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The Gibraltar arc: can various (near)surface observations be explained through lithospheric-scale forces?

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Located in between the slowly converging African and Eurasian continents, the western Mediterranean region contains a tight arcuate orogeny, built mostly throughout the Late Cenozoic: the Gibraltar Arc. The Gibraltar Arc is a tightly curved arc located between the Moroccan Rif in the south and the eastern Betics in the north, thereby largely encircling the Alboran Sea basin. Transpressive strain from the present-day relative motion between Africa and Europe is distributed over a wide region in the Gibraltar Arc region. Seismic hazard may be significant.

Geodetic velocities in the Gibraltar Arc show motion separate from both stable Eurasia and Africa. This could potentially be related to the presence of a significant volume of subducted lithosphere in the upper mantle beneath the Gibraltar Arc and the Betics. A number of previous studies attribute the separate motion of the Gibraltar Arc to coupling with the asthenosphere (either mantle tractions driving the Alboran basin from below or a resistive drag force acting on the Gibraltar slab), whereas gravitational potential energy (GPE) within the involved lithospheres was suggested to only have a second-order and local effect. The quantity and quality of (surface) observations in the Gibraltar Arc, and particularly the Moho model, have substantially improved in the past couple of years. This motivates us to revisit the question of the relative contribution of GPE and the asthenosphere: Can the observed GNSS velocities be explained by lithospheric forces, or is deeper (asthenospheric) forcing needed also?

We use finite element models of the region to perform a grid search to find the most probable values of the model force parameters and their uncertainties. We compare the model predictions with GNSS velocities and with sense of shear along (potentially) active lithospheric fault zones. We consider an updated Moho topography map to calculate the GPE-derived forces. With the grid approach, we identify trade-offs between the effective lithospheric viscosity, effective fault resistance and net slab forcing. Thereby, we construe Gibraltar Arc surface kinematics in view of tectonic forces and estimate the slip rate deficit on major fault zones.

Preliminary results indicate that models with a relatively low-magnitude viscosity for the Alboran basin, when compared to the Atlantic, African and Iberian domains, result in model predictions that better fit with the surface observations. This results from the higher resolution GPE field in the Alboran basin area, which produces larger magnitude forces that act on a weaker lithosphere. Gravitational pull from the Gibraltar slab does not appear to be transferred to the surface efficiently.