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Republic of Poland

JAGIELLONIAN UNIVERSITY IN KRAKÓW

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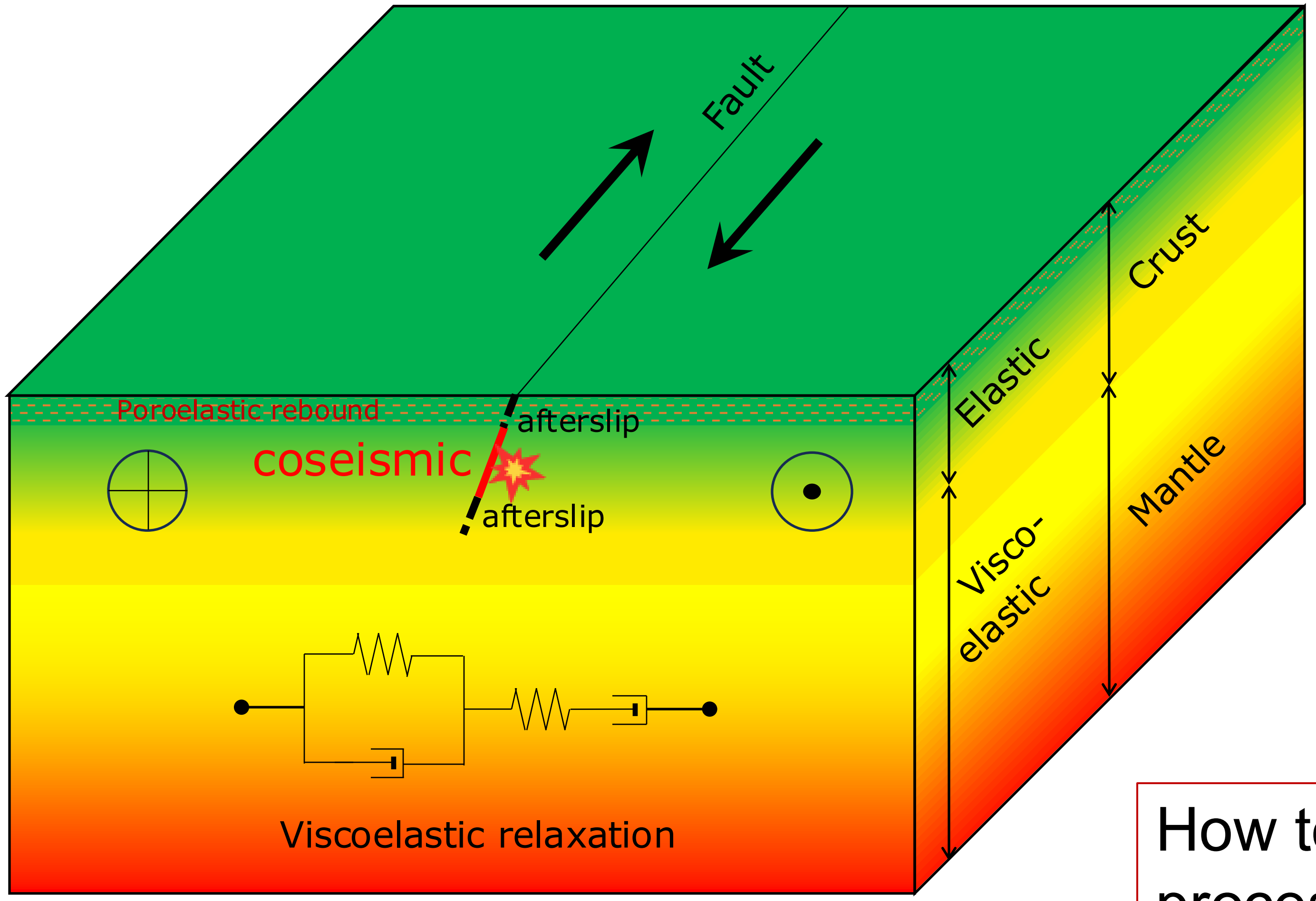
FRINGE 2026

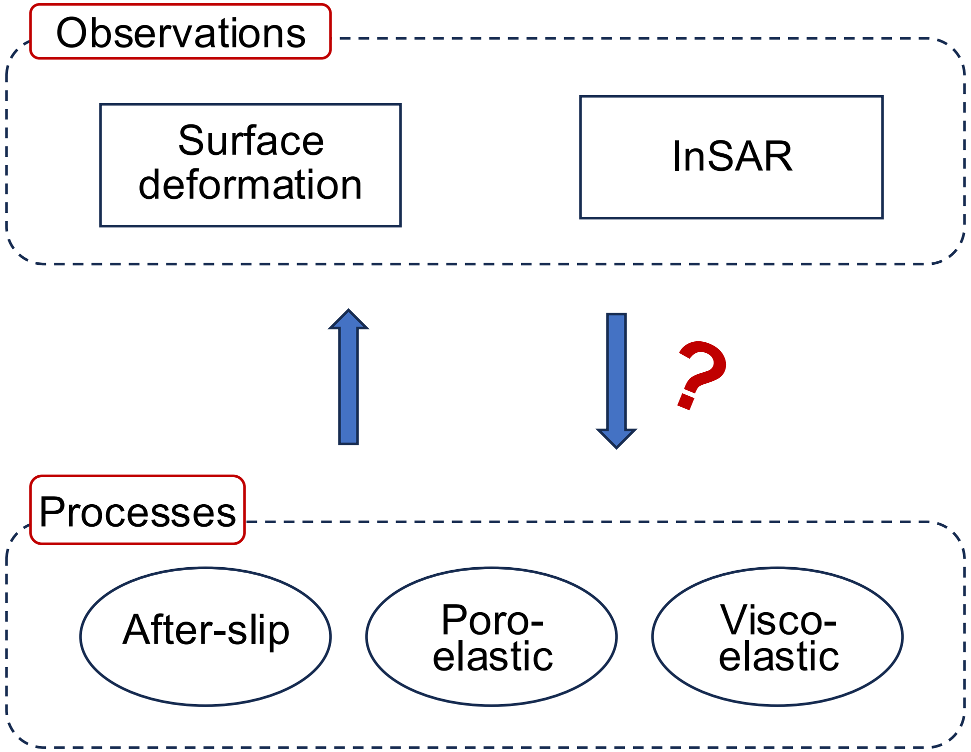
Asymmetric deformation after the 2023 Türkiye earthquakes

Jihong Liu, Sigurjón Jónsson

King Abdullah University of Science and Technology (KAUST)

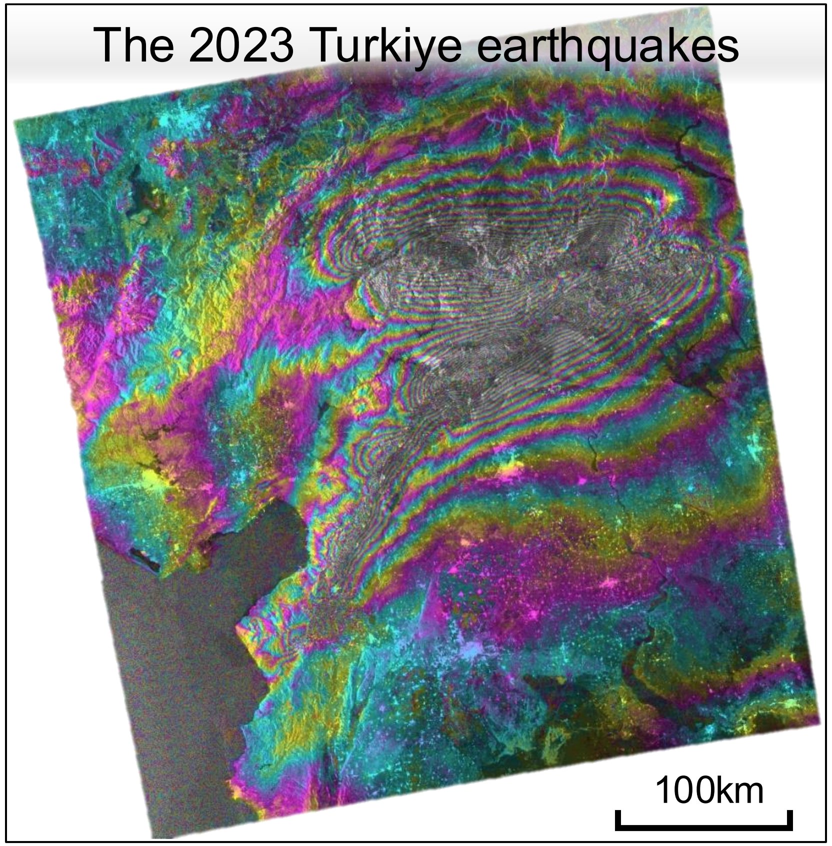
Postseismic processes after earthquakes





How to distinguish different postseismic processes with InSAR observations

InSAR capabilities



- Known as its **<u>spatial capability</u>** of high density and large coverage

- The increasing SAR datasets enable to capture the postseismic deformation process in **<u>a full-dimensional manner</u>**
  - ✓ **Spatial pattern**
  - ✓ **Temporal evolution**
  - ✓ **In three dimensions (EW, NS, Vertical)**

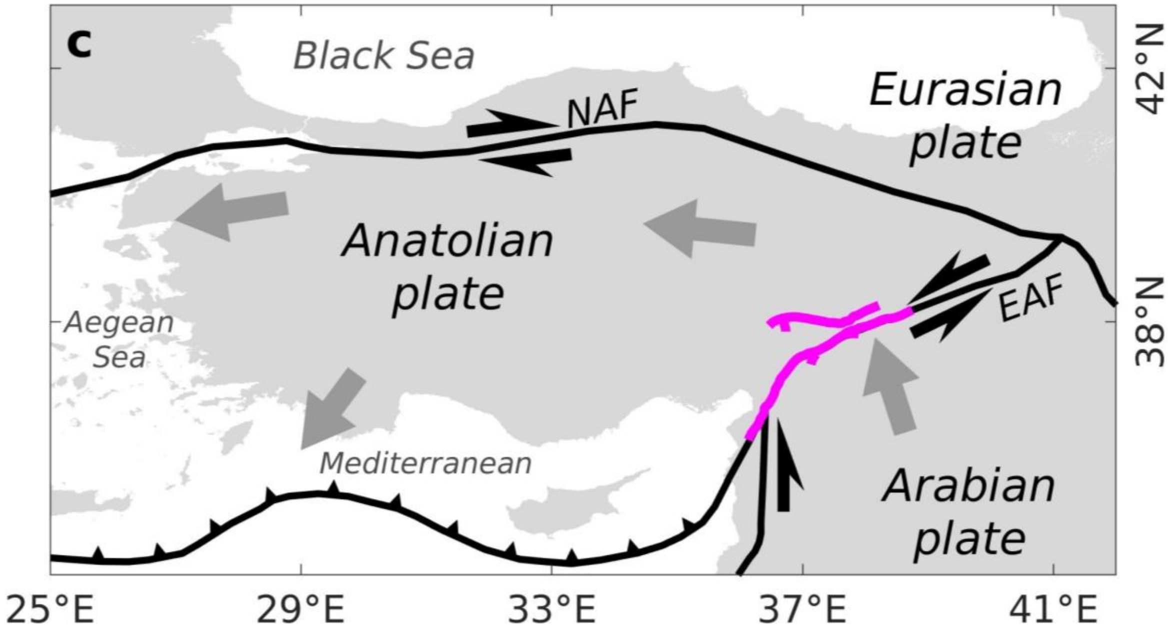
Postseismic processes *meet* InSAR full-dimensional disp.

