Progress report for the 2008 SCEC project

Assessing Strain Rates in Southern California

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Overview

The objective of this project is to estimate the contemporary three-dimensional strain rate field in southern California and its relationship to long-term crustal kinematics, transient deformation signals and their sources, and the forces driving deformation of the southern California crust. To that end, we have first focused our efforts on determining and modeling the vertical GPS velocity field to better understand the precision of vertical GPS velocity measurements and the constraints they place on the buoyancy, rheology, and state of stress within the lithosphere. This work was published in *GRL* in 2008, see Fay et al., 2008b.

We have focused thus far on the region in Figure 1 containing the southernmost Sierra Nevada and Walker Lane Belt, and northern Mojave Desert. The GPS stations were chosen based on their data quality, length of observation, and station geometry (~perpendicular to the strike of the Sierra Nevada Mountains and nearby faults). Figure 1 shows the horizontal velocities that show that horizontal deformation in the region is dominated by right-lateral shear strain oriented NW-SE with secondary left lateral shear oriented ~NE-SW (accommodated by the left lateral Garlock fault).

Determining absolute vertical velocity is difficult due to a number of imperfectly understood global processes that deform the surface of the earth and displace its center of mass [e.g., Blewitt et al., 2001]. We therefore restrict our study to relative vertical velocities, with a local reference frame defined by the average of 5 long-running GPS stations near Yucca Mountain in southern Nevada (Fig. 1). We have carefully analyzed GPS position timeseries to determine relative vertical velocities and these are given in Figure 2. Relative to Yucca Mountain, we find that stations in the Walker Lane Belt are approximately stable (negligible vertical velocity), stations in the southern Sierra Nevada are going up at ~0.5 mm/yr, and stations SE of the Sierra Nevada are going down at ~0.5 mm/yr. Vertical velocity precision is ~0.2-0.3 mm/yr indicating rates of 0.5 mm/yr are resolvable and that long-running GPS stations are potentially useful for constraining the vertical deformation field.

There are a number of potential processes to cause vertical motion of the earth's surface and thus far we have explored the role of post-seismic viscoelastic relaxation, in particular that caused by the 1872 Owens Valley and 1952 Kern County earthquakes. We calculated the present-day vertical velocity caused by these events with many models that span possible viscoelastic structures of the lithosphere. The predicted velocities are shown in Fig. 2b and c. While the data are in general more consistent with the viscosity of the lower crust greater than that of the upper mantle, it is difficult to find a single, layered viscoelastic structure to explain all of the observations. This suggests that lateral viscosity variations may be important, or other, more recent events such as the 1992 Landers and 1999 Hector Mine earthquakes may have produced observable vertical signals in our study area.

Future Work

We continue to analyze and model southern California geodetic data (funded by this and other SCEC and NSF proposals) to determine horizontal kinematics (paper in prep by Spinler et al.), vertical kinematics (papers in prep by Gressett et al., and Bennett et al.), and crustal geodynamics (papers in prep by Fay et al.). In particular, we will focus our attention in the future on the horizontal strain rate field and vertical velocity field in the vicinity of the Transverse Ranges where there appears to be a correspondence between upper mantle flow and active crustal deformation (Fay et al., 2008a).

References

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Fay, N. P., R. A. Bennett, J. C. Spinler and E. D. Humphreys (2008a), Small-scale upper mantle convection and crustal dynamics in southern California, *Geochem. Geophys. Geosyst*, *9*, Q08006, doi:10.1029/2008GC001988.

Hammond, W. C., C. Kreemer, and G. Blewitt (2008), Geodetic constraints on contemporary deformation in the northern Walker Lane: 3. Central Nevada seismic belt postseismic relaxation, in *Late Cenozoic Structure and Evolution of the Great Basin – Sierra Nevada Transition*, edited by J. Oldow and P. Cashman, Geol. Soc. Of Am. Special Volume, in press.

