Inferring slip rates using seismic-cycle models: The role of paleoseismic data

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- We infer fault slip rates using surface velocity data

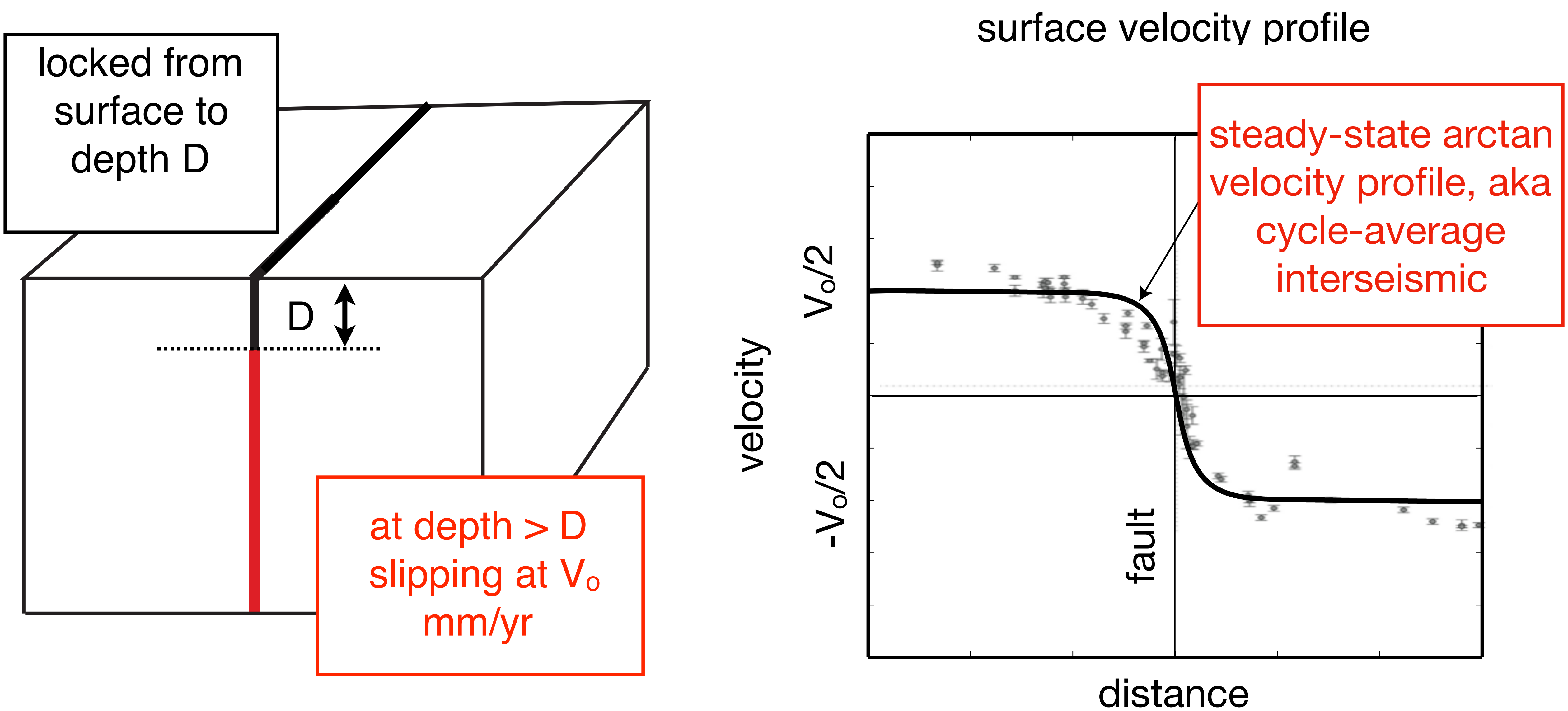
- Large earthquakes cause time-dependent perturbations to the surface velocity field

- I use viscoelastic earthquake-cycle models to estimate and remove these perturbations

- Magnitudes of these viscoelastic perturbations depend most on date and size of last big event and mean recurrence time.

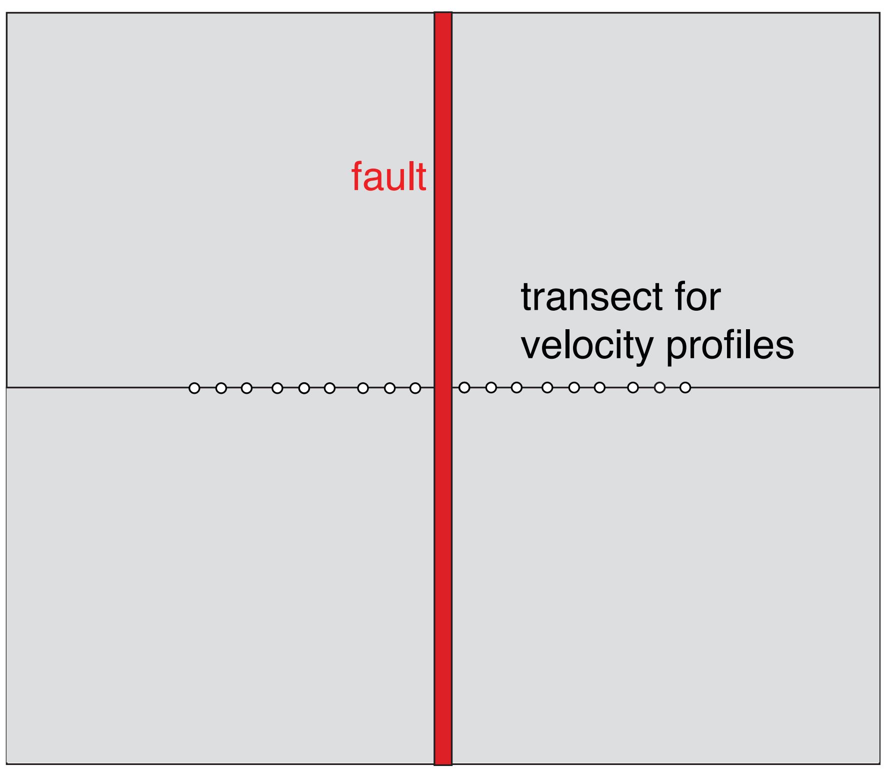
- For M in low 7's and below, perturbations are usually too small to matter after the immediate postseismic interval

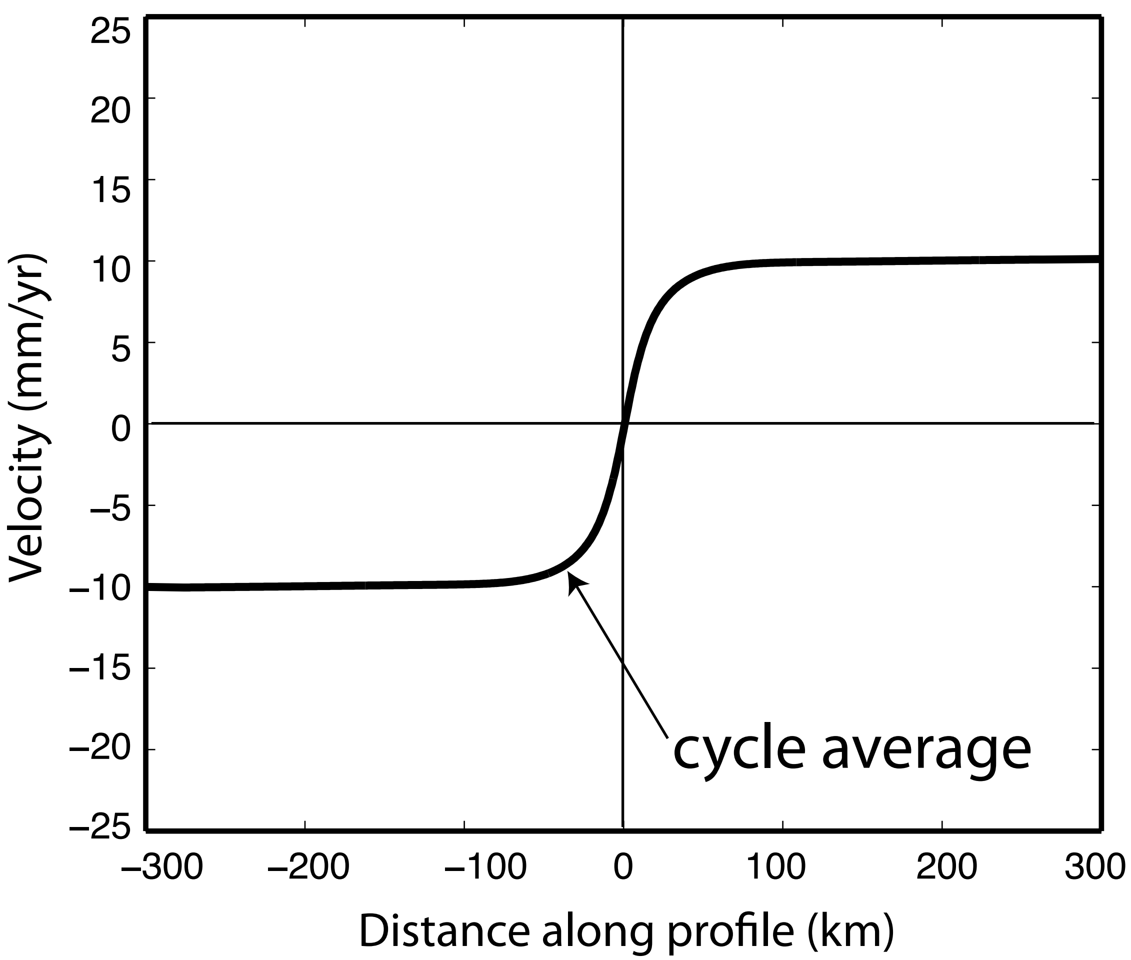
Inferring fault slip rates from geodetic data



