
Faults with little interaction have alignment coefficient close to 0



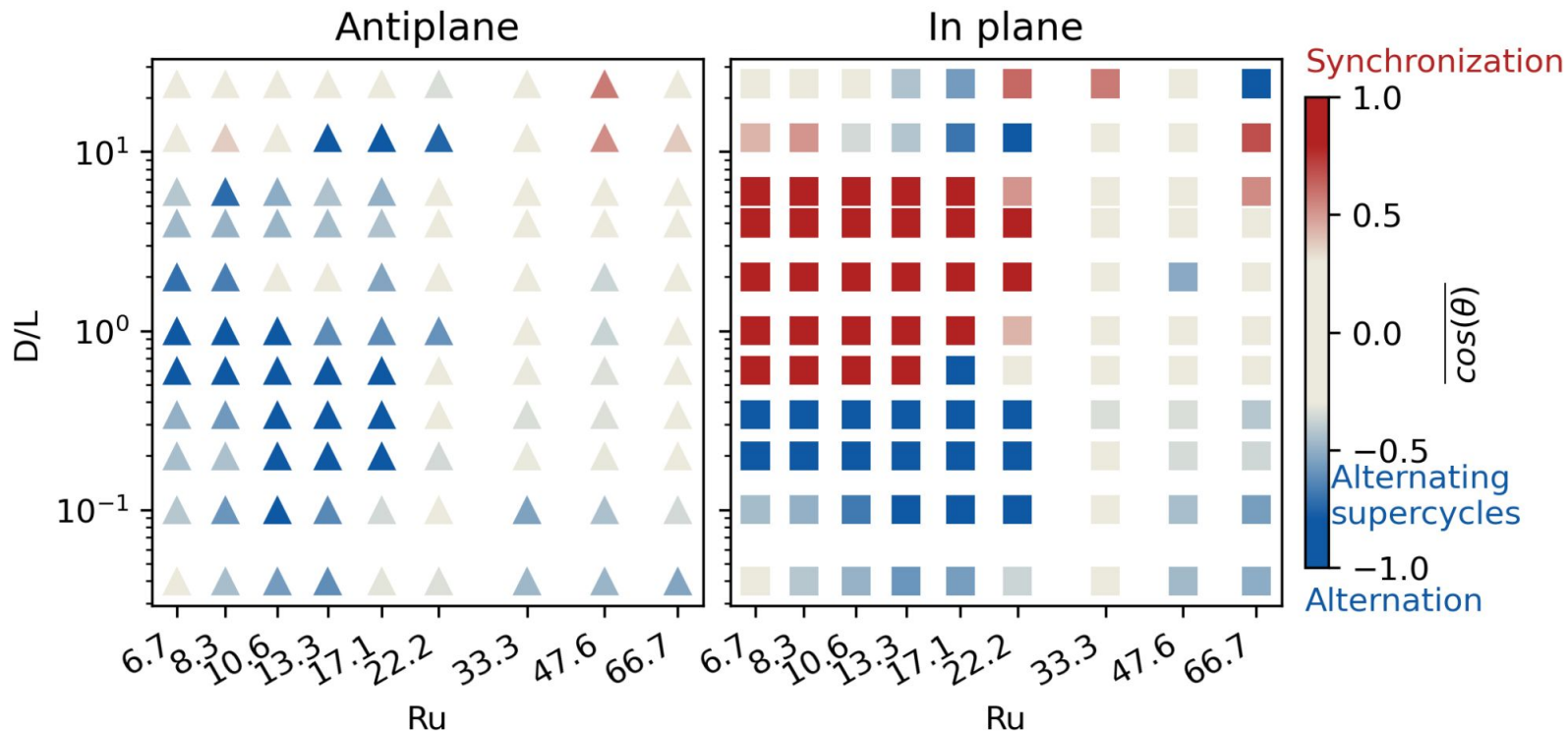
Alternating supercycles lead to alignment coefficients < -0.5



