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

Thomas Herring, Robert King and Mike Floyd

Period: 2015/01/01-2015/03/31

Table of Contents

Summary

Under the GAGE Facility Data Analysis subcontract, 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 12/15/2015 to nominally 03/14/2015, time series velocity field analyses for the GAGE reprocessing analyses (1996-2015), earthquake effects during the interval (no detectable events this quarter), position offsets from antenna changes, comparison between results from the previous quarter. Because the quarterly reports are due near the start of the month and the data used in the finals processing has an age between 2-3 weeks, early in the month the finals results the last two weeks of the previous month are not available. For this quarter the last finals results were for March 14, 2015. No new "bad" sites were added this quarter. We have retained the list and explanation from previous quarters for completeness of this report. Associated with the report are the ASCII text files that are linked into this document.

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

GPS Analysis of Level 2a and 2b products

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.

Level 2a products: Final products

The final products are generated weekly and are based on the final IGS orbits. 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 also remains the same since the average number of sites is about the same. In this quarter 1882 sites were processed compared to 1871 for the previous quarter.

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: Dec 15, 2014 and March 14, 2015

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 Dec 15, 2014 and March 14, 2015. 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 site 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 1.2 mm for all centers and as low as 0.7 mm for NMT and PBO north component. The up RMS scatters are less than 4.7 mm and as low as 4.0 mm. 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 1871, 1870 and 1870 sites for PBO, NMT and CWU analyzed in the finals analysis between Dec 15, 2014 and March 14, 2015. Histograms of the RMS scatters are shown in Figure 1-3.

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
PBO	0.8	0.8	4.0
NMT	0.7	0.8	4.3
CWU	1.0	0.9	4.7
70%			
PBO	1.0	1.0	4.7
NMT	1.0	1.0	5.2
CWU	1.2	1.1	5.5
95%			
PBO	2.1	2.0	7.5
NMT	2.2	2.2	7.9
CWU	2.4	2.3	8.6

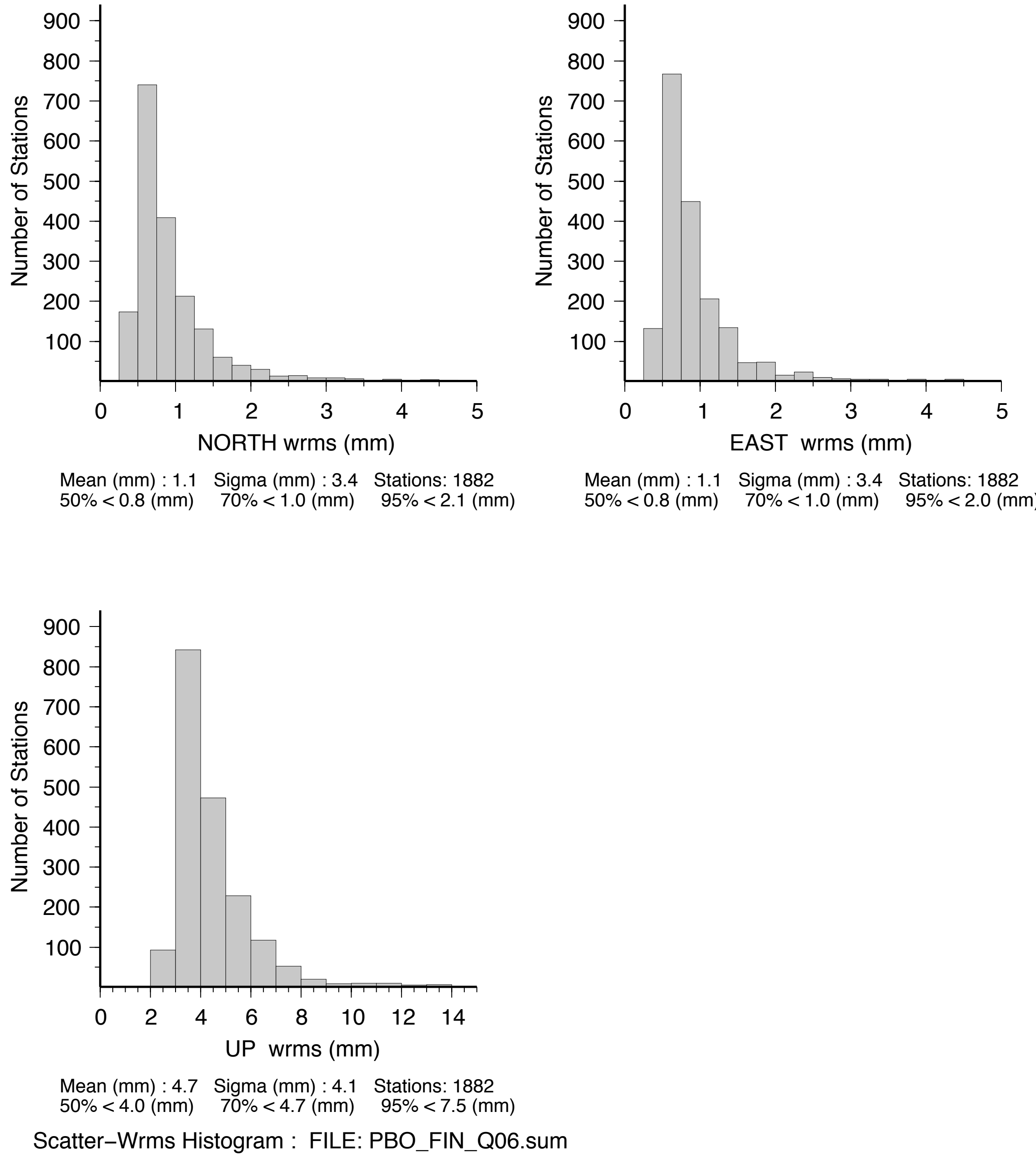


Figure 1: PBO combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1881 sites analyzed between Dec 15, 2014 and March 14, 2015. Linear trends and annual signals were estimated from the time series.

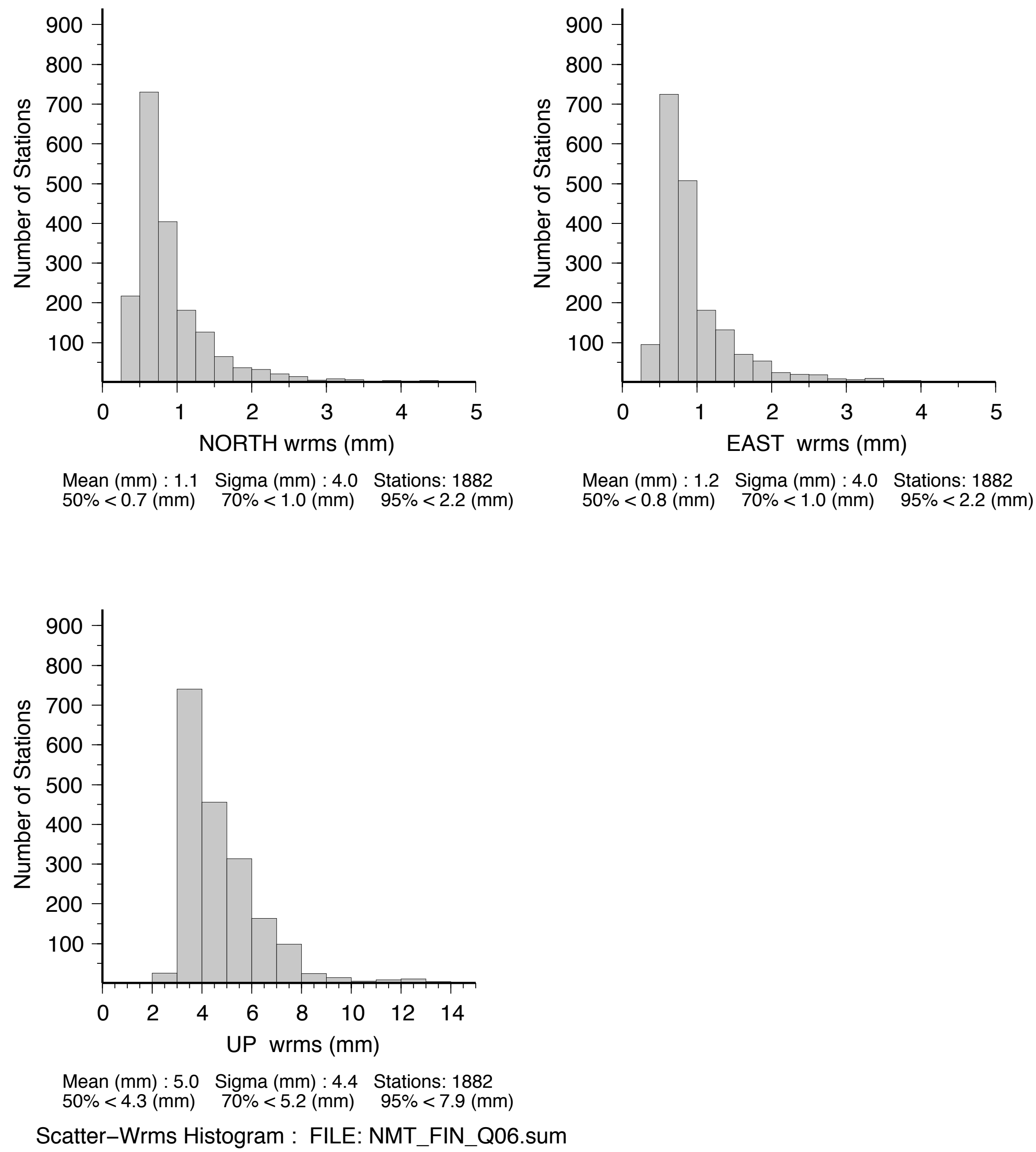


Figure 2: NMT combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1882 sites analyzed between Dec 15, 2014 and March 14, 2015. Linear trends and annual signals were estimated from the time series.

