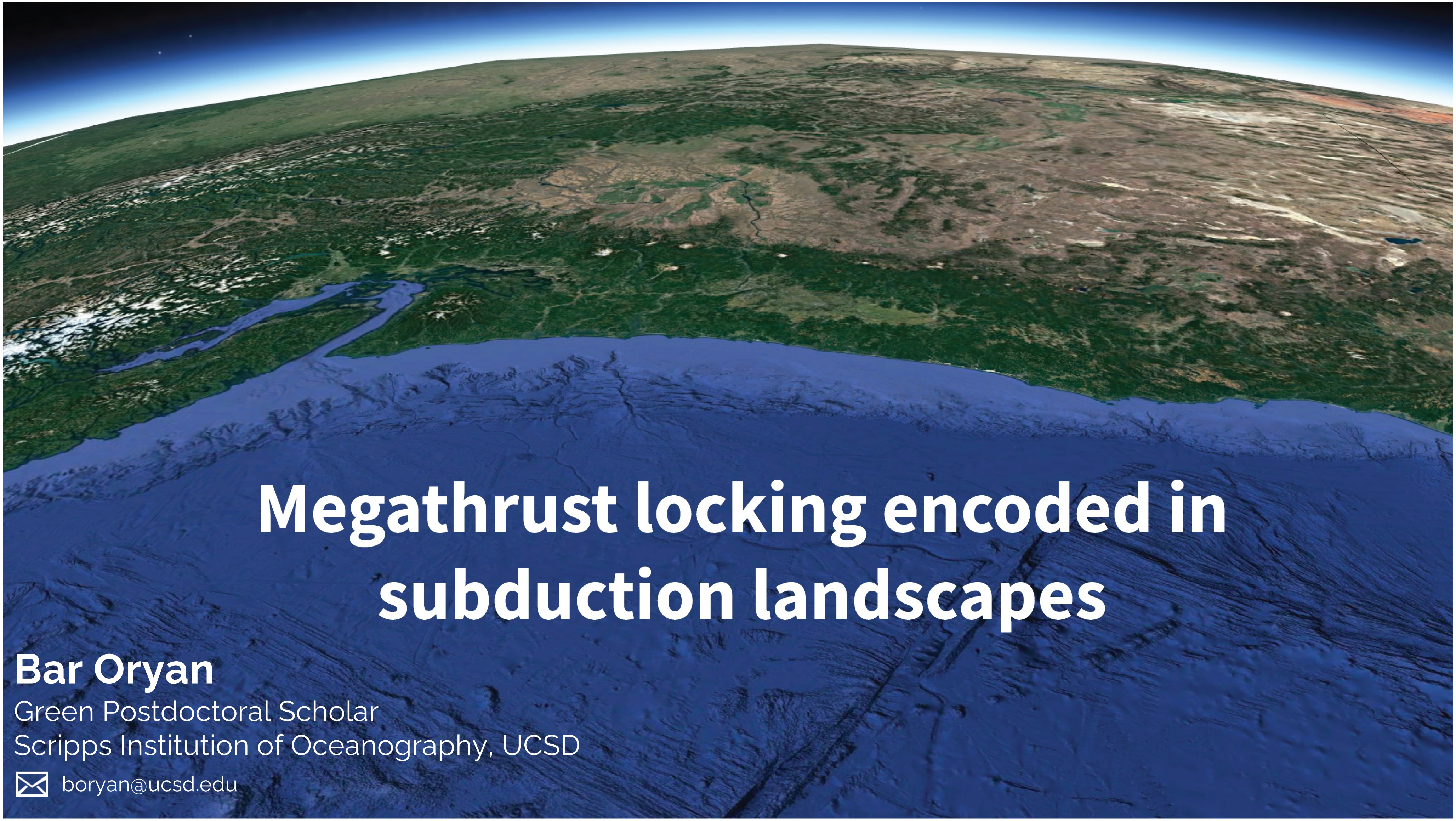
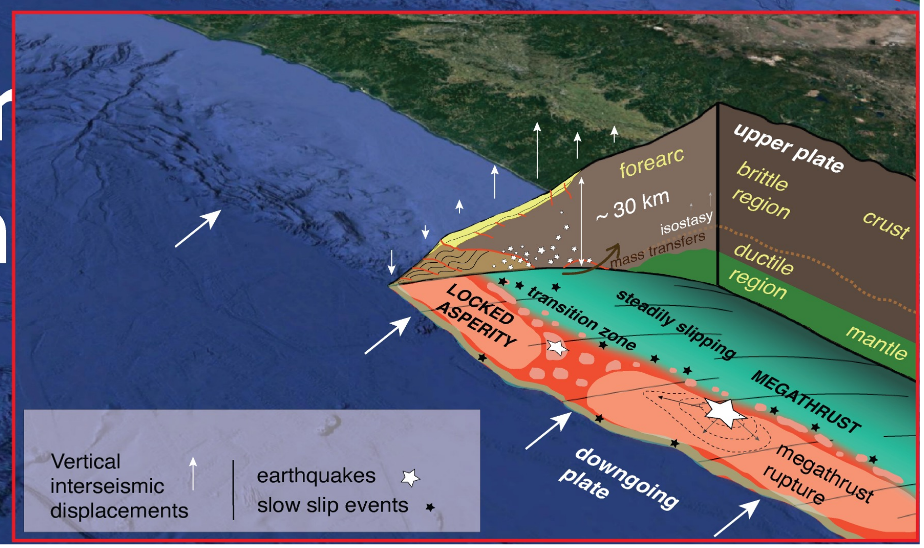


Megathrust locking encoded in subduction landscapes

Bar Oryan
Green Postdoctoral Scholar
Scripps Institution of Oceanography, UCSD
boryan@ucsd.edu

Megathrust lockir
subduction la



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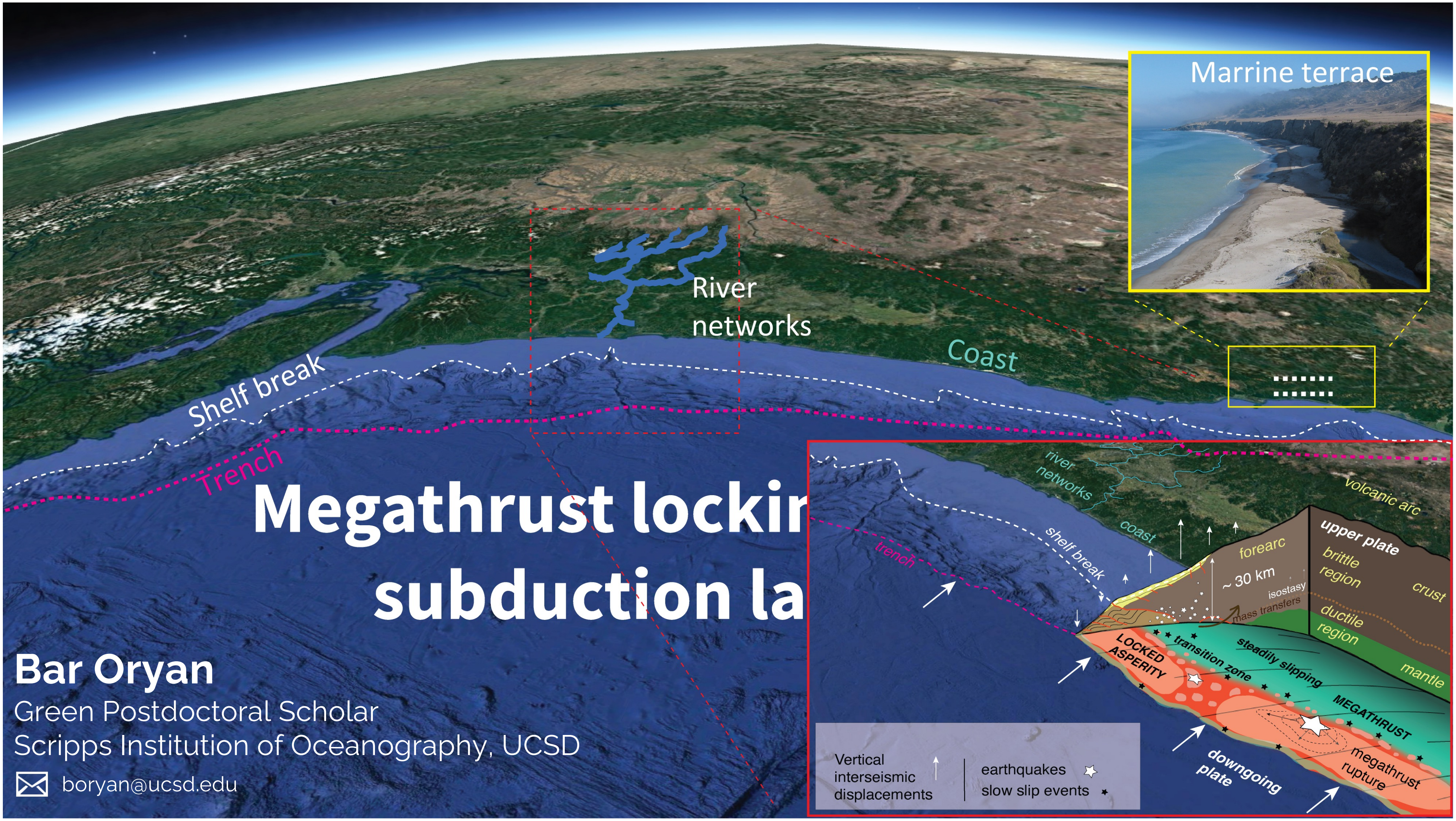
Marrine terrace
River networks
Coast
Shelf break
Trench
Megathrust lockir
subduction la
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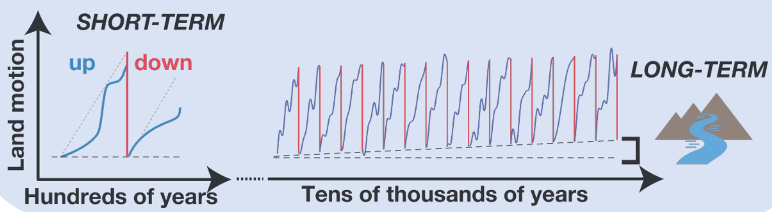
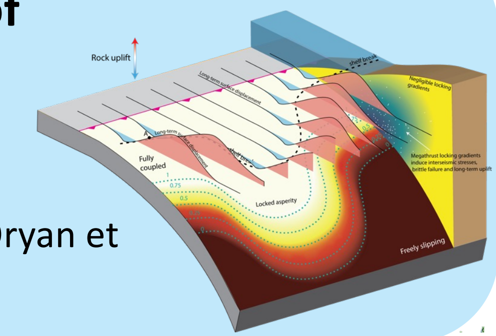
river networks
volcanic arc
coast
shelf break
trench
upper plate
forearc
brittle region
crust
~ 30 km
isostasy
mass transfers
ductile region
mantle
LOCKED ASPERITY
transition zone
steadily slipping
MEGATHRUST
megathrust rupture
downgoing plate
Vertical interseismic displacements
earthquakes
slow slip events

TALK OUTLINE

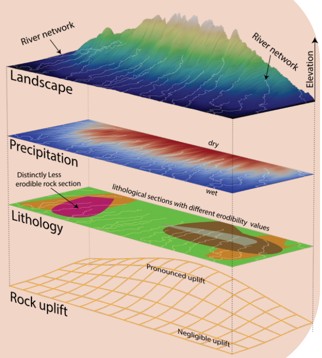
Introduction



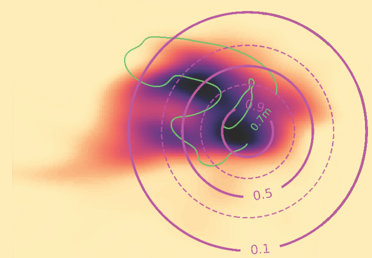
Fingerprints of Megathrust Locking in Subduction Landscapes [Oryan et al.,2024]



Inferring Long-Term Tectonic Uplift from Bayesian Inversion of Landscapes [Oryan et al. in review]



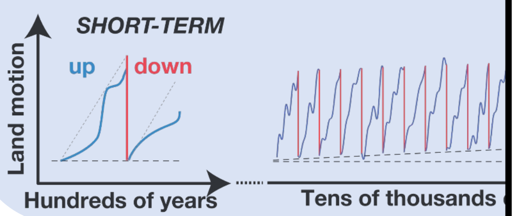
Future research



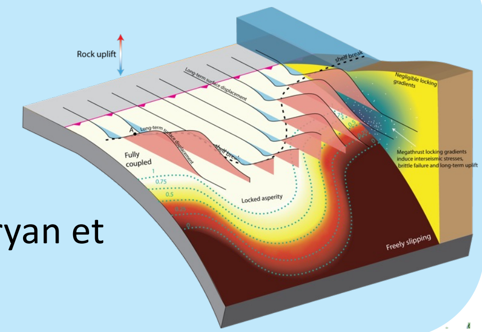
UNIVERSITY OF OREGON

TALK OUTLINE

Introduc



[Oryan et



Scan me for slides and references.

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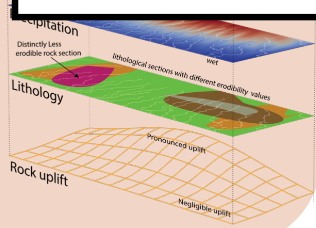
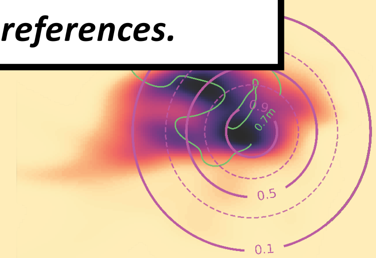


re research



UNIVERSITY OF OREGON

Section 1 - Introduction

Utagawa Kokunimasa, woodblock print, 1896

GREAT MEGATHRUST EARTHQUAKES IN THE PAST 20 YEARS

1. 2004 Sumatra-Andaman Earthquake (Mw 9.3)

- **Date:** December 26, 2004
- **Location:** Off the west coast of northern Sumatra, Indonesia
- **Impact:** Triggered a catastrophic tsunami, causing over 230,000 deaths across 14 countries.

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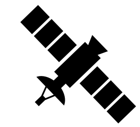
3. **2011 Tōhoku Earthquake (Mw 9.1)**
   - **Date:** March 11, 2011
   - **Location:** Off the east coast of Honshu, Japan
   - **Impact:** Generated a massive tsunami, leading to nearly 16,000 deaths and the Fukushima nuclear disaster.

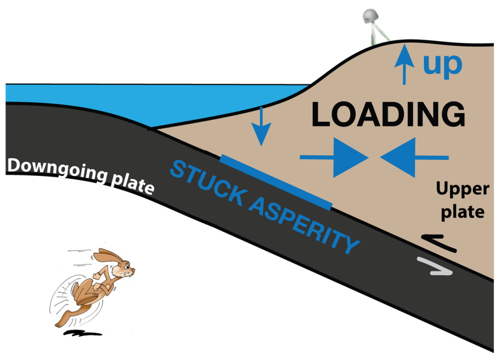
EARTHQUAKE CYCLES IN SUBDUCTION ZONES

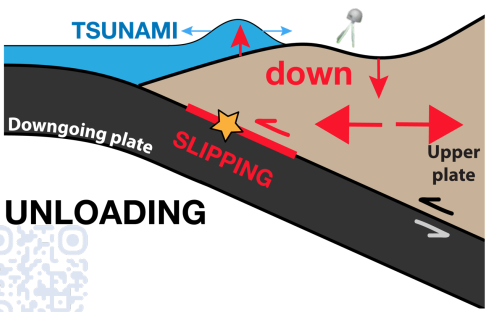


Long-term: downgoing plate descends beneath the upper plate in stick-slip fashion.

Interseismic: locked section is “stuck”. Creeping section moves slowly.

Stress build up





Coseismic: locked section moves abruptly.

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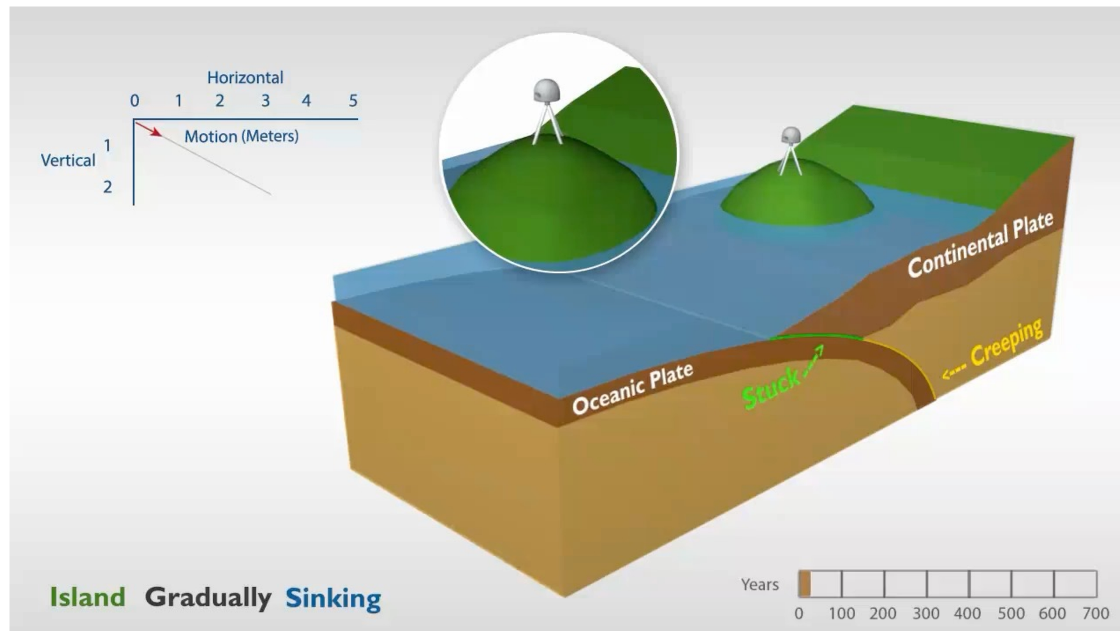

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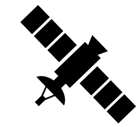

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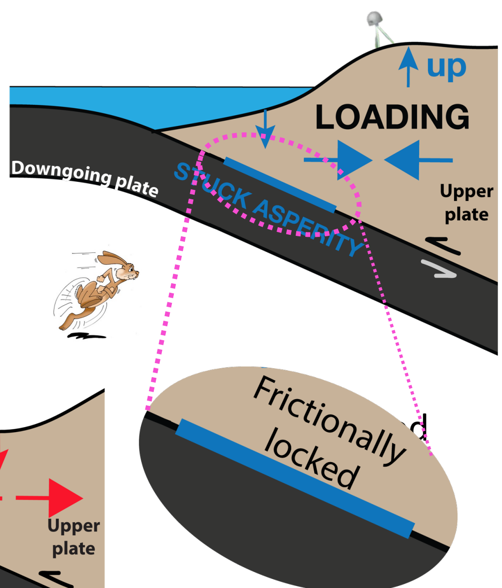

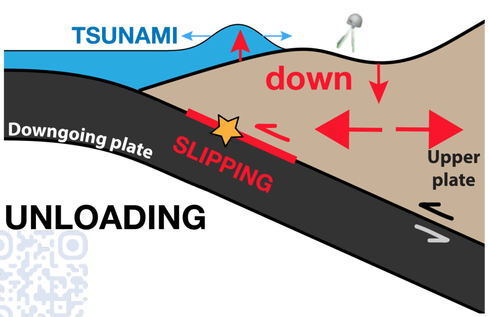

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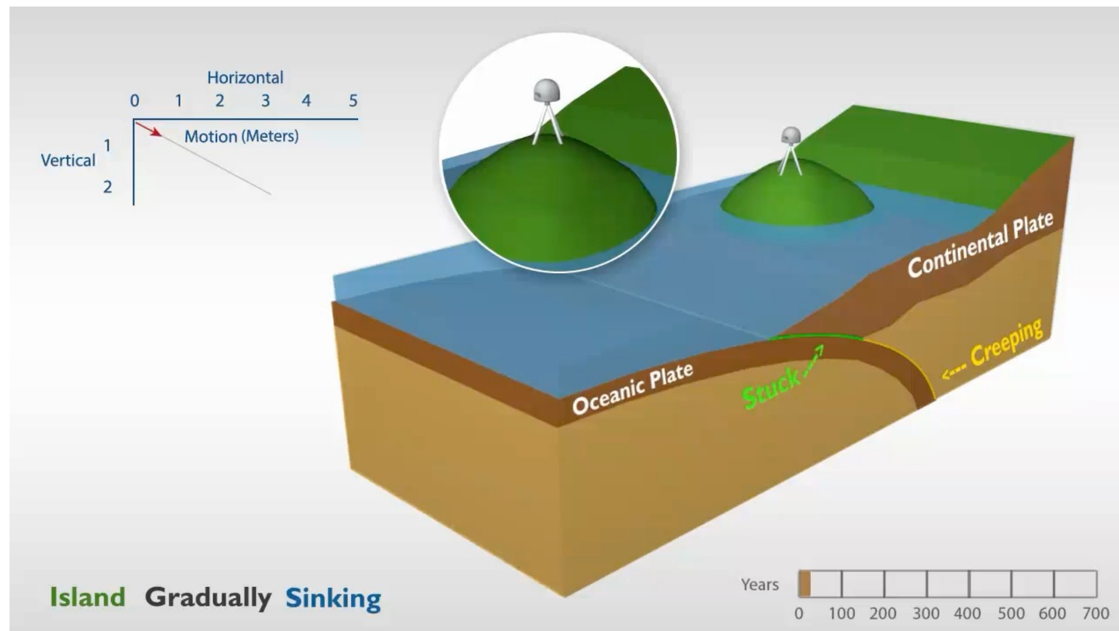

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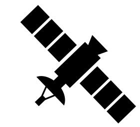

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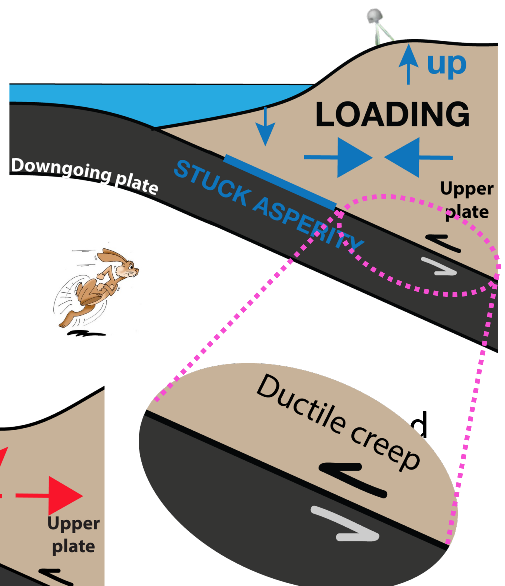

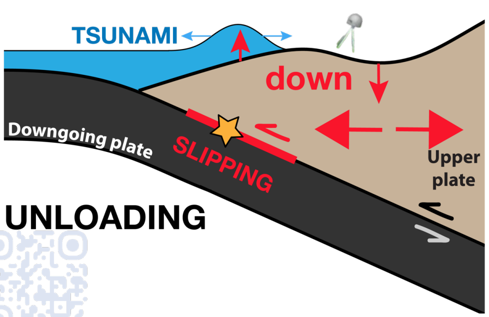

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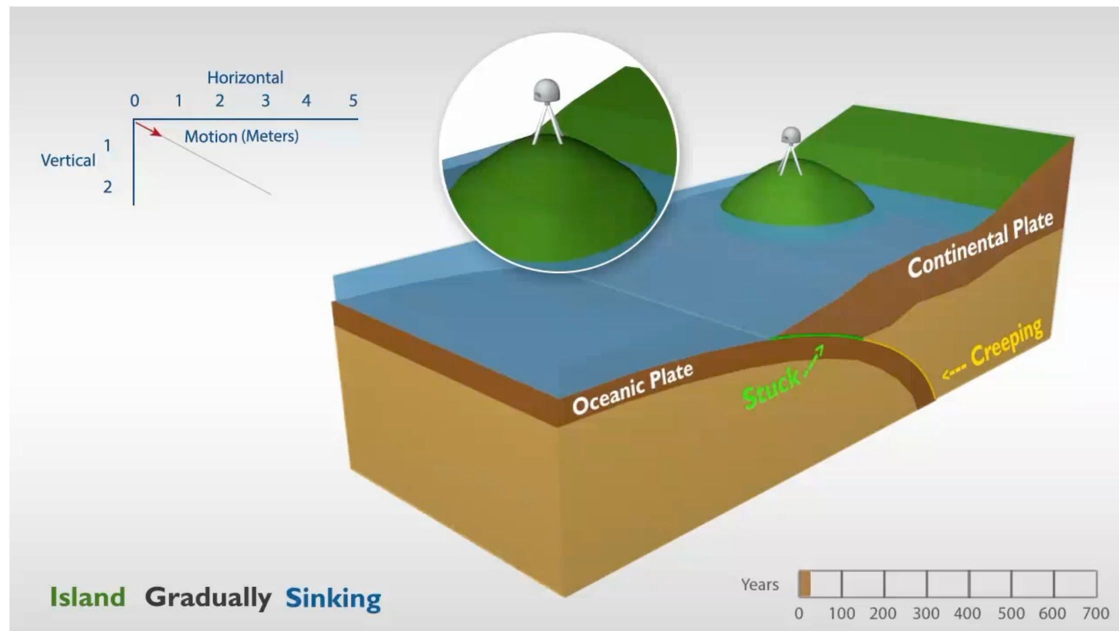

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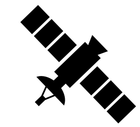

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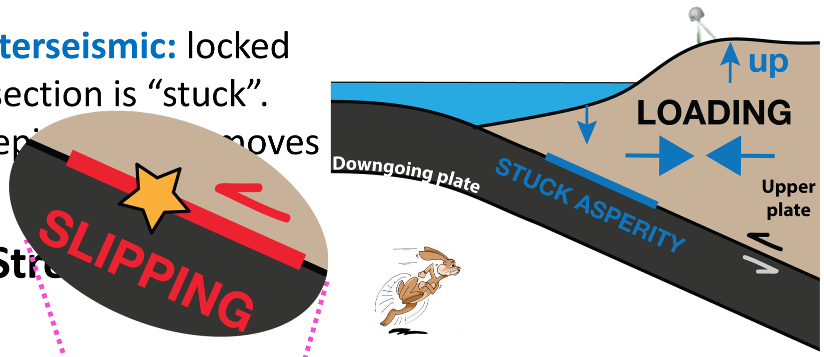
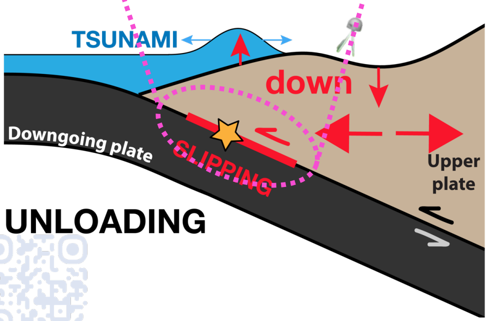


Str...



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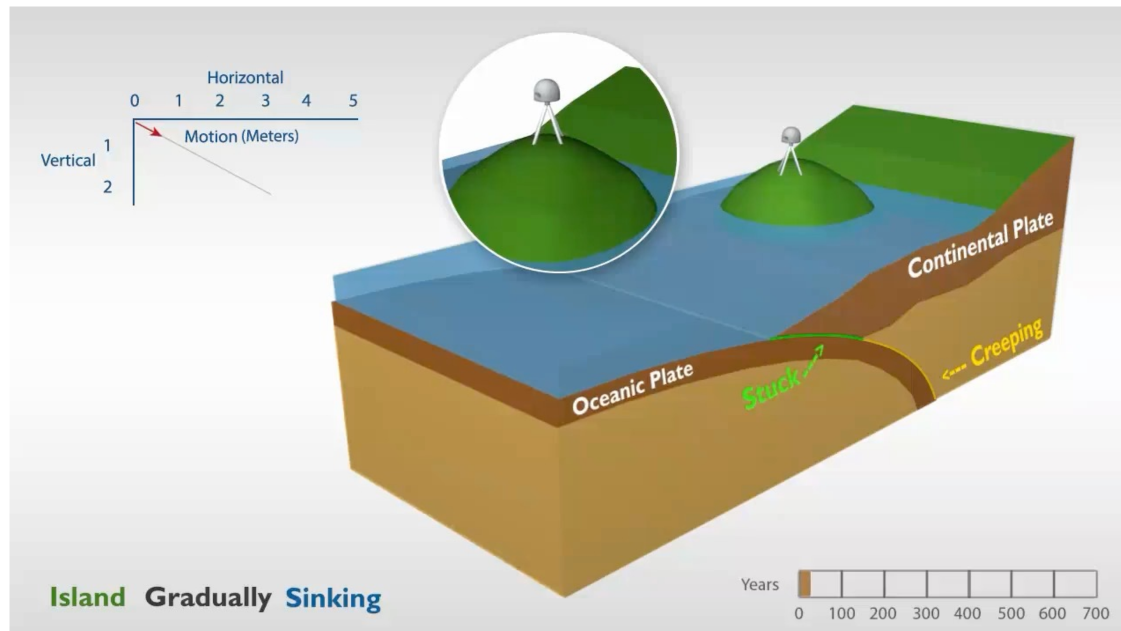
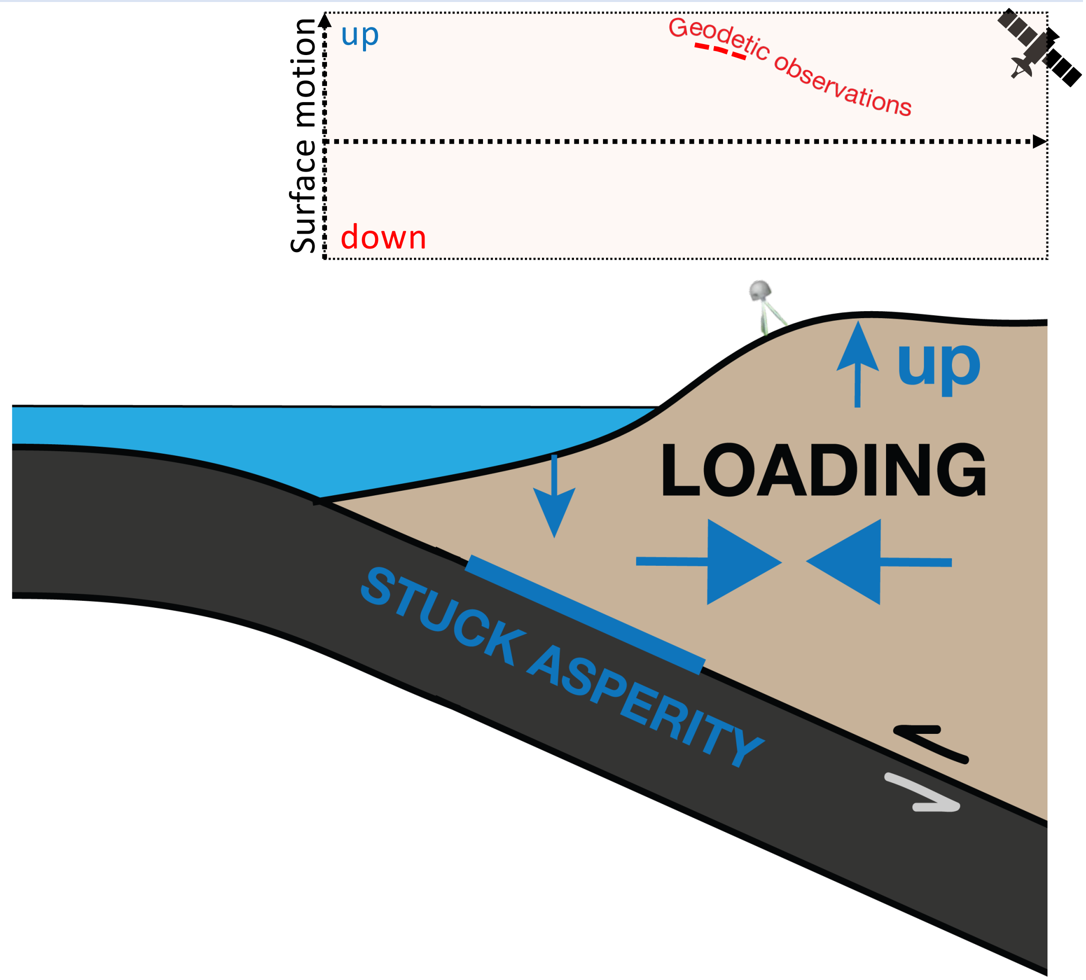


CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

- Deployment of GNSS stations and InSAR data collection have greatly **improved** the **availability** of **geodetic** data in recent decades.



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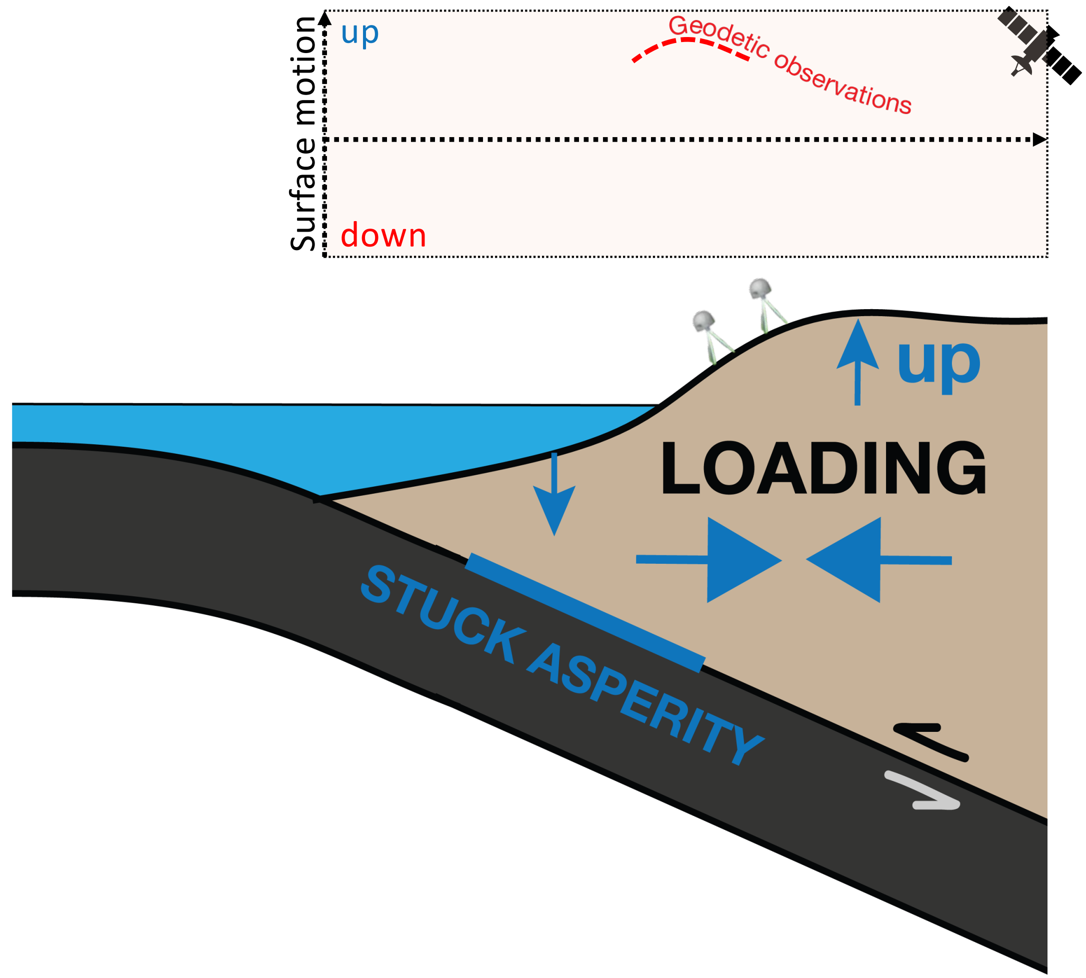

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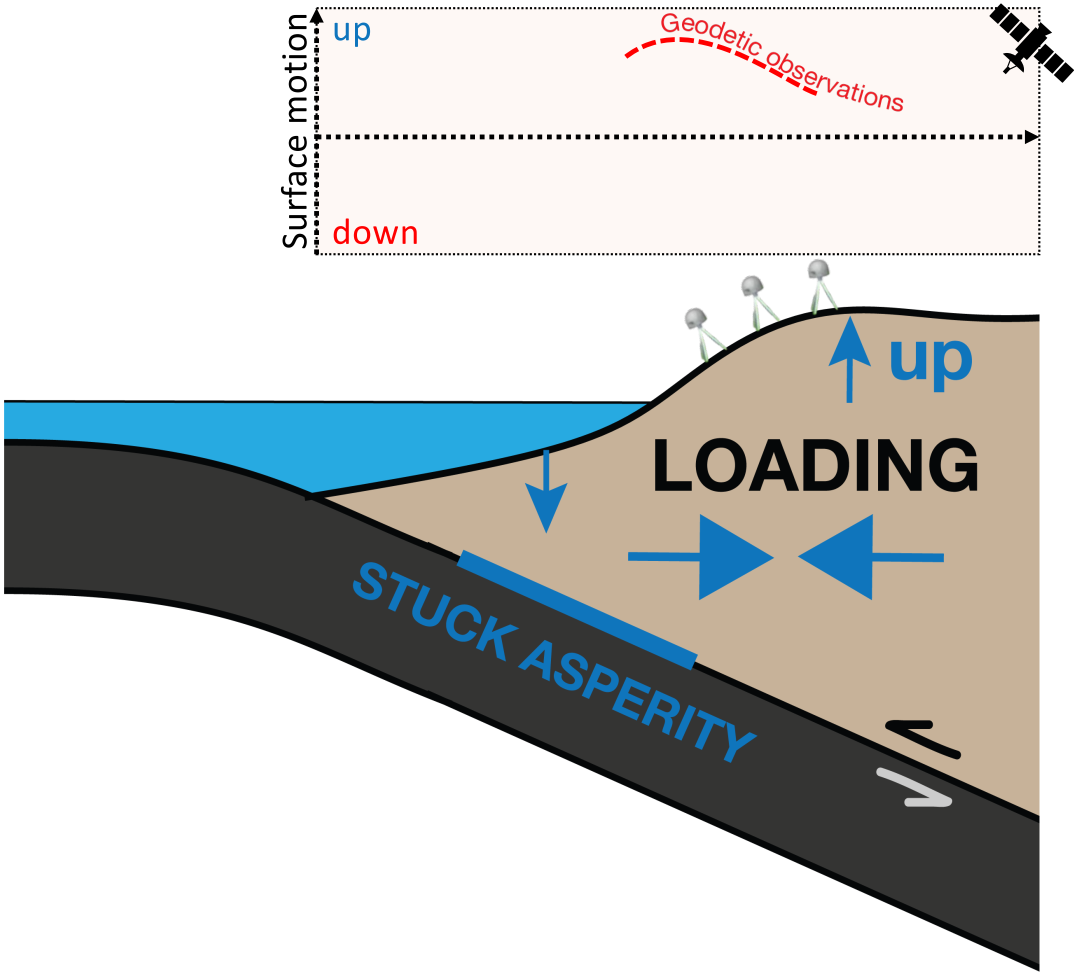

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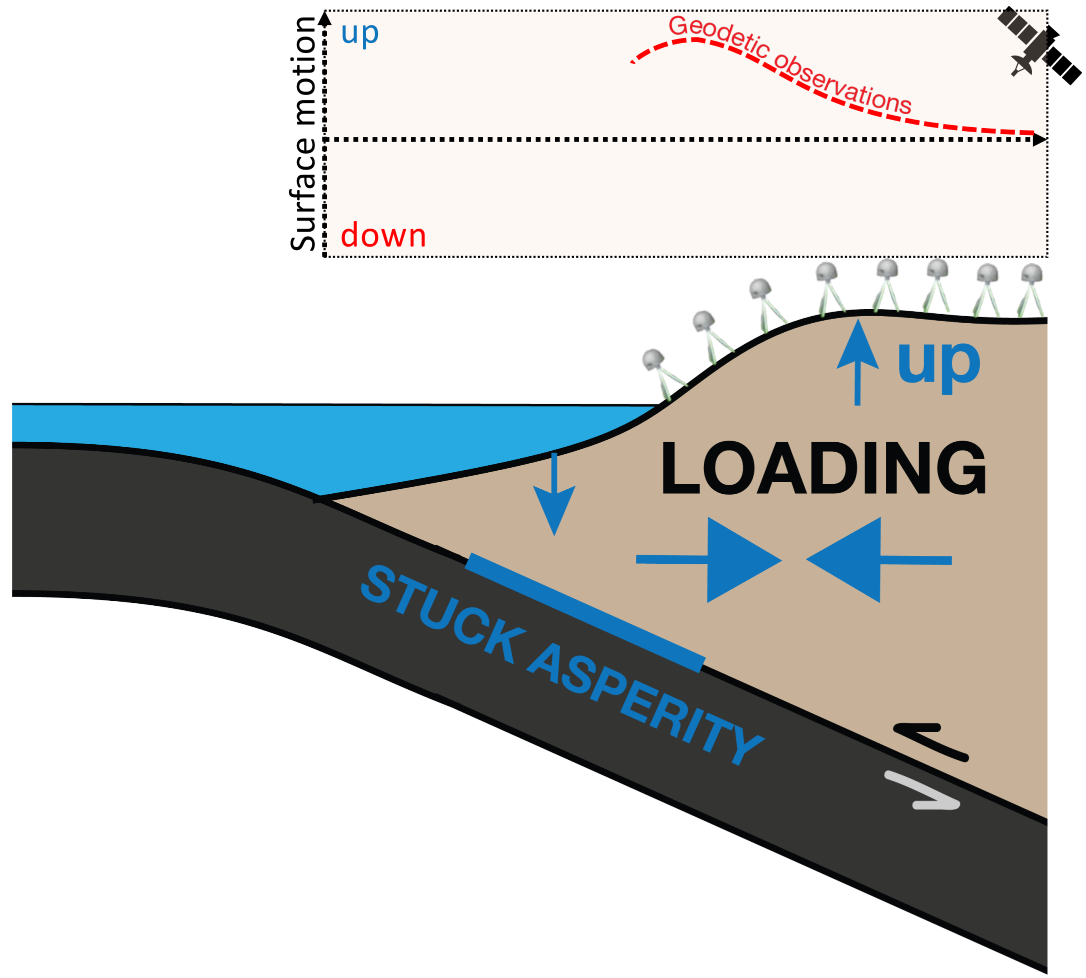

CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

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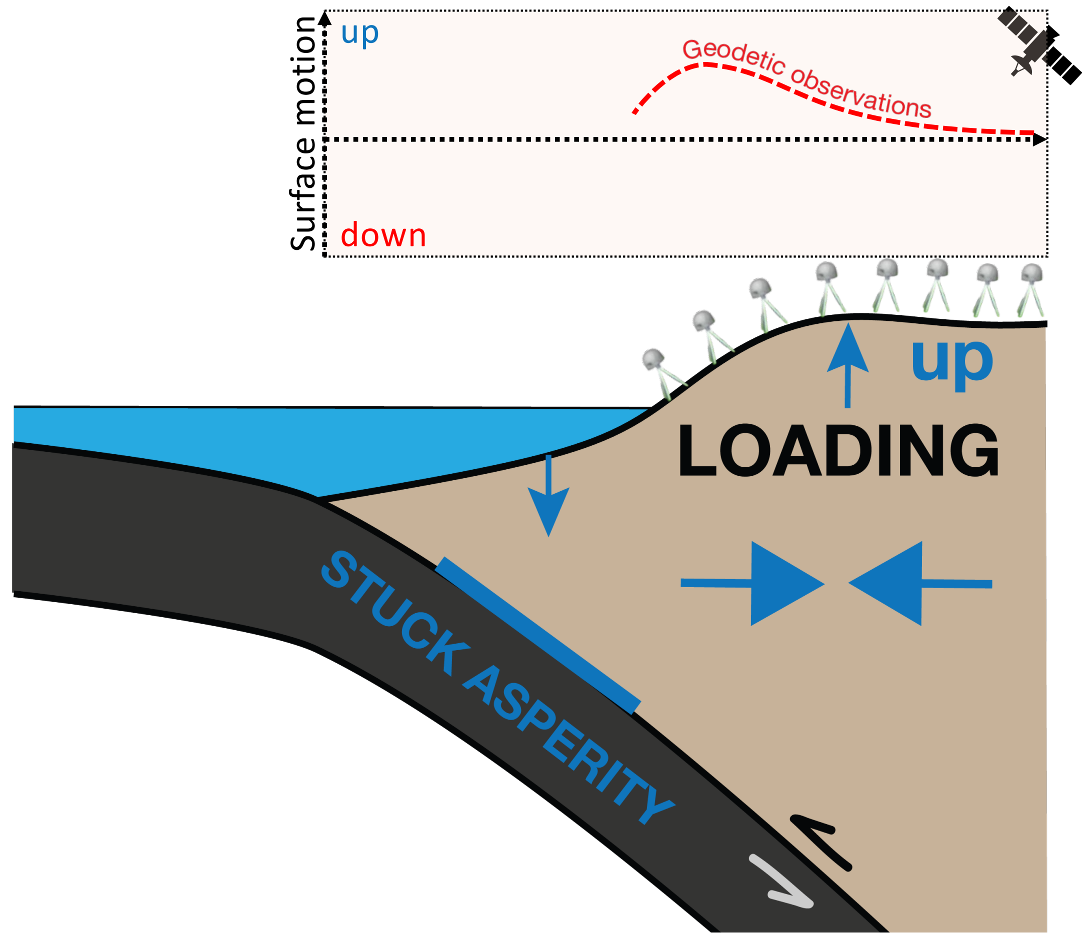
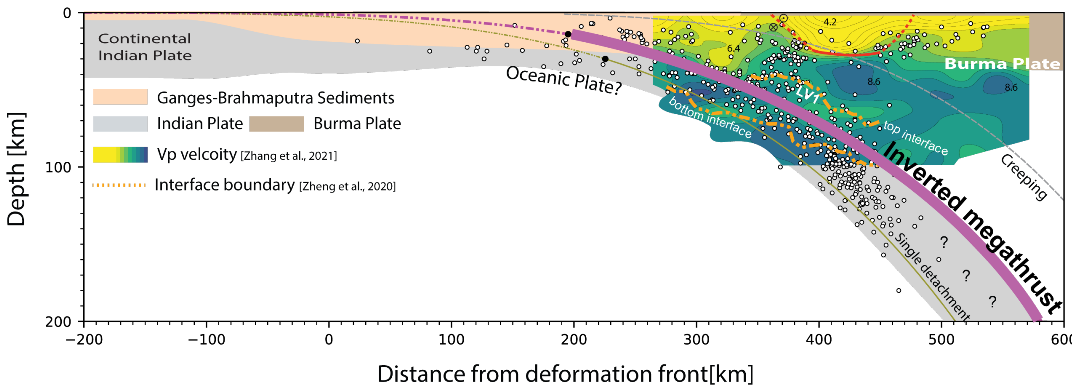


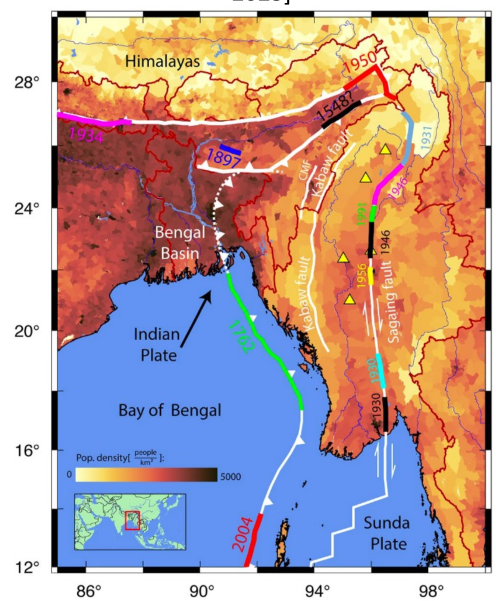
CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

Inversion of Indo-Burma megathrust geometry from GNSS data [Oryan et al., 2023]



- Inversion for **megathrust convergence rate** and **geometry** underscores the hazard associated with the Indo-Burma megathrust and its potential impact on approximately 200 million people living in the Bengal Basin.

