USGS Award Number: G10AC00138

Title of award:
Western Great Basin Geodetic Network Operations, 2010-2014

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Project website with data products:
http://geodesy.unr.edu

Term covered by this award
Start: March 1, 2010
End: February 28, 2015

Abstract: Major Goals of the Project:

This project is a move toward integrating seismic and geodetic networks to addresses NEHRP objectives by 1) measuring the rate, pattern and style of secular crustal deformation that leads to earthquakes, 2) bringing GPS into the mode of operational earthquake event characterization, 3) encouraging research in broadest-band seismology and monitoring of Earth surface motions. The overall project is a collaborative effort between the Nevada Geodetic Laboratory (NGL) and the Nevada Seismological Laboratory (NSL), which both reside in the College of Science at the University of Nevada, Reno. This report is for the geodetic component of the project, for which Bill Hammond (whammond@unr.edu) is the main contact.

Our first major goal has been to expand NEHRP-supported GPS network operations into the western Basin and Range and Walker Lane, to support monitoring and seismic hazard studies of the Reno/Carson City/Tahoe metropolitan areas. With NEHRP support we surveyed 48 core sites of the Mobile Array of GPS for Nevada Transtension (MAGNET) semi-continuous network that are nearest to these areas, and other sites in the region that are critical to the goals of NEHRP. These surveys improved the geographic coverage and precision of measurement of crustal deformation in the region. The data are used to calculate GPS velocities that are in turn used to constrain slip rates on faults that are important parameters used as one input to calculate the US National Seismic Hazard Maps.

Our second major goal is to respond to earthquake events and seismic swarms that occur within the footprint of MAGNET. Currently our protocol is to respond if an M6 or greater event occurs, though we have responded to numerous smaller events and the approximately yearly seismic swarms. The measurement of pre-event velocities, outlined in the first objective, is crucial to estimate the pre-event position needed to estimate coseismic motion that occurs in an earthquake or swarm.

Our third major goal is to extend collaboration with NSL by establishing high-rate, low-latency GPS streams, collocated with seismic stations where possible. These streams will enable research in the broadest-band seismology, integrating seismic and GPS time series, development of early warning systems using GPS.

Work Performed

Data Collection in MAGNET

MAGNET is a semi-continuous network comprised of geodetic monuments that consists of steel pins in stable rock formations, usually bedrock (Figure 1). Currently there are 400 MAGNET stations distributed at approximately 20 km spacing in western Nevada, eastern California, with a few in Arizona, Utah, and Oregon (Figure 2). The stations are, except for a few, not telemetered and require visitation to install the stations with remote solar power and retrieve data from compact flash memory. In this 5 year cooperative agreement we collected data at MAGNET stations to lengthen time series and improve

rate estimates on 48 stations in the Reno/Carson/Tahoe region (Table 1 and Figure 3). Time series duration nearly doubled for most stations during this time. Site locations and equipment used to survey the sites are detailed in Tables 2 and 3. Future discovery based on our data will be possible because we share all MAGNET data by pushing it to the UNAVCO archive for community use within three months of collection. See http://www.unavco.org/data/gps-gnss/data-access-methods/dai2/app/dai2.html# and select "MAGNET" under Network/Campaign when searching for data.

We introduced two prototype real-time GPS stations that demonstrated the feasibility of establishing MAGNET-style stations collocated with NSL seismic instrumentation, to telemeter the data using the NSL digital IP network, and process it with low latency at NGL. These stations LMRR and WVRT telemeter their data directly using the Nevada Seismological Laboratory's IP network (Table 4). Their locations are shown in Figure 3.

Figure 1) Essential equipment of the MAGNET GPS Network. Lower left) Ford F350 with security shell, Upper left) Zephyr Geodetic antenna deployed at MAGNET station. Lower right) rigid solar panel near yellow Pelican box and 12V 33 amp-hour battery, illustrating typical setup for data collection, power and security of station.

