Quarterly Report
Massachusetts Institute of Technology
GAGE Facility GPS Data Analysis Center Coordinator
And
GAGE Facility GAMIT/GLOBK Community Support

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Period: 2017/07/01-2017/09/30

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Summary

Under the GAGE Facility Data Analysis subaward, MIT has been combining results from the New Mexico Tech (NMT) and Central Washington University (CWU). In this report, we show analyses of the data processing for the period 2017/06/14 to 2017/09/16, time series velocity field analyses for the GAGE reprocessing analyses (1996-2017). Several earthquakes were investigated this quarter but none generated coseismic displacements > 1mm. There were some earthquakes that could not be assessed due to no available post-earthquake data although the expected magnitudes for an coseismic displacements were small. For this quarter, the last finals results were for September 16, 2017. Associated with the report are the ASCII text files that are linked into this document.

Our monthly reports now contain the estimates of the offsets in the time series due to equipment changes and earthquakes and we generate events files for coseismic offsets and postseismic log terms (when needed) using a Kalman filter time series analysis.

Under the GAGE Facility GAMIT/GLOBK Community Support we report on activities during this quarter.

GPS Analysis of Level 2a and 2b products

ITRF2014 transition

The GAGE analyses are in a transition between the ITRF2008 and ITRF2014 systems. During this quarter, the GAGE ACs submitted IGS14 SINEX files generated with either JPL IGS14 orbits and clocks (CWU) or IGS IGS14 orbits (NMT). Both ACs used the IGS14 antenna phase center model. Two weeks of results, 1200 and 1201, were submitted and these are being compared currently. Of most interest will be the average scale difference between the two analyses and we are working to add the IGS combined SINEX file results to the NMT solutions to see if this improves the scale estimates. Only stations in the IGS SINEX file that are used in the NMT analysis will be included and thus there will be no increase in the number of station in the combined solutions.

Level 2a products: Rapid products

Final and rapid level 2a products have been in general generated routinely during this quarter. The description of these products, the delivery schedule and the delivery list remain unchanged from the previous quarter and will not be reported here. The rapid products continue to be generated in IGS14 by CWU while NMT uses IGS08 to be consistent with the methods used for the final products.

Level 2a products: Final products

The final products are generated weekly and are based on the final IGS and JPL (CWU) orbits. The IGS08 ANTEX phase center model is used by both ACs. The description of these products, the delivery schedule and the delivery list remain unchanged from the previous quarter and will not be reported here. Data volumes being transferred remains about the same. In this quarter 1913 stations were processed which is 80 more than last quarter. The CWU finals and other products are generated with IGb08 consistent orbits and clocks generated by JPL. NMT results are generated using the IGS14 orbits but still retaining the IGb08 antenna model file to be consistent with the CWU analyses.

Level 2a products: 12-week, 26-week supplement products

Each week we also process the Supplemental (12-week latency) and six month supplemental (26-week latency) analyses from the ACs. The delivery schedule for these products is also unchanged.

Analysis of Final products: June 15, 2017 and September 16, 2017

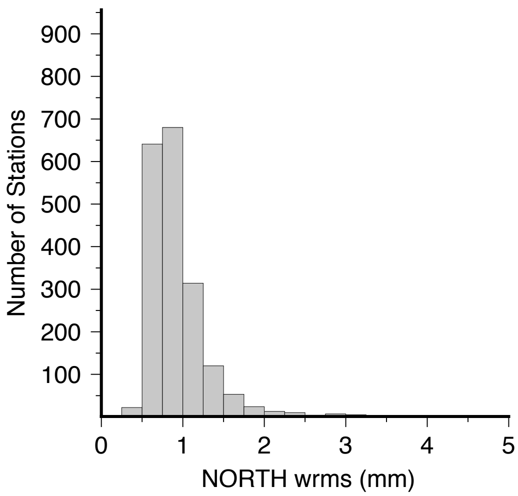
Each month, we submit reports of the statistics of the PBO combined analyses and estimates of the latest velocity fields in the NAM08 reference frame based on the time series analysis of data between 1996 and month preceding the report (we need to allow 2-3 weeks for the generation of the final products). For this report, we generated the statistics using the ~3 months of results generated between June 15, 2017 and September 16, 2017. These results are summarized in Table 1 and figures 1-3.

For the three months of the final position time series generated by NMT, CWU and combination of the two (PBO), we fit linear trends and annual signals and compute the RMS scatters of the position residuals in north, east and up for each station in the analysis. Our first analysis of the distribution of these RMS scatters by analysis center and the combination. Table 1 shows the median (50%), 70% and 95% limits for the RMS scatters for PBO, NMT and CWU. The median horizontal RMS scatters are less than or equal 1.02 mm for all centers and as low as 0.80 mm for NMT and PBO North and 0.80 mm for PBO east components. The up-RMS scatters are less than or equal 4.5 mm for all analyses and as low as 3.80 mm for the PBO solution. These statistics are similar to last quarter. Seasonal changes in atmospheric delay properties will introduce small variations in these values quarter to quarter. In the NAM08 frame realization, scale changes are not estimated. If scale changes were estimated, the up scatter would be reduced but the sum of scale change RMS and the lower height scatter would equal the values shown in Table 1. The detailed histograms of the RMS scatters are shown in Figures 1-3 for PBO, NMT and CWU.

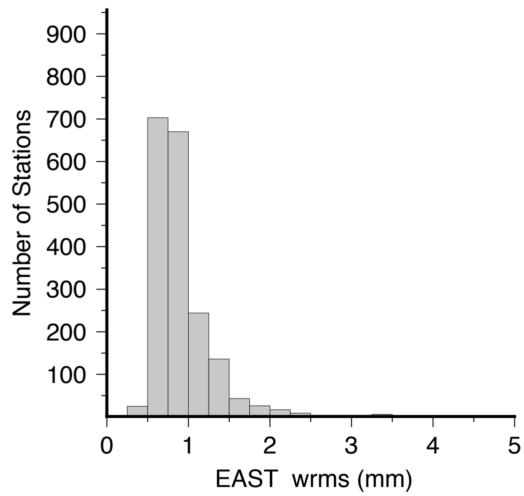
Table 1: Statistics of the fits of 1913, 1913 and 1911 stations for PBO, NMT and CWU analyzed in the finals analysis between June 15, 2017and September 16, 2017. Histograms of the RMS scatters are shown in Figure 1-3.

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
PBO	0.80	0.80	3.80
NMT	0.80	0.90	3.90

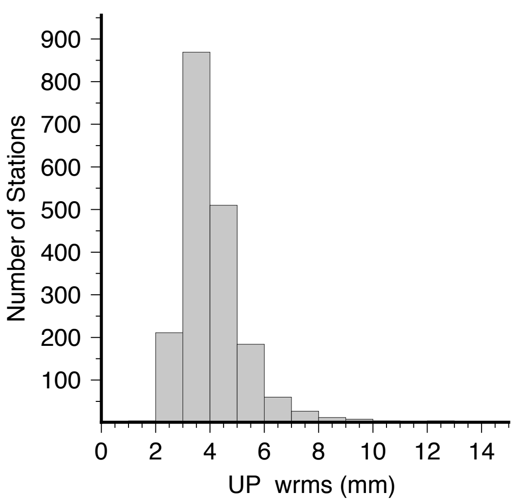
CWU	1.00	0.90	4.50
70%			
PBO	1.00	1.00	4.40
NMT	1.00	1.00	4.50
CWU	1.20	1.10	5.20
95%			
PBO	1.60	1.70	6.50
NMT	1.70	1.90	7.00
CWU	2.00	1.90	7.80



Mean (mm) : 1.1 Sigma (mm) : 4.0 Stations: 1913
50% < 0.8 (mm) 70% < 1.0 (mm) 95% < 1.6 (mm)



Mean (mm) : 1.1 Sigma (mm) : 4.0 Stations: 1913
50% < 0.8 (mm) 70% < 1.0 (mm) 95% < 1.7 (mm)



Mean (mm) : 4.5 Sigma (mm) : 5.2 Stations: 1912
50% < 3.8 (mm) 70% < 4.4 (mm) 95% < 6.5 (mm)

Scatter-Wrms Histogram : FILE: PBO_FIN_Q16.sum

Figure 1: PBO combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1913 stations analyzed between June 15, 2017 and September 16, 2017. Linear trends and annual signals were estimated from the time series.

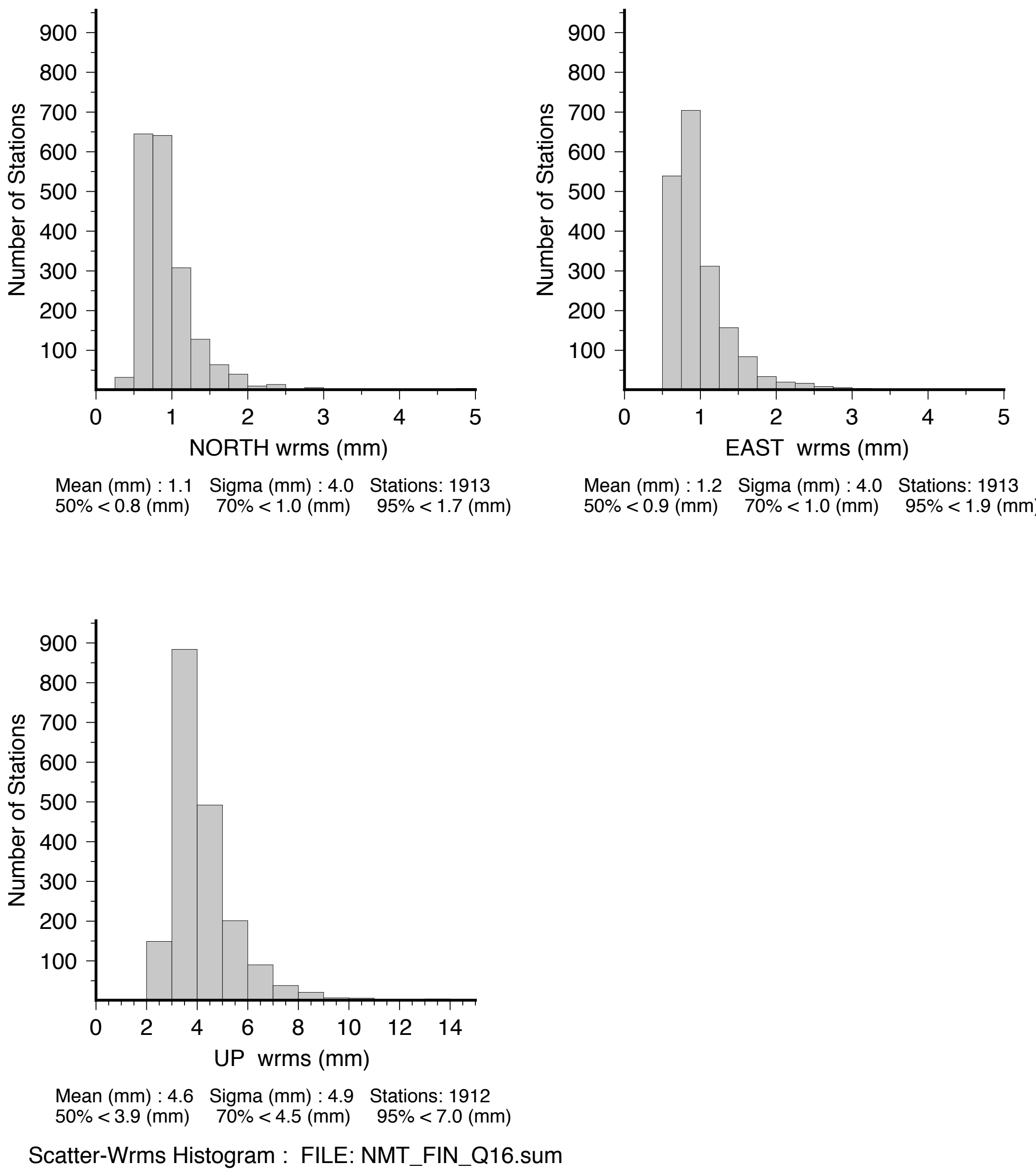


Figure 2: NMT combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1913 stations analyzed between June 15, 2017 and September 16, 2017. Linear trends and annual signals were estimated from the time series.