Population density and previous earthquakes in the Indo-Burma subduction zone region [Oryan et al., 2023]



Oryan et al., 2023

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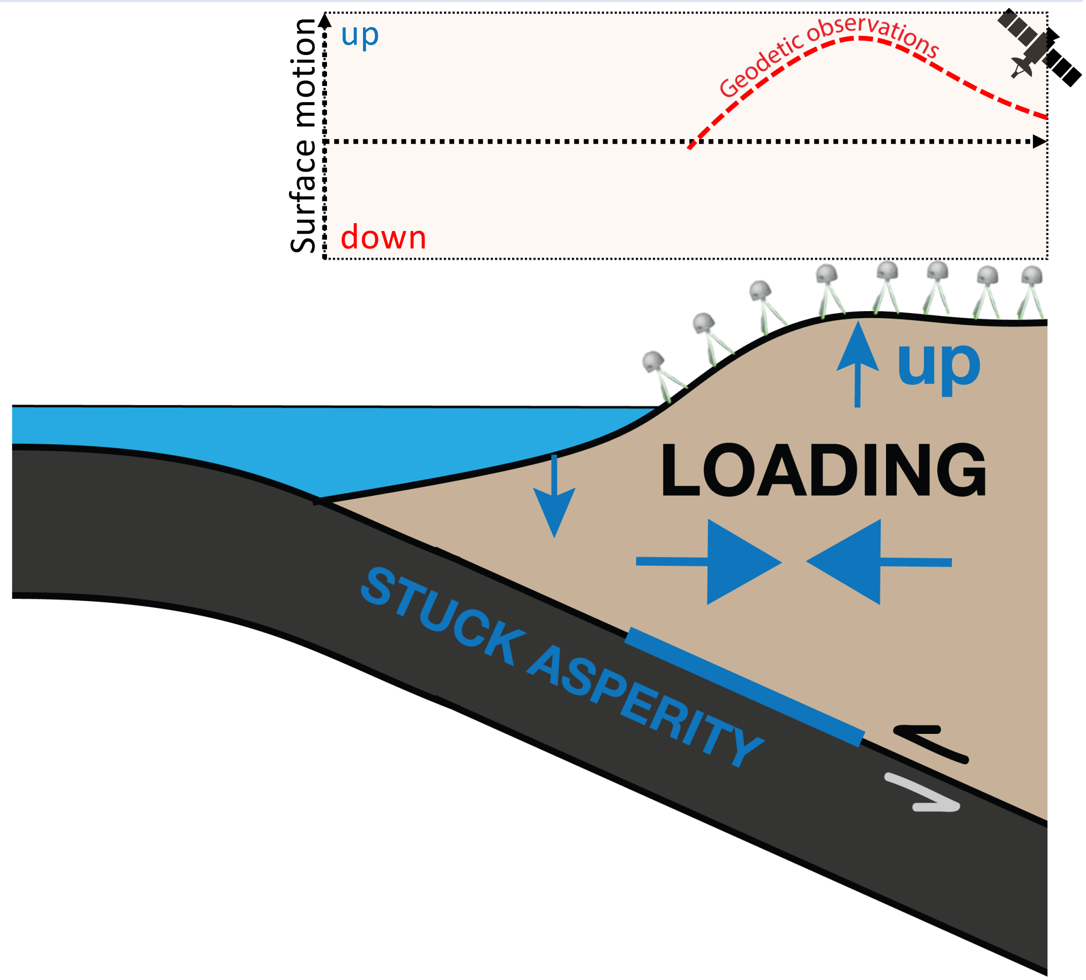

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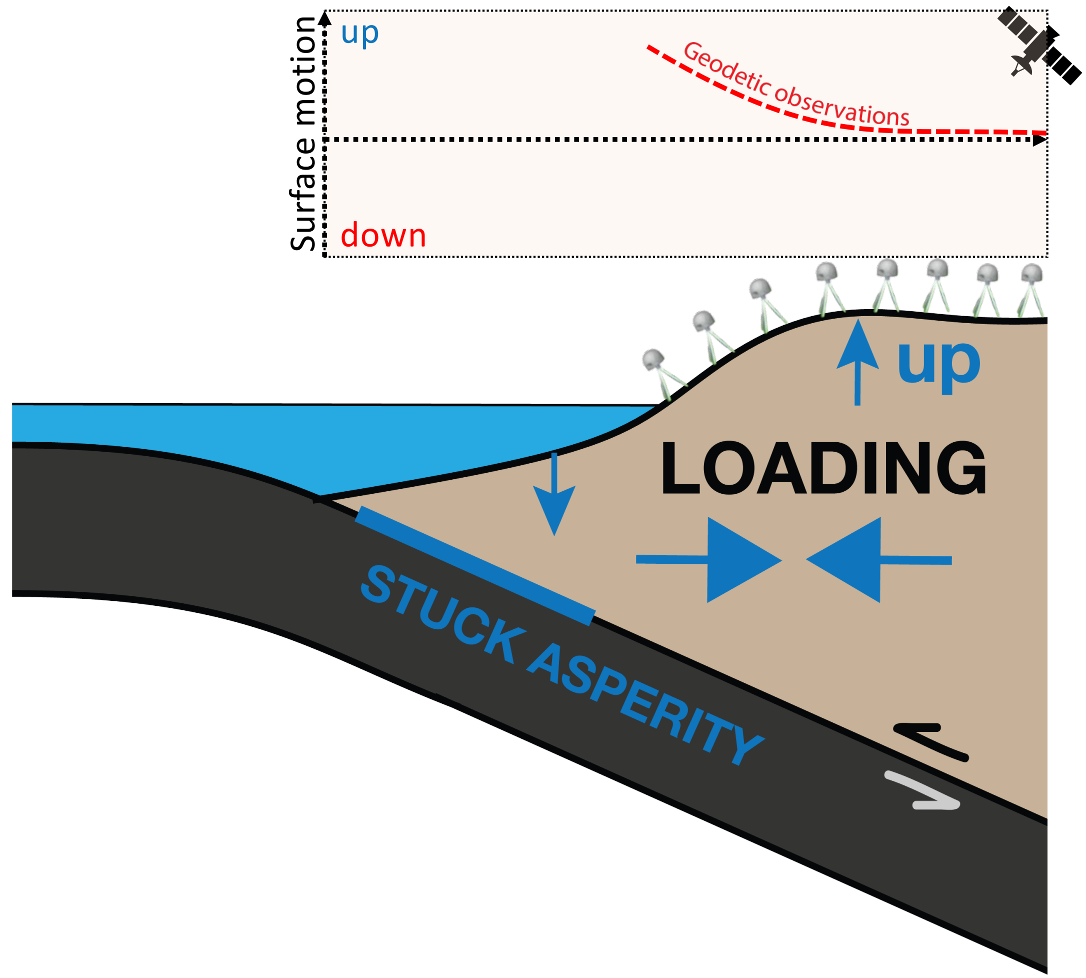

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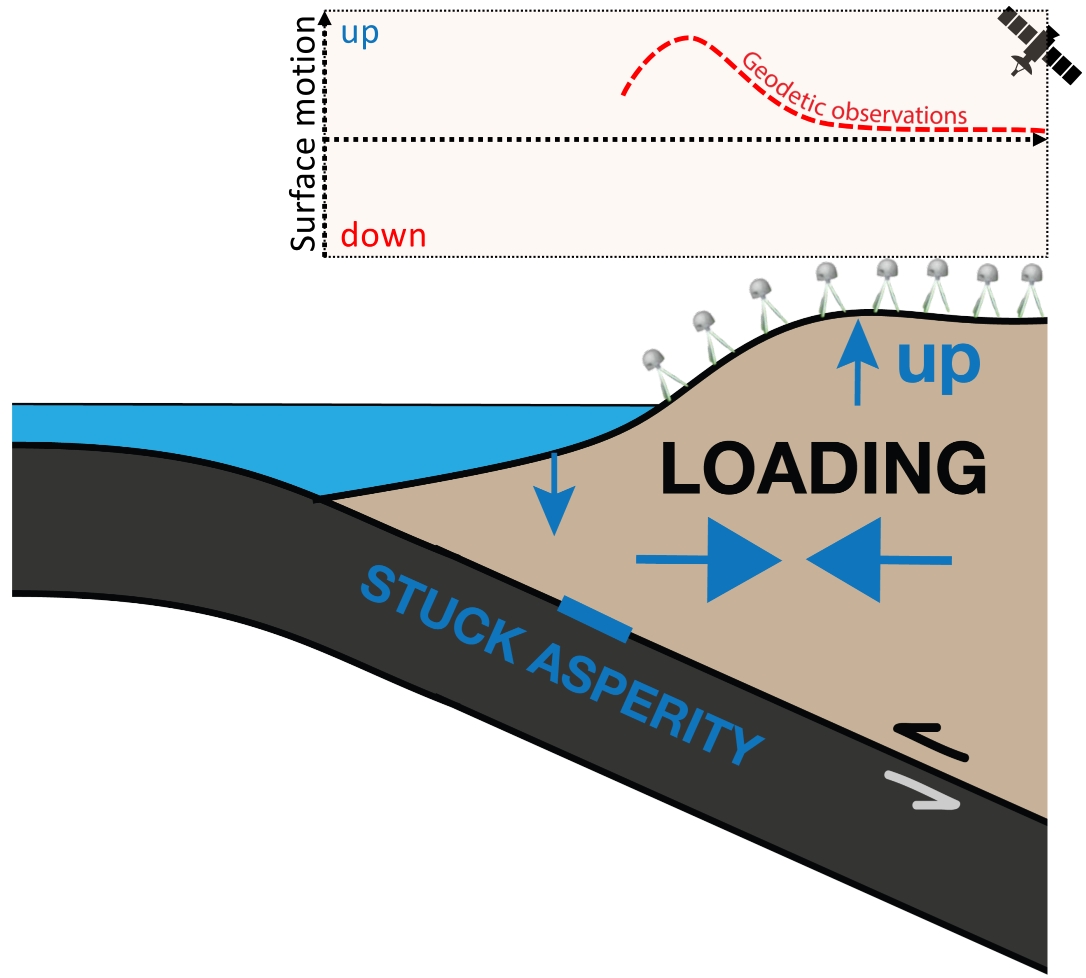

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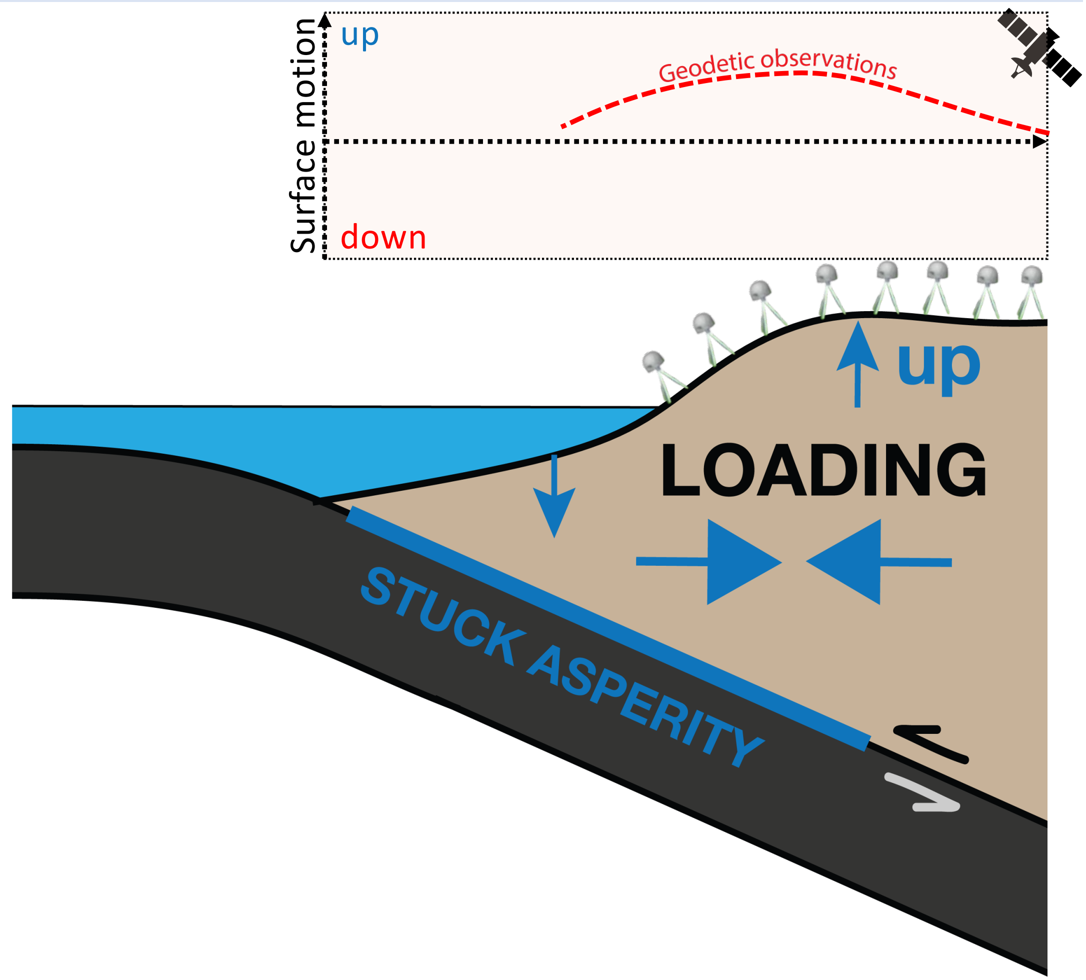

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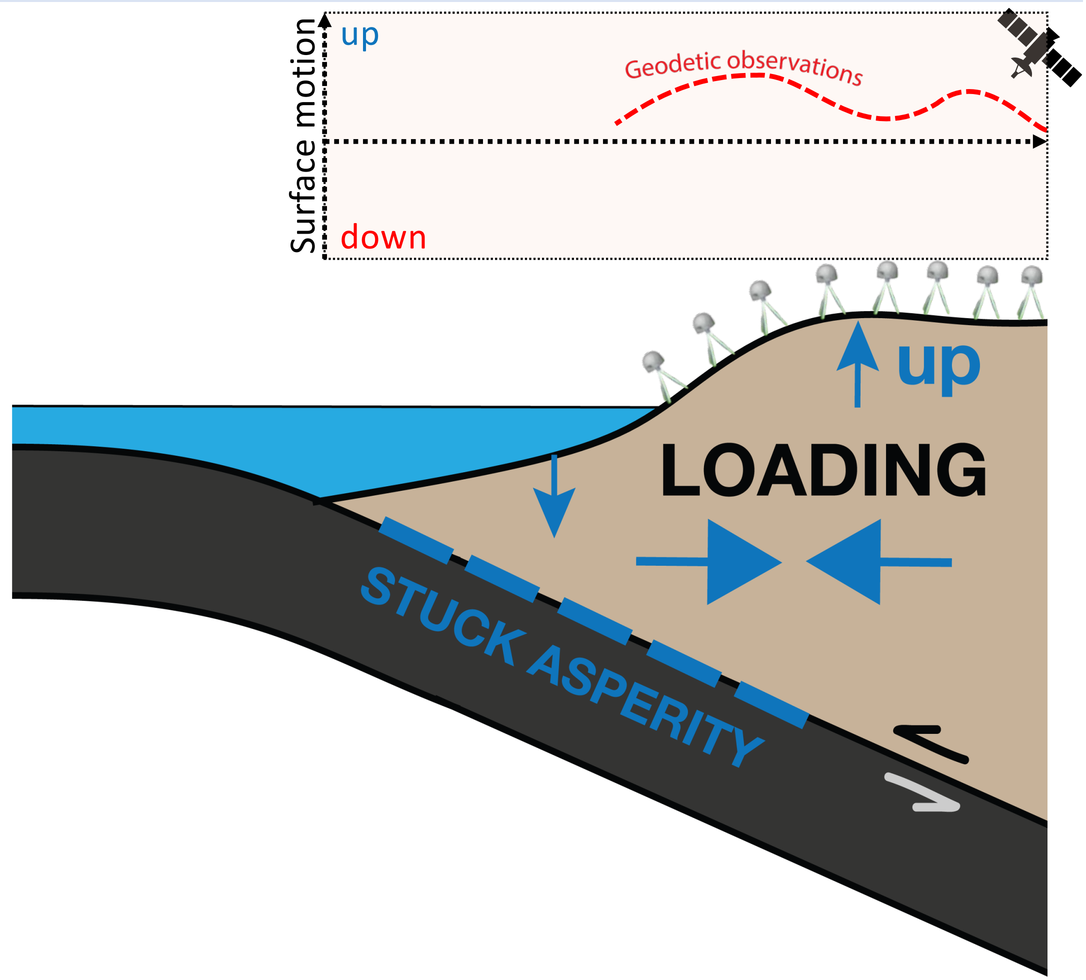

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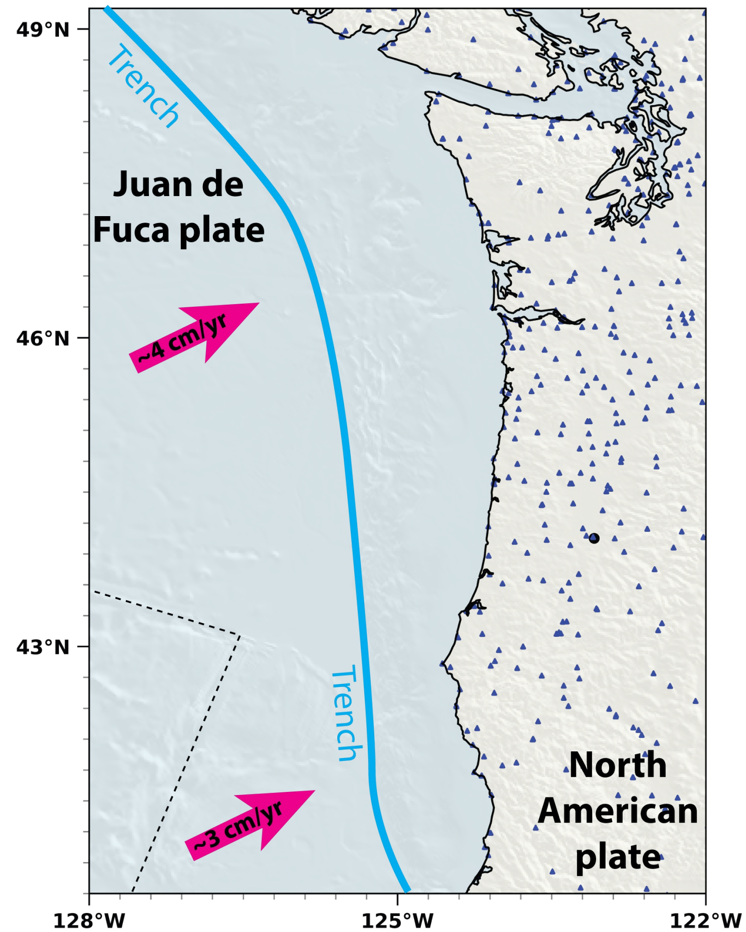
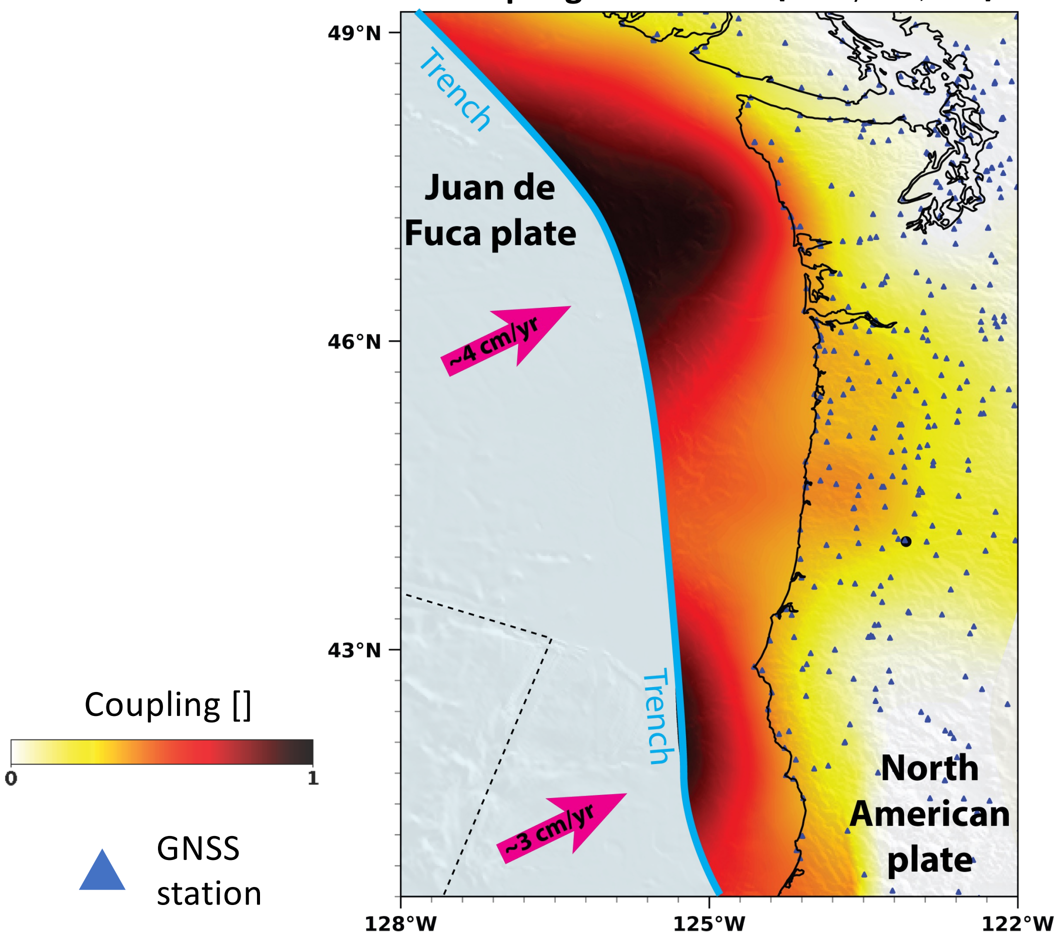


GNSS station

CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

- Locked asperities along the megathrust are often represented using coupling maps.

Coupling in Cascadia [Lindsey et al., 2021]



CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

- Locked asperities are often represented using coupling maps.
- Regions with high coupling values are considered locked and stationary.

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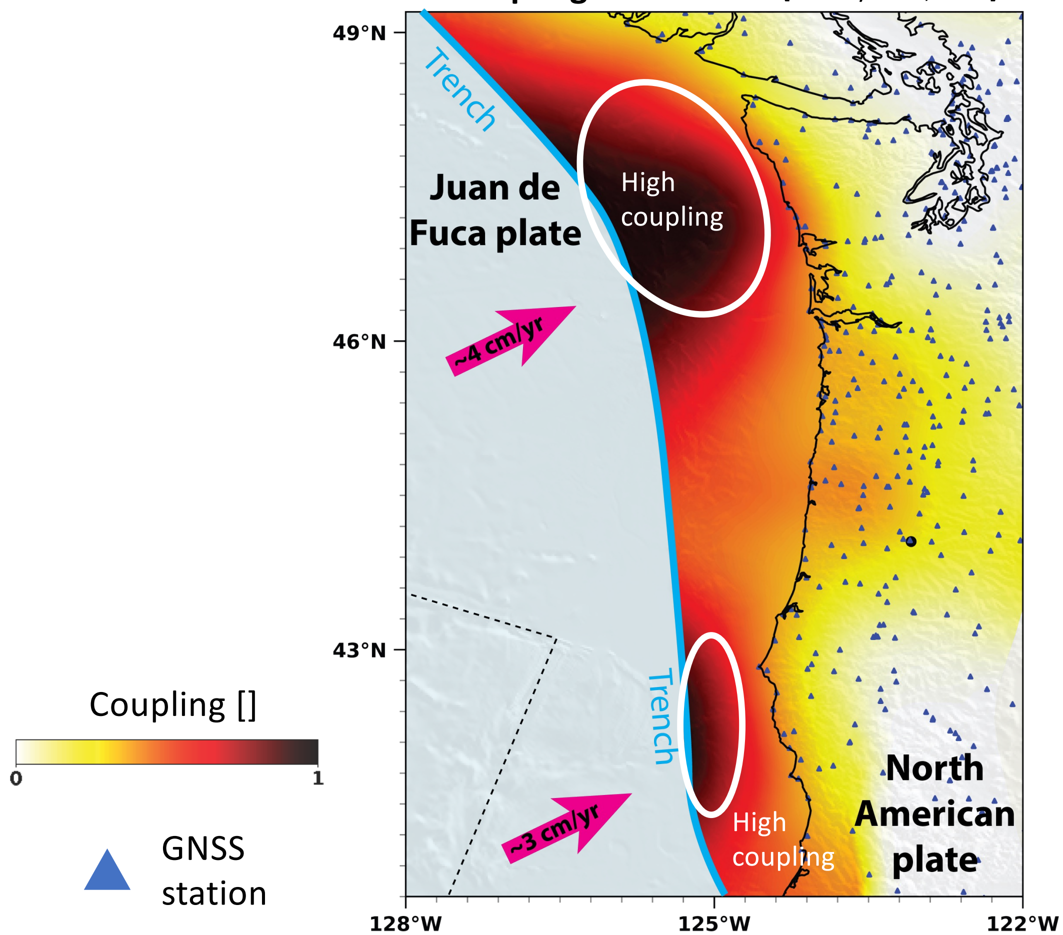

CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

- Locked asperities are often represented using coupling maps.
- Regions with high coupling values are considered locked and stationary.
- These locked regions are believed to accumulate interseismic stresses and are more likely to generate megathrust events.

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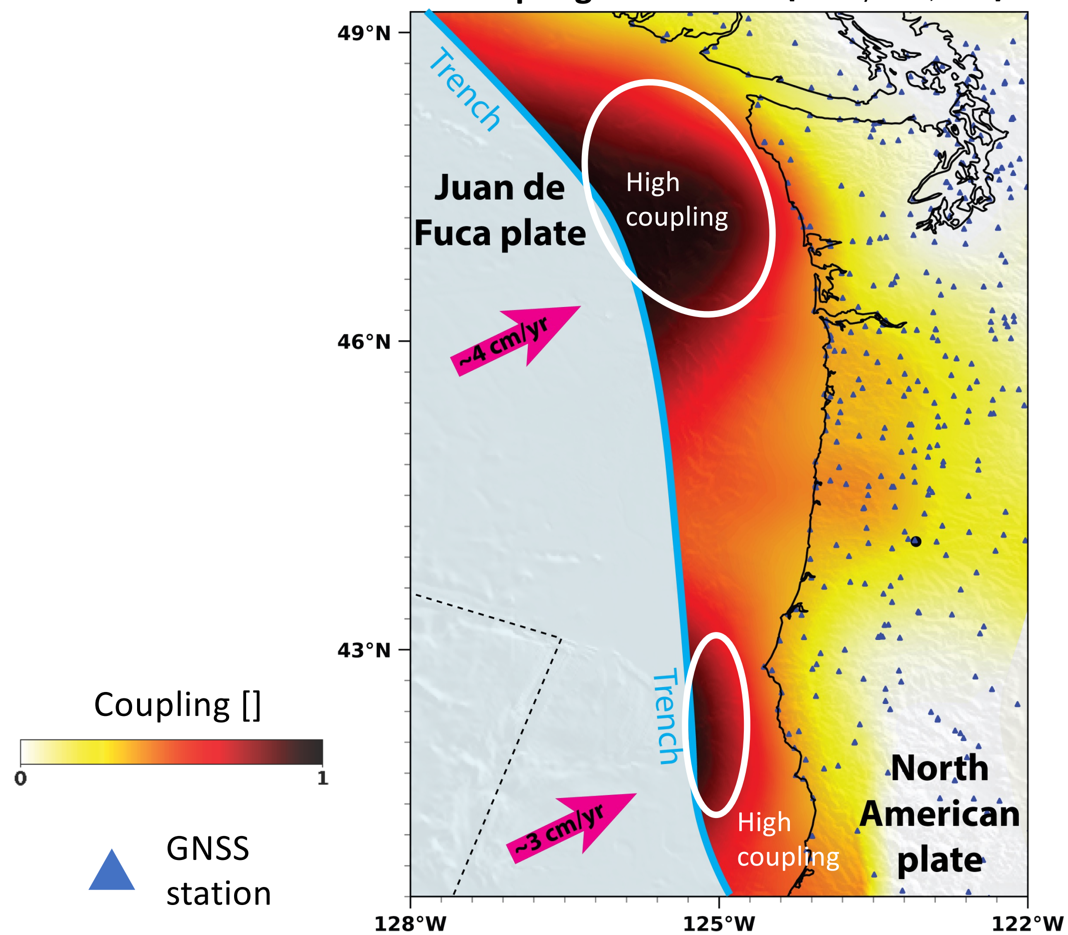
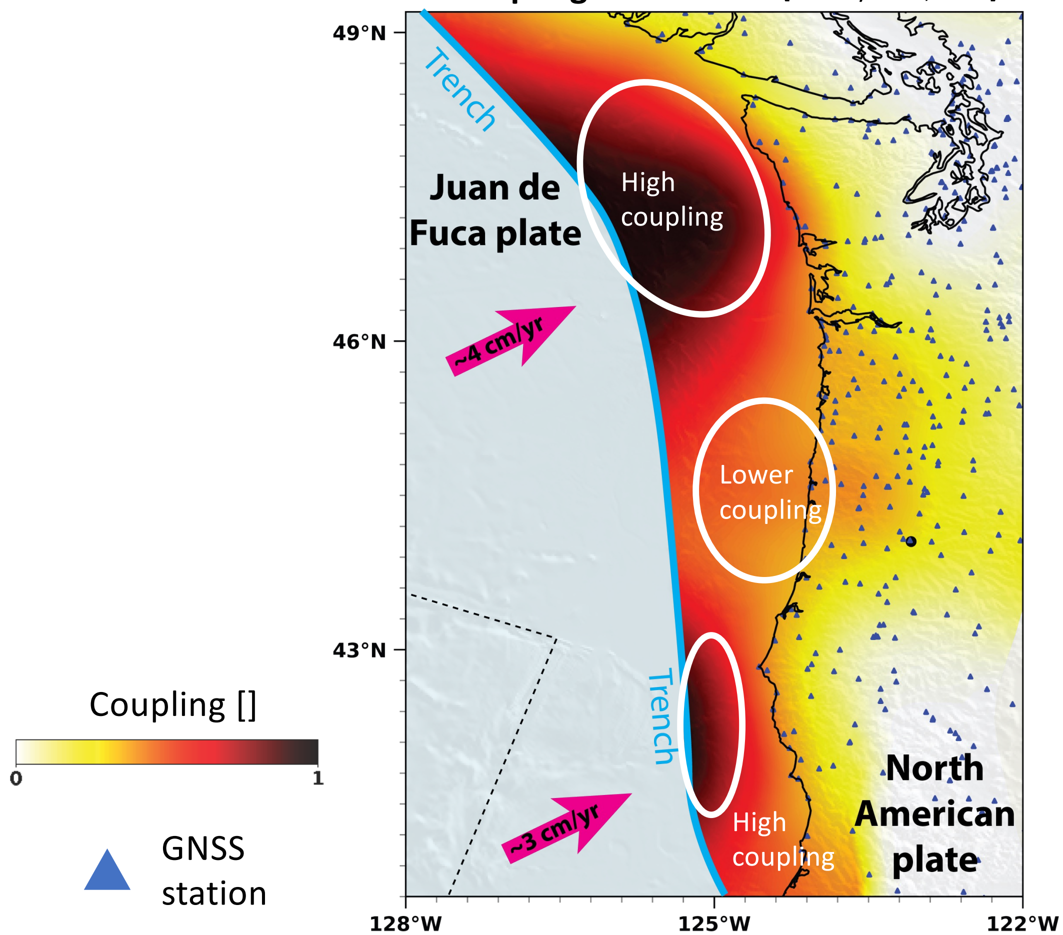


CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

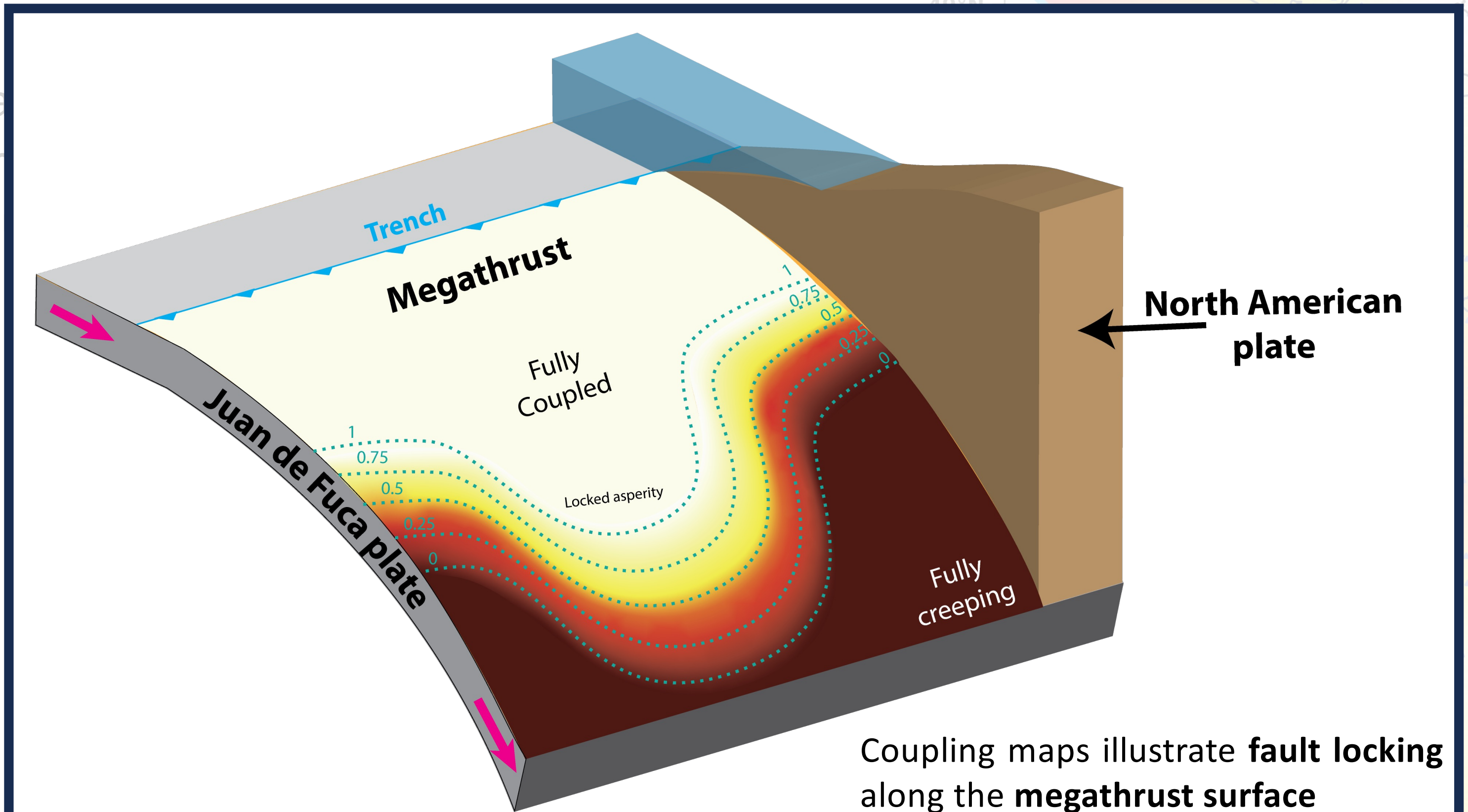
- Locked asperities are often represented using coupling maps.
- Regions with high coupling values are considered locked and stationary.
- These locked regions are believed to accumulate interseismic stress and are more likely to generate megathrust events.
- In contrast, regions with low coupling values are thought to creep during the interseismic period and are less likely to rupture.

Coupling in Cascadia [Lindsey et al., 2021]



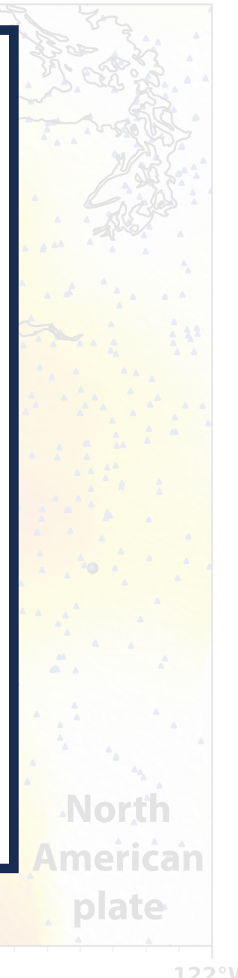
CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

- Locked a
megathr
using co



Coupling maps illustrate **fault locking** along the **megathrust surface**

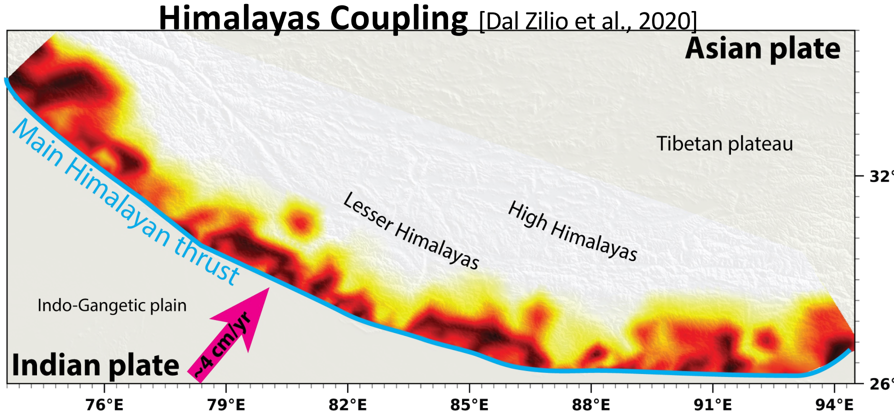
GNSS station



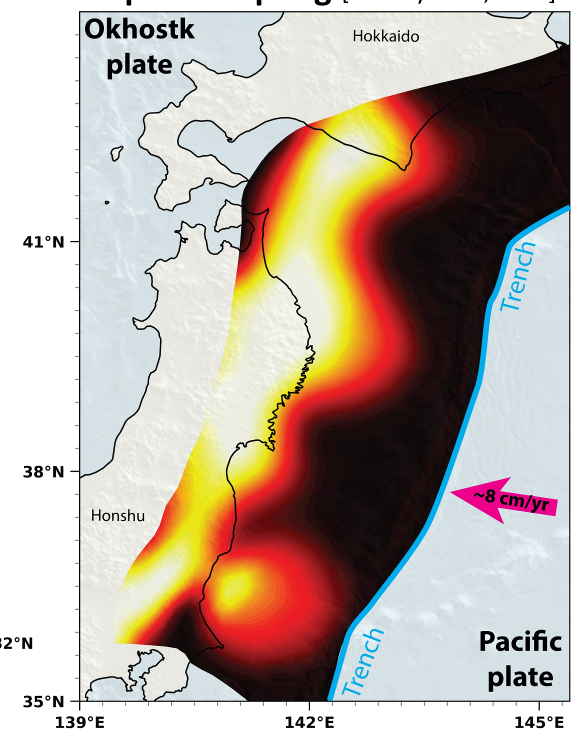
CONSTRAINING MEGATHRUST HAZARD IN SUBDUCTION ZONES

Coupling maps are used to illustrate fault locking variability across **nearly all megathrusts where geodetic data is available.**

Himalayas Coupling [Dal Zilio et al., 2020]

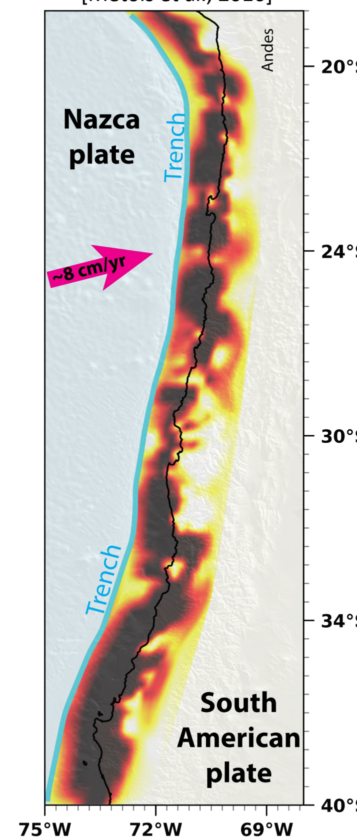


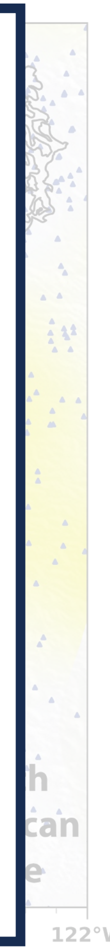
Japan Coupling [Lindsey et al., 2021]



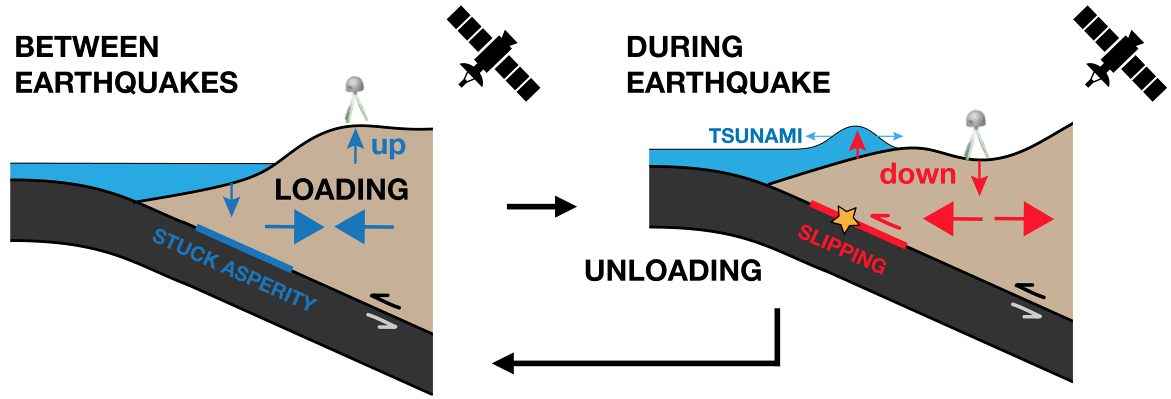
Chile Coupling

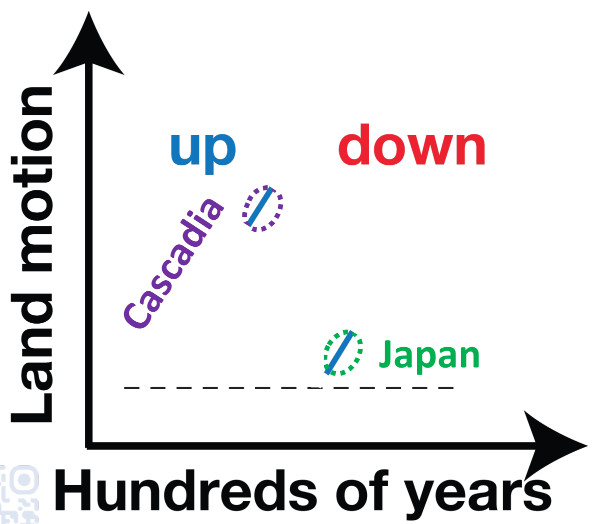
[Métois et al., 2016]





TEMPORAL LIMIATIONS OF GEODETIC DATA COVERAGE





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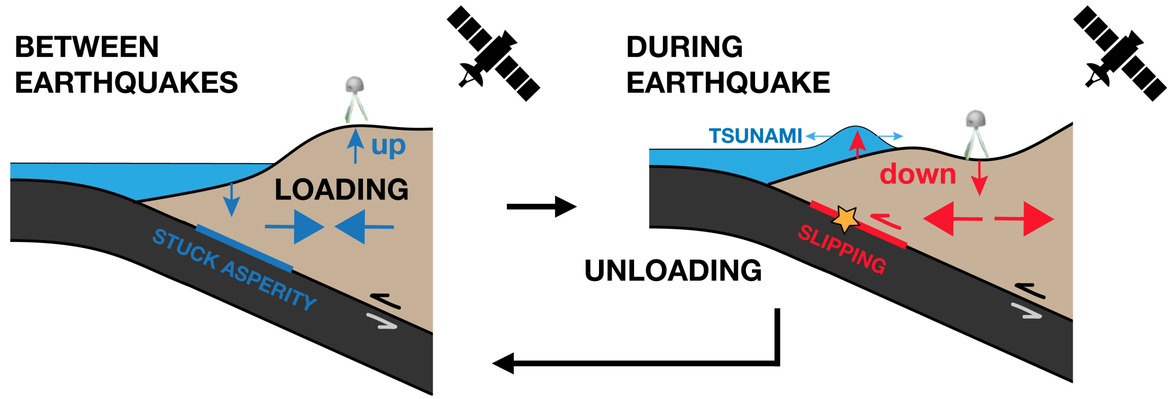

