Subduction sculpting when megathrusts sleep: How interseismic deformation encodes a signature of plate locking in forearc landscapes

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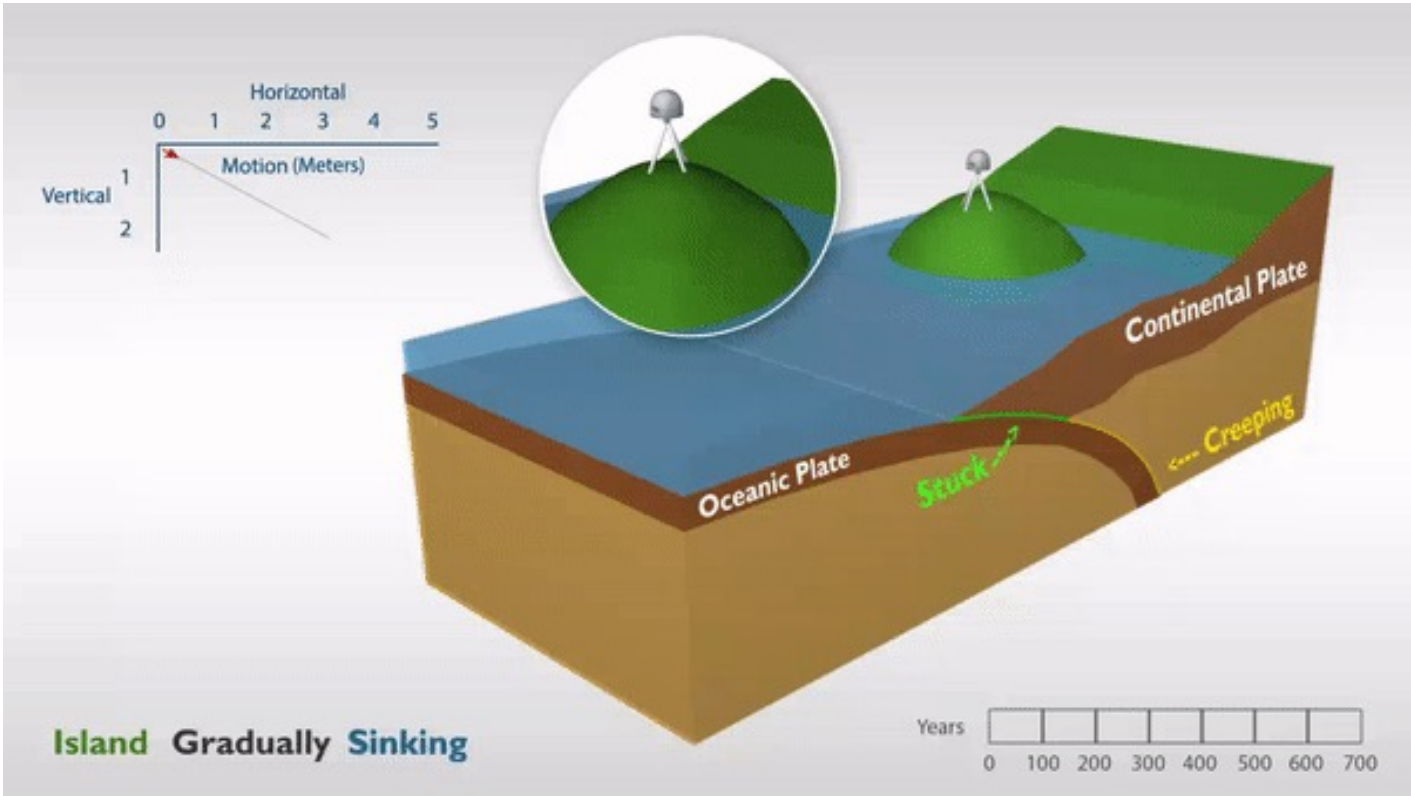
THE STANDARD ELASTIC EARTHQUAKE CYCLE MODEL

Long-term: downgoing plate descends beneath the upper plate in stick-slip fashion.



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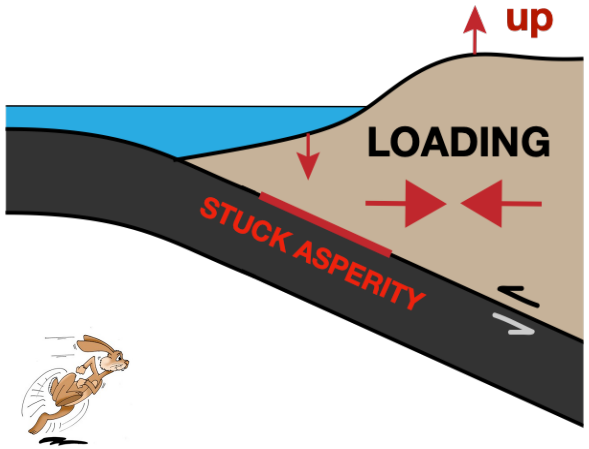

