Technical Report:

Effect of Loading-Induced Horizontal Deformation on the Community Geodetic Model

We summarize here 2 sub-studies that we undertook as part of this project.

A. Correlation of Atmospheric Pressure Loading Model to GPS Stations in the Eastern Nevada Region – Project performed by undergraduate student at UNR

Atmospheric pressure loading (APL) has previously been detected in GPS position time-series, accounting for a portion of the overall variance. In theory, removal of APL on the GPS time-series should improve local and regional analysis of tectonic and transient signals. The Global Geodetic Observing System (GGOS) APL model provides the expected surface displacements due to pressure systems. This model shows primarily vertical effects from APL with a range of +/- 20 mm while the horizontal components only amount to +/- 2 mm. Modeled pressure fronts appear on both local and continental scales with maximum displacements lasting hours to days. This model is analyzed using Nevada Geodetic Laboratory stations in the IGS08 reference frame. The thirty-eight stations in the study area are located in the eastern Nevada region, where environmental and hydrological noise is low and where potential topographic effects on the pressure systems are expected small. The correlations for the detrended data and the model, with the seasonal signal removed, are calculated using the Pearson correlation as well as with principal component analysis. Results of the correlation are positive, but weak, with an average of 0.07 and a maximum of 0.21 when the seasonal signal is removed. Maximum correlations are found to be independent of location, with close proximity stations showing varied correlation values. The second principal component of the detrended data was found to match the first component of the seasonal removed data with results matching the Pearson correlation. Further removal of additional causes of variance may improve the distinction of APL in the GPS signal. An example of our results is shown in Figure 1. In Figure 2 we show an intriguing observations that the correlation between the observed vertical displacements and the APL prediction is consistently larger if we shift the model one day forward. We have not yet an explanation why APL may have a delayed instead of a purely instantaneous elastic response.

B. Evaluating Seasonal Deformation in the Vicinity of Active Fault Structures in Central California Using GPS Data – Project performed by graduate student at UNR

We analyze eight-years (2008 – 2016) of GPS data in order to develop a robust seasonal model of dilatational and shear strain in Central California. Using an inversion, we model each GPS time series in our study region to derive seasonal horizontal displacements for each month of the year. These positions are detrended using robust MIDAS velocities, destepped using a Heavyside function, and demeaned to center the time series around zero. The stations we use are carefully chosen using a selection method which allows us to exclude stations located on unstable, heavily subsiding ground and include stations on sturdy bedrock. In building our seasonal strain model, we first filter these monthly seasonal horizontal displacements using a median-spatial filter technique called GPS Imaging to remove outliers and enhance the signal common to multiple stations. We then grid these seasonal horizontal filtered displacements and use them to model our dilatational and shear strain field for each month of the year.

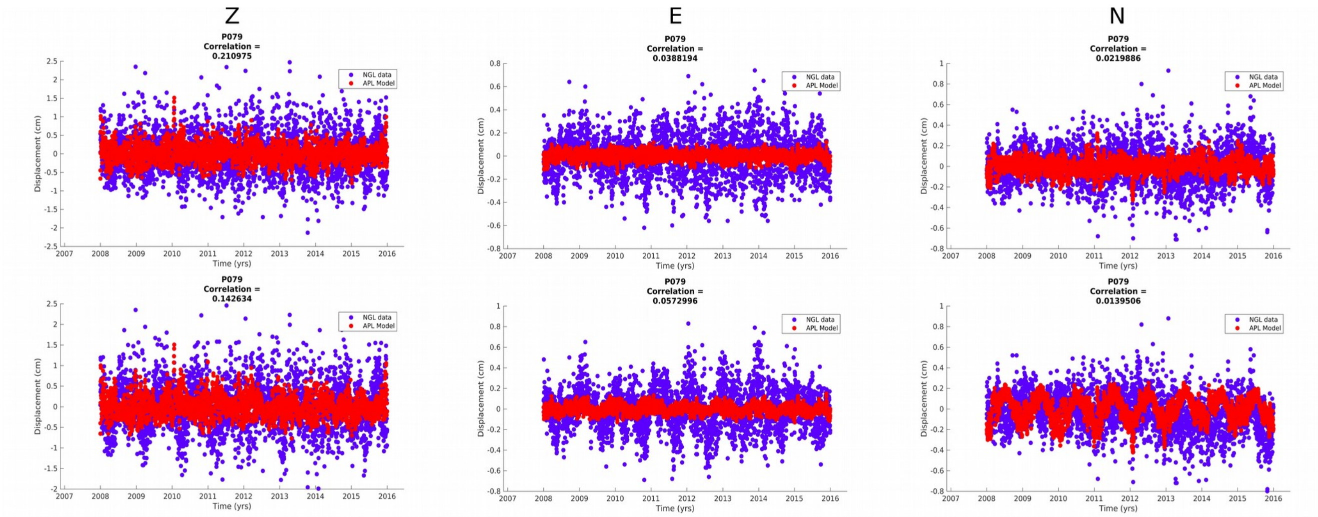

Figure 1: *Observed time-series (blue) and predicted displacements due to atmospheric pressure loading (APL; red) for station P079. Columns are different components, and top row has an annual signal removed from the data and model. Correlation coefficients are indicated at top of each panel.*

