Eurasia's Deformation as a Consequence of Plate-Scale Forces: a Model Study

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MOTIVATION

The motivation of our work is to predict present-day lithospheric deformation of the Eurasian plate by integrating plate-scale forces in mechanical equilibrium and estimates of lithospheric rheology.

INPUTS: FORCES and RHEOLOGY

We use mechanically balanced models based on plate interaction (Fig. 1) (continental collision, plate boundary friction at transform faults and subduction contacts, and slab roll-back forces), lithospheric body forces (from lateral variations in topography and density structure) (Fig. 2) and convective tractions including dynamic topography. These forces satisfy the torque balance constraint, drive Eurasia in the observed direction of absolute motion and fit observed horizontal stress directions to first order. Boundary forces and lithospheric body forces have larger imprint on Eurasia forcing than mantle tractions.

Following Tesauro et al. (2012) we assume five different lithospheric compositions, using their geotherms and crustal thicknesses to estimate depth-dependent rheological profiles, making use of the stress field to compute vertically averaged viscosity of each element of the model (Fig. 3).This map gives a large mismatch in some areas of the model (Western Tibetn Plateau and Aegean). Given the integration times of 100-500yr, large part of the plate presents elastic behavior (high viscosity) meanwhile a small fraction has viscous flow. Therefore, a weak zone of viscous flow in steady state surrounded by elastic material is a consistent representation of the viscosity structure of Eurasia.

