Long-Lived Postseismic Deformation Following the 2001 Mw 7.8 Kokoxili (Tibet) Earthquake from GNSS and Multi-Mission InSAR

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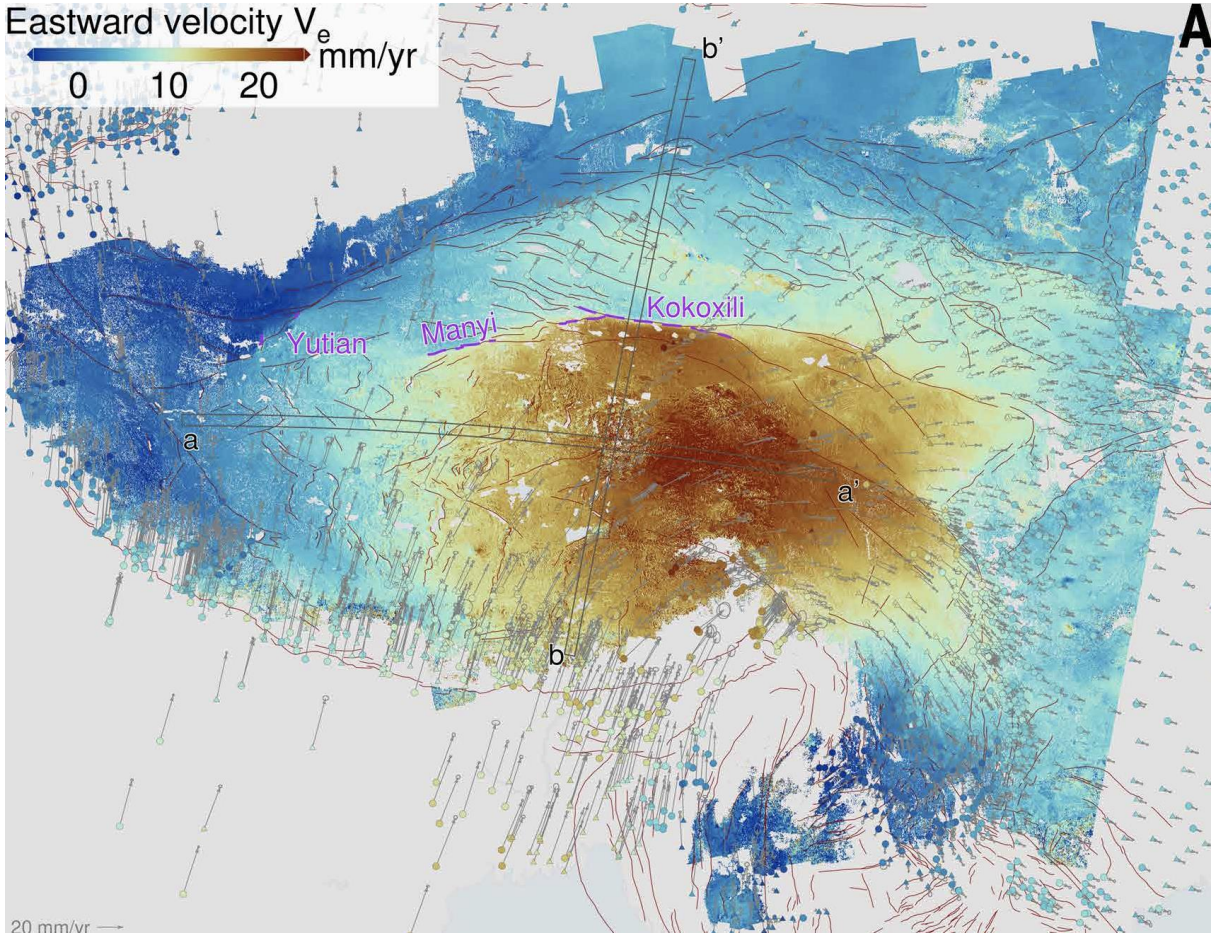
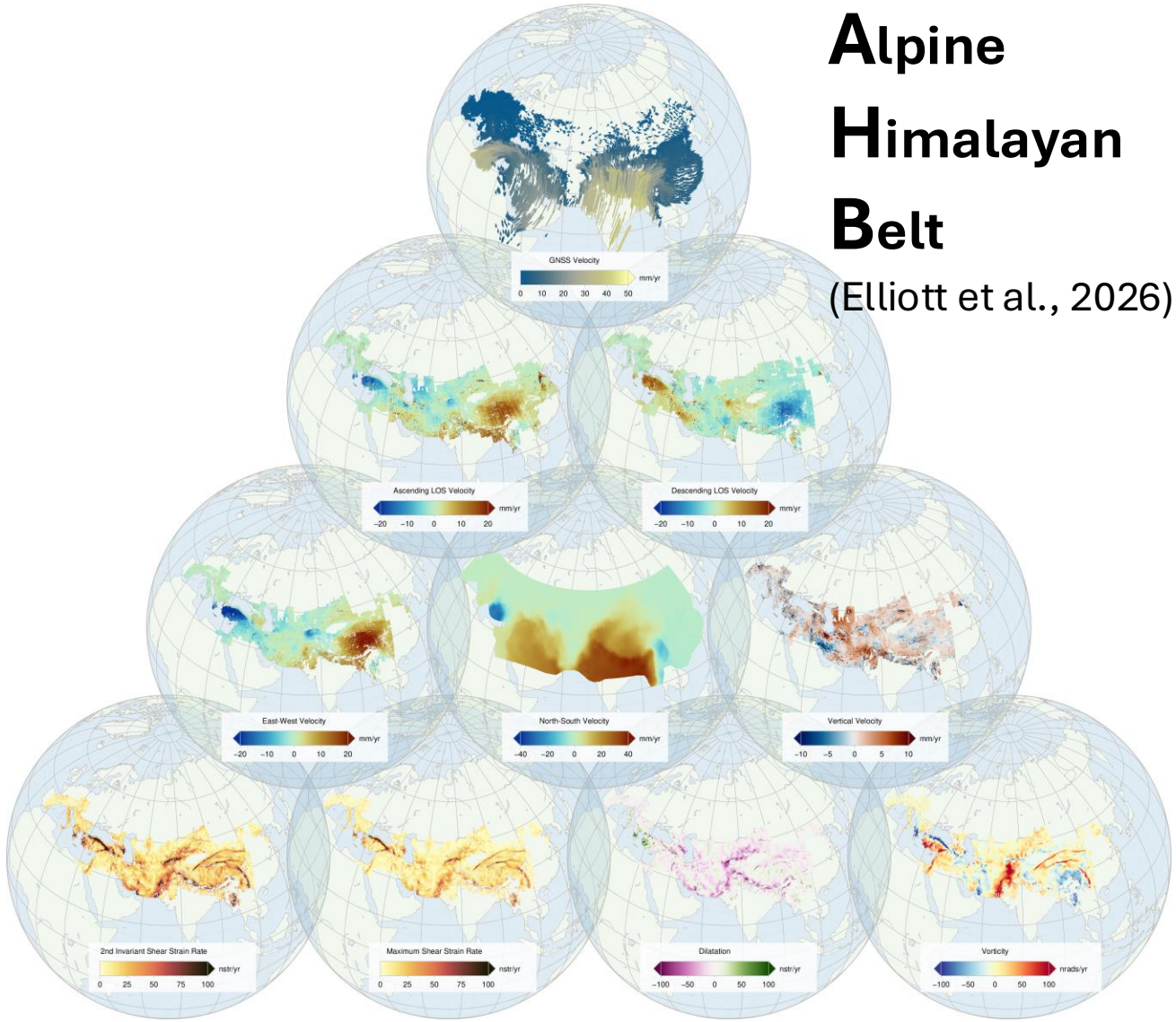
Continental-Scale Velocity/Strain Rate Fields



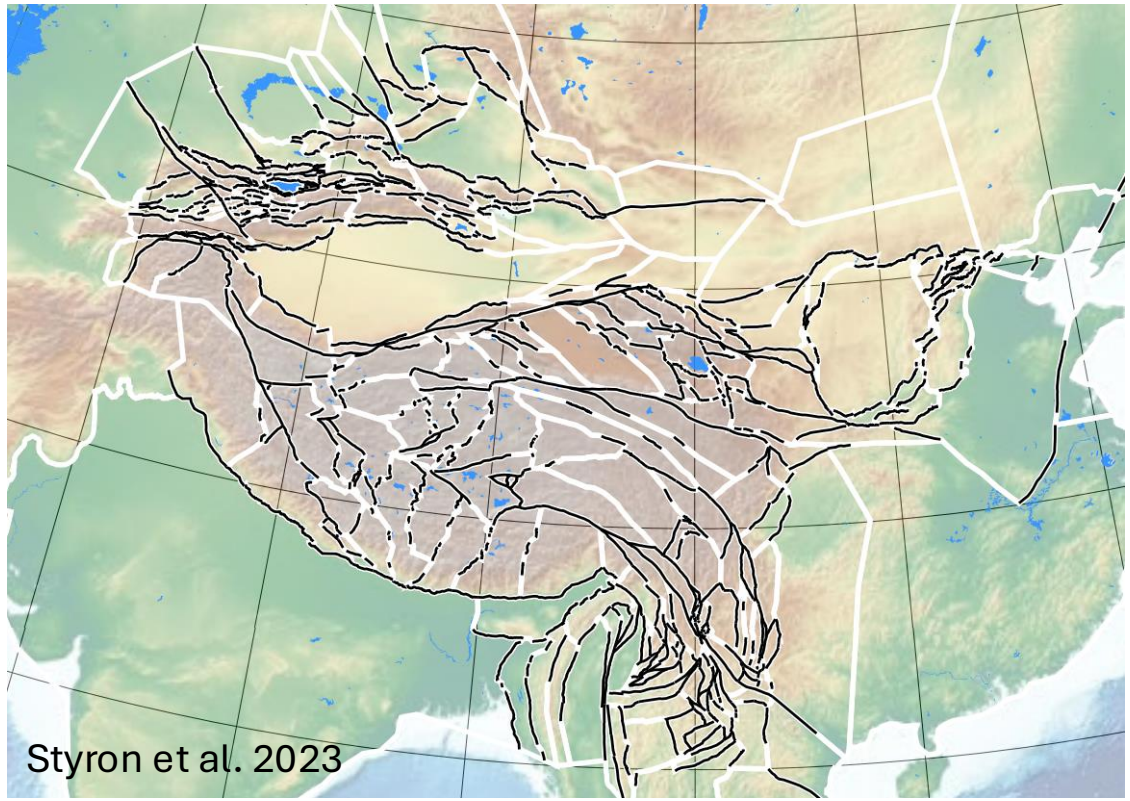
Tibetan Plateau (Wright et al., 2026)



Alpine Himalayan Belt (Elliott et al., 2026)

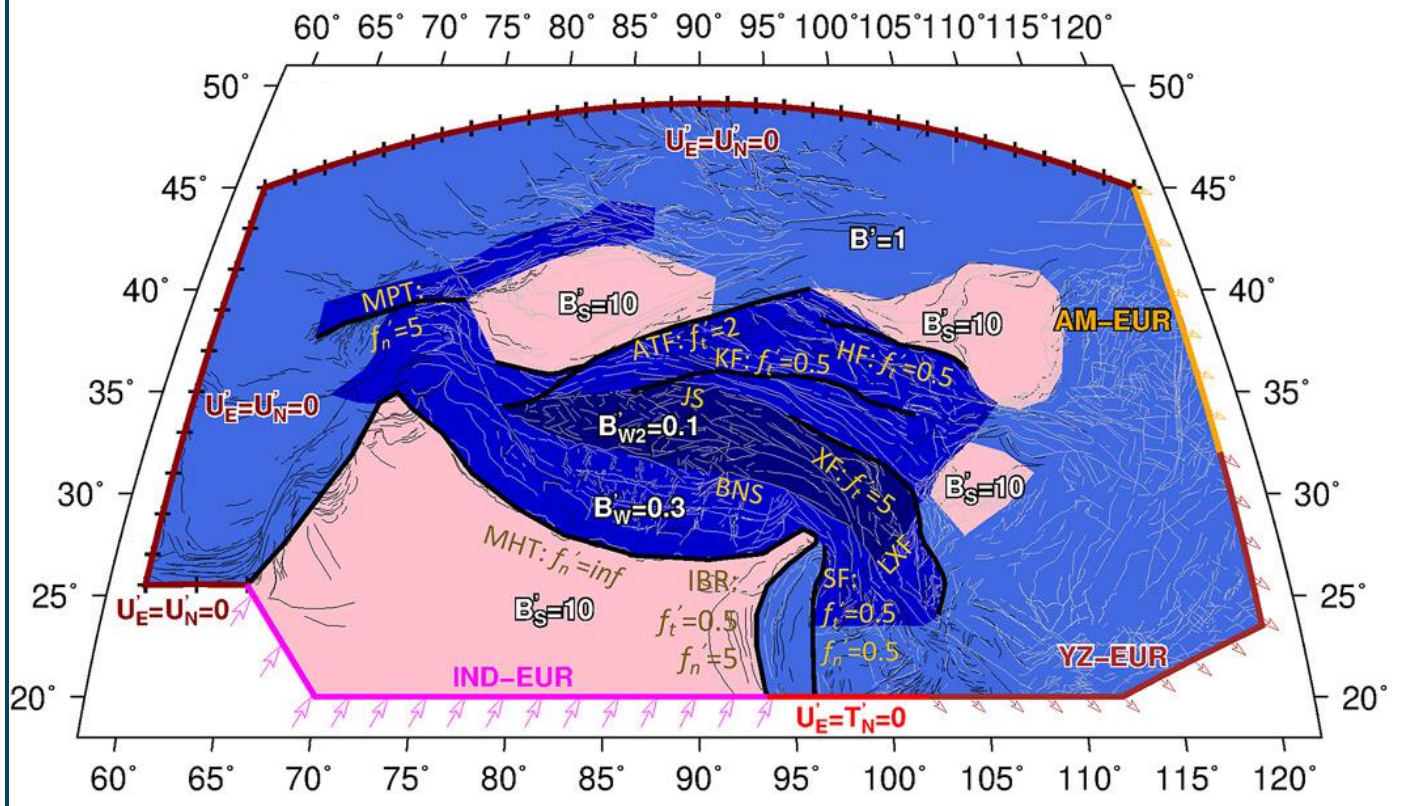
Modelling of Continental Deformation

- Kinematic models



Block models -> slip rates -> hazard models (e.g. GEM)

