

Slip-deficit estimation with a 3D fault model of the North Anatolian Fault by using InSAR time series

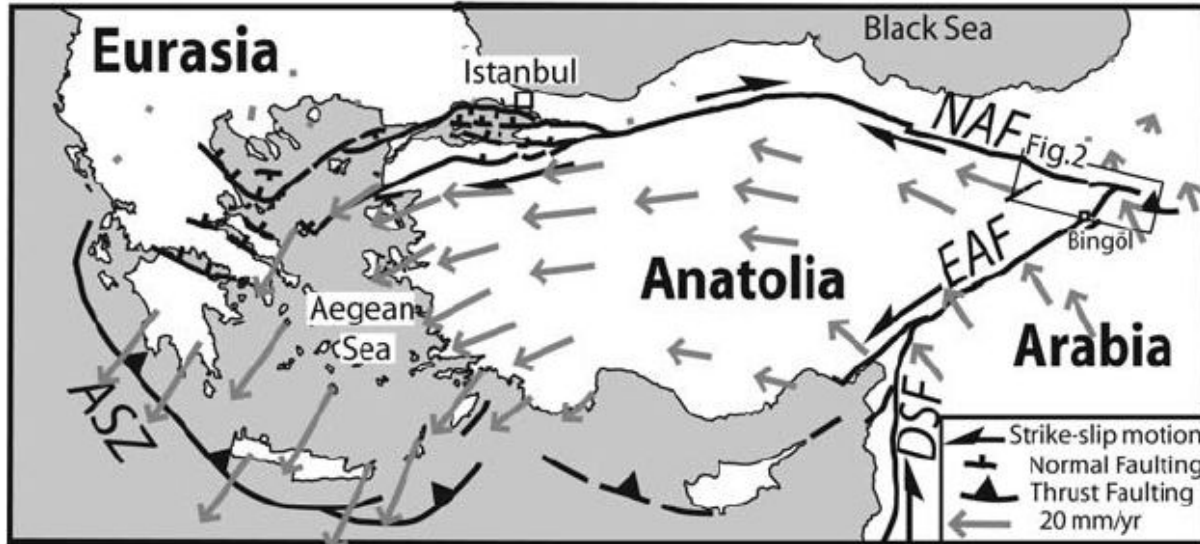


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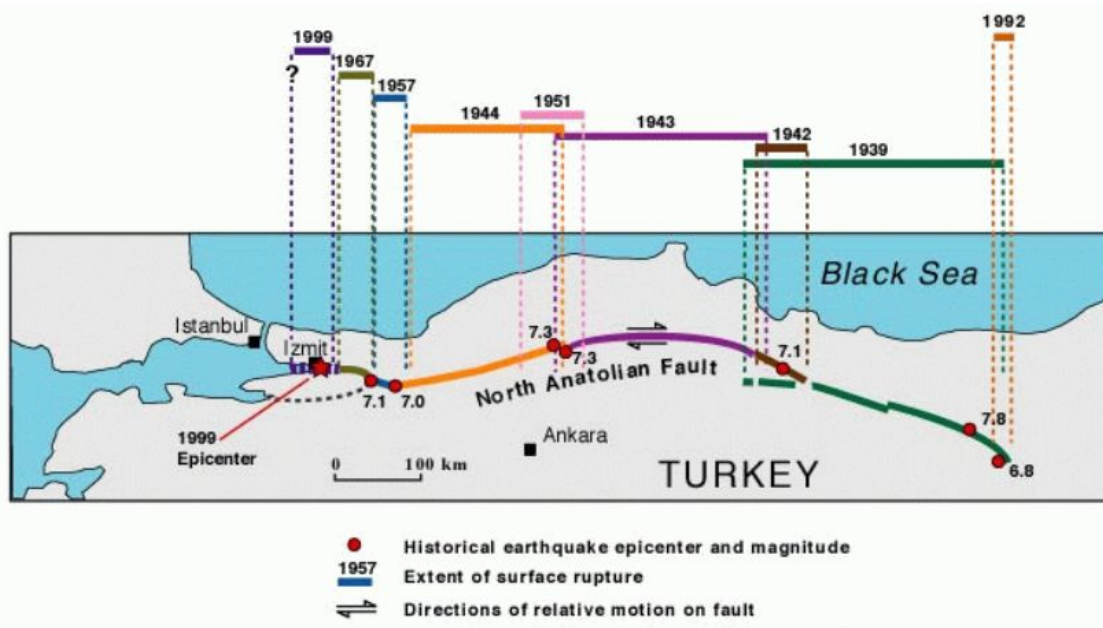
Study area: the North Anatolian Fault



Hubert-Ferrari et. al., 2009

- We study the North Anatolian Fault (NAF), a major right-lateral strike-slip fault zone in the north of Turkey.
- Here the Eurasian plate borders the Anatolian plate.

