Fully Dynamic Simulations of Earthquake Cycle on a 2D Strike-Slip Fault Surrounded by Damaged Zones

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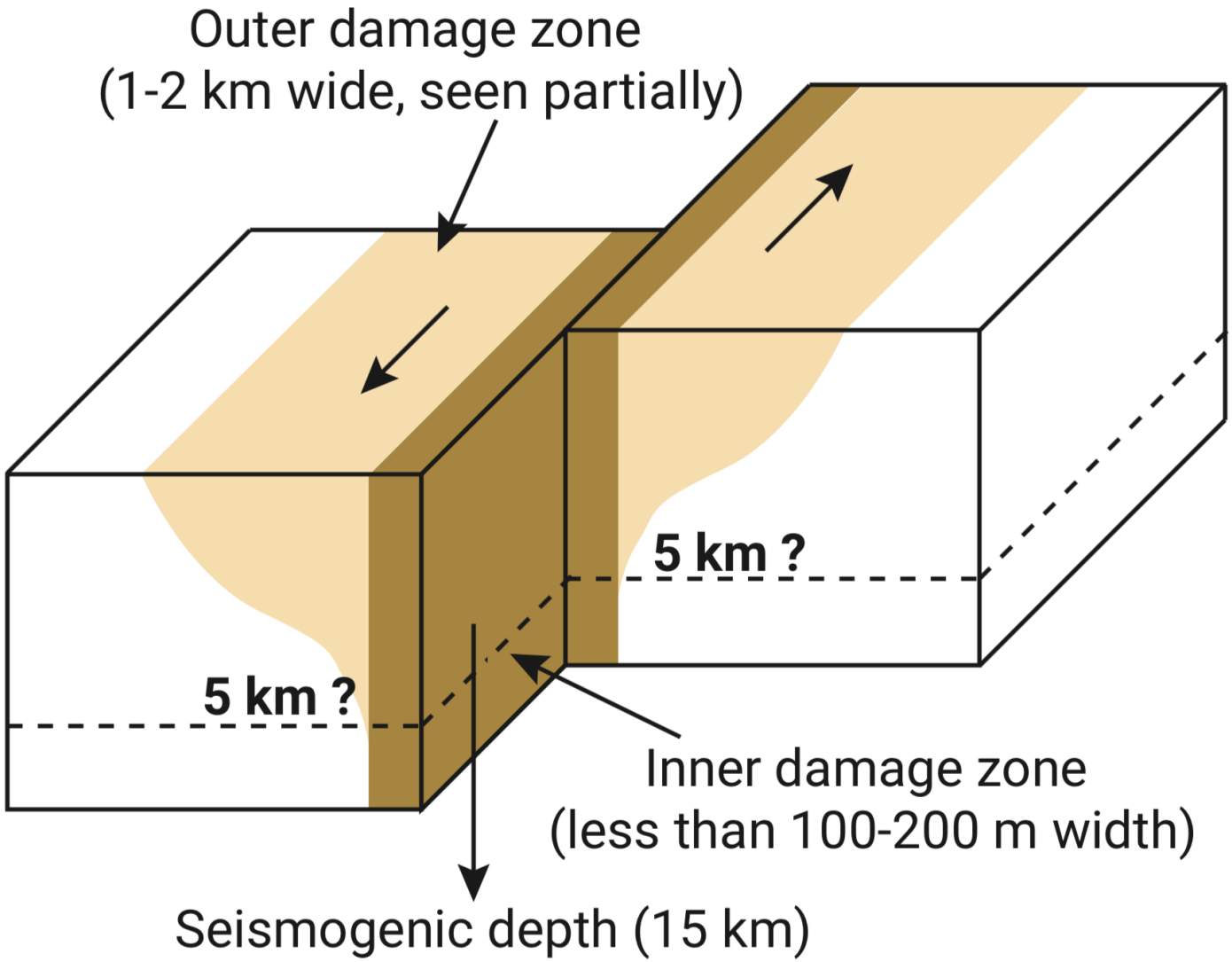
Overview

- 2D Numerical simulation of long-term fault slip using a spectral element method. Fully dynamic scheme for nucleation, rupture propagation, and postseismic deformation integrated with the aseismic phase.
- Strike-slip fault with mode III rupture (e.g., San Andreas), surrounded by a narrow damaged zone of low rigidity (Fault Zone).
- Complex slip pattern with multiple earthquakes of various magnitudes. A characteristic type magnitude-frequency distribution observed in simulations with narrow fault zones.

