Annual Report 1999

Piñon Flat Observatory: Continuous Monitoring of Crustal Deformation

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The Southern California Earthquake Center provides partial support of Piñon Flat Observatory (PFO), as part of its infrastructure activities. PFO provides high-precision strain data, 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 growing SCIGN GPS array.

OBSERVATORY OPERATIONS:

Our emphasis at PFO has been on providing the highest quality data possible, and on improving our data-handling procedures. We record all the long-period signals at PFO on a PC-based datalogger that is downloaded weekly. The weekly downloads are checked for data quality, and at intervals are assembled automatically to produce the raw time series for all sensors. In the past year we made a sustained effort to produce ‘‘final’’ series that run close to the present; all major series are now edited through the end of our last ‘‘data segment’’ (1999:299, or October 26).

RESULTS:

Figure 1 shows one result from these efforts: the record from the NW-SE laser strainmeter over the last 15 years. This period encompasses the entire cycle of increased seismicity that began in southern California with the North Palm Springs earthquake in 1986. The two main features visible are the large, several-year postseismic response to the Landers earthquake in 1992.5; this ended in early 1995 with what originally appeared to be a resumption of the previous strain rate. More recent data show that in fact the rate seen on this instrument is now significantly different (50% greater) than it was for the period prior to the Landers shock. We look forward to seeing what behavior will be associated with the 17 October 1999 (1999:289) M_W 7.1 Hector Mine earthquake, which occurs just at the end of this figure. As **Figure 2** shows, these two earthquakes are in approximately the same location as viewed from PFO, and therefore might be expected to produce similar effects.

The one definite result so far is that the immediate postseismic strains from Landers and from Hector Mine are not similar. These responses are shown in **Figure 3**. In both cases the coseismic part of the response has been removed—though we would note that for the Hector shock we believe we successfully recorded the coseismic offsets, something not accomplished for the Landers event because of power interruptions. The difference between the postseismic behavior for these two cases provides reassurance that what we are seeing is not, for example, some kind of site response to strong shaking, since that would presumably be similar for both events. Rather, it would appear that we are seeing a more regional signal—though its source remains unclear. (We have submitted a separate science proposal to SCEC to examine this question).

Thanks to our operation of two other laser strainmeters at Durmid Hill, near the San Andreas fault (**DHL** in **Figure 2**) we are also able to examine the coseismic and postseismic responses in different places. (Strictly speaking, we ought not to include the DHL results here, as it is not funded by SCEC, but they are too interesting to ignore). Because DHL is 140 km from the epicenter, and 104 km for PFO, we would expect the coseismic and and postseimic response to be about one-third as large. Instead, it was much larger, so large in fact that it exceeded the range of the recording system. We estimate it as about 10^{-6}, roughly ten times the size of the offset at PFO (**Table 1**). Given the proximity of this instrument to the San Andreas fault, and the occurrence of surface cracking on this section of that fault, we conclude that this large response reflects triggered slip on the San Andreas: something seen before in other large earthquakes.

Table 1.

Source	Type	Deformations						
		tensor/vector			components			
Strains		e_{11}	e_{22}	e_{12}	e_{EW}	e_{NS}	$e_{NW\text{-}SE}$	e_{NE}
PFO	Theory	-56	+510	+91	-56	+510	+136	
	Obs	+170$^{?}$	+357	--$^{?}$	+170$^{?}$	+357	+177	
DHL	Theory		+61			+61		-32
	Obs		~1200			~1200		~1200
Tilts		Ω_1	Ω_2		$\Omega_{106.3°}$	$\Omega_{0.5°}$		
PFO	Theory	-2	-144		+38	-144		
	Obs	+16	-116		+47	-116		

Strain are in units of 10^{-9} $\Delta l/l$ (nanostrains); 1-axis east, 2-axis north.
Tilts are in units of 10^{-9} radians; 1-axis east, 2-axis north; positive tilt down in given direction.
Model: single plane, centered at 34.533394 -116.266441; strike -30°; dip 85°; 5 m slip over 30x10 km, for a Moment 4.5e19 N-m, Mw 7.1.

