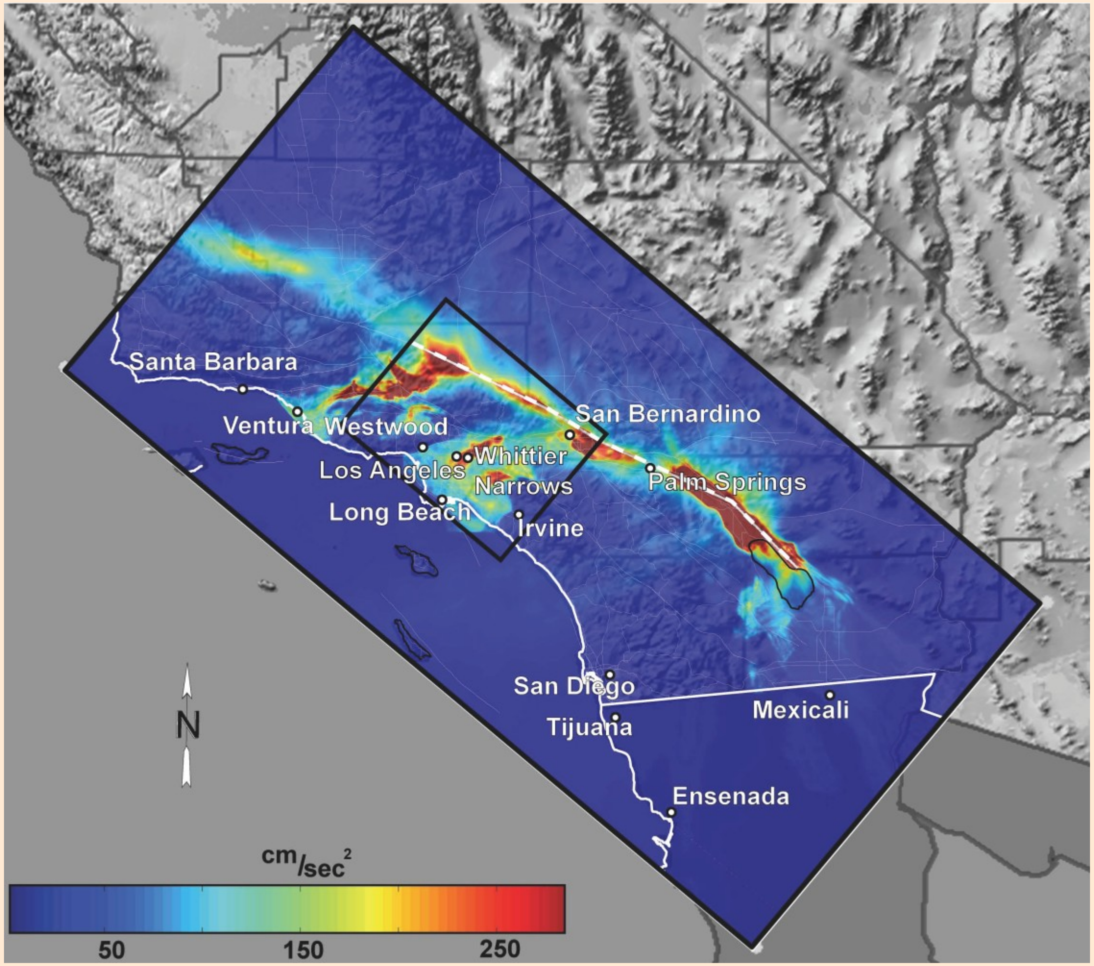
Ground Motion Simulation Schedule of Tasks

Completion Date	Task	Lead	Work Period
Nov 2008	Workshop preparation on dynamic rupture models for dipping faults	Harris ~10 people	
Nov 2008	Complete the verification/testing of dynamic rupture models	Harris	Apr 08 – Nov 08
Dec 2008	Select 2-3 best dynamic rupture codes from SCEC WG	Harris	Dec 08
Mar 2009	Workshop on selection of parameters to use in suite of simulations for the dynamic rupture models	Harris	
Jun 2009	Conduct simulations using dynamic rupture models (2-3 modelers) to create a library of sources	Harris and selected modelers	Jan-Jun 09
Jul 2009	Apply method to develop equivalent kinematic sources from dynamic rupture sources	Archuleta	Jun-Jul 09
Aug 2009	Complete modules for kinematic platform, including current methods used in engineering applications	Graves	Apr 08 – Jun 09
Sep 2009	Setup and testing of nonlinear site response models given inputs at base of the volcanic section	Itasca	Mar – Sep 09
Oct 2009	Conduct simulations using kinematic platform for YM scenario (M6.5)	PGE	Sep–Oct 09
Dec 2009	Apply non-linear site response to linear site simulations	Itasca	Oct-Dec 09
Jan 2010	Parameterize pdf of GM for YM scenario eqk	Abrahamson	Jan 09

Rupture Dynamics

Ralph J Archuleta
Department of Earth Science and Institute for Crustal Studies
University of California, Santa Barbara



K.B. Olsen, S.M. Day, L.A. Dalguer, J. Mayhew, Y. Cui, J. Zhu, V.M. Cruz-Atienza, D. Roten, P. Maechling, T.H. Jordan, D. Okaya, and A. Chourasia, submitted, GRL 2008

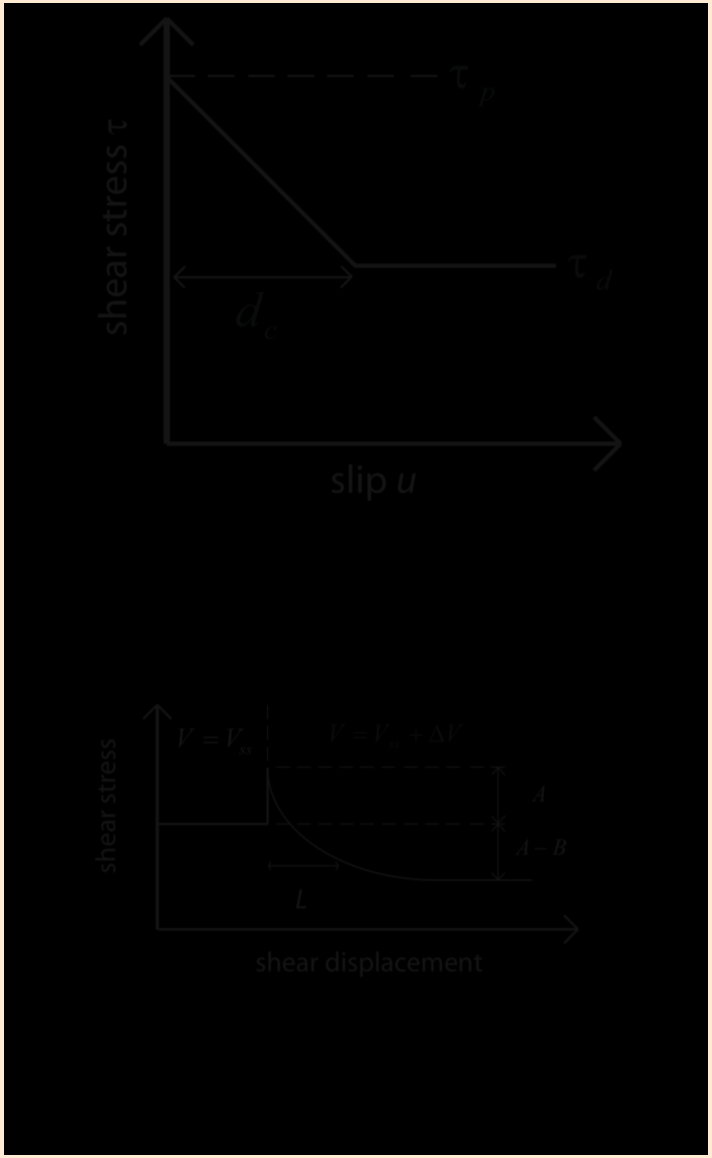
Ground Motion Simulation Schedule of Tasks

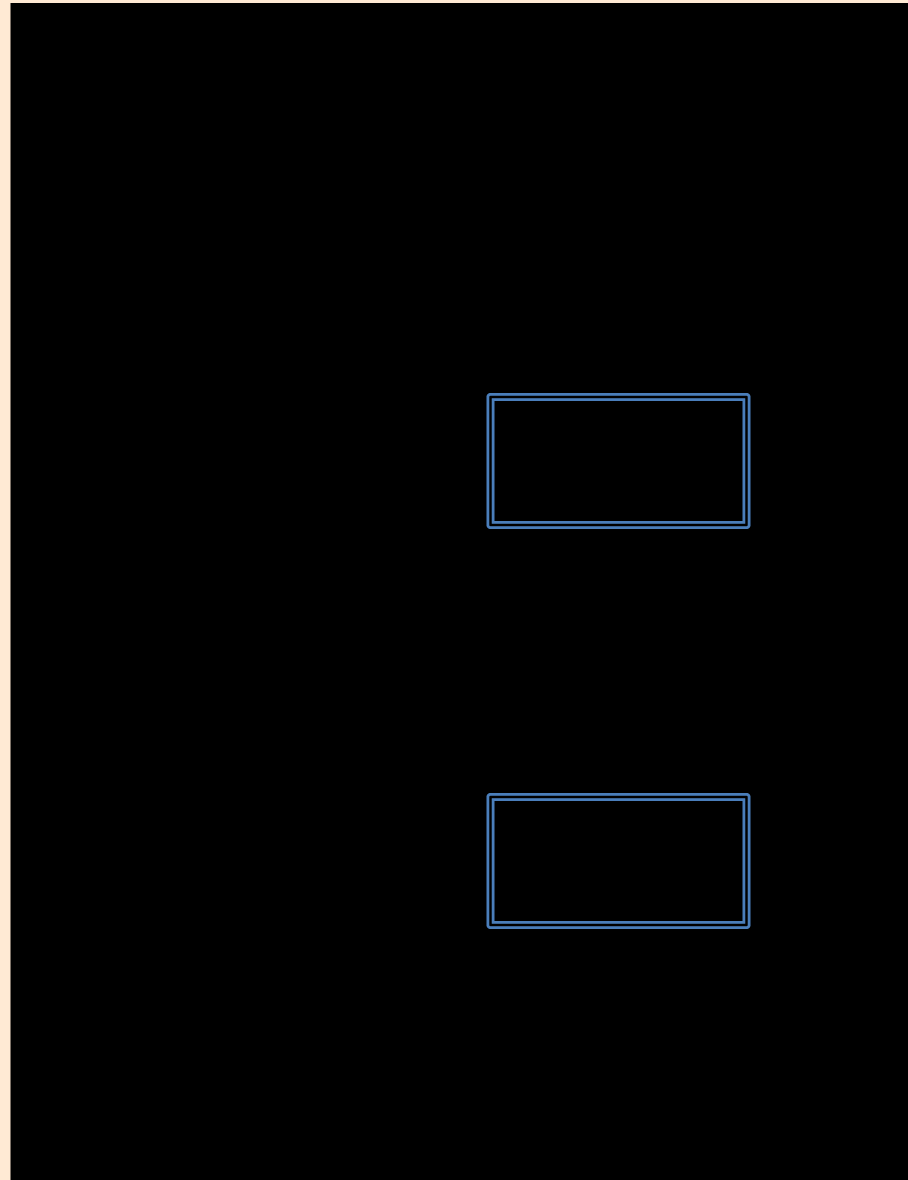
Completion Date	Task	Lead	Work Period
Nov 2008	Workshop preparation on dynamic rupture models for dipping faults	Harris ~10 people	
Nov 2008	Complete the verification/testing of dynamic rupture models	Harris	Apr 08 – Nov 08
Dec 2008	Select 2-3 best dynamic rupture codes from SCEC WG	Harris	Dec 08
Mar 2009	Workshop on selection of parameters to use in suite of simulations for the dynamic rupture models	Harris	
Jun 2009	Conduct simulations using dynamic rupture models (2-3 modelers) to create a library of sources	Harris and selected modelers	Jan-Jun 09
Jul 2009	Apply method to develop equivalent kinematic sources from dynamic rupture sources	Archuleta	Jun-Jul 09
Aug 2009	Complete modules for kinematic platform, including current methods used in engineering applications	Graves	Apr 08 – Jun 09
Sep 2009	Setup and testing of nonlinear site response models given inputs at base of the volcanic section	Itasca	Mar – Sep 09
Oct 2009	Conduct simulations using kinematic platform for YM scenario (M6.5)	PGE	Sep–Oct 09
Dec 2009	Apply non-linear site response to linear site simulations	Itasca	Oct-Dec 09
Jan 2010	Parameterize pdf of GM for YM scenario eqk	Abrahamson	Jan 09

Ongoing Research within SCEC Directly Related to Extreme Ground Motion

- Validate and verify numerical codes for dynamic rupture in 3D including dipping faults and faults with nonplanar geometry.
- Explore and develop constitutive laws for friction.
- Explore and develop models for off-fault damage.
- Execute 3D dynamic rupture codes with various constitutive laws.
- Develop a platform that allows for computing broadband synthetics from kinematic faulting models.
- Develop kinematic models that account for correlation among parameters.

