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Project title: Addressing the geology-geodesy rate debate for the southernmost San Andreas fault zone, southern California

Principal Investigator: Dr. Richard A. Bennett
Assistant Professor
Department of Geosciences
University of Arizona
Tucson, AZ 85721-0077
Tel: (520) 621-2324
Fax: (520) 621-2672

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NON-TECHINCAL SUMMARY

If real, inferred discrepancies between Holocene and late Pleistocene estimates for slip rate and geodesy-based estimates for elastic strain accumulation on the northernmost part of the southernmost San Andreas fault zone would require a drastic rethinking of our basic understanding of the earthquake cycle and earthquake recurrence. But lingering uncertainty in existing geologic and geodetic estimates presently hampers definitive conclusions. To address uncertainties on the geodetic side of the equation, we initiated a straightforward GPS experiment targeting the general region occupied by Joshua Tree National Park (JTNP). This region is particularly important because it contains the active link between the southernmost San Andreas fault zone, which appears to rupture only during very large earthquakes, and the eastern California shear zone, which has itself ruptured in two M>7 earthquakes in the last decade. Cumulative offsets of recently recognized right-lateral strike slip faults, which cut through the Little San Bernardino Mountains near JTNP, are significantly smaller than might be expected based on existing geodetic solutions for crustal velocity, perhaps suggesting that the fault zone is nascent. Similar geology-geodesy discrepancies exist elsewhere in the world region, but the arid, open, high desert environment afforded by the JTNP region provides an exceptional opportunity to make substantial improvements to geodetic deformation rates. Detailed understanding of the slip rate of the San Andreas fault is also critical to hazards assessment for the heavily populated San Bernardino and Los Angeles counties. There is a growing body of research suggesting that some faults in JTNP trade-off with the strands of the San Andreas flanking the southern San Bernardino Mountains, such that high rates of activity on one set of faults correlate with low rates on the other.

The network that we have developed to address the issues consists of 10 existing geodetic monuments and 12 new high stability monuments within and around Joshua Tree National Park. Our primary goal is to improve slip rate estimates for the southern San Andreas fault zone. We hope to either obviate or sharpen the geology-geodesy slip rate debate. An important secondary goal of the experiment is to provide needed ties between modern SCIGN/PBO/SCEC GPS velocity fields, and precise, pre-Landers/Hector Mine trilateration strain rate data. Comparisons between and combinations of the data sets should provide new insight on possible long-lived transient strains associated with the earthquakes. These goals overlap directly with Element III of the EHP, and specific priorities identified by the SC Panel.

RESULTS

We are generating important new data pertinent to understanding the deformation field associated with San Andreas fault zone. We established a high precision GPS network that uses stable fixed height monuments. Since September 2005, we have performed seven GPS measurement campaigns (Figure 1). We are in the process of analyzing these data and interpreting the results in terms of San Andreas and ECSZ strain accumulation.

Preliminary determination of crustal velocities at 21 sites using data from a subset of the new campaign stations plus data from nearby continuous stations from the SCIGN/PBO NUCLEUS, and PBO networks are shown in Figure 1. All of our campaign data from September 2005 to September 2007 were used. We also analyzed continuous GPS data for the eleven-year period of January 1996 through September 2007.

We used the GPS-determined site velocity estimates to constrain elastic loading rates for model block boundaries representing the SSAF through Coachella Valley and San Gorgonio Pass, the Pinto Mountain and Blue Cut faults of the ETR, and several faults of the ECSZ in the southern Mojave Desert. We estimated relative block motions accounting for elastic strain on locked faults using weighted least squares such that common mode rotation and translation attributable to reference frame uncertainty contribute no power to the misfit. The fit of the model to the GPS observations is reasonable for this preliminary stage of the project (Figure 2). Using a fault geometry that includes the Pinto Mountain and Blue Cut faults of the ETR (Figure 2), we obtained fault loading rate estimates for the SSAF that are consistent with the majority of estimates for both long- and short-term fault slip rate based on tectonic geomorphology and paleoseismology, respectively. ECSZ fault geometry is presently not modeled accurately enough for a useful comparison of GPS and geologic rate estimates. We are presently working on these and other improvements to the model.