Alternating ruptures have alignment coefficient close to -1

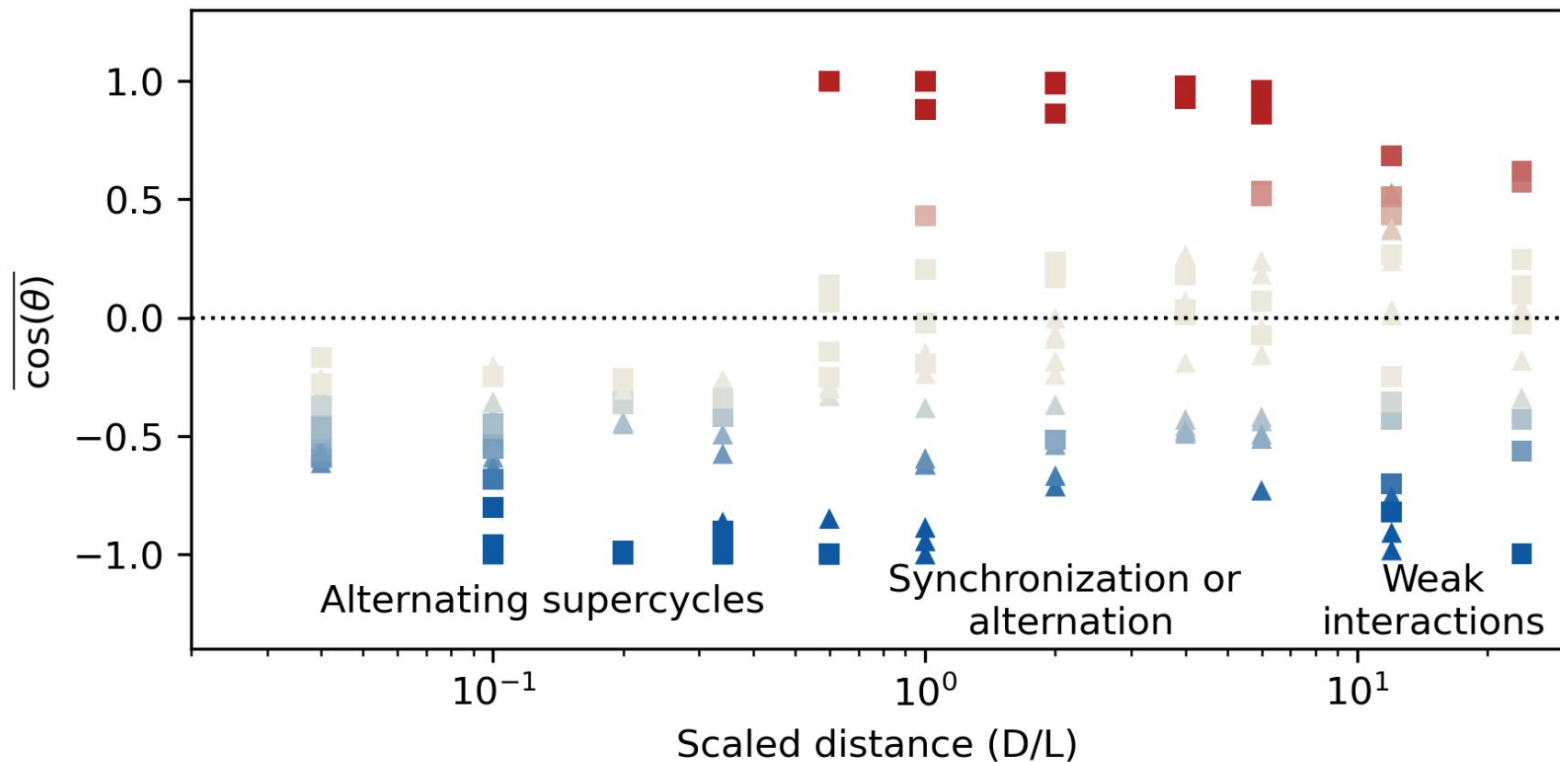


Alternating supercycles and **alternating ruptures** occur when the faults are close irrespective of the instability ratio and loading conditions.