Friction Laws

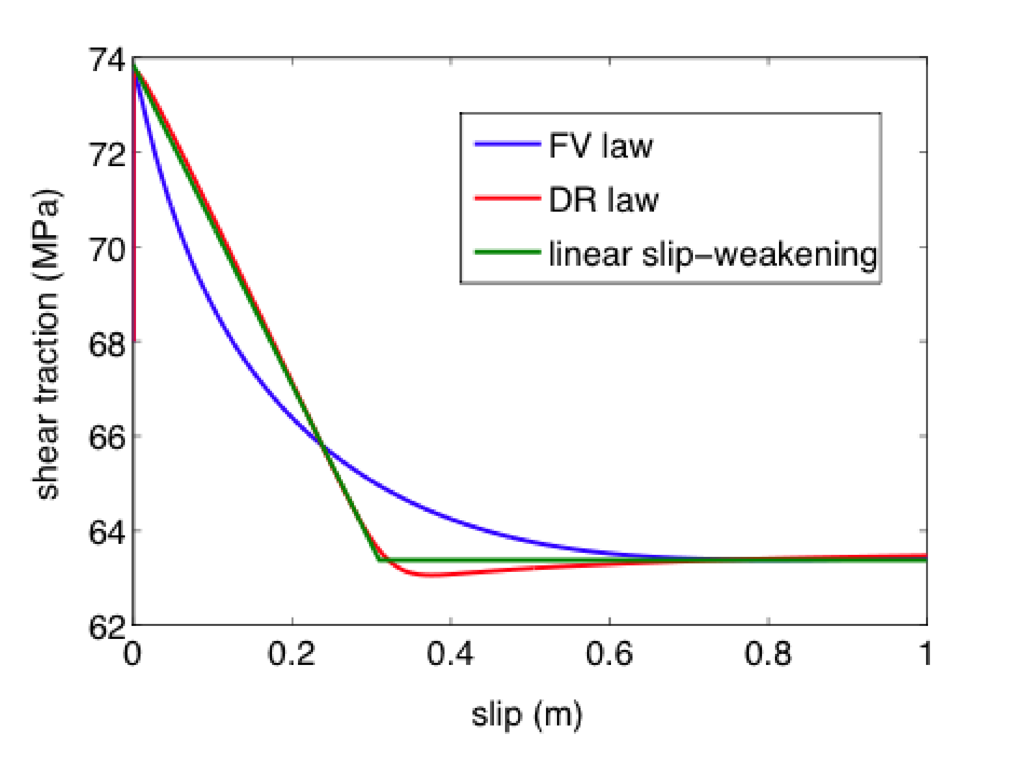




A Constitutive Model for Fault Gouge Deformation in Dynamic Rupture Simulations
Eric G. Daub and Jean M. Carlson, submitted, JGR

Slip-Weakening Curves

FV and DR laws do not explicitly depend on slip – how does shear strength weaken with slip for these laws?



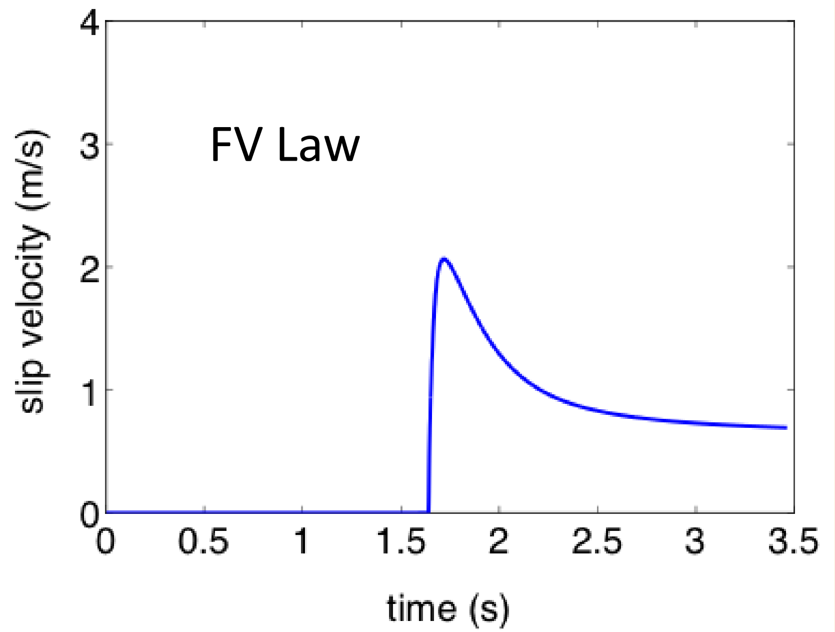
Slope of curves are inversely proportional to *L*.

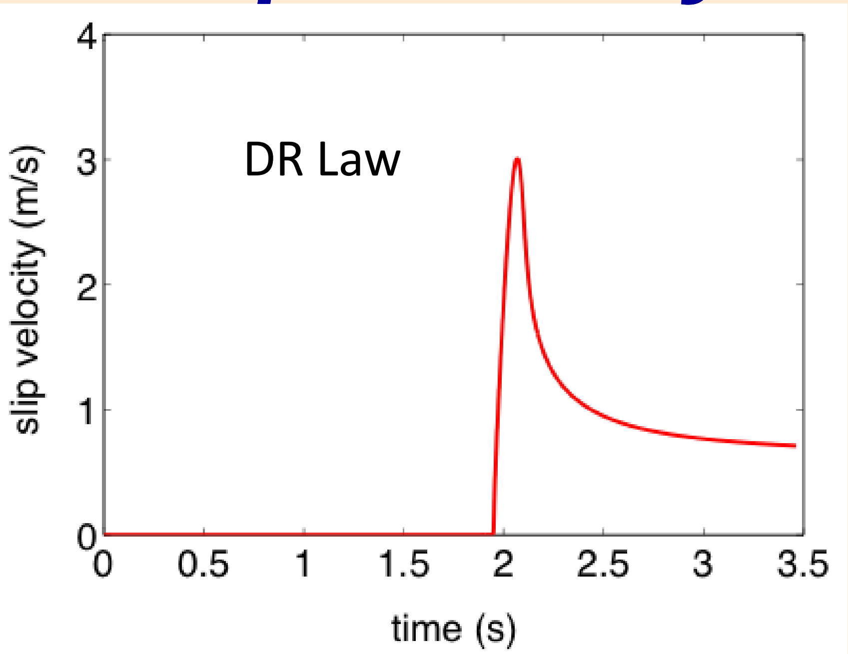
FV law is different from other laws because *L* is a function of slip velocity.

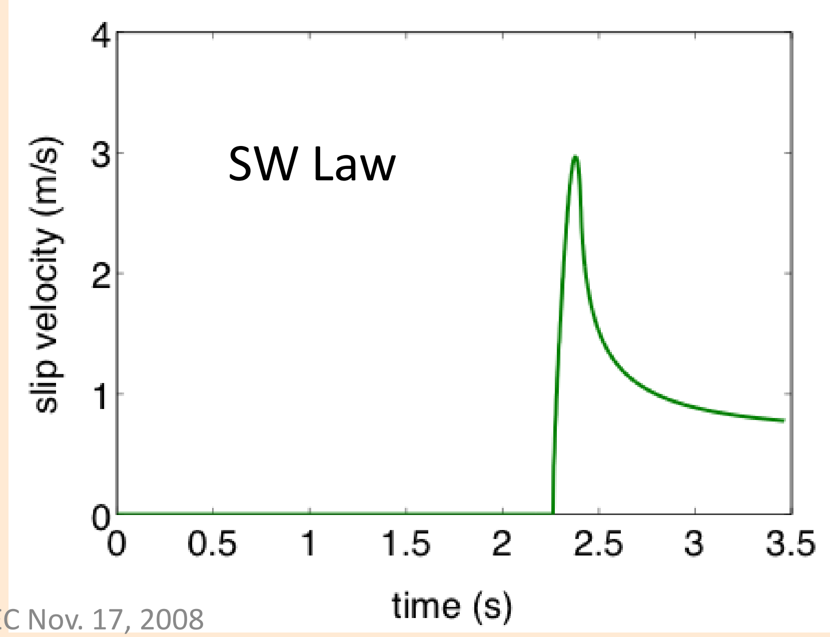
Parameters chosen to match area under the curves (frictional work).

