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Realistic interseismic strain rate uncertainties from inherently sparse GNSS-networks

Taco Broerse[1], Mario D'Acquisto[1,2], Rob Govers[1], Celine Marsman[1], and Alireza Amiri-Simkooei[3]
[1]Utrecht University, Faculty of Geosciences, Department of Earth Sciences, Utrecht, Netherlands (d.b.t.broerse@uu.nl)
[2]GFZ German Research Centre for Geosciences, Potsdam, Germany
[3]Faculty of Civil Engineering and Geosciences, Delft University of Technology, Delft, The Netherlands

Before geodetically derived strain and rotation rates can be robustly compared to geological or seismological observations, we need reliable strain rate uncertainties. Various methods exist to compute strain rates from GNSS-derived interseismic velocities, but a realistic representation of interpolation uncertainties has remained a challenge. The main problem is that commonly used deterministic interpolation methods do not account for uncertainty resulting from the absence of information in between observation sites. We apply stochastic interpolation by means of ordinary kriging to propagate errors both from discontinuous data coverage as well as from observation uncertainties to our strain rate estimates. However, interseismic horizontal surface velocities in tectonically active regions are spatially highly non-stationary, with high spatial variability around active faults and lower velocity variability in tectonically more stable regions. This requires an extension of traditional ordinary kriging approaches. For interpolation uncertainties that reflect the local variability and spatial correlation of the observed surface velocities, we apply a novel method that incorporates the spatially variable statistics of the underlying data. We estimate realistic uncertainties and covariances of the interpolated velocity field. For regions with a high spatial velocity variability, we find a large increase in uncertainty with increasing distance from observation sites, while in areas with little spatial variability, we estimate a small increase in uncertainty with distance. Subsequently, we propagate interpolated velocity covariance to strain rate uncertainties, such that we can assess the statistical significance of the interpolated strain rate field. Applied to a number of actively deforming regions, including the Pacific coast of North America and Japan, we show to what degree we can robustly determine strain rates based on available GNSS-derived velocities. Realistic uncertainties assist the community to better discriminate continuous or localized deformation on active faults from the available geodetic data.