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: 2017/10/01-2017/12/31

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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 2017/09/14 to 2017/12/09, time series velocity field analyses for the GAGE reprocessing analyses (1996-2017). Several earthquakes were investigated this quarter and some generated coseismic displacements > 1mm. An event file created for the 2017/09/19 18:15 UTC M7.1 earthquake ESE of Ayutla. This event is Event41. Also, an event file, event 42, was created for the 2017/11/13 02:29 M6.5 16km SE of Jaco. We also added a postseismic log for event 40, September 8, 2017, with a decay time of 10 days. The postseismic signal can be clearly seen at OXTH. 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 December 9, 2017. Associated with the report are the ASCII text files that are sent with this document.

The quarter we also generated and sent to UNAVCO the annual velocity field analysis using the full SINEX solutions. This solution is still in the ITRF2008 system as realized by the PBO frame definition. We are waiting for JPL to generate clock and orbit products in the ITRF2014 system so that CWU can generate solutions in this frame. NMT is well underway in generating ITRF2014 reprocessed solutions using the IGS orbit products generated in the ITRF2014 system. A description of this velocity analysis is given below.

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 but this transition has been delayed by the lack of historical and current final orbit and clock estimates from JPL. Currently, final orbit products are not being generated in IGS14 by JPL which has not allowed CWU to transition to IGS14. During the previous quarter, the GAGE ACs submitted IGS14 SINEX files generated with either JPL IGS14 orbits and clocks (CWU) or IGS IGS14 orbits (NMT). JPL orbit and clock products are available in IGS14 for the 2016. Both ACs used the IGS14 antenna phase center model. Two weeks of results, 1200 and 1201, (2016/10/23-2016/11/05) were submitted and these have been compared. Of most interest is the average scale difference between the two analyses and the IGS solution for stations in the GAGE region. We have also added the IGS combined

SINEX file results to the NMT solutions to see the impact on the scale estimates. Only stations in the IGS SINEX file that are used in the NMT analysis are included and thus there will be no increase in the number of station in the combined solutions.

The results of the scale change estimates, expressed as mean height differences at the reference frame sites, are shown on Figure I1 and Table I1. Four analyses are presented. Two are the solutions CWU and NMT submitted and the other two are related to incorporating the IGS generated SINEX files into the NMT solutions to help better define the scale estimates. Based on the table and figure, including the IGS SINEX files (with only the stations common to the NMT analysis, does reduce the mean differences to the CWU analysis. It is also encouraging to see that the temporal variations in the scale estimates are very similar between the CWU (RMS 2.5 mm) and NMT (RMS 2.0 mm) analysis as well as the IGS only solution (RMS 1.5 mm) when the reference frame sites are chosen from the GAGE list of sites. On average only 59 GAGE reference frame sites are available in the IGS SINEX files compared to the 570-580 sites used in the CWU and NMT realizations. The combined NMT and IGS solution has the smallest RMS scatter (about the mean) of the mean height differences, 1.9 mm and a mean of 1.9 mm. In 2016, there is a ~1 mm scale difference expected between IGb08 and IGS14. The current comparison is consistent with earlier studies of the differences between CWU and NMT analyses and indicates the IGS14 reprocessing by CWU can start when JPL products are available.

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 1884 stations were processed which is 29 less 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 months supplemental (26-week latency) analyses from the ACs. The delivery schedule for these products is also unchanged.

Table I1: Mean differences of scale estimates (expressed as height differences) for the 1920-1920 test IGS 14 analyses. The RMS values are above the mean.

Analysis	Mean ΔH (mm)	RMS ΔH (mm)	# Reference sites
CWU	3.31	2.48	575
NMT	0.52	2.02	582
NMT+IGS	1.87	1.91	582
IGS	1.52	1.72	59

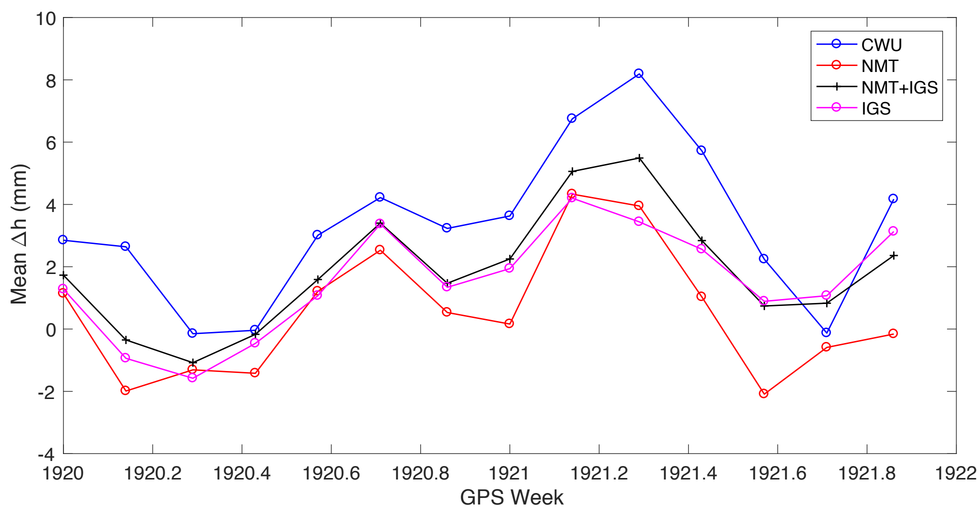

Figure I1: Estimates of the scale differences, expressed as mean height differences between daily frame solutions and the GAGE realization of IGb08.

Analysis of Final products: September 17, 2017 and December 9, 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 September 17, 2017 and December 9, 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 0.74 mm for NMT North and 0.78 mm for PBO east components. The up-RMS scatters are less than or equal 4.9 mm for all analyses and as low as 4.27 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 1884, 1884 and 1881 stations for PBO, NMT and CWU analyzed in the finals analysis between September 17, 2017and December 9, 2017. Histograms of the RMS scatters are shown in Figure 1-3.

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
PBO	0.76	0.78	4.27
NMT	0.74	0.81	4.59
CWU	0.96	0.92	4.90
70%			
PBO	0.96	0.99	4.87
NMT	0.94	1.03	5.15
CWU	1.19	1.14	5.55
95%			
PBO	1.82	1.91	7.14
NMT	1.91	1.98	7.27
CWU	2.19	2.14	8.11

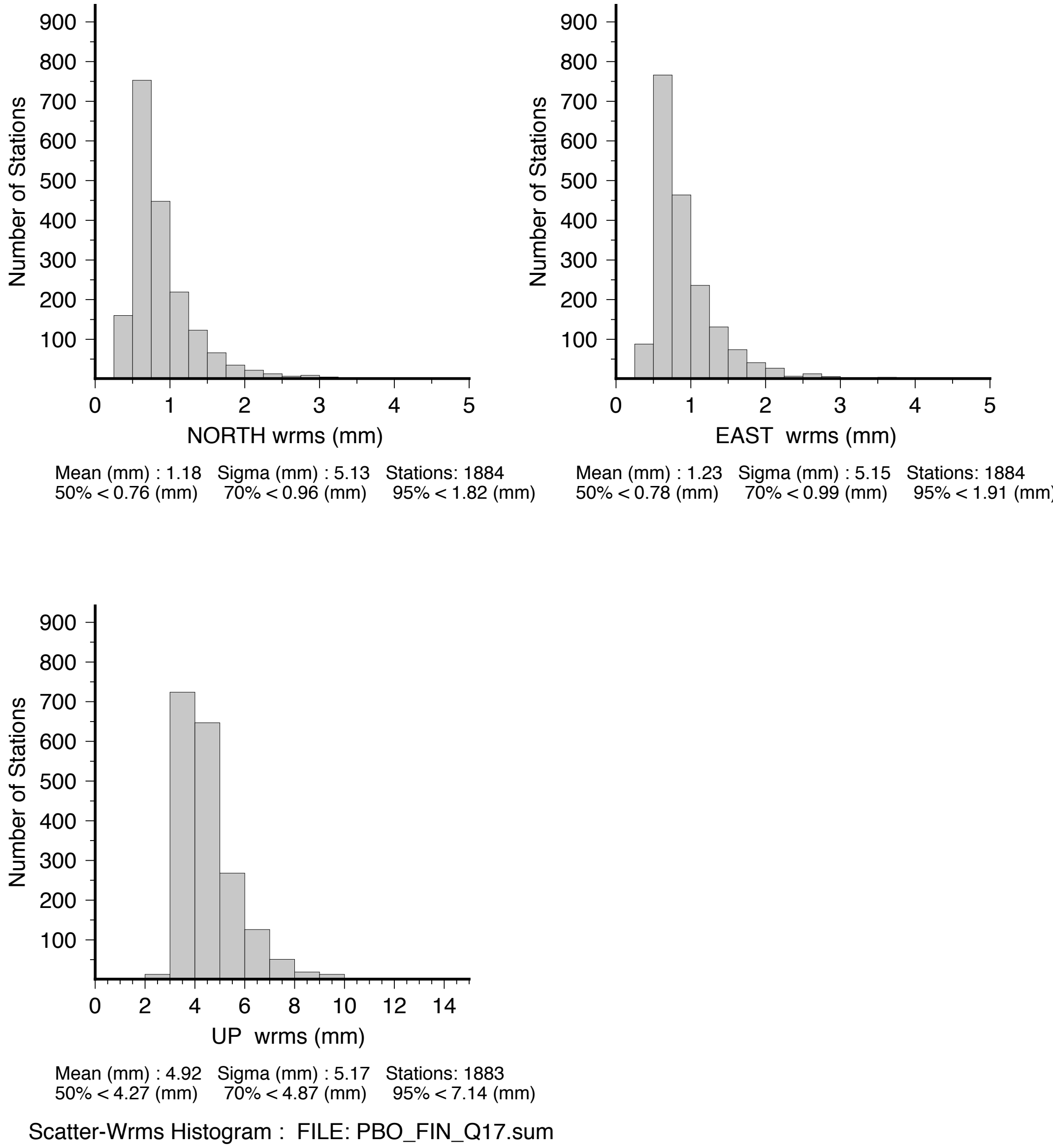

Figure 1: PBO combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1884 stations analyzed between September 17, 2017 and December 9, 2017. Linear trends and annual signals were estimated from the time series.

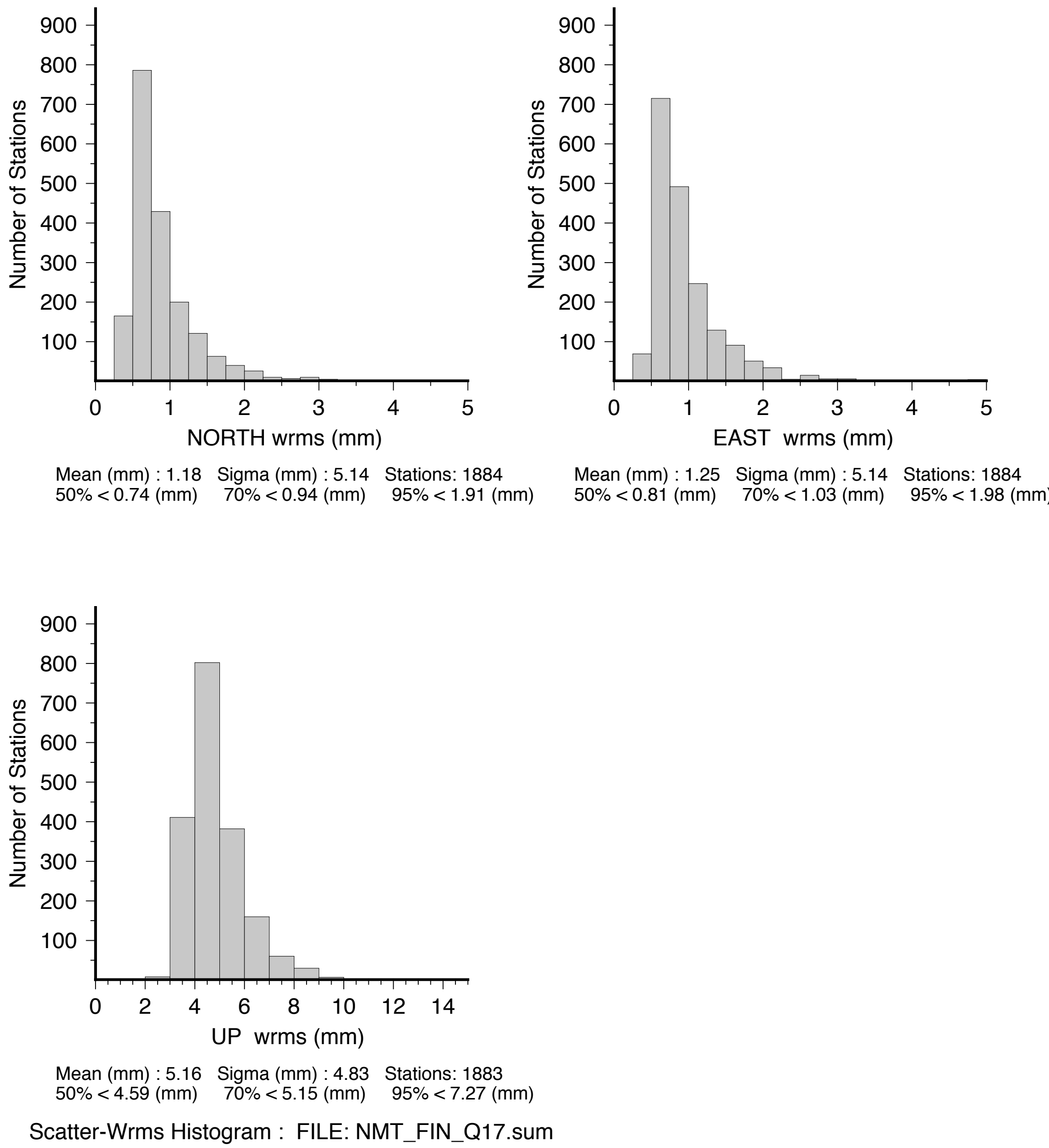

Figure 2: NMT combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1884 stations analyzed between September 17, 2017 and December 9, 2017. Linear trends and annual signals were estimated from the time series.