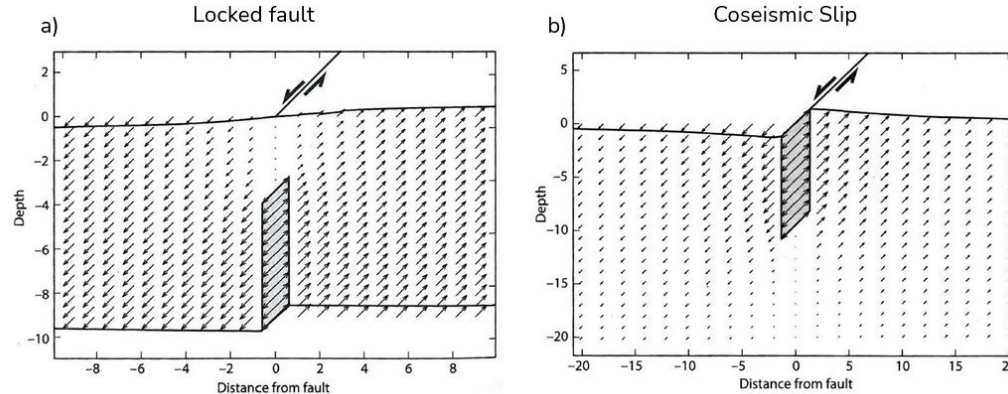
Past seismicity at the NAF



Saribiyik & Aydın, 2003

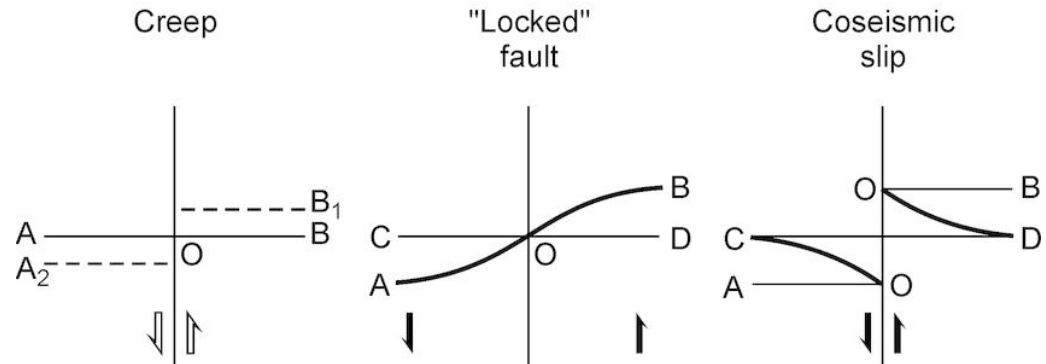
- The NAF has a history of high seismic activity.
- In the 20th century it experienced a series of progressive ruptures that started in the eastern part of the NAF and continued to wander westwards until the most recent big earthquakes of Izmit and Düzce in 1999.
- The potential strength and location of future earthquakes is dependant on the fault loading of fault segments.

Fault tectonics and surface displacement



Segall, 2011

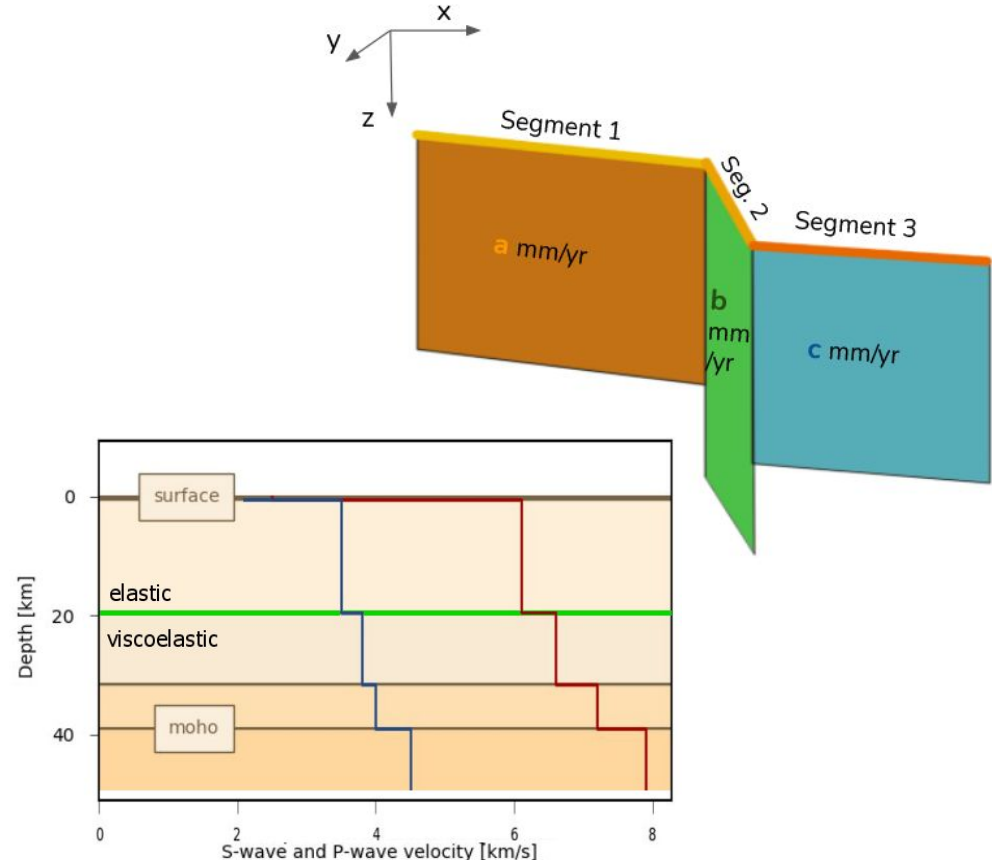
- Fault loading can be estimated, by studying surface displacement.
- During the coseismic phase, when an earthquake happens, the fault ruptures and there is displacement along the fault, as the stress releases.



