Numerical simulation of dynamic triggering of slow slip events in California (and New Zealand)

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Simulation of dynamic triggering using rate-and-state

- Gomberg et al., 1998; Spring-slider model
- Perfettini et al., 2003 (a,b); 1D fault in 2D medium, earthquakes
- Wei et al., 2015; 1D fault in 2D medium, creep events on SAF system
- Wei et al., under review; 1D fault in 2D medium, slow slip events in New Zealand
- Recent manuscripts from Japanese groups
- Other (?) tremor (?)

Dynamic perturbation

Aging law

$$\frac{d\theta}{dt} = 1 - \frac{V\theta}{D_c} - \alpha \frac{\theta}{b\sigma} \frac{d\sigma}{dt} \quad (1)$$

where alpha is an empirical factor, ~0.2 for *f* = 0.6.

The concept is that, as normal stress increases, there will be an introduction of a new population of asperity contacts of younger ages than that is already present before the extra loading, and therefore the average age of all contacts (old + new) decreases.

Linker & Dieterich, 1992

Dynamic perturbation

Equation of elasticity (quasi-dynamic):

$$\tau = \sigma\left[f_0 + a\ln(V/V_0) + b\ln(V_0\theta/D_c)\right] = \tau_0 - \sum K_{ij}(\delta_j - V_{pl}t) - \eta V \quad (2)$$

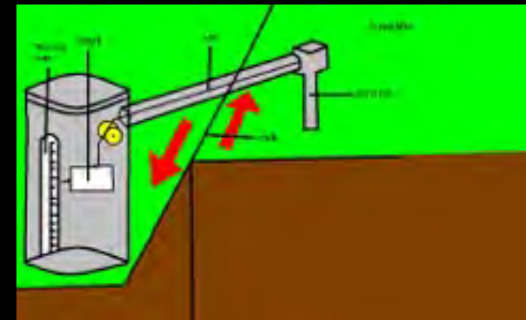
Take time derivative of the above equation and organize, we get

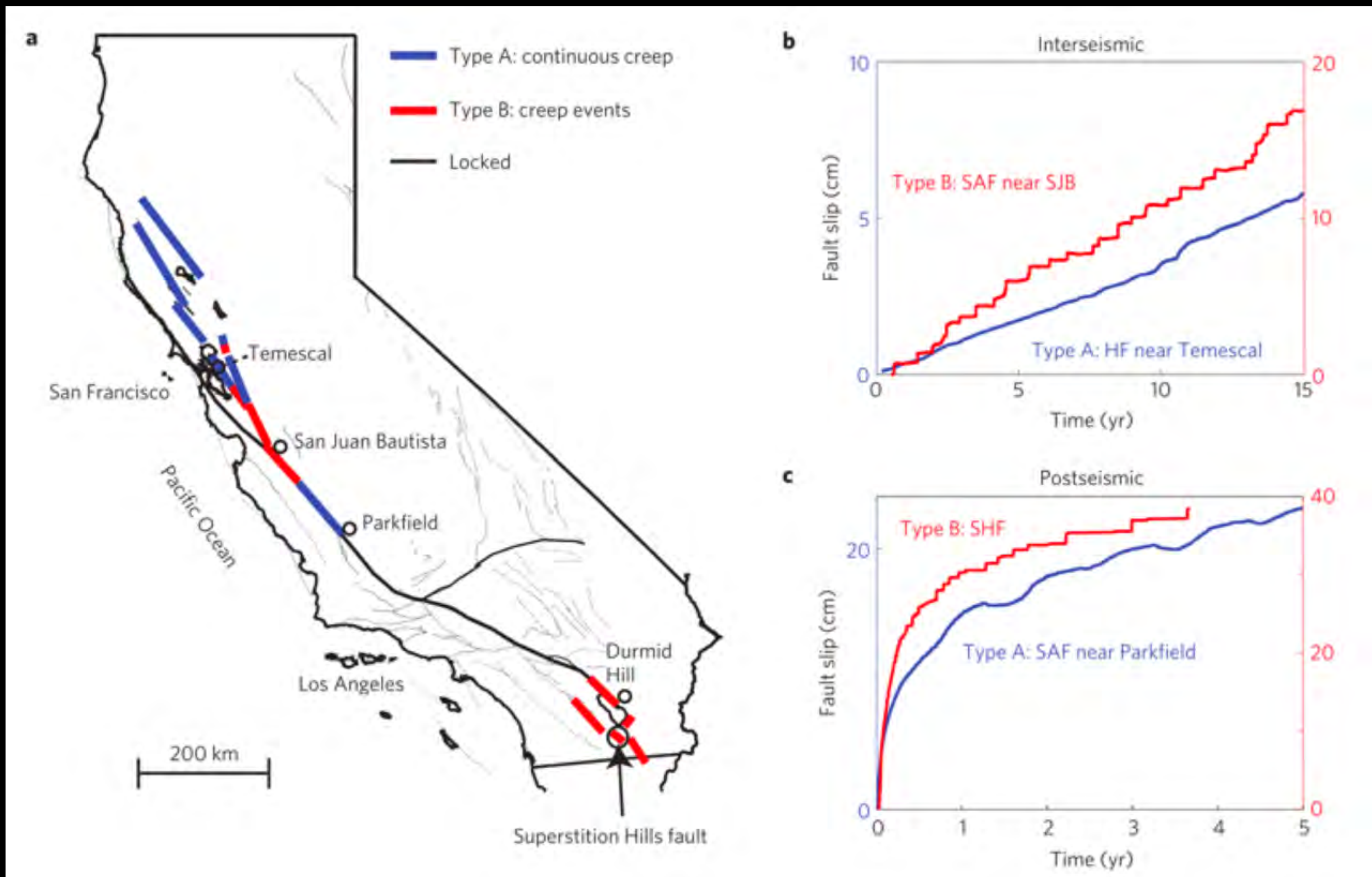
$$\frac{dV}{dt} = \frac{1}{a\sigma/V + \eta}\left[-\sum K_{ij}(V_j - V_{pl}) - \frac{b\sigma}{\theta}\frac{d\theta}{dt} + \frac{d\tau_0}{dt} - frc\frac{d\sigma}{dt}\right] \quad (3)$$

where $frc \equiv f_0 + a\ln(V/V_0) + b\ln(V_0\theta/D_c)$.

We solve the coupled equations (1) and (3) during dynamic perturbations, note that $\frac{d\sigma}{dt}$, $\frac{d\tau_0}{dt}$ and σ are also time-variable. Time step is inversely proportional to max slip rate on the fault but kept at 0.002 second during dynamic perturbation.