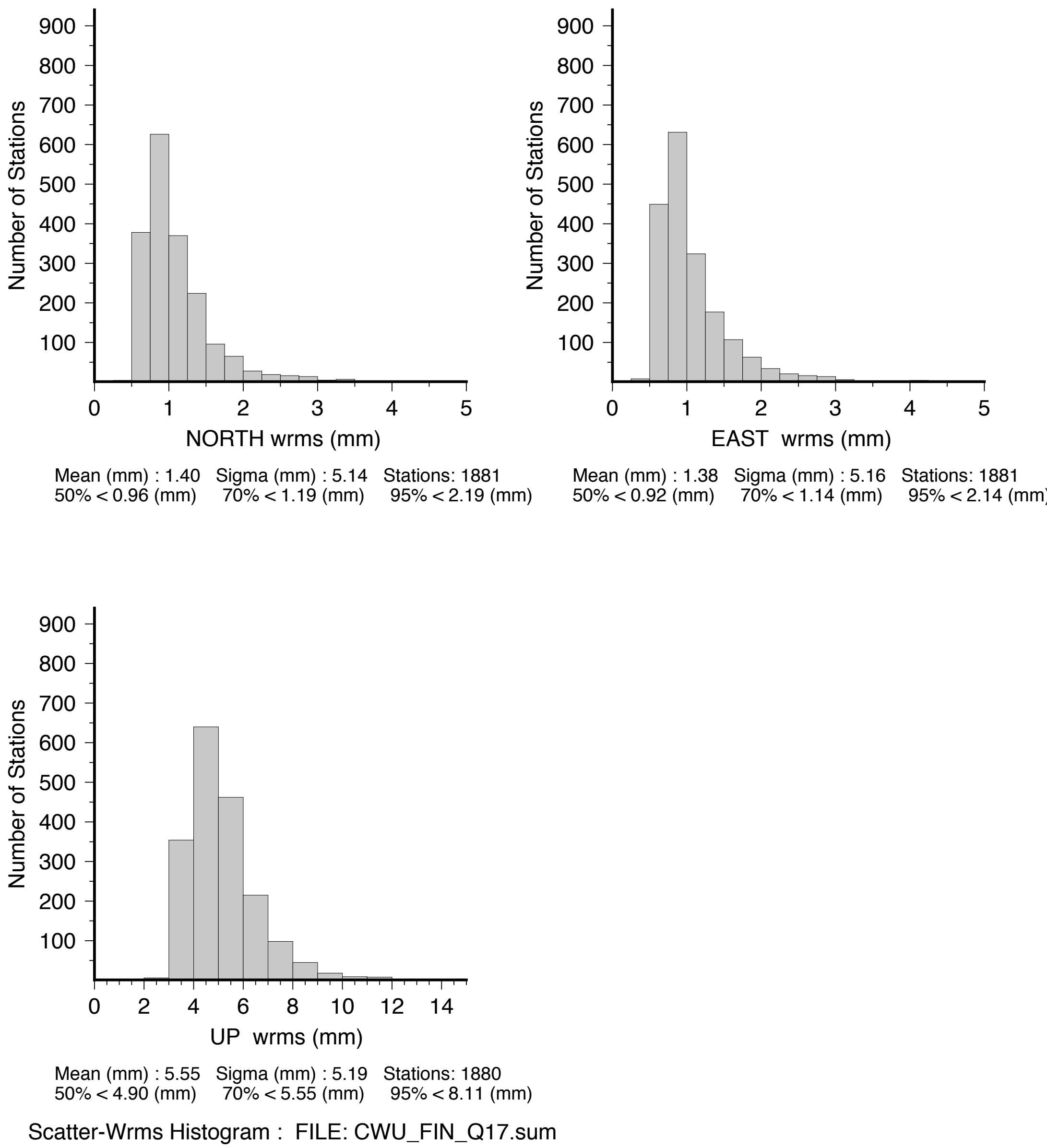

Figure 3: CWU combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1881 stations analyzed between September 17, 2017 and December 9, 2017. Editing removes two stations for North and Up. Linear trends and annual signals were estimated from the time series.