Damaged Fault Zone Geometry



Material Properties of Observed Fault Zones

Table 1. Summary of Material Properties of Main Fault Zones

Fault Zones	Width (m)	Velocity Reduction (%)	Q_s	References
San Andreas	~ 150	30–40	10–40	*Lewis and Ben-Zion* [2010]
	~ 200			*Li et al.* [2006]
San Jacinto	125–180	35–45	20–40	*Lewis et al.* [2005]
	150–200	25–60		*Yang and Zhu* [2010]
Landers	270–360	35–60		*Li et al.* [2007]
	150–200	30–40	20–30	*Peng et al.* [2003]
Hector Mine	75–100	40–50	10–60	*Li et al.* [2002]
Calico	~ 1500	40–50		*Cochran et al.* [2009]
	~ 1300	40–50		*Yang et al.* [2011]
Nojima	100–220			*Mizuno et al.* [2008]
Anatolian	~ 100	50	10–15	*Ben-Zion et al.* [2003]

Observations from San-Andreas Fault

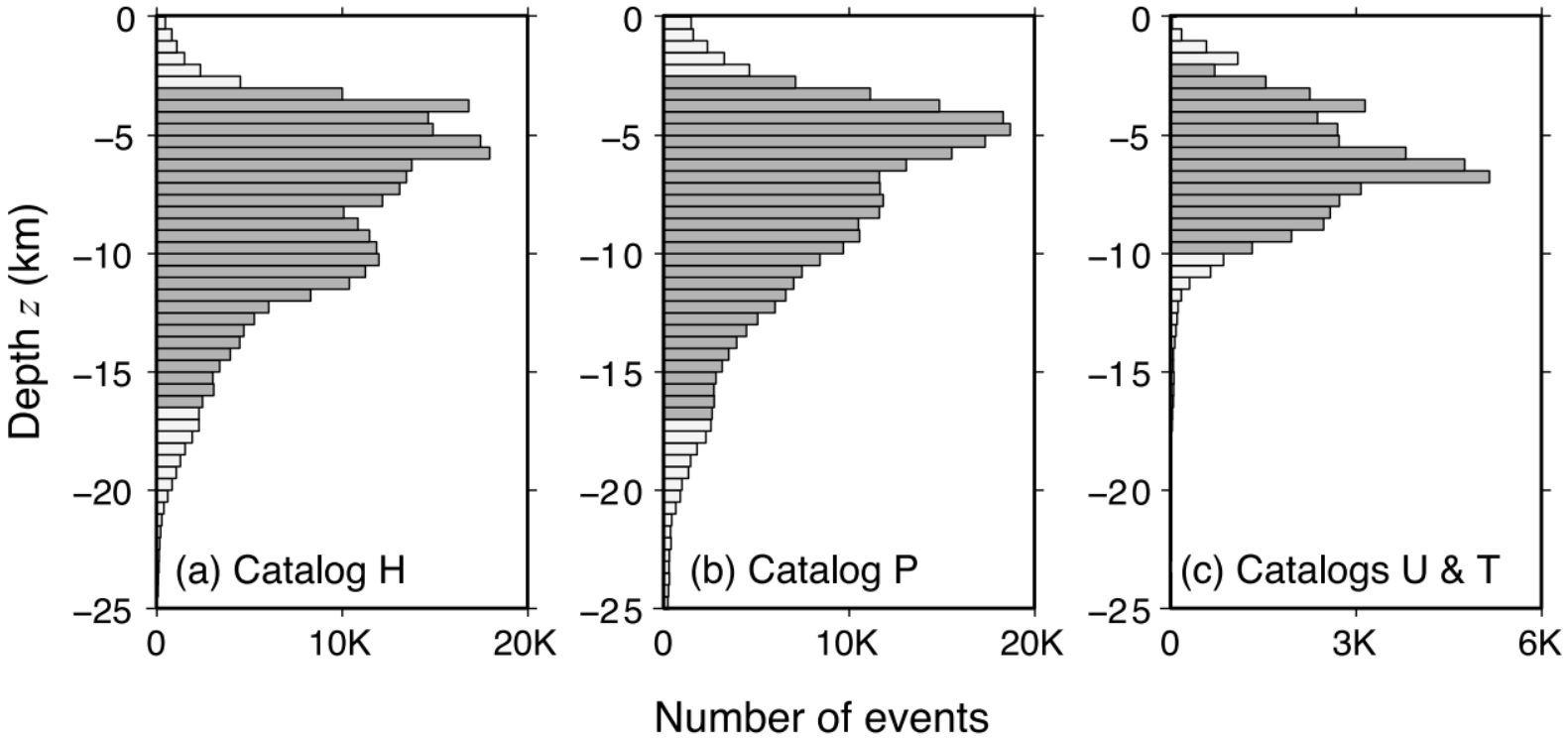
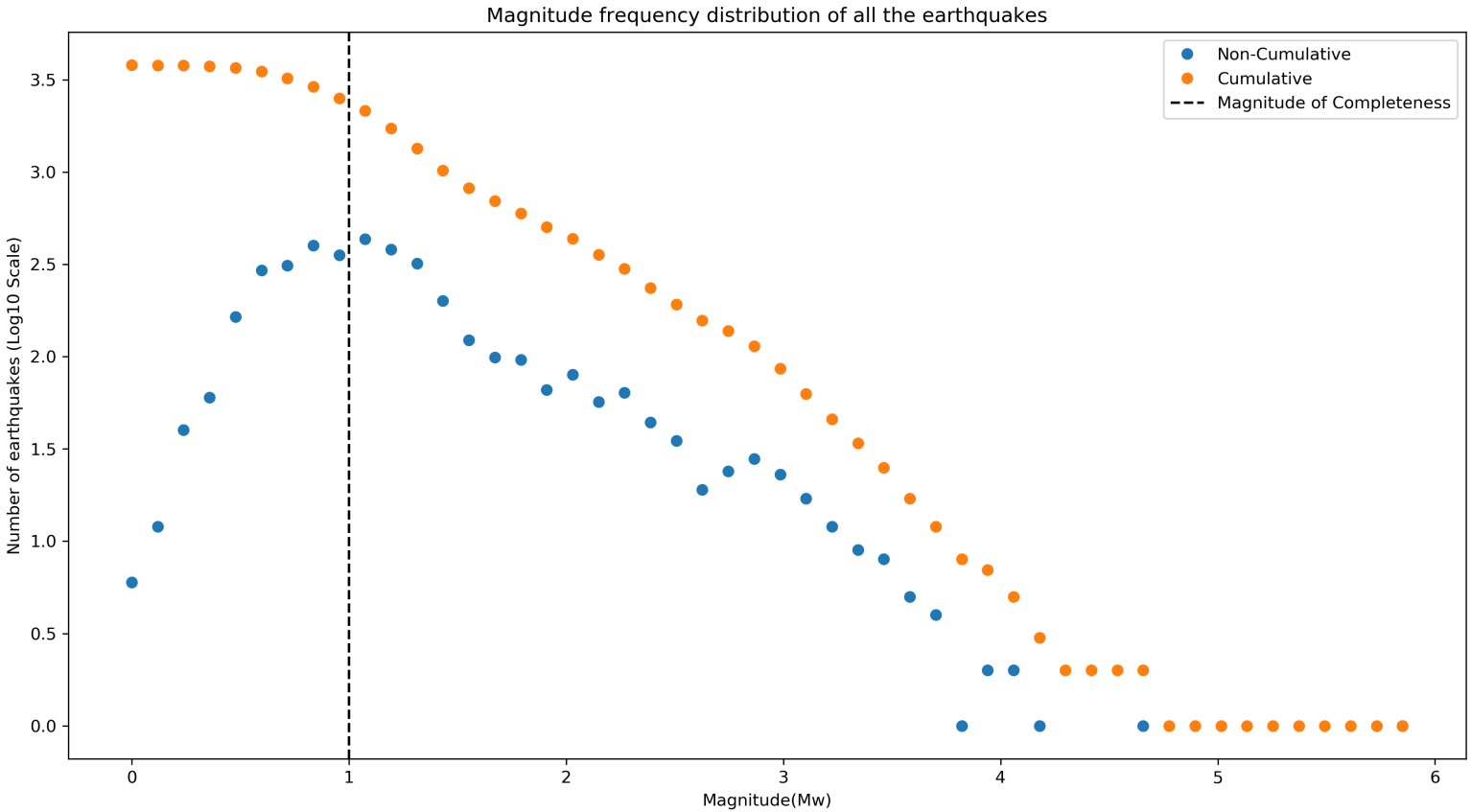
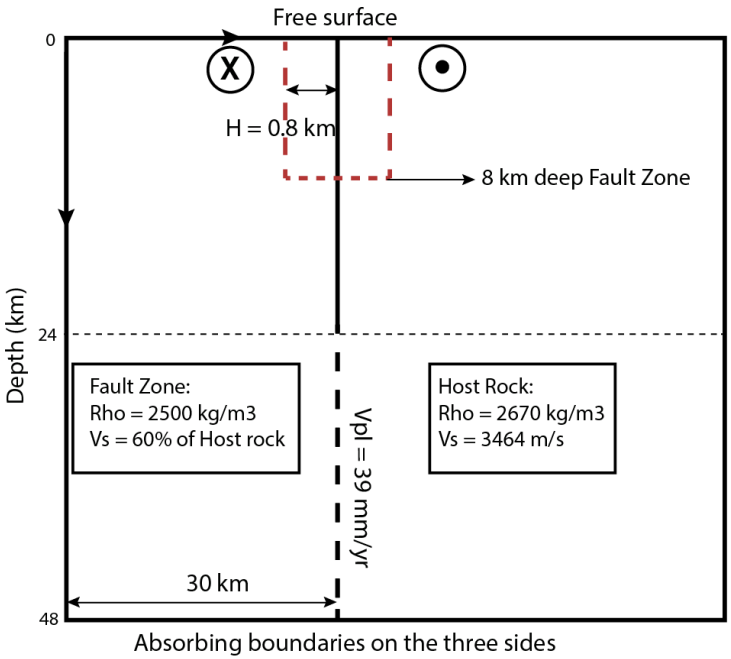


