Collaborative Research (USC): Geodetic Analysis of Three-Dimensional Active Faulting in the Ventura Basin

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Non-technical Summary: Data from the continuous GPS network SCIGN can be used to constrain models of fault geometry and fault slip rates, both of which are important input parameters for seismic hazard assessment. First, however, we must filter the time series in the best way possible to remove any deformation signals not due to fault motion or tectonic strain, e.g. changes in the local groundwater storage. This work presents a test case of using principle component analysis as filtering technique for GPS time series, which works well for removing non-tectonic noise when the noise is not consistent from station to station.

Results: The mitigation of future earthquake damage relies on accurate prediction of earthquake source characteristics including fault configuration and slip rate. The three-dimensional configuration of active faulting in the Ventura basin is partially constrained by seismic reflection, well control, and predictions of fault geometry using cross-section restoration. However, critical elements of the fault system that control seismic hazard estimates remain unresolved. In order to validate proposed fault models and fault slip rates of the Ventura basin faults we will utilize the geodetic data available from the Southern California Integrated Geodetic Network (SCIGN) in conjunction with 3D mechanical models.

The currently available geodetic data measures ground deformation with unprecedented spatial and temporal resolution. However, it is important to remove non-tectonic signals from the GPS time series since these are almost certainly caused by fluid removal or injection into the ground, and are not related to fault motion. We have analyzed the GPS time series using a combination of filtering techniques to remove these non-secular motions. Since one of the filtering techniques is somewhat new, we tested how it worked on synthetic time series to ensure the filtering did not add artifacts to the time series or otherwise bias the tectonic motion. Graduate student Ken Austin spent the year writing the programs to perform the analysis and display the time series, testing these programs on the synthetic time series he constructed, and reporting the results at SCEC, UNAVCO, and AGU meetings.

In order to remove the groundwater or atmospheric signals in the time series, which often vary seasonally, a principal component analysis (PCA) approach [*Aoki and Scholz*, 2003; *Savage*, 1995; *Savage and Thatcher*, 1992] was used to identify the primary temporal modes of the signal. This method is useful for resolving simultaneously observed data into a superposition of several orthogonal common modes and we have tested its usefulness for removing non-tectonic signals from GPS time series [Austin and Owen, abs, 2004]. By using a PCA instead of a traditional sinusoid fit, we avoid the a priori requirement that the non-tectonic motion is a sinusoid with constant amplitude.

We ran tests on synthetic time series where we could test how well we can recover the long-term velocity (i.e. tectonic motion) from the synthetic time series when we add noise and seasonal signals. The synthetic time series contained white noise, as well as linear and sinusoidal trends that varied in both sign and magnitude (figure 1). In most cases a portion of the sinusoidal signal carried through with the linear trend, however we have found that the PCA is most effective at separating the tectonic and seasonal components when the seasonal signals vary in temporal phase at the different sites.

The next step was to apply the PCA filtering to the GPS time series from the Ventura region. In figures 2 and 3 we show preliminary results from our analysis of SCIGN stations in and around the Ventura basin. In order to avoid the redundancy of reprocessing the initial network data, we are using the unfiltered time-series products available from both SCIGN processing centers, JPL and SOPAC. The position estimates from the SCIGN network data from the two processing centers have been shown to be in good agreement, with mean differences between the two processing centers being about 0.1 mm in the horizontal and 0.5 mm in the vertical. We remove the common mode bias [Wdowinski et al., 1997] before applying the PCA. The estimated horizontal and vertical velocities are shown in Figure 2, and two examples of the time series filtering are shown in Figure 3.

Figure 1.