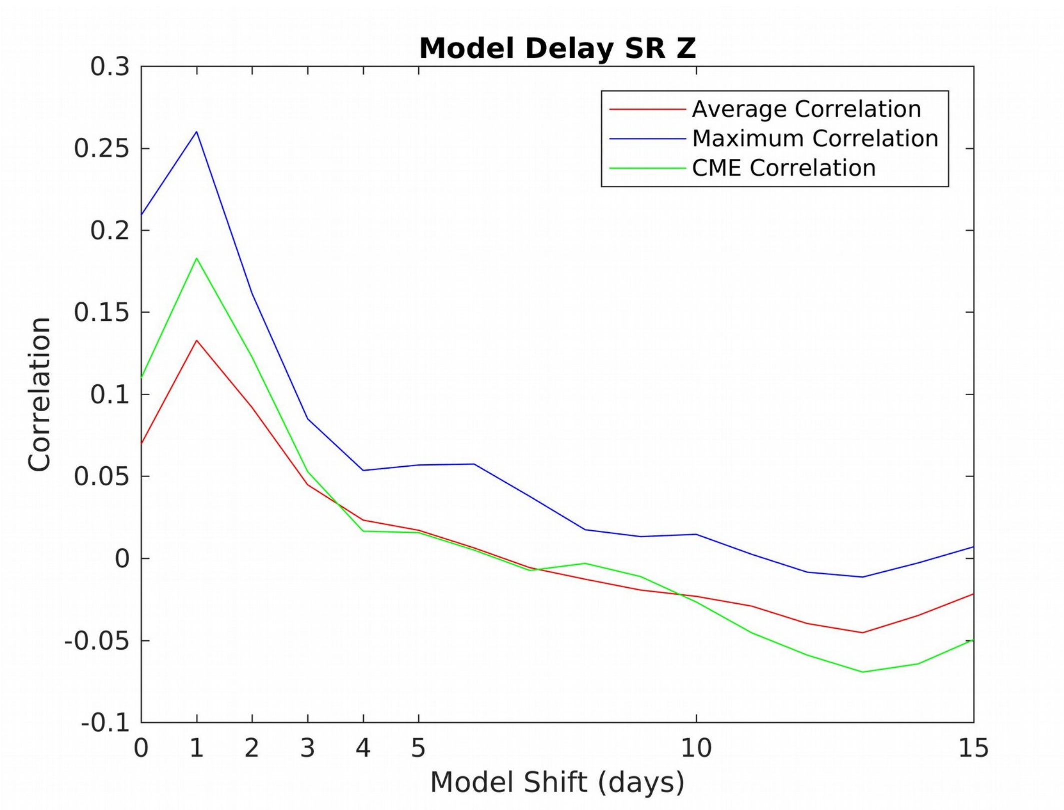

Figure 2: *Correlation coefficients between vertical time-series and APL predictions as well as the region's common-mode error (CME) and APL as a function of a positive time-shift in the data. The results suggest that APL may have a 1-day delayed effect on crustal displacements. This results needs further investigation.*

We setup our model such that a large portion of the strain in the region is accommodated on or near the San Andreas and Calaveras Faults. We test this setup using two sets of synthetic data and explore how varying the a priori faulting constraints of the on and off-fault standard deviations in the strain tensor affects the output of the model. We additionally extract strain time series for key regions along/near the San Andreas and Calaveras Faults.

