Understanding Interactions of Small Repeating Earthquakes Through Models of Rate-and-State Faults

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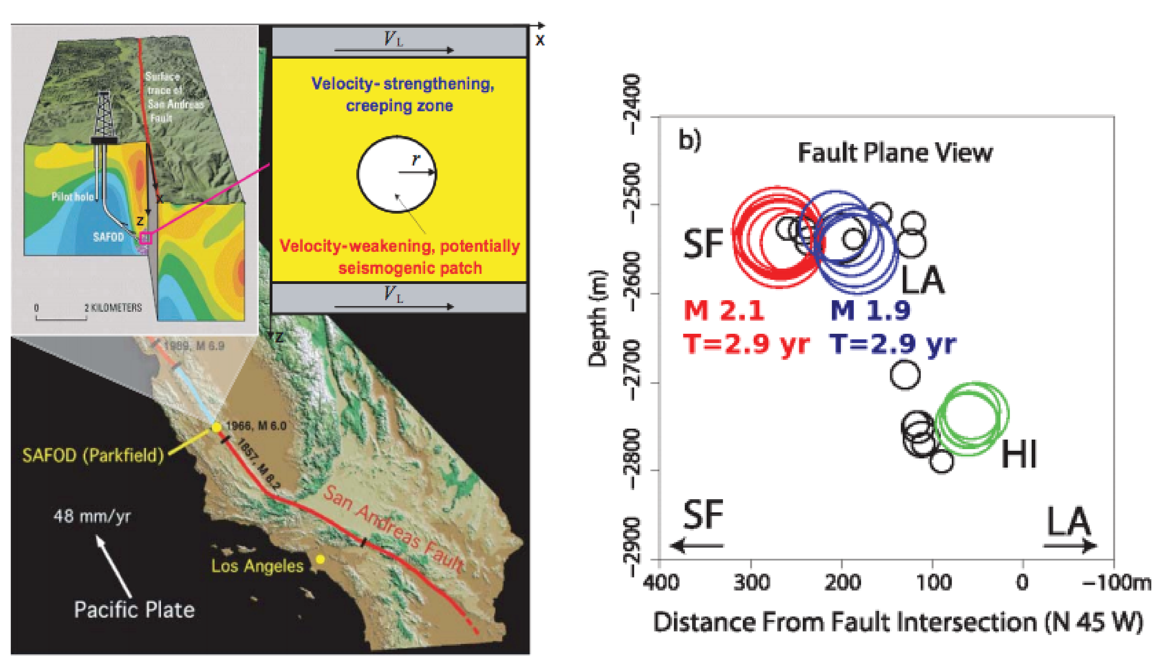
I. Motivation from Repeaters on the San Andreas Fault

Due to their short recurrence times and known locations, small repeating earthquakes are widely used to study earthquake physics. Some of the repeating sequences are located close to each other and appear to interact. For example, the "San Francisco" (SF) and "Los Angeles" (LA) repeating sequences, which are targets of the San Andreas Fault Observatory at Depth (SAFOD), have a lateral separation of less than 70 m. The LA events tend to occur within 24 hours after the SF events, suggesting a triggering effect.



(Figures from Chen & Lapusta, 2009)

Our goal is to study interaction of repeating earthquakes in the framework of rate-and-state fault models, in which repeating earthquakes occur on velocity-weakening patches embedded into a larger velocity-strengthening fault area. Such models can reproduce behavior of isolated repeating earthquake sequences, in particular, the scaling of their moment versus recurrence time and the response to accelerated postseismic creep (Chen & Lapusta, 2009, Chen et al., 2010).

Two Major questions that we would like to answer:

1. How far does the interaction between the patches extend?

2. What dominates the interaction - static stress change due to coseismic slip of one patch or accelerated (postseismic) creeping between the velocity weakening patches?