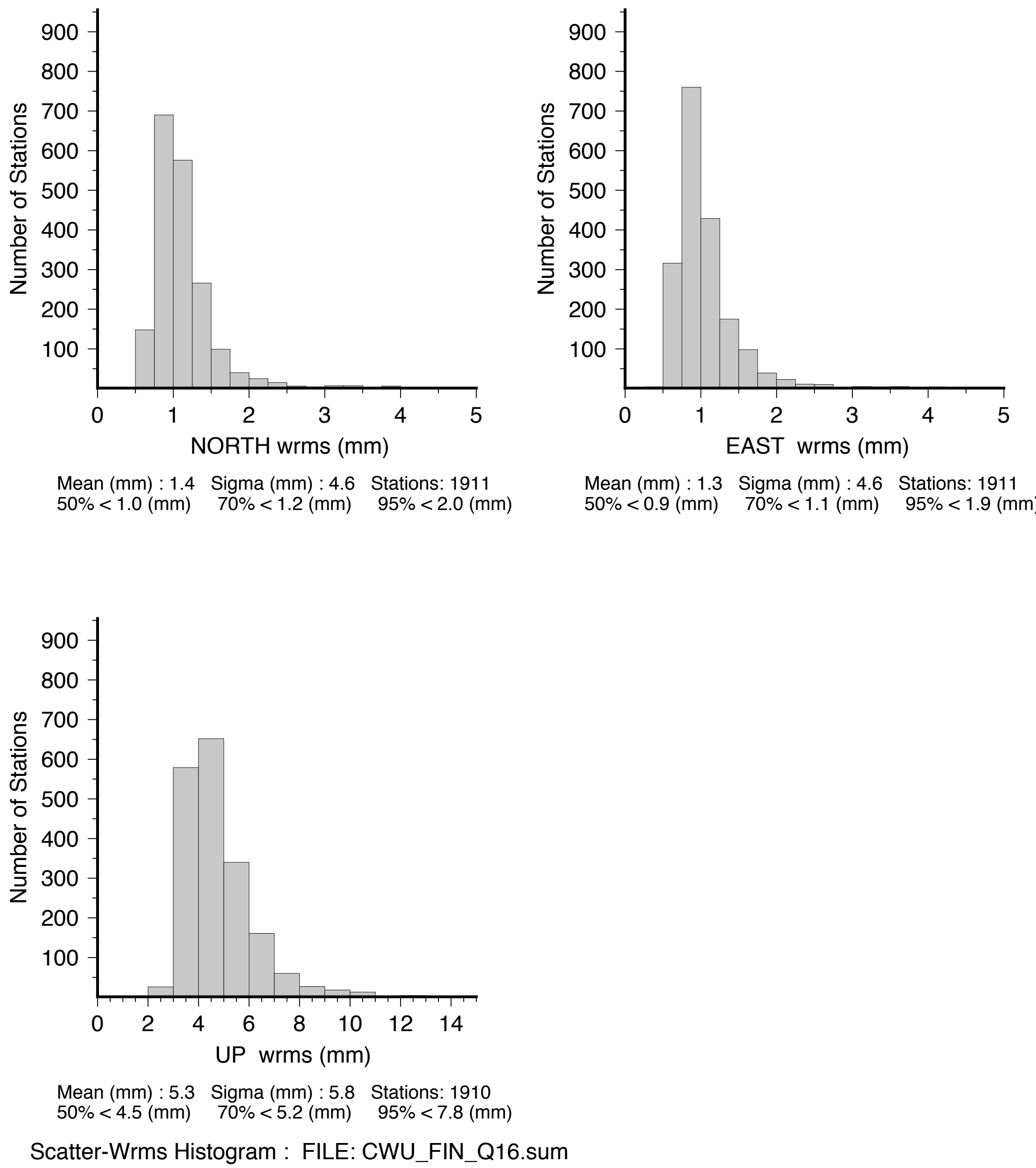


Figure 3: CWU combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1911 stations analyzed between June 15, 2017 and September 16, 2017. Editing removes two stations for North and Up. Linear trends and annual signals were estimated from the time series.

For the PBO combined analysis, we also evaluate the RMS scatters of the position estimates by network type. The figures below are based on our monthly submissions but here we use nominally 3 months of data to evaluate the RMS scatters. In Table 2, we give the median, 70 and 95 percentile limits on the RMS scatters. The geographical distributions of the RMS scatters by network type are shown in Figures 4-9. The values plotted are given in PBO_FIN_Q16.tab. There are 1831 stations in the file for sites that have at least 2 measurements during the month. The contents of the files are of this form:

```
Tabular Position RMS scatters created from PBO_FIN_Q16.sum
ChiN/E/U are square root of chisquared degree of freedom of the fits.
Values of ChiN/E/U near unity indicate that the estimated error
bars are consistent the scatter of the position estimates

.Site      #    N (mm)  ChiN      E (mm) ChiE   U (mm)  ChiU      Years
 1LSU     94      1.0   0.47      1.6    0.67     7.5   0.70      14.40
 1NSU     94      1.1   0.56      1.0    0.58     4.5   0.58      13.67
 1ULM     94      1.0   0.54      1.0    0.58     5.5   0.73      14.26
 7ODM     94      0.9   0.50      0.9    0.57     4.5   0.70      16.41
…
 ZBW1     93      1.0   0.47      1.0    0.56     4.5   0.61      14.29
 ZDC1     94      0.9   0.43      1.0    0.59     5.4   0.73      14.29
 ZDV1     94      0.9   0.41      0.9    0.51     4.2   0.59      14.29
 ZKC1     94      0.8   0.42      0.8    0.43     4.8   0.64      14.29
 ZLA1     94      0.8   0.38      0.9    0.51     4.0   0.53      14.29
 ZME1     94      1.1   0.57      1.0    0.54     5.2   0.67      14.52
 ZMP1     94      1.0   0.46      0.7    0.43     4.0   0.57      14.76
 ZNY1     94      1.0   0.46      0.9    0.50     4.0   0.55      14.67
 ZSE1     93      0.8   0.36      0.8    0.50     3.2   0.46      14.67
 ZTL4     94      0.9   0.46      1.0    0.53     5.7   0.71      14.86
```

Table 2: RMS scatter of the position residuals for the PBO combined solution between June 15, 2017 and September 16, 2017 divided by network type. The division of networks is based on the JAVA script unavcoMetdata.jar with network codes PBO, Nucleus, Mid- SCIGN_USGS , America GAMA, COCONet and Expanded PBO

Network	North (mm)	East (mm)	Up (mm)	#Sites
Median (50%)				
PBO	0.80	0.70	3.50	887
NUCLEUS	0.80	0.80	3.50	206
GAMA	0.80	0.80	4.70	15
COCONet	1.30	1.40	6.00	110
USGS_SCIGN	0.80	0.80	3.70	134
Expanded	0.90	0.90	4.30	561
70%				
PBO	0.90	0.90	3.90	
NUCLEUS	0.80	0.80	3.80	
GAMA	0.80	0.90	4.90	
COCONet	1.50	1.60	6.80	
USGS_SCIGN	1.00	0.90	4.10	
Expanded	1.10	1.10	4.80	
95%				
PBO	1.40	1.30	5.30	
NUCLEUS	1.30	1.10	5.40	
GAMA	0.90	0.90	5.20	
COCONet	3.10	4.80	12.50	
USGS_SCIGN	1.90	1.70	6.30	
Expanded	1.60	1.90	6.50	

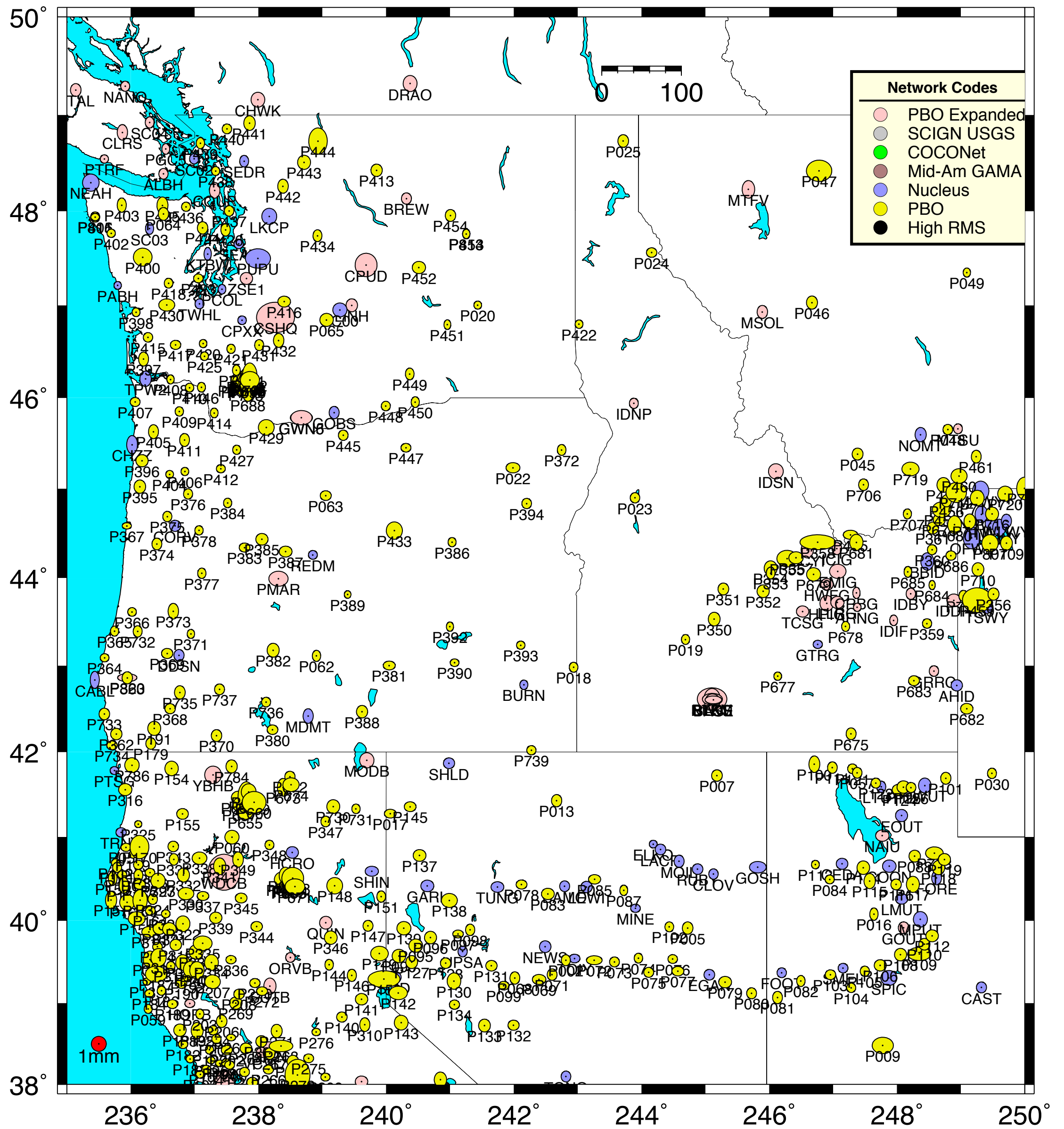


Figure 4: Distribution of the RMS scatters of horizontal position estimates from the PBO combined analysis for the Northern Western United States. The color of the ellipses that give the north and east RMS scatters denotes the network given by the legend in the figure. The small red circle shows the size of 1 mm scatters. Sites shown with black circles have combined RMS scatters in north and east greater than 5 mm or are sites that have no data during this 3-month interval.

