CONSTRAINING COSEISMIC FRICTIONAL PROPERTIES DURING THE 2012 NICOYA M7.6 EARTHQUAKE FROM NEAR-FIELD OBSERVATIONS AND 3-D NUMERICAL SIMULATIONS

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Introduction

Frictional properties on faults are critical in controlling earthquake rupture process, and thus are important for seismic hazard assessment. The **weakening phenomena** on faults under seismic slip rates has been shown in laboratory experiments (Fig. 1) and seismic observations. **Present approaches in estimating frictional properties include laboratory friction experiments and inversions based on near-field observations. However, the frictional properties on megathrusts are still mysterious due to the lack of samples on faults and adequate near-field observations.**

Our study: we determine the frictional properties on the **megathrust** during the 2012 M7.6 earthquake (Fig. 2) with constraints from near-field GPS (low-rate & high-rate) records for coseismic static displacements and velocity waveforms, by conducting dynamic rupture simulations.

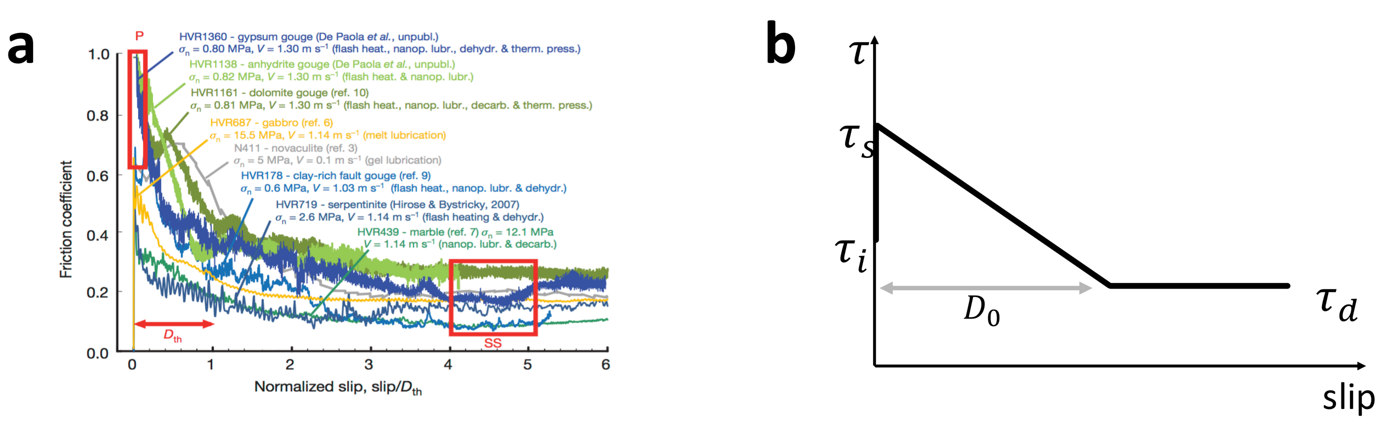


Figure 1: (a) Slip weakening phenomena in laboratory experiments (Di Toro et al., 2011); (b) Linear slip weakening law.