Daub and Carlson, submitted, JGR

Time Histories – Slip Velocity



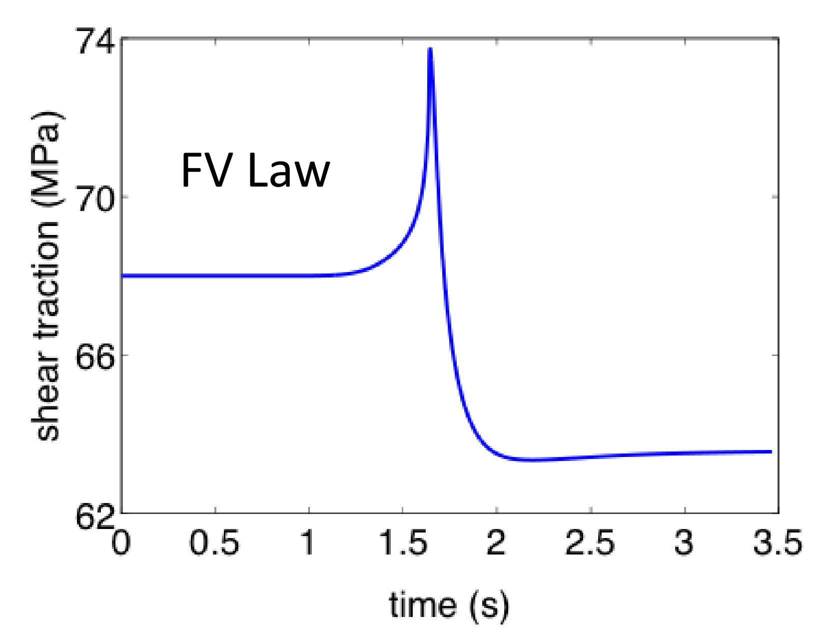


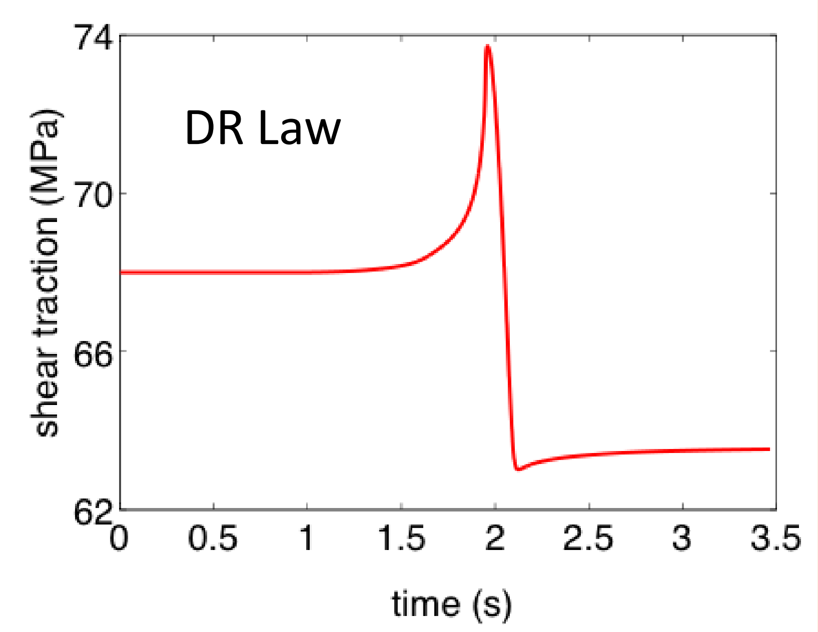


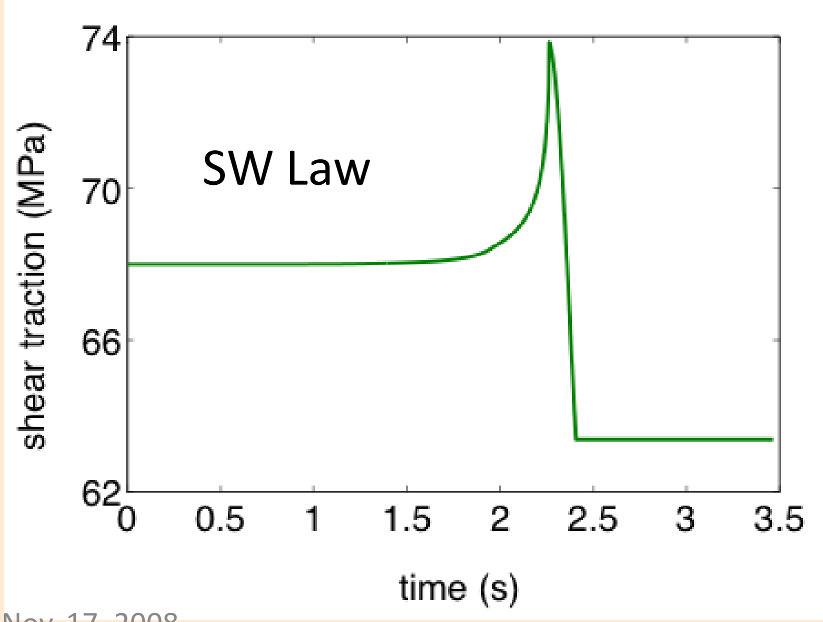
Rupture arrives earliest for FV law, then DR, and SW law is last. Slip rate is smaller for the FV law, DR and SW are identical.

Daub and Carlson, submitted, JGR

Time Histories – Shear Traction







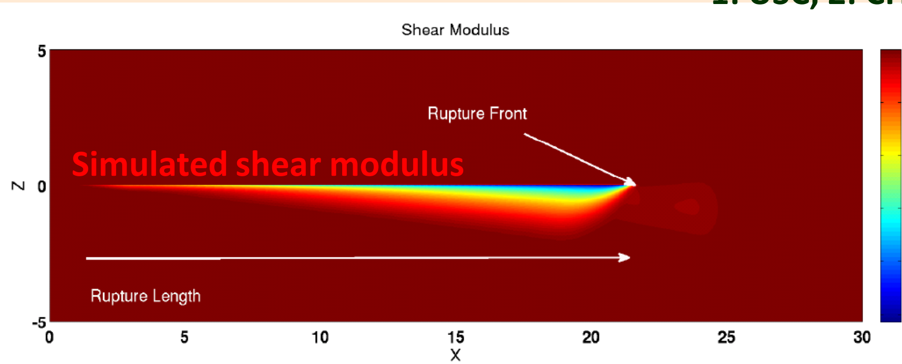
Traction evolution is very similar for all laws. FV law takes slightly longer to drop from peak stress to minimum stress. Stress on crack interior is fairly constant for DR and FV laws.

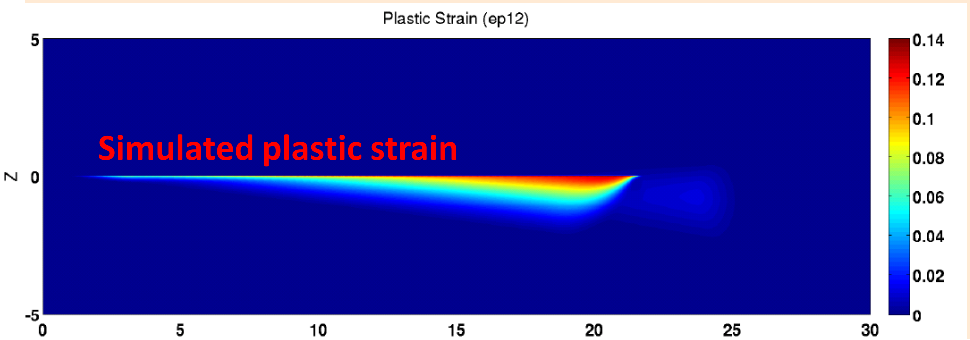
Daub and Carlson, submitted, JGR

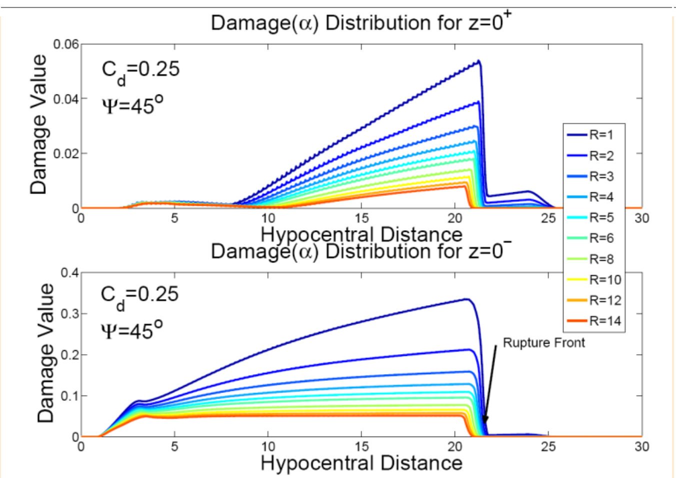
Interaction Between Dynamic Rupture and Off-fault Brittle Damage

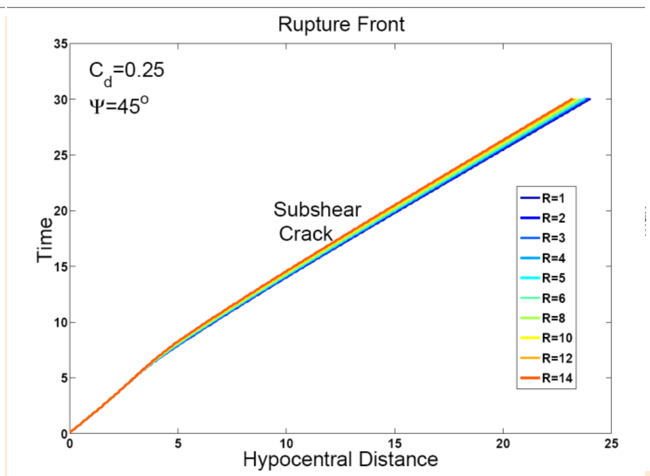
Shiqing Xu[1], Jean-Paul Ampuero[2], Yehuda Ben-Zion[1] and Vladimir Lyakhovsky[3]

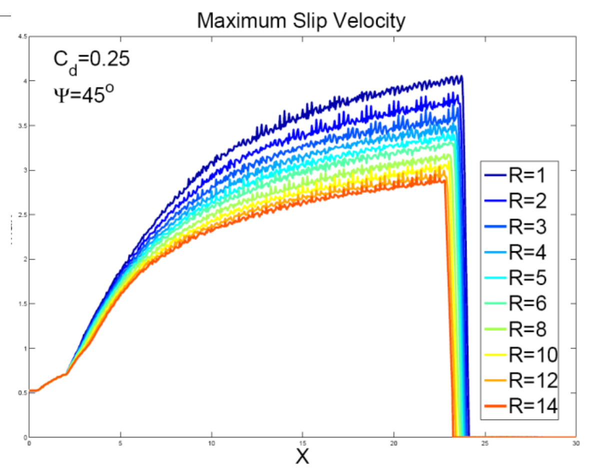
1: USC, 2: CIT, 3: Geol. Surv. Israel











Main equations of the damage rheology:

stress-strain relation [illegible]

elastic moduli - damage variable [illegible]

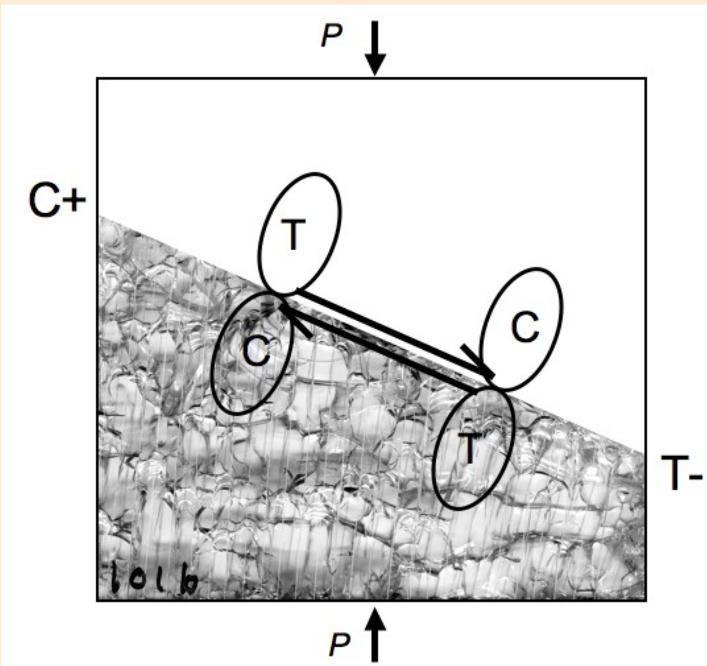
evolution of damage variable [illegible]

damage-related plasticity [illegible]

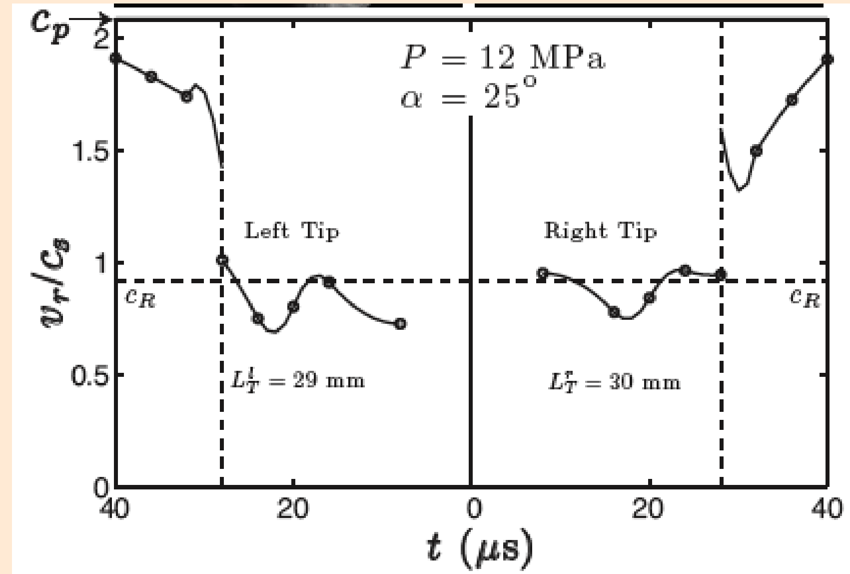
Main references on the damage model

Lyakhovsky, Ben-Zion, Agnon (JGR, 1997)
Ben-Zion and Lyakhovsky (GJI, 2006)
Lyakhovsky and Ben-Zion (GJI, 2008)