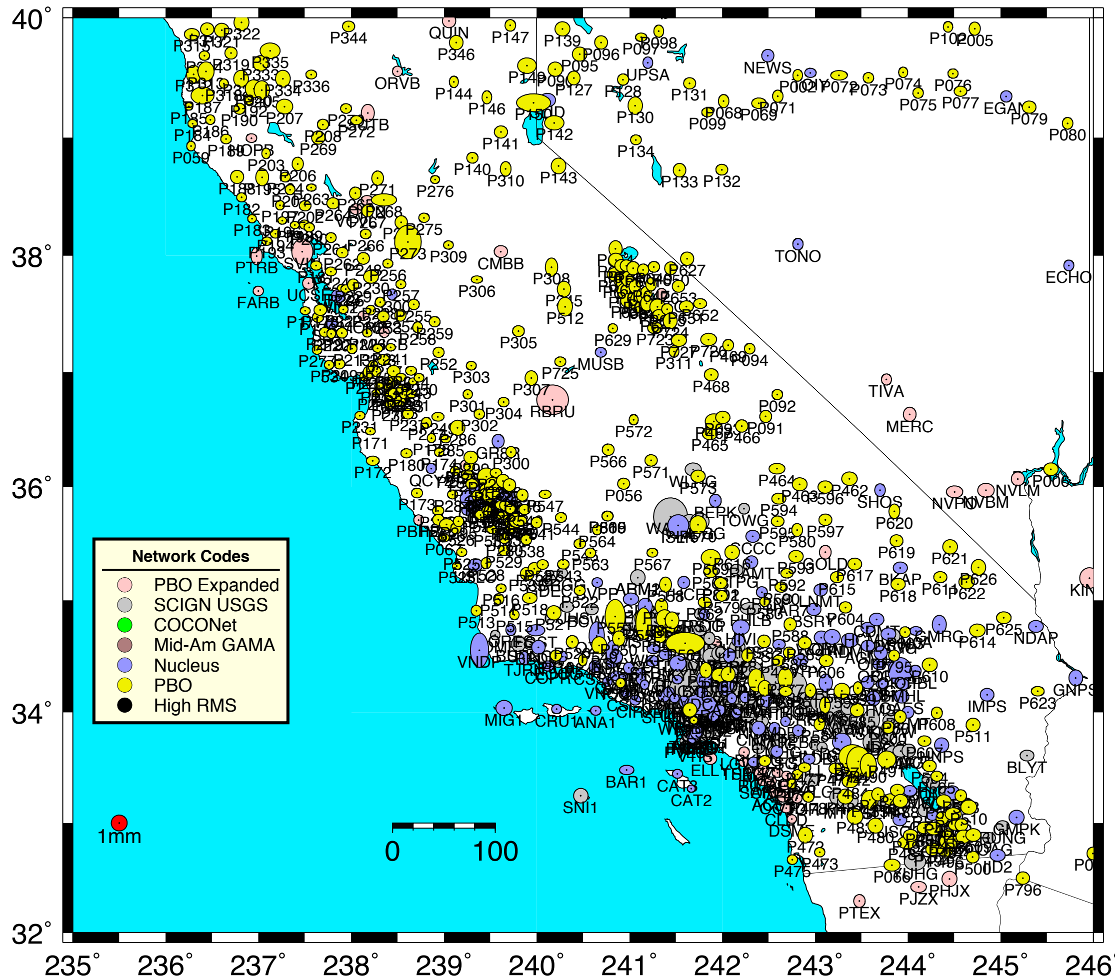


Figure 5: Same as Figure 4 except for the Southern Western United States. Black circles in the Yucca mountain region have no data during this 3-month period.

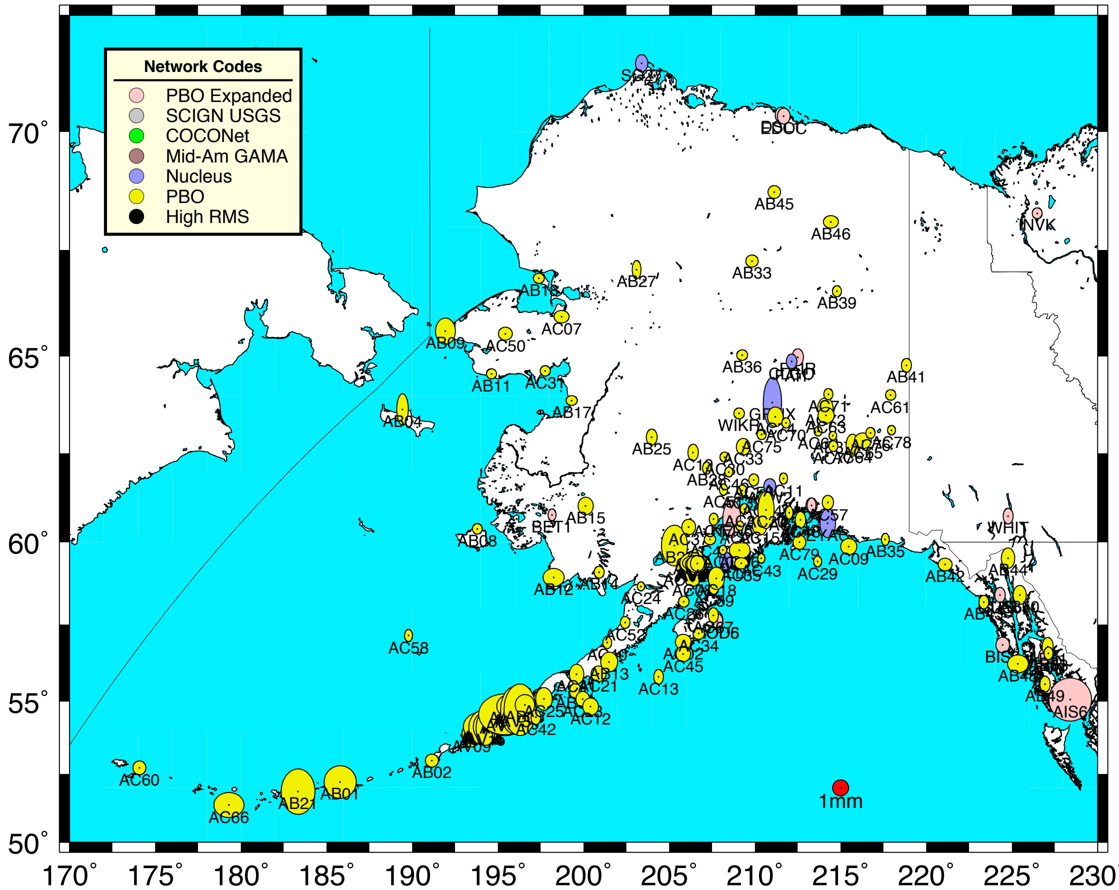


Figure 6: Same as Figure 4 except for the Alaskan region.