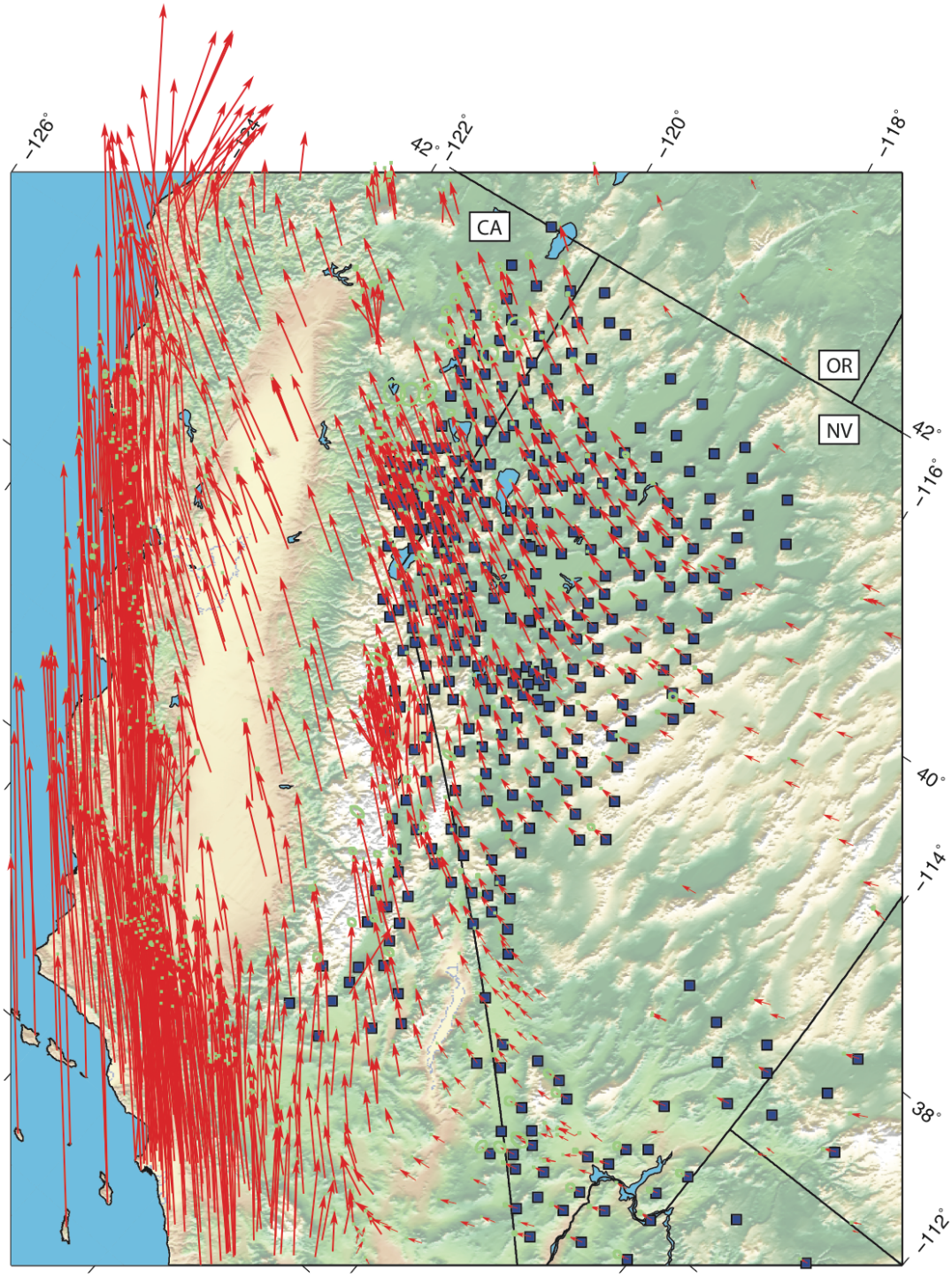

Figure 2) GPS velocity field in California and Nevada, western Great Basin, showing horizontal GPS velocities (red vectors) with respect to North America reference frame NA12 (*Blewitt et al.* 2013). Blue squares are locations of MAGNET stations. USGS funded surveying on 48 stations nearest to Reno, NV, (Figure 3), but we also responded to various seismic events and swarms throughout the MAGNET footprint.

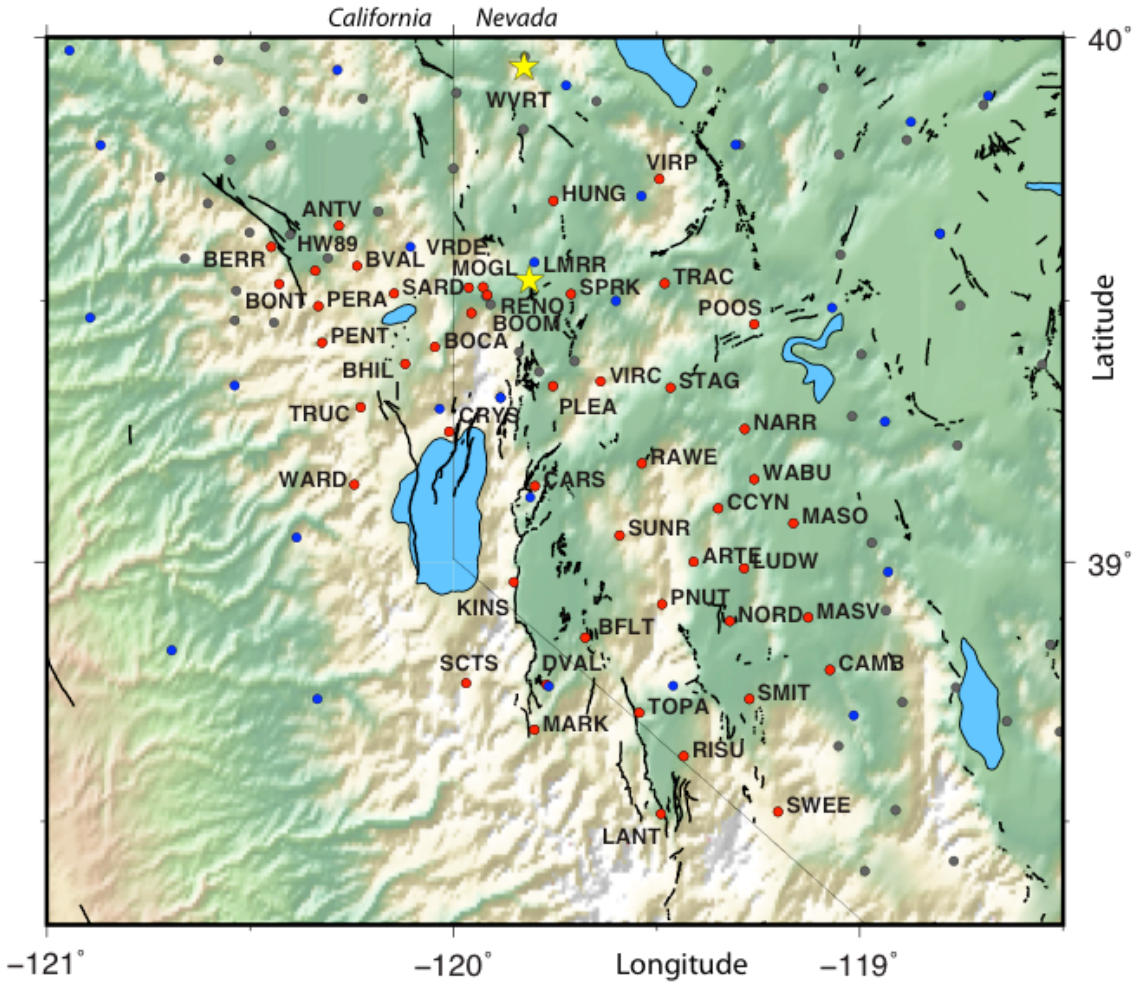

Figure 3) 48 MAGNET sites are supported by the USGS NEHRP Geodetic Networks program (red circles with site 4-character IDs). Other MAGNET stations are shown (gray circles) with sites of the EarthScope Plate Boundary Observatory (blue). Yellow stars show locations of real-time GPS stations WVRT and LMRR. No other MAGNET stations have telemetry.

