Analyzing coupled interaction of fault segments

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Introduction

❖Most avtive fault exhibit a hetrogeneous behavior i.e. having creeping segment adjacent to locked segments. These creeping segments can change the behavior of an earthquake cycle of adjacent locked segment or undergo some behavioral changes. Hence understanding the behavior of these segments is important to better understand the physics of earthquakes.

a) b)

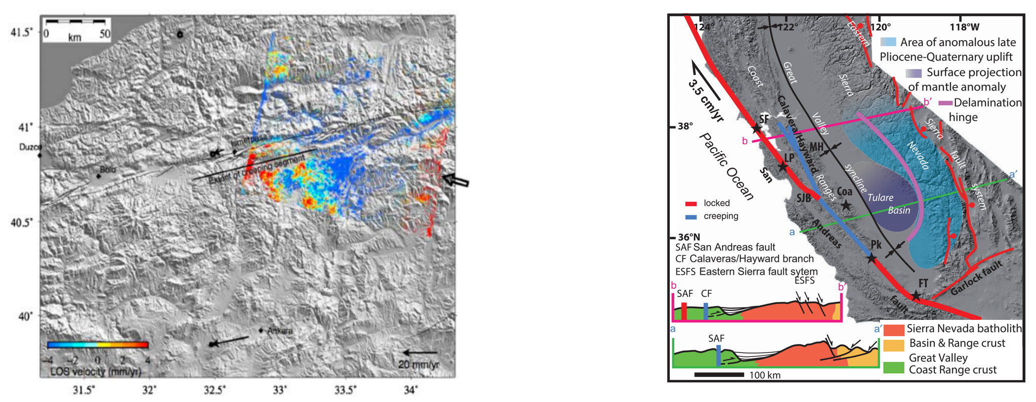

Fig.1:a) N. Anatolian fault (Kaneko,2013) **b) San Andreas fault (Pourheit and Sleeby,2013)**

❖Two different models i.e. burridge knopoff(BK) and continuum model are commonly used to model earthquakes. In the current study a BK model is used with two sliders to study the interaction between creeping segment and locked segment.

a) b)

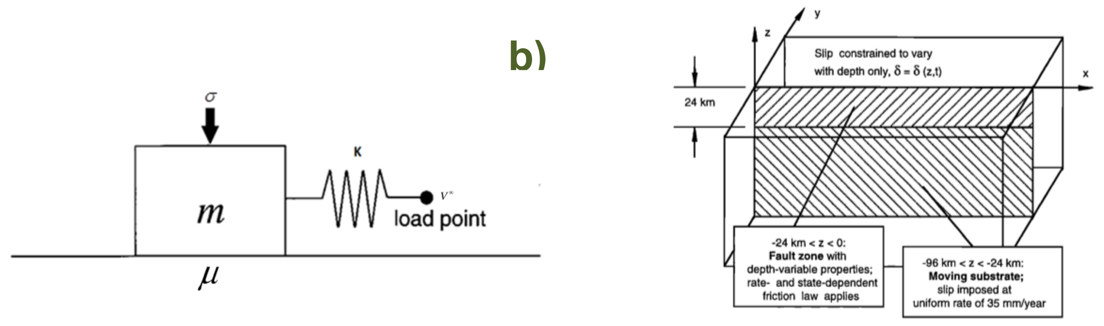

Fig. 2: Earthquake fault models, a) BK model b) continuum model

Modeling

❖A 1D BK model is utilized to model the fault behavior. In this model earthquake is simulated by an assembly of blocks. Each of these blocks is connected to the its neighboring block by an elastic spring. All blocks are connected to the moving plate by an elastic spring. All blocks are subjected to a frictional force. In this study, we utilized rate and state frictional law(Segall, 2010).

Inertia + spring force + friction + loading force = 0

$$m\ddot{u}_i = k_{si}(v_\infty t - u_i) + k_i(u_{i+1} - u_i) - \tau_{friction} ----(i)$$

$$\mu = \left[\mu^* + a\ln\frac{v}{v^*} + b\ln\frac{\theta v^*}{D_c}\right] ---------(ii)$$

$$\frac{d\theta}{dt} = 1 - \frac{V\theta}{Dc} -----------------(iii)$$

a > b rate strengthening , a < b rate weakening

✧ Our BK model is composed of two blocks. One of these blocks is given a rate strengthening property and the other has rate weakening property. Th model is tested both with and without an external perturbation. This perturbation is applied to analyze the dynamics of the system under the effect of a passing seismic wave(Kostic et al.,2014).