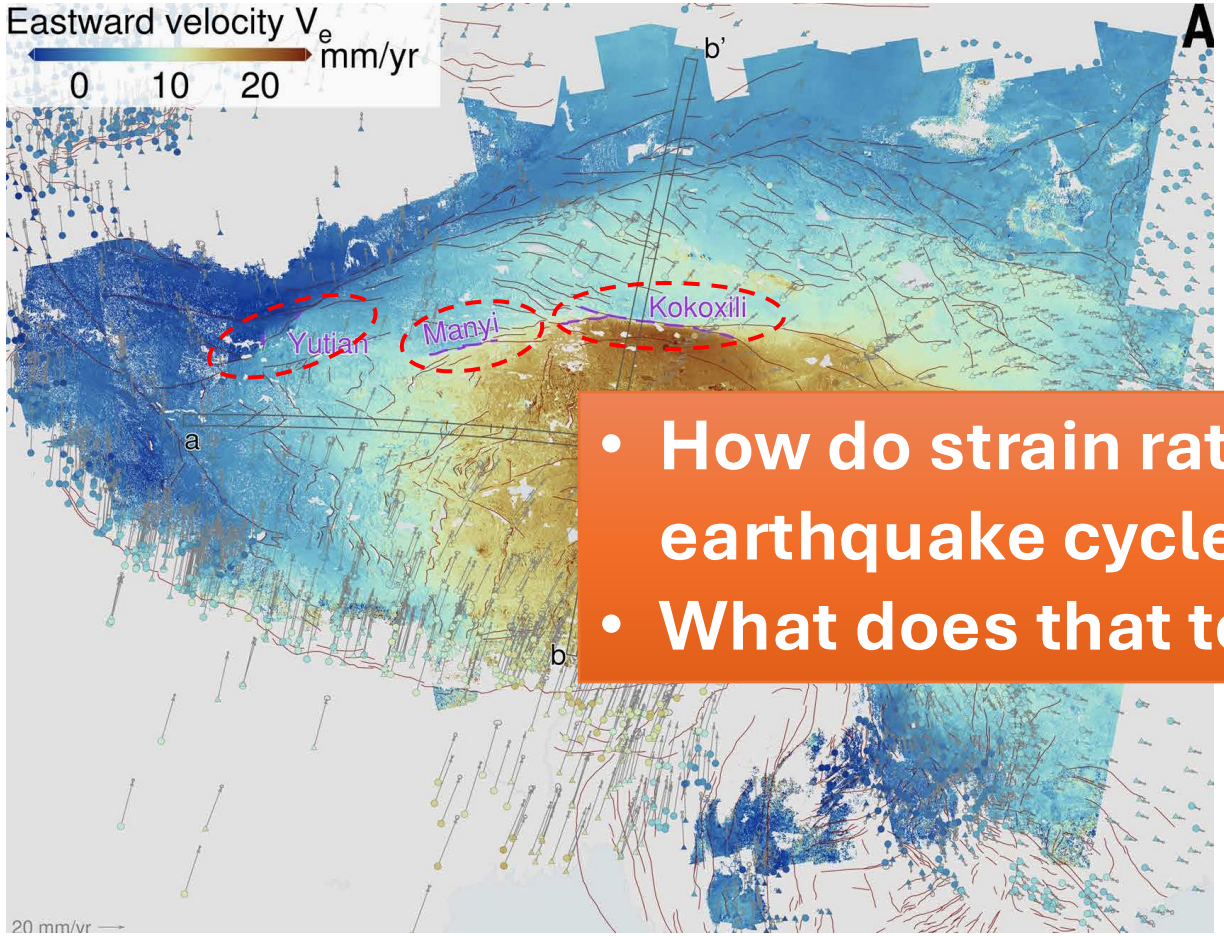
- Dynamic models



Faulted viscous continuum models -> forces/rheology (Fang et al., 2024)

Models assume **steady-state "interseismic" deformation**

But… velocity fields clearly include long-lived transients



- **How do strain rates evolve through the earthquake cycle?**
- **What does that tell us about rheology?**

(Wright et al., 2026)

The Earthquake Cycle

Strain rate is **time-dependent.**

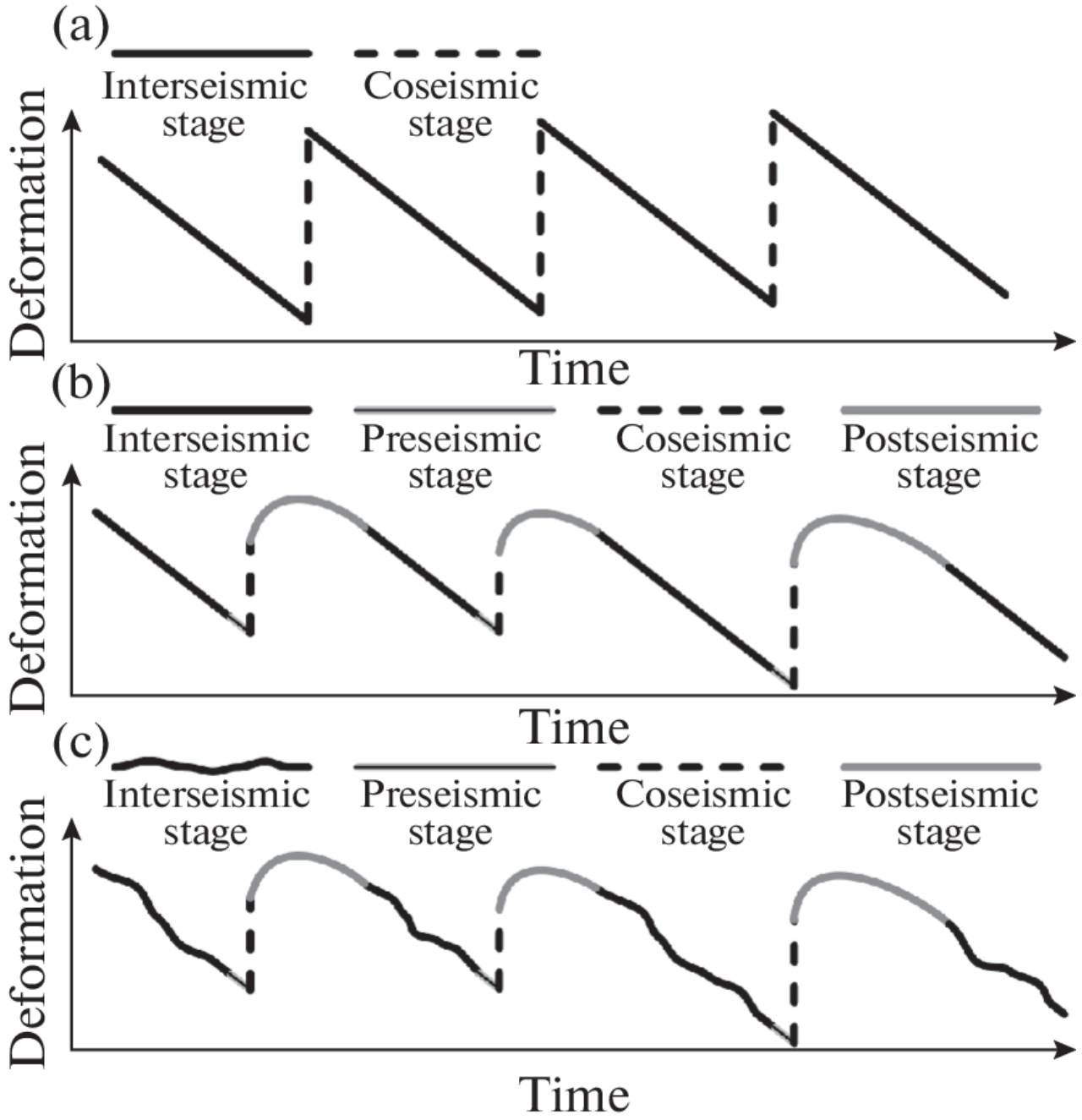
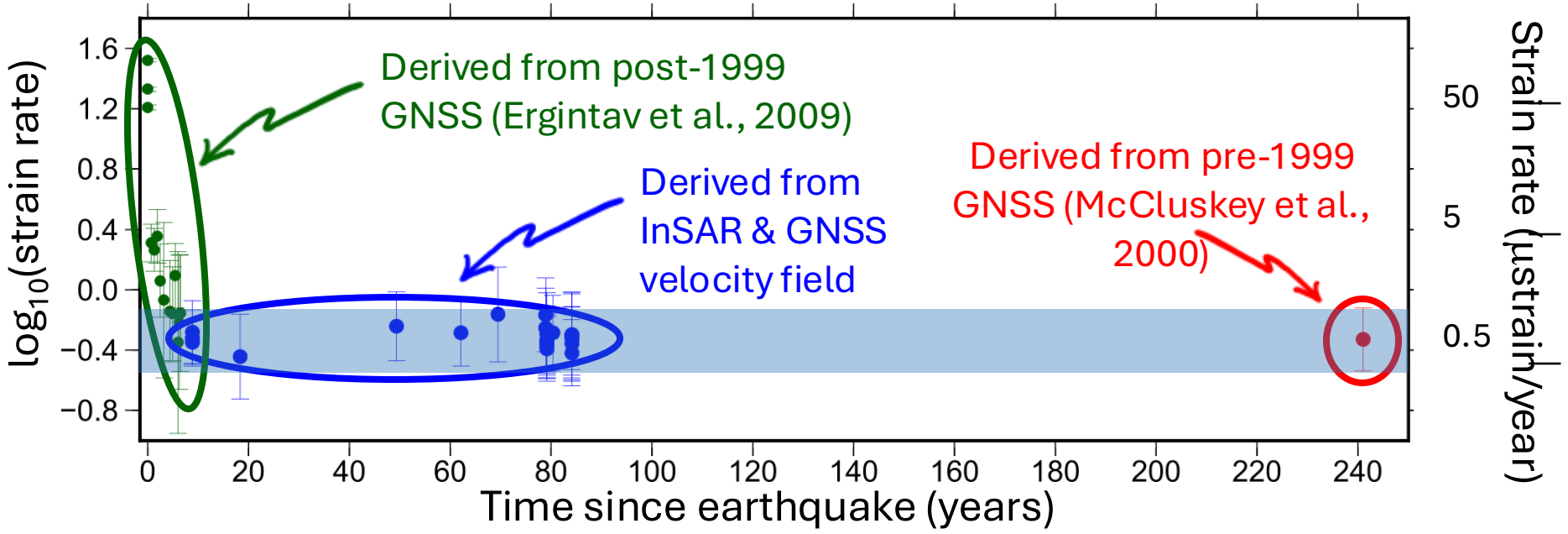


Figure from Vladirimova 2024

Strain rate vs time for North Anatolian Fault

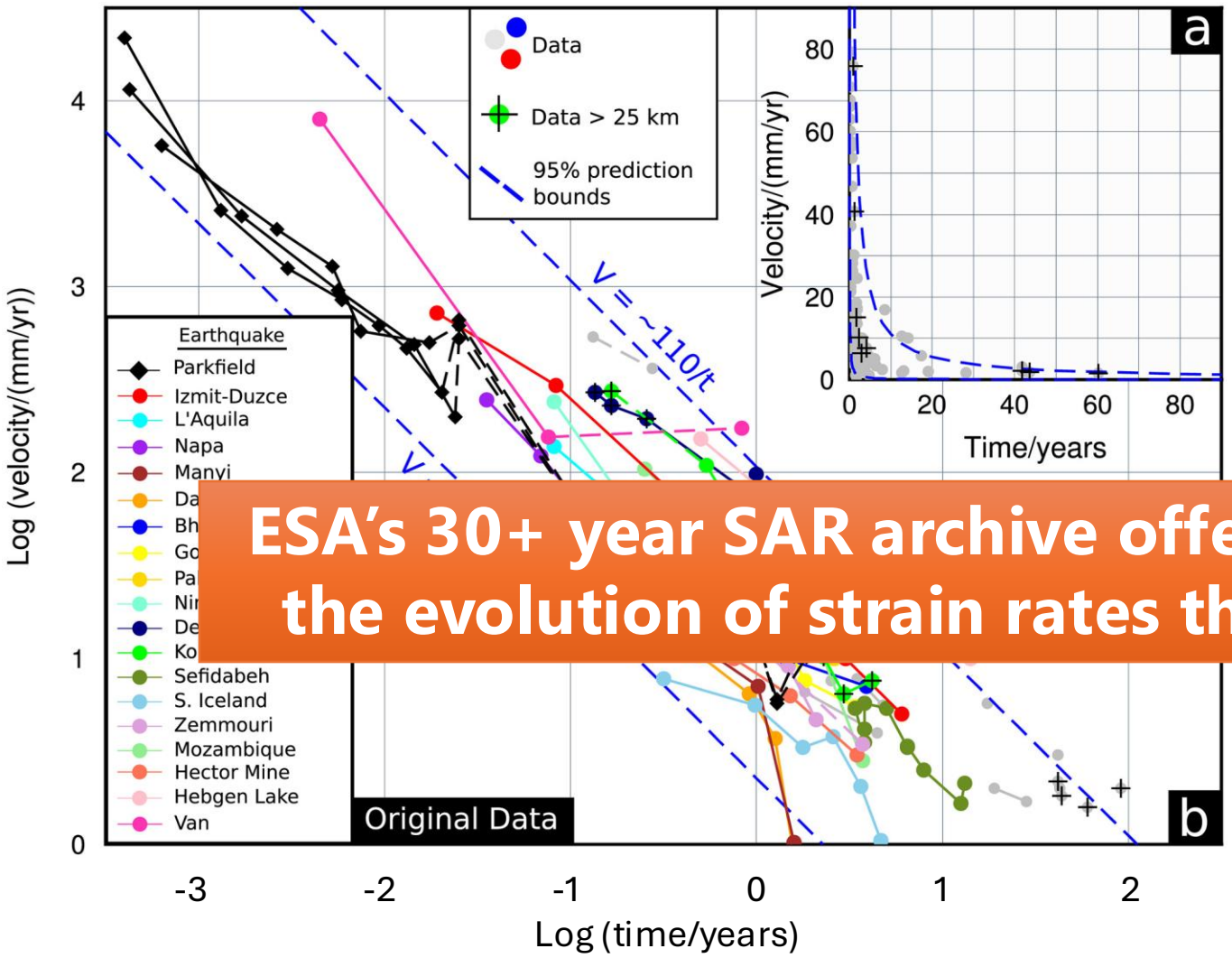
Key constraint is from **pre-earthquake strain**



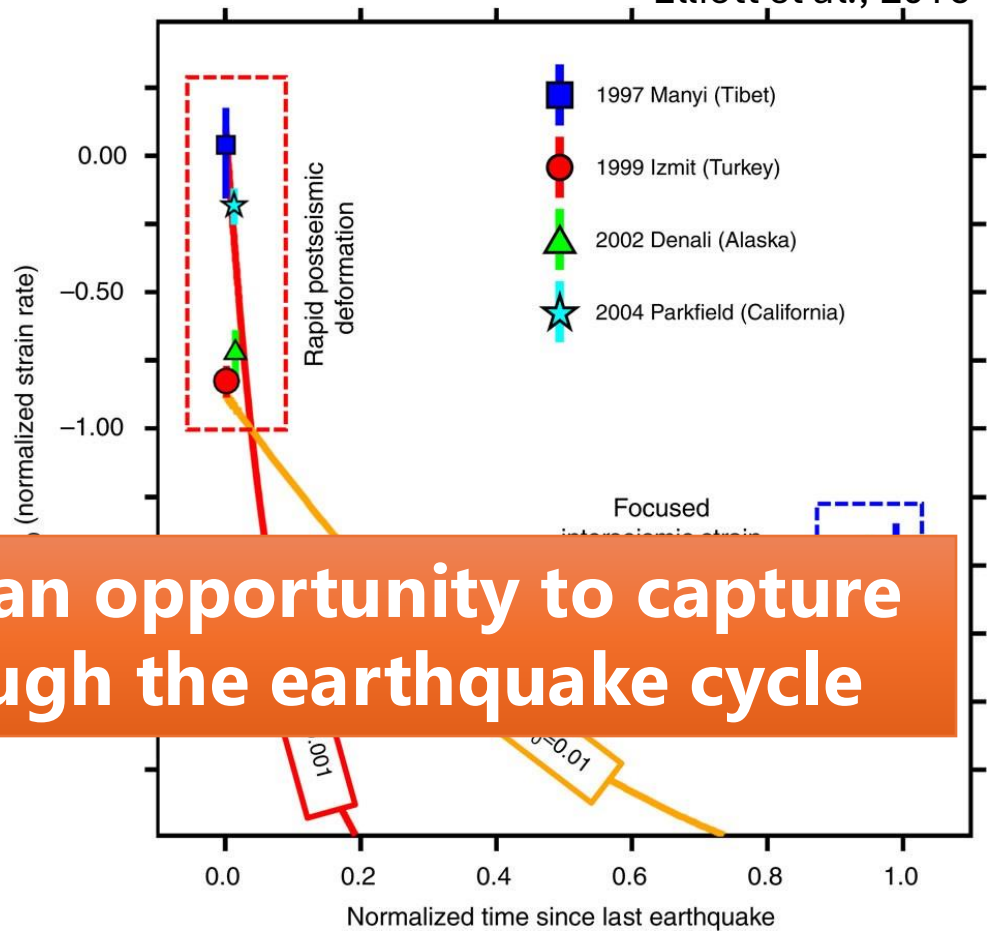
NAF returns to near steady-state — after ~decadal postseismic transient .

