Piñon Flat Observatory: Continuous Monitoring of Crustal Deformation

Report for 2004

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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.

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.

In the absence of a significant geophysical event, it is in the nature of this kind of data collection that there may not be something new to report in the data every year; however, even without events, the accumulation of data can reveal new information. **Figure 1** shows a possible example in the best and longest record we have, from the NW-SE laser strainmeter. As this figure shows, we recorded a large, several-year postseismic response to the Landers earthquake in 1992.5; this ended in early 1995. We have also recorded significant signals from the 16 October 1999 Hector Mine earthquake, though the postseismic strains from Hector Mine are much smaller. These data show that the multi-year strain rate seen on this instrument was significantly higher between these two earthquakes than for the period before or after them: a particular observation not available from other systems, and one that (obviously) could be made only with continuing long-term support.

Activities at PFO fall into several groups, covered in the following sections: improvements in data access, general maintenance, instrument rebuilds (supported by NSF), and the activities of other groups at the site (supported, also by other agencies).

2. Data Access

To get data from the PFO instruments to the wider community, we need (1) reliable data links from the site to our lab; (2) a system to collect the data and send it over these links; and (3) the procedures and personnel to make the data available to the community in an easily-usable form. The first of these has been available for some time, through the NSF-funded HP/WREN (*hpwren.ucsd.edu*) project, which provides wireless Internet connections to remote sites around San Diego; and RoadNet (*roadnet.ucsd.edu*), which integrates remote field sensors into a seamless data-transfer system. We have 45 Mb/s TCP/IP capability at the repeater on Toro Peak, overlooking PFO, with a radio link to the PFO trailer providing 8 MBits/s to the local network. We have also made progress on the other two elements:

