Final Technical Report

Award Number:	02HQR0017
Project Title:	Collaborative Research with UCLA and University of Nevada, Reno: Regional stress evolution model and differentiation of afterslip and viscoelastic relaxation processes of Landers and Hector Mine earthquake sequence
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Abstract

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We have derived a crustal deformation field in the Mojave Shear Zone and its vicinities for the time period of 1970-2004 using all the EDM and GPS data observed in the region available to us. The deformation field is composed of two parts. The first part covers a time period prior to the Landers earthquake 1970-1992.5, and the deformation field was modeled as steady, reflecting the long term secular deformation in the region. The second part covers a time period from the Landers earthquake to 2004, and the deformation field includes, besides the secular deformation, the coseismic jumps and postseismic displacements of the 1992 Landers and 1999 Hector Mine earthquakes. The postseismic deformation is best modeled as a logarithmic function, with a universal decay time constant of 10 days. The postseismic deformation fields of the two earthquakes mimic the coseismic deformation patterns, but with much smaller amplitudes. The resolved secular velocities, coseismic jumps, and postseismic displacements are listed in tables for further studies of stress/strain evolution, fault zone rheology, and earthquake interactions of the region.

Report

This project is composed of two parts. The first part is about production of the crustal deformation field pre- and post-Landers earthquake in the Mojave Shear Zone, which was performed mainly at UCLA; and the second part is about modeling the deformation field to infer the associated mechanisms, which was conducted mainly at the University of Nevada, Reno. This report describes mainly the portion of works done at UCLA.

Derivation of Secular Velocity Field in Mojave Shear Zone and its Vicinities

We have derived a secular velocity field in the Mojave Shear Zone and its vicinities using all the GPS and EDM data available to us. This work has been done along with the endeavor by the Southern California Earthquake Center to produce a series of Crustal Motion Maps, for which the PI was also a major participant. Some of the works, however, were particularly done for this

project. This velocity field is vitally important for this project for the definition of pre-Landers background deformation field, in order to isolate distinctively the postseismic deformation signals. This task was done through taking the following measures to complete the pre-Landers GPS processing and integrating GPS and EDM data into a consistent solution with a spatial coverage broader than that of their separate solutions.

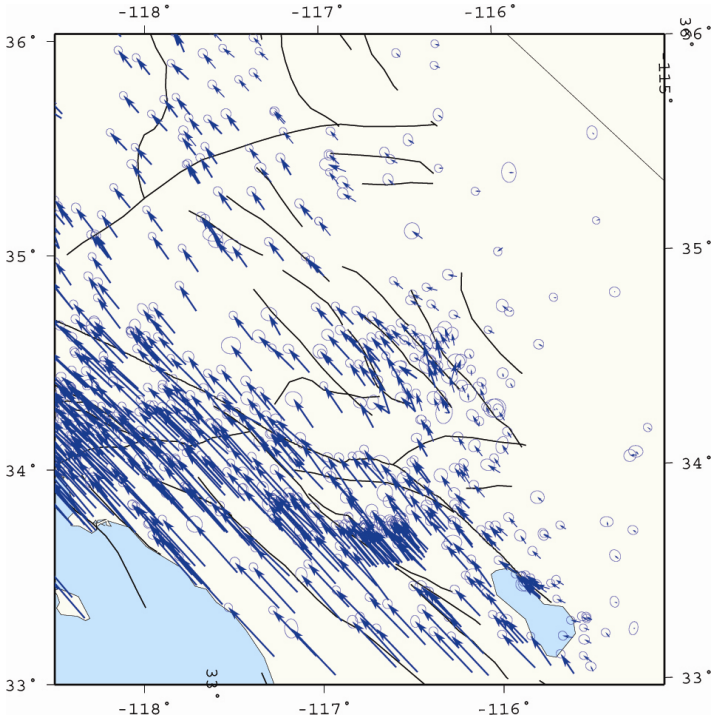

Figure 1. Secular velocity field in the Mojave Shear Zone and its vicinities derived using GPS and EDM datasets. Error ellipses are 95% confidence.