SCEC Publications

Fay, N. P., R. A. Bennett, and S. Hreinsdóttir (2008b), Contemporary vertical velocity of the central Basin and Range and uplift of the southern Sierra Nevada, *Geophys. Res. Lett.*, 35, L20309, doi:10.1029/2008/GL034949. This paper is SCEC contribution number 1223.

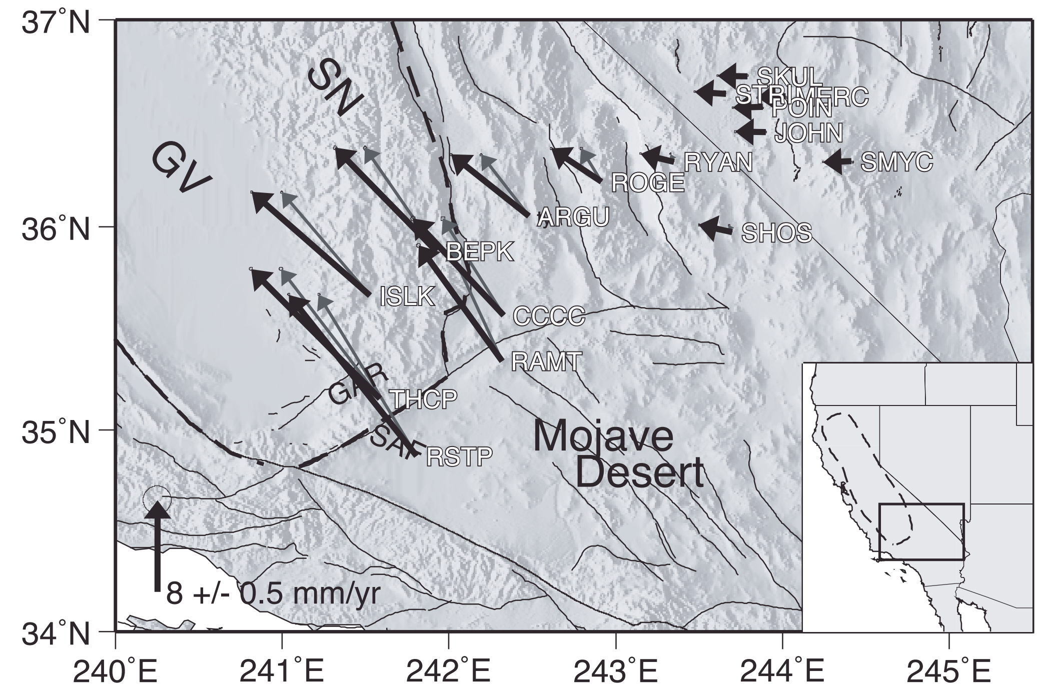

Figure 1. Study area showing GPS stations (4-letter codes), faults (thin grey lines) and geographic features (GV, Great Valley; SN, Sierra Nevada; GAR, Garlock fault, SAF, San Andreas fault). Black vectors show horizontal velocity relative to stable North America and thin grey vectors show velocity relative to the average of the 5 Yucca Mountain sites (SKUL, STRI, MERC, POIN, JOHN). Error ellipses give the 95% confidence region.