The sensitivity of postseismic processes to the full-dimensional displacements

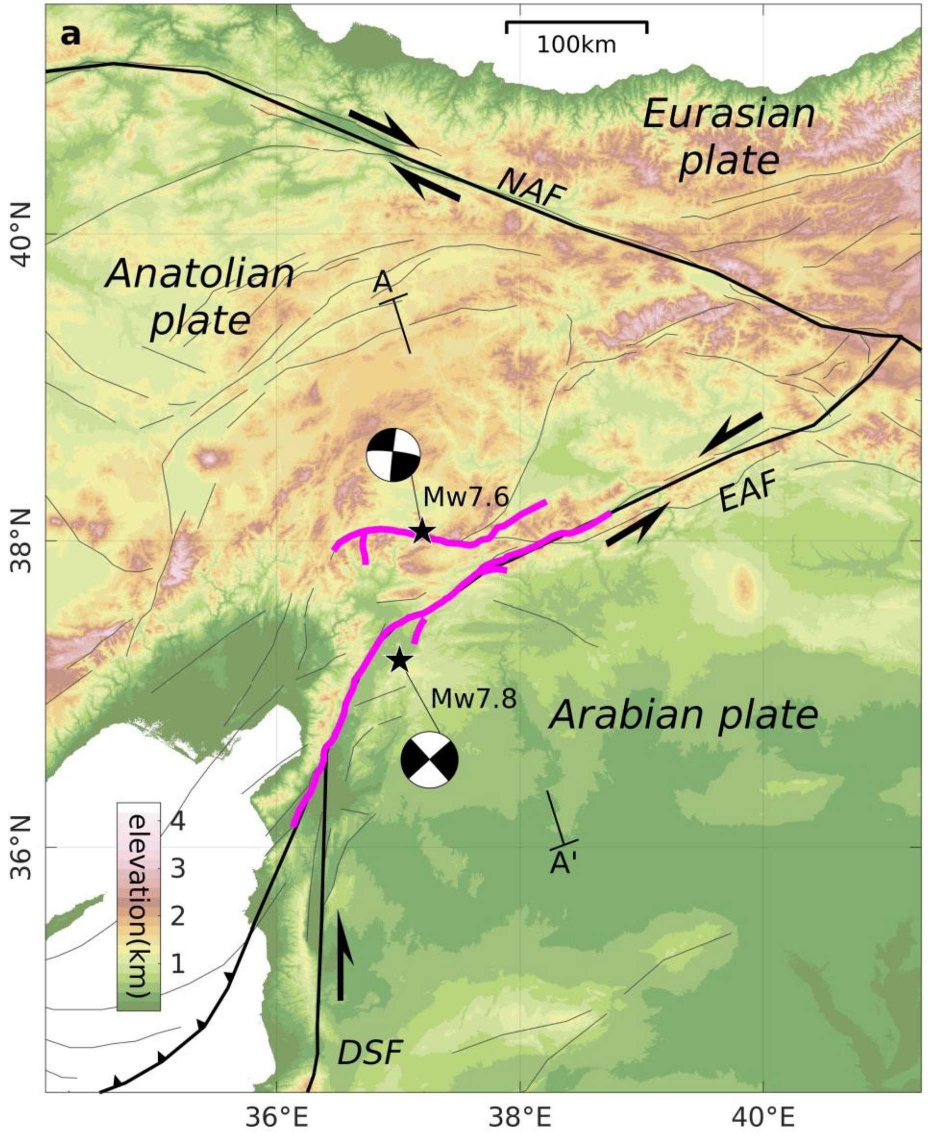
	Spatial	Temporal behaviour	EW	NS	Vertical
Afterslip	Large area	**Symmetric**	**Similar pattern** with coseismic phase		
Viscoelastic	Large area	could be **Asymmetric** with viscosities	**Similar pattern** with coseismic phase		Complex, depending the process depth
Poroelastic	Large area	Short, fluid rebanlance process	Usually neglegible		**Reverse to** the coseismic phase

Potential to distinguish

The 2023 Turkiye earthquakes



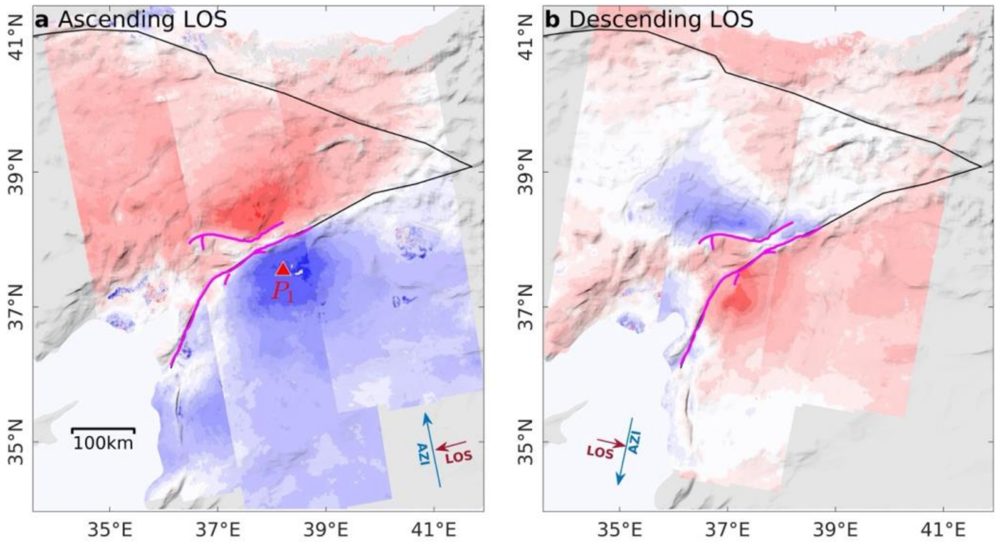
- Two Mw7.8 & 7.6 Eqs. occurred around EAF in 2023
- Westward movement of the Anatolian plate from complex tectonic background
- Quite contrast of geological setting across EAF



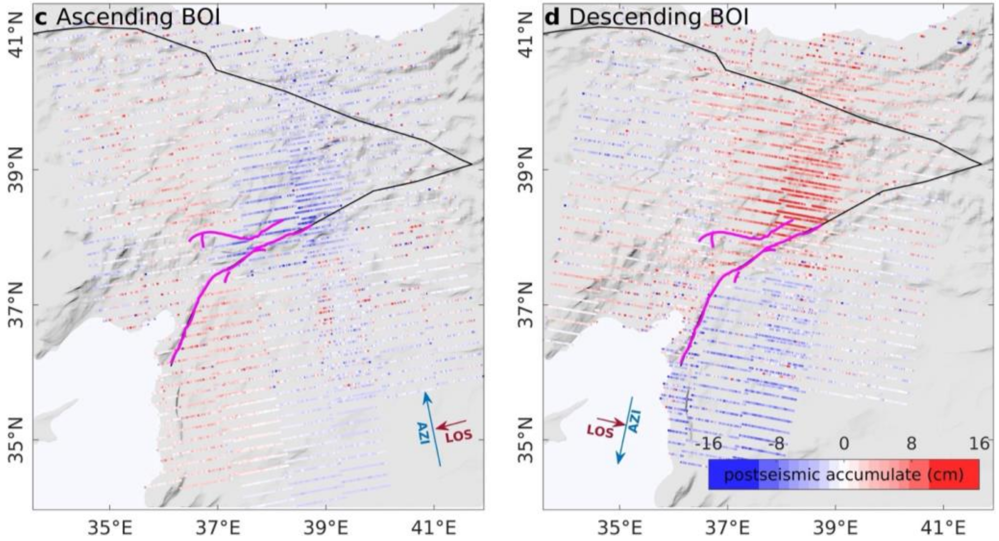
Highly complex postseismic deformations

Two-year postseismic displacement with InSAR

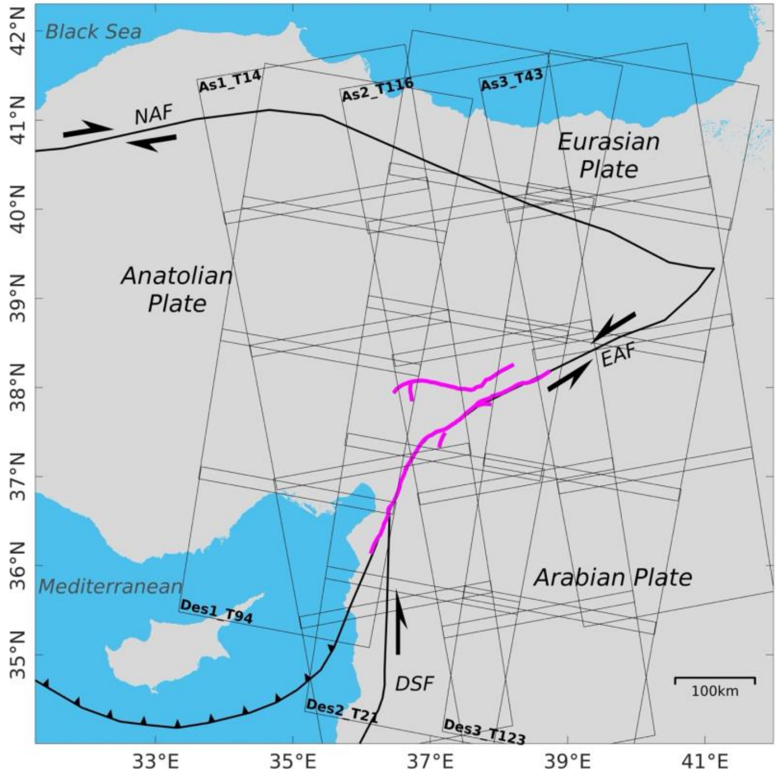
InSAR accumulative displacement **(EW and Vertical)**



