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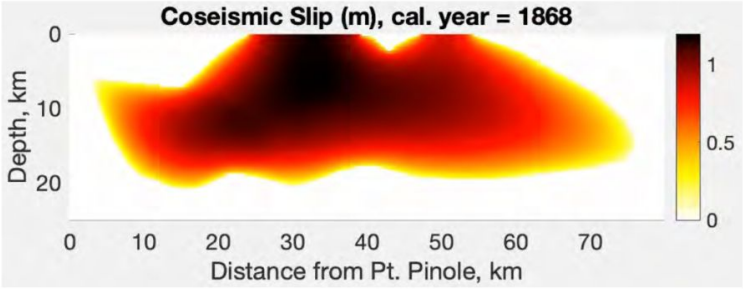
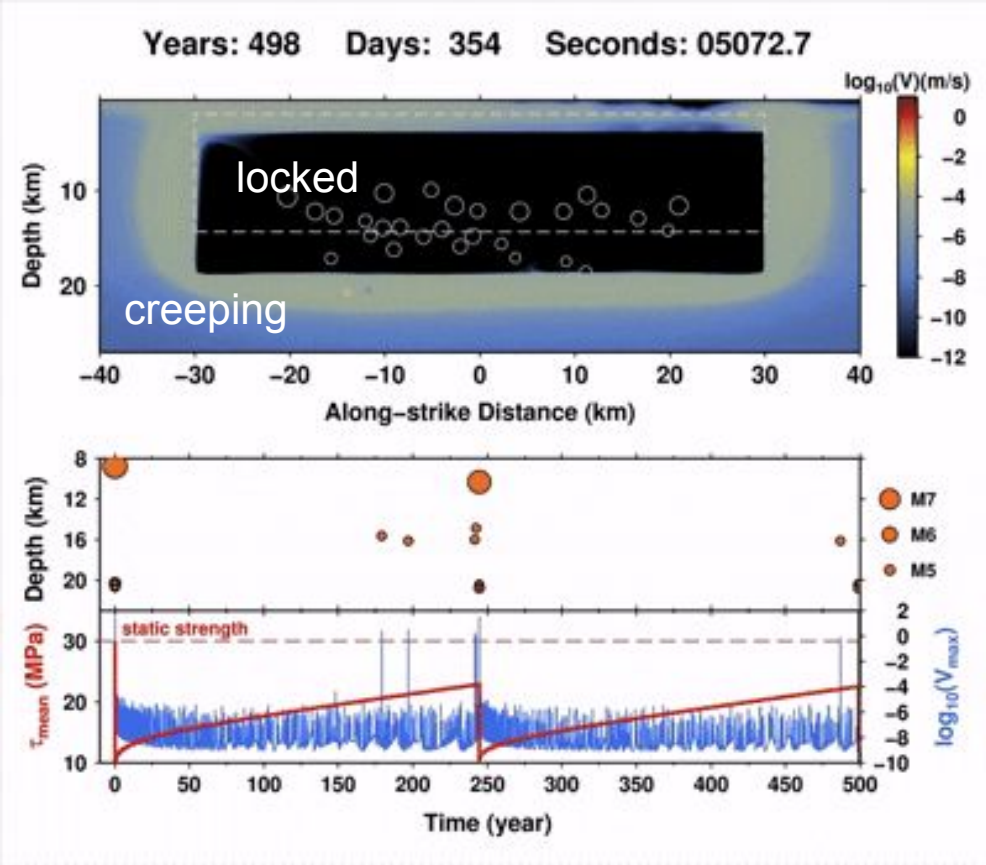
Open Problems in Earthquake System Science - a modeling perspective

Observation: interseismic fault decoupling
(Roland Bürgmann's talk on Sunday)

Often observed in **numerical models**





Heterogeneous fault loading due to adjacent creep can reproduce gradual fault decoupling