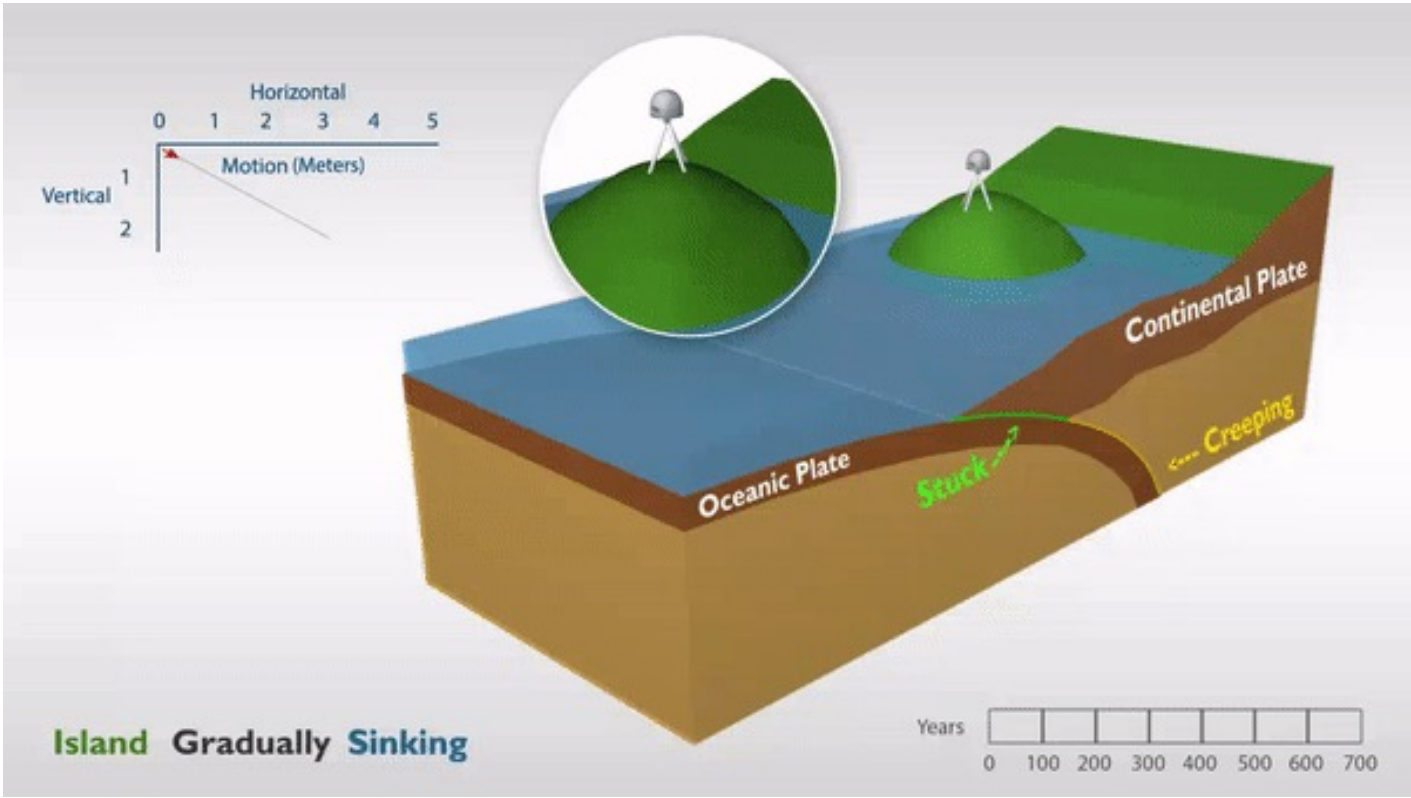

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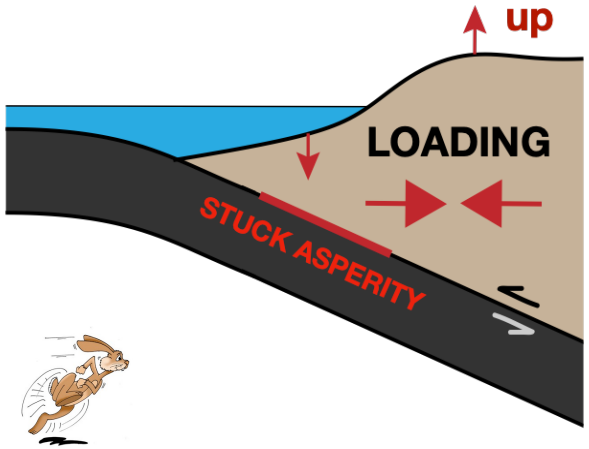
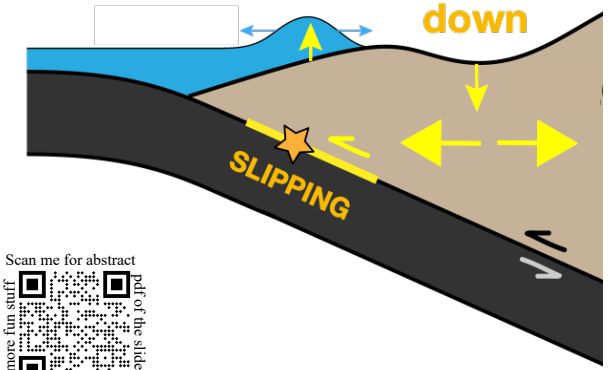
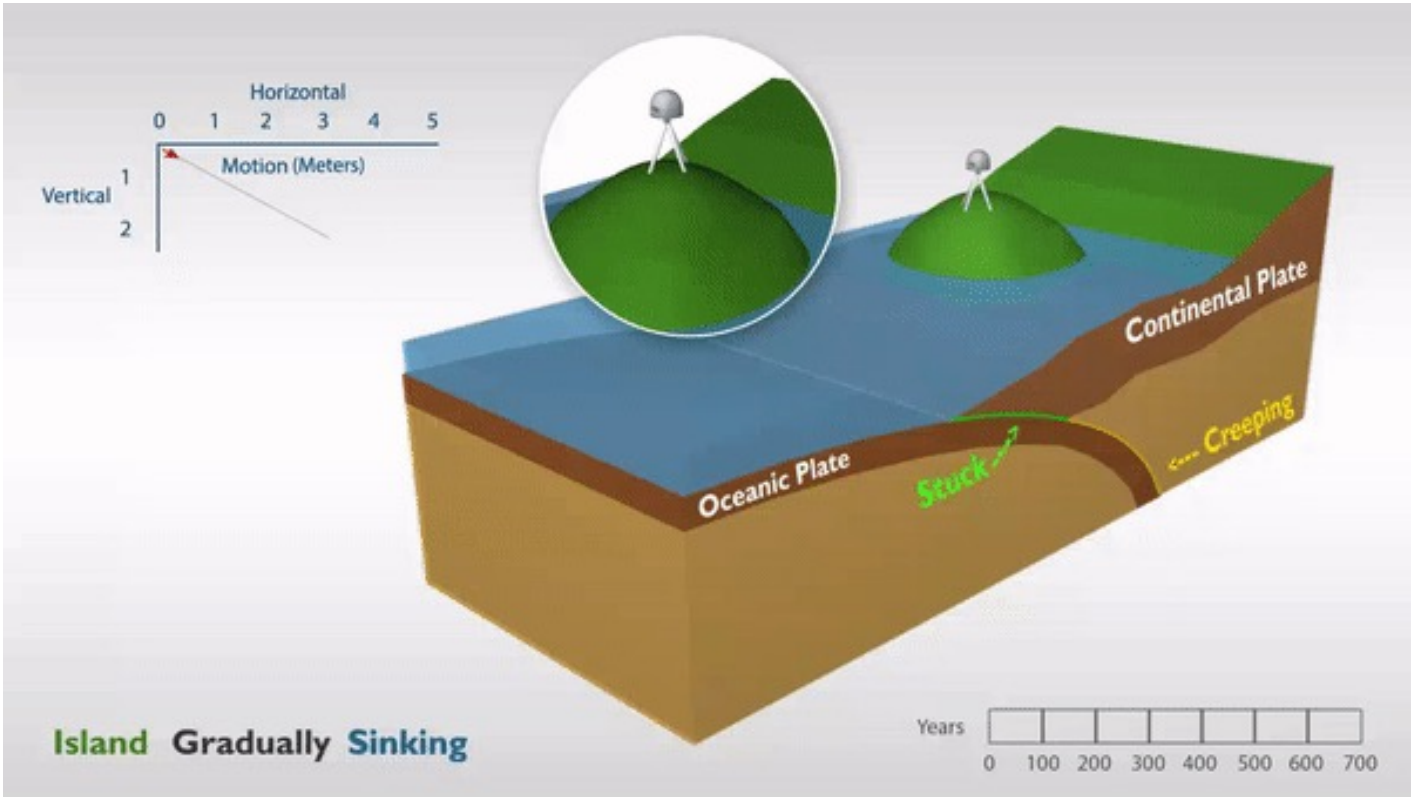




Coseismic: locked section moves abruptly. Upper plate deform elastically in an opposite sense.



No off-fault permanent deformation!

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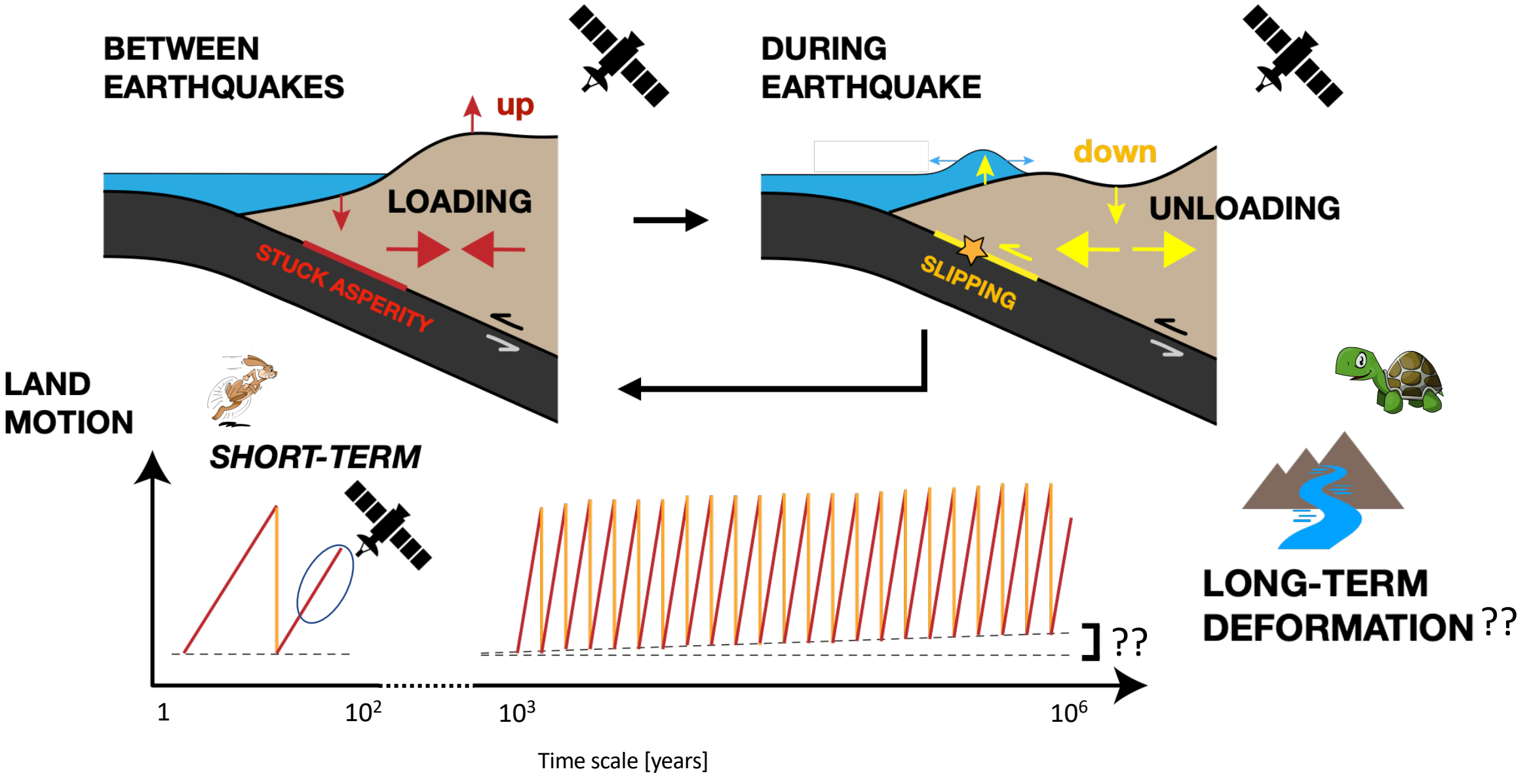
SHORT- AND LONG-TERM DEFORMATION DURING EARTHQUAKE CYCLES