BOI accumulative displacement **(NS)**



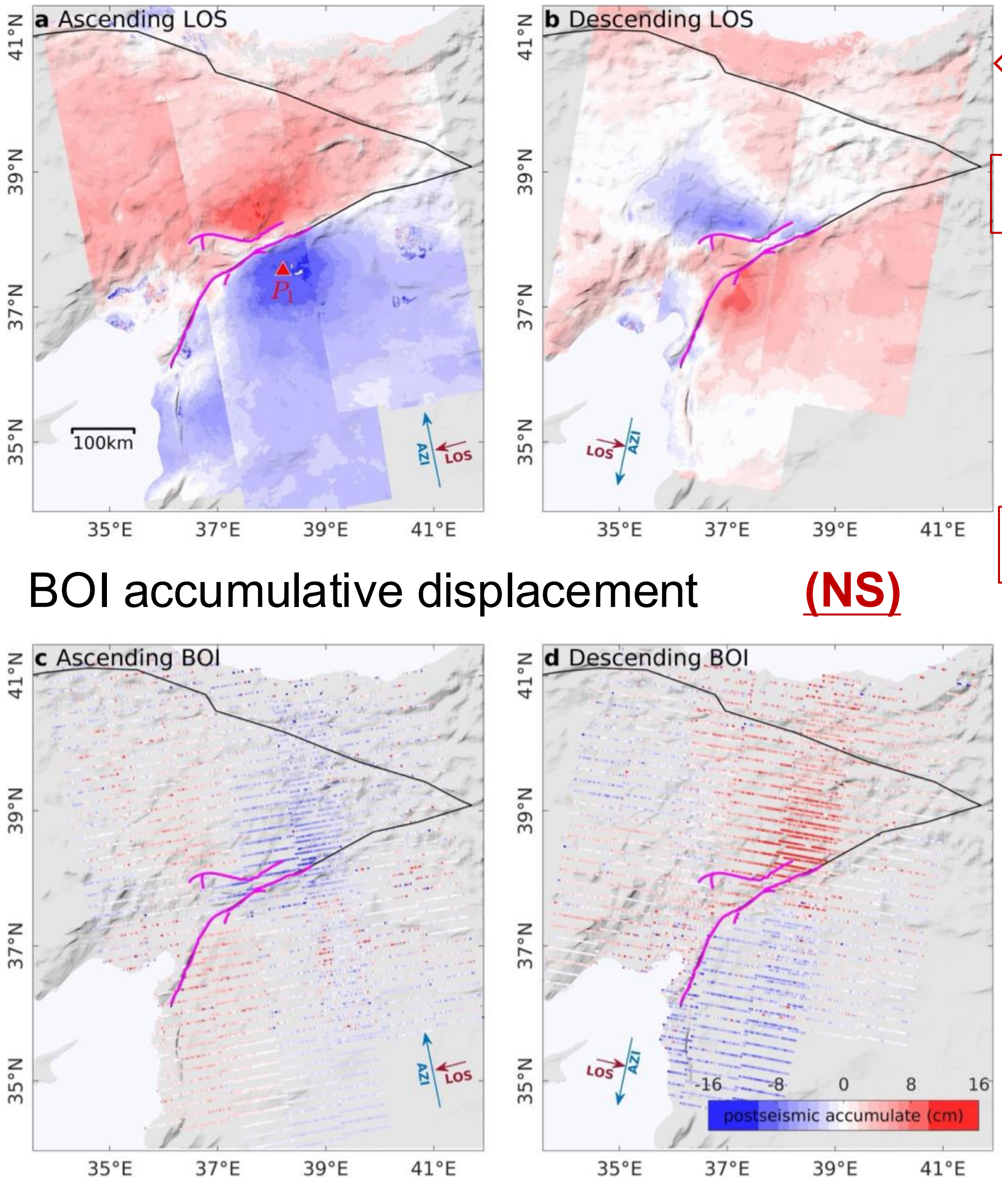
SAR image coverage



Two-year postseismic displacement with InSAR

InSAR accumulative displacement **(EW and Vertical)**

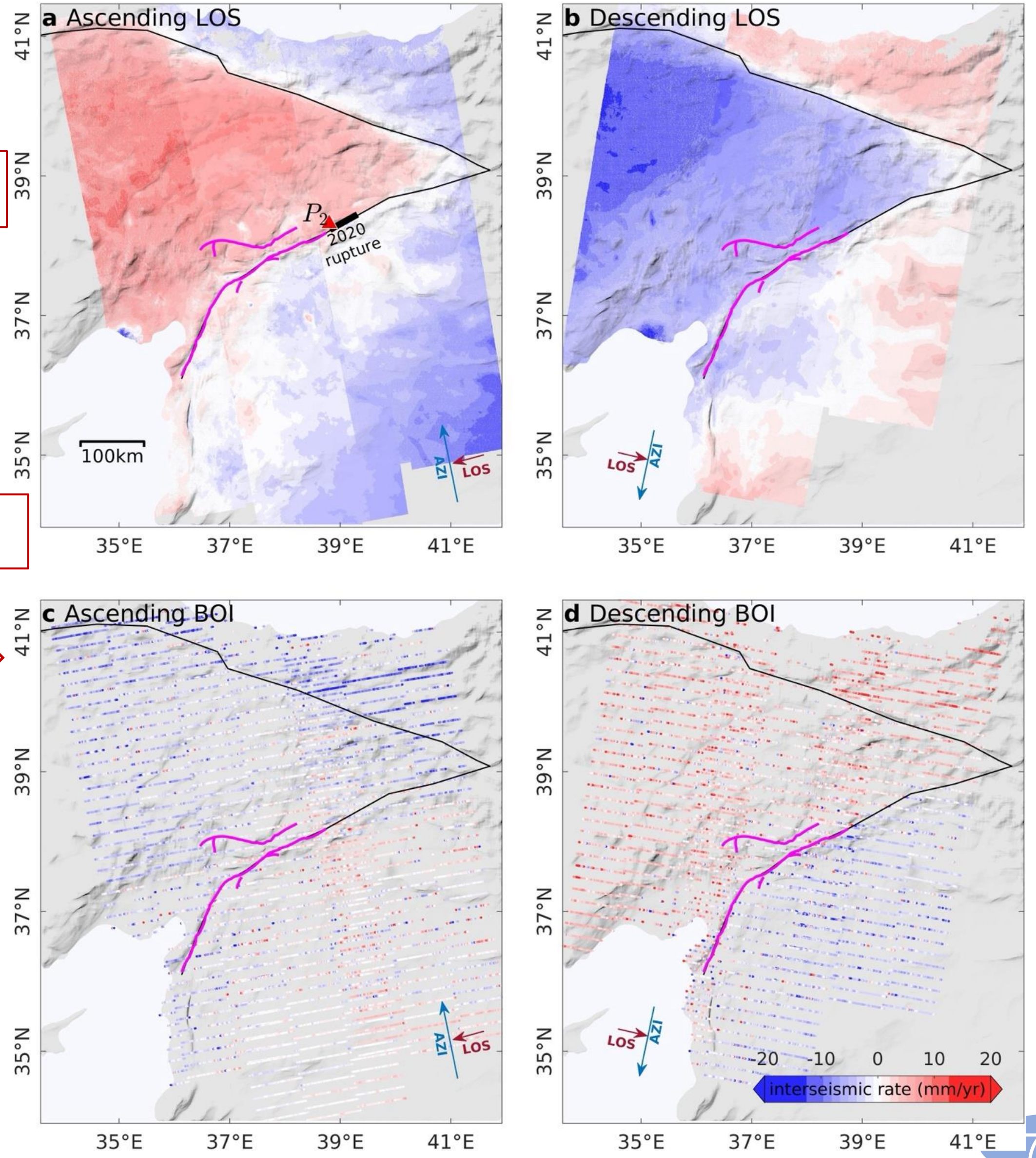
BOI accumulative displacement **(NS)**



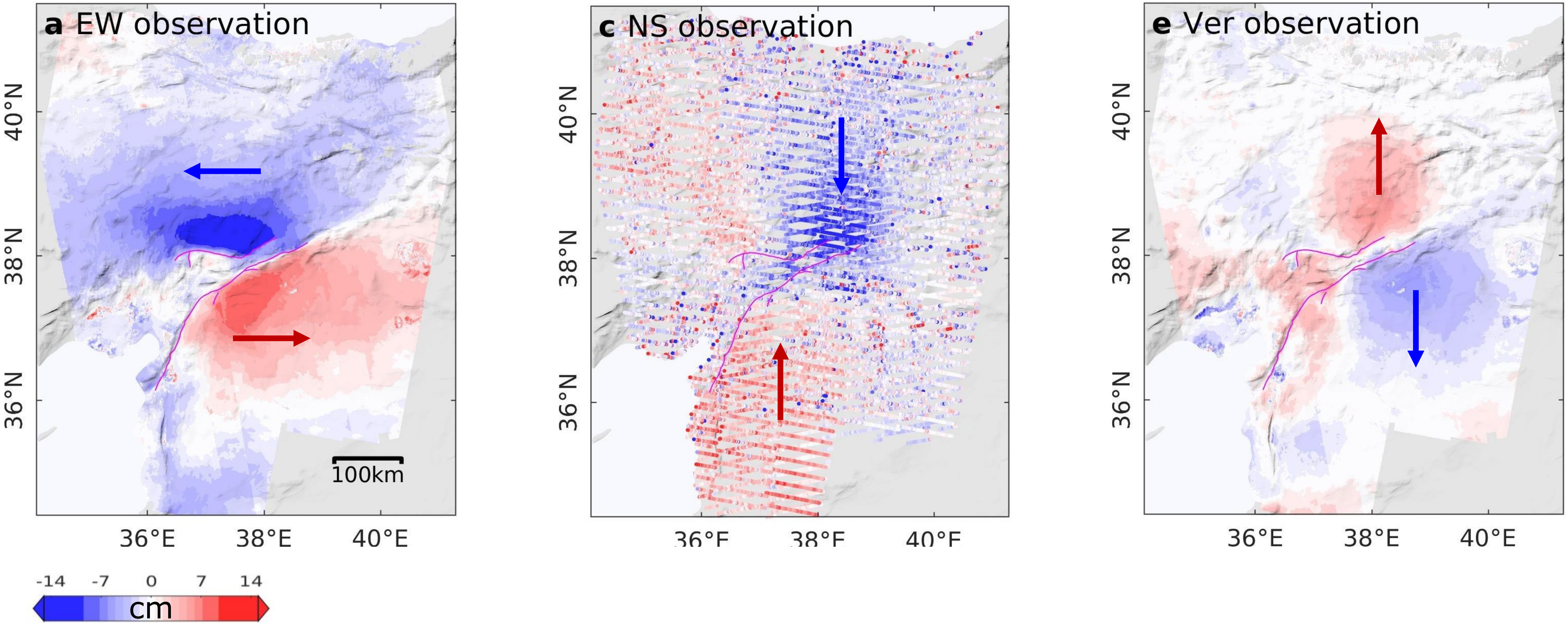
Postseismic

Corrected by

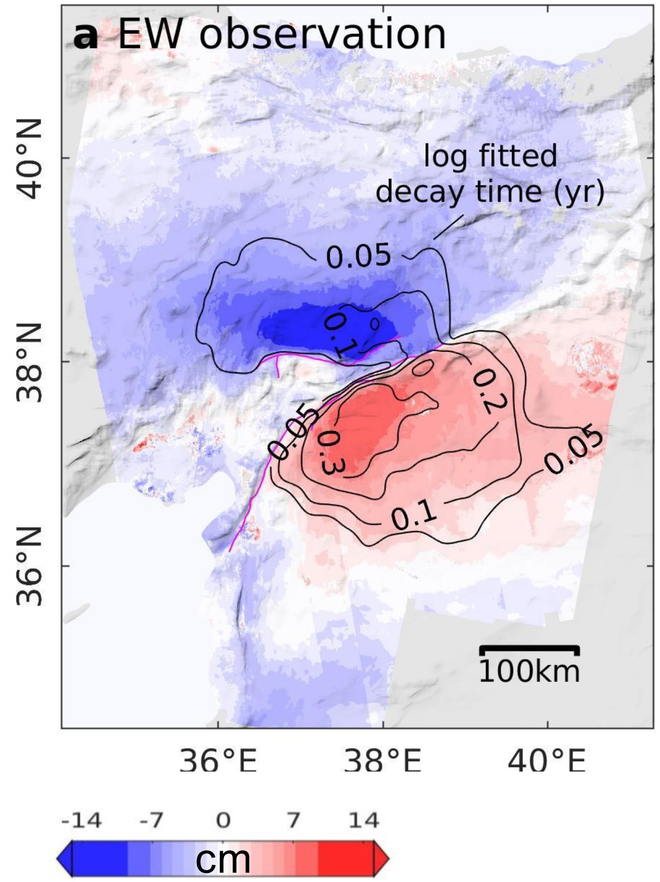
Interseismic

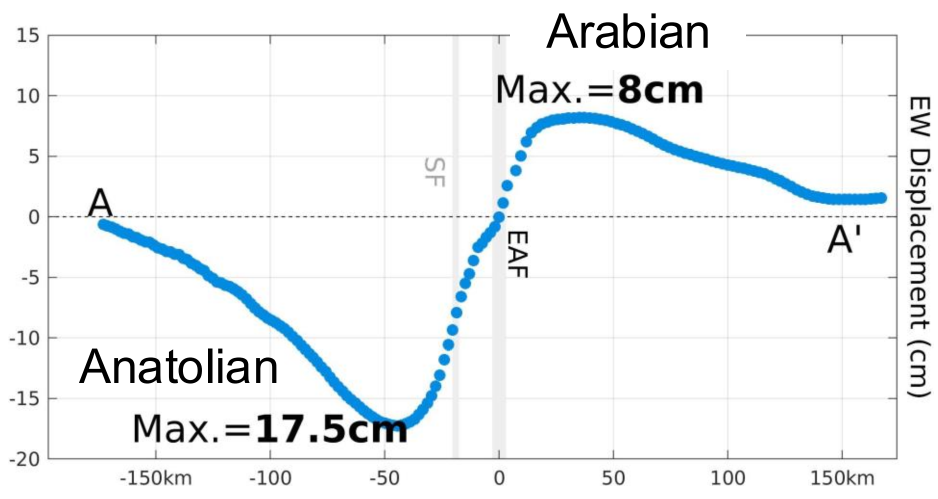


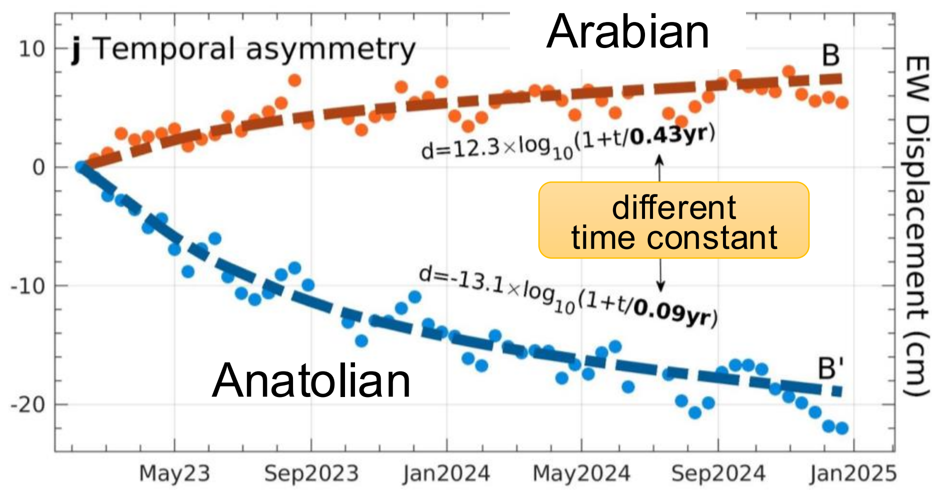
Time series of three-dimensional postseismic displacements
(Feb. 2023 – Dec. 2024, ~2yrs)



Time series of three-dimensional postseismic displacements







Viscoelastic relaxation

- Viscosity contrast results in different magnitude and dec behavior of deformation