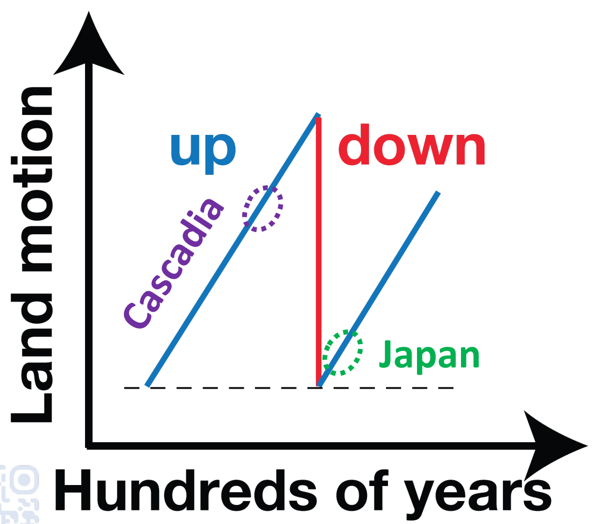

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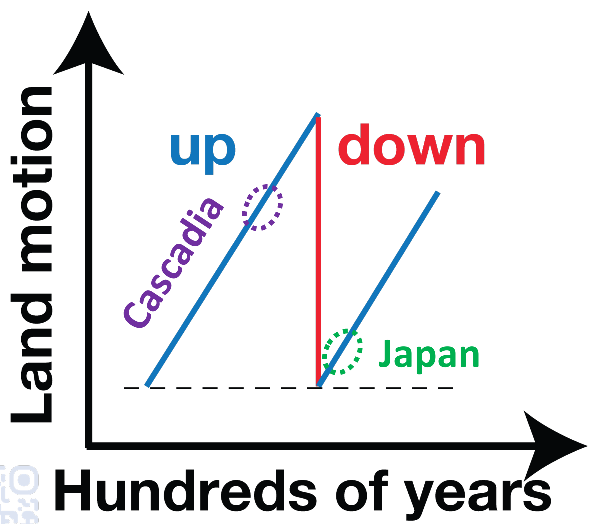

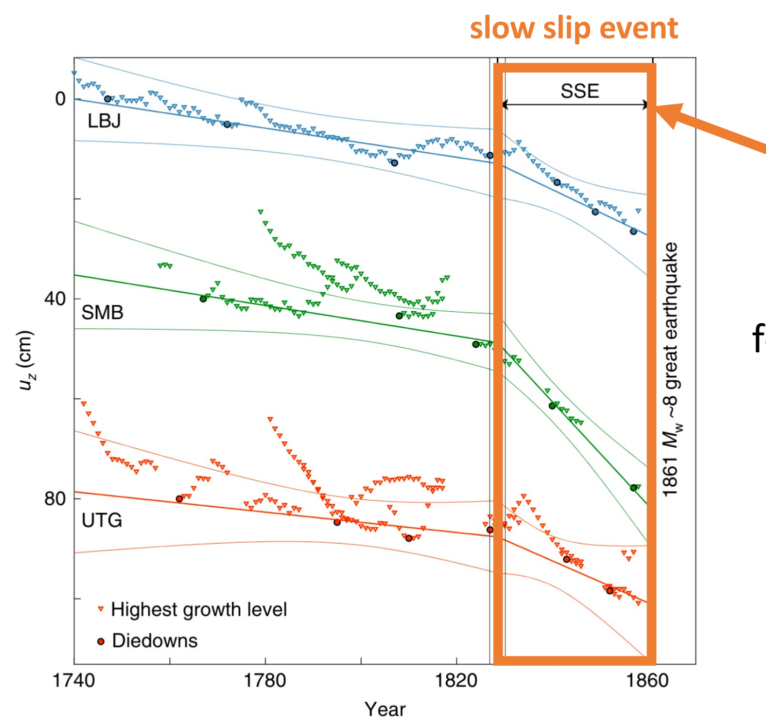

~40 years long slow slip event found in the coral reef record in Sumatra [Mallick et al., 2021]

Geodetic observations indicate that the state of **coupling may evolve through time.**

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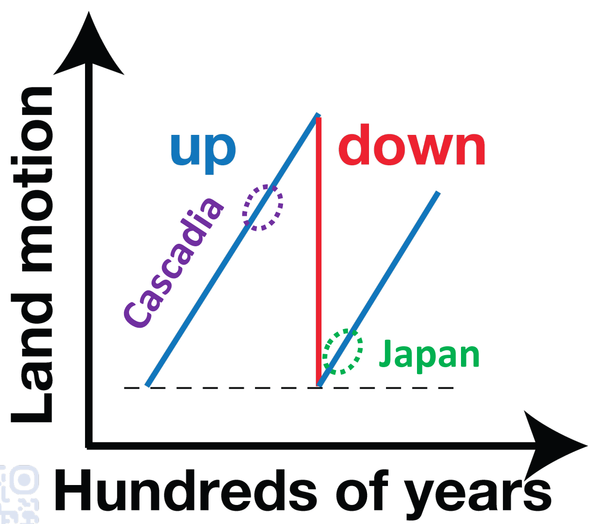
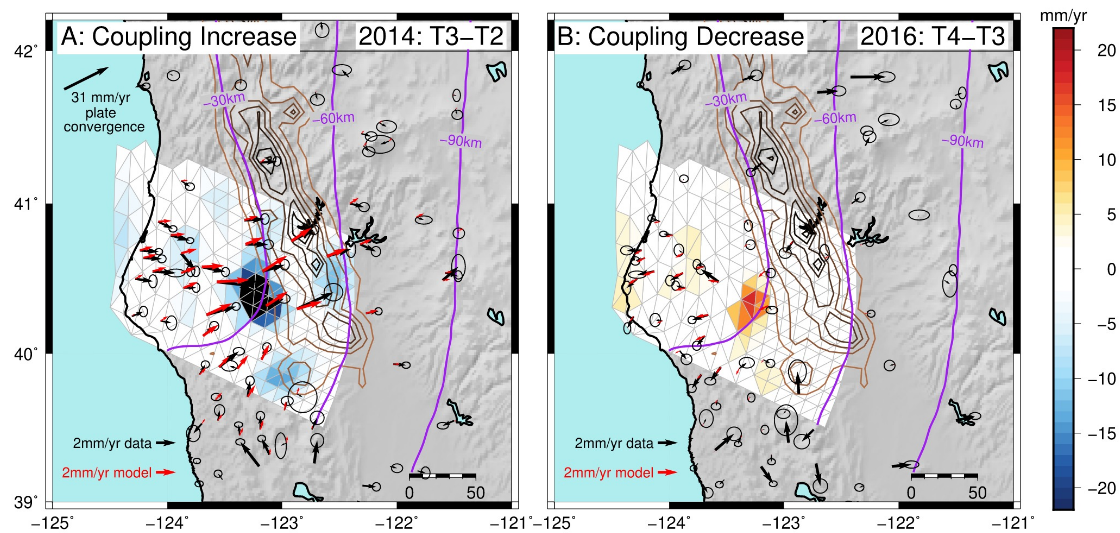


Cascadia coupling varies between 2014 and 2016 possibly driven by fluid migration [Materna et al., 2019]



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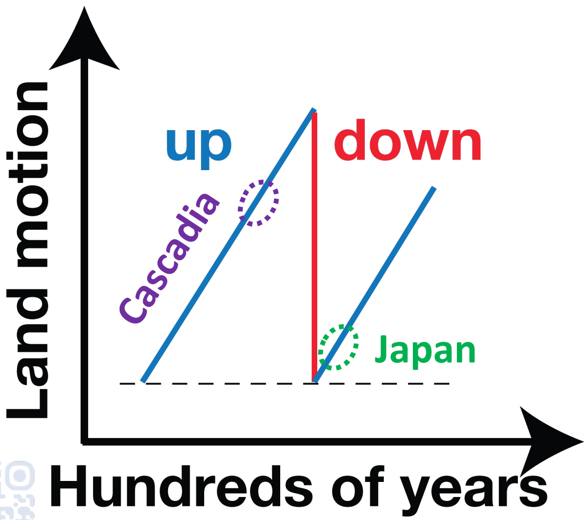
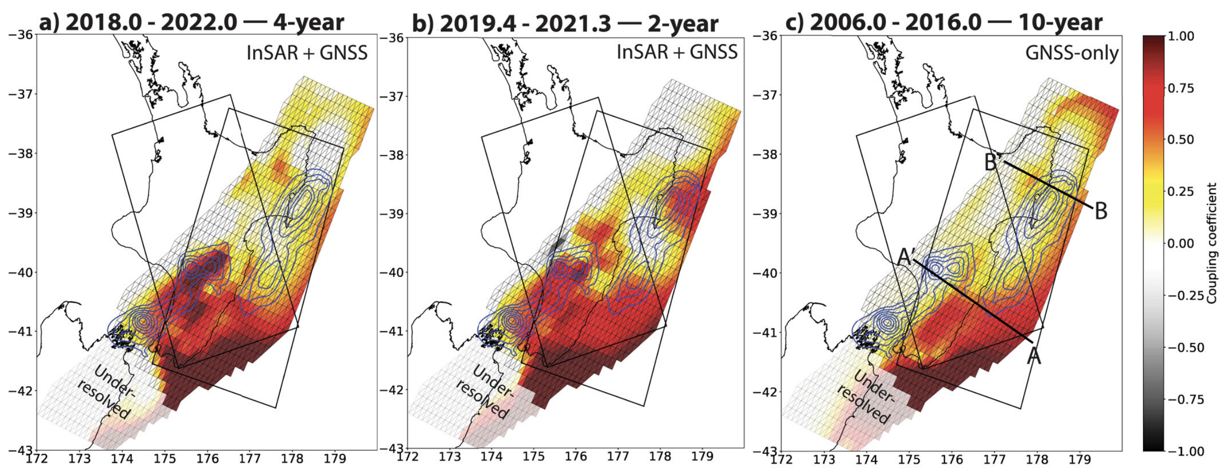


Locking in Hikurangi Subduction Zone varations based on different temporal resolution [Maubant et al., 2023].



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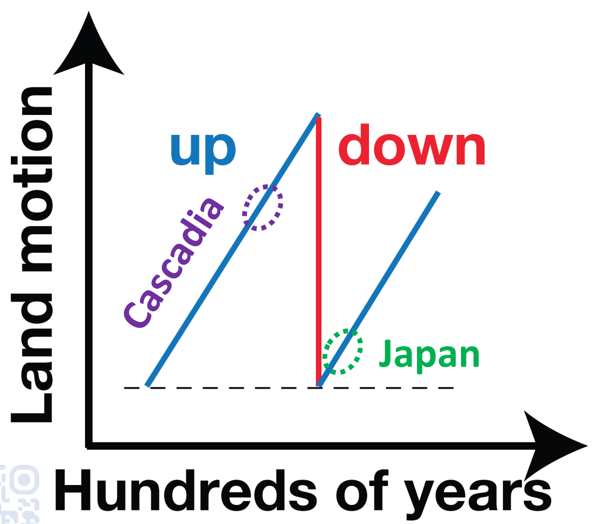
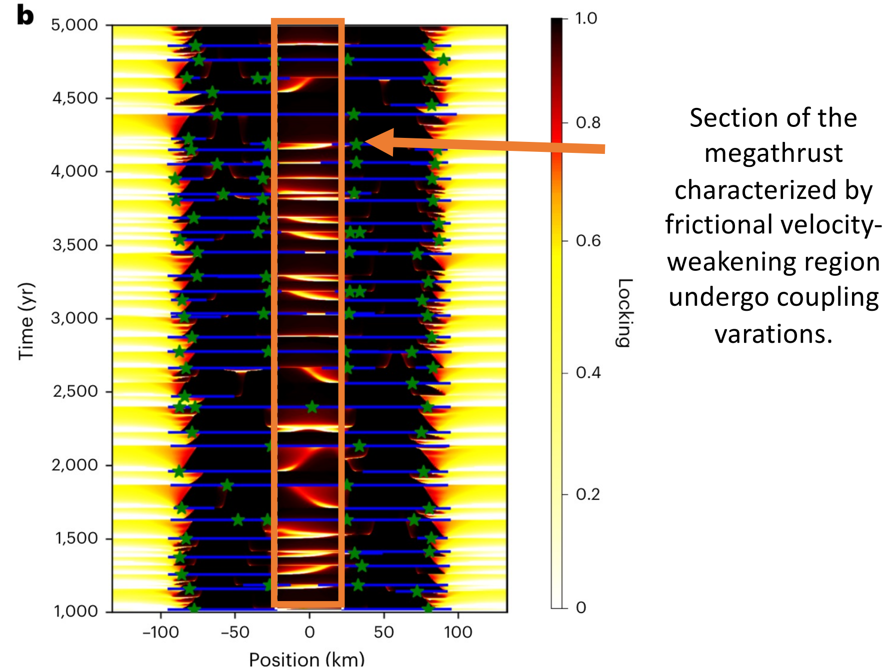


Velocity-weakening regions along the megathrust may **undergo significant changes in coupling** [Molina-Ormazabal et al., 2023].



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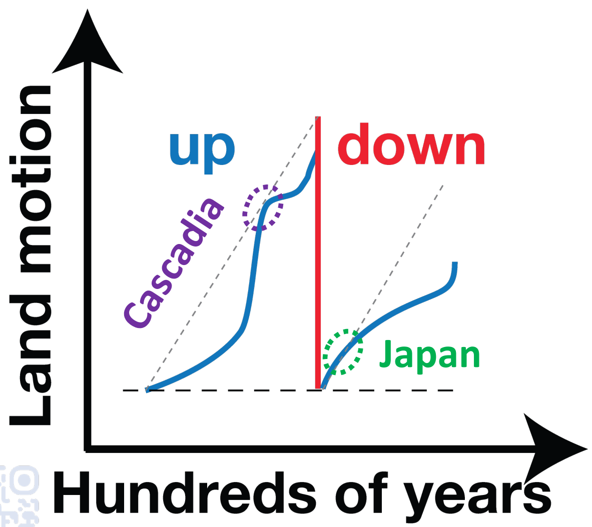
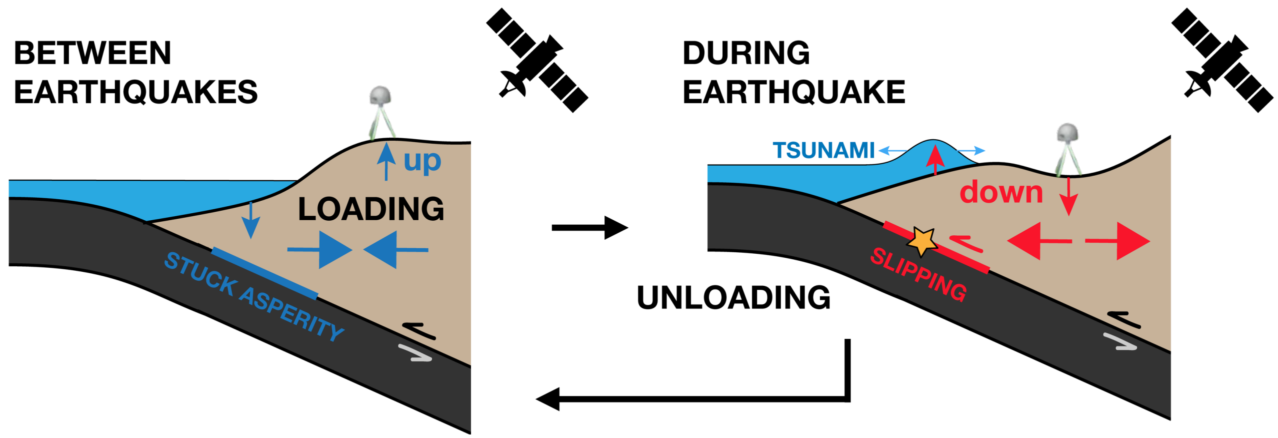
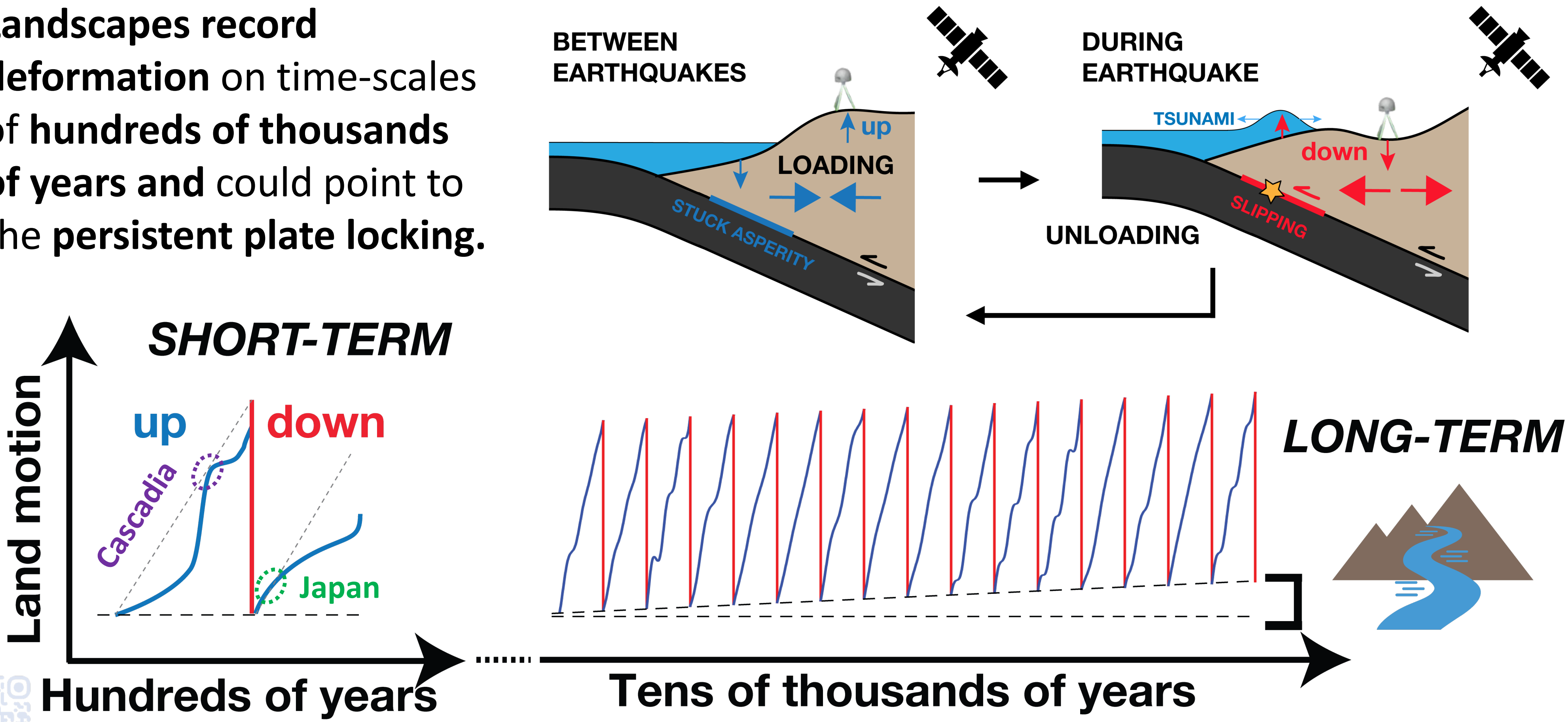




Current geodetic efforts to constrain coupling may be **overlooking key deformation components.**

SUBDUCTION LANDSCAPES AS LONG-TERM RECORDS OF EARTHQUCKE CYCLES DEFOMATION

Landscapes record deformation on time-scales of **hundreds of thousands of years and** could point to the **persistent plate locking.**



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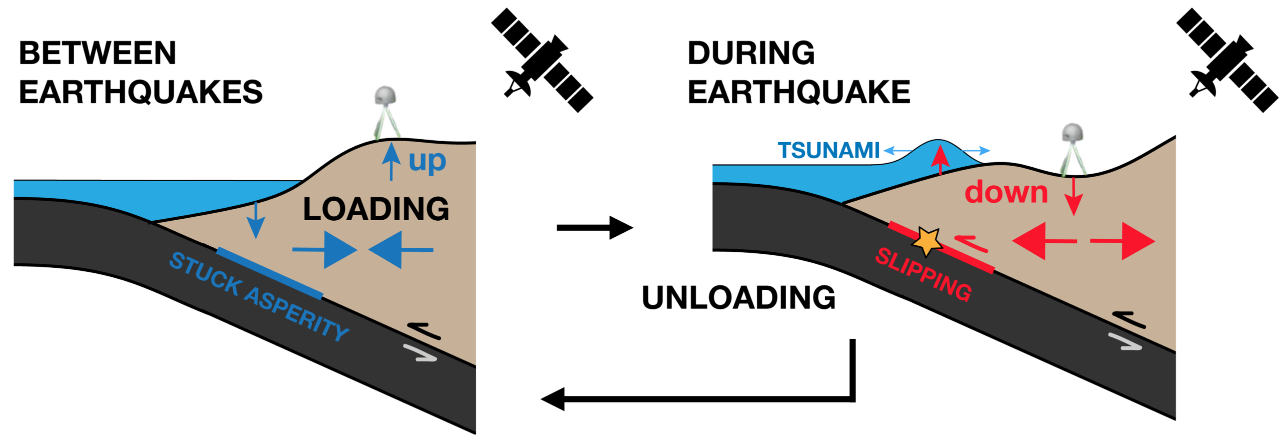
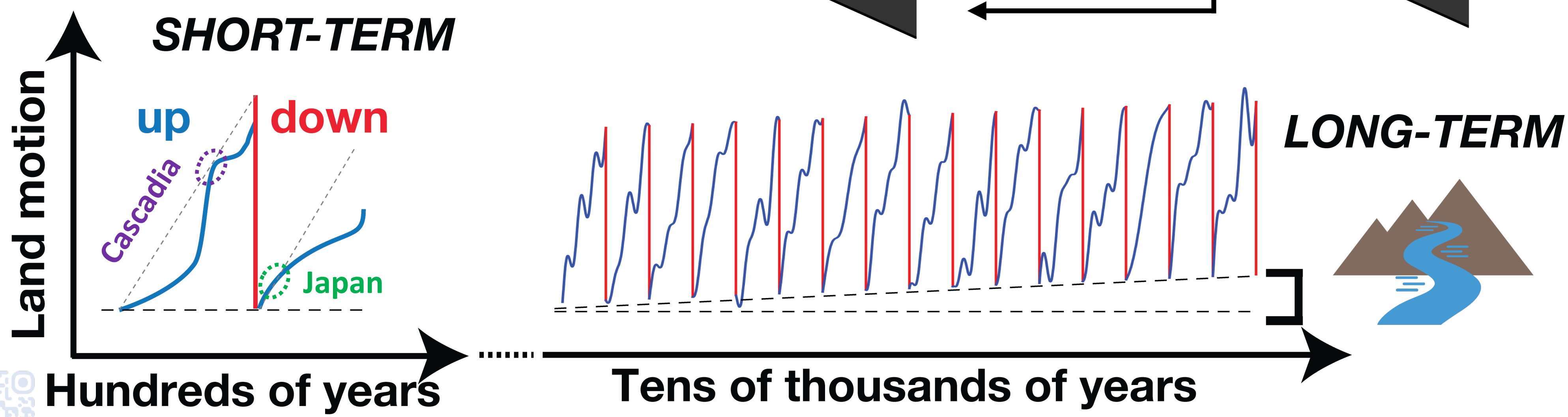
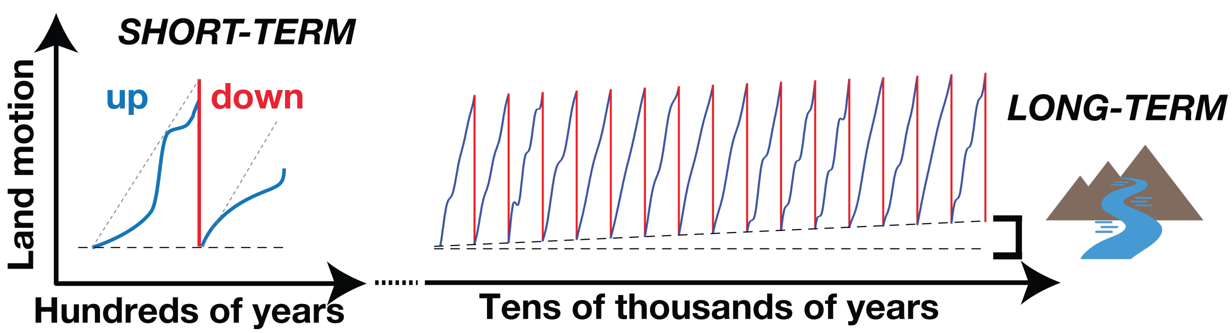


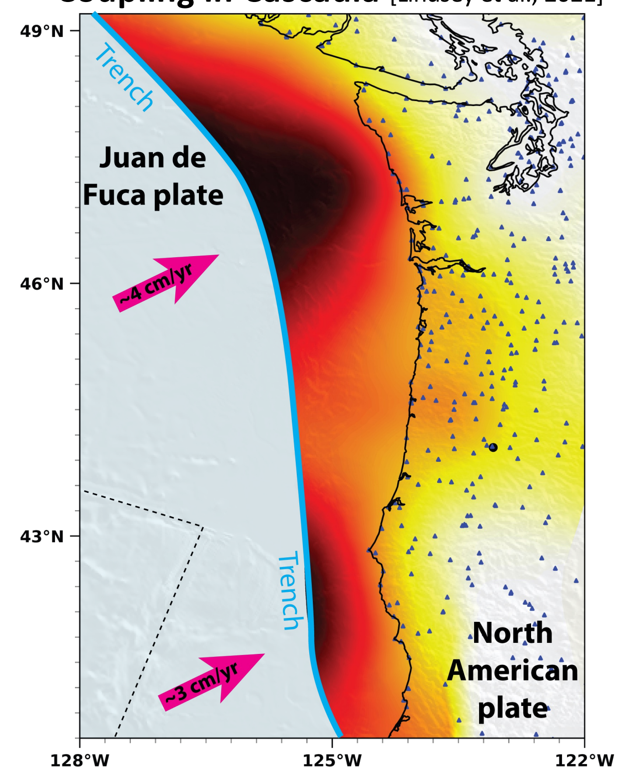


KEY POINTS SO FAR

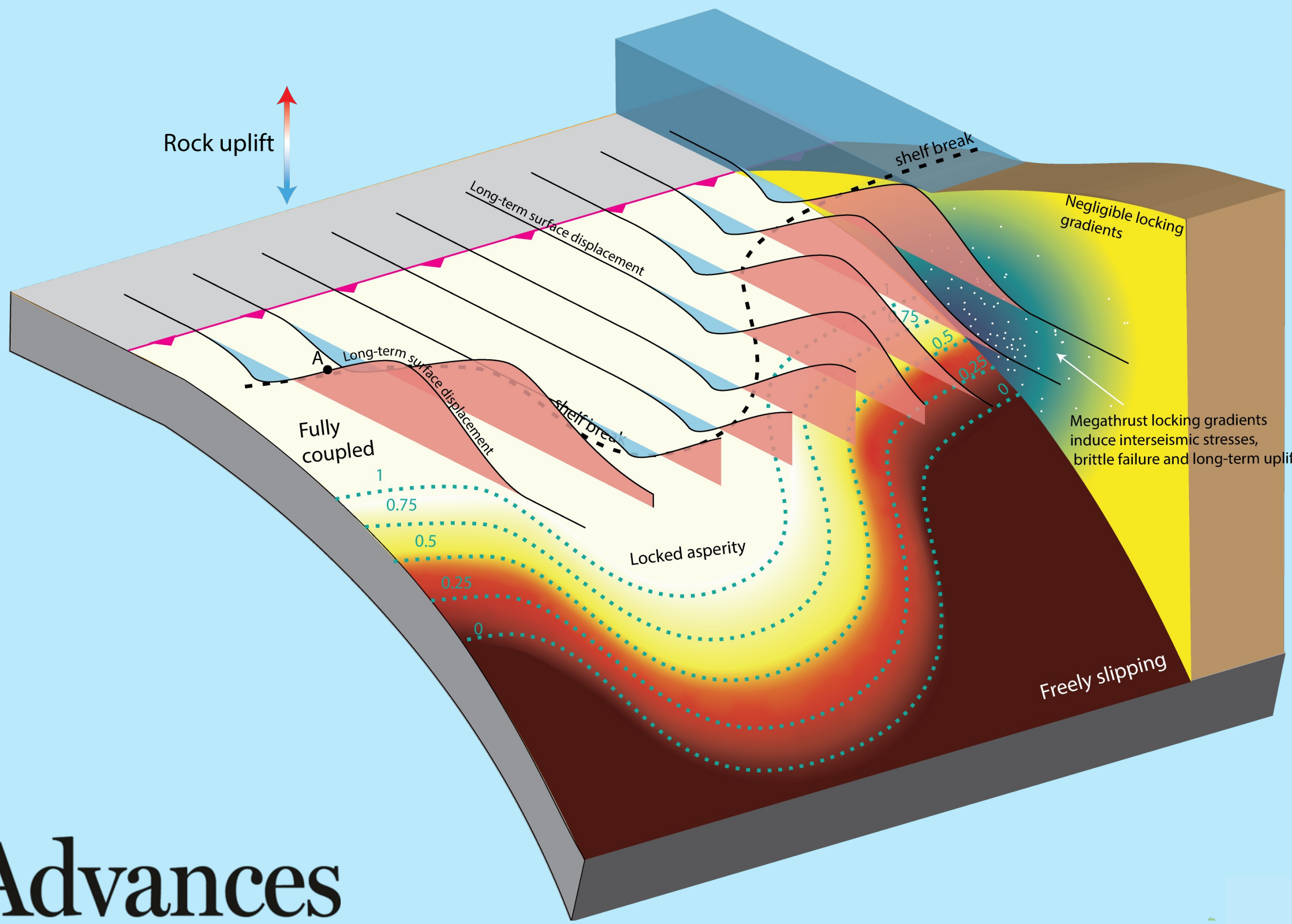
- Geodetic documentation of upper plate deformation help constrain the hazard associated with megathrust earthquakes**.**
- Geodetic data captures only a **small fraction** of the timescale over which **earthquake cycles operate.**
- **Landscapes record deformation** on time-scales of **hundreds of thousands of years and** could point to the **persistent plate locking.**



Coupling in Cascadia [Lindsey et al., 2021]



Section 2 - Fingerprints of Megathrust Locking in Subduction Landscapes



ScienceAdvances

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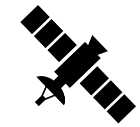
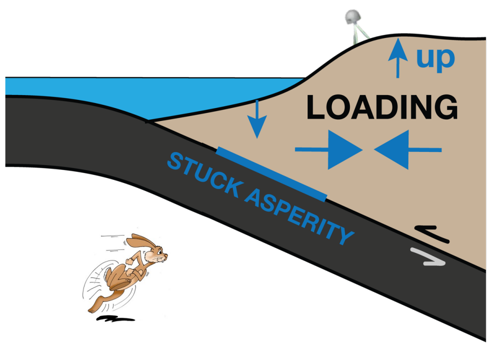
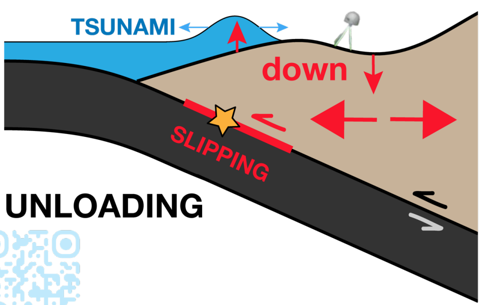
ELASTIC EARTHQUAKE CYCLES IN SUBDUCTION ZONES

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

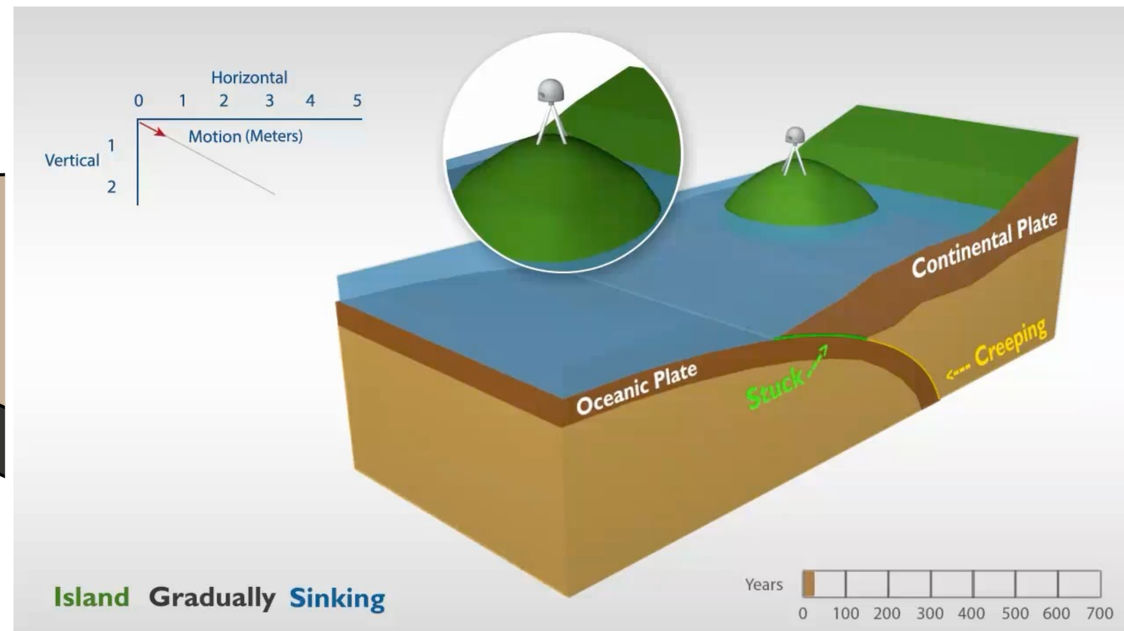


Interseismic: locked section is "stuck". Creeping section moves slowly. Upper plate deform **elastically**





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



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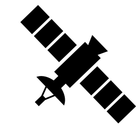

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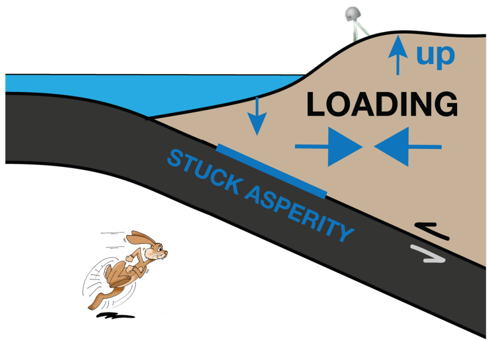

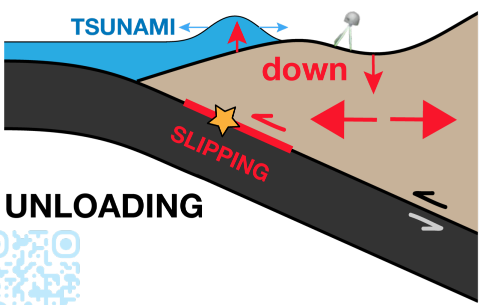

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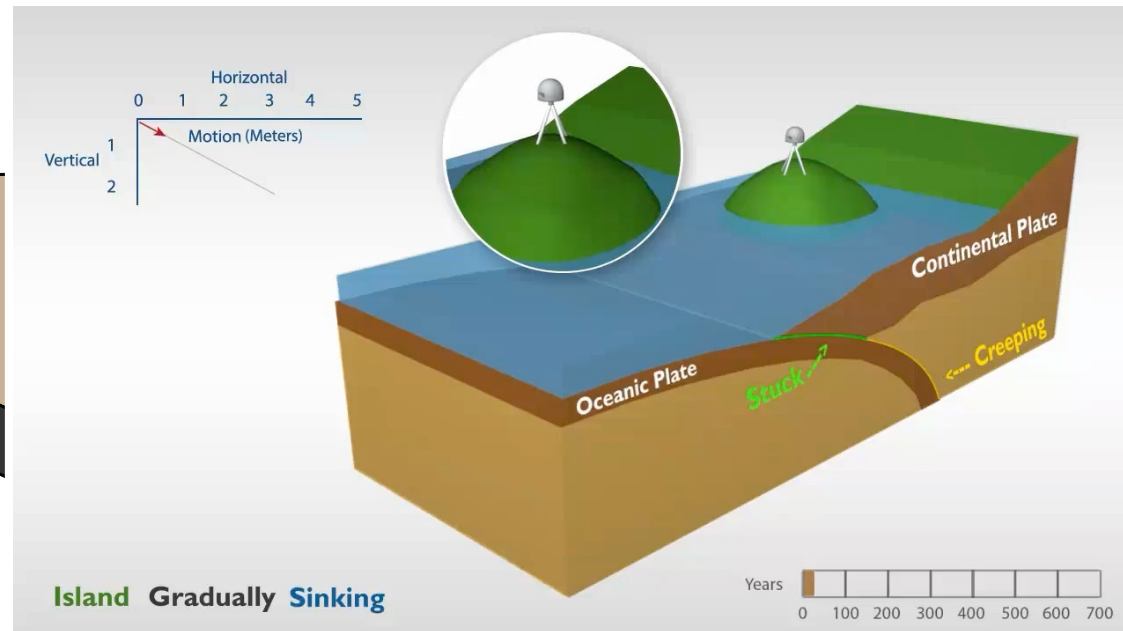
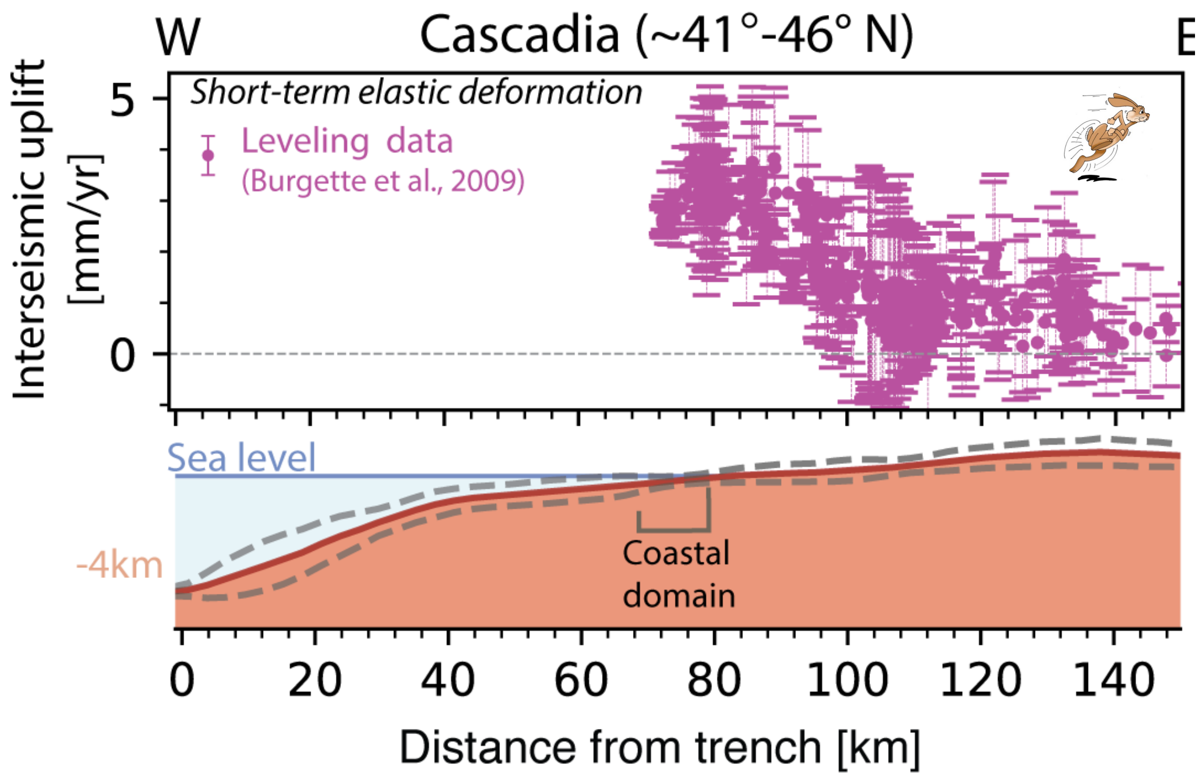


No off-fault permanent deformation!