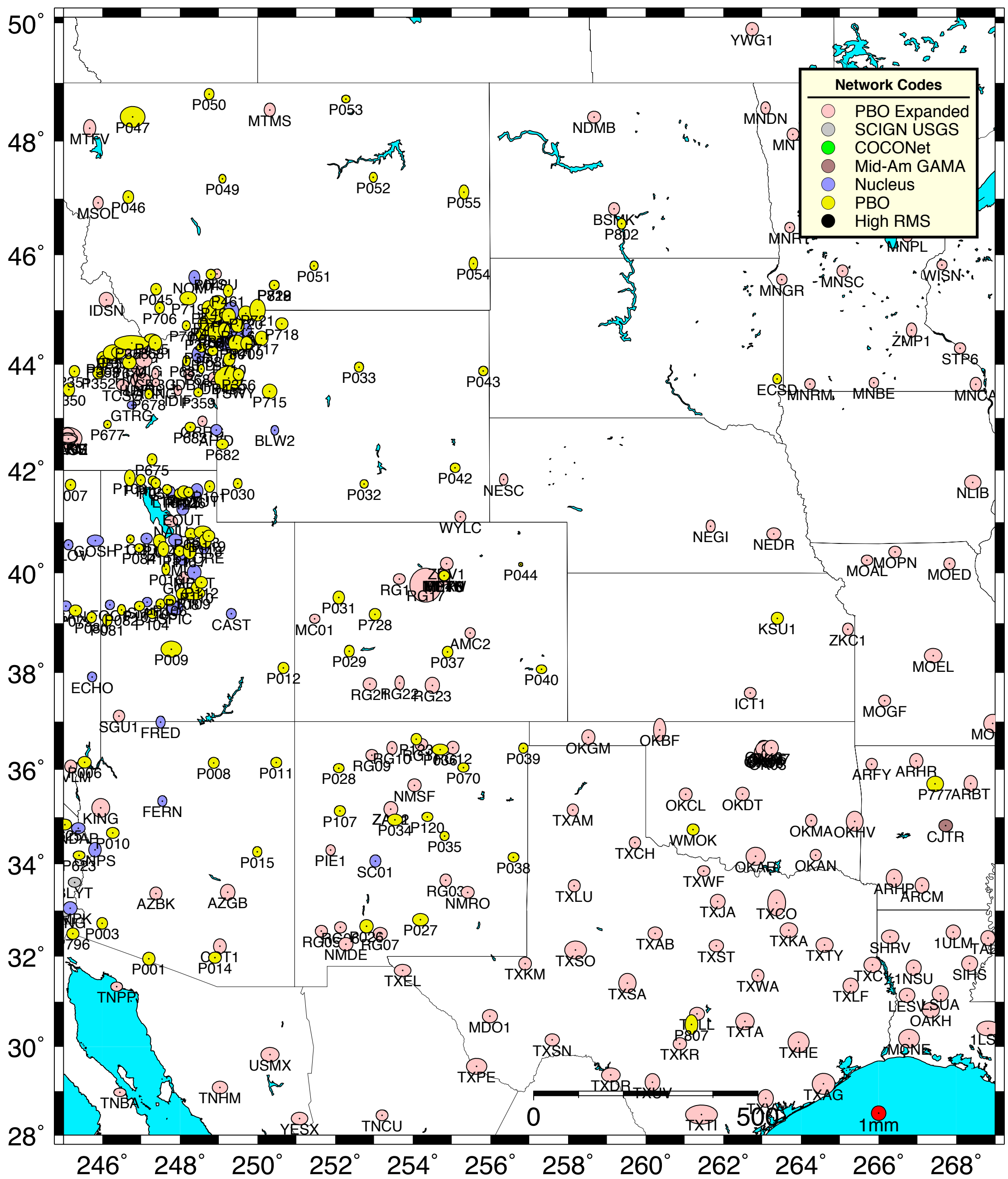


Figure 7: Same as Figure 4 except for the Central United States

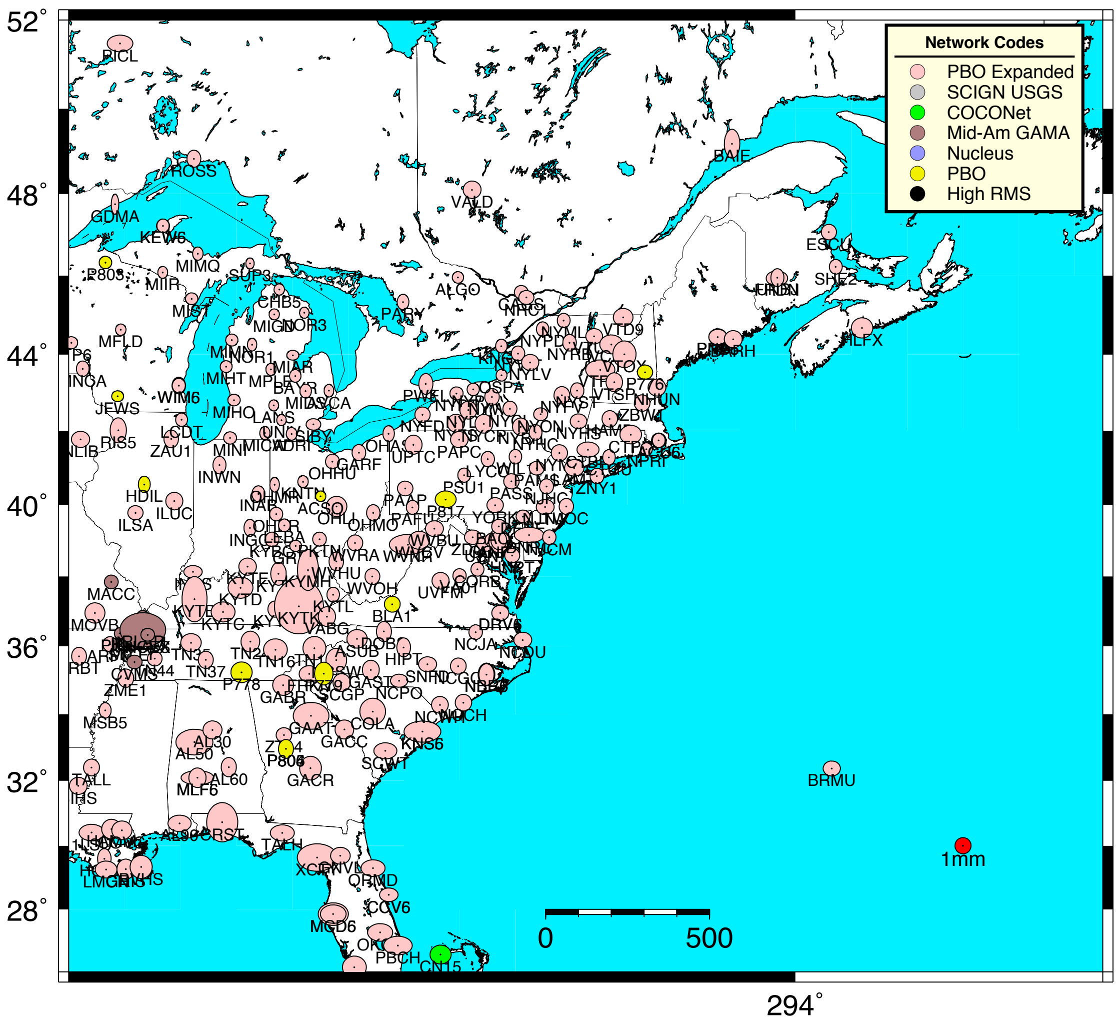


Figure 8: Same as Figure 4 except for the Eastern United States

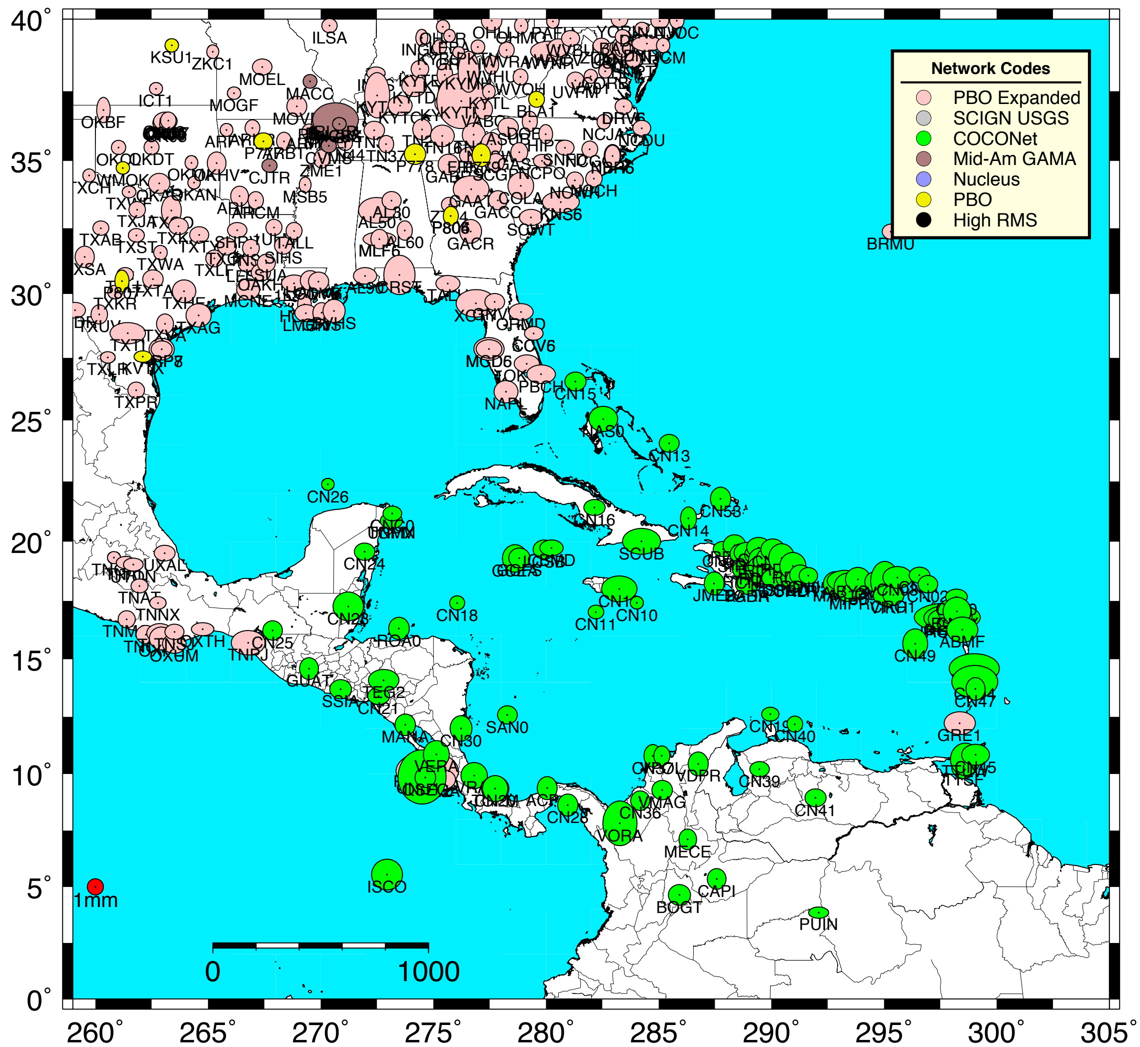


Figure 9: Same as Figure 4 except for the Caribbean region.

GLOBK Apriori coordinate file and earthquake files

As part of the quarterly analysis we run complete analysis of the time series files and generate position, velocity and other parameter estimates from these time series. These files can be directly used in the GLOBK analysis files sent with the GAGE analysis documentation. These links point to the current earthquake and discontinuity files used in the GAGE ACC analyses: All_PBO_eqs.eq All_PBO_ants.eq All_PBO_unkn.eq. The GLOBK apriori coordinate file All_PBO_nam08.apr is the current estimates based on data analysis in this quarterly report. Starting in Q06, we added a GLOBK apriori coordinate file based on the latest SNIPS PBO velocity file that are generated monthly. The SNIPS file updates the coordinates and velocities of stations that have changed in some significant fashion since the generation of the primary apriori coordinate file. The current file is All_PBO_nam08_snips.apr. Both of these apriori files are read with the –PER option in GLOBK (i.e., no periodic terms are applied). In these files, comments have a non-blank character in the first column and text after a ! in lines is treated as a

comment. The apriori file contains Cartesian XYZ positions and velocities in meters with the epoch of the position in decimal years (day of year divided by days in the specific year). The comments contain the standard deviations of the estimates and are not specifically used in GLOBK (yet). The GEOD lines give geodetic coordinates and not directly used (information only). The EXTENDED lines give the extended parts of the model parameters. Specifically, OFFSETS are NEU position and velocity offsets at the times of discontinuities. The velocity changes are all zero in the PBO analyses. The Type in the comment at the end of line indicates the type of offset. If a name is given, then this is an antenna or unknown origin offset. For earthquakes, EQ is the type and two characters after is the code for the earthquake. If postseismic motion is model, then LOG or EXP EXTENDED lines will appear. The time constant of the function is given after the date (days) and the amplitudes in meters in NEU frame is given after that. The comment contains the standard deviations in mm. PERIODIC terms give the period (days) after the date and then cosine and sine terms in NEU. The periodic terms are not used in the standard GLOBK analyses. The comment contains the standard deviations. The GLOBK apriori coordinate file contains annual periodic terms but these are not used in the daily reference frame realization.
When interpreting the offsets in the apriori file, it is important to note that these are obtained for a simultaneous analysis of all data from a site. If the residuals to the fit are systematic, the offsets often will not be the same as an offset computed from analysis of shot spans of data on either side of the offset. We are considering adding such an analysis type in the future.
The Kalman filter estimated offsets are now supplied monthly as part of the monthly reports.

Snapshot velocity field analysis from the reprocessed PBO analysis.

In our monthly reports, we generate "snapshot" velocity fields in the NAM08 reference frame based on the time series analysis of all data processed to that time. We have now started to distribute the snapshot fields (SNAPS) and the significant updates to the standard PBO velocity file (SNIPS file) in standard PBO velocity field format. These files are distributed in the monthly reports. For this quarterly report, we generate these velocity estimates for the reprocessed results and the current GAGE analyses that are in the NAM08 reference frame. There are 2235 stations in the combined PBO solution which is slightly larger than the 2224 stations reported in the last quarter. The statistics of the fits to results are shown in Table 3. In this analysis, offsets are estimated for antenna changes and earthquakes. Annual signals are estimated and for some earthquakes, logarithmic post-seismic signals are also estimated. The full tables of RMS fit along with the duration of the data used are given in the following linked files: pbo_nam08_170916.tab, nmt_nam08_170916.tab and cwu_nam08_170916.tab. The velocity estimates are shown by region and network type in Figures 10-16. The color scheme used is the same as Figures 4-9. The snapshot velocity field files are linked as: pbo_nam08_170916.snpvel, nmt_nam08_170916.snpvel and cwu_nam08_170916.snpvel.

Table 3: Statistics of the fits of 2235, 2234 and 2227 stations analyzed by PBO, NMT and CWU in the reprocessed analysis for data collected between Jan 1, 1996 and September 16, 2017.

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
NMT	1.10	1.20	5.80
CWU	1.40	1.30	6.10
PBO	1.10	1.20	5.40
70%			
NMT	1.50	1.60	6.60
CWU	1.70	1.60	6.80
PBO	1.50	1.50	6.00
95%			
NMT	3.30	3.30	9.40
CWU	3.50	3.40	10.20
PBO	3.30	3.30	9.20

Different tolerances are used for maximum standard deviation in each of the figures so that regions with small velocity vectors can be displayed at large scales without the plots being dominated by large error bar points. The standard deviations of the velocity estimated are computed using the GLOBK First-order-Gauss-Markov Extrapolation (FOGMEX) model that aims to account for temporal correlations in the time series residuals. This algorithm is also called the "Realistic Sigma" model.

A direct comparison of the NMT and CWU solutions shows the weighted root-mean-square (WRMS) difference between the two velocity fields is 0.08 mm/yr horizontal and 0.75 mm/yr vertical from differences of all stations in the two solutions that have velocity sigmas that sum to less than 100 mm/yr. The χ^2/f of the difference is $(1.13)^2$ for the horizontal and $(1.86)^2$ for the vertical component. These comparisons are summarized in Table 4. As noted in previous reports, adding small minimum sigmas (added in a root-sum-squared sense), computed such that χ^2/f is near unity changes the statistic slightly (Table 4). With the FOGMEX correlated noise model used to compute the velocity sigmas, the comparison statistics are close but still 13-86% optimistic over expectations. The 10-worst stations, in the order they are removed, are OXPE, P588, MTA1, P502, P509, P599, AC59, P483, P556, MYT2 when the added sigmas are not applied and IND1, P797, P588, P502, P556, P599, P483, P509, AC59, MYT2 when the values given in Table 4 are sum-squared into the velocity sigma estimates. This list is similar to the list in the previous quarter although this time we have split the list into two parts. Some stations have been added and others removed.

Table 4: Statistics of the differences between the CWU and NMT velocity solutions with no transformation between them. The stations common to the CWU and NMT solutions are used which is a slightly smaller number than in either solution. The PBO, NMT and CWU solutions themselves have 2225, 2234 and 2227 stations whose velocities can be determined to better than 100 mm/yr. WRMS is weighted-root-mean-scatter and NRMS is $\sqrt{(\chi^2/f)}$ where f is the number of comparisons.

Solution	#	NE WRMS (mm/yr)	U WRMS (mm/yr)	NE NRMS	U NRMS
All Normal	2214	0.08	0.75	1.13	1.86
Edited-10_worst	2204	0.07	0.74	1.07	1.83
Less than median (0.15 0.54 mm/yr)	1202	0.06	0.67	1.11	1.99
Added minimum sigma NE 0.01 U 0.50 mm/yr					
All Normal	2214	0.08	1.00	1.11	1.06
Edited-10 worst	2204	0.08	0.97	1.04	1.03
Less than median (0.15 0.74 mm/yr)	1202	0.06	0.76	1.07	0.90