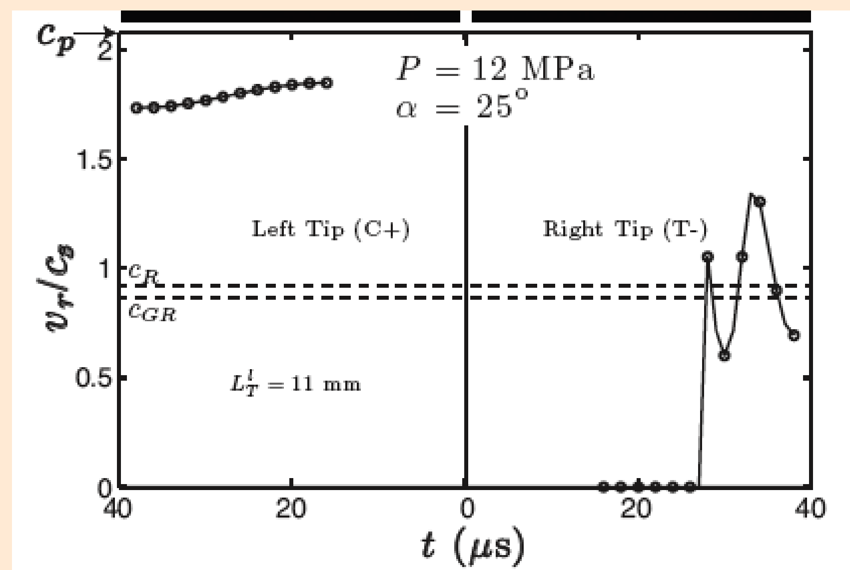
Experimental Results for Damage



No Damage

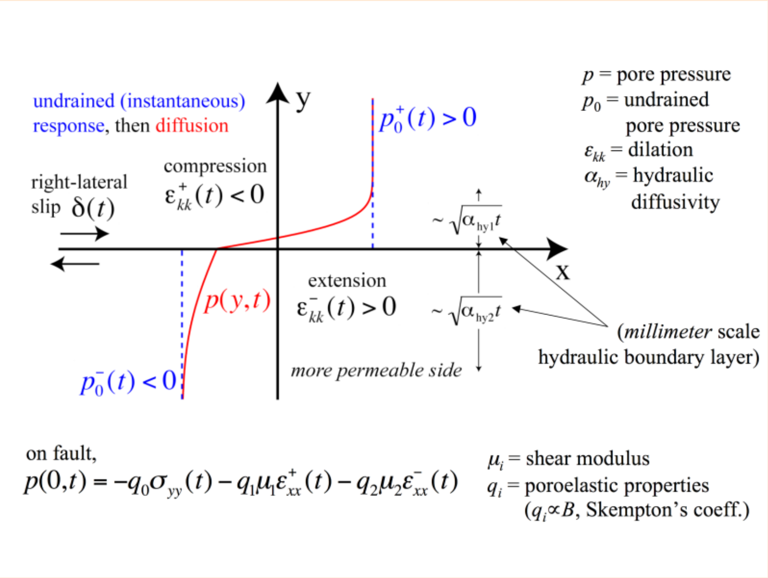


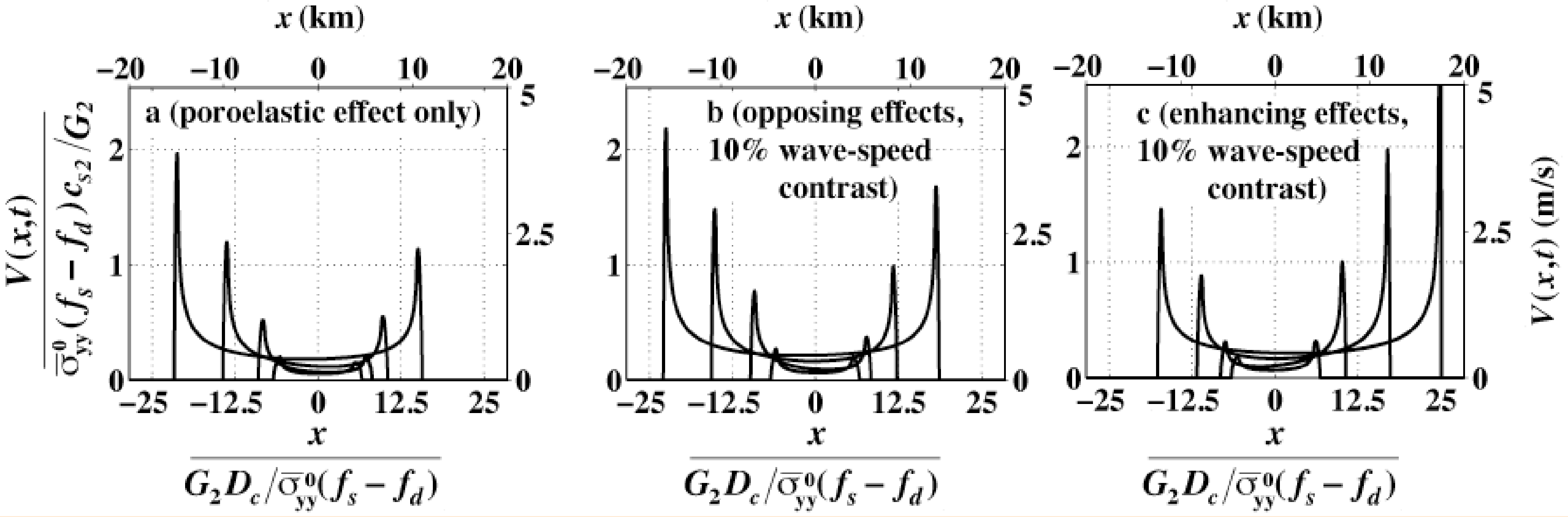
With Damage



Biegel, Bhat, Sammis, Rosakis, submitted, JGR

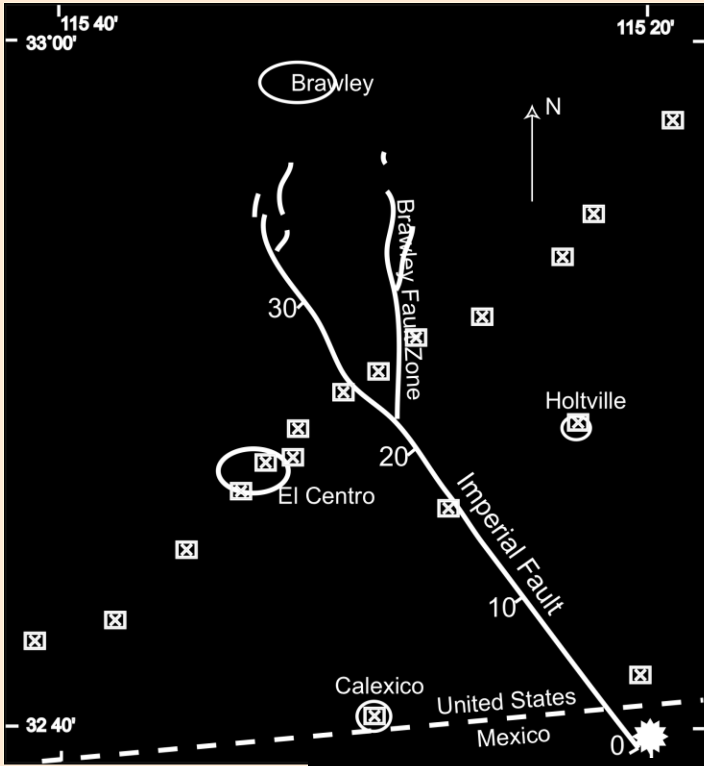
Poroelastic Effects

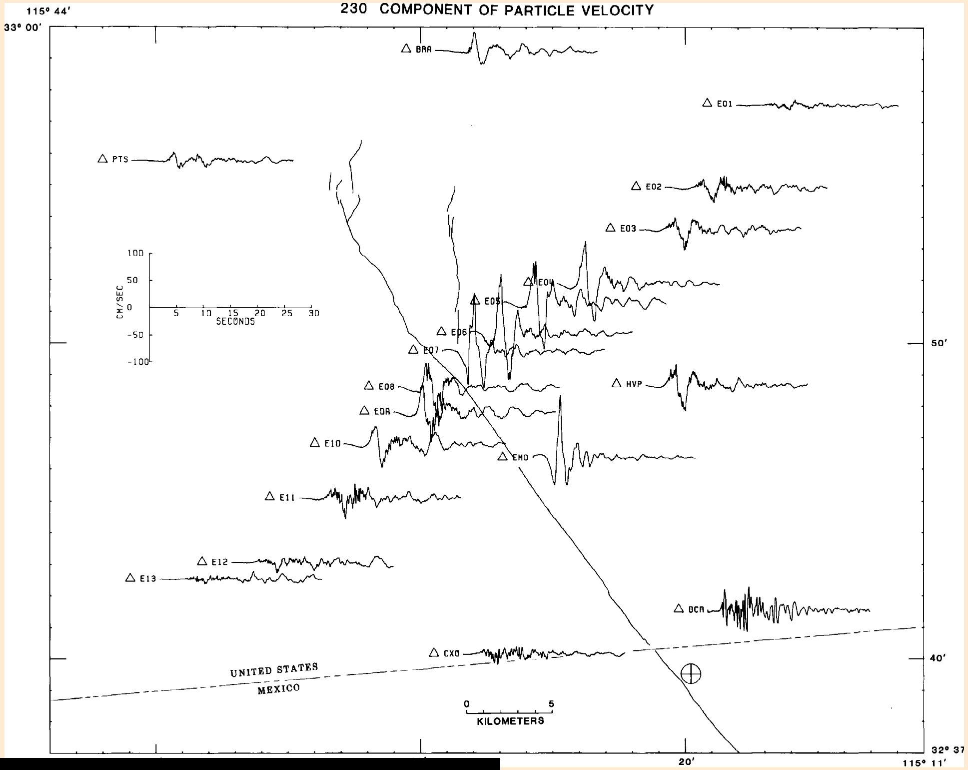


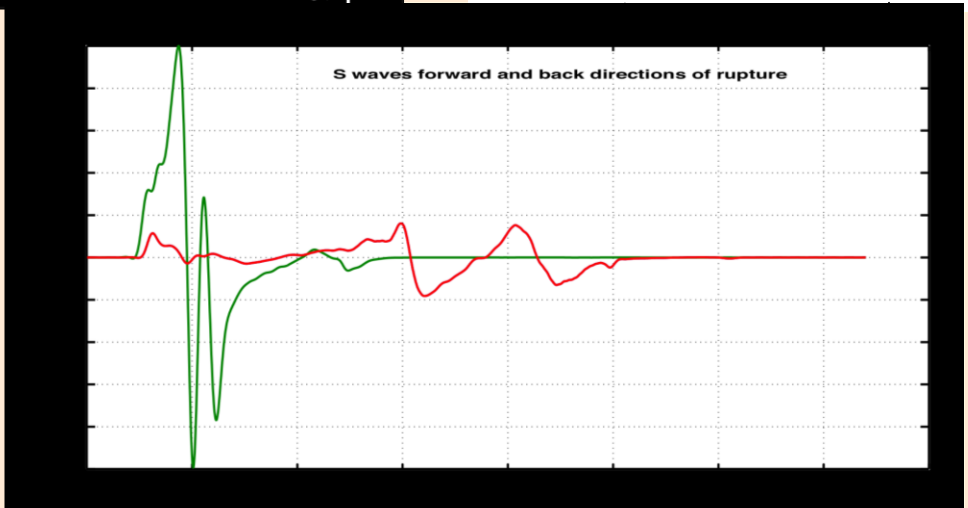


Dunham and Rice, JGR, 2008

Rupture Directivity: Imperial Valley

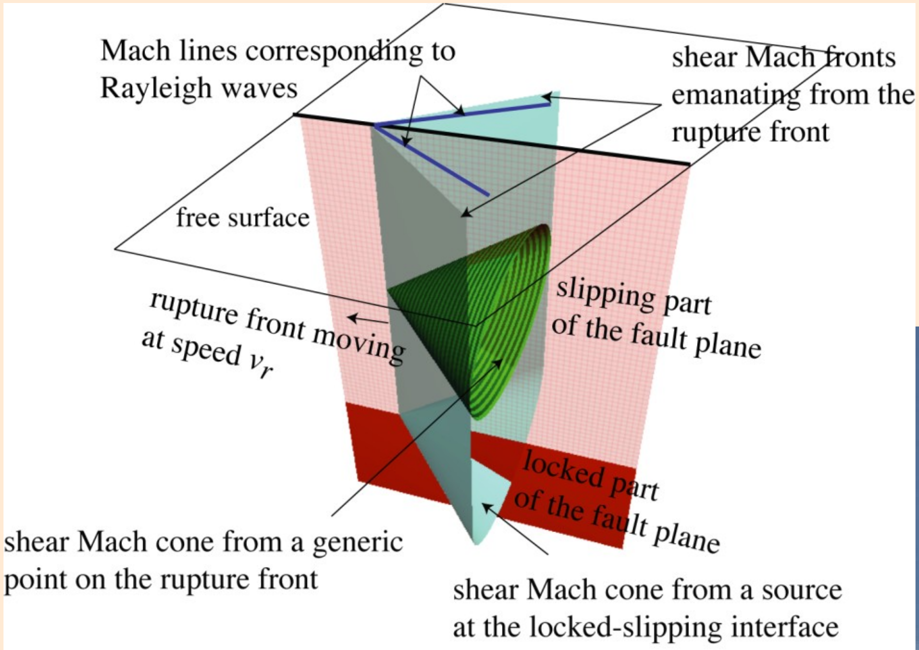






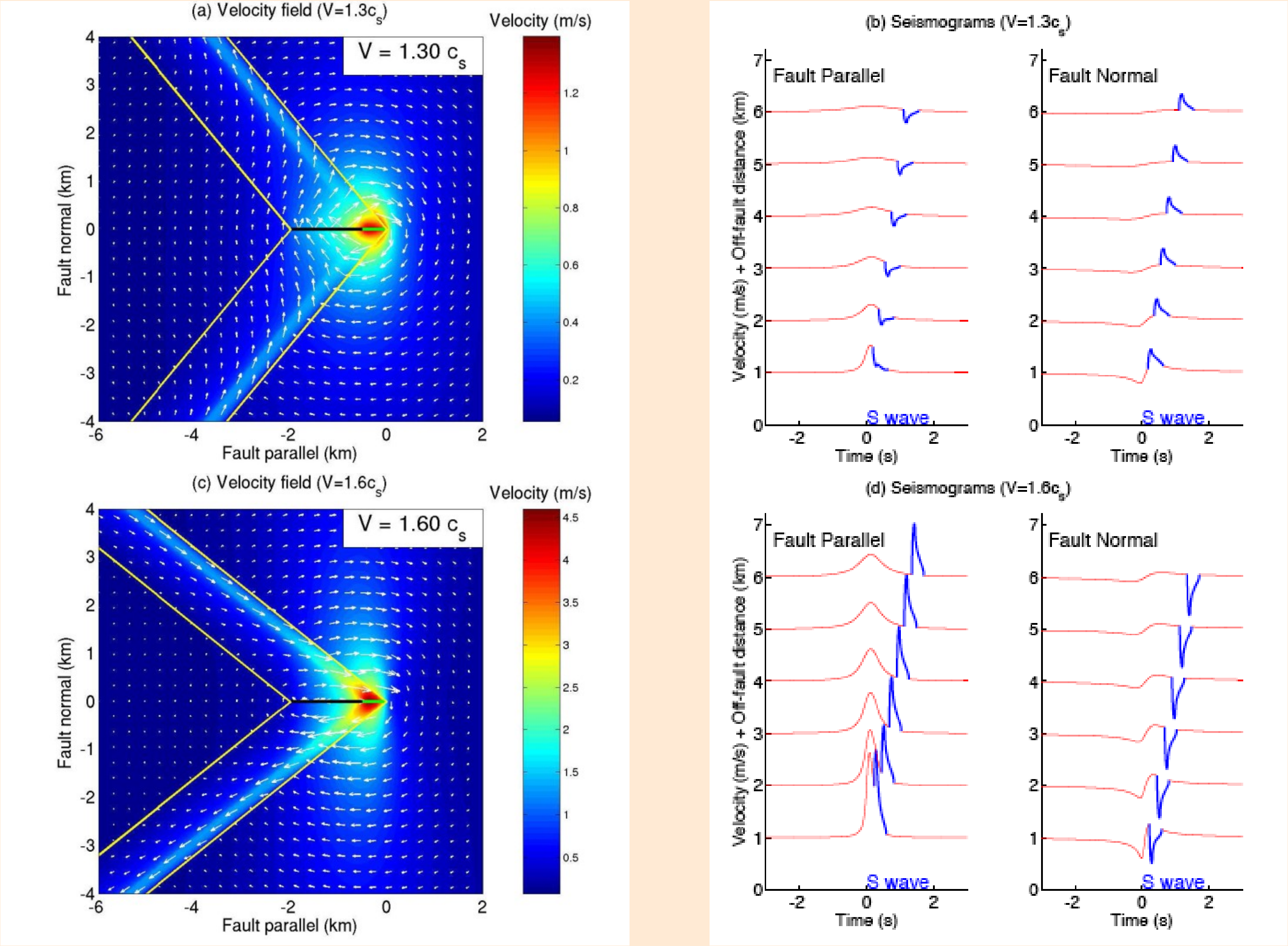
Archuleta, 1984

Supershear Rupture



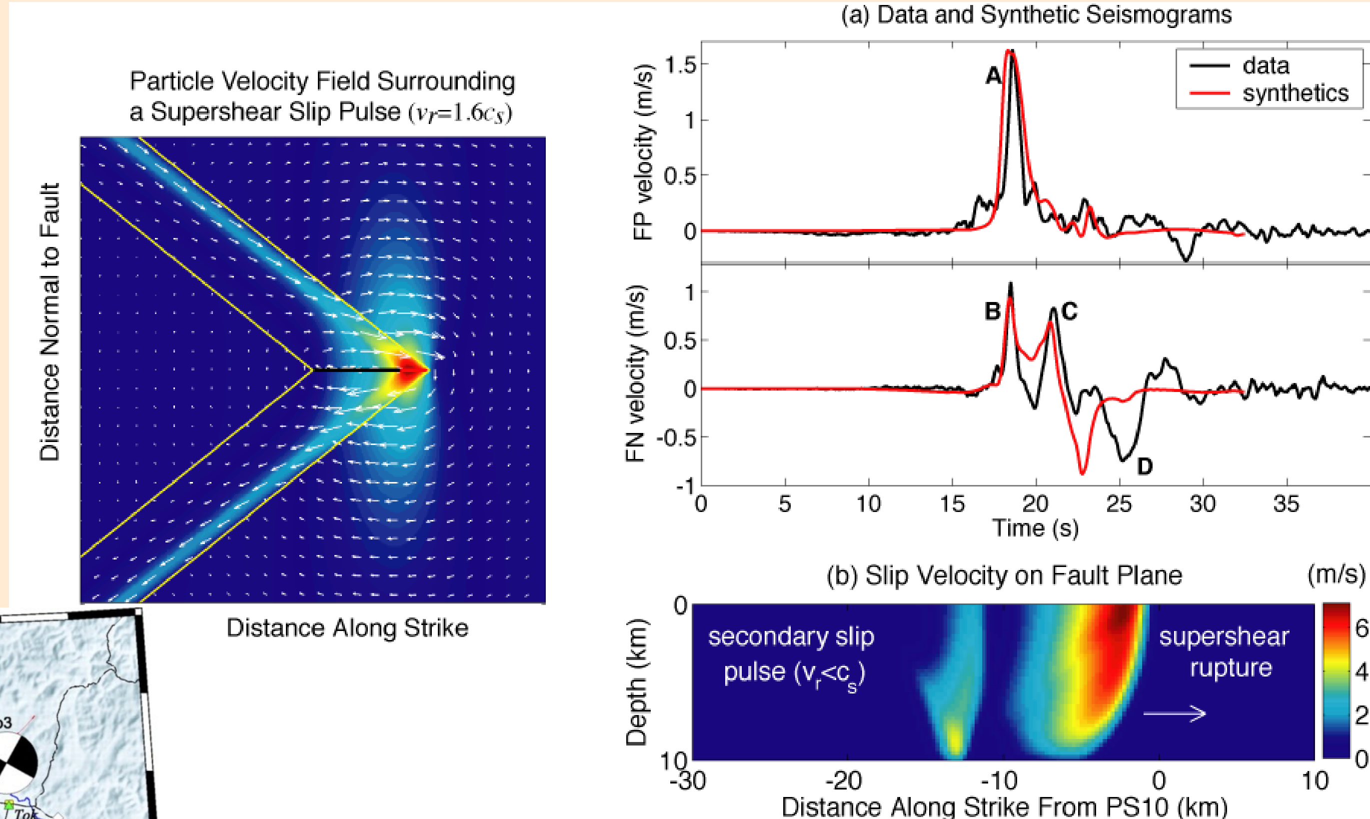
Dunham, 2008

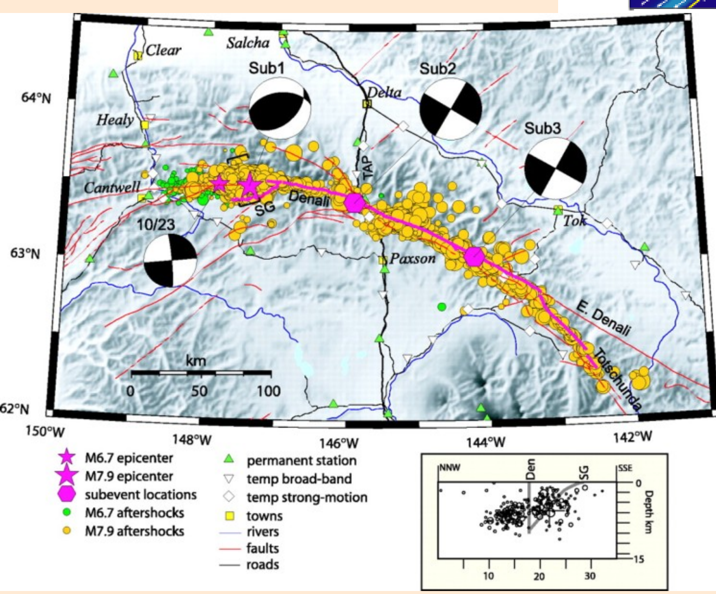