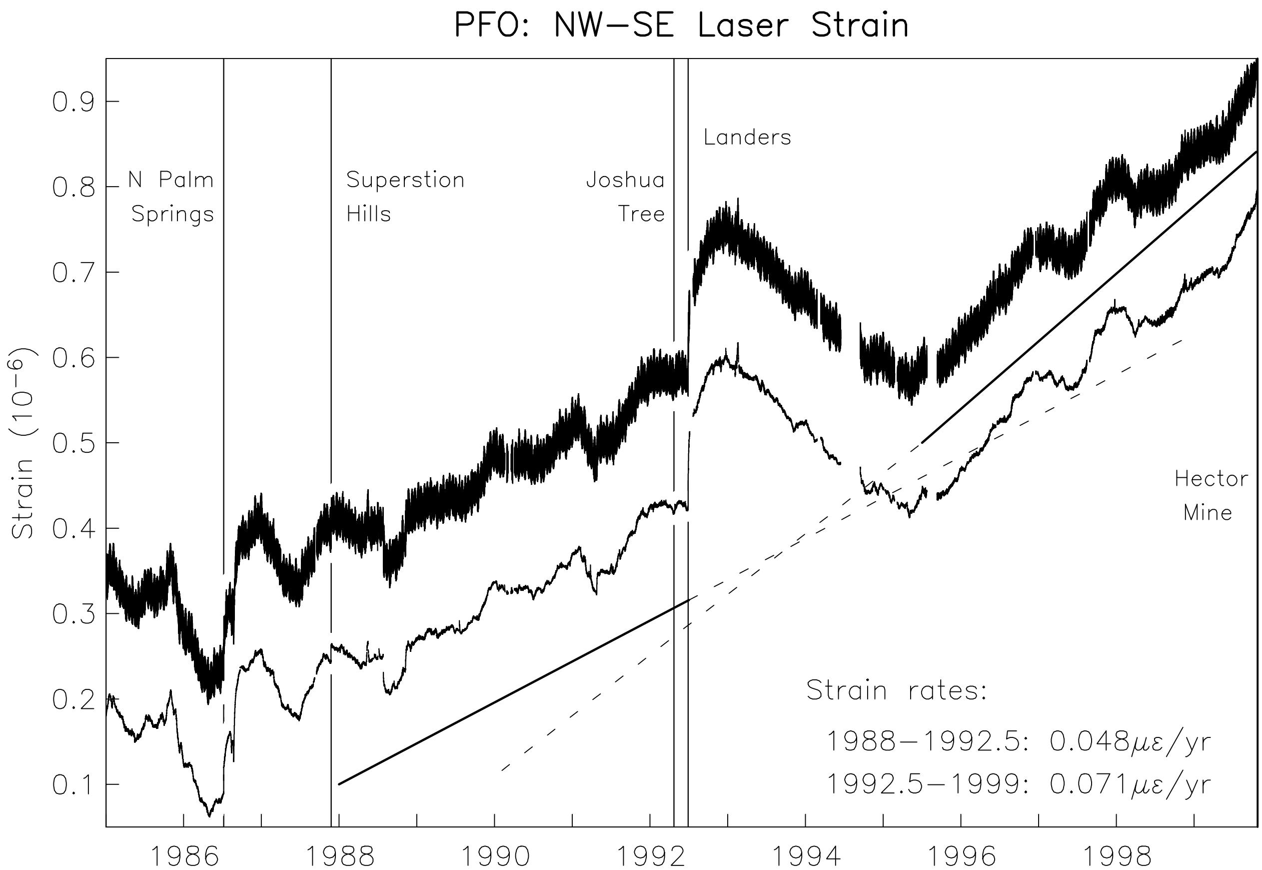
Figure 4 shows the strain at DHL before and after the Hector shock. The long-term strain contraction prior to the earthquake has been steady over the measurement duration (since 1994), and corresponds to the rate expected from interseismic strain accumulation on the San Andreas. The exceptions to this are the offsets labeled as B.1/2/3 and C, D, E in **Figure 4**. These events, authenticated by appearing on fully independent strainmeters at DHL, we attribute to slip on the adjacent San Andreas fault. Event C, occurring immediately after the Hector Mine earthquake (recall the coseismic offset has been removed) begins the immediate postseismic response which is much larger than at PFO, suggesting, again, a source closer to DHL: it is notable that the Hector earthquake appears to have triggered an earthquake swarm nearby (in the Brawley seismic zone), with at least 14 shocks of magnitude 2 and above from 1 to 12 hours after the Hector mainshock. Even more provocative is that the data from DHL and PFO do not rule out the possibility of there having been some form of precursory deformation (as has always been true before): recordings from both sites suggest a change in the strain field commencing with the Hector preshock sequence.