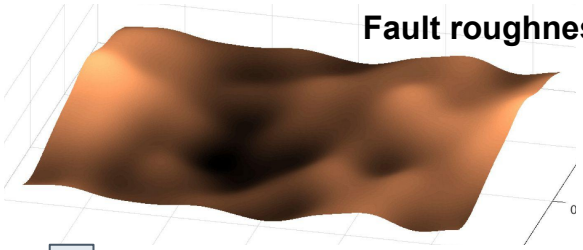
Ingredients:

planar fault

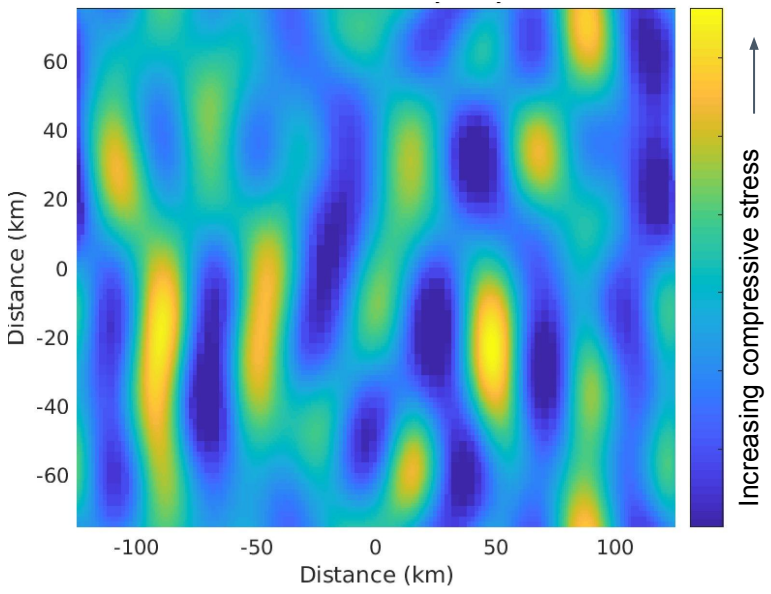
rate-state friction with heterogeneous (a-b)

thermal pressurization (optional)

Jiang and Lapusta (2016)

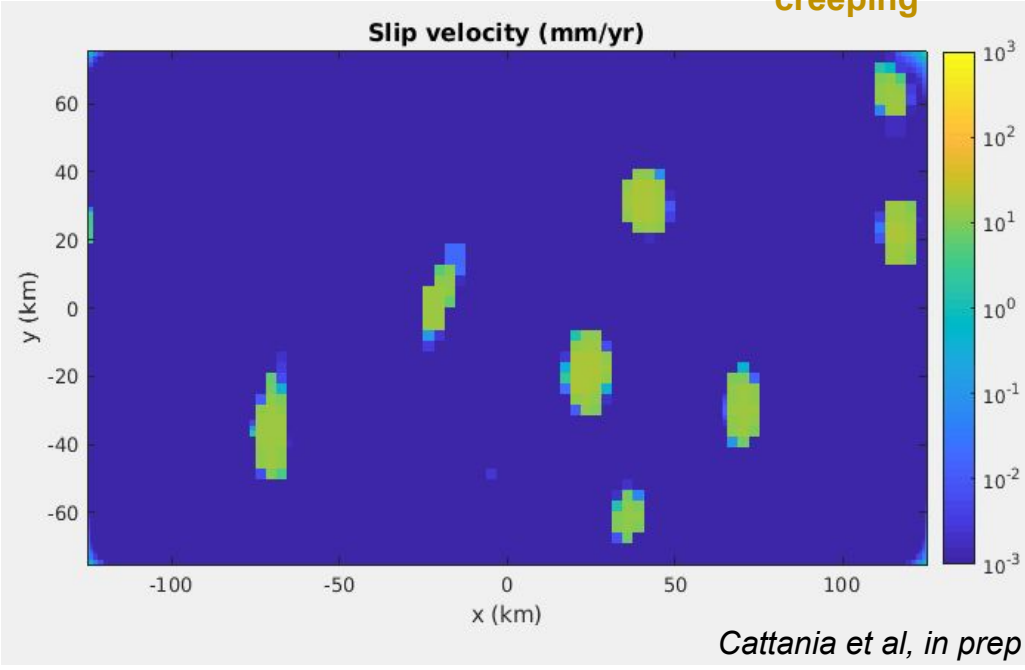


Normal stresses heterogeneity
(e.g. Cattania and Segall, 2021; Romanet et al, 2021)