Data processing

All data in our archive as of this writing (May 19, 2015) have been processed using the GIPSY/OASIS precise point positioning software. The data are processed at UNR by Dr. Geoffrey Blewitt as part of a solution that includes over 13,500 sites globally. A detailed description of the data processing methodology and underlying models is available at http://geodesy.unr.edu/gps/ngl.acn.

Data Products Distribution

The main website through which NGL data products can be accessed is http://geodesy.unr.edu. Stations may be identified and searched for using a clickable and zoomable Google map that is available to perform geographic searches: http://geodesy.unr.edu/billhammond/gpsnetmap/GPSNetMap.html. When a particular site whose name is known is desired it is best to use text search on the station list page: see http://geodesy.unr.edu/NGLStationPages/GlobalStationList

The processed solutions have been aligned to ITRF2008 (the IGS08 GPS-only realization of ITRF2008) and a custom North America reference frame NA12 (described in *Blewitt et al.,* 2013). Time-series files for each of these frames, in both x, y, z and north, east, up (neu) coordinates have been generated and are available online in text and graphic form. For every station there is a web page, e.g. for MAGNET station RENO it is http://geodesy.unr.edu/NGLStationPages/stations/RENO.sta. All products for the station can be found through links to graphic and text files of the solutions, a map showing location, coordinates, and RINEX header information.

The latency of time series products is driven by the latency of availability of JPL products needed for GIPSY processing, namely the GPS satellite orbit, clock and transformation parameter files. These come in final (latency about 2 weeks), rapid (latency next day) and ultrarapid (latency 1.5 hours). Solution sample rates are available in 5 minute and 24 hour files. More details on the latency of the different products can be found at ftp://gneiss.nbmg.unr.edu/README.

Final Solutions are generated using JPL's final orbit products on 24 hour files, for over 13,500 stations distributed around Earth. These solutions are available after roughly two weeks, the latency on the final orbits. We update these solutions weekly, and the web pages are regenerated daily to keep pace with the new solutions, including the rapid solutions that are discussed below.

Rapid Solutions. We now provide 24-hour rapid solutions (next day) for roughly 4000 continuous stations many of which are in California and Nevada, others are distributed around North America. This set includes all continuous stations for which daily data are available in a box defined by 30˚< latitude < 45˚, -125˚< longitude < -110˚. These solutions are available following earthquakes and can be used to rapidly estimate displacements and characterize the slip, as they were for the 2014 Napa earthquake (*Hammond et al.,* 2014a). A solution for the previous day is usually available by 9 am the following day. See http://geodesy.unr.edu/NGLStationPages/RapidStationList for a list of stations for which rapid solutions are available.

Rapid 5-minute solutions. For over 4000 stations providing continuous data we provide rapid (next day) 5-minute solutions. These solutions provide 5-minute sample interval time series that are available the day following arrival of the data. These are aligned to a global reference frame defined by JPL rapid orbits, which are generated by holding fiducial stations fixed to IGS08. Using these time series we have successfully estimated

displacements from several large earthquakes (including the Craig, Alaska Jan. 5, 2013 M7.5 and, the August 2012 Brawley sequence, and the August, 2014 Napa earthquake) at multiple GPS stations the day after the events.

Ultrarapid solutions For 2508 stations providing continuous data we generate ultrarapid (1.5 hour latency) solutions. These solutions provide 5-minute sample interval time series that are updated every hour and appear on our web page. For a list of stations that have 5 minute ultrarapid solutions see http://geodesy.unr.edu/NGLStationPages/UltraStationList. While these solutions do have some excursions in their time series, especially near day boundaries at midnights, they will be able to reveal very large displacements shortly after large ground moving events.

Other Products

In addition to the results from processing of GPS station RINEX files, we are now also providing online summary tables of all data processed by NGL. These tables are in text format, suitable for automated machine reading, and are routinely updated to reflect new stations, data, solutions and time series duration. The also show the original station name if it was changed in order to keep unique 4-character IDs in our processing system.

List of all GPS station names, latitude, longitude and height:

- ftp://gneiss.nbmg.unr.edu/rapids/llh

Lists of all GPS data holdings are available for each form of solution latency and sample rate:

- http://geodesy.unr.edu/NGLStationPages/DataHoldings.txt
- http://geodesy.unr.edu/NGLStationPages/DataHoldingsRapid5min.txt
- http://geodesy.unr.edu/NGLStationPages/DataHoldingsRapid24hr.txt
- http://geodesy.unr.edu/NGLStationPages/DataHoldingsUltra5min.txt

There are now available and linked from every station page a set of Quality Assurance (QA) files that are routinely generated and correspond to the final solutions. A Guide to the QA files is available at

- ftp://gneiss.nbmg.unr.edu/qa/QA.pdf

Results Obtained

Maintaining a geodetic network in the western Great Basin has resulted in improved understanding of the tectonics of the northern Walker Lane, Great Basin, and Sierra Nevada. The data have supported many detailed studies of crustal deformation, fault slip rates, block rotations, comparisons to geologic, and seismic structural studies (see References section). We categorize the areas where MAGNET has contributed into three areas follows:

1) We have used MAGNET to chart with new detail and scope the rates, patterns and styles of fault slip rates on dozens of fault systems in the western Great Basin (*Jha*, 2010; *Hammond et al.,* 2011a; *Bormann et al*, 2013) and complemented other studies in the western Basin and Range. These data are used as input into strain rate maps that depict the rate and distribution of active crustal deformation (*Kreemer et al.,* 2012; Figure 4). Our data have been used by researchers outside our group to perform detailed studies of Walker Lane fault systems, in some cases we were co-authors on those studies (*del Pardo et al.,* 2012) and in others not (e.g. *Lifton et al.,* 2013), but these studies were performed with our stations, data, and direct support. The organization of Walker Lane faulting is complicated, includes block rotations, dextral, normal, sinistral and oblique slipping faults, stepovers and oroclinal flexures that make measurement and modeling the deformation a challenge. The deformation field may be evolving over time, as the system works toward becoming a more efficient set of through going faults, and off-fault deformation could accommodate a significant fraction of the potential earthquake moment. Recent studies have brought a new appreciation for the implications of the predominance of dextral shear in the geodetic signal that seems to be in many localities missing in a geologic record that is dominated by normal faulting (*Wesnousky et al*., 2012; *Hammond et al*., 2014). This situation is motivating geologists to focus more attention on the possibility that strike slip faulting is present but unaccounted for.

2) Response to seismic swarms in the western Great Basin. MAGNET data have complemented seismic data to understand the vigorous seismic swarms that strike the western Great Basin region roughly once every year or two. The latest example is the Sheldon swarm in northwest Nevada that began in July 2014 and, as of this writing in May 2015, over 5000 earthquakes have occurred with a maximum magnitude of M 4.7. So far we have not detected anomalous displacement of any MAGNET stations owing to the Sheldon swarm, though our nearest station (LNGV) is roughly 10 km from the swarm centroid, so displacements were not expected given the cumulative magnitude of the events. We also responded to the 2011 swarm in Hawthorne, Nevada, for which we found barely detectible offsets at one station (LUCK) nearest the swarm centroid. We also responded to several smaller swarms but did not find significant deformation. One motivation for our response is to determine whether larger aseismic deformation is driving or accompanies the swarm, as was the case for the 2008 Mogul Nevada swarm in Reno. Another motivation is to have instrumentation in place to measure a larger earthquake if the swarms turn out to be fore-shocks of a major event that can significantly effect residents.

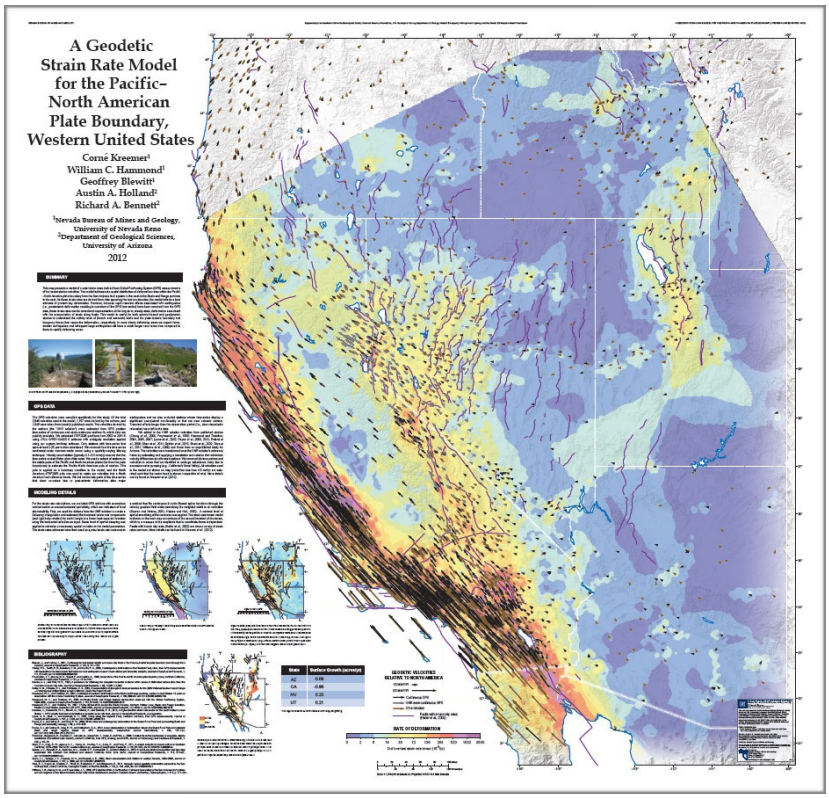

Figure 4) Crustal strain rate map depicting the magnitude of strain rate, hot colors for high strain rate, cool colors for lower strain rate (Kreemer et al., 2012). MAGNET data are essential for charting the strain rate patterns in the western Great Basin. This map is available for free download at http://www.nbmg.unr.edu/dox/m178.pdf

3) Studies of vertical motions throughout the Sierra Nevada/Great Basin transition are becoming more robust largely because of the geographic coverage and precision that is afforded by MAGNET. These measurements are bringing to the table what amounts to a new geophysical observable that is very complementary to measurements of horizontal tectonic strain accumulation (Figure 5). The vertical motions reveal uplift along the entire length of the of the Sierra Nevada, and clearly image the viscoelastic postseismic uplift associated with the 20th century earthquakes of the Central Nevada Seismic Belt and southern Mojave (Figure 5). These motions will have an affect on the horizontal displacement time series and products on which those are based, e.g. block models and slip rate estimates, so need to be understood completely through future research. The vertical rates will provide a new and improved means for separating the long term progressive crustal strain from short term transients.