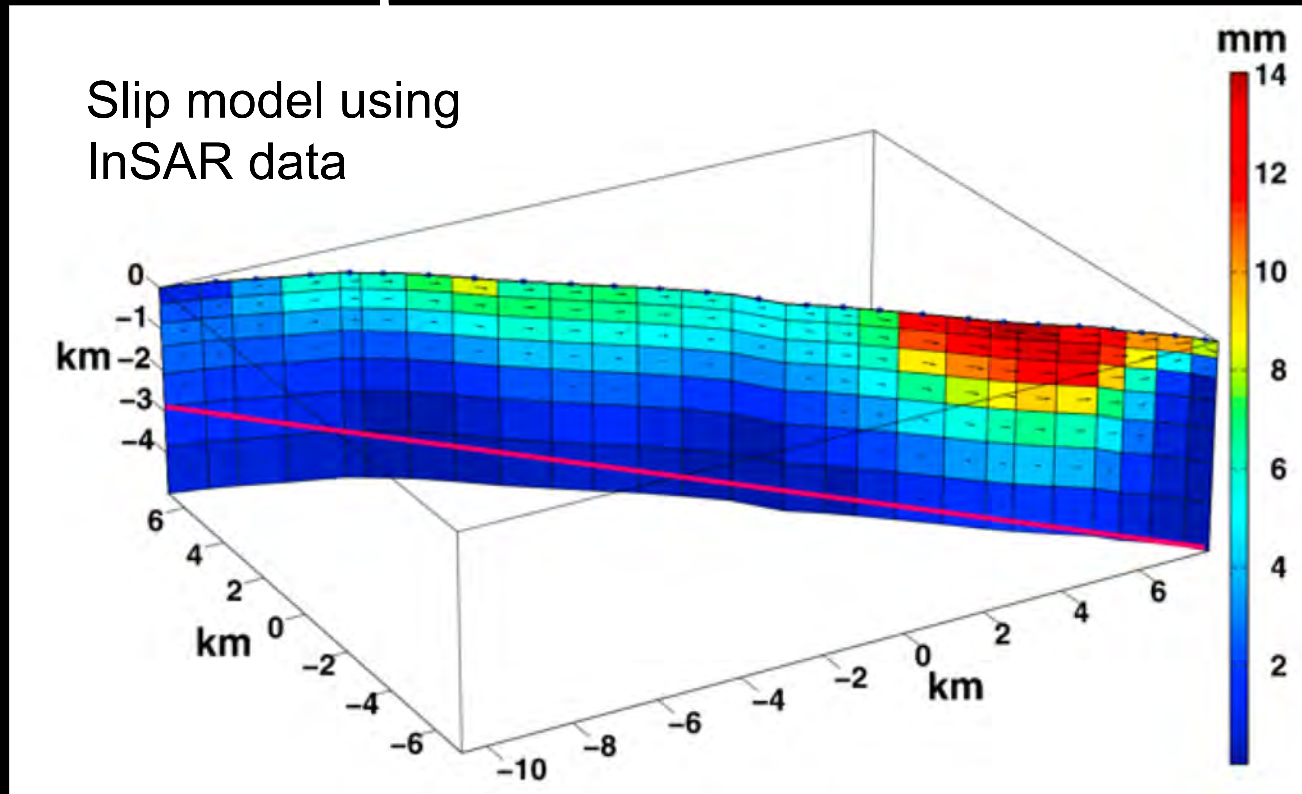
Observations in California (creep events)

