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Anisotropic variance-covariance operators to constrain fault conditions in dynamical inversions

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A common strategy for calculating vertically-averaged deviatoric stresses in a given region involves two stages. The first is the kinematic inverse problem. Using the GPS data, this involves designing a grid system and then calculating area-averaged minimum strain rate tensors for the grid cells. This is achieved through a velocity interpolation that uses rotation functions at the knot points which are the free parameters of te inversion. Two separate variance-covariance operators (for the velocity and the strain rates) are commonly used.

Once a strain rate field is obtained, one can then pose a second inverse problem for the dynamics which is governed by a combined effect of lateral tectonic forcing (namely the boundary conditions) and the lateral variations of the gravitational potential energies which we calculate using Airy isostasy assuption, we neglect the basal tractions.The target is to obtain a stress field that satisfies both the thin-sheet force-balance equations and match the styles of the strain rates.

The objective in this work is to develop a mathematical algorithm in which we can also enforce no-length-change conditions along the faults in the dynamical inversion within a variational approach. The technique uses variance-covariance operators that give us the possibility of imposing no-length-change conditions along the major faults. In three dimensions, this condition translates to a no-stress condition if no further cracks are created in the continuum. A further mathematical analysis reveals that imposing further conditions on the faults such as the slip rates causes the present formulation of the inverse problem to become ill-posed.

We tested this new approach in a computational domain that encompasses Greece, the Aegean Sea and Western Anatolia. The southern boundary of the domain is defined by the Hellenic Arc. Through the use of the modified variance-covariance operators we obtained better style matching in the areas where we observe the highest strain rates (namely the Corinth Strait and the Marmara region), however the total misfit (summed over the grid cells) slightly increases. Our second result is more surprising, we found that if we imposed these fault conditions in a diffuse manner, over several grid cells with decreasing weights away from the faults, rather than imposing them solely on the cells that cover the faults, our style matching improves further, suggesting a large-scale fibrous behaviour in parts of the Aegean.