The California CORS Program

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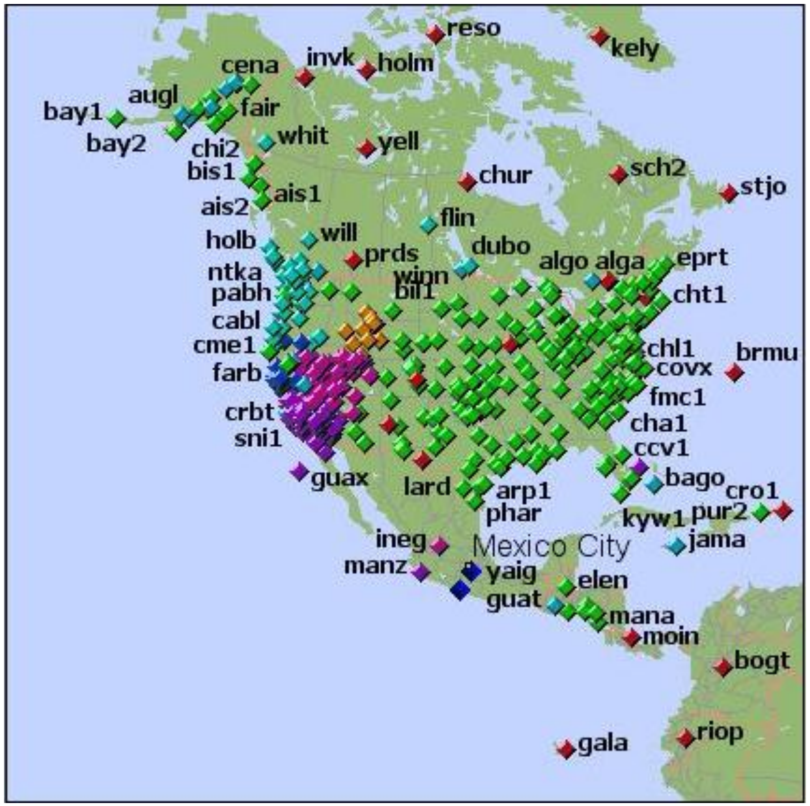
CORS Users Forum

National Geodetic Survey, NOAA/NOS

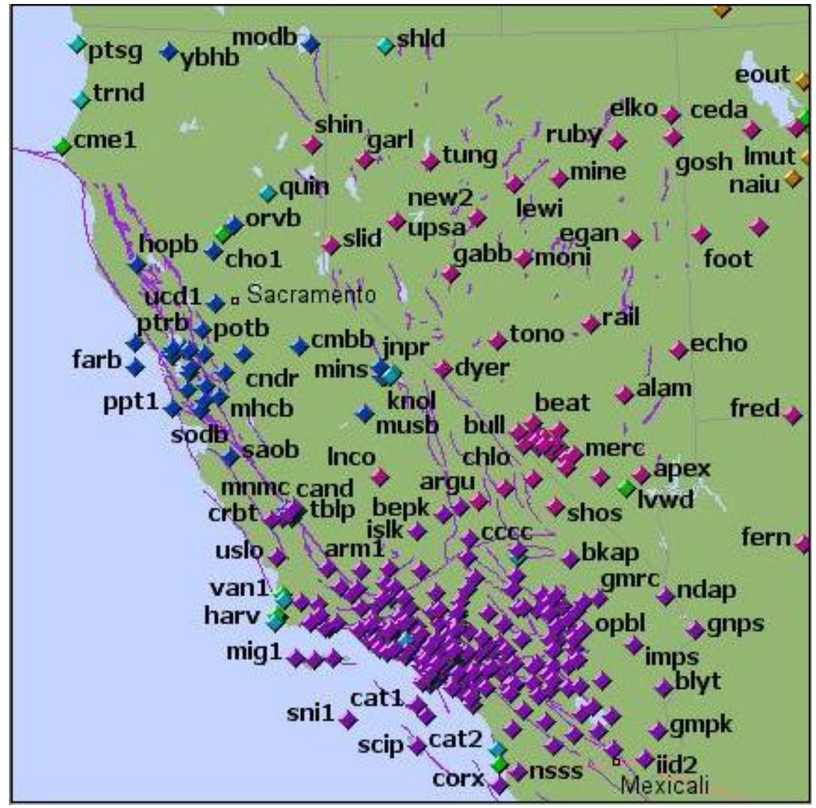
Silver Spring, Maryland

April 19, 2002

Current State of CORS in California



CORS in North America



CORS in California and Nevada

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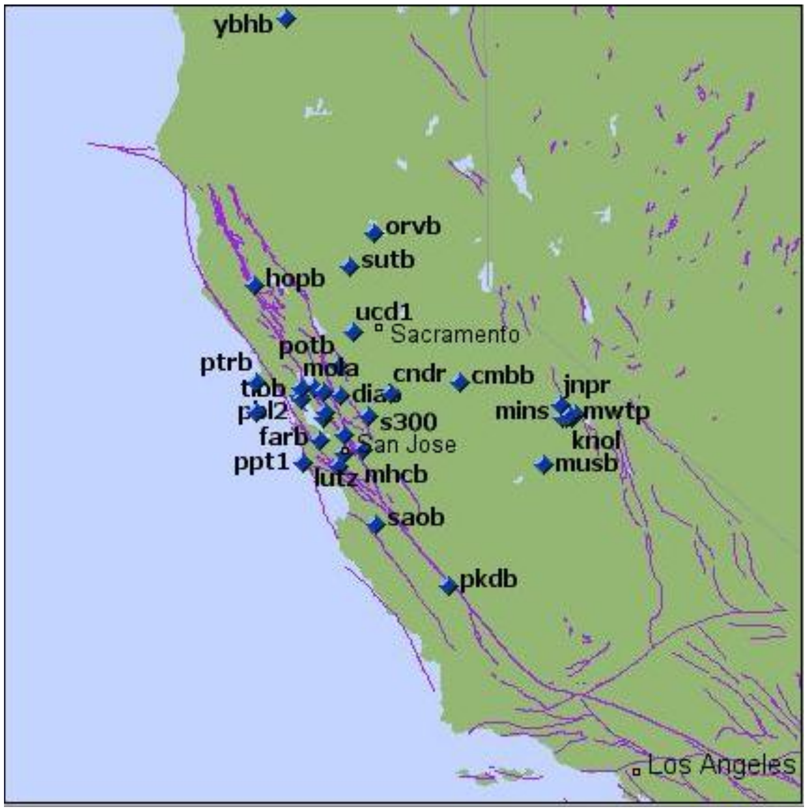
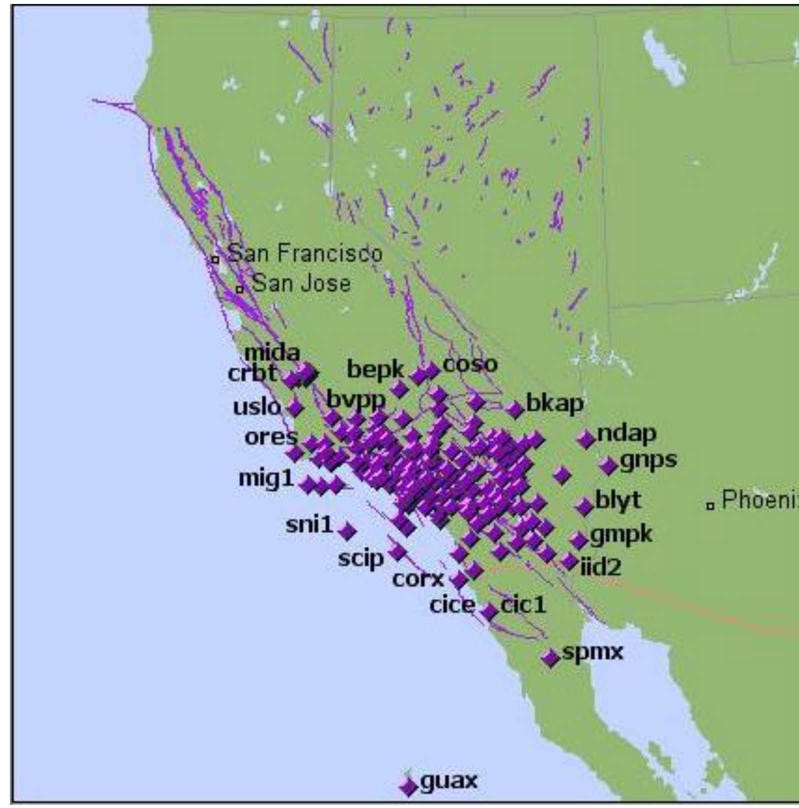
Current State of CORS in California



