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A Geodetic Strain Rate Model for the Pacific-North American Plate Boundary, western United States

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We present a model of crustal strain rates derived from GPS measurements of horizontal station velocities in the Pacific-North American plate boundary in the western United States. The model reflects a best estimate of present-day deformation from the San Andreas fault system in the west to the Basin and Range province in the east.

Of the total 2,846 GPS velocities used in the model, 1,197 are derived by ourselves, and 1,649 are taken from (mostly) published results. The velocities derived by ourselves (the “UNR solution”) are estimated from GPS position time-series of continuous and semi-continuous stations for which data are publicly available. We estimated ITRF2005 positions from 2002-2011.5 using JPL’s GIPSY-OASIS II software with ambiguity resolution applied using our custom Ambizap software. Only stations with time-series that span at least 2.25 years are considered. We removed from the time-series continental-scale common-mode errors using a spatially-varying filtering technique. Velocity uncertainties (typically 0.1-0.3 mm/yr) assume that the time-series contain flicker plus white noise. We used a subset of stations on the stable parts of the Pacific and North American plates to estimate the Pacific-North American pole of rotation. This pole is applied as a boundary condition to the model and the North American – ITRF2005 pole is used to rotate our velocities into a North America fixed reference frame. We do not include parts of the time-series that show curvature due to post-seismic deformation after major earthquakes and we also exclude stations whose time-series display a significant unexplained non-linearity or that are near volcanic centers. Transient effects longer than the observation period (i.e. slow viscoelastic relaxation) are left in the data.

We added to the UNR solution velocities from 12 other studies. The velocities are transformed onto the UNR solution’s reference frame by estimating and applying a translation and rotation that minimizes the velocities at collocated stations. We removed obvious outliers and velocities in areas that we identified to undergo subsidence likely due to excessive water pumping.

For the strain rate calculations we excluded GPS stations with anomalous vertical motion or annual horizontal periodicity, which are indicators of local site instability. First, we used the stations from the UNR solution to create a Delaunay triangulation and estimated the horizontal strain rate components (and rigid body rotation) for each triangle in a linear least-squares inversion using the horizontal velocities as input. Some level of spatial damping was applied to minimize unnecessary spatial variation in the model parameters. The strain rates estimates were then used as a priori strain rate variances in a method that fits continuous bi-cubic Bessel spline functions through the velocity gradient field while minimizing the weighted misfit to all velocities. A minimal level of spatial smoothing of the variances was applied.

The strain rate tensor model is shown by contours of the second invariant of the tensor, which is a measure of the amplitude that is coordinate frame independent. We also show a map of the tensor style and of the signal-to-noise ratio of the model.