Multi-Scale Effective Friction Laws for Fault-Scale Dynamic Rupture

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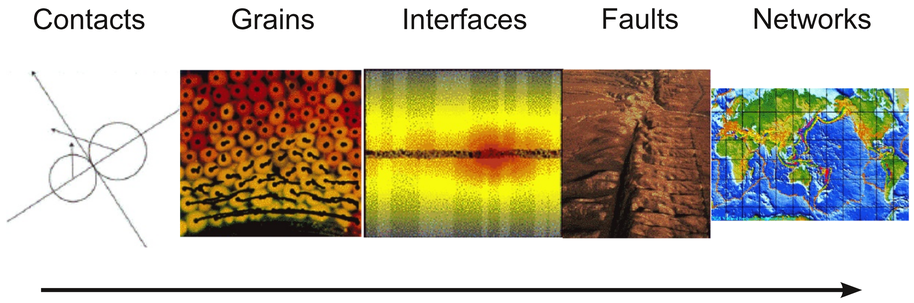
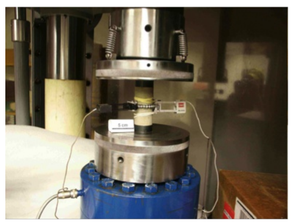
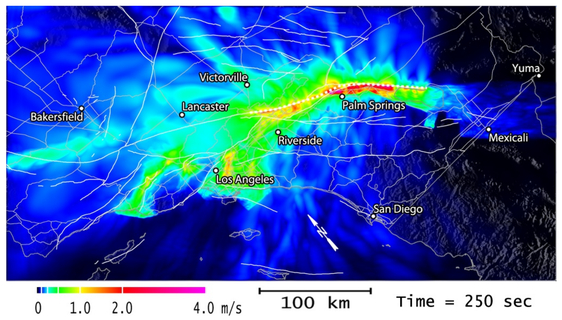
Earthquakes are Multi-Scale

Earthquake problem spans a huge range of length and time scales from grains to fault networks. How to capture appropriate physics at one scale and incorporate into simulations at larger scale?



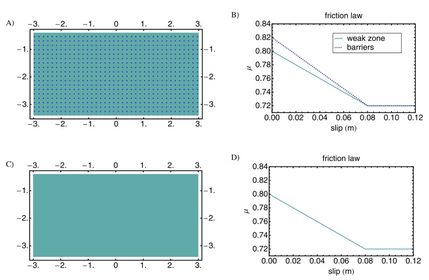
Friction Law at Fault Scale?

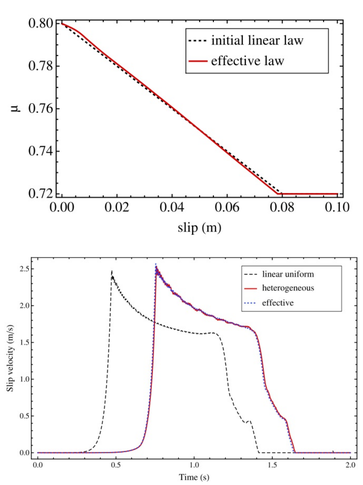




Problem: Friction is measured in laboraory at scale of ~cm to ~m, but rupture simulations at fault scale need grid spacings of ~10 m to ~100 m, depending on frequencies of interest

Goal: develop method for determining effective friction laws suitable for this scale that capture the small-scale physics of rupture at sub-grid scales.

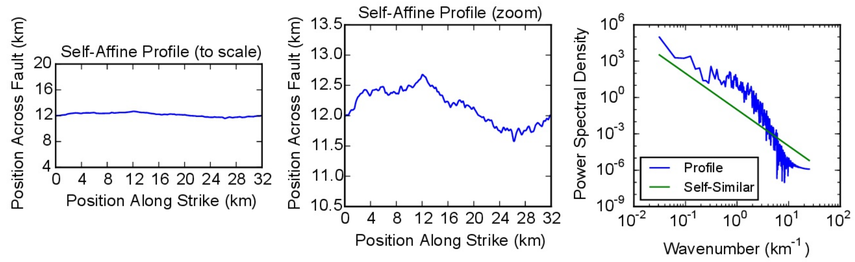


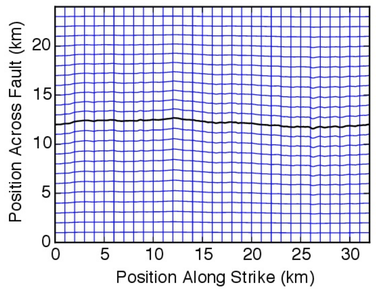


Similar concept to Latour et al. (2012), but instead of homogenizing fault, want to coarse grain the system and encode information into friction law