San'kov et. al, 2013

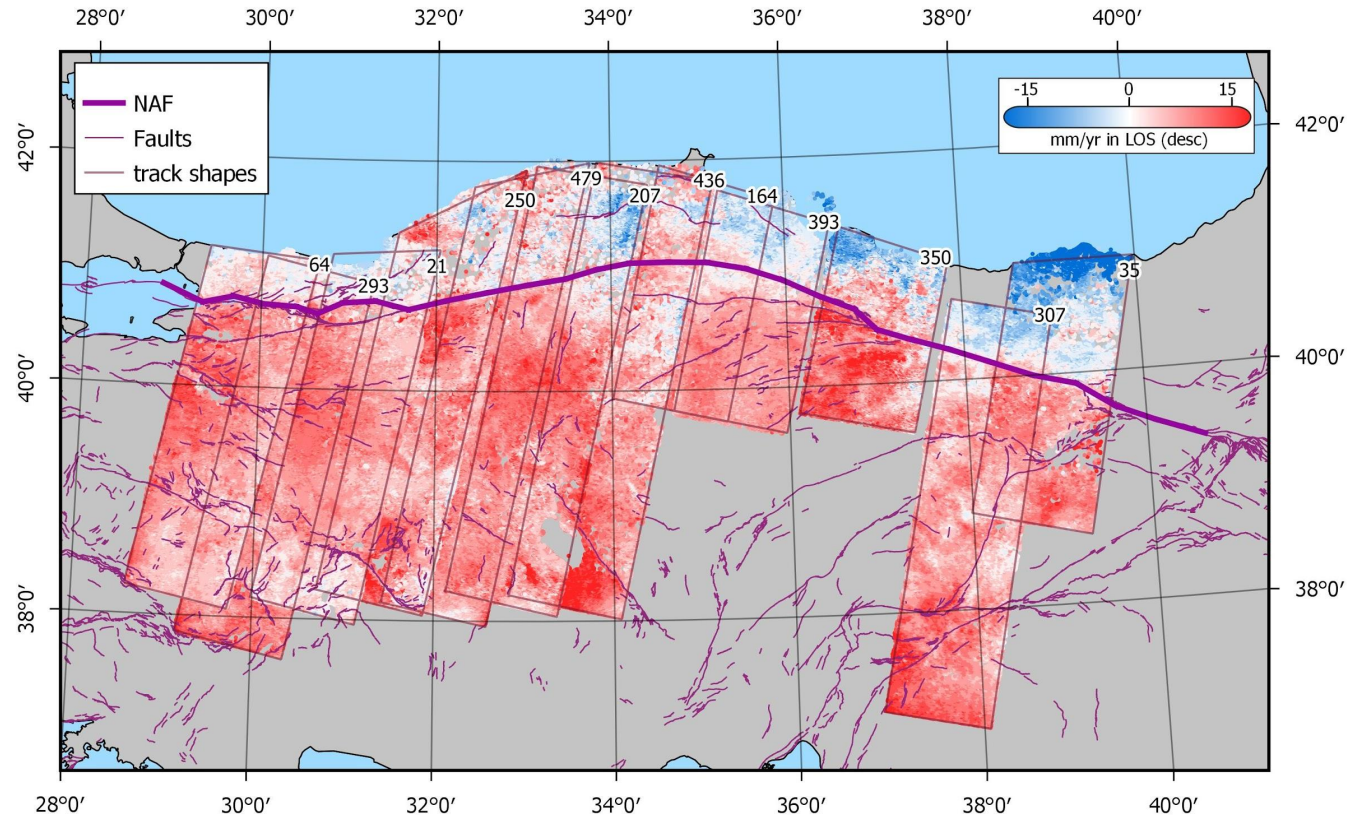
Objective

- Time series of space-borne interferometric Synthetic Aperture Radar (InSAR) data can be used to measure surface displacement, which corresponds to crustal deformation.
- We aim to study the fault loading of the NAF, by optimizing for **slip deficit** and **locking depth** along the fault, using InSAR time series data.
- The fault is represented by several planar rectangular sources and the medium model is a **viscoelastic layered half space** model.
- The result is a **3D-model** of the distribution of slip rates and locking depths along the NAF.



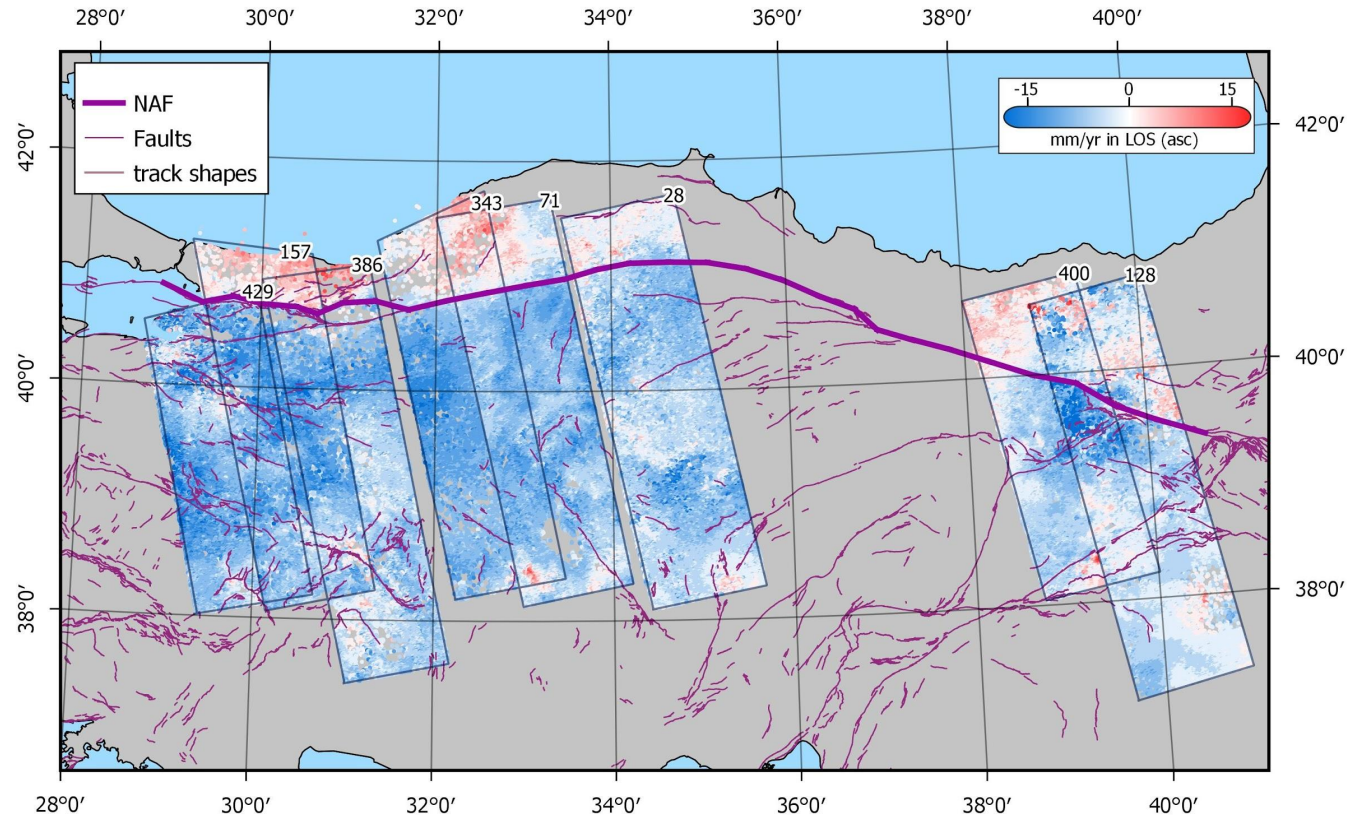
InSAR time series displacement data - descending tracks