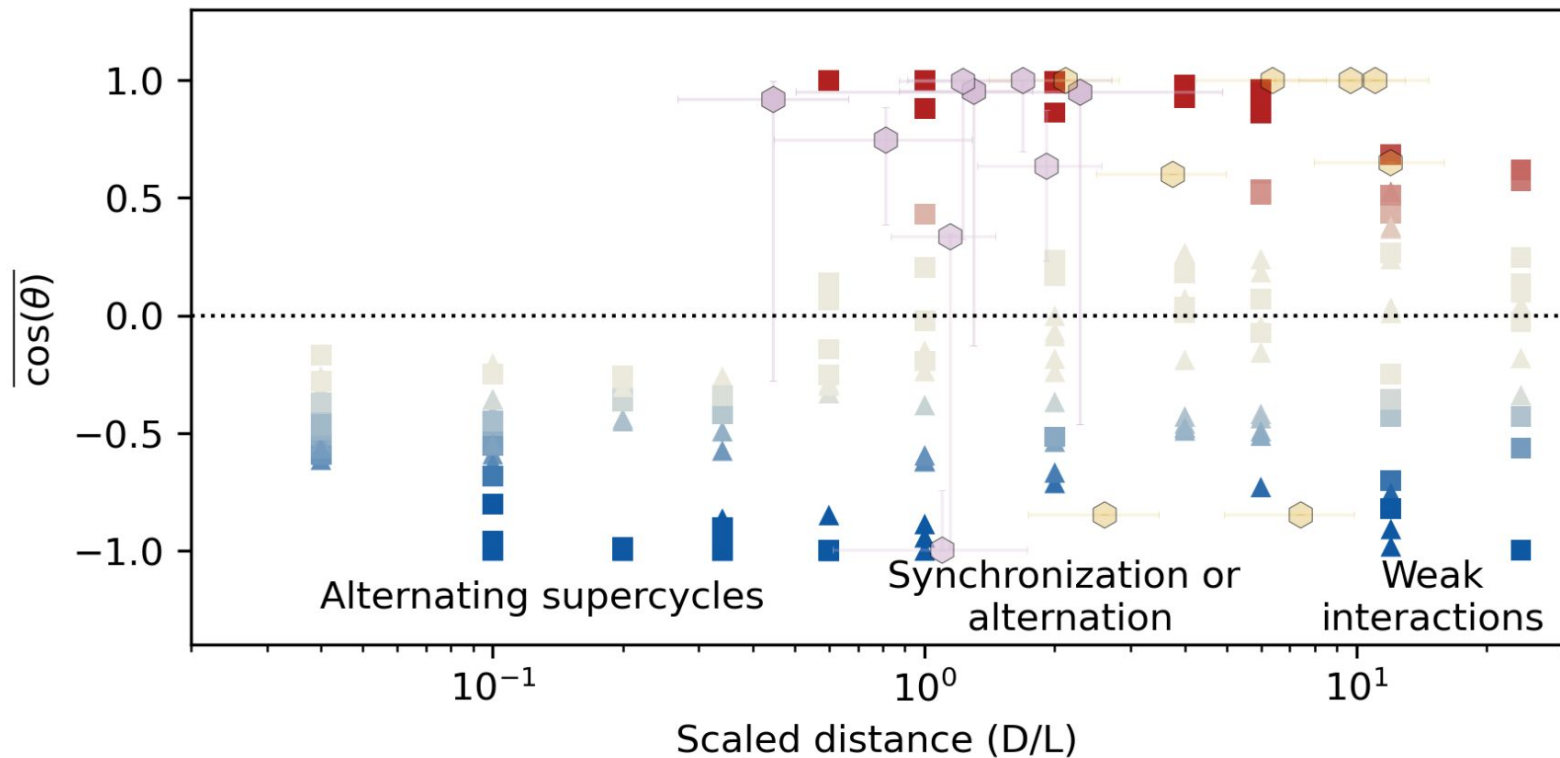


Synchronization occurs for $Ru < 23$ and $0.5 < D/L < 8$ under in plane conditions.

The distance between the faults is the **primary control on the resulting interactions**, with the instability ratio playing a secondary role

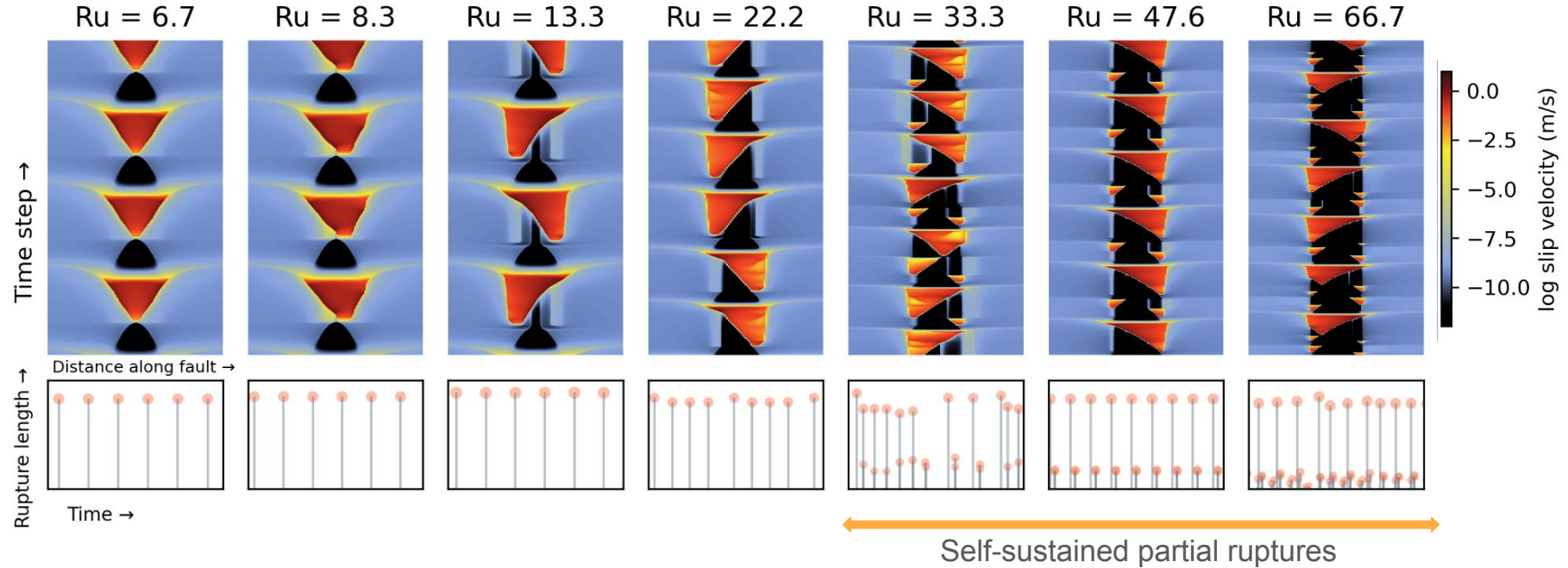


Data from incremental slip rate records fall within the space proposed by the models → **fault interplay resulting primarily from stress interactions**