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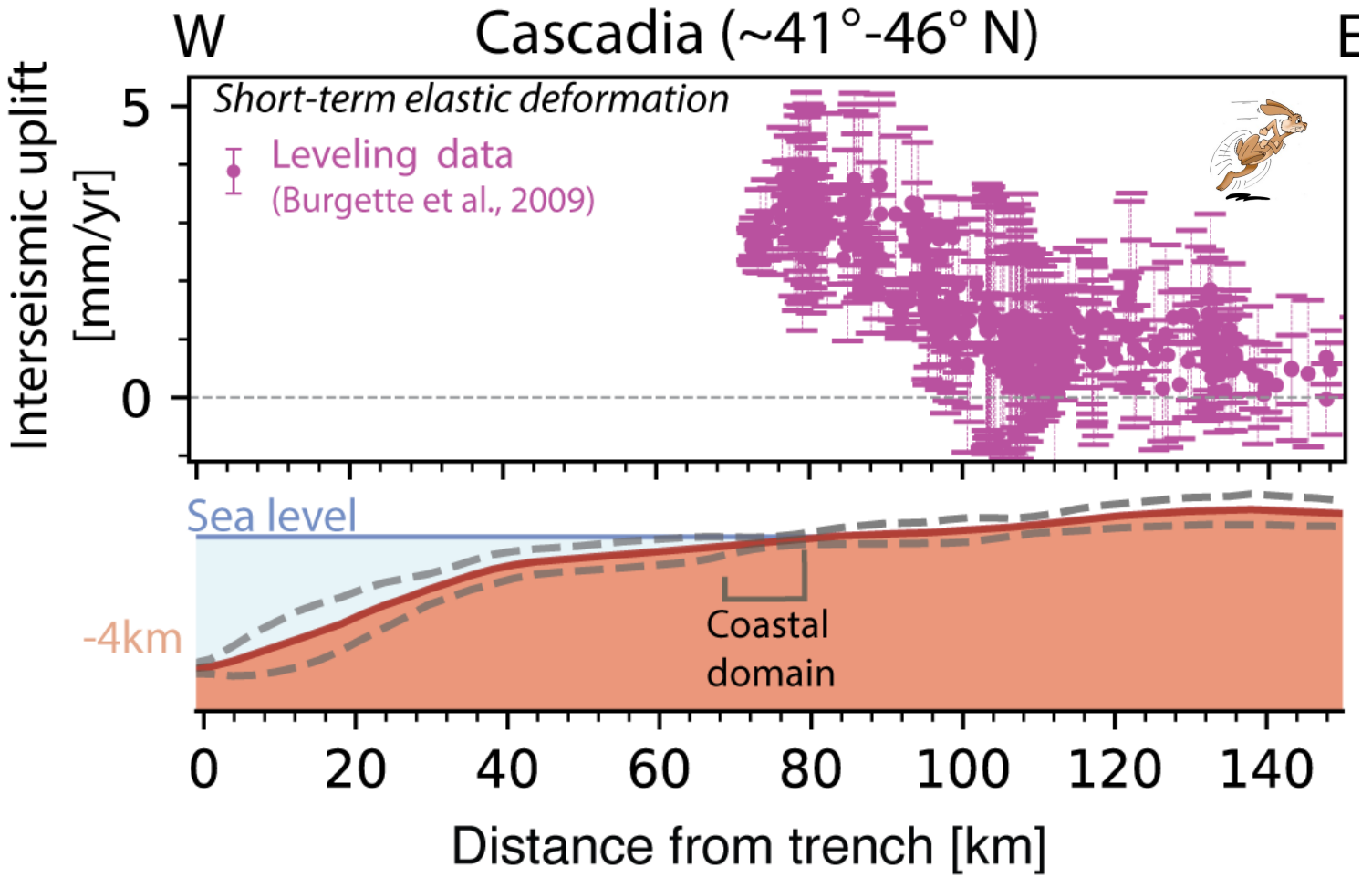
SHORT-TERM DEFORMATION IN CASCADIA



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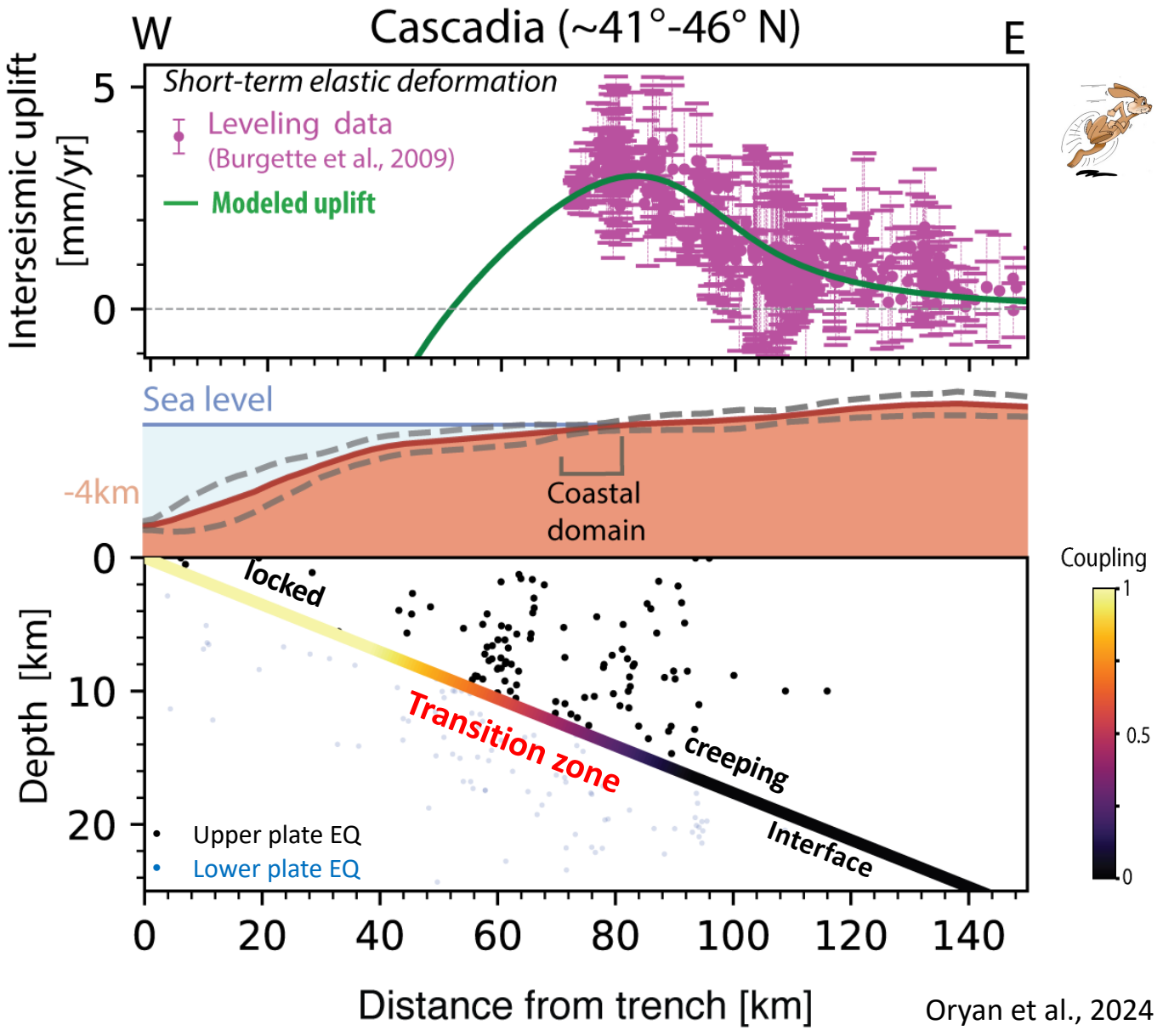
SHORT-TERM DEFORMATION IN CASCADIA

- **Short-term (elastic)** uplift shows a peak above the transition zone.



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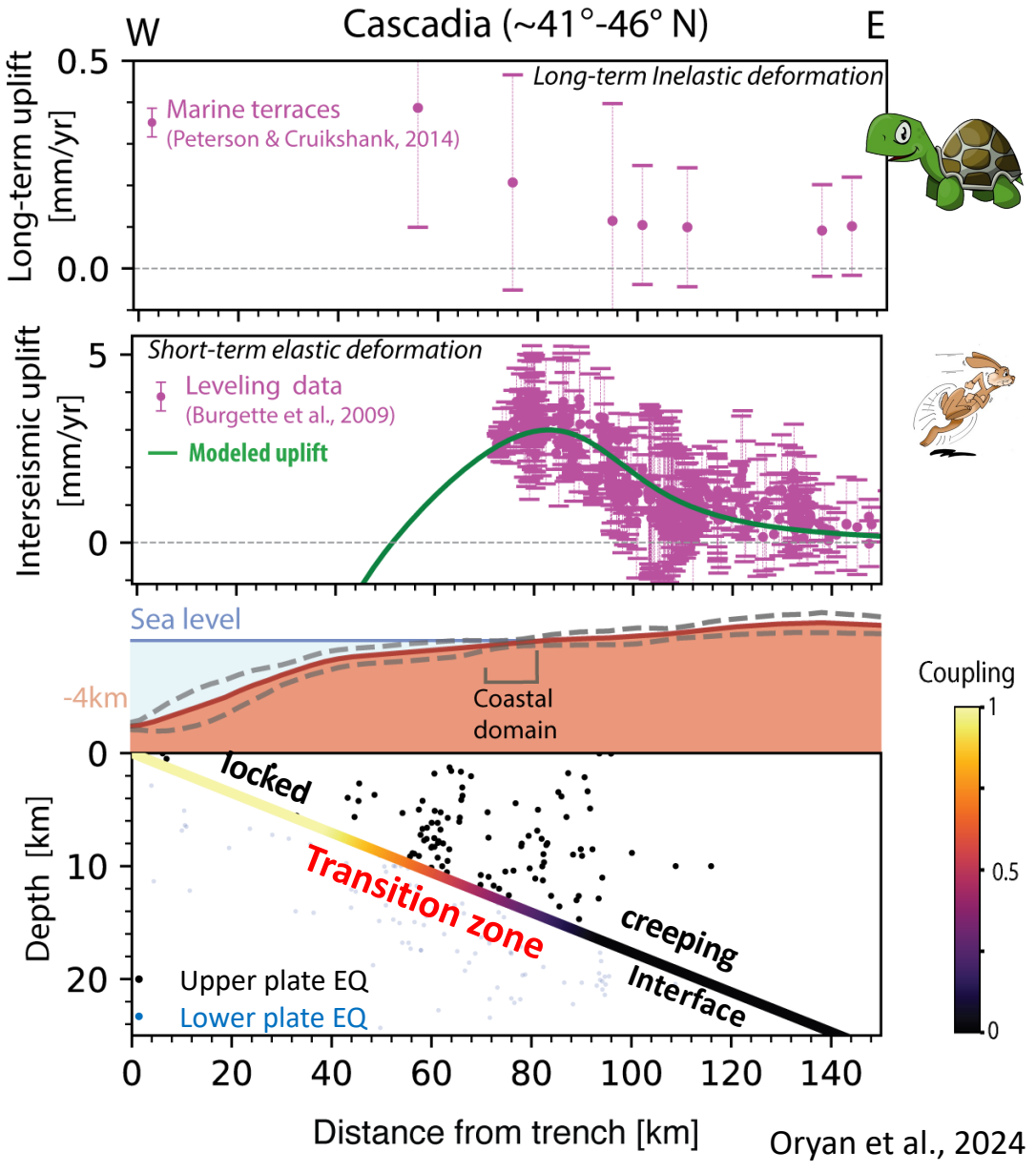