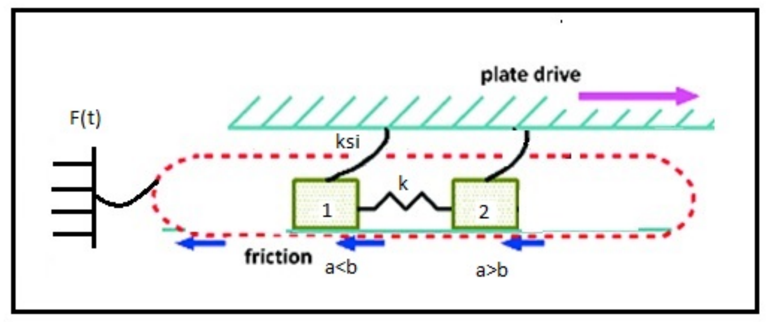

Fig. 3: Bk model having two sliders with perturbation applied

Inertia + spring force + friction + loading force + external force = 0

$$F(t) = F_0 \sin(\frac{2\pi t}{T}) e^{[(t-t_0)/t_w]^2} --------(iv)$$

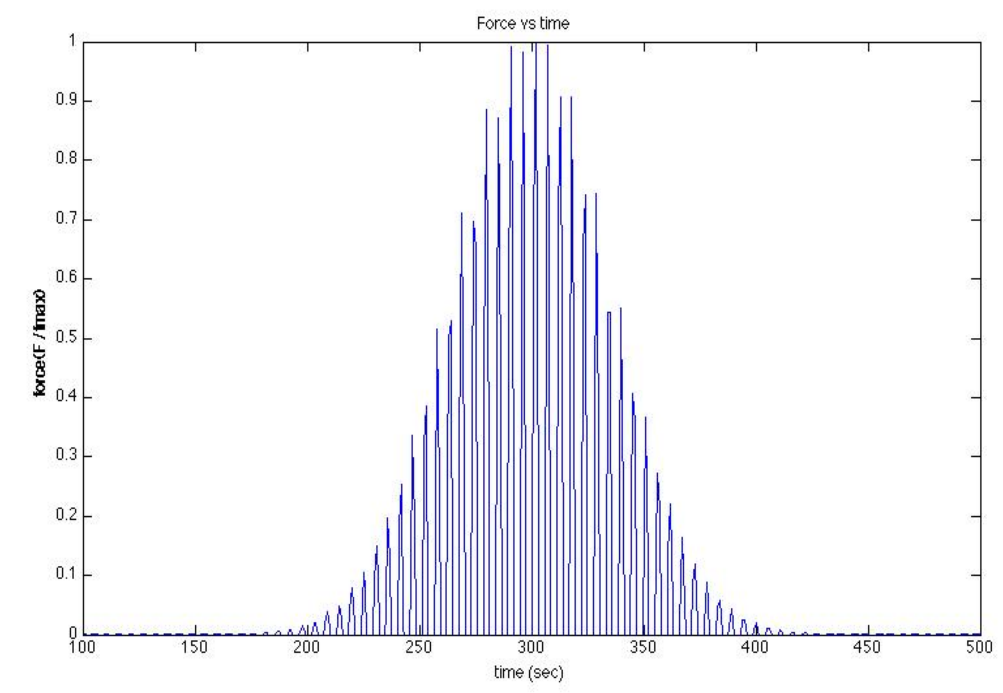

Fig. 4: F(t) shown in non-dimensional form(positive values shown)

✧Research Questions:

✧ Either due to the external or internal forcing, does the velocity strengthening patch adjacent to the locked segments slip seismically at some stage?

✧ Can multiple sliders slip at the same time(a mega event)?

✧ Does the creeping segment behaves in an explainable way(aseismic/seismic/slow earthquakes) or there is chaotic behavior that is hard to explain ?

✧ How the coupled interaction of patches affect the periodicity of earthquakes?

✧ What is the instantaneous response of creeping patch to the external forcing ?

Results

✓ The creeping slider mostly follows the steady state behaviour with an acceleration seen right after the locked segments slips seismically. The locked segments shows a complete earthquake cycle with regular recurrence interval.

a) b) c)

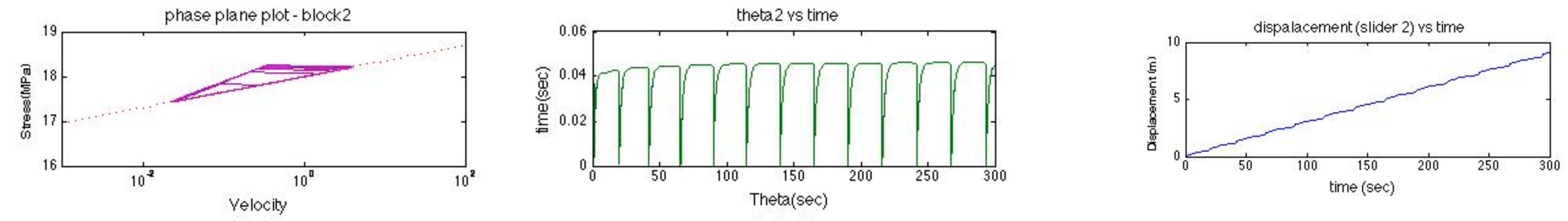

Fig. 5: Plots showing the behavior of creeping segment with time a) phase plane plot b) state variable with time c) displacement with time