Ground Motion Carried Off the Fault



Dunham and Archuleta, GRL 2005

Supershear: Denali Fault

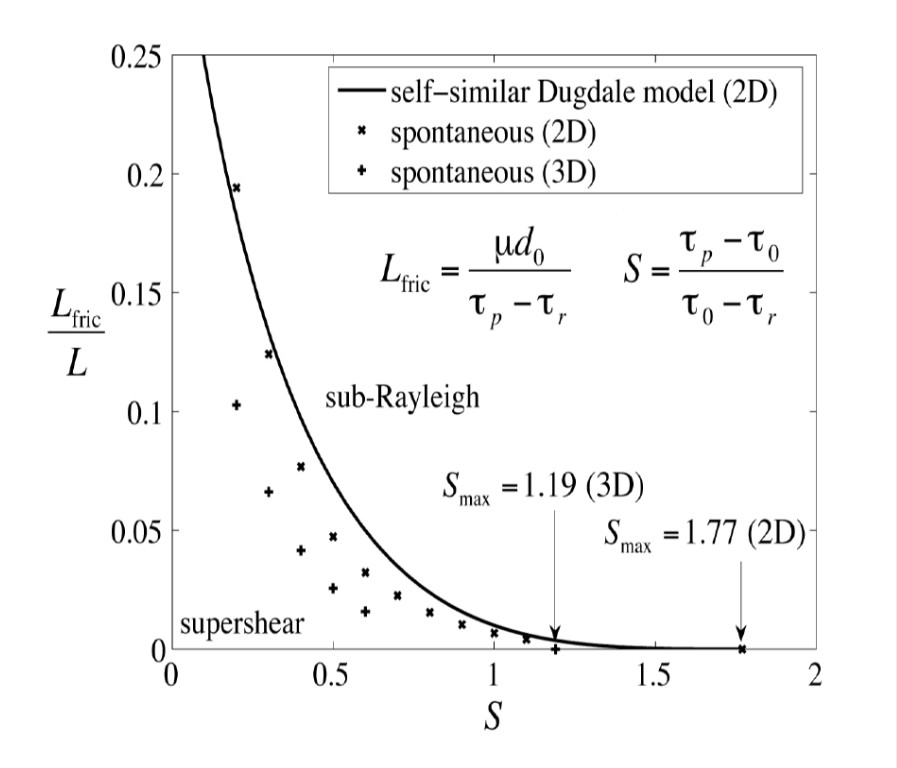




D. Eberhart-Phillips et al., Science 300, 1113 -1118 (2003)

Dunham & Archuleta, 2006

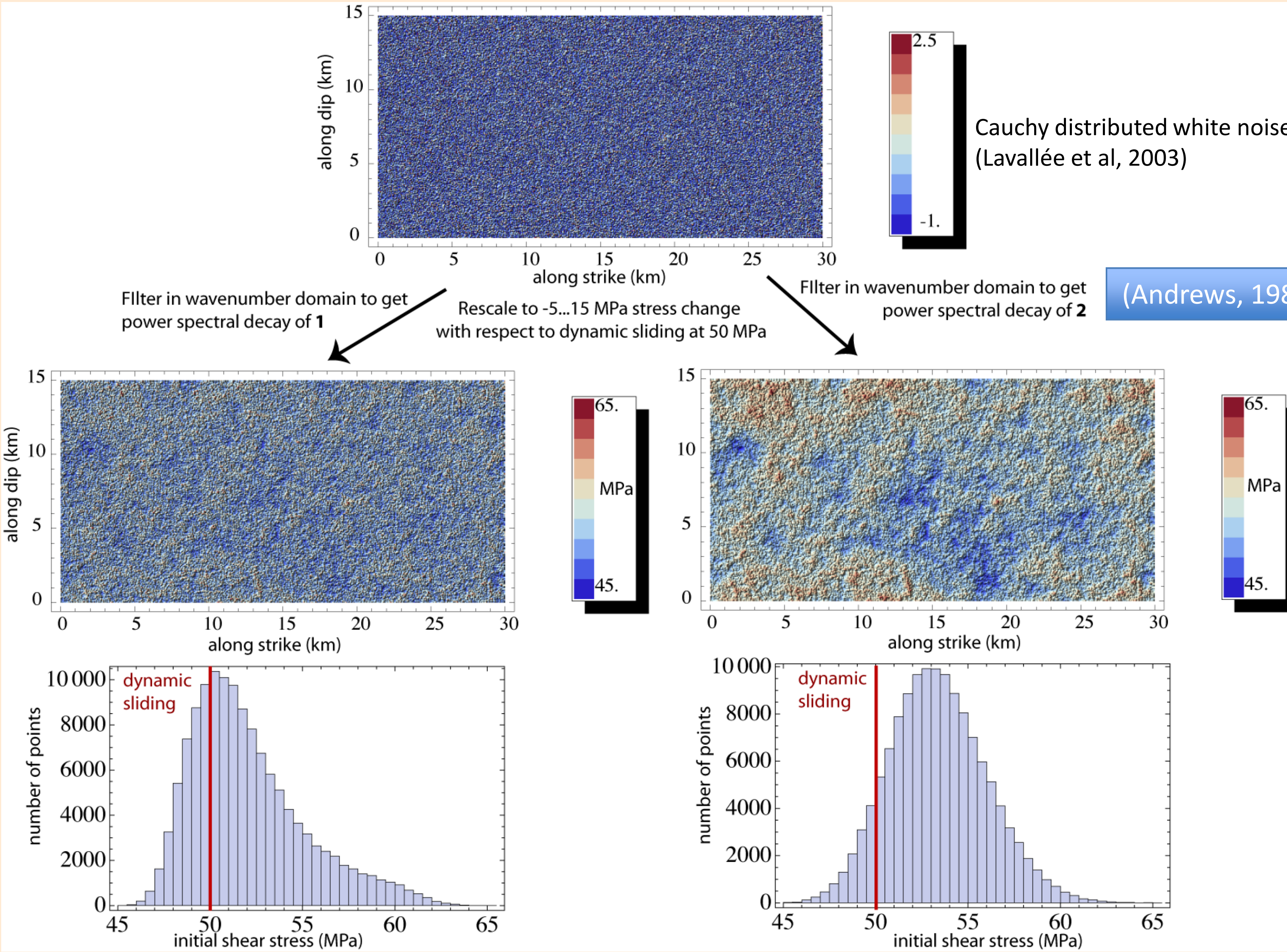
Conditions for Supershear Rupture



"Plot of (inverse of) supershear transition length vs. seismic S ratio (small S means high initial stress, fault close to failure). There is nice agreement between the analytical prediction of transition length in the self-similar Dugdale model with numerical results from spontaneous rupture calculations in 2D. Numerical