Community Service

PI Hammond contributed one of the 4 geodetic block models for the western US for the new USGS National Seismic Hazard map revisions due out in 2014. This effort was

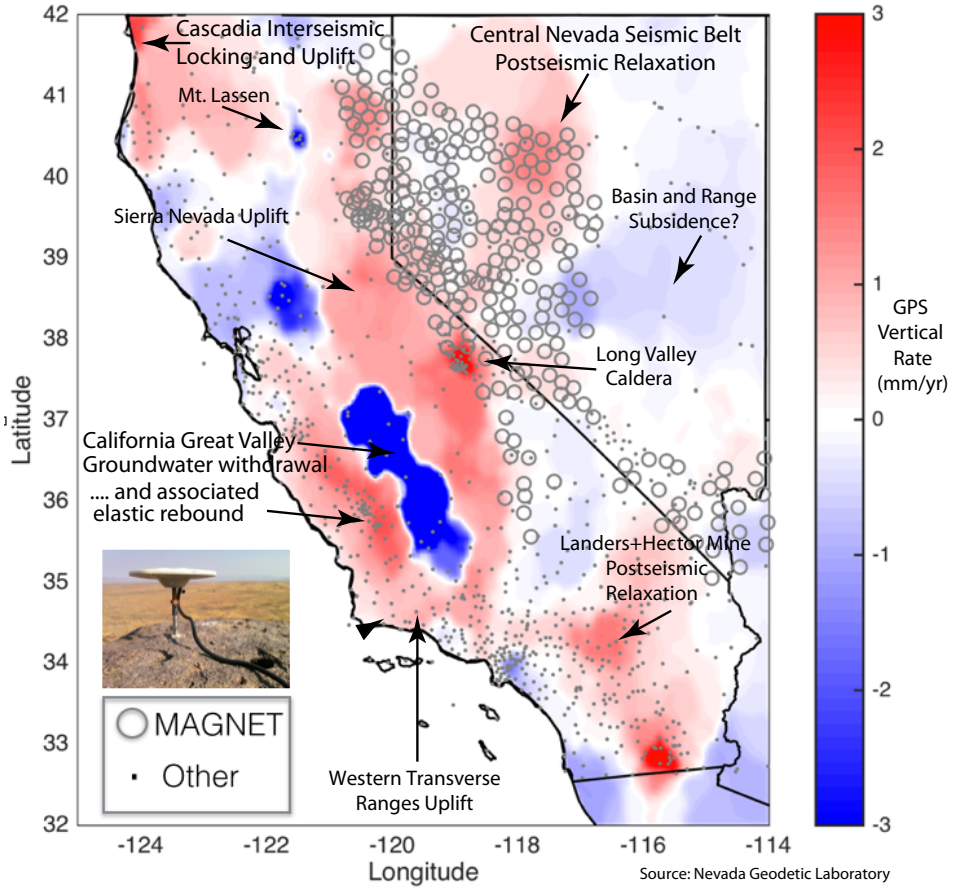

Figure 5. Vertical GPS velocity from robust non-parametric estimation, using weighted median spatial filtering and interpolation. GPS solution are aligned to IGS08. Continuous (gray dots) and semi-continuous GPS stations from the MAGNET GPS network (gray circles) with time series over 5 years long are used to constrain the vertical rates.

coordinated by Mark Petersen and resulted in a USGS open file report published as part of the maps documentation (*Petersen et al.*, 2014). PI Hammond received no support for this work other than through NEHRP geodetic networks (other than travel support to attend the workshops). He is also participating in the CGM effort that has been coordinated by Jessica Murray under the auspices of SCEC, helping that group with access to the NGL solutions. Already, participation in that effort has resulted in an improvement in NGL processing. The time series comparison exercised identified an antenna calibration software bug at NGL that resulted in a constant time series offset for some stations. The issue was quickly corrected.

PI Hammond served as Chair of the NSF EarthScope Plate Boundary Observatory, rotating off December 31, 2013. Also in 2013, he helped UNAVCO staff to coordinate a workshop on Real Time GPS. He is currently secretary of the Geodesy section of AGU, and is an associate editor for the Bulletin of the Seismological Society of America. He has made many invited presentations at conferences based on the GPS data collected in MAGNET.

Ongoing Work

The Sheldon Swarm in northwest Nevada is persisting in its activity. Recently seismicity has continued and migrated southward so it is possible that we will capture future transient deformation or have instrumentation present for a larger future earthquake. We have coordinated with Dan Dzurisin (USGS CVO) who is deploying GPS receivers at six stations in the near field to the swarm to complement our more regional 20 km spacing distribution of stations. We will continue to monitor the progress of deformation and have offered to occupy the USGS stations with our equipment if theirs is needed to monitor other locations.

Many upgrades of the MAGNET GPS networks' web-based data products pages are planned, including adding DOI information for each station, supplying rates, steps and time series model information for each station, improved searching of the database. We have received support for another 5 year cooperative agreement with the USGS to continue our work on MAGNET.