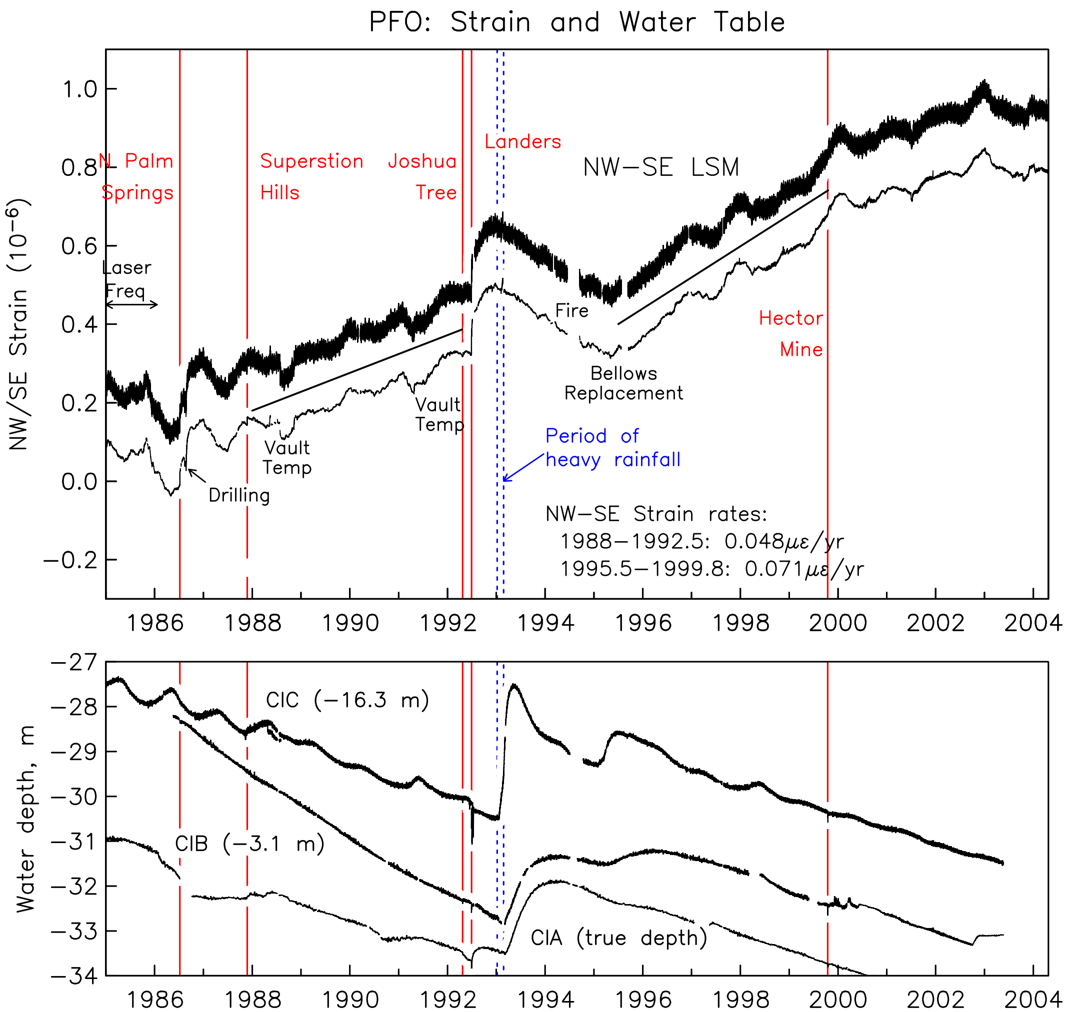

Figure 1

Telemetry and Data Recording. In 2002, using part of the funds Scripps provides at a match to SCEC support, we purchased an Internet-compatible data recorder for PFO: a copy, extended to handle 128 channels, of our current onsite datalogger, which also provides automated and off-site control of strainmeter beam-steering and vacuum pumpdowns. (The development of this was funded by the DOE Yucca Mountain Project). The extension to 128 channels revealed some serious problems with the system not seen in our earlier 32-channel systems; through close cooperation with the system developer, we have been able to resolve these, and this datalogger is now under final test in our lab. We expect to install it at PFO before the end of the year.

Data Handling. The datalogger will provide raw data in real time through RoadNet, though our standard processing relies instead on a daily download. We have developed systems for producing combined raw data files and making them available on our Web site (*jacinto.ucsd.edu*); the main series of 5-minute sample data from the sites in Glendale and Durmid Hill are updated fortnightly, and we will do the same with the PFO data once the new logger is installed. A bigger challenge is providing the data in a “cleaned-up” form that that more users can deal with; a challenge, since some of the data editing can only be done by experienced personnel. We are working on this problem with support from the PBO, and will apply whatever developments we make to the PFO data. In the mean time, we have produced a release of our processing software, so that other users can work more easily with strainmeter data (Agnew 2004).

3. General Maintenance

Over the course of the year, we average 1–2 trips per month both to introduce new equipment and to fix problems with the instruments: 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: for example, all of our air conditioners are more than 15 years old (they have a nominal 7-year lifetime). We are currently using funds from the Green Foundation (Dallas) and from the SIO Director's Office to purchase new ones, and are in the process of installing them. We submitted an NSF proposal in January 2003 for a substantial purchase of standby and replacement equipment, along with upgrades to automate more of the operation. This, competing in a crowded field, was well reviewed but not funded; we submitted a revised version in June 2004 (the first available date).