II. Rate-and-State Fault Model

Governing friction law:

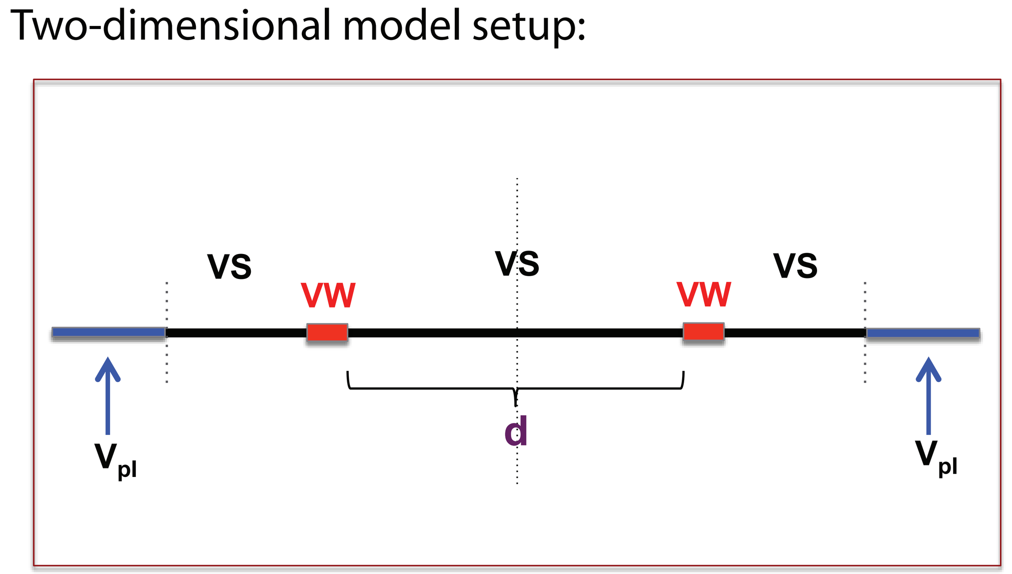
$$\tau = \bar{\sigma}[f_0 + a\ln(V/V_0) + b\ln(V_0\theta/L)]$$

$$\frac{d\theta}{dt} = 1 - V\theta/L$$

Aging law describing the evolution of the state variable θ

At steady state: $\theta_{ss} = L/V, \quad \tau_{ss} = \bar{\sigma}[f_0 + (a-b)\ln(V/V_0)]$

Two-dimensional model setup:



VW: a – b < 0

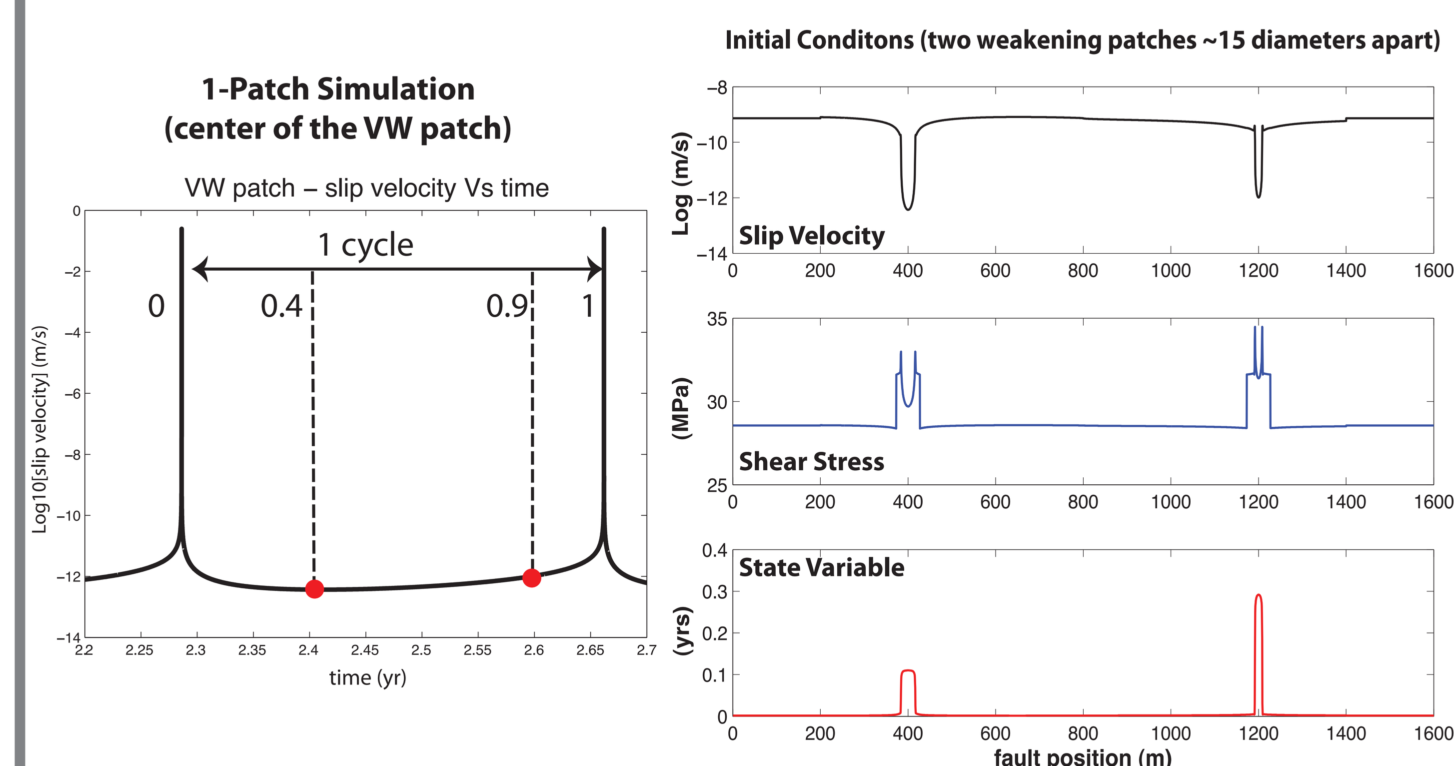
VS: a – b > 0

Plate loading region (friction is not resolved)

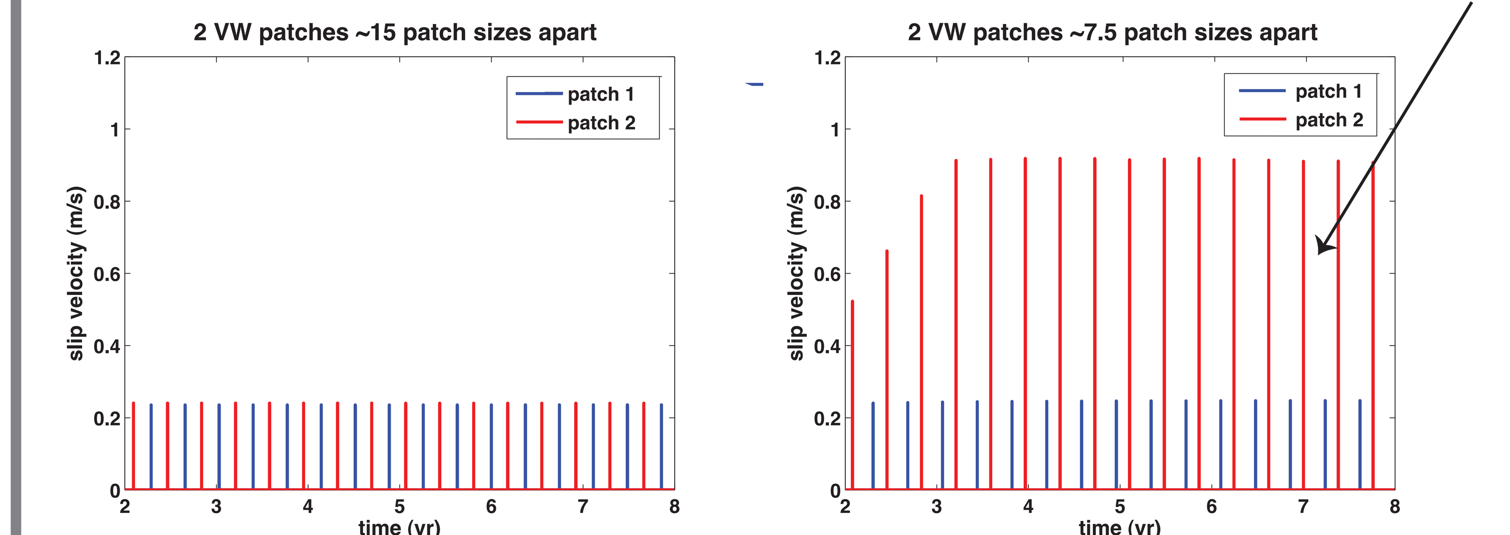
III. Exploring the Interaction Between Patches with Change of Distance