- D = ~ 10-20 km
- insensitive to time since previous major earthquake
- GPS velocities around this fault would never vary

Large earthquakes cause time-dependent perturbations to surface velocities





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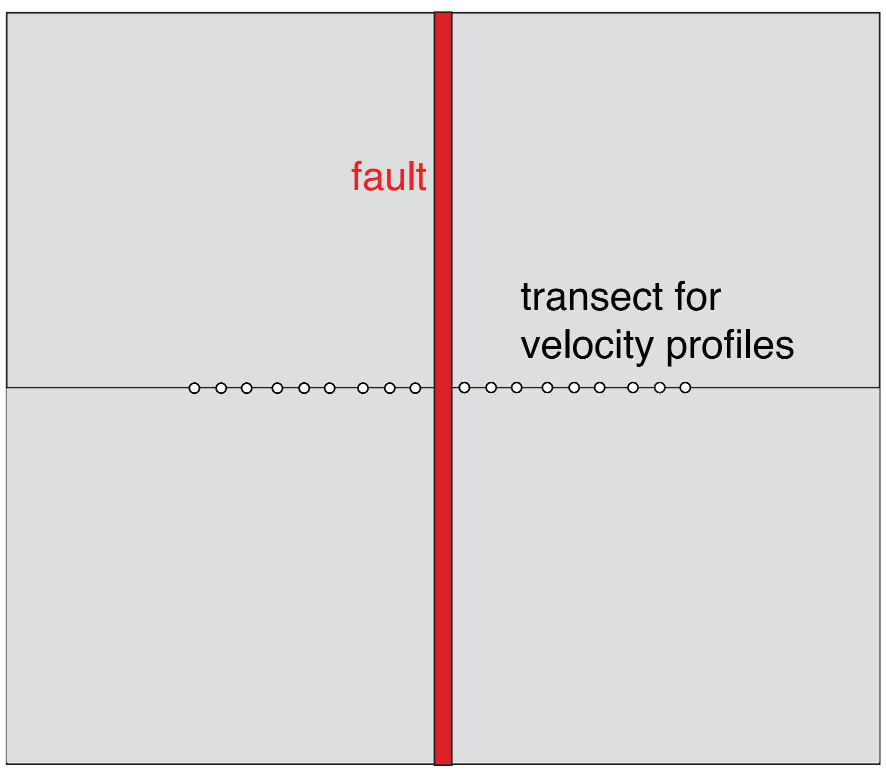

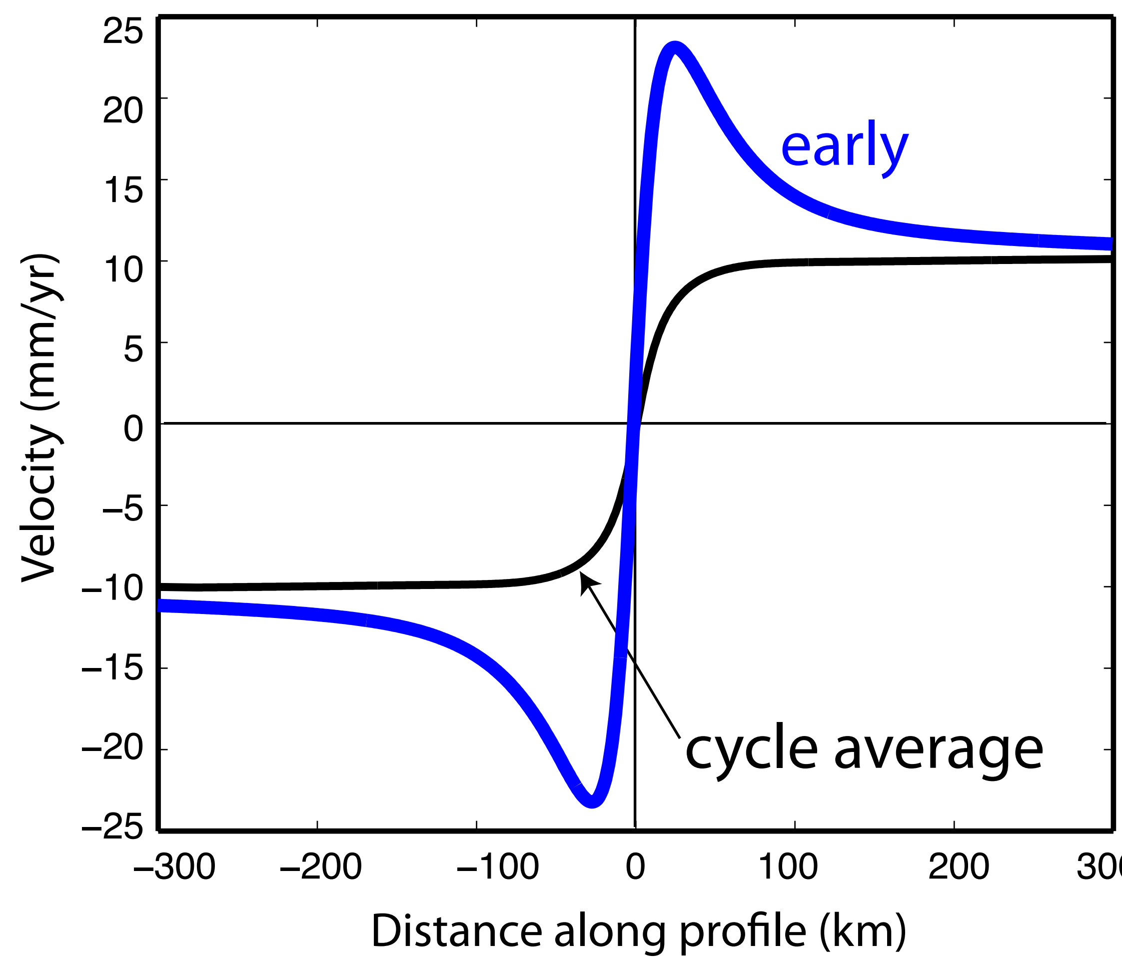

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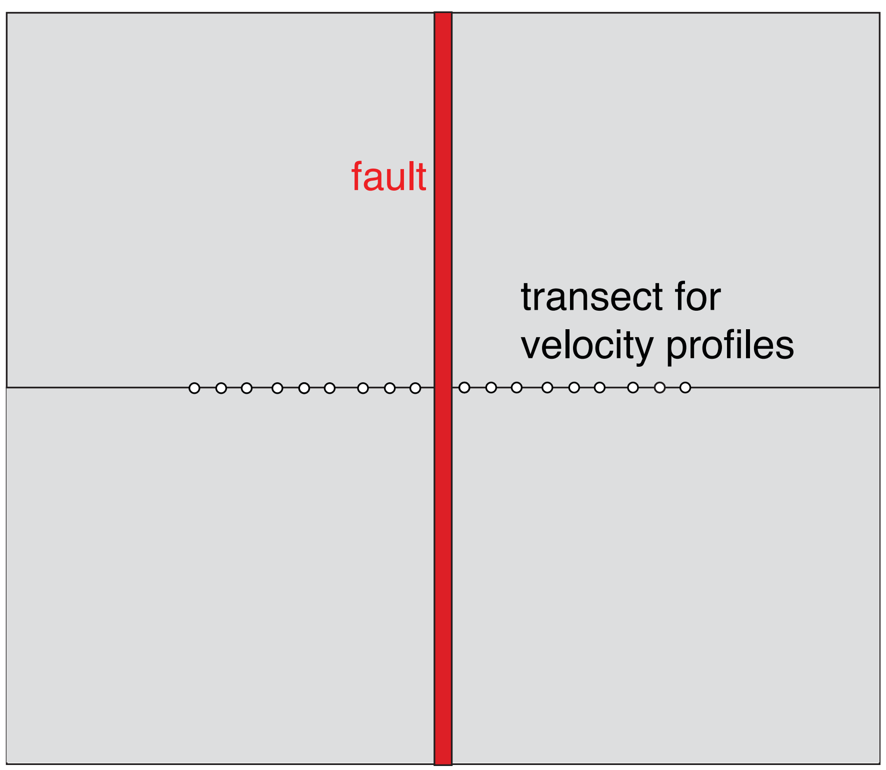