(Hussain et al., 2018)

Postseismic decay lasts up to 100 years



Elliott et al., 2016



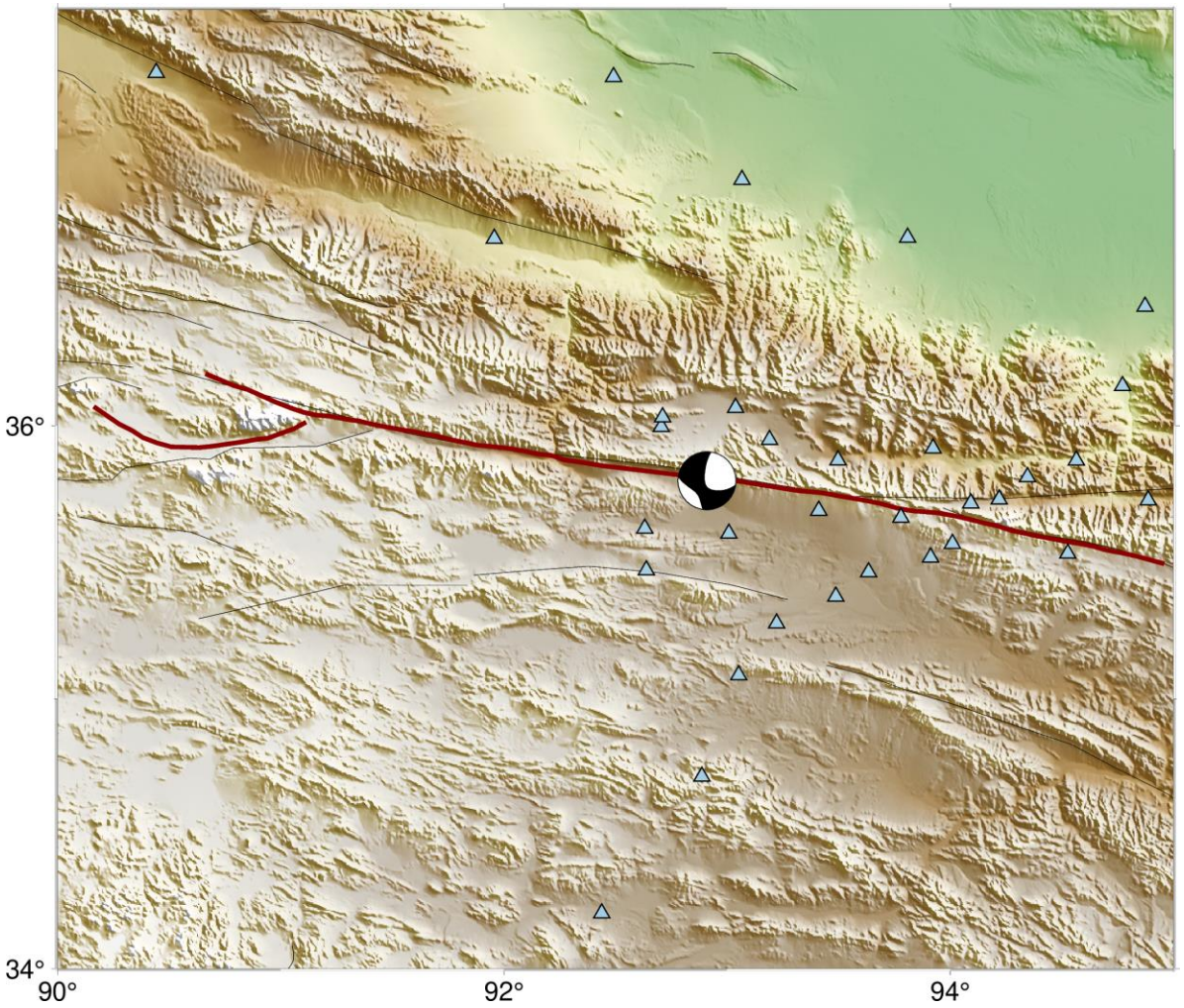
ESA's 30+ year SAR archive offers an opportunity to capture the evolution of strain rates through the earthquake cycle

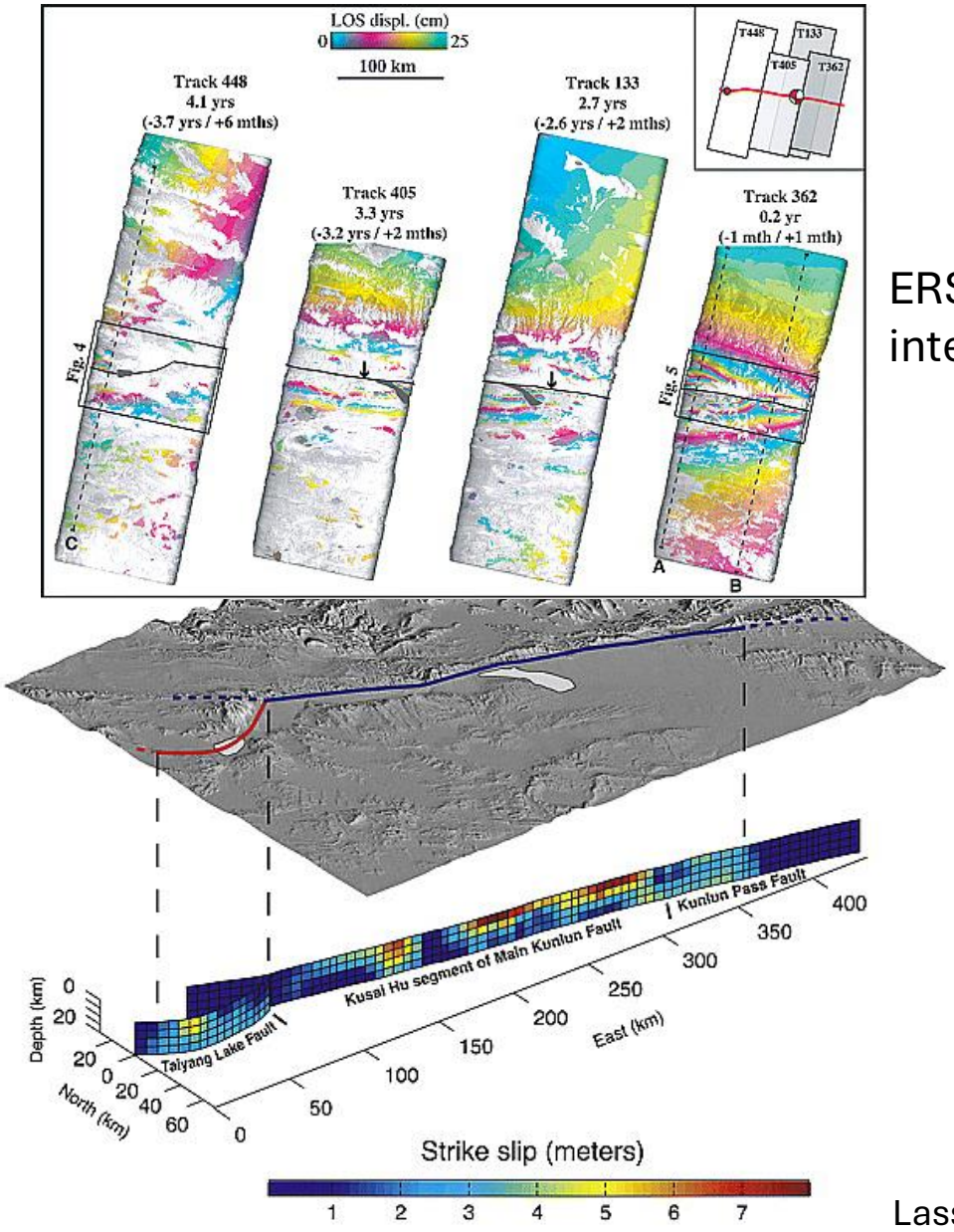
- Key constraints come from early postseismic and late interseismic periods
- Few earthquakes have such observations (but the number is growing)

Ingleby & Wright, 2017

2001 Mw 7.8 Kokoxili (Tibet) Earthquake

Ideal natural laboratory with long observation window

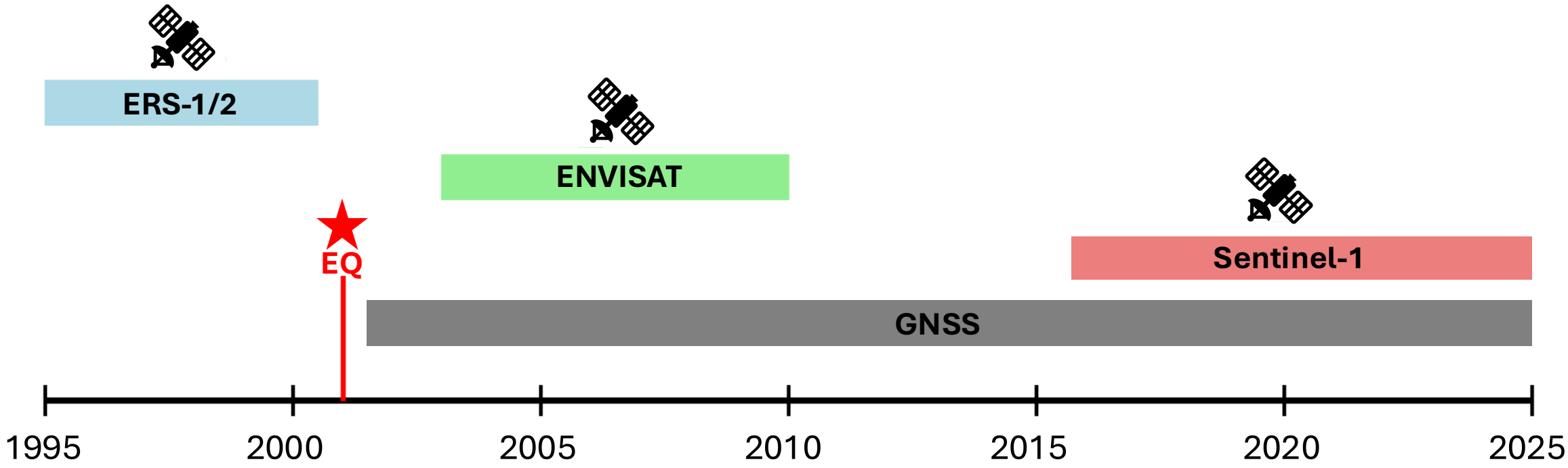




ERS coseismic interferograms

Lasserre et al., 2005

Available Data

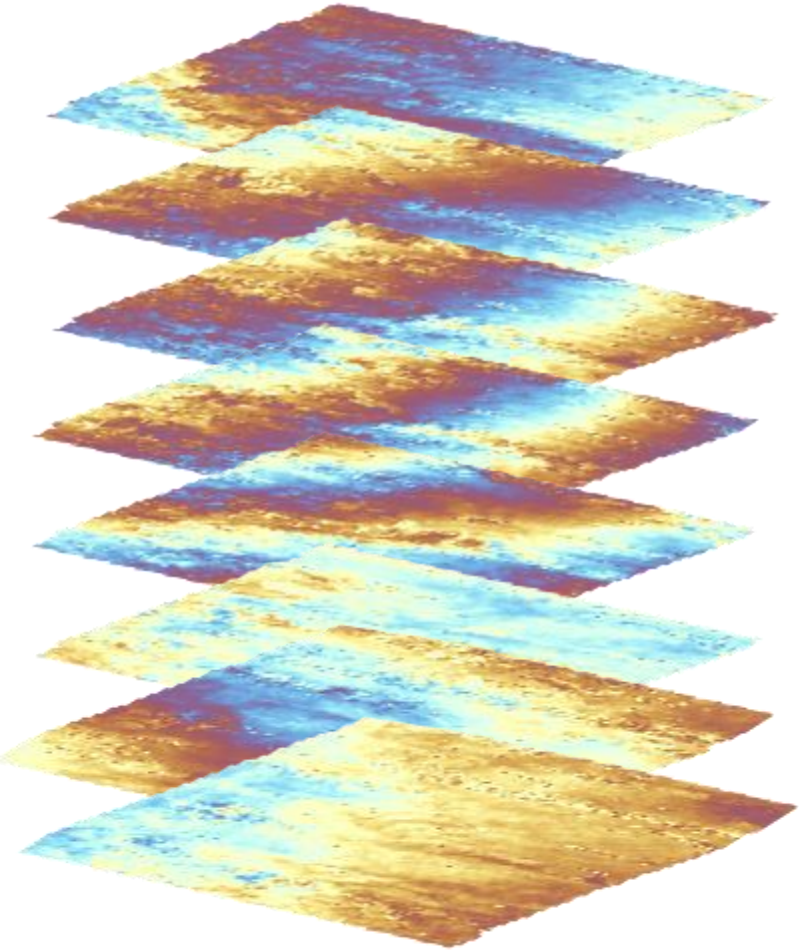


- Rich **multi-decadal dataset**
- Key gaps, particularly in the early period
- Sparse GNSS coverage

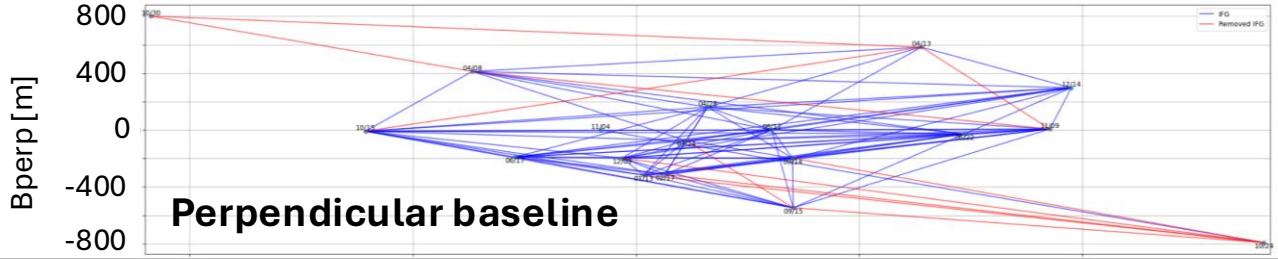
ERS Methods (Old School)