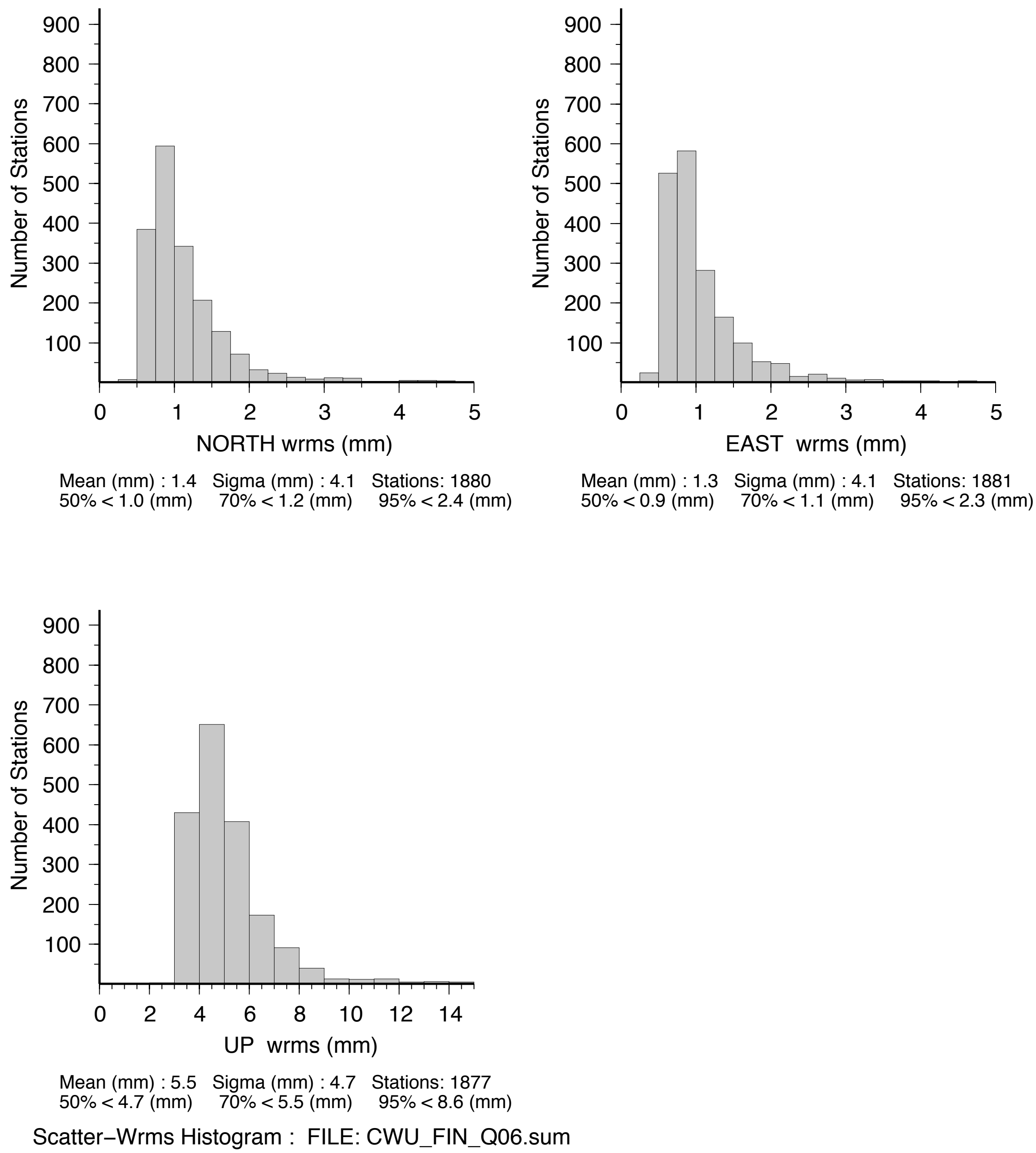


Figure 3: CWU combined solution histograms of the North, East and Up RMS scatters of the position residuals for 1877 sites analyzed between Dec 15, 2014 and March 14, 2015. Linear trends and annual signals were estimated from the time series.

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_Q06.tab. There are 1882 sites in the file. The contents of the files is of this form:

```
Tabular Position RMS scatters created from PBO_FIN_Q06.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     90       0.8   0.52       1.2   0.78      4.3    0.70      11.89
 1NSU     90       0.7   0.44       0.8   0.51      4.2    0.66      11.16
 1ULM     90       0.7   0.44       0.7   0.44      4.8    0.84      11.75
 7ODM     89       1.5   0.79       0.8   0.52      4.2    0.62      13.90
 …
 ZLA1     89       1.1   0.55       0.7   0.41      4.4    0.58      11.78
 ZME1     90       1.0   0.51       0.7   0.40      5.4    0.72      12.01
 ZNY1     90       0.7   0.35       0.7   0.44      3.8    0.56      12.16
 ZSE1     90       0.9   0.40       0.6   0.35      5.2    0.70      12.16
 ZTL4     90       0.6   0.31       0.8   0.45      4.1    0.57      12.35
```

Table 2: RMS scatter of the position residuals for the PBO combined solution between Dec 15, 2014 and March 14, 2015 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, Expanded_PBO, COCONet and Expanded_PBO

Network	North (mm)	East (mm)	Up (mm)	#Sites
Median (50%)				
PBO	0.7	0.7	3.7	883
NUCLEUS	0.7	0.7	3.5	208
USGS SCIGN	0.8	0.8	3.7	110
Expanded	0.8	0.8	4.6	579
GAMA	0.5	0.6	5.4	13
COCO Net	1.4	1.4	5.5	89
70 %				
PBO	0.9	0.9	4.2	
NUCLEUS	0.8	0.8	4.1	
USGS SCIGN	0.9	0.9	4.0	
Expanded	1.1	1.1	5.3	
GAMA	0.6	0.6	5.8	
COCO Net	1.7	1.8	6.5	
95%				
PBO	2.1	1.9	7.2	
NUCLEUS	1.4	1.2	6.1	
USGS SCIGN	1.6	1.5	5.0	
Expanded	2.4	2.1	8.0	
GAMA	1.1	2.0	6.0	
COCO Net	2.7	3.9	11.2	