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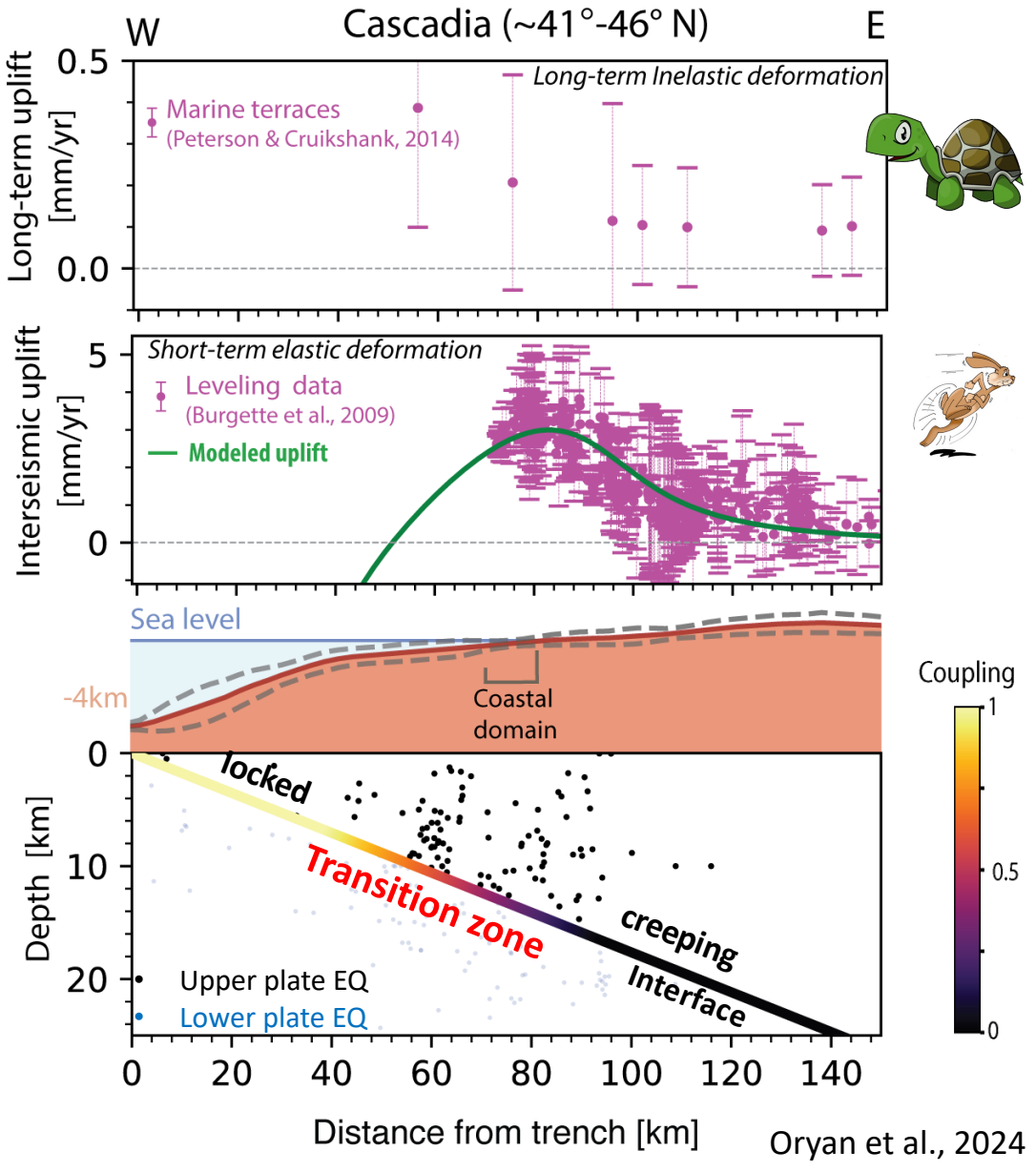

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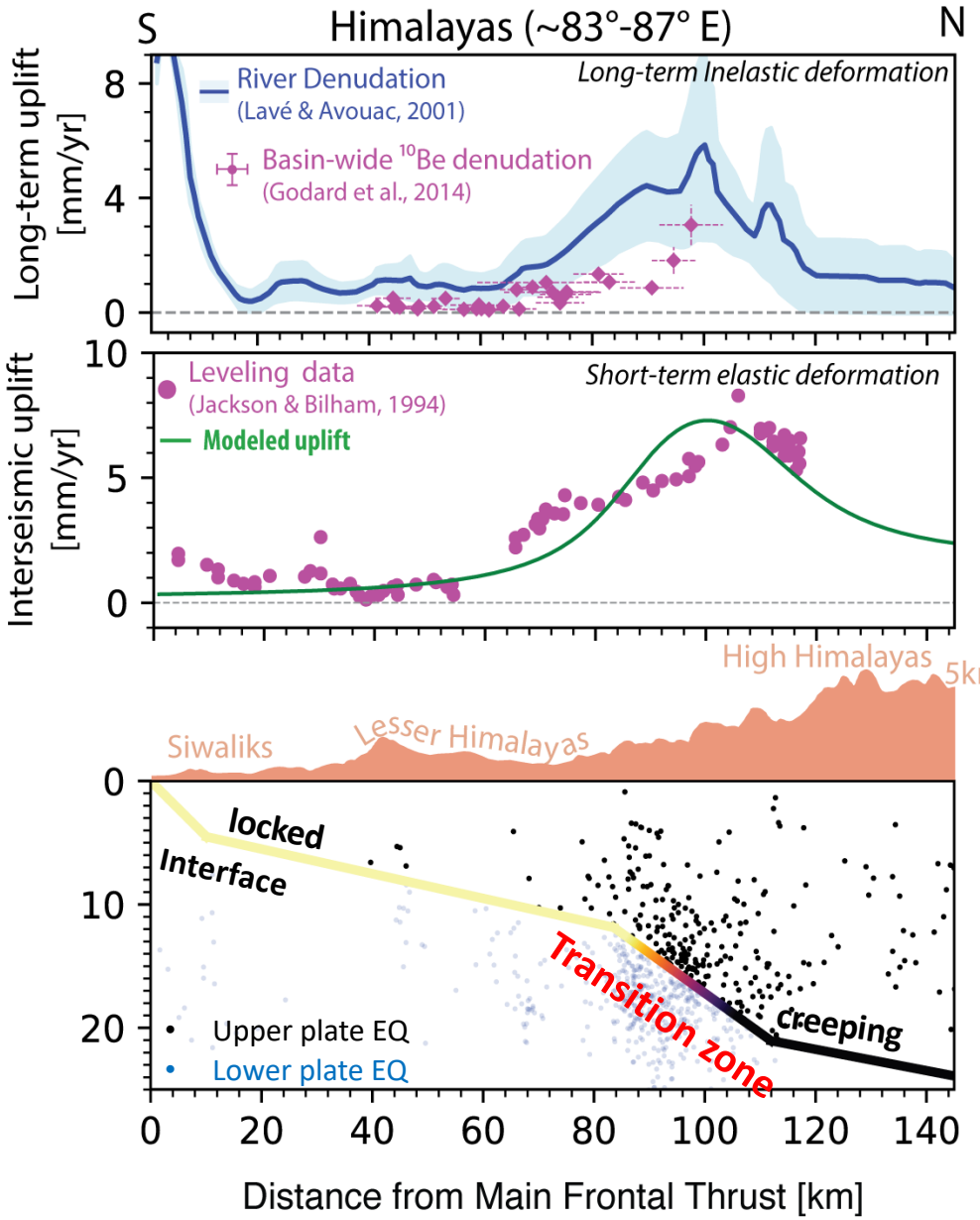

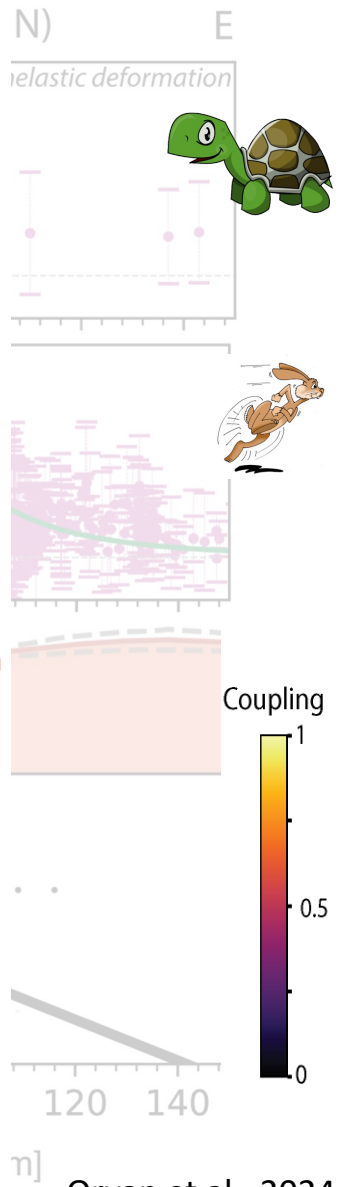

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SHORT- AND LONG-TERM DEFORMATION IN CHILE