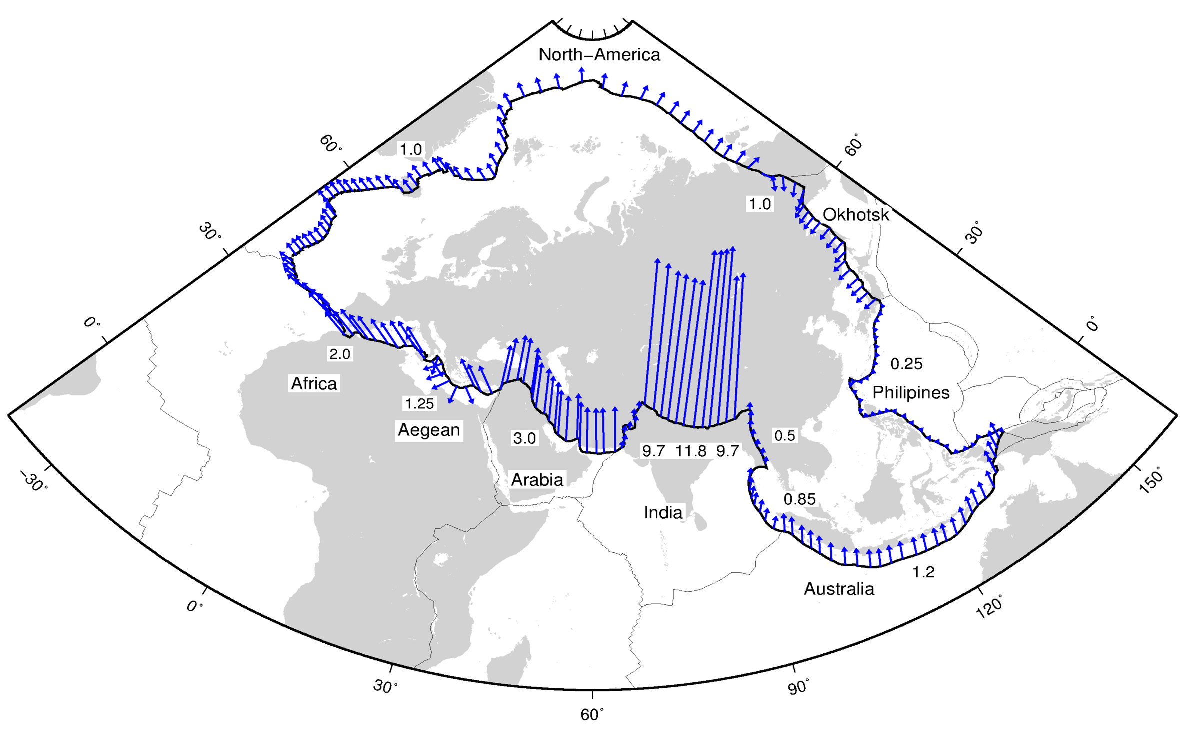

Fig. 1.: Edge forces of the model, where numbers are average magnitudes in TN/m. Non-uniform distribution of forces along the India boundary (varying from 0 to 11.8 TN/m) in contrast to the uniform velocity of India is needed to match the data.

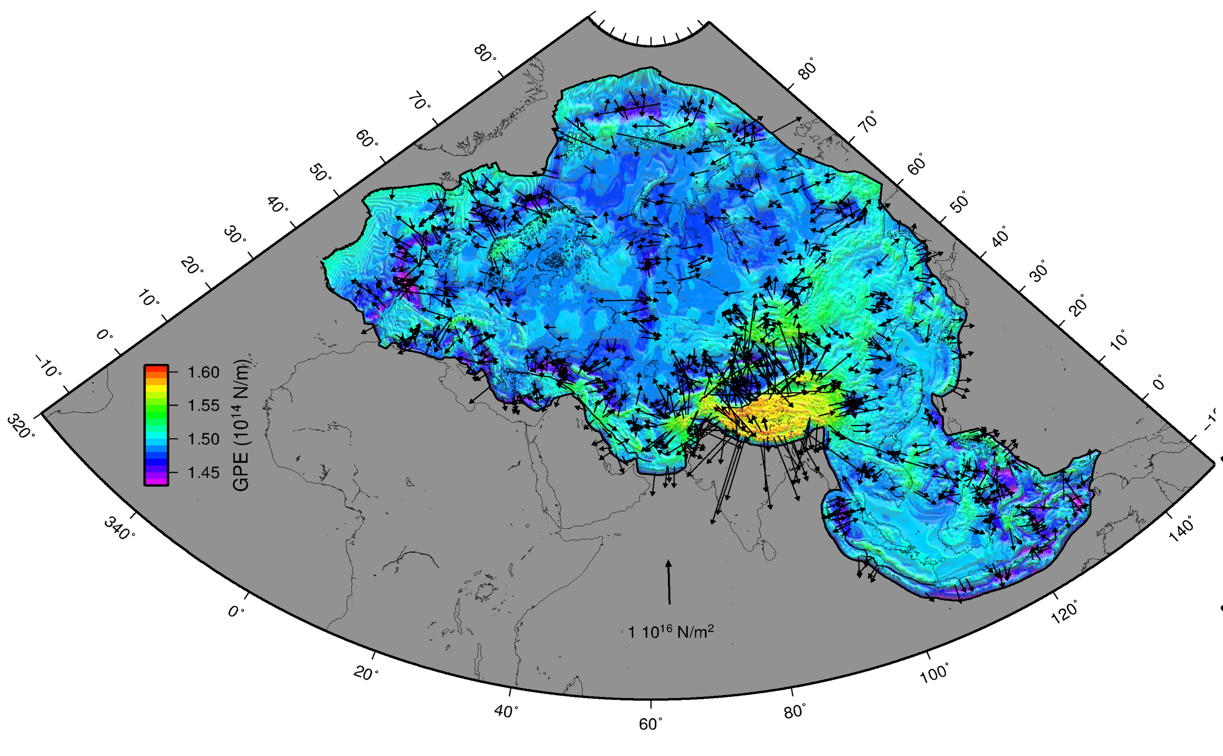

Fig. 2.: Gravitational Potential Enerty (contour values) and corresponding Lithospheric Body Forces (arrows).