Major process

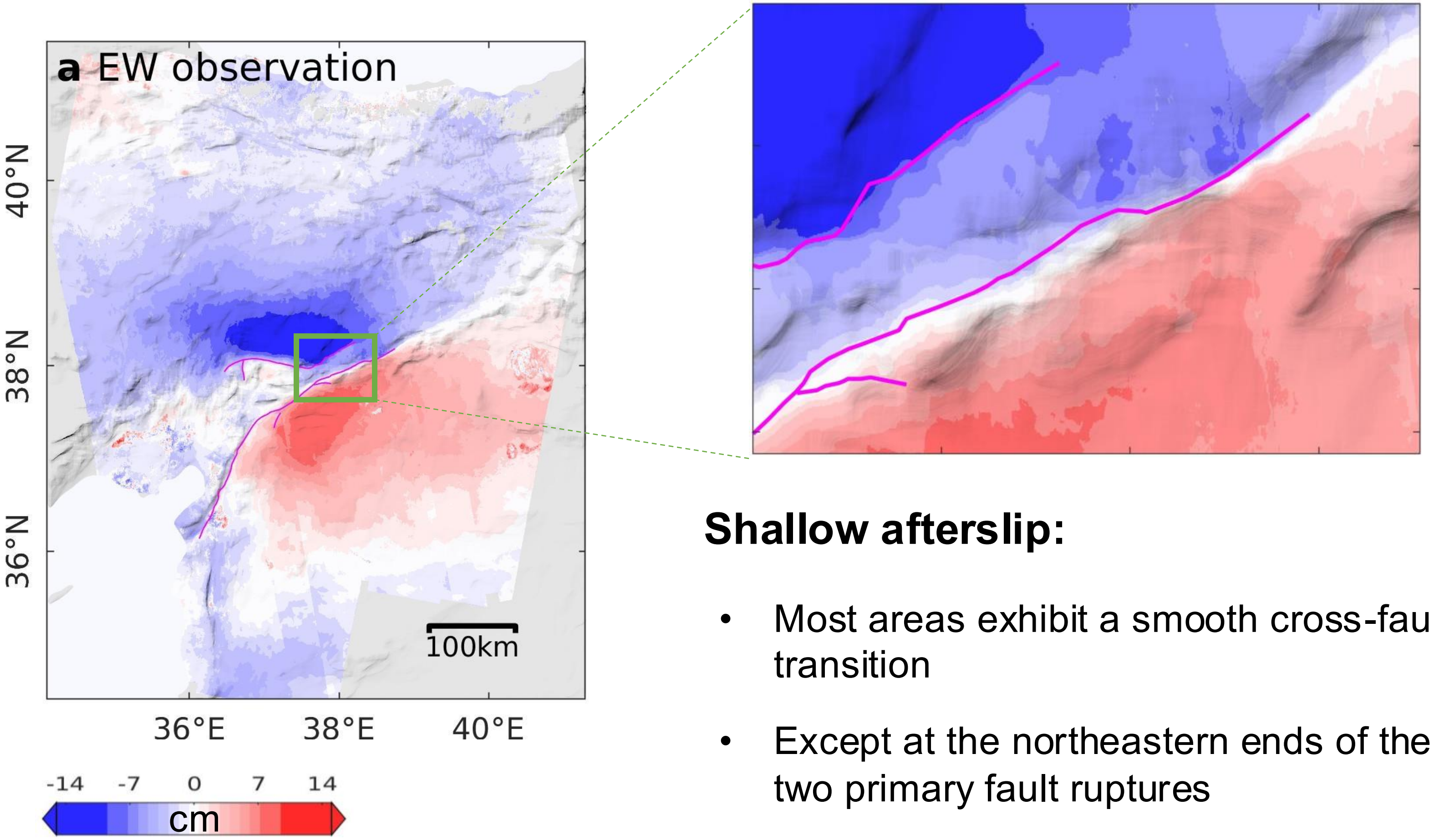
Spatial Asymmetry

Temporal Asymmetry

Afterslip on non-vertical faults?

- Elastic
- Deforming simutaneously on both sides
- Spatial but no temporal asymmetry

Time series of three-dimensional postseismic displacements



Shallow afterslip:

- Most areas exhibit a smooth cross-fault transition
- Except at the northeastern ends of the two primary fault ruptures
- **Negligible contribution from shallow afterslip**

Viscoelastic relaxation

- Viscosity contrast results in different magnitude and de[c]
behavior of deformation

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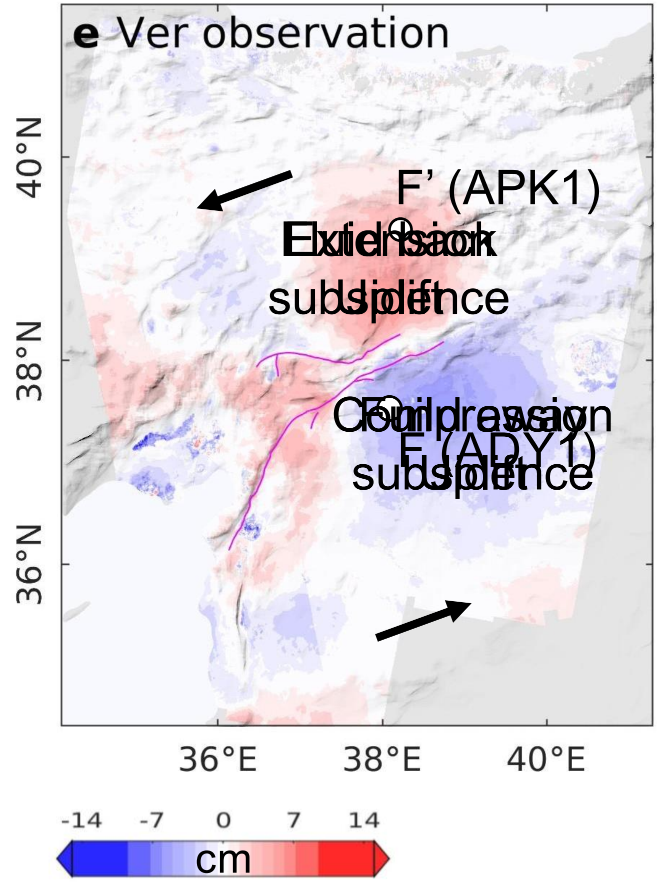
Time series of three-dimensional postseismic displacements