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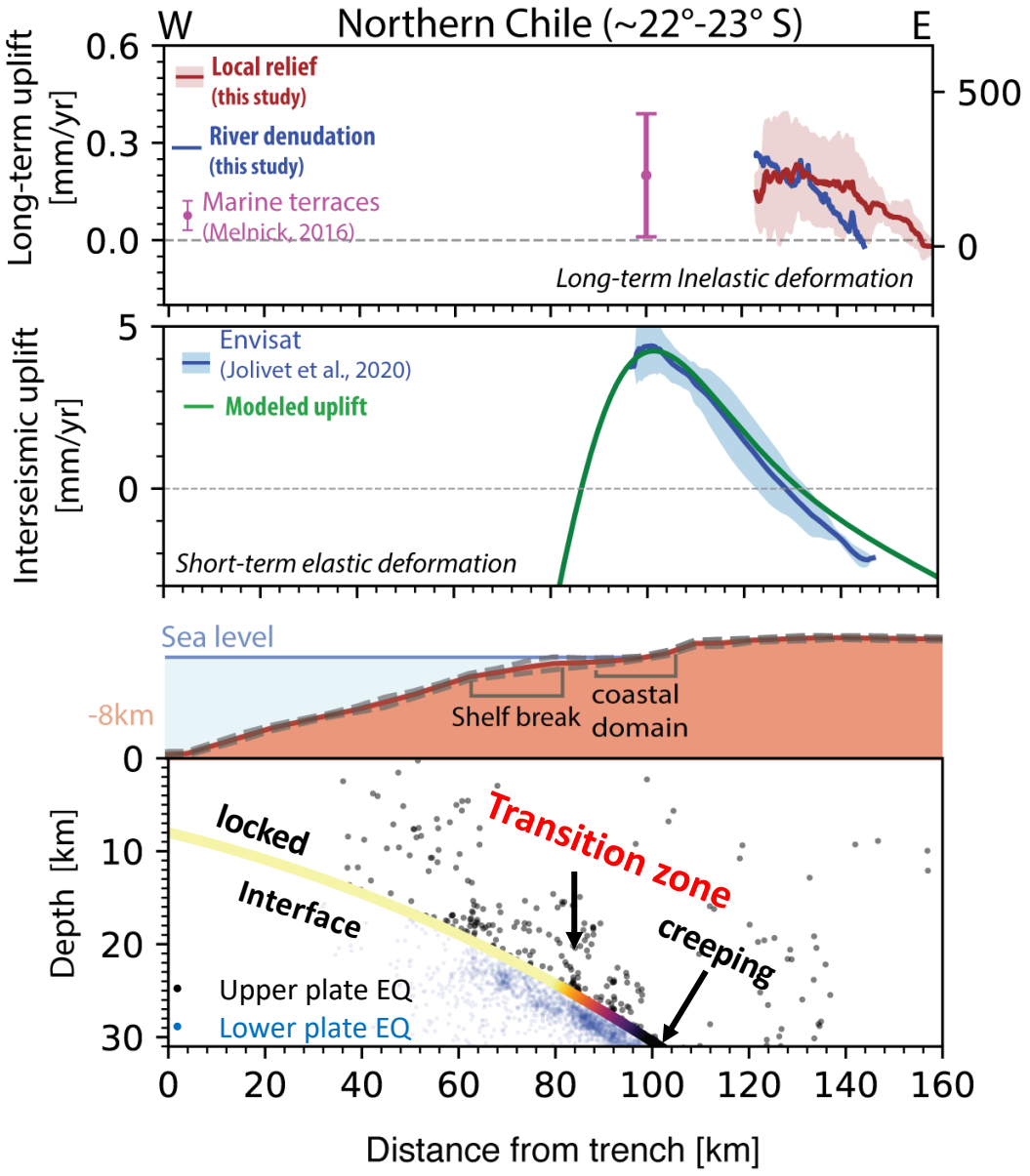

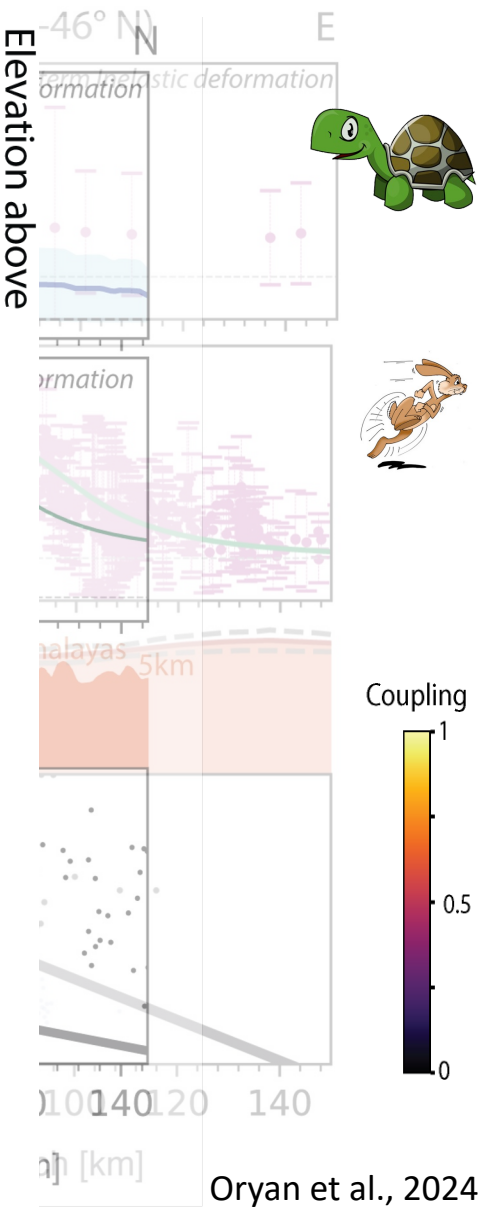

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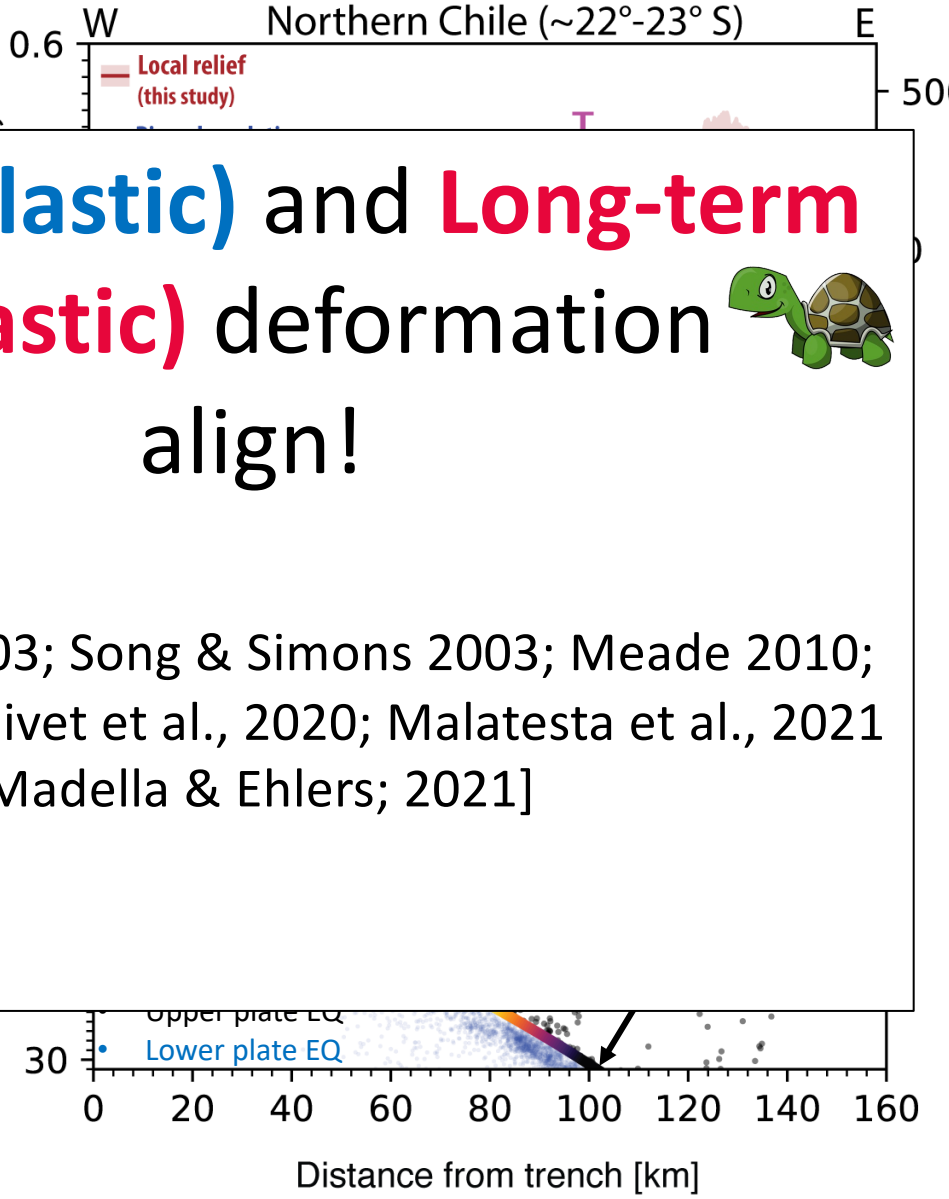
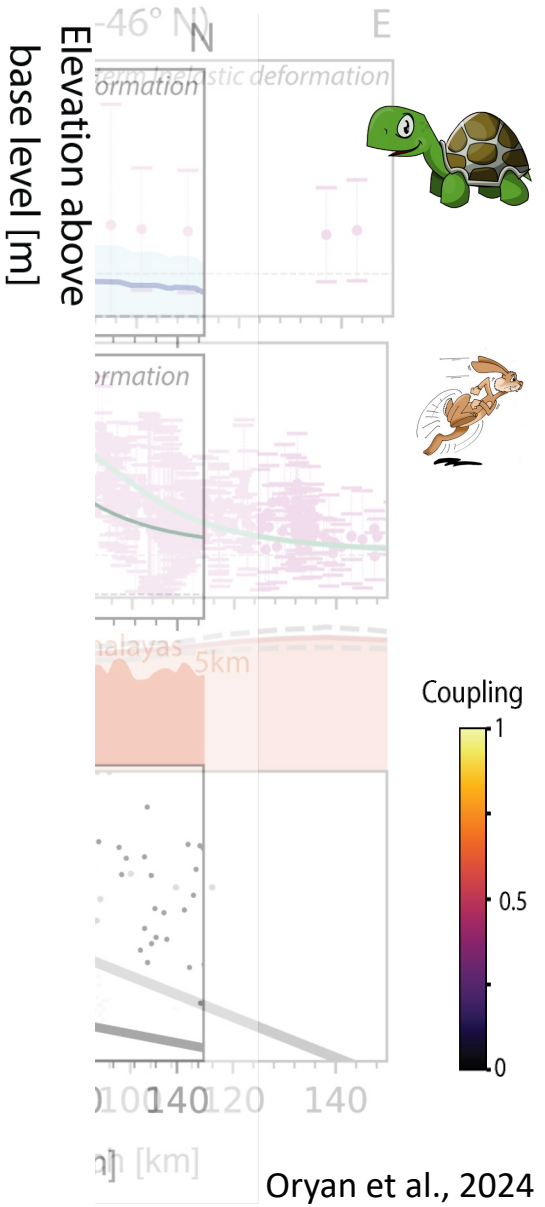
Short- (elastic) and Long-term (inelastic) deformation align!