results for unbounded faults in 3D are also shown. The trend is similar in 3D, but the transition length is about twice as long as in 2D for the same value of S. In 3D, a sufficiently narrow fault width suppresses the transition; the critical width is approximately 0.8 times the transition length on an unbounded fault."

Dunham, JGR, 2007

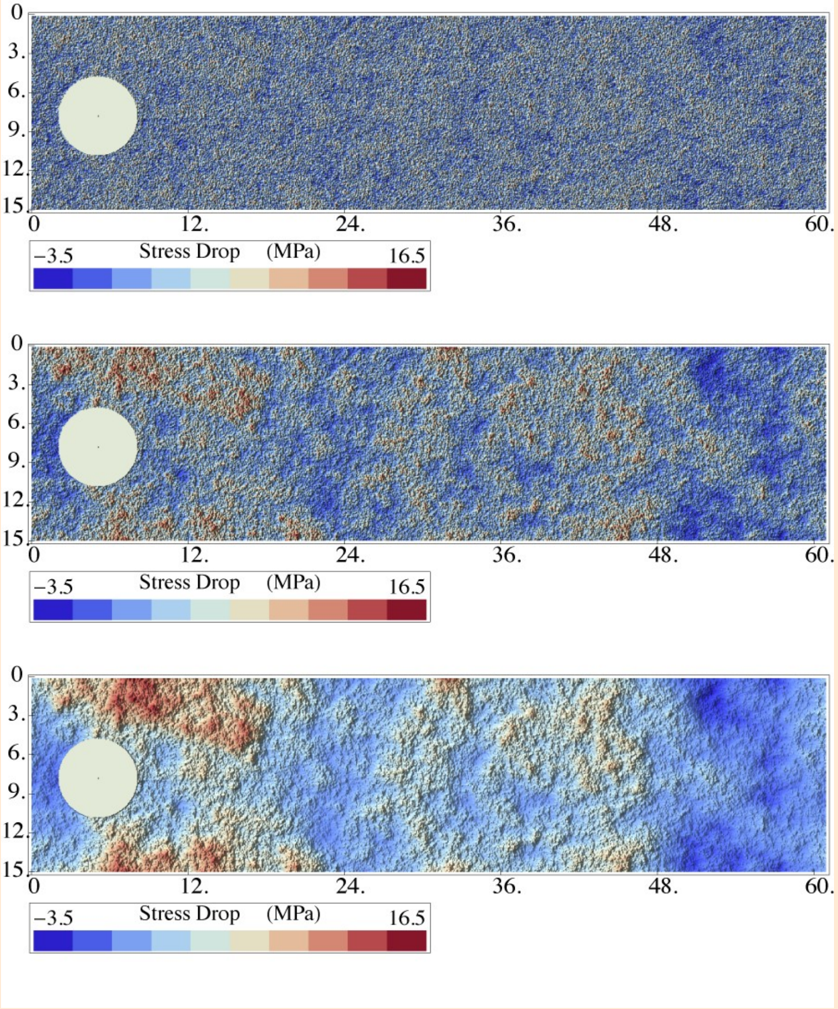
Power Law for Initial Shear Stress



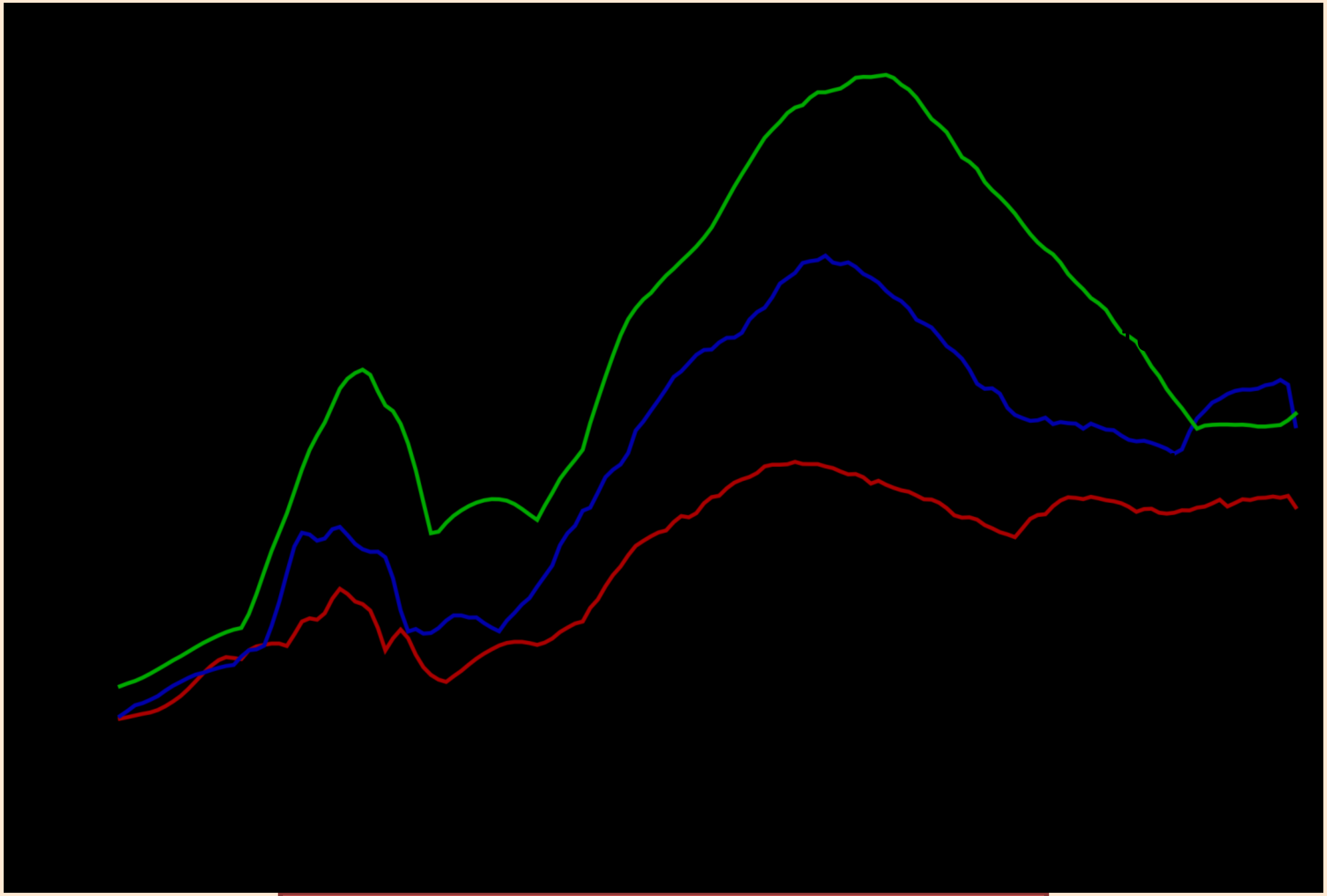
(Andrews, 1980)

Different Autocorrelation for Stress Drop

Initial stress spatial variation with power spectral decays of 1, 2 and 3. The amplitude distribution is identical for each.



