Annual Report to Southern California Earthquake Center: Piñon Flat Observatory: Continuous Monitoring of Crustal Deformation

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1. Major Goals and Activities

Support from the Southern California Earthquake Center through this grant covers part of the operation of a facility for the continuous measurement of strain changes in southern California: Piñon Flat Observatory (PFO), between the San Jacinto and San Andreas faults. The instruments at PFO (three laser strainmeters and two longbase tiltmeters) measure crustal deformation in Southern California for periods from seconds to years. **Figure 1** shows the locations of the strainmeters, along with the USGS-supported instrument at Durmid Hill (DHL), near the southern end of the San Andreas fault, and the new strainmeters that have been added by the Plate Boundary Observatory project as part of Earthscope. By recording strain over this wide range of frequencies these measurements provide a nearly unique bridge between seismology and geodesy that is rarely available.

This award provides funding for operation of PFO, including support for power distribution, data recording, preliminary data-processing, and data distribution: all fairly basic activities, but all needed if the observatory is to function productively.

2. Accomplishments and Changes

2.1. Signals Recorded

Aseismic strain signals (both rapid and prolonged) were observed on strainmeters and creepmeters at the southern end of the San Andreas fault, at Durmid Hill (DHL), between April and June, 2008. The nature of the strain data, and associated creep measurements, suggests that a significant part of these signals was caused by shallow creep on the San Andreas fault. The strain signals also show that a wide range of periods was involved: 10 to 10^2 s for individual events, and 10^7 s for the duration of the sequence, and for an associated change in strain rate. We obtained very interesting records from the Durmid Hill strainmeters; with 1-s sampling, and a high signal-to-noise, the DHL records give very high resolution, both in strain and in time, of these aseismic strain changes; in terms of time resolution, much finer than the data collected by any earlier measurements. However, the PFO instruments (and the strainmeters at SCS, nearer-by) did not show any signals, as would be expected from creep events localized on the San Andreas.