Dynamic Rupture on Complex Faults

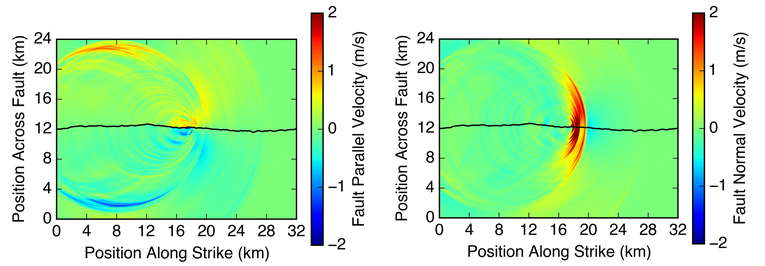
Model earthquake rupture on complex, non-planar faults, varying the minimum wavelength of roughness. Goal is to use a friction law to approximate the effect of the smallest wavelengths of roughness (which are known to be important for rupture propagation)





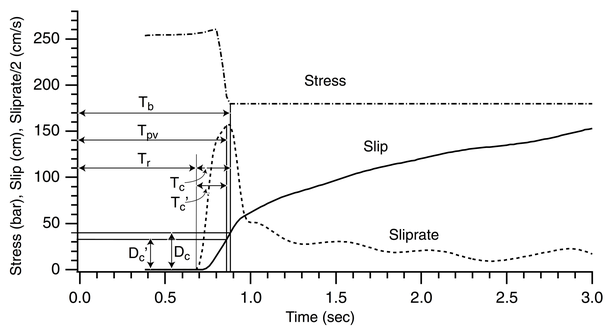
Handle complex geometry with coordinate transforms and high order central finite differences on a structured grid

Example Rupture



Can We Capture Small-Scale Heterogeneity as Friction?

Large-scale ruptures cannot resolve small-scale heterogeneities. Small scale heterogeneities influence rupture in several ways. Can stop rupture (stress perturbations from small perturbations largest for complex fault). Breaking through small heterogenities also produces high frequency radiation.

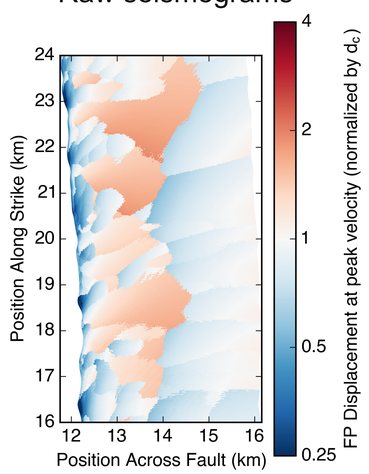


Friction quantified by peak value, sliding value, and length scale over which friction evolves. Aim to quantify what the fault effectively sees as we move away from the fault.

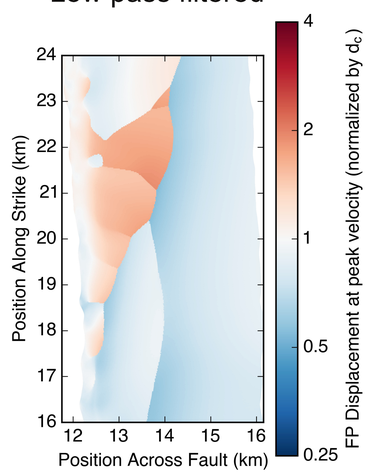
Mikumo et al. (2003) method to estimate frictional length scale from seismograms (left) -- does it work for complex faults?

Rough Fault (min wavelength 400 m)

Raw seismograms

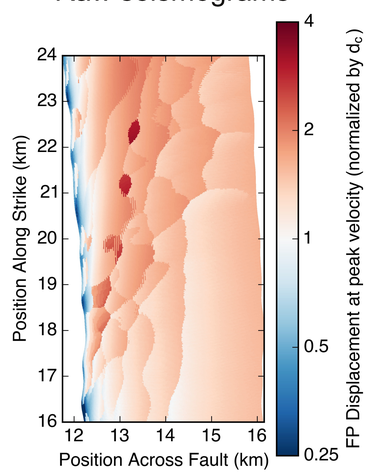


Low pass filtered



Smoother Fault (min wavelength 800 m)

Raw seismograms



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