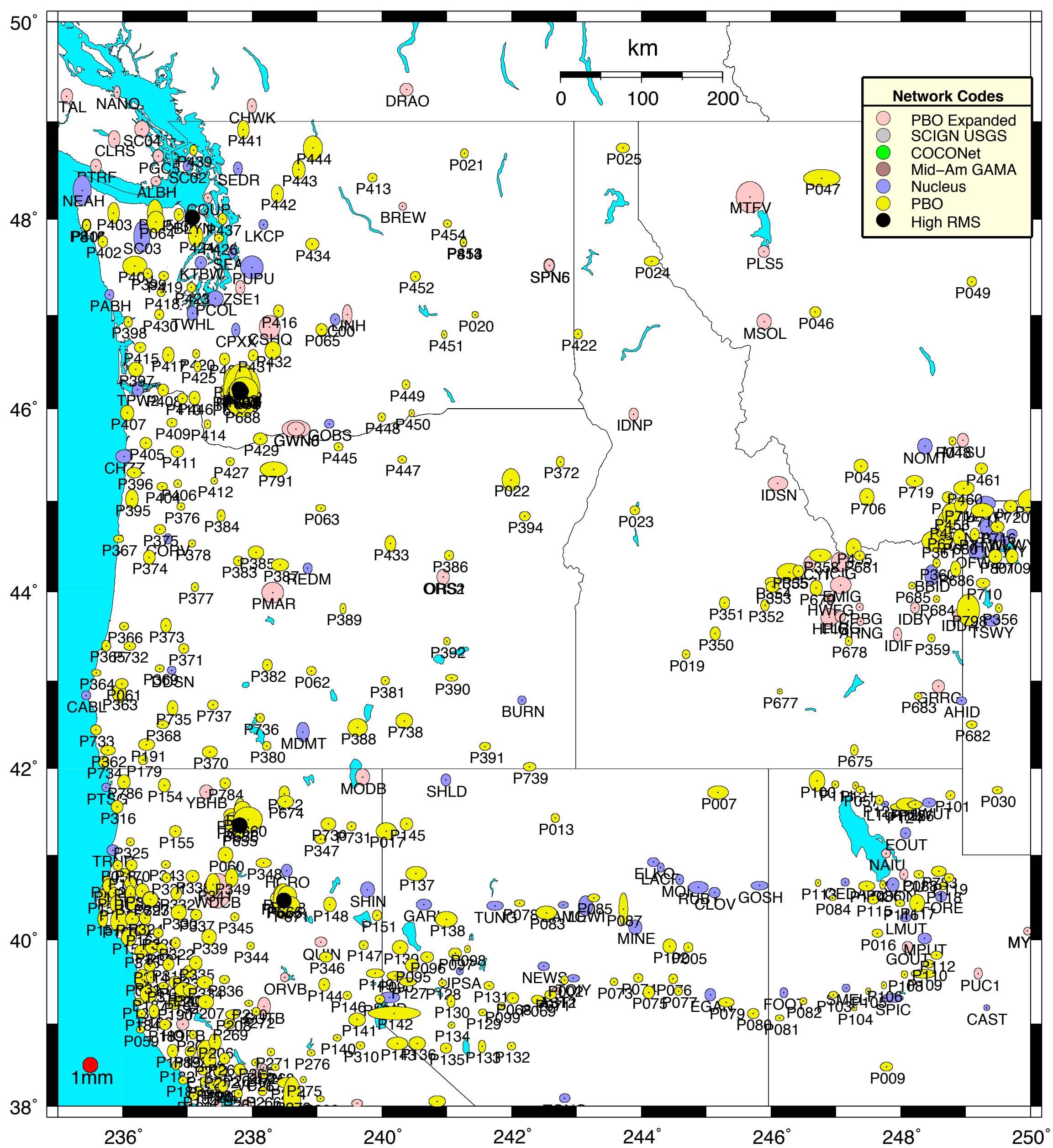


Figure 4: Distribution of the RMS scatters of horizontal position estimates from the PBO combined analysis for the Northern Western United States. The color of the ellipses that give the north and east RMS scatters denotes the network given by the legend in the figure. The small red circle shows the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

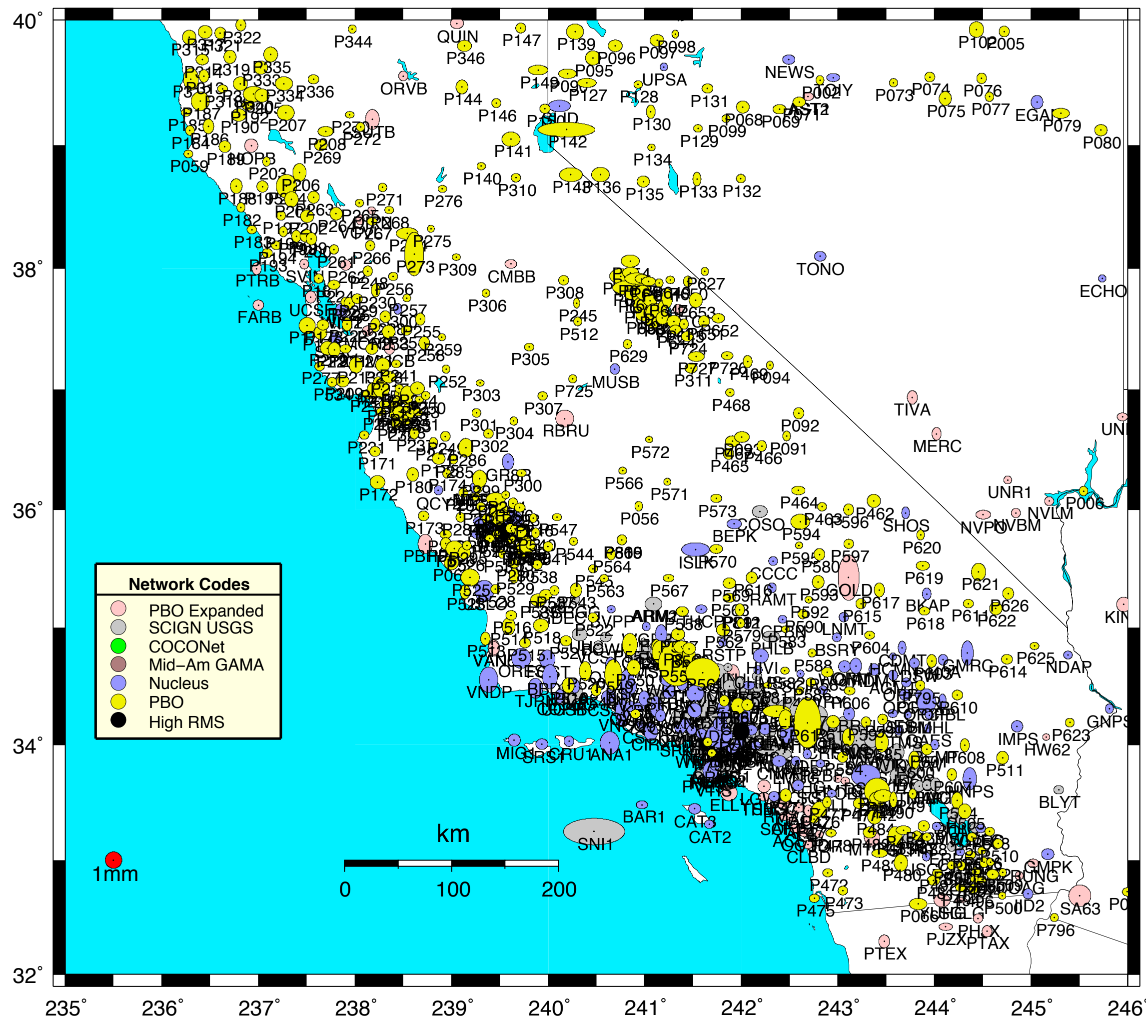
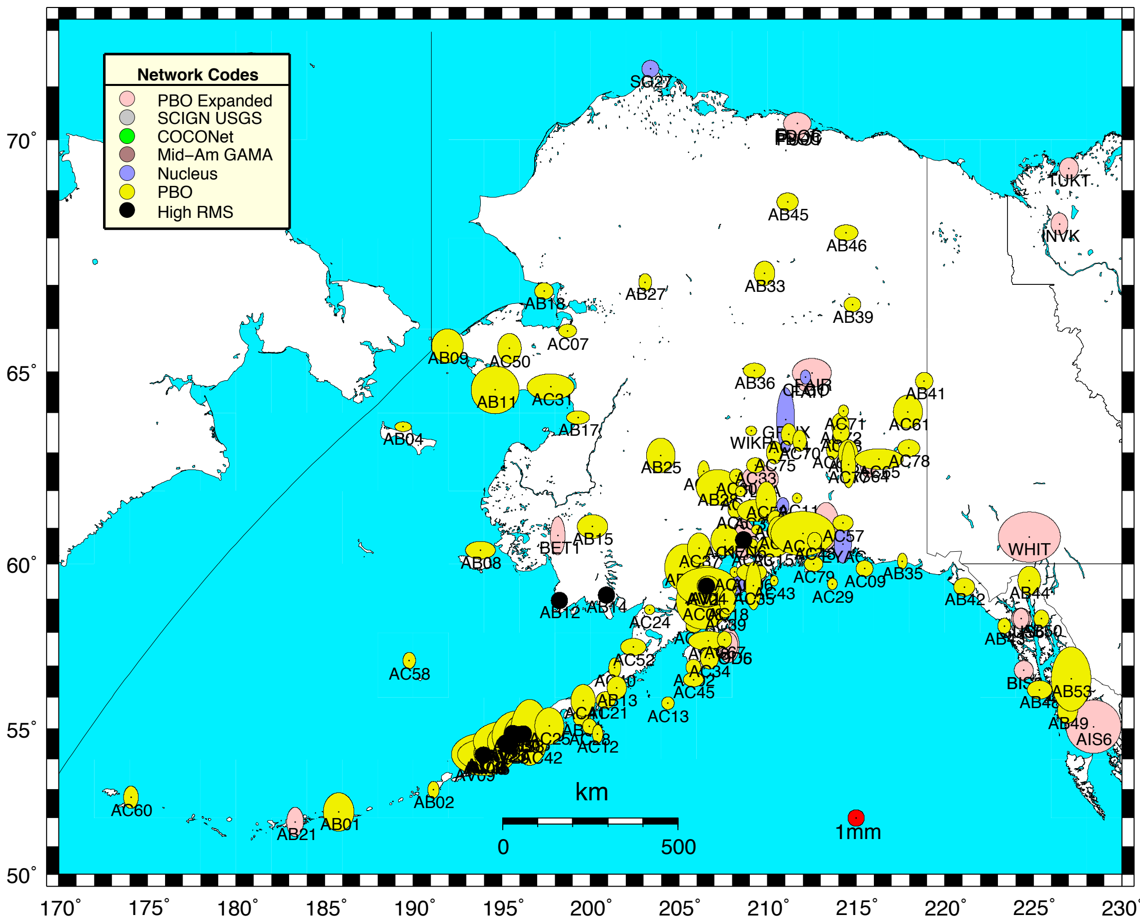


Figure 5: Same as Figure 4 except for the Southern Western United States. Black circles in the Yucca mountain region have no data during this 3-month period.