1. GPS data collection in the Mojave Shear Zone region started in the late 1980s and early 1990s. The early data, however, were quite heterogeneous in several folds. One of the problems involved was that multiple GPS receiver types were used, some of which were not quite compatible with each other in terms of observational epoch synchronization (some epochs were off by almost one second). Such off-synchronization resulted in difficulty in forming double-differences during data processing. We regrouped the data according to their observational epoch time tags, and processed them separately using the GAMIT software. The output files were loosely constrained separate solutions, which were subsequently combined using the GLOBK software. Baseline repeatability has been improved, particularly among the sites observed using the similar types of GPS receivers.
2. Another problem we discovered and dealt with was an observational time tag offset between the L1 and L2 phase data for the early L series of Ashtech receiver units, used by the USGS and some county surveyors in the early 1990s. Such an offset was found to be about 30 milli-second, enough to cause positioning bias up to 10 millimeters. We imposed a time tag shift of 30 milli-second for the L2 phase data, and successfully surpassed the resultant biases.
3. The third problem we coped with was severe GPS signal degradation due to implementation of Selective Availability (SA) in 1990 and 1991. Although SA would have only short term

effects for data time series, it dizziered the GPS signal carrier frequency to such a degree that automatic cycle slip fixing became unreliable. We ended up with hand-fixed the cycle slips existed in the carrier-beat phase data observed from several GPS campaign surveys conducted in 1990 and 1991, providing critical estimates for pre-Landers epoch positions for sites such as Sandhill, located only about 10 km east of the epicenter of the 1992 Landers quake.

4. Combination of pre-Landers GPS and EDM solutions. We have combined the pre-Landers GPS and EDM velocity solutions to obtain a broadly covered pre-Landers secular velocity field in the Mojave Shear Zone and its vicinities. The EDM solutions were obtained from the Crustal Motion Map project of SCEC. Station velocities were tied together for GPS and EDM at some collocated stations located outside of the Landers epicentral area, to provide a stable reference frame for EDM velocities within. The resultant velocity field is shown in Fig. 1 and listed in Table S1 at http://scec.ess.ucla.edu/~zshen/sca_postseis.html.

Derivation of Landers and Hector Mine Coseismic and Postseismic Deformation Fields

We also updated our GPS data processing to better derive the Landers and Hector Mine coseismic and postseismic crustal deformation fields. Major accomplishments include the following.

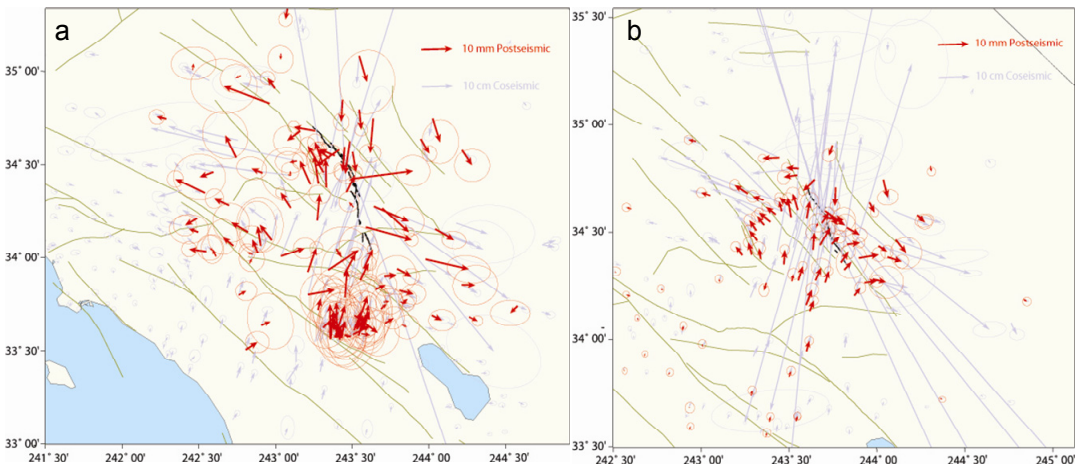

Figure 2. Postseismic displacements following (a) the 1992 Landers and (b) the 1999 Hector Mine earthquakes. Red vectors are amplitudes of the logarithmic relaxation functions. Light purple vectors are the coseismic displacements, shown here for comparison. Error ellipses are 95% confidence.

1. Reprocessing of the post-Landers GPS data, 1992.5-2004.8. We have reprocessed some of the GPS data collected following the Landers quake in the epicentral area using the GAMIT software. Corrections were made during processing, for example, for observations made using the Ashtech L-series receivers, as mentioned above, with regional and some global continuous stations incorporated. The loosely constrained daily solutions were output for further modeling.
2. The loosely constrained GPS daily solutions have been modeled to solve for station initial positions, coseismic jumps, and postseismic displacements. The postseismic displacements are assumed to behave decaying logarithmically, in the form of:

$$P(t) = P_0 \log_{10}(1 + (t - t_0)/T)$$

where P_0 is the amplitude, t_0 the epoch of earthquake, and T the decaying constant. We used

QOCA software to fit the data and obtain the results. Examination of the postfit residuals shows that the logarithmic decay function works particularly well to explain the postseismic data. A simple decaying constant of 10 days provides the best fit to the data, indiscriminative of site locations and observational epochs with respect to the epicentral location and occurrence time. The site coseismic and postseismic displacements of the two quakes are shown in Fig. 2 and listed in Tables S2 and S3 at http://scec.ess.ucla.edu/~zshen/sca_postseis.html respectively.