These preliminary results suggest that the upper crust in the vicinity of the SSAF zone accommodates relative plate motion by transrotation within the ETR, involving slip on major large-offset fault zones separating relatively rigid crustal blocks. Slip on the numerous secondary small-offset faults located within SSAF-bounding crustal blocks do not appear to contribute appreciably to the pattern of elastic strain accumulation, but we are in the process of devising ways to more rigorously assess the role of these faults (from the geodetic perspective). One important realization from this study so far is that fault geometry inferred from geodesy is non-unique. Constructive and destructive interference of strain fields associated with the major faults comprising complex fault systems with closely spaced faults results in strain rate patterns that might be mistakenly attributed to new faults if geodetically determined velocity gradients are interpreted independent of mapped faults.

PUBLICATIONS

Bennett, R.A., M.L. Anderson, S. Hreinsdottir, G. Buble, J. Spinler, S. Thompson: GPS constraints on crustal deformation in the eastern Transverse Ranges Province, southern California, EOS Trans. AGU, Fall meeting, 2006.

Spinler, J.S., R.A., Bennett, M.L. Anderson, S. Hreinsdóttir, Present-day loading rate of southern San Andreas and eastern California shear zone faults from GPS geodesy, JGR, in preparation.

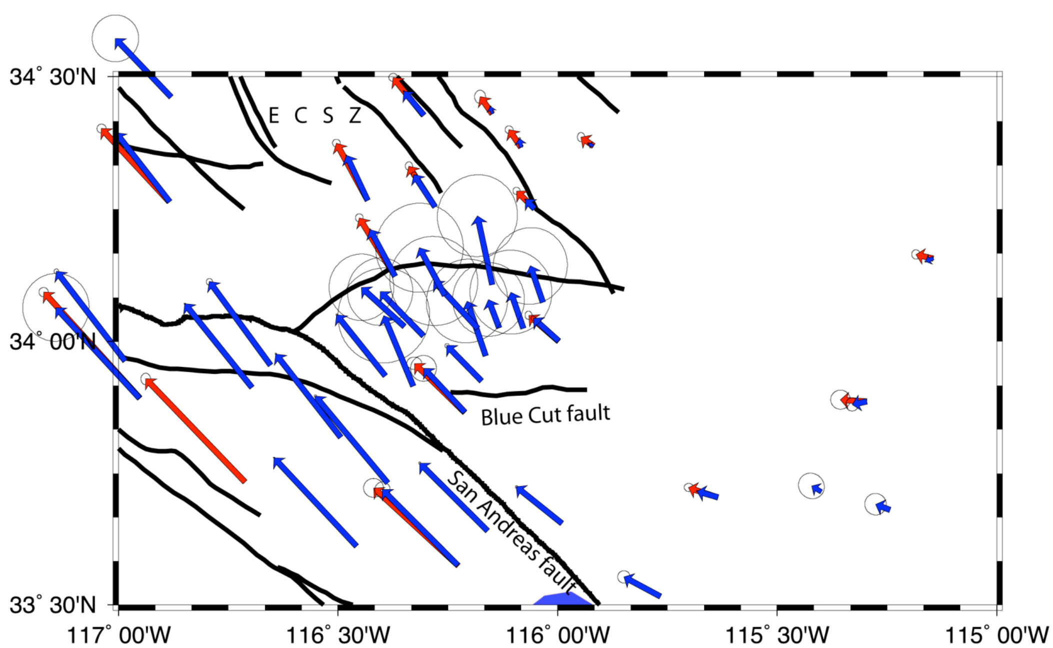

Figure 1. Preliminary GPS velocity field for the Joshua Tree GPS network for the period of September 2005 to September 2006 (blue arrows). Also shown are rates from PBO velocity solution (red arrows). Small systematic differences between PBO solution and our solution are related to different realizations of the North America reference