Network Codes
PBO Expanded
SCIGN USGS
COCONet
Mid–Am GAMA
Nucleus
PBO
High RMS
km
0
500
1mm
70˚
65˚
60˚
55˚
50˚
170˚
175˚
180˚
185˚
190˚
195˚
200˚
205˚
210˚
215˚
220˚
225˚
230˚
SG27
AB45
AB46
AB33
AB39
AB27
AB18
AC07
AB09
AC50
AB11
AC31
AB17
AB04
AB36
AB41
AC61
AC78
AB25
WHIT
TUKT
INVK
BET1
AB15
AB08
AB12
AC24
AC09
AB35
AB42
AC29
AC79
AC52
AC58
AC45
AC13
AB13
AC21
AC12
AC42
AB02
AV09
AC60
AB21
AB01
AB44
AB53
AB49
AIS6
AC57
AC75
AC70

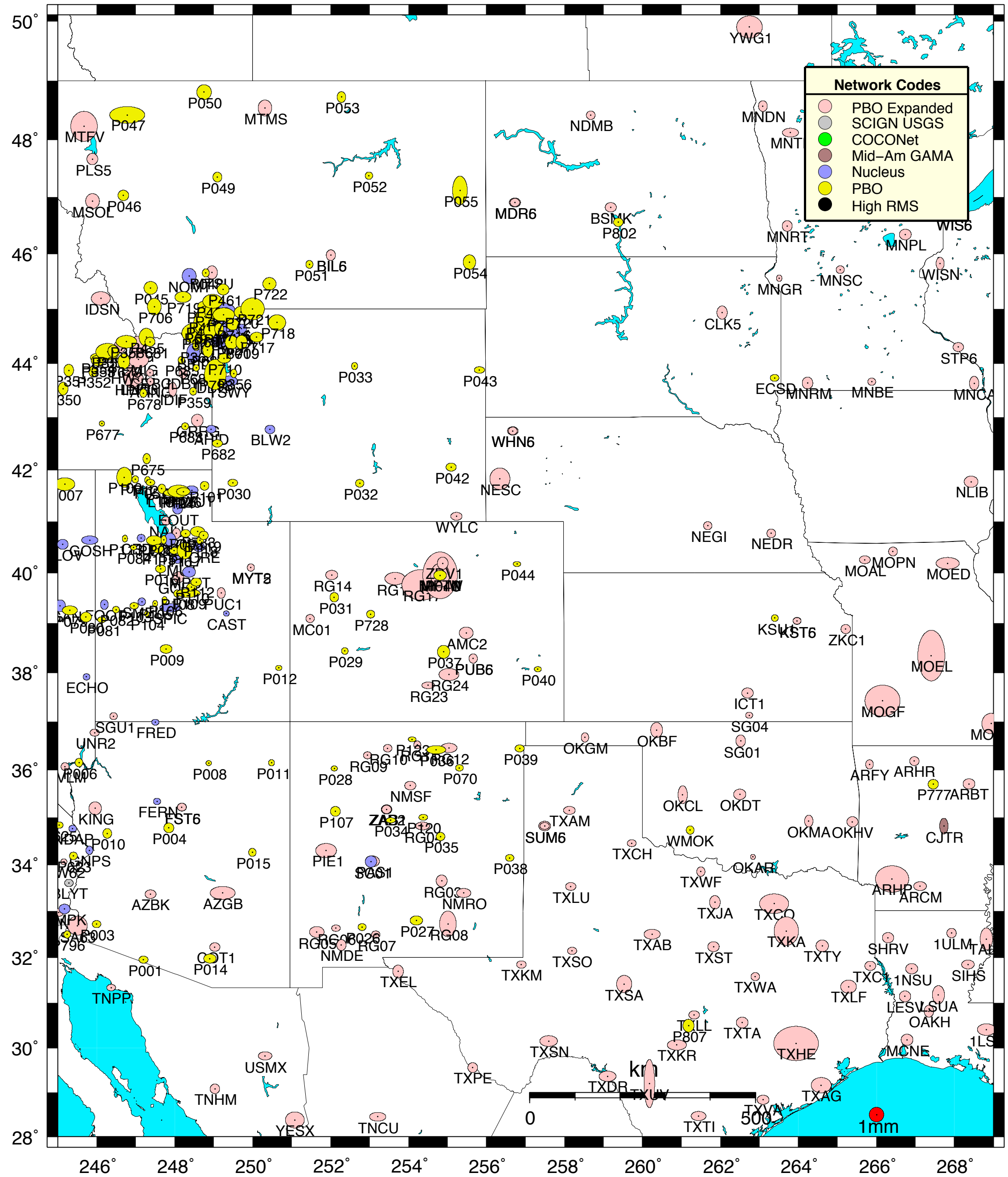


Figure 7: Same as Figure 4 except for the Central United States

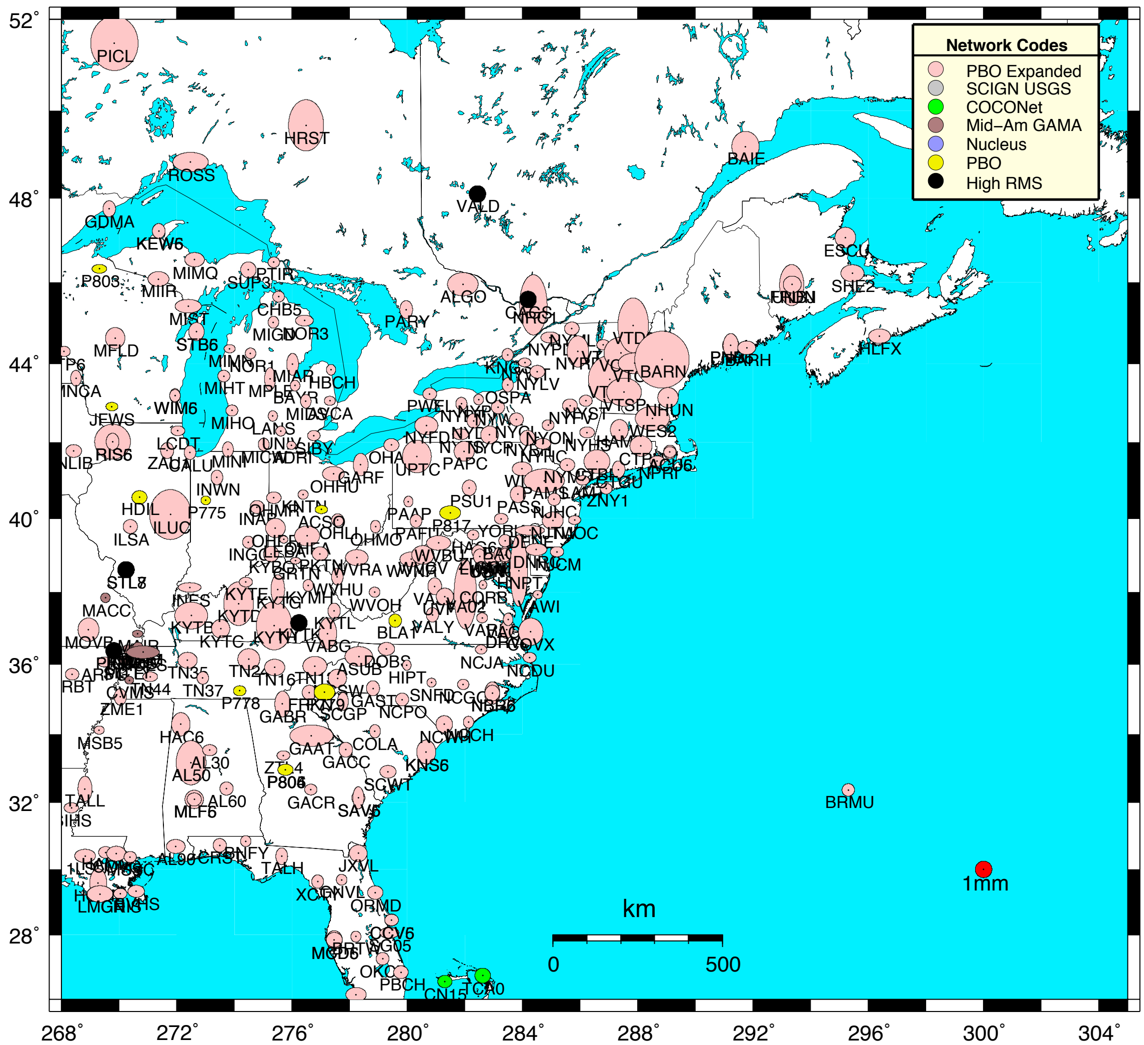


Figure 8: Same as Figure 4 except for the Eastern United States

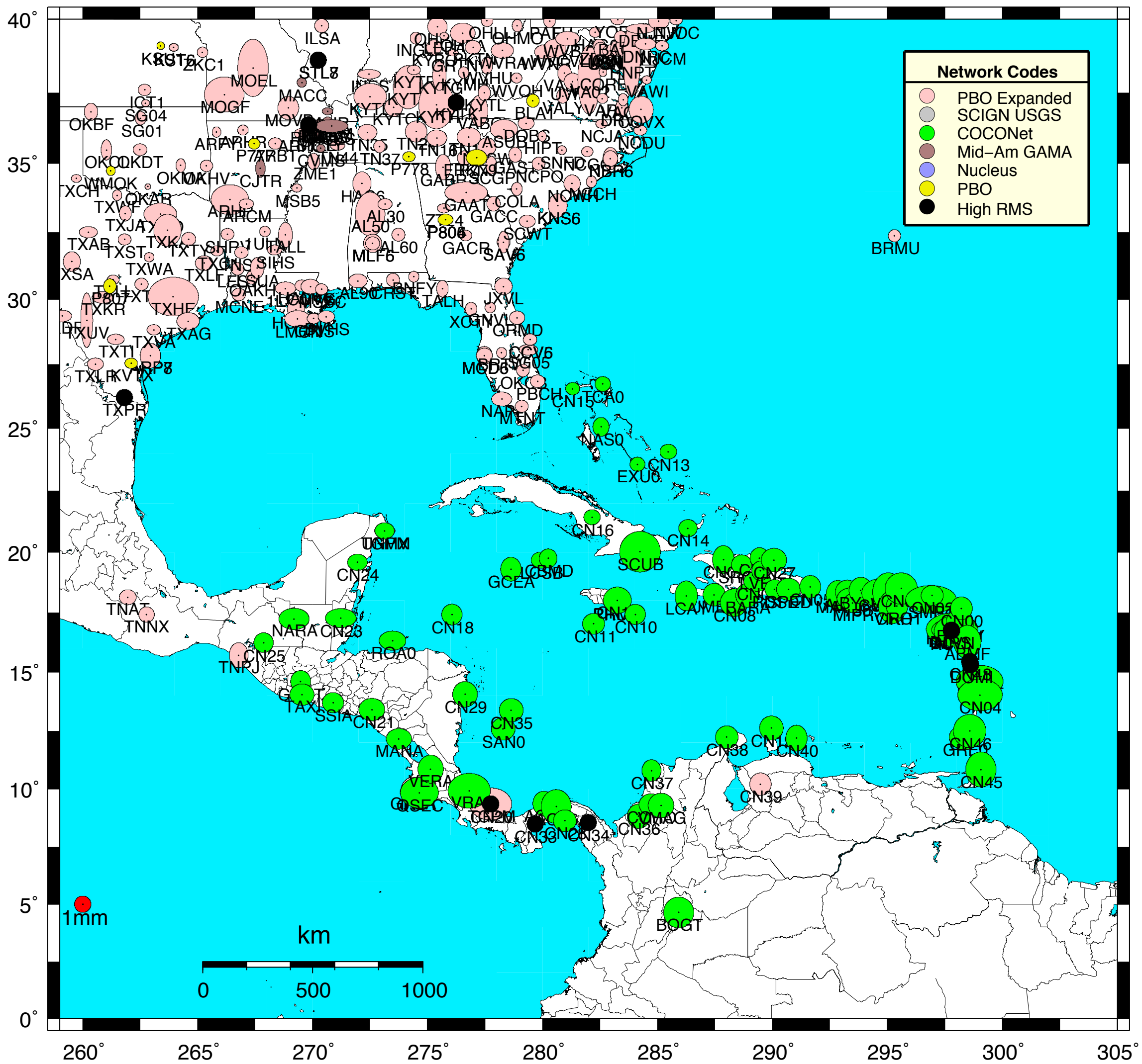


Figure 9: Same as Figure 4 except for the Caribbean region.

Analysis of large RMS sites

In Table 3, reproduced from earlier quarters, gives a summary of the qualitative description of the nature of the times series of all the sites with large RMS scatters (black circles shown in Figures 4-9). Snow is often the reason and falls into types: one class where the snow is systematic for a period of time with normal looking results in between and the other class where it is difficult to see any good data in the time series. For example P665 in in first category and P690 is in the second category. For some sites, it is not clear what is happening at the site. No new sites were added this quarter.

Table 3: Description of time series characteristics of sites with high RMS scatter (black symbols on figures above)

Long (deg)	Lat (deg)	Site	Description
198.2537	58.9508	AB12	Snow with some periods of OK data

197.3865	66.8584	AB18	Strange long period systematics with excursions in 2008 and 20012 (10-15 mm in east)
209.2560	65.0304	AB36	Strange annual
227.1328	56.5848	AB53	Snow events and may be systematic between events.
215.4762	59.8685	AC09	Evolving Rate change 2012-2013
212.0004	60.8487	AC14	Snow events; NE look flat in between but height may have curvature
211.9068	60.5182	AC16	Snow events; but OK in between but height may have curvature as for AC14 (probably annual)
210.6475	60.9292	AC20	Long period N systematic
212.2608	59.8558	AC30	Little data 2007.7-2009.1 with large gap and snow systematic
209.3149	62.6712	AC33	Snow with flat in between (systematic snow).
209.2068	59.3758	AC35	Long period N and E systematic
207.3761	60.0815	AC47	Generally systematic; long lived snow.
179.3013	51.3781	AC66	Curvature offset 14/06/23
289.1134	41.7433	ACU6	Offset 06/12/21
297.7861	16.7408	AIRS	Multi-year variations
228.4008	55.0689	AIS6	Bi-modal data separated by ~5-10 mm NE, EQ like log 2012/10/28 N, 13/01/06 E offset
297.6595	82.4943	ALRT	Lots of variations, does not quite look like snow but maybe.
264.5149	29.3015	ANG1	Slow event ~22 mm N, 6 mm E between 2004/05/26-2004/06/14, offset near end
210.8677	61.5978	ATW2	Clear E offset from Denali Earthquake, 2002 11 3 22 12, but much larger decadal systematic
262.2437	30.3117	AUS5	Unknown break 2002 10 12
206.5553	59.3626	AV04	Bad snow but flat in between
206.5773	59.3629	AV05	Little data between 2004.6-2005 and 2005.6-2006.1, run off at end
