# Piñon Flat Observatory: Continuous Monitoring of Crustal Deformation

## Report for 2006

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## 1. Introduction

The Southern California Earthquake Center provides partial support of Piñon Flat Observatory (PFO), as part of its data collection activities. PFO provides high-precision strain data which is used both for studies of the seismic cycle in Southern California, and for comparison with other types of measurements of crustal deformation: notably data from the SCIGN GPS array.

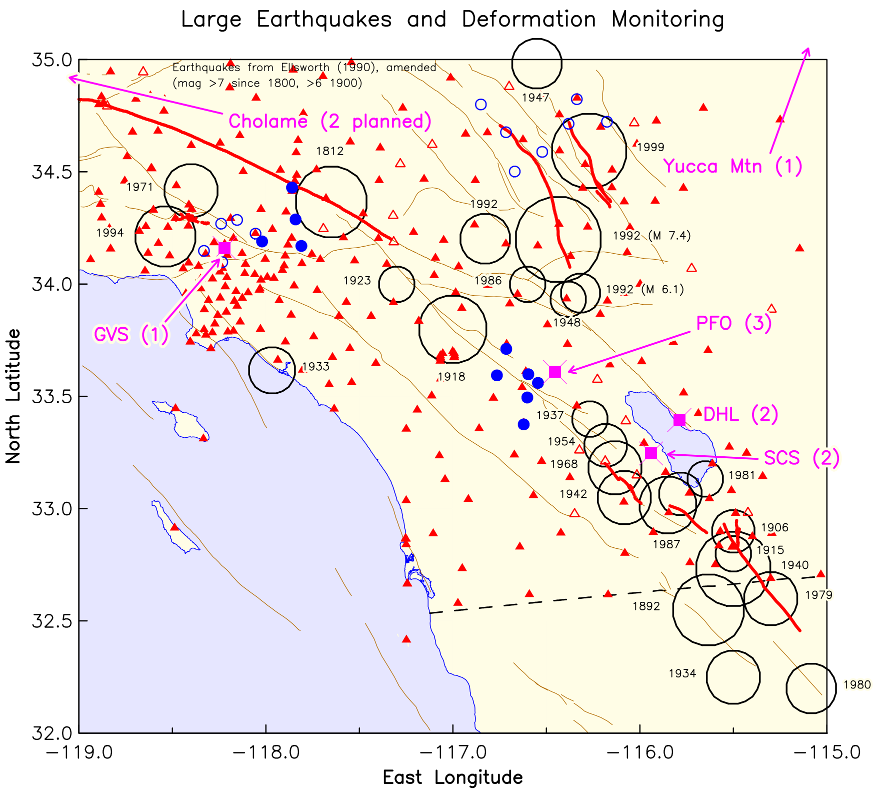


**Figure 1**

SCEC funds help to keep the observatory operating to continue to measure crustal deformation: at this point the data from the longbase and other instruments at PFO, provide the longest ultra-broad-band records of crustal motion (from minutes to years) available from any plate boundary. The cost of running the observatory includes salaries for technical personnel, travel costs for them to visit the site, supplies, and of course the power bill. In addition, SCEC funds provide some support of senior personnel (Wyatt) to oversee the activity, deal with more complicated problems, and improve on data access. **Figure 1** shows the locations of longbase strainmeters (purple), borehole strainmeters (blue) and continuous GPS (red) in southern California: open symbols are planned installations. Much of this expansion is due to the PBO component of EarthScope, though such funds can only be used to construct new systems, not support old ones. Besides PFO, there were two existing long-base strainmeters in southern California. One of these (DHL1) is at Durmid Hill, and was constructed with funds from NEHRP, which now supports it through a combined grant covering DHL1 and part of PFO. The other strainmeter, in Glendale (GVS), was constructed as part of SCIGN, and is now supported, like much of SCIGN, through the NSF Nucleus program run by UNAVCO. The PBO program is to include five long-base strainmeters. The first was a second component at DHL (DHL2), completed in June 2005, which will add significantly to our ability to monitor strain changes along the southern San Andreas. The second and third are at Salton City (SCS: SCS1 and SCS2), on the western side of the Salton Sea; these instruments began operation on October 1, 2006, just in time to show no strain signal from a large creep event on the Superstition Hills fault. Operation of all three PBO instruments, as with the last two—to be built in Cholame—will be supported by NSF through EarthScope.