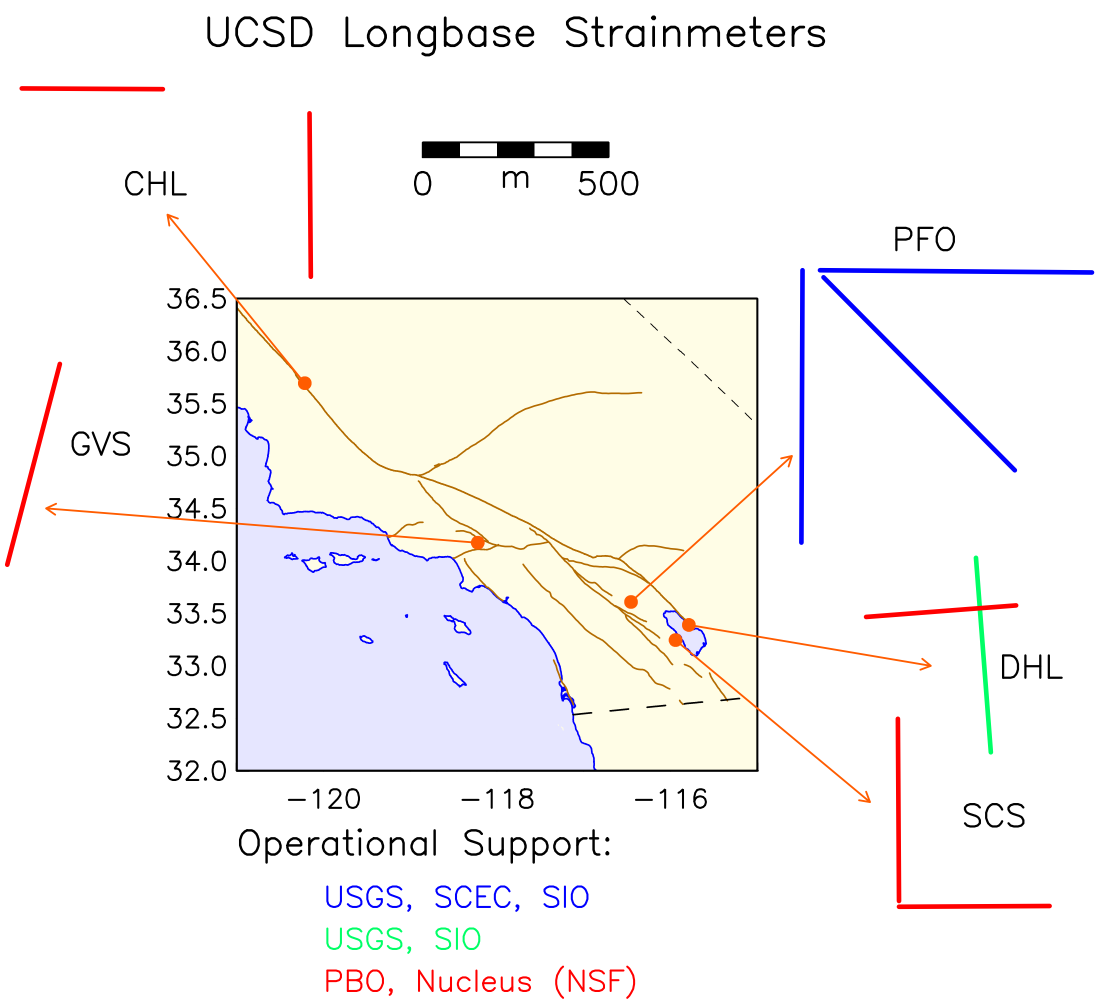

Figure 1: Laser strainmeters in California. All of the systems are telemetered by radio links and Internet to UCSD, with data streamed, and also downloaded daily.

Figure 2 shows the long-term signals for the NW-SE strainmeter at PFO. The "bump" after 1992.5 is postseismic strain from the Landers earthquake; the apparent offset at the earthquake is actually rapid aseismic strain change, starting immediately after the event, which then reversed and returned to the preseismic rate. Following the 1999 Hector Mine earthquake, the rate seems to have slowly decreased and by 2004 had reversed again, only to abruptly change following the 2005 Anza earthquake: a provocative result. This very low strain-rate after the Anza event, which is at odds with the expected secular deformation, persists to the present. Of course with this limited data-set we do not have a full understanding of these variations, which are unprecedented in the previous record of interseismic strain, except to say that they correlate neither with instrument changes nor with the (occasional) groundwater recharge events.