194.1022	54.1531	AV13	Some snow intervals each year
206.5718	59.3474	AV20	Snow; bad winter 2008 and 2010
195.4195	54.5717	AV26	Heavily skewed in U and E
195.2768	54.4924	AV27	Maybe snow. Bad in 2009 winter, systematic 2014.
195.4139	54.4724	AV29	Lots of snow
195.6131	54.8467	AV35	Snow but more random in nature. Looks noisy between snow times.
196.2191	54.8315	AV38	Very skewed in N and U. Unknown break: 2011 6 15 6-7 mm in East.
196.0015	54.8113	AV39	Also skewed, systematic, gap 2010.8-2011.5,
300.3909	13.0880	BDOS	Multi-year trends; E 2007-2011 15 mm
223.5204	58.7829	BMCP	Snow most likely but noisy in nature
244.2703	33.3646	BOMG	Multiyear systematic; break 2011 8 18 (looks slow; EQ Postseismic?); offset at El Mayor Cucapah

			(10/04/04).
291.9863	46.8684	CARM	Un-modeled breaks
277.7437	9.3517	CN20	Noisy CWU processing; NMT seems OK.
281.9852	8.5489	CN34	Systematic with maybe a tree growing nearby.
240.3261	34.9426	CUHS	Strong loading signal with change around 2011.0
270.3565	35.5414	CVMS	Bad "antenna" 2013/03/18- 2014/02/26. Firm ware update on 2014/02/26; +8N,-12E offset.
298.6109	15.3062	DOMI	Noisy site. NMT missing at start of data.
250.6167	-27.1482	EISL	Noisy site
297.8057	16.7948	GERD	Slow slip 2006 and 2010.
242.6021	34.2039	GHRP	Some snow but slow slip in 2007-2007.5
249.4640	44.6136	HVWY	Multiyear systematic: Yellowstone.
240.9918	34.3985	KBRC	Even with bad antenna between 2002/12/04-2004/05/25 removed, still multiyear systematic.
208.6498	60.6751	KEN5	Strange multimodal positions in N and E.
208.6498	60.6748	KEN6	Similar behavior to KEN5 suggesting motions are real (on same USCG tower apparently).
267.9549	30.2214	KJUN	Maybe bad antenna between 2004/07/29-2005/01/25 but no log entries. Offset at end of data 2008/08/12,
207.8066	57.6177	KOD1	Strange deviations in 1999.1-1999.9.
207.8066	57.6177	KOD5	No overlap with KOD1 but has similar excursion 2012.1-2012.3 (but KOD6 only partially sees event). USCG site
276.2404	37.1515	KYTK	Systematic with bad antenna: 2013/08/12-2014/01/31; then offset
241.7967	33.7878	LBCH	Bad antenna 2000/01/03-2003/02/03 and replaced. Still multiyear systematic.
278.1928	28.8262	LEES	Un-modeled offset 2011/09/15.
249.5998	44.5651	LKWY	Yellowstone multiyear systematic changes
241.9966	34.1119	LONG	Probably a failing antenna starting Jan 2007. CWU having problems processing data.
285.4171	44.6197	LOZ1	Noisy with N U annual (removed late 2013).
247.7532	41.5921	LTUT	Bad antenna from start 2002/10/23-2008/04/18 large annual in all components
273.7510	12.1489	MANA	Large slow slip events in 2004/10 and 2012/08/27+2012/09/05 (fast EQ)
241.7559	33.9391	MHMS	Most likely bad antenna from 2000/01/12 to 2012/02/15 when it was replaced. ASH701945B_M during bad times.
254.7377	39.9954	NISU	Antenna offsets but no log (ends 2009.5).
243.9323	34.1410	OAES	Failed antenna. 1999/03/05-2007/09/11: Maybe some data until 2000/10/13.
249.1688	44.4511	OFW2	Long period systematic (Yellowstone)
297.7723	16.7504	OLVN	Skewed in E&U, slow type event in 2009.5