3. Production of the post-Landers station position time series. The station position time series since the Landers quake (1992.5-2004.8) have been produced. This was done through imposing generalized constraints to the station positions for reference frame stabilization. We first forward predicted the station positions of each daily solution using the station velocity, coseismic, and postseismic parameters resolved in previous step, and computed the seven parameters for translation, rotation, and scale associated with the model predicted station positions. We then transformed the daily solution into the reference frame defined by the seven parameters under tight constraints. Selected site postseismic time series after the transformation are shown in Fig. 3. The complete postfit residual time series are documented in Table S4 at http://scec.ess.ucla.edu/~zshen/sca_postseis.html. A total deformation field can be obtained from the time series by simply adding the model predicted contributions from the velocities and coseismic, and postseismic displacements back.

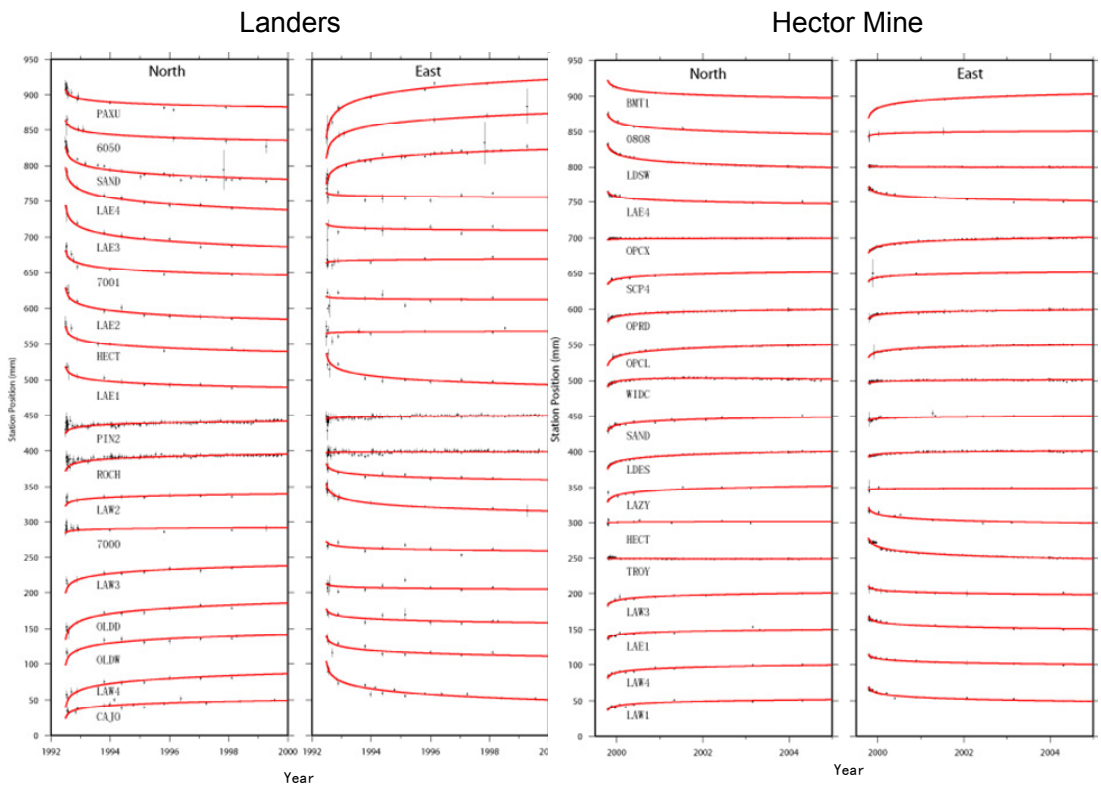

Figure 3. Selected station horizontal position postseismic time series for the 1992 Landers and 1999 Hector Mine earthquakes. Station names are denoted under their north component panels. Red curves are the logarithmic model predicted displacements.

Bibliography

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