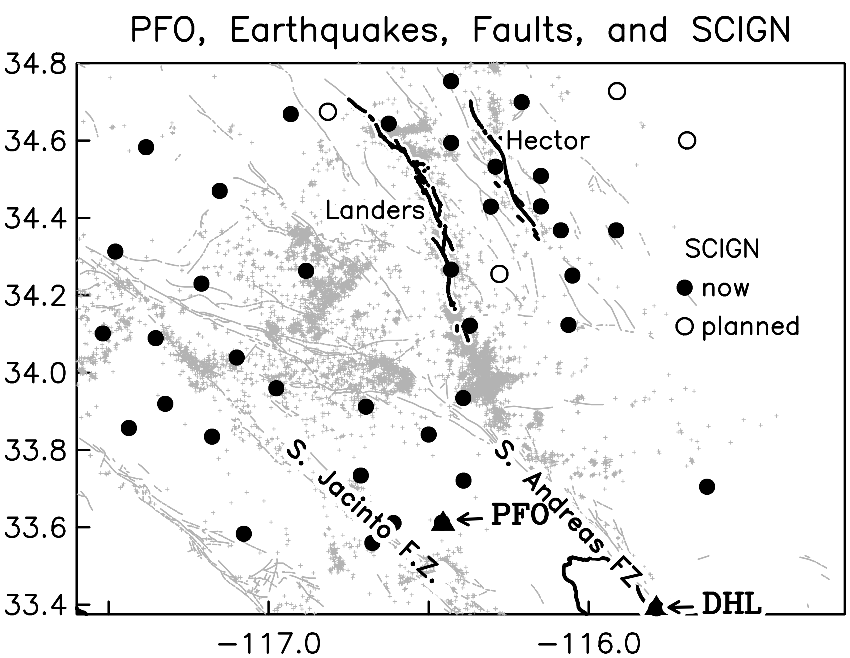
The long-term NS strain rate at DHL has also undergone a complete reversal from its earlier secular rate, as occurred at PFO after the Landers earthquake (**Figure 1**). However, as **Figure 4** shows, a significant portion of the post-Hector response has taken place in abrupt events, which do not coincide with any local earthquakes. Again, we do not see these at PFO. Having the two observatories in operation allows us to say that the source of these events must be close to DHL: again, quite likely the San Andreas fault.