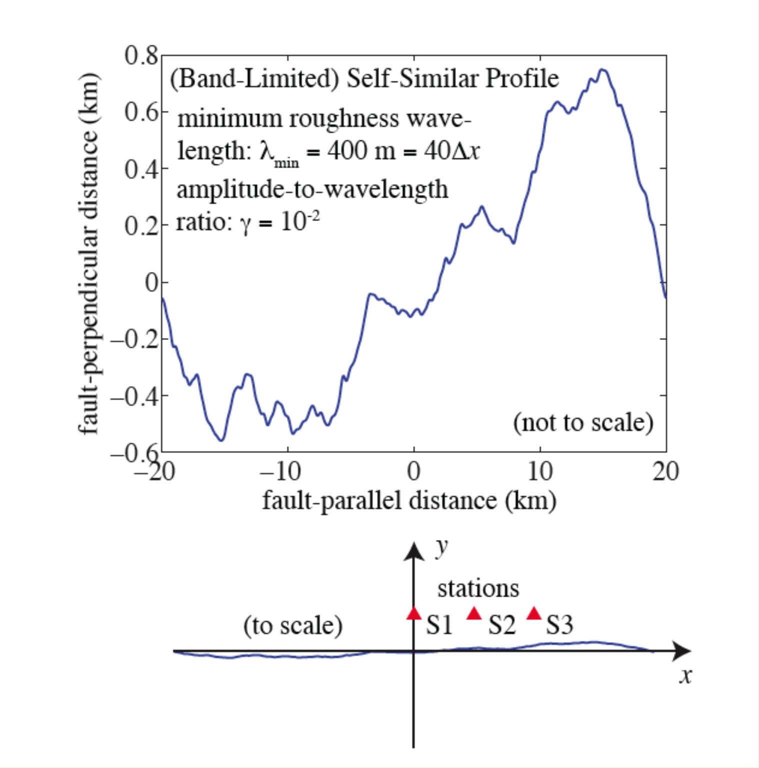
Ground Motion: Initial Stress Spectral Decay 1, 2, 3

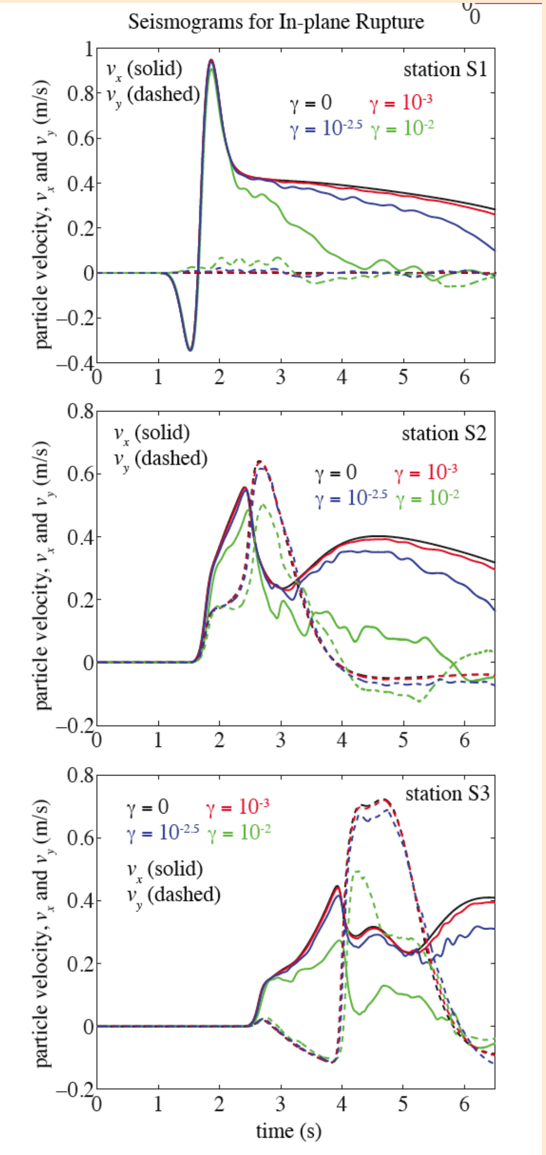


Significant difference in ground motion

Average slip, i.e., seismic moment, is the same for all three models.

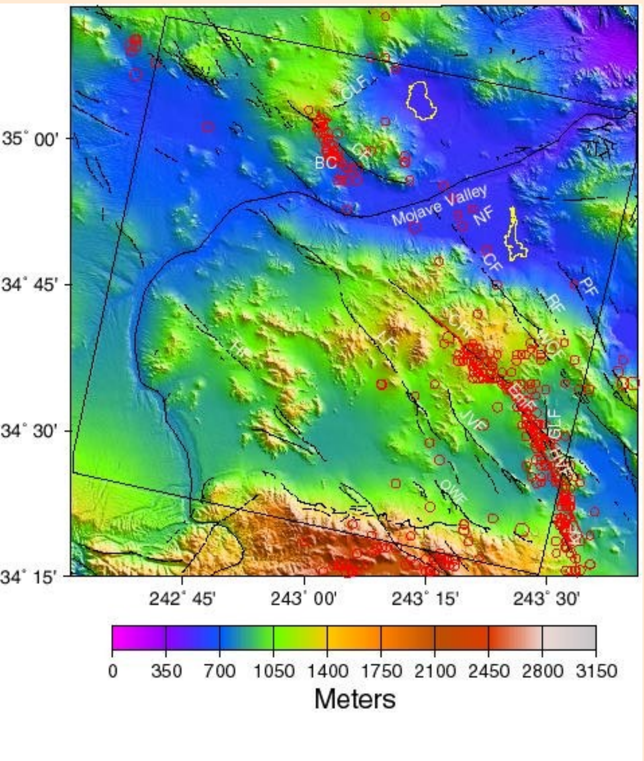
Roughness

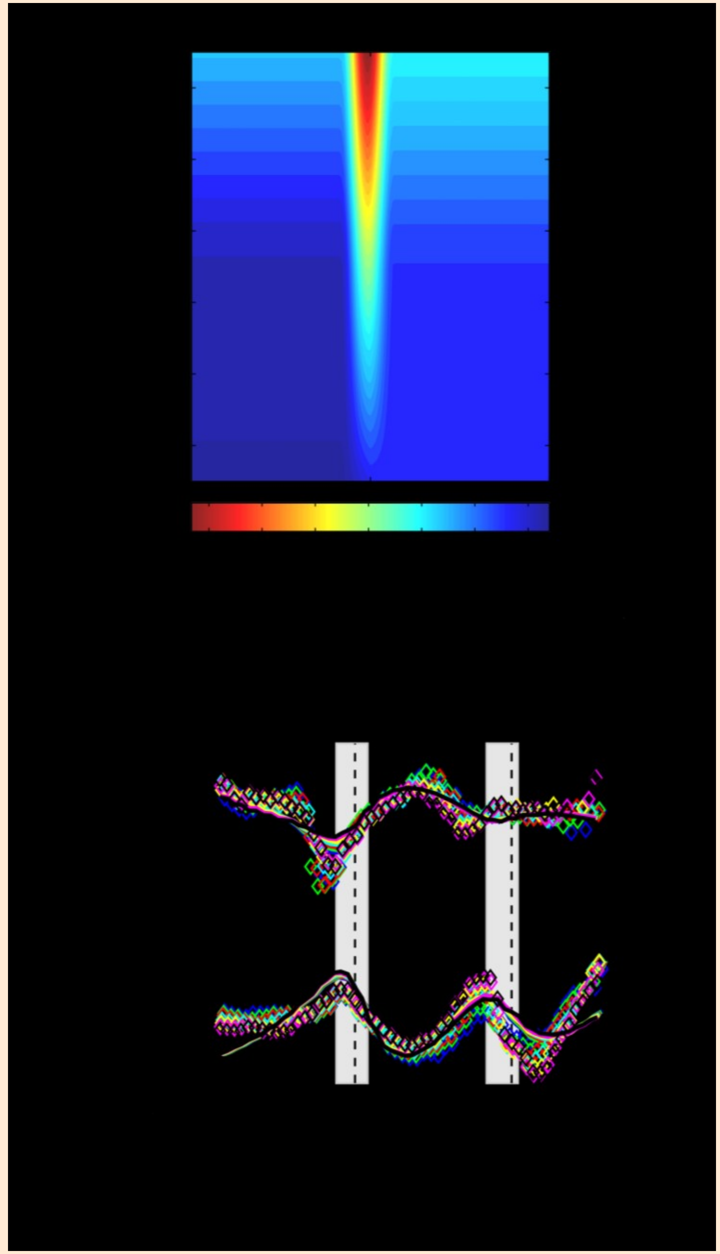




Belanger and Dunham, SCEC Annual Mtg., 2008

Material Properties within the Fault Zone





Reduction of P wave velocity within the Calico Fault zone.

From Cochran, Fialko, Shearer et al., 2008

Some Questions

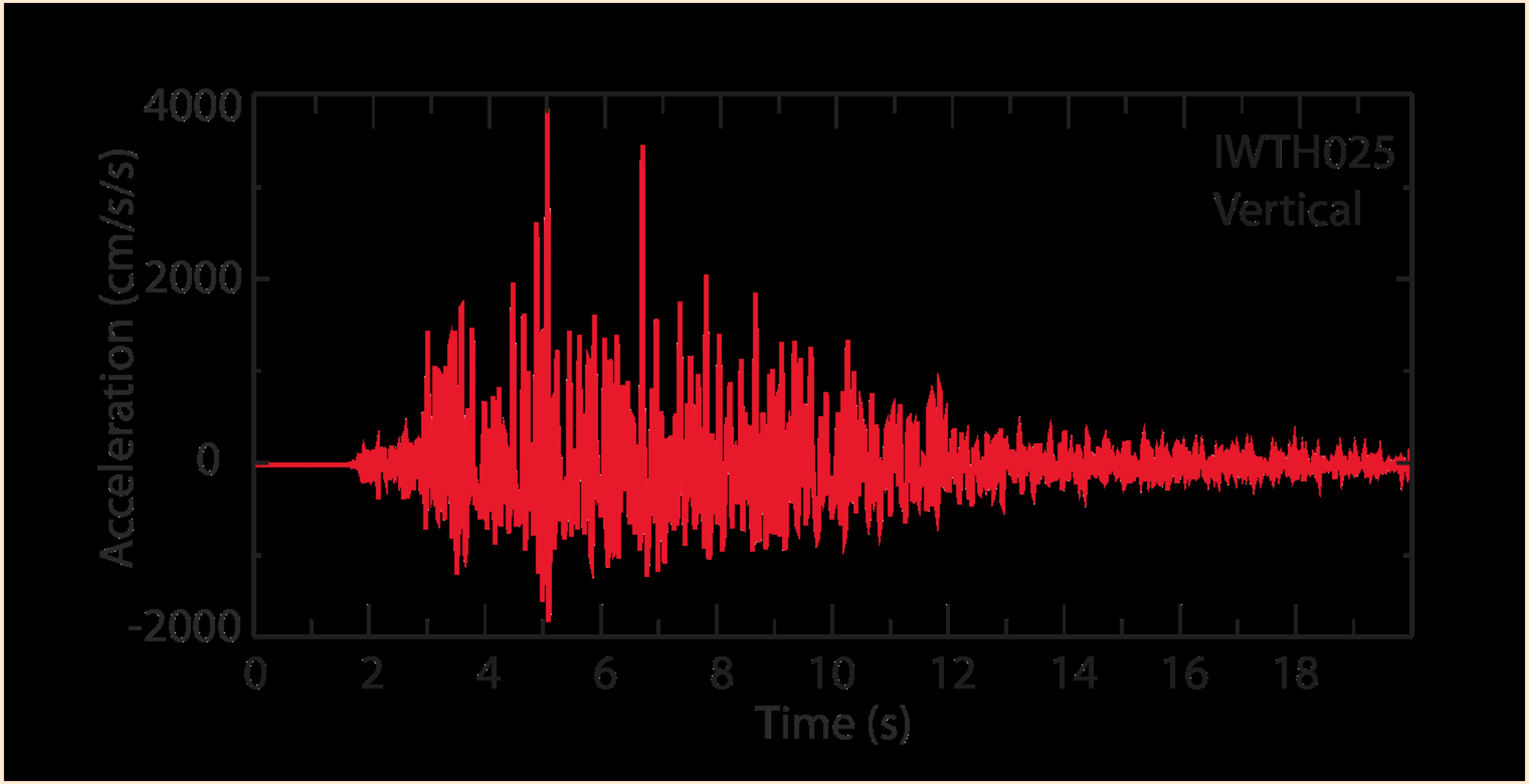
• How do the input parameters substantially change the radiated ground motion?

• How are we going to constrain the range of values for the input parameters? For example, is there a probability density function that can be used for each parameter?

• How do we describe the variation in space, i.e., along the full length and width of the fault, of the input parameters? What constraints do we have?

• Are there observable predictions from the various models that will allow us to distinguish among them which is most relevant to the earthquake process?