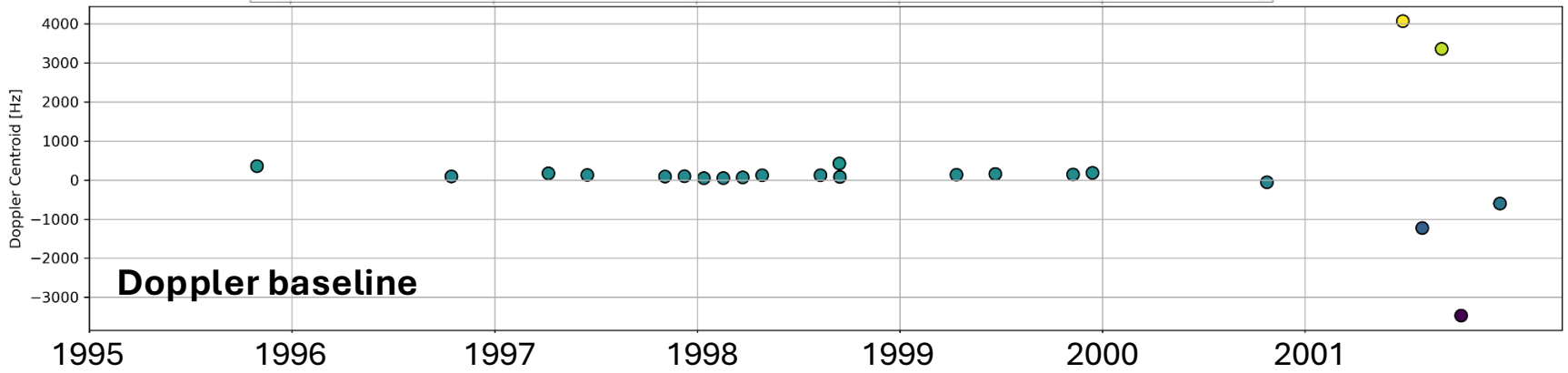
- Limited acquisitions in time, issues with baselines
- Stripmap mode (narrower coverage)
- Orbital errors
- Modern time series methods
- But also need old-school approaches (Wright et al., 2001)

Make ERS-1/2 Interferograms (1995-2001)

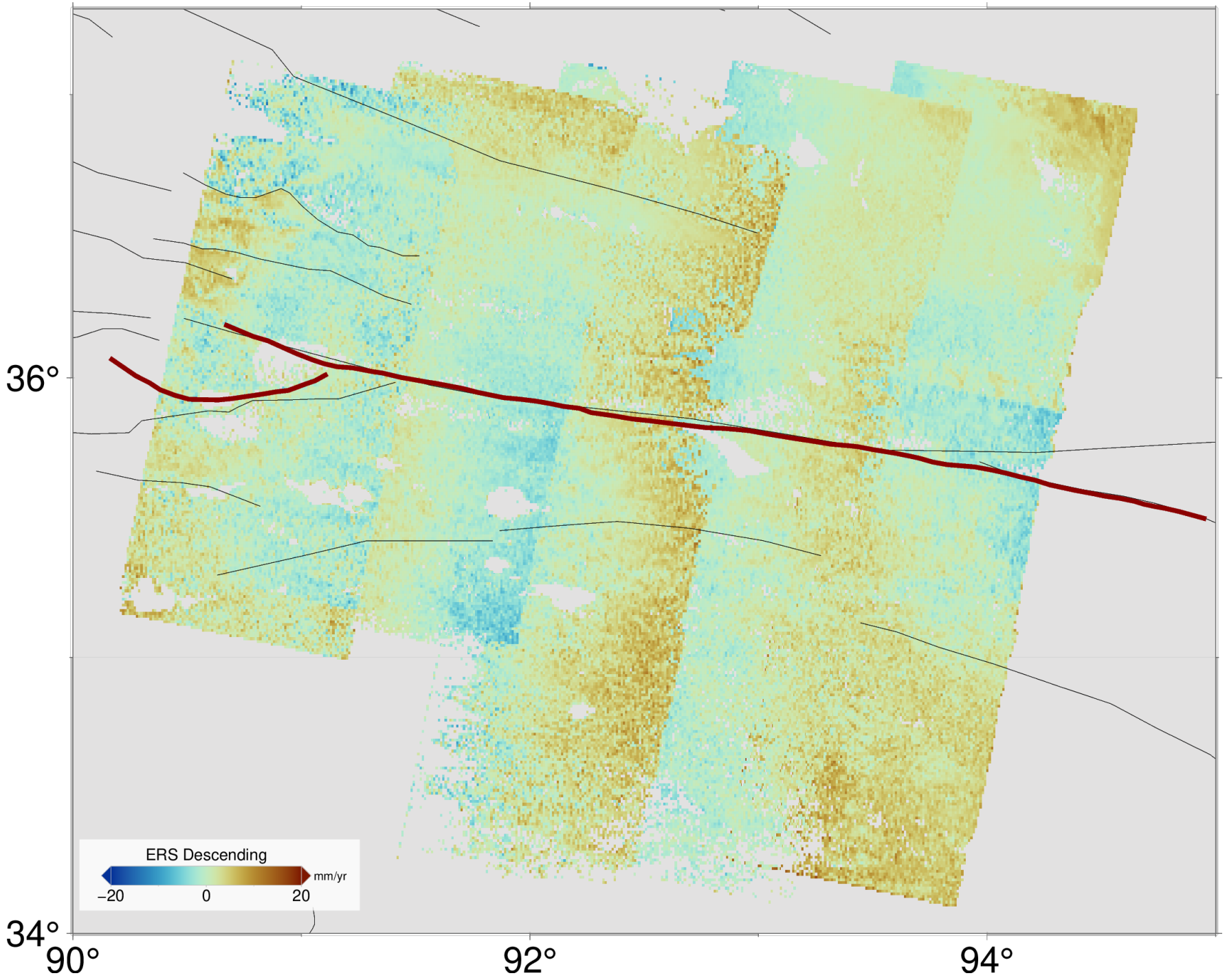


Interferogram Network

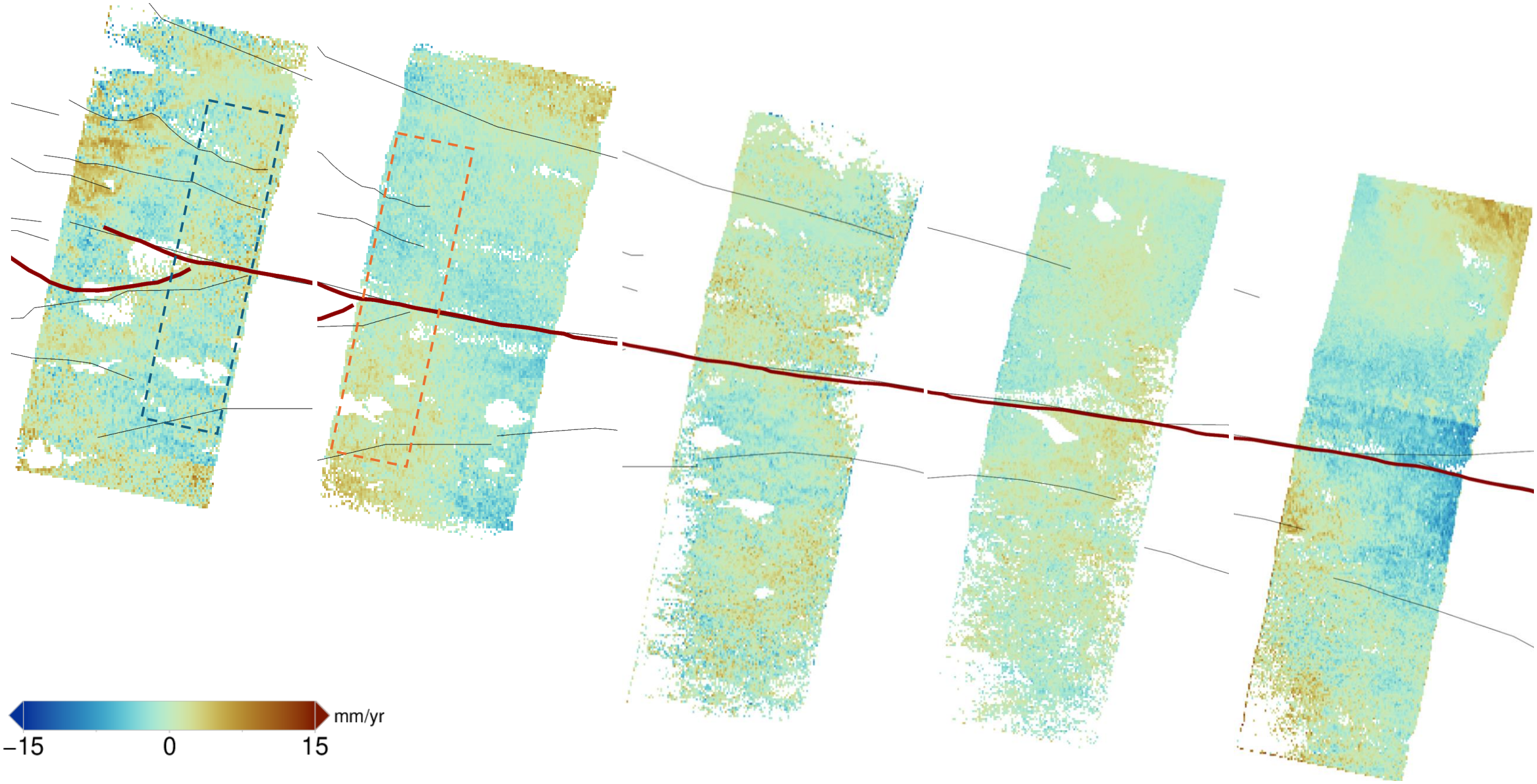


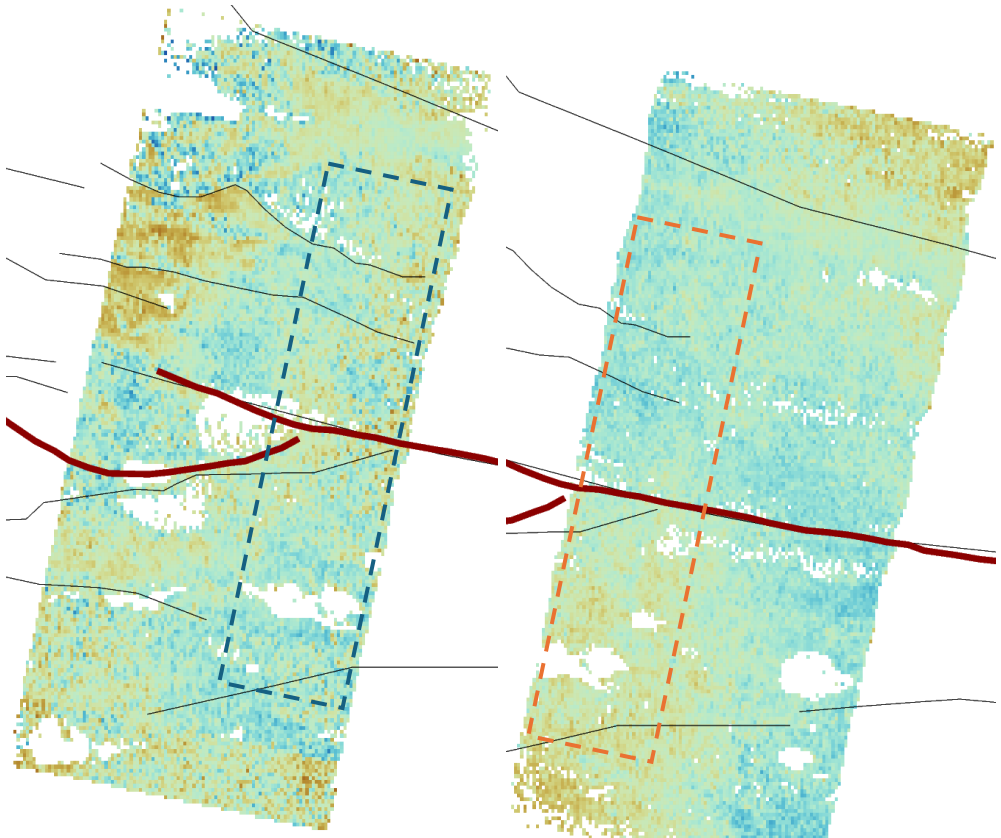


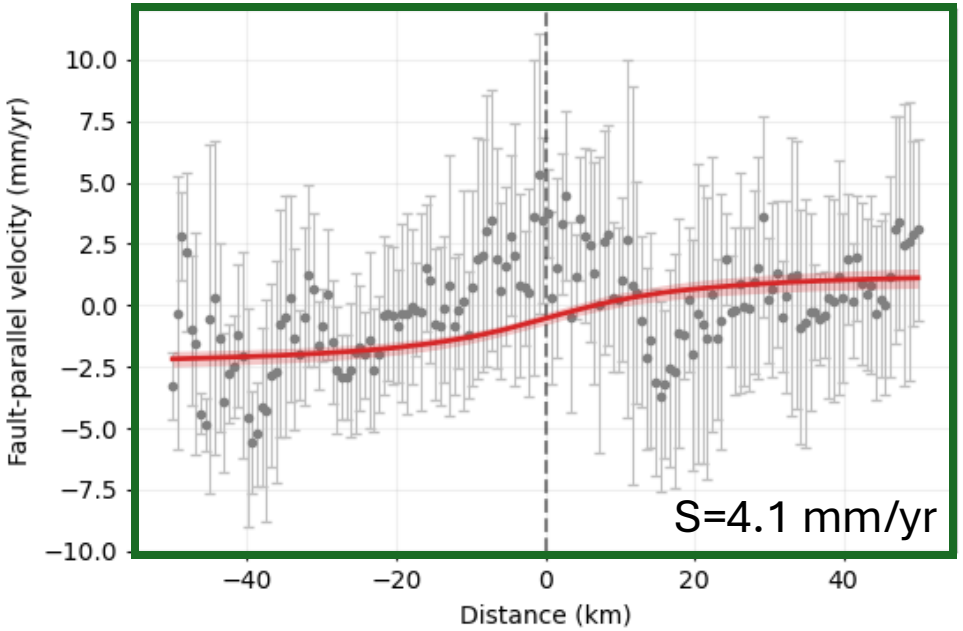
Invert for ERS LOS Velocities (LiCSBAS)