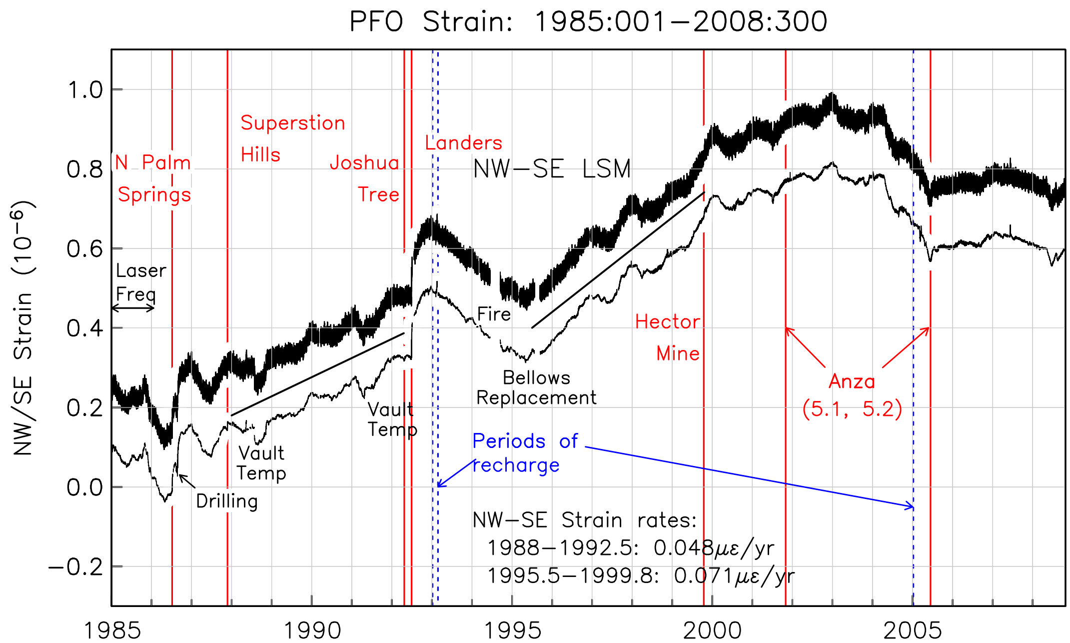

Figure 2

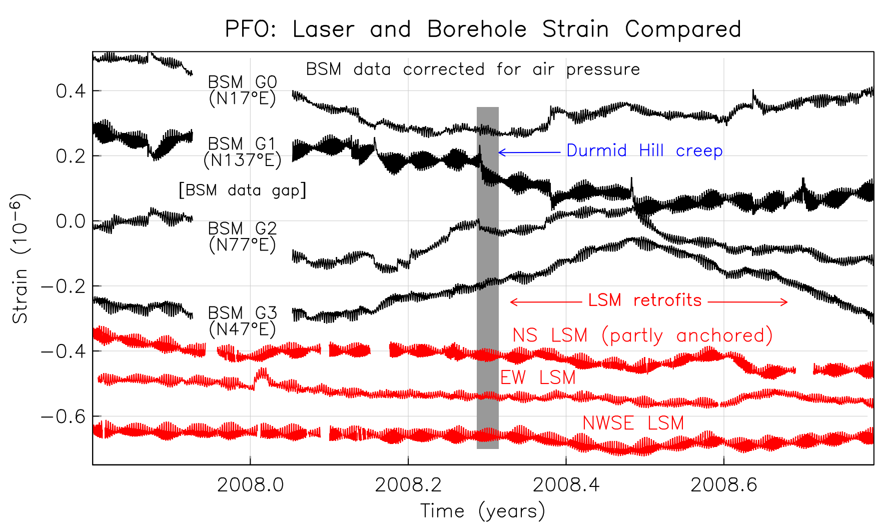

Figure 3

2.2. Instrument Comparison

PBO has installed a number of borehole strainmeters (BSM's) in the Anza area, largely in response to the PFO observations of aseismic slip from the 2005 Anza earthquake (as reported last year). While these instruments will be very useful, they do not replace the long-base strainmeters. **Figure 3** shows the most recent year of data from the PBO BSM that was installed at PFO in summer 2006. Each BSM has four sensors, three measuring internal strain at angles of 60°, and a fourth (redundant sensor) to make a right-angled pair for instrument validation. We have removed a slope and best-fitting exponential from each channel, since at the longest periods (and at this early stage of the installation) these trends give strain rates about 100 times the tectonic rate; we have also removed the best-fitting air-pressure response, which for these BSM's is large, implying a sensitivity to vertical strain. We also show the data from the three laser strainmeters, which surround the BSM location, and so must be measuring the same strain in the rock. The NS laser instrument is not anchored to depth at one end, and so is noisier than the other two. It is clear that for periods longer than a week or two, the LSM's show much better stability; the BSM data also show a number of events, some correlated between different sensors, which, not being visible on the LSM's, are not coming from the earth on the scale of 1 km. This plot also indicates the time of the prolonged aseismic slip episode detected by the DHL strainmeters alongside the Salton Sea; as noted above, the absence of a signal at PFO confirms that the moment release there was not more widespread.