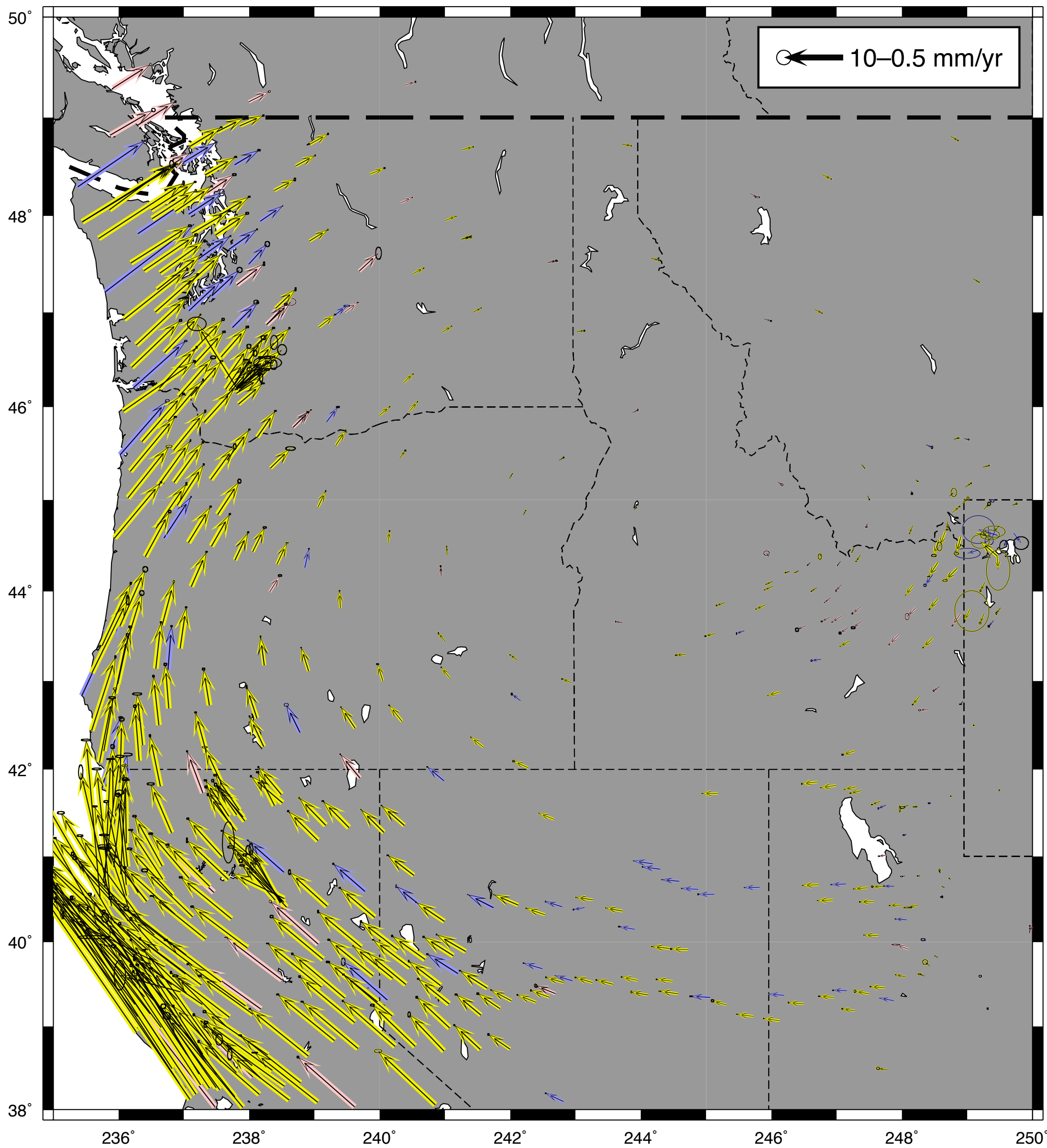


Figure 10: Velocity field estimates from the combined PBO solutions generated using time series analysis and the FOGMEX error model. 95% confidence interval error ellipses are shown. The color scheme of the vectors matches the network type legend in Figure 4. Only velocities with horizontal standard deviations less than 2 mm/yr are shown (this value is reduced from previous reports due the improved velocity sigmas).

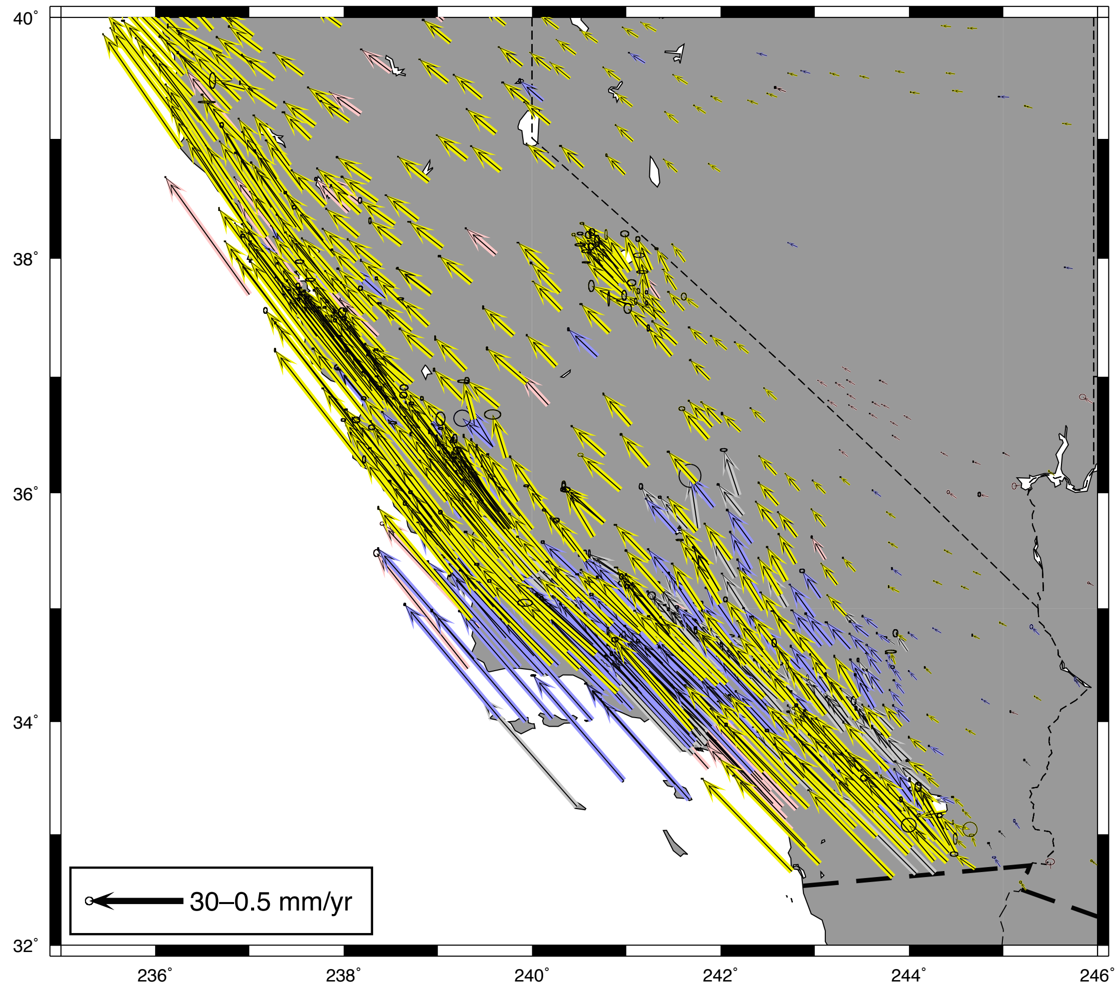


Figure 11: Same as Figure 10 except for South Western United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown.

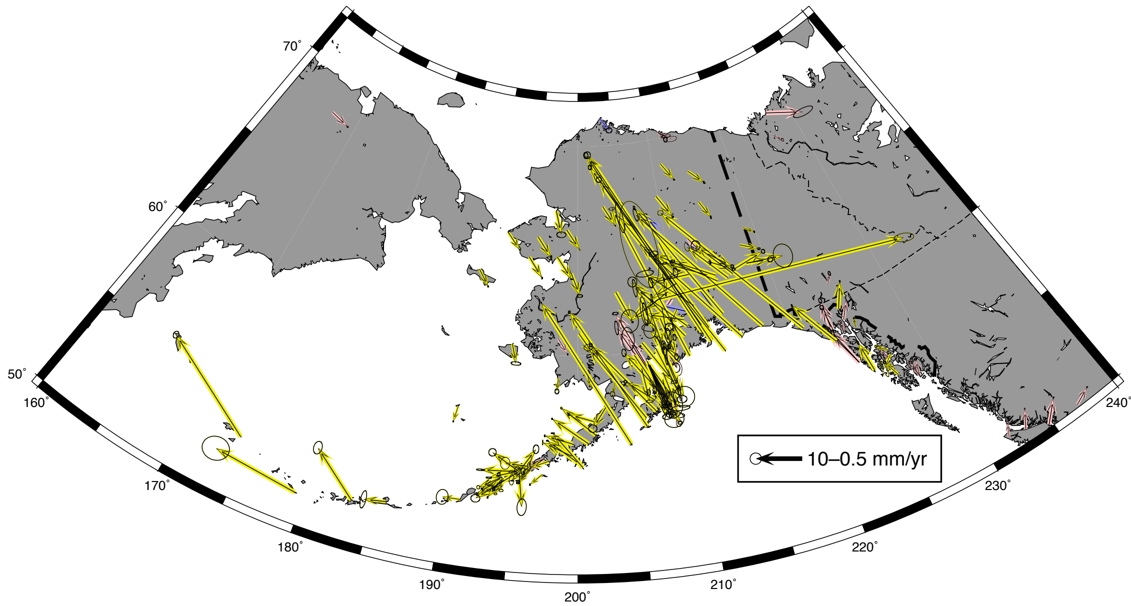


Figure 12: Same as Figure 10 except for Alaska. Only velocities with horizontal standard deviations less than 5 mm/yr are shown

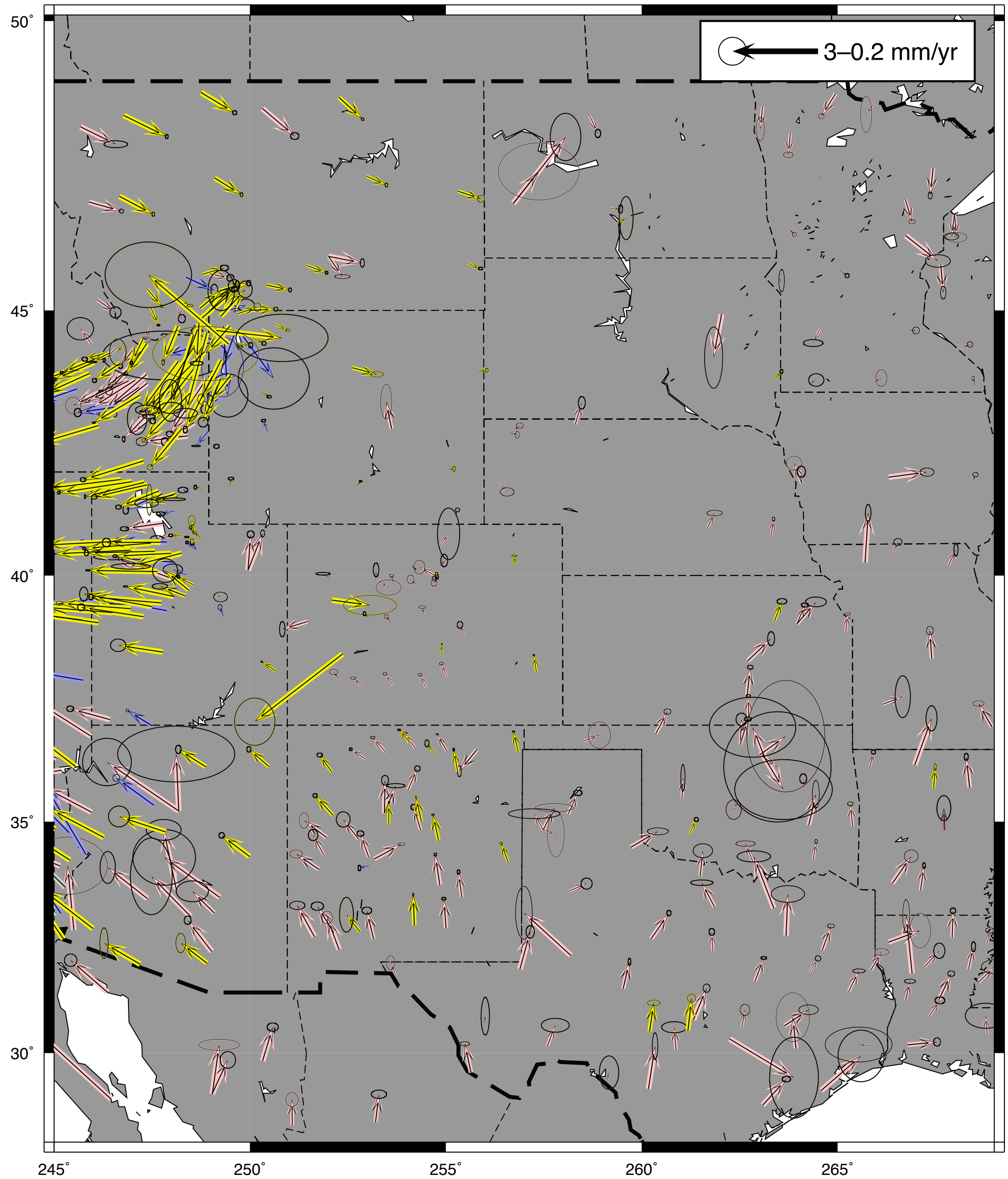


Figure 13: Same as Figure 10 except for Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown.