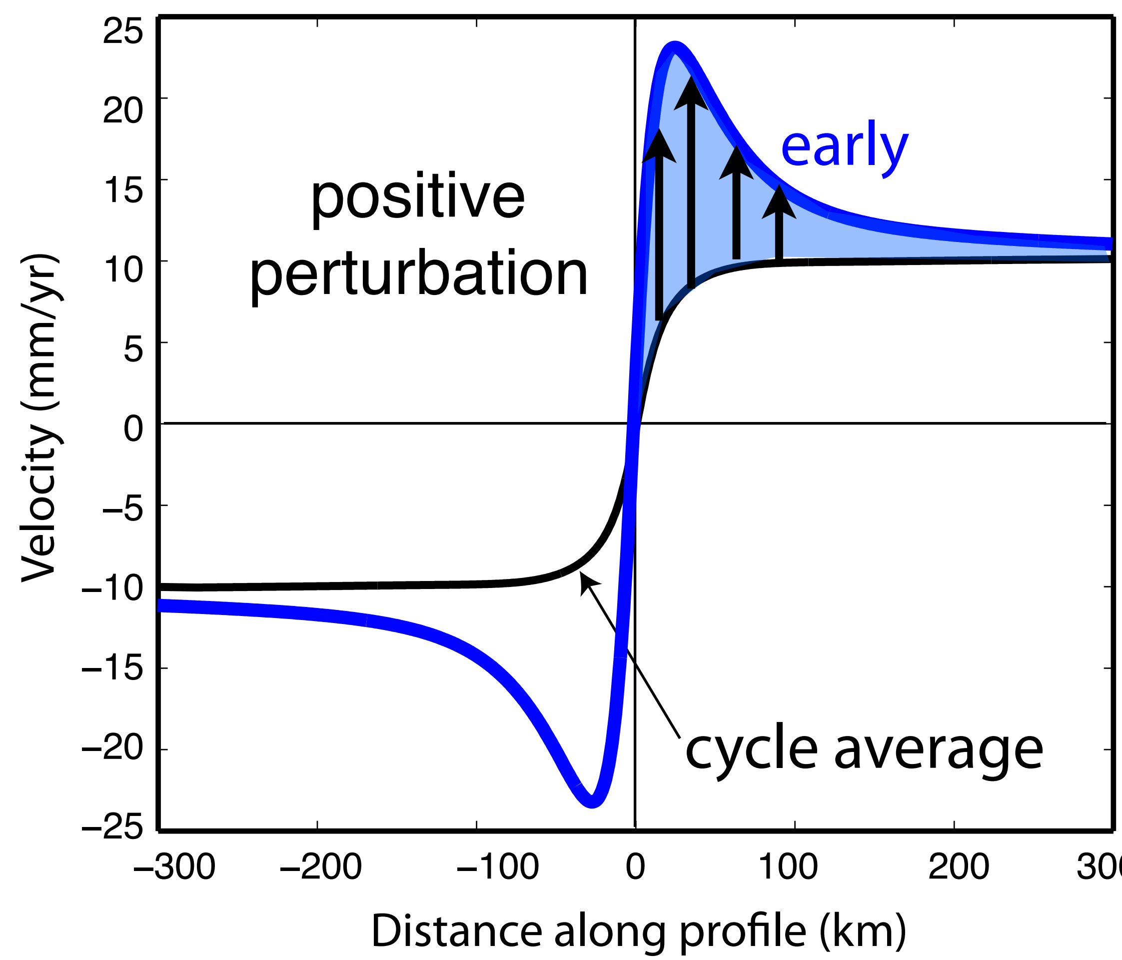

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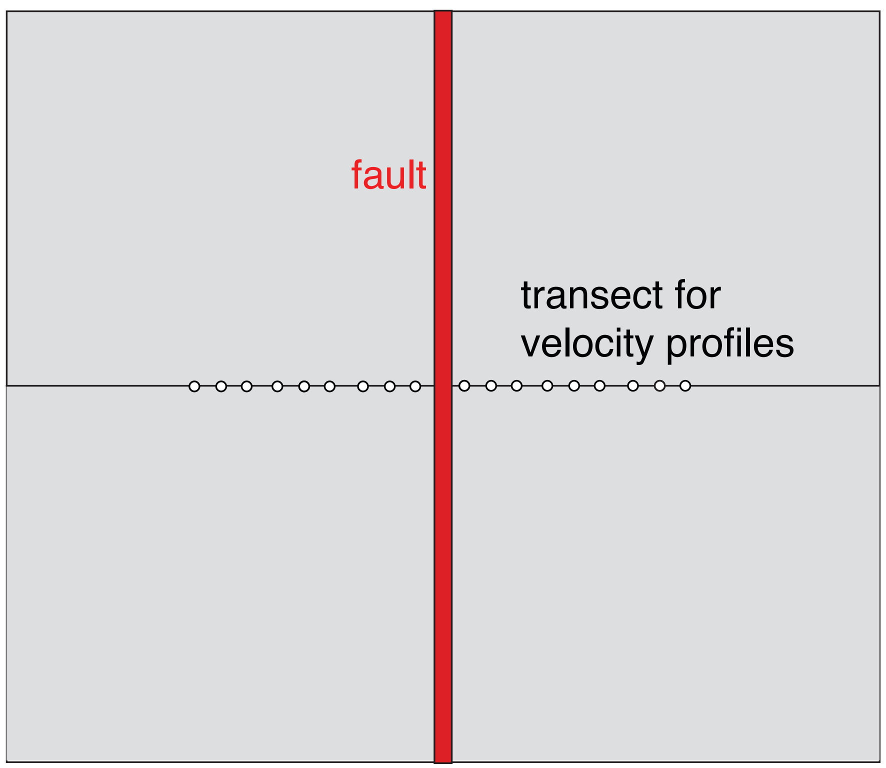