frame. Although rate uncertainties are large (after only one year of campaign observation), the pattern of deformation is nevertheless beginning to emerge. Rates of motion north of the Blue Cut fault are significantly faster than could be explained by elastic strain associated with the San Andreas fault alone. The Joshua Tree GPS network provides dense coverage across the transition region between the eastern California shear zone (ECSZ) and the San Andreas fault system. Continued measurement of the Joshua Tree GPS campaign network will provide important new constraints

on the nature of this transition, including the role of transverse (i.e., East-West striking) faults such as the Blue Cut fault. If an appreciable amount of deformation is accommodated to the east of the San Andreas fault at this latitude it has important implications for the slip rate on the southern San Andreas fault.

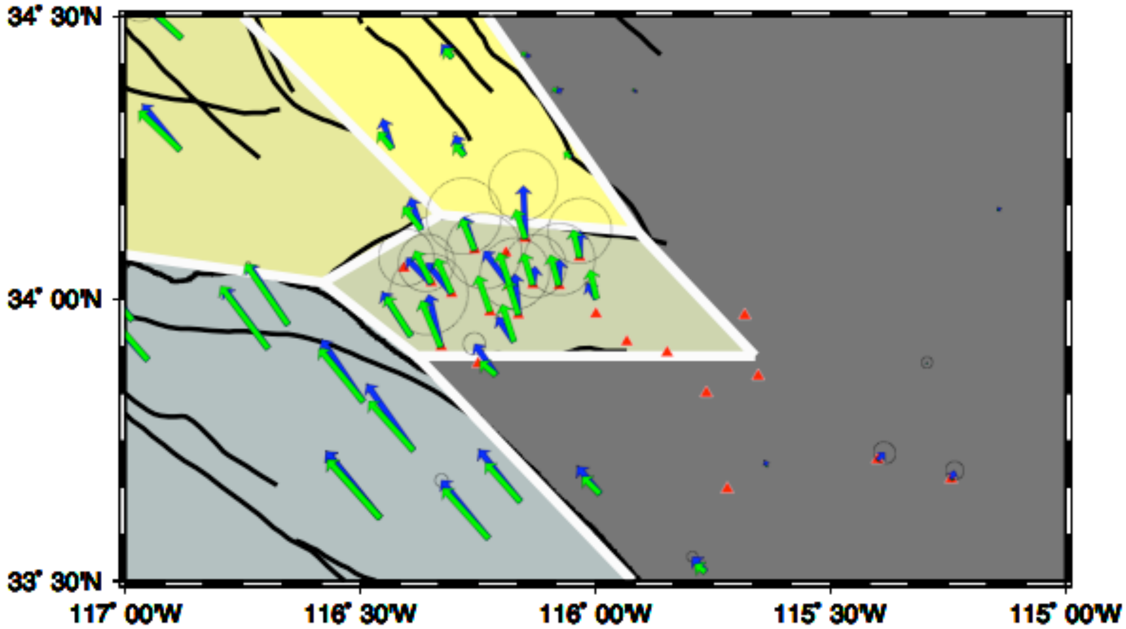

Figure 2. Preliminary modeling of the GPS results suggests that the Blue Cut and Pinto Mountain faults play an important role in the contemporary tectonics of the region. This figure shows a very simple elastic block model for the region that serves as a starting point for our investigation. The model consists of several blocks (colored region) separated by strike slip faults (fat white lines). The green arrows show the observed GPS velocity solution, and the blue arrows show the model velocities. Model slip rates determined by inversion match geological slip rates along the San Andreas fault remarkably well. These results suggest that GPS is now sufficiently precise that useful tectonic results may be obtained within only a single year of tri-annual GPS measurements, but precise constraints on present-day slip rates require continued monitoring.