Using GPS to Monitor Elastic Strain on the San Andreas and Jacinto faults in the San Bernardino Area

Nicholas Vaughn

My internship was spent with Dr. Sally McGill, a Geology professor at California State University, San Bernardino. It was my job to assist her with the GPS Campaign that she runs twice a year, and then to compile and process the data that would be collected. I also had to repeat this task for the previous campaign data, to make sure it was all as up-to-date as possible and was all processed in the same manner.

The first three weeks of my internship were spent helping Sally with the Cal State San Bernardino GPS Campaign. I arrived a week before all the participants to help Sally calibrate the equipment and make sure it was all in place. I also practiced setting up the receivers over benchmarks, so I could help demonstrate it for the other participants.

During the actual GPS Campaign, I went to my site where my partner and I would set up our equipment over the benchmark, make sure it was collecting data, and then we'd just sit around for several hours until the afternoon crew arrived to relieve us. We did that for five days. Once all the data was collected, Sally held a workshop explaining what all the data meant and showed us how we might model it. That was a hint of what I would be doing later in the summer.

As soon as the GPS Campaign was over, I was given my real summer task. It would be my job to compile all the GPS data CSUSB had collected for the past 5 campaigns. They have done a summer and winter campaign every year since 2002, and only bits and pieces of their data had been analyzed and processed. Sally wanted me to take what had been processed, along with what had not, and compile it all into one large file so all the information was at her fingertips.

After about a week, I had records from all the data previously processed in one master file and could begin processing the data that hadn't been. To process the GPS data, I had to FTP the Rinex file (the file that contains all the data collected each day by the receivers) to a server at CSUSB. Then I would email that FTP address to Auto GISPY, a service from Jet Propulsion Labs specifically designed for this sort of work. Auto GIPSY could figure out coordinates for where our receiver was and those would be put on JPL's FTP site. After I retrieved those, I could add that data to the spreadsheet.

Unfortunately, we hit several snags with this process. The most common issue we had was when JPL would fail to process our file. For whatever reason, it was an "ill-formatted Rinex file" and as such we couldn't get results. In the future, Dr. McGill will try using teqc to make the Rinex files instead of using the Ash2Rin software that came with the receivers. Perhaps AutoGIPSY will not find formatting problems with Rinex files created by teqc. Occasionally, JPL would send us results but after we retrieved them, they were incomplete. We also had instances where the data set we received was complete, but it was very inaccurate. The error bars would be in the thousands of meters. These problems probably arose when AutoGIPSY was unable to find a consistent solution to the data. In some cases these problems were due to an incorrect day number in the Rinex filename. Two of the nine receivers used were an older model, which would name the data file with the day number at the time the instrument is turned off. In some cases this turned out to be just after midnight, Greenwich Mean Time, and so the file only contained a few minutes of data from the day for which the file was named. Most of the data in the file was for the previous day, yet AutoGIPSY only retrieves the orbital data based on the day number in the file name. Thus AutoGIPSY may not have had sufficient data to find a consistent solution for those files. We fixed the day numbers in the file names and this solved some of the problems with incomplete and inaccurate output, but not all of them. In the end, we didn't find an answer to all of our problems, but we did find an alternative.

