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Joint optimization of elastic parameters and velocity boundary conditions for the estimation of plate rigidity using geodetic data.

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Geodetic data accurately describe interseismic deformation in seismogenic zones. A well-known approach consists in assuming that interseismic geodetic field results from the relative slip of rigid blocks along faults. These models allow a joint estimation of fault slip rate, locking depth and plate rotation.

We propose another approach which assumes that lateral variations of effective elastic thickness control the interseismic deformation of the lithosphere. Thus, we use an inverse method to estimate the distribution of the elastic thickness of the lithosphere on continents from geodetic measurements. The rigidity is supposed to vary continuously and is modeled by a discrete set of parameters along a regular spatial grid. By optimizing this set of parameters, we seek a solution which reproduces at best the interseismic GPS velocity field.

Our method uses a plane-stress finite element code (CAMEF) to predict the velocity field (forward modeling). The inverse method is based on the minimization of a cost function representing the difference between the modeled velocity field and the GPS data. The boundary conditions have to be imposed on the model but are not precisely known (they come from the interpolation of data close to the edges of the studied area). Here, we propose a joint minimization of both elastic parameters and velocity field on the model boundary.

In order to evaluate iteratively the best set of parameters, we use a global semi-deterministic optimization algorithm that needs to compute the gradient of the cost function with respect to these parameters. This gradient can be evaluated by the method of finite differences. In order to speed up the calculations, we evaluate it by the adjoint state method. Because the gradient computation by adjoint state method is independent from the number of parameters, this allows to perform inversion with refined grid of parameters.

We present results that compare the joint optimization of elastic parameters and boundary conditions with analytic solutions. We also attempt to retrieve a discontinuous rigidity distribution with a strong inclusion embedded in a low rigidity medium. We finally apply our method to a real GPS data field on southern California. This confronts us with an heterogeneous distribution of data and measurement errors.