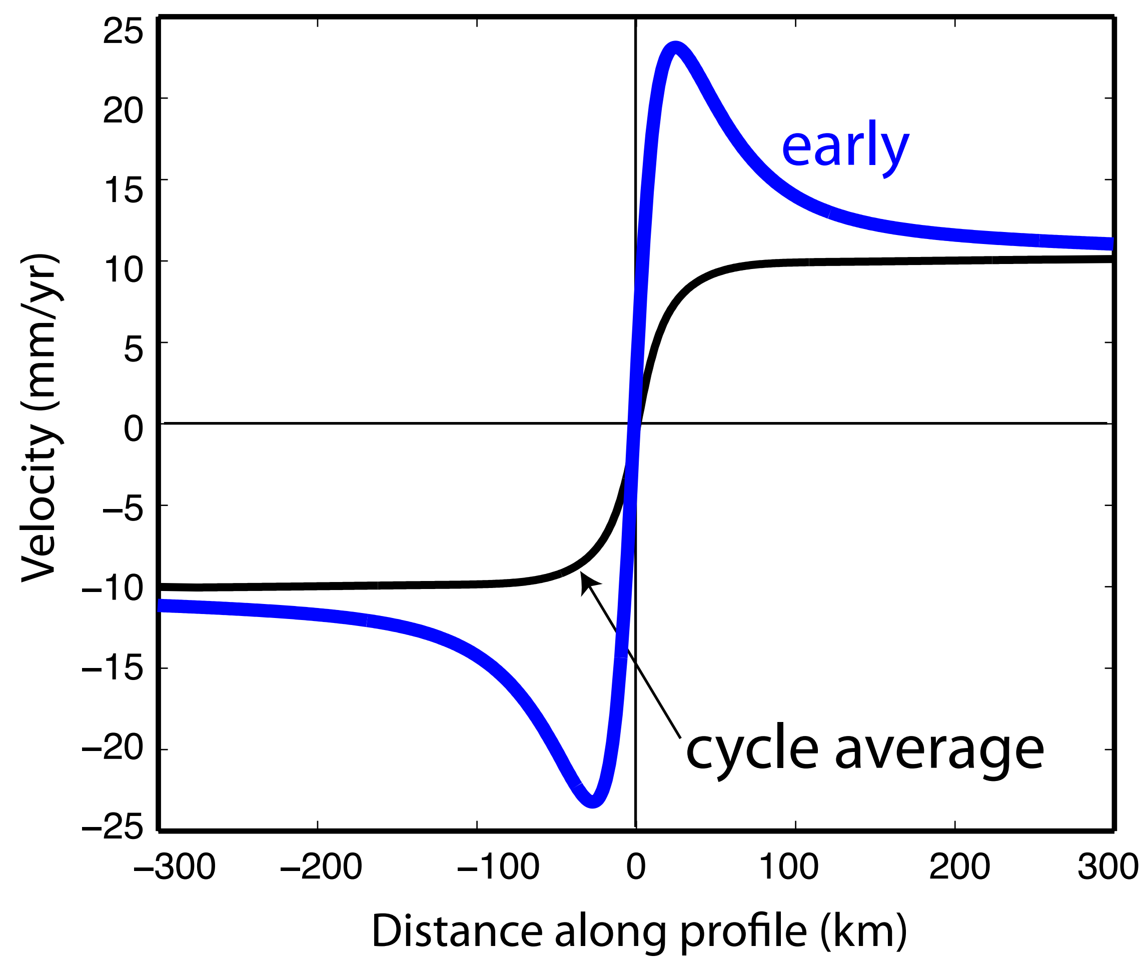

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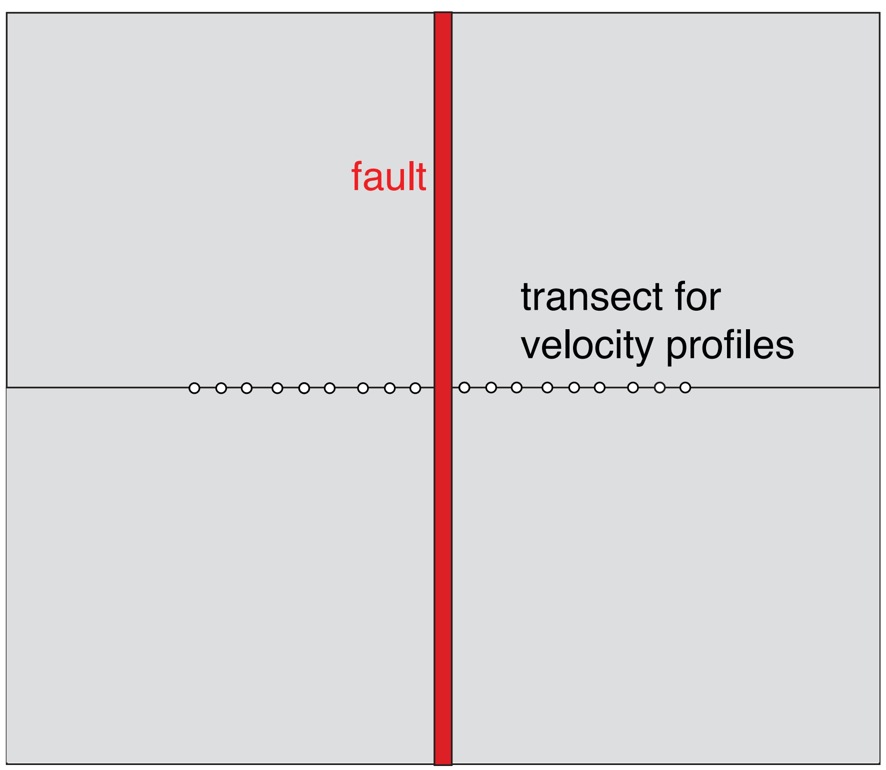