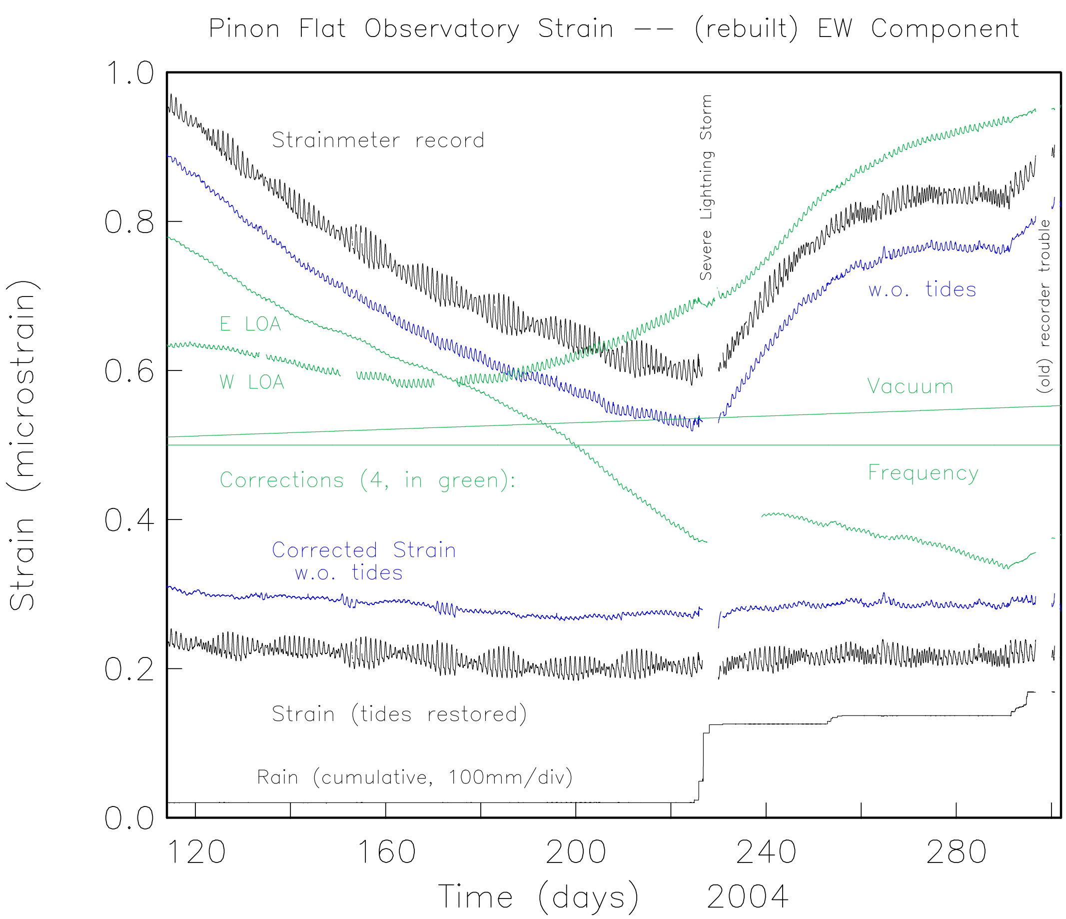

Figure 2

4. Instrument Rebuilds

In an earlier proposal to NSF, we had proposed to fully rebuild and anchor the EW long-base strainmeter, since independent high-stability strain measurements help considerably in interpreting low-level signals. We received reduced funding for this; because of building the SCIGN strainmeter in Glendale (GVS), and a strainmeter for the Yucca Mountain project (YMS) we did not start major reconstruction until 2002; this was completed in late 2003. **Figure 2** shows the data from this system. The benefits of deep-anchoring (W and E LOA monument-motion signals) are quite evident, leading to a high quality record of secular strain.

5. Other Activities

There have been a number of other activities at PFO during the last year; even for those not funded by SCEC, its support of the facility helps to keep it available for these many other efforts.

Seismic Test Facilities. With funds from NSF Ocean Sciences and other sources (not SCEC) we are constructing an expanded set of subsurface vaults and boreholes that will house existing seismometers (such as the IDA/IRIS/EarthScope system) and provide a community facility at which interested researchers can test and calibrate seismic instruments. The vault includes two rooms with seismic piers (granite piers especially installed) and two rooms with facilities for mass testing of instruments. One of these will house a ring-laser gyro system with seismic sensitivity being installed by a group from the Technical University of Munich, Germany; when this is complete, it will make PFO the only place in the world with the ability to measure seismic displacements, rotations, and strains.