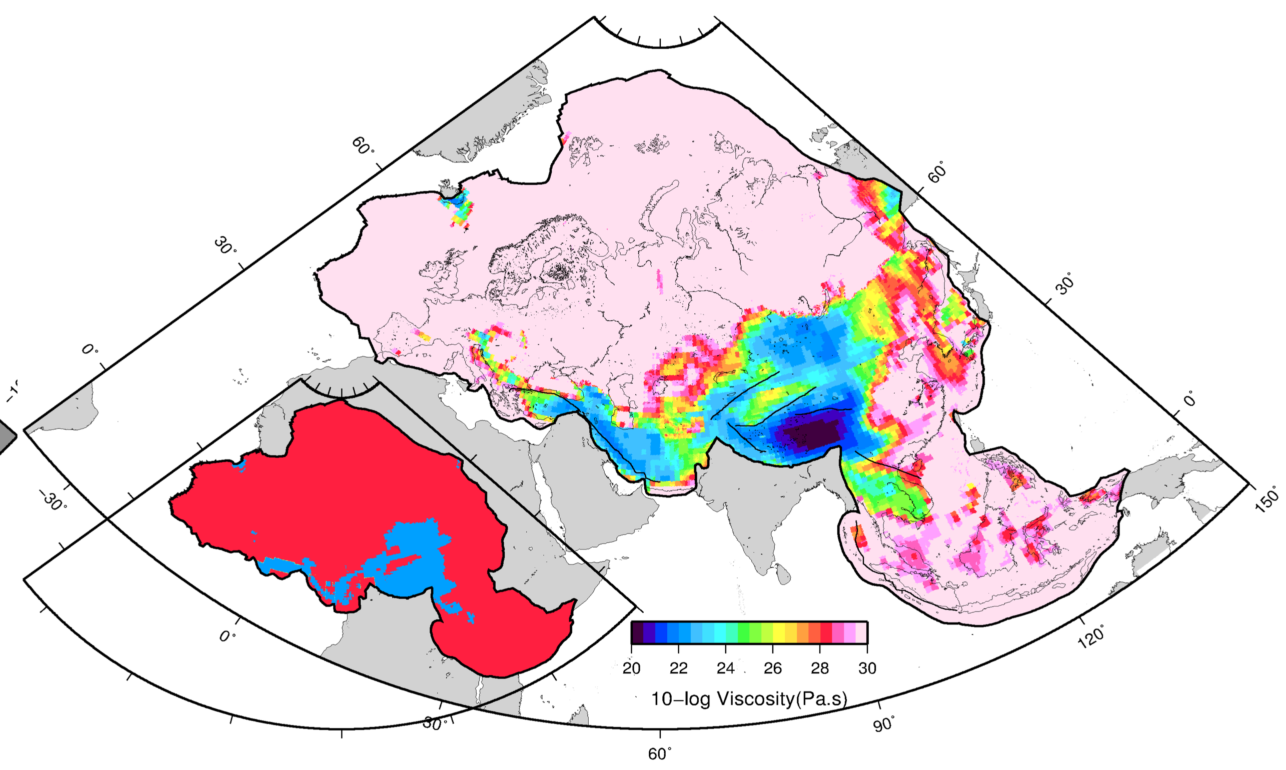

Fig. 3.: 10-log of the vertically averaged lithospheric viscosity (Pa.s). Simplified viscosity model displayed in the inset.

DEFORMATION RESULTS

We employ plane stress spherical finite elements (GTecton) and a linear visco-elastic rheology to compute the lithospheric-averaged mechanical response of the model.