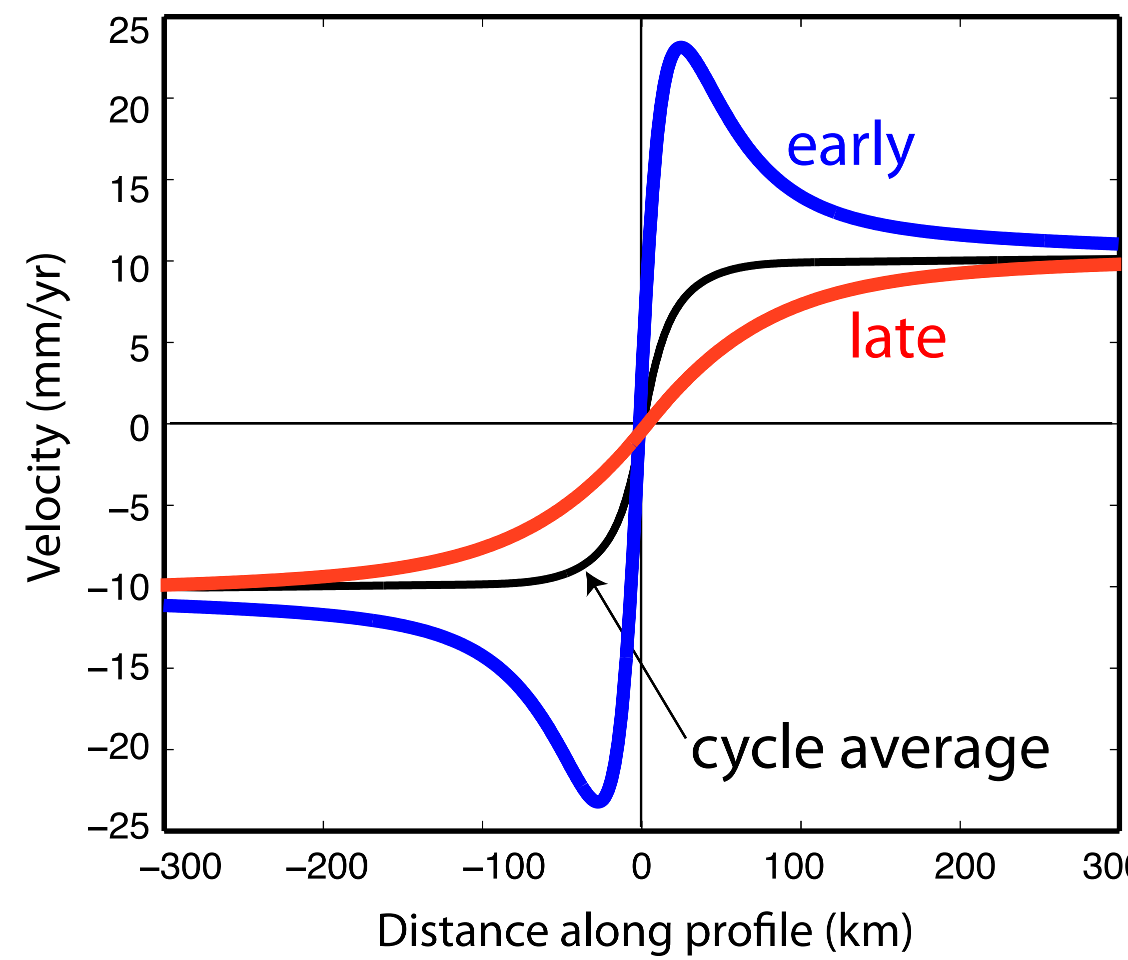

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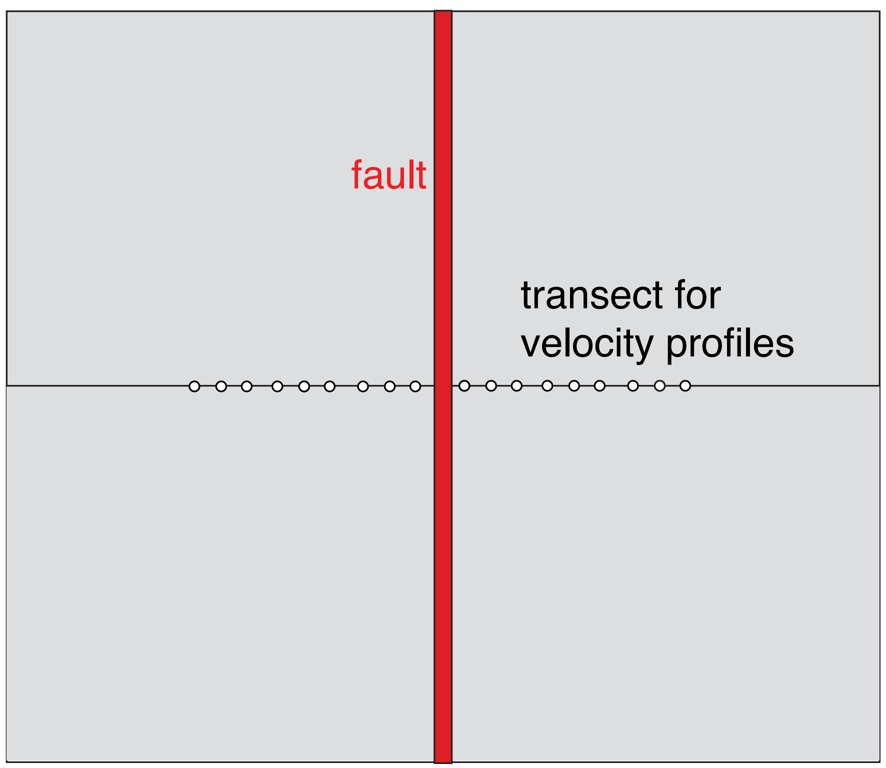
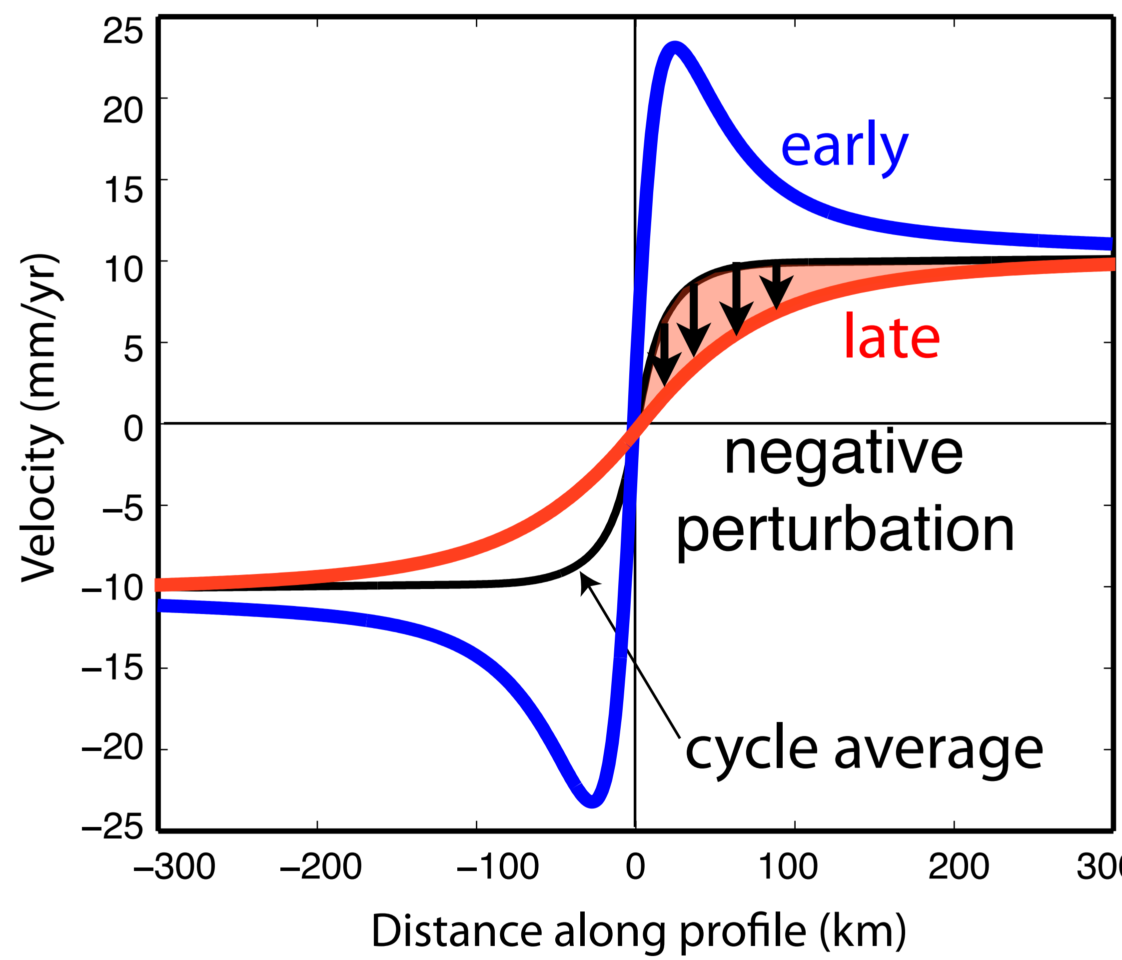
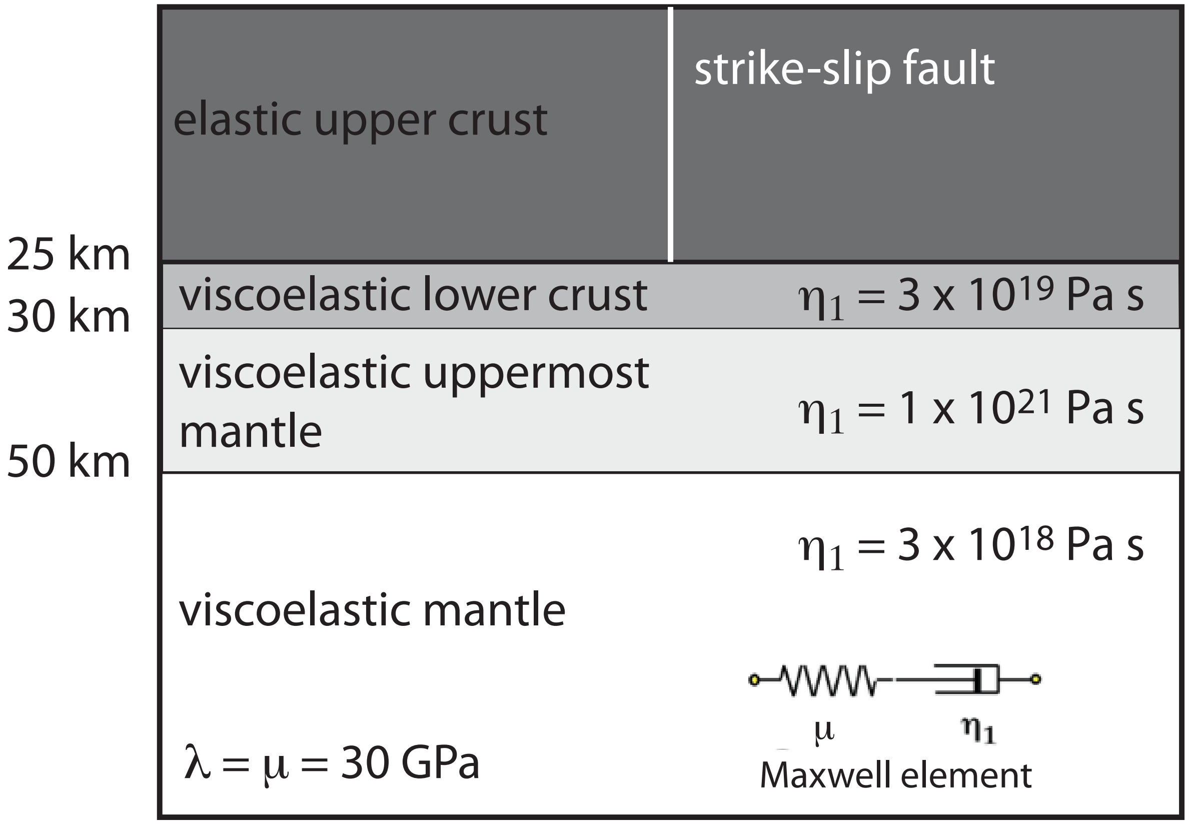




Earlier SSAF project: characteristic M 7.9 earthquakes, layered rheological structures



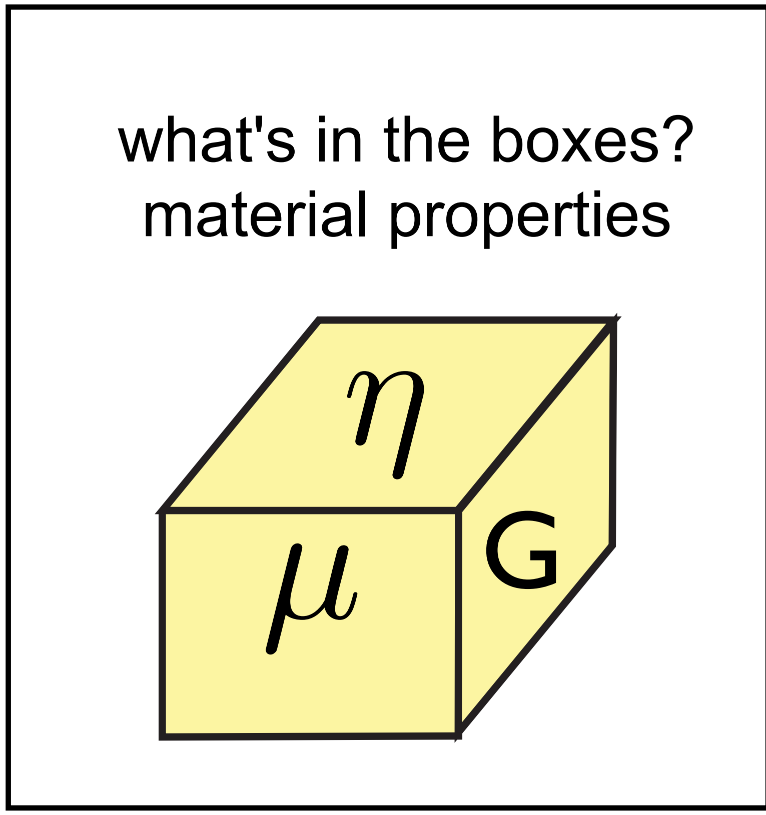
Characteristic M 7.9 earthquakes every 300(!) years on the 1857 rupture

