SCEC Crustal Motion Map: Collaborative Analysis

Report for 2004

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1. Introduction

The Southern California Earthquake Center has supported the development of a number of community models, one of which is the Crustal Motion Map, or CMM (formerly known as the Horizontal Deformation Velocity Map). Version 1.0 of this was released in October 1996, and version 2.0 in July 1998. Release of a third version was delayed by the need to respond to the Hector Mine earthquake, by the inclusion of considerably more data than had been used in the previous versions, and by our desire to organize the analysis in such a way that further upgrades and improvements would be relatively straightforward. The final release of Version 3 was made on August 1, 2003; see *http://epicenter.usc.edu/cmm3*.

2. CMM Update Activities

Over the past year we have made good progress towards an new version of the CMM which will provide even more complete coverage, and address some of the remaining issues in Version 3. Our goal remains one that is, so far as we know, unique in the crustal-motion community: to collect all relevant GPS data and process them in a consistent fashion, so as to produce the fullest possible set of station velocities for use in geophysical interpretation, including seismic hazard estimation. We will give a number of examples below of how this project combines data sets that otherwise would be difficult to evaluate, or would not be used at all.

2.1. Data Archiving

The first task is to get the data, from whatever source, and put them into a standard form—the more carefully this is done, the easier the subsequent processing. As always, all data we get are publicly available at the SCEC Data Center. **Figure 1** shows the locations for which we archived data in this year—though by no means all of the data were actually collected in the last year. As has happened before, the occurrence of an earthquake provoked data collection: in this case two earthquakes, the San Simeon and Parkfield events. In connection with these earthquakes we have archived data collected by Caltrans in 1993, by UC Berkeley in 2002-2003, by the USGS in 2003-2004, and by Caltrans again in 2004. Along the Eastern California Shear Zone we archived data collected by Central Washington University in 2001, and by the USGS in 2003 and (near Landers) in 2004. The patch of data east of Los Angeles comes from surveys from 1997-1999 by Greg Lyzenga at Harvey Mudd, and from 2000-2004 by Sally McGill at Cal State San Bernardino. The data in Baja California come from surveys by JPL and the University of Miami from 1993 through 2001. The very dense coverage of the Coachella and Imperial Valleys is from surveys by the USGS Water Resources Division in 1996 and 1998, and by Caltrans in 2004; these are examples of data that would normally end up inaccessible by the academic community.

We estimate the average cost of processing each data file at about ten dollars—a very good deal for SCEC, since this is about 1% of the cost of data collection in the field. Not all of these

