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A GPS resurvey of the Anza gap region, California: preparation for an earthquake on the San Jacinto fault

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Introduction

The San Jacinto fault is one of the most important structures accommodating Pacific-North America plate boundary deformation in southern California. After the San Andreas fault, it has the highest slip rate of the structures south of the 'Big Bend' (e.g. Meade and Hager, 2005; Fay and Humphreys, 2005). Several of the major population centers of the Inland Empire and desert cities (such as the cities of Riverside and San Bernardino and their environs) lie close to the mapped fault (e.g. Figure 1).

The San Jacinto fault has been seismically active in the recent past, with six M>6 earthquakes since the start of the 20th Century, distributed along most of its length; the latest being a Mw 6.5 event in 1968, along the Coyote Creek segment. Existing hazard analyses suggest that both the San Jacinto valley (in particular) and Anza segments have significant probabilities of contemporary earthquake rupture in coming decades (WGCEP, 1994). The Anza segment is also the site of a prominent ~20 km seismic gap, known as the 'Anza Gap' (e.g. Sanders and Kanamori, 1984). Given the high probability of a future earthquake on the northern San Jacinto fault, therefore, it is imperative that we address questions of data completeness and suitability ahead of time, so that we are prepared to collect data as efficiently as possible in the aftermath of a future event.

At the start of the project, a search of the UNAVCO and SCEC archives revealed 18 sites surrounding the San Jacinto valley and Anza segments of the San Jacinto fault that had not been surveyed since 2000. Nine further sites were identified that had only been measured in recent LiDAR ground truth surveys along the trace of the fault itself, and eight more potential targets, never surveyed before, from GPS from National Geodetic Survey benchmark lists. These sites are located at distances from less than 1 km up to 20 km from the surface fault trace, and fill in the gaps between continuous GPS sites from the Southern California Integrated GPS Network (SCIGN) and Plate Boundary Observatory (PBO). As resolution of slip at all depths of a fault depends on surface observations across a wide fault-perpendicular aperture, observations from these off-fault sites will be important for constraining (in particular) deep coseismic slip and/or postseismic afterslip in the event of an earthquake on either or both segments of the fault.

Figure 1: A typical setup of our field instrumentation during a survey in the Anza Valley, CA. GPS Campaign station G077, near Anza, Riverside County, CA

The GPS resurvey

Field reconnaissance and resurveying of the selected sites was undertaken in two periods, from June–August 2008 (by A. M. and G. F.), and from November 2008–February 2009 (by B. L.) Of the 35 sites targeted in our fieldwork, 13 were not found or were found to be damaged beyond use, and one more (TEMO) was destroyed during the course of the project. The remaining 21 sites were surveyed (e.g. Figure 1) using the PI's equipment – six Trimble R7 receivers with Zephyr geodetic antennas, with Leica wooden tripods and tribrachs. Details of the sites surveyed, along with dates of most recent surveys and the condition of the marks are listed in Table 1; the locations of the sites are shown in Figure 2.

Post-acquisition, data were recovered from the receivers, and converted from the proprietary Trimble format to RINEX format the UNAVCO 'teqc' software. For a preliminary look at the data, we use the Jet Propulsion Lab's (JPL) Automated Gipsy (AG) service to calculate position and covariance matrices from these RINEX files. Estimates of station velocity are computed using our own linear recursive (Kalman) filter code. It is clearly not possible to derive velocity estimates from stations that have only a single occupation, but we can derive velocity estimates from some stations that have had two to three occupations in the last 10-20 years. Although velocities can be produced from such a temporally sparse dataset, clearly a more temporally dense set of data will greatly improve the accuracy and reliability of these estimates. An example time series plot from station G075 is shown in Figure 3.

We have created a website (http://waddle.ucr.edu/~brad; Figure 4) to disseminate information about our geodetic network, results from our surveys, and raw data in the form of RINEX files. In addition, site descriptions for all marks have been updated and/or revised to reflect their current status.