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Table 1. Site/monument information for GPS stations:

Locality	Site ID	Type	Monument	Install Date
Antelope Valley	ANTV	Semi-continuous	Steel Pin In Rock	01-May-2007
Artesia Lake	ARTE	Semi-continuous	Steel Pin In Rock	03-May-2007
Berry Creek	BERR	Semi-continuous	Steel Pin In Rock	18-Aug-2007
Bodie Flat	BFLT	Semi-continuous	Steel Pin In Rock	24-May-2007
Boca Hill	BHIL	Semi-continuous	Steel Pin In Rock	25-Jul-2008
Boca Ridge	BOCA	Semi-continuous	Steel Pin In Rock	28-Oct-2005
Bonta Saddle	BONT	Semi-continuous	Steel Pin In Rock	18-Aug-2007
Boomtown	BOOM	Semi-continuous	Steel Pin In Rock	13-May-2008
Bear Valley	BVAL	Semi-continuous	Steel Pin In Rock	01-May-2007
Cambridge Hills	CAMB	Semi-continuous	Steel Pin In Rock	20-Oct-2005
Carson City	CARS	Semi-continuous	Steel Pin In Rock	07-Oct-2005
Churchill Canyon	CCYN	Semi-continuous	Steel Pin In Rock	03-May-2007
Crystal Bay	CRYS	Semi-continuous	Steel Pin In Rock	14-Oct-2005
Diamond Valley	DVAL	Semi-continuous	Steel Pin In Rock	08-Oct-2005
Hungry Valley	HUNG	Semi-continuous	Steel Pin In Rock	24-Nov-2004
Highway 89	HW89	Semi-continuous	Steel Pin In Rock	01-May-2007
Kingsbury Grade	KINS	Semi-continuous	Steel Pin In Rock	07-Oct-2005
Walker	LANT	Semi-continuous	Steel Pin In Rock	08-Oct-2005
Ludwig	LUDW	Semi-continuous	Steel Pin In Rock	22-Oct-2005
Markleeville	MARK	Semi-continuous	Steel Pin In Rock	22-Jun-2007
Mason Butte	MASO	Semi-continuous	Steel Pin In Rock	03-May-2007
S. Mason Valley	MASV	Semi-continuous	Steel Pin In Rock	26-Apr-2007
Mogul	MOGL	Semi-continuous	Steel Pin In Rock	22-Apr-2008
Churchill Narrows	NARR	Semi-continuous	Steel Pin In Rock	03-May-2007
Nordyke Pass	NORD	Semi-continuous	Steel Pin In Rock	25-Jan-2007
Carpenter Ridge	PENT	Semi-continuous	Steel Pin In Rock	18-Aug-2006
Perazzo Meadows	PERA	Semi-continuous	Steel Pin In Rock	20-Jul-2007
Pleasant Valley	PLEA	Semi-continuous	Steel Pin In Rock	15-Oct-2005
Pine Nut Valley	PNUT	Semi-continuous	Steel Pin In Rock	20-Sep-2007
Talapoosa	POOS	Semi-continuous	Steel Pin In Rock	16-Mar-2004
Rawe Peak	RAWE	Semi-continuous	Steel Pin In Rock	17-Dec-2005
Reno	RENO	Semi-continuous	Steel Pin In Rock	30-Jan-2004
Risue Canyon	RISU	Semi-continuous	Steel Pin In Rock	22-Jun-2007
Sardine Valley	SARD	Semi-continuous	Steel Pin In Rock	12-Oct-2005
Scotts Lake	SCTS	Semi-continuous	Steel Pin In Rock	15-Sep-2008
Smith Valley	SMIT	Semi-continuous	Steel Pin In Rock	05-Nov-2005
Sparks	SPRK	Semi-continuous	Steel Pin In Rock	17-Nov-2004
Stagecoach	STAG	Semi-continuous	Steel Pin In Rock	27-Oct-2006

Sunrise Pass	SUNR	Semi-continuous	Steel Pin In Rock	02-Nov-2005
Sweetwater Summit	SWEE	Semi-continuous	Steel Pin In Rock	22-Oct-2005
Topaz	TOPA	Semi-continuous	Steel Pin In Rock	22-Oct-2005
Tracy	TRAC	Semi-continuous	Steel Pin In Rock	07-Jul-2004
Truckee	TRUC	Semi-continuous	Steel Pin In Rock	14-Oct-2005
Virginia City	VIRC	Semi-continuous	Steel Pin In Rock	16-Mar-2004
Virginia Peak	VIRP	Semi-continuous	Steel Pin In Rock	17-Mar-2004
Verdi, East	VRDE	Semi-continuous	Steel Pin In Rock	22-Apr-2008
Wabuska	WABU	Semi-continuous	Steel Pin In Rock	27-Oct-2006
Ward Peak	WARD	Semi-continuous	Steel Pin In Rock	10-Aug-2005
Winnemucca Valley	WVRT	Continuous	Steel Pin In Rock	01-Nov-2011
University of NV, Reno	LMRR	Continuous	Steel Plate To	31-Mar-2011