Bay Area Regional Deformation Array (BARD) - 50 stations



Southern California Integrated GPS Network (SCIGN) - 250 stations

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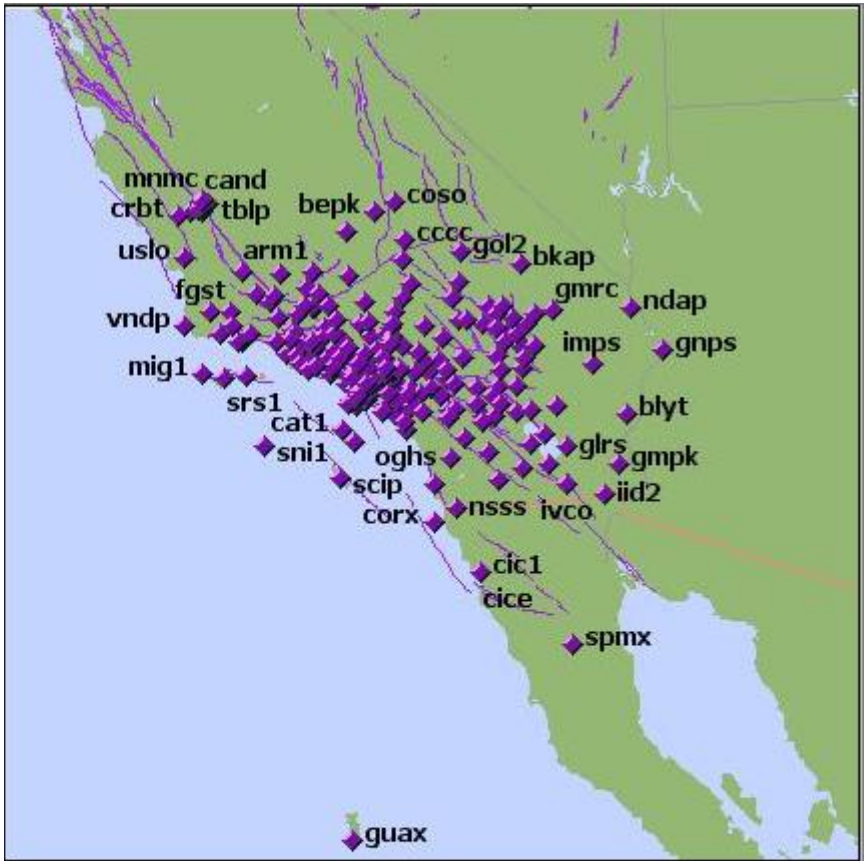
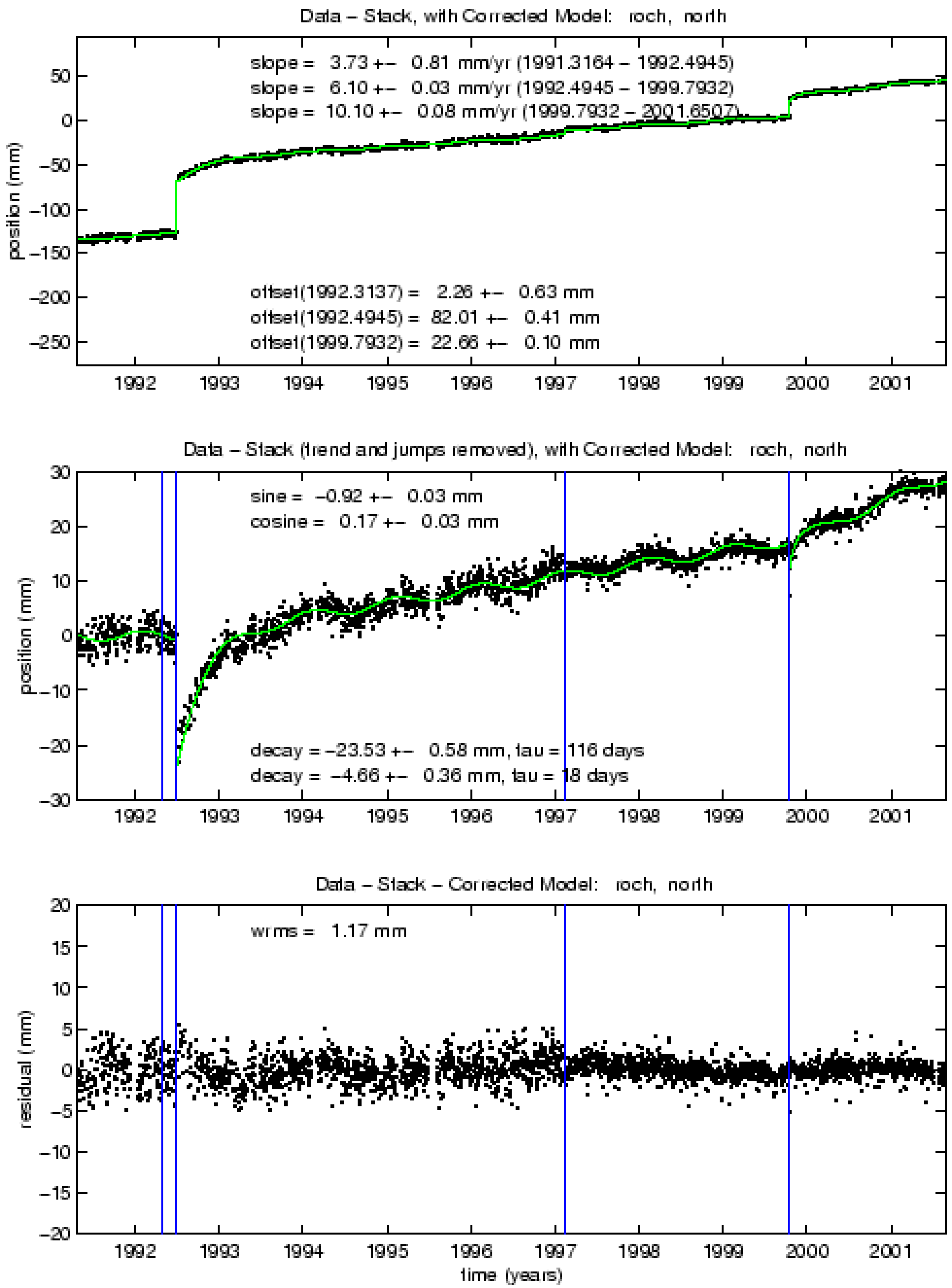
History of CORS in California

- *Starting with the destructive San Francisco earthquake in 1909, California has been an incubator for the application of high precision geodetic measurements. Scientists at NGS and its predecessor agency, the Coast and Geodetic Survey, have been very active in this arena.*
- *Geophysical scientists have led the development of GPS geodesy for the study of crustal deformation and earthquakes in California, first by field surveys (starting in mid 1980's), then by continuously monitoring stations. One of the first regional CORS network in the world (the Permanent GPS Geodetic Array) was established in southern California in 1990.*
- *The destructive 1994 Northridge earthquake spurred a significant increase in GPS monitoring stations in southern California and led to the establishment of the Southern California Integrated GPS Network (SCIGN).*
- *Along with similar efforts in northern (BARD array) and eastern California (BARGEN array), the number of CORS sites in the state is more than 350. The geophysical community is seeking to more than double the number of CORS stations in California through NSF's EarthScope/PBO Project.*

Southern California Integrated GPS Network (SCIGN)



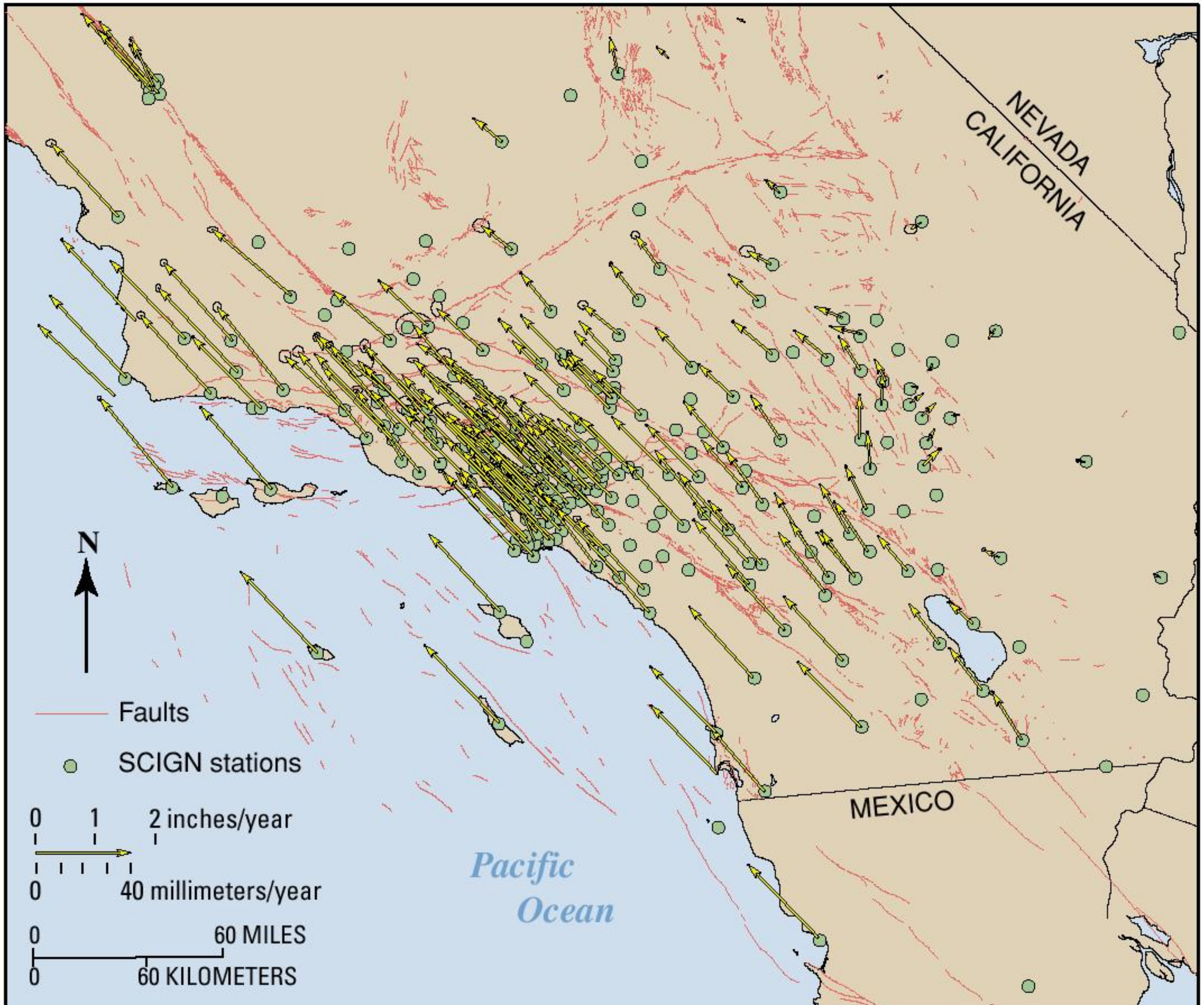
SCIGN is at the forefront of high precision continuous GPS measurements of crustal deformation with innovations in site instrumentation, stable monuments, data analysis, archiving and dissemination.