SHORT-TERM DEFORMATION IN CASCADIA



Oryan et al., 2024

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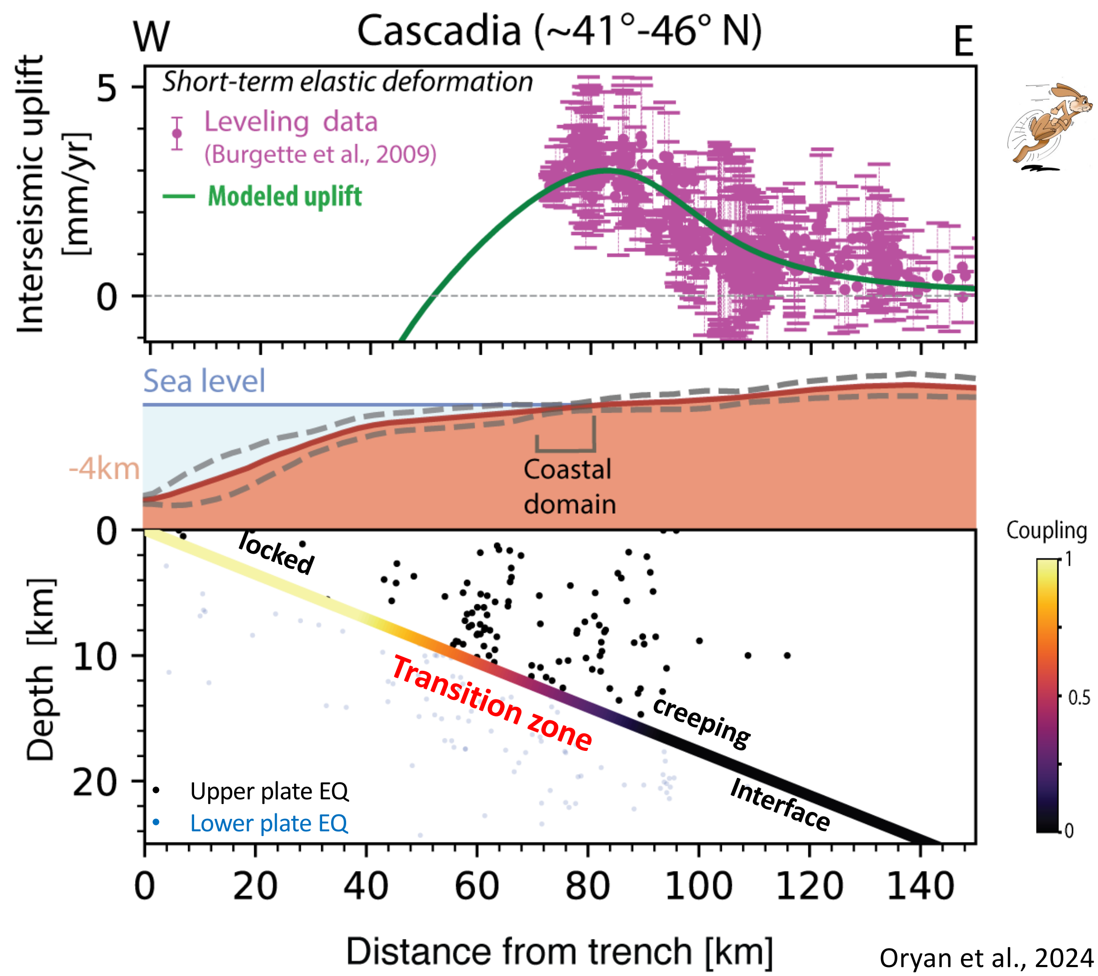

Oryan et al., 2024

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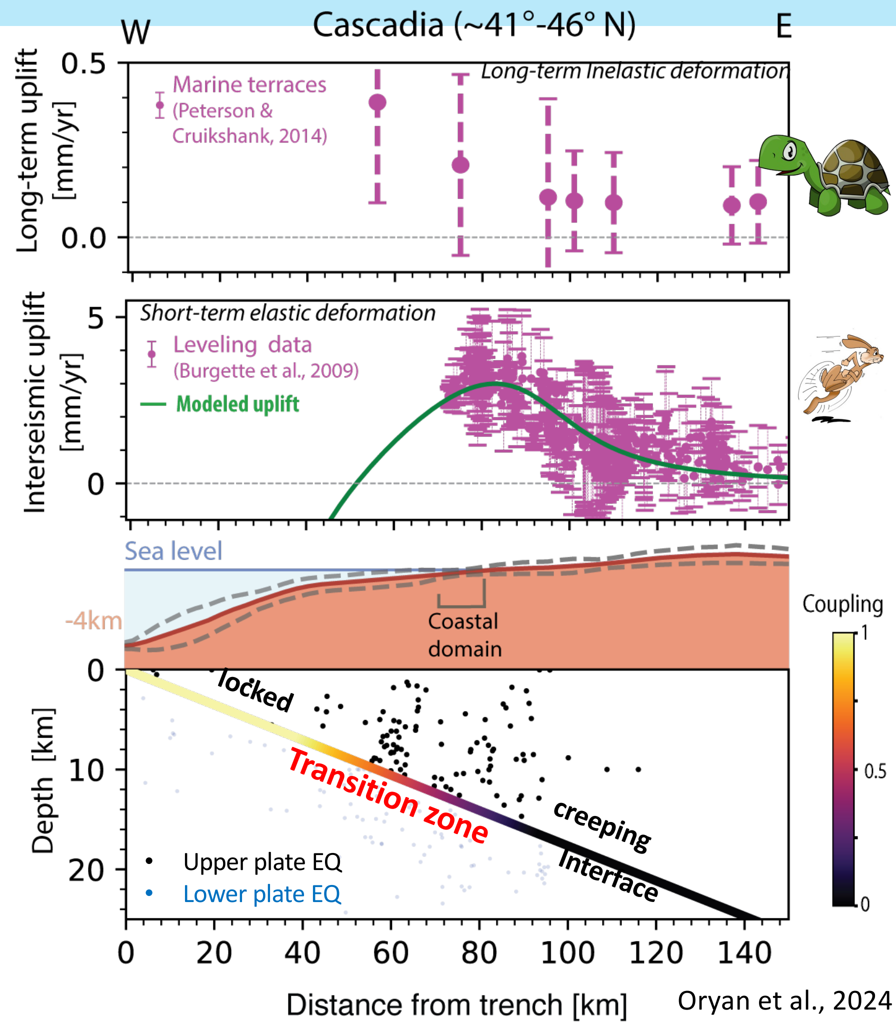

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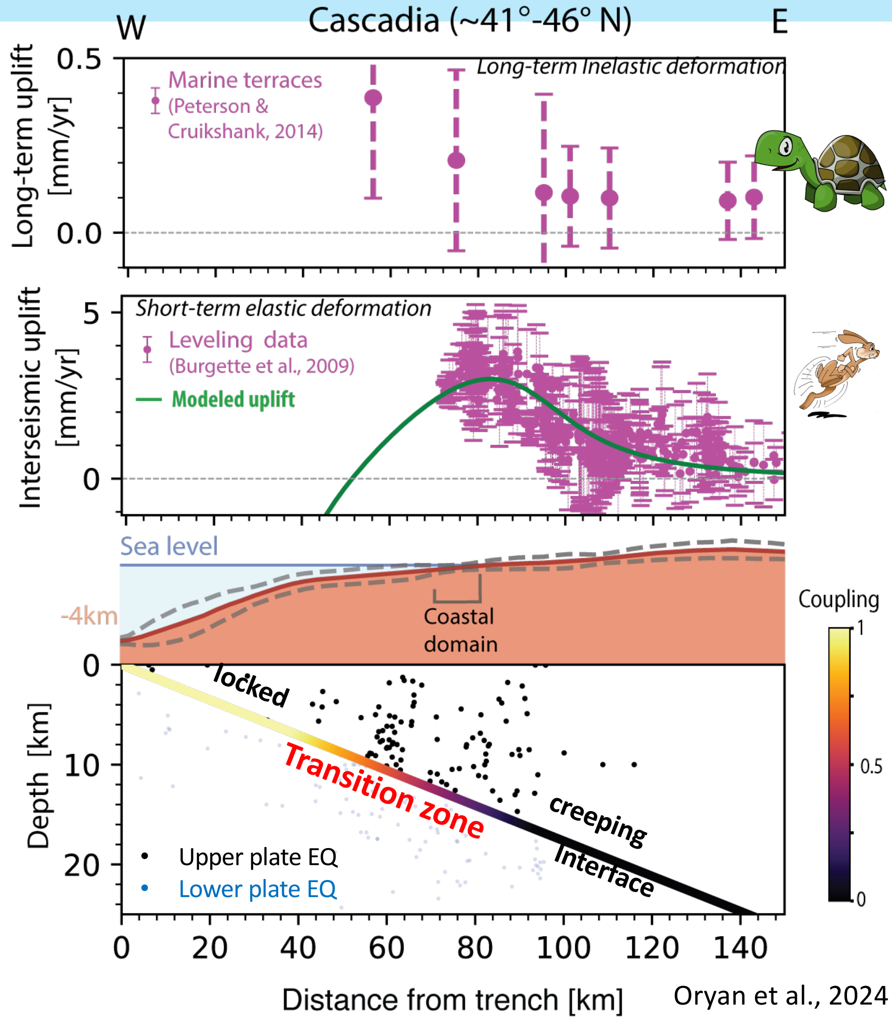
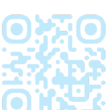


Oryan et al., 2024



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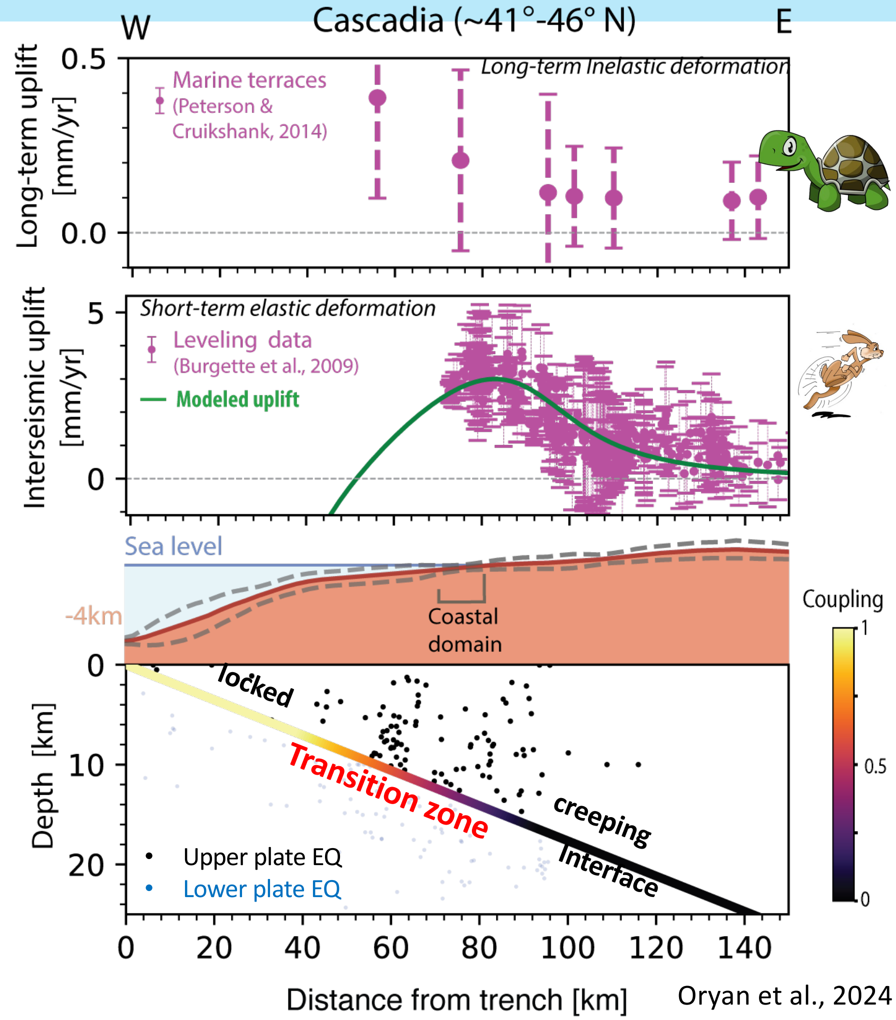

Oryan et al., 2024

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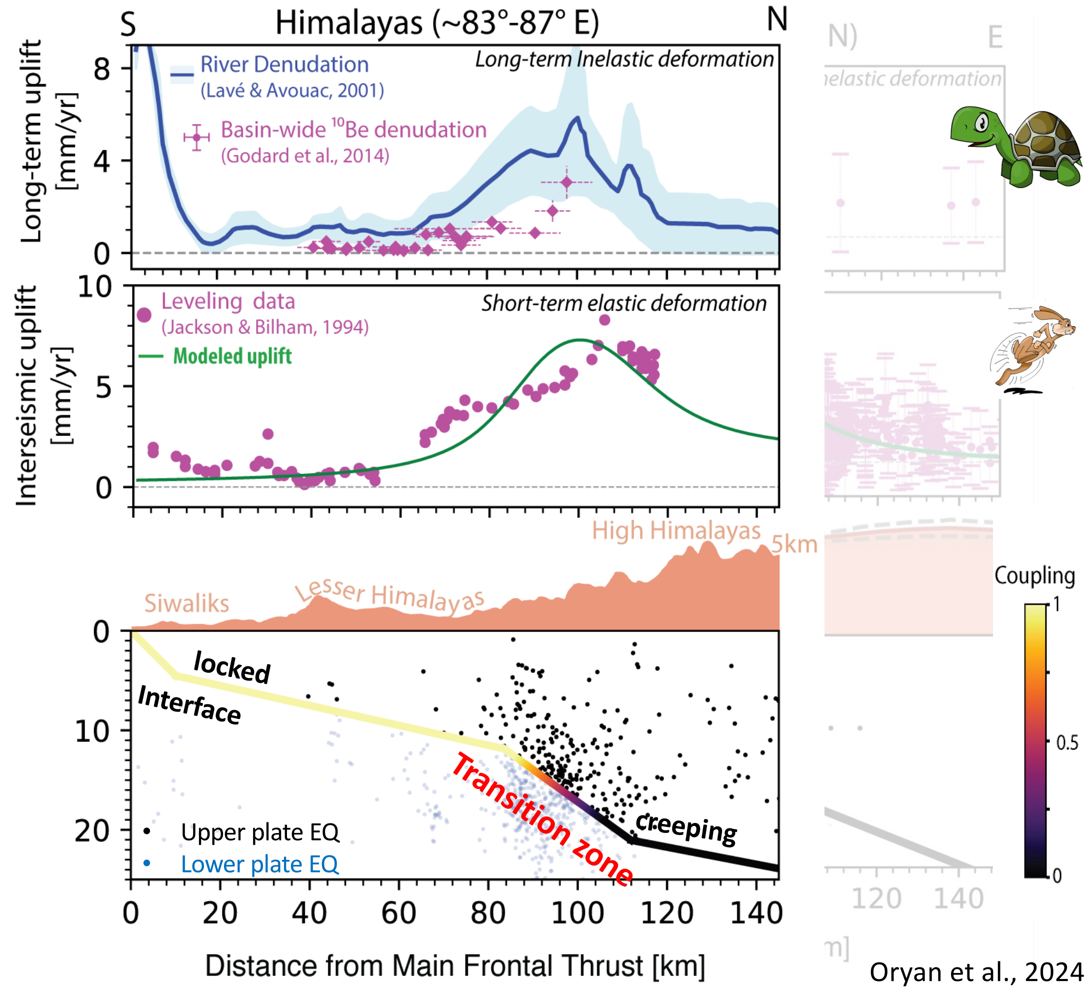

Oryan et al., 2024

SHORT- AND LONG-TERM DEFORMATION IN CHILE

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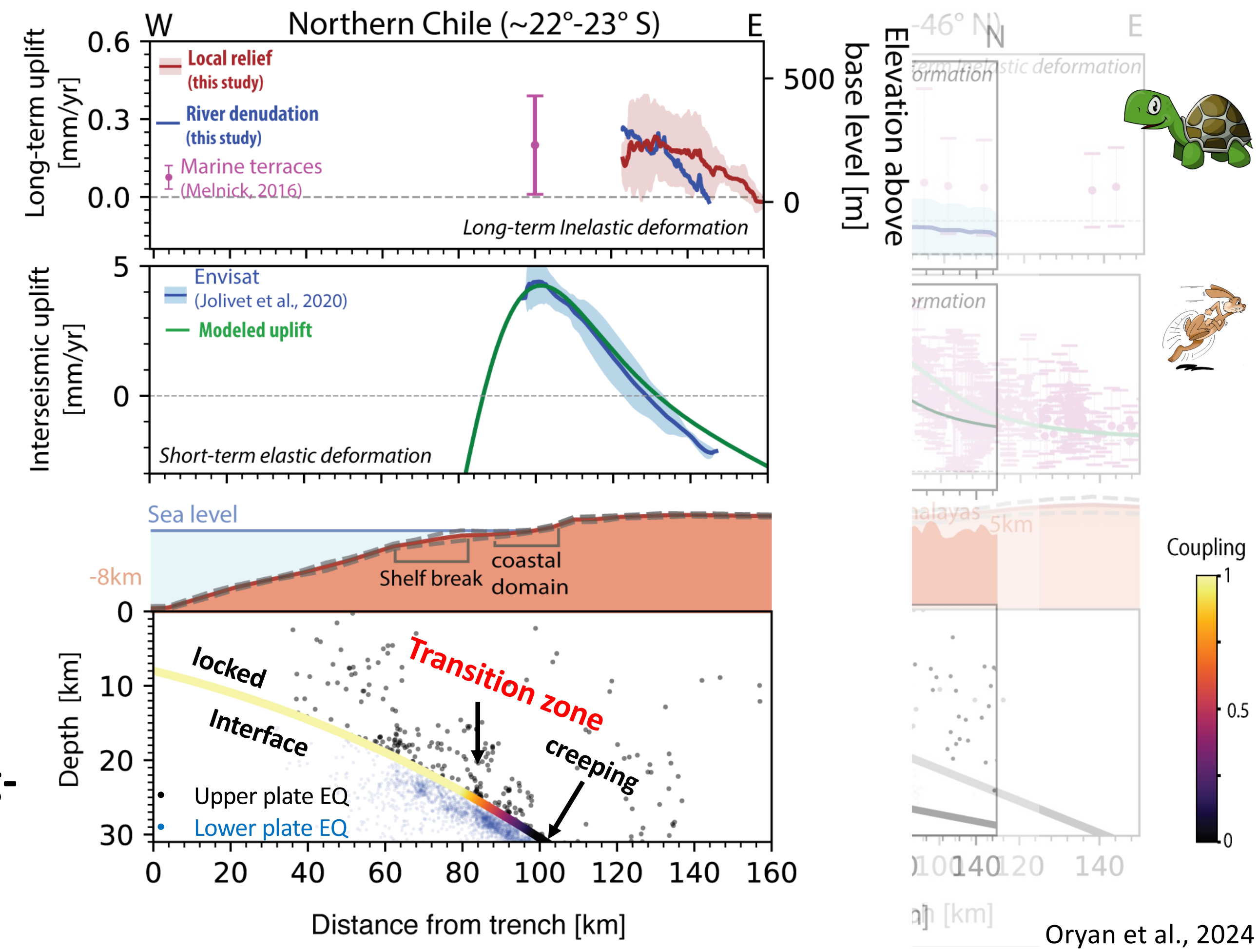
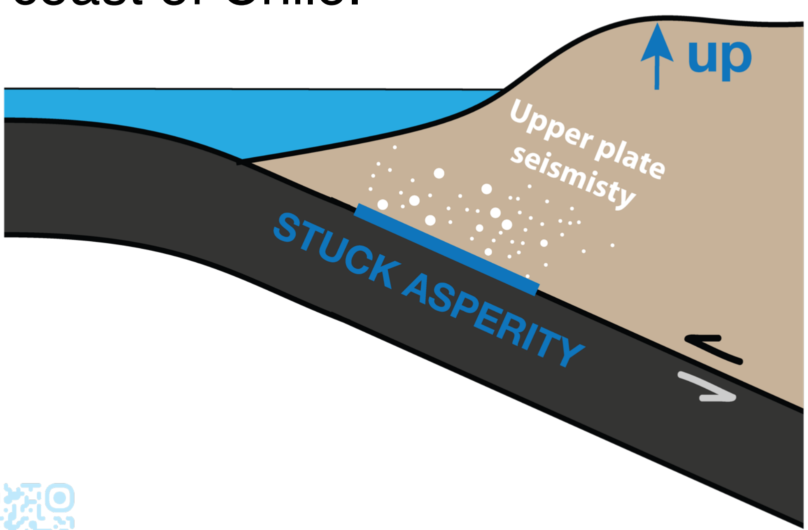
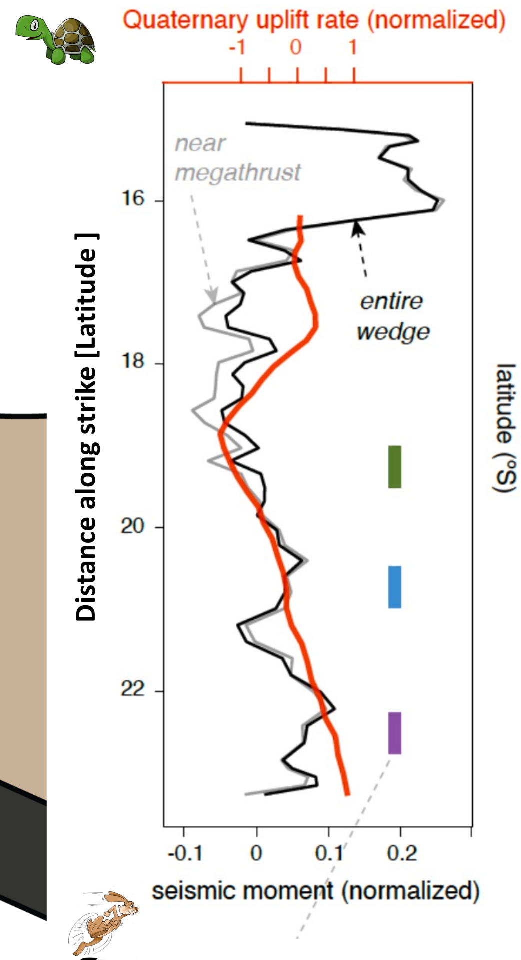


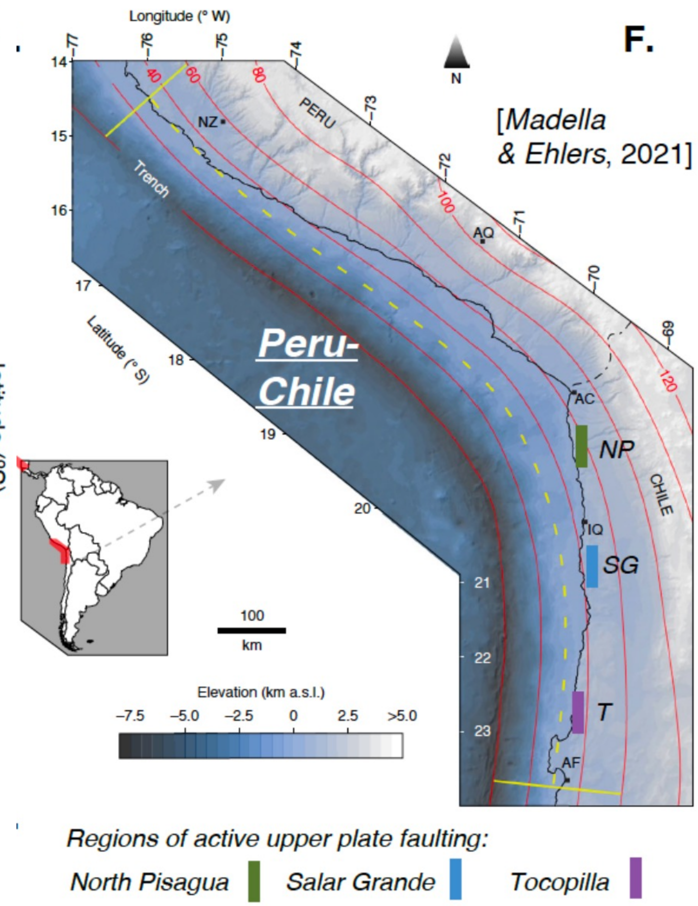
Oryan et al., 2024

UPPER PLATE SEISMISTY AND LONG-TERM UPLIFT IN CHILE

Moment release of earthquakes within a distance of 15km of the interface correlates with **long-term coastal uplift** rates along the coast of Chile.

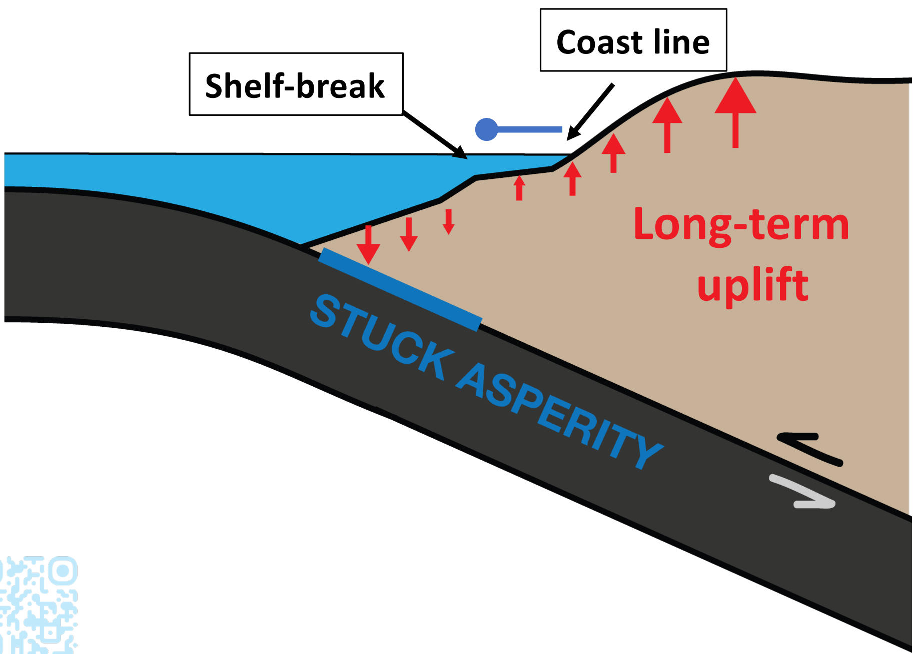


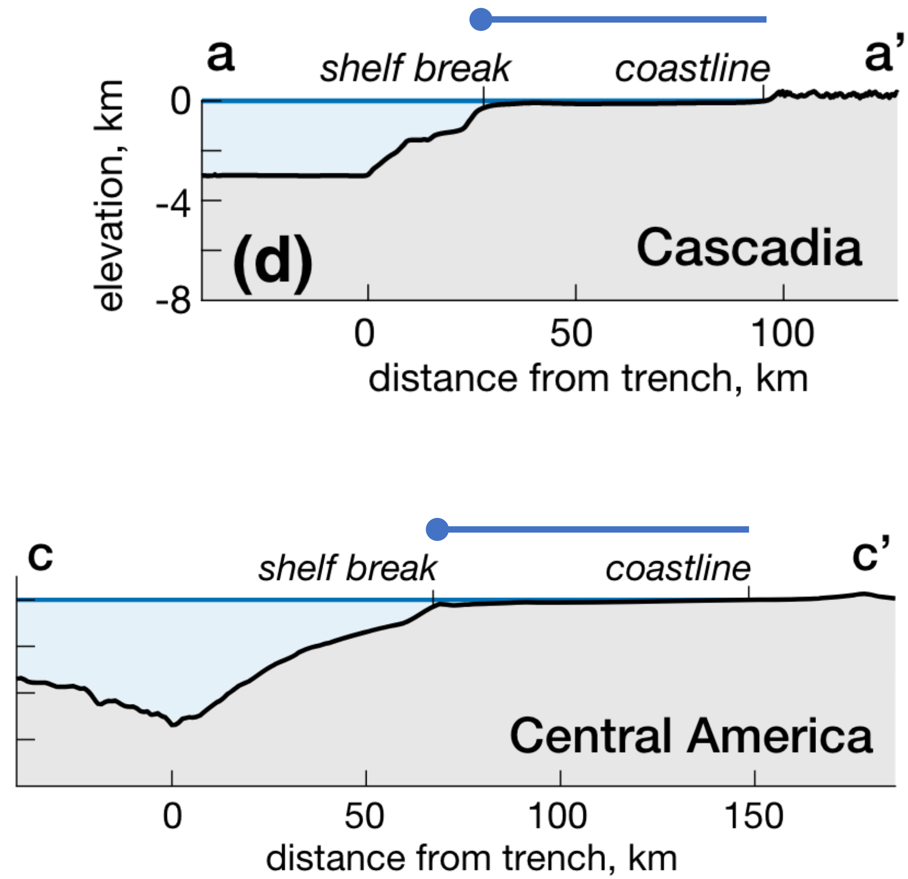




WHAT CAN WE LEARN FROM SHELF BREAKS?

Shelf breaks in active margins are considered a **hinge line,** separating the field of **long-term uplift** from **subsidence**.

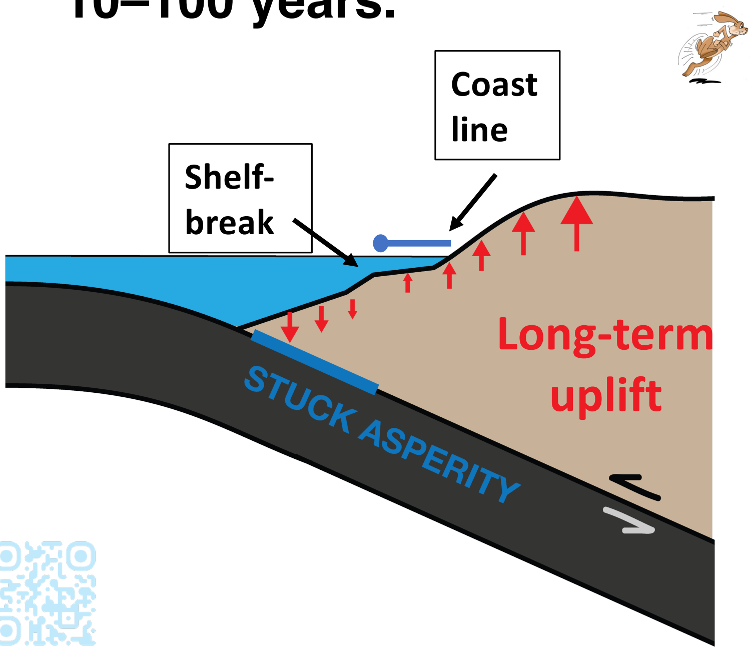




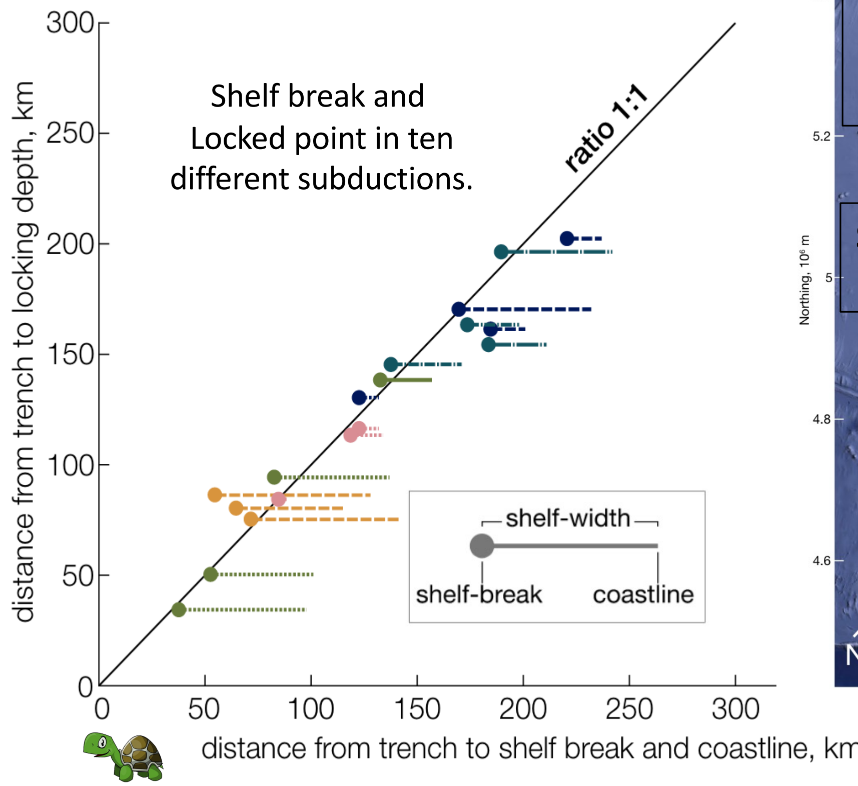
Malatesta et al., 2021

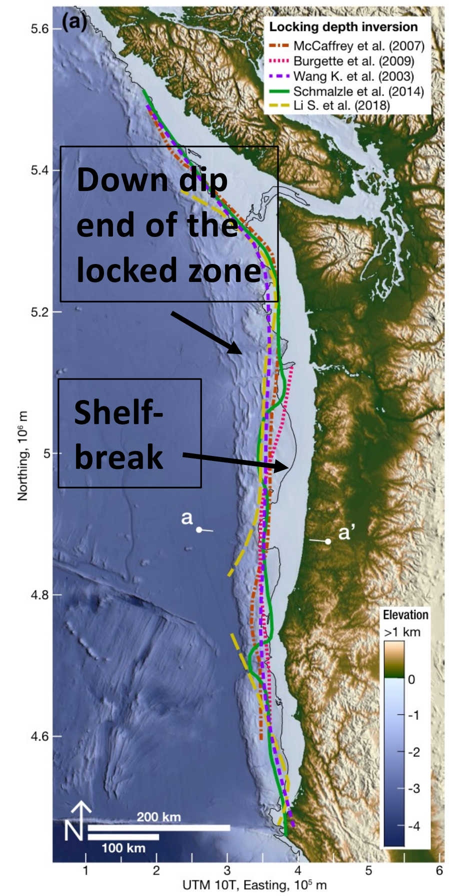
WHAT CAN WE LEARN FROM SHELF BREAKS?

The morphology of active margins, evolving on time scales of **100s of kyr** shows similarities to ongoing deformation documented **over 10–100 years.**



Shelf break and down dip **end of the locked zone coincide** [Malatesta et al., 2021]





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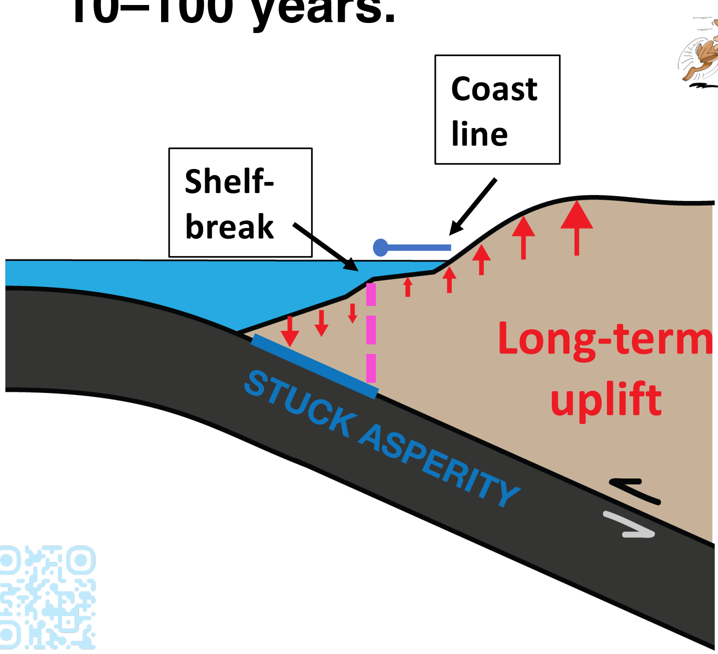

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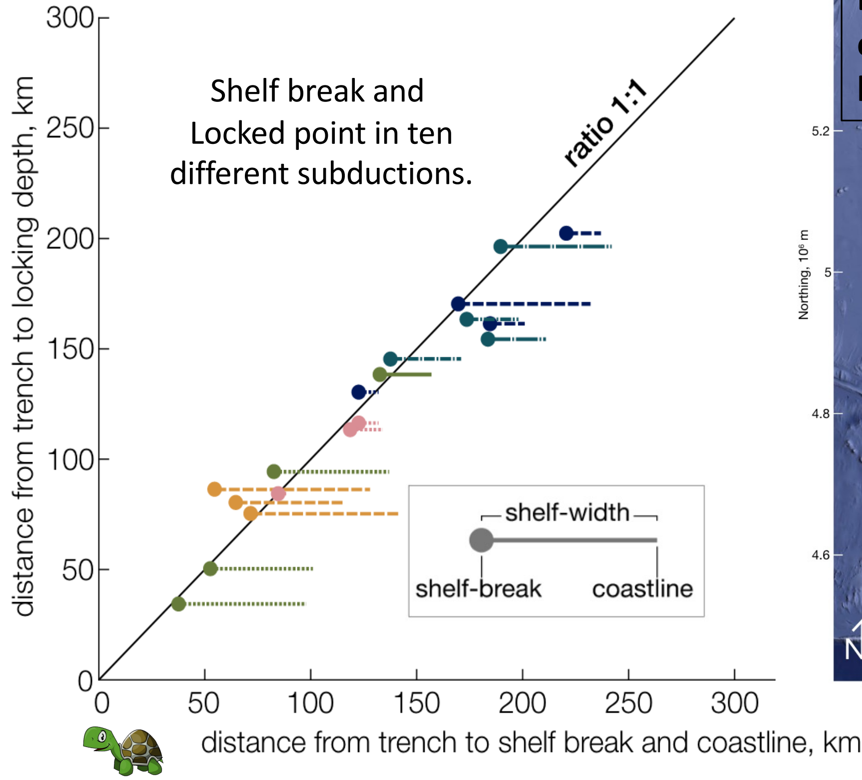

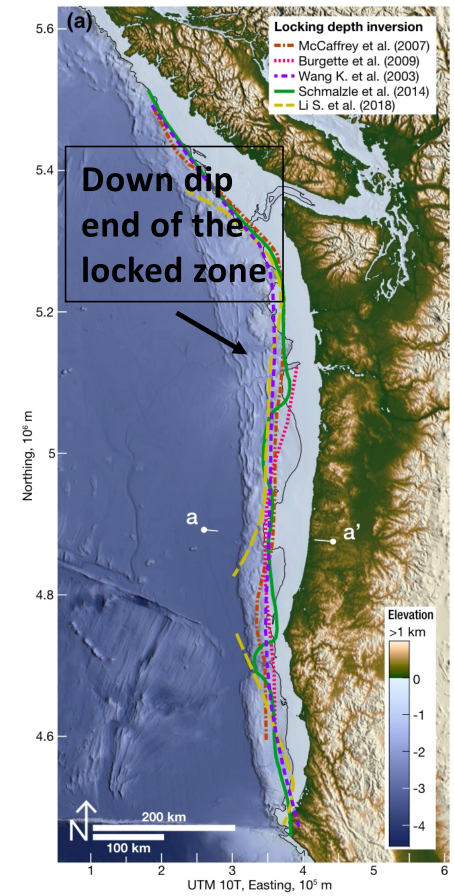

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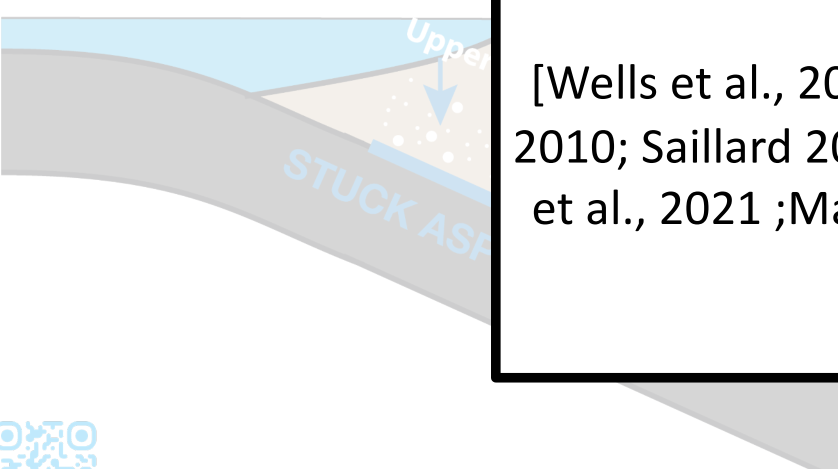
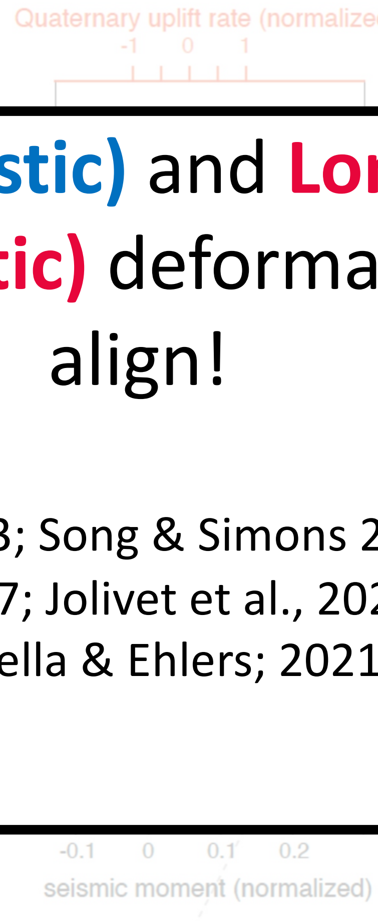
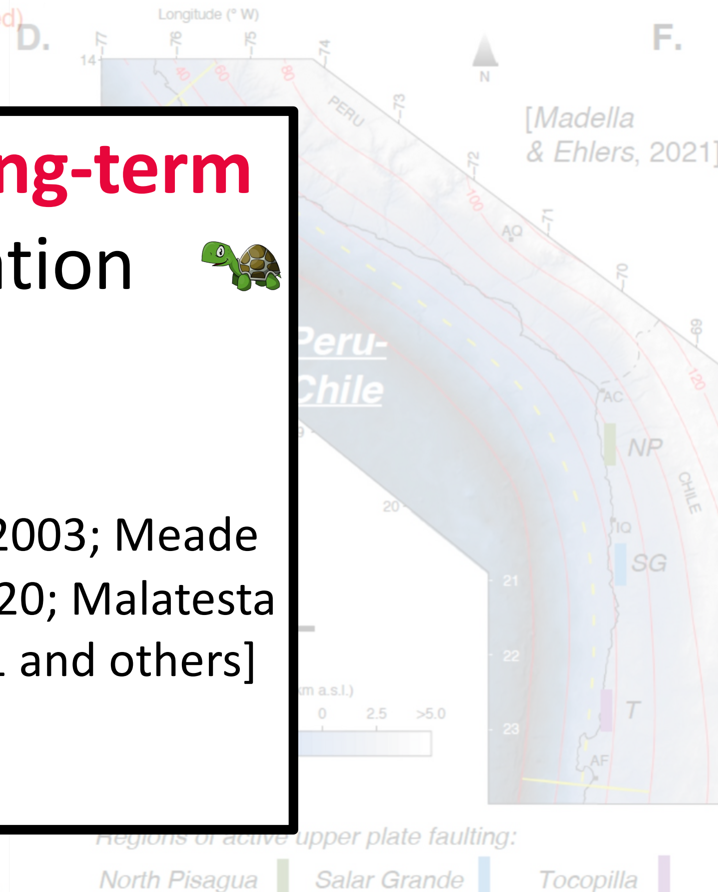




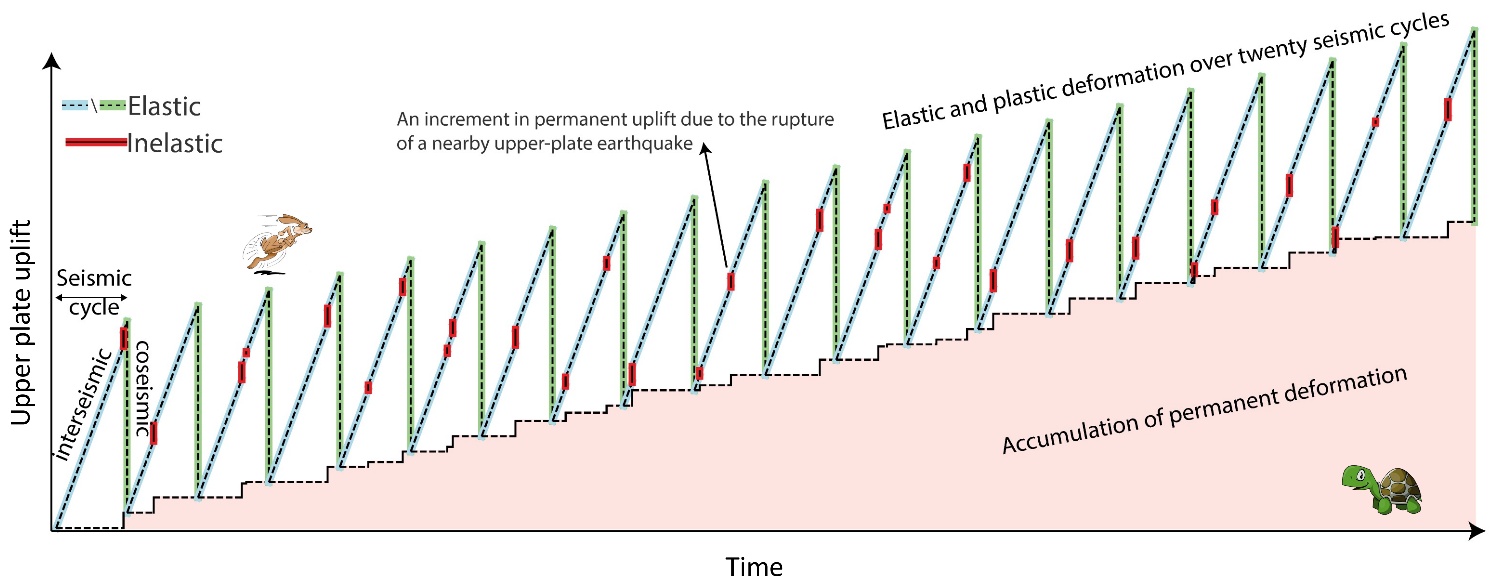


Short- (elastic) and **Long-term (inelastic)** deformation align!

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

HOW INTERSEISMIC FAULT LOCKING IMPRINTS SUBDUCTION LANDSCPES ?

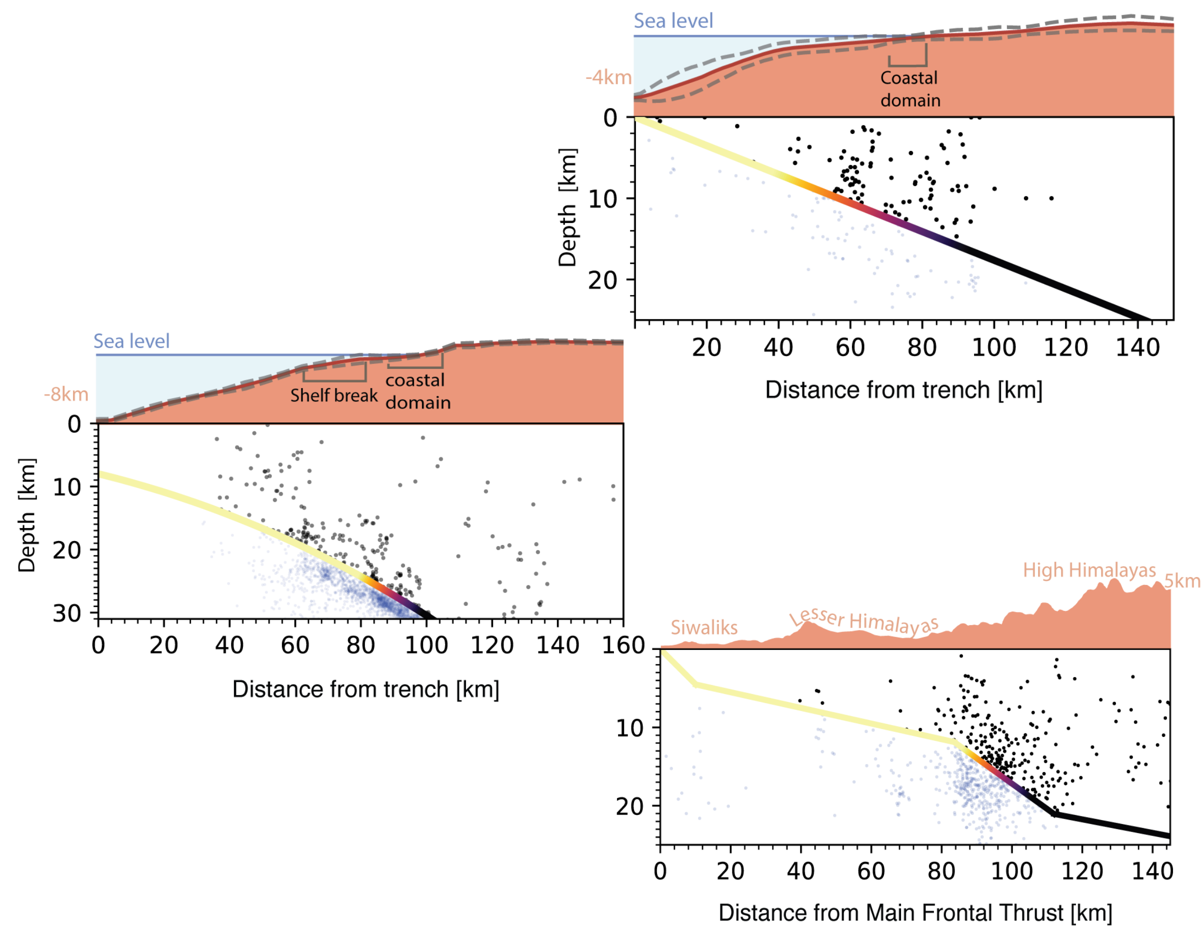
- **Interseismic upper plate stresses** induced by locking gradients push parts of the upper plate to **failure** generating overriding plate earthquakes.
- Repeated **failure** over multiple earthquake cycles explains the overlap between short- and long-term deformation.



Oryan et al., 2024

MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

- Current interseismic recorded seismicity represents a **snapshot of the long-term processes** that gradually shape topography.
- We extend the upper plate seismic record by generating upper plate earthquakes, **representing the complete signature of earthquake cycles**.



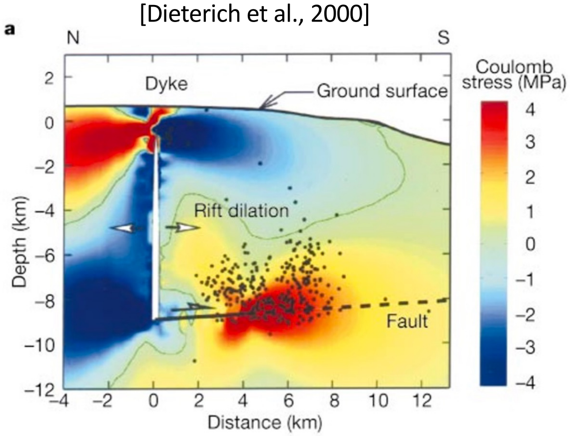
Oryan et al., 2024

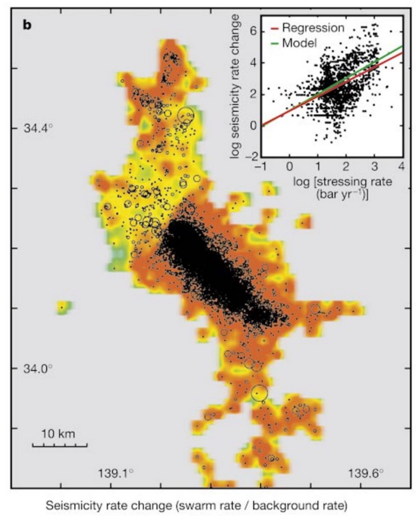
MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

We rely on the Dieterich approach and link **seismicity rate** with **temporal and spatial stressing rates**.