Several factors influence deformation, such as definition of Eurasia's reference frame and the distribution of the edge forces. Here we consider the influence of including the major active faults and show our best-fitting model

Velocity Field

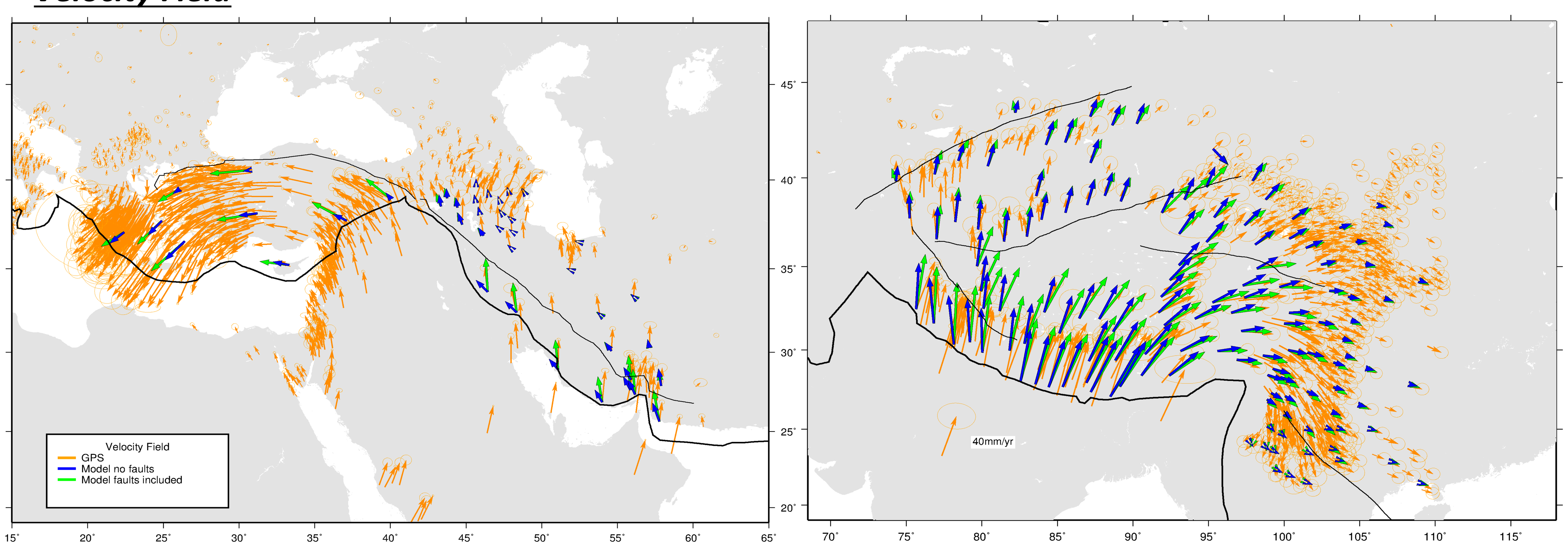

Fig. 4.: GPS horizontal velocity field (orange arrows and corresponding error elipses) of the Eurasian plate (mm/yr) from Gan et al.(2007) and Nocquet (2012). Model horizontal velocity fields for two opposite situations: major active faults are included (green) and no faults are included in the model (blue). We explain 70% of the velocities in Tibetan Plateau and surrondings, and 50% of the velocities in the Aegean-Anatolia-Zagros (large misfit in the Caucasus region).