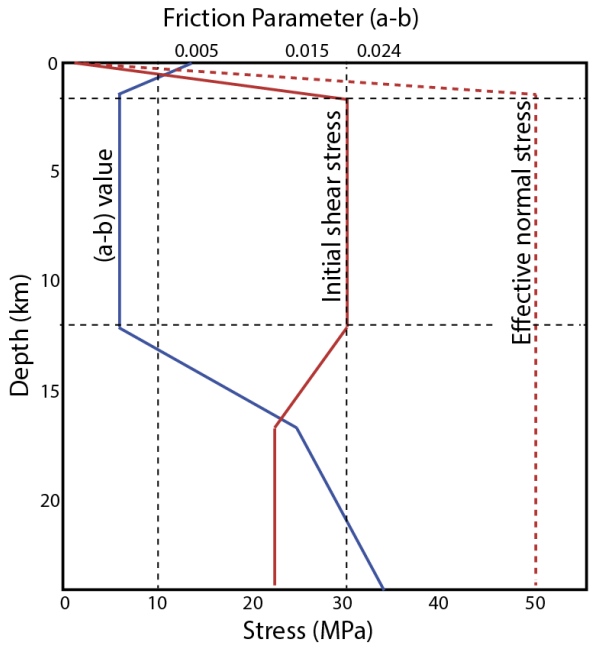
Figure 3. Depth distributions of relocated earthquakes in the fault segment catalogs. Events from (a) catalog H and (b) catalog P in southern California and (c) catalogs U and T in northern California. The darker shaded bars mark the medial 90% of all events in the catalogs. Note that seismicity is generally shallower in northern California (Figure 3c). The downward bias in catalog H (Figure 3a) is likely an artifact of the 3-D velocity model used for earthquake relocation.