Inverting earthquake rate data to infer stress changes

[Dieterich et al., 2000]



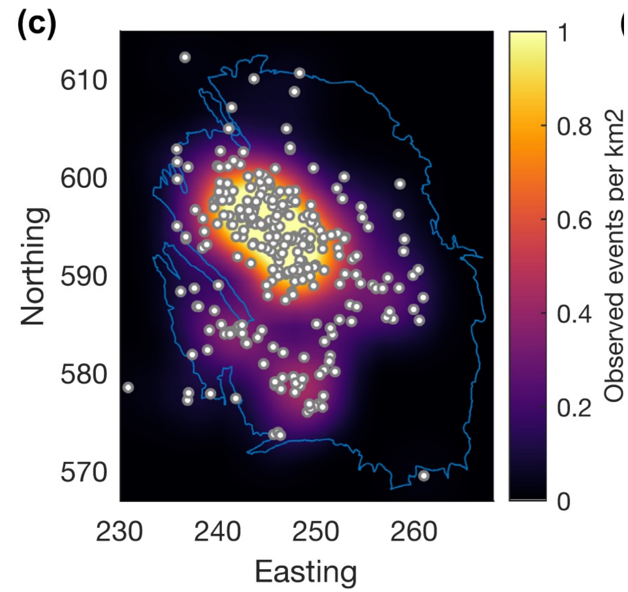


Predicting seismicity distribution arising from magma intrusions

[Toda et al., 2002]

Predicting seismicity distribution from induced stress changes at Groningen gas field

[Heimisson et al., 2021]



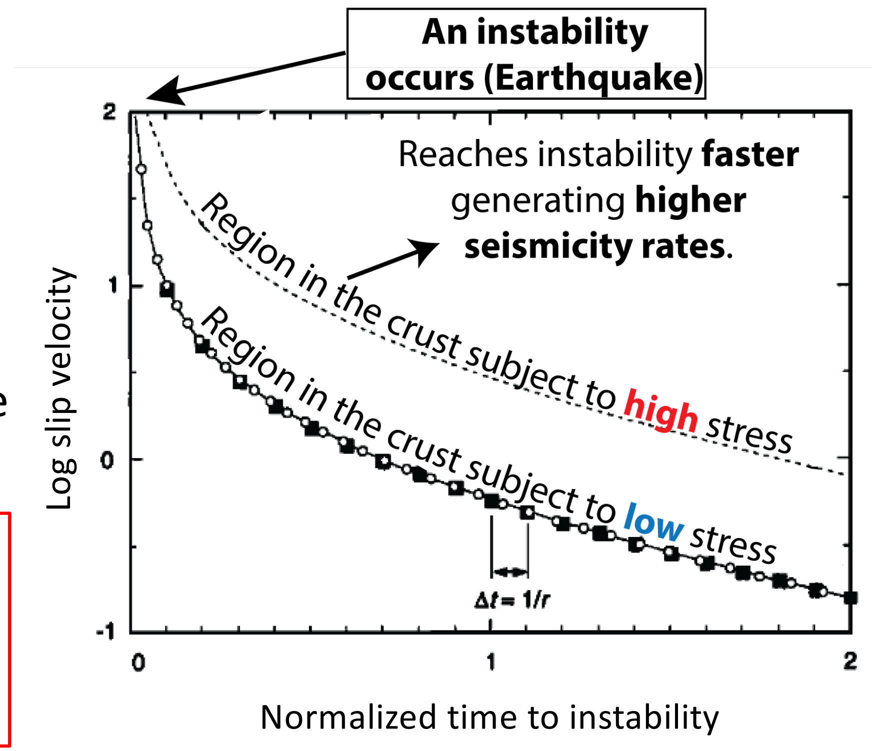
MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

- The Dieterich approach models the crust as a series of independent nucleation points governed by rate-and-state friction, progressing toward instability.
- Higher stressing rate will reduce the time to reach instability.

Underlying assumption:

The state variable, θ, in rate-and-state friction follows $\frac{\theta\dot{\delta}}{D_c}$>>1 so θ=$\theta_0\exp(-\frac{\delta}{D_c})$ and as such the slip velocity:

$$\dot{\delta} = \left\{ \left[\frac{1}{\dot{\delta}_0} + \frac{H\sigma_n}{\dot{\tau}} \right] \exp\left(-\frac{\dot{\tau}t}{A\sigma_n} \right) - \frac{H\sigma_n}{\dot{\tau}} \right\}^{-1} .$$



Dieterich 1994

MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

- We rely on the Dieterich

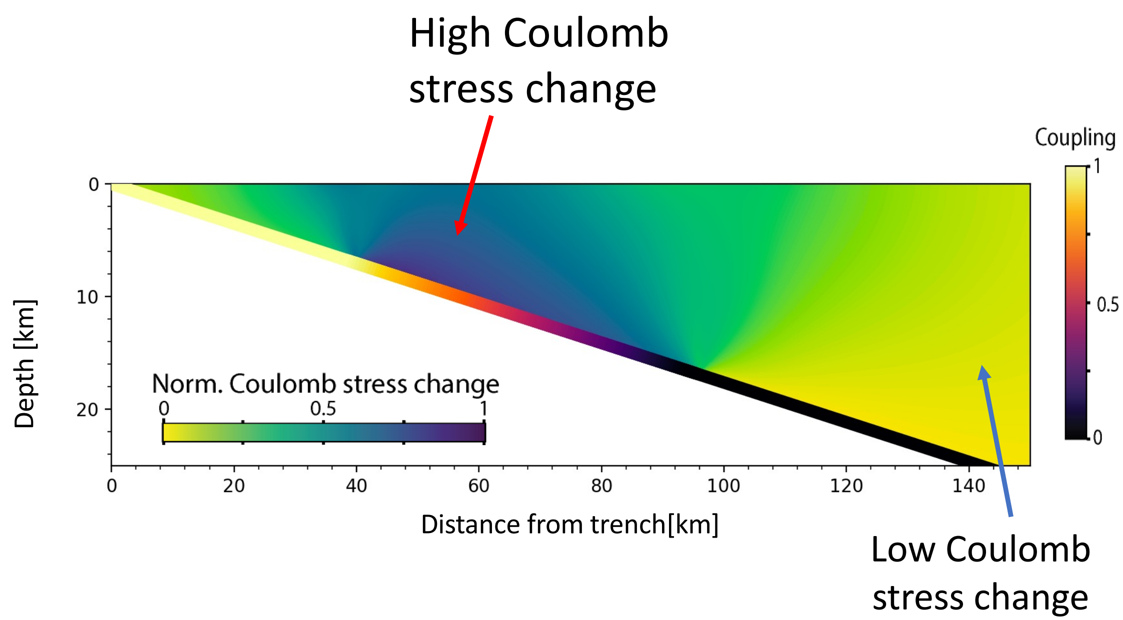
Predicting seismicity distribution

The Dieterich framework is widely used to describe the **spatial** and temporal distribution of **seismicity from changes in stress and stress rate**:

[Stein et al. (1997); Parsons et al. (2000); Toda et al. (2002); Helmstetter & Shaw (2006); Segall & Lu (2015); Kroll et al. (2017); Heimisson & Segal (2018); Cappa et al. (2019); Hager et al. (2021); Toda & Stein (2022); Heimisson et al. (2022) and more]

MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

- We compute upper plate Coulomb stress change imparted by **locking gradients.**
- We **populate millions of synthetic earthquakes** spanning thousands of years and dozens of seismic cycles according to the **Coulomb stress change**.
- Apply the Okada solution to compute **cumulative long –term surface** displacements from seismic events.

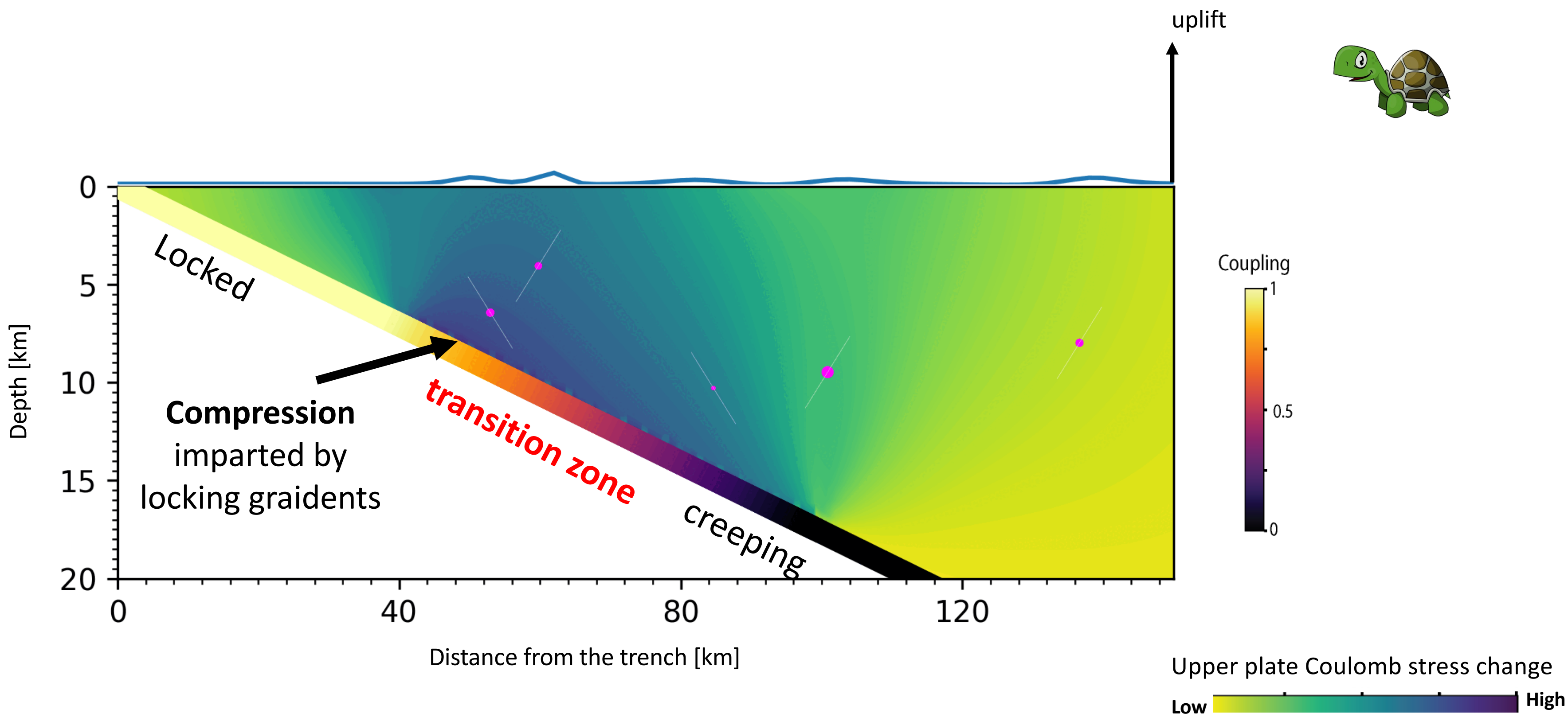


Coulomb stress change assuming thrust optimally orientated faults (30°)

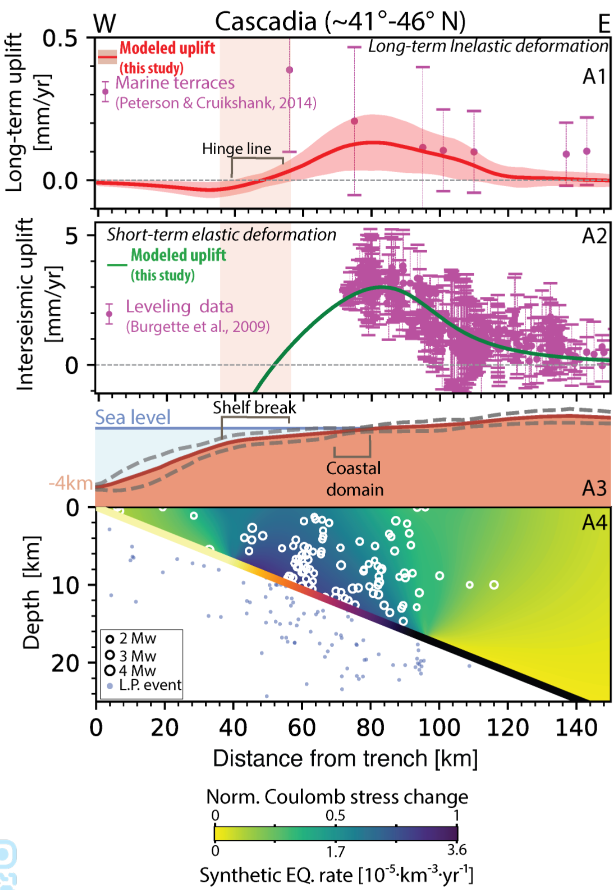
MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

10 degree dip, fully locked to 40km

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



DEFORMATION IN CASCADIA,HIMALYAS AND CHILE



Oryan et al., 2024

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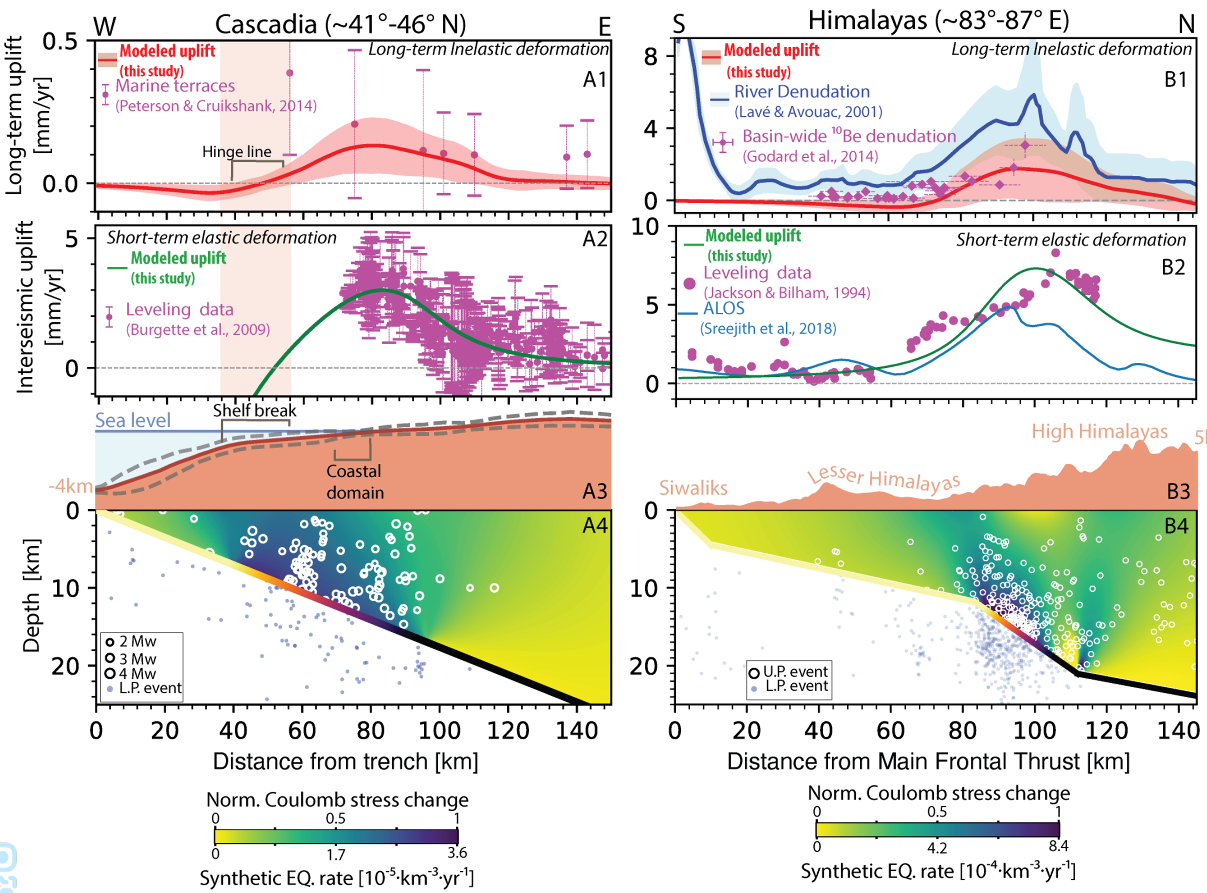

Oryan et al., 2024

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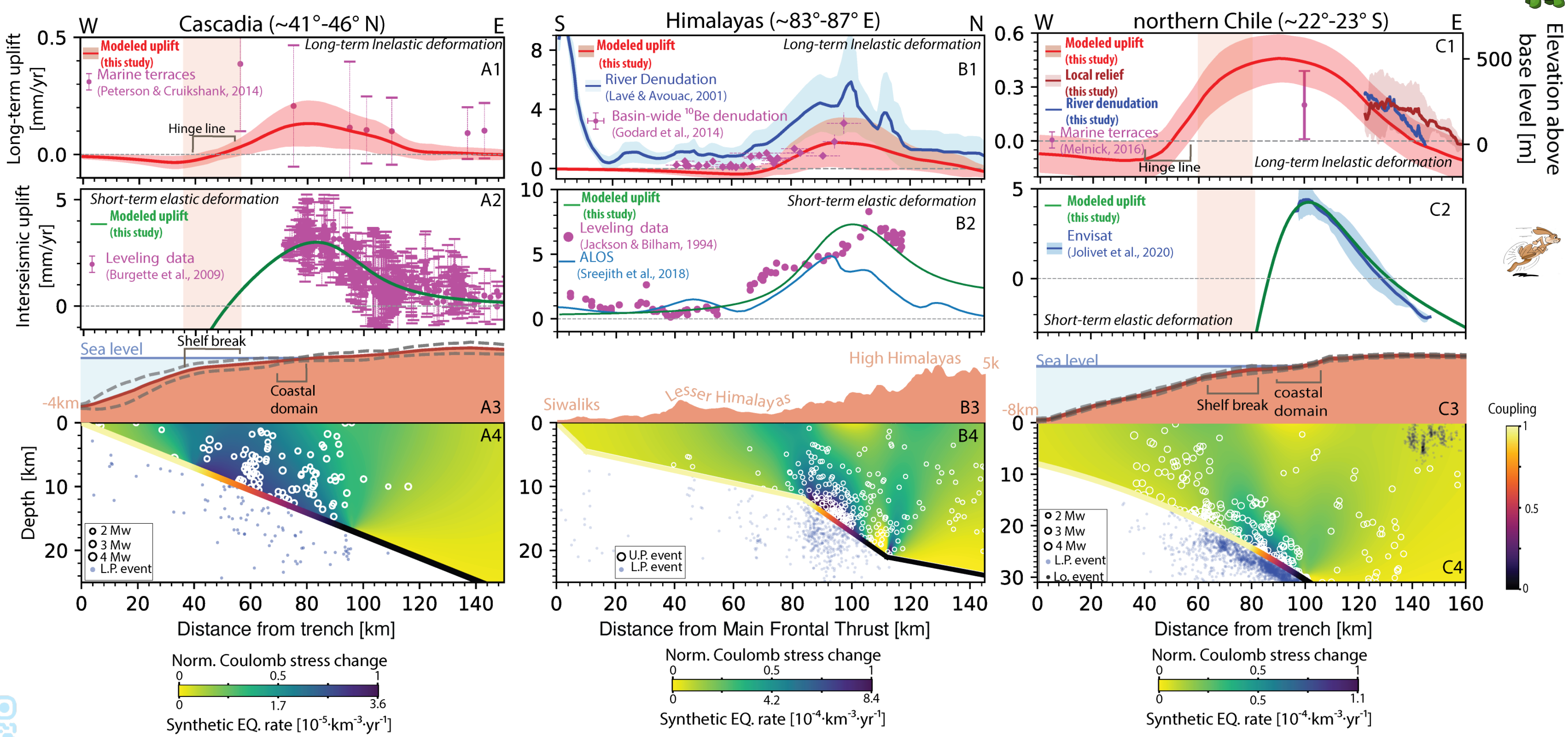
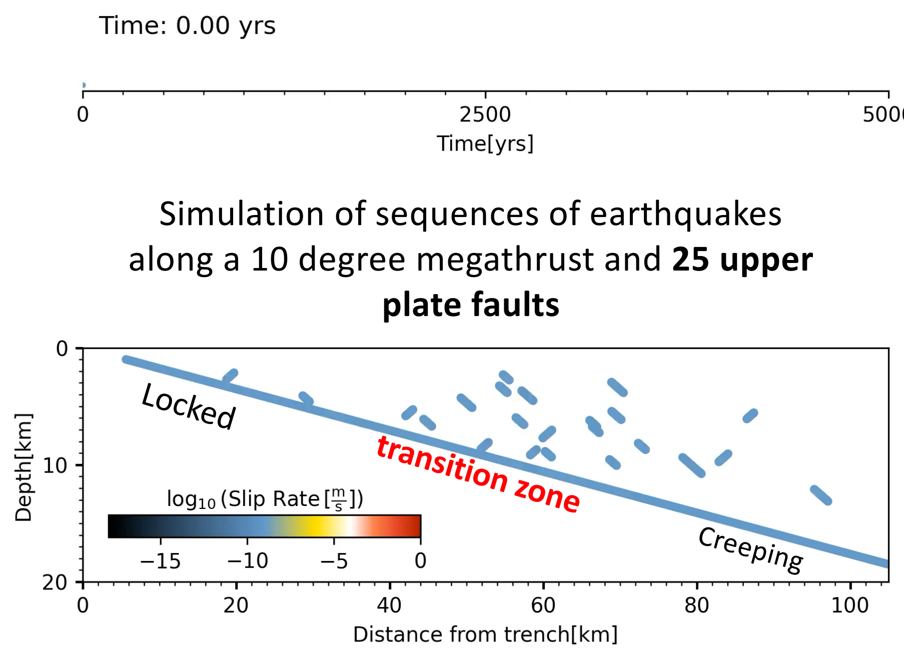


Oryan et al., 2024

MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

- Simulations of seismic cycles along a megathrust fault, combined with discrete, randomly distributed upper plate faults governed by rate-and-state friction laws, reveal that:
  - Upper plate faults can **fail interseismically** and generate earthquakes.



Oryan et al., in prep.

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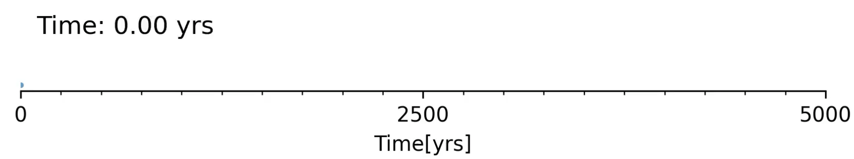
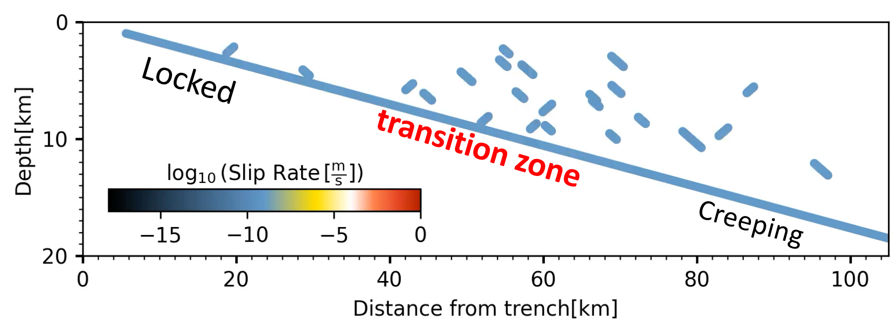


Simulation of sequences of earthquakes along a 10 degree megathrust and **25 upper plate faults**



Oryan et al., in prep.

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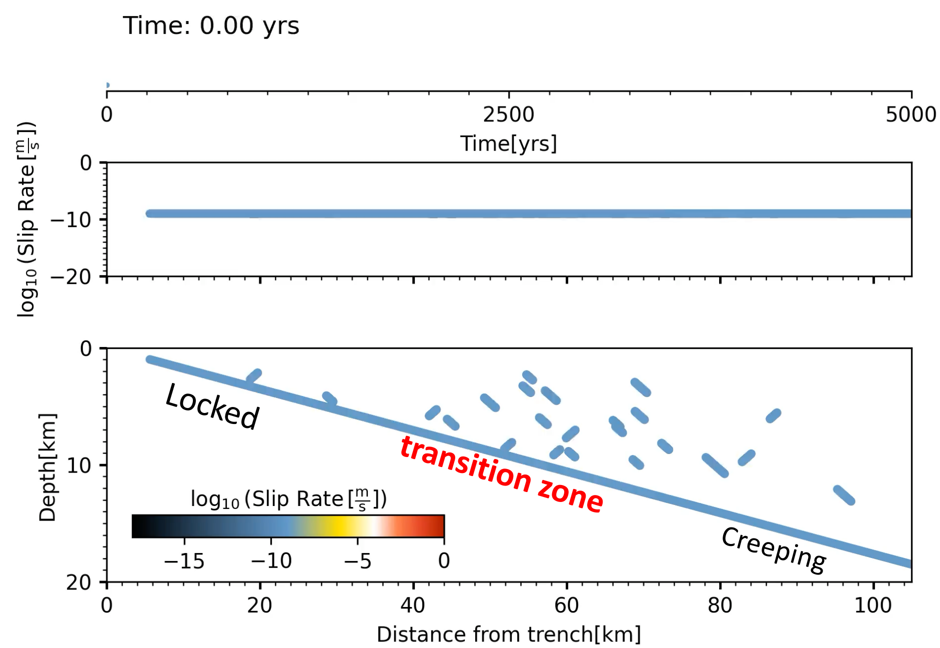
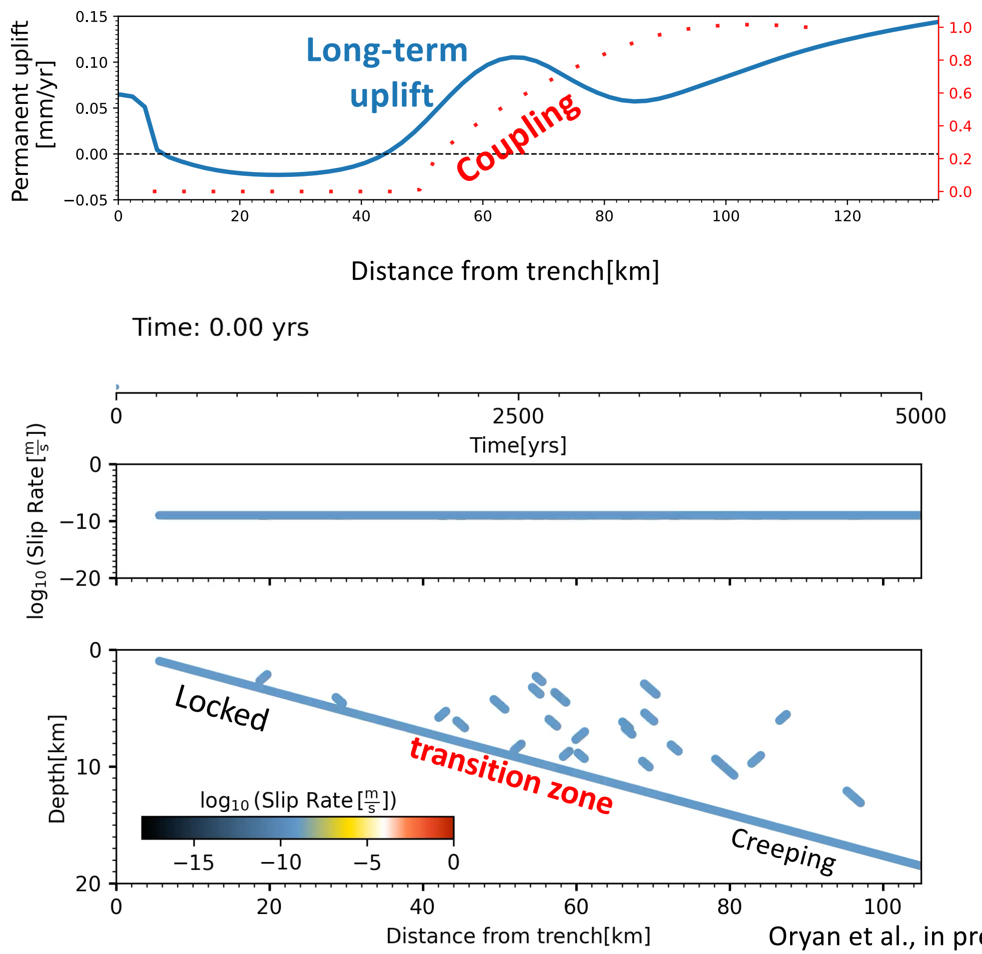


Oryan et al., in prep.

MODELING INTERSEISMIC INELASTIC DEFORMATION ACROSS UPPER PLATES

- Simulations of seismic cycles along a megathrust fault, combined with discrete, randomly distributed upper plate faults governed by rate-and-state friction laws, reveal that:
  - Upper plate faults can **fail interseismically** and generate earthquakes.
  - **Permanent uplift**, observed after four seismic cycles, **peaks above the transition zone**.

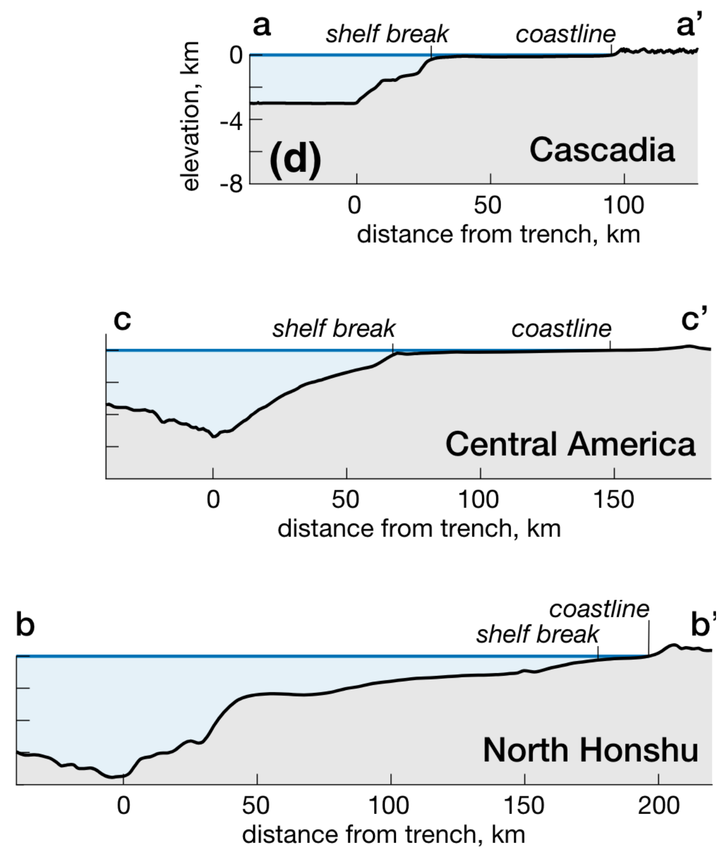
Oryan et al., in prep.



Oryan et al., in prep.

IMPLICATIONS FOR LONG-TERM PLATE COUPLING

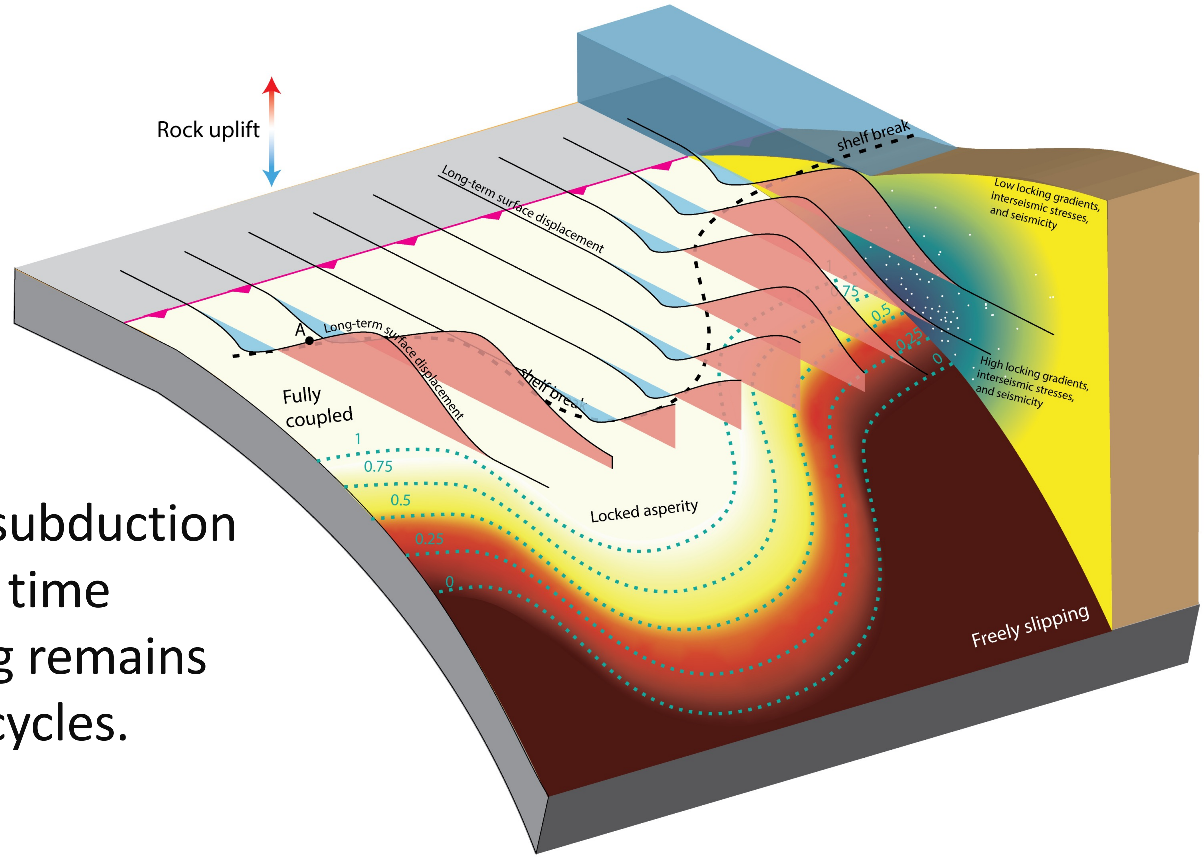
- Our results imply that the downdip pattern of megathrust locking tends to **remain steady over hundreds of thousands of years**.
- Could the absence of a landscape signature indicative of frequent changes in megathrust coupling?



Malatesta et al [2021]

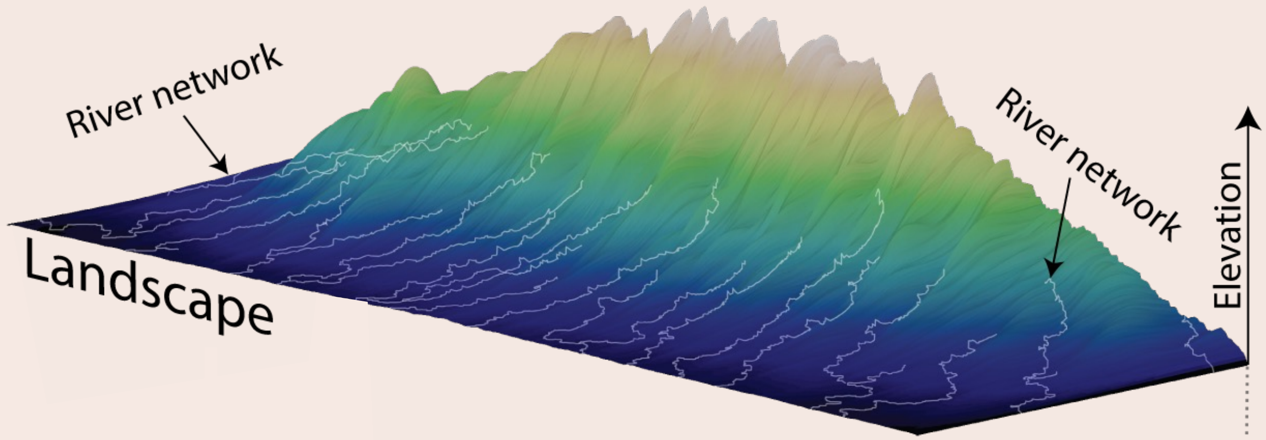
KEY POINTS SO FAR

- 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.



Oryan et al., 2024

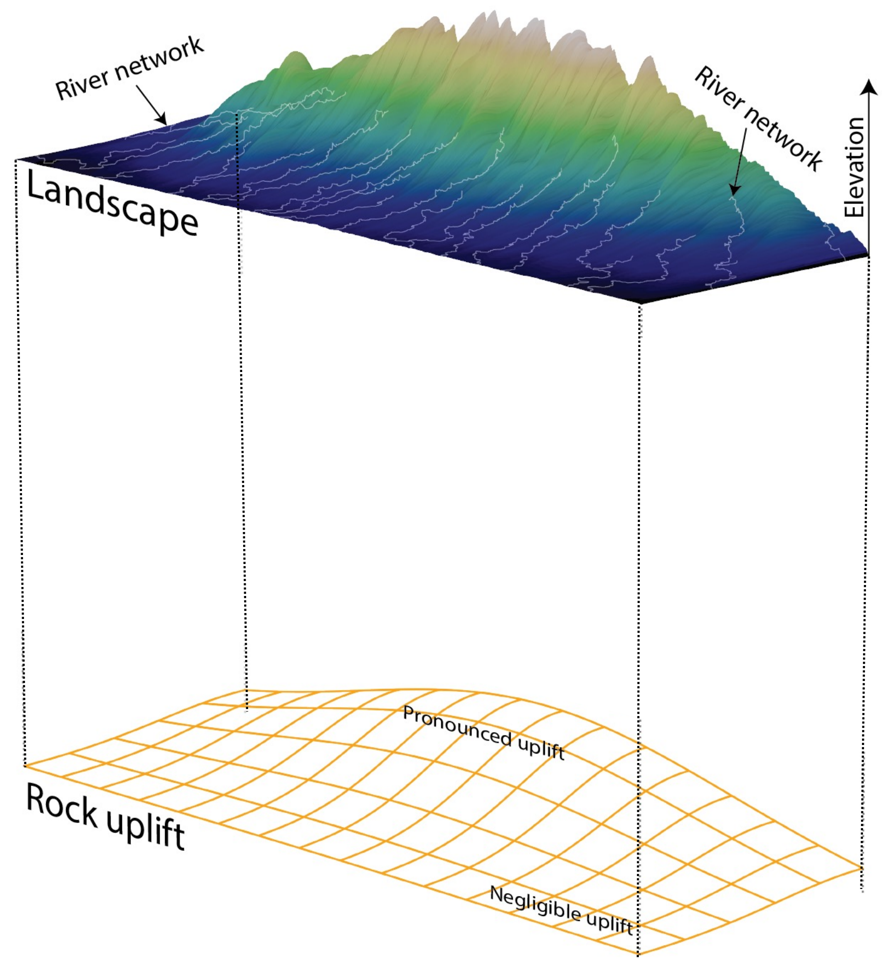
Section 3 - Inferring Long-Term Tectonic Uplift from Bayesian Inversion of Landscapes



Oryan et al., in review , https://doi.org/10.31223/X5T407

INFERRING LONG-TERM TECTONIC UPLIFT FROM BAYESIAN INVERSION OF LANDSCAPES

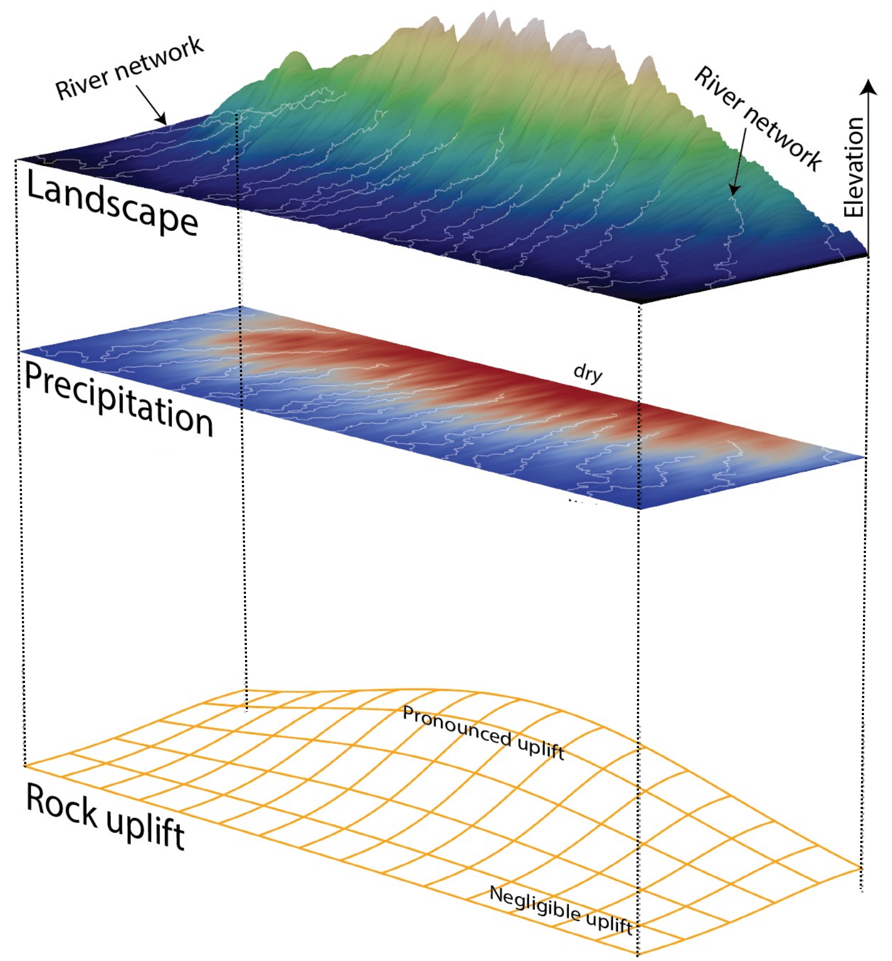
- Landscapes encode the forcing of **tectonic uplift**



Oryan et al., 2024 (in review)

INFERRING LONG-TERM TECTONIC UPLIFT FROM BAYESIAN INVERSION OF LANDSCAPES

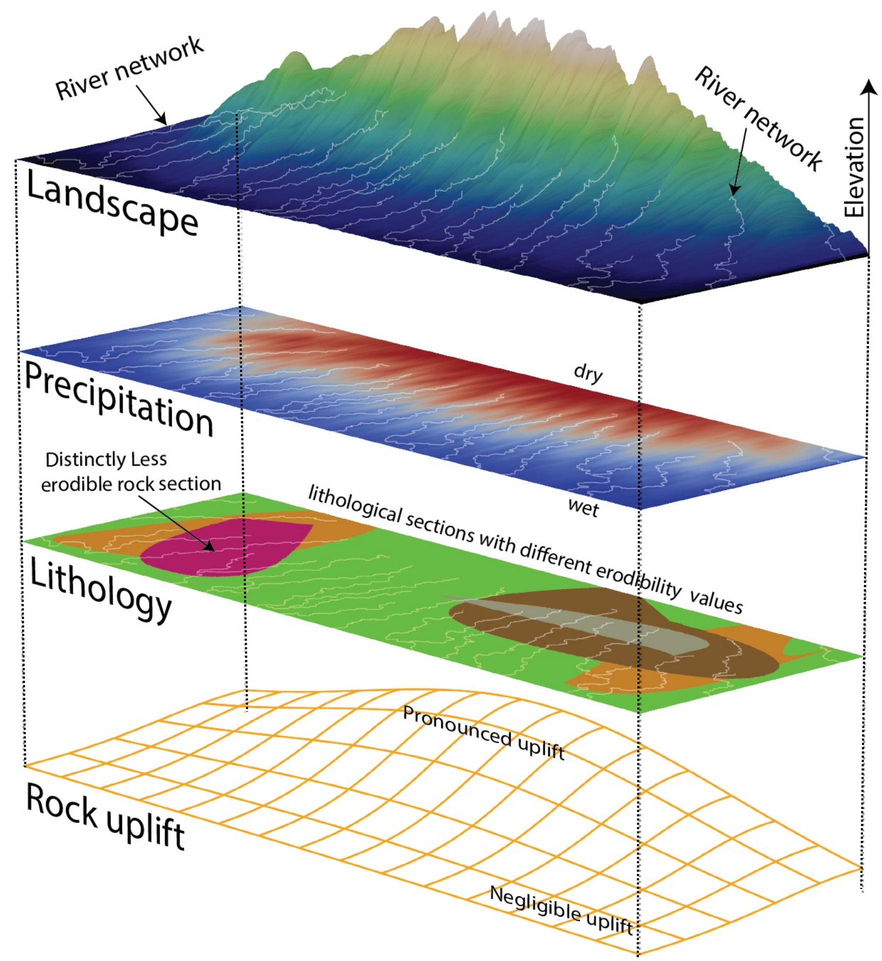
- Landscapes encode the combined forcing of **tectonic uplift** and erosion driven by **climate**



Oryan et al., 2024 (in review)

INFERRING LONG-TERM TECTONIC UPLIFT FROM BAYESIAN INVERSION OF LANDSCAPES

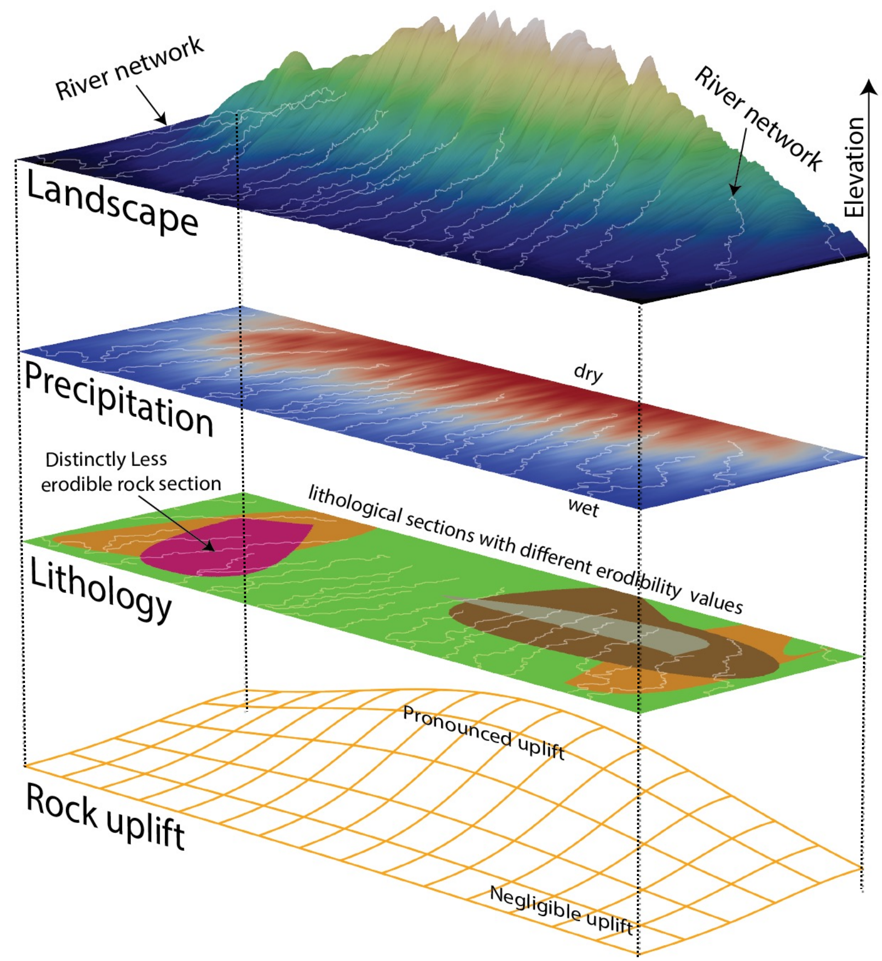
- Landscapes encode the combined forcing of **tectonic uplift** and erosion driven by **climate** and **rock erodibility**.