If the Vertical from afterslip:

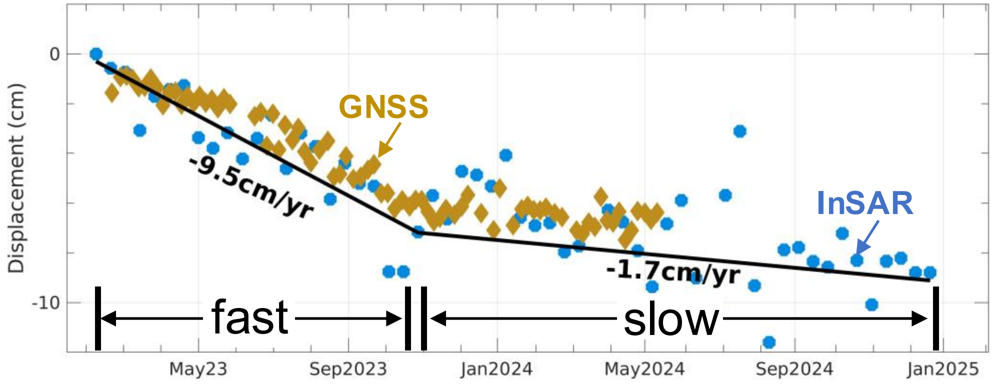
Left-lateral strike slip results in subsidence in NE, uplift in SE,

Opposite from the observations

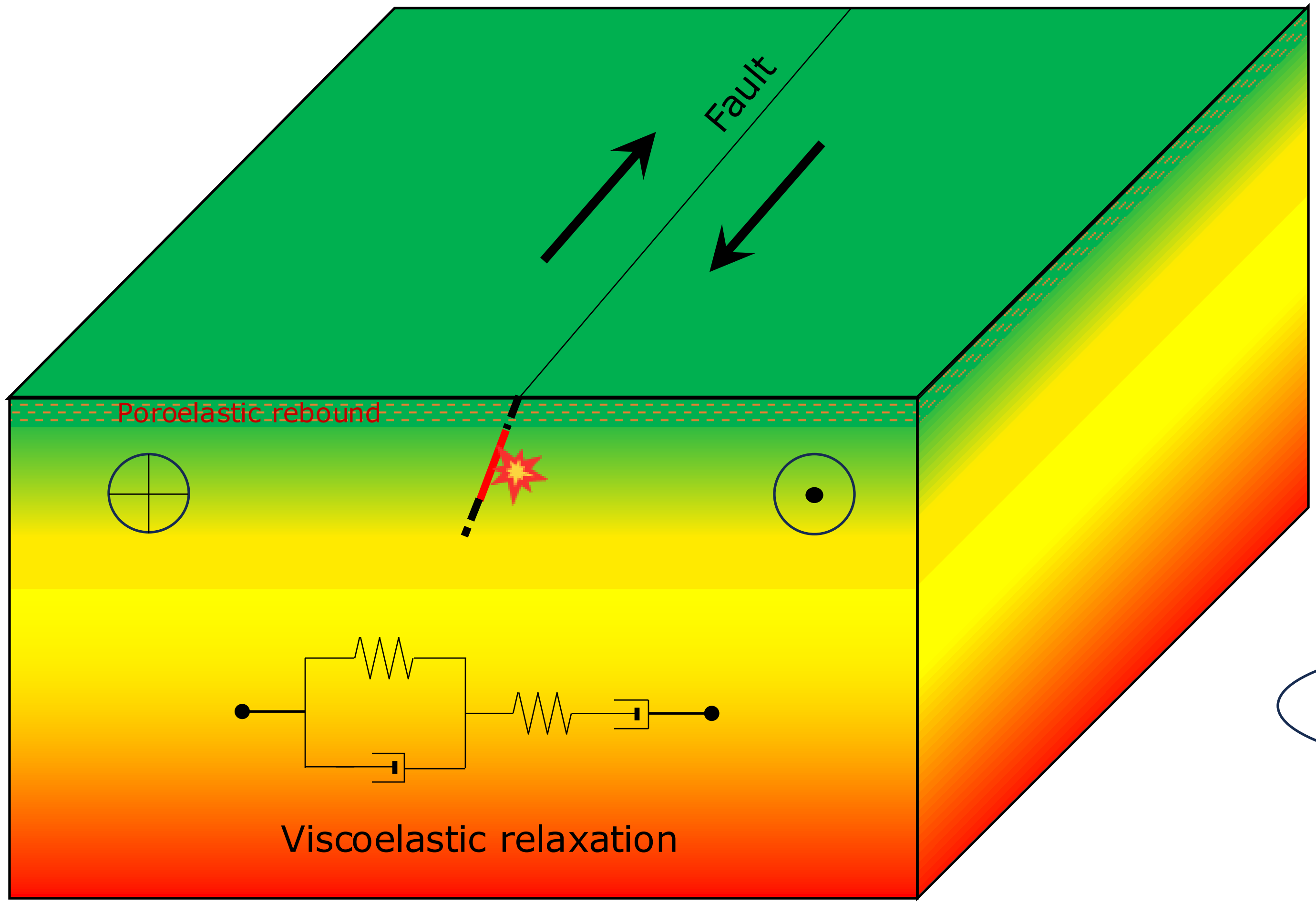
If the Vertical from poroelastic rebound:

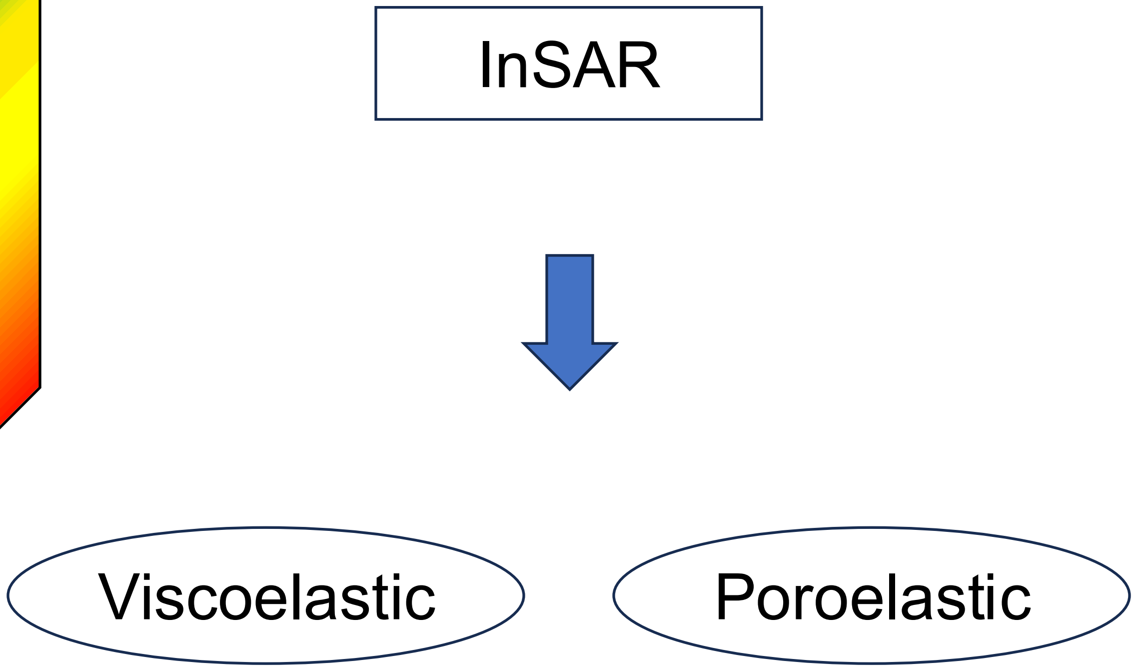
Left-lateral strike slip results in uplift in NE, subsidence in SE,

Align with the observations



Align with the faster post-earthquake fluid migration during the first several months