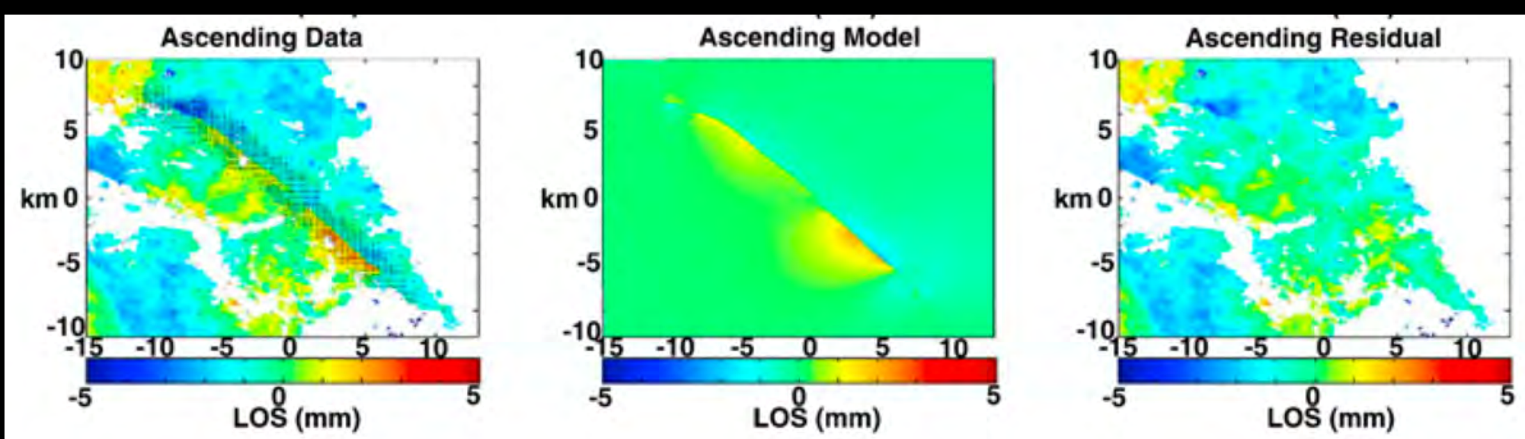




Wei et al., 2013

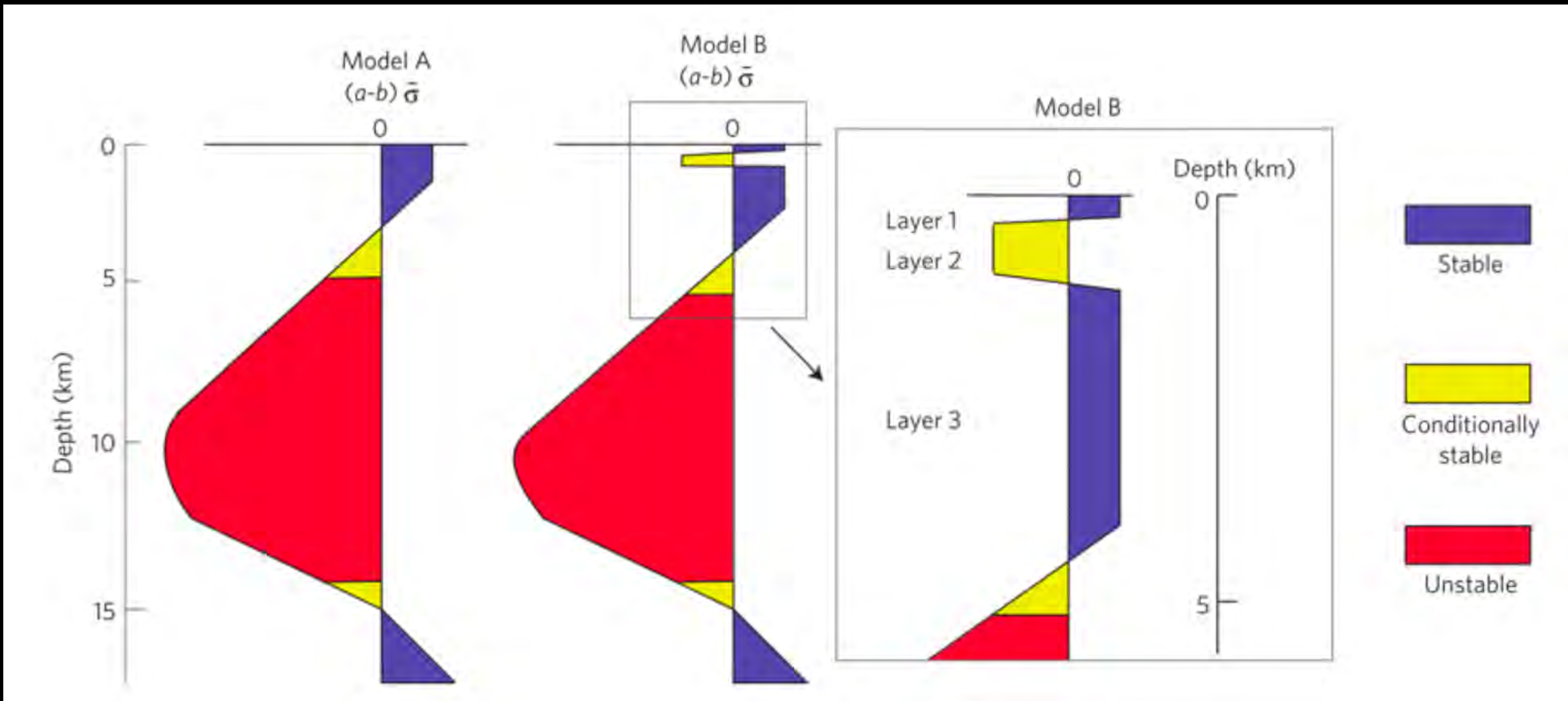
Creep events on the Superstition Hills Fault





Wei et al., 2009

We propose shallow heterogeneity as the source of creep events

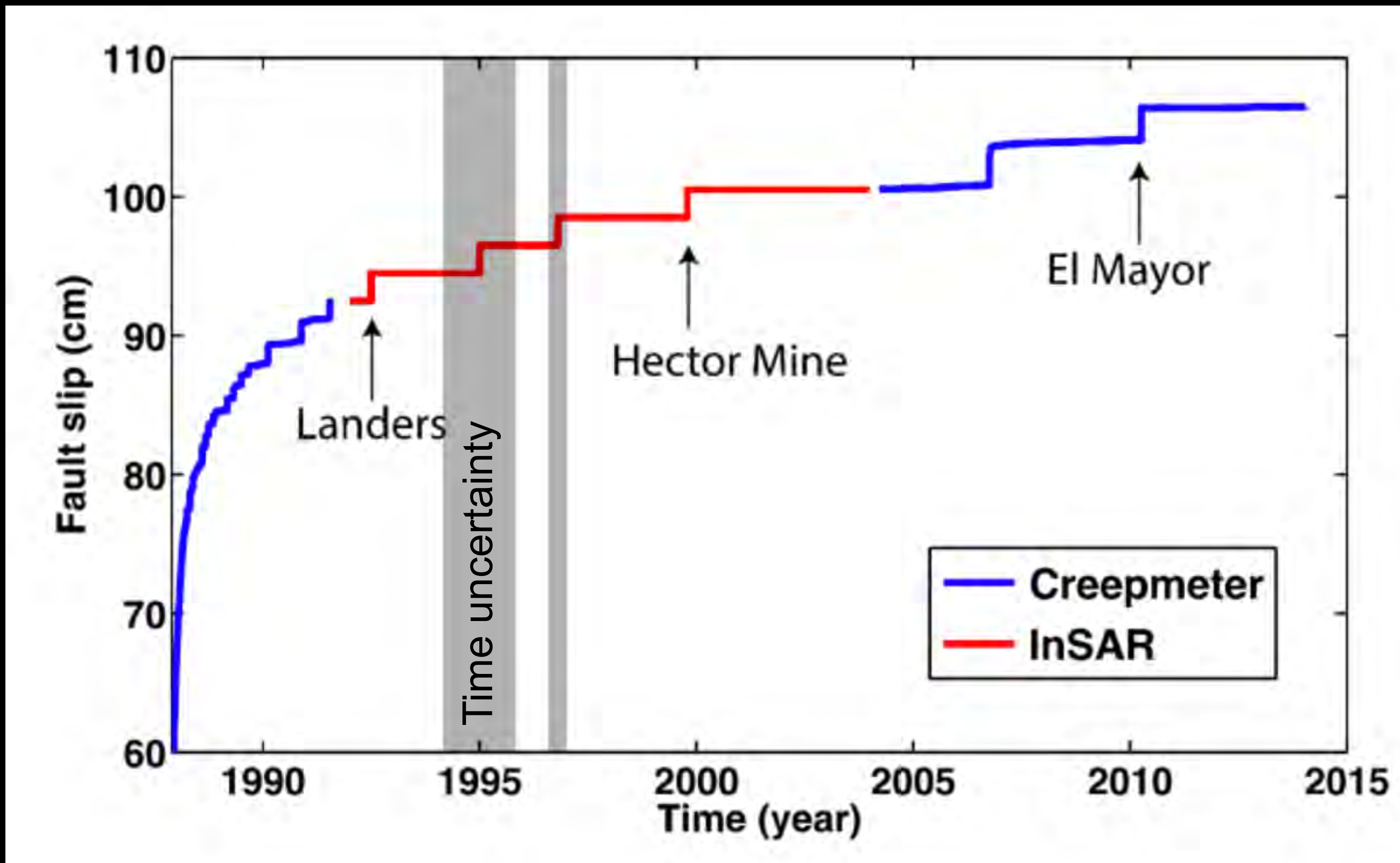


Two points:
Wesson, 1988;
Brodsky and Mori, 2007

Geological origin: rhyolite intrusion (well log) near SHF; stratigraphic data from the southern Salton Trough