262.3462	16.1512	OXTU	Systematic; 2009.8; break 2012/04/23 (gap) ends early 2013.
239.2898	36.2568	P299	Strong ground water signal in all components.
239.7230	36.3044	P300	Very large multiyear deviations (creep on San Andreas?)
237.0366	39.8457	P323	Starts 2007.6 and fails 2008.0; ends 2008.1
244.2679	32.7597	P494	Washer on antenna until 2011/09/21 when removed (no log entry). Strange height systematic.
240.9996	37.6130	P630	Strong N seasonal with trend change mid-2011.
241.0841	37.6053	P631	Very skewed, strong seasonal all components, trend change 2011.8 dNv 11 mm/yr, dUv 13 mm/yr
241.1833	37.5914	P642	Similar to P631 but not soo skewed. Same rate changes.
241.1800	37.6770	P646	Large systematic in East and Up (±10 mm deviations from linear)
237.8042	41.3448	P656	Large gaps and big snow in 2010, 2011.
238.4742	40.4561	P665	Snow events most years
238.5326	40.4658	P667	Snow events most years
237.8101	46.1800	P690	Snow events: Different in nature to P665 and P667 (more radon and longer % of year)
237.7977	46.2103	P693	Similar to P690 (these sites will be hard to edit)
237.8358	46.1990	P695	Similar to P690 but with long period rate change.
237.8234	46.1876	P697	Similar to P690 but less extreme; long term east variations.
237.7968	46.1898	P699	Similar to P690. Offset in east in mid 2006 (gap) already in All_PBO_unkn.eq file.
249.0664	43.7864	P708	Snow events most years but could be edited (similar to P665)
249.4885	44.7183	P716	Long-term curvature in NE from 2006-2014. Change in rate after gap.
237.8631	46.2446	P792	Gaps in time series with snow events; skewed in N. Maybe break in 2012-04 but hard to tell due gap in data.
269.8248	36.3703	PIGT	Strange bi-modal in 2000 (start until Apr 2001) and then systematic since then with possible rate change Apr 2009 (1 mm/yr N largest)
270.6546	36.4742	RLAP	Bad antenna 2005/10/06-2009/08/10 (replaced at end)
250.3118	31.3683	SA24	Strange seasonal signal plus broken antenna.
321.5405	72.5796	SMM1	Greenland Summit ice site. Trend change after 29 m antenna move 2013/07/09
270.8834	13.6971	SSIA	Data 2000/09/28-2010/07/18 has variable large offset; rate change in 2012 after large gap.
141.8448	43.5286	STK2	Earthquake looking offset 2003/09/25 with "log", unknown offset 2011/03/11 undocumented.

270.2411	38.6113	STL7	Noisy in NE; STL8 looks fine.
209.5797	62.3077	TLKA	Long term systematics and strange seasonal; possible break 2002/11/04 (not documented).
297.8367	16.7643	TRNT	Major slow slip events in 2007, 2010 (same as GERD)
227.0057	69.4382	TUKT	Lots of systematic strange seasonal signals; slow offset E 2013.
261.4357	28.4680	TXTI	Strange multiyear deviations in the North (10mm deviations from linear)
249.7133	44.6395	WLWY	Deviations associated with Yellowstone.

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 Q06, we modify this files by adding 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 sites 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.

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 2112 sites in the combined PBO solution, 28 more than last quarter, in the analyses and the statistics of the fits to results are shown in Table 4. 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 fits along with the duration of the data used are given in the following linked files: pbo_nam08_150314.tab, nmt_nam08_150314.tab and cwu_nam08_150314.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_150314.snpvel, nmt_nam08_150314.snpvel and cwu_nam08_150314.snpvel.

Table 4: Statistics of the fits of 2112, 2111 and 2104 sites analyzed by PBO, NMT and CWU in the reprocessed analysis for data collected between Jan 1, 1996 and March 14, 2015.

Center	North (mm)	East (mm)	Up (mm)
Median (50%)			
PBO	1.1	1.2	4.7
NMT	1.1	1.3	4.5
CWU	1.4	1.4	5.5
70%			
PBO	1.5	1.6	5.4
NMT	1.5	1.7	5.4
CWU	1.7	1.7	6.3
95%			
PBO	3.3	3.2	8.6
NMT	3.4	3.2	8.4
CWU	3.5	3.3	10.1

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 which 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 0.10 mm/yr horizontal and 0.38 mm/yr vertical in direct difference of all sites with in 0.5 meters of each other (2124 comparisons). The χ^2/f of the difference is $(1.25)^2$ for the horizontal and $(1.20)^2$ vertical components. These comparisons are summarized in Table 5. As noted in previous reports, adding small minimum sigmas, computed such that χ^2/f is near unity changes the statistic slightly (Table 5). With the FOGMEX correlated noise model used to compute the velocity sigmas, the comparison statistics are close but still 30% optimistic over expectations. The 10-worst sites are AC59_GDN, MCD5_GPS, MCD1_GPS, P801_GPS, P486_GHT, P599_GHT, SAV1_GPS, SAV5_GPS, JNPR_GPS, LST1_GPS. The GHT extension to the 4-character code indicates that these sites are affected by postseismic motion after the 1999 Hector Mine earthquake. The difference in velocity estimates arises from different treatments of the Hector Mine postseismic between the two analyses. The tsfit program has tolerances on the uncertainties on the postseismic log estimates that determine if the parameter is estimated or not. If the uncertainty is too large then it is assumed that there is not enough sensitivity to the parameter (due to the elapsed time from the earthquake to the first data at the site) and the log estimate is removed. For the _GHT sites above, the Hector mine postseismic was treated differently in the two analyses i.e., one case they were estimated and the other not estimated. The SAV5 site appears because there are multiple sites at this location that do not overlap in time. The difference occurs between the (non-overlapping in time) SAV5 and SAV1 sites. LST1 is a site used only a small number of times by NMT (92 days) and is close to 1LSU which is used in both the NMT and CWU analyses.

Table 5: Statistics of the differences between the CWU and NMT velocity solutions with no transformation between them. In these comparisons sites with the same names and within 0.5 meters of each other are included and the total number of comparisons is larger than the number of stations. The PBO, NMT and CWU solutions themselves have 2106, 2106 and 2097 sites. WRMS is weighted-root-mean-scatter and NRMS is $\mathrm{sqrt}(\chi^2/f)$ where f is the number of comparisons.

Solution	#	NE WRMS (mm/yr)	U WRMS (mm/yr)	NE NRMS	U NRMS
All	2124	0.10	0.38	1.25	1.20
Edited -10 worst	2107	0.09	0.37	1.16	1.16
Less than median (0.15 0.41 mm/yr)	1182	0.07	0.29	1.23	1.11
Added minimum sigma NE 0.06 U 0.20 mm/yr					
All	2124	0.14	0.49	1.00	0.98
Edited -10 worst	2109	0.13	0.46	0.91	0.93
Less than median (0.16 0.46 mm/yr)	1182	0.09	0.34	0.79	0.80