Table 2. Site location information for GPS stations

Station	State	County	X (m)	Y (m)	Z (m)	Latitude (°)	Longitude (°)	Height (m)
ANTV	California	Sierra	-2480598.13	-4248214.25	4048573.76	39.643	-120.281	1681.05
ARTE	Nevada	Douglas	-2437816.95	-4324853.72	3993341.44	39.000	-119.409	1638.27
BERR	California	Sierra	-2494455.84	-4243630.51	4045281.48	39.602	-120.448	1930.84
BFLT	Nevada	Douglas	-2462969.51	-4322275.20	3980698.23	38.854	-119.676	1597.08
BHIL	California	Nevada	-2477959.83	-4271604.54	4026152.40	39.379	-120.118	1988.84
BOCA	California	Nevada	-2471393.98	-4272834.63	4028973.97	39.411	-120.045	2058.88
BONT	California	Sierra	-2495724.02	-4249066.30	4039441.64	39.531	-120.428	2319.12
BOOM	Nevada	Washoe	-2462489.24	-4272748.21	4034551.54	39.476	-119.956	2106.18
BVAL	California	Sierra	-2480218.58	-4255077.42	4042207.18	39.565	-120.237	2042.54
CAMB	Nevada	Lyon	-2419417.11	-4351643.82	3975317.40	38.792	-119.073	1519.04
CARS	Nevada	Carson City	-2462235.20	-4299408.14	4005911.51	39.145	-119.799	1750.20
CCYN	Nevada	Lyon	-2429641.89	-4321136.64	4002109.00	39.102	-119.348	1532.08
CRYS	California	Placer	-2474477.40	-4284239.21	4015102.01	39.249	-120.010	2098.10
DVAL	California	Alpine	-2473248.10	-4323762.85	3972966.76	38.764	-119.770	1729.51
HUNG	Nevada	Washoe	-2439682.43	-4267910.74	4052489.46	39.689	-119.754	1552.39
HW89	California	Sierra	-2488024.44	-4250952.83	4041197.37	39.556	-120.340	1688.78
KINS	Nevada	Douglas	-2472544.51	-4308352.50	3990008.84	38.961	-119.851	1738.61
LANT	California	Mono	-2460518.16	-4350915.90	3951429.79	38.515	-119.489	1801.51
LMRR	Nevada	Washoe	-2449317.07	-4274499.50	4039518.21	39.539	-119.813	1373.70
LUDW	Nevada	Lyon	-2428804.20	-4330799.33	3992218.87	38.988	-119.285	1526.87
MARK	California	Alpine	-2478577.27	-4327737.67	3965518.09	38.677	-119.801	1827.15
MASO	Nevada	Lyon	-2416609.62	-4330540.15	3999568.36	39.074	-119.163	1354.58
MASV	Nevada	Lyon	-2420072.69	-4343125.23	3983961.21	38.893	-119.127	1391.27
MOGL	Nevada	Washoe	-2458305.37	-4270592.66	4038425.15	39.525	-119.926	1517.53
NARR	Nevada	Lyon	-2419459.06	-4314388.92	4015059.61	39.255	-119.283	1287.81
NORD	Nevada	Lyon	-2434954.03	-4335447.15	3983397.76	38.886	-119.320	1476.99
PENT	California	Nevada	-2491977.31	-4260591.45	4029993.23	39.419	-120.323	2524.99
PERA	California	Sierra	-2489963.07	-4255670.66	4035604.89	39.488	-120.332	2026.07
PLEA	Nevada	Washoe	-2452159.50	-4289670.94	4022305.61	39.336	-119.754	1699.53
PNUT	Nevada	Douglas	-2446686.61	-4326877.59	3986665.84	38.919	-119.487	2202.07
POOS	Nevada	Lyon	-2410918.68	-4303329.81	4032466.86	39.455	-119.260	1637.80
RAWE	Nevada	Lyon	-2440912.49	-4308017.69	4009642.80	39.188	-119.536	1724.18
RENO	Nevada	Washoe	-2398864.94	-4226912.64	4039439.32	39.922	-119.576	1488.40
RISU	Nevada	Douglas	-2452433.77	-4346579.49	3960998.13	38.626	-119.433	1706.39
SARD	California	Sierra	-2475219.93	-4262143.74	4037584.78	39.513	-120.146	1871.57
SCTS	California	Alpine	-2488354.88	-4315471.96	3973714.69	38.767	-119.968	2458.18
SMIT	Nevada	Lyon	-2436440.18	-4346697.45	3970516.32	38.736	-119.272	1615.38
SPRK	Nevada	Washoe	-2442566.74	-4280542.02	4037203.70	39.512	-119.710	1362.16
STAG	Nevada	Lyon	-2430470.99	-4301879.14	4021881.98	39.334	-119.466	1351.99
SUNR	Nevada	Douglas	-2449914.76	-4314167.61	3997895.92	39.051	-119.591	1908.65
SWEE	Nevada	Lyon	-2438583.53	-4363209.05	3951964.37	38.519	-119.201	2108.12
TOPA	Nevada	Douglas	-2457911.58	-4336857.64	3968349.89	38.710	-119.542	1797.68
TRAC	Nevada	Storey	-2424690.35	-4289107.90	4038956.61	39.532	-119.480	1413.02
TRUC	California	Placer	-2489123.64	-4271991.50	4019138.42	39.296	-120.228	2141.29
VIRC	Nevada	Storey	-2443152.75	-4294278.93	4023361.61	39.346	-119.637	2013.94
VIRP	Nevada	Washoe	-2418956.53	-4276784.59	4056360.63	39.731	-119.493	2078.86
VRDE	Nevada	Washoe	-2460974.77	-4269077.87	4038325.92	39.524	-119.962	1469.71
WABU	Nevada	Lyon	-2421015.45	-4321390.43	4006787.91	39.158	-119.259	1381.40
WARD	California	Placer	-2495656.21	-4280550.45	4006726.54	39.148	-120.243	2569.92
WVRT	Nevada	Washoe	-2436105.86	-4249208.27	4074305.53	39.944	-119.826	1690.10

Table 3. Equipment: GPS Receivers. Receivers in MAGNET are moved frequently. 62 GPS receivers are continually cycled through 400 stations in the network. Hence listing an equipment change for each installation or retrieval event would be impractical. We therefore provide a list of each GPS receiver that could potentially survey each of the sites. All GPS receivers in MAGNET are Trimble 5700, R7 or R9 dual-frequency receivers with Trimble Zephyr antennas, except for one station that uses a fixed D/M Choke Ring (LMRR). There are some Zephyr II antennas, but we do not mix antennas in occupations, i.e. each station is surveyed with a single type of antenna.