A useful benchmark: isolated fault, same boundary conditions

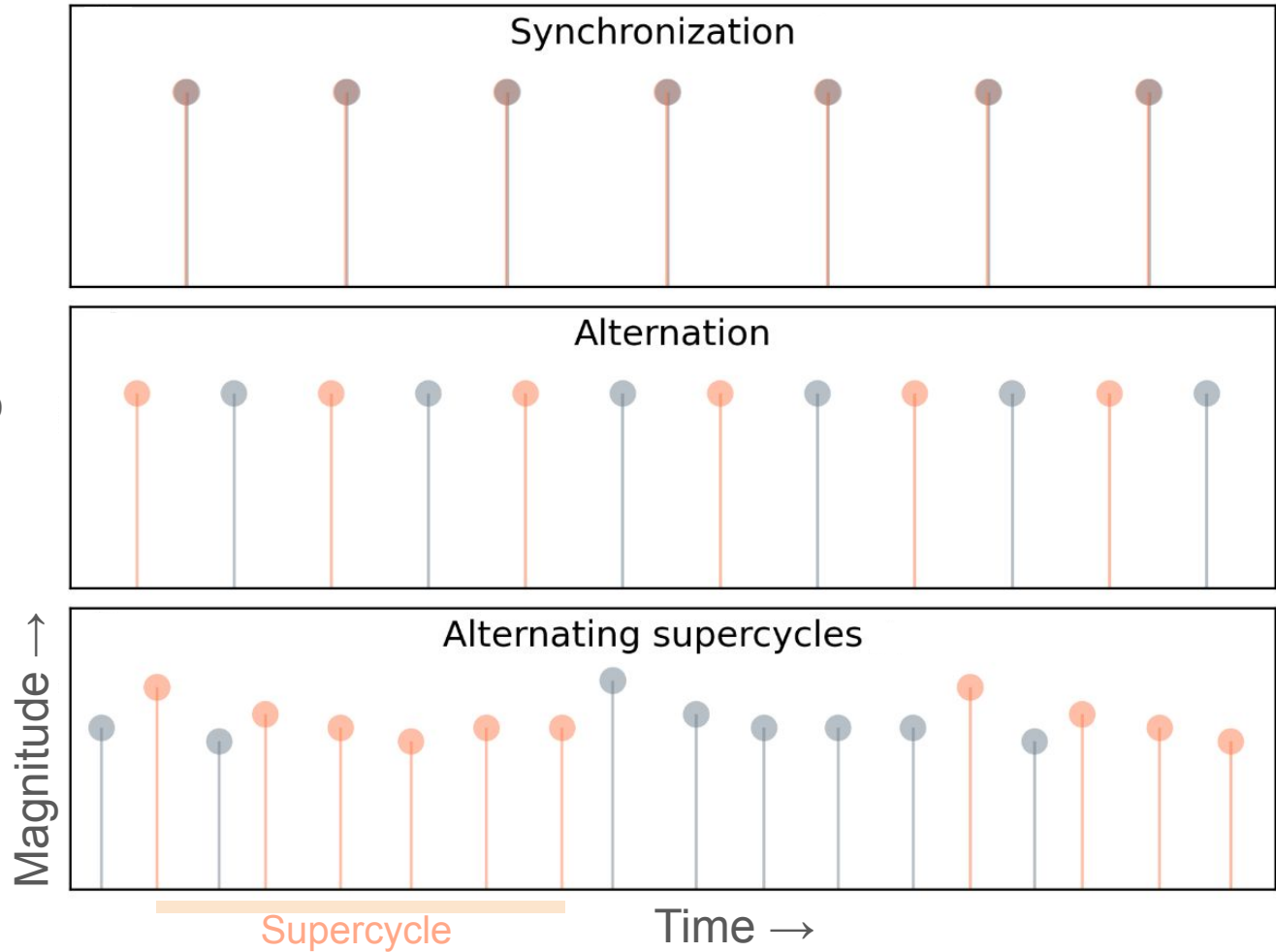
Antiplane

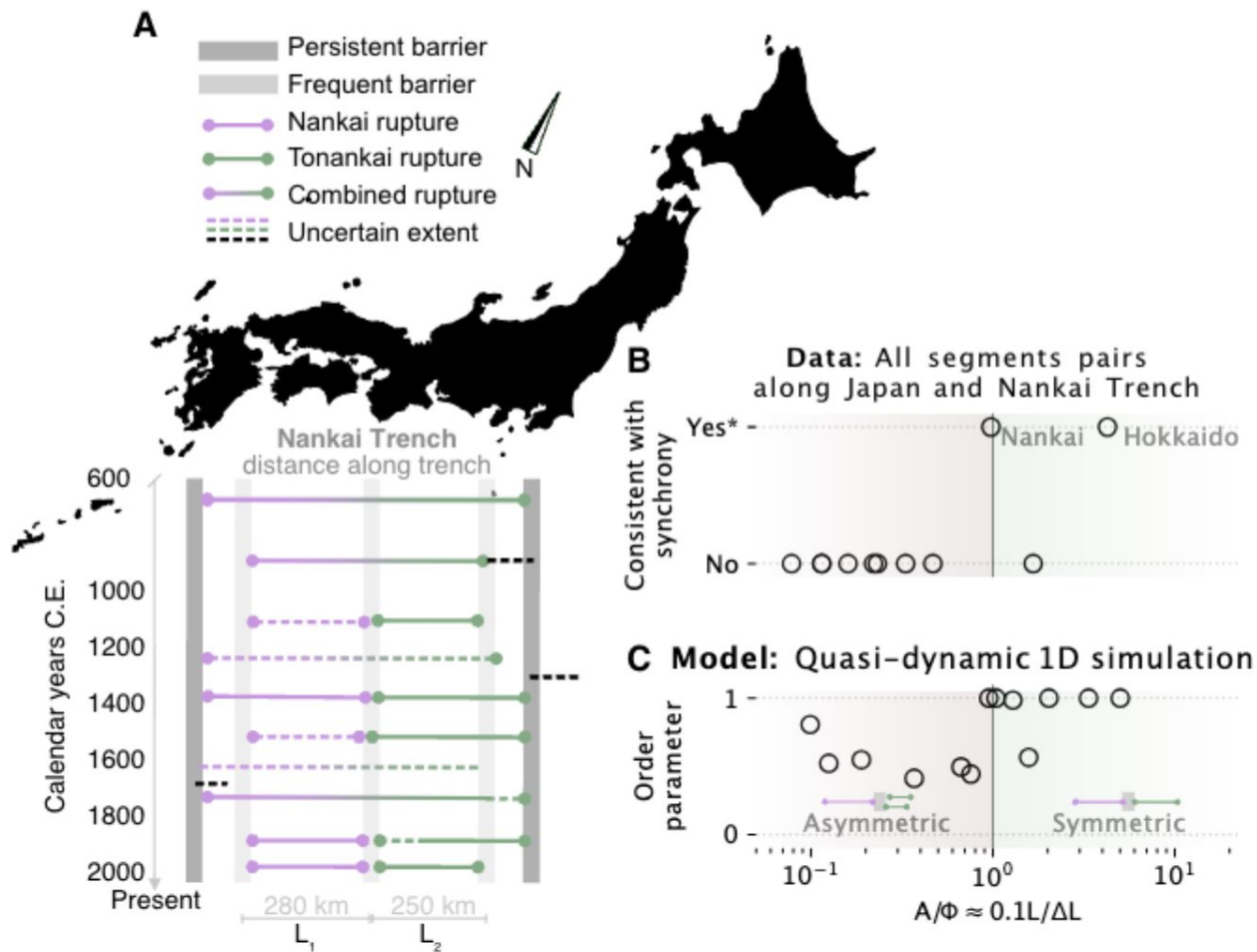