2.3. Instrument Upgrades

We again made significant progress on several fronts related to instrument performance and observatory operations. Over the course of the year, we averaged 1 trip per month to deal with upgrades and problems, and for planned preventive maintenance. Using NSF I&F funds, and capital funds from the Green Foundation (Dallas) and from the SIO Director's Office we were able to introduce three new data-logger controllers to the laser strainmeters at PFO; these provide both for better operation and for some redundancy in the recordings, as the original centrally-located 128-channel logger is being maintained in operation. Progress on the strainmeters included the replacement of the photomultiplier optical detector systems (now some 3 decades old), by modern photodiode detectors, greatly improving reliability. For one of the PFO strainmeters (NS) a number of difficult vacuum leaks were finally located–a substantial investment in time–and the instrument converted to low-power vacuum pumping. We also improved the temperature control of the optics enclosures on this instrument.

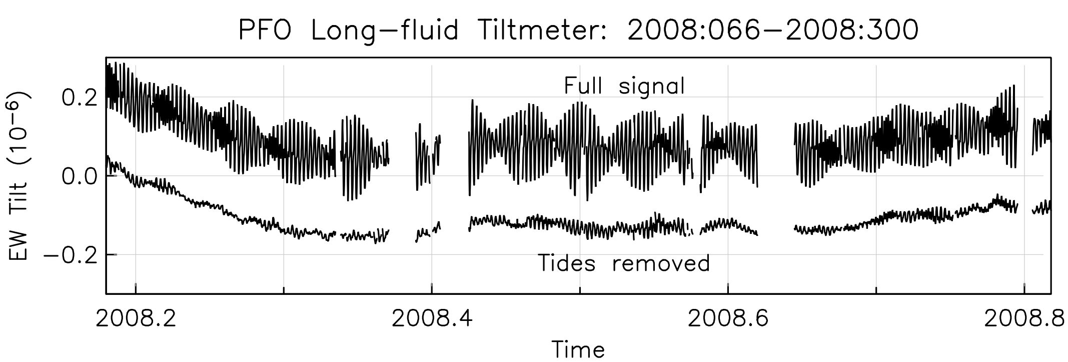

Figure 4

In the 1980's we constructed two long-base tiltmeters at PFO, with USGS and NSF support. These have given excellent records, for example showing the same post-Landers transient in tilt that **Figure 3** shows in strain. Unfortunately, a severe lightning storm in mid-2004 destroyed much of their electronics. Rebuilding was slowed by higher-priority tasks and the 18-month illness of the technician most familiar with the system; but over the last few years these have been reconstructed. **Figure 4** shows recent data from the EW instrument.

3. Data Management Practices

Thanks to having a person dedicated to data processing (for both this work and to meet PBO requirements), we have continued to progress on timely processing of signals and improving general access to the data. We are pleased to report that all edited laser strainmeter data are now being archived in parallel with the PBO data at the NCEDC, using the XML format developed by ourselves and PBO. We had been delayed in establishing this archive owing to personnel changes in the PBO group at UNAVCO, but this pathway is now complete and in use. We continue to make older data available on request. Plots of real-time raw data from the two sites are accessible through the Anza ROADNet system; a full description of this is provided at `http://pfostrain.ucsd.edu`.

4. Continuity of Operations and Response Planning

To improve continuity of the recordings we have placed all strainmeter systems, including new temperature controllers, are on uninterruptible power supplies, such that power outages up to 1 hour do not affect the operation (for PFO, line outages can be for many days, but at this site we have a standby generator). All data are both telemetered and stored on-site; the on-site PC dataloggers can easily preserve several years of data.

5. Problems or Concerns

With the substantial upgrade investments made in the past two years, and those remaining (funded by NSF and SIO) we are optimistic that we will not face serious operational problems in the coming year. Our biggest challenge lies in personnel; with the ending of PBO construction funds the technical staff size has fallen from 6 to 3 since July 2008. Those leaving (Steve Bralla for another position at IGPP, and Steven Dockter and Frank Cheng to a startup company) took with them 46 man-years of experience. The remaining staff (Frank Wyatt, Don Elliott, and our new data person, Billy Hatfield) are adequate, we hope, to keep the systems shown in Figure 1 running–but funding remains a challenge.