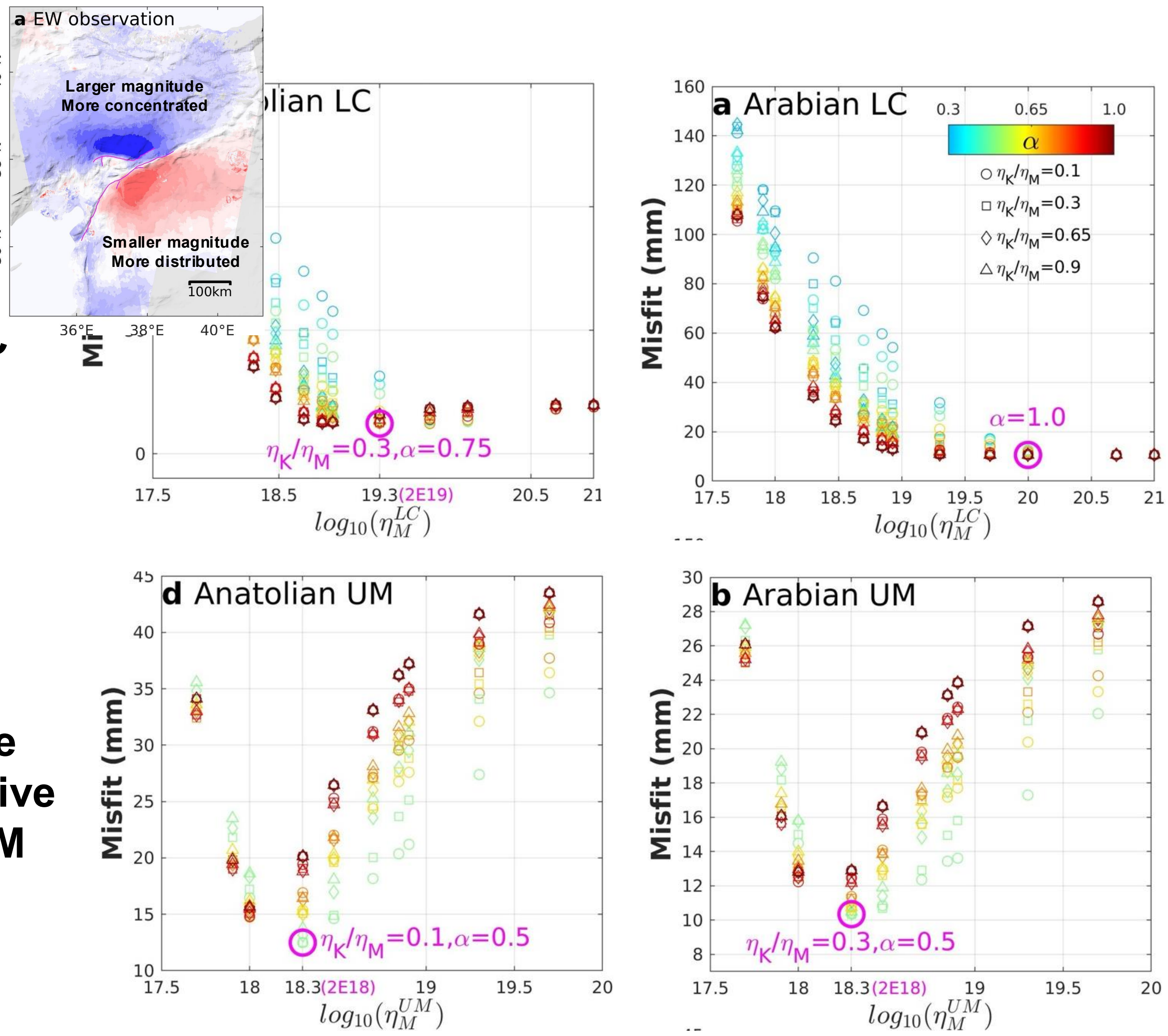

Fault
Poroelastic rebound
Viscoelastic relaxation

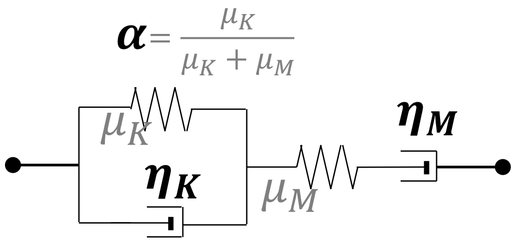

InSAR
Viscoelastic
Poroelastic

Viscoelastic modeling

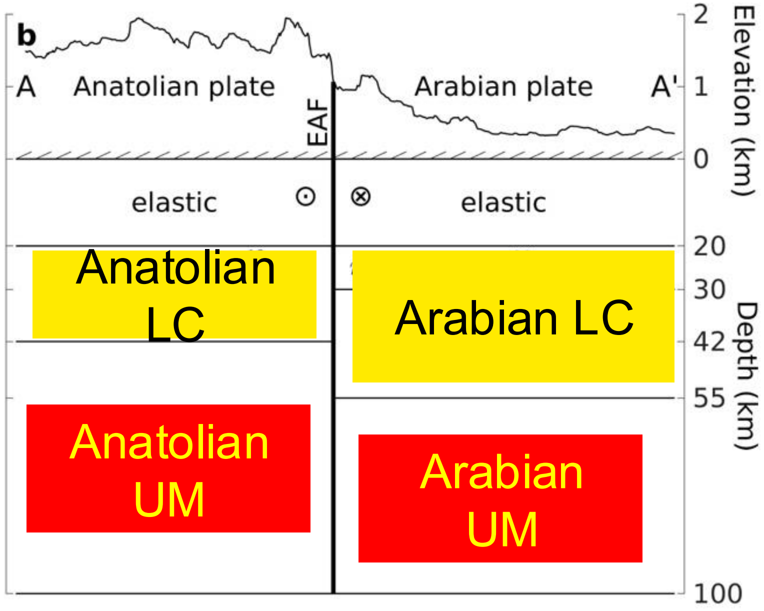
Less sensitive to LC

More sensitive to UM



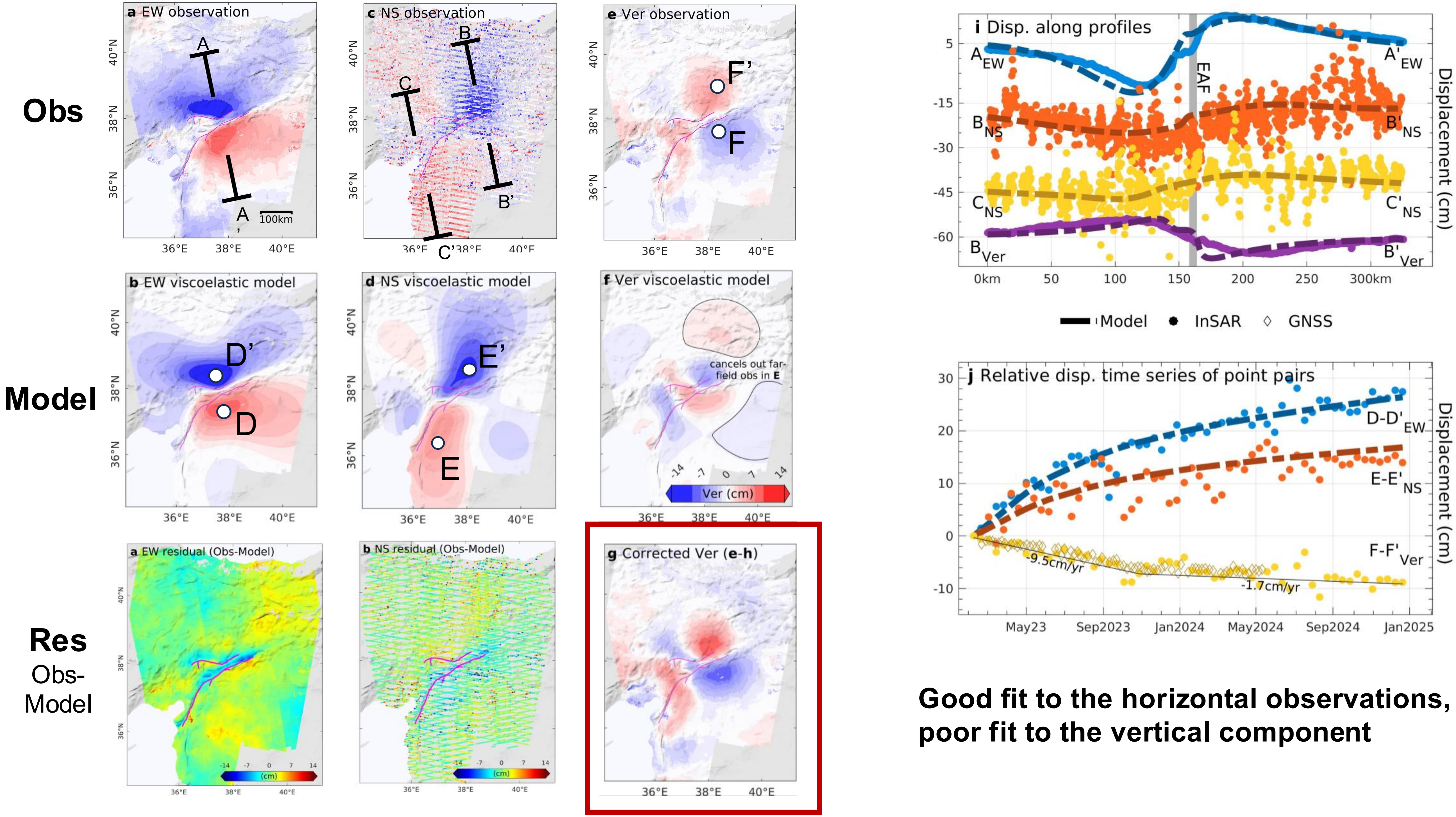


Burger body



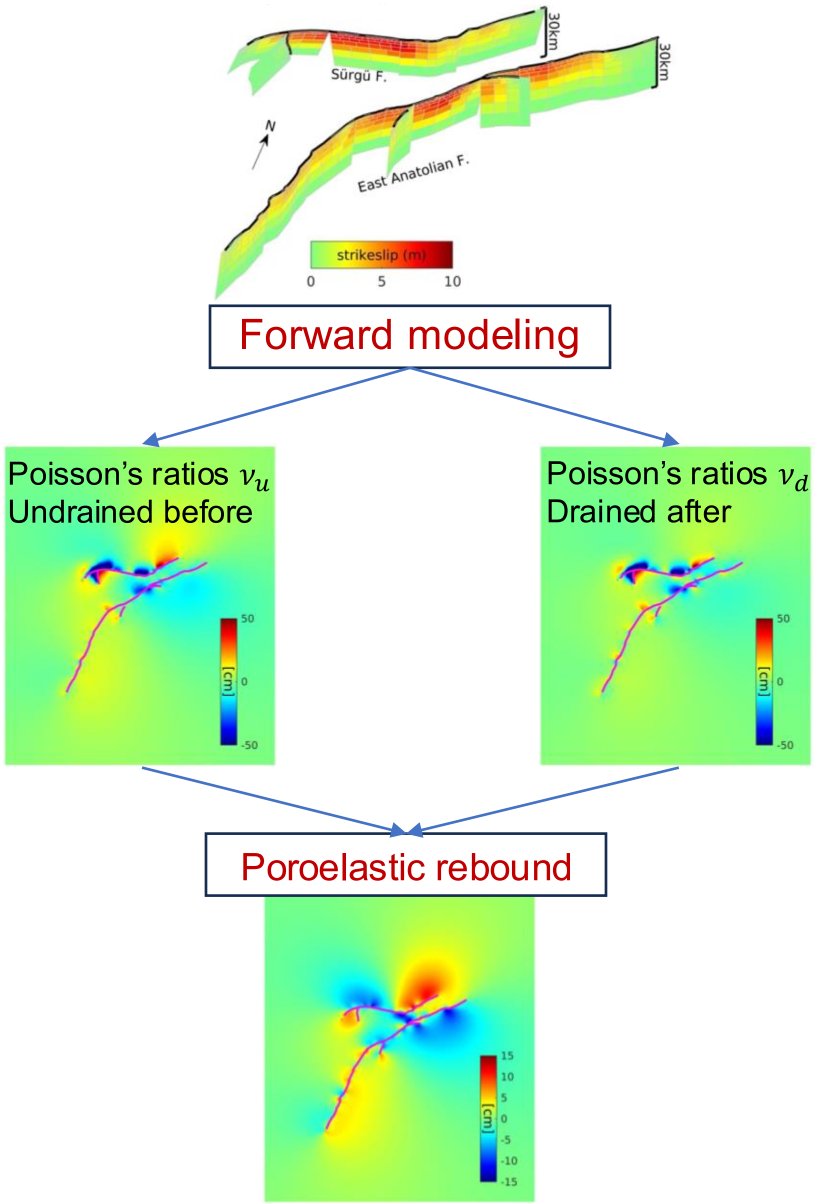
❖ **Asymmetric interplate structure and property**