Larger instability ratio supports self-sustained partial ruptures

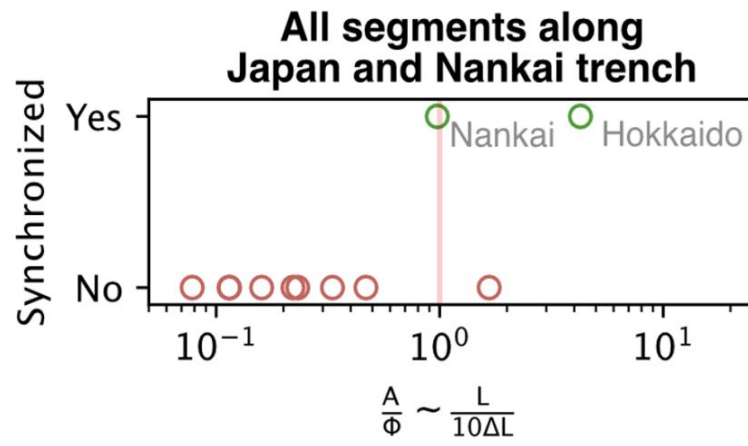
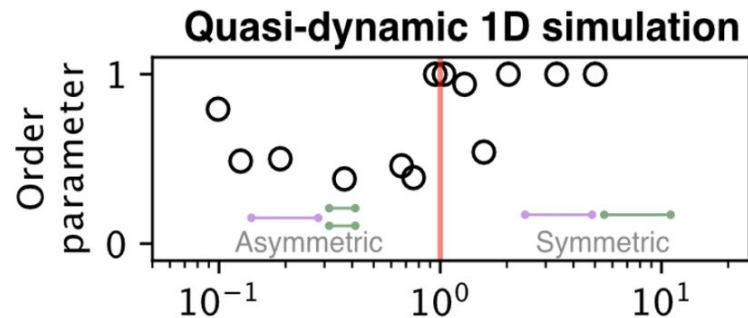
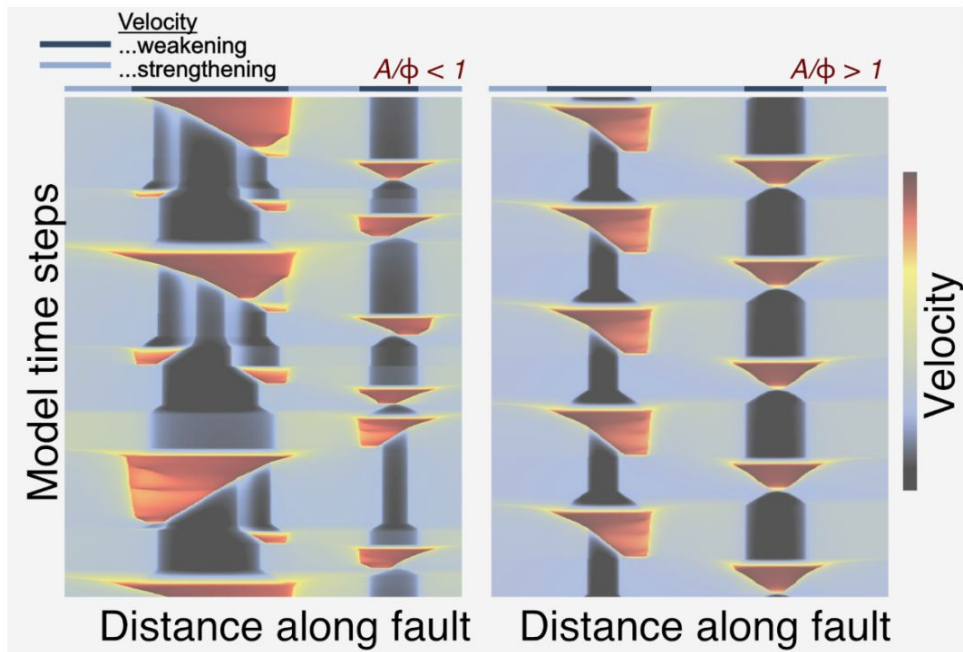
Fault 1 | Fault 2