UNR #	Type	Receiver S/N	Antenna Type	Antenna S/N	Antenna Height
06	Trimble 5700	0220315988	Zephyr Geodetic	?	0.01
07	Trimble 5700	0220315989	Zephyr Geodetic	12475004	0.01
08	Trimble 5700	0220315990	Zephyr Geodetic	12470909	0.01
09	Trimble 5700	0220325901	Zephyr Geodetic	12470910	0.01
10	Trimble 5700	0220316061	Zephyr Geodetic	12532408	0.01
11	Trimble 5700	0220316063	Zephyr Geodetic	12471080	0.01
12	Trimble 5700	0220316065	Zephyr Geodetic	?	0.01
13	Trimble 5700	0220316068	Zephyr Geodetic	?	0.01
14	Trimble 5700	0220316075	Zephyr Geodetic	12541639	0.01
15	Trimble 5700	0220316077	Zephyr Geodetic	12532404	0.01
16	Trimble 5700	0220316079	Zephyr Geodetic	12518444	0.01
17	Trimble 5700	0220316080	Zephyr Geodetic	12532360	0.01
18	Trimble 5700	0220316005	Zephyr Geodetic	12471107	0.01
19	Trimble 5700	0220320644	Zephyr Geodetic	12422800	0.01
21	Trimble 5700	0220320675	Zephyr Geodetic	12475115	0.01
22	Trimble 5700	0220325900	Zephyr Geodetic	12501717	0.01
23	Trimble 5700	0220325945	Zephyr Geodetic	12578100	0.01
24	Trimble 5700	0220340251	Zephyr Geodetic	12652403	0.01
25	Trimble 5700	0220325926	Zephyr Geodetic	12652470	0.01
26	Trimble 5700	0220334390	Zephyr Geodetic	12682300	0.01
27	Trimble 5700	0220327663	Zephyr Geodetic	12482194	0.01
28	Trimble 5700	0220325924	Zephyr Geodetic	12482242	0.01
29	Trimble 5700	0220340244	Zephyr Geodetic	12652390	0.01
30	Trimble 5700	0220327661	Zephyr Geodetic	12682236	0.01
31	Trimble 5700	0220325920	Zephyr Geodetic	12652370	0.01
32	Trimble 5700	0220340250	Zephyr Geodetic	12652474	0.01
33	Trimble 5700	0220340255	Zephyr Geodetic	12652395	0.01
34	Trimble 5700	0220340258	Zephyr Geodetic	12652482	0.01
35	Trimble 5700	0220325916	Zephyr Geodetic	12682234	0.01
36	Trimble 5700	0220325942	Zephyr Geodetic	12682185	0.01
37	Trimble 5700	0220332753	Zephyr Geodetic	12652494	0.01
38	Trimble 5700	0220325929	Zephyr Geodetic	12652541	0.01
39	Trimble 5700	0220340249	Zephyr Geodetic	12482188	0.01
40	Trimble R7	0220360641	Zephyr Geodetic	60080603	0.01
41	Trimble R7	0220360689	Zephyr Geodetic	60080490	0.01
42	Trimble R7	0220368059	Zephyr Geodetic	60069144	0.01
43	Trimble R7	0220359174	Zephyr Geodetic	60080604	0.01
44	Trimble R7	0220360639	Zephyr Geodetic	60100957	0.01
45	Trimble R7	0220357133	Zephyr Geodetic	60080893	0.01
46	Trimble R7	0220359182	Zephyr Geodetic	60080433	0.01
47	Trimble R7	0220359178	Zephyr Geodetic	60100792	0.01
48	Trimble R7	0220359175	Zephyr Geodetic	60100943	0.01
49	Trimble R7	0220365420	Zephyr Geodetic	60100981	0.01
50	Trimble R7	0220365423	Zephyr Geodetic	60100849	0.01
51	Trimble R7	0220360651	Zephyr Geodetic	60072525	0.01
52	Trimble R7	0220360645	Zephyr Geodetic	60069148	0.01
53	Trimble R7	0220359183	Zephyr Geodetic	60080521	0.01
54	Trimble R7	0220360642	Zephyr Geodetic	60100912	0.01
55	Trimble R7	0220360650	Zephyr Geodetic	60165468	0.01
56	Trimble R7	0220375239	Zephyr Geodetic	60165776	0.01
57	Trimble R7	0220389861	Zephyr Geodetic	60165579	0.01
58	Trimble R7	0220389868	Zephyr Geodetic	60165809	0.01
59	Trimble R7	0220389870	Zephyr Geodetic	60165542	0.01
60	Trimble R7	0220389871	Zephyr Geodetic	60165724	0.01
61	Trimble R7	0220389873	Zephyr Geodetic	60165591	0.01
R3	Trimble NetR9	5038K70477	Zephyr Geodetic II	1441027420	0.01
R4	Trimble NetR9	5038K70478	Zephyr Geodetic II	1441023168	0.01
R5	Trimble NetR9	5039K70874	Zephyr Geodetic	60187068	0.01
R6	Trimble NetR9	5038K70604	Zephyr Geodetic	60189052	0.01
R7	Trimble NetR9	5039K70982	Zephyr Geodetic II	1441031178	0.01
R1	TrimbleNetRS	4646125546	AOA D/M Choke Ring	60189052	0.01
R2	TrimbleNetRS	4646125540	Zephyr Geodetic II	?	0.01

Table 4. Telemetry Information. Most MAGNET stations have no telemetry. Data are picked up manually by vehicle access to the station. Two stations WVRT and LMRR have telemetry described in the table below.

Station	Telemetry type	Where are daily RINEX files available?	RINEX file sample interval, sec	Real time stream available?	If real time stream is available, sample interval, sec
WVRT	IP Radio on NSL private network	UNAVCO archive	15 s	Only to NGL at this time	1 Hz.
LMRR	Wired internet connection	UNAVCO archive	15 s	Only to NGL at this time	1 Hz.