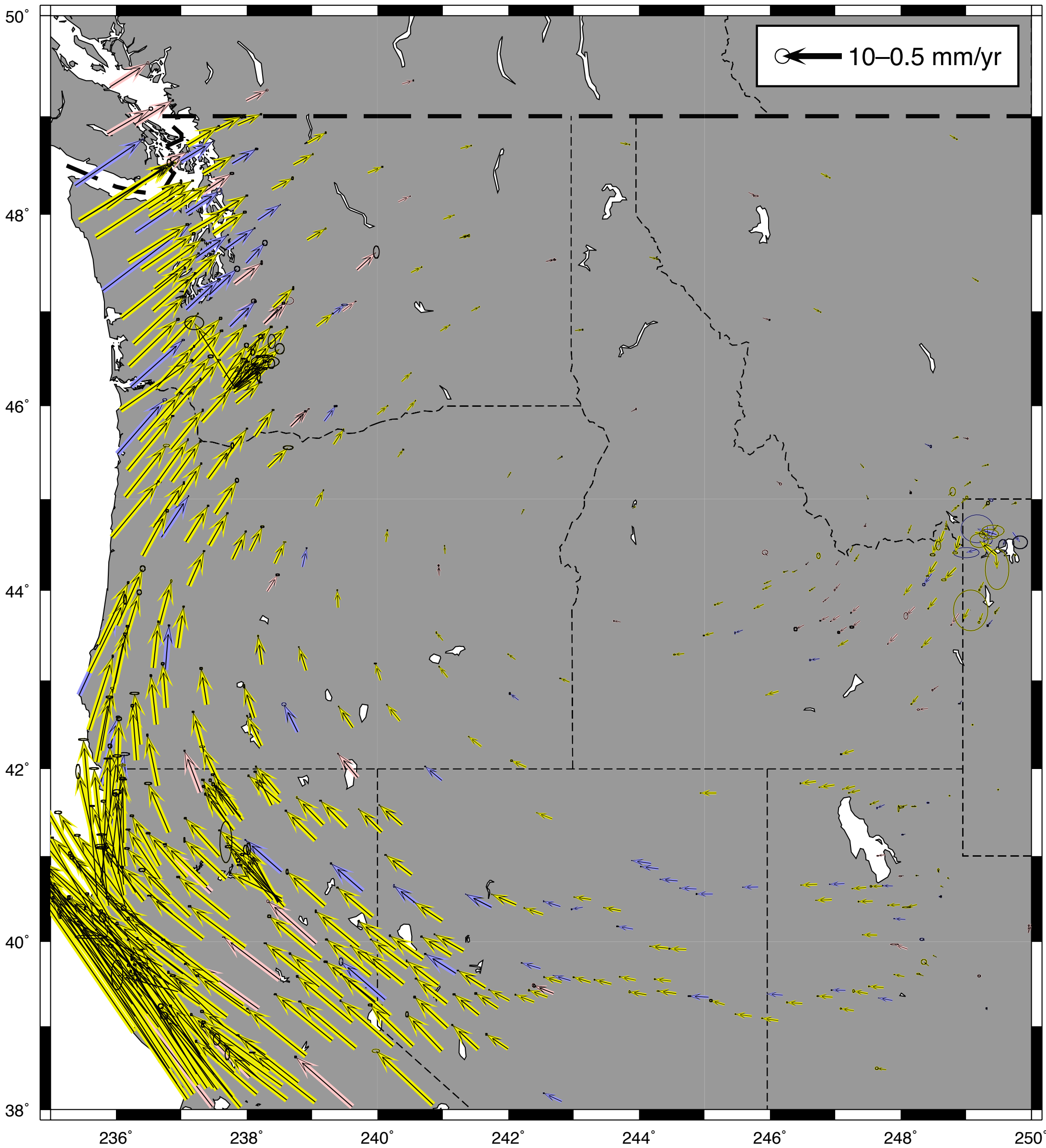


Figure 14: Same as Figure 10 except for Western Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown. Anomalous vectors at longitude 250^{o} are in the Yellowstone National Park and most likely are showing volcanic processes.

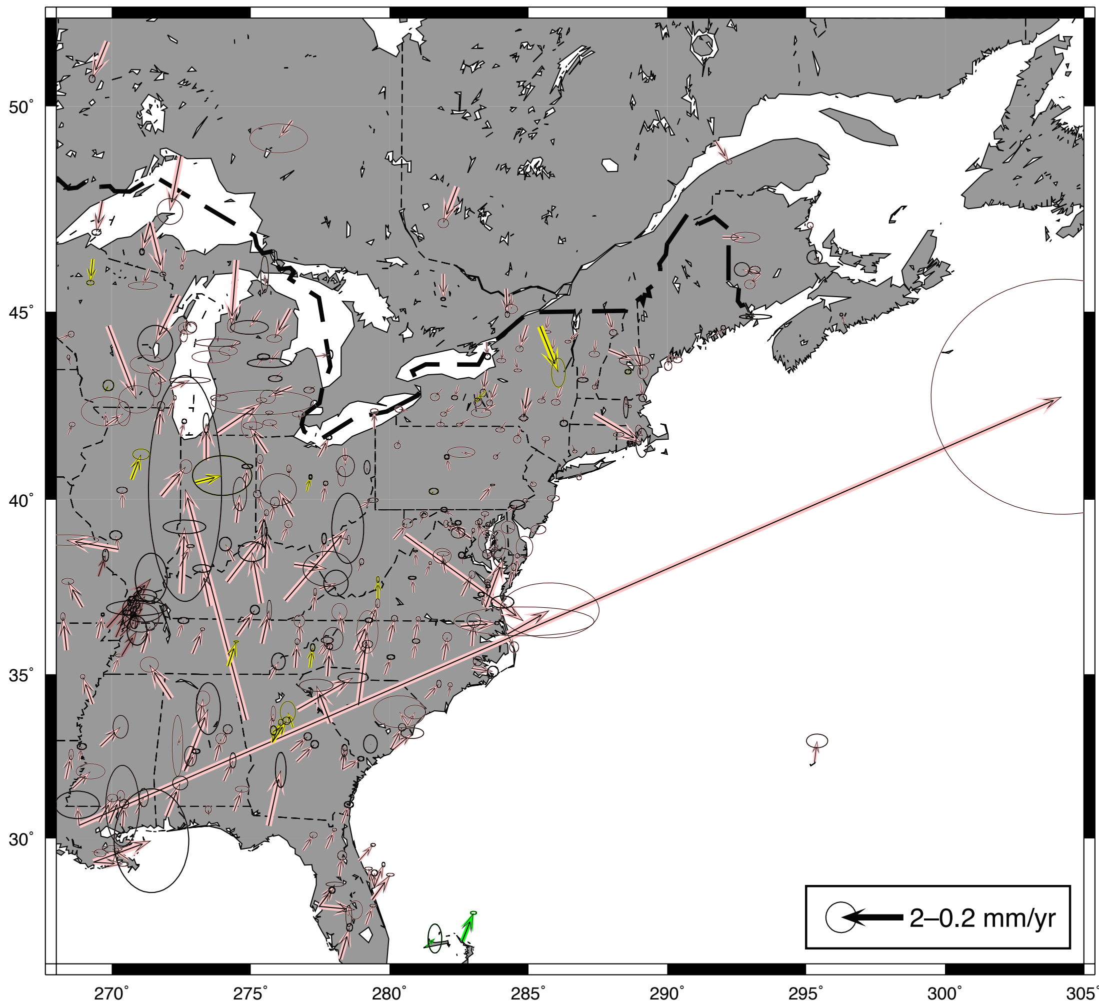


Figure 15: Same as Figure 10 except for the Eastern United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown. The systematic velocity of sites in the Northeast and central US show deviations for current GIA models in the horizontal velocities. The large outlier is LST1 which has only a short amount of data (less than 1 year). The vertical motions match quite well but geodetic vertical motions are already included in the development of the models. Horizontal GIA motions will affect the North America Euler pole from ITRF2008.

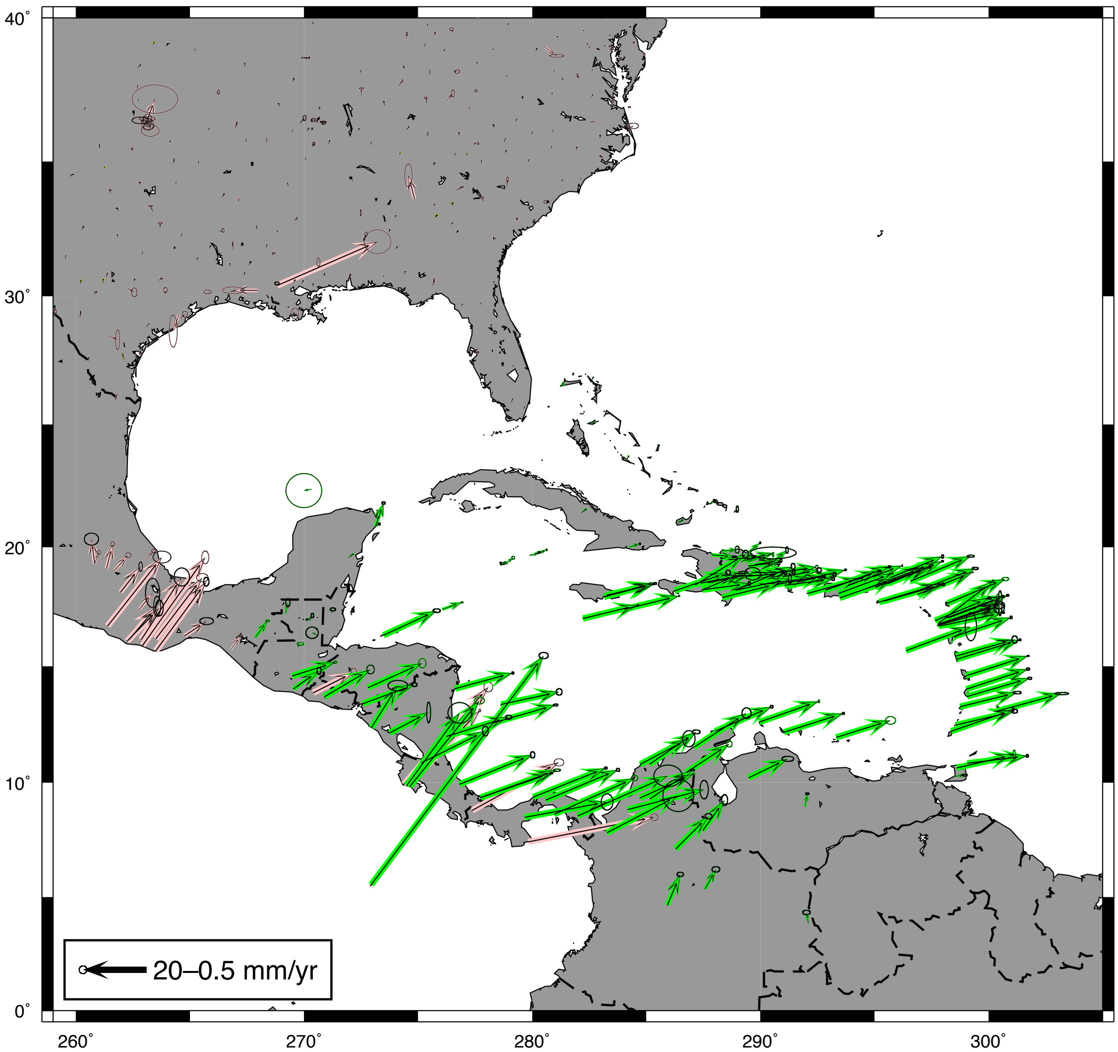


Figure 16: Same as Figure 10 except for the Caribbean region. Only velocities with horizontal standard deviations less than 5 mm/yr are shown.

Earthquake Analyses: 2017/06/14-2017/09/15.

We use the NEIC catalog to search for earthquakes that could cause coseismic offsets at the sites analyzed by the GAGE analysis centers. We examined the following earthquakes. In these output, each earthquake that might have generated coseismic displacements is numbered and the "SEQ Earthquake # n" starts the block of information about the earthquake. The EQ MM lines, give station name, distance from hypocenter (km), maximum distance that could cause coseismic offsets > 1 mm, and the "CoS" (coseismic offset) value is the possible offset in the mm. The eq_def lines give the event number, latitude, longitude, radius of influence, and depth of event followed by the date and time of the event. If an event is found to be significant, the event number is modified to reflect the total number of events so far included in the PBO analyses. Large events are often given a two-character code to reflect their location (e.g., PA is Parkfield).