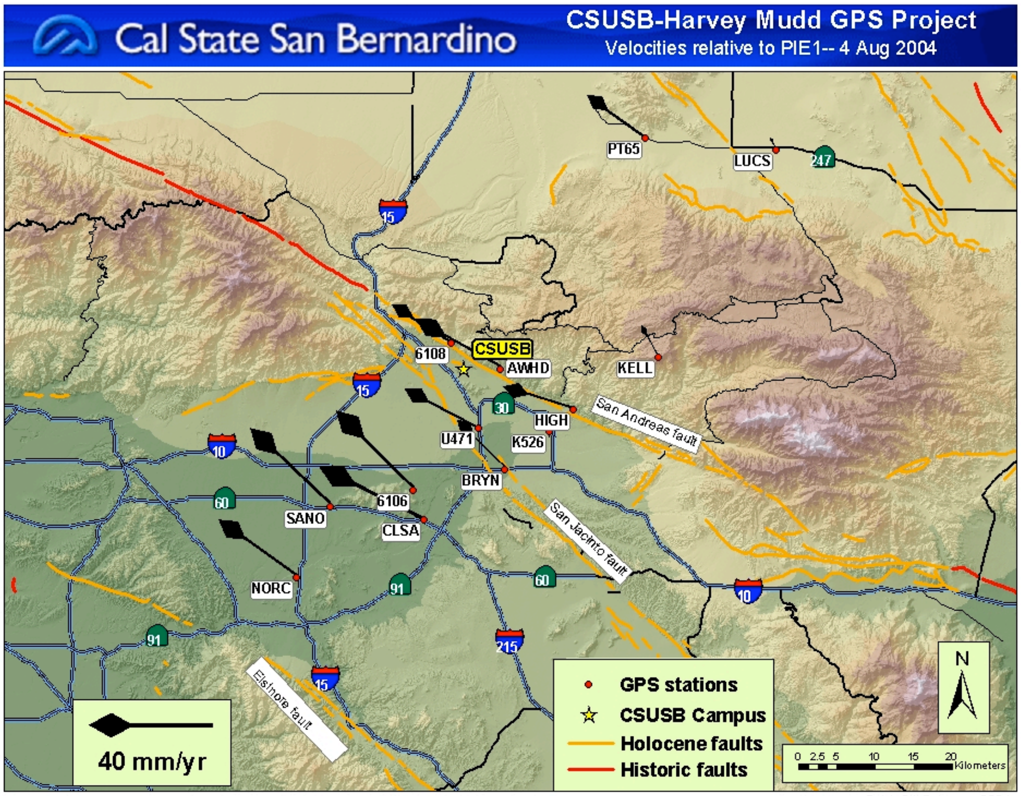
The alternative was called SCOUT, a service of the SOPAC website. We could submit Rinex files to SCOUT and it would send us back results in terms of latitude and longitude. While we don't yet have a way to convert these coordinates into the UTM coordinates that we were previously using, Sally believes there is a method to convert them and is in the processing of finding someone who can offer assistance.

In the end, approximately 70% of our files have been processed by JPL's Auto GIPSY. The results we have received are good for the most part, but don't completely fit our hypothesis. Of the 11 sites, most have good-to-average correlations between time and velocity in both North and East (see figures 3-5). Unfortunately, some of the sites have a very large scatter in the data and therefore a very low correlation.

Using a GIS Image created by Tom Baker and Sally McGill (Figure 1), the velocities of all our sites relative to the permanent GPS station PIE1 are shown. PIE1 was chosen because we wanted to show our velocities relative to the North American plate and PIE1 is a permanent GPS station in New Mexico. According to this model, all of the sites are moving in the direction that we predicted. However, some of them, including PT65 and AWHD are moving considerably faster than we had expected. There are a few possibilities for the scatter. The first, and most obvious, is that 30% of our data is still missing. With more data to plot, the graphs might clear up a bit.

Another graphic of the data, the CSUSB GPS Data graph (Figure 2) shows the distance of the sites from LUCS along a transect and also their velocities. The graph also shows a curve showing what the expected velocity would be for one possible combination of slip rates and locking depths for the faults that cross this transect. Our model is simplistic and assumes that all the faults are parallel to the transect. Slip rates used for the Helendale, San Andreas, and San Jacinto faults were 2 mm/yr, 25 mm/yr, and 15 mm/yr, respectively, with a universal locking depth of 15 km. This observed GPS velocities fit our predicted model fairly well. We expected low velocities close to LUCS with a relatively steep curve around 46 km, where the transect crosses the San Andreas. We then expected the curve to level off around 65 km. It seems our points on the graph that have the largest error bars are also the sites that have a smaller amount of data. This model is only shown as a reasonable estimate based on the data we had available. Though we could have tried many more locking depths and slip rates, we felt it would be a bit premature to do so, with 30% of our data still unprocessed. Again, PT65 does not seem to fit our projected model (see Figures 2 and 5). Its velocity is anomalously high for its relative location to LUCS. This anomalously high velocity is partly the result of a single data point from 1999, which may be skewing the slope of the line in figure 5. This data point is from data collected by others and available at the SCEC data center. If this data point is omitted, then the velocity of PT65 would be lower.