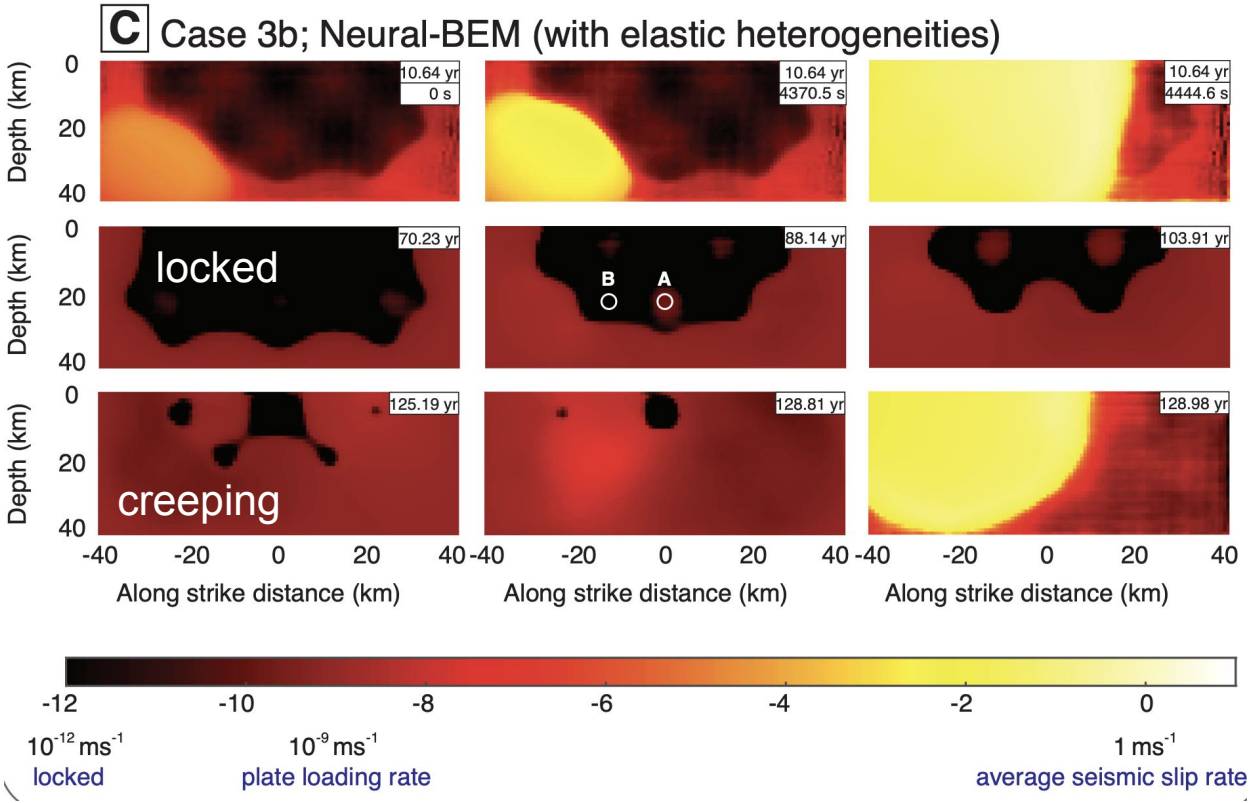
Heterogeneity in normal stress on a rough fault can reproduce gradual fault decoupling

Locked, creeping



Cattania et al, in prep

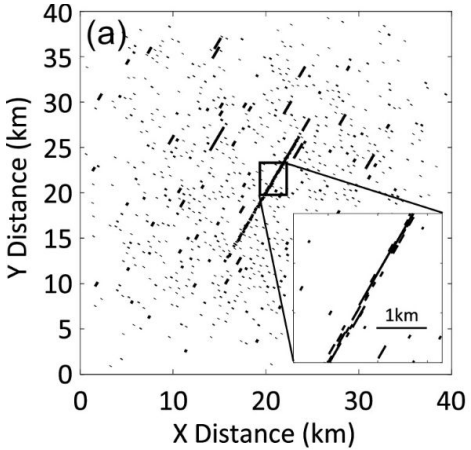
Heterogeneous loading due to elastic heterogeneity can reproduce gradual fault decoupling



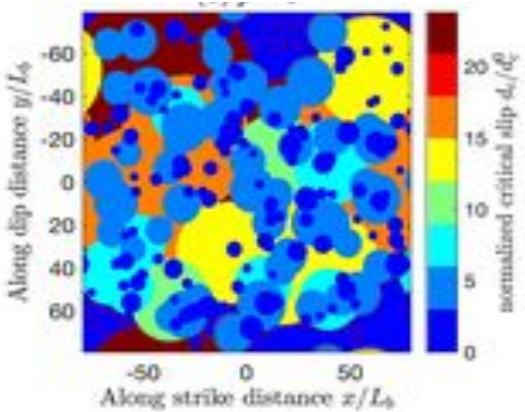
Wang et al., in prep.