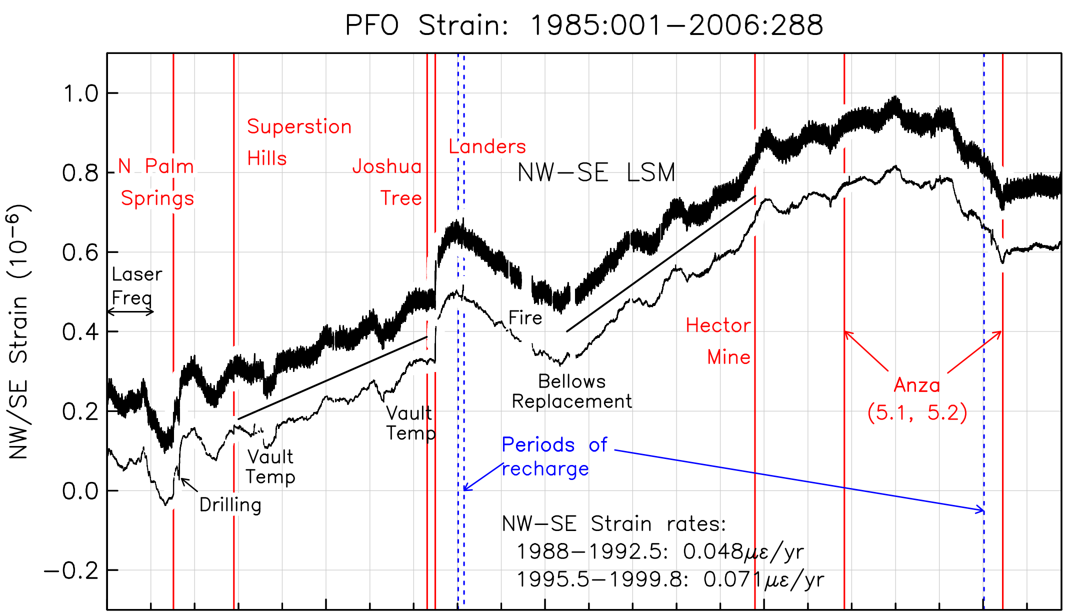


**Figure 2**

## 2. Science Results

It is in the nature of this kind of data collection that there may not be a significant geophysical 'event' every year; however, even without events, the accumulation of data can reveal new information. This year we can give examples of what is learned from longstanding data collection.

**Figure 2** shows the long-term signals for the NWSE strainmeter at PFO, which was (for most of the time shown) the only well-anchored one. 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. The trend in deformation has persisted to the present. We do not have a full understanding of these variations, which are unprecedented in the previous record of

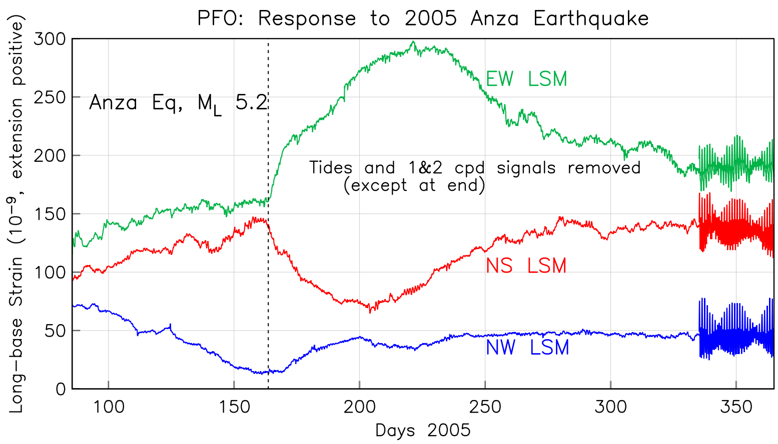


**Figure 3**

interseismic strain, except to say that they correlate neither with instrument changes nor with the (occasional) groundwater recharge events.

**Figure 3** shows the time series from all three long-base strainmeters at PFO, from 120 days before the Anza earthquake to the end of 2005. We have removed the tides, except at the end, for scale. Because of strong ground shaking no coseismic offset was recorded, so we have not tried to show it. All three strain records show a clear rate change after the earthquake. The diversity of responses argues against this being some kind of local response at PFO; if we assume it to be afterslip on the San Jacinto fault, the response is consistent with slip in a region of the fault that showed small earthquakes triggered by the mainshock and outside the aftershock zone, with this aseismic slip then propagating upwards, the total aseismic moment is equivalent to a magnitude ($M_w$) 5.0 event.