Oryan et al., 2024 (in review)

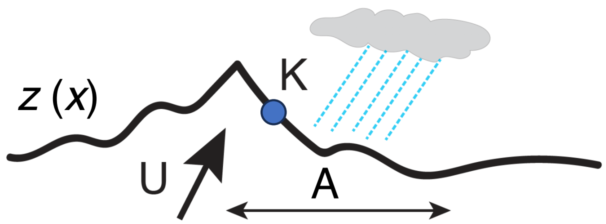
INFERRING LONG-TERM TECTONIC UPLIFT FROM BAYESIAN INVERSION OF LANDSCAPES

- Landscapes encode the combined forcing of **tectonic uplift** and erosion driven by **climate** and **rock erodibility**.
- Disentangling their contributions is essential for using landscapes as quantitative records of crustal deformation.



Oryan et al., 2024 (in review)

RIVER INCISION AT STEADY STATE



$$\boxed{U(X)} = \boxed{K(x)A^m(x)S^n(x)}$$

Tectonic uplift

Local incision rate *(faster for steeper slope **S**, with more water flowing and larger erodibility)*

Parameters:

- erodibility (**K**)
- drainage area (**A**)
- exponents (**m**, **n**)

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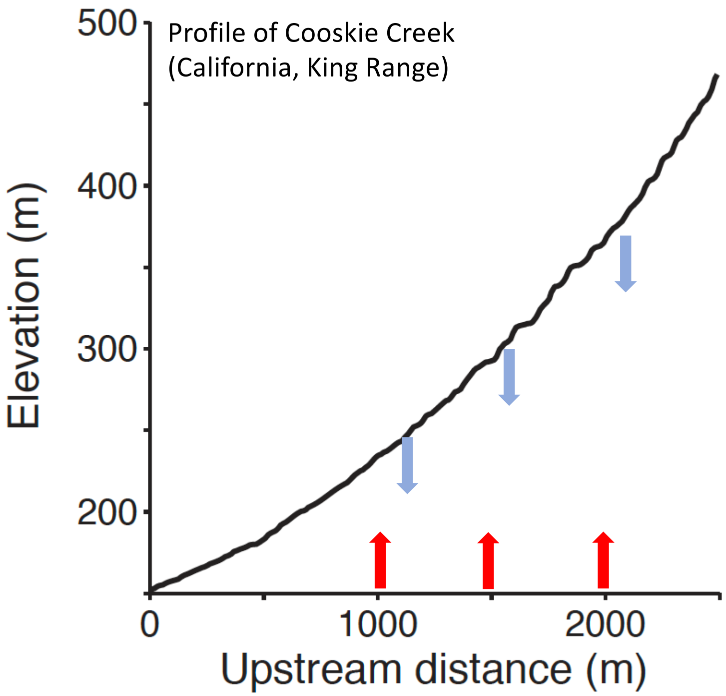

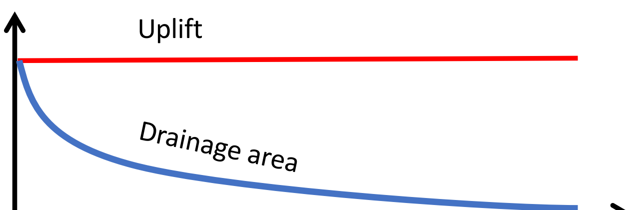

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River concavity reflects:

- Upstream decrease in drainage area
- Shape of uplift
- Spatially variable erodibility
- climate

Perron & Royden, 2013

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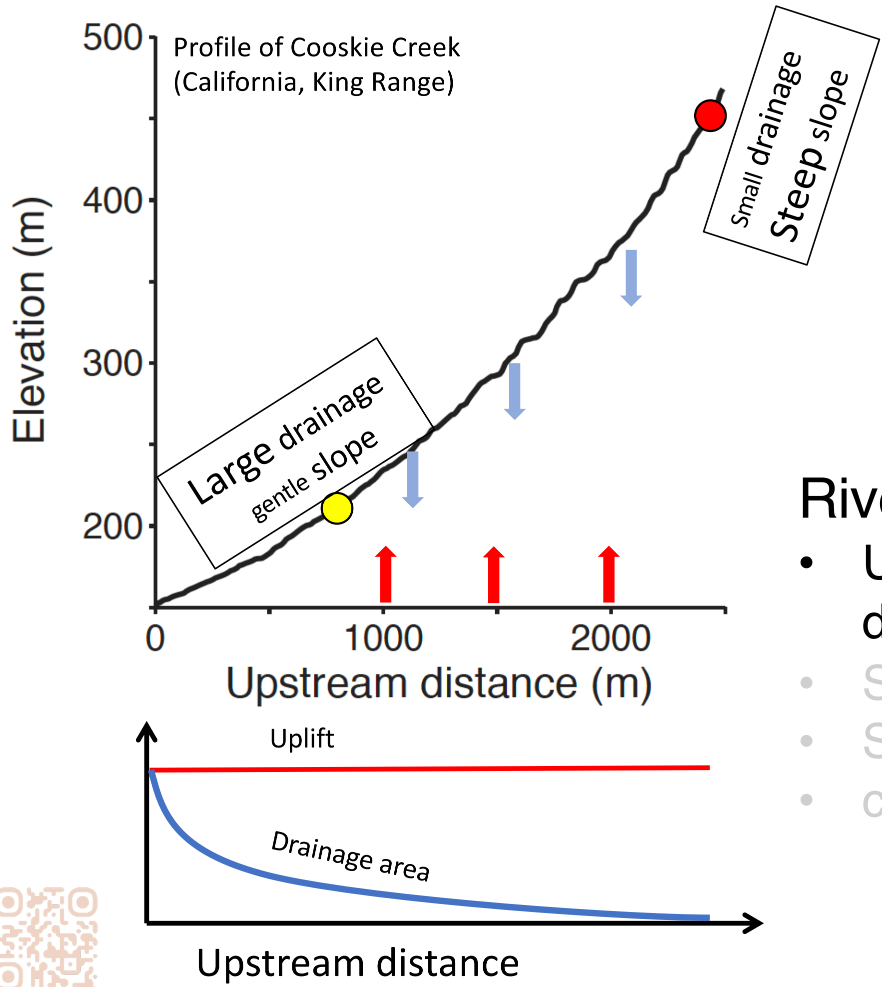

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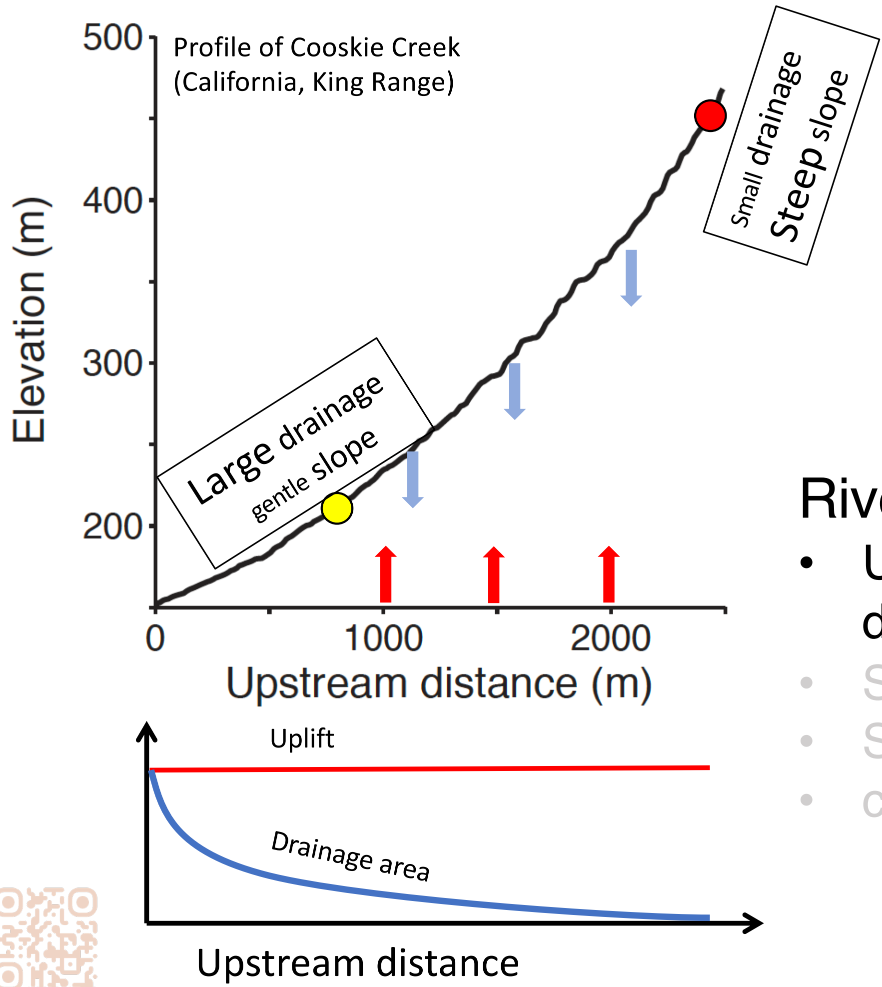
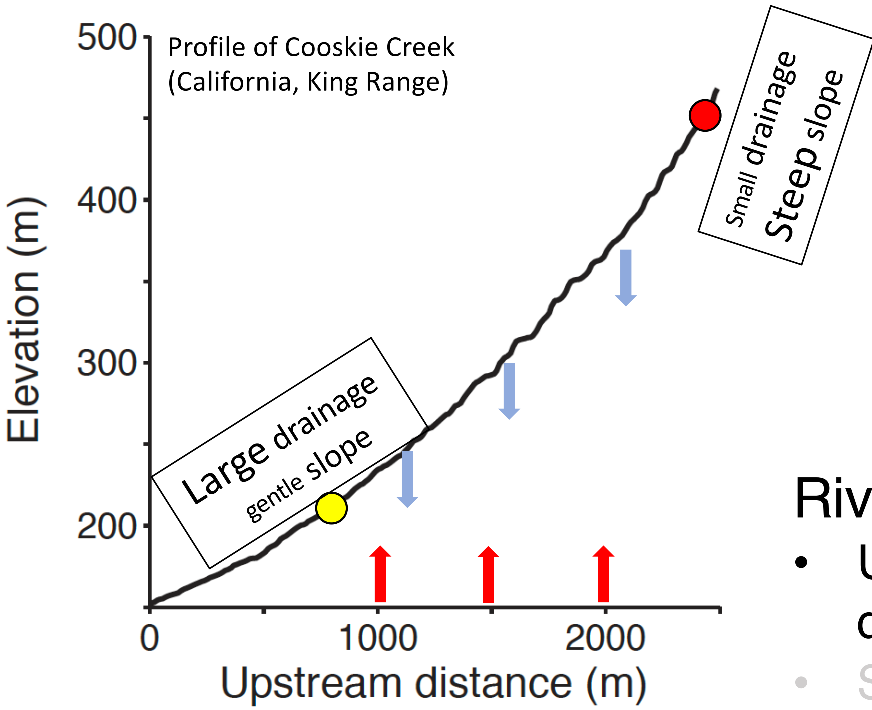
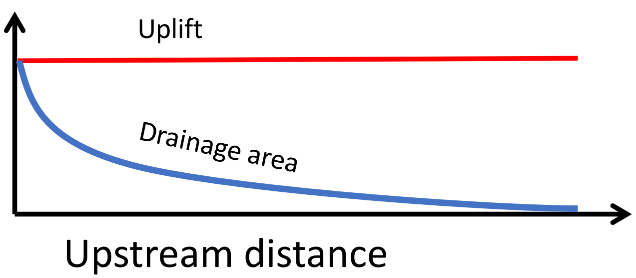


Rive
- U
  d
- S
- S
- c

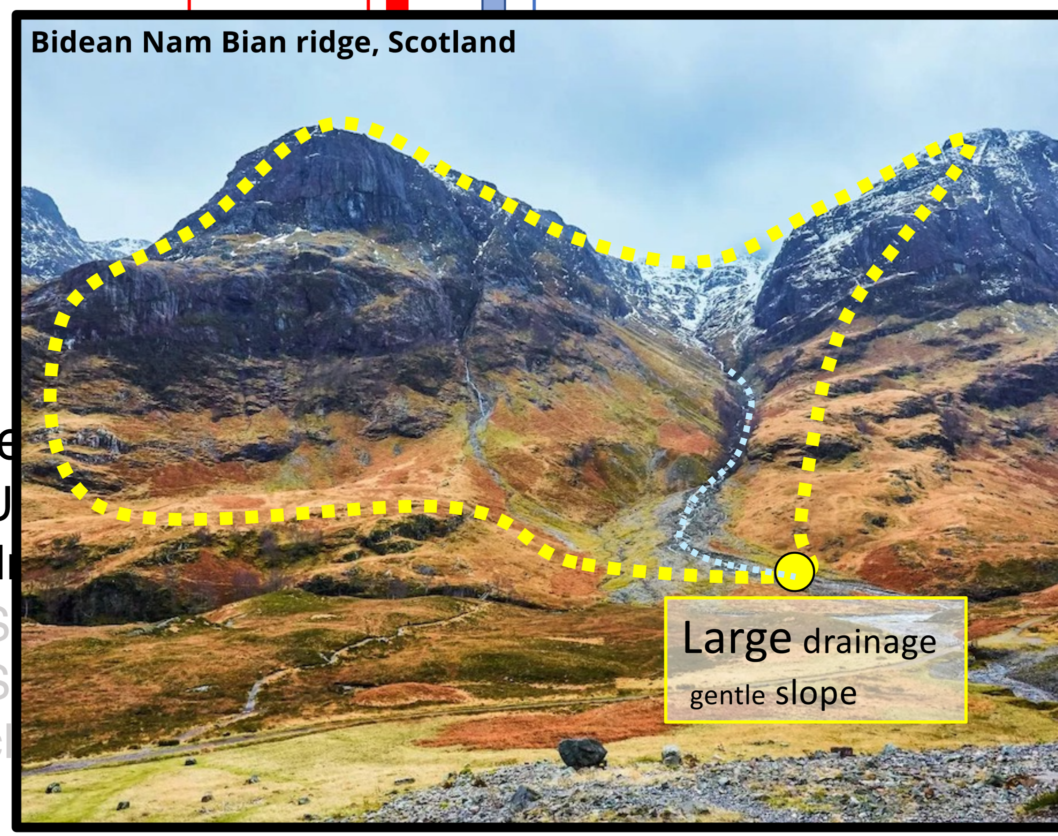
Perron & Royden, 2013

RIVER INCISION AT STEADY STATE



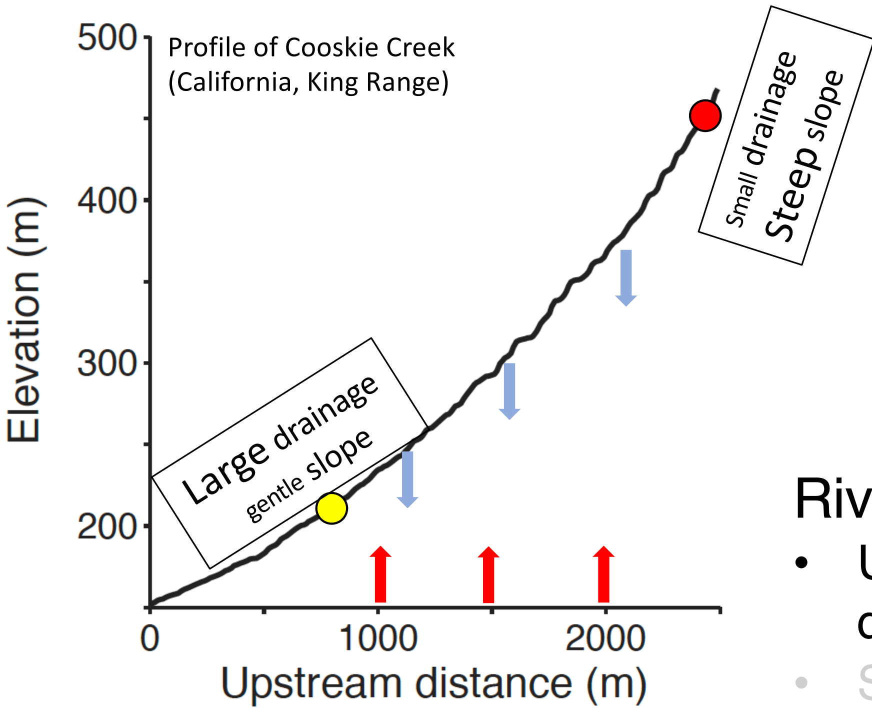


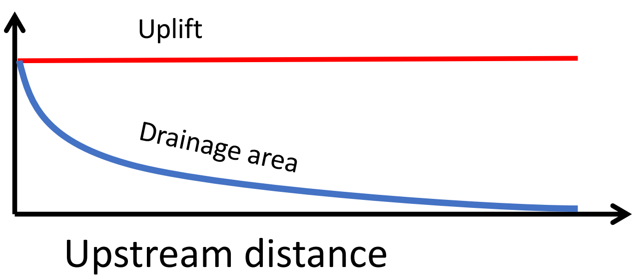
Rive
- U
d
- S
- S
- cl



Perron & Royden, 2013

RIVER INCISION AT STEADY STATE





Rive
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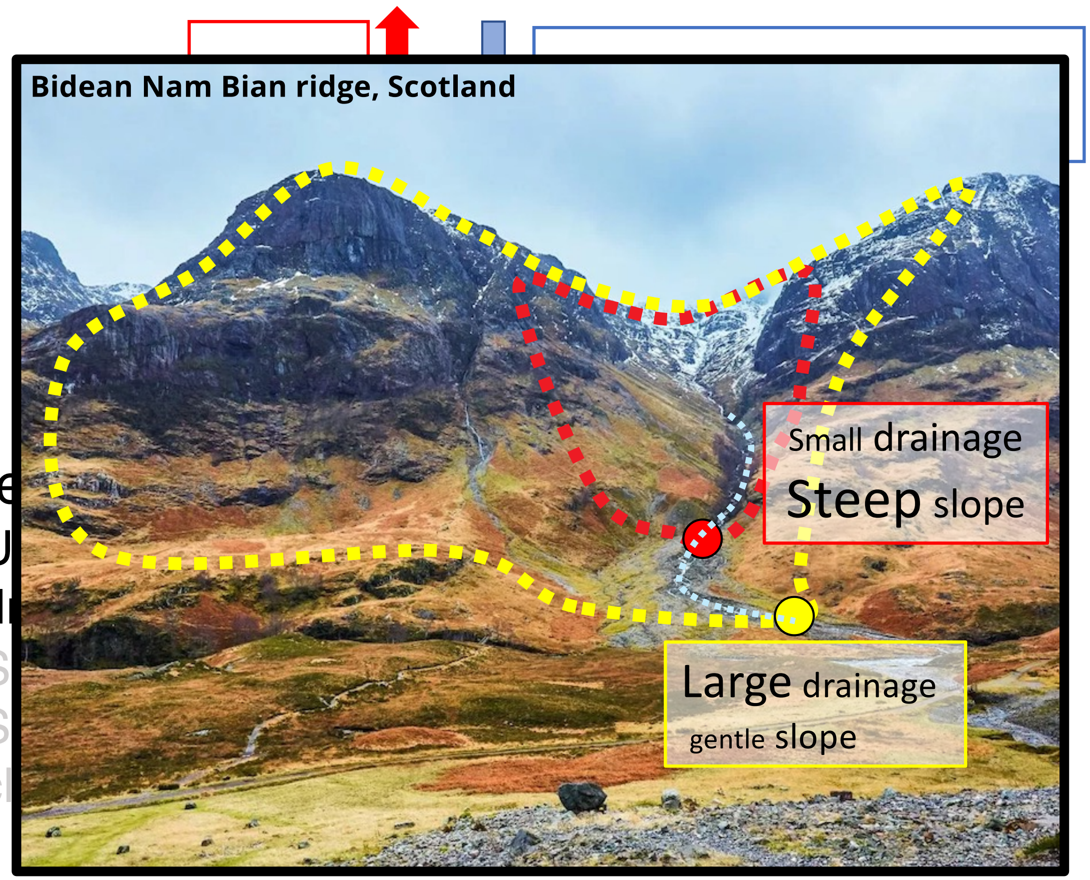
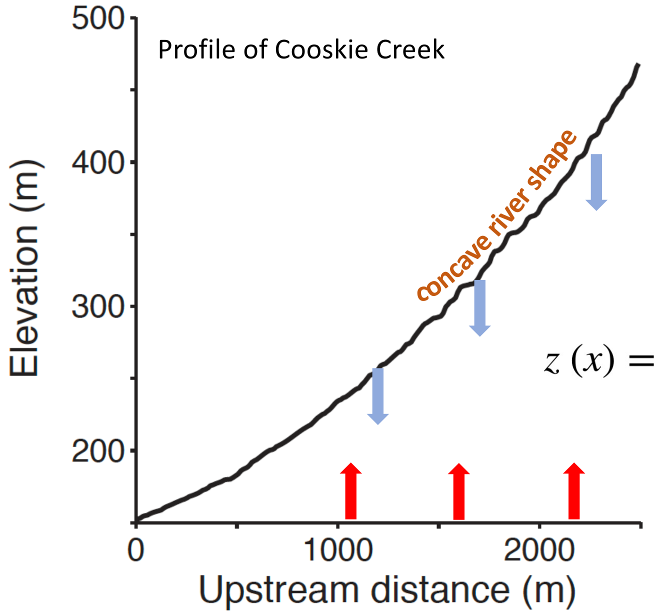


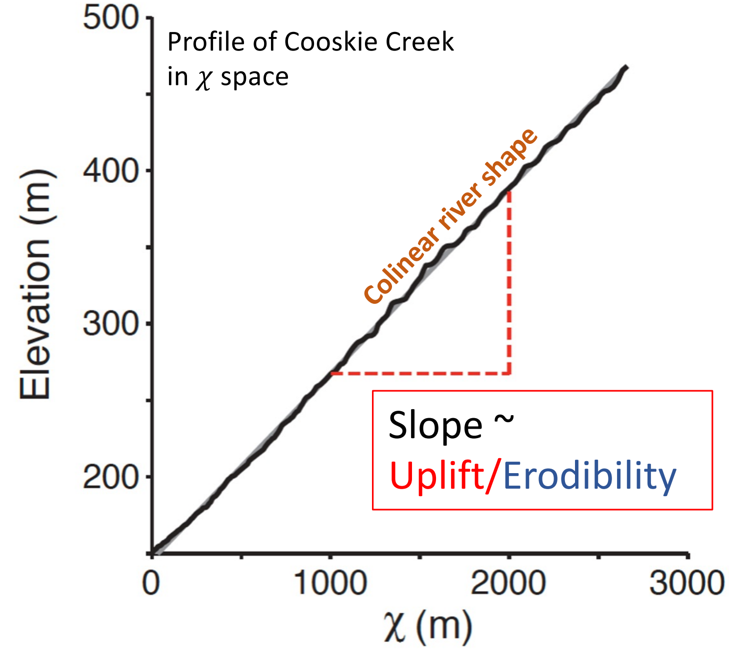
Perron & Royden, 2013

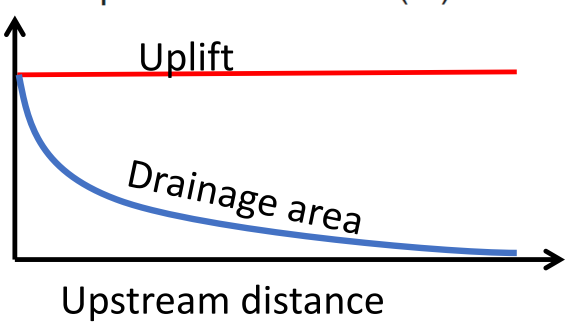
χ – TRANSFORMATION OF RIVERS



$$z\,(x) = z_b + \left(\frac{U_0}{K_0 A_0}\right)^{\frac{1}{n}} \underbrace{\int_{x_b}^{x} \left(\frac{A_0}{A^*\,(x)}\right)^{\frac{m}{n}} d\,x}_{\chi}$$

χ – TRANSFORMATION

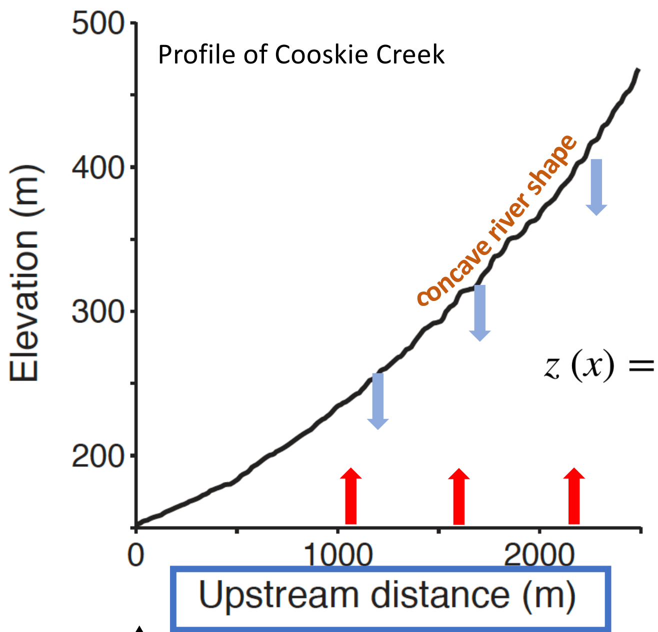




Corrects for upstream decrease in drainage area while assuming uniform spatial uplift

Perron & Royden, 2013

χ – TRANSFORMATION OF RIVERS



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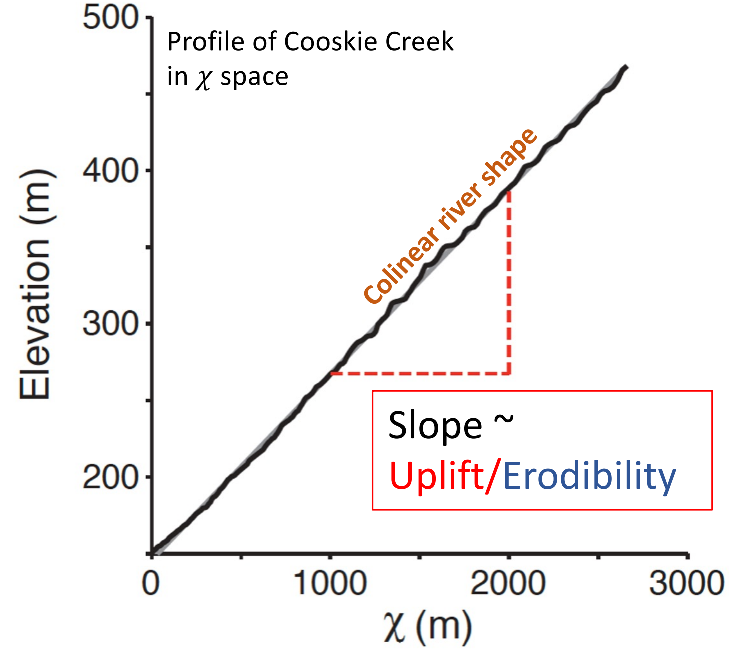

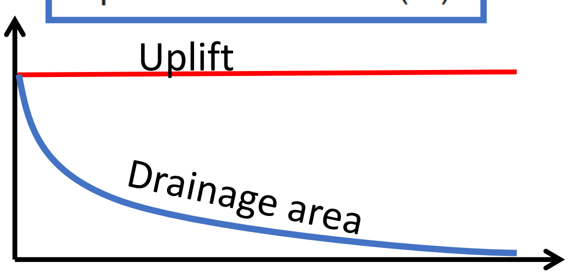

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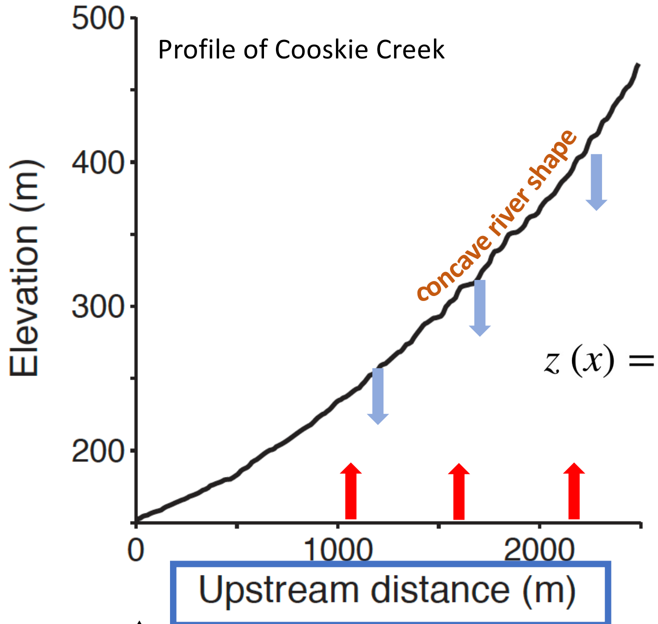
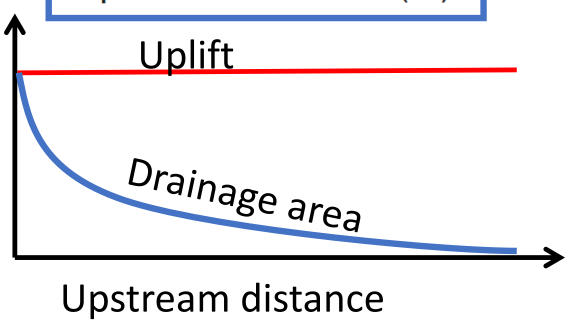
χ - TRANSFORMATION

Perron & Royden, 2013

χ – TRANSFORMATION OF RIVERS





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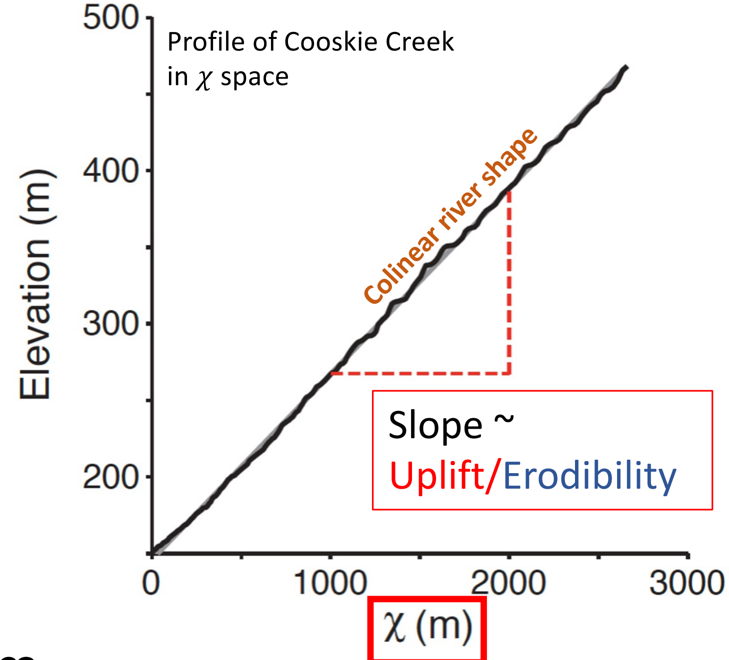
χ – TRANSFORMATION

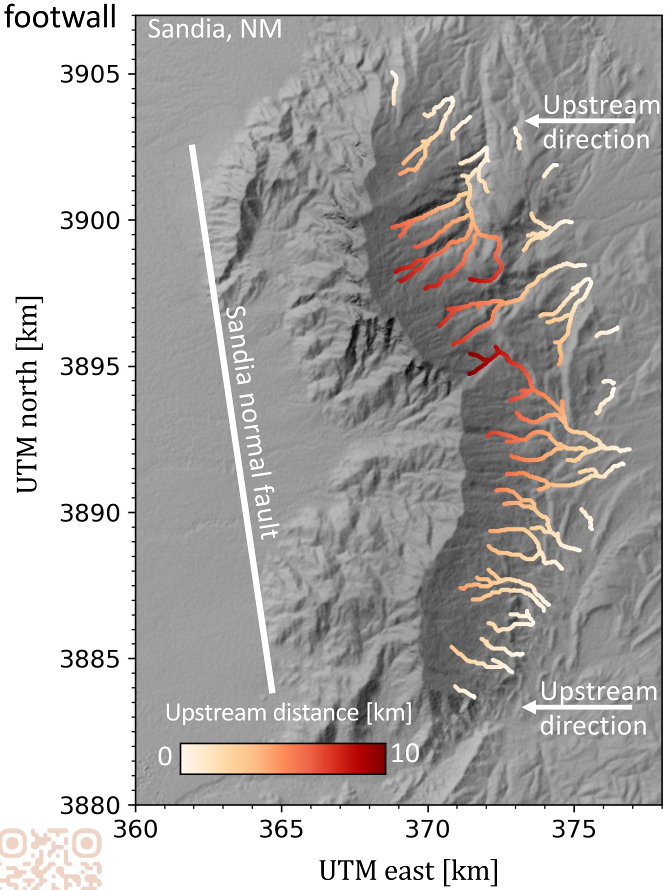


Corrects for upstream decrease in drainage area while assuming uniform spatial uplift

Perron & Royden, 2013

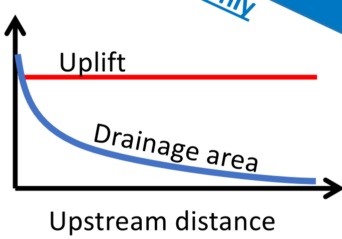
χ – TRANSFORMATION OF RIVER PROFILES IN SANDIA

Application to simple tectonic settings - normal fault footwall



χ – TRANSFORMATION

Corrected for area only



River concavity reflects:

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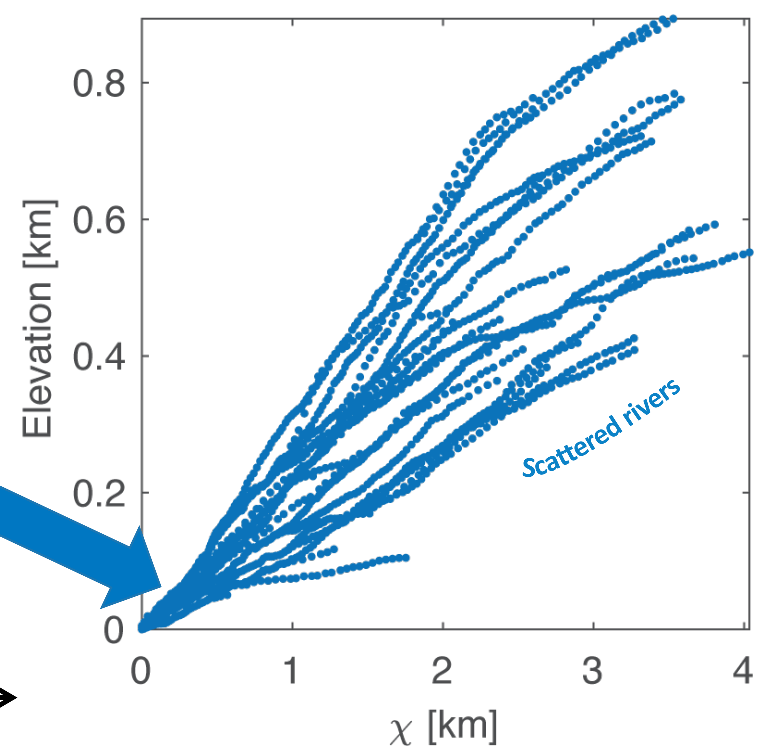
- Shape of uplift
- Spatially variable erodibility and climate

χ space —Sandia rivers



Olive et al., 2022

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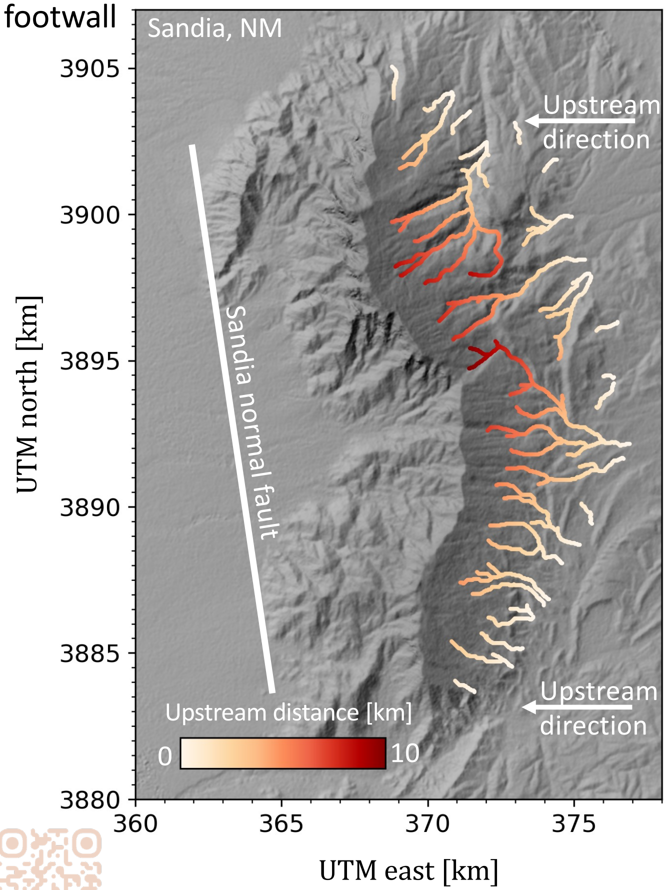

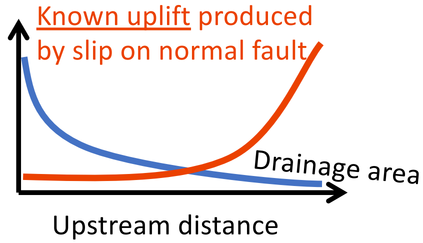

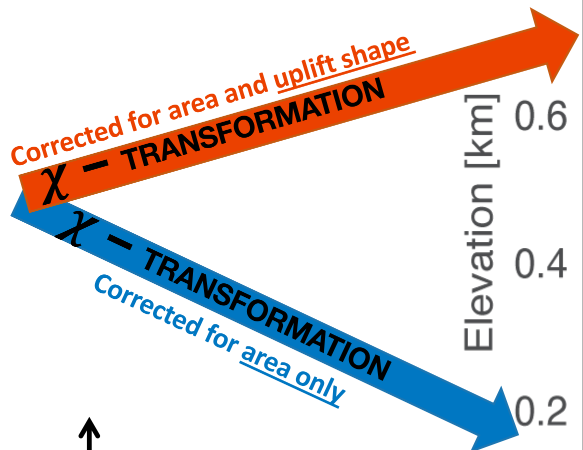

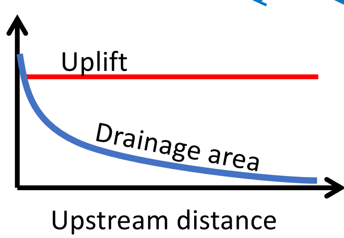

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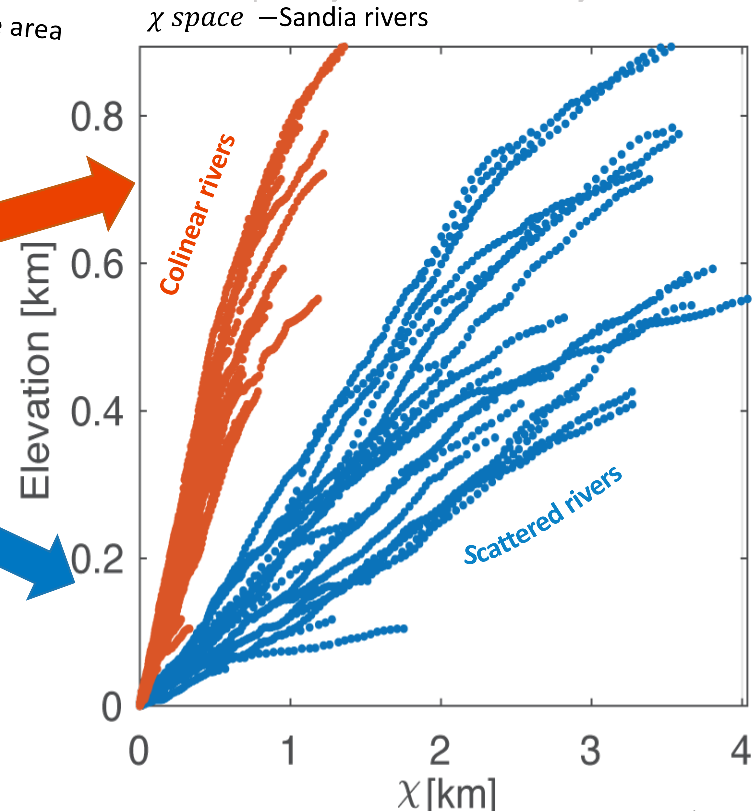

Olive et al., 2022

χ – TRANSFORMATION OF RIVER PROFILES IN THE HIMALAYAS

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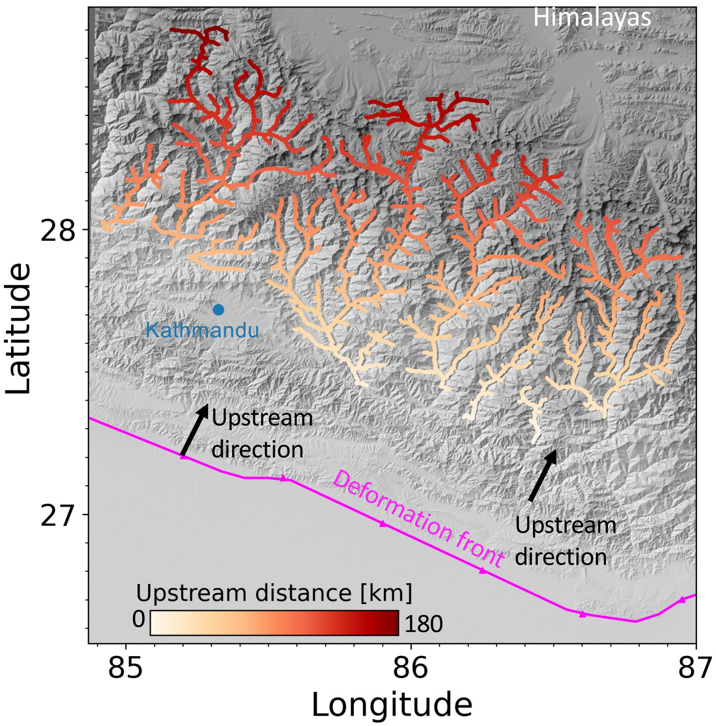

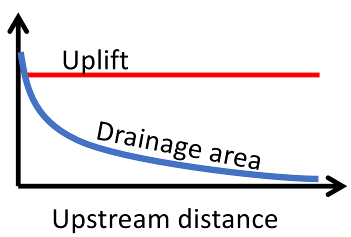

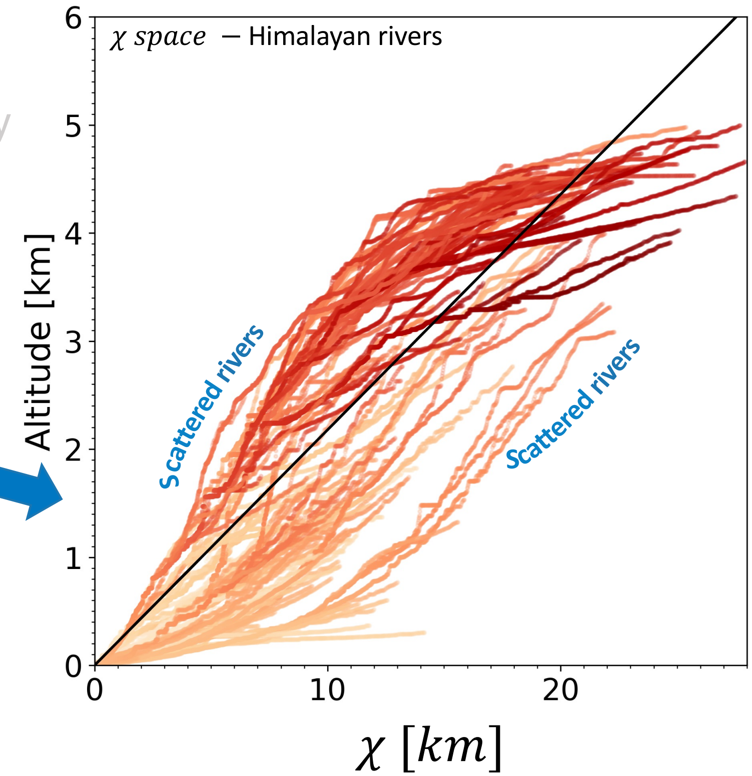

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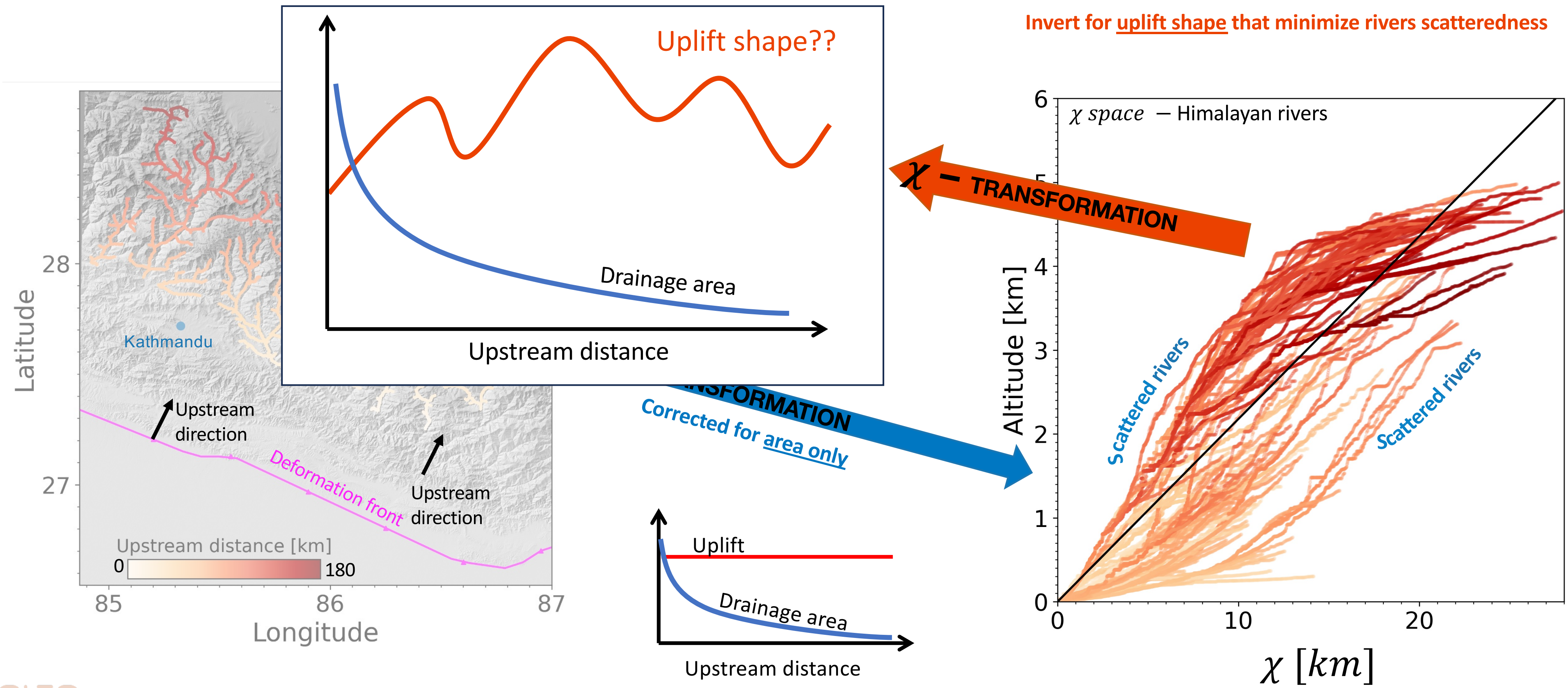