Gutenberg-Richter

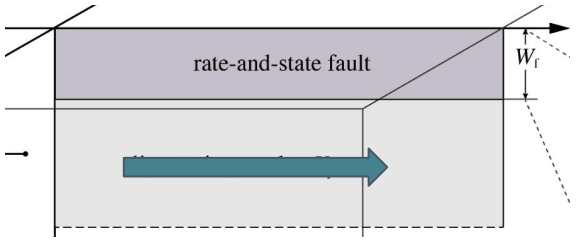
Complex fault network

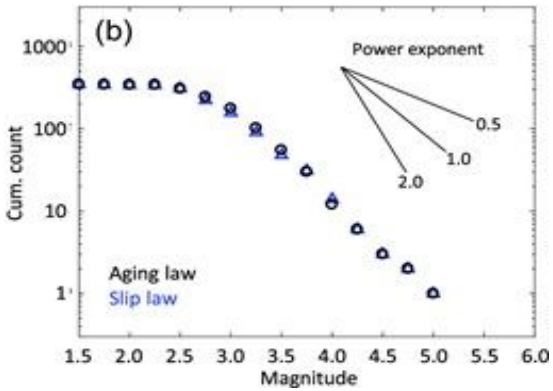


Heterogeneous planar fault

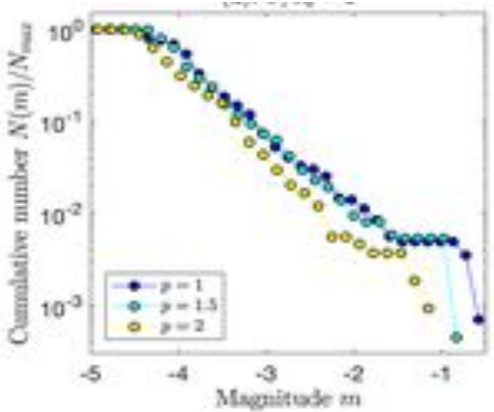


Homogeneous fault loaded from below

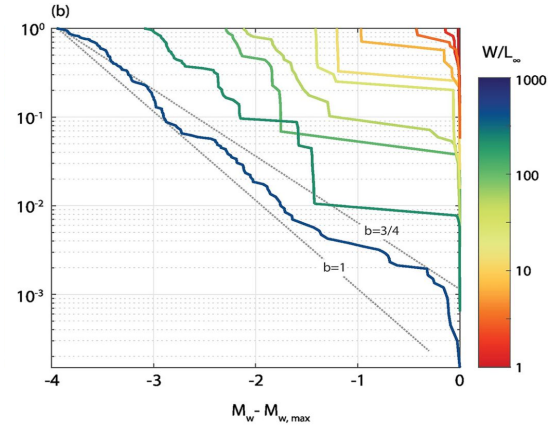




Im and Avouac, 2023

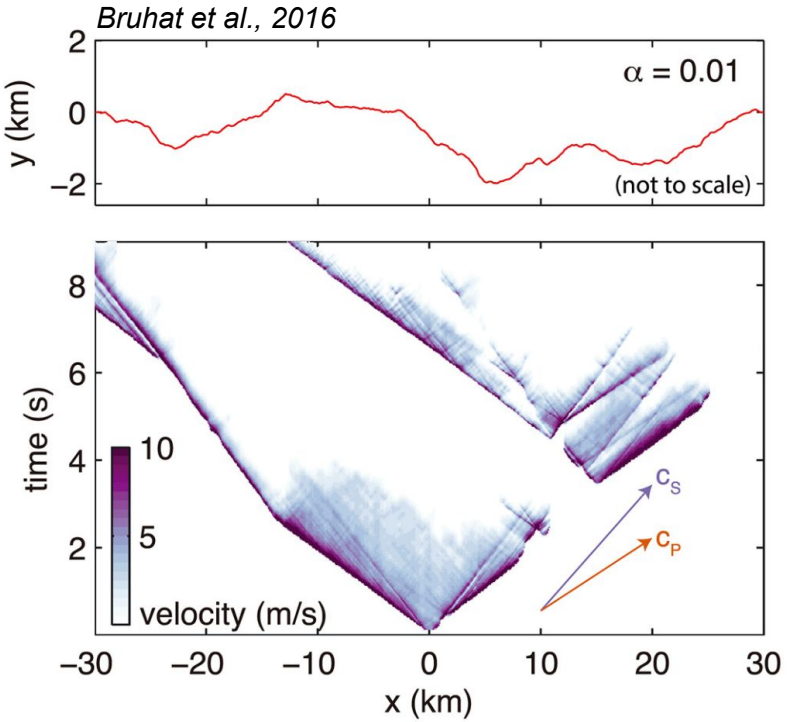


Dublanchet, 2020

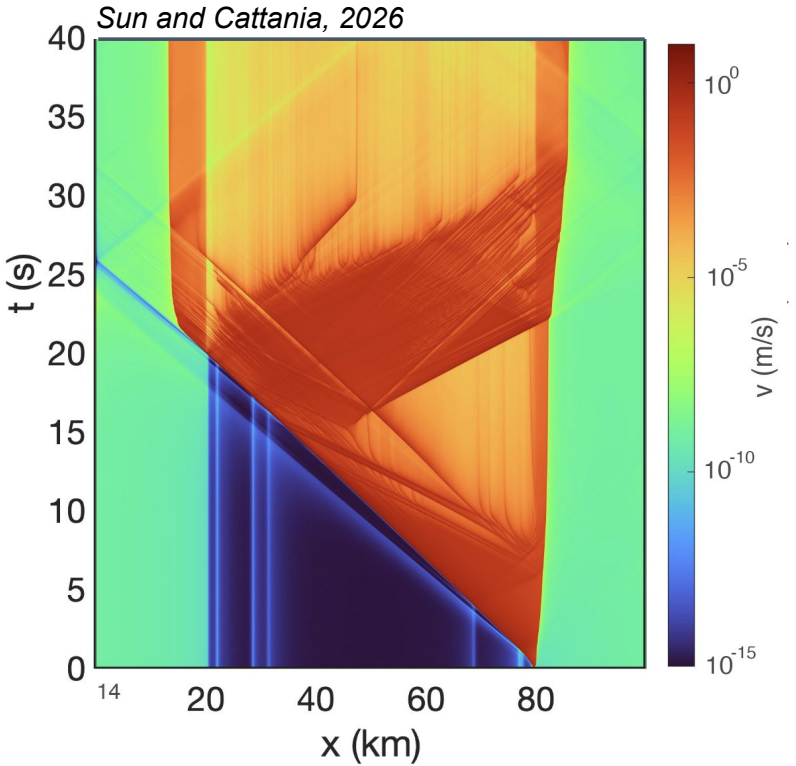


Cattania, 2019

Rupture complexity driven by roughness

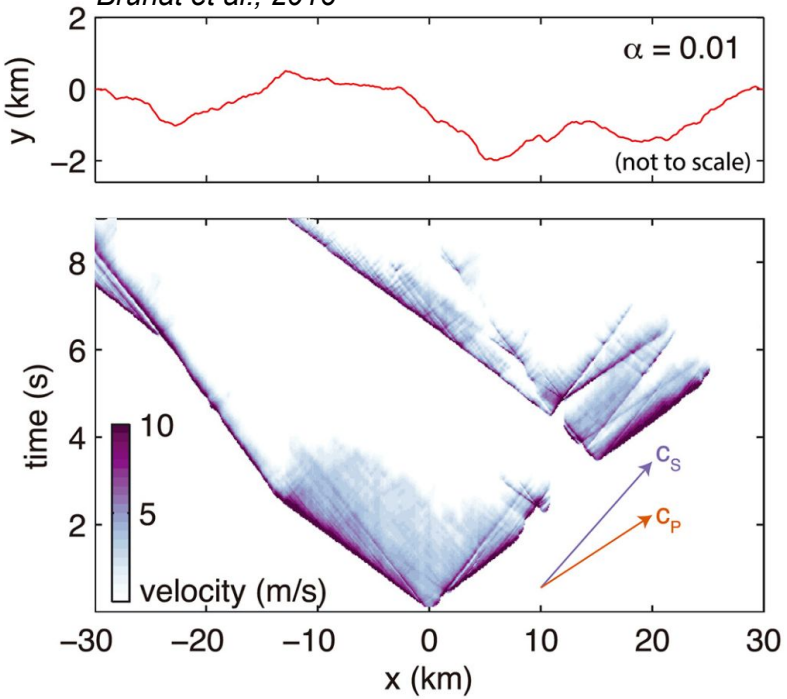