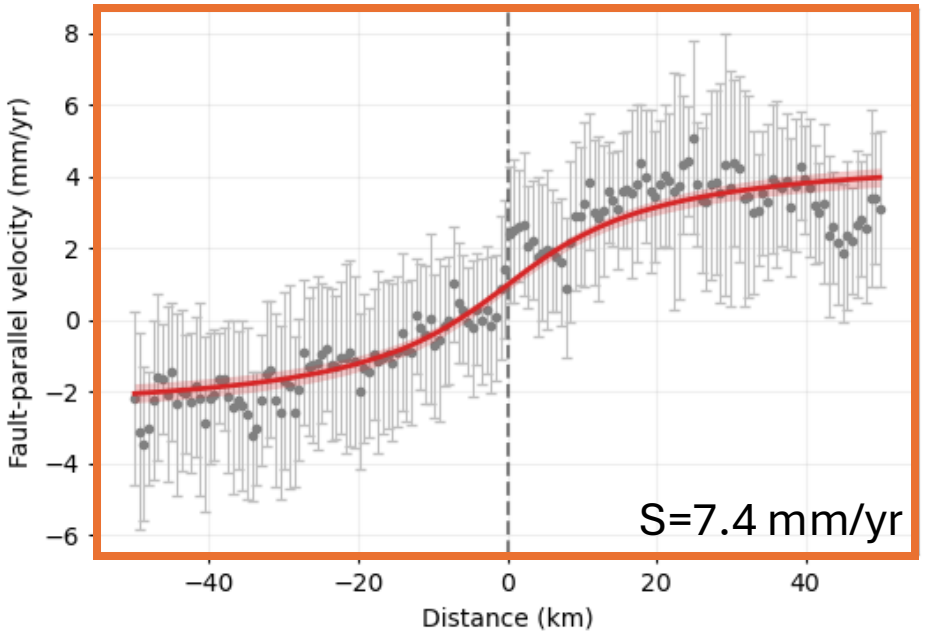


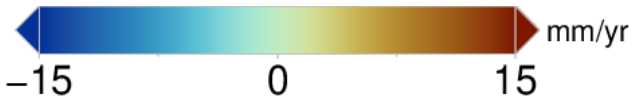
ERS Velocity Field (1995-2001)



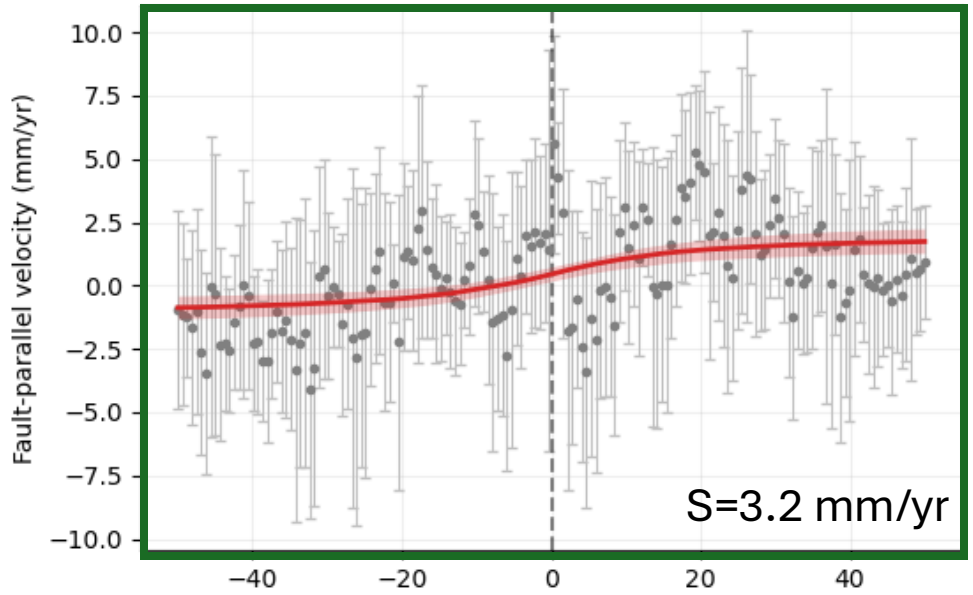


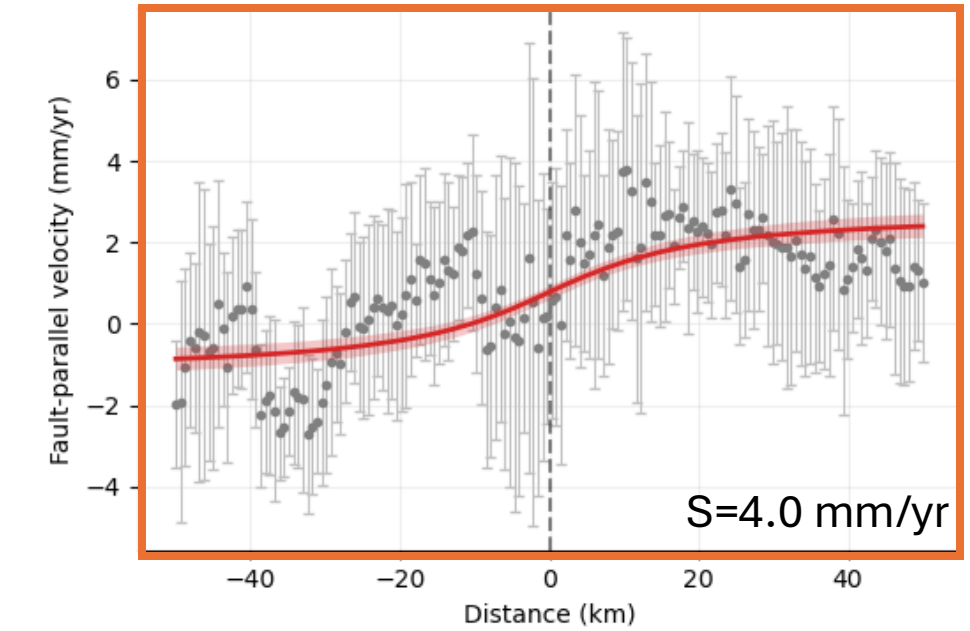


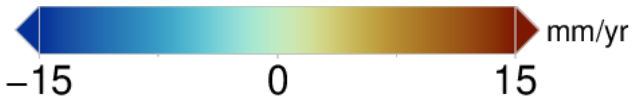


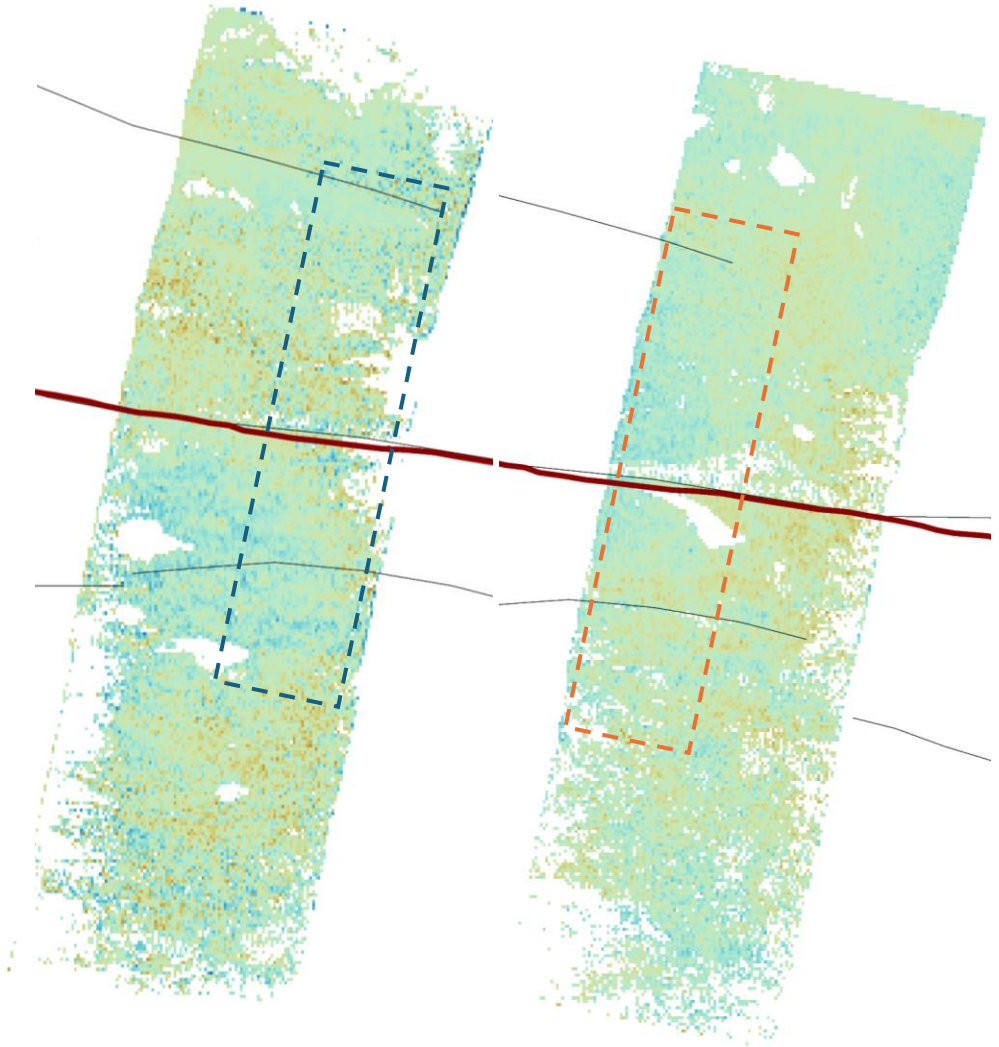


- Linear ramp removed
- Locking depth fixed at 15 km


Fault-parallel velocity (mm/yr)
10.0
7.5
5.0
2.5
0.0
−2.5
−5.0
−7.5
−10.0
−40
−20
0
20
40
S=3.2 mm/yr

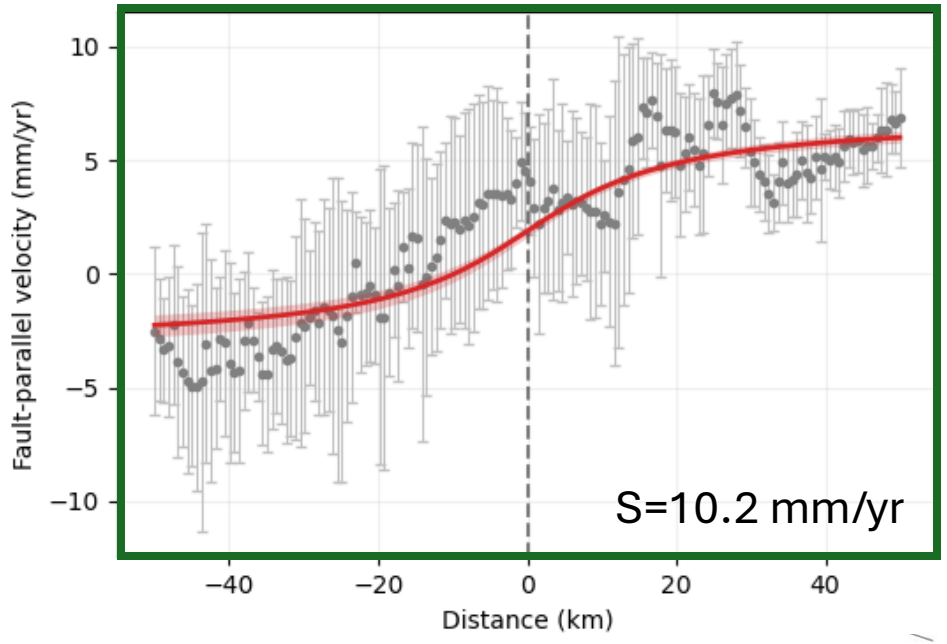

Fault-parallel velocity (mm/yr)
6
4
2
0
−2
−4
−40
−20
0
20
40
Distance (km)
S=4.0 mm/yr