Observations from San-Andreas Fault

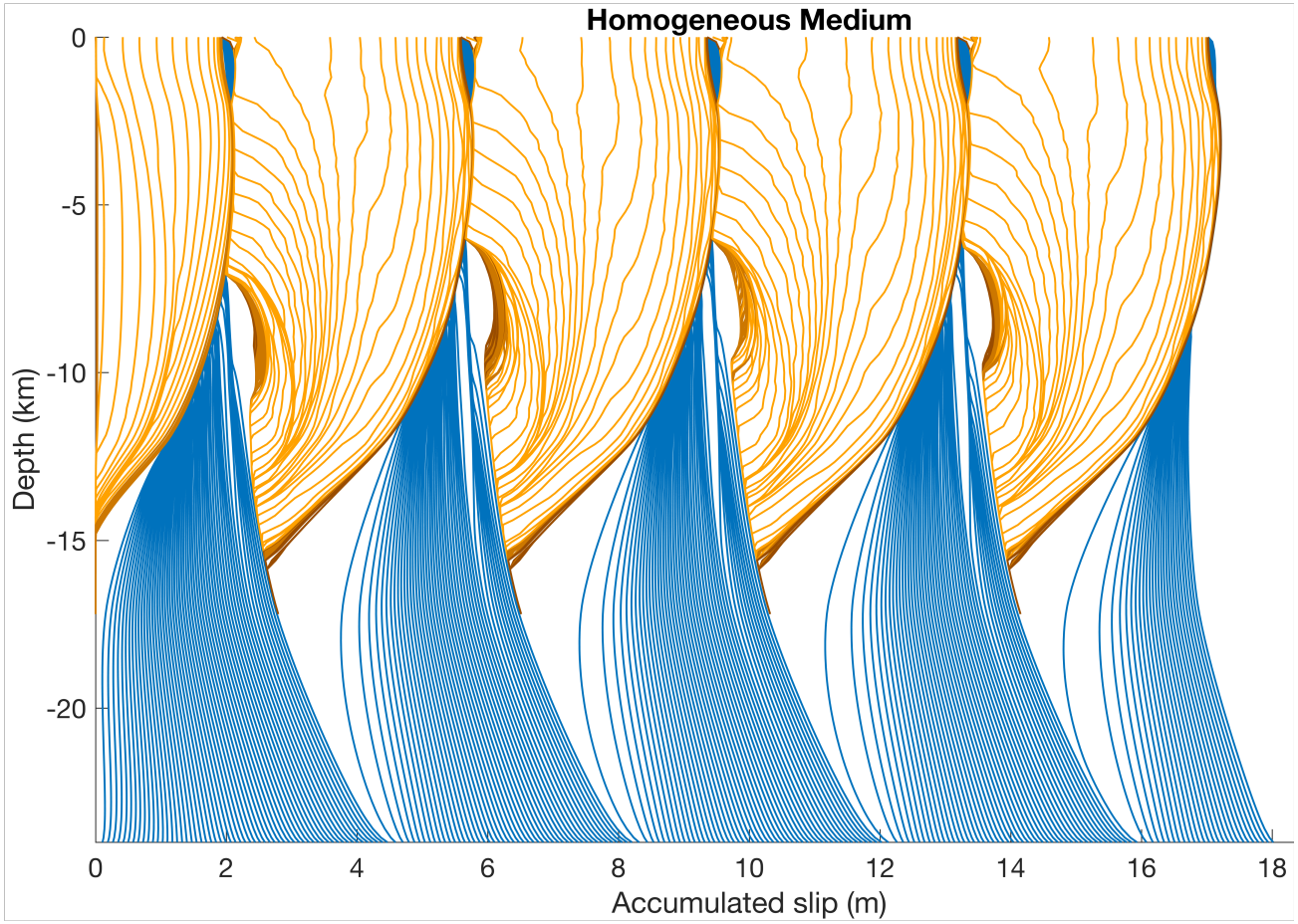


Model Description

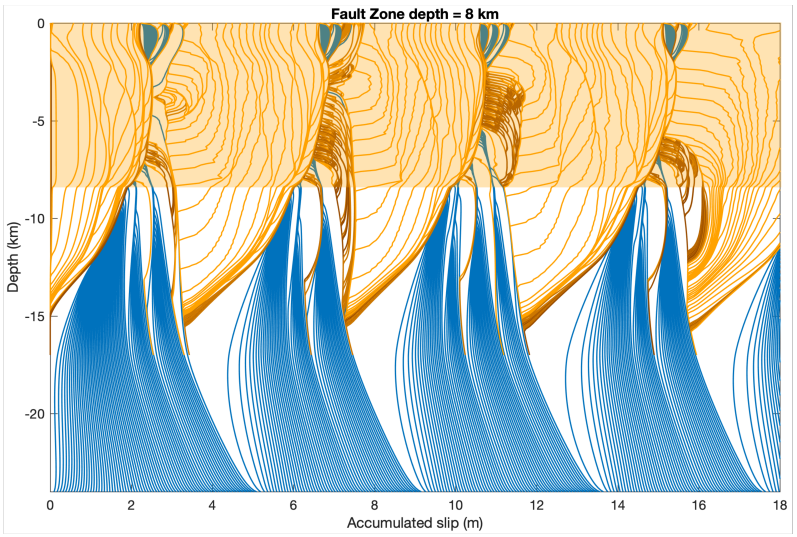