The results we received from the project were fairly good, but not as good as we had hoped for. Most importantly, we would like to continue doing the GPS campaigns and collect more data. In terms of the data we currently posses, hopefully we can discover a means to process all of the Rinex files which should help reduce the scatter.



S. McGill 5 August 2004

Figure 1 – A GIS Model of the area studied with all relevant faults displayed and velocities for each of our sites. These values are in relation to GPS station PIE1.

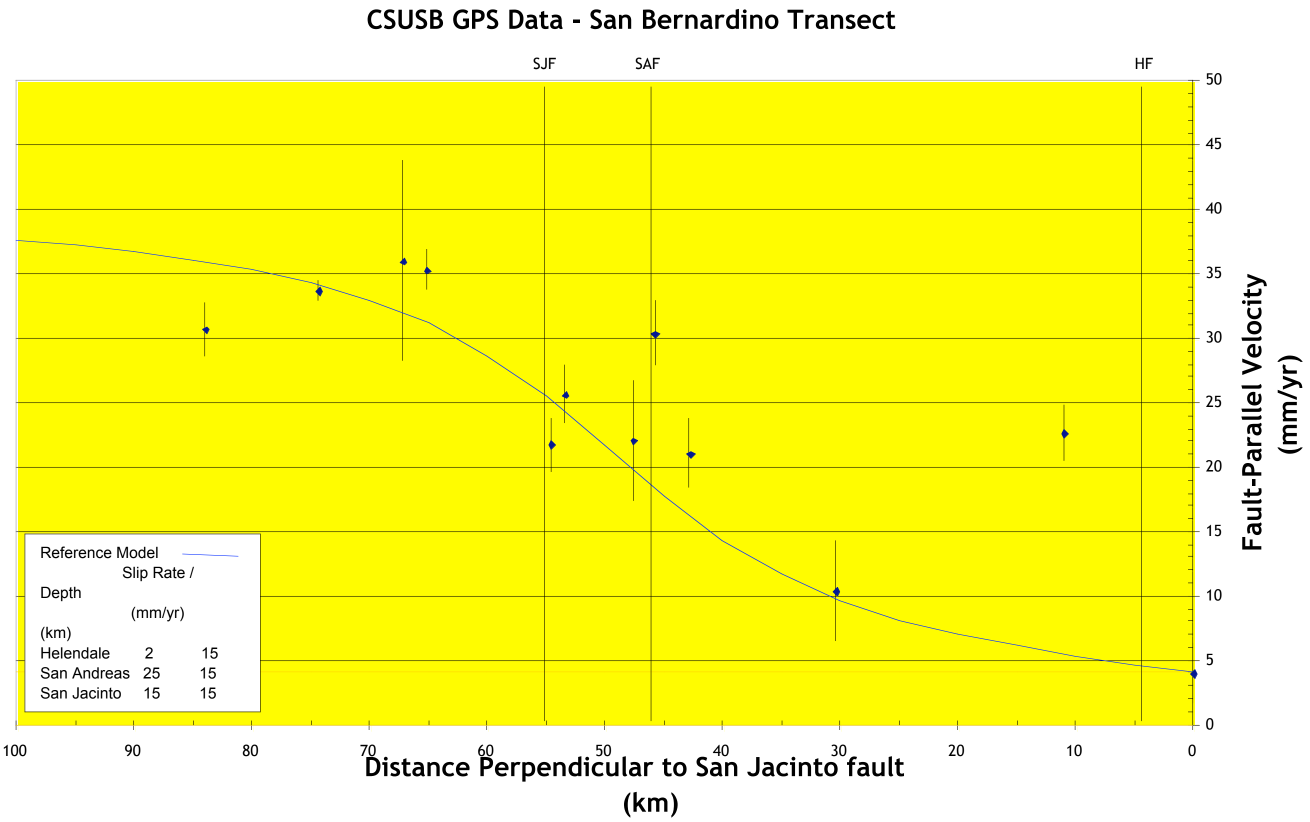


Figure 2 – A graph displaying the Fault Parallel Velocity against the perpendicular distance of each site relative to the San Jacinto fault.