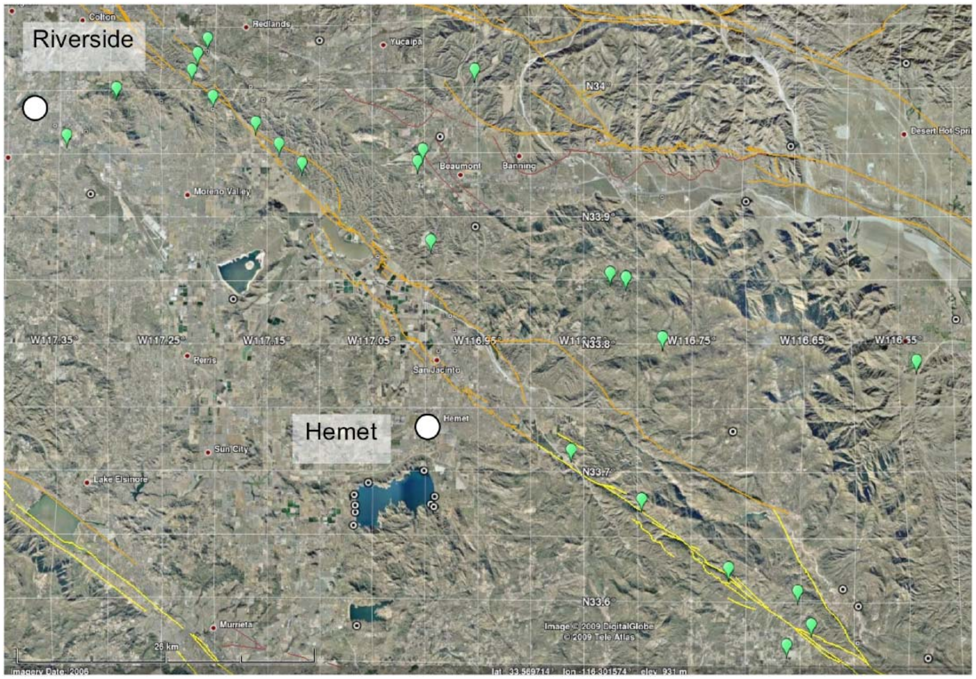
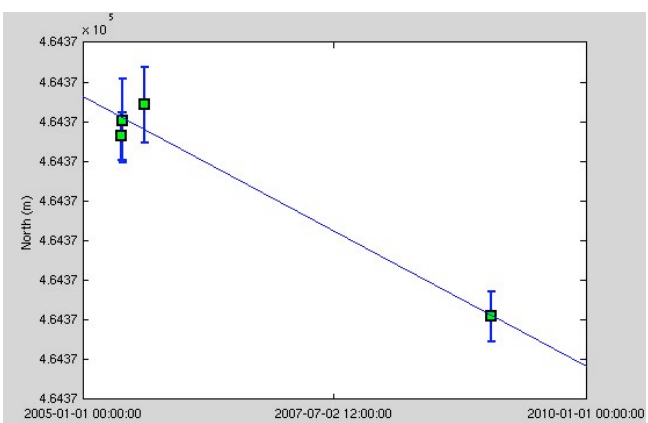


Figure 2: Region surrounding the San Jacinto Fault Zone, showing continuous, campaign, and disturbed GPS monuments. Faults are color coded based on last activity: Red being historically active faults, yellow, Late Quaternary, orange, Latest Quaternary, maroon, unclassified (source: USGS Quaternary Fault and Fold Database). Green markers show surveyed campaign GPS site locations. Circular markers show continuous GPS stations.

a. Northward component of velocity



b. Eastward component of velocity.

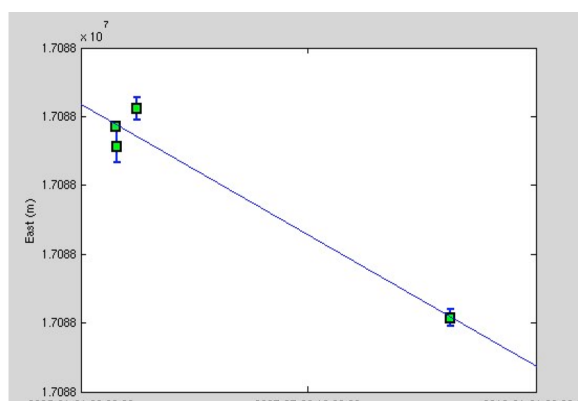


Figure 3: Time series of position estimates from campaign GPS station G075. Example coordinate time series. Velocity estimates are -6.79 mm/yr and -38.06 mm/yr with normed residuals 3.91 mm and 25.66 mm for the North (a.) and East (b.) components, respectively. These plots of station occupation through time illustrate the lack of temporal density of measurements in this network; the large residuals confirm the need for further repeat surveys in order to obtain more precise velocities.