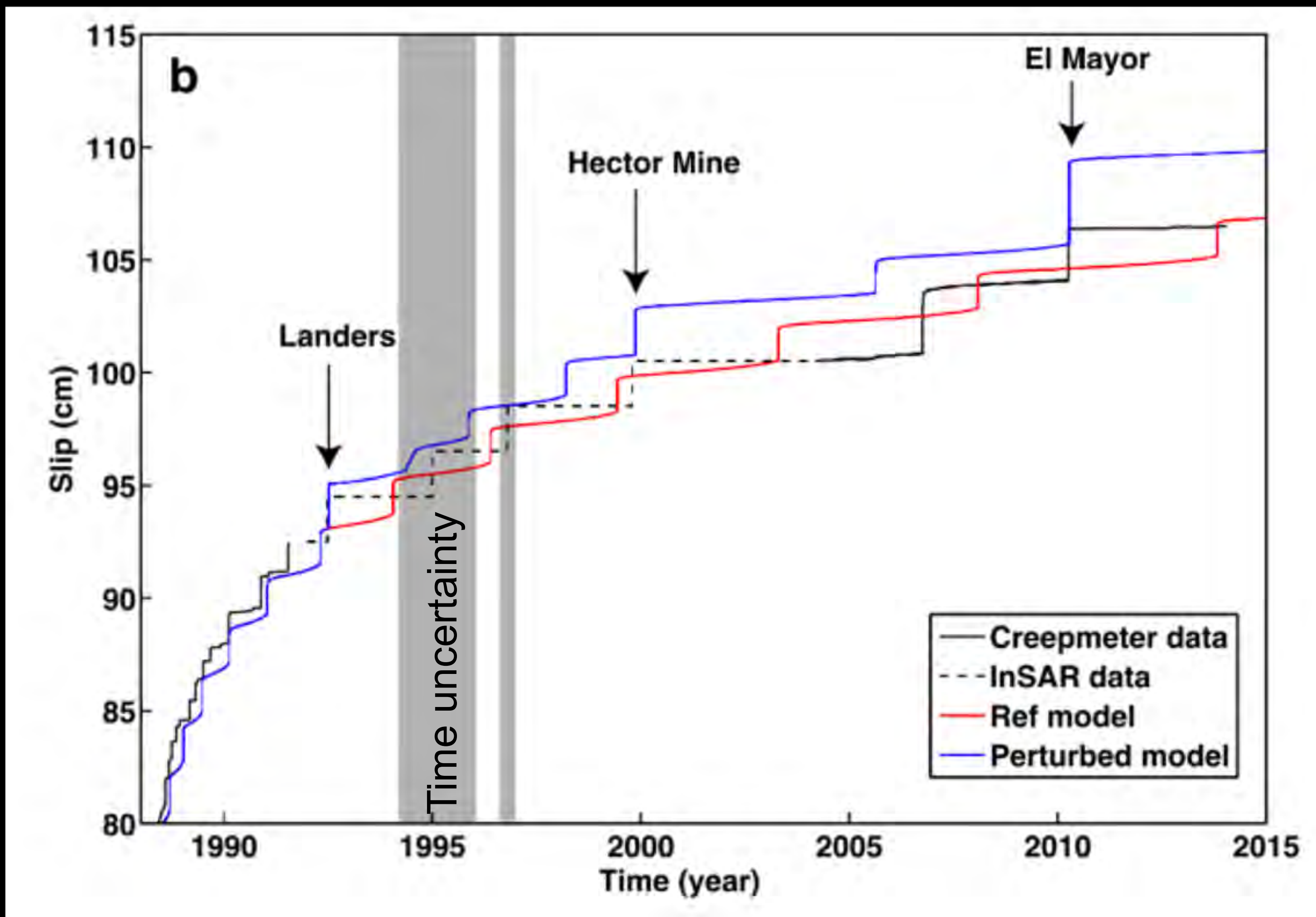
Wei et al., 2013

Superstition Hills Fault – dynamically triggered by many earthquakes



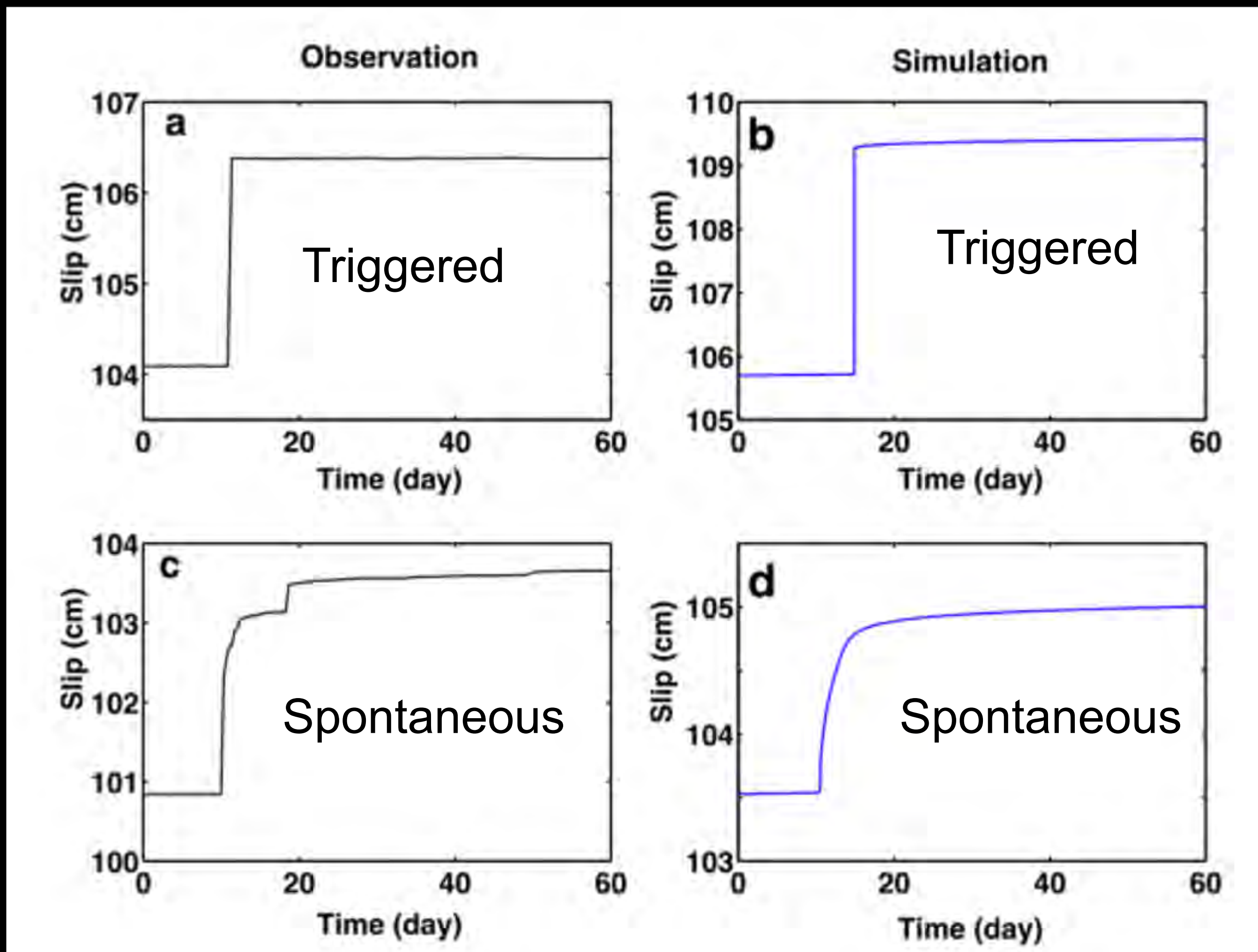
Wei et al., 2015

We can reproduce the dynamic triggering with realistic perturbations



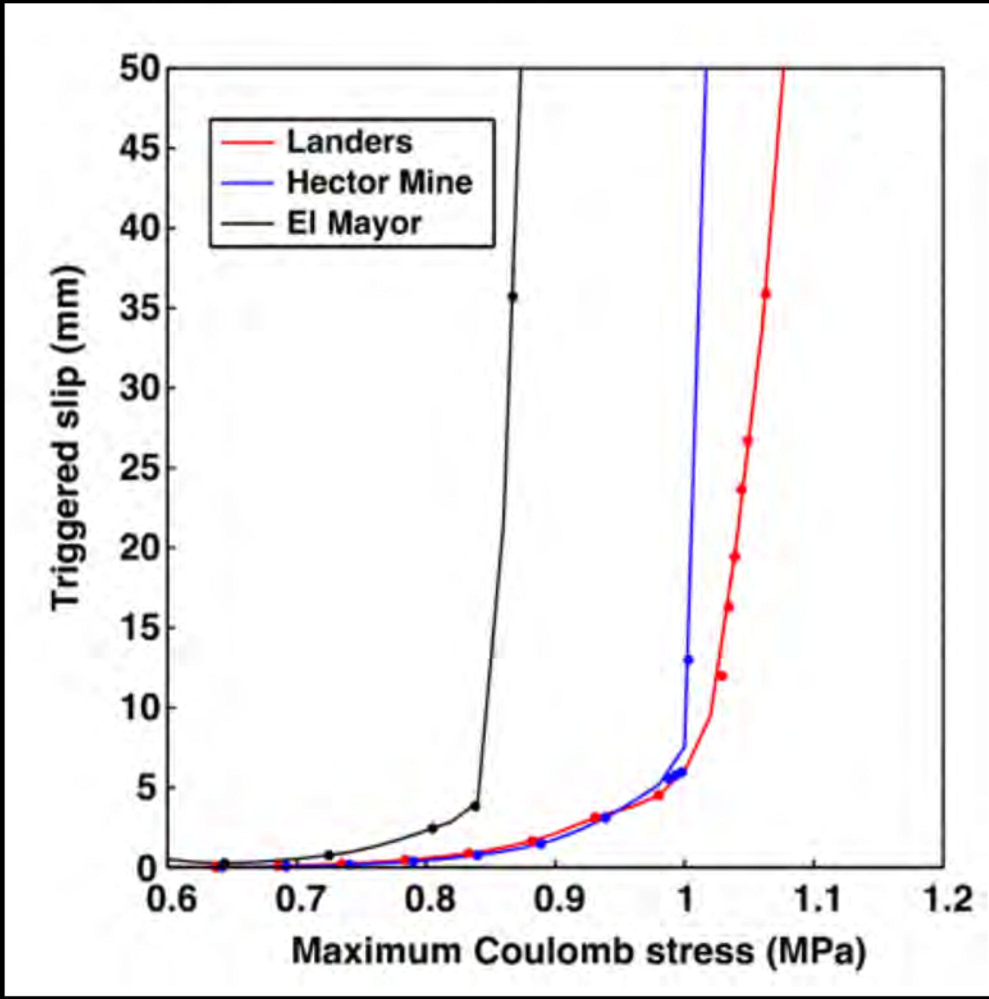