Deformation in California

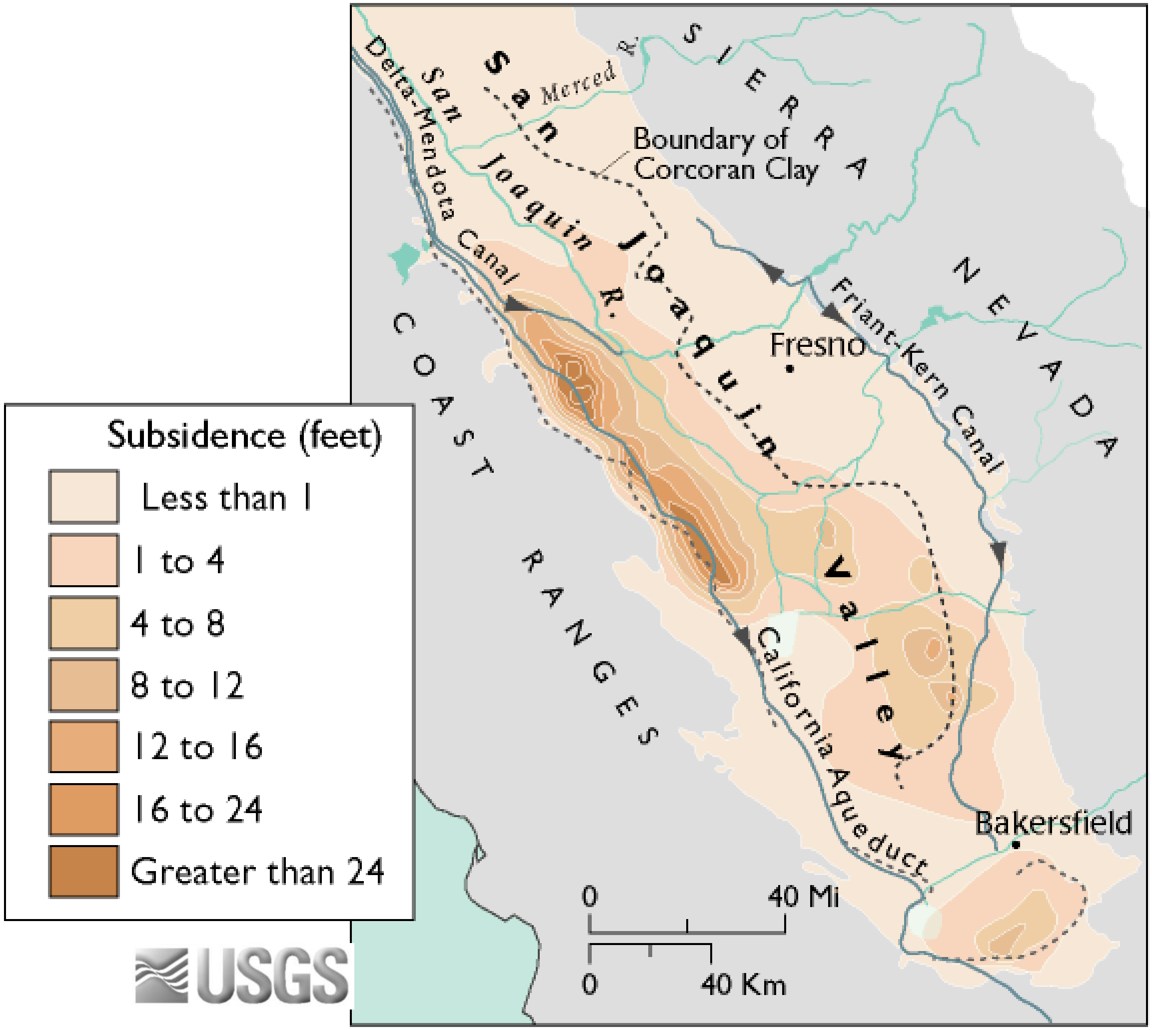
The position time series on the left shows the north position component of the SCIGN site at Pinemeadows (ROCH) changing by almost 200 mm over a 10-year interval. Each point represents a 24-hour solution of GPS data sampled at a 30 s sampling rate. The filtered time series (minus regional common-mode signature) is modeled by three linear trends discontinuous at Landers and Hector Mine earthquakes, three coseismic offsets (Joshua Tree, Landers, Hector Mine earthquakes), two postseismic decays (Landers and Hector Mine), an annual term, and one equipment-change offset. The weighted rms is only 1.2 mm.

Tectonic Motion in Southern California

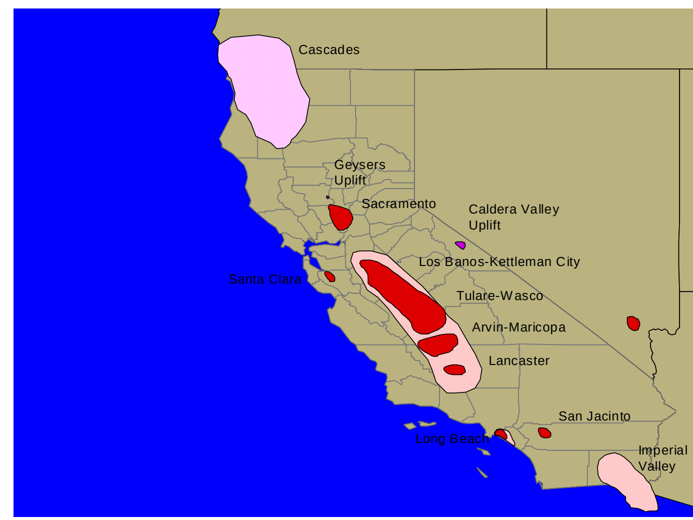


Southern California is the location of the plate boundary between the North America and Pacific plates. The map shows the motion of the SCIGN sites with respect to the North America, including a total motion of about 45 mm/yr across a region about 200 km wide with numerous geologic faults. Determining the architecture of faulting and distribution of strain is critical for earthquake studies.

Subsidence in California



California is also "blessed" with large areas of vertical motion due to fluid extraction (water, oil), and volcanic deformation.



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Vertical motion in Southern California