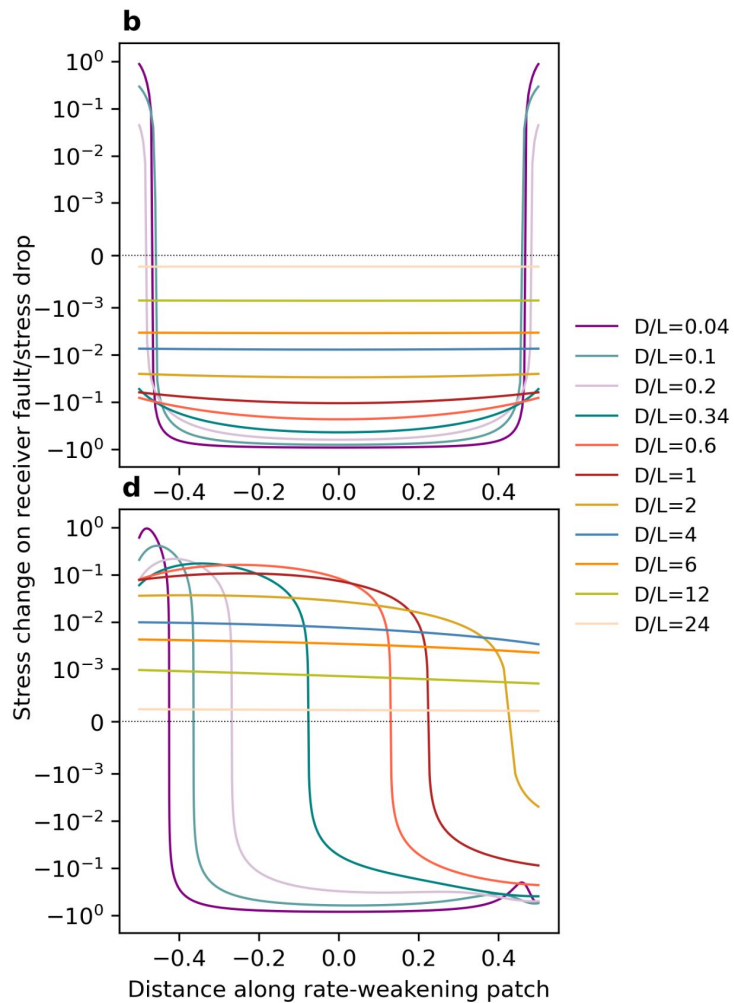
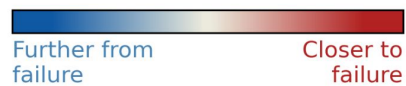
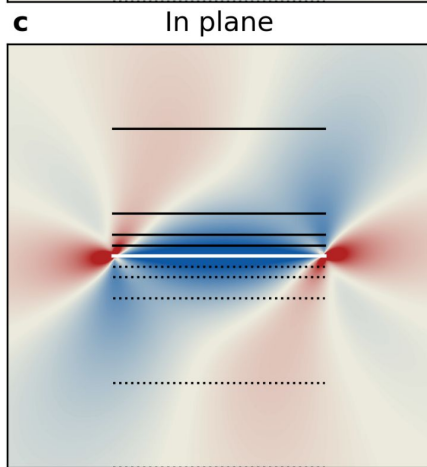
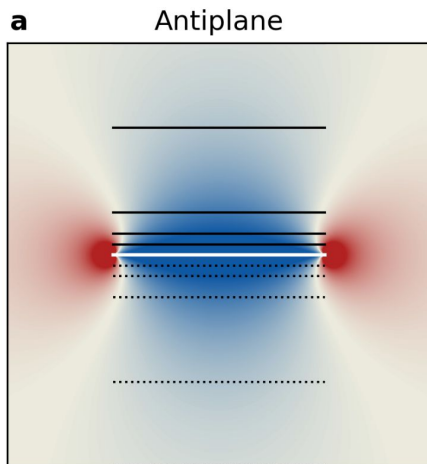
How do elastic interactions contribute to establishing **alternation** and **synchronization**?