- With courtesy of E. Hussain (COMET), we have 12 descending and 8 ascending tracks of InSAR time series data.
- The SAR data was recorded by ESA's Envisat satellite between 2002 and 2010.
- The descending tracks cover the entire fault, while in the ascending tracks, there is a gap between 35° and 38° with no ascending data.

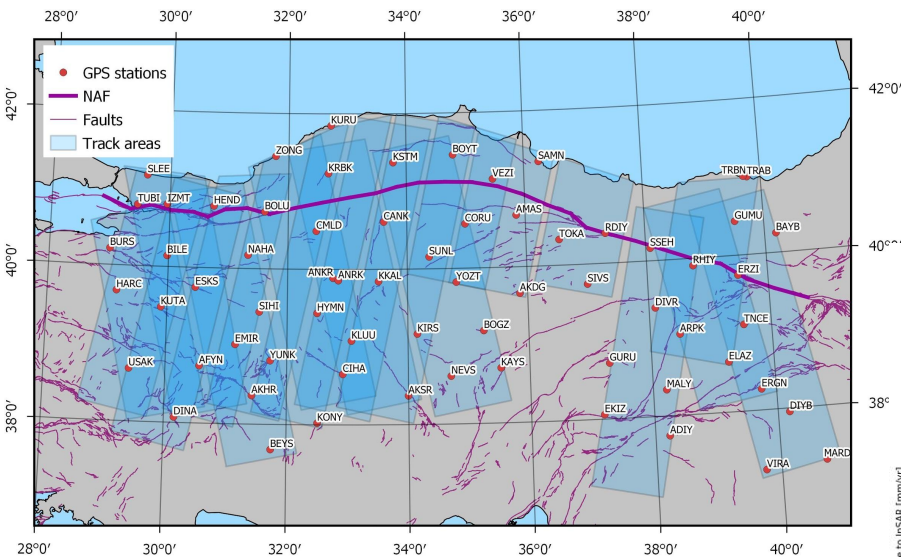


InSAR time series displacement data - ascending tracks

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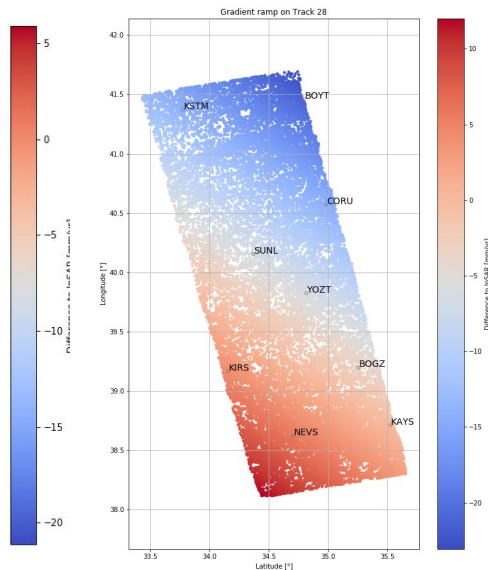
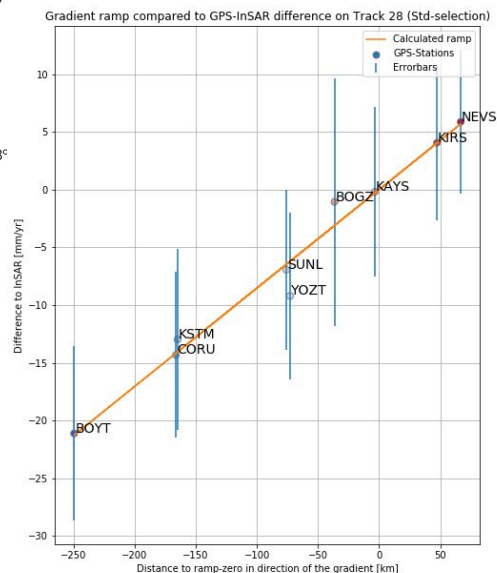