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_Q17.tab. There are 1880 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_Q17.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     86      0.9   0.44        1.2   0.55     5.7   0.58     14.63
 1NSU     85      0.6   0.32        0.8   0.49     3.8   0.54     13.90
 1ULM     86      0.6   0.40        0.8   0.51     4.3   0.67     14.49
 7ODM     86      0.6   0.37        0.6   0.36     3.2   0.51     16.64
…
 ZBW1     86      0.8   0.38        0.9   0.54     4.9   0.71     14.52
 ZDC1     86      0.8   0.43        0.8   0.52     4.6   0.68     14.52
 ZDV1     86      0.7   0.37        1.1   0.63     6.0   0.86     14.52
 ZKC1     86      0.8   0.45        0.6   0.37     4.6   0.69     14.52
 ZLA1     86      0.9   0.46        0.9   0.52     4.0   0.54     14.52
 ZME1     86      0.9   0.50        0.6   0.38     4.6   0.65     14.75
 ZMP1     86      0.7   0.34        0.6   0.40     4.9   0.75     14.99
 ZNY1     86      0.8   0.41        0.8   0.48     5.0   0.72     14.90
 ZSE1     86      0.8   0.38        0.7   0.43     5.0   0.72     14.90
 ZTL4     86      0.7   0.39        0.7   0.40     4.0   0.56     15.09
```

Table 2: RMS scatter of the position residuals for the PBO combined solution between September 17, 2017 and December 9, 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	0.72	0.77	4.10	881
NUCLEUS	0.63	0.68	3.74	207
GAMA	0.60	0.62	4.68	15
COCONet	1.31	1.36	5.73	99
USGS_SCIGN	0.65	0.67	3.63	131
Expanded	0.83	0.81	4.65	551
70%				
PBO	0.91	0.96	4.74	
NUCLEUS	0.75	0.78	4.23	
GAMA	0.65	0.65	4.75	
COCONet	1.62	1.58	6.58	
USGS_SCIGN	0.78	0.83	3.87	
Expanded	0.99	1.01	5.02	
95%				
PBO	1.76	1.76	6.82	
NUCLEUS	1.38	1.31	6.38	
GAMA	0.85	0.74	5.22	
COCONet	3.12	5.57	16.08	
USGS_SCIGN	1.64	1.89	7.36	
Expanded	1.82	1.91	6.94	

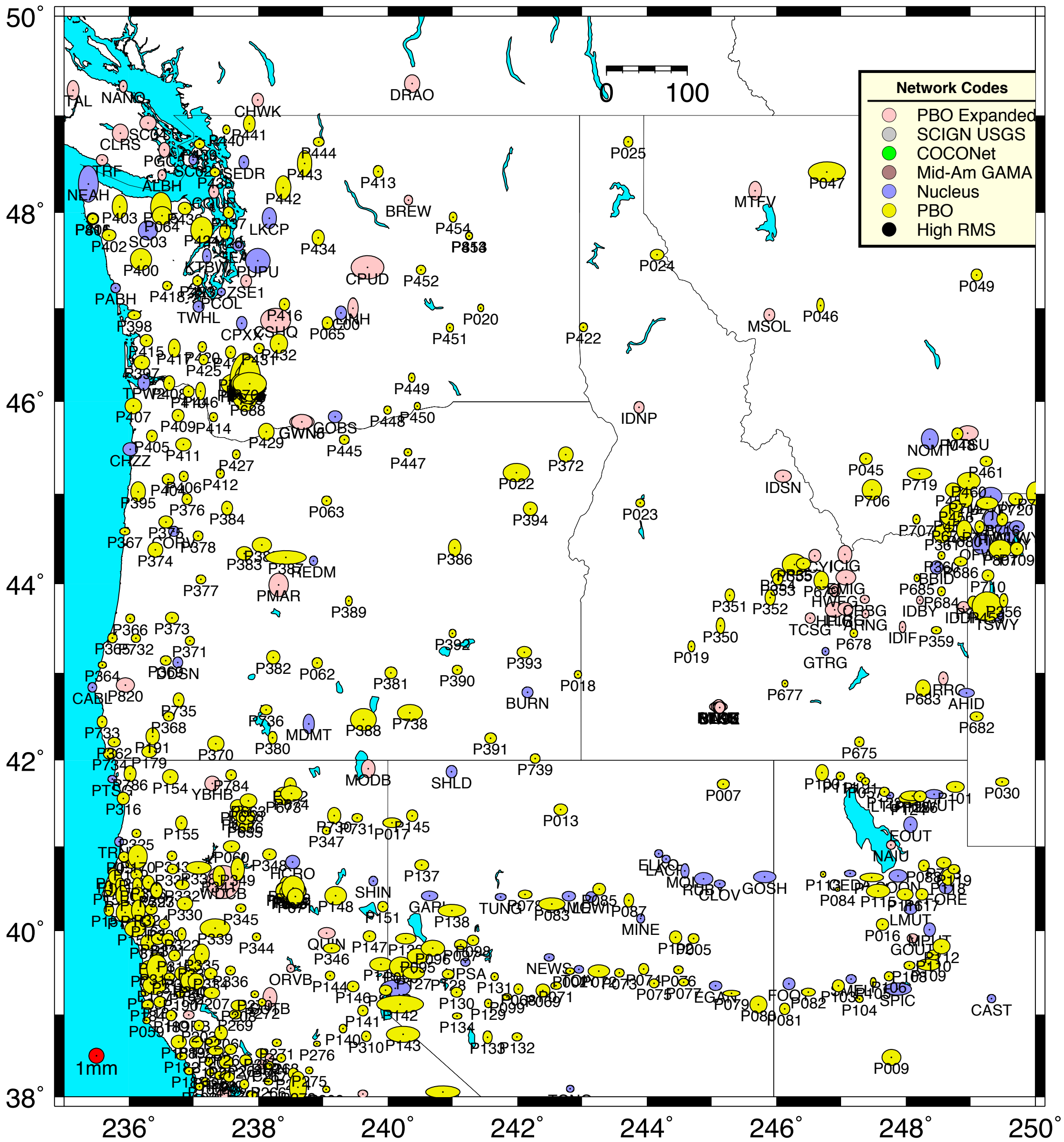

Figure 4: Distribution of the RMS scatters of horizontal position estimates from the PBO combined analysis for the Northern Western United States. The color of the ellipses that give the north and east RMS scatters denotes the network given by the legend in the figure. The small red circle shows the 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.

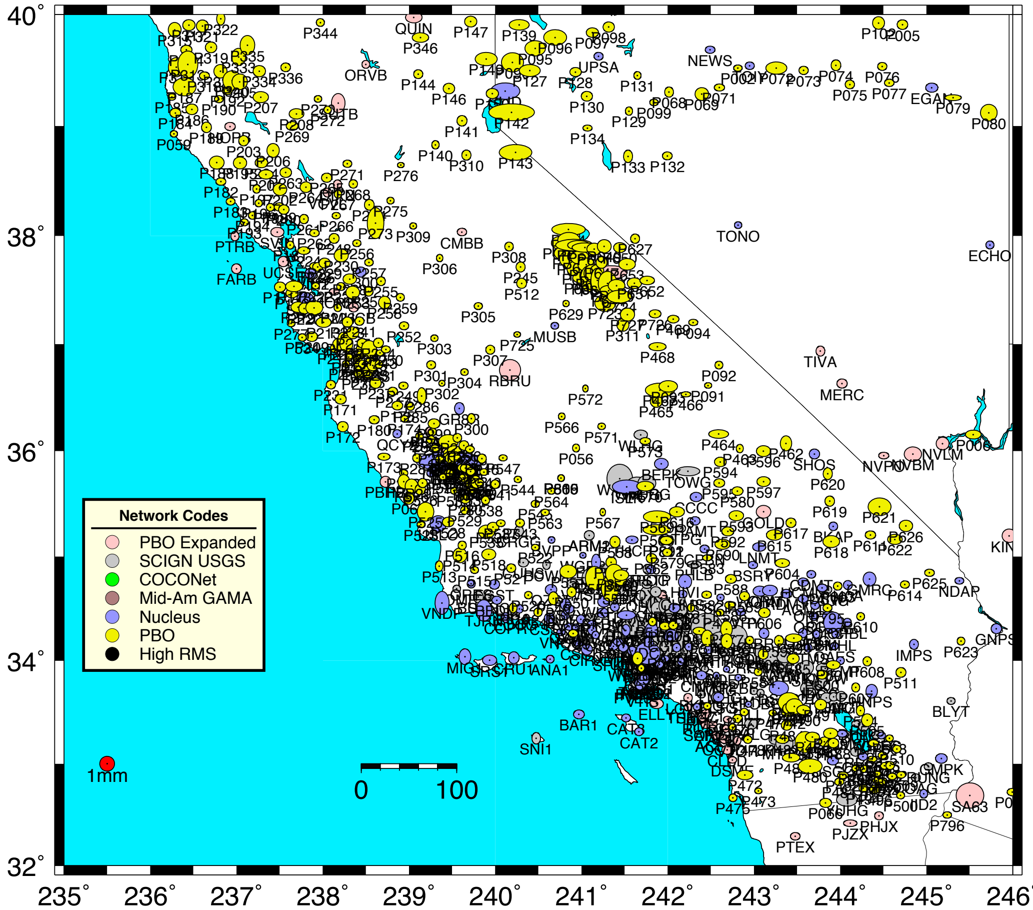

Figure 5: Same as Figure 4 except for the Southern Western United States. Black circles in the Yucca mountain region have no data during this 3-month period.

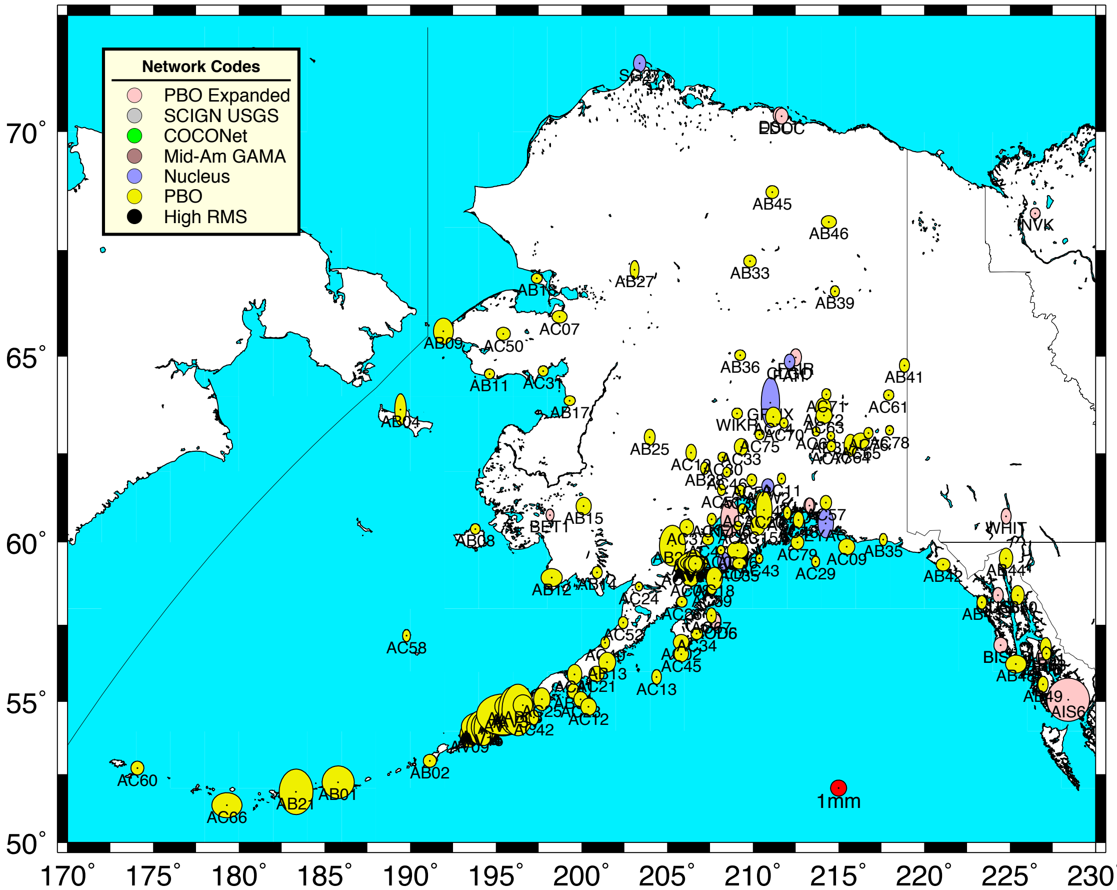

Figure 6: Same as Figure 4 except for the Alaskan region.

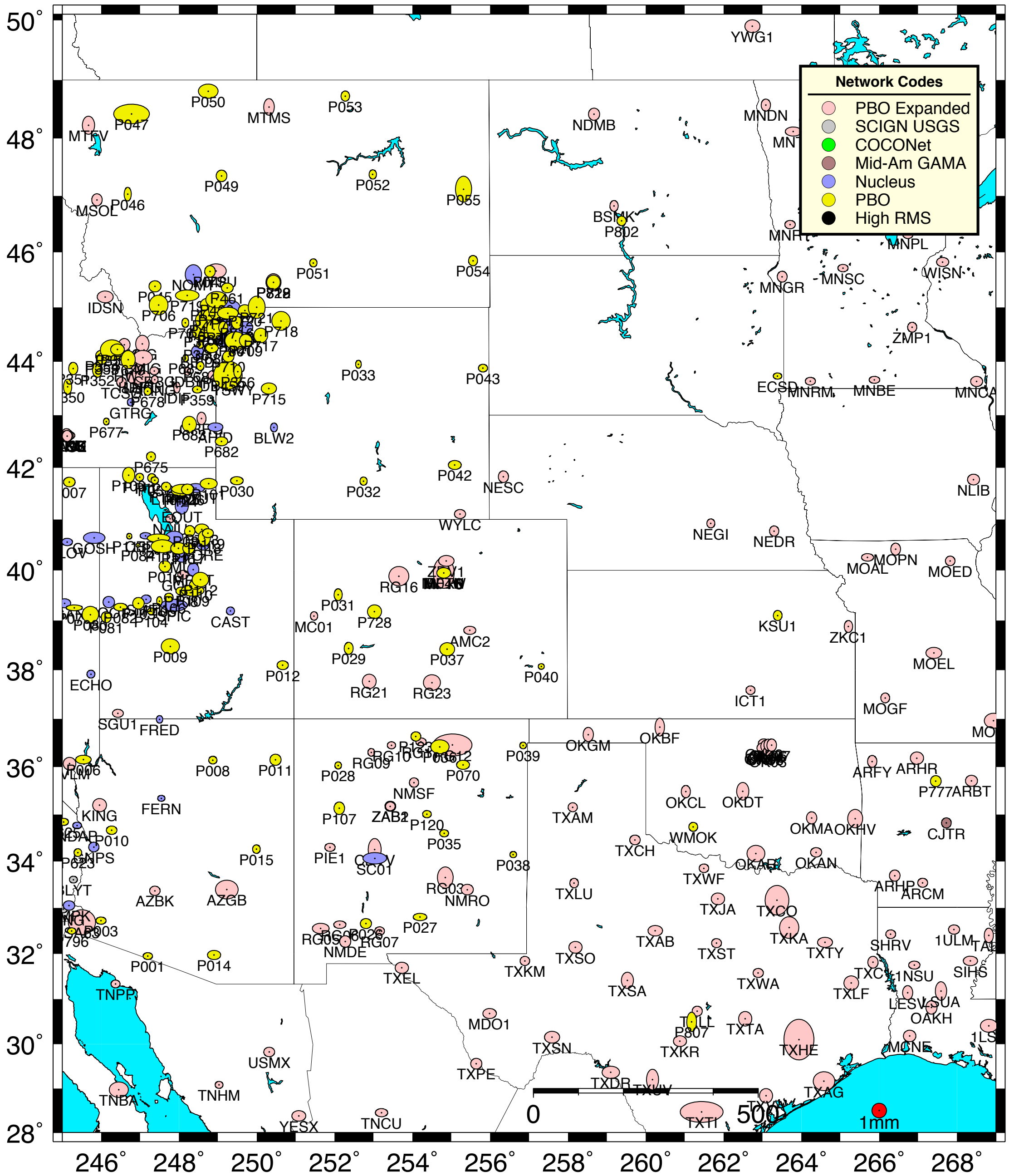

Figure 7: Same as Figure 4 except for the Central United States

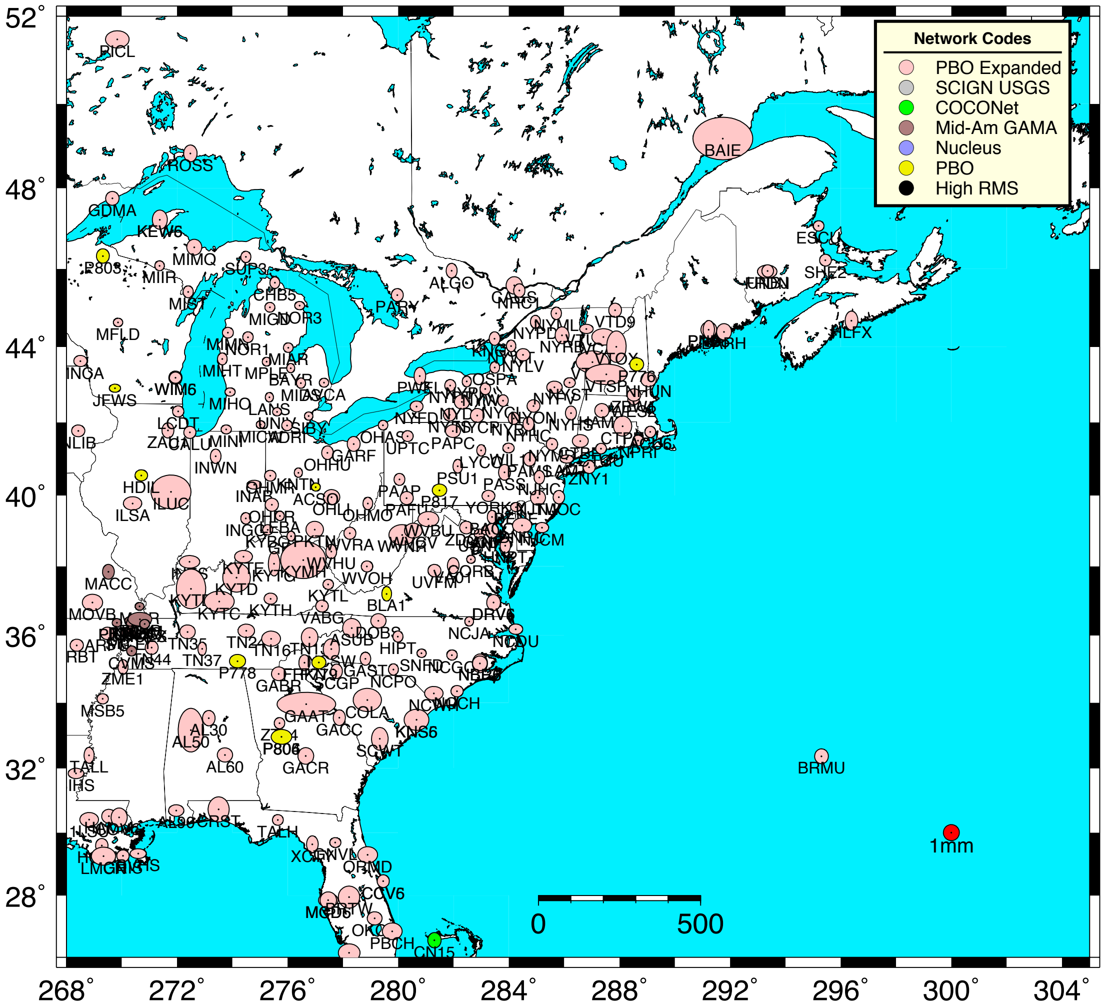

Figure 8: Same as Figure 4 except for the Eastern United States

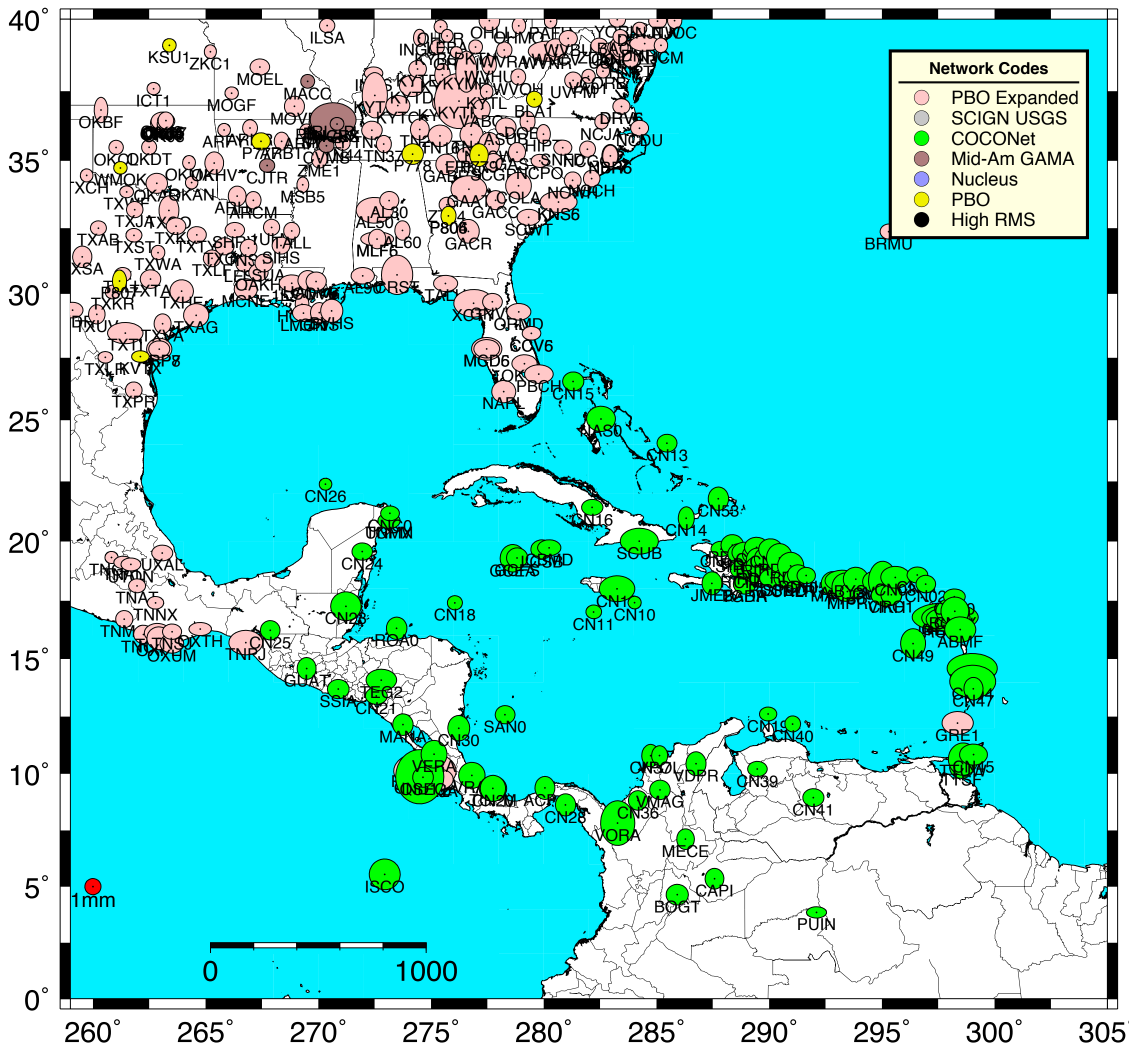

Figure 9: Same as Figure 4 except for the Caribbean region.

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 2239 stations in the combined PBO solution which is slightly larger than the 2235 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_171209.tab, nmt_nam08_171209.tab and cwu_nam08_171209.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_171209.snpvel, nmt_nam08_171209.snpvel and cwu_nam08_171209.snpvel.

Table 3: Statistics of the fits of 2239, 2238 and 2228 stations analyzed by PBO, NMT and CWU in the reprocessed analysis for data collected between Jan 1, 1996 and December 9, 2017.

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
NMT	1.14	1.23	5.82
CWU	1.35	1.34	6.07
PBO	1.14	1.19	5.39
70%			
NMT	1.49	1.59	6.57
CWU	1.67	1.66	6.83
PBO	1.47	1.51	6.06
95%			
NMT	3.35	3.34	9.52
CWU	3.45	3.44	10.22
PBO	3.38	3.32	9.32

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 $(1.16)^2$ for the horizontal and $(1.83)^2$ 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 16-83% optimistic over expectations. The 10-worst stations, in the order they are removed, are P476, OXPE, P502, P556, P599, P509, OK06, AC59, P483, MYT2 when the added sigmas are not applied and P476, OXPE, P556, P502, P599, P509, P483, OK06, AC59, MYT2when 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	2220	0.08	0.73	1.16	1.83
Edited-10_worst	2210	0.07	0.72	1.09	1.81
Less_than_median (0.15 0.53 mm/yr)	1214	0.06	0.66	1.14	2.00
Added minimum sigma NE 0.02 U 0.55 mm/yr					
All_Normal	2220	0.10	0.97	1.09	0.97
Edited-10_worst	2210	0.09	0.95	1.02	0.95
Less_than_median (0.15 0.76 mm/yr)	1214	0.07	0.76	1.01	0.84

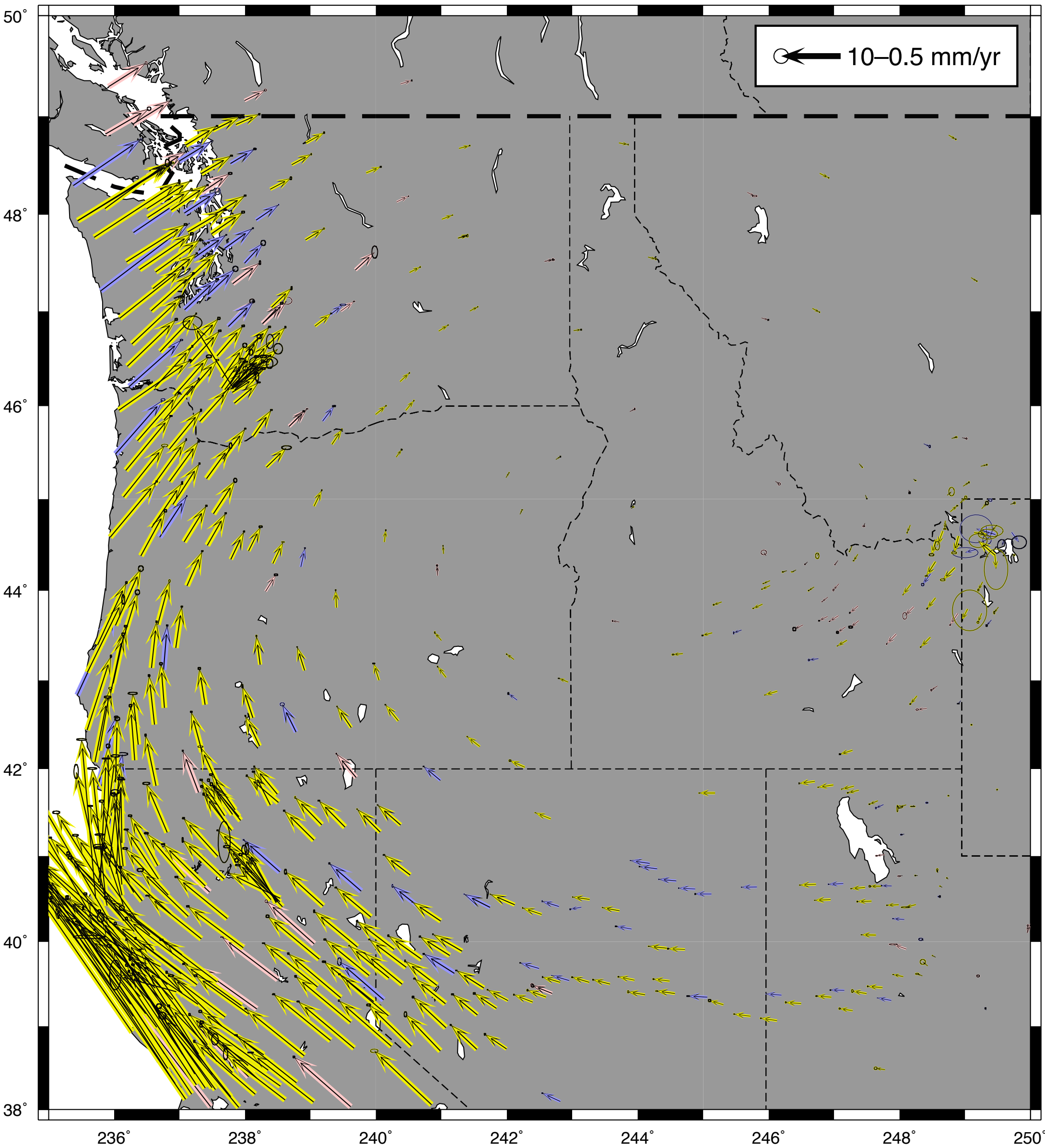

Figure 10: Velocity field estimates from the combined PBO solutions generated using time series analysis and the FOGMEX error model. 95% confidence interval error ellipses are shown. The color scheme of the vectors matches the network type legend in Figure 4. Only velocities with horizontal standard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

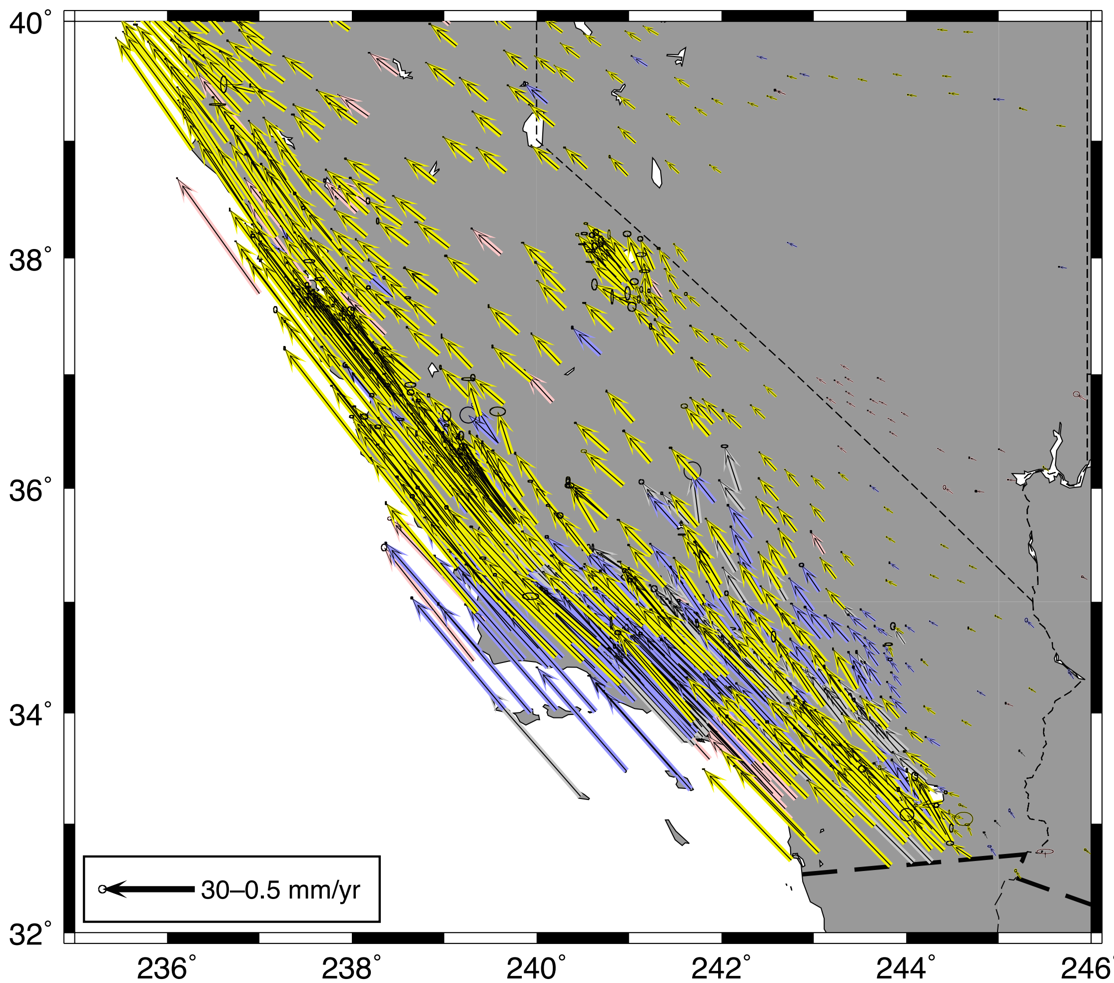

Figure 11: Same as Figure 10 except for South Western United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown.

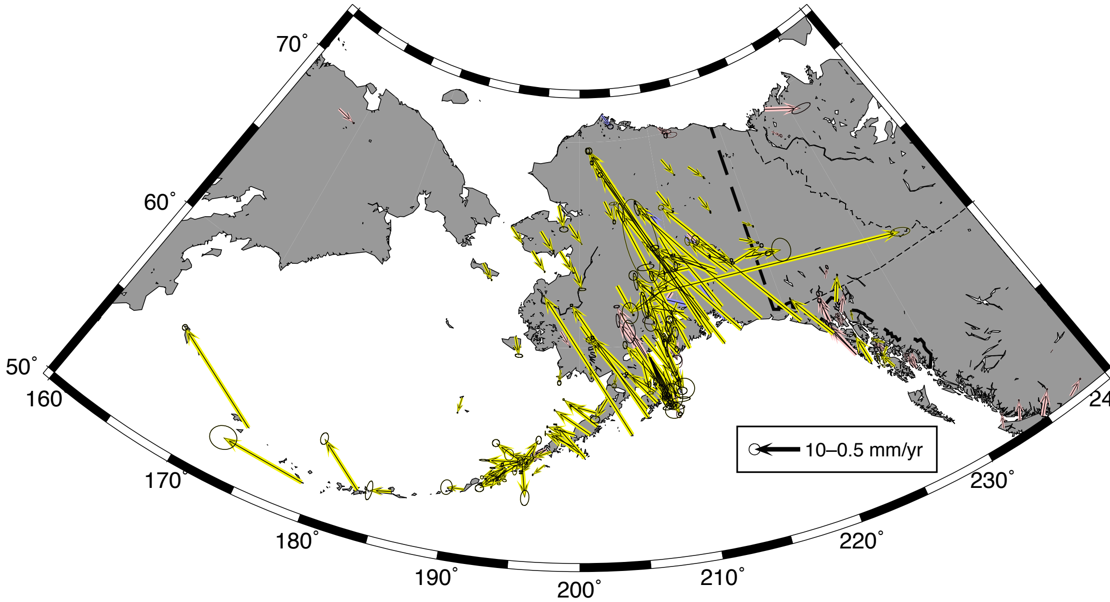

Figure 12: Same as Figure 10 except for Alaska. Only velocities with horizontal standard deviations less than 5 mm/yr are shown

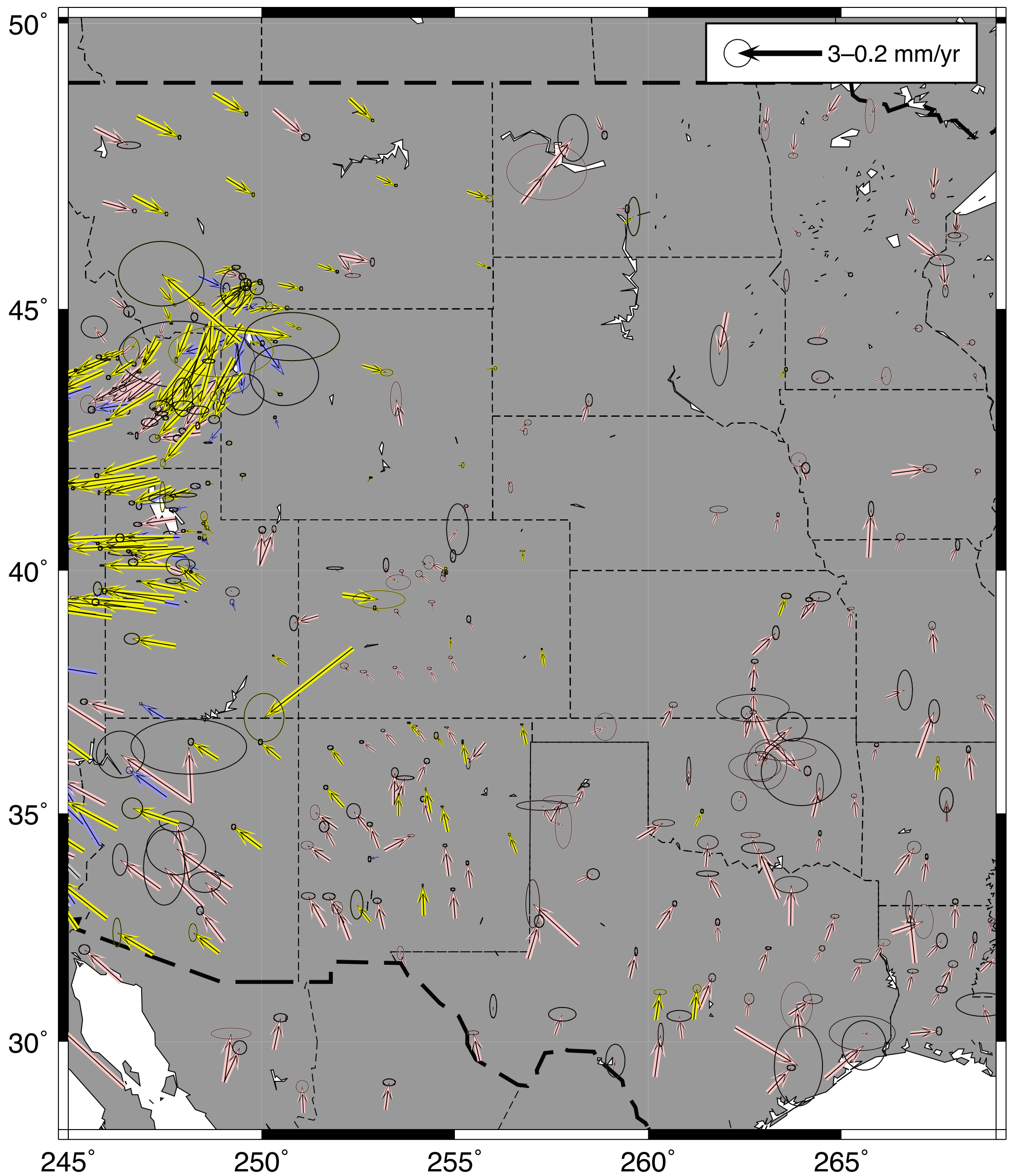

Figure 13: Same as Figure 10 except for Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown.

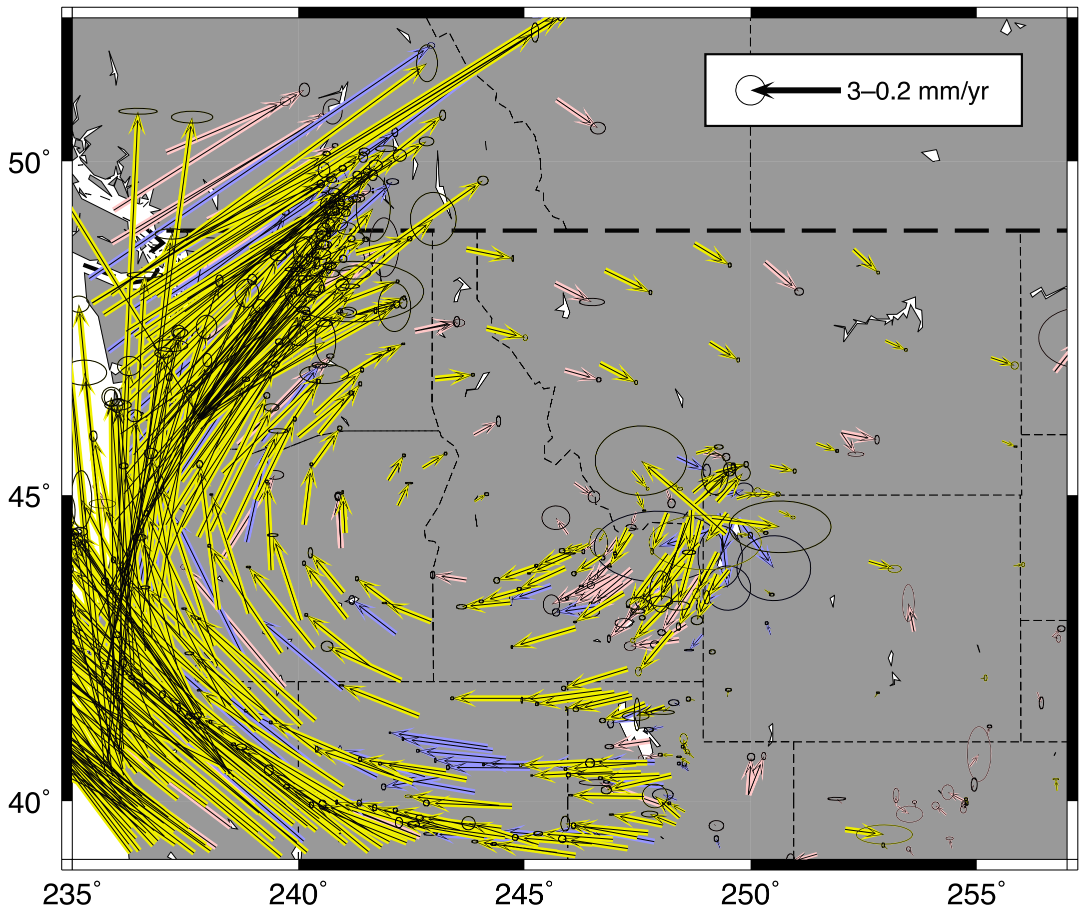

Figure 14: Same as Figure 10 except for Western Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown. Anomalous vectors at longitude 250° are in the Yellowstone National Park and most likely are showing volcanic processes.

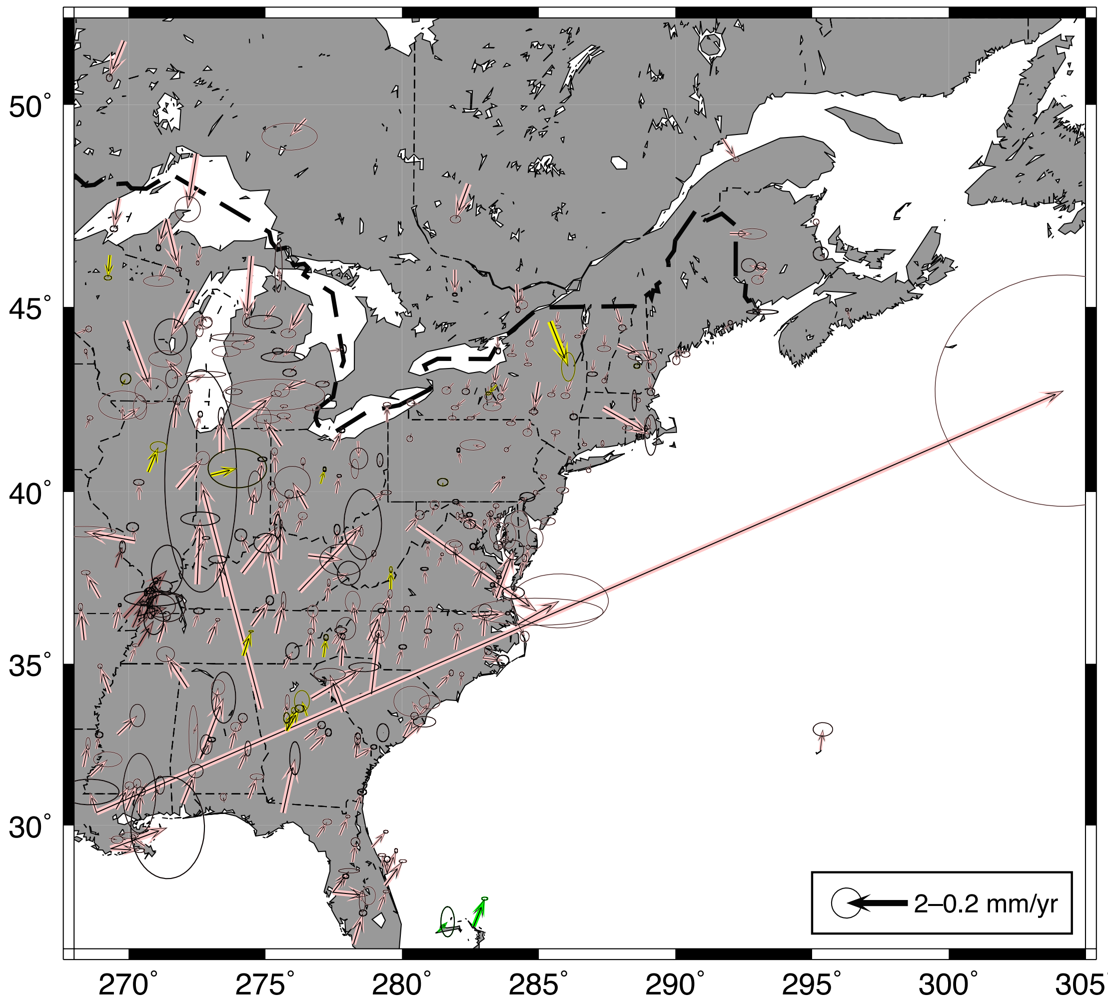

Figure 15: Same as Figure 10 except for the Eastern United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown. The systematic velocity of sites in the Northeast and central US show deviations for current GIA models in the horizontal velocities. The large outlier is 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.

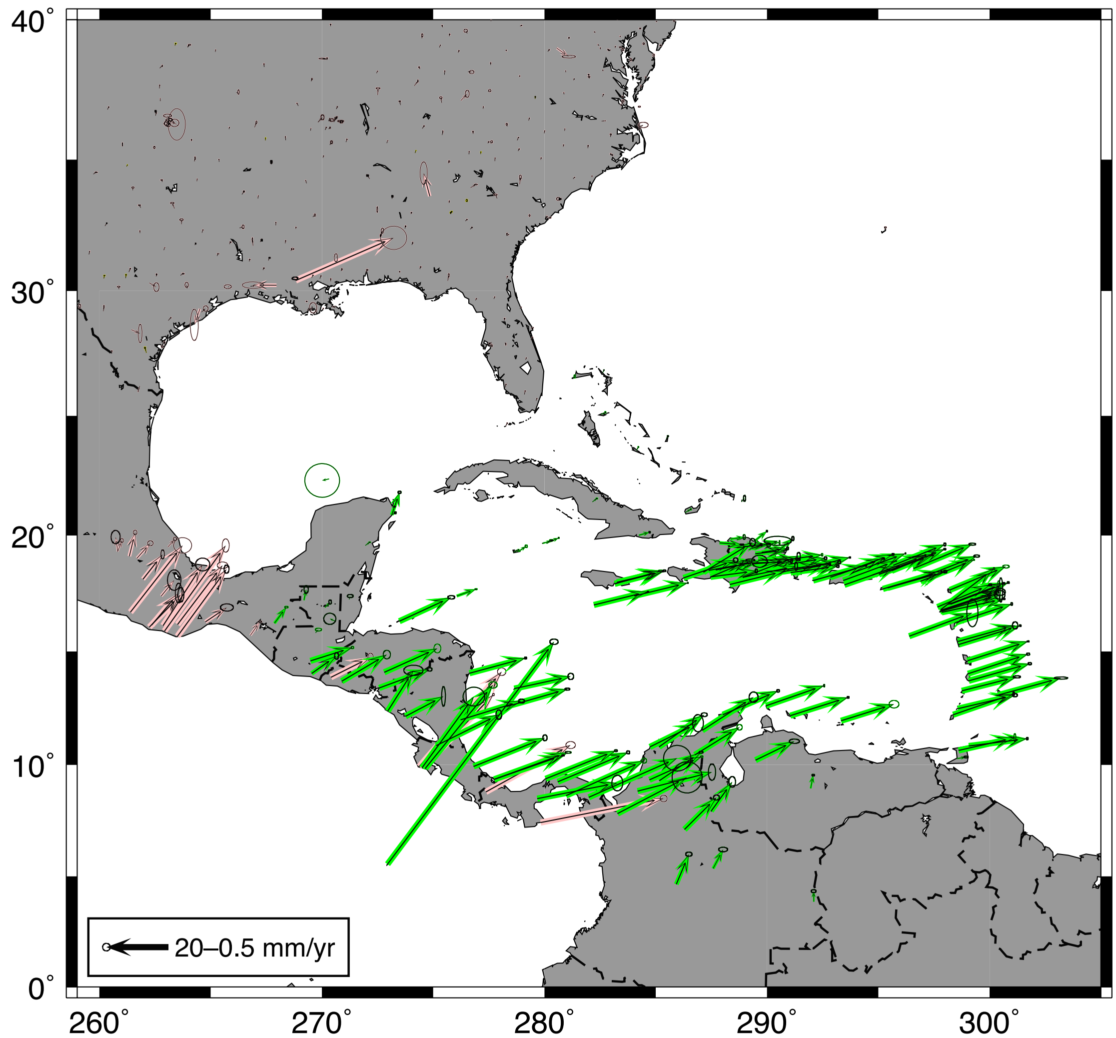

Figure 16: Same as Figure 10 except for the Caribbean region. Only velocities with horizontal standard deviations less than 5 mm/yr are shown.

Earthquake Analyses: 2017/09/14-2017/12/15.

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 September/October 2017.