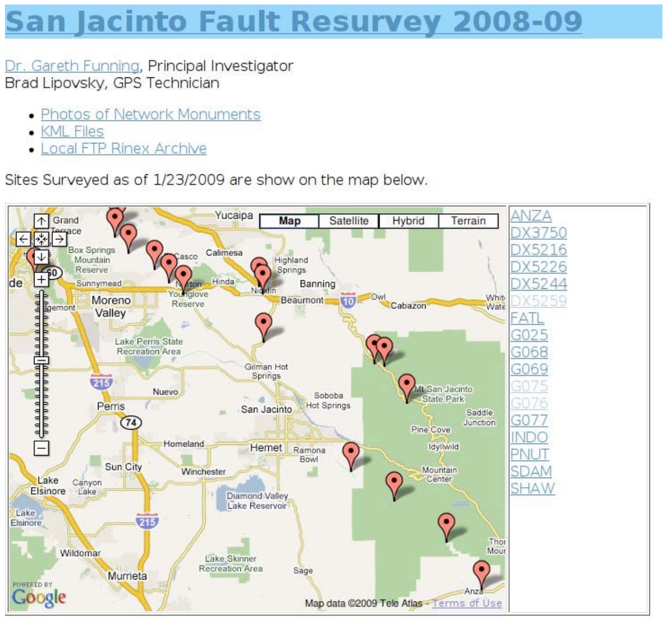


Figure 4: Screengrab from the San Jacinto fault geodesy website (http://waddle.ucr.edu/~brad).

Future Work

In order to more closely constrain long term and transient geophysical signals, we intend to continue to survey and expand our current GPS network. Increased spatial density will strongly benefit from the deployment of new monuments for use in geophysical GPS campaigns. The deployment of new GPS monuments should be guided by a study of optimal network configuration on finite faults (e.g. Blewitt, 2000; Lipovsky and Funning, manuscript in preparation, 2009).

Continued surveying should also allow us to place better constraints on the slip rate of the San Jacinto fault. Knowledge of slip rate is important for the robust estimation of accumulated strain, and to further refine seismic probability models. Estimates from fault system models range from 11.9 +/- 1.2 mm/yr (Meade and Hager, 2005, based on GPS velocity data) to 15.2 +/- 0.9 mm/yr (Fay and Humphreys, 2005, based on GPS velocities and geologic slip rate data). Geologic evidence may indicate an even higher slip rate – from analyses of ages from uplifted Quaternary channels, Kendrick et al. (2002) suggest that the spatiotemporal pattern of uplift seen may be consistent with a slip rate greater than 20 mm/yr, based on comparisons with elastic dislocation models. By reducing the errors in existing geodetic velocities, we will be able to refine, in turn, . Increased temporal density in GPS measurements, acquired through further data collection, will significantly improve the accuracy and reliability of our station velocity estimates.

Table 1: GPS campaign stations involved in our survey. Listing of campaign GPS monuments used in the present work. Station names noted with an asterisk are legacy names which have not yet been assigned a standardized four character abbreviation

Station Name	First GPS Survey	Status
PNUT	1990 Mar 05	Included in present work
METZ	1990 Feb 25	Included in present work
INDO	1990 Mar 01	Included in present work
TABLE*	2008 Jun 28	Included in present work
MCFN	1990 Mar 02	Included in present work
DX5226*	2009 Jan 20	Included in present work
TEMO	1990 Mar 05	Surveyed; subsequently found unusable
DX5216*	2009 Jan 20	Included in present work
0051	1990 Feb 25	Included in present work
BOTR	1990 Feb 21	Included in present work
G069	2005 May 25	Included in present work
ANZA	1990 Mar 02	Included in present work
SDAM	1990 Feb 26	Included in present work
SHAW	1990 Mar 05	Included in present work
G075	2005 May 24	Included in present work
G078	2005 May 24	Included in present work
G077	2005 May 24	Included in present work
G076	2005 May 24	Included in present work
DX3750*	2009 Jan 09	Included in present work
FATL	1990 Feb 26	Included in present work
G068	2005 May 25	Included in present work
G025	2005 May 25	Included in present work
G024	2005 May 27	Not found or found unusable
DX5165	-	Not found or found unusable
DX3749	-	Not found or found unusable
CABA	1995 Feb 18	Not found or found unusable
DX5246	-	Not found or found unusable
DX5241	-	Not found or found unusable
DX5242	-	Not found or found unusable
G070	2005 May 25	Not found or found unusable
G071	2005 May 25	Not found or found unusable
DX3478	-	Not found or found unusable
DX3737	-	Not found or found unusable
DX3817	-	Not found or found unusable
DX3805	-	Not found or found unusable

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