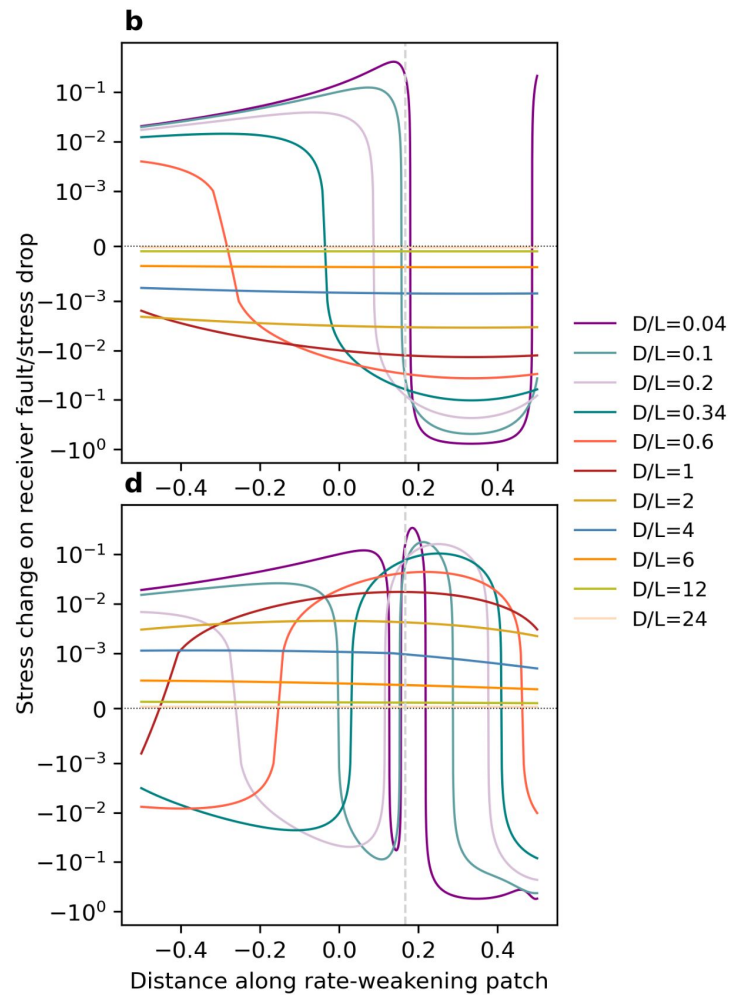
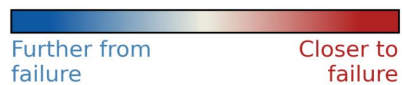
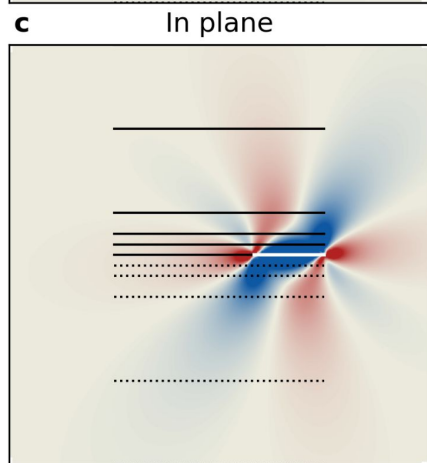
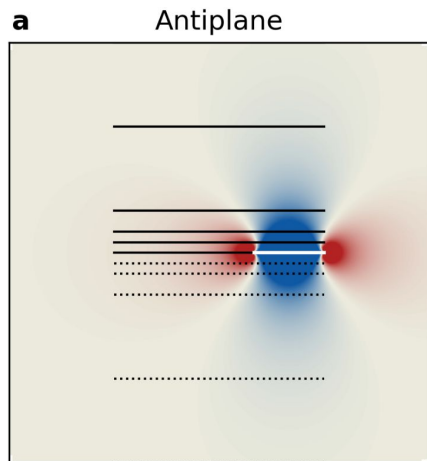




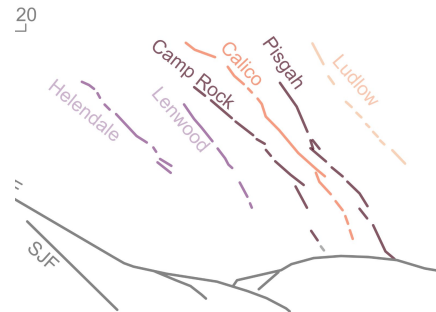
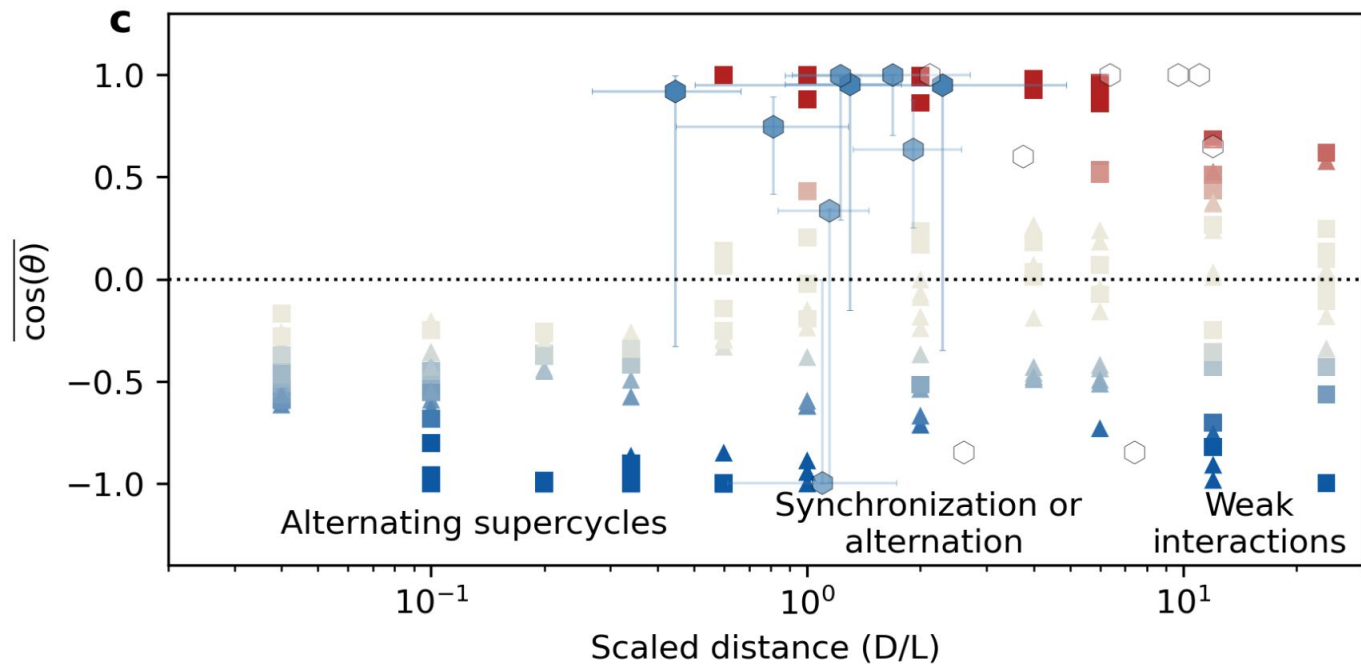
Dascher-Cousineau et al.
(in review)