Wei et al., 2015

Also reproduce the different characteristics of triggered and spontaneous event



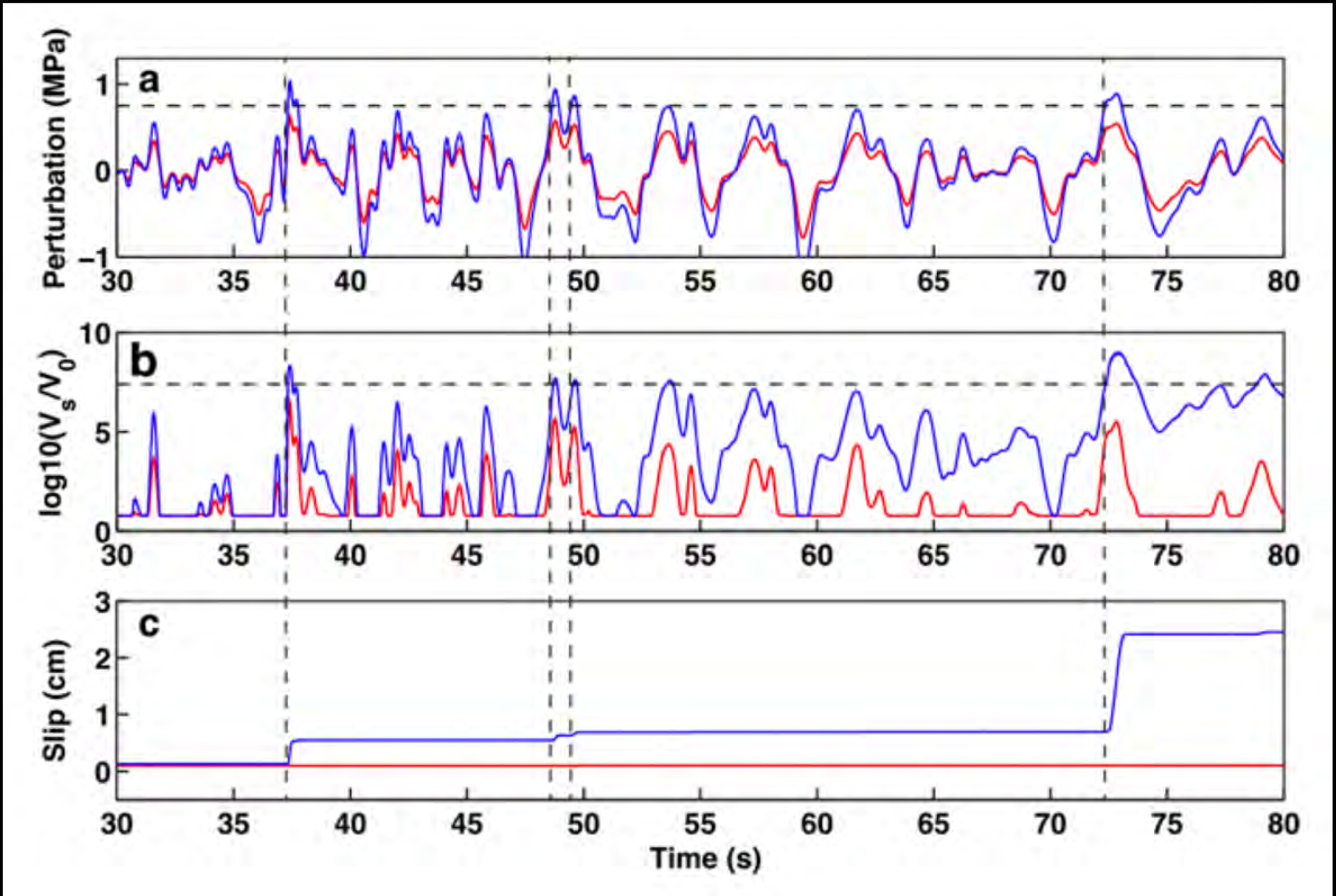
Wei et al., 2015

Size of triggered events scales with the maximum Coulomb stress of perturbations; becomes seismic if perturbation is large enough