Events investigated in June/July 2017..

```
* EQDEFS for 2017 06 14 to 2017 07 15 Generated Mon Jul 17 10:08:47 EDT 2017
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 12 CN25_GPS     140.03     174.30 CoS       4.8 mm
* EQ 12 GUAT_GPS     163.77     174.30 CoS       3.5 mm
* EQ 12 TNPJ_GPS     154.79     174.30 CoS       3.9 mm
* EQ_DEF M6.9 5km NNE of San Pablo
 eq_def    01   14.9823  -91.9882     174.3  8  2017 06 14 07 30    1.4566
 eq_rename 01
 eq_coseis 01  0.0010 0.0010 0.0010      1.4566     1.4566     1.4566
* ----------------------------------
* SEQ Earthquake # 2
* EQ 59 P424_GPS       2.04       8.90 CoS       6.2 mm
* EQ_DEF M3.7 17km WSW of Port Ludlow
 eq_def    02   47.8403 -122.8857       8.9  8  2017 06 16 03 56    0.0004
 eq_rename 02
 eq_coseis 02  0.0010 0.0010 0.0010      0.0004     0.0004     0.0004
* ----------------------------------
* SEQ Earthquake # 3
* EQ 82 MOPR_GPS       7.32       8.70 CoS       0.4 mm
* EQ_DEF M3.5 71km WSW of Rincon
 eq_def    03   18.0948  -67.9991       8.7  8  2017 06 17 00 14    0.0003
 eq_rename 03
 eq_coseis 03  0.0010 0.0010 0.0010      0.0003     0.0003     0.0003
* ----------------------------------
* SEQ Earthquake # 4
* EQ 251 GUAT_GPS     104.03     149.60 CoS       6.7 mm
* EQ 251 SNJE_GPS     146.15     149.60 CoS       3.4 mm
* EQ 251 TAXI_GPS      60.83     149.60 CoS      19.5 mm
* EQ_DEF M6.8 23km SW of Puerto San Jose
 eq_def    04   13.7527  -90.9488     149.6  8  2017 06 22 12 32    1.1270
 eq_rename 04
 eq_coseis 04  0.0010 0.0010 0.0010      1.1270     1.1270     1.1270
* ----------------------------------
* SEQ Earthquake # 5
* EQ 304 P157_GPS       4.57       9.60 CoS       2.8 mm
* EQ_DEF M4.0 28km SW of Rio Dell
 eq_def    05   40.2878 -124.2988       9.6  8  2017 06 24 21 23    0.0009
 eq_rename 05
 eq_coseis 05  0.0010 0.0010 0.0010      0.0009     0.0009     0.0009
* ----------------------------------
* SEQ Earthquake # 6
```

* EQ 327 P609_GPS 6.88 8.70 CoS 0.4 mm
* EQ_DEF M3.5 9km NNW of Banning
 eq_def 06 34.0013 -116.9025 8.7 8 2017 06 25 13 54 0.0003
 eq_rename 06
 eq_coseis 06 0.0010 0.0010 0.0010 0.0003 0.0003 0.0003
* ----------------------------------
* SEQ Earthquake # 7
* EQ 443 AV37_GPS 8.84 13.70 CoS 5.5 mm
* EQ_DEF M4.8 43km SW of False Pass
 eq_def 07 54.6313 -163.9740 13.7 8 2017 06 30 12 09 0.0067
 eq_rename 07
 eq_coseis 07 0.0010 0.0010 0.0010 0.0067 0.0067 0.0067

EQ01: No jump at CN25 at the time of the earthquake but there seems to be a -3.85 +- 0.44 mm east jump on 2017/05/10. Added to UNKN list
EQ02: No offset
EQ03: No data at MOPR since early 2016. No offset expected.
EQ04: No data at SNJE or TAXI. There could be a small -2 mm NE offset but it hard to be certain with noise and systematics in data.
EQ05: No data at P157 since 2017/04/20.
EQ06: No data at P609 since 2016/10/23.
EQ07: Site came back on line a few days before earthquake. No offset in time series.

No offsets can be seen for any of the earthquakes in the list.

Events investigated in July/August 2017.

* EQDEFS for 2017 07 14 to 2017 08 15 Generated Mon Aug 21 09:35:37 EDT 2017
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 149 AC60_GPS 398.72 610.60 CoS 4.6 mm
* EQ_DEF M7.7 198km ESE of Nikol'skoye
 eq_def 01 54.4715 168.8148 610.6 8 2017 07 17 23 35 11.3367
 eq_rename 01
 eq_coseis 01 0.0010 0.0010 0.0010 11.3367 11.3367 11.3367
* ----------------------------------
* SEQ Earthquake # 2
* EQ 498 P507_GPS 4.96 8.80 CoS 0.8 mm
* EQ_DEF M3.6 13km WNW of Calipatria
 eq_def 02 33.1647 -115.6463 8.8 8 2017 07 26 19 44 0.0003
 eq_rename 02
 eq_coseis 02 0.0010 0.0010 0.0010 0.0003 0.0003 0.0003
* ----------------------------------
* SEQ Earthquake # 3

* EQ 853 AC47_GPS   8.59   14.70 CoS   7.5 mm
* EQ_DEF M4.9 43km SSE of Redoubt Volcano
 eq_def   03   60.0770 -152.4709   14.7 8 2017 08 11 06 19   0.0086
 eq_rename 03
 eq_coseis 03 0.0010 0.0010 0.0010   0.0086   0.0086   0.0086
* ----------------------------------
* SEQ Earthquake # 4
* EQ 913 AB21_GPS   9.57   12.10 CoS   2.8 mm
* EQ_DEF M4.6 8km WNW of Adak
 eq_def   04   51.9218 -176.7674   12.1 8 2017 08 13 23 25   0.0040
 eq_rename 04
 eq_coseis 04 0.0010 0.0010 0.0010   0.0040   0.0040   0.0040

EQ01: AC60 is displaced by this earthquake: dNEU 6.5+-0.7 , 16.0+-0.5 -4.7+-1.9 mm. The east offset is similar in size to the M 7.9 Event 32 (lat 51.797 Long 178.760) on 2014 06 23 20 54. The next closest station AC66 has no data at this time. Other nearby stations (AB21 and AB01) do show any offsets. Earthquake added as Event 39.
EQ02: No break seen at P507.
EQ03: No break seen at AC47 (lots of systematics at this site; mostly likely snow).
EQ04: No break seen at AB21.(Gaps in time series but there are data around the time of the earthquake.

Events investigated in August/September 2017.

* EQDEFS for 2017 08 14 to 2017 09 15 Generated Fri Sep 15 09:45:23 EDT 2017
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 353 AV02_GPS   7.55   8.70 CoS   0.2 mm
* EQ_DEF M3.5 95km ESE of Old Iliamna
 eq_def   01   59.2760 -153.5020   8.7 8 2017 08 27 13 07   0.0002
 eq_rename 01
 eq_coseis 01 0.0010 0.0010 0.0010   0.0002   0.0002   0.0002
* ----------------------------------
* SEQ Earthquake # 2
* EQ 427 P201_GPS   7.79   8.70 CoS   0.3 mm
* EQ 427 P204_GPS   5.12   8.70 CoS   0.7 mm
* EQ_DEF M3.5 11km WNW of Calistoga
 eq_def   02   38.6210 -122.7033   8.7 8 2017 08 31 15 60   0.0003
 eq_rename 02
 eq_coseis 02 0.0010 0.0010 0.0010   0.0003   0.0003   0.0003
* ----------------------------------
* SEQ Earthquake # 3
* EQ 440 EPZA_GPS   7.29   20.70 CoS   28.9 mm
* EQ 440 SAJU_GPS   20.38   20.70 CoS   3.7 mm
* EQ_DEF M5.3 10km SW of Nicoya

eq_def 03 10.0901 -85.5275 20.7 8 2017 09 01 07 43 0.0240
eq_rename 03
eq_coseis 03 0.0010 0.0010 0.0010 0.0240 0.0240 0.0240
* ---------------------------------
* SEQ Earthquake # 4
* EQ 469 IDSS_GPS 14.75 20.70 CoS 7.1 mm
* EQ_DEF M5.3 15km E of Soda Springs
eq_def 04 42.6373 -111.4178 20.7 8 2017 09 02 23 57 0.0240
eq_rename 04
eq_coseis 04 0.0010 0.0010 0.0010 0.0240 0.0240 0.0240
* ---------------------------------
* SEQ Earthquake # 5
* EQ 480 IDSS_GPS 5.56 9.10 CoS 1.0 mm
* EQ_DEF M3.8 5km E of Soda Springs
eq_def 05 42.6498 -111.5388 9.1 8 2017 09 03 06 06 0.0005
eq_rename 05
eq_coseis 05 0.0010 0.0010 0.0010 0.0005 0.0005 0.0005
* ---------------------------------
* SEQ Earthquake # 6
* EQ 481 IDSS_GPS 5.65 9.30 CoS 1.4 mm
* EQ_DEF M3.9 8km ENE of Soda Springs
eq_def 06 42.6881 -111.5163 9.3 8 2017 09 03 06 45 0.0007
eq_rename 06
eq_coseis 06 0.0010 0.0010 0.0010 0.0007 0.0007 0.0007
* ---------------------------------
* SEQ Earthquake # 7
* EQ 488 IDSS_GPS 7.67 9.00 CoS 0.4 mm
* EQ_DEF M3.7 9km E of Soda Springs
eq_def 07 42.6676 -111.4951 9.0 8 2017 09 03 11 24 0.0004
eq_rename 07
eq_coseis 07 0.0010 0.0010 0.0010 0.0004 0.0004 0.0004
* ---------------------------------
* SEQ Earthquake # 8
* EQ 519 IDSS_GPS 8.91 9.00 CoS 0.3 mm
* EQ_DEF M3.7 8km ESE of Soda Springs
eq_def 08 42.6381 -111.4983 9.0 8 2017 09 04 19 05 0.0004
eq_rename 08
eq_coseis 08 0.0010 0.0010 0.0010 0.0004 0.0004 0.0004
* ---------------------------------
* SEQ Earthquake # 9
* EQ 527 KEN5_GPS 7.17 9.80 CoS 1.4 mm
* EQ 527 KEN6_GPS 7.17 9.80 CoS 1.4 mm
* EQ_DEF M4.1 5km ESE of Nikiski
eq_def 09 60.6780 -151.2202 9.8 8 2017 09 04 21 06 0.0011
eq_rename 09
eq_coseis 09 0.0010 0.0010 0.0010 0.0011 0.0011 0.0011

```
* ---------------------------------
* SEQ Earthquake # 10
* EQ 562 IDSS_GPS      9.72      11.50 CoS       2.1 mm
* EQ_DEF M4.5 8km SE of Soda Springs
 eq_def   10   42.6118 -111.5234     11.5  8  2017 09 06 04 38    0.0031
 eq_rename 10
 eq_coseis 10  0.0010 0.0010 0.0010      0.0031     0.0031     0.0031
* ---------------------------------
* SEQ Earthquake # 11
* EQ 590 BON2_GPS    1097.23    1155.10 CoS       1.7 mm
* EQ 590 CABA_GPS    1055.91    1155.10 CoS       1.8 mm
* EQ 590 CHIS_GPS    376.44    1155.10 CoS      14.3 mm
* EQ 590 CN18_GPS    1075.95    1155.10 CoS       1.7 mm
* EQ 590 CN21_GPS    703.14    1155.10 CoS       4.1 mm
* EQ 590 CN22_GPS    780.52    1155.10 CoS       3.3 mm
* EQ 590 CN23_GPS    581.31    1155.10 CoS       6.0 mm
* EQ 590 CN24_GPS    783.13    1155.10 CoS       3.3 mm
* EQ 590 CN25_GPS    213.12    1155.10 CoS      44.6 mm
* EQ 590 CN26_GPS    918.37    1155.10 CoS       2.4 mm
* EQ 590 CN29_GPS    1119.62    1155.10 CoS       1.6 mm
* EQ 590 CN30_GPS    1128.87    1155.10 CoS       1.6 mm
* EQ 590 CNC0_GPS     996.59    1155.10 CoS       2.0 mm
* EQ 590 ELEN_GPS     460.10    1155.10 CoS       9.6 mm
* EQ 590 ELVI_GPS    1037.29    1155.10 CoS       1.9 mm
* EQ 590 EPZA_GPS    1040.79    1155.10 CoS       1.9 mm
* EQ 590 GRZA_GPS    1048.38    1155.10 CoS       1.8 mm
* EQ 590 GUAT_GPS     347.73    1155.10 CoS      16.7 mm
* EQ 590 HATI_GPS    1018.63    1155.10 CoS       2.0 mm
* EQ 590 HUA2_GPS    1068.16    1155.10 CoS       1.8 mm
* EQ 590 IND1_GPS    1063.68    1155.10 CoS       1.8 mm
* EQ 590 LAFE_GPS    1116.95    1155.10 CoS       1.6 mm
* EQ 590 LEPA_GPS    1102.16    1155.10 CoS       1.7 mm
* EQ 590 LMNL_GPS    1081.47    1155.10 CoS       1.7 mm
* EQ 590 MANA_GPS     870.42    1155.10 CoS       2.7 mm
* EQ 590 NARA_GPS     392.61    1155.10 CoS      13.1 mm
* EQ 590 OXPE_GPS     372.03    1155.10 CoS      14.6 mm
* EQ 590 OXTH_GPS     212.57    1155.10 CoS      44.8 mm
* EQ 590 OXTU_GPS     439.30    1155.10 CoS      10.5 mm
* EQ 590 OXUM_GPS     306.22    1155.10 CoS      21.6 mm
* EQ 590 PNE2_GPS    1013.53    1155.10 CoS       2.0 mm
* EQ 590 POPT_GPS     481.92    1155.10 CoS       8.7 mm
* EQ 590 PUJE_GPS    1069.78    1155.10 CoS       1.8 mm
* EQ 590 PUMO_GPS    1101.22    1155.10 CoS       1.7 mm
* EQ 590 QSEC_GPS    1078.41    1155.10 CoS       1.7 mm
* EQ 590 ROA0_GPS     782.63    1155.10 CoS       3.3 mm
* EQ 590 SAJU_GPS    1032.18    1155.10 CoS       1.9 mm
```