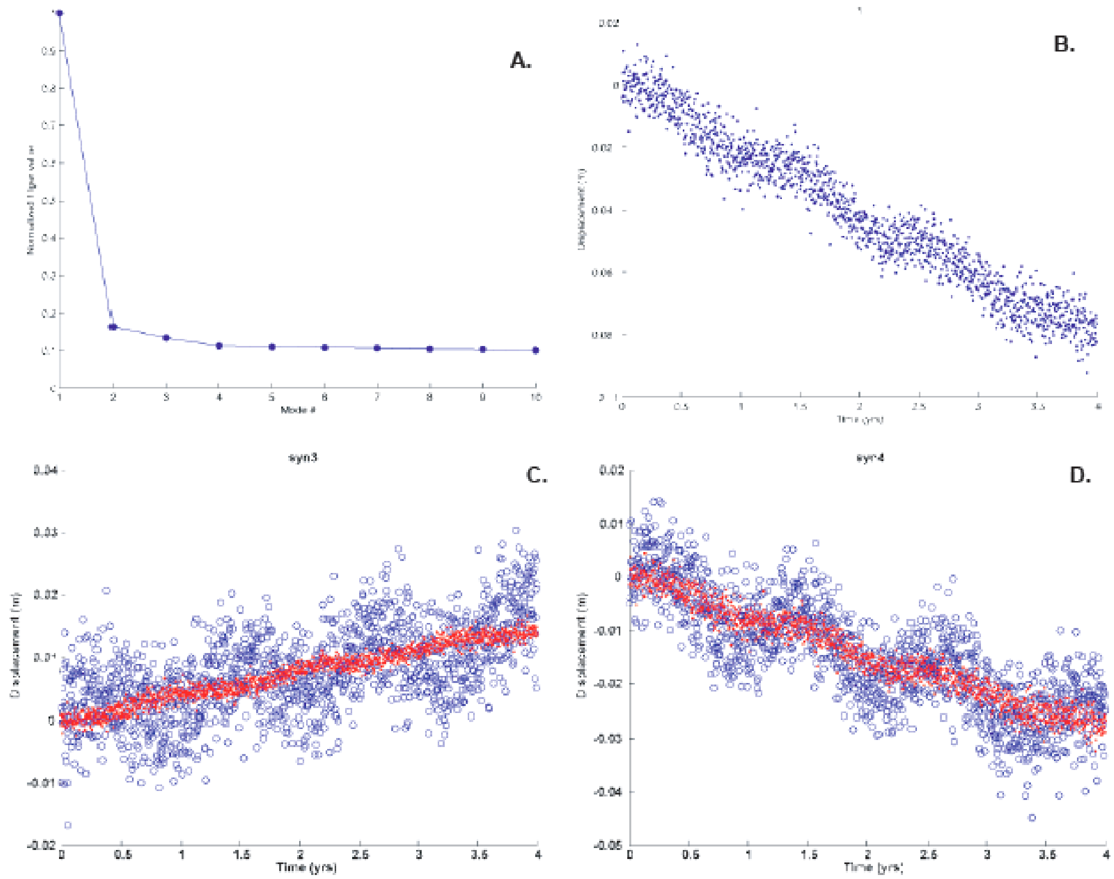

Figure 1. Results of an analysis of a synthetically derived set of time-series, consisting of random noise, a linear trend and 2 sine functions. (A) Plot of normalized eigenvalues of each of the principal components. Mode 1 accounts for approximately 80% of the signal. (B) Plot of the first principal component, the pattern is mostly linear with some portion of the sine functions coming through. (C) Synthetic station 3 with the original data in blue, and the filtered data in red. (D) Synthetic station 4, original data is blue, filtered data is red.