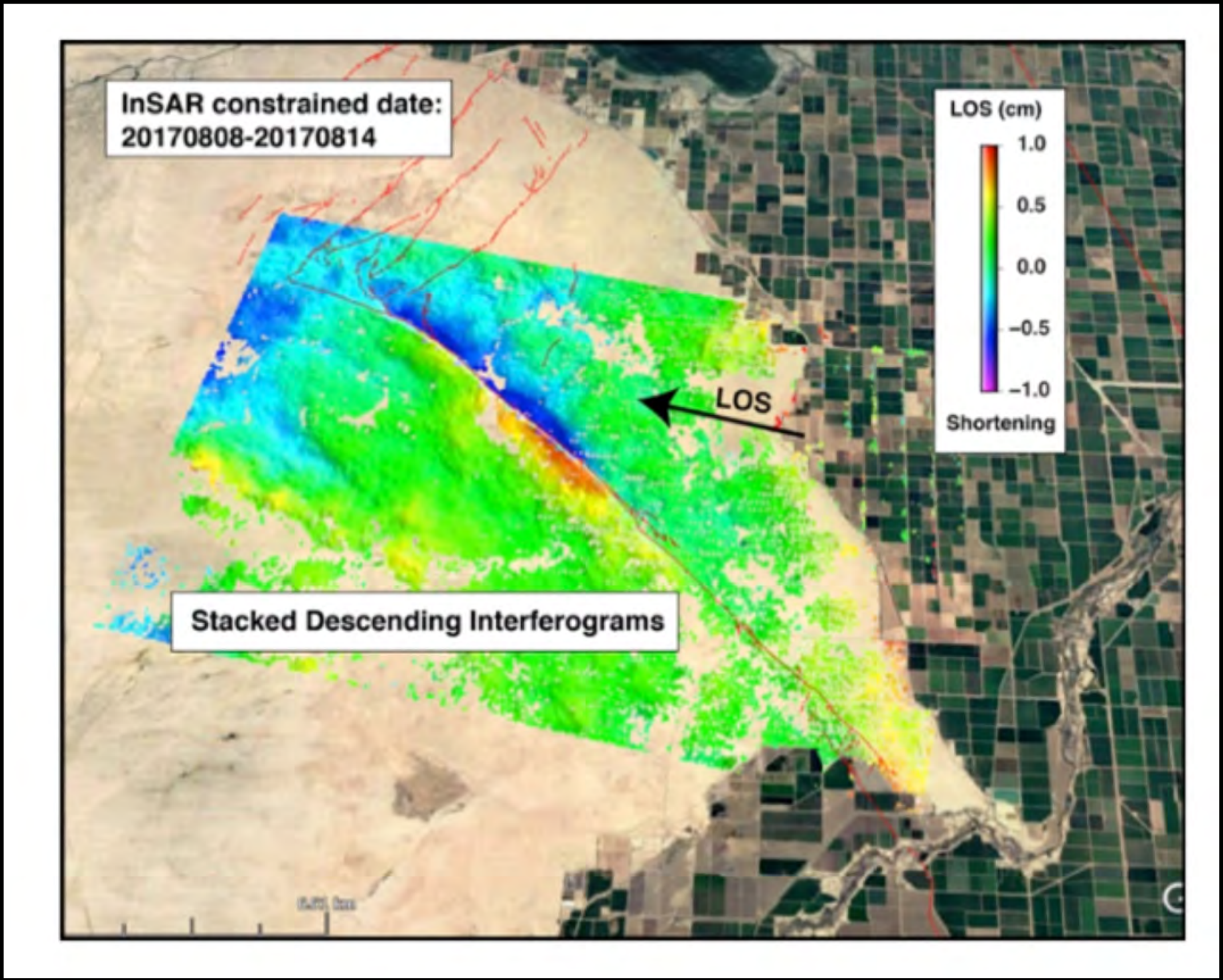
Wei et al., 2015

A dynamic threshold on triggering

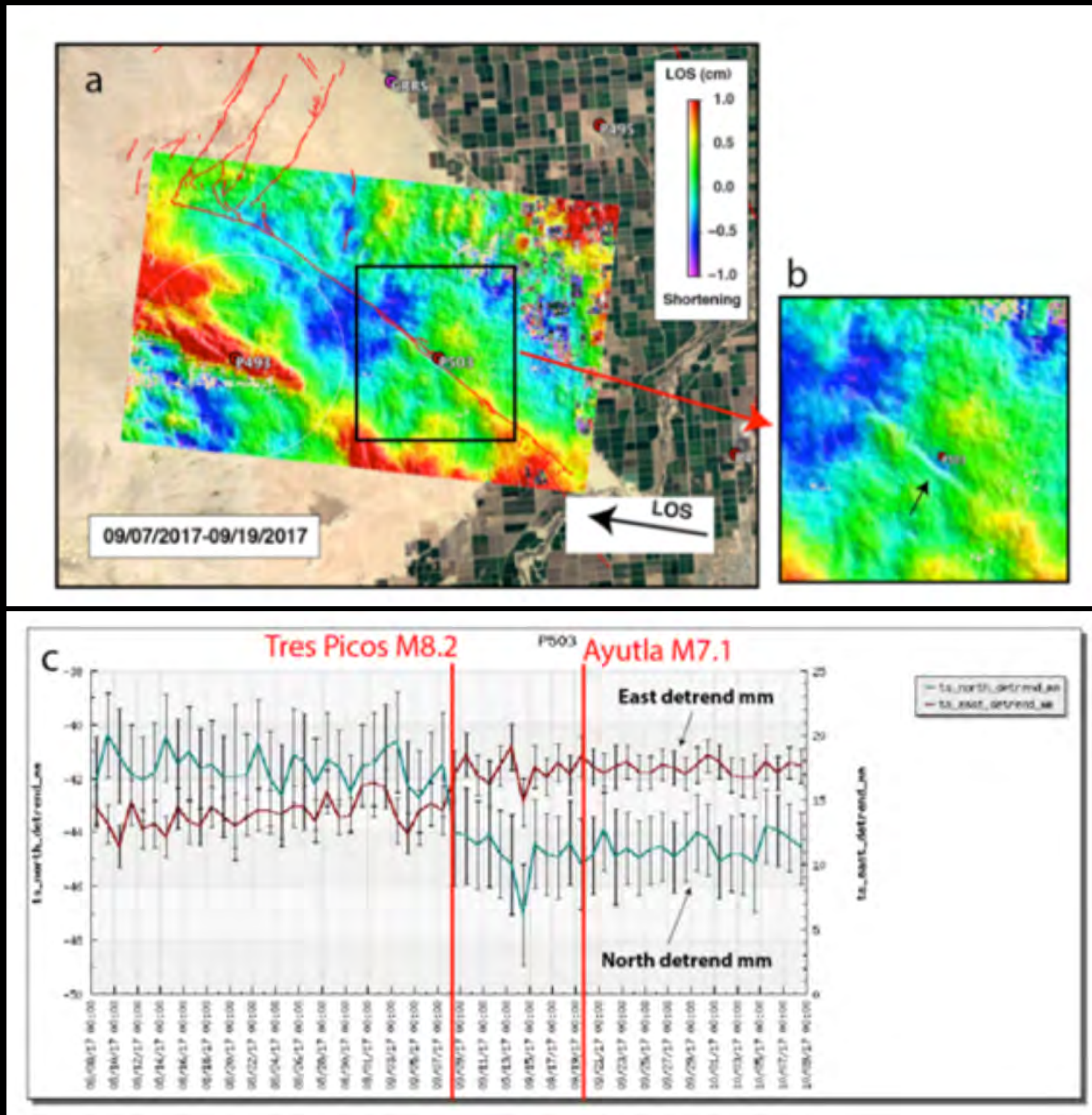


Wei et al., 2015

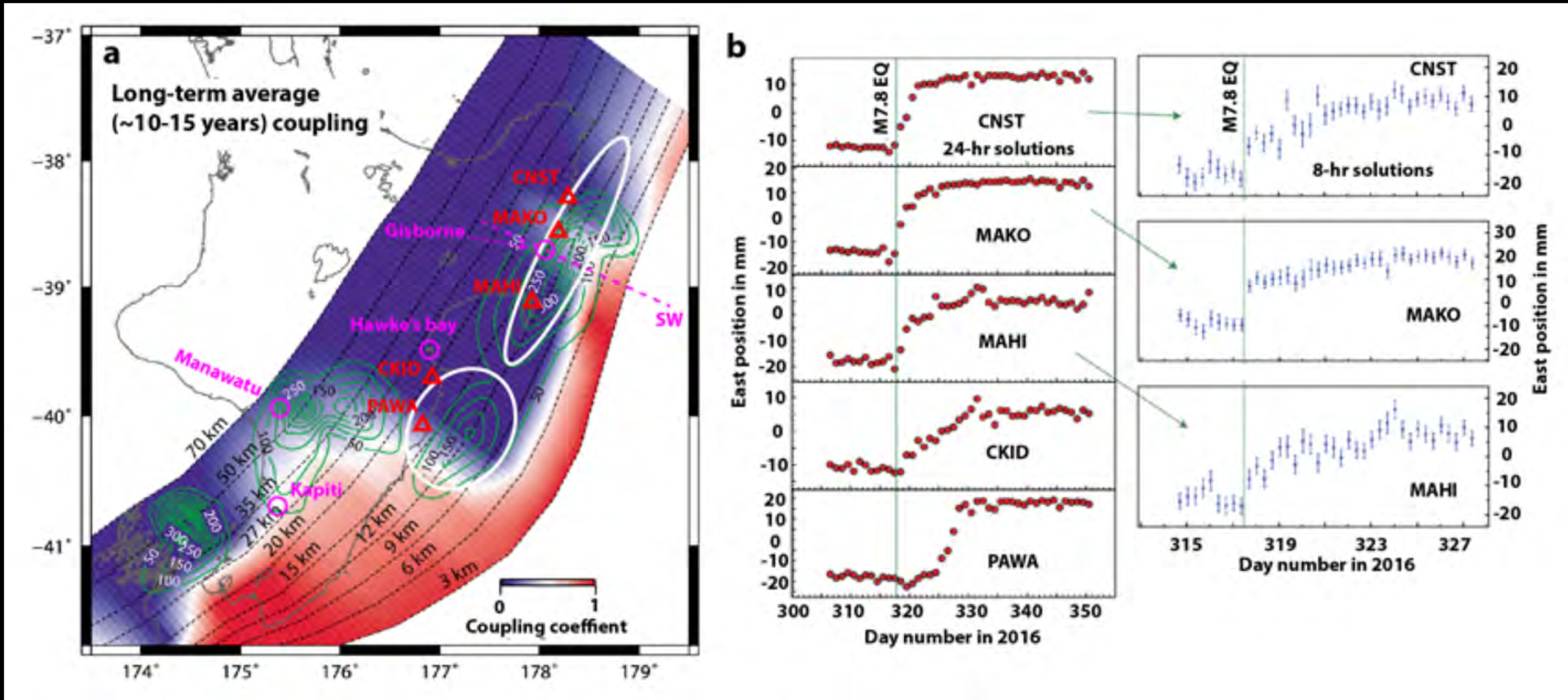
New spontaneous events last summer

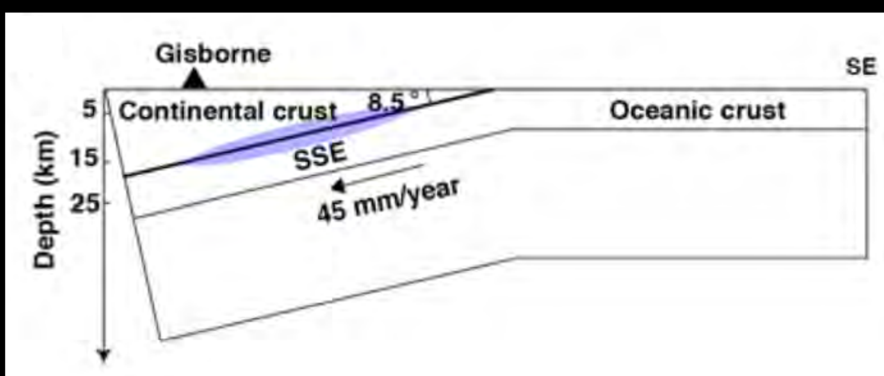


Triggered event by the Tres Picos M 8.2, 3000 km away