[Wells et al., 2003; Song & Simons 2003; Meade 2010; Saillard 2017; Jolivet et al., 2020; Malatesta et al., 2021 ;Madella & Ehlers; 2021]





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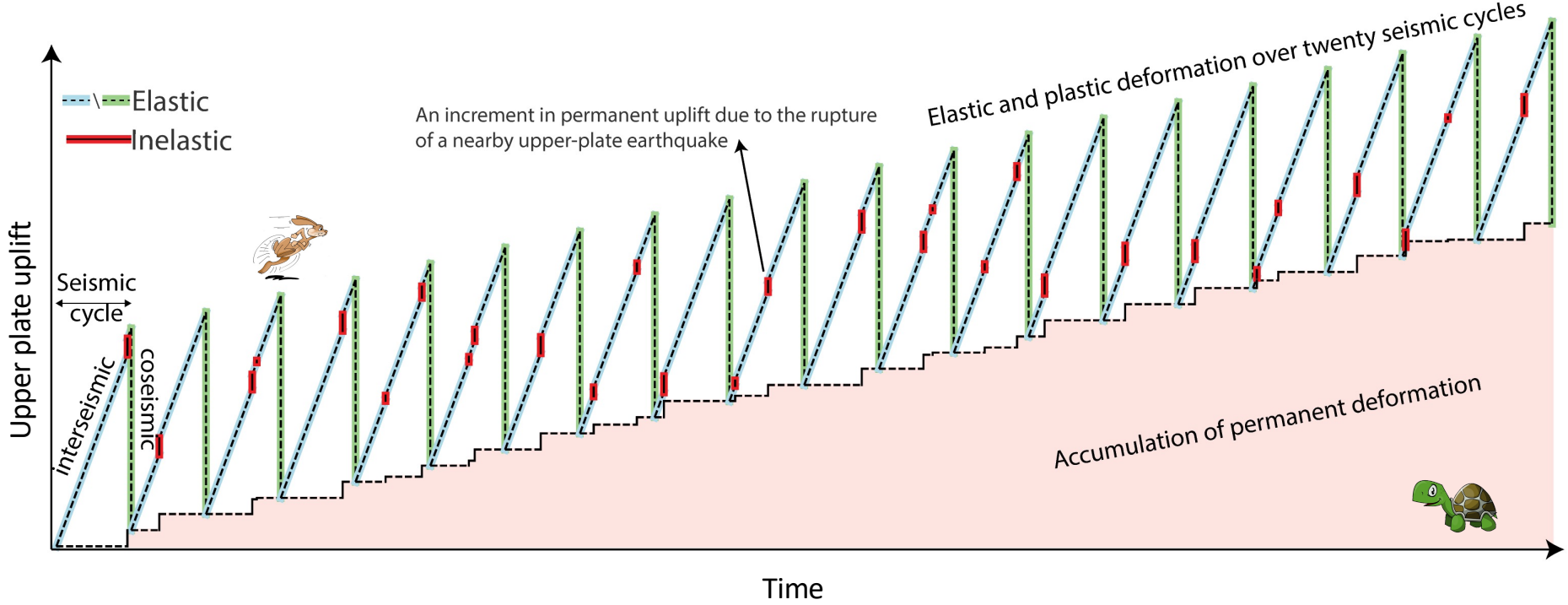
HOW INTERSEISMIC FAULT LOCKING IMPRINTS FOREARCS ?

- **Interseismic upper plate stresses** induced by locking gradients push parts of the upper plate to **failure** generating overriding plate earthquakes.
- Repeated **failure** over multiple earthquake cycles explains the overlap between short- and long-term deformation.



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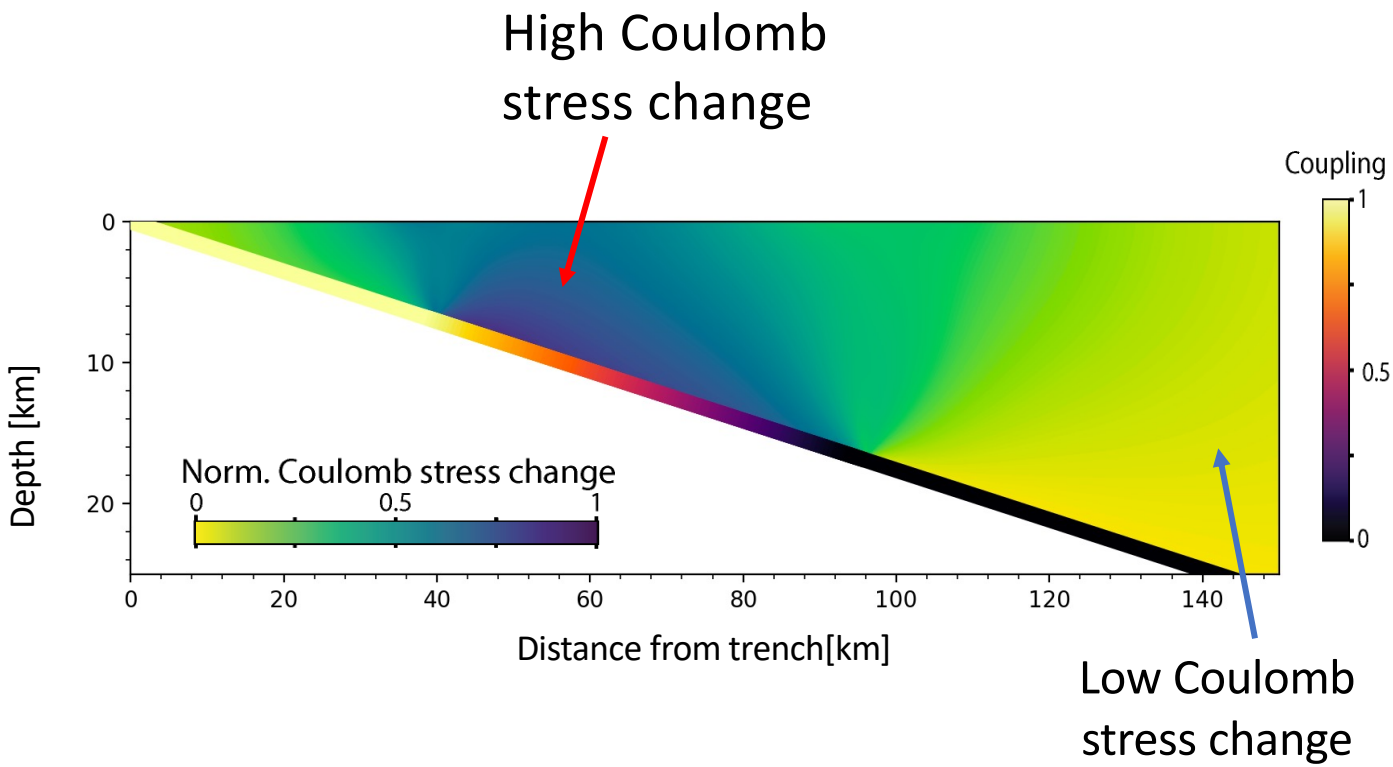
MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

- We compute upper plate Coulomb stress change imparted by locking gradients.
- We link stresses and seismicity [Dieterich, 1994] and populate millions of synthetic earthquakes spanning thousands of years and dozens of seismic cycles according to the Coulomb stress change.
- We use the Okada solution to sum events surface displacement.