Viscoelastic modeling

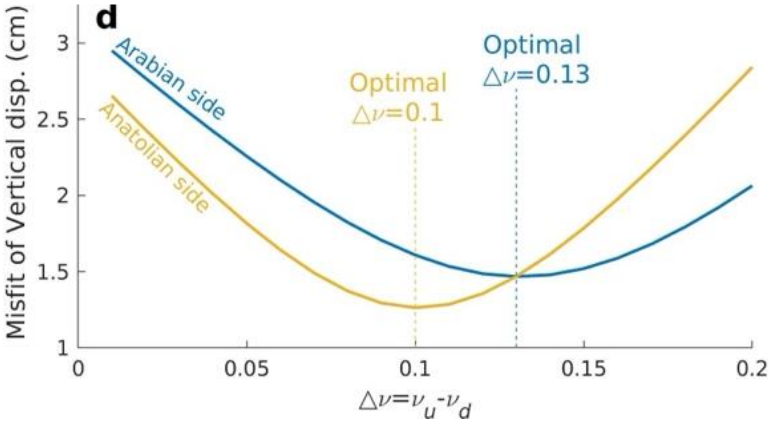


Good fit to the horizontal observations, but poor fit to the vertical component

Poroelastic rebound modeling



Fix ν_u=0.3, vary $\Delta\nu = \nu_u - \nu_d$ from 0.01-0.2, use grid search the get the optimal $\Delta\nu$ value



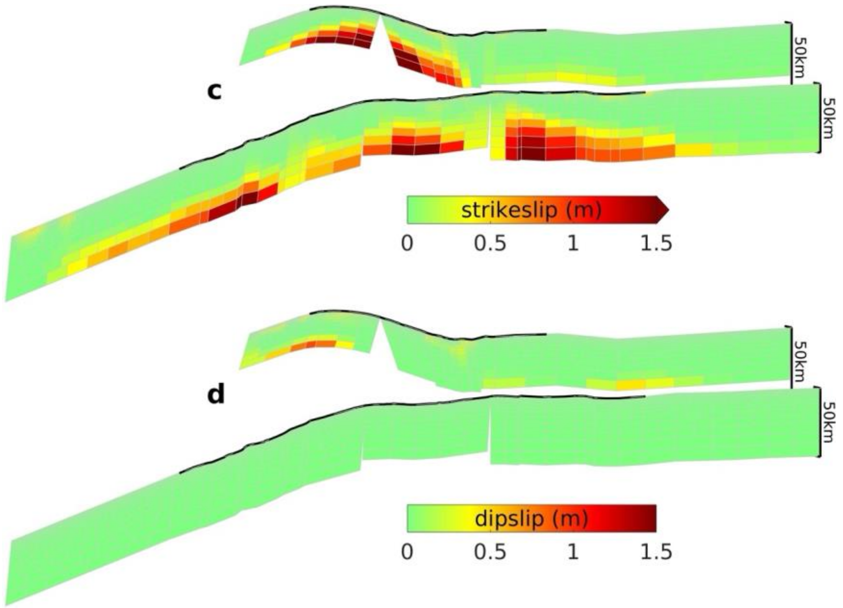
- ❖ Poisson's ratio change Δv as large as 0.1-0.13 rarely reported, typical values are ~0.05
- ❖ **Asymmetric and significant change of the interplate crustal material properties**

How about afterslip?

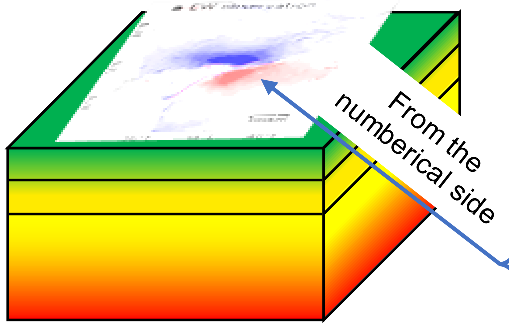
Afterslip and Viscoelastic relaxation modeling:

using a numerical underground model to fit the surface observations

Force afterslip model to fit the observation



This slip model is physically unreasonable with significant slip down to 50km depth



0km

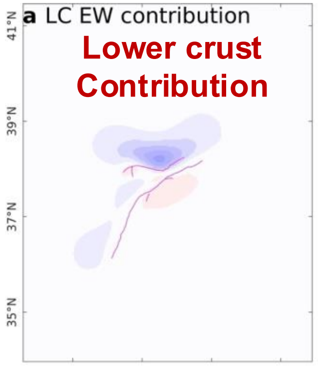
Upper crust: elastic, no obvious deformation in both models

20km

Lower crust: (visco-)elastic, contribute some deformation to the surface

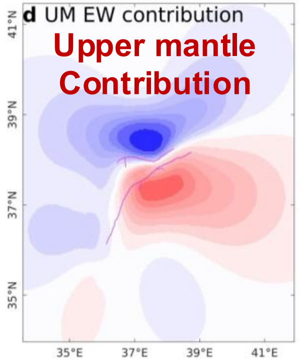
40km

Upper mantle: viscoelastic, contribute deformation to the surface



≪

far small



Viscoelastic

Major mechanism

Take-home messages

- **Full-dimensional** postseismic displacements reveals the spatial and **temporal** deformation asymmetry after the 2023 Turkey earthquakes
- The interplate rheological contrast (viscosity) are modelled across the EAF
- The viscoelastic relaxation and poroelastic rebound are two major processes after the earthquake, rather than the afterslip.

nature communications

Article https://doi.org/10.1038/s41467-026-69992-y

Interplate rheological contrast revealed by asymmetric deformation after the 2023 Kahramanmaraş earthquakes

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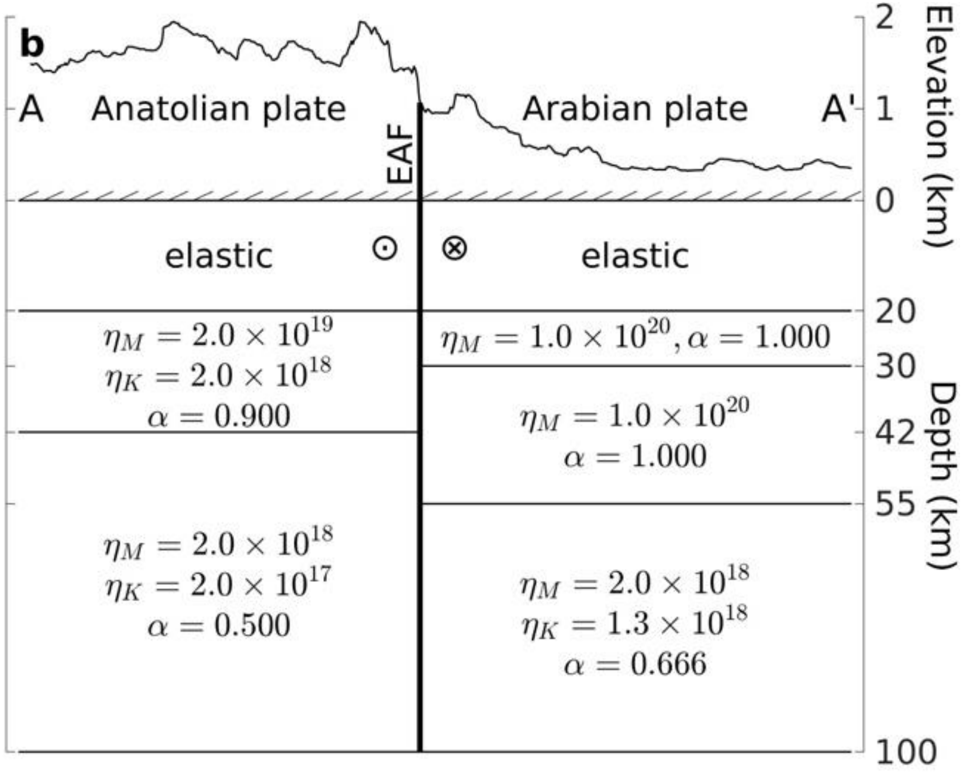
Jihong Liu[1], Sigurjón Jónsson[1], Xing Li[2], Wenqian Yao[3,4] & Yann Klinger[3]