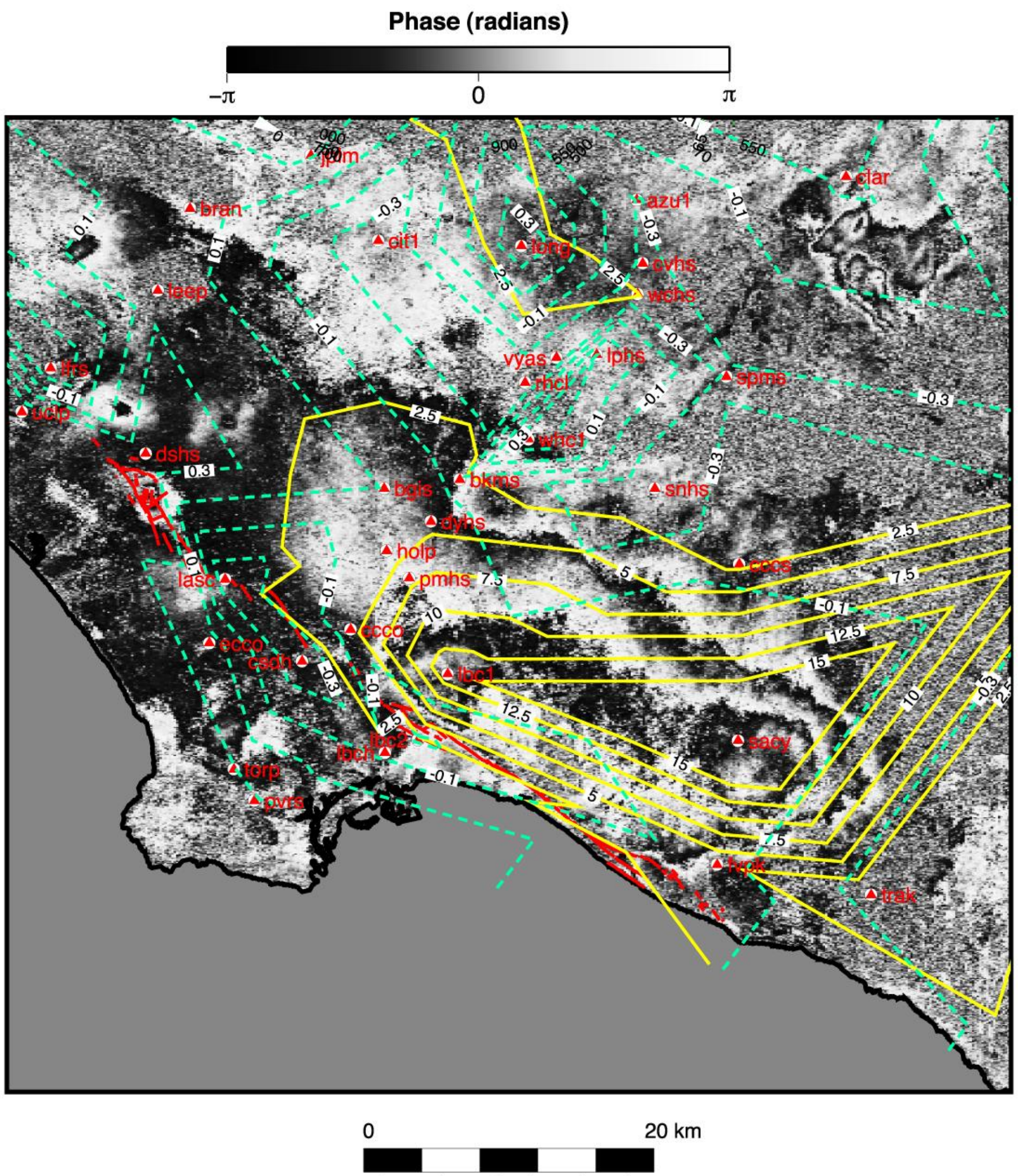


PLATE 2

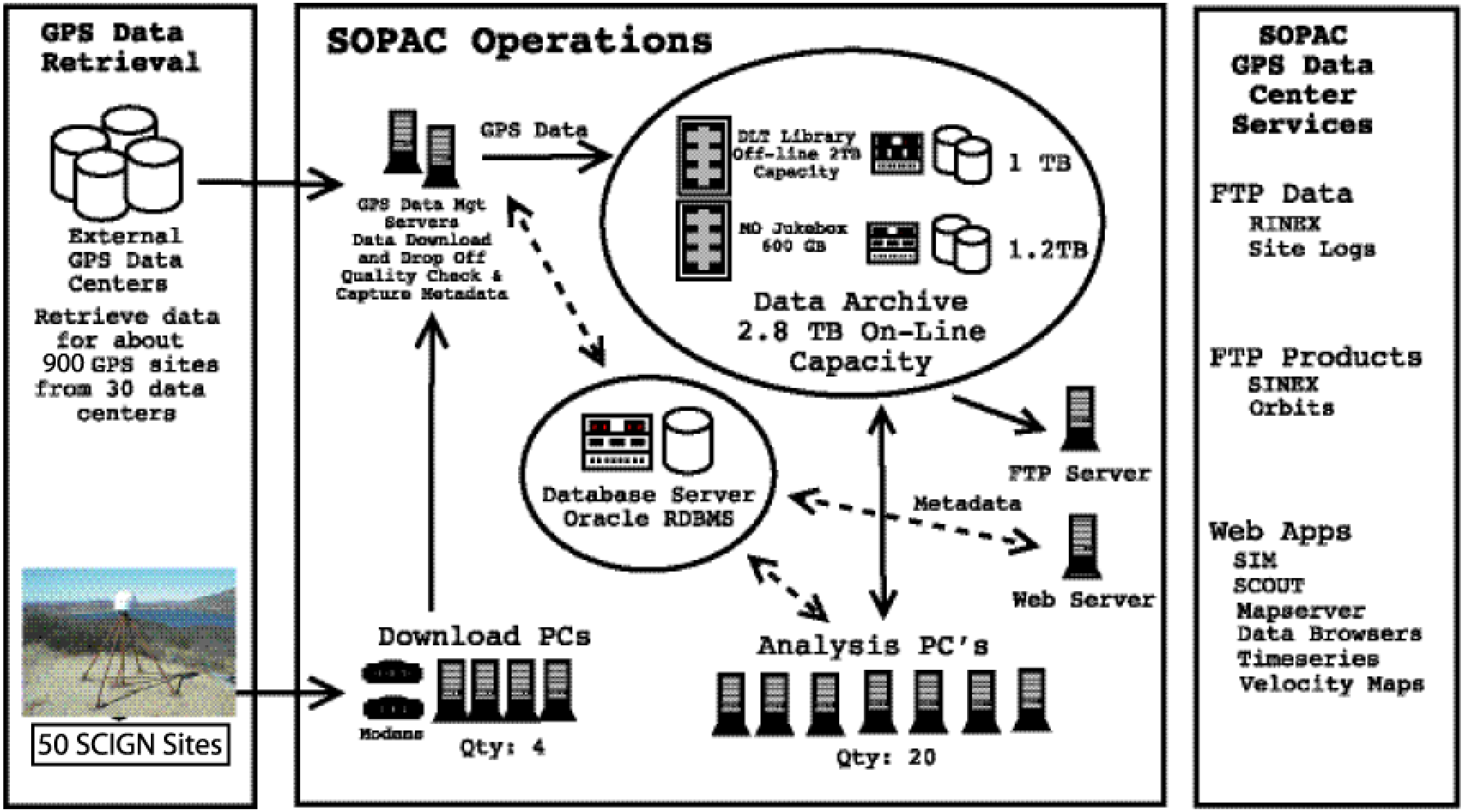
California also relies on other technologies to monitor crustal motion, but these also depend in some way on C ORS. In this example, large areas in the Los Angeles and Orange Counties becomes inflated in April which is consistent with water table measurements and the end of the rainy season. The spatial pattern of the amplitude of the annual signal (solid yellow contours in mm) derived from SCIGN sites is consistent with the shape of the interferometric SAR fringes (black/white image). Each fringe represents about 28 mm of motion in the line of sight to the satellite.

Reference: Watson et al., Journal of Geophysical Research, in press, 2002.

Scripps Orbit and Permanent Array Center (http://sopac.ucsd.edu)

SOPAC is the largest archive of continuous GPS data and data products with about 950 sites from around the world collected every day, including about 350 CORS sites in California.

SOPAC Archive and RDBMS



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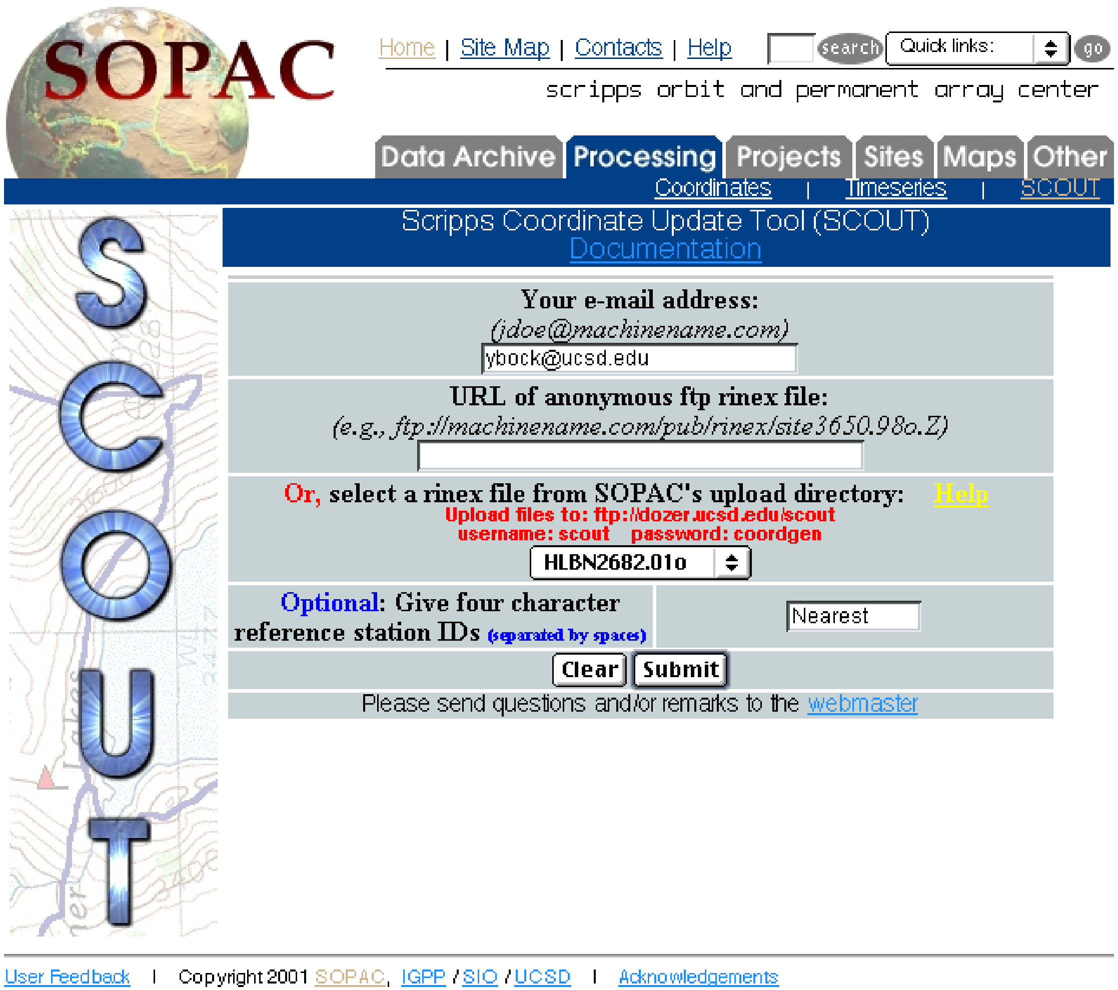
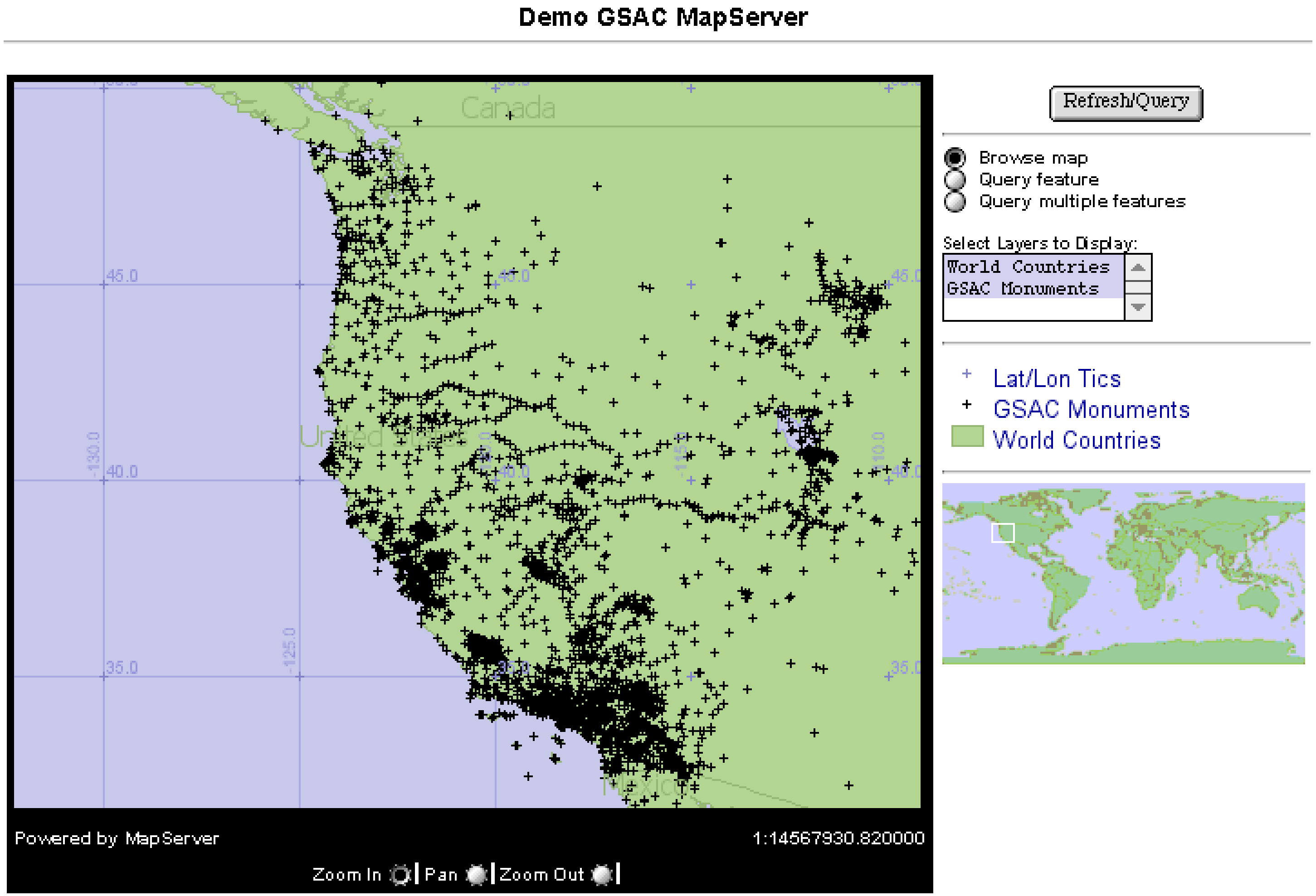
SCOUT: SOPAC Coordinates Update Tool

(http://sopac.ucsd.edu/cgi-bin/SCOUT.cgi)



UNAVCO GPS Seamless Archive: Map of GPS Data - Western U.S.