Coulomb stress change assuming thurst optimally orientated faults (30°)

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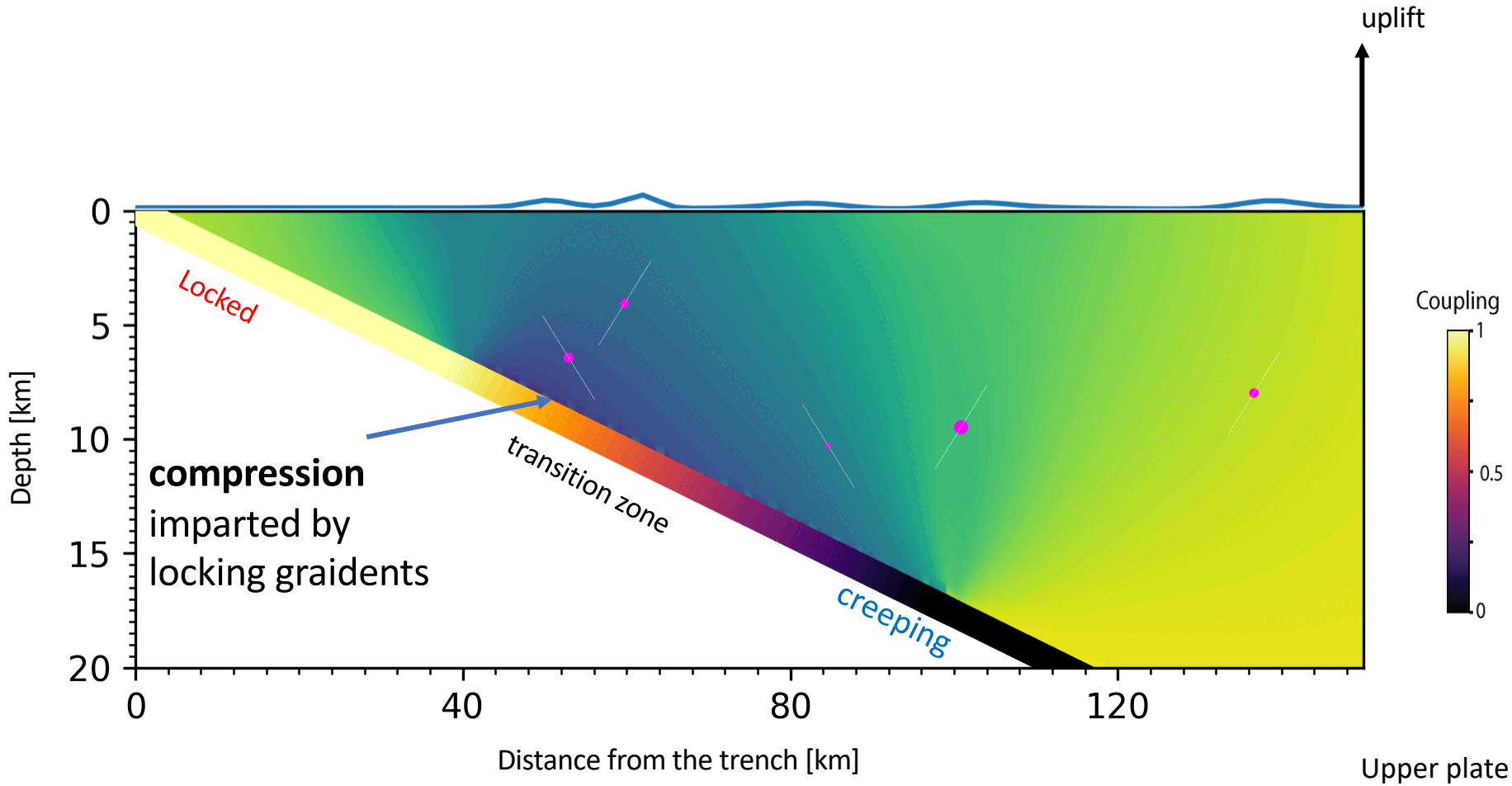
MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

10 degree dip, fully locked to 40km

Uplift during three seismic cycles producing average **long-term** rate of 0.1 mm/yr



Upper plate Coulomb stress change

Low — High

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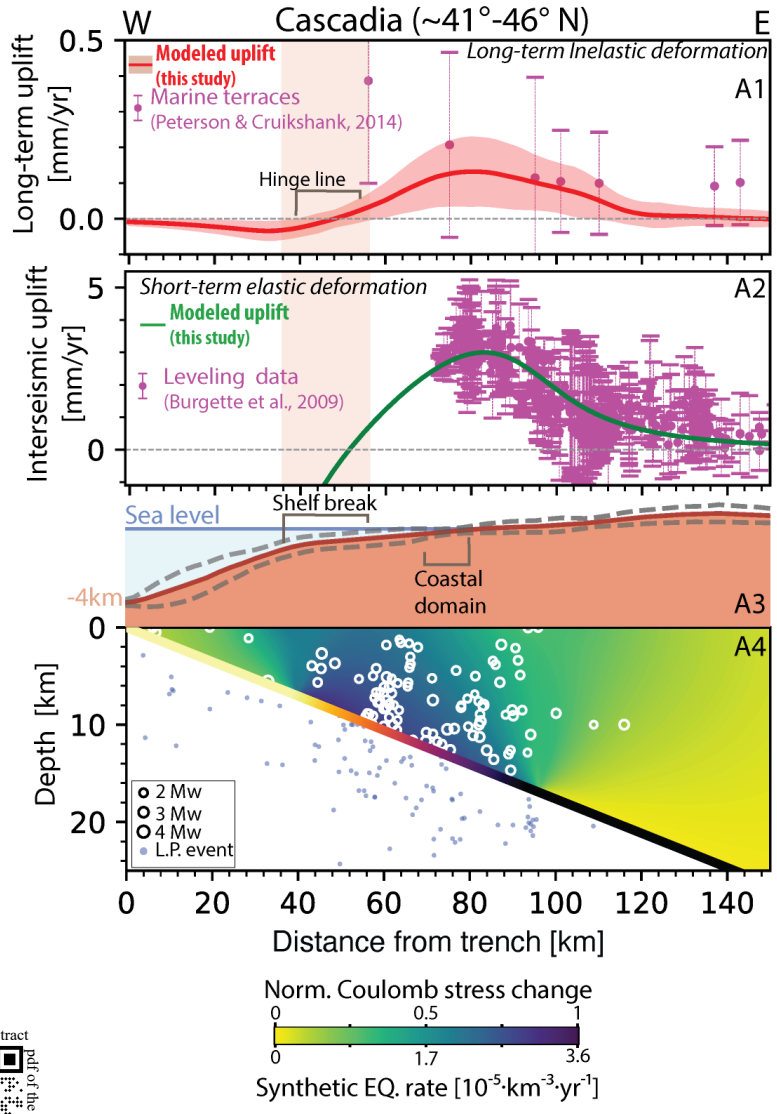
DEFORMATION IN CASCADIA,HIMALYAS AND CHILE



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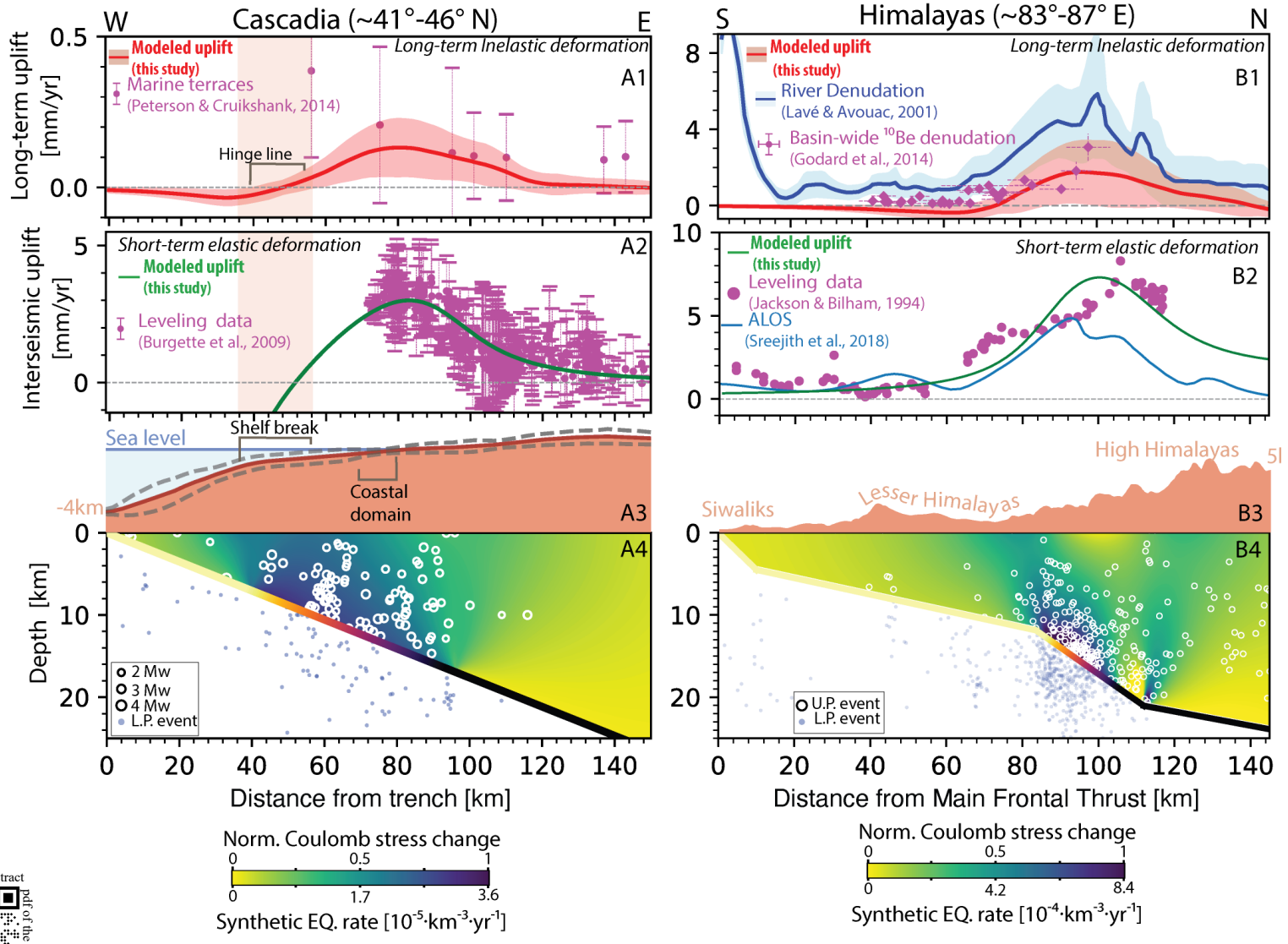
DEFORMATION IN CASCADIA,HIMALYAS AND CHILE