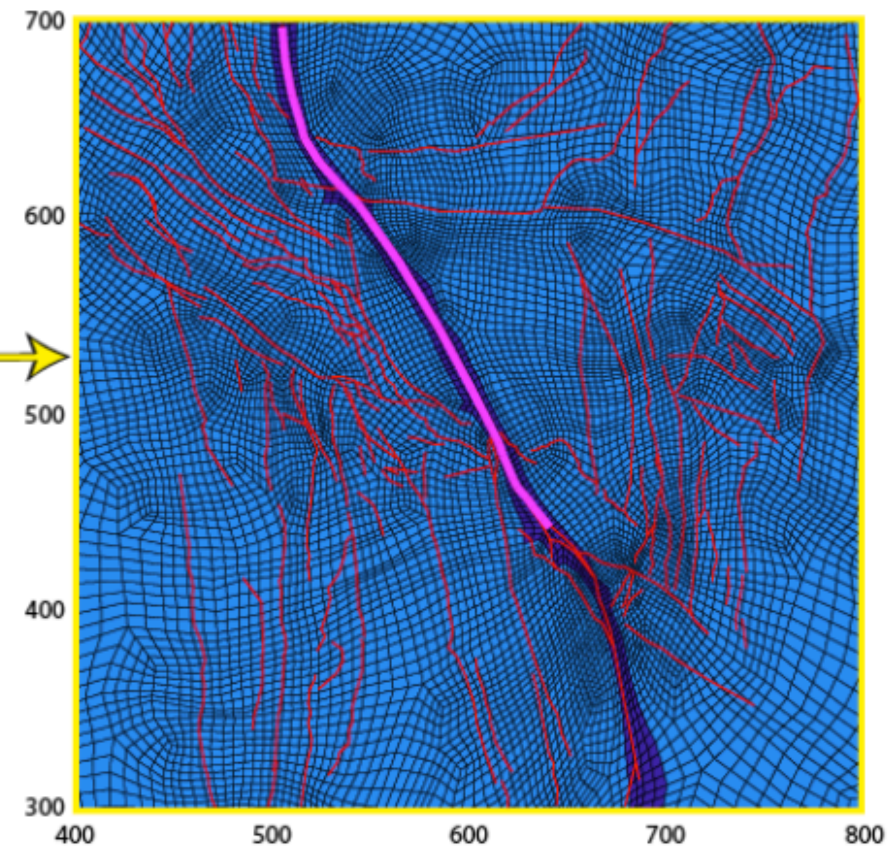
Used semi-analytical code VISCO1D (Pollitz, 1997) to calculate repeated seismic cycles until 'cycle invariance' to get the cycle-average and perturbation ('ghost transient') velocities

Correcting GNSS field for viscoelastic perturbation and then inverting for SSAF slip: estimated slip rate increased by about 5 mm/yr. This agrees with work of Johnson and Segall (2004), Johnson (2013), Tong et al. 2014), and others using different approach.

Next up: relax the layer cake and characteristic earthquake assumptions

Use FEM (PyLith v 2.2), vary rheology and properties

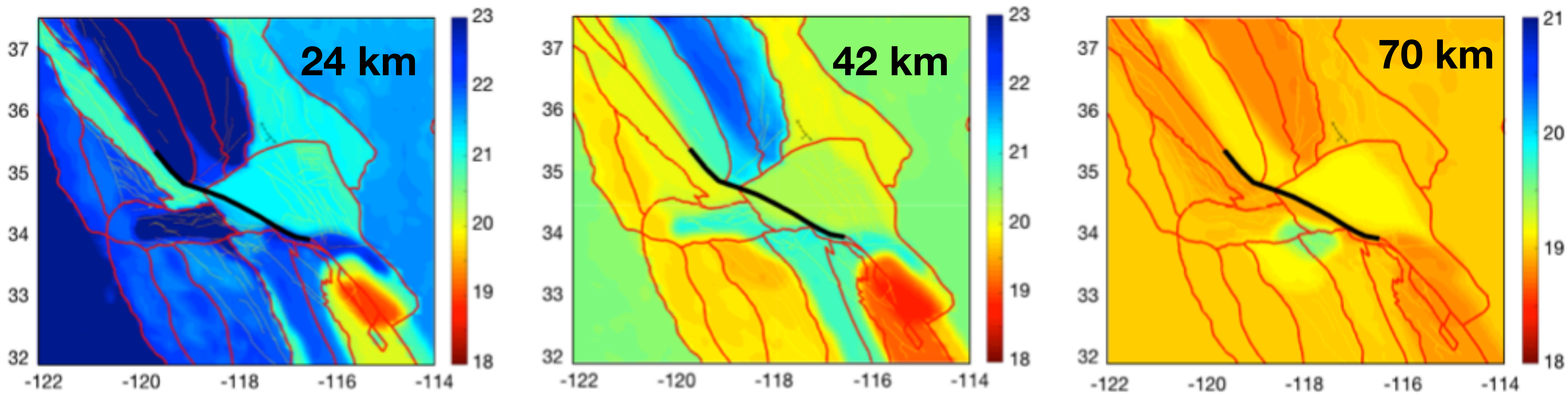




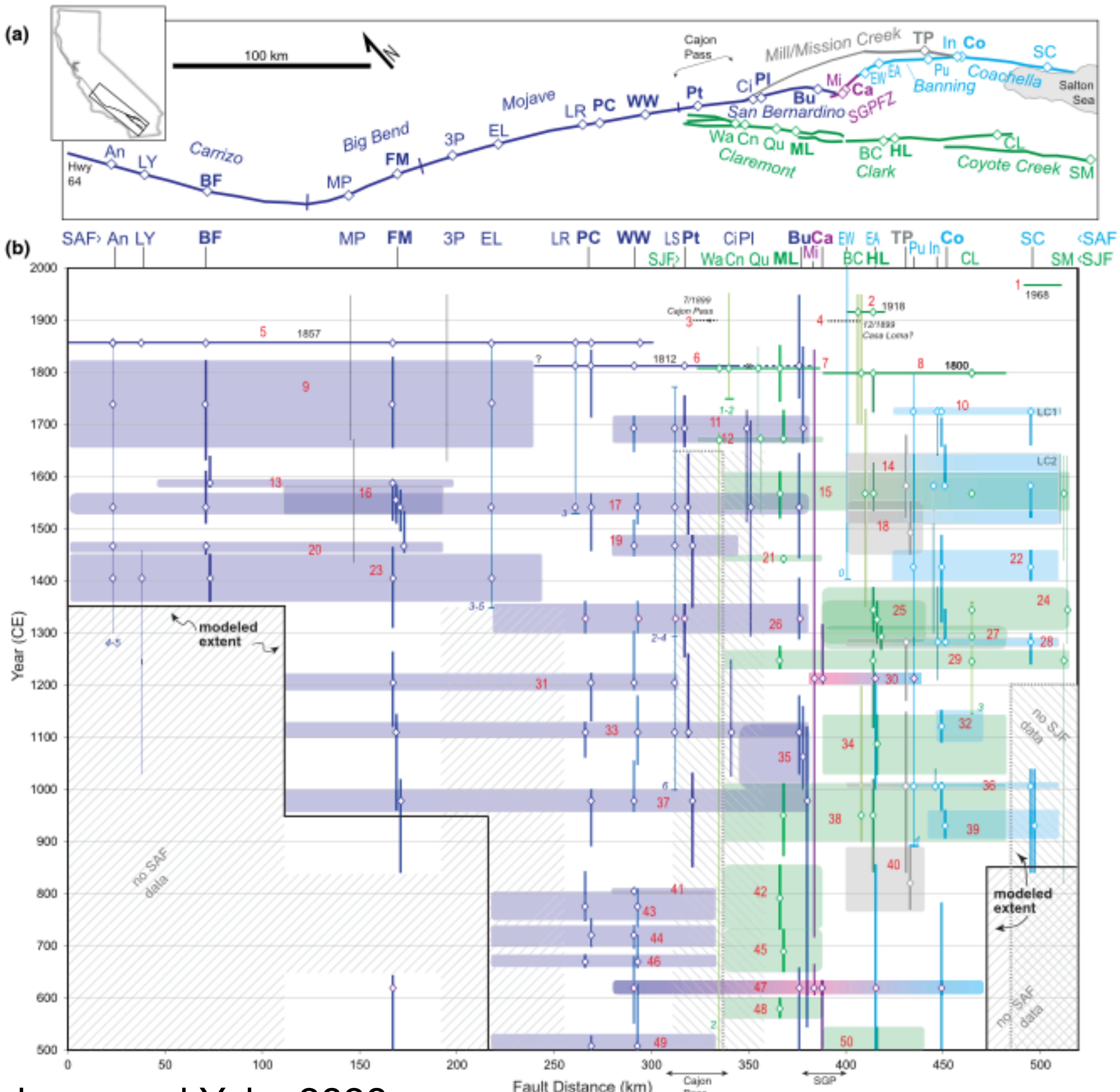
Reference model:
elastic properties from SCEC CVM-H v.5.3.
rheology from SCEC CRM with CTM temps.
Burgers rheology, shear zone properties based on earlier modeling.