Constraint from near-field observations

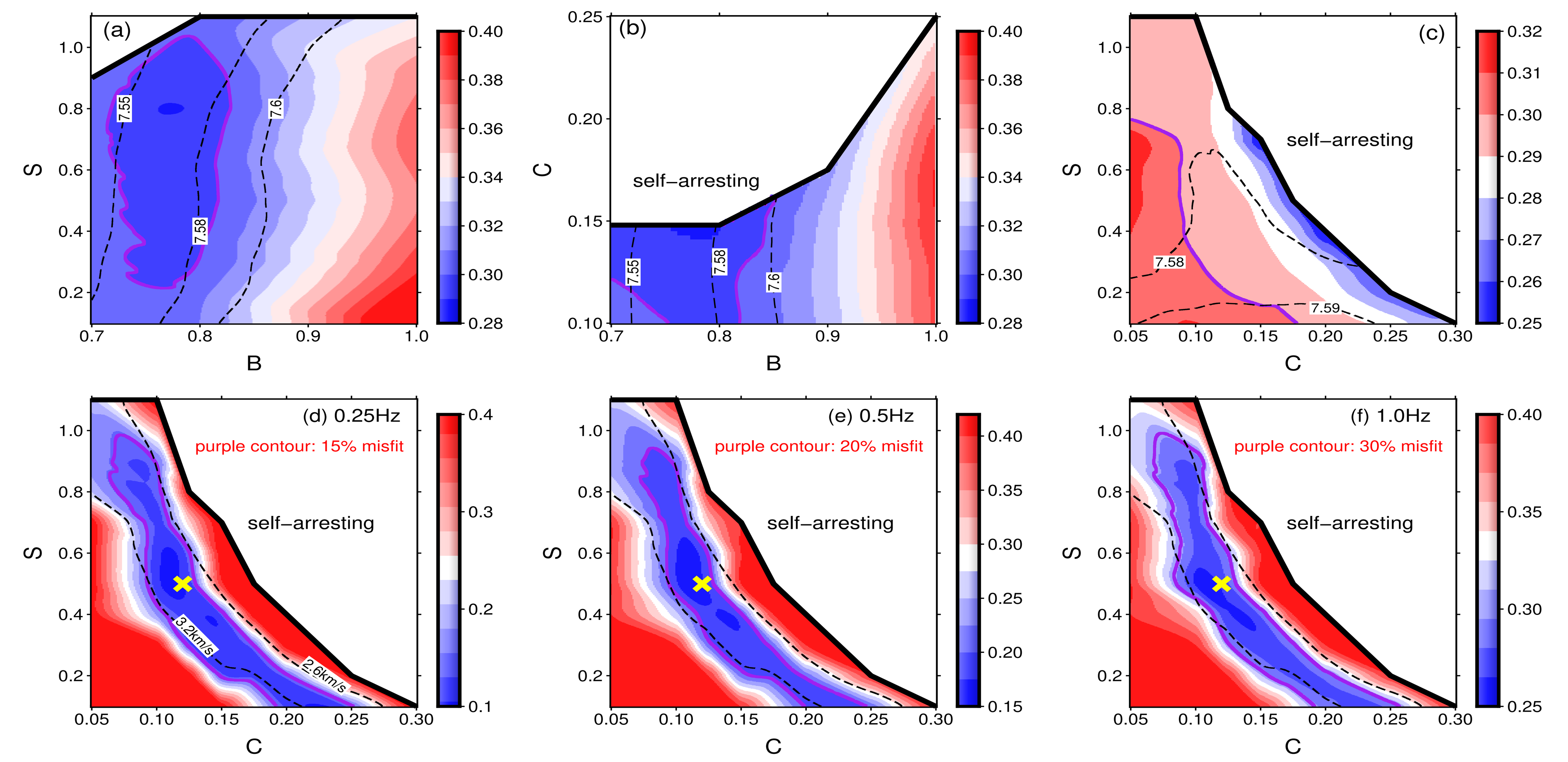


Figure 4: Misfits in coseismic static displacements (a, b, &c) and vertical velocity waveforms (d, e, &f). For (c), (d), (e), and (f), B is fixed to be 0.8; for (a), C is fixed to be 0.1; for (b), S is fixed to be 0.4. In misfit calculations, waveforms are filtered between 0.05-0.25Hz in (d), 0.05-0.5Hz in (e), and 0.05-1.0Hz in (f). Yellow crosses denote the preferred model (C=0.125, B=0.8, S=0.5) in (c), (d), and (e). Black dash lines are contours for moment magnitude in (a), (b), and (c), and for rupture speed in (d), (e), and (f).