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California Spatial Reference Center

"Providing California's geodetic framework for scientific, surveying, engineering, and geographic information systems"

- ***Mandate (in partnership with NGS):***
  - ***Provide the necessary geodetic services to ensure the availability of accurate, consistent, and timely spatial referencing data.***
  - ***Establish the legal spatial reference system for California.***
  - ***Monitor temporal changes in geodetic coordinates due to tectonic motion, volcanic deformation and land subsidence.***

History of the CSRC

- ***The surveying/engineering community in California has worked with and supported the geophysical scientists in GPS measurements of crustal deformation. Surveyors in southern California (Riverside, Los Angeles, San Diego, and Orange Counties) have been at the forefront of this collaboration.***
- ***A group of surveyor activists started a grass roots movement to leverage the GPS infrastructure established for earthquake research as the basis for defining and maintaining a statewide geodetic reference frame. They felt that California had special geodetic needs because of its tectonic setting, extensive land subsidence, and natural hazards, along with one of the largest economies in the world. This effort eventually coalesced into the California Spatial Reference Center. This group has unselfishly promoted the CSRC for the past several years and has started educating the public on its benefits.***
- ***The CSRC organized itself into a Coordinating Council with representatives of all the relevant agencies and organizations in California (more than 40) and an Executive Committee.***

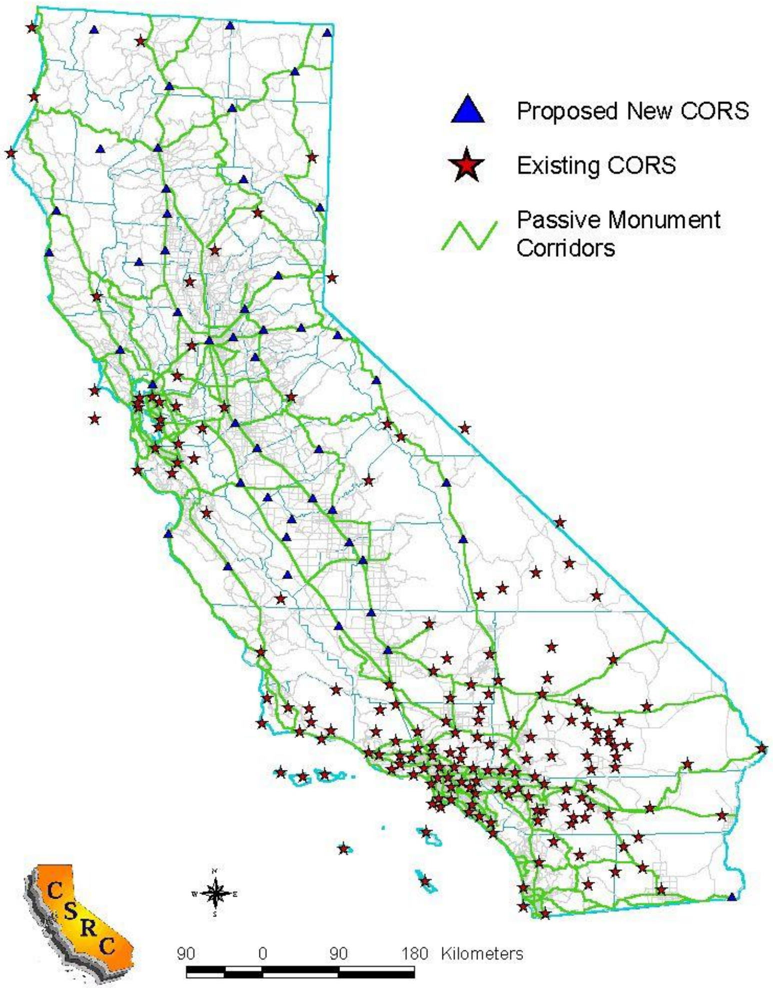
CSRC Highlights

- *CSRC leverages ~$25M investment in geophysical science infrastructure over the last decade (includes SOPAC).*
- *Operational center dedicated at University of California San Diego's Scripps Institution of Oceanography in February, 2001.*
- *CSRC is now an official UCSD Support Group (Bylaws approved as part of process).*
- *Significant increase in funding in FY '01 ($1M from NGS) for height modernization and real-time GPS positioning networks ($80K from Orange County).*
- *$1M FY'02 funds in NGS budget for CSRC. Caltrans funding for CORS/HPGN ITRF2000/NAD83 analysis, and CORS infrastructure.*

NGS and CSRC Partnership

- *CORS coordinates and velocities computed by CSRC are sanctioned by NGS and are the legal basis for surveying in California.*
- *Work jointly to provide seamless links between the databases of the California Spatial Reference Center (CSRC) and the NGS, and to make NSRS data and CSRS data available to users.*
- *CSRC maintains a secondary archive of the national CORS for NGS, and work cooperatively with NGS to archive CORS data collected in North America (including Canada and Mexico).*
- *Cooperate in the preparation and publication of the NAD 2004 and in the production of velocity maps for use in the Horizontal Time Dependent Positioning (HTDP) model.*

CSRC Master Plan



The CSRC has developed a Master Plan a 4-D spatial reference network for height modernization and geodetic control in California that includes a mix of CORS and traditional geodetic monuments along transportation corridors. The actual implementation will probably depend on technological developments such as wide-area RTK, real-time networks, and wireless communications.

Surveying

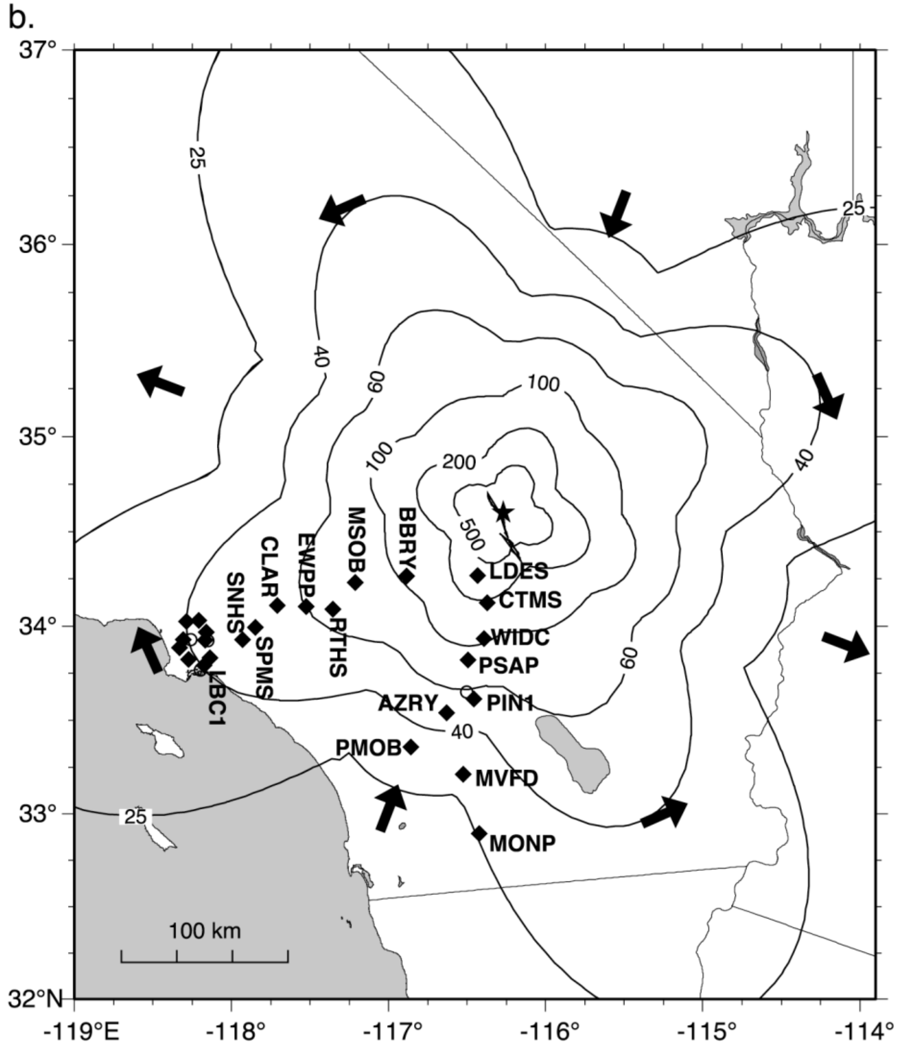
- *Commercially driven*
- *High productivity*
- *Continuous real-time access to data*
- *High sampling rate (1-5 sec)*
- *Near real-time processing*
- *Static datum*

Geophysics

- *Scientifically driven*
- *High accuracy*
- *Daily to hourly access to data*
- *Low sampling rate (30 sec)*
- *Post processing*
- *Dynamic datum*