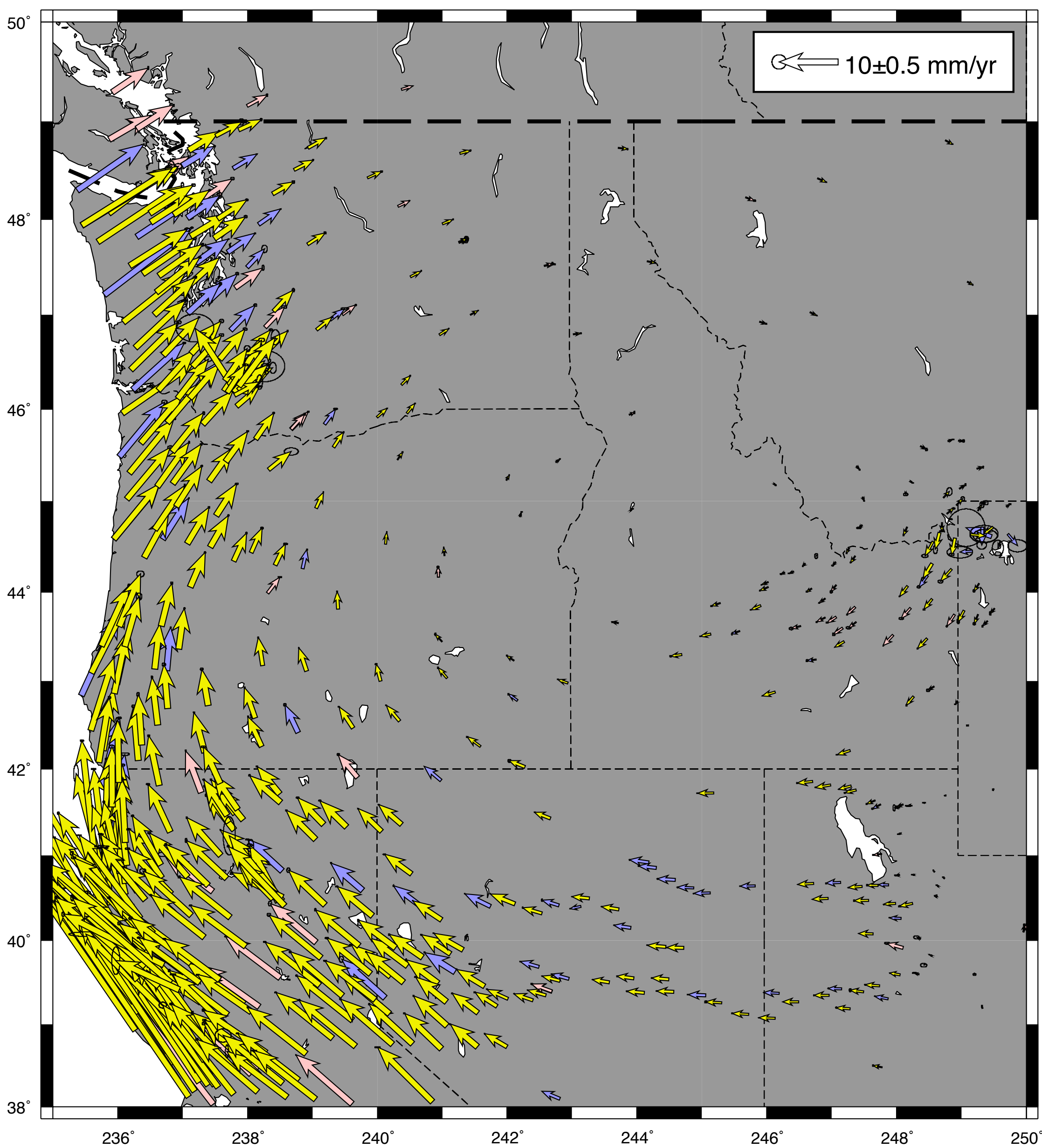


Figure 10: Velocity field estimates from the combined PBO solutions generated using time series analysis and the FOGMEX error model. 95% confidence interval error ellipses are shown. The color scheme of the vectors matches the network type legend in Figure 4. Only velocities with horizontal standard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

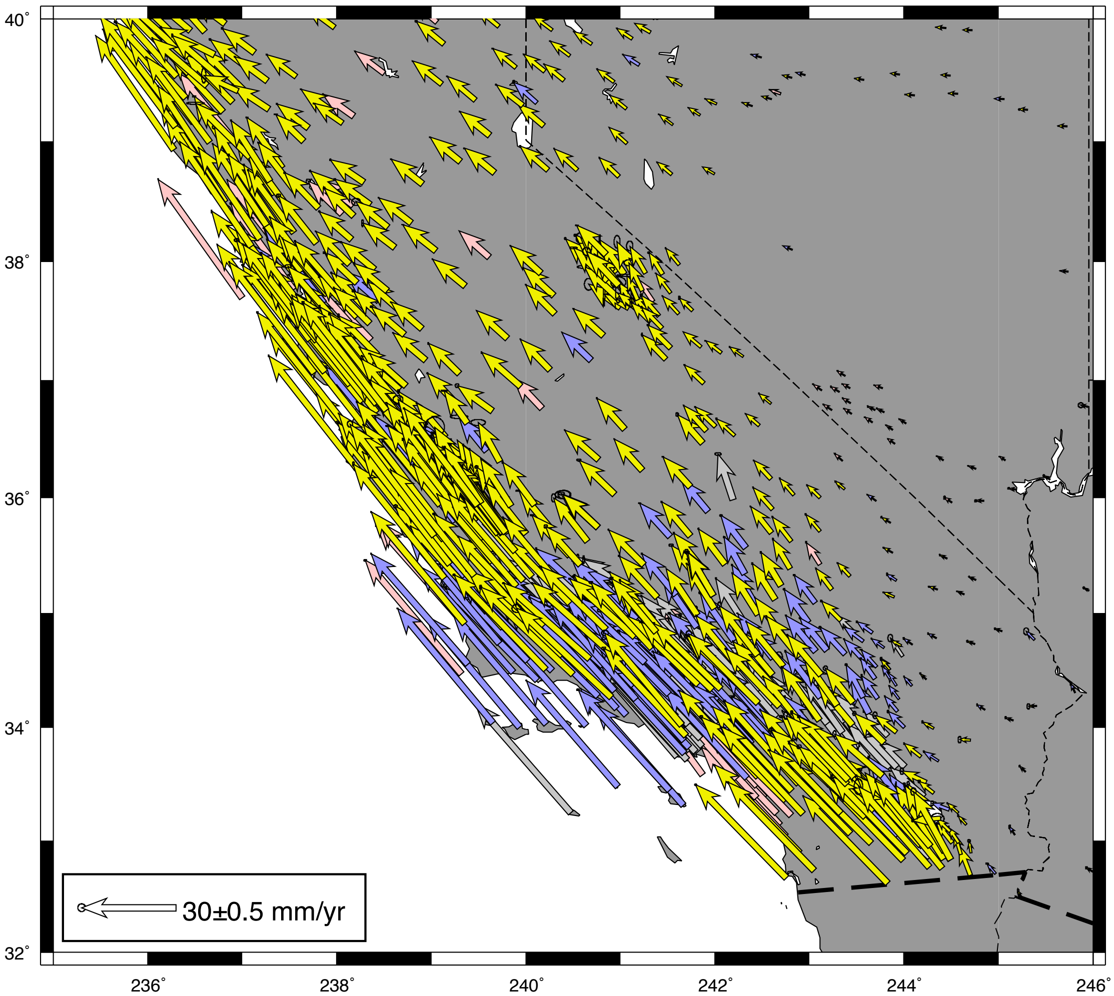


Figure 11: Same as Figure 10 except for South Western United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown.