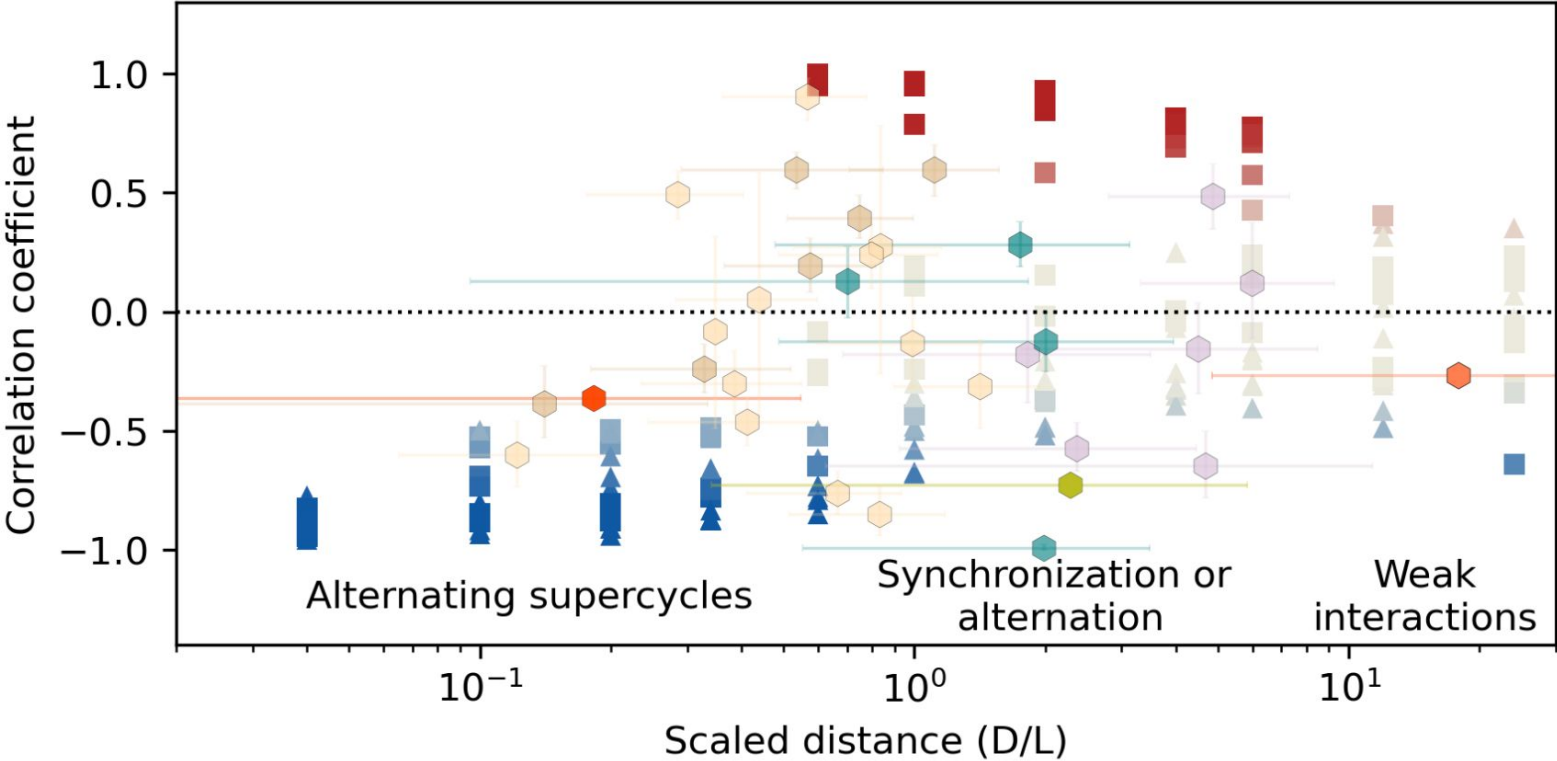




Data from earthquake chronologies fall within the space proposed by the models → **fault interplay resulting primarily from stress interactions**



Data from incremental slip rate records show reasonable agreement with the space proposed by the models



$Ru = 47.6$, $D/L = 0.1$, Antiplane