```
* EQDEFS for 2017 09 14 to 2017 10 15 Generated Mon Oct 16 12:41:47 EDT 2017
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 99 OXTH_GPS     24.55     28.50 CoS      5.5 mm
* EQ_DEF M5.6 10km SE of Salina Cruz
 eq_def   01   16.0895  -95.1384    28.5  8  2017 09 16 14 19    0.0519
 eq_rename 01
 eq_coseis 01  0.0010 0.0010 0.0010     0.0519     0.0519     0.0519
* ----------------------------------
* SEQ Earthquake # 2
* EQ 211 FCTF_GPS      3.72      8.80 CoS      1.4 mm
* EQ 211 LFRS_GPS      5.74      8.80 CoS      0.6 mm
* EQ 211 UCLP_GPS      3.57      8.80 CoS      1.5 mm
* EQ 211 VIMT_GPS      5.77      8.80 CoS      0.6 mm
* EQ_DEF M3.6 5km NW of Westwood
 eq_def   02   34.0867 -118.4757     8.8  8  2017 09 19 06 21    0.0003
 eq_rename 02
 eq_coseis 02  0.0010 0.0010 0.0010     0.0003     0.0003     0.0003
* ----------------------------------
* SEQ Earthquake # 3
* EQ 229 TNAL_GPS     64.06    237.40 CoS     37.9 mm
* EQ 229 TNAT_GPS     67.21    237.40 CoS     34.5 mm
* EQ 229 TNGF_GPS    111.90    237.40 CoS     12.4 mm
* EQ 229 TNMQ_GPS    207.25    237.40 CoS      3.6 mm
* EQ 229 TNNX_GPS    185.34    237.40 CoS      4.5 mm
* EQ 229 UNIP_GPS    111.07    237.40 CoS     12.6 mm
* EQ 229 UTON_GPS     54.61    237.40 CoS     52.2 mm
* EQ 229 UXAL_GPS    194.71    237.40 CoS      4.1 mm
* EQ_DEF M7.1 2km NE of Ayutla
 eq_def   03   18.5678  -98.4808   237.4  8  2017 09 19 18 15    2.4329
 eq_rename 03
 eq_coseis 03  0.0010 0.0010 0.0010     2.4329     2.4329     2.4329
* ----------------------------------
* SEQ Earthquake # 4
* EQ 232 COSO_GPS      5.50      8.90 CoS      0.6 mm
* EQ_DEF M3.6 15km NE of Little Lake
 eq_def   04   36.0193 -117.7698     8.9  8  2017 09 19 18 46    0.0003
 eq_rename 04
 eq_coseis 04  0.0010 0.0010 0.0010     0.0003     0.0003     0.0003
* ----------------------------------
* SEQ Earthquake # 5
* EQ 288 TNPJ_GPS     11.30     13.70 CoS      3.4 mm
* EQ_DEF M4.8 10km NW of Pijijiapan
```

eq_def 05 15.7805 -93.2903 13.7 8 2017 09 21 11 45 0.0067
eq_rename 05
eq_coseis 05 0.0010 0.0010 0.0010 0.0067 0.0067 0.0067
* ----------------------------------
* SEQ Earthquake # 6
* EQ 576 SVGB_GPS 3.93 10.50 CoS 7.5 mm
* EQ_DEF M4.3 10km NNW of Kingstown Park
eq_def 06 13.2473 -61.2747 10.5 8 2017 10 02 12 09 0.0018
eq_rename 06
eq_coseis 06 0.0010 0.0010 0.0010 0.0018 0.0018 0.0018
* ----------------------------------
* SEQ Earthquake # 7
* EQ 713 MHCB_GPS 3.99 9.80 CoS 4.4 mm
* EQ_DEF M4.1 14km ESE of Alum Rock
eq_def 07 37.3135 -121.6720 9.8 8 2017 10 10 00 54 0.0011
eq_rename 07
eq_coseis 07 0.0010 0.0010 0.0010 0.0011 0.0011 0.0011
* ----------------------------------
* SEQ Earthquake # 8
* EQ 774 P190_GPS 5.37 9.40 CoS 1.6 mm
* EQ_DEF M3.9 3km NW of Redwood Valley
eq_def 08 39.2847 -123.2342 9.4 8 2017 10 13 23 11 0.0007
eq_rename 08
eq_coseis 08 0.0010 0.0010 0.0010 0.0007 0.0007 0.0007

EQ01: No offsets apparent although only a 6 days of data before event and this is a large gap after Event 41 so it is difficult to be certain.
EQ02: No offsets seem
EQ03: Saved at Event 41. Maximum displacement is -9.5 mm East at TNAT (this site also offset by Event 40. UTON and TNAL have displacements of 2-5 mm. TNGF has a >2 meter offset on 2017/03/31. Not clear why this offset occurs.
EQ04: No data at COSO since 2015.
EQ05: No data at TNPJ since event. Antenna seems to go bad the day before Event 40.
EQ06: No offset at SVGB.
EQ07: No offset at MHGB.
EQ08: No offset at P190.

Events investigated in October/November 2017.

* EQDEFS for 2017 10 14 to 2017 11 15 Generated Thu Nov 16 09:55:52 EST 2017
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 254 OXTH_GPS 7.51 10.20 CoS 1.6 mm
* EQ_DEF M4.2 5km E of Santo Domingo Tehuantepec
eq_def 01 16.3260 -95.1854 10.2 8 2017 10 23 03 12 0.0014