The 2012 M7.6 Nicoya earthquake

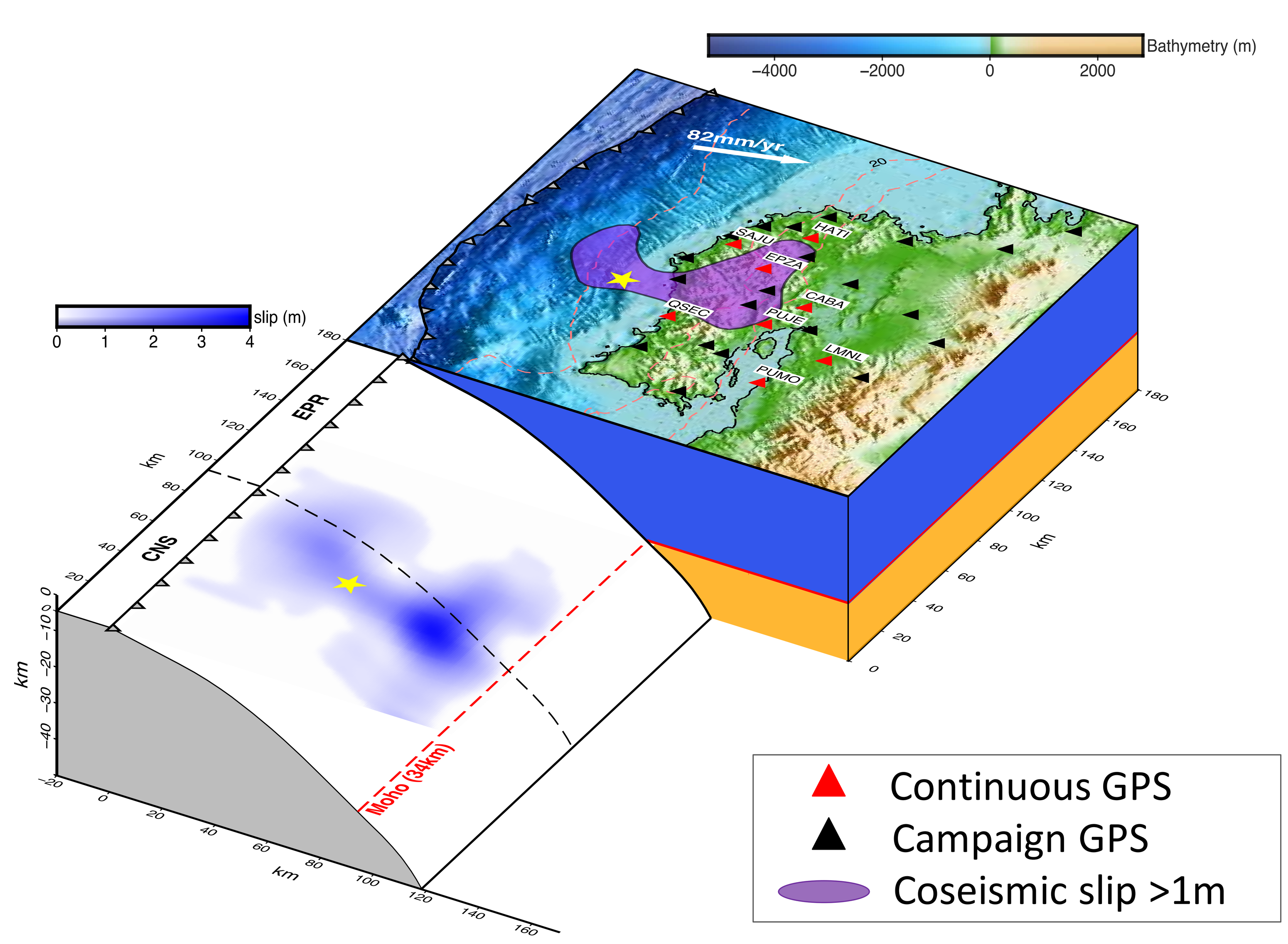


Figure 2: 3-D map for the study region. Upper block: Topography of the study region. The purple area is the projection of the area on the megathrust with slip over 1m in Yue's kinematic model (Yue et al., 2013). The yellow star is the hypocenter in Yue's model. Lightred dash lines are contours of 10, 20, and 30km for the depth of slab top. Bottom block: 3-D model for the megathrust with final slip distribution in Yue's model. The red dash line denotes the depth of Moho. The yellow star is the hypocenter. The black dash line is the boundary between the oceanic crusts originated from Cocos-Nazca spreading center (CNS) and East Pacific Rise (EPR).