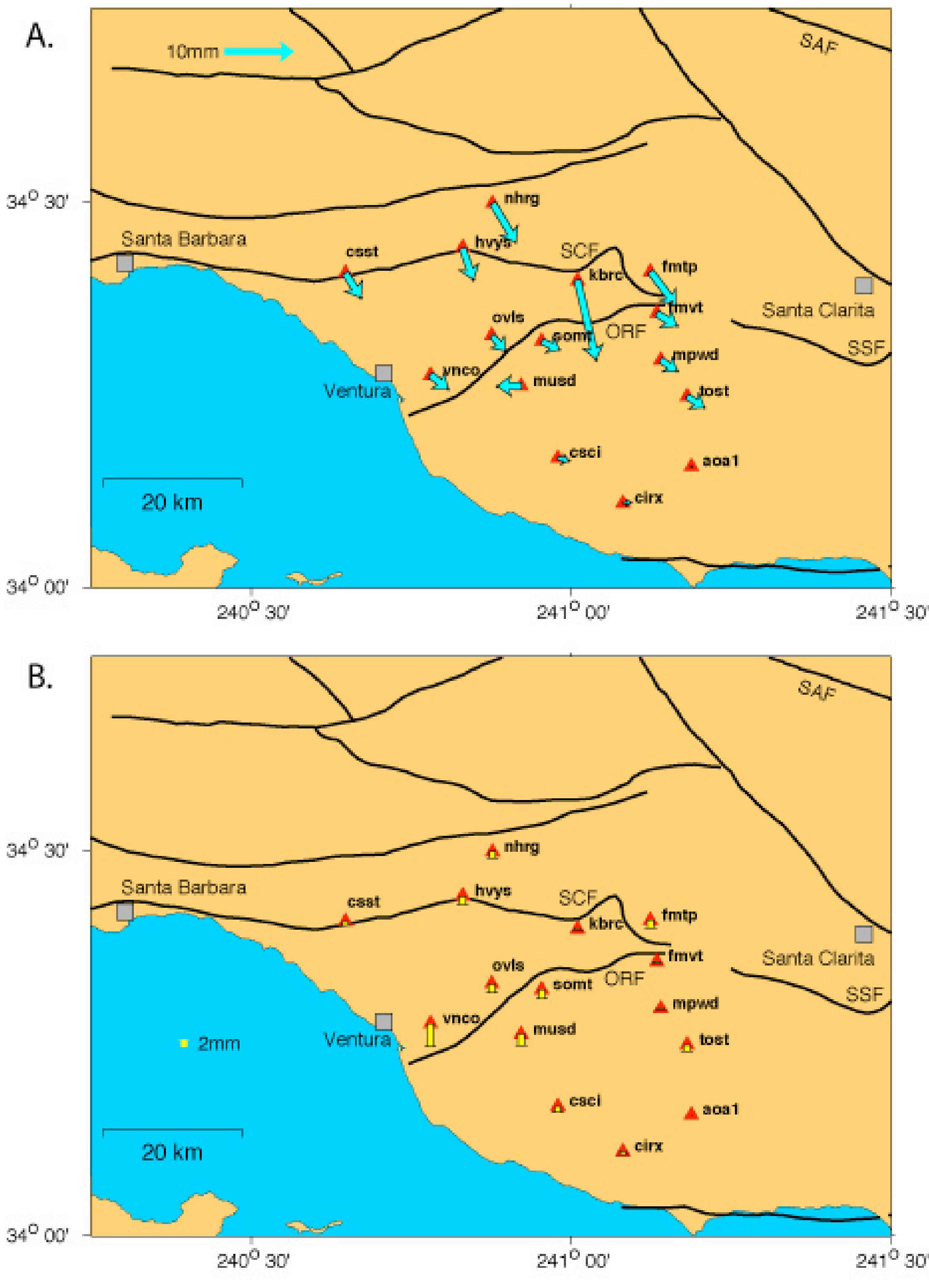

Figure 2. Horizontal (a) and vertical (b) velocities after applying common mode bias and PCA filtering to SCIGN time series. Velocities are shown relative to AOA1.

