Using GPS Derived Shear Strain Rates in Southern California to Constrain Fault Slip Rate, Locking Depth, and Residual Off-Fault Strain Rates

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UCERF3 Velocity Field

Pacific Plate Frame using SNARF PA-NA angular velocity from Hammond and Kreemer [2007]
Method

- Spherical Method [Beavan and Haines, 2001]
- Bi-Cubic Bessel Interpolation of GPS Velocities
- *A priori* information on fault style

\[ u(\hat{r}) = rW(\hat{r}) \times \hat{r} \]

\[
\varepsilon_{\phi\phi} = \frac{1}{\cos \theta} \frac{\partial u_\phi}{\partial \phi} - u_\theta \tan \theta + \frac{u_r}{r} \\
\varepsilon_{\theta\theta} = \frac{\partial u_\theta}{\partial \theta} + \frac{u_r}{r} \\
\varepsilon_{\theta\phi} = \frac{1}{2} \left[ \frac{\partial u_\phi}{\partial \theta} + \frac{1}{\cos \theta} \frac{\partial u_\theta}{\partial \phi} + u_\phi \tan \theta \right]
\]
0.1° x 0.1° Finite Element Grid for Modeling
UCERF3 Velocity Field

Pacific Plate frame

95% Confidence Ellipses

Courtesy of Tom Herring
Model Shear Strain Rates (Pure Strike-Slip Style)
Model Shear Strain Rates (Pure SS) from Inversion of GPS
Bench Marking – Uniform Slip
And Uniform Locking Depth = 10 km

Displacements produced using elastic dislocation model  *Okada* [1992], *King et al.* [1994], *Lin and Stein* [2004]
Bench Marking – Uniform Slip

\[ \nu = \left( \frac{b}{\pi} \right) \arctan\left( \frac{x}{D} \right) \]

\[ \varepsilon_{xy} = \left( \frac{bD}{2\pi} \right) \left( x^2 + D^2 \right)^{-1} \]

Savage and Burford [1973]

Displacements produced using Okada [1992], King et al. [1994], Lin and Stein [2004]
Bench Marking – Uniform Slip

Displacements produced using Okada [1992], King et al. [1994], Lin and Stein [2004]
Bench Marking – Non-Uniform Slip
Effective Locking Depth (SJF) = 6 km
Slip Rate = 12 mm/yr

Effective Locking Depth (SAF) = 7 km
Slip Rate = 17 mm/yr
Tectonic Moment Rate Per Unit Area (0.1° x 0.1°)

\[ \dot{M}_o = 2 \mu V (|\dot{\sigma}| + \sqrt{\dot{\gamma}_1^2 + \dot{\gamma}_2^2}) \]

Tectonic Moment Rate for SC = 2.2x10^{19} N-m/year

30% of total Mo rate is associated with off-fault deformation
An Automated Geodetic Network Processing Tool for Detecting Crustal Strain Transients

PBO Network

PBO Data Archive from UNAVCO
Transient Detection
Movies of Strain from PBO cGPS
2010.5 – 2012.5

Total

Total – Reference = Anomalous
Transient Detection

Our procedure tests the null hypothesis that the time-dependent strain field inferred from the cGPS is equivalent to the long-term steady-state reference solution using the t-statistic:

$$t = \frac{E(\hat{e}_{ij} - e_{ij}^o)}{S_E}$$
Figure 10c

T-statistic Anomalous Strain Accumulation over 2 years
Conclusions

• Horizontal velocity gradient tensor field in SC is well resolved. It can be further improved with joint analysis of InSAR.
• Using shear strain rates associated with pure strike-slip faulting filters out potential contamination from off-fault deformation. This data product may be better suited for resolving fault slip rate and effective locking depths along the major shear zones.
• cGPS valuable for resolving anomalous strain tensor field associated with transients.
Effective Locking Depth = 4 km
Slip Rate = 34 mm/yr

Shear Strain Rate Magnitudes
Effective Locking Depth = 10 km
Slip Rate = 21 mm/yr
Slip rate = 9 mm/yr
Exy Profile

Effective Locking Depth = 6 km
Slip Rate = 41 mm/yr

Distance along profile (meters)

Shear Strain Rate Magnitudes

1x10^-16 yr^-1