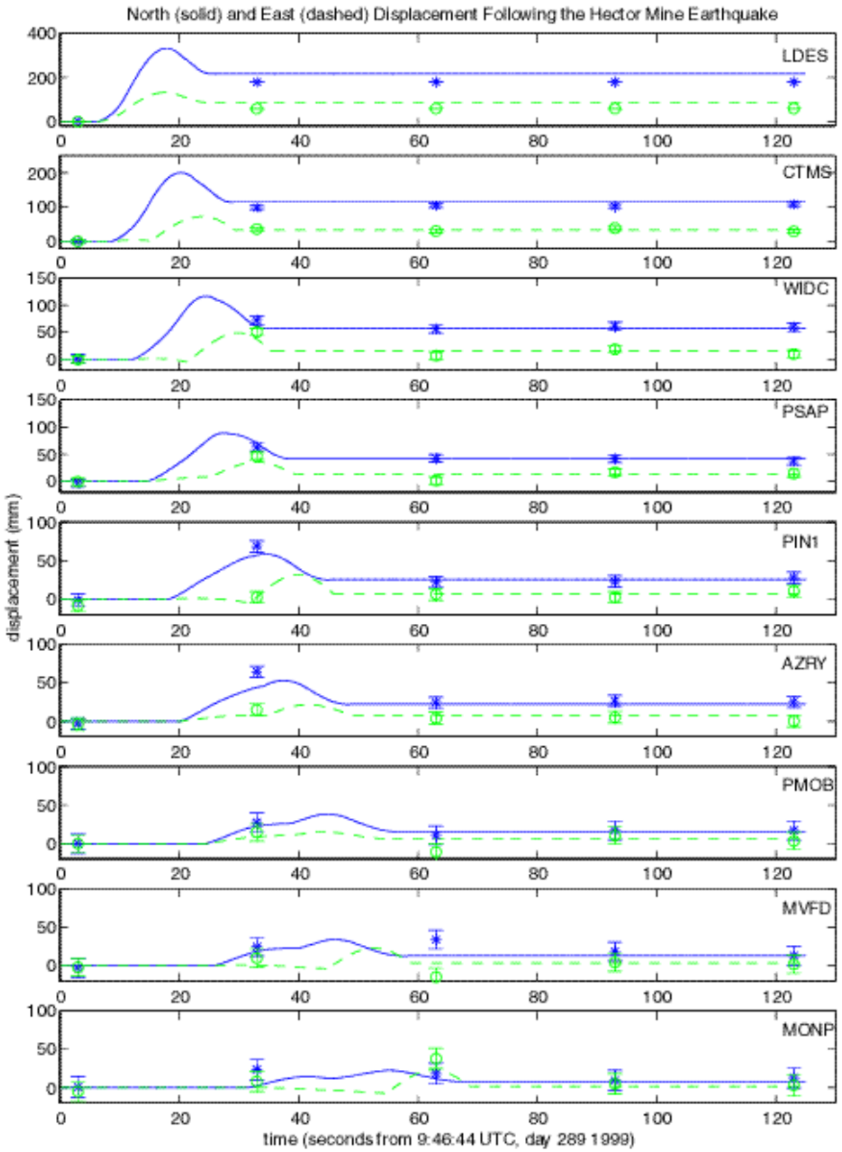
Although CORS are very useful for both the surveying and geophysics communities, the requirements have been different as illustrated in the bullets above. New GPS analysis techniques such as instantaneous (epoch-by-epoch) positioning have demonstrated the usefulness of high-rate, real-time requirements for geophysical science (see next three slides).

Measuring Seismic Ground Motion with CORS



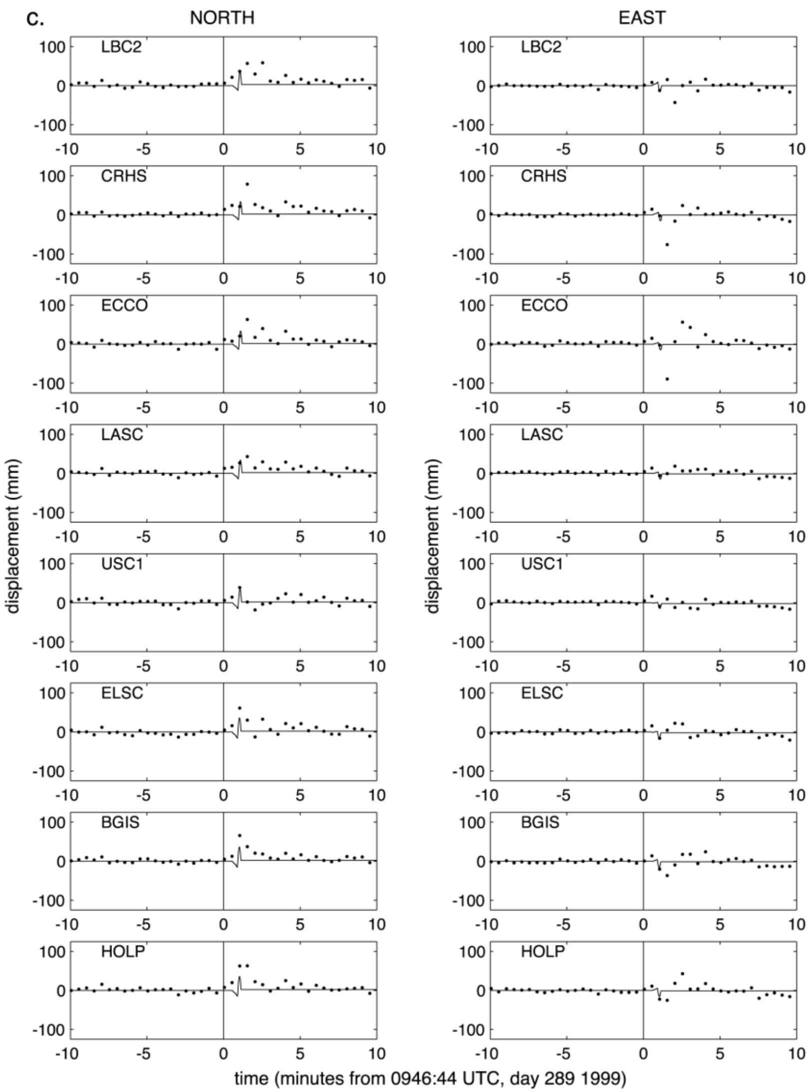
The 1999 Mw=7.1 Hector Mine earthquake (star denotes epicenter) caused significant ground motion (dynamic and permanent) over much of southern California. The contours indicate the amount of horizontal ground motion induced by the earthquake (in mm). The arrows show the direction of motion. The black diamonds indicate a subset of SCIGN sites active during the earthquake.

Measuring Seismic Ground Motion with CORS



Observed and modeled ground displacements along the north-south SCIGN profile in north (blue asterisks and line) and east (green asterisks and line) for 120 seconds after the earthquake. Instantaneous 30 s coordinates of the sites were estimated relative to LDES, closest to the epicenter. Sites are in the order of closest (top) to farthest (bottom) from the epicenter. Note the excellent match between observed and modeled displacements, in particular the 2nd and 3rd set of measurements after the earthquake at sites WIDC (74 km from epicenter), PIN1 (110 km) and MONP (189 km).

Measuring Seismic Ground Motion with CORS



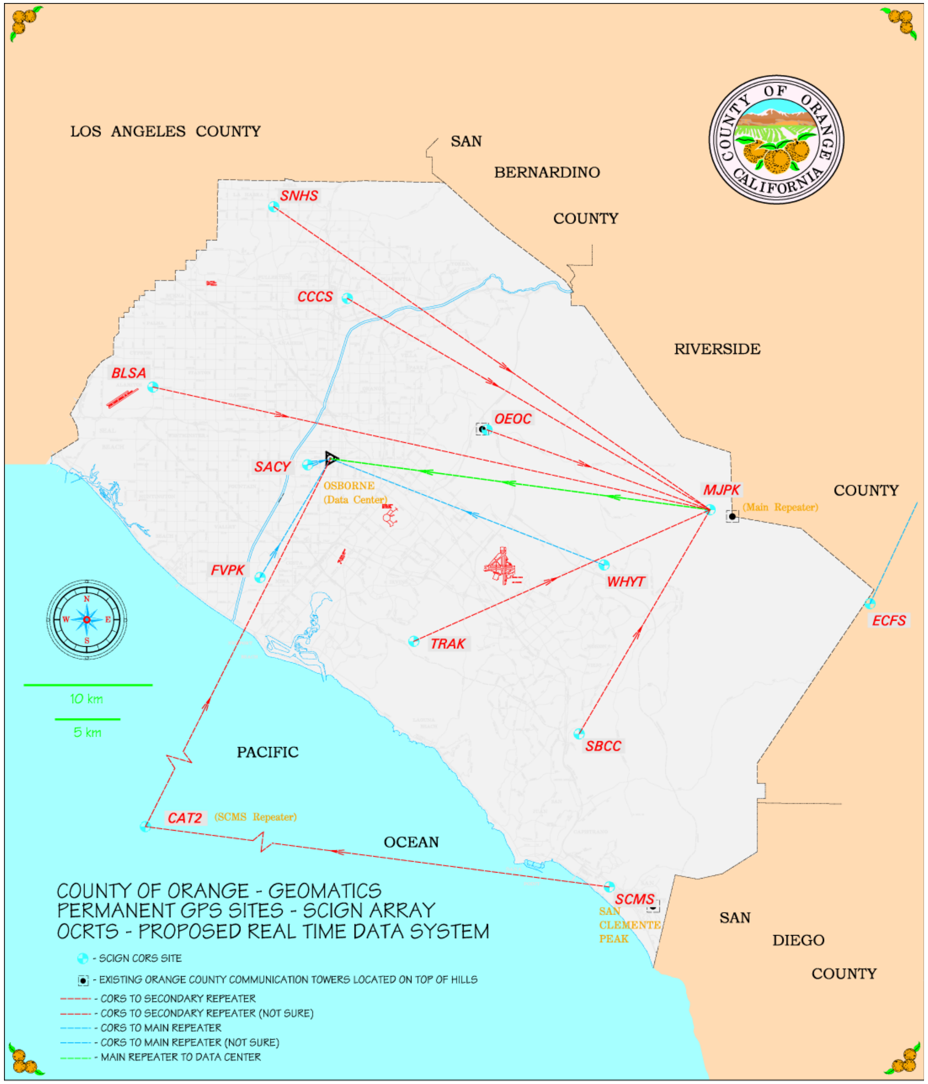
North and East displacements of the SCIGN sites in the Los Angeles basin for the 20 minutes centered on the Hector Mine earthquake.