Figures 3 to 6 – The following are the position vs. time graphs for the North and East velocities of several sites. Figures 3 and 4, 6106 and SANO, are examples of sites with a good correlation, whereas 5 and 6, HIGH and PT65, are examples of sites with a large amount of scatter in the data.

Figures 3a – 6106 North

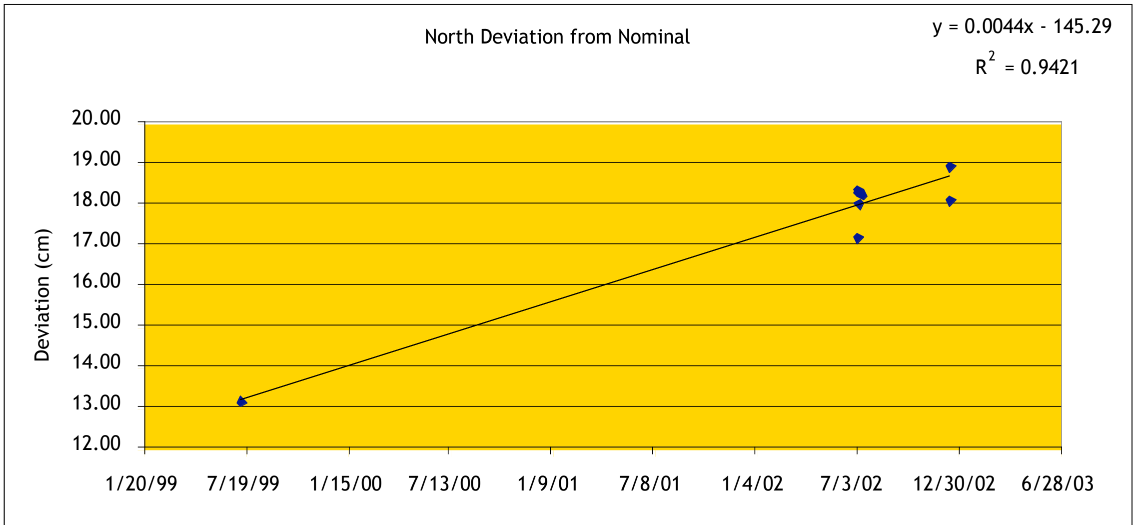


Figure 3b – 6106 East

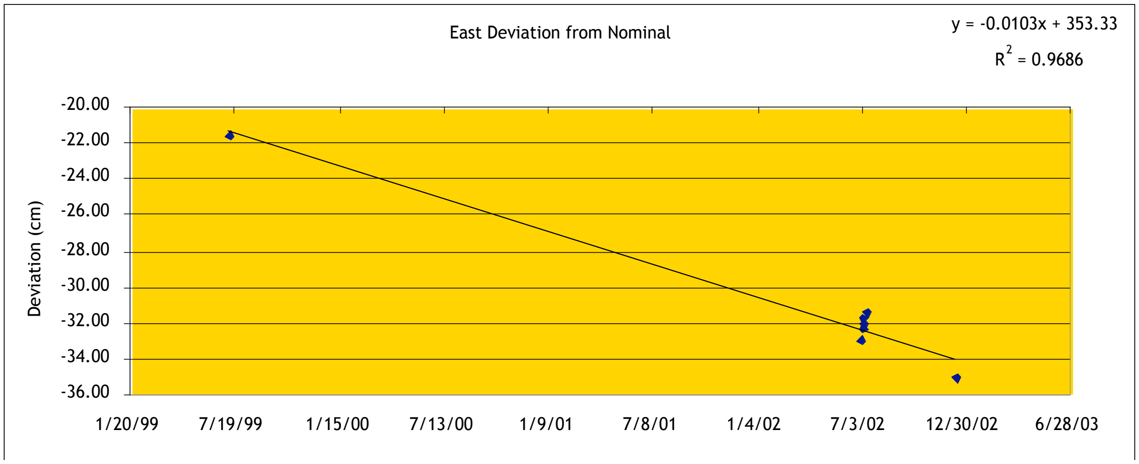


Figure 4a – SANO North

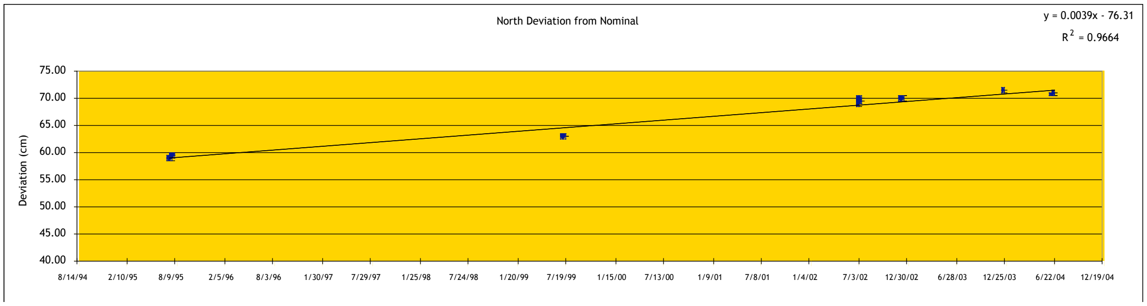


Figure 4b – SANO East