```
 eq_rename 01
 eq_coseis 01  0.0010 0.0010 0.0010      0.0014     0.0014     0.0014
* ----------------------------------
* SEQ Earthquake # 2
* EQ 256 OXTH_GPS       9.16       9.80 CoS        0.8 mm
* EQ_DEF M4.1 7km ESE of Santo Domingo Tehuantepec
 eq_def    02   16.3148  -95.1618       9.8  8  2017 10 23 04 56    0.0011
 eq_rename 02
 eq_coseis 02  0.0010 0.0010 0.0010      0.0011     0.0011     0.0011
* ----------------------------------
* SEQ Earthquake # 3
* EQ 328 HARV_GPS       5.37       10.70 CoS        4.4 mm
* EQ_DEF M4.3 32km SW of Lompoc
 eq_def    03   34.4213 -120.6785      10.7  8  2017 10 26 20 39    0.0020
 eq_rename 03
 eq_coseis 03  0.0010 0.0010 0.0010      0.0020     0.0020     0.0020
* ----------------------------------
* SEQ Earthquake # 4
* EQ 705 P490_GPS       7.76       8.70 CoS        0.3 mm
* EQ_DEF M3.5 22km ESE of Anza
 eq_def    04   33.4620 -116.4667       8.7  8  2017 11 10 00 24    0.0003
 eq_rename 04
 eq_coseis 04  0.0010 0.0010 0.0010      0.0003     0.0003     0.0003
* ----------------------------------
* SEQ Earthquake # 5
* EQ 771 BIJA_GPS      26.14      95.30 CoS       48.9 mm
* EQ 771 BON2_GPS      81.11      95.30 CoS        5.1 mm
* EQ 771 LAFE_GPS      59.02      95.30 CoS        9.6 mm
* EQ 771 LEPA_GPS      74.30      95.30 CoS        6.1 mm
* EQ 771 PUMO_GPS      78.51      95.30 CoS        5.4 mm
* EQ_DEF M6.5 16km SE of Jaco
 eq_def    05    9.5264  -84.5054      95.3  8  2017 11 13 02 29    0.5221
 eq_rename 05
 eq_coseis 05  0.0010 0.0010 0.0010      0.5221     0.5221     0.5221
* ----------------------------------
* SEQ Earthquake # 6
* EQ 793 P247_GPS       9.28       12.00 CoS        2.8 mm
* EQ_DEF M4.6 22km NE of Gonzales
 eq_def    06   36.6305 -121.2443      12.0  8  2017 11 13 19 32    0.0038
 eq_rename 06
 eq_coseis 06  0.0010 0.0010 0.0010      0.0038     0.0038     0.0038
* ----------------------------------
* SEQ Earthquake # 7
* EQ 817 P247_GPS       8.67       9.10 CoS        0.4 mm
* EQ_DEF M3.8 22km NE of Gonzales
 eq_def    07   36.6272 -121.2378       9.1  8  2017 11 15 01 24    0.0005
```

eq_rename 07
eq_coseis 07 0.0010 0.0010 0.0010   0.0005   0.0005   0.0005

EQ01: No offset seen at OXTH but post-seismic from event 40 is clear in the time series (see 2.b above).
EQ02: Same as EQ01
EQ03: No data at HARV since 2014.
EQ04: No offset at P490. Break due to antenna change in July.
EQ05: Offset of -22 mm North at BIJA. Event file will be generated 17/11/17 when rapid becomes available.
EQ06: No offset at P247
EQ07: No offset at P247. Since this event is near end of processing (17/11/15, it will be reevaluated next monthly report.

Events investigated in November/December 2017.

* EQDEFS for 2017 11 14 to 2017 12 15 Generated Tue Dec 19 12:41:11 EST 2017
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 38 P247_GPS   8.67   9.10 CoS   0.4 mm
* EQ_DEF M3.8 22km NE of Gonzales
eq_def   01   36.6272 -121.2378   9.1 8 2017 11 15 01 24   0.0005
eq_rename 01
eq_coseis 01 0.0010 0.0010 0.0010   0.0005   0.0005   0.0005
* ----------------------------------
* SEQ Earthquake # 2
* EQ 568 AC48_GPS   11.13   20.70 CoS   12.4 mm
* EQ_DEF M5.3 72km ESE of Whittier
eq_def   02   60.5552 -147.4303   20.7 8 2017 11 27 22 19   0.0240
eq_rename 02
eq_coseis 02 0.0010 0.0010 0.0010   0.0240   0.0240   0.0240
* ----------------------------------
* SEQ Earthquake # 3
* EQ 632 DNRC_GPS   9.01   9.80 CoS   0.9 mm
* EQ_DEF M4.1 9km ENE of Dover
eq_def   03   39.1977 -75.4325   9.8 8 2017 11 30 21 48   0.0011
eq_rename 03
eq_coseis 03 0.0010 0.0010 0.0010   0.0011   0.0011   0.0011
* ----------------------------------
* SEQ Earthquake # 4
* EQ 666 PDBG_GPS   8.02   9.00 CoS   0.4 mm
* EQ_DEF M3.7 25km NNE of Socorro
eq_def   04   34.2767 -106.7917   9.0 8 2017 12 01 17 13   0.0004
eq_rename 04
eq_coseis 04 0.0010 0.0010 0.0010   0.0004   0.0004   0.0004

