Brittle and Ductile Friction and the Physics of Tectonic Tremor

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NON-VOLCANIC TREMOR

Tremor/LFEs provide observational constraints on deformation and failure of lower crust.
Goal: devlop a simple physical model to capture basic features of observations

WHAT IS UNIQUE ABOUT TREMOR?

Earthquakes: once rupture starts, fault slips steadily as rupture propagates in space and time.

Tremor: fault "chatters" as slip propagates, with small individual events closely grouped in time. Referred to as a tremor "burst."

BRITTLE-DUCTILE FRICTION MODEL

Idea: friction due to both brittle and ductile asperity contacts. Different minerals transition from brittle to ductile at different temperatures and pressures.

Study dynamics of a block slider to model tremor at a single spatial location (a "family")

BRITTLE-DUCTILE FRICTION MODEL

Brittle component: collection of asperities that resist motion and fail suddenly

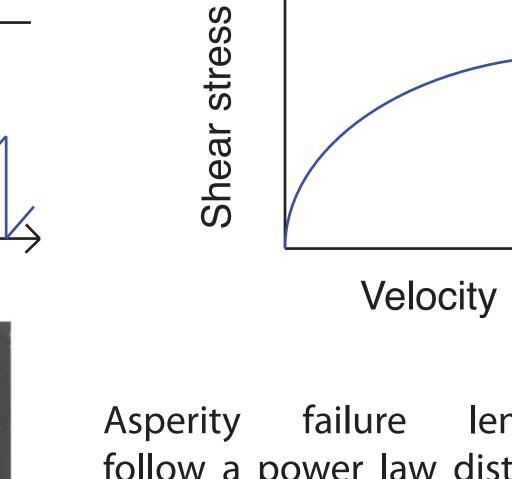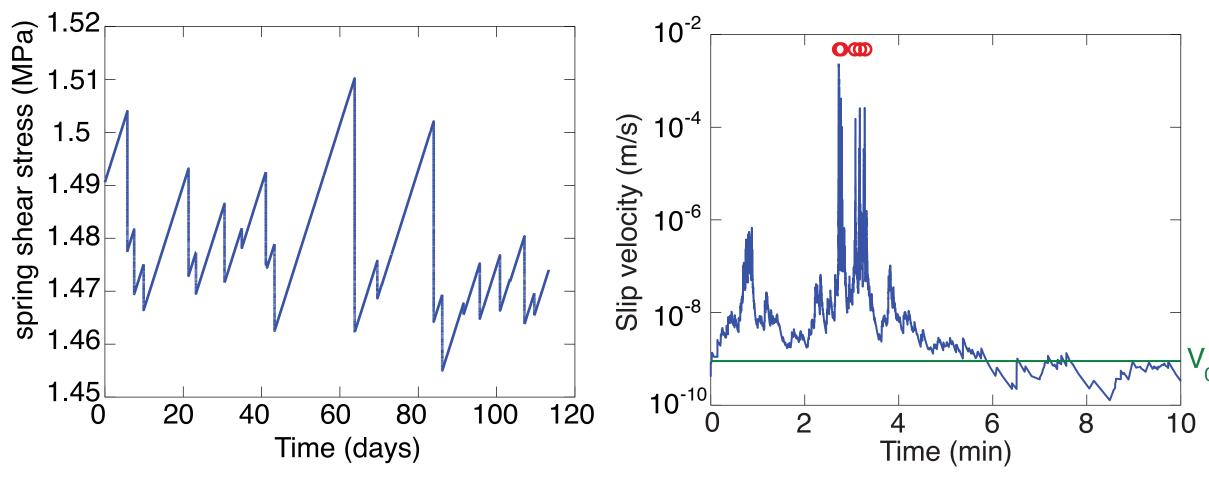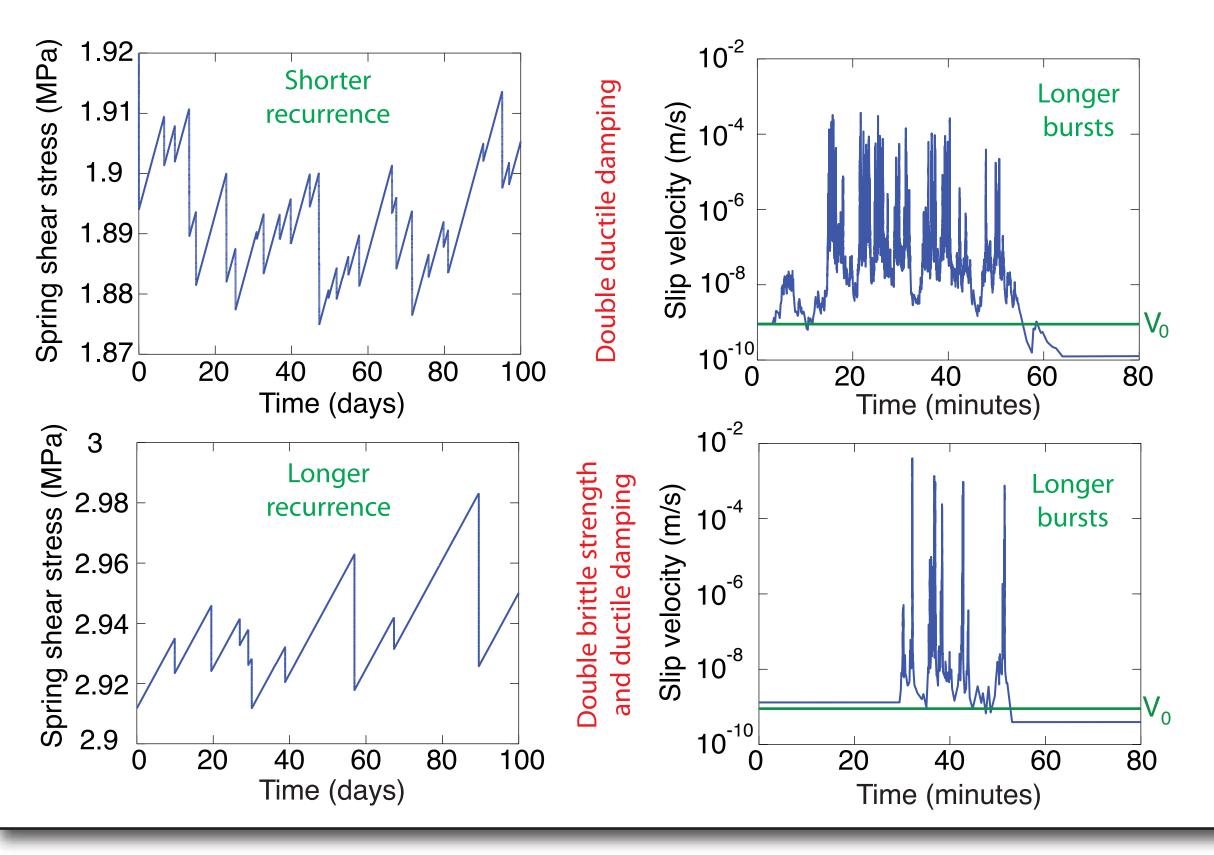Ductile component: increases with log of slip rate as seen in lab experiments

Asperity failure lengths follow a power law distribution, as seen in experiments on roughened surfaces (Dieterich and Kilgore, 1996).

MODEL DYNAMICS

Model produces stick-slip, but each slip event is a burst of closely spaced failures, as seen in observations.
How do parameters affect recurrence time and burst duration (basic seismic observables)?

TYPES OF FAULTING BEHAVIORS

What ranges of parameters lead to various ways of slip accumulation?

Earthquake: fault slips once, stops

Tremor: fault slips in burst of stronger activity that produces detectable seismic waves

Silent slip: fault slips in burst of weaker activity that is not detectable seismically

Steady sliding: fault slips steadily, few transient changes

Increasing ductility

PHASE DIAGRAMS

Tremor occurs over a range of parameters. Varying parameters within region on diagram gives varying recurrence time and burst duration.

Transform axes to "brittleness" and effective normal stress. Brittleness clearly controls behavior. Tremor occurs if ~40-70% of contacts are brittle