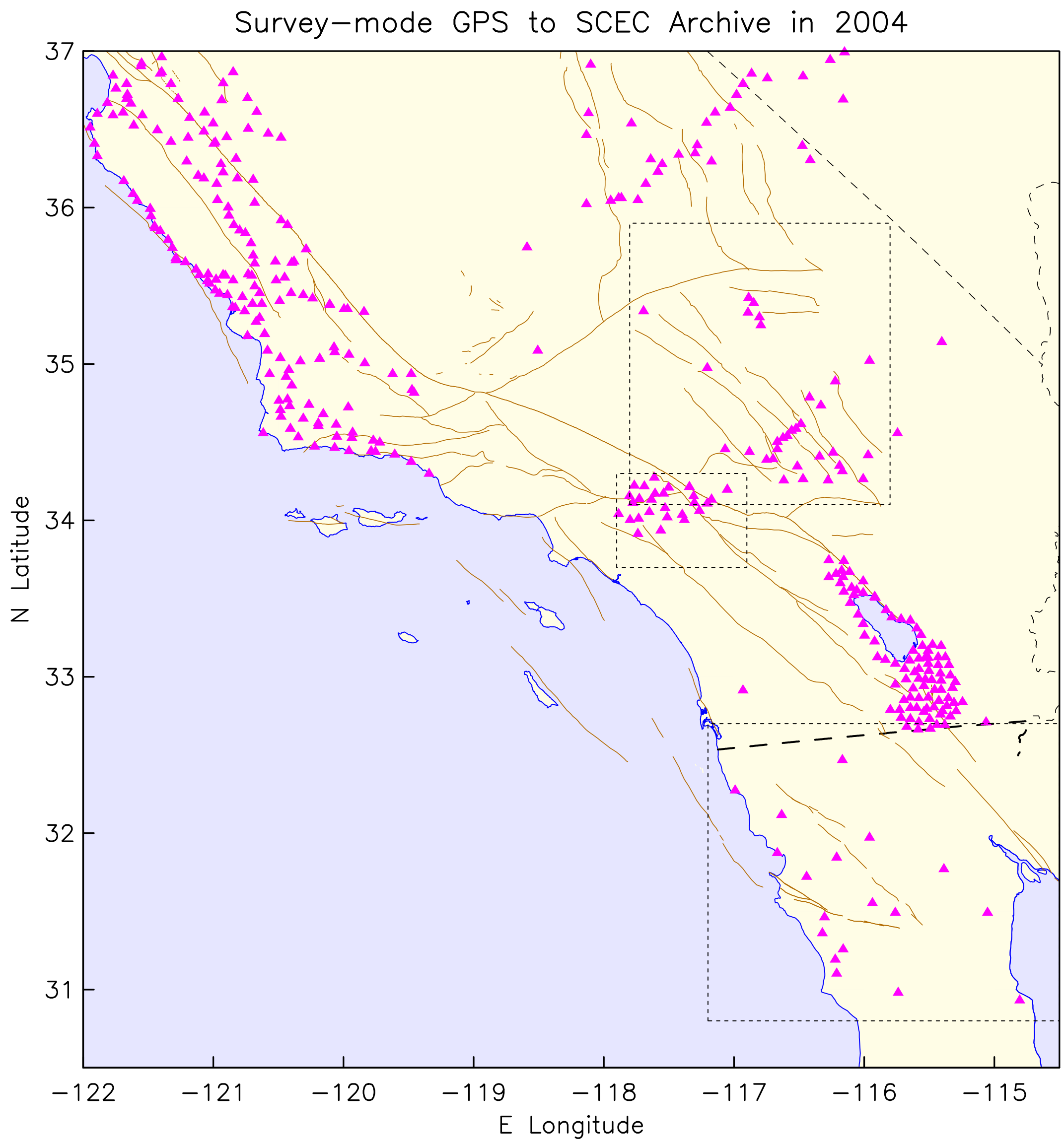

Figure 1

data are of the quality that would be collected with the goal of measuring crustal motion, but all will be useful for that purpose, given either time for motion to accumulate, or a large earthquake.

One byproduct of the archiving work has been the adoption by the PBO of the geolabelling system developed for monument ID's in the archiving software; because of its general utility a short article has been written to document this (Agnew 2005).

2.2. Data Processing

Not all of the data archived this year have been through our processing procedures, so we have still had plenty to do, both in improved processing of older data and in processing of data not included in Version 3.