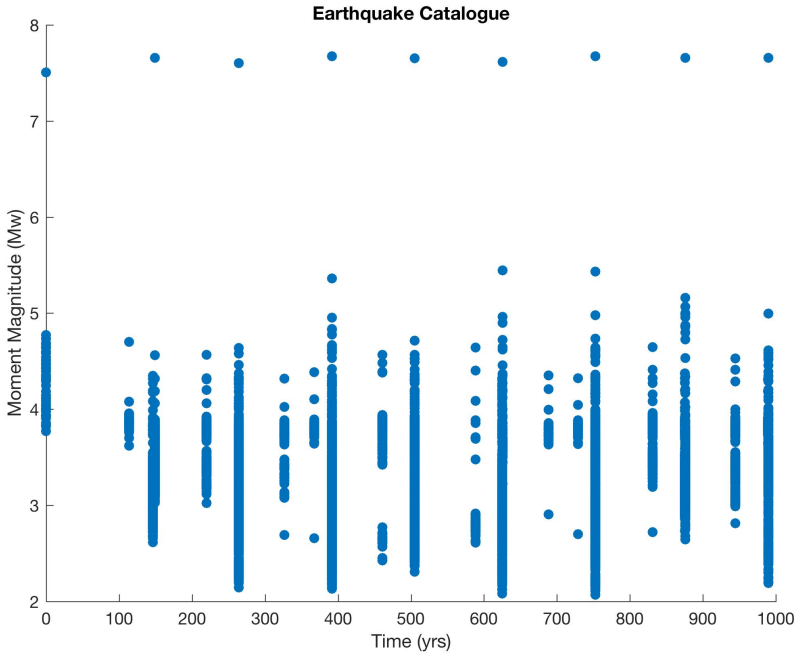


Simulated Results: Homogeneous Medium