* EQ 590 SNJE_GPS 462.99 1155.10 CoS 9.4 mm
* EQ 590 SSIA_GPS 518.63 1155.10 CoS 7.5 mm
* EQ 590 TAXI_GPS 368.40 1155.10 CoS 14.9 mm
* EQ 590 TEG2_GPS 709.50 1155.10 CoS 4.0 mm
* EQ 590 TGMX_GPS 970.51 1155.10 CoS 2.1 mm
* EQ 590 TNAL_GPS 692.57 1155.10 CoS 4.2 mm
* EQ 590 TNAT_GPS 573.82 1155.10 CoS 6.1 mm
* EQ 590 TNCC_GPS 1089.01 1155.10 CoS 1.7 mm
* EQ 590 TNCN_GPS 961.46 1155.10 CoS 2.2 mm
* EQ 590 TNCY_GPS 447.62 1155.10 CoS 10.1 mm
* EQ 590 TNGF_GPS 749.67 1155.10 CoS 3.6 mm
* EQ 590 TNIF_GPS 942.42 1155.10 CoS 2.3 mm
* EQ 590 TNMO_GPS 947.07 1155.10 CoS 2.3 mm
* EQ 590 TNMQ_GPS 555.34 1155.10 CoS 6.6 mm
* EQ 590 TNMR_GPS 1087.63 1155.10 CoS 1.7 mm
* EQ 590 TNNP_GPS 385.80 1155.10 CoS 13.6 mm
* EQ 590 TNNX_GPS 456.69 1155.10 CoS 9.7 mm
* EQ 590 TNPJ_GPS 88.57 1155.10 CoS 258.0 mm
* EQ 590 TNSJ_GPS 322.00 1155.10 CoS 19.5 mm
* EQ 590 UCOE_GPS 998.40 1155.10 CoS 2.0 mm
* EQ 590 UNIP_GPS 749.12 1155.10 CoS 3.6 mm
* EQ 590 UNPM_GPS 970.44 1155.10 CoS 2.1 mm
* EQ 590 UTON_GPS 659.31 1155.10 CoS 4.7 mm
* EQ 590 UXAL_GPS 601.37 1155.10 CoS 5.6 mm
* EQ 590 VERA_GPS 1067.76 1155.10 CoS 1.8 mm
* EQ_DEF M8.1 87km SW of Pijijiapan
 eq_def 11 15.0678 -93.7150 1155.1 8 2017 09 08 04 50 31.6273
 eq_rename 11
 eq_coseis 11 0.0010 0.0010 0.0010 31.6273 31.6273 31.6273

EQ01: No offsets
EQ02: No offsets
EQ03: This event may have produced offsets at EPZA and SAJU. Currently there are no data available that span the earthquake.
EQ04-08: No data at IDSS since 2012. Same is true for Eqs 5-8. Looks like a small swarm event.
EQ09: No offsets
EQ10: Same as EQ04-08
EQ11: This earthquake generated co-seismic offsets at many sites and have been label event 40.
An event report was sent to UNAVCO via LDM. It is too early to tell if there will be significant post-seismic motions.

Antenna Change Offsets: 2017/06/01-2017/08/31

The follow antenna changes were investigated and reported on in the MIT ACC monthly reports.

```
Station  Date      From        To
AV24  2017  6 21  0  0 TRM59800.00  TRM59800.80
NYRB  2017  6  7 15  0 LEIAT504GG   LEIAR20 & LEIS to LEIM
AB43  2017  7 24 23 51 TRM29659.00  TRM59800.80
AC12  2017  7 12 21 27 TRM29659.00  TRM59800.80
NJHC  2017  7 31 17 50 LEIAT504GG   LEIAR10
P490  2017  7 13  0  0 TRM29659.00  TRM59800.80
P590  2017  7 14  0  0 TRM29659.00  TRM59800.00
P735  2017  7  6 19 47 TRM59800.00  TRM59800.80
P796  2017  7 15  0  0 TRM29659.00  TRM59800.80
AB08  2017  8 18  0  0 TRM59800.00  TRM59800.80
MIHT  2017  8  8 18 30 LEIAT504GG   LEIAR20 & LEIS  to LEIM
MIMN  2017  8  8 22 10 LEIAT504GG   LEIAR20 & LEIS  to LEIM
P007  2017  8 18  0  0 TRM29659.00  TRM59800.80
P062  2017  8 29  0  0 TRM29659.00  TRM59800.80
P235  2017  8 12  0  0 TRM59800.00  TRM59800.80
SNI1  2017  8  9  0  0 ASH701945B_M TPSCR.G3
SUP3  2017  8 11 19 18 LEIAT504GG   LEIAR20 & LEIS  to LEIM

Analysis
AV24: WLS dNEU   -5.99 +- 8.12,   3.33 +- 8.57,   3.71 +- 4.32 mm,
       KF dNEU   -3.67 +- 0.79,   0.88 +- 0.79,   6.07 +- 1.28 mm
Long gap since early 2017 before antenna change.  Systematics in time
series so validity of offset not clear.
NYRB: WLS dNEU   -2.66 +- 0.69,  -1.43 +- 1.01,  -0.45 +- 5.79 mm,
       KF dNEU   -2.22 +- 0.39,  -1.73 +- 0.32,   1.14 +- 1.38 mm
Offset can be seen in the time series.
AB43: WLS dNEU   -3.94 +- 3.02,   2.86 +- 0.60,  11.54 +- 9.03 mm,
       KF dNEU   -2.16 +- 0.45,   3.08 +- 0.30,   7.09 +- 1.38 mm
Break is clear in data.  (Other breaks in time series are earthquakes)
AC12: WLS dNEU    6.48 +- 1.04,  -5.72 +- 3.21,  -4.05 +- 3.86 mm,
       KF dNEU    5.50 +- 0.37,  -4.26 +- 0.48,  -2.13 +- 1.01 mm
Large gap in the time series before break so significance of break is
not clear.
NJHC: WLS dNEU   17.45 +- 1.51,  -9.12 +- 1.41, -11.53 +- 9.76 mm,
       KF dNEU   17.58 +- 0.69,  -9.31 +- 0.63,  -9.68 +- 2.44 mm
Offsets are very clear.  Estimates are based on NMT analyses since CWU
results are
affect by the length of time it took to apply the new antenna model.
P490: WLS dNEU    2.49 +- 0.90,  -1.42 +- 0.74,   1.42 +- 4.76 mm,
       KF dNEU    3.68 +- 0.33,  -1.29 +- 0.32,   5.77 +- 1.31 mm
Offsets are clear in the times series.  Site has large log term North.
(-2.8 mm for a -3.4 mm coseismic offset).
P590: WLS dNEU    0.88 +- 3.60,   2.91 +- 0.78,  -2.25 +- 7.22 mm,
       KF dNEU   -0.12 +- 0.34,   2.83 +- 0.30,   0.83 +- 1.16 mm
East offset is clear in time series.
P735: WLS dNEU    1.99 +- 2.05,   3.22 +- 1.85,   0.18 +- 7.62 mm,
       KF dNEU    2.01 +- 0.54,   3.26 +- 0.46,   0.21 +- 1.78 mm
Large gap in time series so significance of offsets is not so clear.
Also strange data
excursion between Jan 20 and Feb 9, 2017 (6, 16, 60 mm in NEU).
Earlier event happed in
Dec 18, 2012 to Jan 5, 2013.  This event was “bell shaped” in North
with amplitude of 20 mm.
```

```
P796: WLS dNEU    4.01 +- 1.28,  -2.28 +- 1.30,   0.32 +- 4.21 mm,
       KF dNEU    3.65 +- 0.37,  -1.66 +- 0.36,   3.01 +- 1.36 mm
Very clear offset in North.  Large east post seismic from El Major
Cucapah (5.3 mm amplitude.)
AB08: WLS dNEU   -2.62 +- 4.45,  11.05 +- 9.36,   3.30 +- 5.42 mm,
       KF dNEU   -2.13 +- 0.42,   1.20 +- 0.48,   6.52 +- 1.10 mm
Data is quite noisy so hard to tell if significant
MIHT: WLS dNEU   -0.12 +- 0.85,   0.47 +- 1.19,  -0.07 +- 13.89 mm,
       KF dNEU   -0.18 +- 0.34,   0.61 +- 0.28,   2.04 +- 1.28 mm
This break looks small but there is a "slow" east break between
2016/07/12 and 2016/08/03 that
moves the site ~-4 mm East.  This may be a processing artefact (see
below).
MIMN: WLS dNEU   -1.32 +- 0.82,  -2.57 +- 1.39,  -6.32 +- 11.35 mm,
       KF dNEU   -1.38 +- 0.46,  -2.38 +- 0.37,  -2.84 +- 1.62 mm
This break is small but the same “slow” event at MIHT can be seen here
as well.
The amplitude is similar ~-4.8 mm at MIMN. These events occur at
different times for
the CWU and NMT solution (2016/07/16 for CWU, Wk 1906 and 2016/07/30
for NMT, Wk 1908)
P007: WLS dNEU    1.33 +- 0.56,   0.69 +- 0.62,  -1.50 +- 9.55 mm,
       KF dNEU    1.17 +- 0.34,   0.52 +- 0.29,   4.34 +- 1.20 mm
Offset is small.
P062: WLS dNEU    2.01 +- 0.58,  -1.11 +- 0.77,   0.49 +- 13.05 mm,
       KF dNEU    1.82 +- 0.39,  -1.20 +- 0.33,   6.59 +- 1.34 mm
Offset is small.
P235: WLS dNEU   -7.72 +- 1.12,   0.47 +- 2.07,  -4.12 +- 11.61 mm,
       KF dNEU   -8.31 +- 0.30,  -0.61 +- 0.30,   0.89 +- 1.24 mm
North offset is very clear.
SNI1: WLS dNEU    3.69 +- 5.29,  11.38 +- 13.38,   7.69 +- 8.62 mm,
       KF dNEU    0.77 +- 0.34,  14.31 +- 0.45,   6.79 +- 1.06 mm
East off set is very clear.
SUP3: WLS dNEU    0.74 +- 7.98,  10.05 +- 2.23,  -6.28 +- 8.96 mm,
       KF dNEU   -0.18 +- 0.38,  10.03 +- 0.26,  -3.06 +- 1.04 mm
East offset is very clear.

Only anomaly is for the MIMN/HT and some other Mixx stations as noted
above.
```

New offsets of unknown origin and data anomalies

CN25 2017 5 10 -3.8 mm East jump for no obvious reason.
TNGF 2017 3 31 Seems like site jumps large amount. dNEU 2011. -362. 661. mm. Looks as if the antenna has been moved but with no log record to indicate why.

GAMIT/GLOBK Community Support

During this quarter, our primary effort has been to code and begin testing the addition of ocean tidal perturbations to our orbital integrator. We have updated tables to support added six new antennas and continued to provide regular updates for differential code biases (DCBs), mapping functions (VMF1), and atmospheric loading required by GAMIT users.

We continue to spend 5-10 hours per week in email support of users. During the quarter, we issued 18 royalty-free licenses to educational and research institutions.