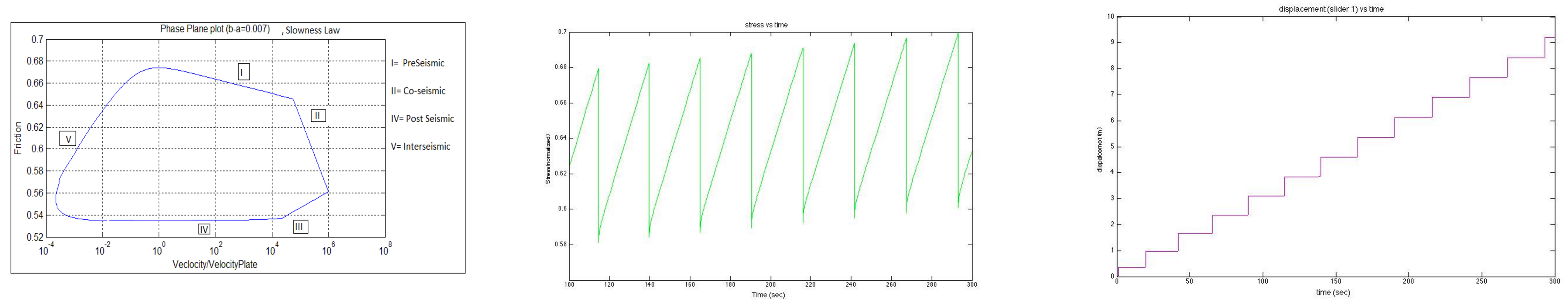

Fig. 6: Plots showing the behavior of locked segment with time a) phase plane plot b) state variable with time c) displacement with time

✓In the absence of an external force the sliders repeat their motion at regular intervals but when a perturbation force is applied there is a detailed response to the external forcing.

a) b)

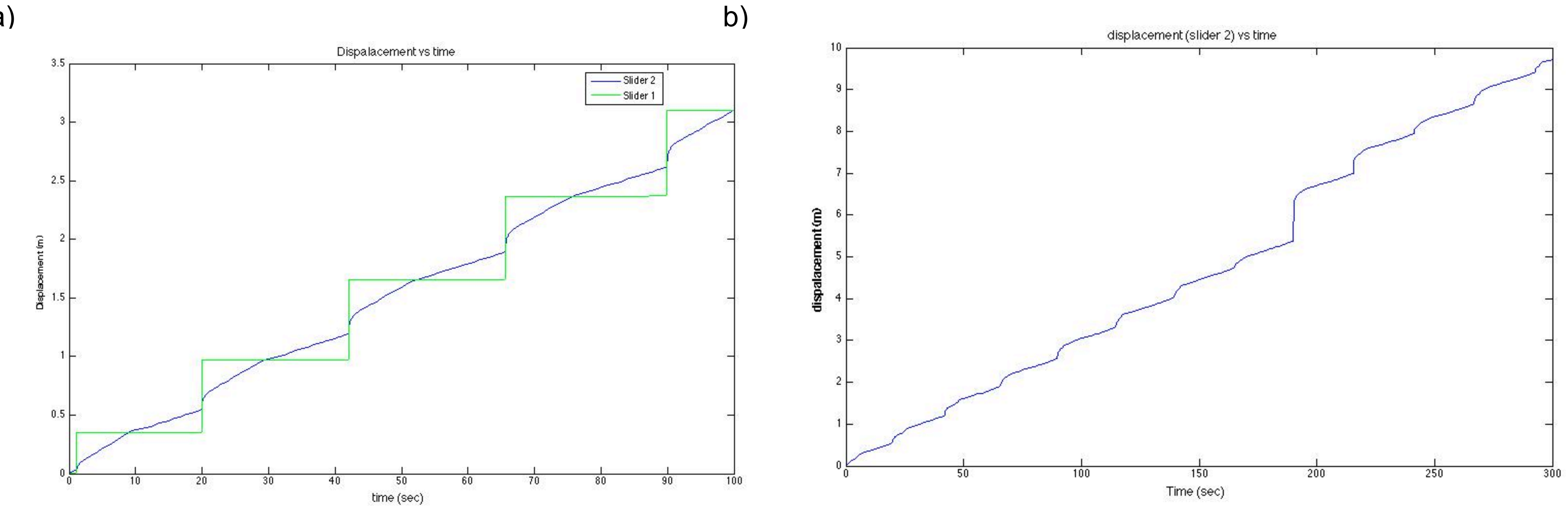

Fig. 7: Plots showing the behavior of creeping segment with time a) without external force b) with external force

Future work

A further extension in 2D of the current model will be done by adding more sliders governed by dislocation creep to represent the ductile fault zone present at depths having temparature higher than 400° C. The same problem will also be solved using 3D continuum model in order to get a deep insight of the results obtained by BK model.

References

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