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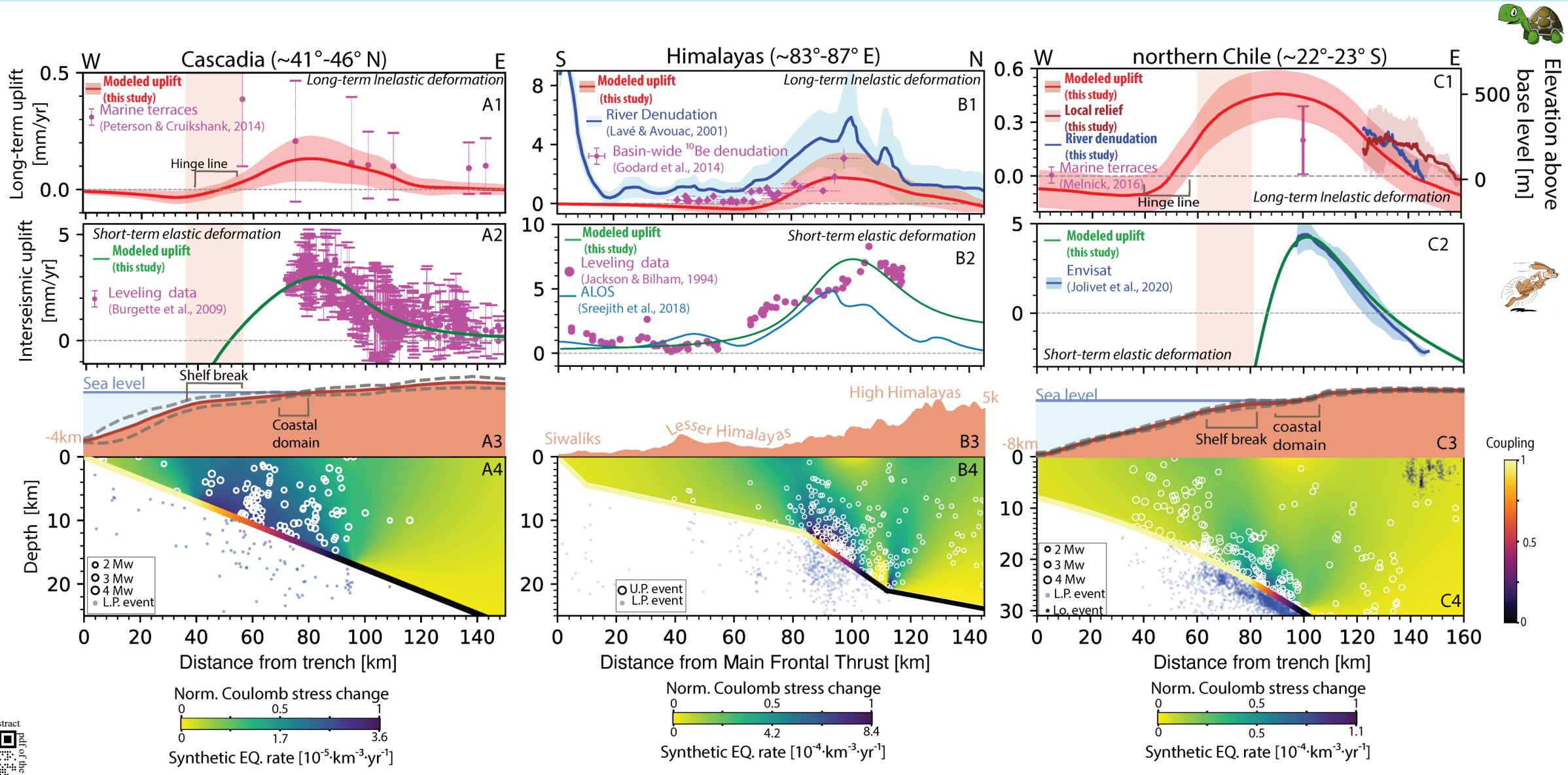

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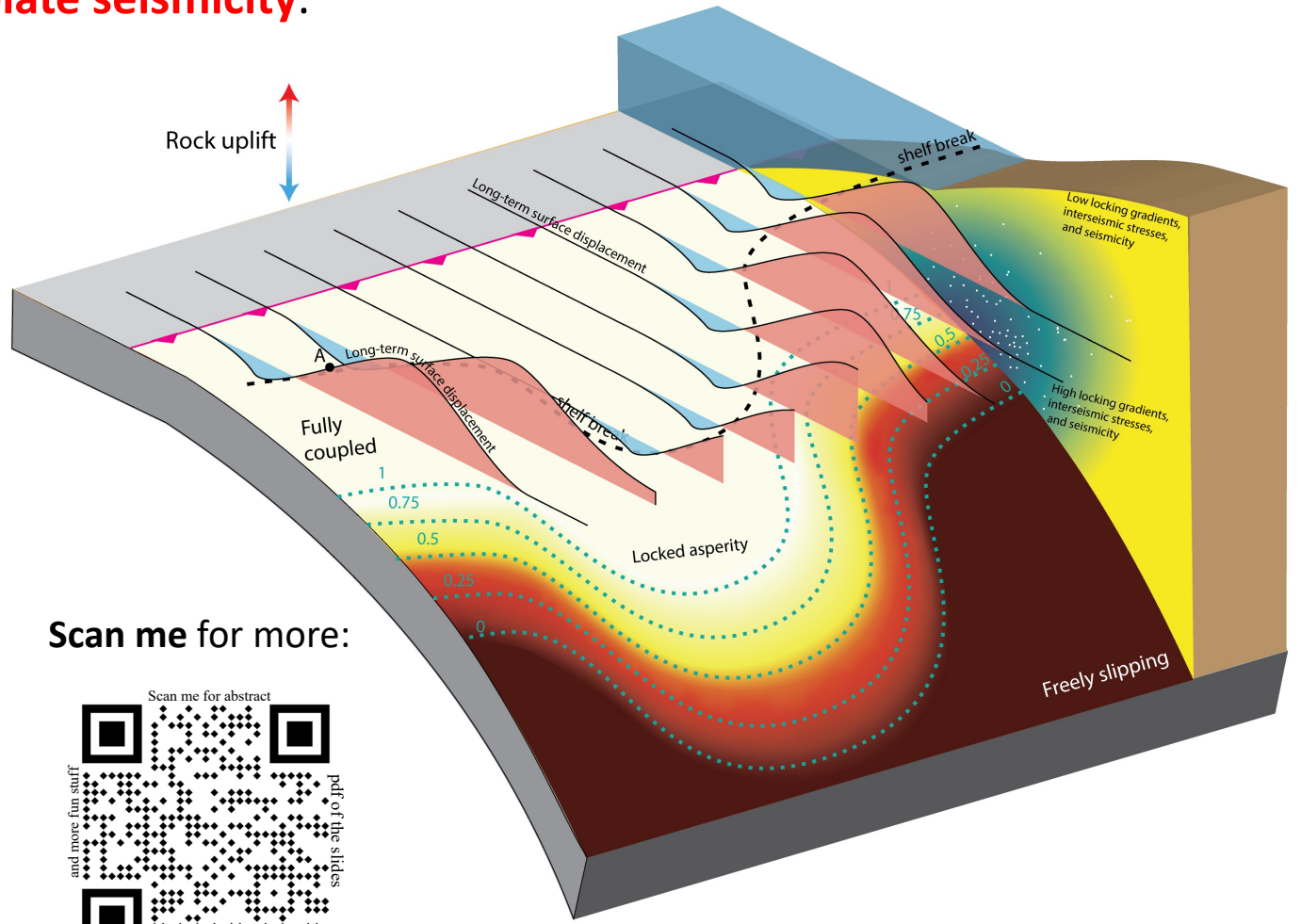
TAKE AWAY MESSAGE

- Variations in the degree of **megathrust locking** generate increments of **non-recoverable brittle deformation** within the overriding plate.
- This is expressed primarily as interseismic **upper plate seismicity**.
- Over time, this process **imprints** subduction landscapes one seismic cycle at a time
- This hints that megathrust locking remains stable over multiple earthquake cycles.



Curious about how geomorphology can help advance our understanding of seismic hazards?

- Visit **EP21C-09 ! Tuesday 09:50AM - 152A**

Interested in understanding how upper plate inelastic deformation influences both coseismic and aseismic megathrust behavior?

- Visit **T41C-3253 ! Thursday AM Poster Hall**

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