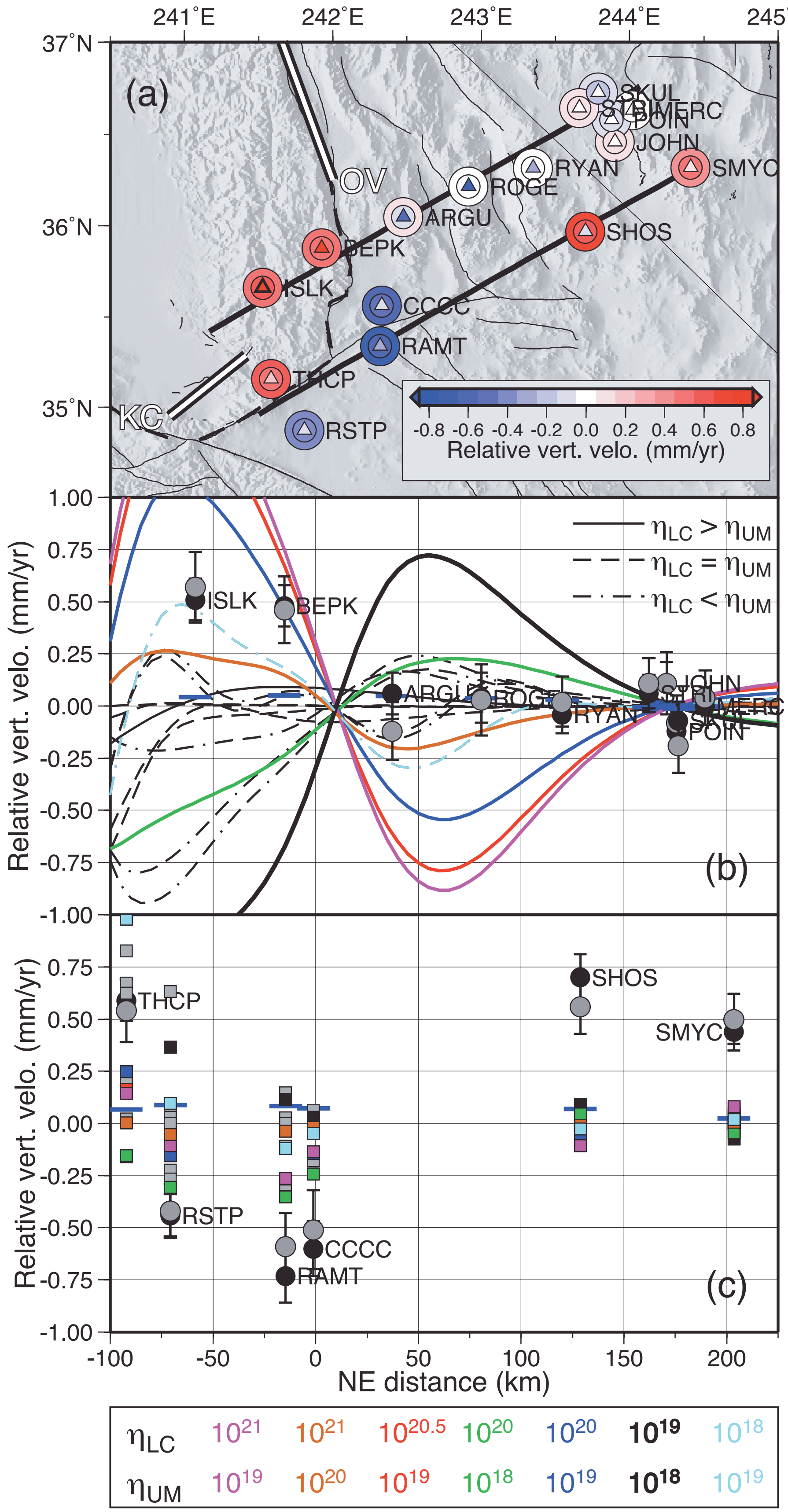

Figure 2. (a) Vertical velocity (colored circles) relative to the average of the 5 Yucca Mtn. sites. Colored triangles show predicted post-seismic vertical velocity utilizing the viscosity structure of Hammond et al. (2008). Double black lines show surface trace of modeled earthquakes (KC, Kern County; OV, Owens Valley). NE-SW lines show profiles of (b) and (c). (b) Observed (dots w/1-sigma error bars) and predicted (curves) vertical velocity for then northern NE-SW profile as a function of distance NE of the Owens Valley earthquake trace. The legend below gives the viscosity structure (Pa-s) corresponding to the colored curves. Blue horizontal bars show the predicted vertical velocity caused by long-wavelength glacial isostatic rebound [Blewitt et al., 2005]. (c) Same as in (b) for the southern NE-SW profile with predicted velocities shown at each station with filled squares. Please see Fay et al. (2008) for data processing and modeling details.