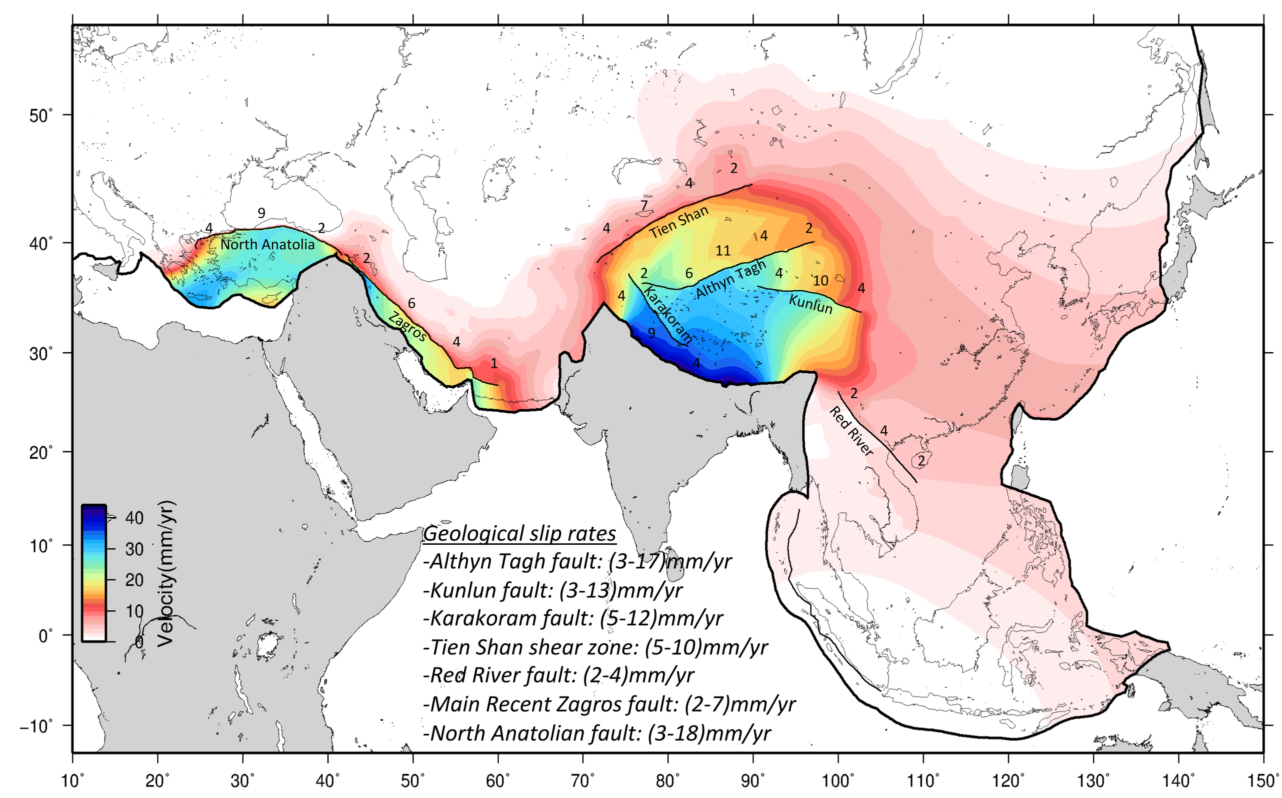

Fig. 5.: Model horizontal velocity field as contour plot (mm/yr). Numbers indicate model slip rates (mm/yr). Direction of slip agrees with observations. Geological slip rates are shown in the legend.