Clearly, the GPS record show large amplitude ground displacements lasting for more than a few minutes at some locations in LA. It is likely that lower frequency signals may be a significant contributor to the overall ground displacement. Seismic data is usually restricted to several seconds after the event.

CSRC 2001 Projects
Funded by NGS

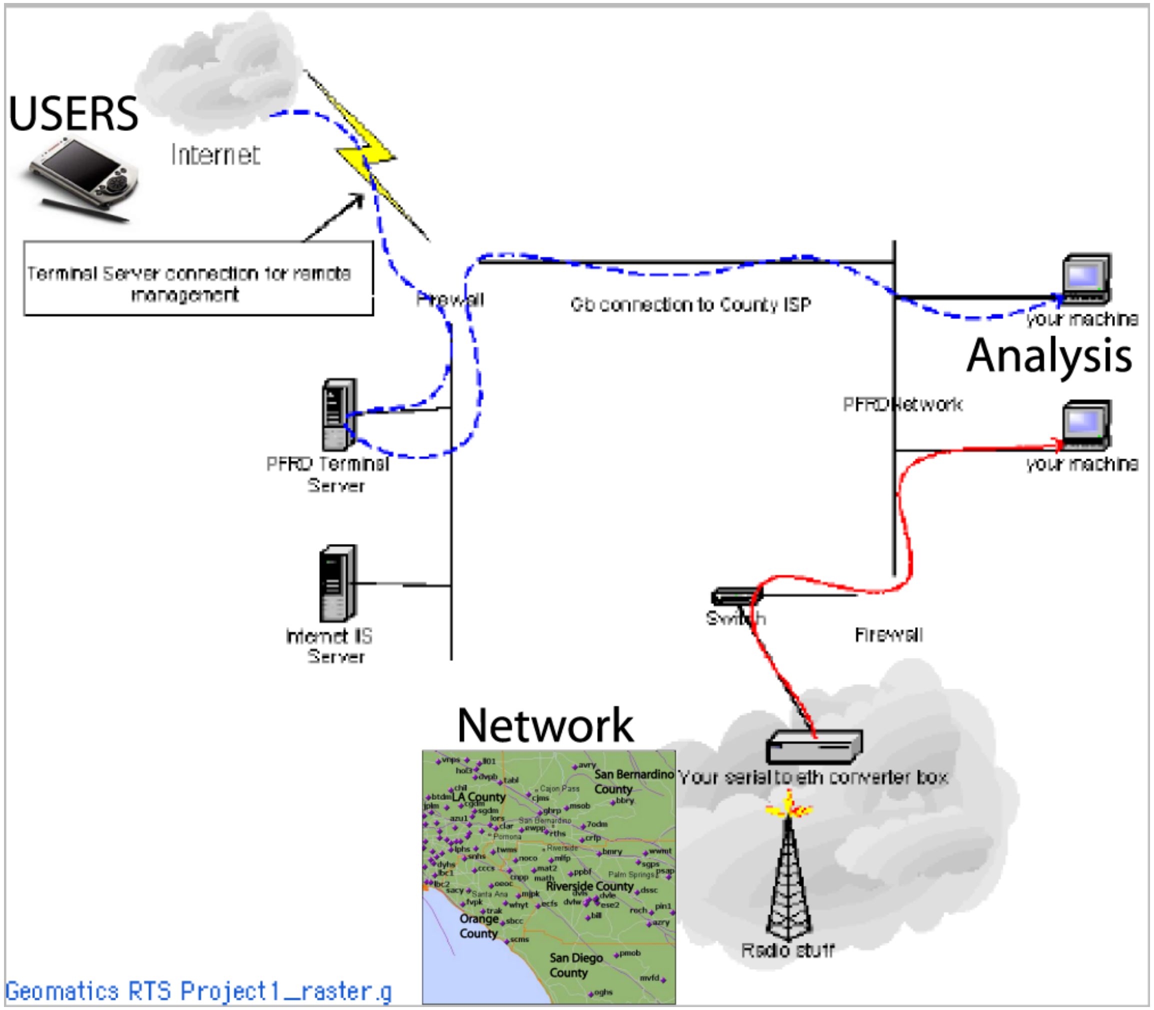
- *California Spatial Reference Network Master Plan*
- *Orange County Real-Time GPS Network*
- *CSRC Data Portal Development*
- *NAVD88 Height Derivation on CORS*
- *South San Francisco Bay Height Modernization*
- *Interferometric SAR (InSAR) and Height Modernization*

Orange County Real-Time Network



- ***RTK Web Service for Orange County's Geomatics/Land Information Division of the County's Public Facilities and Resource Department (PFRD).***
- ***Wireless radio telemetry for the 1 Hz real time data stream from 12 SCIGN/CORS sites.***
- ***Capture data on server. QC data and transfer via TCP/IP to CSRC/SOPAC in real-time (1 sec latency).***
- ***Testing Leica's CRNet and Trimble's VRS software.***

Orange County Real-Time Network - County-Wide RTCM Web Server



- *RTCM server will provide RTK data via TCP/IP sockets.*
- *Wireless Web access to RTCM server.*
- *Eliminate the need for a local RTK base stations and provide a common datum.*
- *Determine in-the-field orthometric heights by providing a geoidal model and a corrector surface.*
- *Position dynamic objects in real-time.*

Some Real-Time CORS Applications

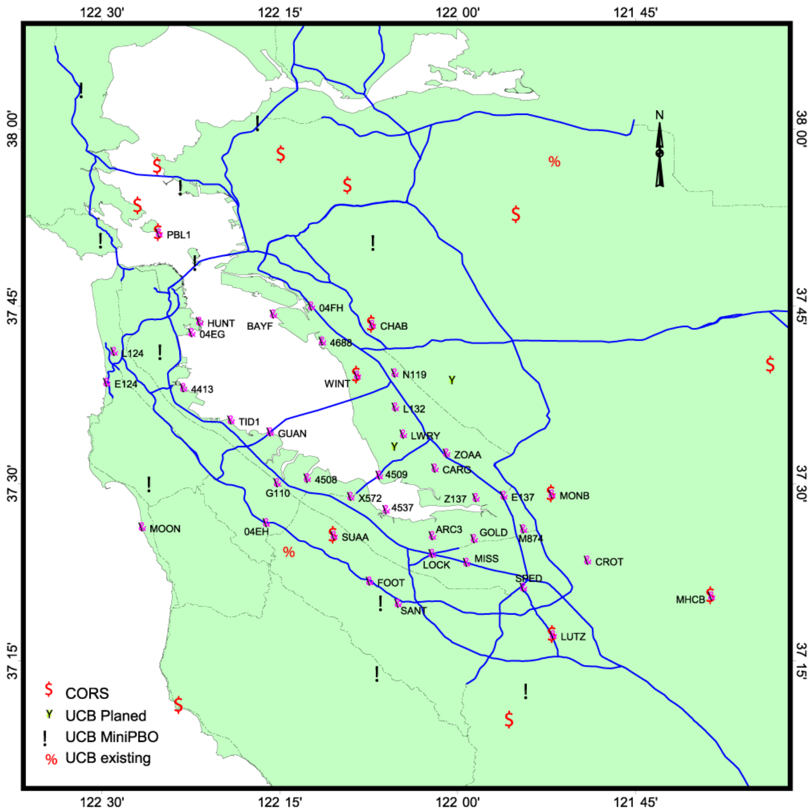
- ***Surveying and Precise GIS***
- ***Emergency Services***
- ***Landslide warning systems***
- ***Dam and bridge deformation***
- ***Vehicle tracking, automated highways, intelligent transportation***
- ***Aircraft landing and harbor approach***
- ***Machine control***

Dam Deformation: Diamond Valley Lake

- *Largest water reservoir in southern California*
- *Three earthen dams*
- *7 GPS receivers sampling at 2 seconds*
- *Maximum distance 8 km*
- *Data streaming by radio modems*
- *Real-time network solution*

Raw data and photo courtesy of Mike Duffy and Cecilia Whitaker, Metropolitan Water District of Southern California