Rupture complexity driven by non-linear friction



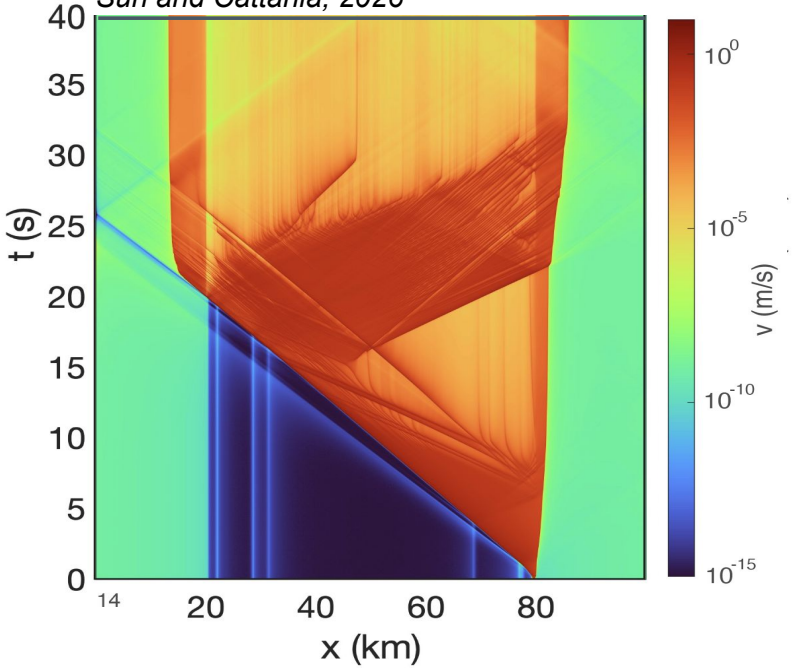
Rupture complexity driven by roughness

Bruhat et al., 2016



Rupture complexity driven by non-linear friction

Sun and Cattania, 2026



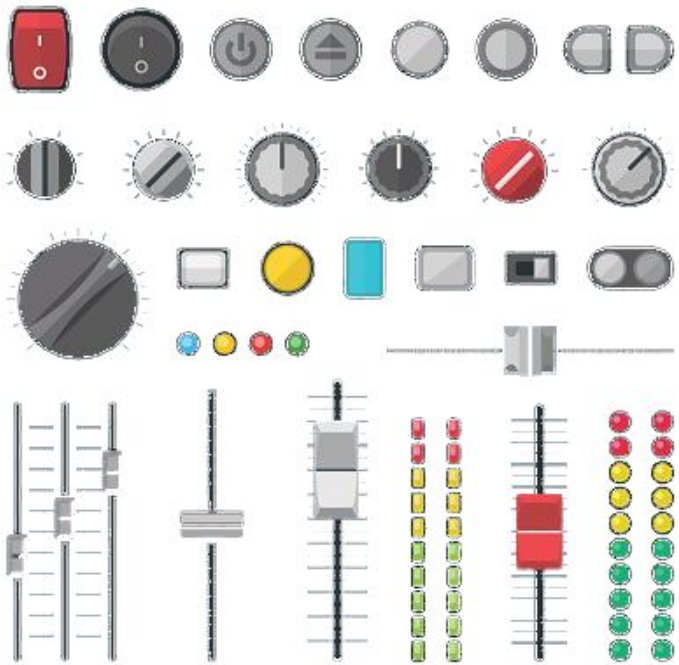
Higher predictability → Lower predictability

To what extent is earthquake behavior controlled by structural complexity vs. non-linear friction/rheology?

What are the implications for earthquake predictability?

Models have many knobs we can turn to match observations

“With four parameters I can fit an elephant, and with five I can make him wiggle his trunk.” (E. Fermi)



Fault geometry

Friction

Bulk and shear zone rheology

Hydrology

…

Model comparison

SEAS benchmarks so far compare a suite of models based on the same physics

Comparing models based on different assumptions is less straightforward, but it can be done (e.g. CSEP evaluation of seismicity foreasts)