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Use of interseismic GPS data: a novel way to evaluate the lithosphere rigidity variations.

Severine Furst (1), Michel Peyret (1), Jean Chéry (1), and Bijan Mohammadi (2)

(1) Université de Montpellier, Géosciences Montpellier, CNRS UMR-5243, 34095 Montpellier, France (severine.furst@gm.univ-montp2.fr), (2) Université de Montpellier, I3M, CNRS UMR-5149, 34095 Montpellier, France

Although the flexure of the lithosphere is well constrained using a simple secular cooling model in the ocean (Stewart and Watts, 1997), this mechanical parameter is not obvious to determine in the continents. One commonly estimates the flexural rigidity, expressed through the effective elastic thickness (T_e) of the lithosphere, by studying the lithosphere's vertical motion induced by long-term geological loads. Here, we suggest a similar approach, using the horizontal velocities to evaluate lateral rigidity variations. To illustrate our method, we select the Western United States zone, where areas with high rigidity (Sierra Nevada) are connected with others displaying low rigidities (San Andreas Fault).

Our technique is based on an inversion problem, aiming to infer the effective rigidity from interseismic strain distribution measured by geodetic methods. The forward problem is defined using the equations of linear elasticity in a plane stress finite element code. This method involves the minimisation of a cost function defined as the quadratic measure of the differences between measured and modeled velocity fields on a discrete set of points. Gradient of the functional, with respect to the independent parameters of the model, is computed using an adjoint formulation. Thanks to this construction, the mapping of the rigidity can be fulfilled with a large number of parameters. The optimisation chart is validated first on synthetic velocity data sets corresponding to the surface motion of a screw dislocation with different locking depths. Then, the effective rigidity variations of the Western United States are estimated using a dense geodetic network.

The inversion displays low effective rigidities along the San Andreas Fault and in the Eastern California Shear zone, while rigid areas are found in the Sierra Nevada and in the South Basin and Range. High rigidity values are strongly correlated with regions presenting small deformations and vice-versa. In addition to these results, we develop an approach built on the new theory about extreme scenarios to evaluate the reliability of our inversion. To do so, we consider parameters uncertainties linked to the propagation of the data error through the optimisation procedure. With this uncertainties map, we join an estimation of the confidence to the computed rigidity distribution. Finally, we compare the rigidity variations and deformation to the results from the literature.