MANY variations were also run.

SCEC CRM effective viscosities assuming CTM and "reasonable" strain rates



AND vary rupture parameters



Scharer and Yule, 2020

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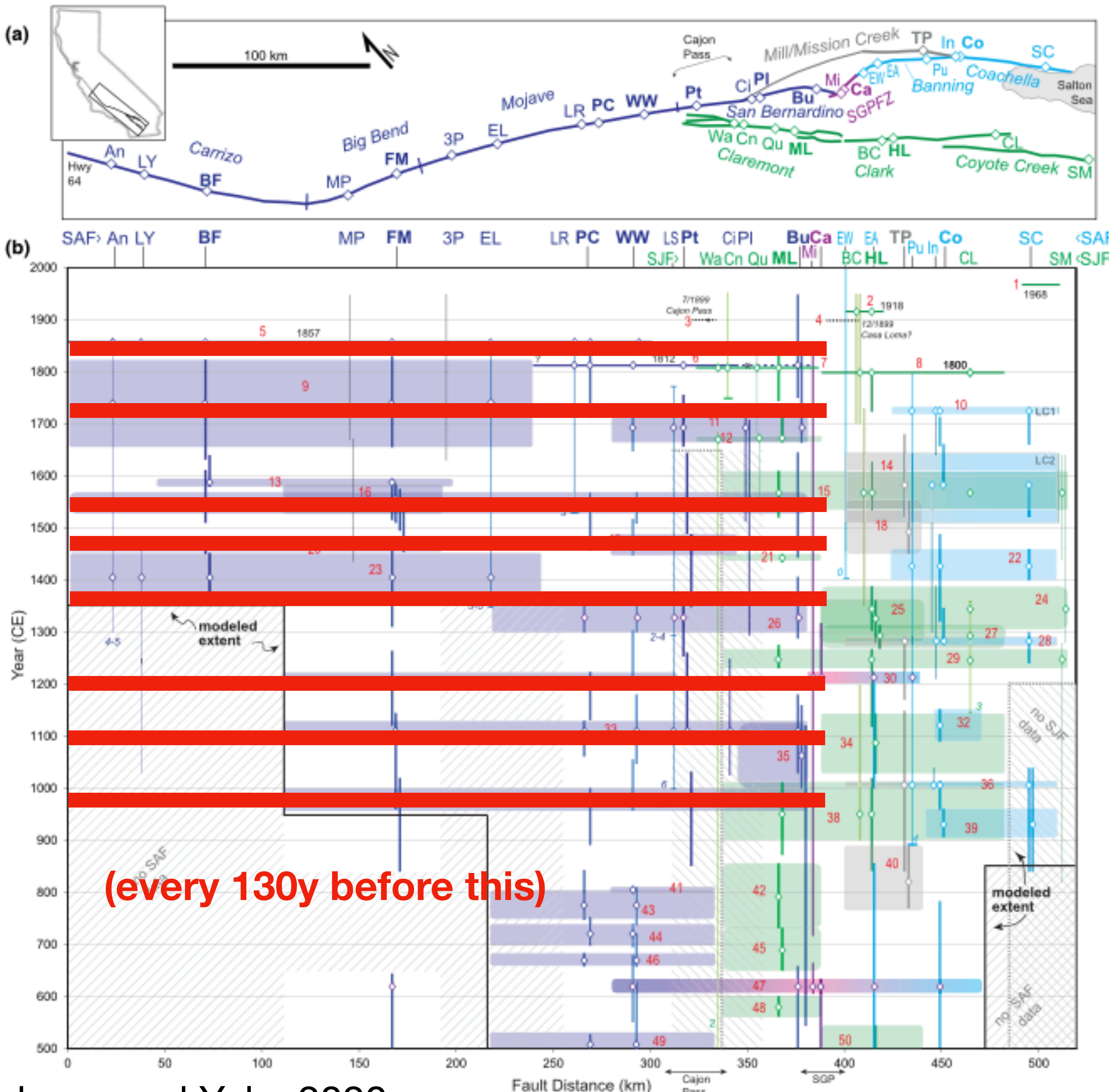
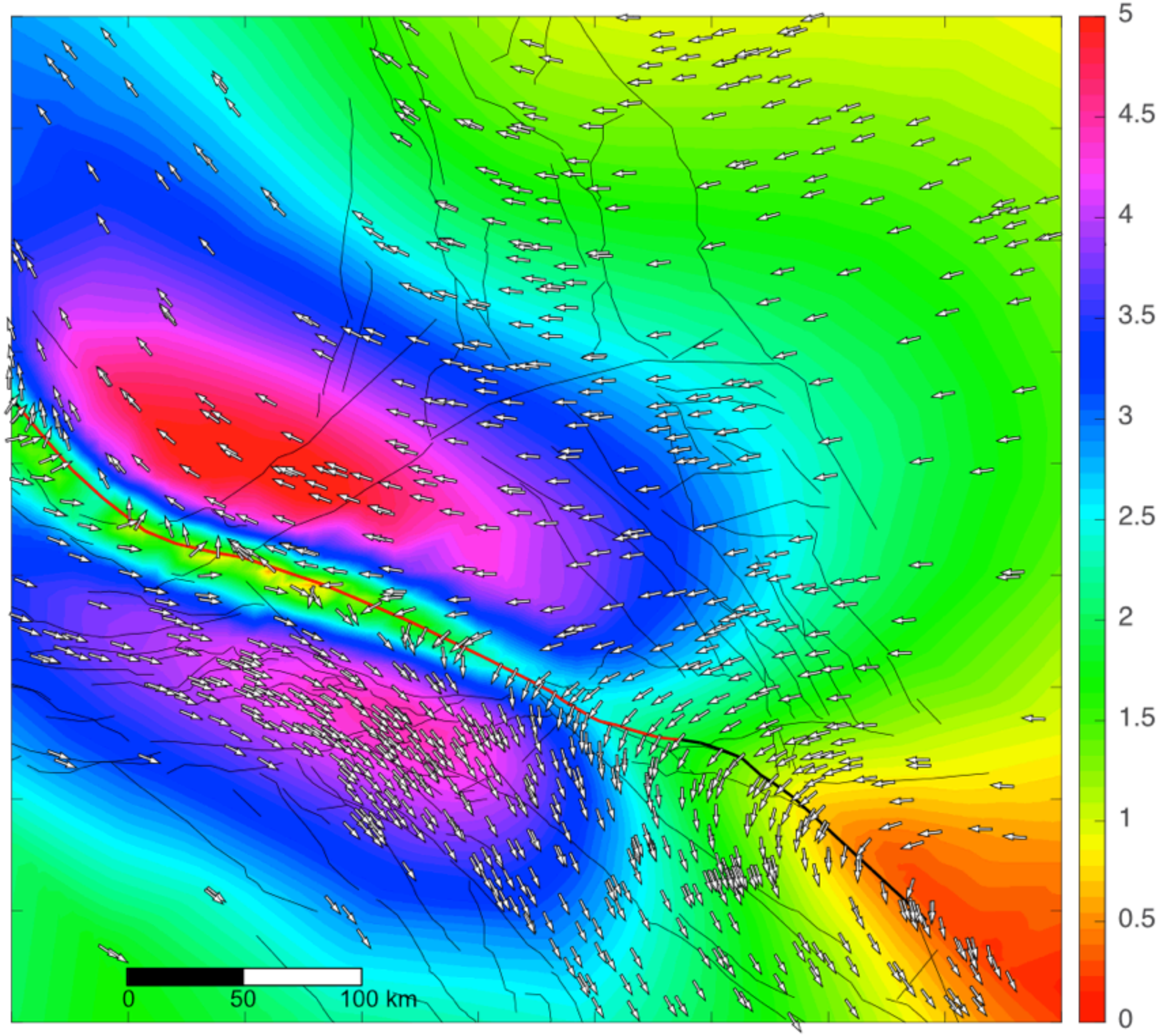


reference model: SSAF quakes with 4.4 m slip, 2 m @ San Bern. M 7.82. (34 mm/y and 16 mm/y)

other model suites:
(1) vary mean interseismic interval 100-200y
(2) vary irregularity BUT keep slip rate and 1857 event the same