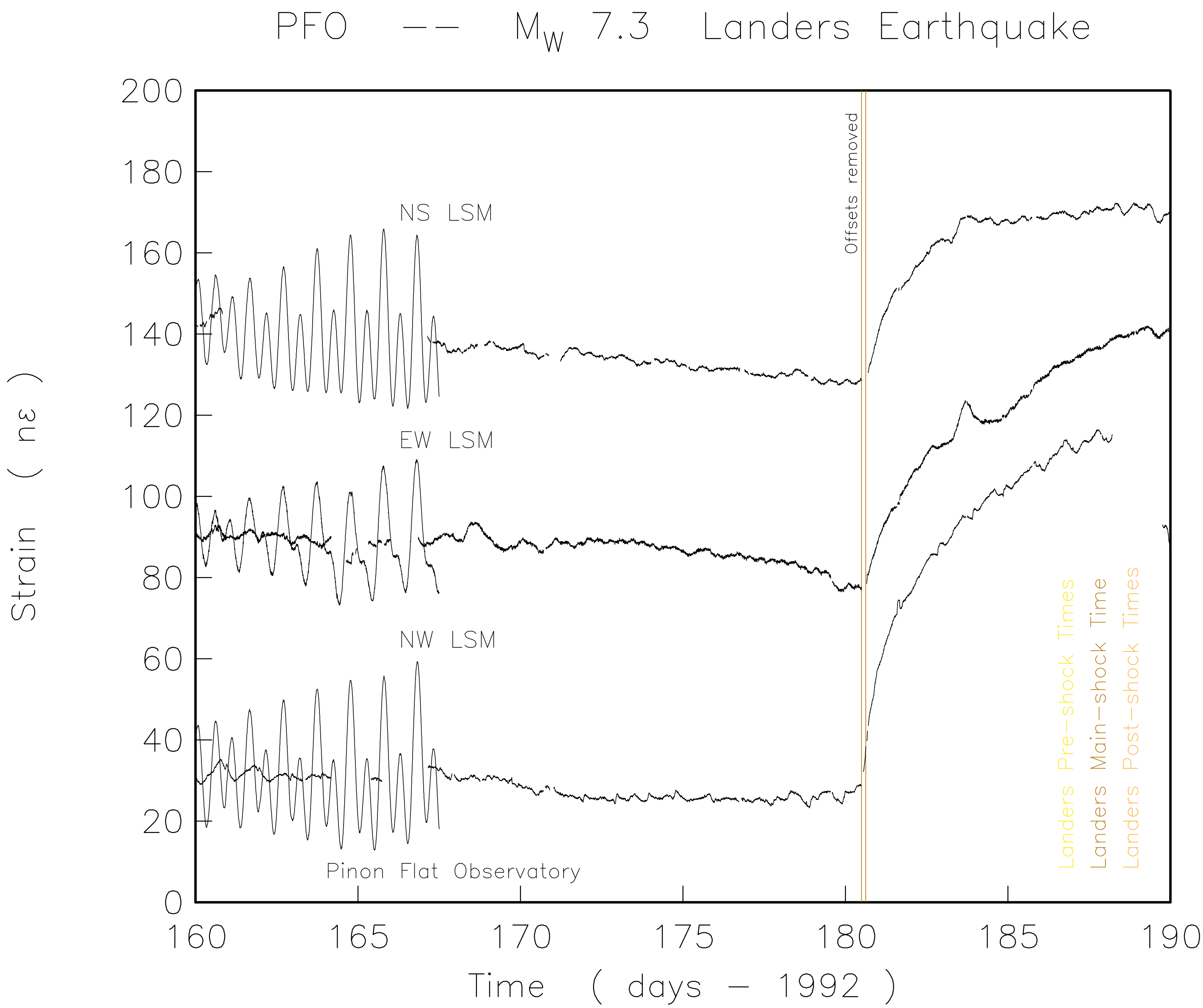
OTHER ACTIVITIES—A REPRESENTATIVE LISTING:

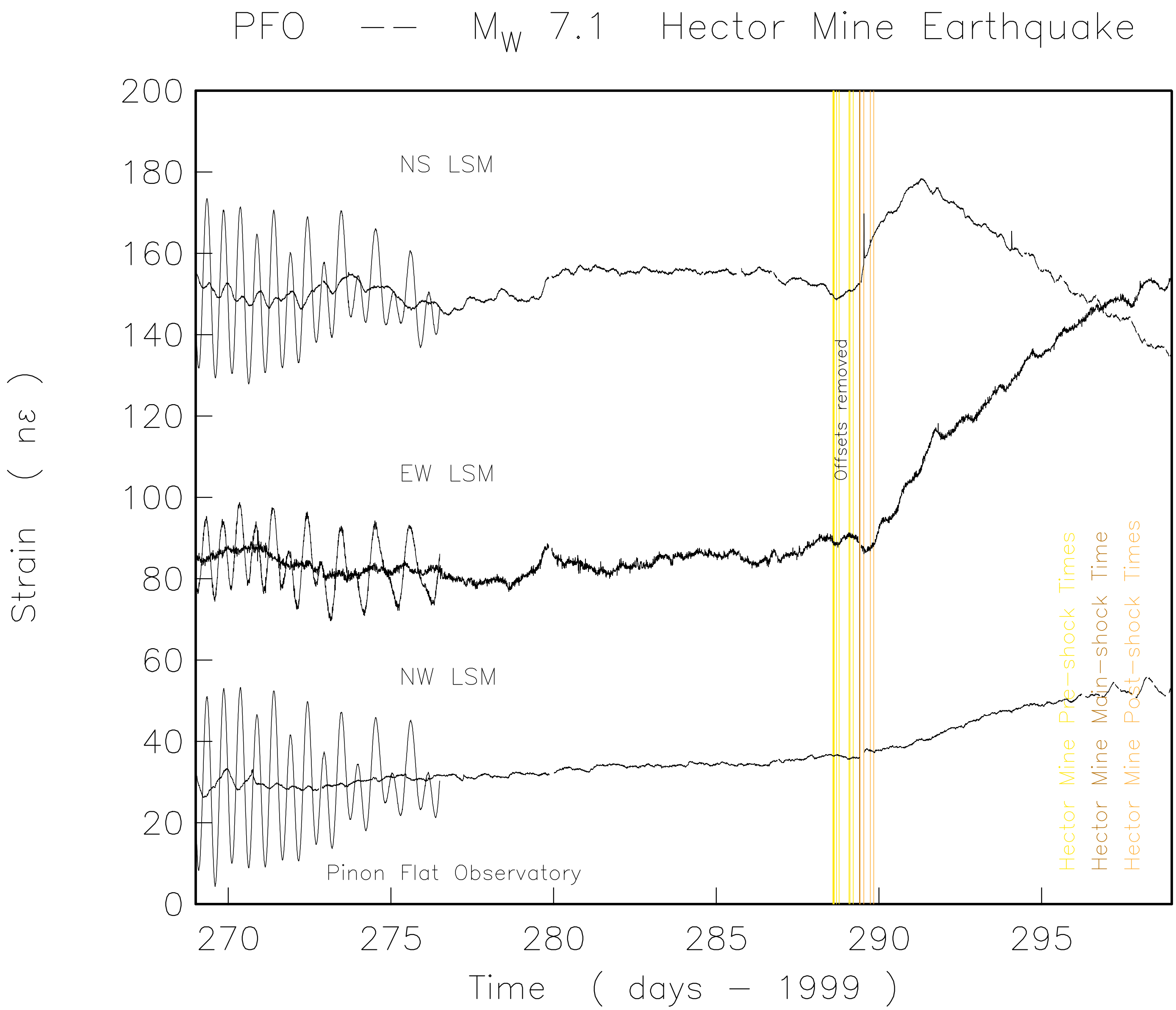
The NW-SE laser strainmeter was fully converted to operate on uninterruptible power in 1999. This has greatly improved the continuity of the recordings. The main recording-trailer's power wiring was entirely replaced with a set of parallel power-lines, again for improved reliability (and for safety from growing shorting concerns) and for ease in introducing back-up power to critical systems. Using institutional support we were able to refurbish and repaint all of the out-buildings at the facility.