Processing - Detrending with GPS

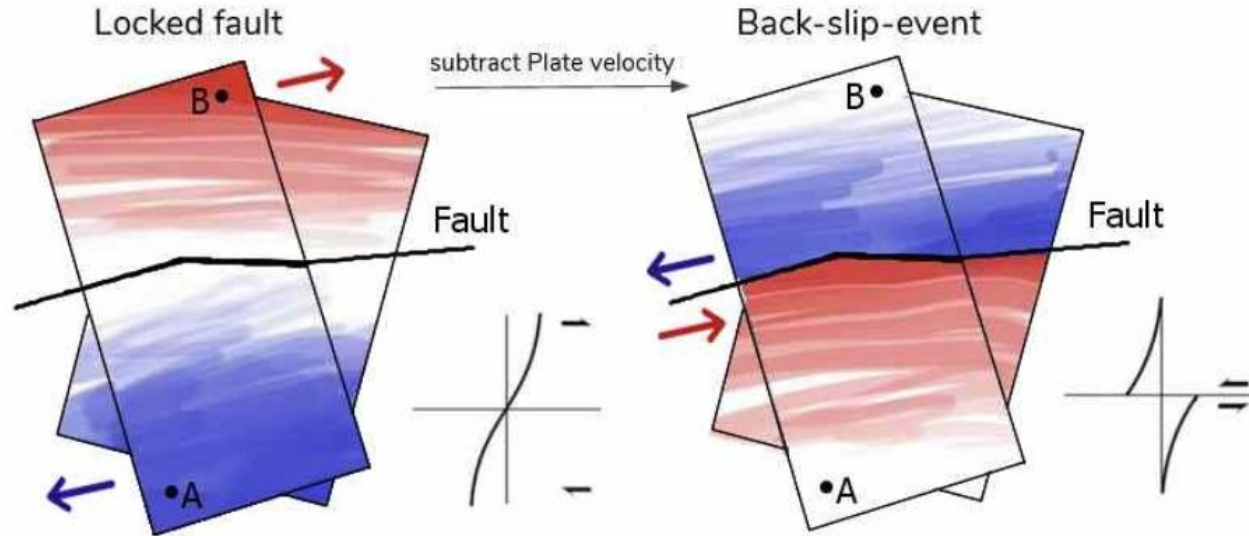


- We obtained the GPS velocities from the *Nevada Geodetic Laboratory GPS-Network*.
- But: some tracks have few stations so there is susceptibility to uncertainties of single stations.

- We used GPS station based velocities to detrend the data tracks by calculating the difference and removing the ramps from the tracks.
- This also brings all tracks into an Eurasia-fixed reference system.



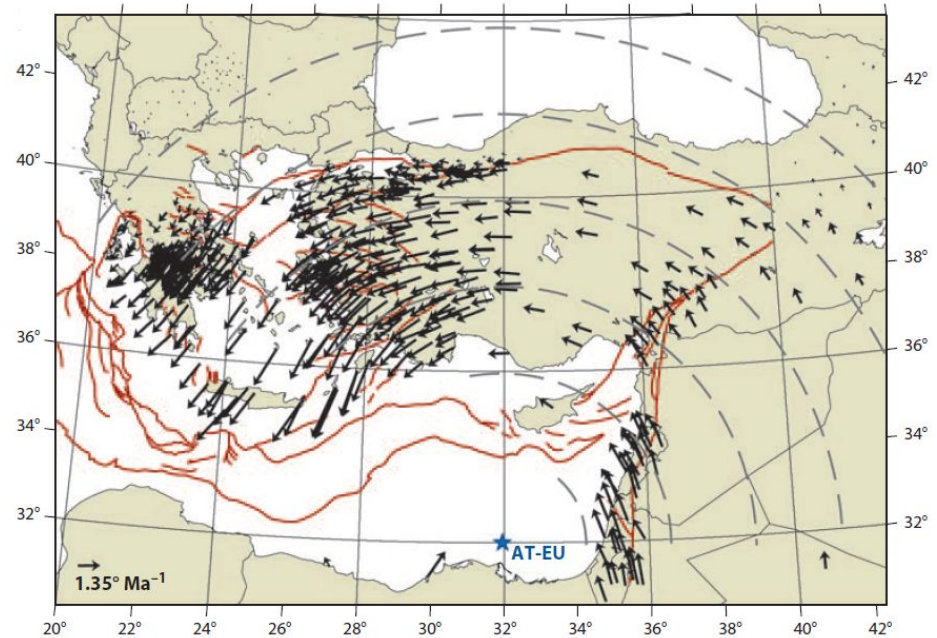
Back-slip approach - 2D



- To estimate the slip-deficit, we use a **back-slip approach**.
- We subtract the plate velocity (velocities at points A and B are assumed to be plate velocities here) from all data points on the respective plate, to simulate a back-slip event.
- The slip (back-slip) of this event then can be optimized for.
- This back-slip represents the **slip-deficit**.

Spatial variation of plate velocity - using an Euler pole

- Since our 3D model covers such a large area along the entire fault, the spatial variation of plate velocity across the plate becomes relevant.
- For a back-slip approach, we can not assume one plate velocity for all data tracks on the entire plate, but have to regard the spatial variation across the plate.
- For this, we use an **Euler pole**, estimated by Le Pichon and Kreemer in 2010 for the Anatolia-Eurasia system, and calculate a different plate velocity for every single data point.
- We then subtract this velocity from the data to simulate the back-slip event.