(a) Setting Up the Interaction Problem

- The initial conditions for a 2-patch simulation are taken from a 1-patch simulation, with patches displaced half a cycle apart.
- This allows us to clearly quantify the interaction. **If events on two patches occur closer than half a cycle apart, this indicates interaction.**



(b) Change in Inter-Event Time

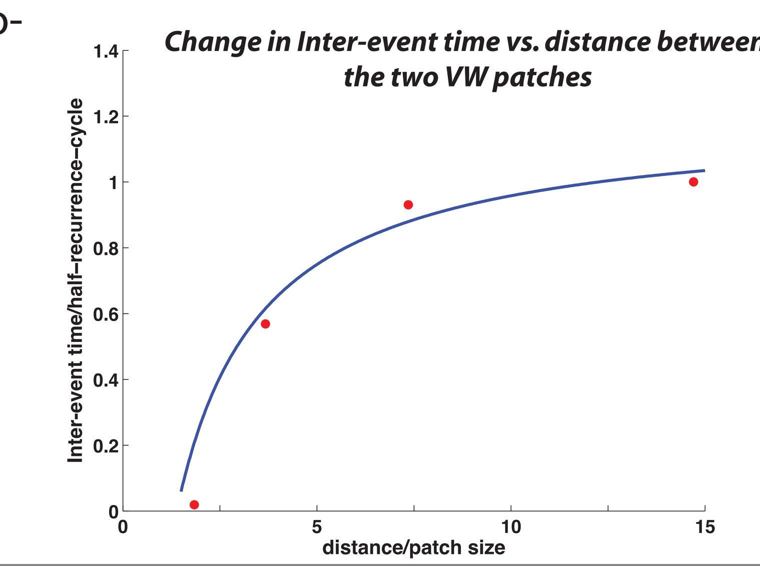


Assuming two non-interacting homogeneous repeating sequences, time separation between their seismic events (δt) should be half a cycle apart,