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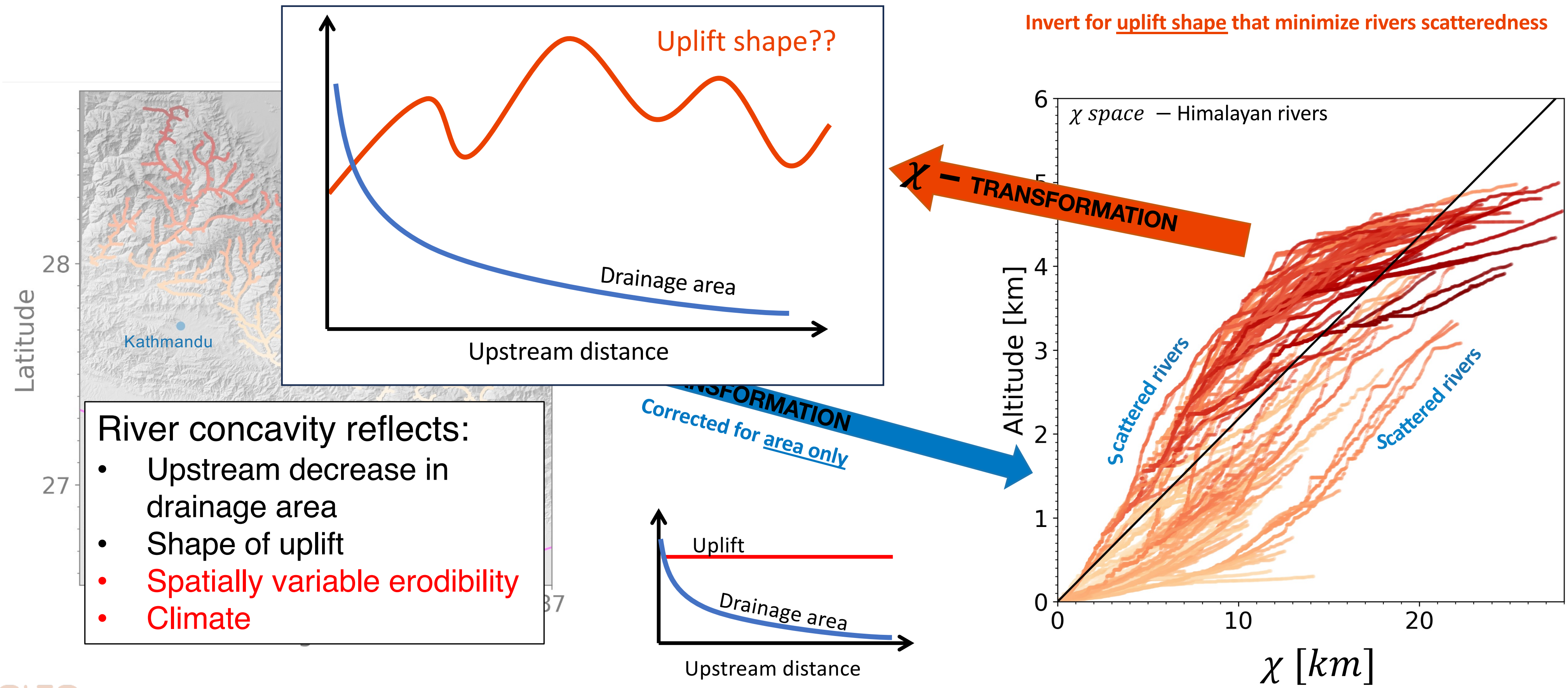

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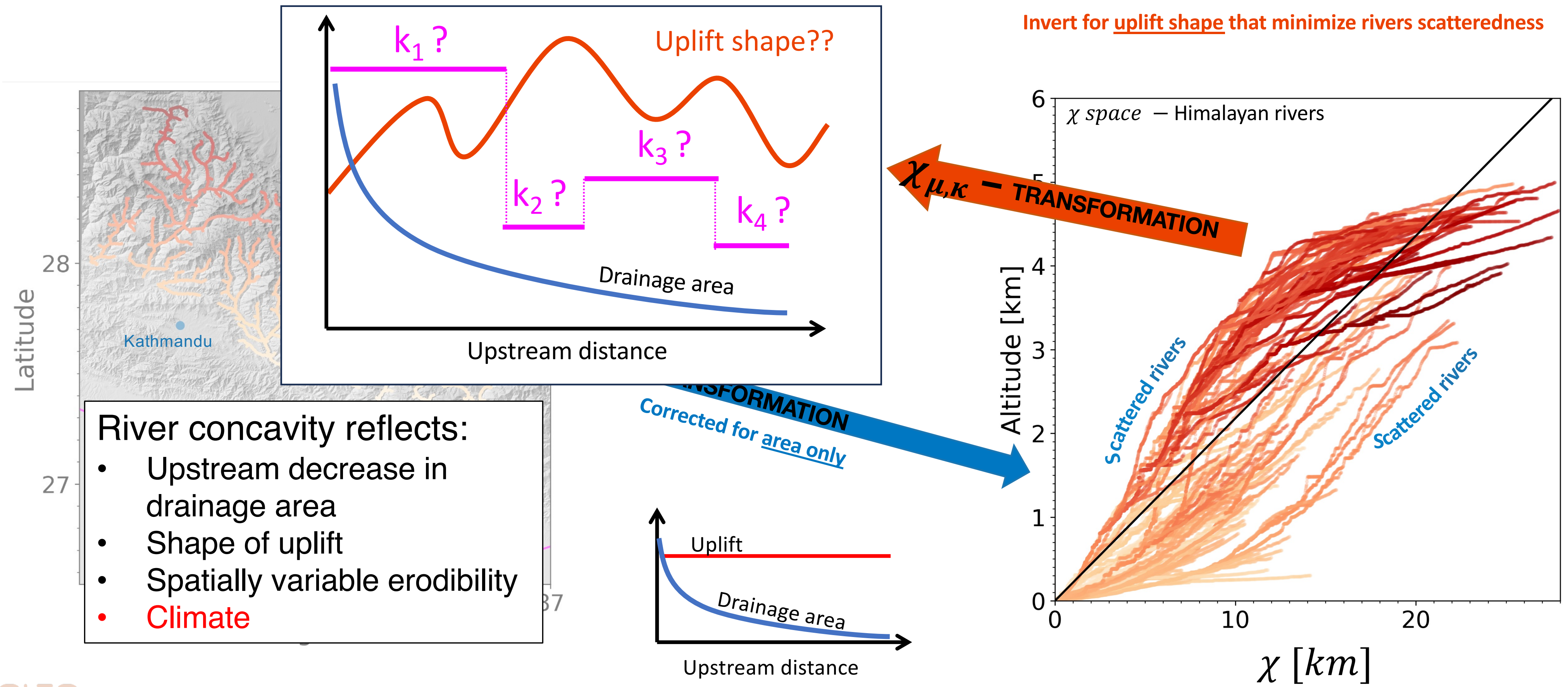

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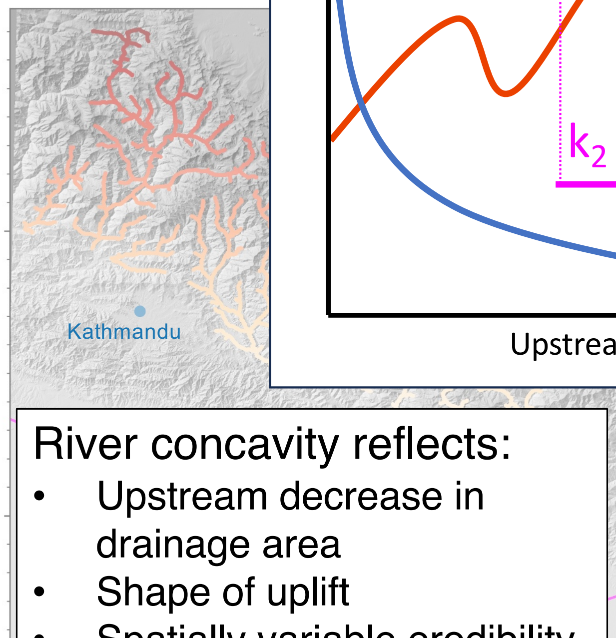
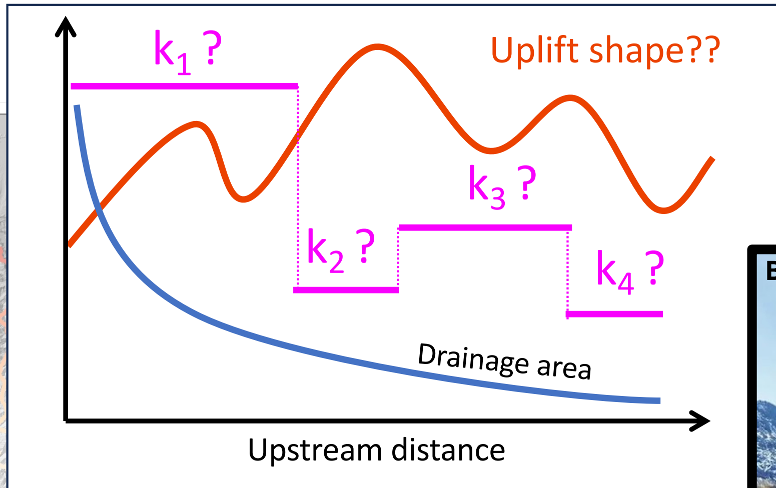
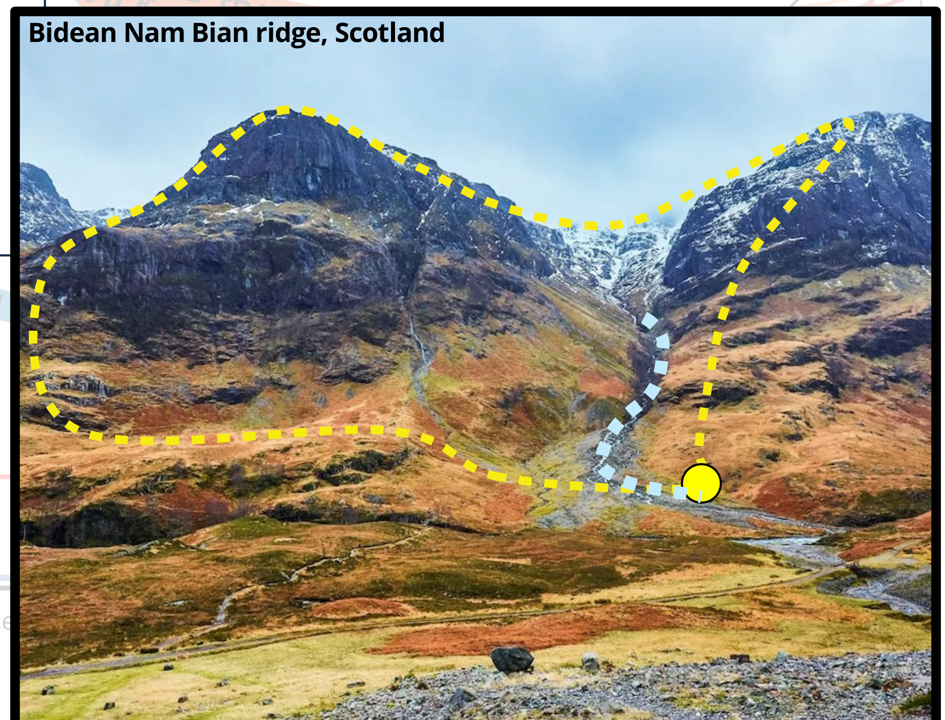


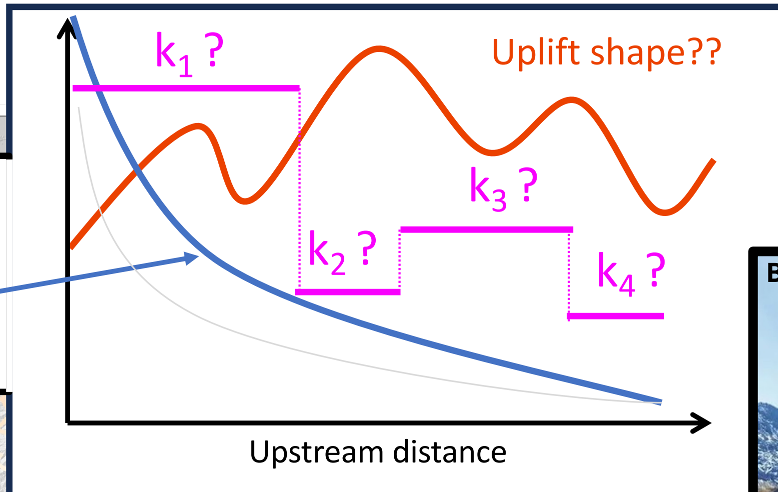


River concavity reflects:

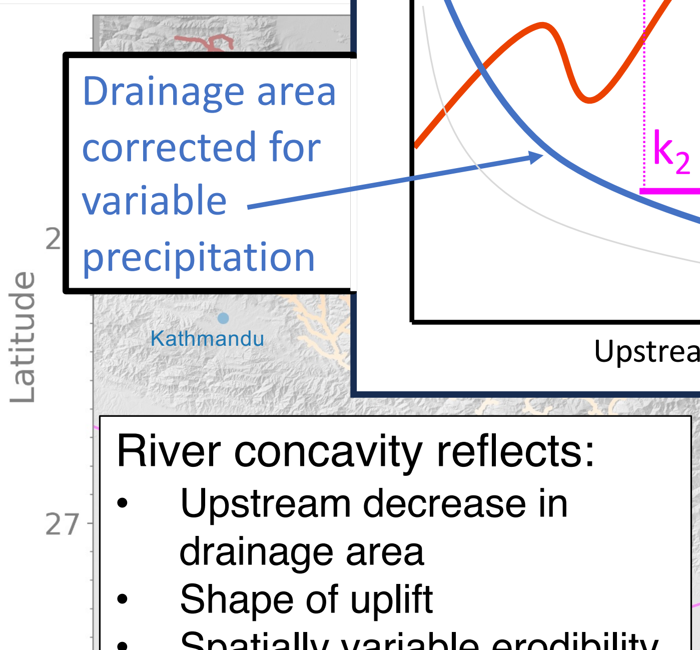
- Upstream decrease in drainage area
- Shape of uplift
- Spatially variable erodibility
- Climate



$\chi_{u,k}$ – TRANSFORMATION OF RIVER PROFILES IN THE HIMALAYAS



Drainage area corrected for variable precipitation



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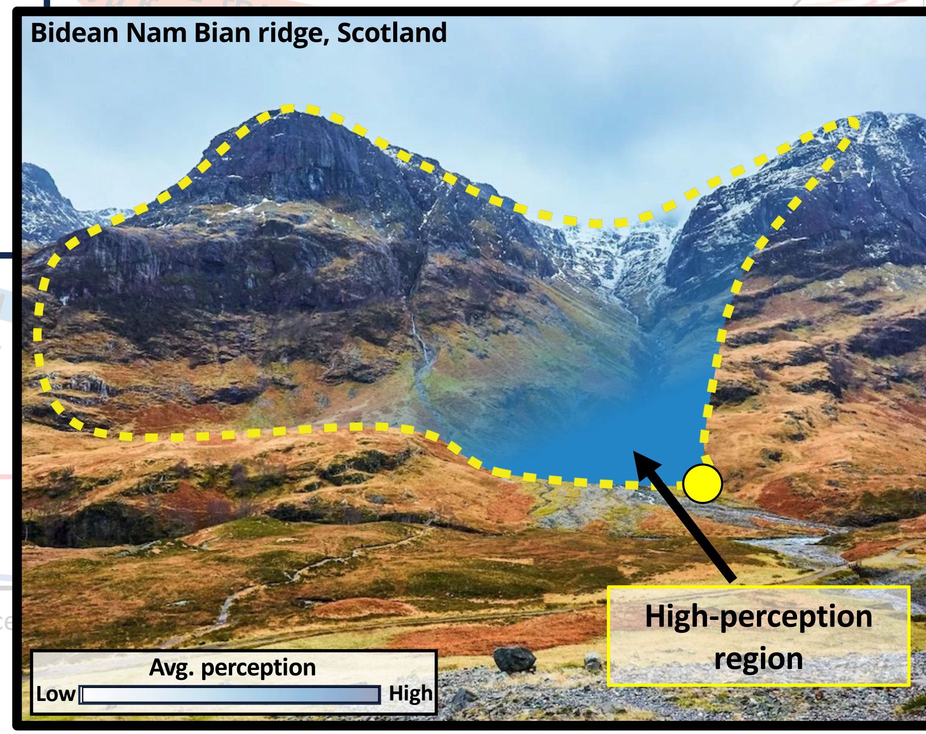

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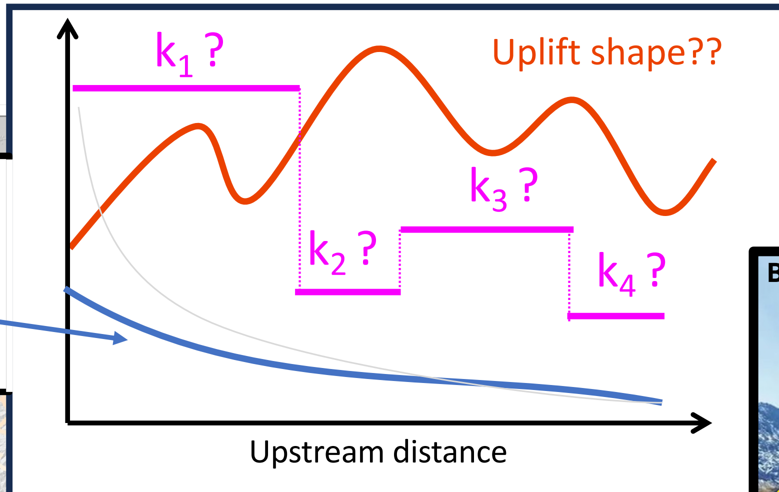

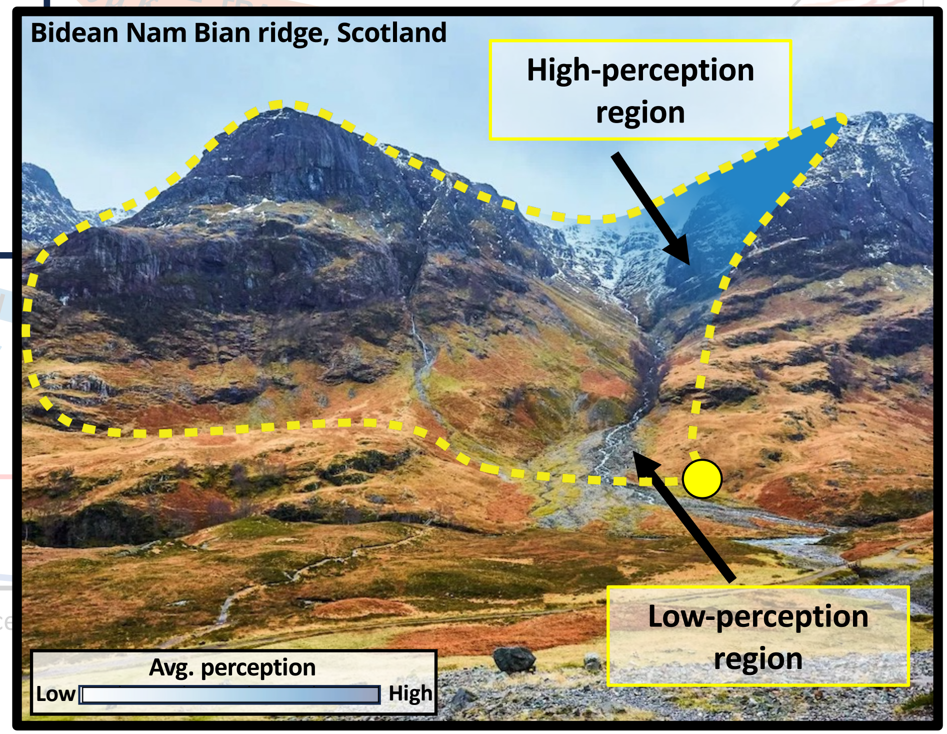

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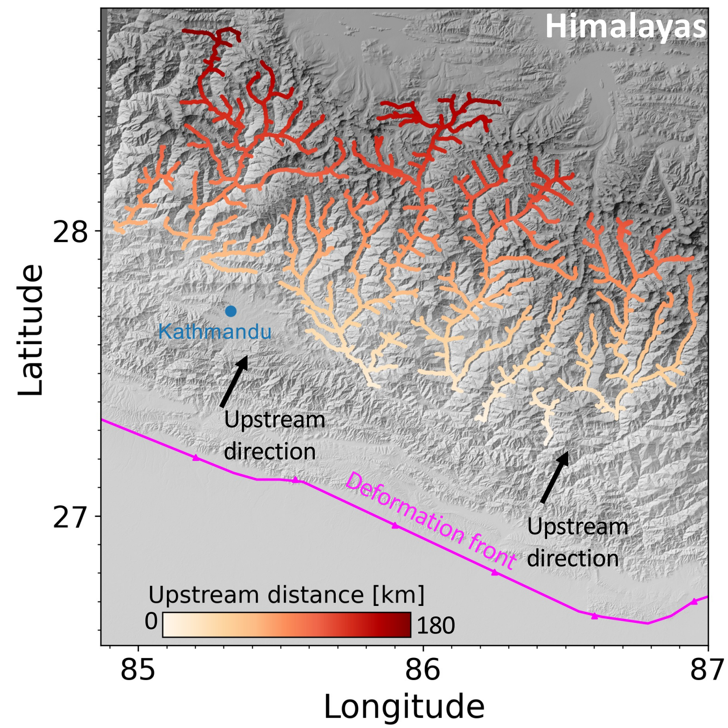
INVERTING HIMALAYAS USING $\chi_{u,k}$ TRANSFORMATION



Oryan et al., 2024 (preprint)

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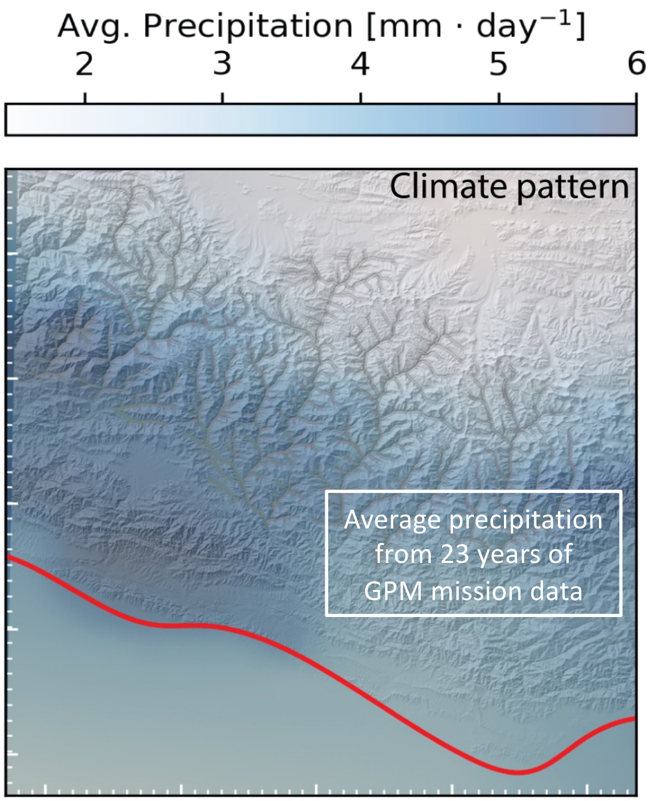

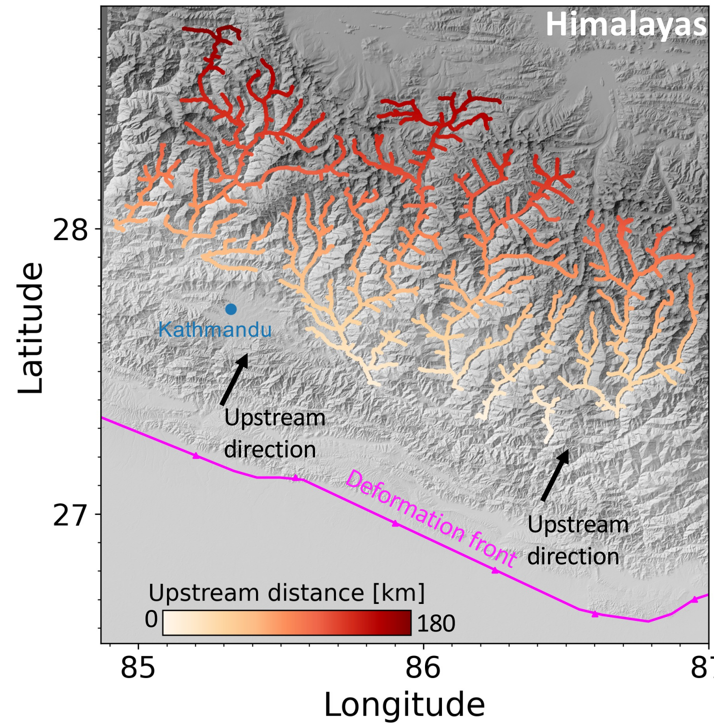

Oryan et al., in review

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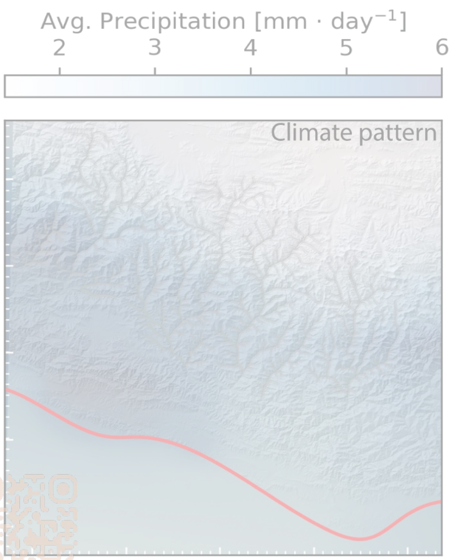
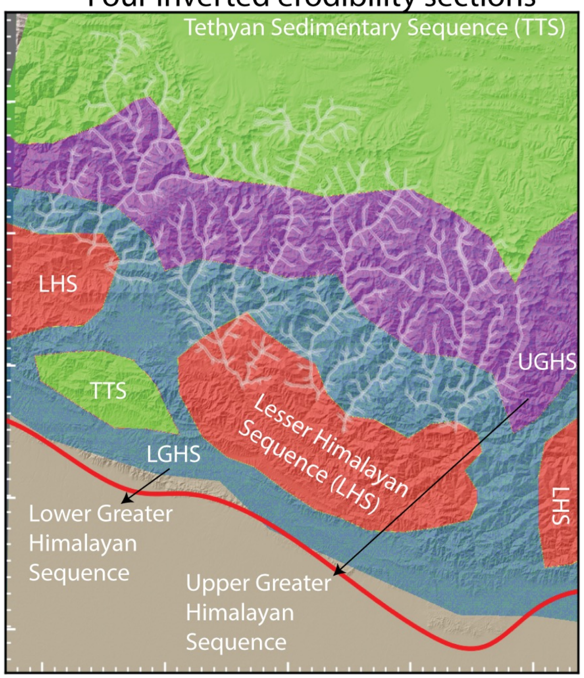
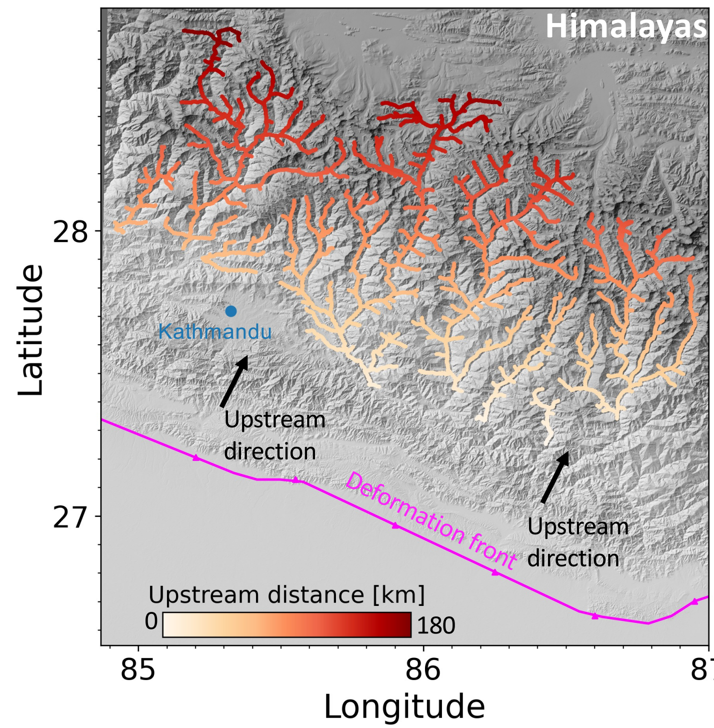


Four inverted erodibility sections





Oryan et al., in review

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1. Compute drainage area corrected for climate [e.g., Leonard & Whipple, 2021; Leonard 2023].
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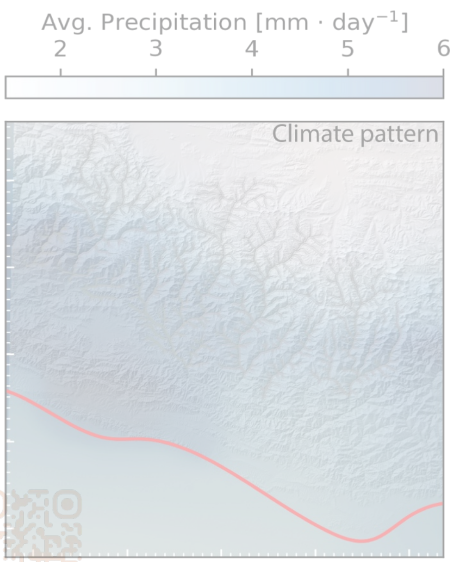
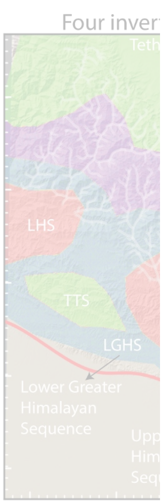
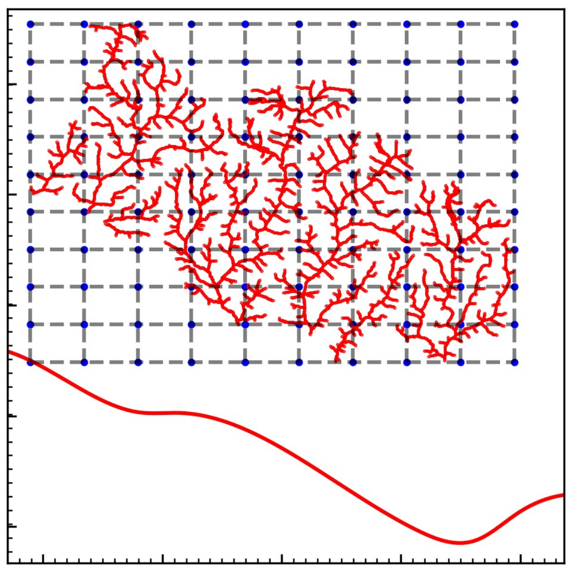
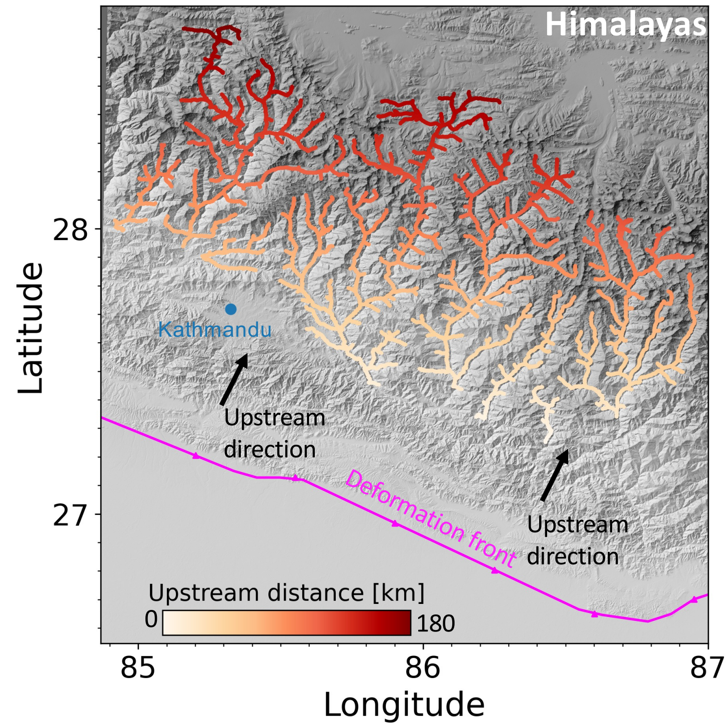
3. Describe 2D uplift surface using interpolating B-spline functions extending across the river network.









Oryan et al., in review

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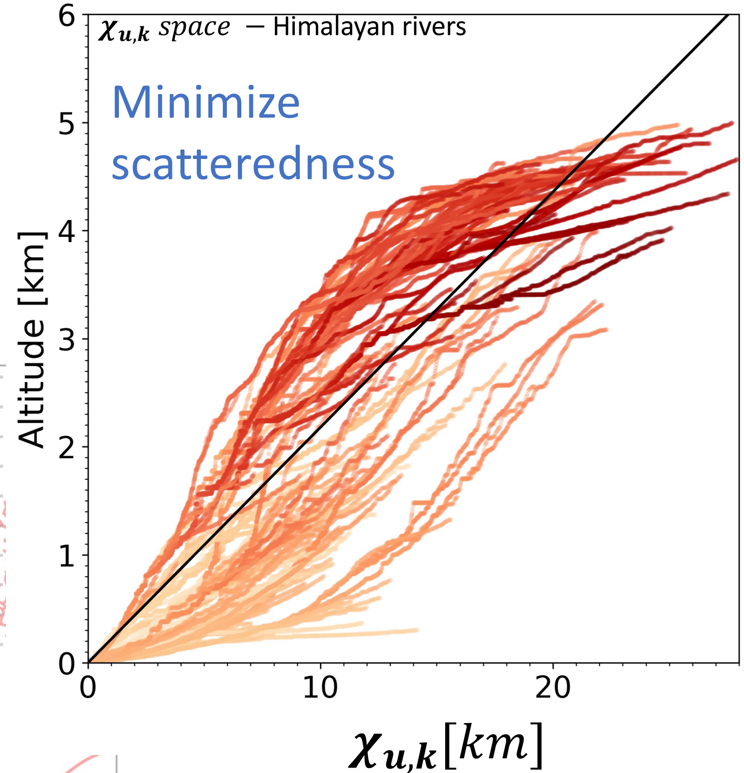
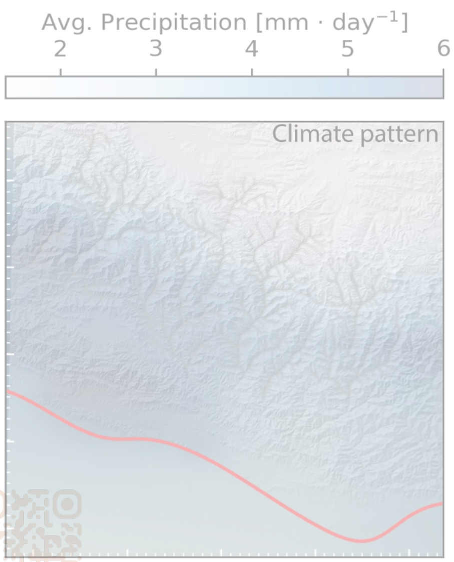
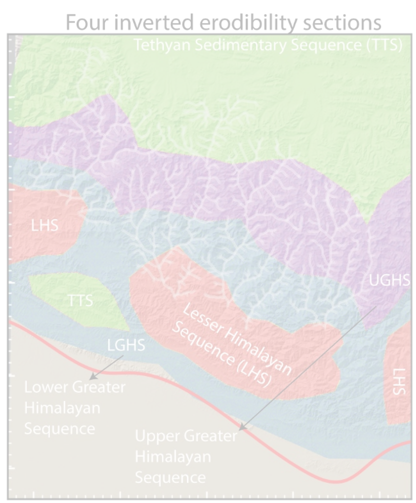
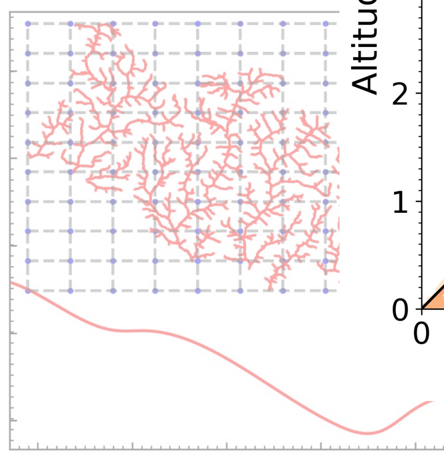
4. Invert for uplift and erodibility values minimizing $\chi_{u,k}$.





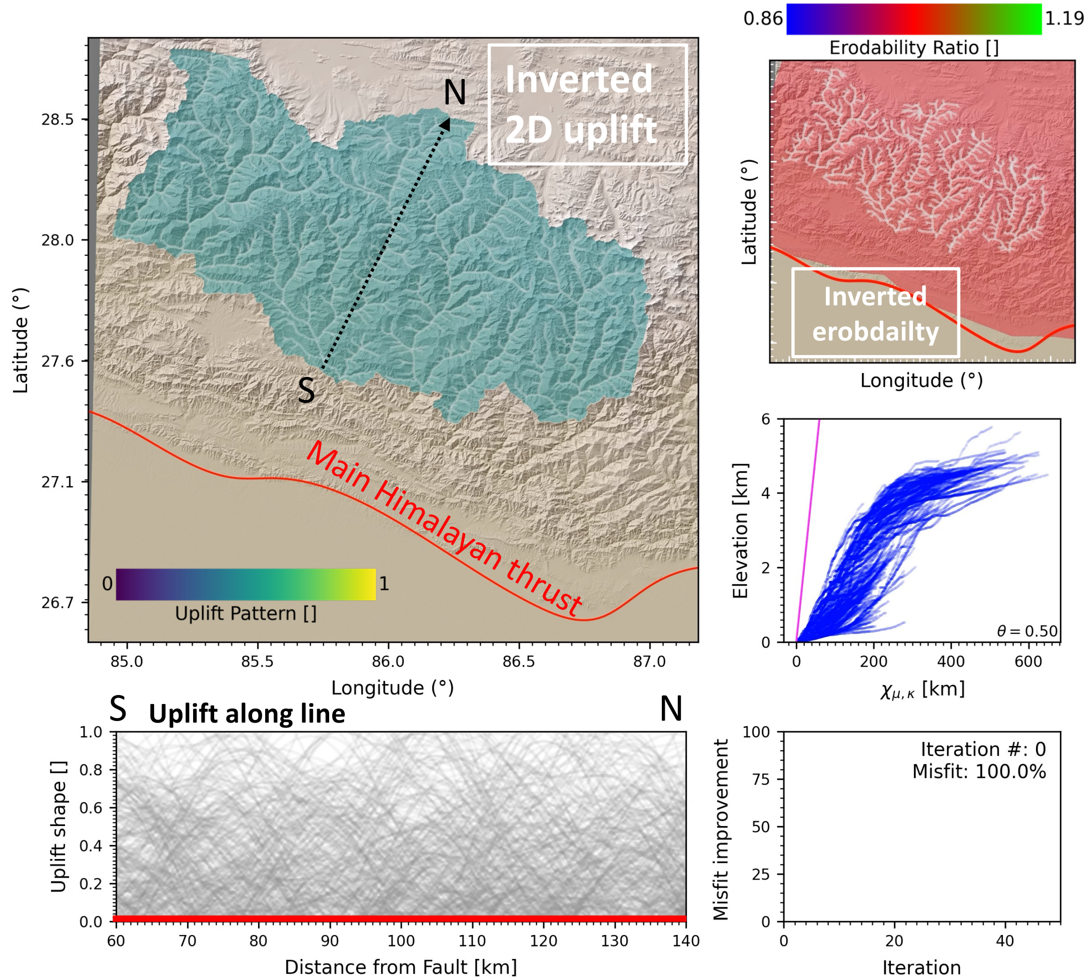




Oryan et al., in review

INVERTING HIMALAYAS USING $\chi_{u,k}$ TRANSFORMATION

- Inversion of 120,000 river nodes spanning 18,000km^2 using Bayesian Quasi-Newton inversion method.
- Inverting for 144 parameters describing the uplift pattern and 4 erodibility values that best linearizes river profiles in $\chi_{u,k}$ space.



