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Plate Rigidity Inversion Using Interseismic GPS Velocity Field

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Interseismic velocity field provided by geodetic methods in tectonically active areas is often interpreted using the concept of thick elastic blocks cut by slipping faults at depth. This approach is purely kinematical and the best adjusment between observed and modeled velocity fields is obtained by searching the fault slip rate distribution along the block boundaries below the seismogenic depth. Here, we adopt a different viewpoint in which interseismic strain occurs in response to remote forces or velocities imposed by the plates. In this case, lithosphere and faults control interseismic strain rate thanks to their rheological properties. If one assumes that faults are fully locked within the seismogenic zone, strain rate variations must occur in response to lateral variations in the elastic rigidity of the lithosphere. In line with this view, low rigidity zones should lead to high interseismic strain while high rigidity areas remain weakly deformed.

We present a mathematical method to approximate the observed GPS velocity field by a mechanical model displaying a horizontally variable plate rigidity. We adopt an optimisation scheme that aims to minimize a cost function representing the offset between velocities provided by a forward elastic model and by GPS data (interseismic velocity field). The plate rigidity is described by a small number of parameters defined on control points associated to a distribution function. An optimization algorithm then allows to minimize the cost function by computing successive direct problems and the sensitivity of the cost function with respect to control parameters. We first apply this method to search the rigidity distribution in the case of a well-posed problem for which 1) the rigidity map is a priori known 2) the data velocity field is the FEM solution of the direct problem. This approach allows us to define a parametrization suitable to describe respectively sharp and smooth rigidity variation and also to implement a strategy in which the parameter space is progressively enriched during the optimization process. Then we use the southern California zone in the vicinity of the San Andreas Fault to test the ability of the method to solve the rigidity distribution over an interplate area. This zone is of a special interest because it is crossed by numerous active faults. Also, it includes different tectonical areas such as the border of the Pacific plate, the San Andreas fault zone and the Mojave region. Therefore, one can expect that the analysis of the continuous GPS velocity field (CMM3) leads to contrasted rigidities across the studied domain. We discuss the rigidity distribution obtained by our method in the light of heat flow, seismology and tectonic knowledge of southern California.