```
* ---------------------------------
* SEQ Earthquake # 5
* EQ 800 P485_GPS      9.45      9.50 CoS       0.6 mm
* EQ_DEF M4.0 14km NE of Julian
 eq_def    05   33.1478 -116.4792      9.5  8  2017 12 07 00 34    0.0008
 eq_rename 05
 eq_coseis 05  0.0010 0.0010 0.0010      0.0008     0.0008     0.0008
* ---------------------------------
* SEQ Earthquake # 6
* EQ 815 SSIA_GPS      9.31      11.00 CoS       1.8 mm
* EQ_DEF M4.4 3km NNW of Soyapango
 eq_def    06   13.7631  -89.1709     11.0  8  2017 12 07 16 04    0.0024
 eq_rename 06
 eq_coseis 06  0.0010 0.0010 0.0010      0.0024     0.0024     0.0024
* ---------------------------------
* SEQ Earthquake # 7
* EQ 851 P642_GPS      4.47      8.90 CoS       1.3 mm
* EQ_DEF M3.7 12km W of Toms Place
 eq_def    07   37.5513 -118.8155      8.9  8  2017 12 08 17 07    0.0004
 eq_rename 07
 eq_coseis 07  0.0010 0.0010 0.0010      0.0004     0.0004     0.0004
* ---------------------------------
* SEQ Earthquake # 8
* EQ 854 P642_GPS      4.95      9.10 CoS       1.3 mm
* EQ_DEF M3.8 12km W of Toms Place
 eq_def    08   37.5473 -118.8103      9.1  8  2017 12 08 22 20    0.0005
 eq_rename 08
 eq_coseis 08  0.0010 0.0010 0.0010      0.0005     0.0005     0.0005
* ---------------------------------
* SEQ Earthquake # 9
* EQ 859 P642_GPS      4.69      8.70 CoS       0.9 mm
* EQ_DEF M3.5 11km W of Toms Place
 eq_def    09   37.5502 -118.8065      8.7  8  2017 12 09 02 28    0.0003
 eq_rename 09
 eq_coseis 09  0.0010 0.0010 0.0010      0.0003     0.0003     0.0003
* ---------------------------------
* SEQ Earthquake # 10
* EQ 937 P312_GPS      9.89      10.40 CoS       1.1 mm
* EQ 937 P313_GPS      9.07      10.40 CoS       1.3 mm
* EQ 937 P314_GPS     10.20      10.40 CoS       1.0 mm
* EQ_DEF M4.3 17km WSW of Laytonville
 eq_def    10   39.6077 -123.6458     10.4  8  2017 12 14 04 58    0.0017
 eq_rename 10
 eq_coseis 10  0.0010 0.0010 0.0010      0.0017     0.0017     0.0017
```

EQ01: No offset

EQ02: No offset
EQ03: No offset
EQ04: There is no data from PDBG since November 2016. The estimated size is small enough that it is unlikely there will be an effect/
EQ05: No offset
EQ06: No offset
EQ07-09: No offset. All of these events are in a similar location and none seem to offset P642. This site has large systematics and skewness.
EQ10: No apparent offsets but P313 is missing data but still no clear offset. P312 seems to have a "vegetation growing" problem.

Antenna Change Offsets: 2017/09/01-2017/12/31

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