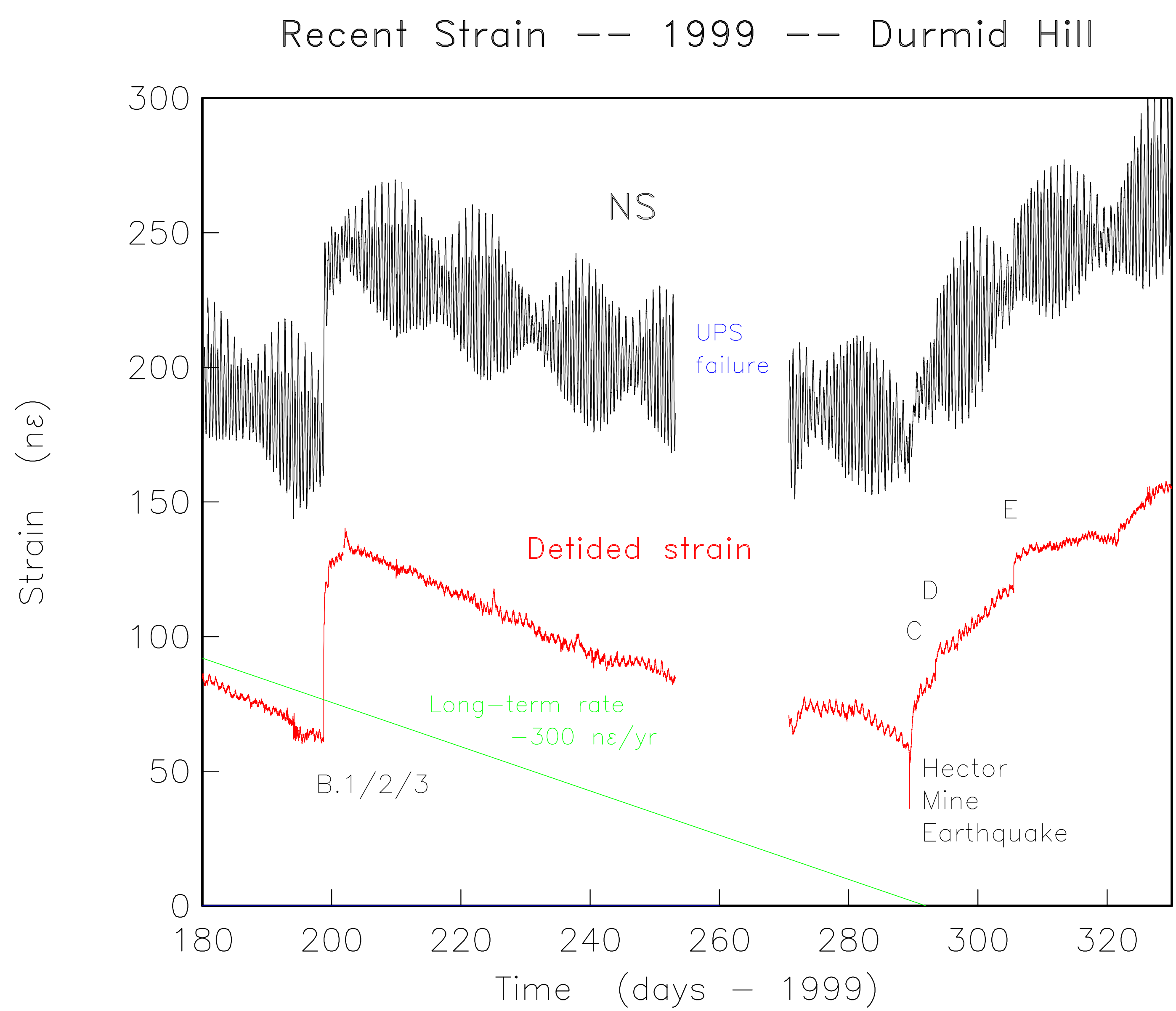
Because of our experience with end-monument stability for the long-base systems at PFO, we have again provided input on the design, planning, and field-testing of monuments for the SCIGN array. This work is separately funded by SCIGN, but something that our efforts at PFO make possible. This year our work in this area has been to contribute to the design and fabrication of a shallow-anchored tripod monument used for rapid installations of new SCIGN sites after the Hector earthquake. During 1999 also we carried out extensive testing on the influence of nearby fences and trees on GPS positioning estimates, repeatedly moving test-objects in and out of the local area.


PFO: NW−SE Laser Strain
Strain (10⁻⁶)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1986
1988
1990
1992
1994
1996
1998
N Palm
Springs
Superstion
Hills
Joshua
Tree
Landers
Hector
Mine
Strain rates:
1988−1992.5: 0.048με/yr
1992.5−1999: 0.071με/yr


PFO, Earthquakes, Faults, and SCIGN
34.8
34.6
34.4
34.2
34.0
33.8
33.6
33.4
−117.0
−116.0
Hector
Landers
SCIGN
now
planned
S. Jacinto F.Z.
S. Andreas FZ
PFO
DHL


PFO -- M_W 7.3 Landers Earthquake
NS LSM
EW LSM
NW LSM
Offsets removed
Pinon Flat Observatory
Landers Pre-shock Times
Landers Main-shock Time
Landers Post-shock Times
Strain (nε)
Time (days - 1992)
0
20
40
60
80
100
120
140
160
180
200
160
165
170
175
180
185
190


PFO -- M_W 7.1 Hector Mine Earthquake
NS LSM
EW LSM
NW LSM
Pinon Flat Observatory
Offsets removed
Hector Mine Pre-shock Times
Hector Mine Main-shock Time
Hector Mine Post-shock Times
Strain (nε)
Time (days - 1999)
0
20
40
60
80
100
120
140
160
180
200
270
275
280
285
290
295



Recent Strain -- 1999 -- Durmid Hill
Strain (nε)
Time (days - 1999)
NS
UPS
failure
Detided strain
Long-term rate
-300 nε/yr
B.1/2/3
C
D
E
Hector
Mine
Earthquake
300
250
200
150
100
50
0
180
200
220
240
260
280
300
320