The End

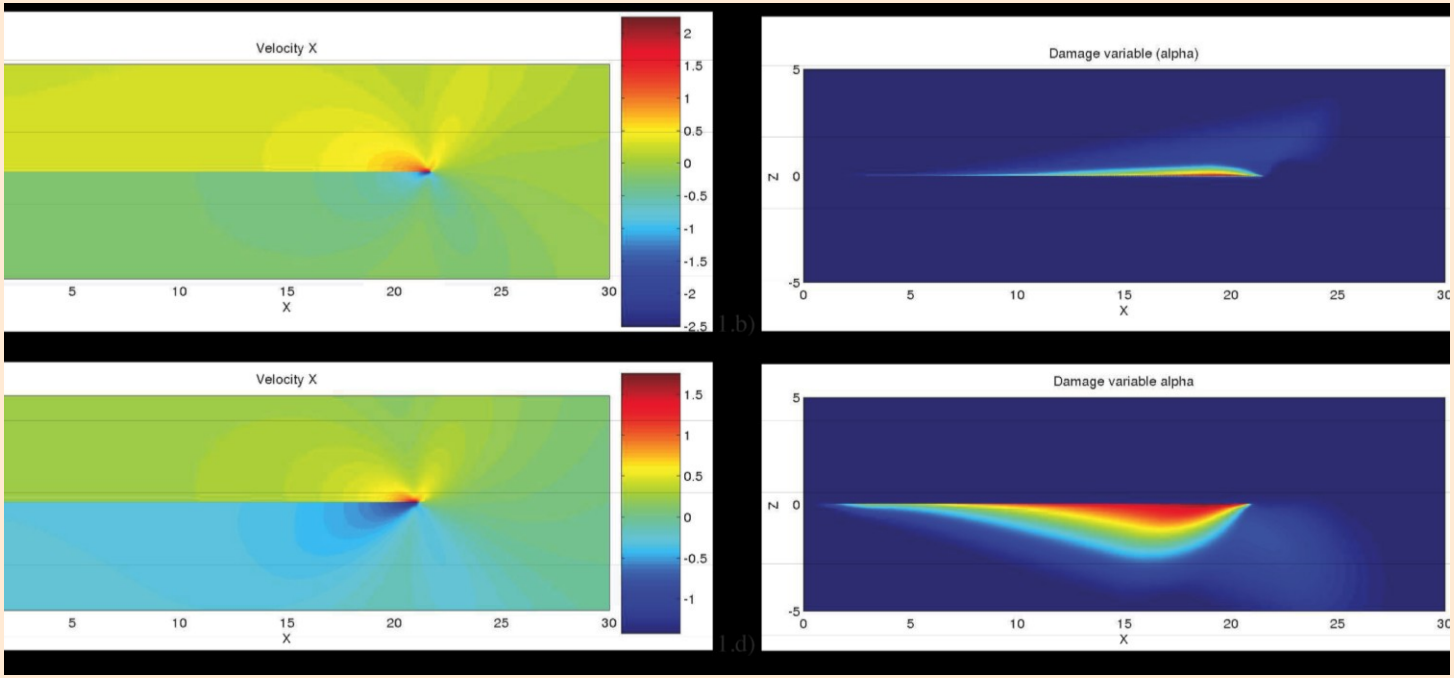


My co-workers: Jan Schmedes, Daniel Lavallée, Eric Dunham, Pengcheng Liu, Qiming Liu

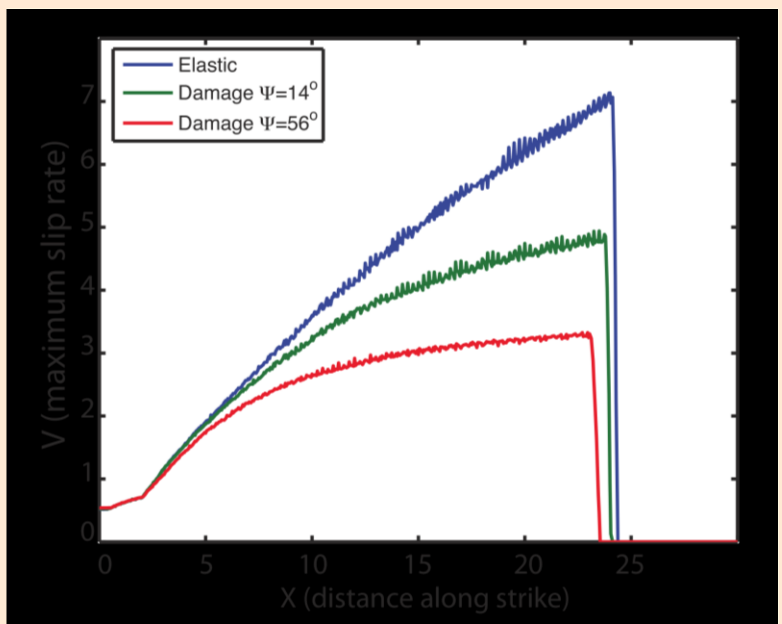
Fault Damage: Effect on Vmax

Ψ=14∨

Ψ=56∨

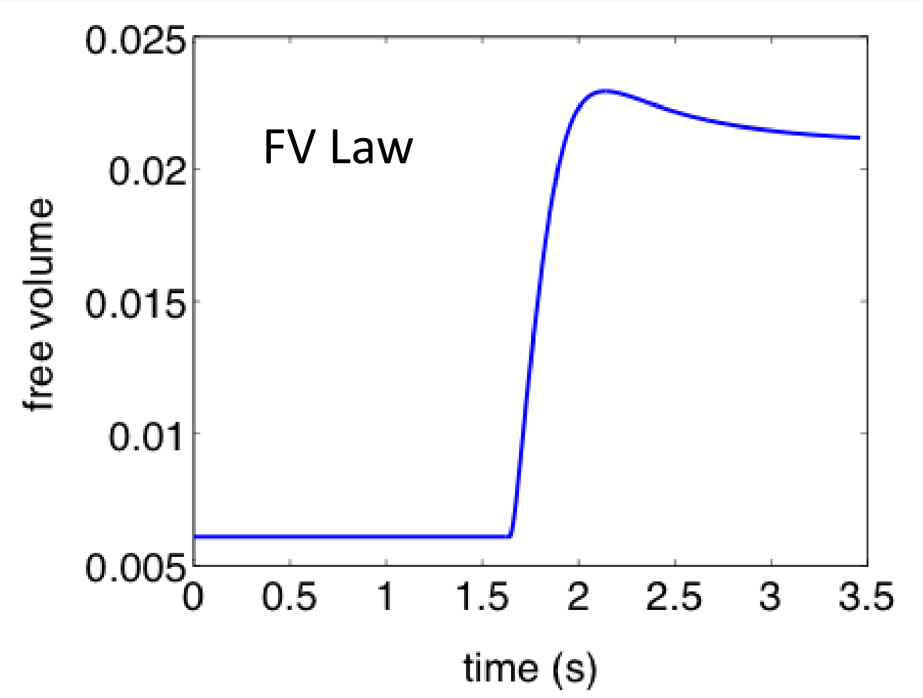


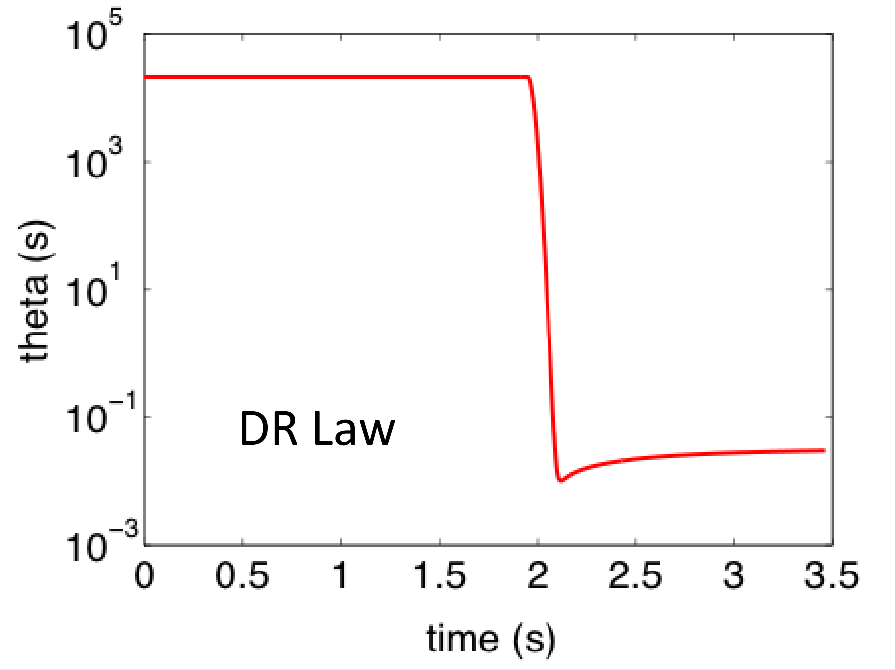
Friction: Slip Weakening



Ampuero, Ben-Zion, Lyakhovski, SSA 2008

Time Histories – State Variables



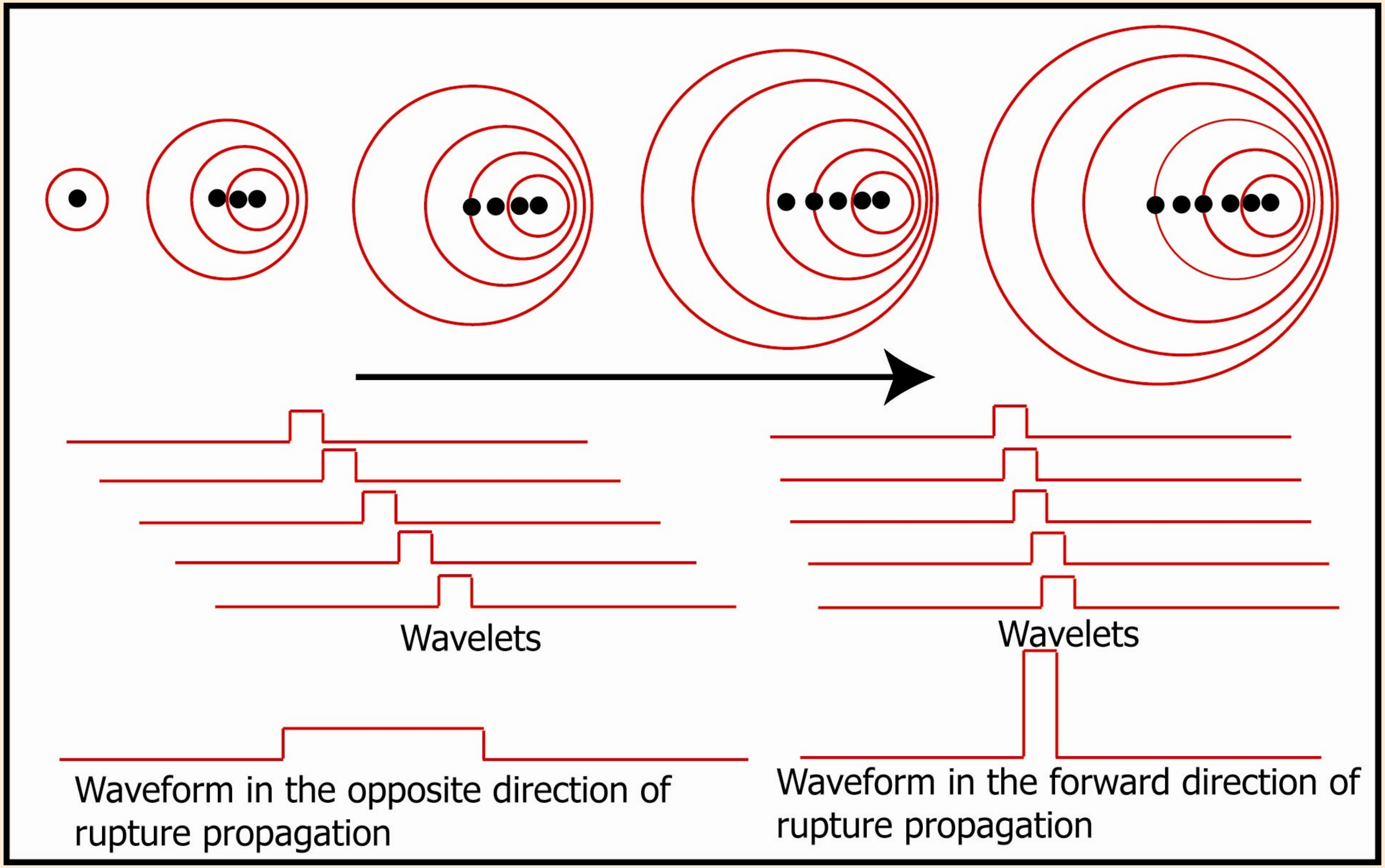


Rupture front arrival causes rapid dilation for the FV law, then gradual compaction on the crack interior. The peak free volume corresponds to minimum frictional strength.

Similarly, crack tip arrival causes a dramatic decrease in the asperity contact lifetime. Minimum value of the state variable also corresponds to minimum shear traction.

Daub and Carlson, submitted, JGR

Rupture Directivity



Benioff, 1955