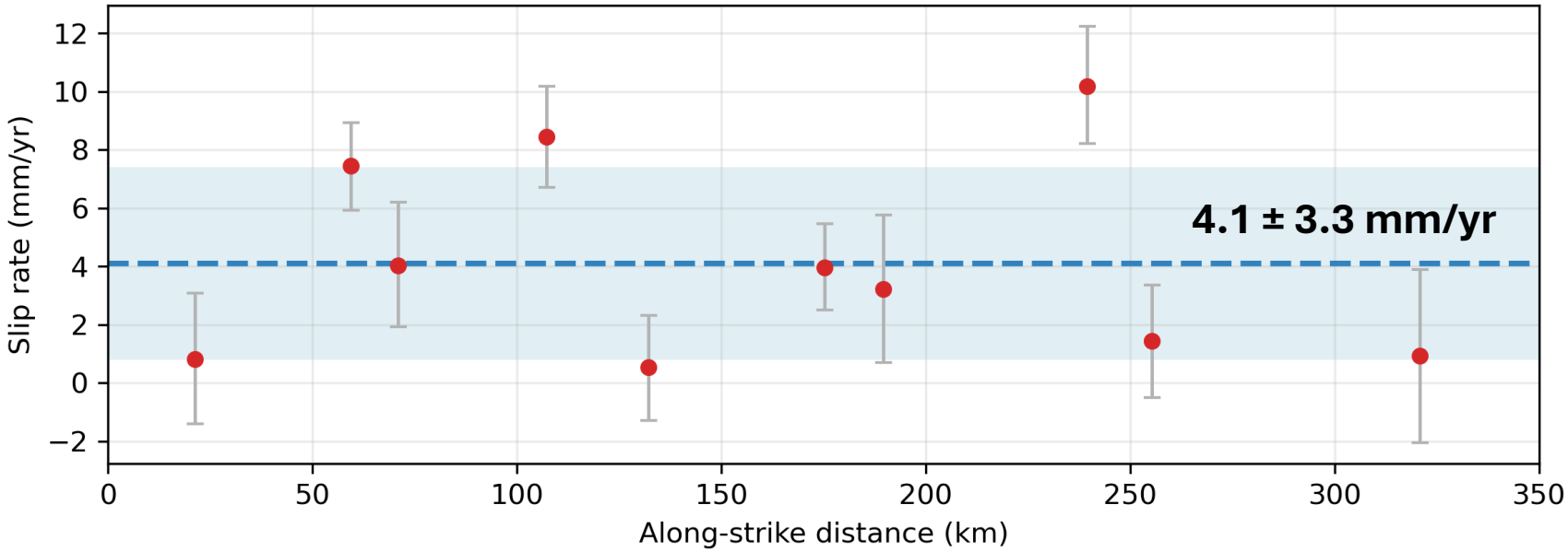

mm/yr
−15
0
15

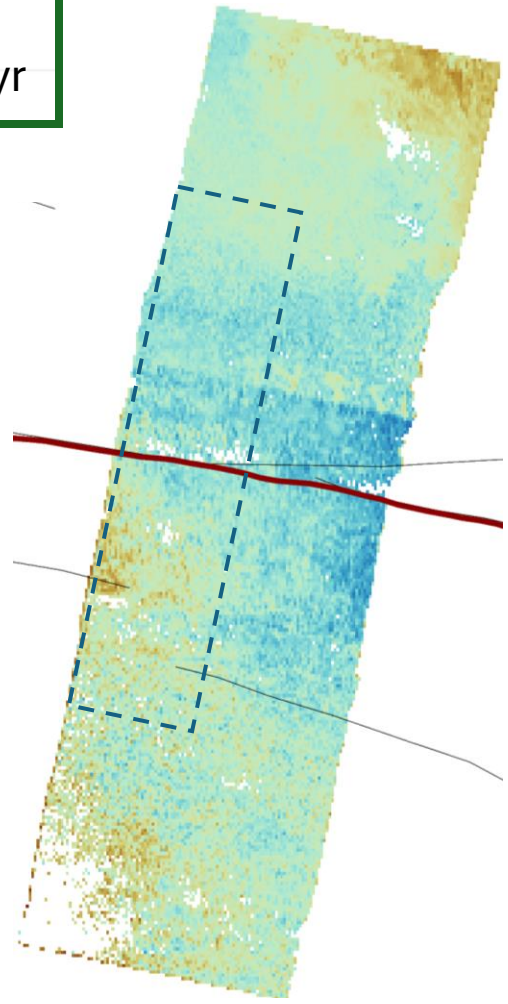


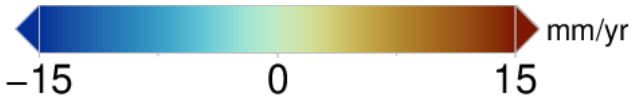
1-7 mm/yr distributed over ~100 km

Strain rates of $1 - 7 \times 10^{-8}/yr$

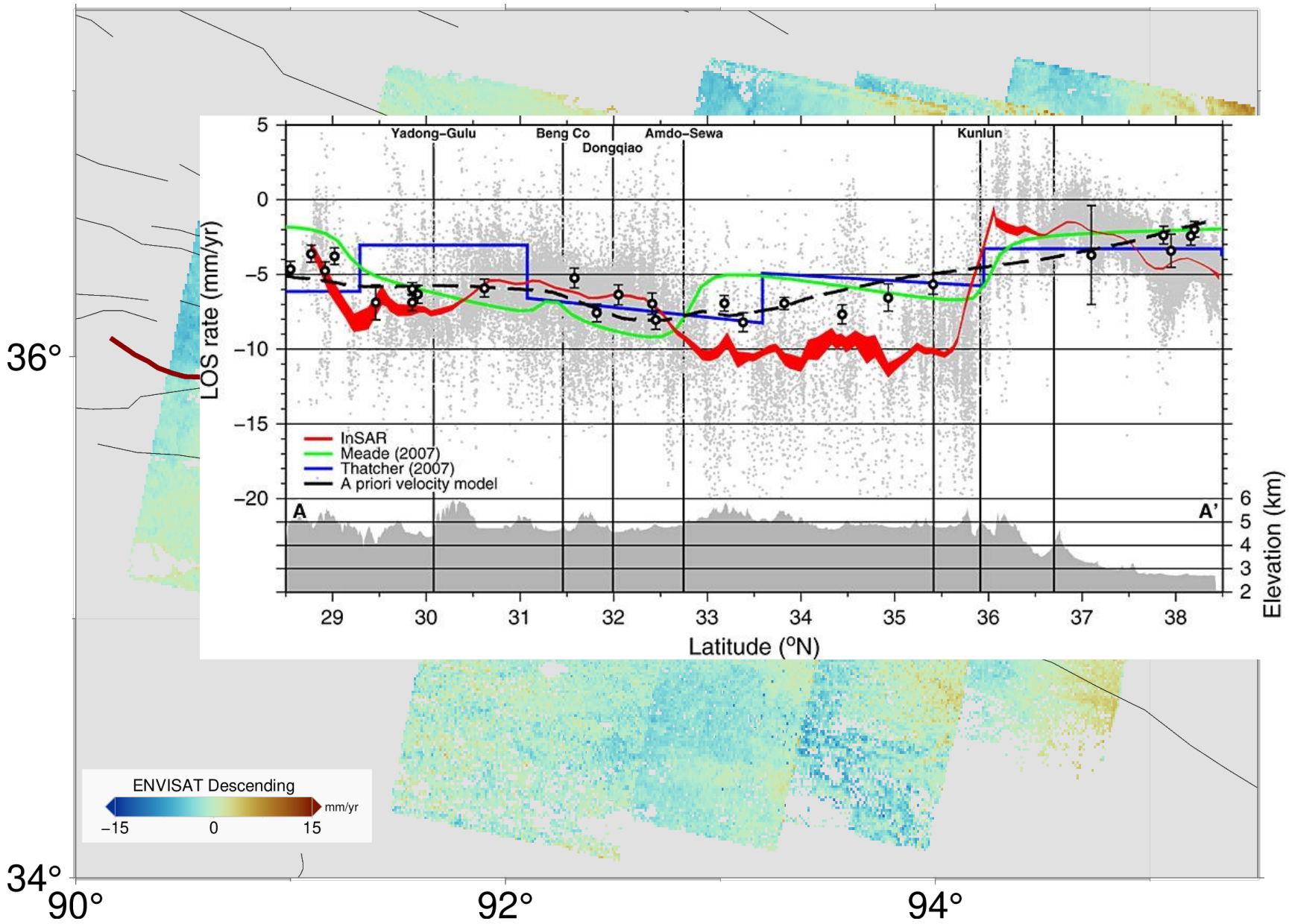


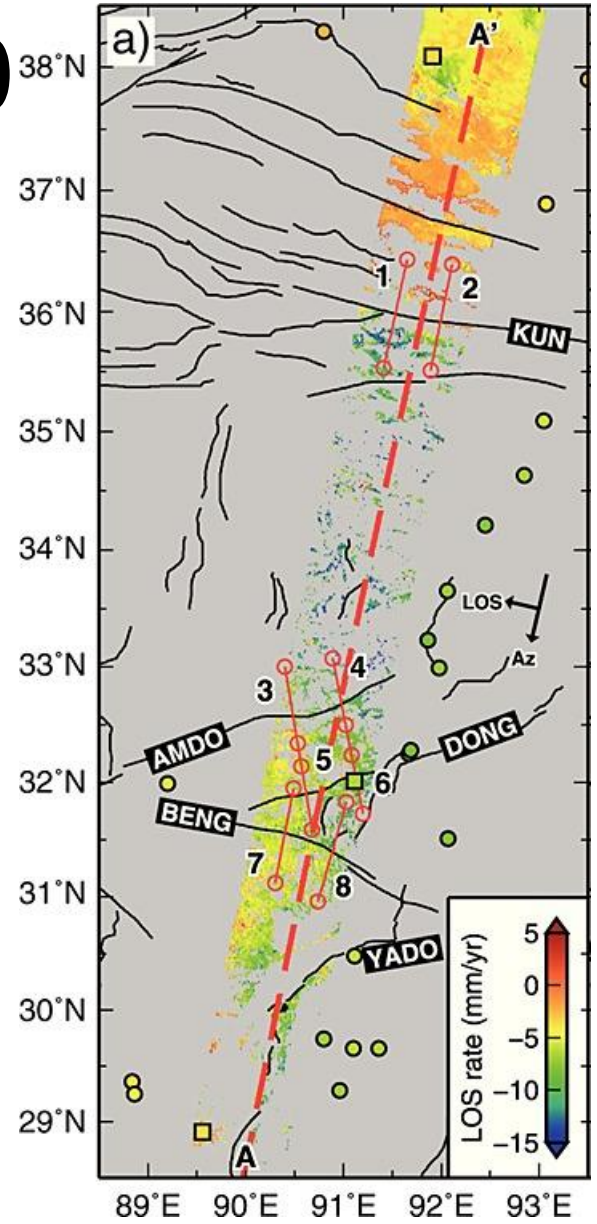






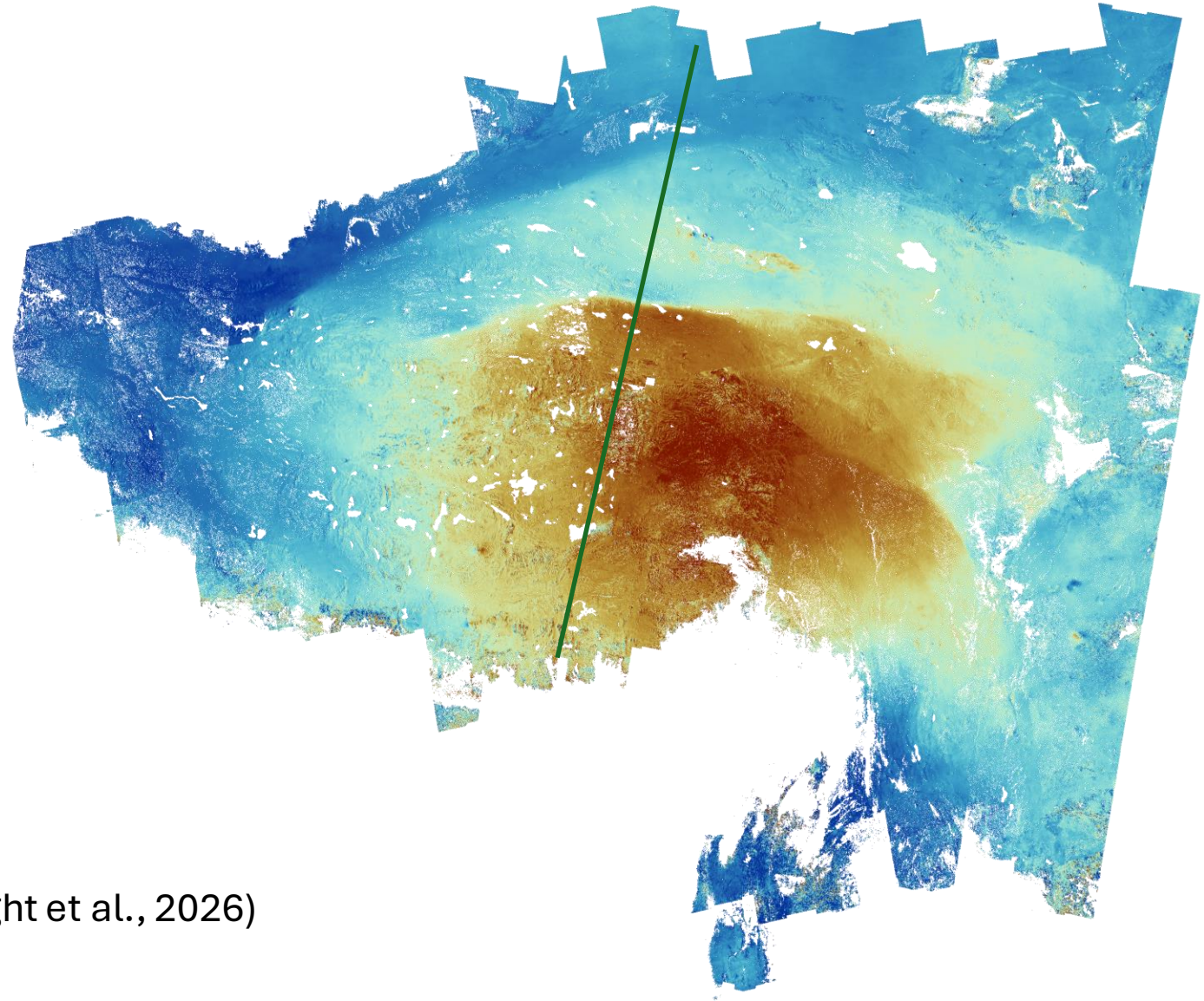
ENVISAT Velocity Field (2003-2010

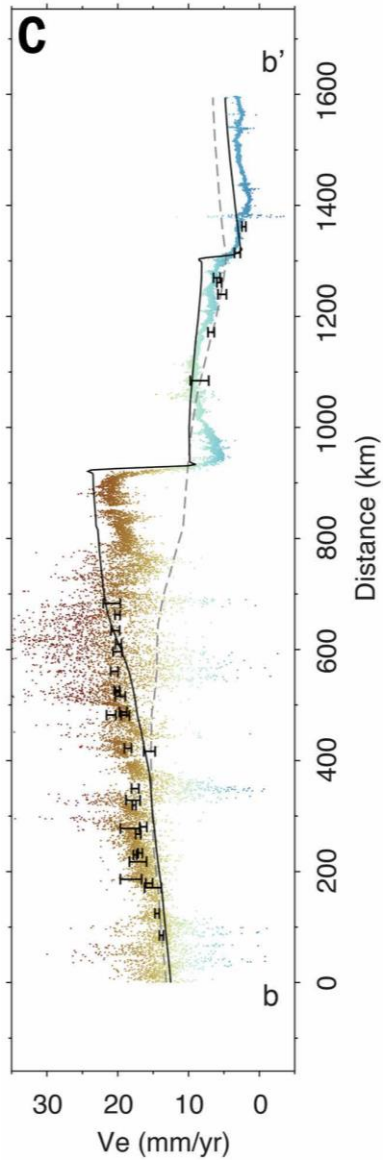




Garthwaite et al., 2013

Sentinel-1 Velocity Field (2016-2024)