More Real-Time GPS Networks



South San Francisco Bay Height Modernization Project

Southbay Proj. Points

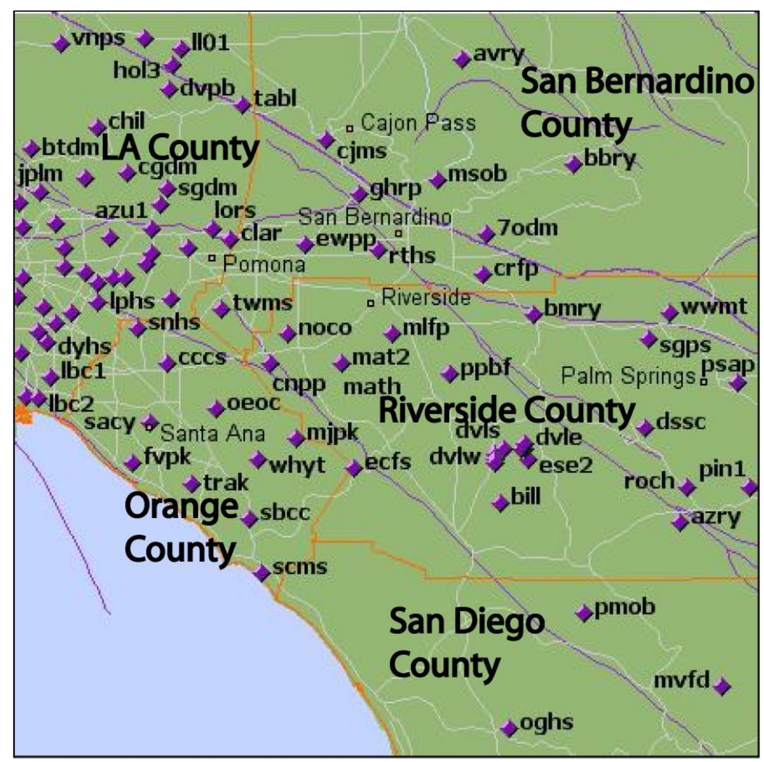
Roads

Primary road with limited access

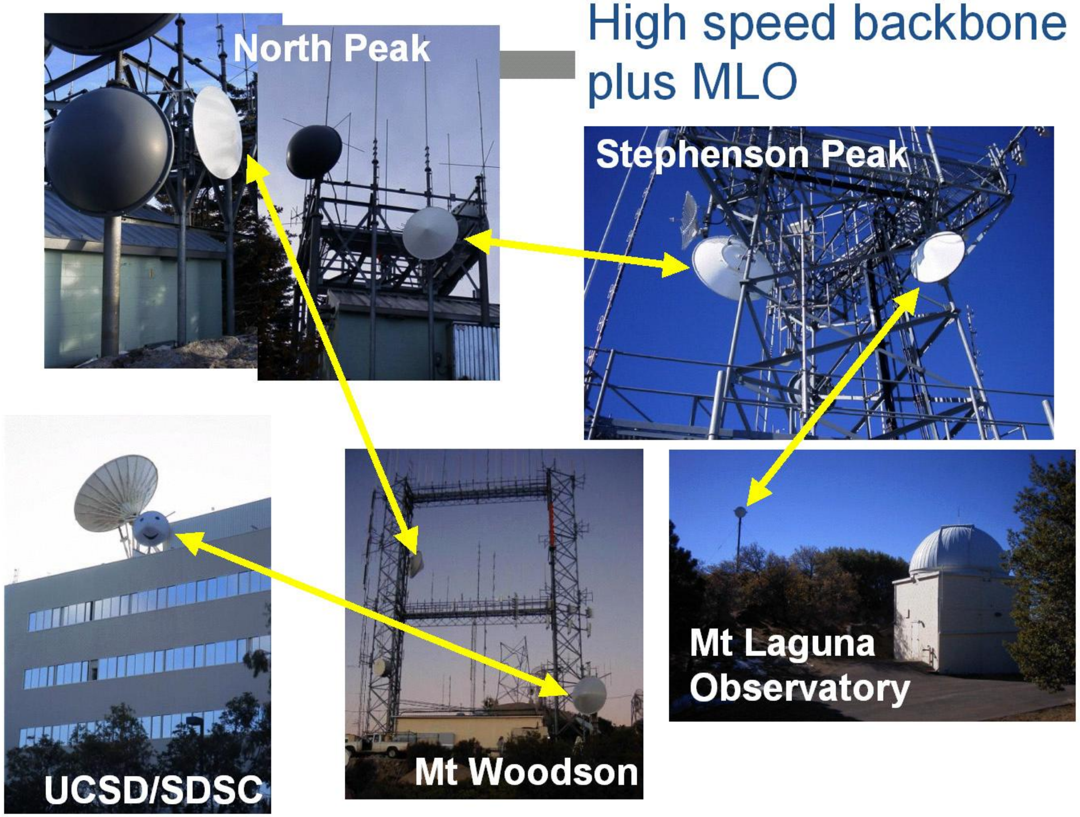
Primary road

4-ch id	Station name	4-ch id	Station name	4-ch id	Station name
4508	941 4508 C TIDAL	04EG	HPGN D CA 04 EG	MONB	MONUMENT PEAK BARD
4509	941 4509 H	04EH	HPGN D CA 04 EH	MOON	MOON 2
4537	941 4537 NO 4 RESET	04FH	HPGN D CA 04 FH	MHCB	MT HAMILTON BARD
4688	941 4688 B TIDAL	SANT	HPGN D CA SAN ANTONIO	N119	N 1197
ARC3	ARC 34	SPED	HPGN D CA SAN PEDRO	PBL1	POINT BLUNT 1
BAYF	BAYFARM	MISS	HPGN D CA MISSION	4413	SEAPLANE
CARG	CARGILL	HUNT	HUNTER WEST RM 1	GOLD	SCVWD BM 290
CHAB	CHABOT BARD CORS	LOCK	LOCKHEED	SUAA	SUAA STANFORD CORS
CROT	CROTHERS	L124	L 1241	TID1	TIDAL 1
E124	E 1241	L132	L 1326	WINT	WINT WINTON
E137	E 1371	LWRY	LOWRY	X572	X572 RESET
FOOT	FOOTHILL	LUTZ	LUTZ LI	Z137	Z 1370
G110	G 110 RESET	M874	M 874	ZOAA	ZOA A
GUAN	GUANO ISLAND RESET				

OCRTN is a prototype for other installations within the State such as Western Riverside County (below) and the SF Bay Area (to the left).



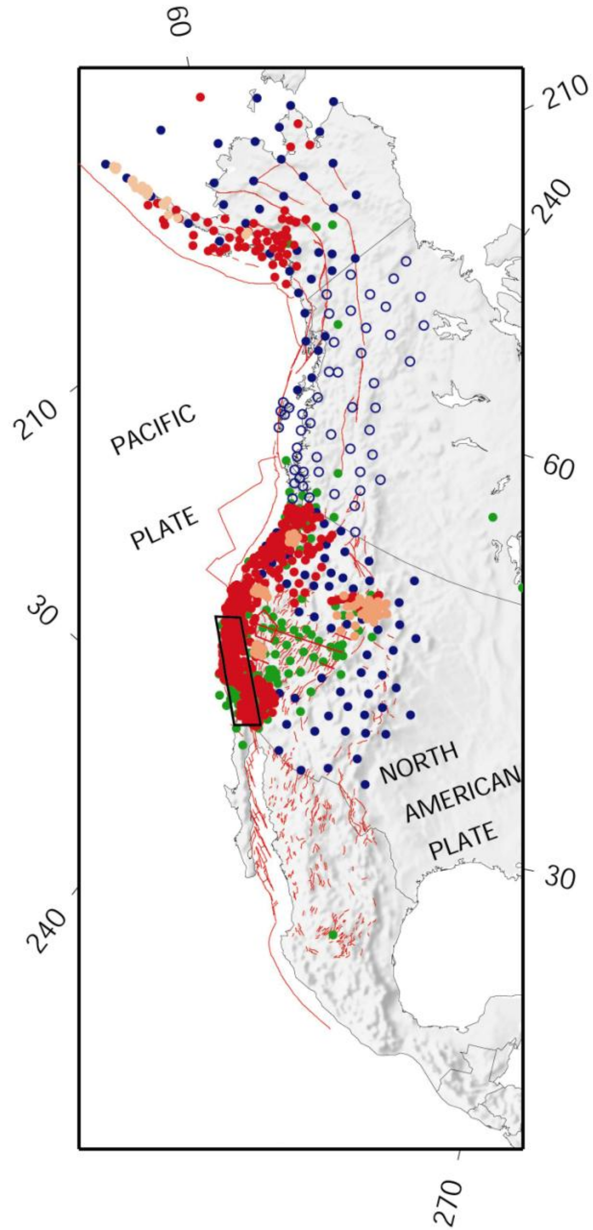
Southern California
Real-Time GPS Network



Real-time upgrades of SCIGN will take advantage of high-speed communications infrastructure developed at UCSD's Supercomputer Center (SDSC) and Scripps for seismic and other scientific data.

Present/Future of CORS in California

- *Ongoing conversion of GPS arrays to real-time*
- *Densification by CSRC and PBO*
- *Use of these arrays by the public, e.g. SCIGN/ California Spatial Reference Center – Orange County*
- *Proliferation of precise real-time applications*
- *Enhanced real-time communications; wireless Internet (3G) and/or satellites*
- *Development of Web Services based on modern IT methods, for dissemination of data and metadata.*
- *Three-frequency satellite constellation: GPS+, GLONASS, European Galileo*
- *Multi-frequency measurement engines < $0.5 k*

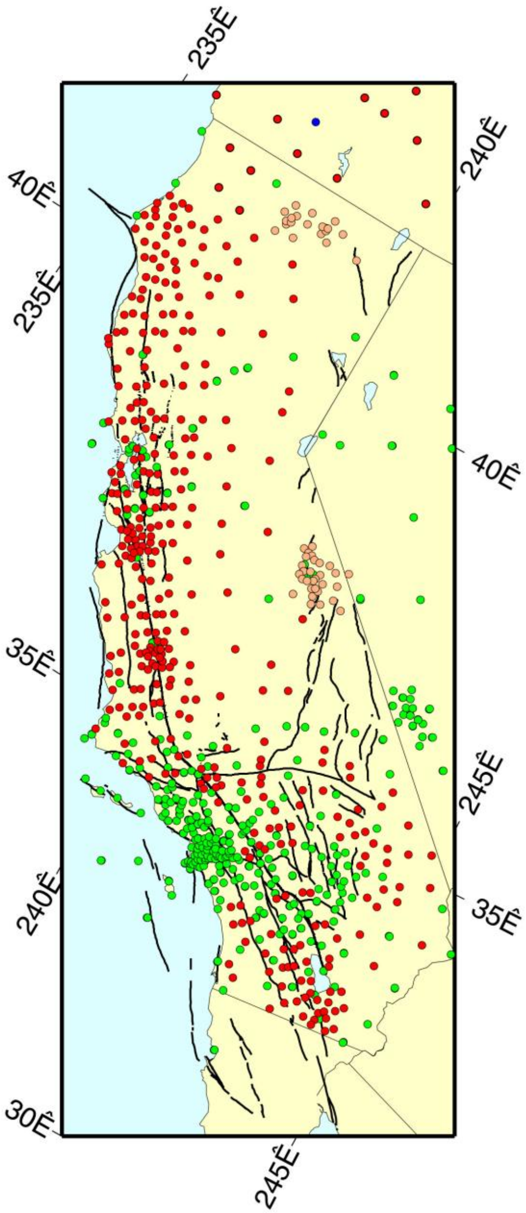


A New View Into Earth
earthscope

Plate Boundary Observatory (PBO)

❖**Existing sites:**
- **PANGA, BARD, EBRY, BARGEN, LVC, SCIGN**

❖**New sites:**
- **Backbone and clusters:**
  - **Alaska and Cascadia**
  - **Volcanic complexes**
  - **San Andreas fault zone**



A New View Into Earth
earthscope

PBO San Andreas plan

❖**Existing sites:**
- **BARD, SCIGN, LVC, and BARGEN**

❖**New sites:**
- **Clusters along San Andreas fault, especially along transitions from creeping to locked sections**