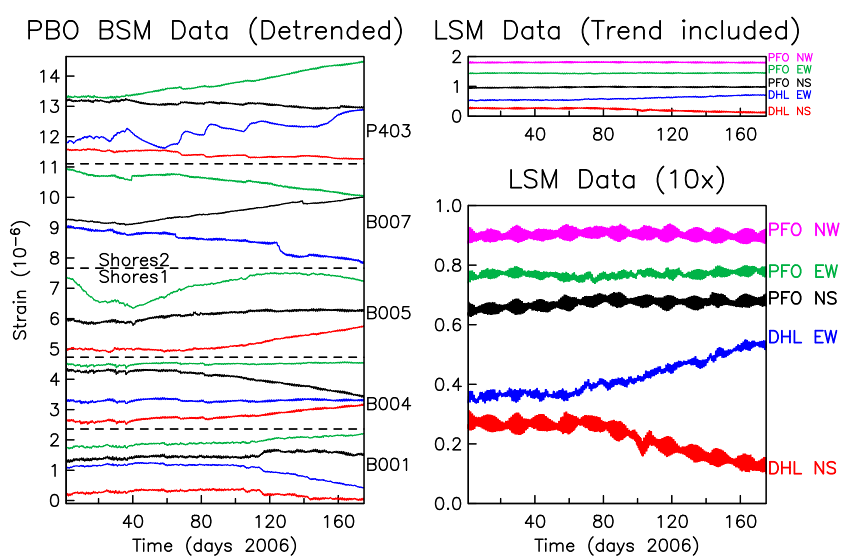


**Figure 4**

As **Figure 1** shows, PBO has installed a number of borehole strainmeters (BSM's) in the Anza area, largely in response to this observation of aseismic slip. These instruments will be very useful, but they do not replace the PFO strainmeters. To show this, **Figure 4** plots data from existing PBO BSM sites (4 sensors per system) along with LSM data at the same scale and expanded. Over periods of a few weeks and longer, the LSM's show much better stability; some of the BSM systems show more strain change in two weeks than the the PFO NWSE LSM (**Figure 2**) has experienced in two decades.

One candidate strain-event in this support-period came from a pair of PBO borehole strainmeters located next to the San Jacinto fault, just in-board of PFO. On January 2, 2007, the colocated borehole instruments recorded a large exponential signal, and we were immediately asked to check for corroborating evidence. The PFO strainmeters showed this period to be quiescent, at orders of magnitude below the observed strain rates. Later it was determined that the land-owner had, at this time, added a hundred cubic yards of soil above the borehole instruments.

Since the early 1980's, we have monitored water-level changes in four wells at PFO, which were originally drilled for borehole strainmeters in 1981. All of these show tidal changes as the fractured-granite system responds to tidal changes in strain. A recent re-examination of these data, in collaboration with Prof. Emily Brodsky and Jean Elkhoury of UCLA, shows changes in these tides (in some wells) coincident with earthquakes that have produced strong shaking at the site: both permanent changes (until the next shock) and transient changes that decay over the weeks following the earthquake. These presumably reflect changes in the local hydraulic regime, and can serve as a useful model for understanding how cracks in the crust can be affected by, and heal after, large dynamic strains—a topic of clear interest for understanding possible dynamic triggering of earthquakes. A preliminary report (Elkhoury *et al.* 2006) has been published.

## 3. Observatory Operations

In the past year we have also made significant progress on several specific items related to observatory operation. Of course, there is also maintenance of many items; over the course of the year, we average 1–2 trips per month both to introduce new equipment and to fix problems. Typically the latter involves work on the facility and the laser strainmeters (lasers and vacuum systems). Much of the work reflects the age of some of the equipment at PFO; we have been using recently granted NSF I&F funds, and capital funds from the Green Foundation (Dallas) and from the SIO Director's Office to purchase some much needed new equipment. In this past year we were able to upgrade the strainmeter vacuum systems, and will be upgrading the data-logging control in the coming year, permitting greater remote-control of the strainmeters.

### 3.1. Data Access

Thanks to various upgrades, and even more to our being able to employ a dedicated person for data processing (needed to meet PBO requirements), we are able to make realistic plans for prompt public access to PFO data, which will be archived at the NCEDC. Specifically, from the start of 2007-support raw data will be provided daily as downloaded from the datalogger; PBO has developed tools for conversion to SEED. Fully-corrected and edited data will be provided in the XML format used by PBO, with a latency of no more than six months. Plots of raw data will continue to be available in real time through the Anza RoadNet system; see http://mercali.ucsd.edu/waveform.cgi; for PFO strainmeters, for the NS LSM at PFO, click on PFO1, channels 36 (NS), channels 37 (EW), and channels 38 (NS) (NWSE). We continue to make older data available on request.

## References

Elkhoury, J. E., E. E. Brodsky, and D. C. Agnew (2006). Seismic waves increase permeability, *Nature*, **441**, 1135-1138.