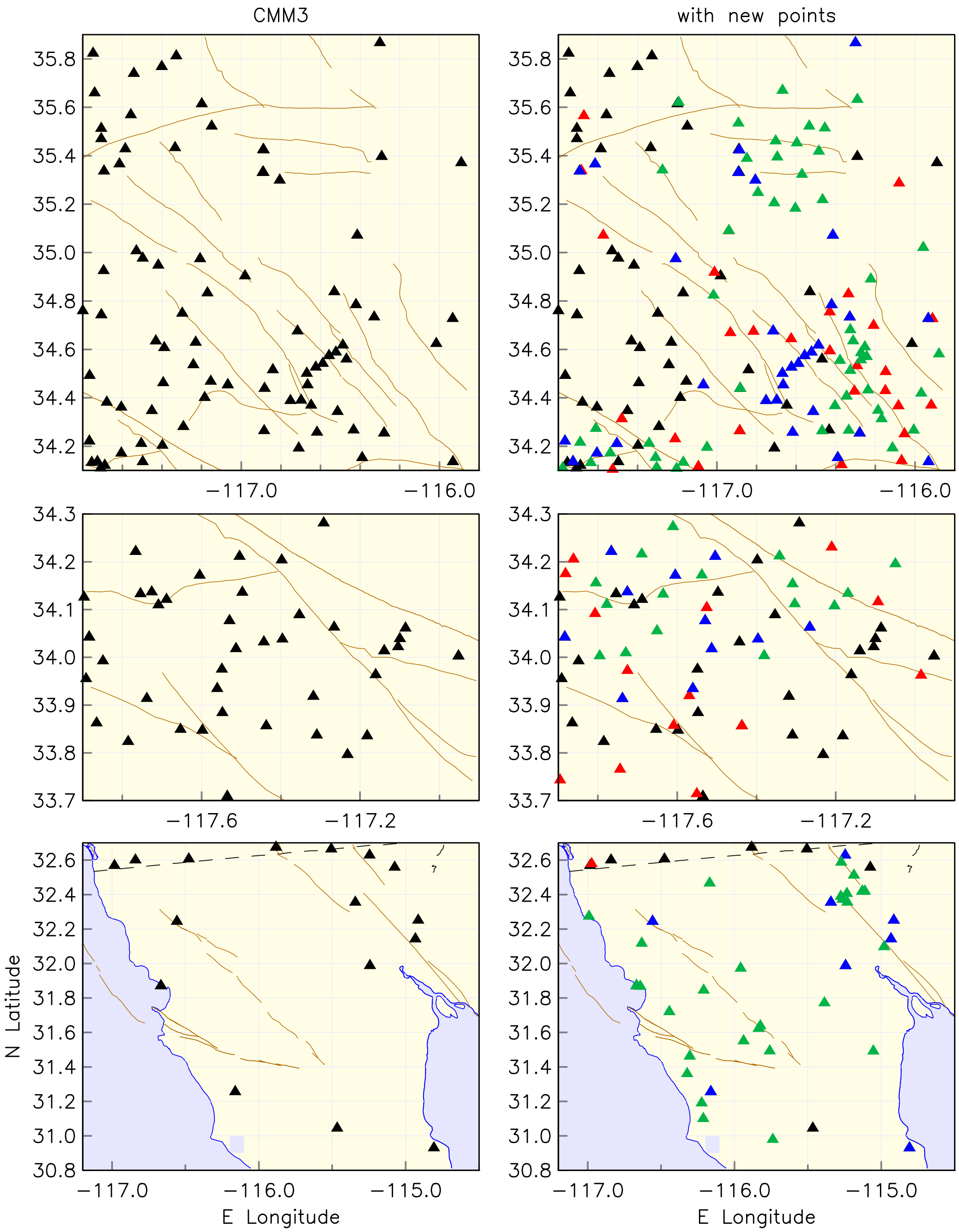

Figure 2

A particular effort in the last year was to reanalyze the data from the' 1990-1991 period—a special focus at UCLA. This period is important because it includes some of the data needed to define pre-Landers rates of deformation. But, because of severe SA condition, mixing of receiver type, and unsynchronized sampling epochs for certain type of receivers, processing of the 1990 data has been difficult and time consuming. During this year we gained considerable experience, including the separate processing of TI-4100 and other data, careful refinement of orbits through iteration (very important for some days), manual editing of phase data, and multi-day orbit solutions. We ended up redoing all the useful data for that year, a considerable volume given the number of campaigns done during that time. This will give us smaller errors for these sites, as well as some velocities for sites for which this epoch of data was previously unusable.

The inclusion of new data into the processing includes both the newly archived data described above, and data that were available but too late in time to be useful. In particular, choosing a fixed cutoff date in late 2001 for Version 3 meant that many SCIGN stations, and also data in the Hector area, were not included.