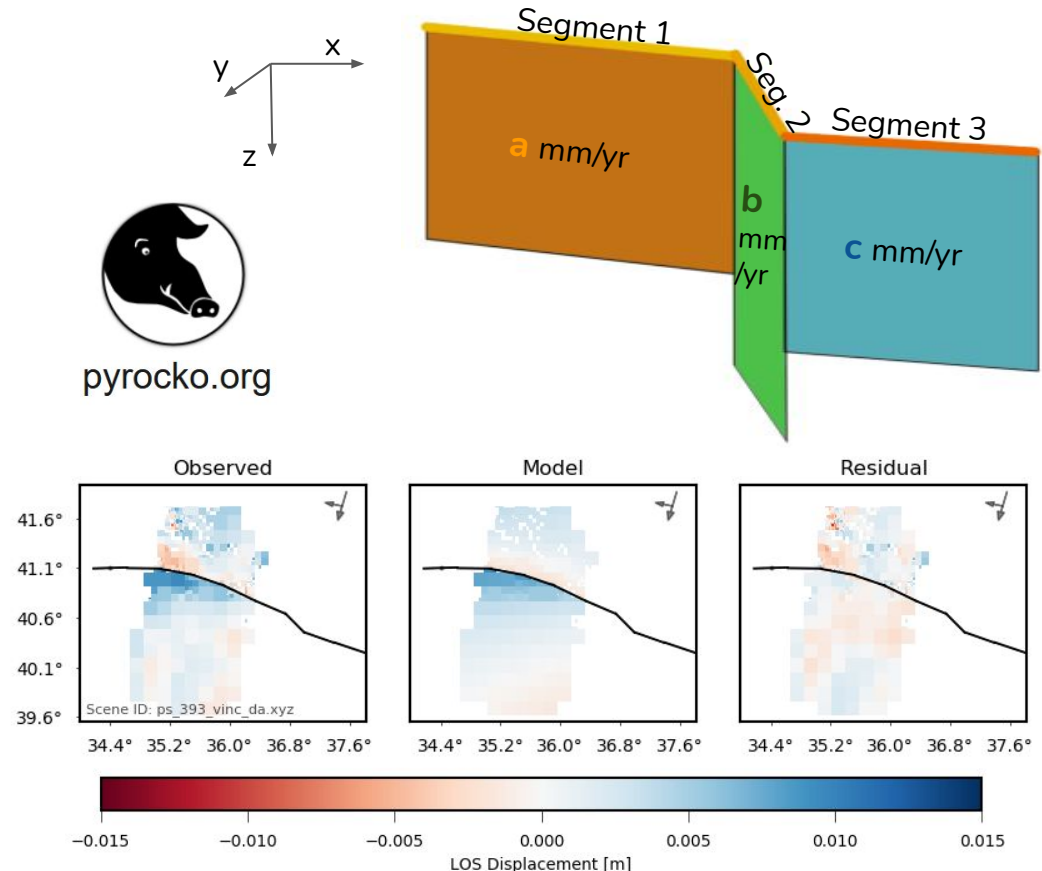


Le Pichon & Kreemer, 2010

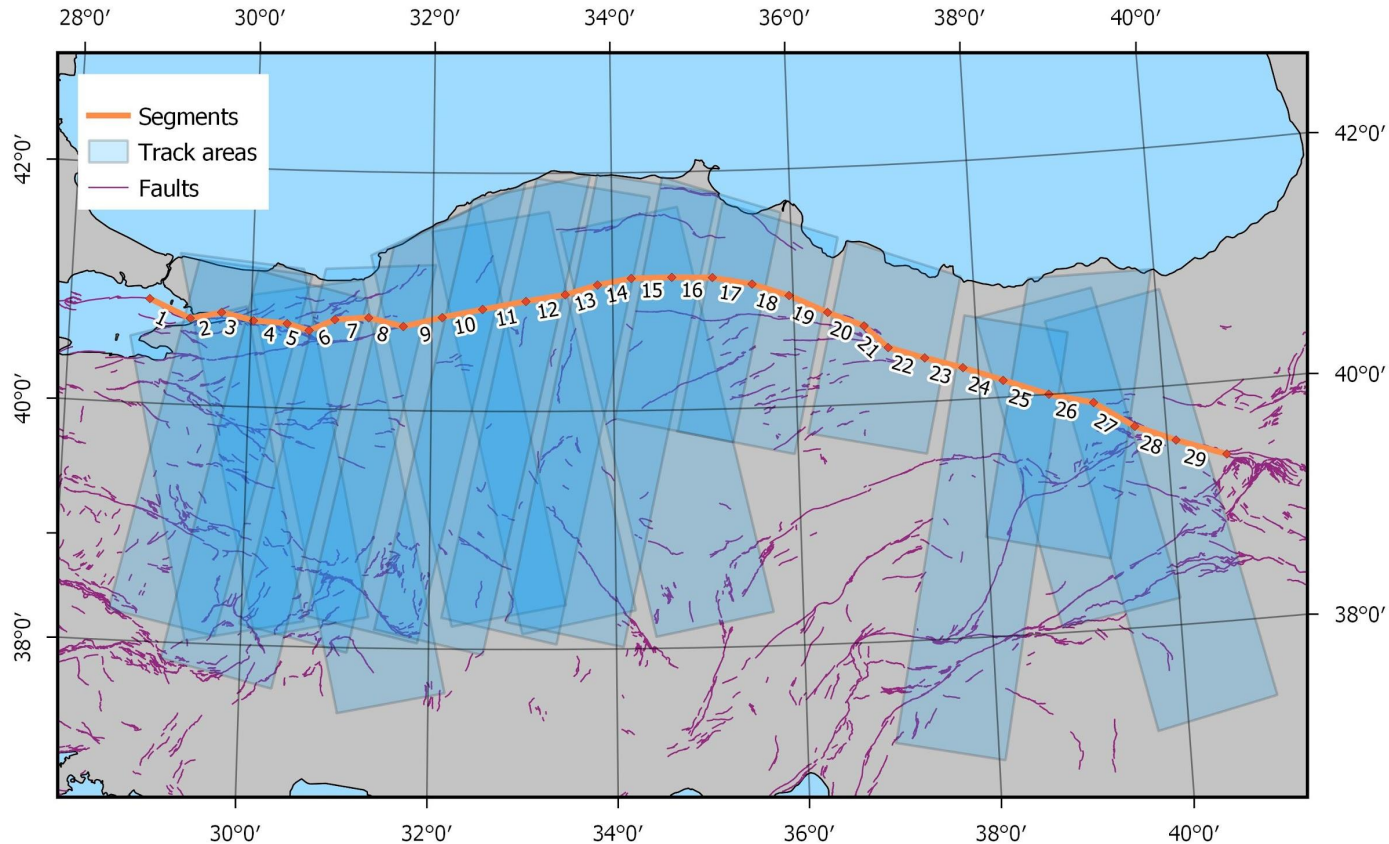
Eurasia-Anatolia Euler pole:

Latitude:	32.02°
Longitude:	31.96°
Rate:	1.307 °/Ma

- We optimize the data of the simulated back-slip event with a direct search algorithm and account for noise through geostatistics.
- The fault is represented by 29 rectangular planar source segments for which each a locking depth and a back-slip (slip-deficit) is optimized.
- The fault geometry is assumed to be right-lateral strike slip for all segments.
- To perform the optimization, we use the open source software tool **grond** from the **pyrocko** project.

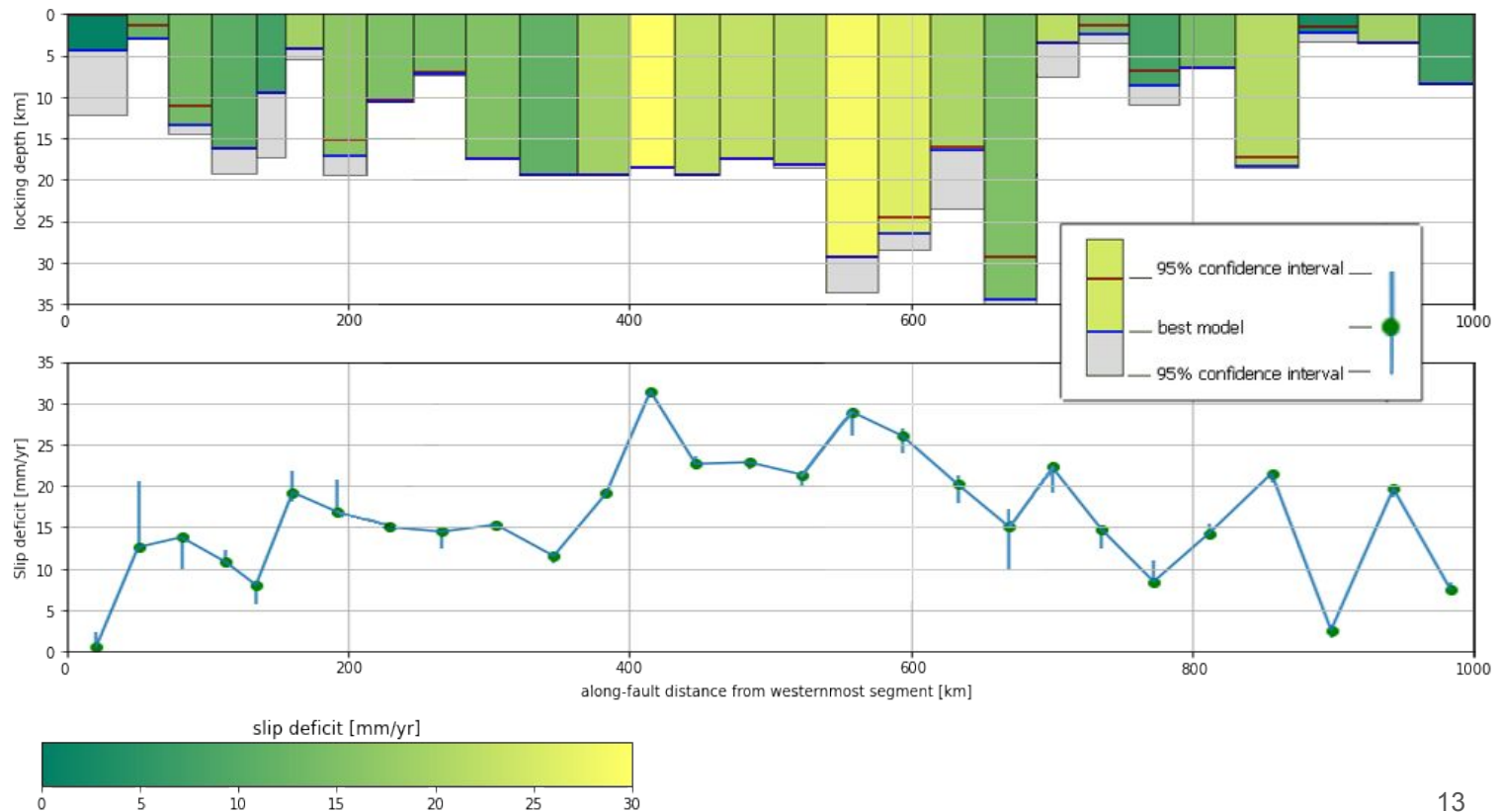


Representation of the fault with planar segments



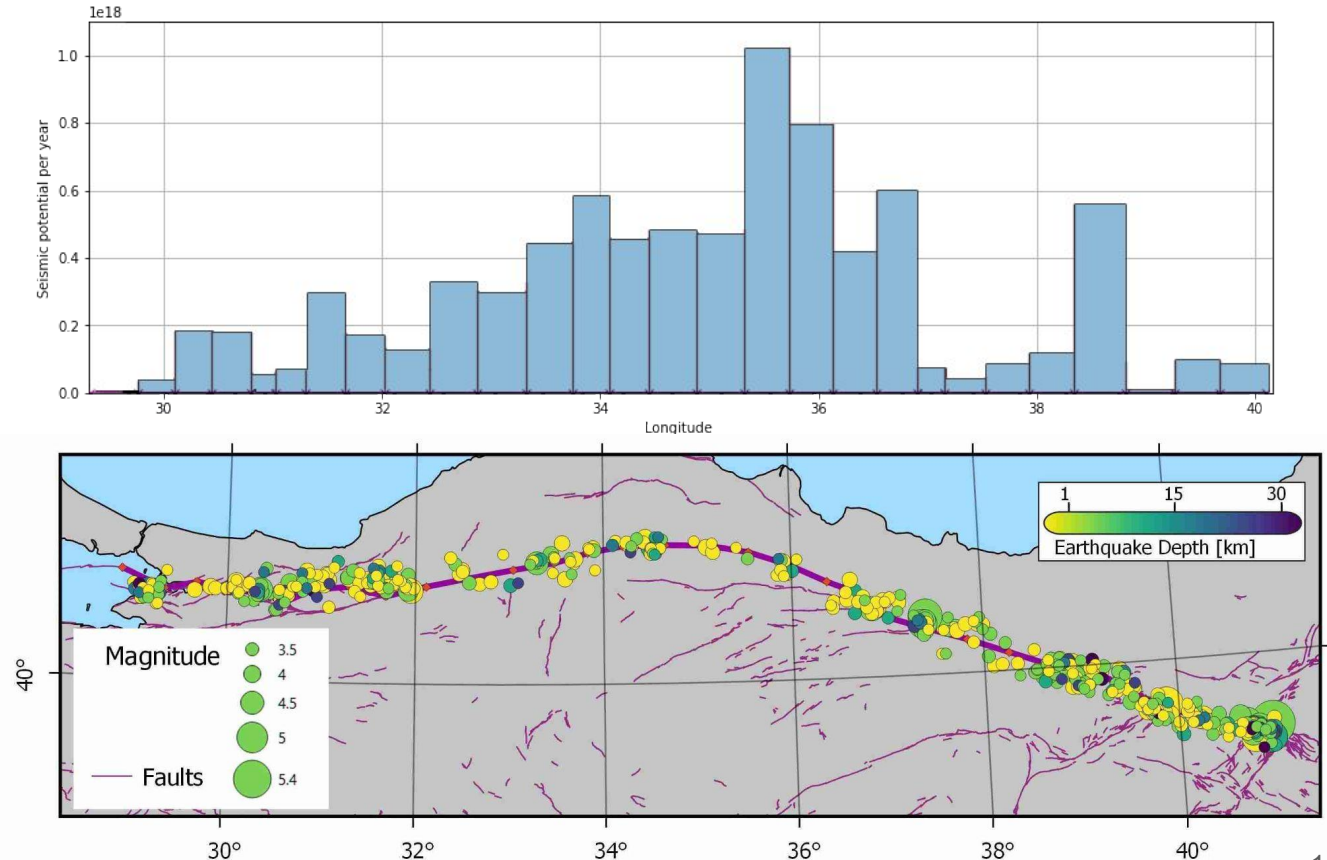
Preliminary Results

- The results show high locking depths and slip-deficits in the central parts of the NAF.
- The eastern and western parts show lower seismic potentials.



Seismic potential and Earthquakes during the observation period

- We estimated the seismic potential per year, that builds up at each segment, from the slip deficits and locking depths.
- A comparison with all major earthquakes (from the European- Mediterranean Seismological Centre) that happened along the fault from 2002 to 2010 confirms little stress release in the central segments.
- Meanwhile, earthquakes occurred in the eastern and western segments more frequently and in bigger magnitude.



- Data coverage: The spatial data coverage is poor in some areas and some tracks are influenced by noise.