Water Wells. Since the early 1980's, we have monitored water-level changes in four wells at PFO (originally drilled for borehole strainmeters). 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.

GPS Monumentation Another long-running PFO project is the operation of a pair of closely-spaced continuous GPS stations, PIN1 and PIN2, which are 50 m apart and both monumented using the drilled-braced monuments that have become a standard for SCIGN and the PBO (these two also happen to be the prototypes). In the last year we have undertaken a reanalysis of the data from these sites, and a review of the documentation of the (many) changes at them, to put together as complete a time history as possible (Wyatt and Agnew 2004). **Figure 3** shows the results. After correcting to a common point on the monuments, a number of offsets remain at the 1-2 mm level, probably because of errors in the antenna models for the early data (before 1997). When these are removed, we see remarkably little relative motion. We are working with Dr. Simon Williams (Bidston Observatory, Liverpool) on an analysis of this and other similar series. a preliminary result for the PFO data is that, after the offsets are removed, random-walk noise in the horizontals is below 0.2 mm/$\sqrt{\text{yr}}$, a small value that confirms the quality of these installations (Agnew *et al.* 2005).

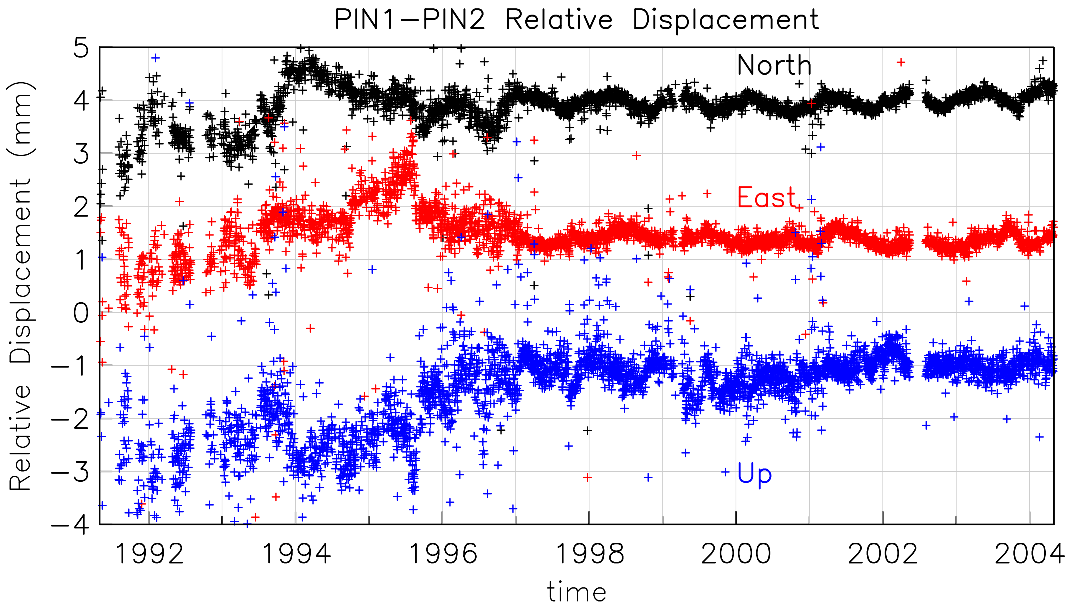

Figure 3

References

D. C. Agnew, “PIASD: Programs for the Interactive Analysis of Strainmeter Data,” SIO Technical Report, in press (2004).

D. C. Agnew, S. D. P. Williams, F. K. Wyatt, and Y. Bock, “Testing monument stability with short-baseline GPS measurements.,” In preparation (2005).

F. K. Wyatt and D. C. Agnew, “The PIN1 and PIN2 GPS Sites at Piñon Flat Observatory,” SIO Technical Report, in press (2004).