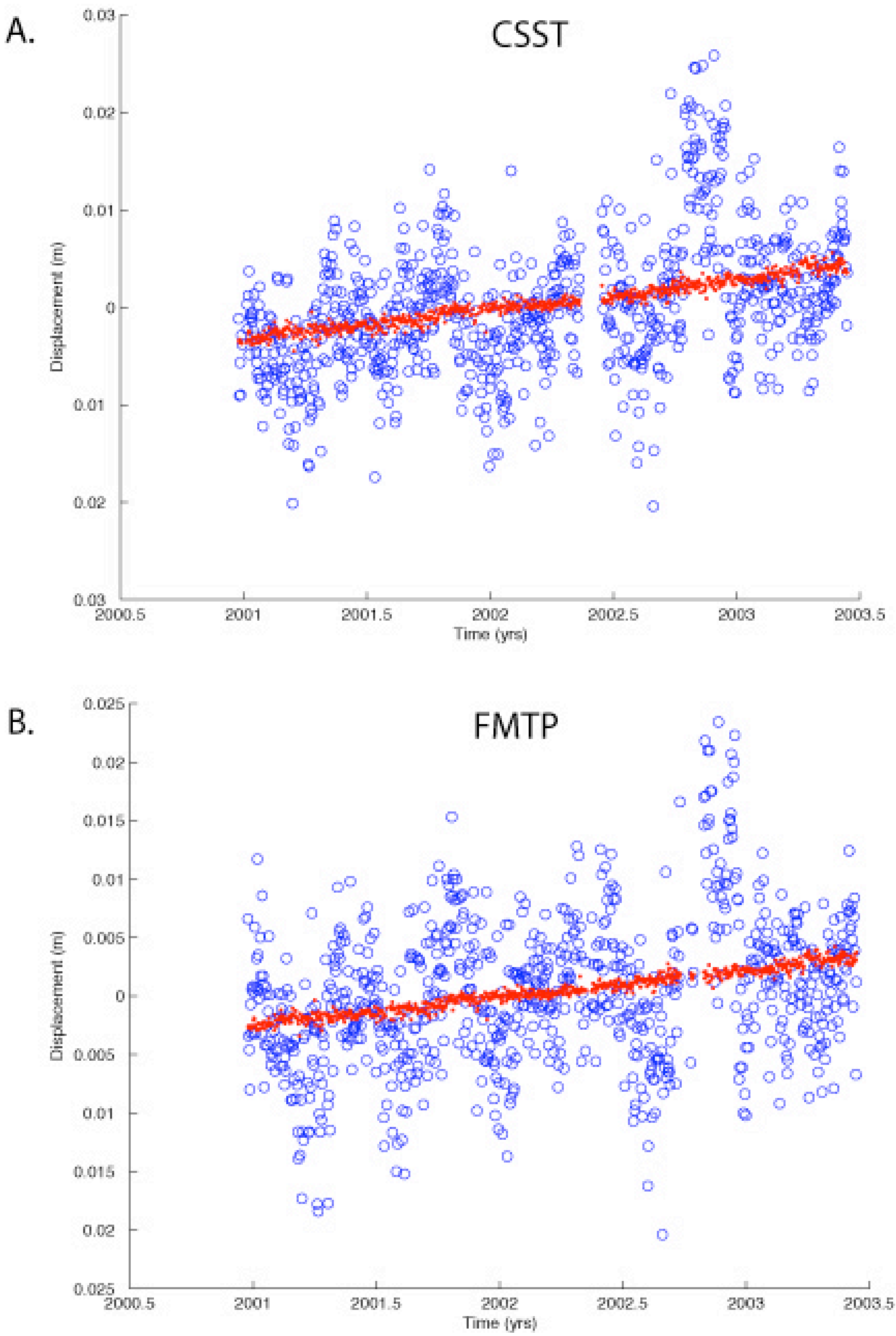

Figure 3. Original (blue circles) and filtered (red dots) time series for two of the Ventura region sites.

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Data Availability: Filtered time series for the Ventura region GPS sites are available (as ASCII files) upon request from Professor Susan Owen, phone number (213) 740-6308 and email owen@terra.usc.edu.