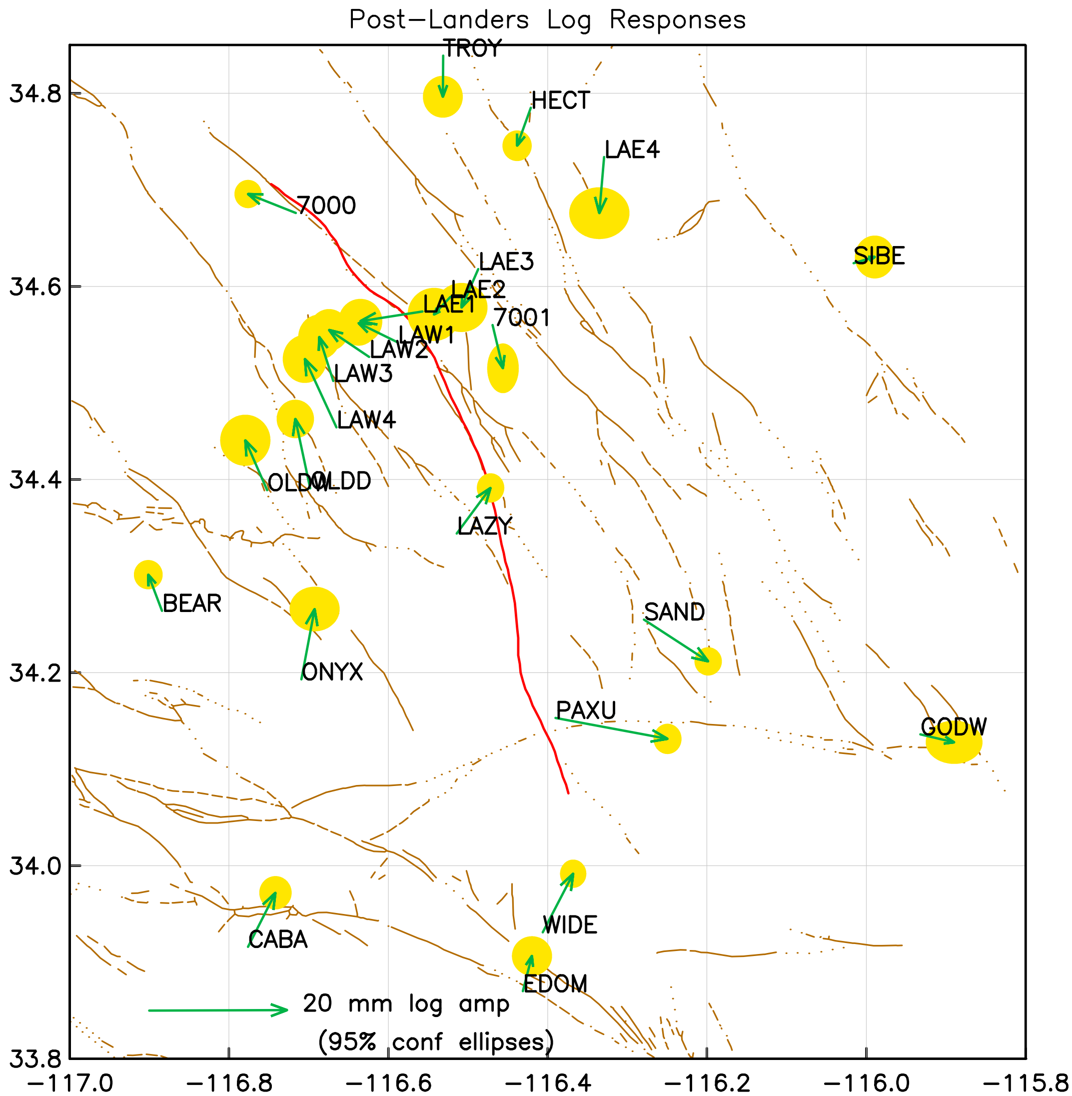

Figure 3

Figure 2 (in three frames, shown as dashed boxes in **Figure 1**) shows the impact of our efforts. In each pair of maps, the left shows the CMM points, and the right the same points, in blue if there is more data for them. Red points are SCIGN stations that will be added, and green survey-mode stations that will be added. The bottom plot shows the northern Baja California region, for which we will be adding the new points to other ones surveyed by CICESE, to produce a much more complete velocity field. The center plot shows the region east of Los

Angeles, with new stations and additional data from observations from Harvey Mudd and Cal State San Bernardino, as well as many more SCIGN sites; this densification of the velocity field will help in understanding the mechanics of junction between the San Andreas and San Jacinto faults. The top plot shows the Eastern Mojave, with many new measurements (and updated ones) from the Hector Mine earthquake (which we previously excluded from our analysis), as well as new points nearer the Garlock fault observed by the US Geological Survey. While the groups that collected the data have often published the results of their own analyses, only the CMM effort will produce a uniform set processed in a consistent way.

2.3. Modeling Deformation

A difficulty in producing interseismic rates for the CMM has been the occurrence of several large earthquakes; as noted above, this has required us to deal with older and more difficult data. This has also presented a challenge in deciding how extensive postseismic unsteady rates are, and how we should deal with them— something we are learning better how to do for the Landers earthquake as the time series from the better-instrumented Hector Mine event continues to lengthen. An excellent fit to the data appears to be a displacement of the form $\mathbf{x}(t) = \mathbf{a} \log_e(1 + t/t_0)$, with $t_0 = 10$ days. (We show an example of such a time series in our proposal for this year). Given this assumed function form, we have estimated **a** for many of the stations in the Landers area, even those with relatively sparse temporal sampling; the **a** vectors are shown in **Figure 3**. These Landers results suggest that even well away from the earthquake, there would still be significant contributions to the velocity: an amplitude of 10 mm for **a** would mean a current velocity of 0.8 mm/yr.

References

D. C. Agnew, “GHAM: a compact global geocode suitable For sorting,” *Comput. Geosci.* (2005).