```
Station  Date             From         To
HOUM   2017  9 13 19 57  ASH701945E_M   TRM57971.00
OKDT   2017  9 20 17  0  TRM22020.00+GP LEIAS10
P047   2017  9 27 15 20  TRM29659.00    TRM59800.80
P489   2017  9 20 22  4  TRM29659.00    TRM59800.80
P628   2017  9 20  1 10  TRM29659.00    TRM59800.00
P690   2017  9 26 19 31  TRM29659.00    TRM59800.80

COPR   2017 10 24 16 54  ASH701945B_M   TRM59800.80
HOLB   2017 10 26 20 10  TRM59800.00    SEPCHOKE_B3E6
P022   2017 10 11  0  0  TRM29659.00    TRM59800.00
P133   2017 10 20  0  0  TRM29659.00    TRM59800.80
P134   2017 10 19  0  0  TRM29659.00    TRM59800.80
P394   2017 10 11 16 44  TRM29659.00    TRM59800.80

P072   2017 11  9  0  0  TRM29659.00    TRM59800.80
P300   2017 11 13 22  1  TRM29659.00    TRM59800.80
P302   2017 11 21 20  7  TRM29659.00    TRM59800.80
P682   2017 11 30 20 51  TRM29659.00    TRM59800.00

Analysis
HOUM WLS dNEU    2.15 +- 2.50,   3.08 +- 4.00,  -2.47 +- 9.47 mm,
      KF dNEU    1.22 +- 0.53,   2.04 +- 0.62,  -3.61 +- 1.80 mm
Large annual and gap in data make the significance of this offset
difficult to assess.
OKDT WLS dNEU    2.06 +- 6.14,   7.05 +- 5.65,  20.74 +- 12.27 mm,
      KF dNEU   -1.81 +- 0.44,   5.03 +- 0.40,  20.75 +- 1.54 mm
Offset is clear in data although there is a 10-year long curvature to
the time
series especially in North.
P047 WLS dNEU   -0.59 +- 1.12,   2.94 +- 1.16,   3.43 +- 7.50 mm,
      KF dNEU   -0.43 +- 0.41,   2.92 +- 0.34,   4.45 +- 1.27 mm
Time series is noisy and offset is not so clear.
P489 WLS dNEU    4.20 +- 2.52,  -2.58 +- 0.71,   1.65 +- 3.94 mm,
      KF dNEU    4.13 +- 0.33,  -2.47 +- 0.29,   4.37 +- 1.08 mm
Gap before antenna replacment by North offset looks significant. Long
term post-seismic
curvature to North time series.
```

P628 WLS dNEU   -1.96 +- 1.77, -6.87 +- 3.68, -10.82 +- 7.35 mm,
KF dNEU   -1.45 +- 0.49, -6.91 +- 0.67, -8.01 +- 1.70 mm
Large gap of 9 months (with bad data before antenna failure). Significance of
offset not clear. Bad snow data in early years.
P690 WLS dNEU   -9.71 +- 4.42,   4.18 +- 7.99,   3.03 +- 15.28 mm,
      KF dNEU   -7.79 +- 0.53,   2.40 +- 0.62,   2.57 +- 1.59 mm
Lots of snow data and 4 month gap before antenna replacement. Heavy editing of
snow data changes results a little (dEast 4.11 +- 0.71; dU 4.10 +- 1.67 mm).

Anomaly if large (2 meter) jump at TNGF 2017 3 31 (dNEU 2011. -362. 661. mm)

COPR: WLS dNEU   11.40 +- 25.89, -1.04 +- 6.56,   1.10 +- 8.37 mm,
       KF dNEU   5.24 +- 0.52, -0.89 +- 0.36,   3.26 +- 1.28 mm
Break in North can be seen. The WLS estimate is poor because site has curavature
between 2002 and 2017 with a peak-to-peak offset off 11 mm in North and 5 mm in East.
HOLB: WLS dNEU   3.41 +- 5.14, -1.74 +- 6.10, 11.22 +- 18.78 mm,
       KF dNEU   2.64 +- 0.42, -2.60 +- 0.34,   9.95 +- 1.29 mm
Break is small with some bad days as ACs updated the meta data for the site. The
site shows a strange earthquake "post-seismic" signal starting 2012/05/03.
10-day tau log estimates are -2.6 mm N and 2.4 mm E.
P022: WLS dNEU   5.75 +- 0.68,   3.02 +- 0.72,   0.11 +- 6.82 mm,
       KF dNEU   5.70 +- 0.31,   3.06 +- 0.26,   1.19 +- 0.99 mm
Break is clear in the time series.
P133: WLS dNEU   1.98 +- 1.37,   0.61 +- 1.05, -2.72 +- 7.24 mm,
       KF dNEU   1.39 +- 0.33,   0.17 +- 0.30,   1.92 +- 1.16 mm
Small break in this case
P134: WLS dNEU   0.89 +- 1.06, -1.23 +- 1.31, -4.41 +- 10.27 mm,
      KF dNEU   1.38 +- 0.37, -0.92 +- 0.34, -0.69 +- 1.30 mm
Small break again.
P394: WLS dNEU   1.89 +- 0.46,   0.90 +- 1.22,   0.64 +- 5.97 mm,
       KF dNEU   1.96 +- 0.27,   0.66 +- 0.24,   2.13 +- 0.89 mm
Break in north is clear. Other components are not so clear.

P072 WLS dNEU   3.12 +- 1.07, -0.03 +- 0.50,   3.59 +- 4.77 mm,
      KF dNEU   2.49 +- 0.32, -0.02 +- 0.28,   6.35 +- 1.05 mm
North can be seen, Height is noisy and not clear.
P300 WLS dNEU   -6.86 +- 18.79, -10.46 +- 34.52,   3.13 +- 7.54 mm,
      KF dNEU   -4.72 +- 0.53,   -4.93 +- 0.67,   8.14 +- 1.01 mm
Very systematic which explains large sigma of WLS solution and difference
from KF solution. NE offsets very clear. Some of height difference may be
finals versus rapid differences.
P302 WLS dNEU   0.43 +- 8.06, -5.54 +- 14.94, -0.63 +- 15.89 mm,
      KF dNEU   0.06 +- 0.38, -1.50 +- 0.43,   5.55 +- 1.19 mm
Systematic but not as much as P300. No clear NE offsets as estimated by the
Kalman filter. Some of height difference may be finals versus rapid differences.
P682 WLS dNEU   2.08 +- 0.96,   0.72 +- 1.38, -3.70 +- 10.73 mm,