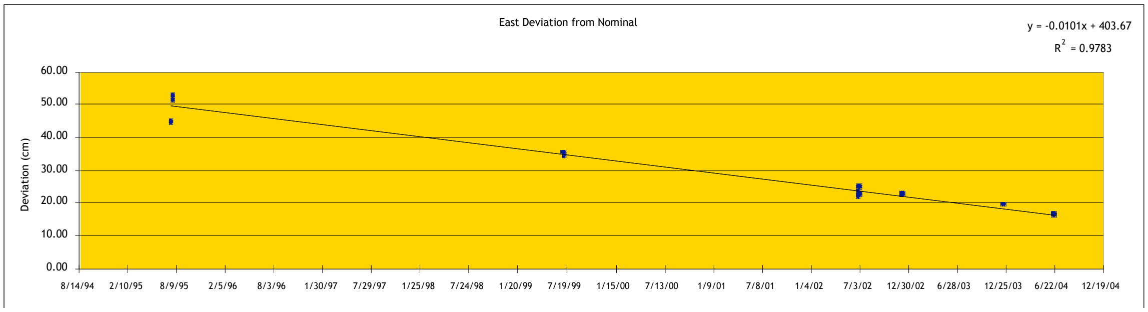


Figure 5a – PT65 North

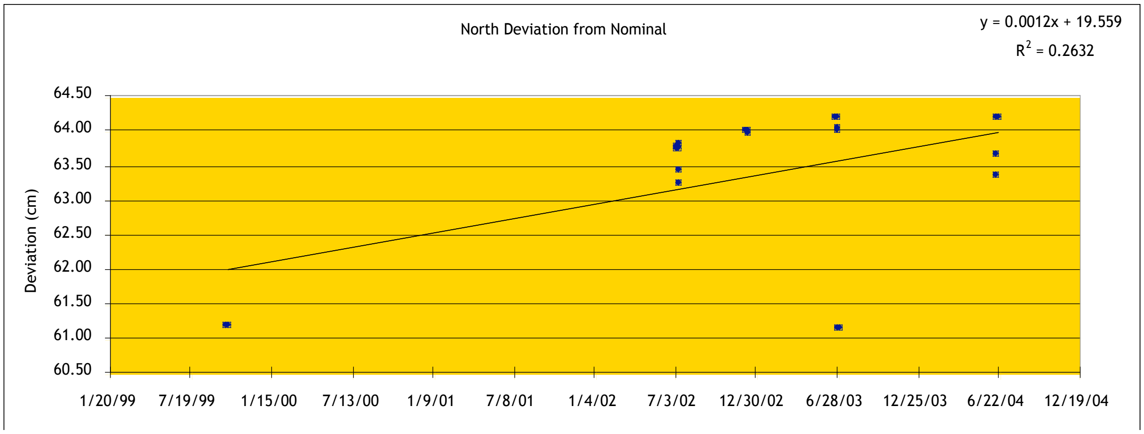


Figure 5b – PT65 East

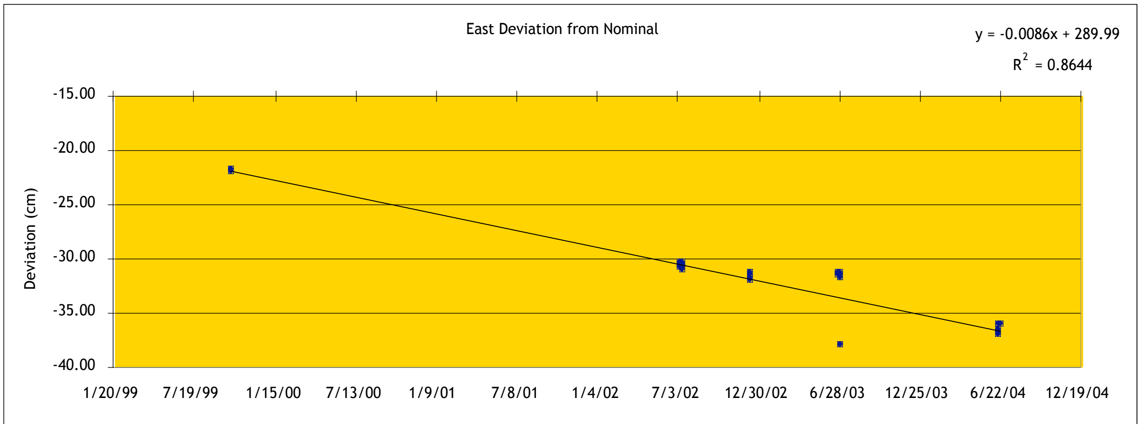


Figure 6a – HIGH North

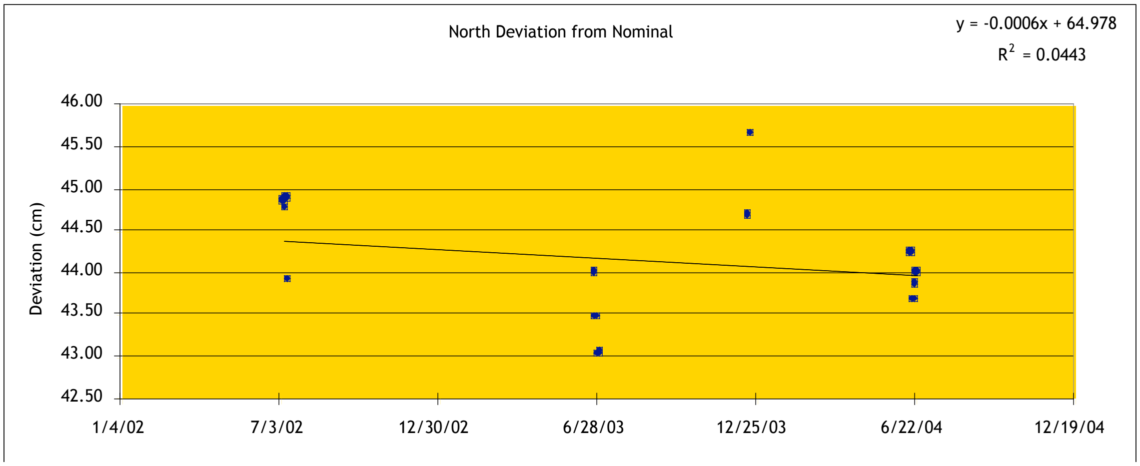


Figure 6b – HIGH East