- GPS-Stations: Some tracks cover only a few stations, here the overall trend of ramps are very susceptible to errors from single stations. There are also additional small scale trends that originate in the way the Eurasia-based reference system for the stations is calculated.
- Assumed plate velocity: The Euler pole predicted idealistic plate velocity does not represent the measured plate velocity well everywhere.
- Depth sensitivity: Locking depth estimates often reach the given upper limit, however this seems to have only a small influence on the slip deficit. This makes the locking depth and derived seismic potentials less certain than slip deficit estimates.

[illegible]

Conclusion

Achievements

- We created the first 3D-model of the NAF accounting for varying slip rates and locking depths, utilizing with InSAR-time-series data in a viscoelastic layered half space model.
- The observed trends are in overall agreement to earlier studies.
- The distribution of derived seismic potential is also in agreement to the seismic events in the observation period.

Potential issues and improvements:

- There are long-wavelength trends in the InSAR data and/or deformation off the NAF main fault branch that may cause biases.
- The poor spatial coverage in some areas makes the results for segments in these areas unreliable.
- Our model does not account for potential segmentation along depth direction and we generally have a low sensitivity for locking depths.

The quality of the results could greatly benefit from data with higher spatial and temporal resolution, possibly such as time series of the newer Sentinel 1 mission SAR data.

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