Thanks for your time

Q & A

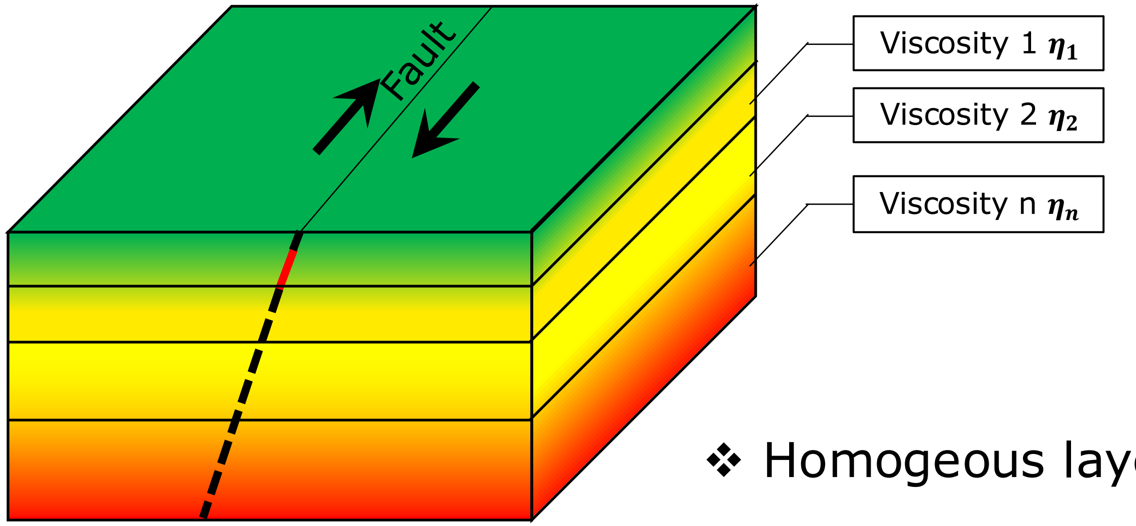
Viscoelastic modeling

Underground structure



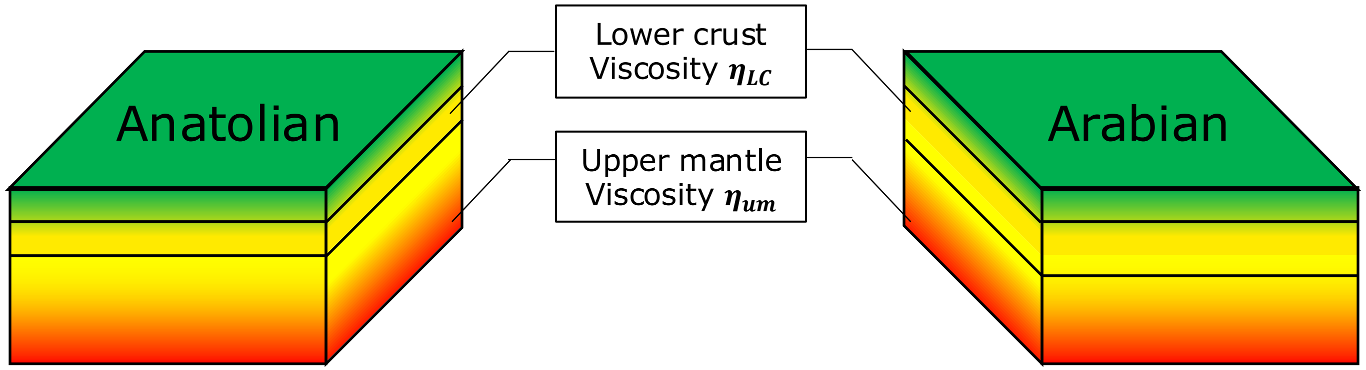
Determined based on seismic velocity

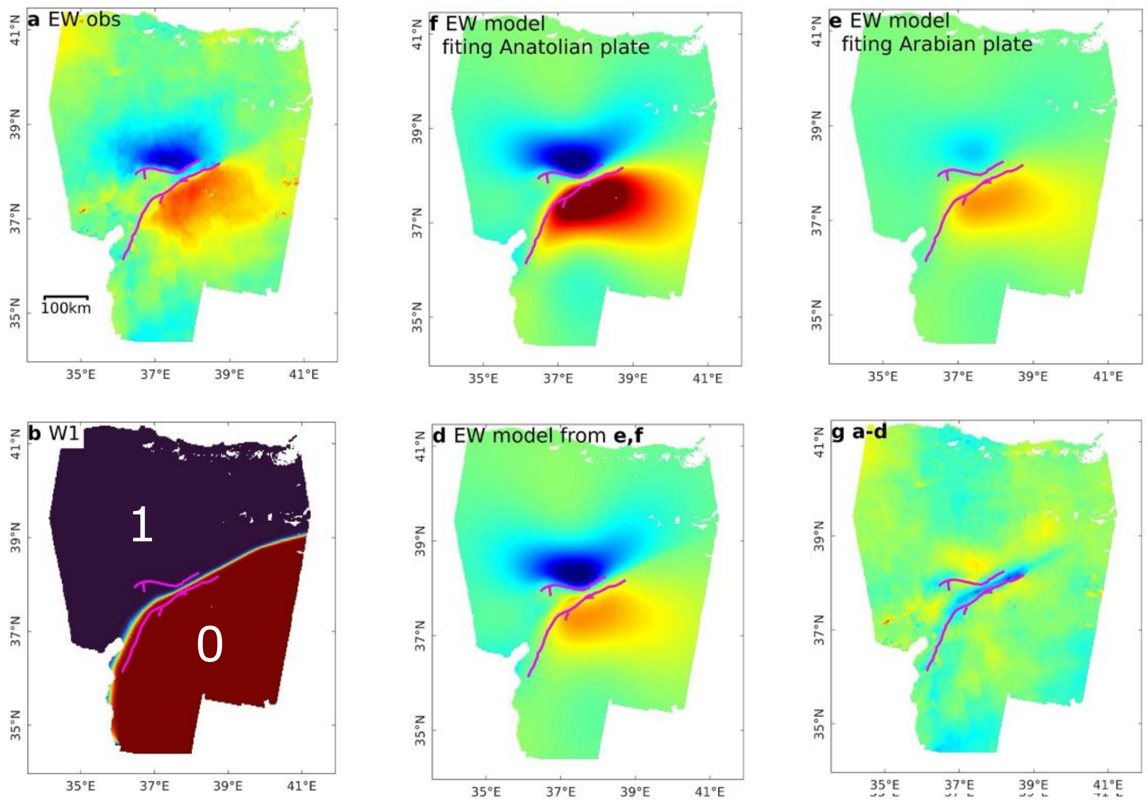
Software
GFZ PSGRN/PSCMP



- Homogeous layers
- **Unsuitable for heterogeneous structures**

Viscoelastic modeling



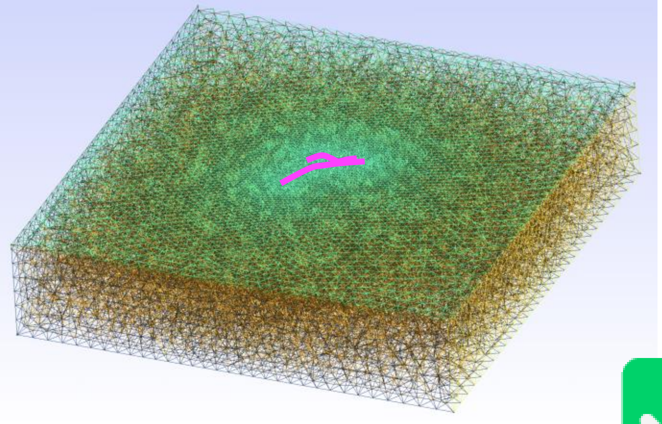


- Seperately determine the visvosity for both plates
- The optimal viscosity is obtained by the grid search method when misfit between observations and model predications is minimum on the target plate
- The viscoelastic flow under one plate will not affect the surface deformation on the other side

Validation by Finite Element Model

Viscoelastic modeling

- ➢ Construct mesh, 3-D heterogenous structure
- ➢ Using our best-fit viscosity values on both sides to get deformation predications
- ➢ Change parameters on one side to check the



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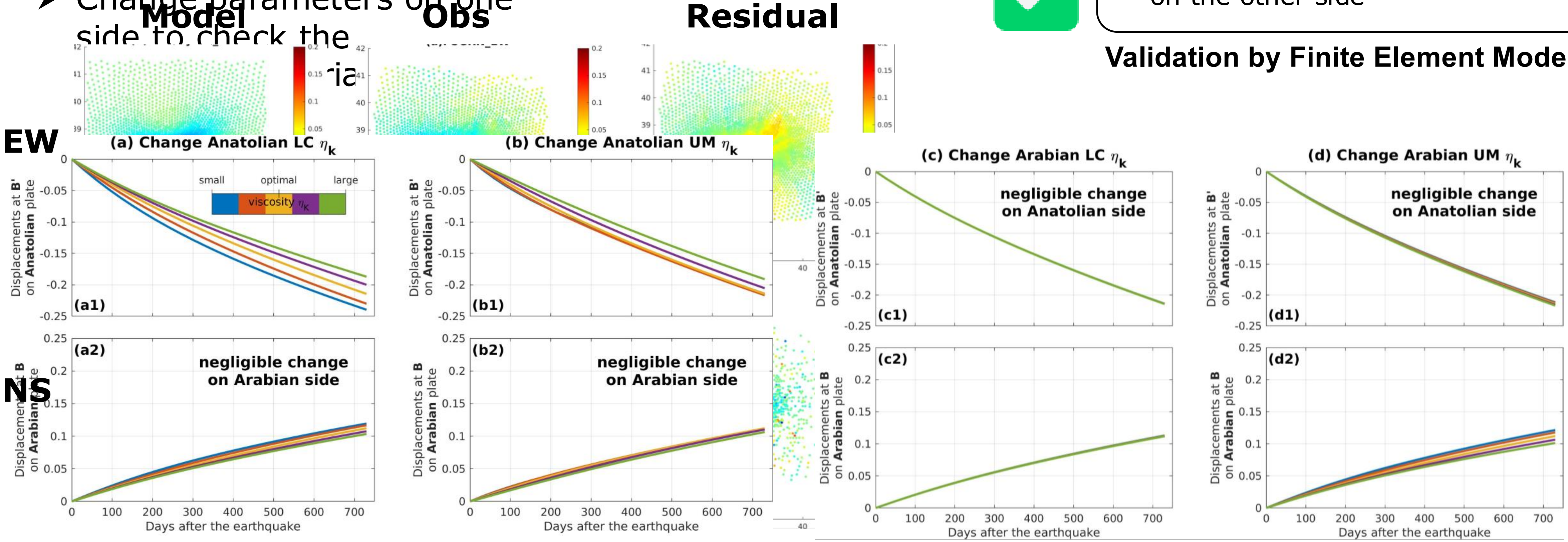
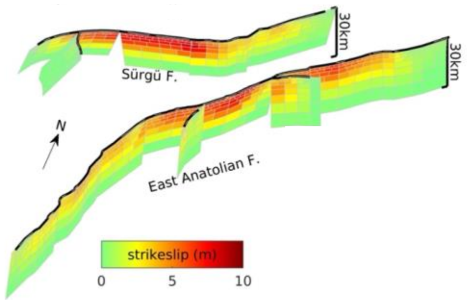
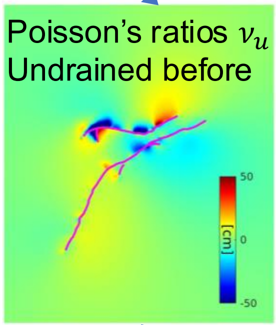
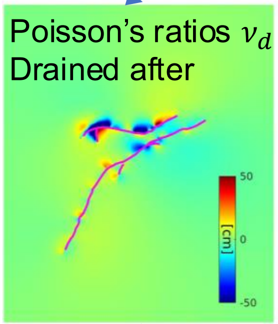


Poroelastic rebound modeling

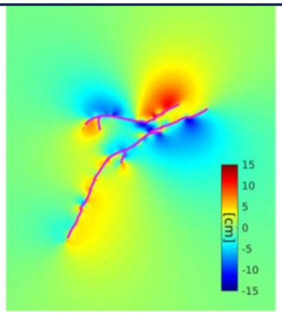


Forward modeling





Poroelastic rebound



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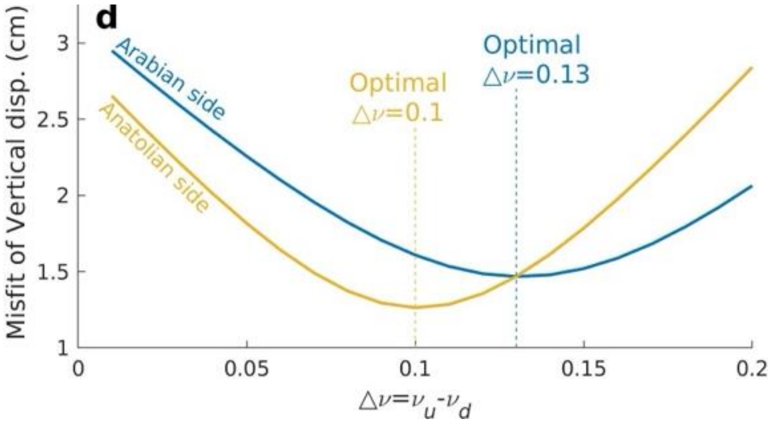

Different ν_u values DO NOT change the optimal $\Delta\nu$