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Tectonic stress estimates for Europe through Bayesian inversion of GNSS velocities

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Natural stress magnitudes are a basis for informed decisions on the safety of underground activities, but they are incompletely constrained. As natural stresses are the consequence of tectonic processes, a physically consistent force model of the entire Eurasian lithosphere is used to constrain the intraplate stress field based on observed GNSS velocities.

We consider forces due to lateral gradients in gravitational potential energy, tractions by bounding plates, and mantle convective tractions. Our thin sheet model includes variable lithosphere thickness, major fault zones and viscoelastic geological provinces. We use a Metropolis-Hastings algorithm to sample fault resistive shear tractions, slip rates, viscosities and magnitudes of driving and resistive tractions.

Our median model fits observed velocities well in many regions. Trench suction along the Ryukyu and Hellenic forearcs in conjunction with resistive shear tractions on the Makran, Himalayan, Sumatra, Philippine and Nankai megathrust reproduce the complex observed velocities in these regions. However, significant misfit remains in other regions. Fault slip rakes and rates agree with observations along most fault zones. The satisfactory fit in Western Europe can be attributed to plate boundary tractions from Nubia convergence.

Some model parameters are well constrained. Low resistive shear traction rates (<3 MPa/m) are obtained for faults involved in the clockwise velocity rotation of the East Himalayan Syntaxis (Xianshuihe, Kunlun and Sagain). Higher resistive shear traction rates (>8 MPa/m) are estimated for faults that accommodate the India-Eurasia convergence (Karakorum, Main Pamir, and Altyn Tagh).

The median model matches maximum horizontal compressive directions from the World Stress Map fairly well. It shows high maximum shear stresses (50 MPa) in the Pannonian-Aegean-Anatolian region and Fennoscandian shield. Contrasting lithospheric thicknesses between the East European Craton and western Europe result in a stress contrast. Low maximum shear stresses (10 MPa) are estimated in the Pyrenees region, Ligurian-Provençal basin, Northern Apennines, Armoriscan massif, and the Massif central.