```
      KF dNEU     1.94 +- 0.35,  -0.01 +- 0.30,    0.54 +-  1.19 mm
North offset can seen. Other components are less clear.
```

New offsets of unknown origin and data anomalies

P642 Very clear skewness with clear outliers at the end of 2017. Site also have large systematics.
P312 Looks like a vegetation growing problem since early 2014. Apparent break 2015/04/28.
P300 In Central Valley. Very clear changes in horizontal motions with very little height signal. Since mid-2016, strong rotation on motion towards mountains. GR8R and P302 do something similar (especially in East.) P304 and P303 in valley proper shows large vertical signal. P307 also in valley is quite different.

2017 GAGE Velocity field to GPS Week 1977 2017-12-02

These notes add supplemental information to "Notes on the 2016 PBO Velocity field to Week 1925 2016-12-03" https://www.unavco.org/data/gps-gnss/derived-products/docs/GAGE_GPS_Velocity_Release_Notes_20161203.pdf and "Notes on the 2015 PBO Velocity field to Week 1870 2015-11-14" https://www.unavco.org/data/gps-gnss/derived-products/docs/GAGE_GPS_Velocity_Release_Notes_20151223.pdf

The 2017 GAGE full velocity solution includes GPS data from GPS week 0834 (Jan-01-1996) to week 1977 (Dec-02-2017). Time tag on LMD queue is 20171227092717.

The complete analysis of the full GAGE velocity field generated from SINEX files (i.e., incorporating full variance covariance matrices and allowing re-alignment of the reference frame for the velocity field) is now being released. The 2015 release documents the methods being used to generate these velocity fields. These methods remain unchanged and here we update the tables derived from those methods.
The process noise models, in the form of random walk time-step variances or process noise (RWPN) are given in All_PBO.rw. These values are generated by analysis of the position residuals from fitting the time series for each site. Sites that have process noise values greater than 100.0 mm^2/yr are not included in this velocity solution so that they do not contaminate nearby sites. Twenty sites are excluded based on this criterion (AC09, AC30, AV05, BLKM, BUEG, CN44, EOCG, FCTF, HVHS, NTOE, OLO1, OLO4, OLO5, OLO7, P056, P323, P656, RHCG, SMMx and WLHG). Most of these sites have a combination of large systematics and/or short durations of valid data. We also impose a minimum RWPN value of 0.05 mm^2/yr. 481 sites have computed RWPN values less than this value. The process noise statistics are generated from the time series using the GAMIT/GLOBK script sh_gen_stats based on tsfit fits to the time series with the realistic sigma algorithm used to account for correlated noise. The tsfit solution also generates a list of site position estimates not to be used in the velocity solution because they are outliers (either due to bad analyses, antenna failures or snow on antennas). The current list of edited site position estimates is given in All_PBO_edits.eq. These edits can by AC or for both ACs. The total GAGE time series contain 8781560 station-days. The outlier

criteria remove 12885 (0.15%) of NMT and 62548 (0.71%) of CWU station-days of solutions.

The processing divides the 2230 sites analyzed into 29 networks each with approximately 79 site locations. (The final number of estimated parameters for each network depends on the number of breaks needed at each site. The networks need from 103 to 286 individual site names to accommodate the discontinuities). There is no overlap between the sites in the first 28 networks. A 29th network is created to tie all the other 28 networks into a single solution. To form the sites in the 29th network, three sites for each network are chosen so as to minimize the trace of the covariance matrix of the estimates of rotation and translation using these sites. Weights assigned to each site in accord with the expected variance of the velocity estimate for the site (i.e., combination of the RWPN and duration of data at the site). If equal weights are given to each site, this algorithm is the same as choosing the three sites that cover the largest area. The details of the sites in each network are given in All_PBO_netsel.use. The analyses of the 29 networks can be run in parallel and takes a few hours to run. The combination of the 29 networks uses ~8 Gbytes of memory and the NMT and CWU combination, along the equating of velocities (with a constraint of ±0.01 mm/yr) at sites with discontinuities takes about two days of CPU time. The NMT and CWU velocity solutions are then merged to form the PBO solution combined solution. This combination uses ~28 Gb of memory and also takes about 34 hrs to complete. The velocity combinations use loose constraints and we align the reference frame as we wish at the end of the combination. We generate four reference frame realizations: (1) A North America frame aligned to our current NAM08 frame using 1241 sites in our hierarchical list of reference frame sites; (2) A North America frame aligned to IGb08 rotated into the North America frame using the 36 sites original used in ITRF2008 to define the North America plate and (3) and (4) are the same as (1) and (2) except the reference velocities are in a NNR reference frame.

The full GLOBK SINEX velocity solution allows us to re-align the reference frames based on the combination of all of the data collected between 1996 and current day (2017-12-02 GPS Week 1977 for this analysis). The time series analyses for velocities is much faster but the daily solutions need to be aligned the reference frame each day based on an earlier realization of the frames. The current NAM08 frame was originally aligned to the reference frame using data through August of 2014 – about three and half years ago. Tables 1 and 2 compare the WRMS and NRMS scatters of the differences between the velocity estimates obtained by the two GAGE ACs and the combination of the two ACs using different analysis methods. Table 1's caption explains the naming scheme used to describe the solutions. There are the three analysis centers, NMT, CWU and their combination PBO. The velocity estimates are generated with three different methods (1) GLOBK SINEX combinations, GK (2) time series analyses using weighted least squares (LS) and (3) time series analyses using a Kalman filter of the time series (KF). The time series LS analysis is the one that generates the monthly GAGE SNAPSHOT fields. The GK analysis can be aligned to the current NAM08 frame (NA) or be realigned to the IGb08 frame (IG). In all analyses, the same process noise models, discontinuities and post-seismic non-linear models (based on time series analyses) are used. The comparisons do not re-align the velocity fields in any way. The RMS values are based on the simple difference between the estimates. The numbers of stations do not match between the analyses because the GK analyses exclude sites with large process noise values. Tables 3 and 4 show the same type of comparison when we restrict the sites to the best 761 stations in the solution. (These stations have velocity standards less than the median standard deviations in north, east and up in all three components, 0.16, 0.15 and 0.46 mm/yr, respectively). The number of stations is less than half the number of stations because the standard deviation condition must be met in all components). The NRMS values are very consistent with those in Tables 1 and 2 suggesting that even the sites with the smallest sigma match in accordance with their sigmas.

Over all the agreement between the different methods of estimating the velocities are very good with the WRMS difference in the NE components typically <0.2 mm/yr (including comparison to the PBO 2016 and PBO 2015 velocity solutions) and in height less than 0.8 mm/yr. The NRMS scatter of the differences is typically less than unity showing that the error bars are of the somewhat larger than the differences. There are correlations between these solutions so the NRMS scatter being less than unity should be expected.

The official PBO velocity solution is aligned to our current NAM08 frame to keep consistency of the results and to avoid discontinuities. The current IGb08 is now about 7-years old and was replaced by ITRF2014 (IGS14) for official products on January 29, 2017 (http://www.igs.org/article/igs14-reference-frame-transition). Current GAGE final-orbit products are still generated in the IGb08 system while we wait for JPL to generate orbit and clock products in the IGS14 system.

Along with this release of the velocity field we also release a folder with ancillary files and results similar to the files released for the Reviews of Geophysics paper. The contents of the DOI_171202 folder are described in Table 5.

Table 1: Comparison of North and East velocities between different velocity field determination methods. No transformation parameters between the fields have been estimated. The codes for the solutions are: CCC_TTYY where CCC is the center NMT, CWU or the combined PBO analysis; TT is the type of analysis:
GK – GLOBK Kalman filter; TS – time series fit; and YY is combination of method and reference frame: LS – least squares, KF – Kalman filter; NA – NAM08, IG – IGb08 rotated to NA. The final entries PBO_2016 and PBO_2015 are the earlier 2016 and 2015 PBO full solution generated in December 2016 and November 2015. # is the number of common sites in the solutions.

Soln1 - Soln2	#	N mean (mm/yr)	N WRMS (mm/yr)	N NRMS	E mean (mm/yr)	E WRMS (mm/yr)	E NRMS
PBO_GKNA- CWU_GKNA	2202	-0.02	0.07	0.361	-0.00	0.07	0.347
PBO_GKNA- NMT_GKNA	2207	0.01	0.05	0.259	0.00	0.06	0.305
CWU_GKNA- NMT_GKNA	2201	0.03	0.12	0.597	0.00	0.13	0.633
PBO_GKNA- PBO_TSLS	2208	-0.02	0.14	0.893	-0.01	0.14	0.857
PBO_GKNA- PBO_TSKF	2208	-0.03	0.16	0.876	-0.01	0.15	0.815

PBO_GKNA-	CWU_TSLS	2200	-0.02	0.15	0.969	-0.01	0.15	0.939
PBO_GKNA-	CWU_TSKF	2191	-0.03	0.17	0.916	-0.01	0.16	0.869
PBO_GKNA-	NMT_TSLS	2207	-0.02	0.18	1.126	-0.02	0.17	1.041
PBO_GKNA-	NMT_TSKF	2207	-0.04	0.19	1.004	-0.02	0.17	0.906
PBO_GKNA-	PBO_GKIG	2208	-0.02	0.12	0.566	0.21	0.24	1.143
PBO_GKNA-	CWU_GKIG	2202	0.03	0.11	0.502	0.24	0.27	1.263
PBO_GKNA-	NMT_GKIG	2207	-0.02	0.14	0.648	0.18	0.22	1.083
PBO_GKNA-	PBO_2016	2167	-0.02	0.20	0.981	-0.00	0.18	0.865
PBO_GKNA-	PBO_2015	2130	-0.04	0.25	1.181	-0.04	0.22	1.036

Table 2: Similar to Table 1 except here the mean horizontal velocity (HzMean, HzWRMS, HzNRMS) and vertical velocity (U columns) are compared.

Soln1 -	Soln	#	HzMean (mm/yr)	HzWRMS (mm/yr)	HzNRMS	U Mean (mm/yr)	U WRMS (mm/yr)	U NRMS
*								
PBO_GKNA-	CWU_GKNA	2202	-0.01	0.07	0.354	-0.03	0.29	0.490
PBO_GKNA-	NMT_GKNA	2207	0.01	0.06	0.283	-0.03	0.16	0.308
CWU_GKNA-	NMT_GKNA	2201	0.01	0.12	0.615	0.00	0.41	0.714
PBO_GKNA-	PBO_TSLS	2208	-0.02	0.14	0.875	-0.02	0.42	0.909
PBO_GKNA-	PBO_TSKF	2208	-0.02	0.16	0.846	-0.10	0.47	0.976
PBO_GKNA-	CWU_TSLS	2200	-0.01	0.15	0.954	-0.05	0.46	0.979
PBO_GKNA-	CWU_TSKF	2191	-0.02	0.17	0.893	-0.12	0.51	1.025
PBO_GKNA-	NMT_TSLS	2207	-0.02	0.17	1.084	-0.46	0.78	1.616
PBO_GKNA-	NMT_TSKF	2207	-0.03	0.18	0.956	-0.45	0.76	1.478
PBO_GKNA-	PBO_GKIG	2208	0.10	0.19	0.902	-0.44	0.51	0.960
PBO_GKNA-	CWU_GKIG	2202	0.14	0.21	0.961	-0.22	0.37	0.626
PBO_GKNA-	NMT_GKIG	2207	0.08	0.19	0.892	-0.58	0.68	1.321
PBO_GKNA-	PBO_2016	2167	-0.01	0.19	0.925	0.11	0.45	0.840
PBO_GKNA-	PBO_2015	2130	-0.04	0.24	1.111	0.16	0.62	0.980

Table 3: Comparison of North and East velocities similar to Table 1 except we limit the sites to those that have horizontal and vertical velocities sigmas both less than the median horizontal and vertical velocity sigmas. (Reason there are less than 1115 sites is because both horizontal and vertical sigma conditions must be satisfied.) To be included in this table the north and east velocity sigmas must be less than 0.16 and 0.15 mm/yr and the height velocity sigma less than 0.46 mm/yr.

Soln1 -	Soln2	#	N mean (mm/yr)	N WRMS (mm/yr)	N NRMS	E mean (mm/yr)	E WRMS (mm/yr)	E NRMS
PBO_GKNA-	CWU_GKNA	761	-0.01	0.06	0.357	0.01	0.06	0.363
PBO_GKNA-	NMT_GKNA	761	0.01	0.04	0.239	-0.00	0.04	0.296
CWU_GKNA-	NMT_GKNA	761	0.02	0.09	0.572	-0.01	0.10	0.637
PBO_GKNA-	PBO_TSLS	761	-0.03	0.10	0.871	-0.01	0.09	0.754
PBO_GKNA-	PBO_TSKF	761	-0.03	0.11	0.774	-0.00	0.09	0.679

PBO_GKNA-	CWU_TSLS	761	-0.03	0.10	0.867	-0.01	0.09	0.796
PBO_GKNA-	CWU_TSKF	761	-0.02	0.10	0.751	0.00	0.10	0.703
PBO_GKNA-	NMT_TSLS	761	-0.02	0.11	0.977	-0.01	0.10	0.872
PBO_GKNA-	NMT_TSKF	761	-0.03	0.11	0.806	-0.01	0.10	0.703
PBO_GKNA-	PBO_GKIG	761	0.01	0.11	0.680	0.21	0.24	1.498
PBO_GKNA-	CWU_GKIG	761	0.05	0.10	0.565	0.25	0.27	1.670
PBO_GKNA-	NMT_GKIG	761	0.01	0.12	0.783	0.19	0.22	1.407
PBO_GKNA-	PBO_2016	761	-0.02	0.09	0.589	0.00	0.09	0.572
PBO_GKNA-	PBO_2015	761	-0.02	0.13	0.787	-0.02	0.12	0.714

Table 4: Same as Table 3 except for the combined horizontal and vertical comparison.

Soln1 -	Soln2	#	HzMean (mm/yr)	HzWRMS (mm/yr)	HzNRMS	U Mean (mm/yr)	U WRMS (mm/yr)	U NRMS
PBO_GKNA-	CWU_GKNA	761	-0.00	0.06	0.360	0.01	0.21	0.486
PBO_GKNA-	NMT_GKNA	761	0.00	0.04	0.269	-0.03	0.12	0.318
CWU_GKNA-	NMT_GKNA	761	0.01	0.09	0.606	-0.03	0.29	0.708
PBO_GKNA-	PBO_TSLS	761	-0.02	0.09	0.815	0.00	0.26	0.795
PBO_GKNA-	PBO_TSKF	761	-0.02	0.10	0.728	-0.09	0.33	0.965
PBO_GKNA-	CWU_TSLS	761	-0.02	0.10	0.832	-0.03	0.29	0.866
PBO_GKNA-	CWU_TSKF	761	-0.01	0.10	0.728	-0.12	0.37	1.024
PBO_GKNA-	NMT_TSLS	761	-0.02	0.11	0.926	-0.42	0.65	1.860
PBO_GKNA-	NMT_TSKF	761	-0.02	0.10	0.756	-0.43	0.64	1.733
PBO_GKNA-	PBO_GKIG	761	0.11	0.19	1.163	-0.41	0.46	1.193
PBO_GKNA-	CWU_GKIG	761	0.15	0.21	1.246	-0.18	0.29	0.659
PBO_GKNA-	NMT_GKIG	761	0.10	0.18	1.139	-0.56	0.62	1.677
PBO_GKNA-	PBO_2016	761	-0.01	0.09	0.581	0.11	0.28	0.695
PBO_GKNA-	PBO_2015	761	-0.02	0.12	0.751	0.17	0.40	0.860

Table 5: Ancillary and velocity fields supplied with this solution (folder DOI_171202/)

File	Description
All_PBO.rw	Random walk parameters by station for use in GLOBK Kalman filter
All_PBO_ants.eq	List of epochs of discontinuities due to antenna and radome changes in GLOBK EQ-format. There are 1531 entries.
All_PBO_edits.eq	List of sites and times of position estimates removed from the final velocity solution combination either because they are outliers (e.g., snow/ice on antenna) or have large standard deviations (75433 entries).
All_PBO_eqs.eq	List of 42 earthquakes included for co-seismic offset discontinuities. 11 of these earthquakes include parameterized logarithmic post-seismic terms.

All_PBO_unkn.eq	List of sites and epochs of discontinuities in position time series that occur for unknown reasons (or unknown times when an antenna partially fails).
All_PBO_netsel.use	List of sub-networks used to create the combined velocity solution.
All_PBO.stab	Hierarchical list of reference frame sites used to define the NAM08 reference frame
All_PBO_nam08.apr	GLOBK apriori position, velocity and extended entry format file defined in NAM08 frame
All_PBO_igs08.apr	GLOBK apriori position, velocity and extended entry format file defined in IGS08 frame
pbo.final_nam08.20171202.vel	Combined velocity field based on GLOBK SINEX file analysis in the NAM08 reference frame. PBO velocity field file format.
cwu.final_nam08.20171202.vel	CWU velocity field based on GLOBK SINEX file analysis in the NAM08 reference frame. PBO velocity field file format.
nmt.final_nam08.20171202.vel	NMT velocity field based on GLOBK SINEX file analysis in the NAM08 reference frame. PBO velocity field file format.
pbo.snaps_nam08.20171202.vel	Combined velocity field based on time series analysis in the NAM08 reference frame. PBO velocity field file format.
cwu.snaps_nam08.20171202.vel	CWU velocity field based on time series analysis in the NAM08 reference frame. PBO velocity field file format.
nmt.snaps_nam08.20171202.vel	NMT velocity field based on time series analysis in the NAM08 reference frame. PBO velocity field file format.
pbo.final_igs08.20171202.vel	Combined velocity field based on GLOBK SINEX file analysis in the IGS08 reference frame. PBO velocity field file format.
pbo.tswls_nam08.20171202.gvl	Combined velocity field based on time series weighted least squares (WLS) analysis in the NAM08 reference frame. GLOBK velocity field file format.
pbo.tskfa_nam08.20171202.gvl	Combined velocity field based on time series Kalman filter (KF) analysis in the NAM08 reference frame. GLOBK velocity field file format.
pbo.kfiga_nab08.20171202.gvl	Combined velocity field based on GLOBK SINEX file analysis in a North America reference frame directly realized from the IGb08 reference frame sites. GLOBK velocity field file format.

cwu.tswls_nam08.20171202.gvl	CWU velocity field based on time series weighted least squares (WLS) analysis in the NAM08 reference frame. GLOBK velocity field file format.
cwu.tskfa_nam08.20171202.gvl	CWU velocity field based on time series Kalman filter (KF) analysis in the NAM08 reference frame. GLOBK velocity field file format.
cwu.kfiga_nab08.20171202.gvl	CWU velocity field based on GLOBK SINEX file analysis in a North America reference frame directly realized from the IGb08 reference frame sites. GLOBK velocity field file format.
nmt.tswls_nam08.20171202.gvl	NMT velocity field based on time series weighted least squares (WLS) analysis in the NAM08 reference frame. GLOBK velocity field file format.
nmt.tskfa_nam08.20171202.gvl	NMT velocity field based on time series Kalman filter (KF) analysis in the NAM08 reference frame. GLOBK velocity field file format.
nmt.kfiga_nab08.20171202.gvl	NMT velocity field based on GLOBK SINEX file analysis in a North America reference frame directly realized from the IGb08 reference frame sites. GLOBK velocity field file format.

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 now tested these models and compared ocean tide perturbations with results from the NGS orbit integrator and comparison suggests that there are no errors in the coding of the ocean tide potential terms. In our test, 24-hour orbit integrations, the 3-D RMS effect of the ocean tide perturbations vary between 20 and 50 mm, depending on orbital plane, with most if the differences being along track. The RMS differences between the orbit perturbations from two programs, with no parameter adjustments are less than 2 mm in all components. We are also evaluating the effects of other orbit models including the solid-Earth and ocean pole tides and albedo models.

We have updated tables to support added 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 20 additional royalty-free licenses to educational and research institutions. Some of these licenses are being issued to support the GAMIT/GLOBK training class being organized by Prof. Ramji Dwivedi at Geographic Information System (GIS) Cell, Motilal Nehru National of Technology (MNNIT) Allahabad, India. The course will take place January 22-26, 2018 in Allahabad, India.