Preferred dynamic rupture model

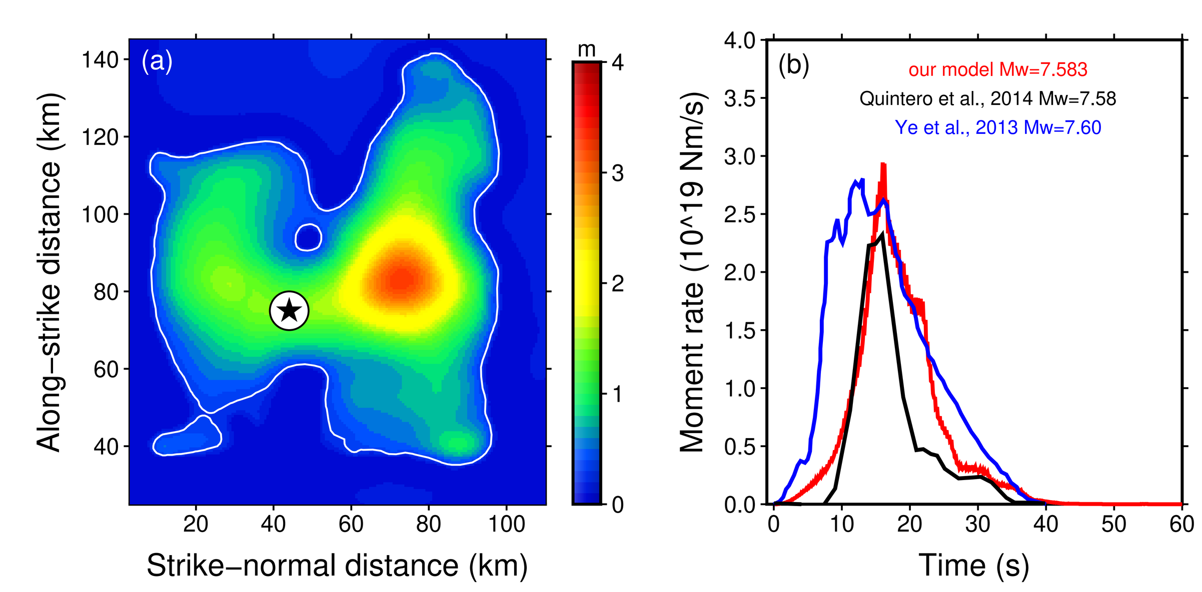
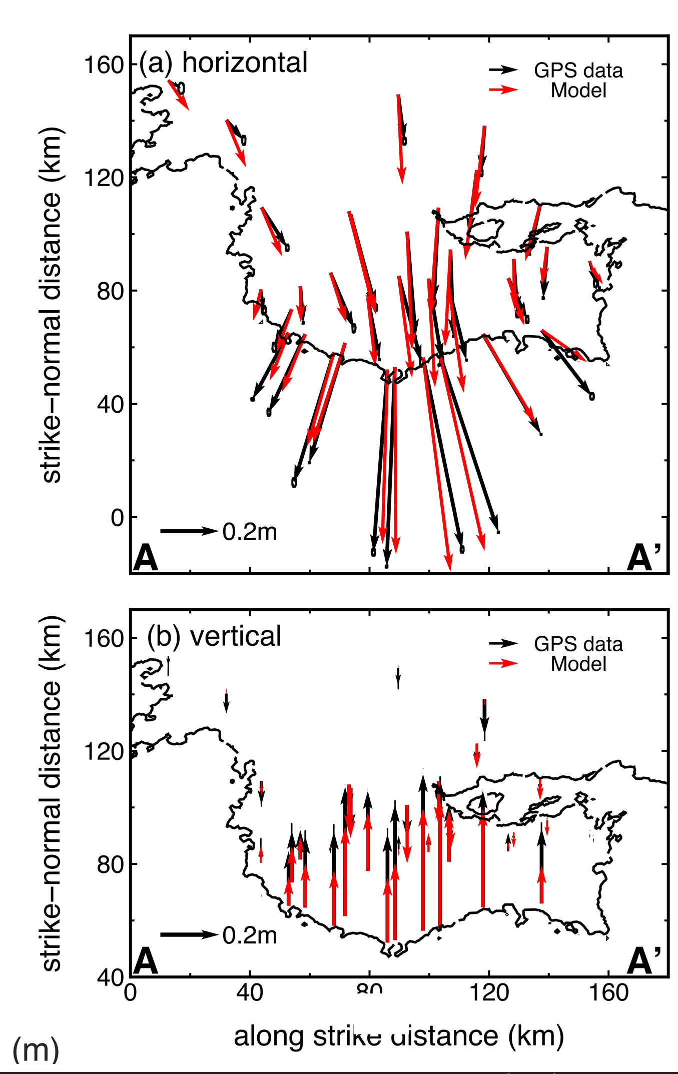