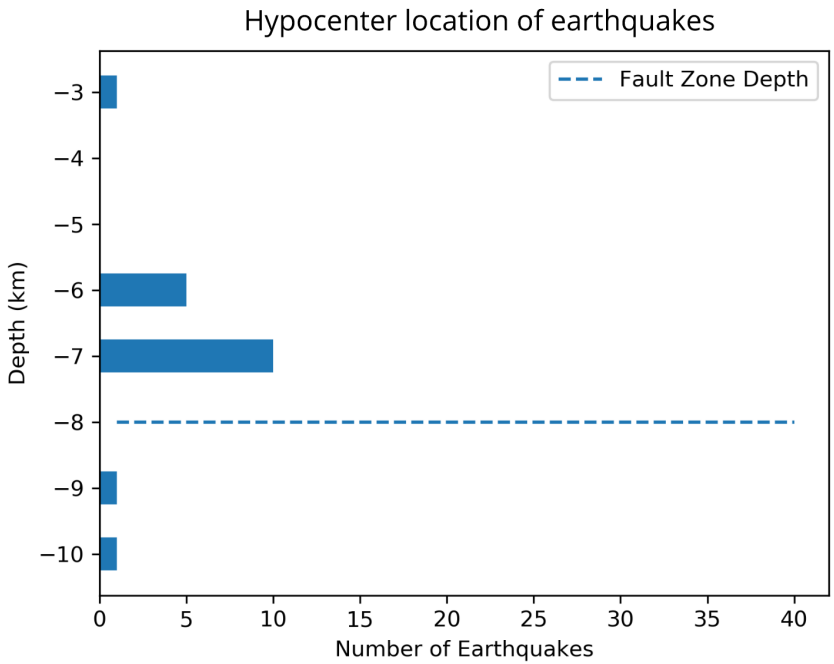


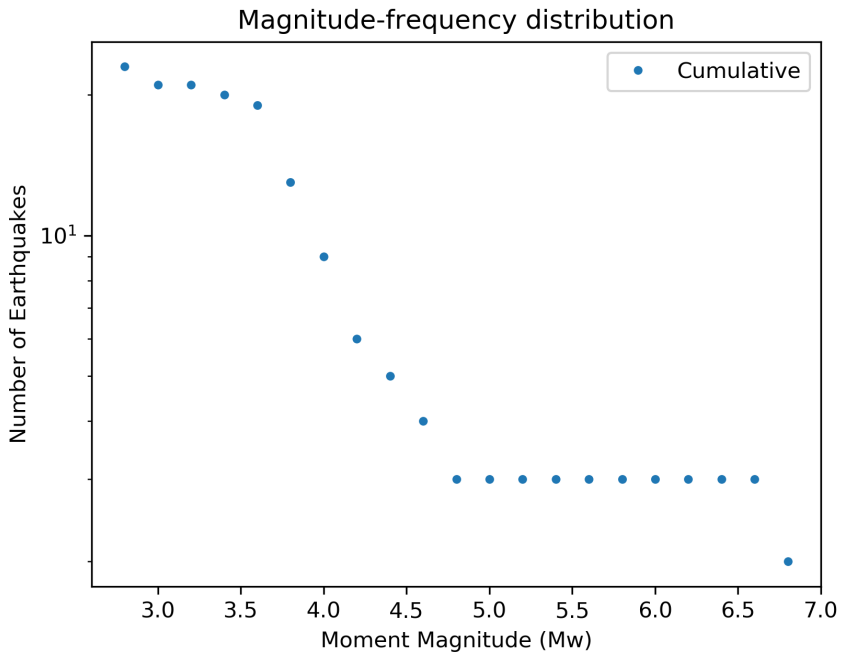
Simulated Results: 8 km Deep, 1.5 km Wide Fault Zone