The 2016 Kaikoura earthquake dynamically triggered SSE

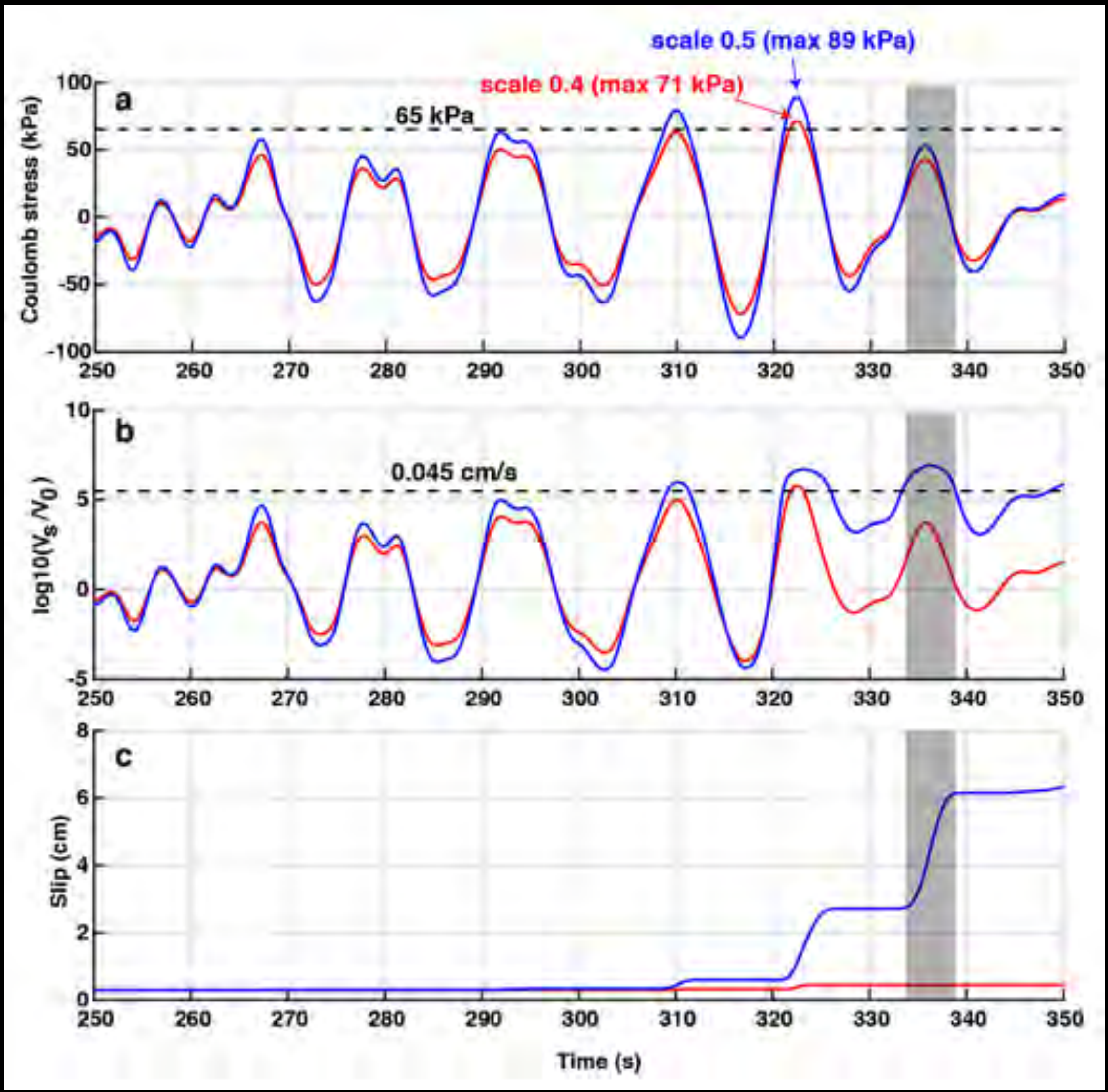




Modified from Wallace and Beavan, 2010; Wallace et al., 2017

Wei et al., under review

Threshold changes during perturbation



Once the perturbation amplitude exceeds an initial threshold, prolonged stress perturbations tend to decrease the triggering threshold hence promote dynamic triggering of SSEs.

Therefore, shallow SSEs are more likely to be dynamically triggered than their deep counterparts because of enhanced stress perturbation (magnitude and duration) from the sedimentary wedge.

Wei et al., under review