Figure 5: Our preferred dynamic rupture model (B=0.8, C=0.125, S=0.5). (a) The final slip distribution in the preferred model. The black star denotes the location of the nucleation zone. (b) Moment rate functions in our preferred model (red), Quintero et al., 2014 (black), and Ye et al., 2013 (blue).



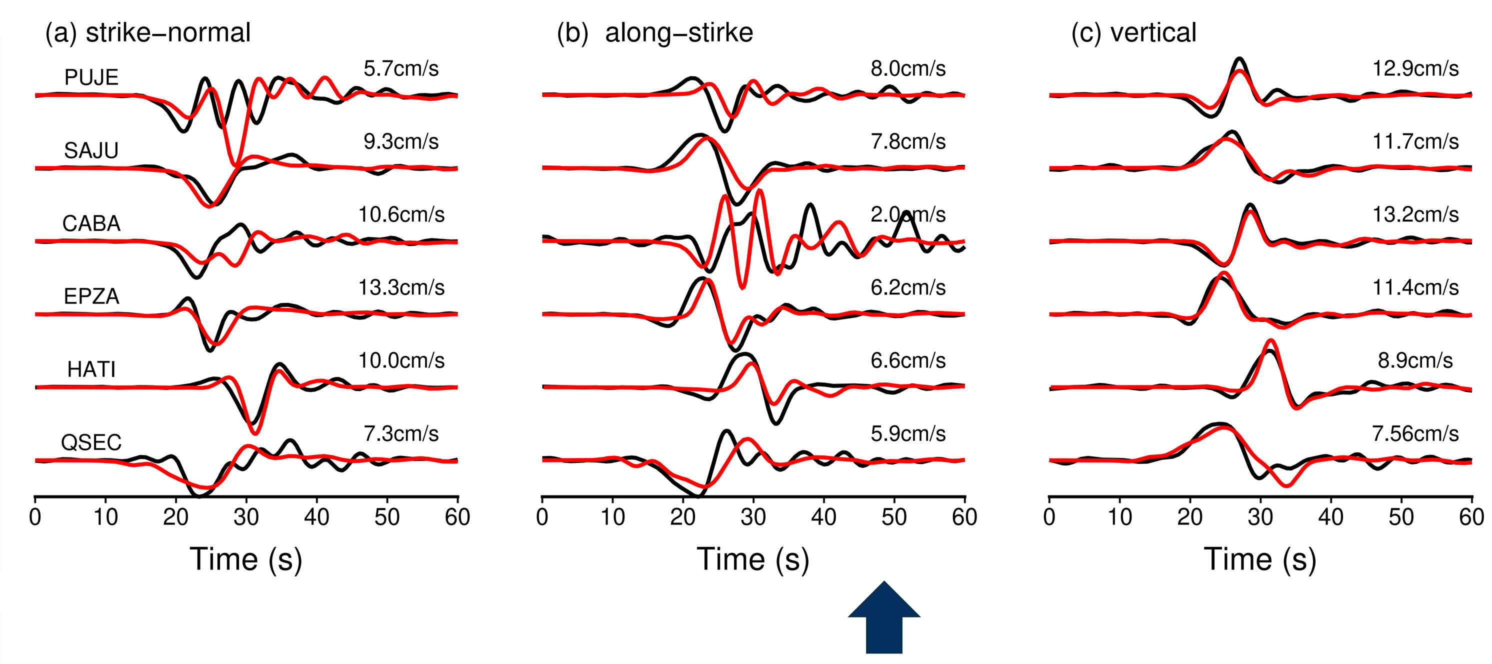


Figure 6: Three components of velocity waveforms from GPS data (black) and our preferred dynamic rupture model (red). Waveforms are filtered between 0.05-0.25Hz.

Figure 7: Observed (black) and modelled (red) coseismic static displacements at local GPS stations. (a) Horizontal component. (b) Vertical component.

Parameter setup in dynamic models

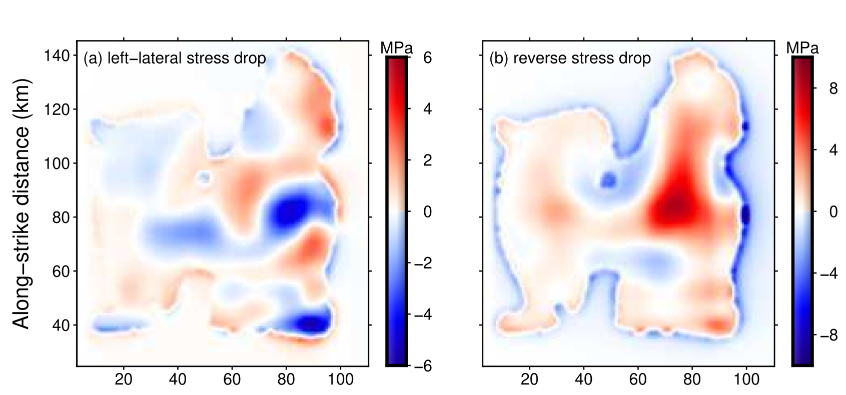


Figure 3: Static stress drop ($\overrightarrow{\Delta\tau_{kin}}$) derived from Yue's kinematic model (Yue et al., 2013), plotted in the left-lateral component (a) and the reverse component (b).

$$D_0 = \mathbf{C} * u_{kin}$$

$$\vec{\tau_i} = \vec{\tau_d} + \mathbf{B} * \overrightarrow{\Delta\tau_{kin}}$$

$$\tau_s = (1 + \mathbf{S}) * (|\vec{\tau_i}| - |\vec{\tau_d}|) + |\vec{\tau_d}|$$

Three free parameters: C, B, S

C controls weakening distance (D_0);

B controls initial stress level;

S determines strength drop.

Dynamic stress (τ_d) is prescribed to be uniform (i.e. 10MPa).

Conclusion

1, We derive a dynamic model for the 2012 Nicoya M7.6 earthquake, which can fit the coseismic static displacements and waveforms at near-filed GPS stations;

2, We determine the preferred coseismic frictional parameters for this event with constraints from GPS data. The average critical weakening distance is ~0.25m, with average strength drop of 3.6MPa. The fracture energy is ~ 0.45×10⁶ J/m^2, which is relative low comparing to general values for other earthquakes with similar magnitudes derived from spectrum;

3, We determine suitable ranges for frictional properties, which can be applied in future dynamic rupture simulations.

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