Vertical axis rotation rate, uplift rate and effective shear strain rate fields

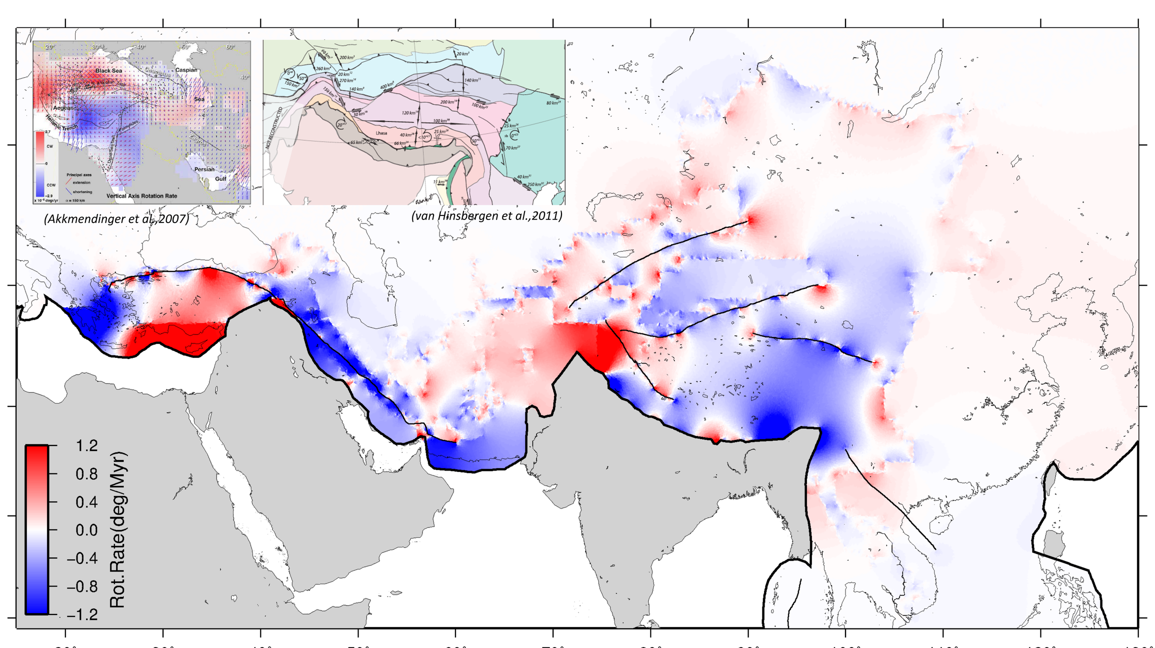

Fig. 6.: Vertical axis rotation rate of the Eurasian plate (degree/Myr). Negative values (blue) represent clockwise rotation and positive values (red) represent counter-clockwise rotation. Our results agree with observations in the Tibetan Plateau and surrondings.

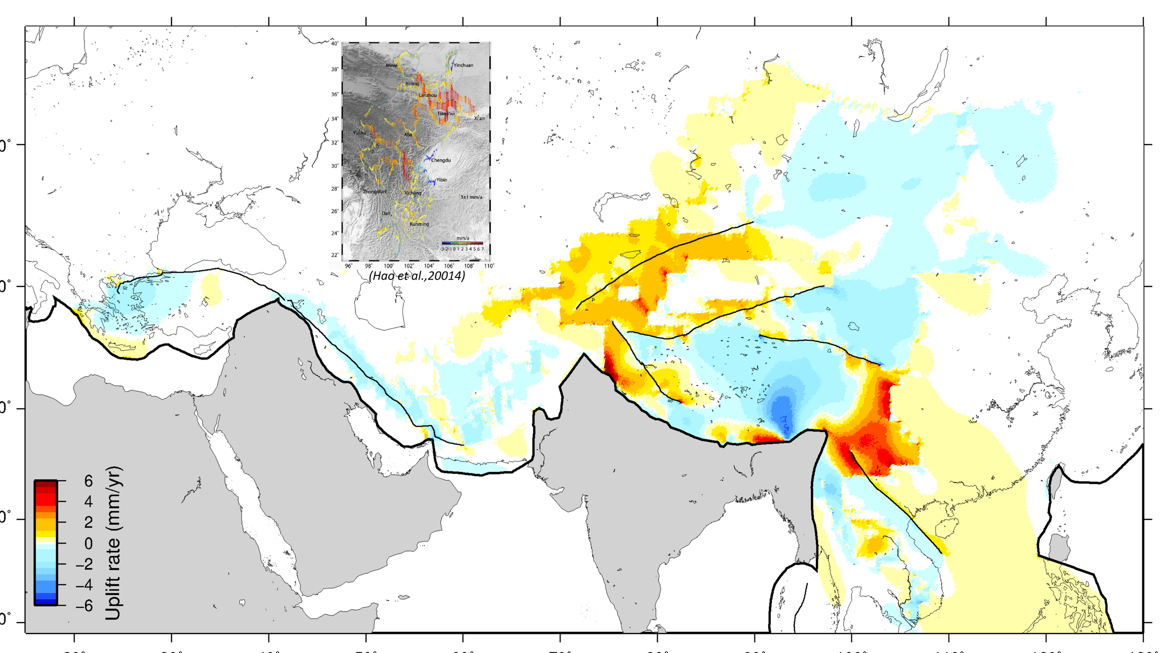

Fig. 7.: Uplift rate of the Eurasian plate (mm/yr). Yellow/red colours represent uplift (up to 6 mm/yr) and blue colours represent subsidence. Uplift in eastern Himalayas Syntaxis, Pamir and Tien Shan agree with observations.