Simulated Results: MFD and Earthquake Location

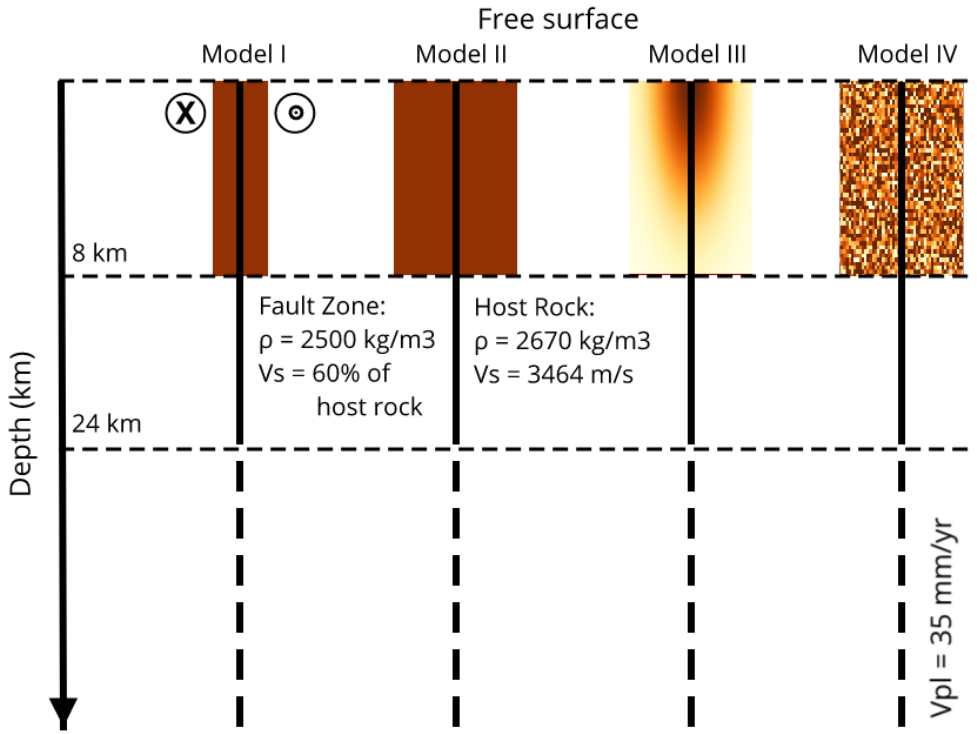


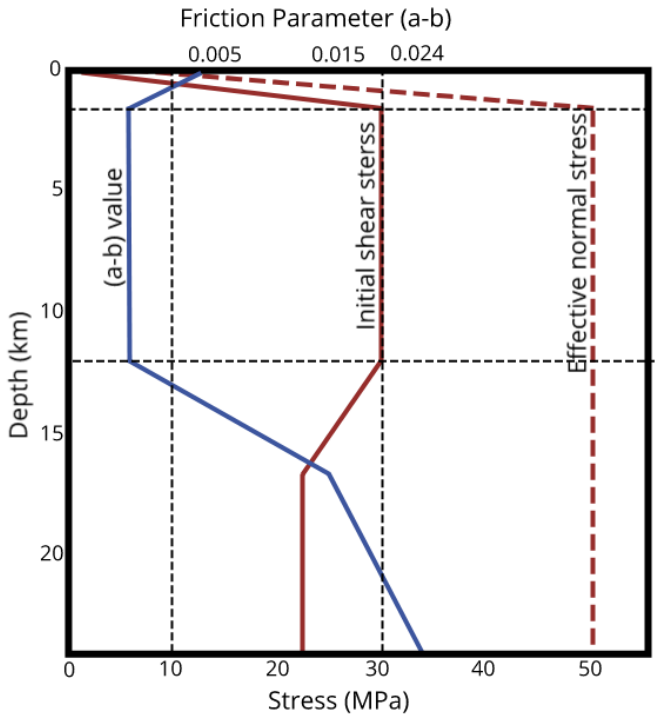


Conclusions

- The presence of fault zone promotes stress heterogeneity.
- This stress heterogeneity gives rise to a power law distribution of earthquakes.
- The distribution is more similar to characteristic type earthquake distribution.
- Earthquake cycle simulations with dynamic treatment of inertial effects gives a more realistic view of earthquake distribution in the presence of a material heterogeneity.

Future Work


Free surface
Model I
Model II
Model III
Model IV
8 km
24 km
Depth (km)
Fault Zone:
ρ = 2500 kg/m3
Vs = 60% of
host rock
Host Rock:
ρ = 2670 kg/m3
Vs = 3464 m/s
Vpl = 35 mm/yr


Friction Parameter (a-b)
0.005
0.015
0.024
(a-b) value
Initial shear sterss
Effective normal stress
Depth (km)
0
5
10
15
20
0
10
20
30
40
50
Stress (MPa)

That's All Folks!!