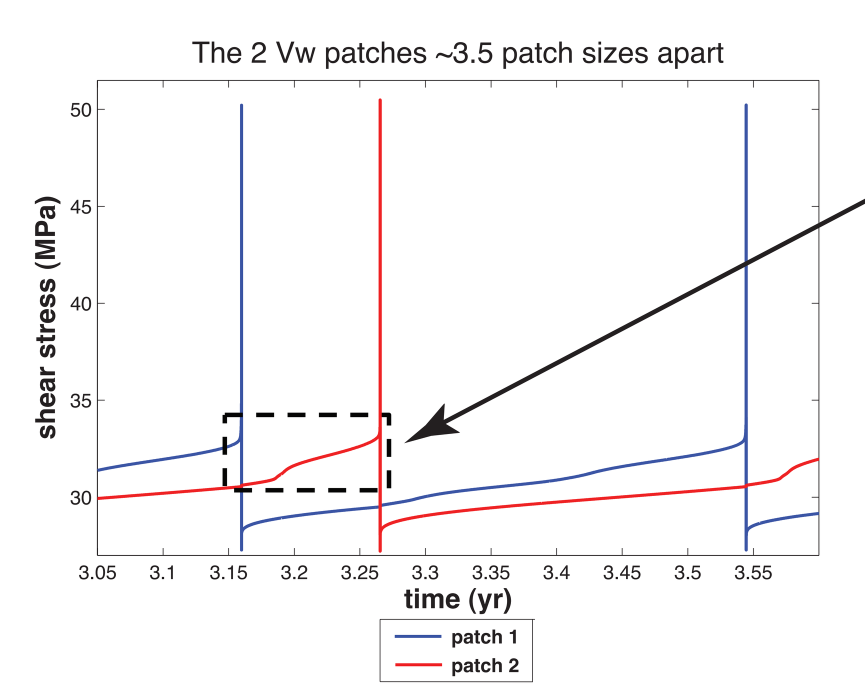
i.e. δt/half-recurrence-cycle = 1

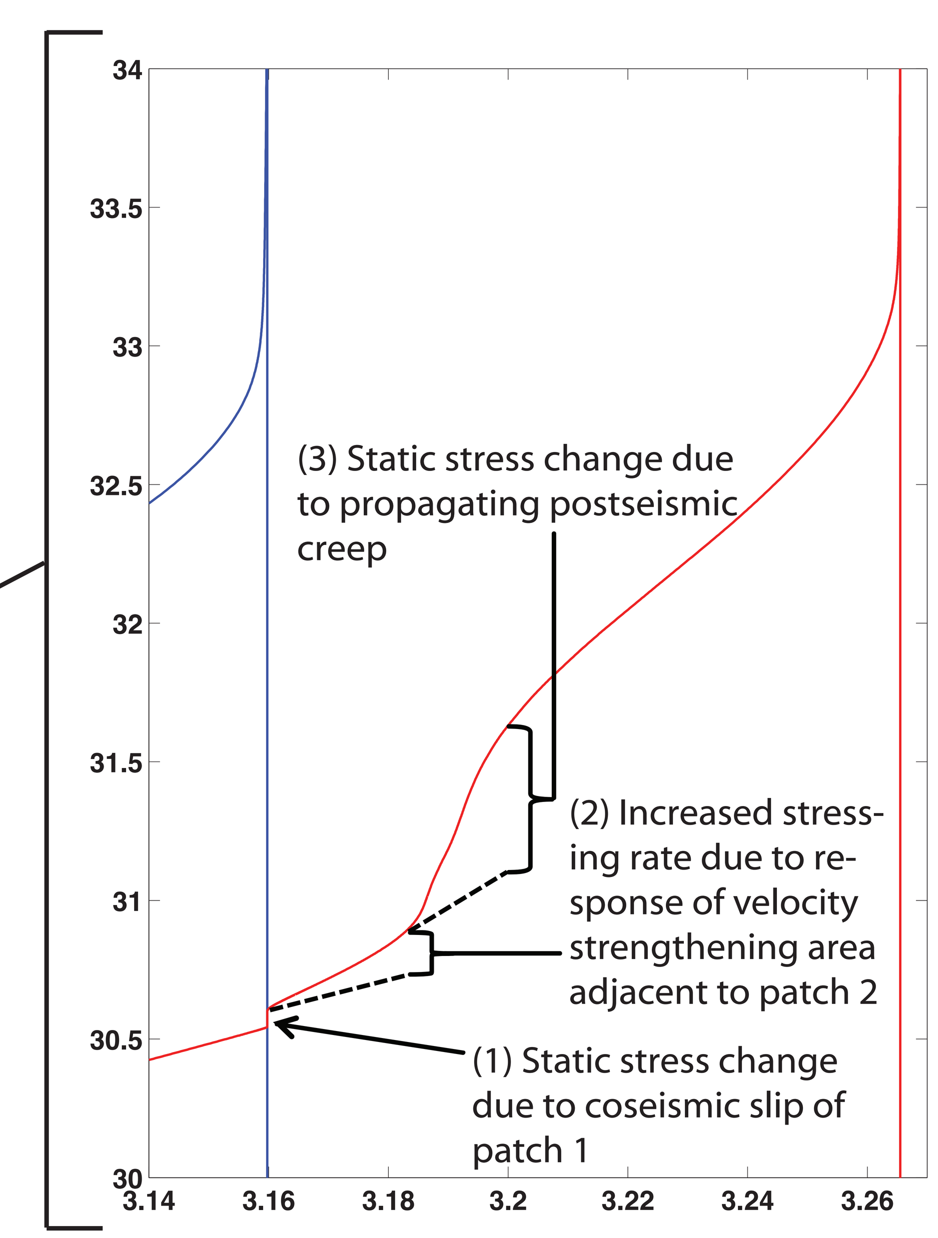
Approximation:

$Y \sim (1 + 1/x)^x$



(c) Different Kinds of Static Stress Change



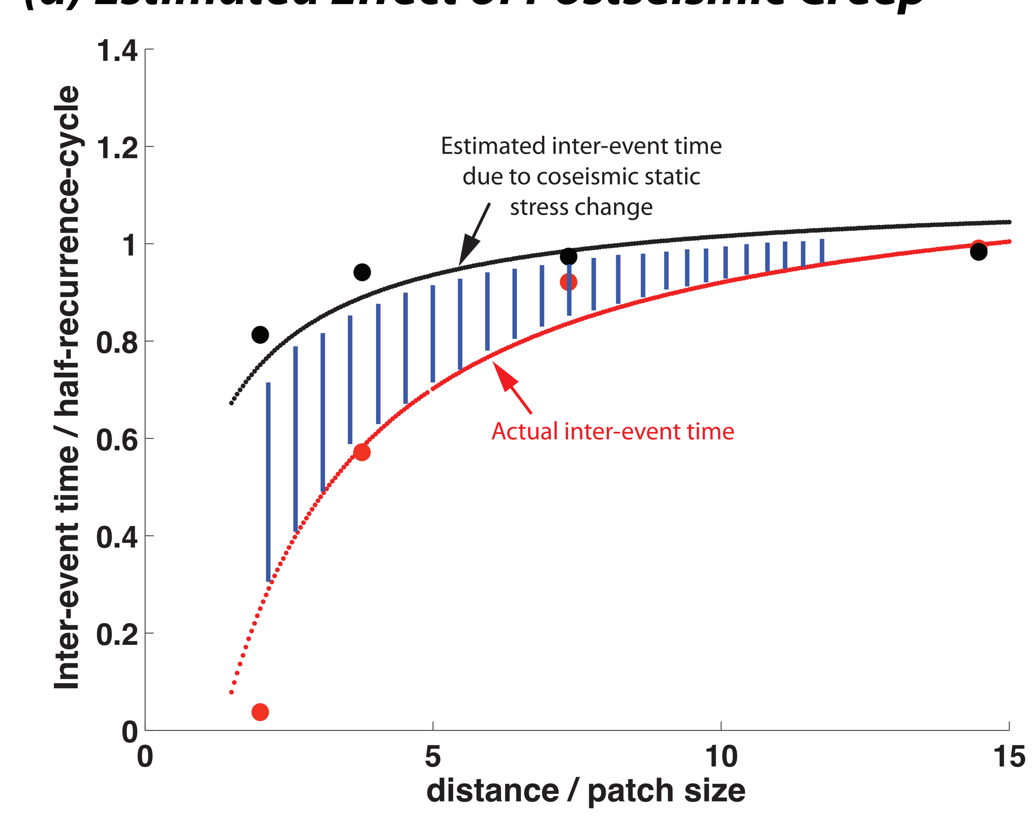


An event on patch 1 (vertical blue line) causes different kinds of static stress change on patch 2:

(1) Direct static stress change due to coseismic slip
(2) Increased stressing rate due to response of velocity strengthening area adjacent to patch 2
(3) Evolving stress change due to propagating coseismic creep

In most of our calculations, (3) dominates.

(d) Estimated Effect of Postseismic Creep



Positive shear stress step accelerates time to instability by $\Delta\tau/\dot{\tau}_{loading}$

Subtracting this from the actual inter-event time gives estimation of effects caused by postseismic creep.

IV. Conclusion and Future Work

Conclusion

- Specific imposed initial conditions in a 2-patch simulation allow us to examine interaction of VW patches through the change of inter-event time.
- In our simulations, static stress change caused by the propagating coseismic creep seems to be the dominating factor governing interactive behavior.

Future Work

- Theoretical understanding of these effects.
- Including heterogeneity of the fault and time-dependent perturbations.
- Applying the model to field observations (i.e. the SF and LA repeating sequences).
- Considering dynamic triggering, both dynamic stress change and physical properties changes.