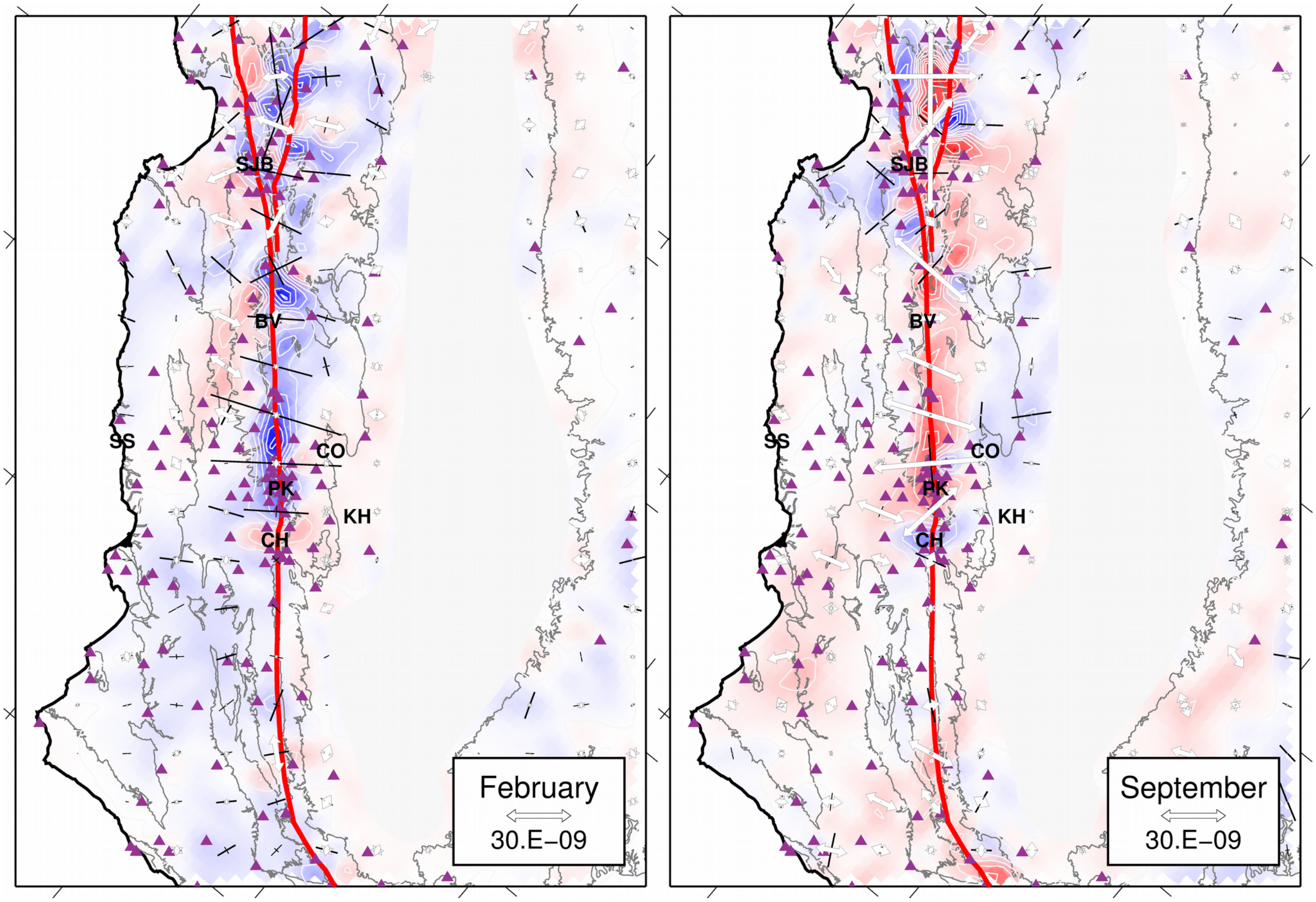

Figure 3: *Contours of dilatational strain (red is positive/extensional, blue negative/compressional) for the central San Andreas Fault (shown in oblique Mercator projection). Also shown are principal strain axes, as well as GPS locations (triangles). Left panel is monthly displacement derived from seasonal model for just the month of February, and right panel is for September (see text for details). Note the large seasonal variation along the creeping segment and the absence thereof along the locked section.*

Our strain model shows that the majority of the seasonal strain peaks in the negative dilatational strain component during the February/March wet season and in the positive dilatational strain component during the August/September dry season along the frictionally weak, main creeping section of the San Andreas Fault (Figure 3). The north transitional creeping zone along the San Andreas Fault and the Calaveras Fault display general similarities with this trend. The southern-half of the San Andreas southern transitional creeping section displays a small opposing anomaly, with peak positive dilatational strain in the February/March wet season and peak negative dilatational strain in the August/September dry season. Only a small amount of positive dilatational strain appears in the frictionally strong, locked section south of Cholame during the month of June. Otherwise seasonal strain in this section of the San Andreas Fault is virtually undetectable by GPS measurements. The observed spatial and temporal variation in fault-normal extension is roughly consistent with the rate of small earthquakes. We postulate several hydrologic causes for this seasonal signal, which we plan to explore further in future work.