Mean solution

Posterior sample

Oryan et al., in review

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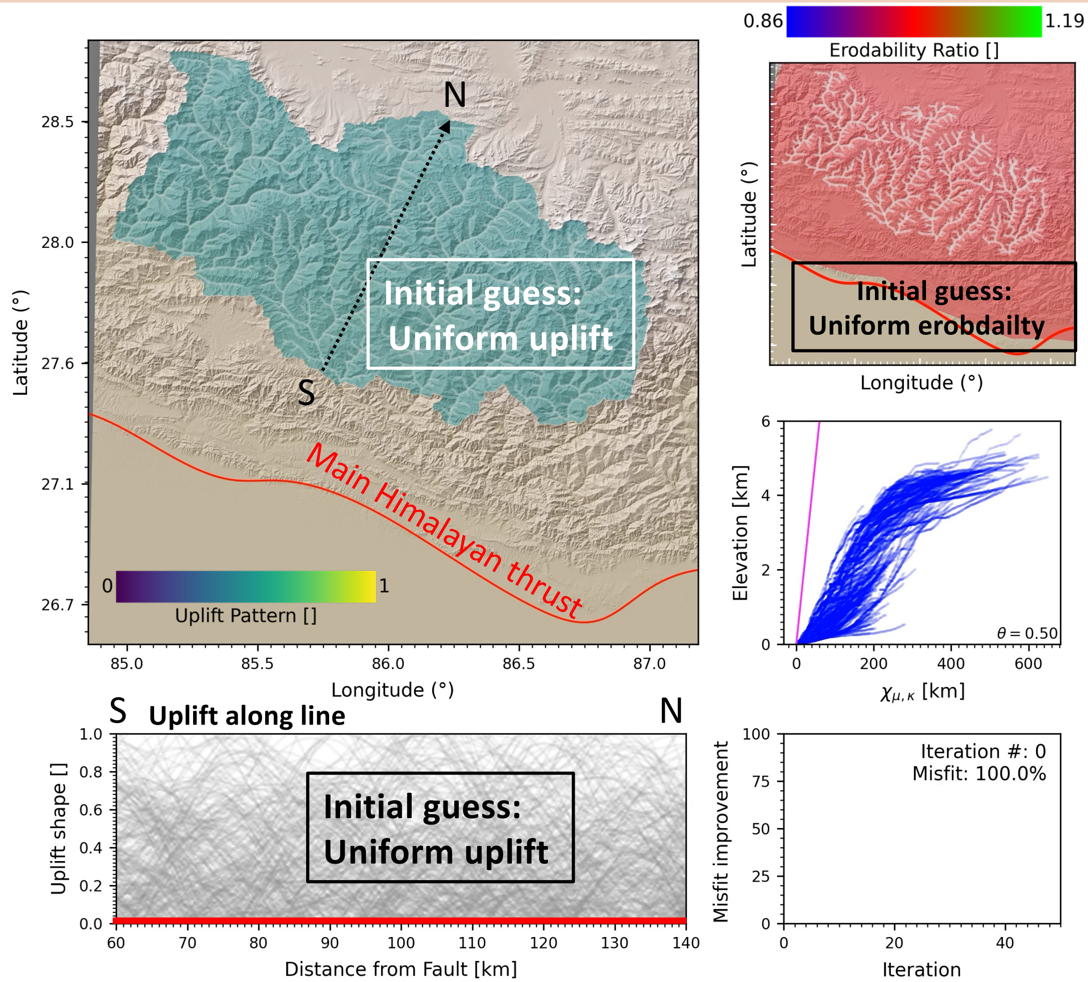

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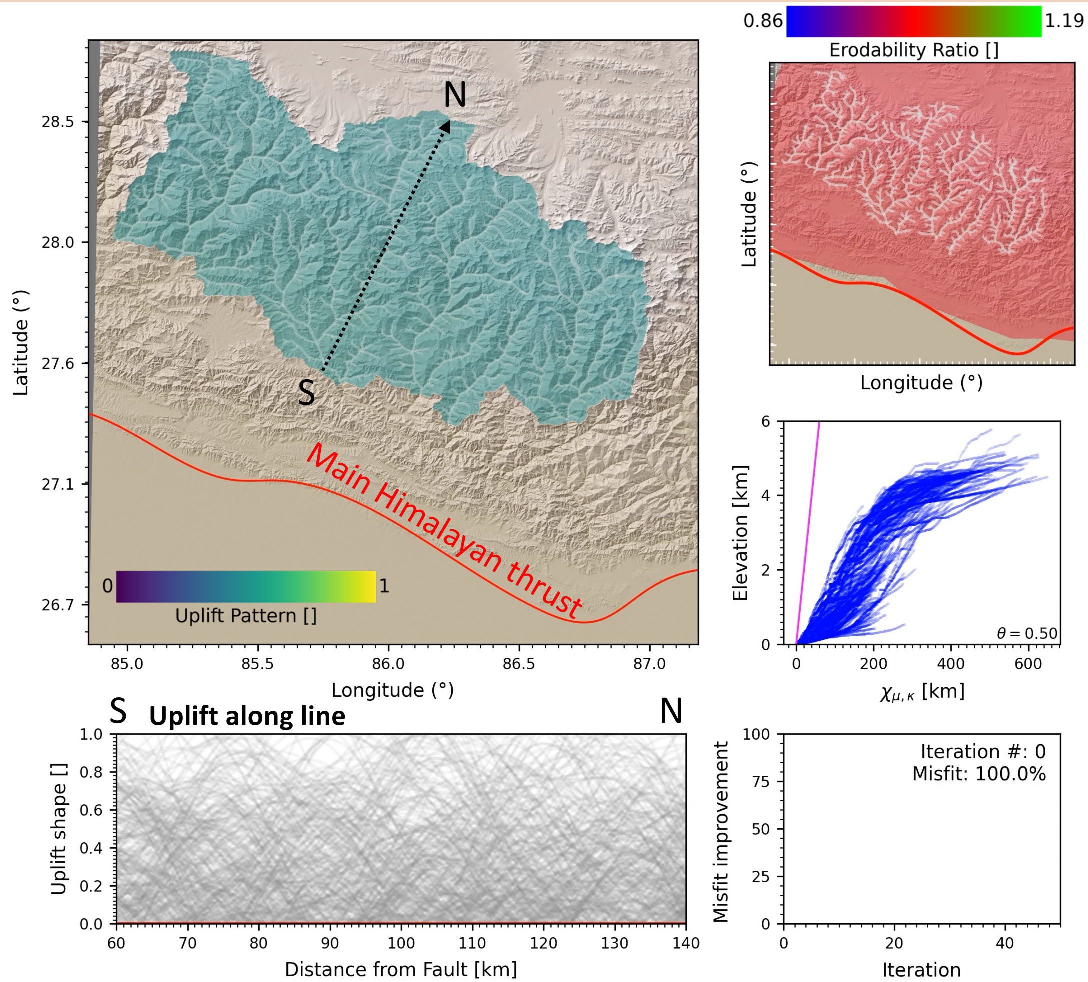

Mean solution

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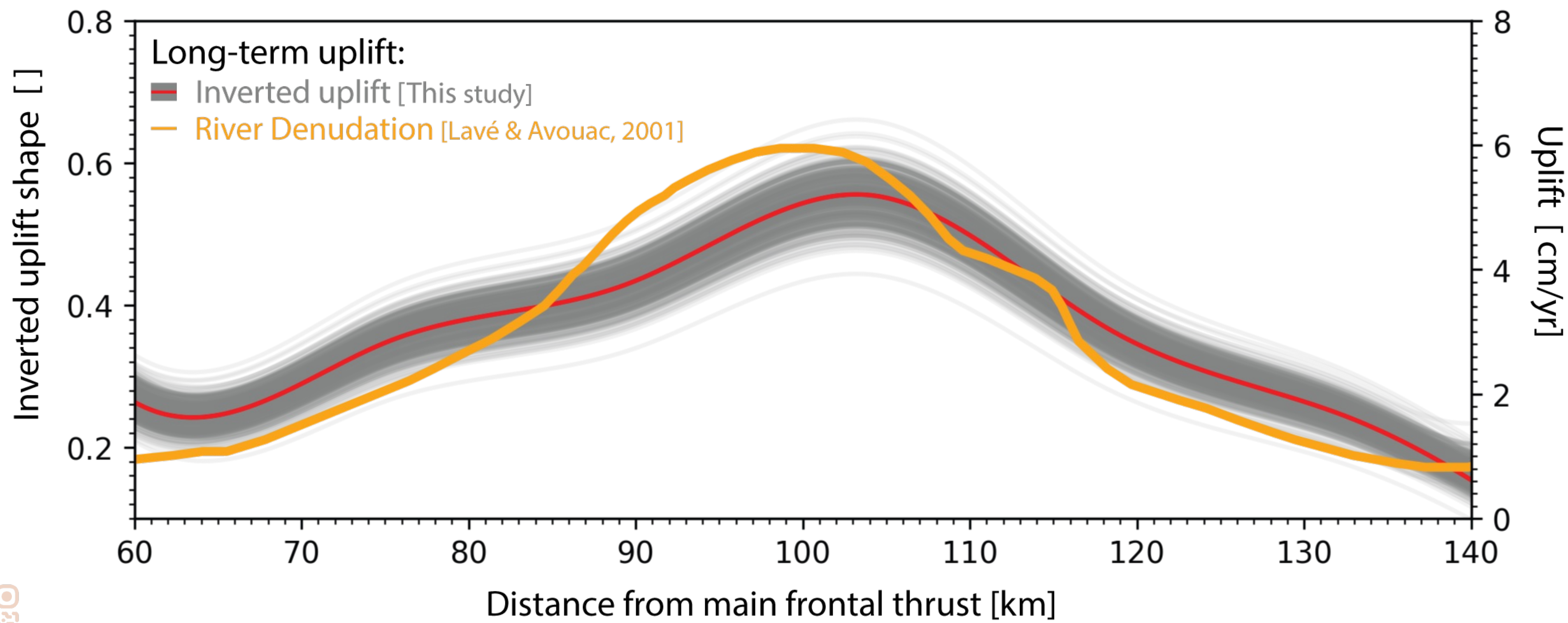
Oryan et al., in review

RETRIEVED UPLIFT PATTERN RESEMBLE PREVIOUS ESTIMATES

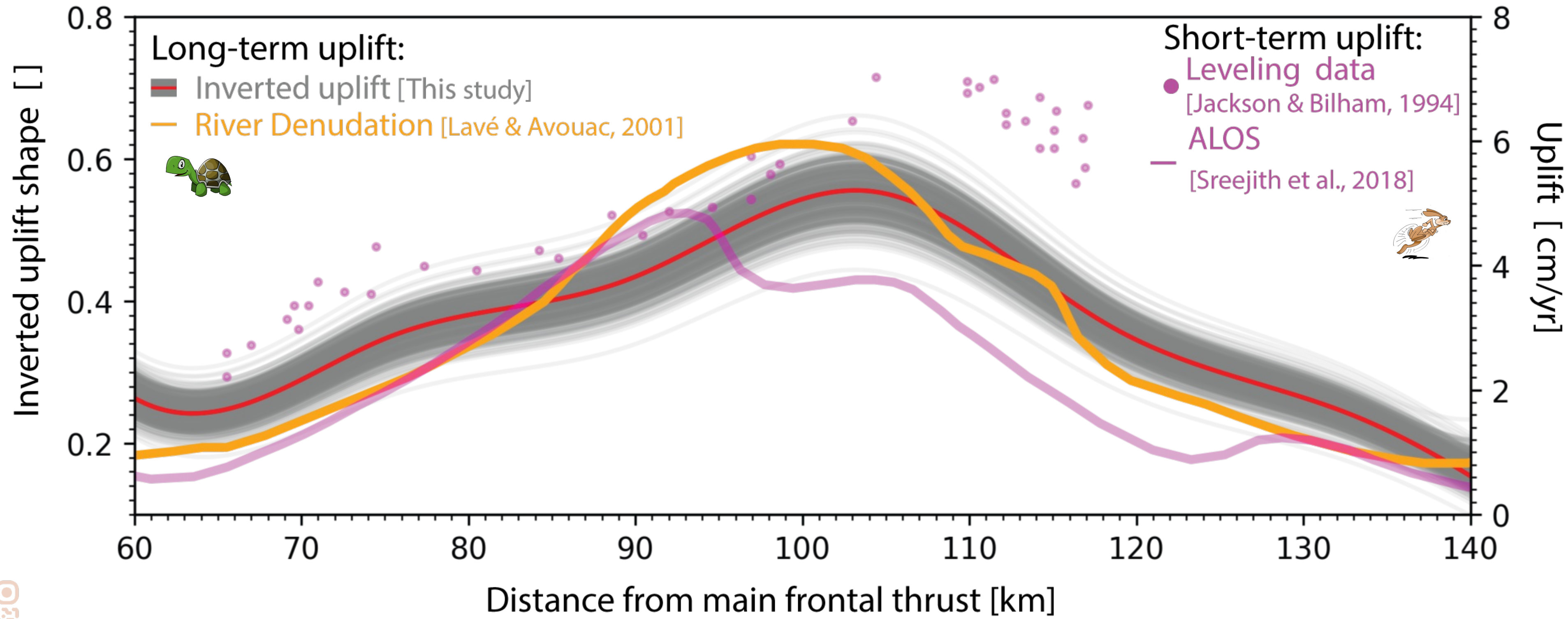
- Inferred long-term uplift matches denudation rates.



Oryan et al., in review

RETRIEVED UPLIFT PATTERN RESEMBLE PREVIOUS ESTIMATES

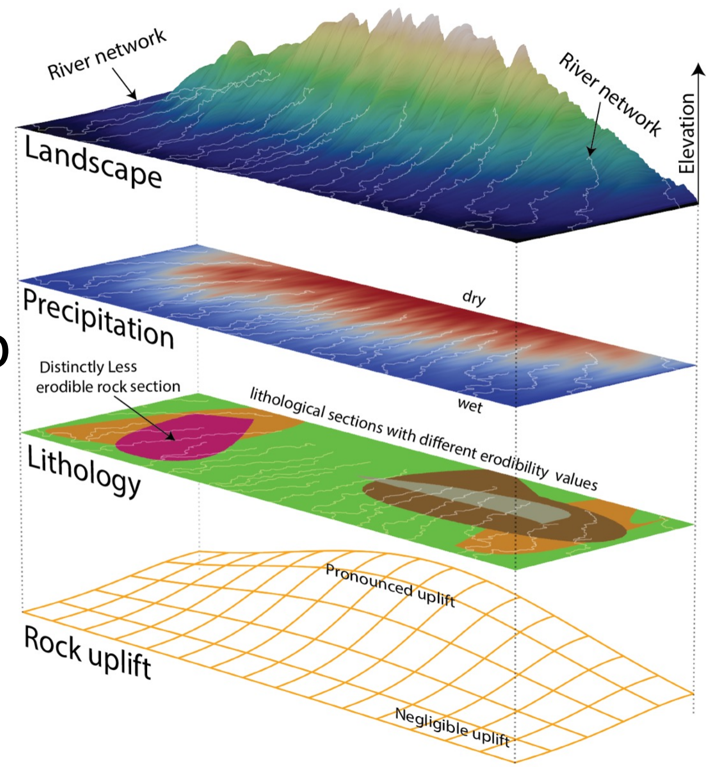
- Inferred long-term uplift matches denudation rates.
- Uplift shape is comparable with shape of short term interseismic uplift.

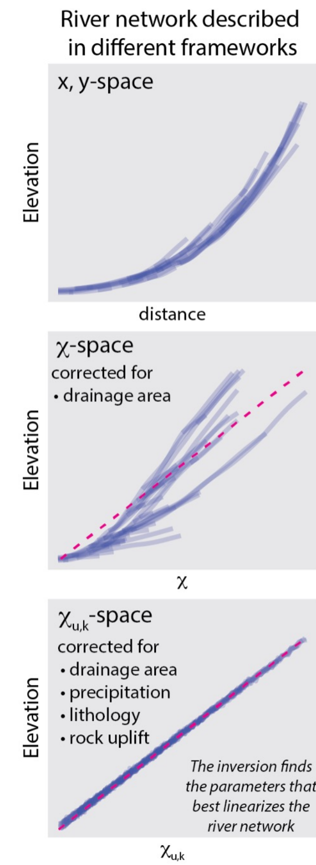


Oryan et al., in review

KEY POINTS SO FAR

- Inversion in $\chi_{u,k}$ space can disentangle the contributions of tectonics, climate and erodibility from landscapes.
- This approach opens the door to leveraging time-averaged signals preserved in landscapes to infer crustal deformation across different timescales.



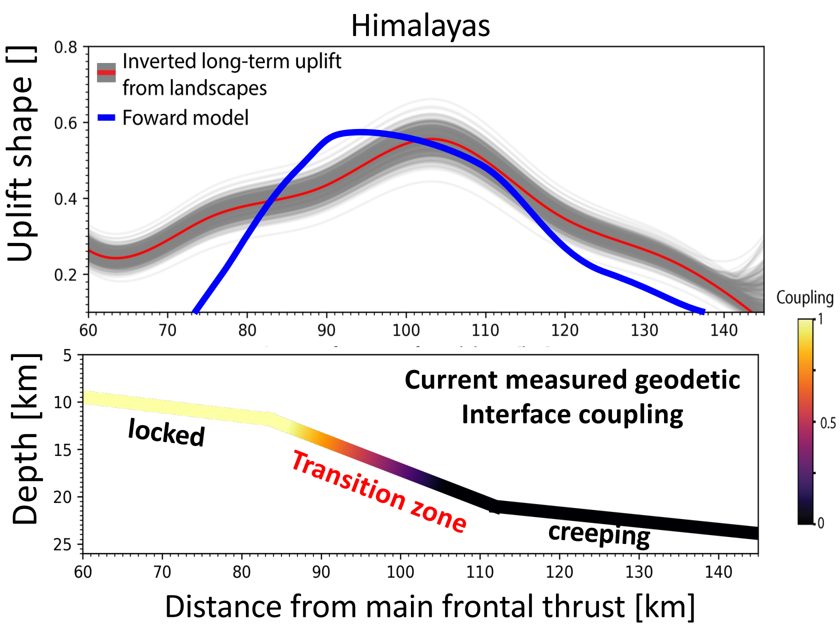


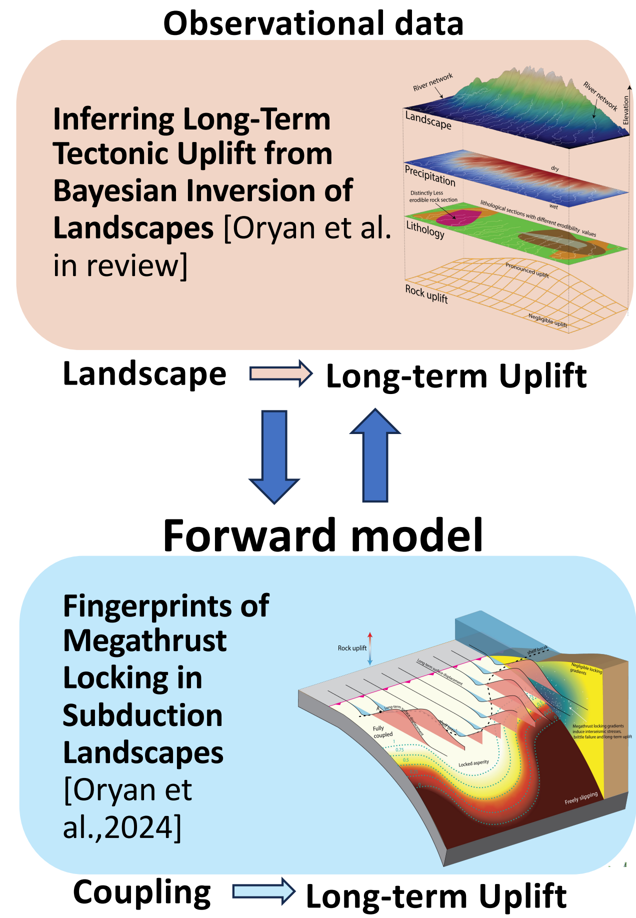
Section 4 – Research Program at the University of Oregon

UNIVERSITY
OF OREGON

INVERTING LANDSCAPES FOR PERSISTENT PLATE LOCKING

- My group will use the frameworks described in sections 2 and 3 to **invert forearc landscapes for long-term megathrust coupling.**





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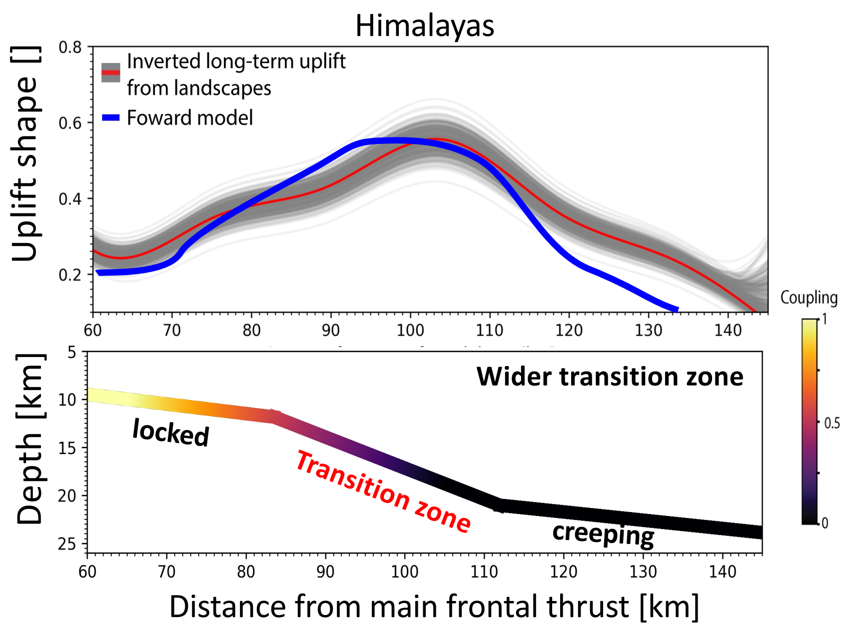
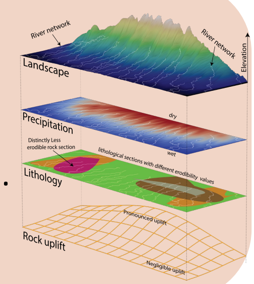


Observational data

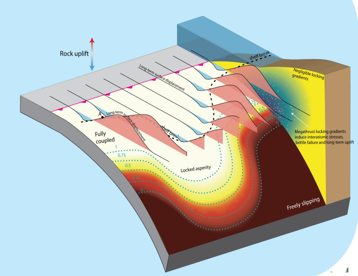
Inferring Long-Term Tectonic Uplift from Bayesian Inversion of Landscapes [Oryan et al. in review]



Landscape ⇨ **Long-term Uplift**

Forward model

Fingerprints of Megathrust Locking in Subduction Landscapes [Oryan et al.,2024]



Coupling ⇨ **Long-term Uplift**

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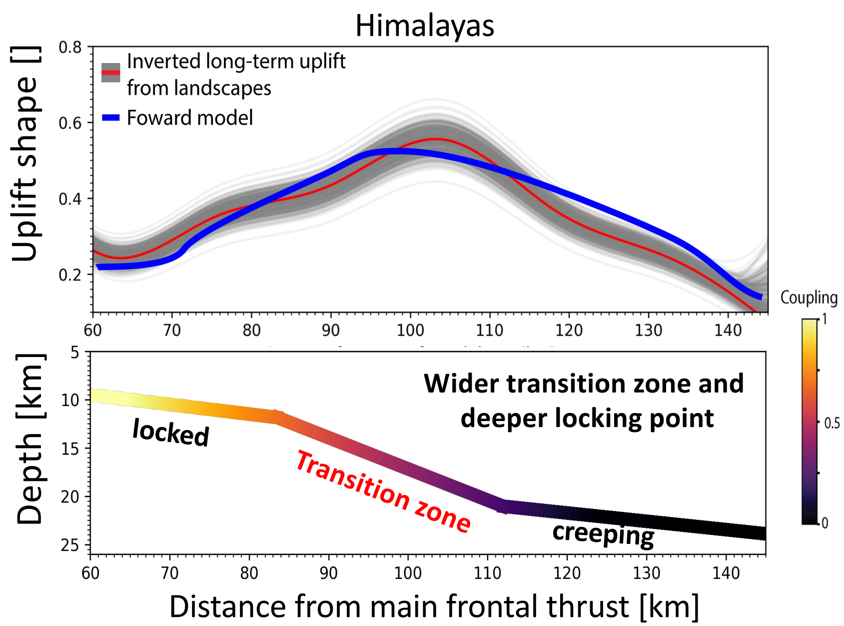

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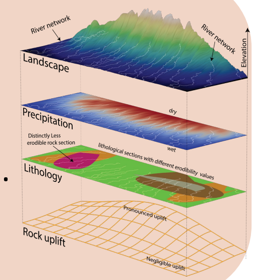

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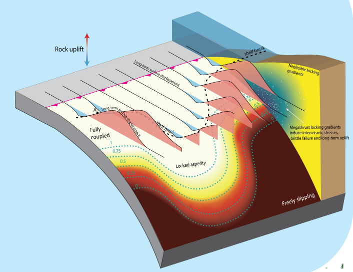

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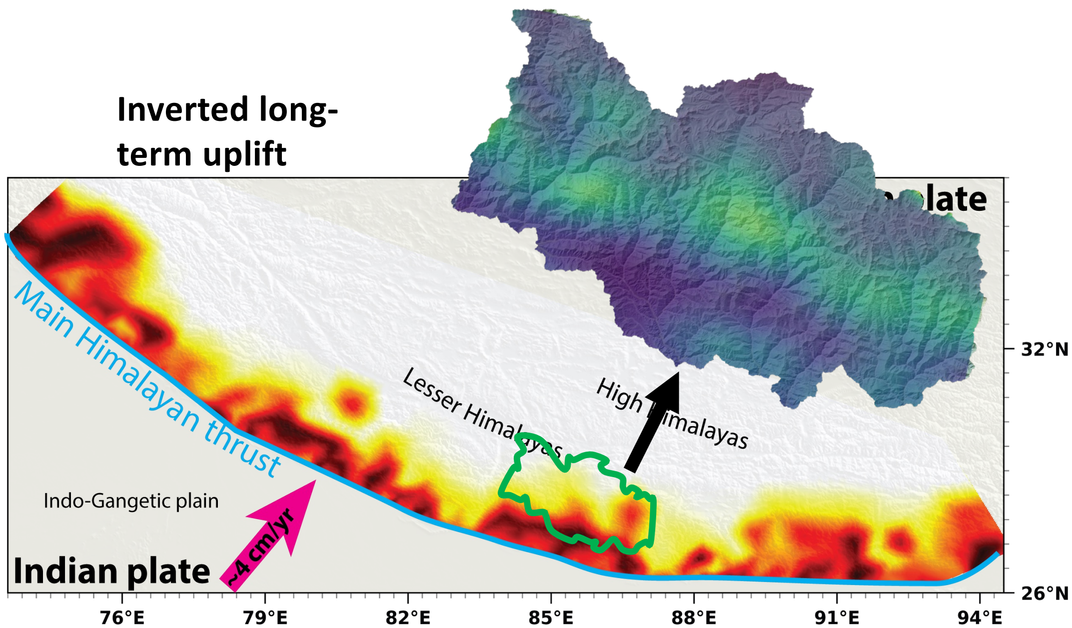
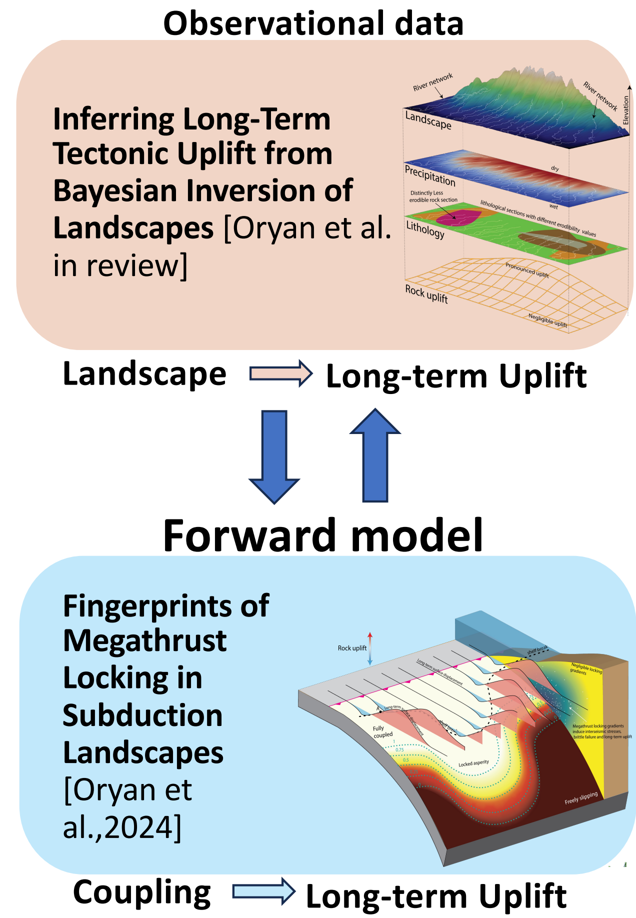
Inverted long-term uplift





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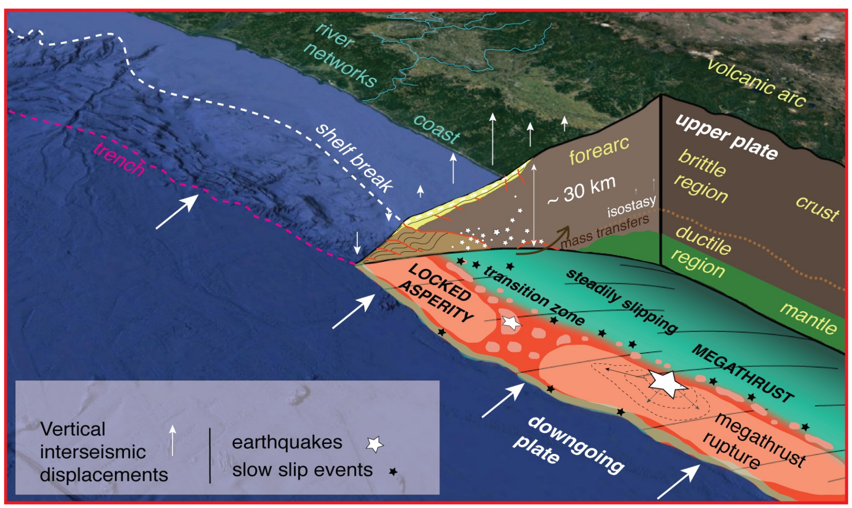

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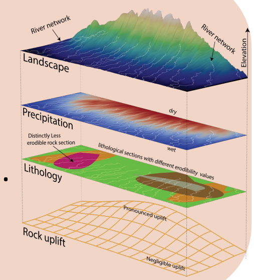

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⇓ ⇑

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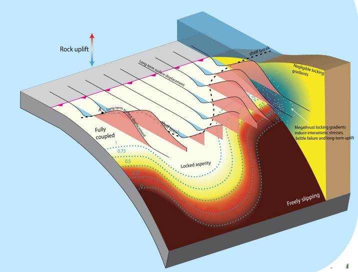
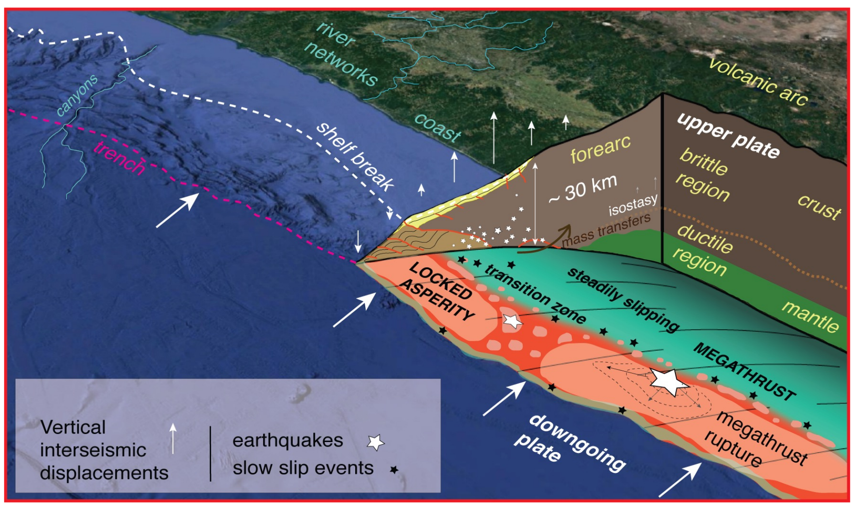


Coupling ⟹ Long-term Uplift

INVERTING LANDSCAPES FOR PERSISTENT PLATE LOCKING

- My group will use the frameworks described in sections 2 and 3 to **invert forearc landscapes for long-term megathrust coupling.**
- We will strive to expand our observational record and use **submarine canyons**.



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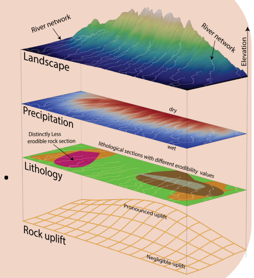

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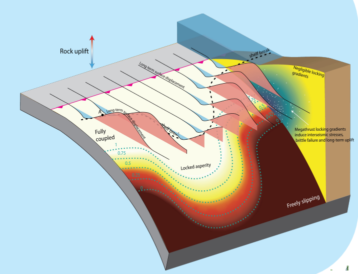
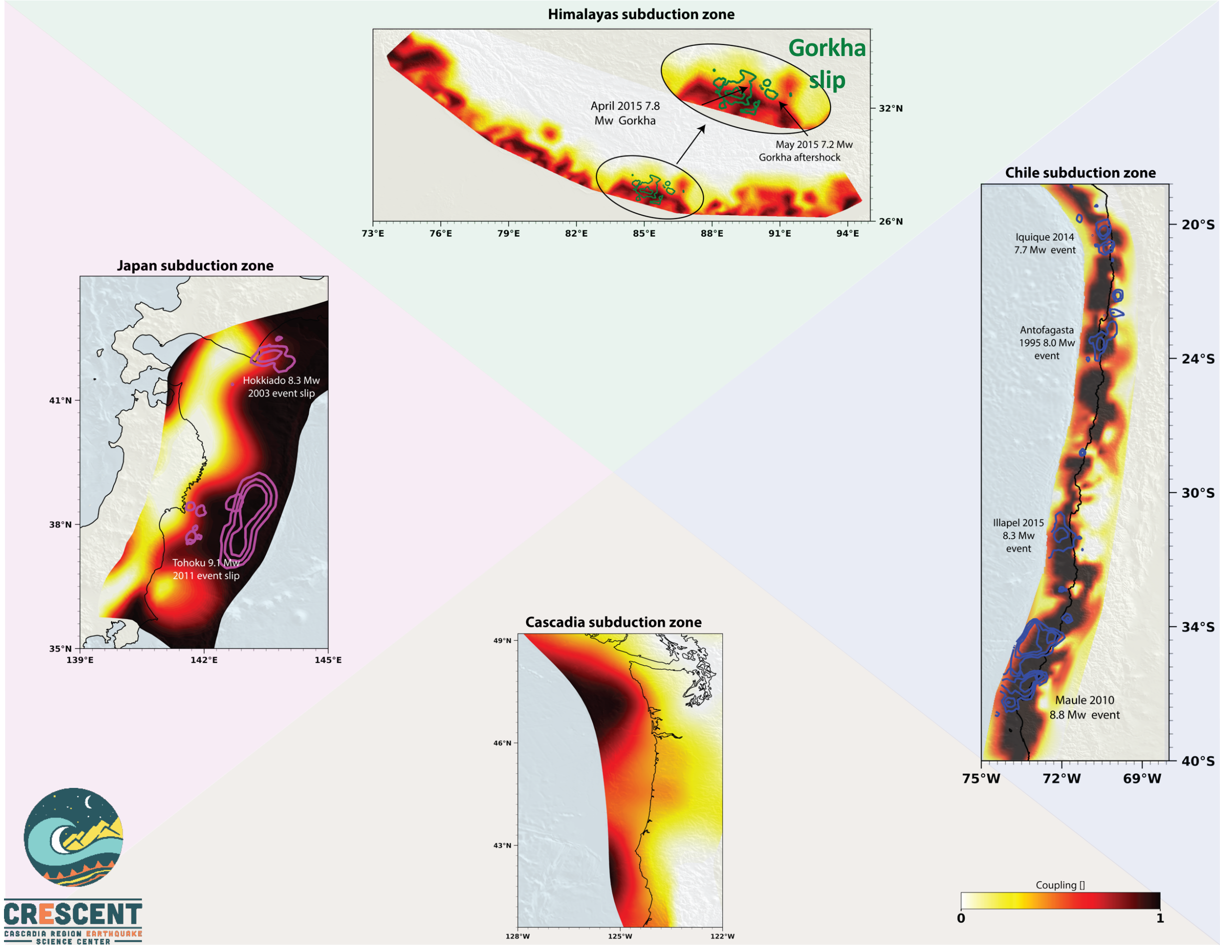


Coupling ⇨ **Long-term Uplift**

UNIFYING MEGATHRUSTS FAULTS USING OPTIMAL TRANSPORT AND MACHINE LEARNING TOOLS

- My group will use machine learning and optimal transport tools to compute geodetically and physically consistent geometric mappings between megathrusts.



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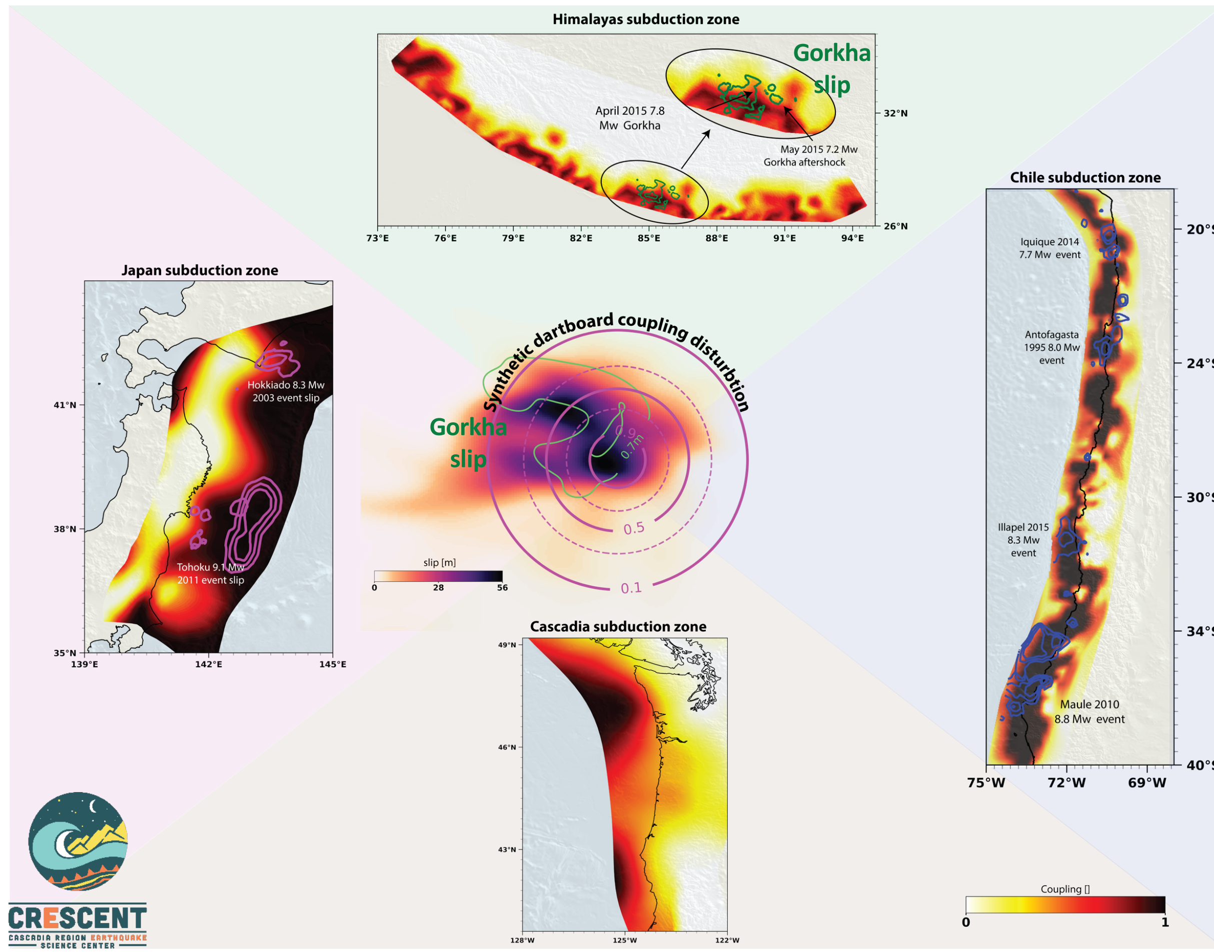

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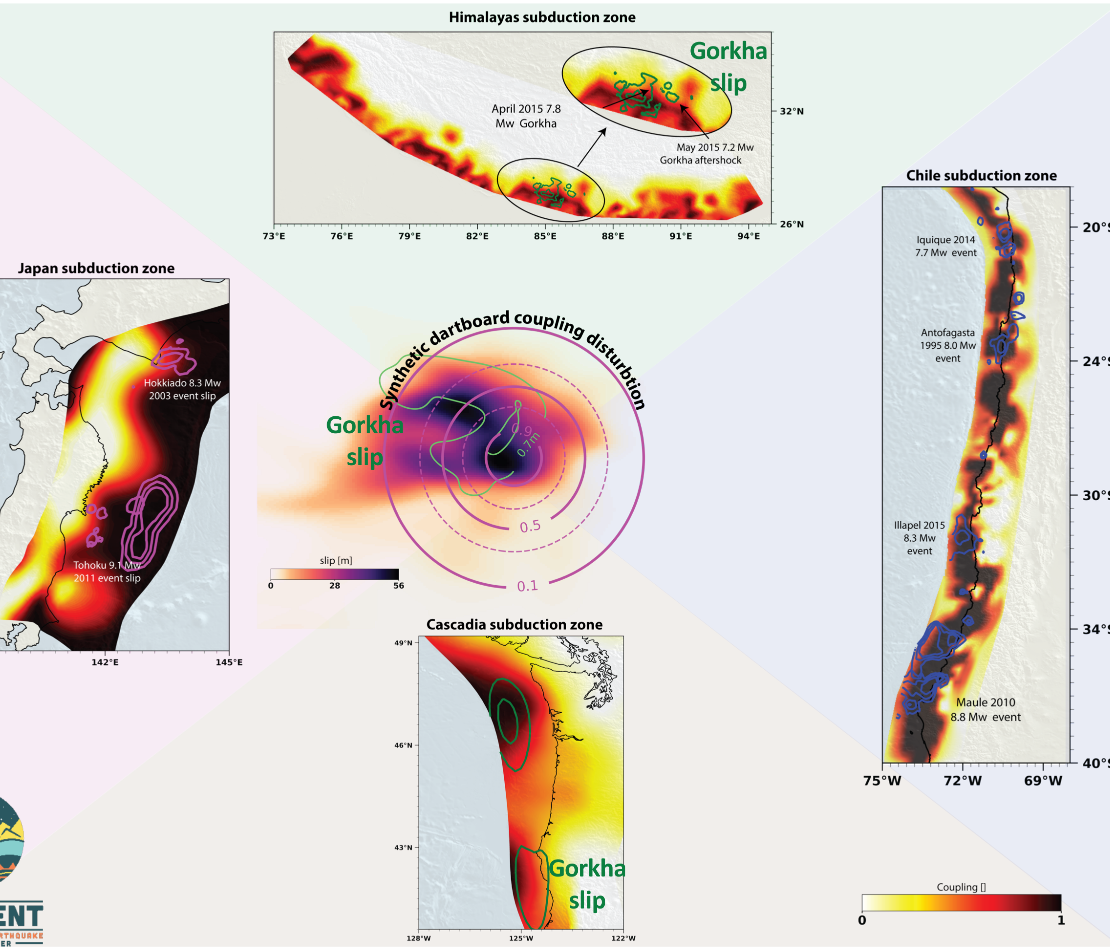
- This approach will **extend our seismo-geodetic observational** record several-fold and allow us to assess seismic hazard more robustly.



CRESCENT
CASCADIA REGION EARTHQUAKE SCIENCE CENTER

THE ENERGY BUGDET OF EARTHQUAKE CYCLES

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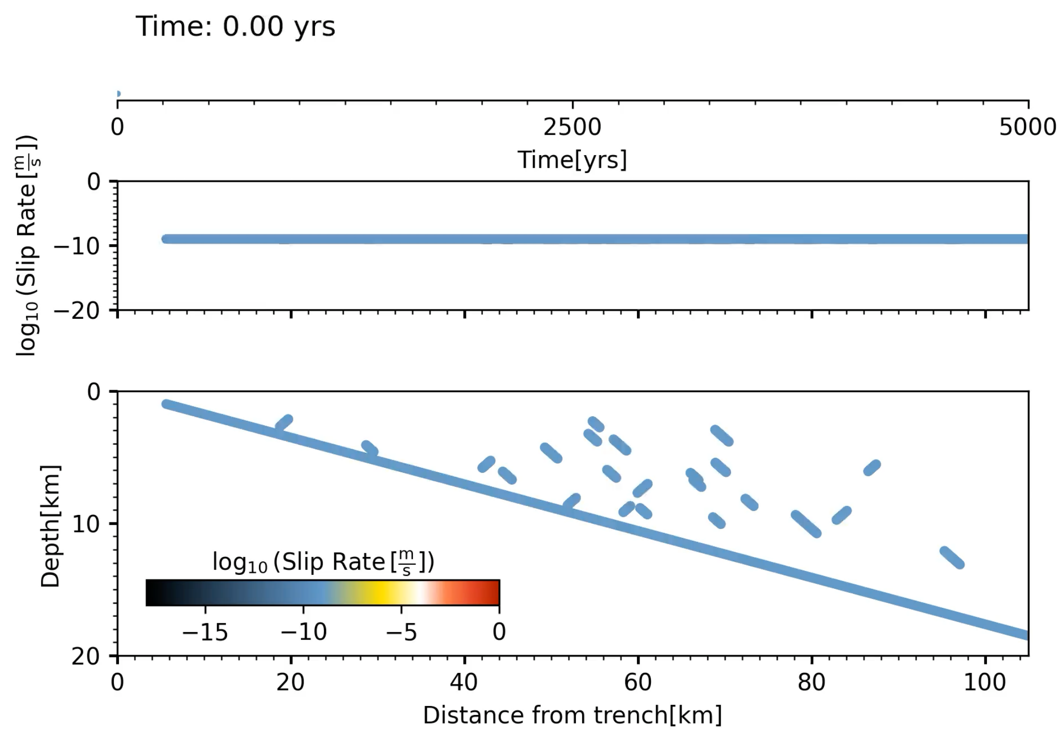

Oryan et al., in prep.

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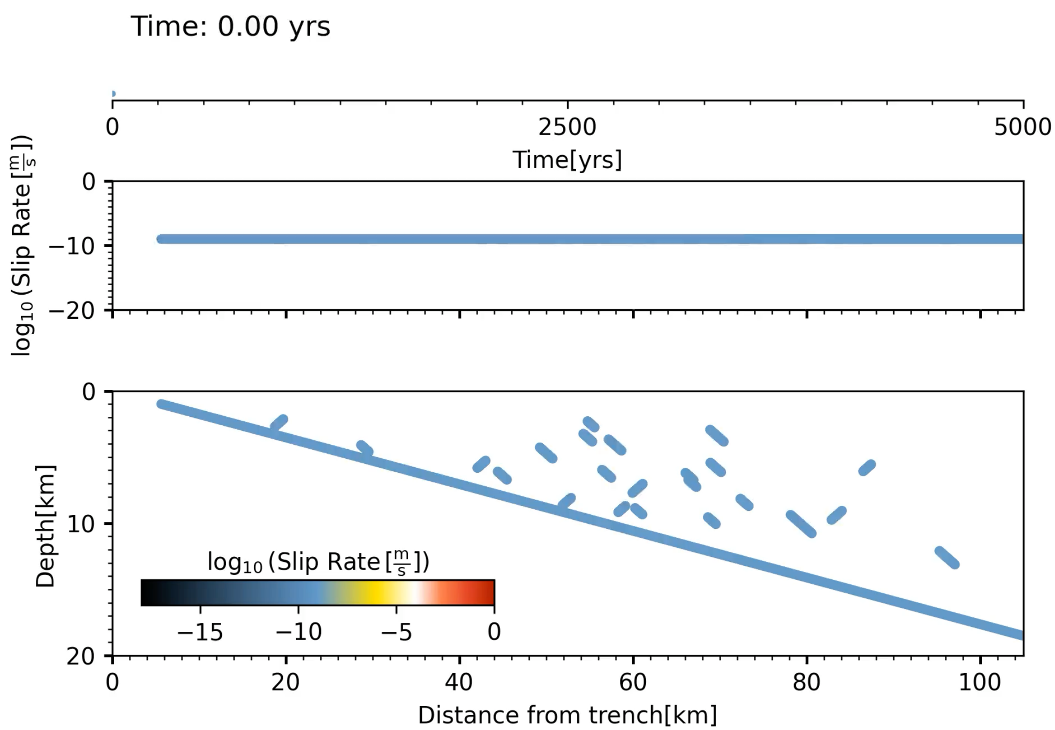
- **Unraveling Energy Distribution in Subduction Zones:** We will study the rheological properties that govern the balance between elastic deformation (fueling earthquakes) and inelastic strain (shaping subduction zone landscapes).



Oryan et al., in prep.

ACKNOWLEDGEMENTS

Alice Gabriel

Boris Gailleton

Dave May

Jean-Arthur Olive

Jeena Yun

Lucile Bruhat

Luca Malatesta

Mike Steckler

Roger Buck

Romain Jolivet

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