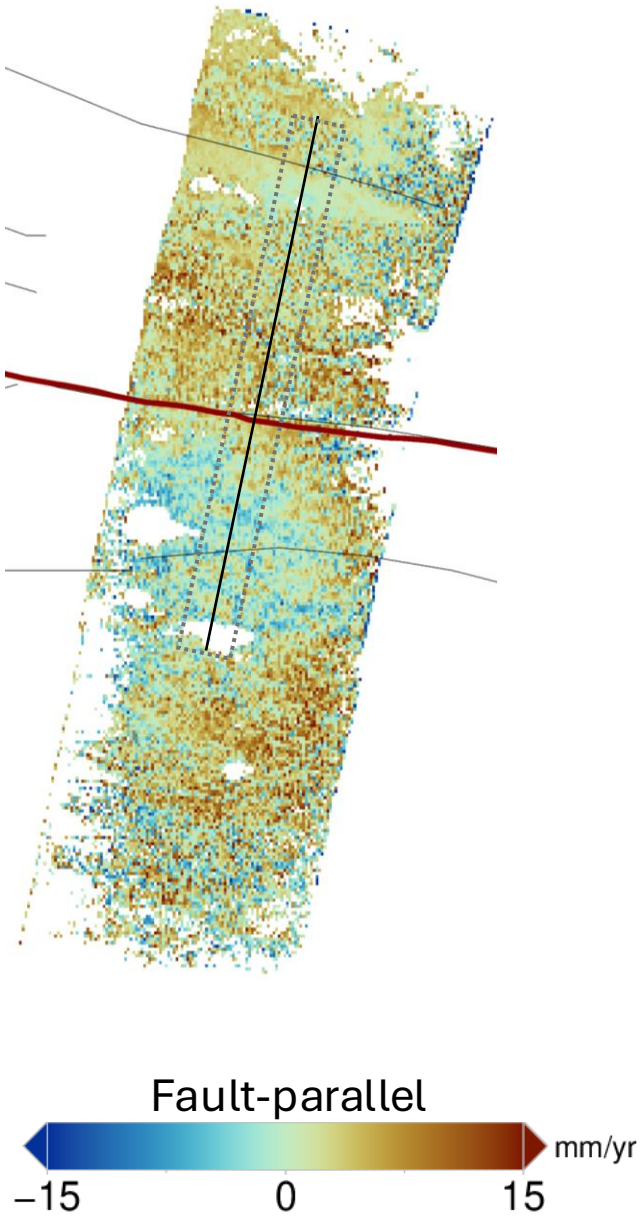


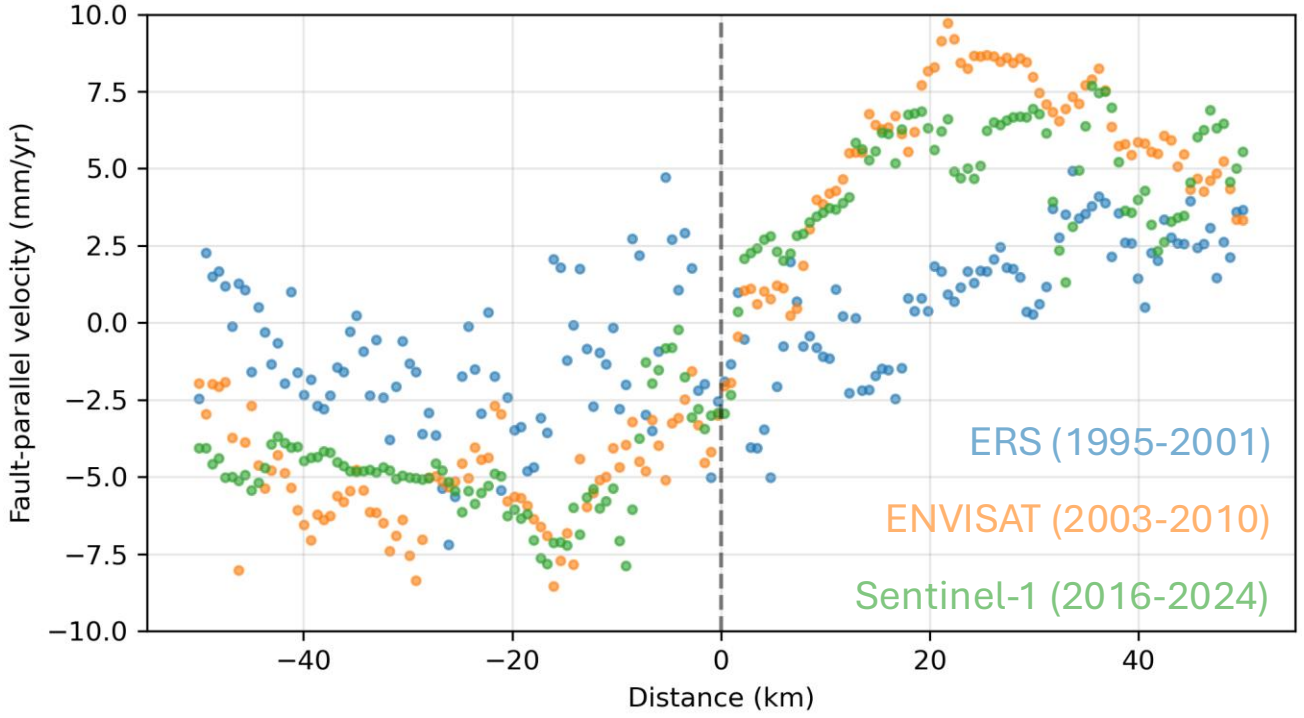
(Wright et al., 2026)

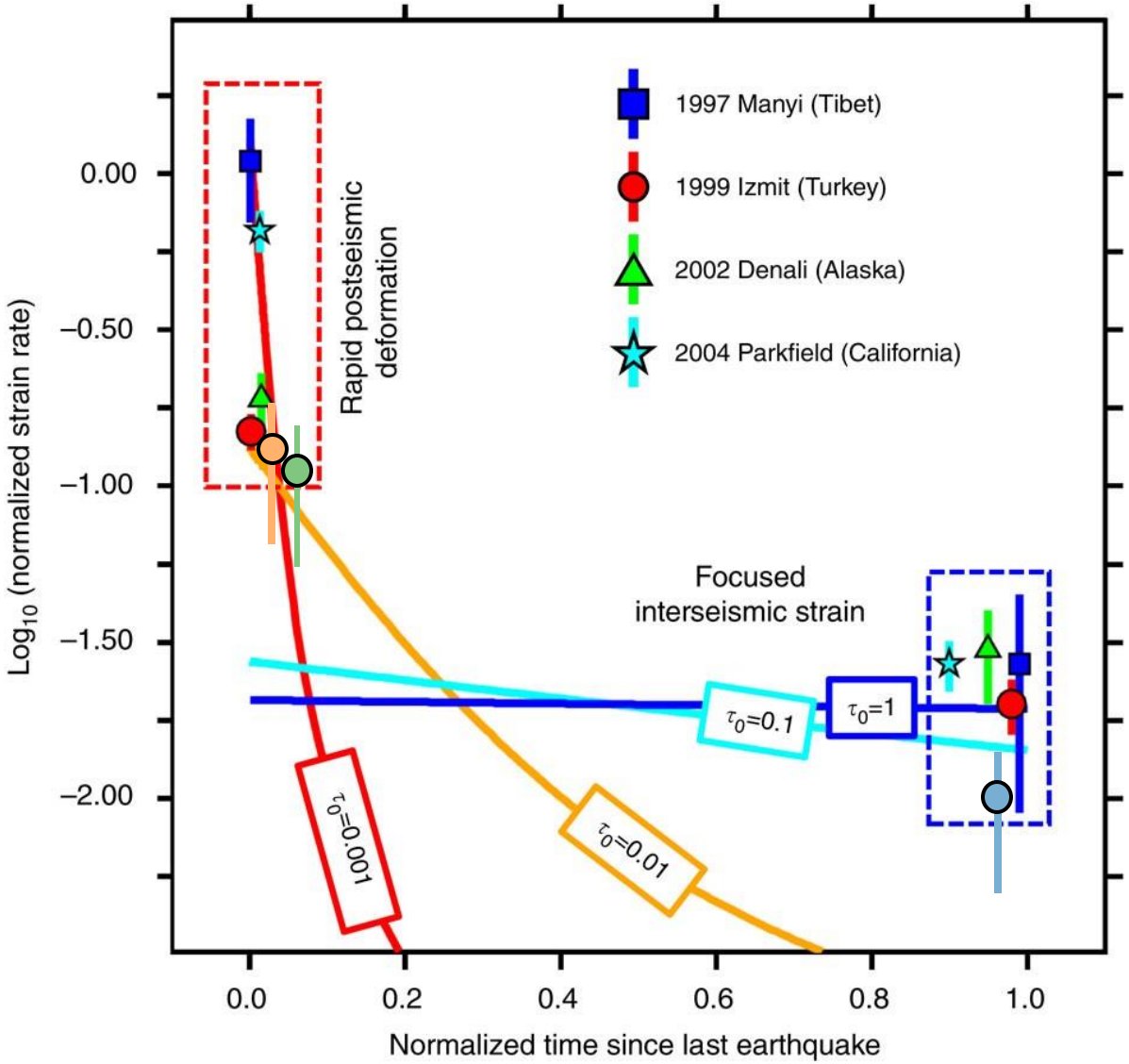
ERS (1995-2001)

ENVISAT (2003-2010)

Sentinel-1 (2016-2024)



