A probabilistic estimation of surface strain rates from GPS measurements

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Abstract

The analysis of crustal deformation can be done using GPS times series, which provide information on surface displacement rates at the GPS stations location. Horizontal rates measured at a finite set of stations can be interpolated to reconstruct a continuous velocity field, the gradient of which can be used to infer surface strain rates [e.g. Haines & Holt, 1993; Kreemer et al. 2000, 2014]. However, this inverse problem does not have a unique solution, and standard interpolation schemes are prone to well-known issues: they do not efficiently cope with the uneven spatial distribution of stations and the user has to arbitrarily define regression parameters that bias the solution in a statistical sense. For example, the choice of a smoothing parameter has a critical influence on the solution [e.g. Smith & Wessel, 1990; Shen et al. 2015]. Furthermore, they do not allow for the propagation of uncertainties from the data to the final solution.

Here we propose a new probabilistic method to estimate surface strain rates from horizontal displacement rates measured on GPS time series. We use a Bayesian framework, and parameterize the continuous velocity field using Delaunay Triangulation, and develop a Markov chain Monte-Carlo sampling algorithm to take into account the non-uniqueness of the solution [Tarantola, 2005; Bodin et al., 2012]. The outcome of our approach is a complete probabilistic distribution for the strain rate tensor. We perform synthetic tests to illustrate the behavior of our algorithm on simple configurations, and then compare its performances with the widely used bicubic spline-in-tension interpolations conducted over (i) the slowly deforming Balkan Peninsula and (ii) across the Levant plate boundary. We show that our approach provides significantly better results on noisy and unevenly spatially distributed data, while offering a full access to the uncertainties associated with our solution.

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