Scharer and Yule, 2020

Viscoelastic perturbation to velocity field, for reference model



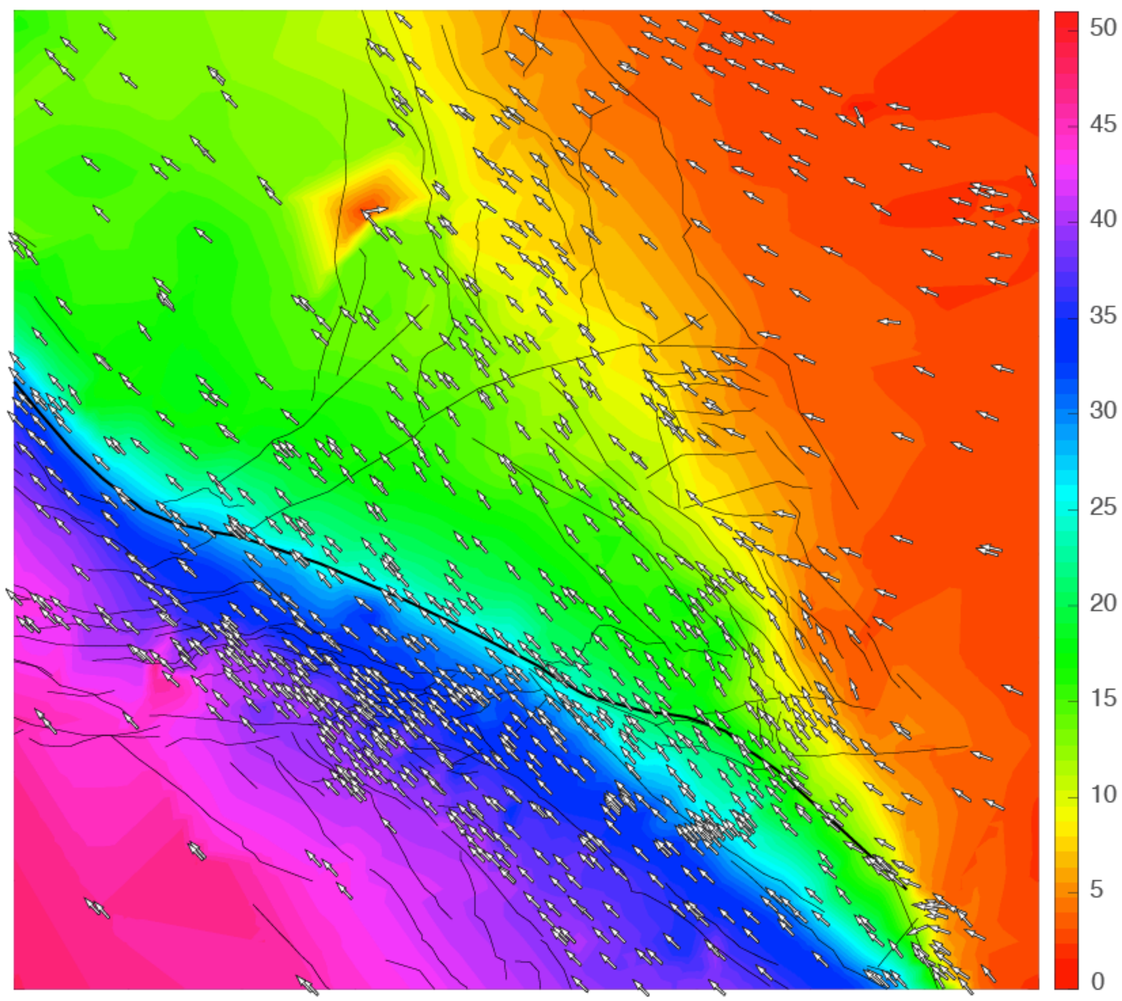
reference model: max is 5 mm/y

range in maximum perturbation for other models: 3.7 to 6.1 mm/y

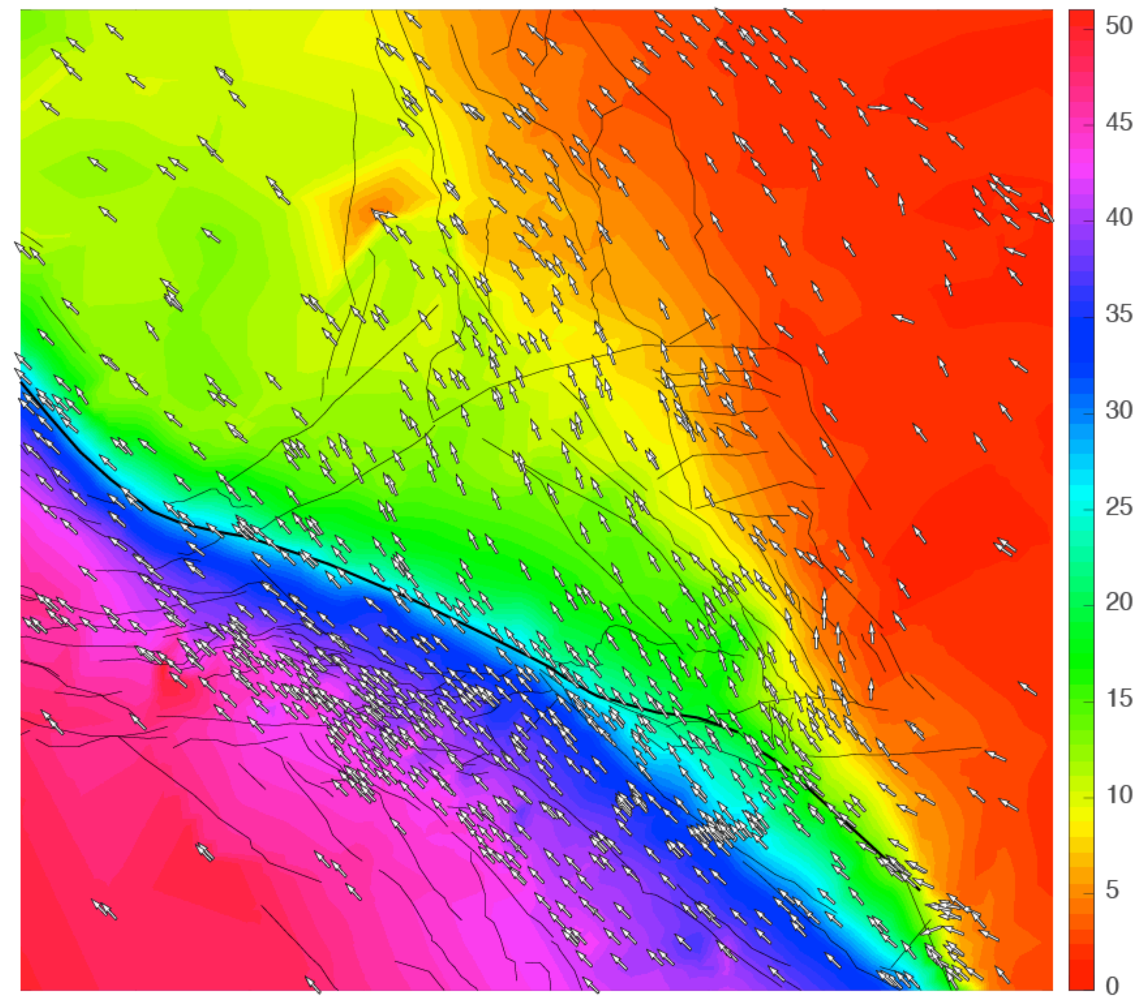
sensitive to mean *interevent time, size and timing of most recent quake* (not varied for this study)

also rheology of course

what didn't matter much: irregularity of pre-1857 earthquake occurrence BUT I did not look at more frequent, smaller earthquakes before correction



after correction



Doesn't look impressive but this change increased modelers' slip rate estimates for the SSAF by about 5 mm/yr, bringing it closer to geologic estimates (Zeng et al., 2022, Shen (2022), Evans (2022), Pollitz (2022))

For M 7.2 or smaller quakes, the perturbations would be negligible

What mattered (ITO paleoseismology)?

- Date of last “big” event
- Mean slip and length of last “big” event
- Mean recurrence interval

If slip is accommodated via more frequent M 7.4 events rather than rarer M 7.9 events, perturbations to surface velocities may be small enough to ignore

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