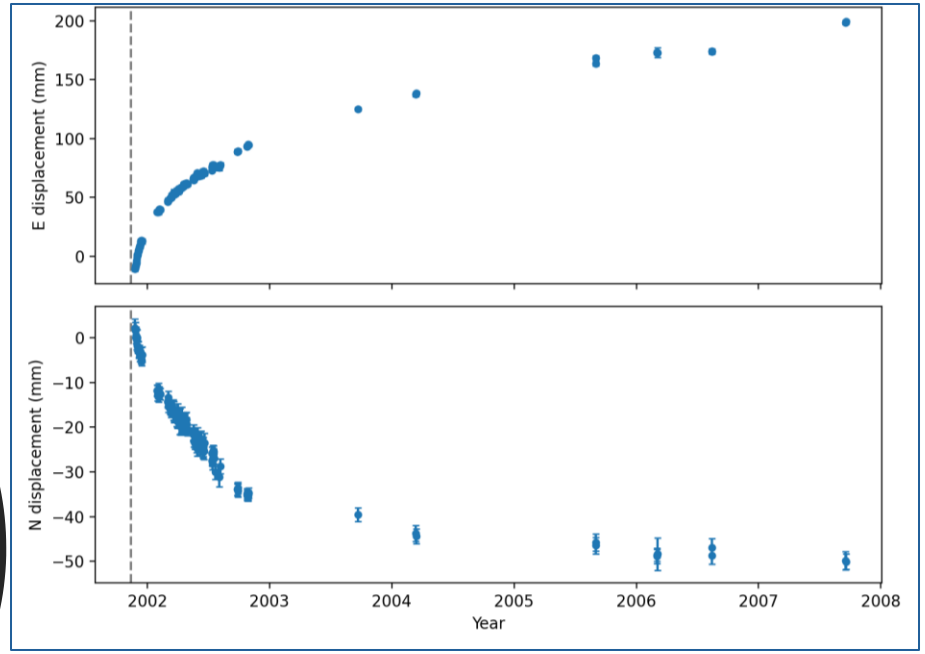




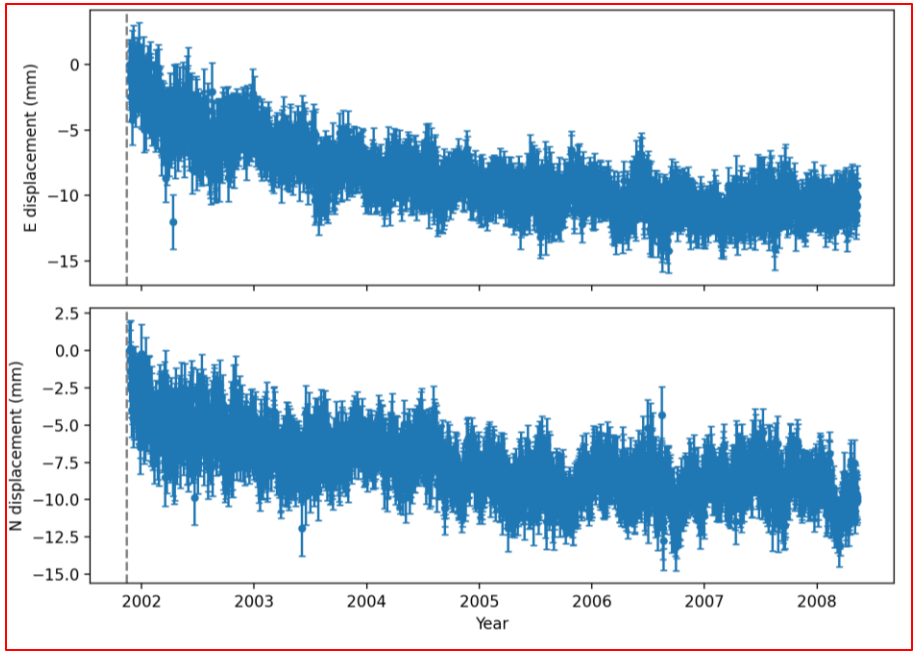
Elliott et al., 2016

GNSS Time Series

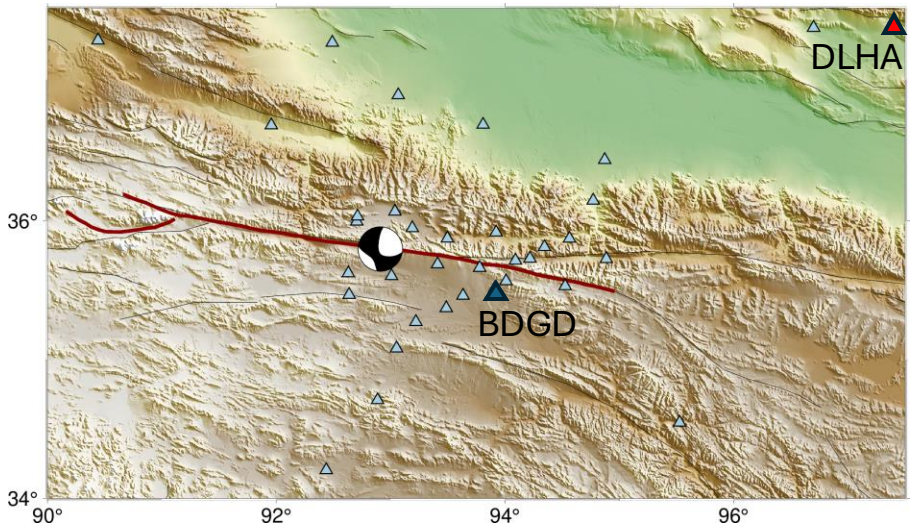
BDGD



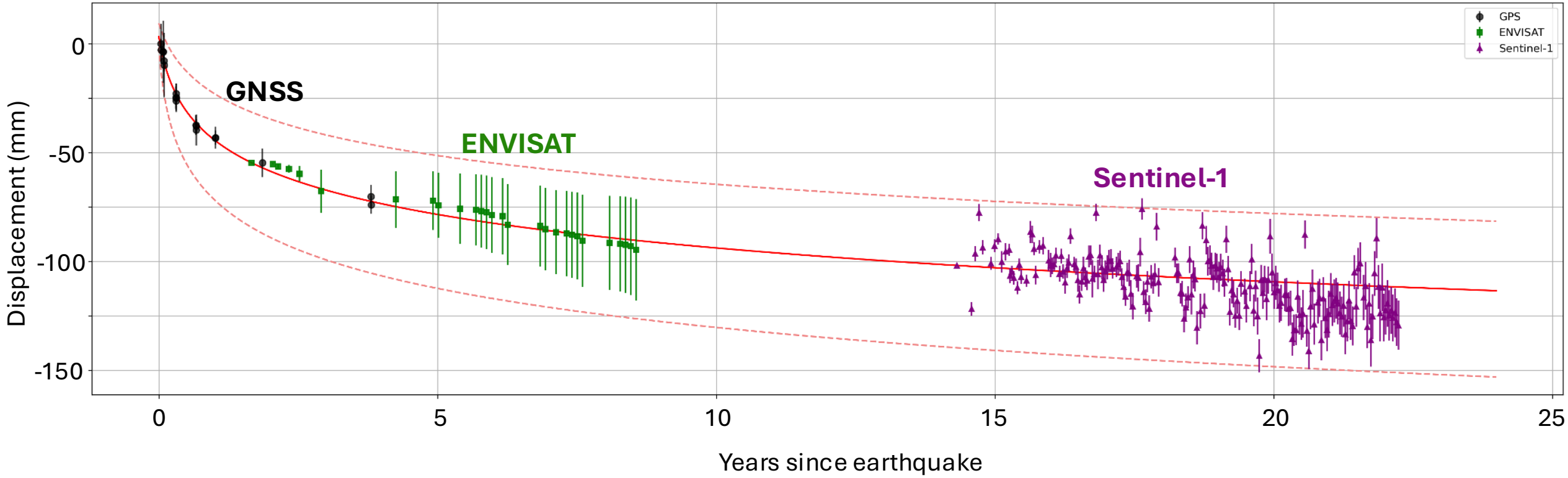
DLHA



He et al., 2018



Combined Postseismic Displacement Time Series



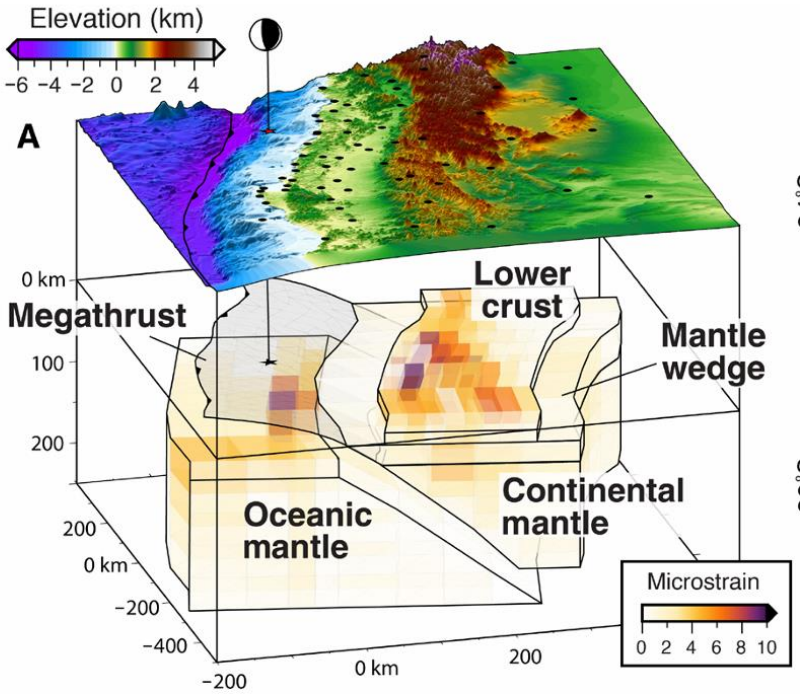
Key Observational Findings

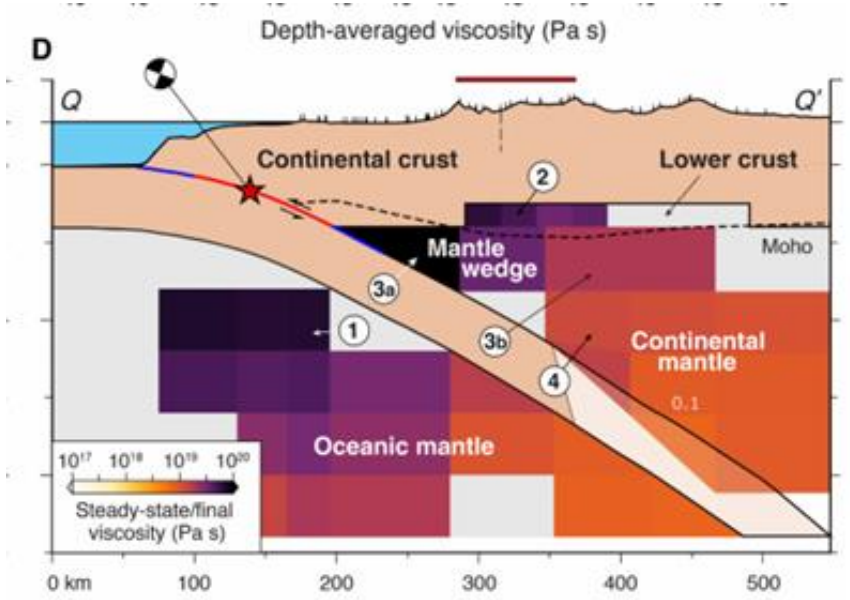
- Strong temporal variability
- Long-lived postseismic signals; not yet approaching steady state
- Spatial contrasts across the fault
- Low but fault-focused pre-earthquake strain rates in ERS data (slip rate of 4.1 ± 3.3 mm/yr)

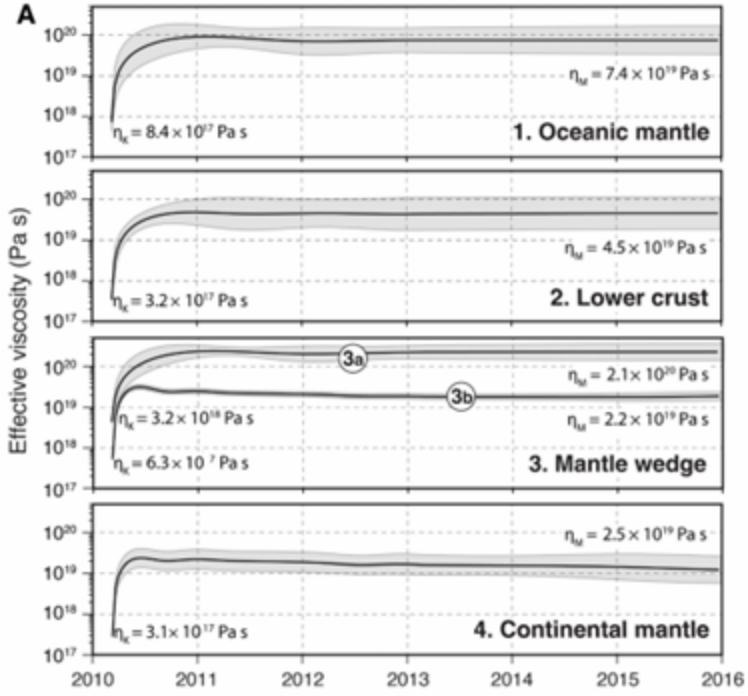
Focused strain late in the earthquake cycle implies a strong substrate ($\eta \geq 10^{20}$ Pa·s), while rapid postseismic deformation requires localised weak zones or afterslip.

Future work: Invert for afterslip and distributed anelastic strain

Weiss et al., Sci. Adv., 2019

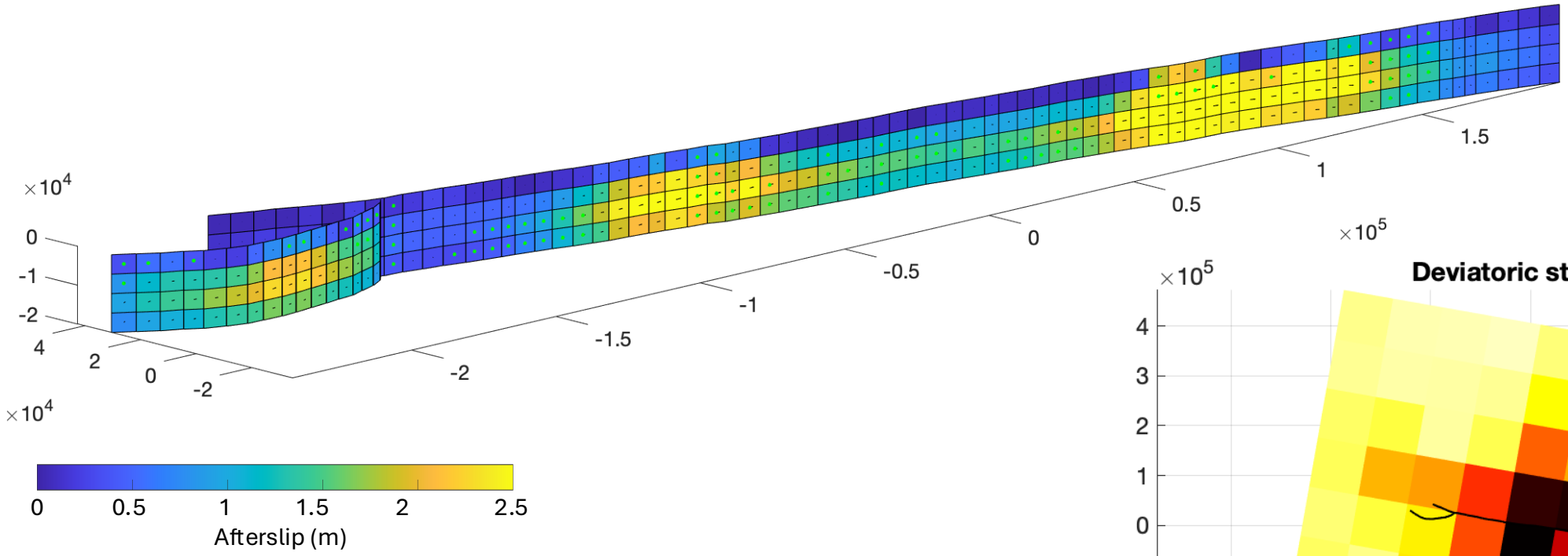


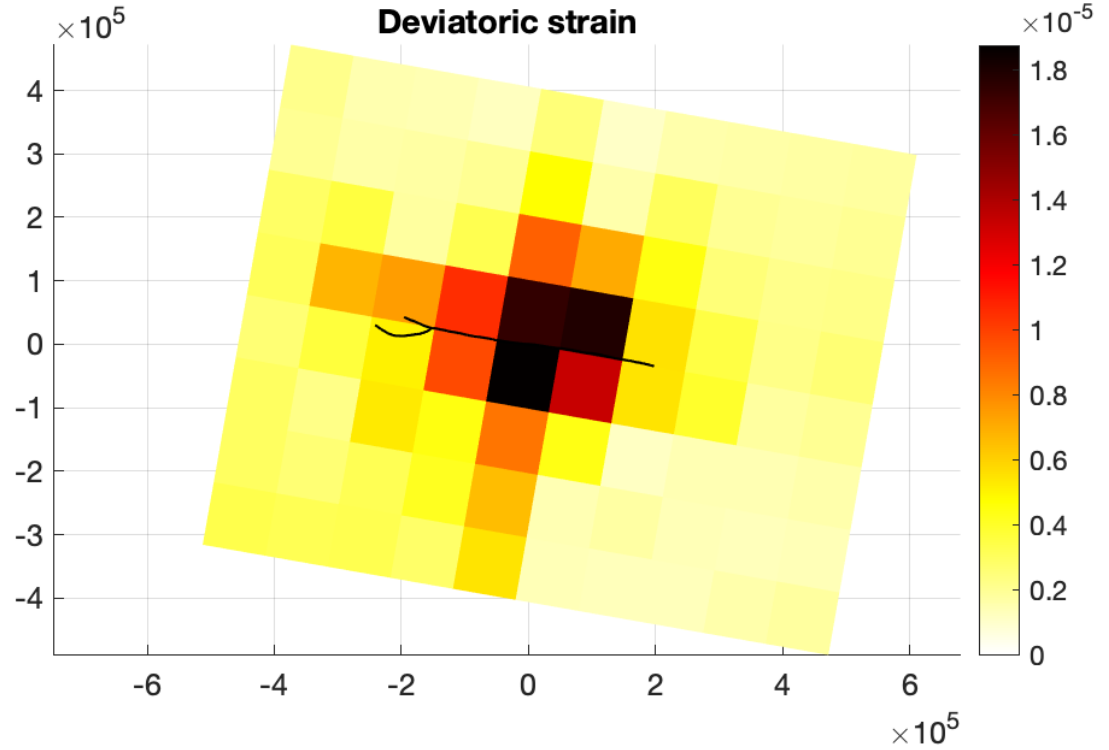




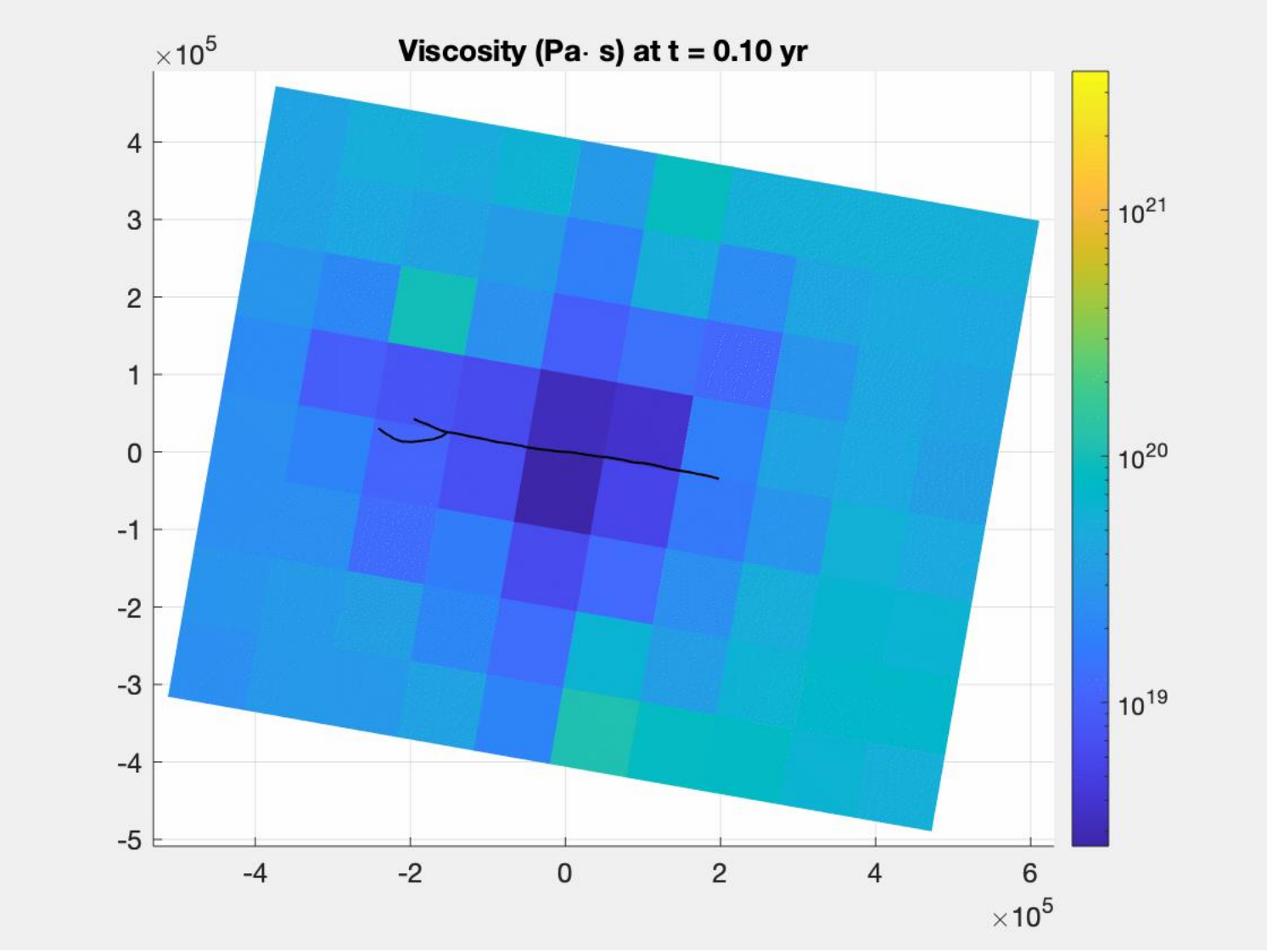
Strain Rate history + Stress evolution ⟹ Spatial and Temporal distribution of rheology

Future work: Invert for afterslip and distributed anelastic strain





Rheological Interpretation



We infer **time-dependent viscosity** without prescribing flow laws.

(testing with synthetics)

Take-Home Messages

- Large-scale velocity fields are **not steady-state**.
- Strain-rate maps can be **transient-contaminated**.
- Postseismic deformation persists for decades.
- Pre-earthquake strain is essential constraint.
- Rheology varies in space AND time (ongoing work).

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