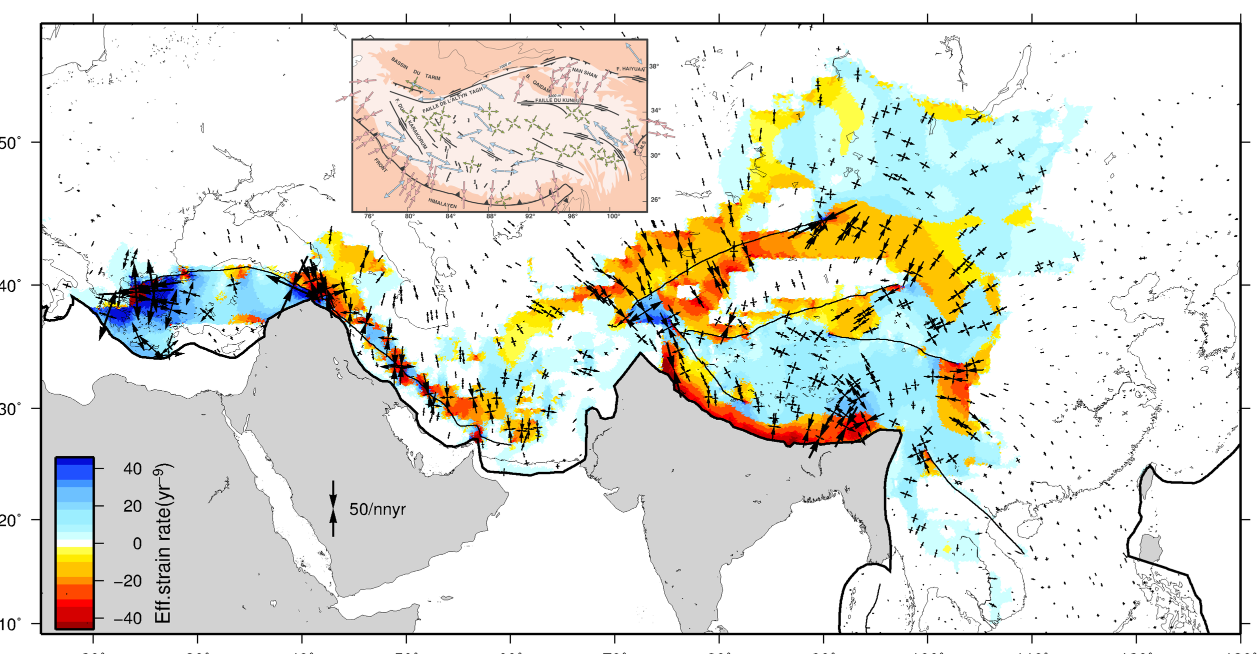

Fig. 8.: Effective shear strain rate field of the Eurasian plate (yr^{-9}). Arrows represent strain field and yellow/red (blue) colours represent shortening (extension). Extension in inner Tibetan Plateau and Aegean, and shortening in Himalayas front belt, Tien Shan and Zagros match observations

CONCLUSIONS

- We successfully model the deformation of the Eurasian plate
- Predicted velocities are not significantly affected by faults in the Tibetan Plateau and surroundings but they are in Zagros. Frictionless faults slip rates agree with geological observations to first order and slip in the observed direction.
- Clockwise vertical axis rotation rates and uplift rates in Eastern Himalayas Syntaxis, extension in inner Tibetan Plateau, counter-clockwise rotation rates in Western Himalayas and shortening and uplift rates in Tien Shan agree with observations.
- Clockwise/counter-clockwise rotation and shortening/extension rates in Zagros/Anatolia-Aegean agree with observations.

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