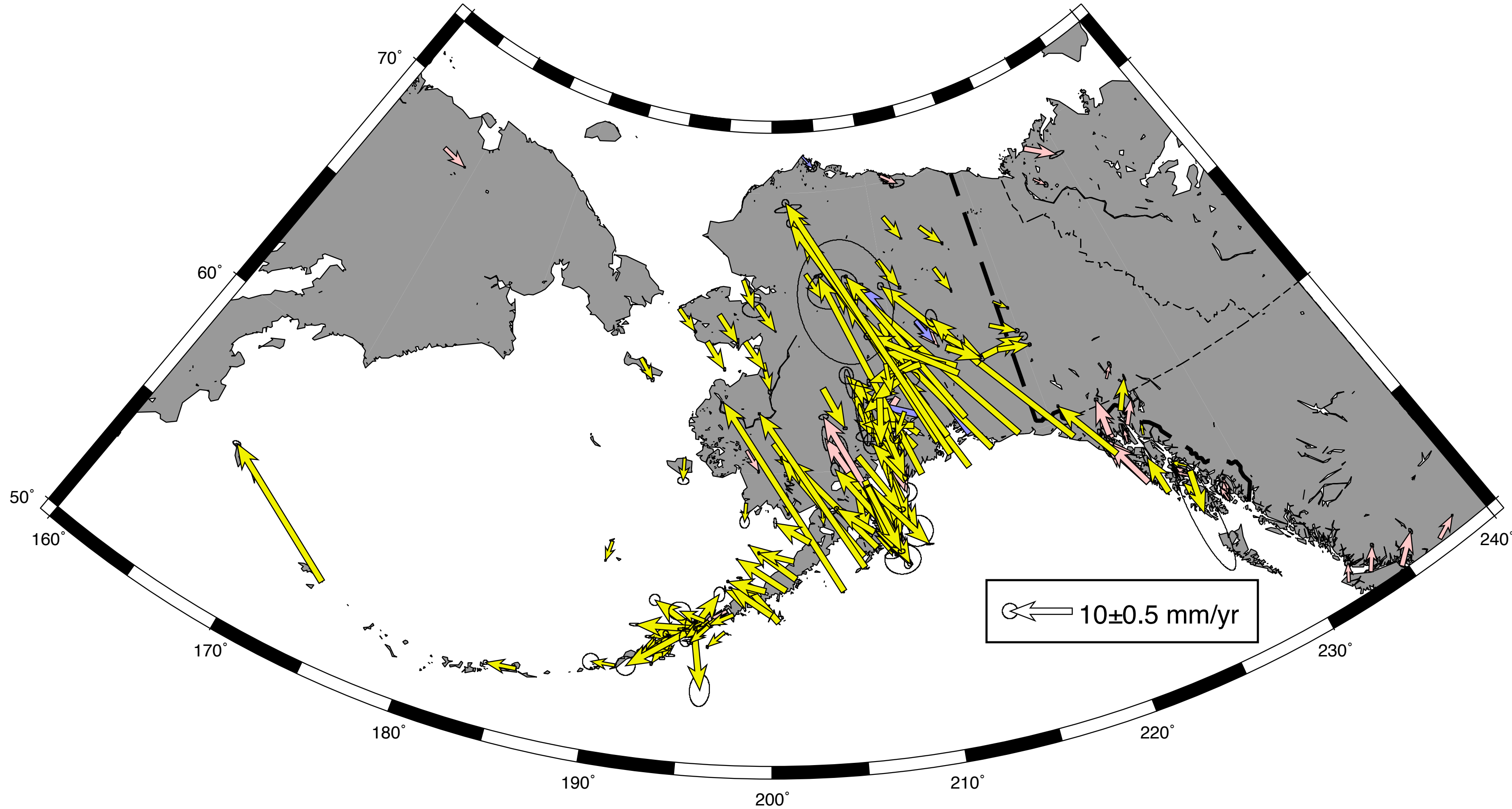


Figure 12: Same as Figure 10 except for Alaska. Only velocities with horizontal standard deviations less than 5 mm/yr are shown.

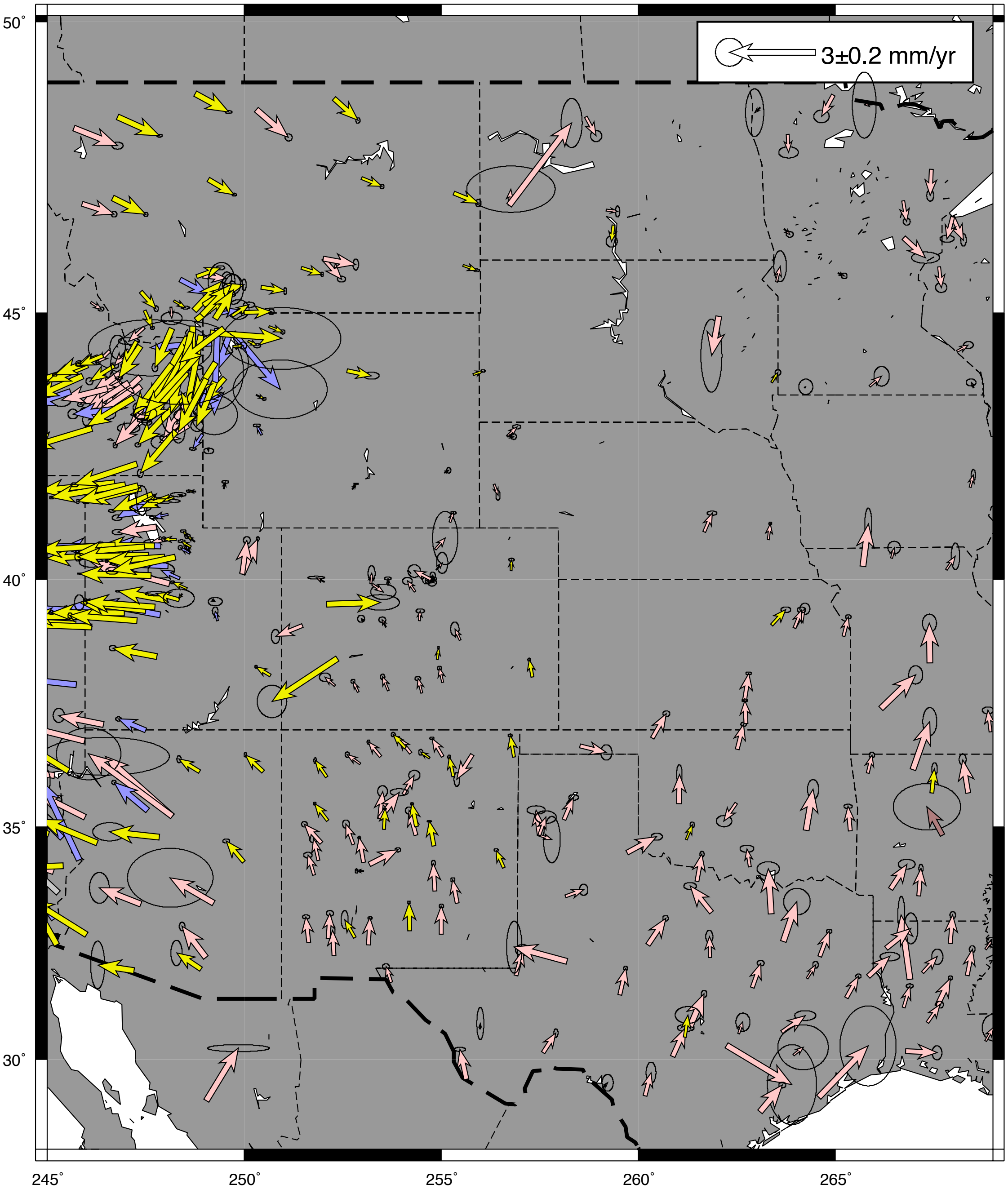


Figure 13: Same as Figure 10 except for Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown.

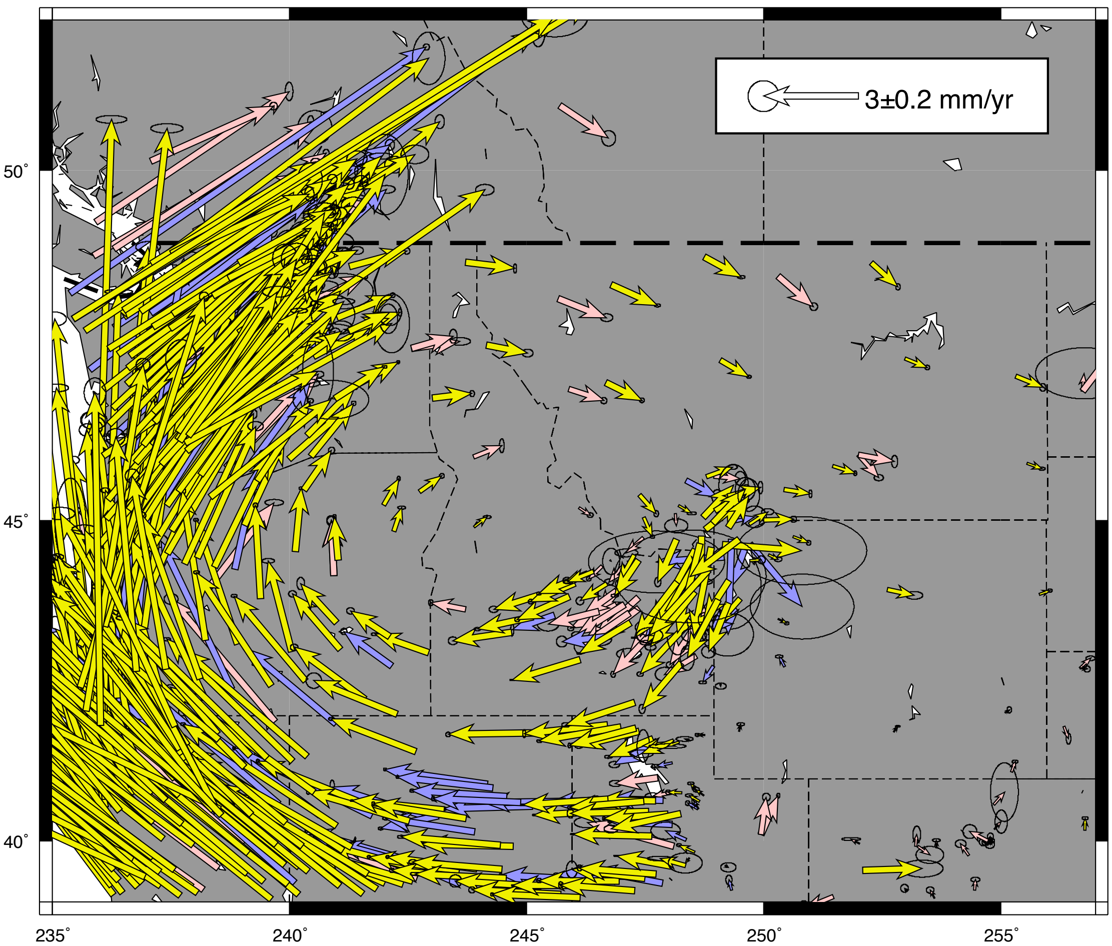


Figure 14: Same as Figure 10 except for Western Central United States. Only velocities with horizontal standard deviations less than 1 mm/yr are shown. Anomalous vectors at longitude 250° are in the Yellowstone National Park and most likely are showing volcanic processes.

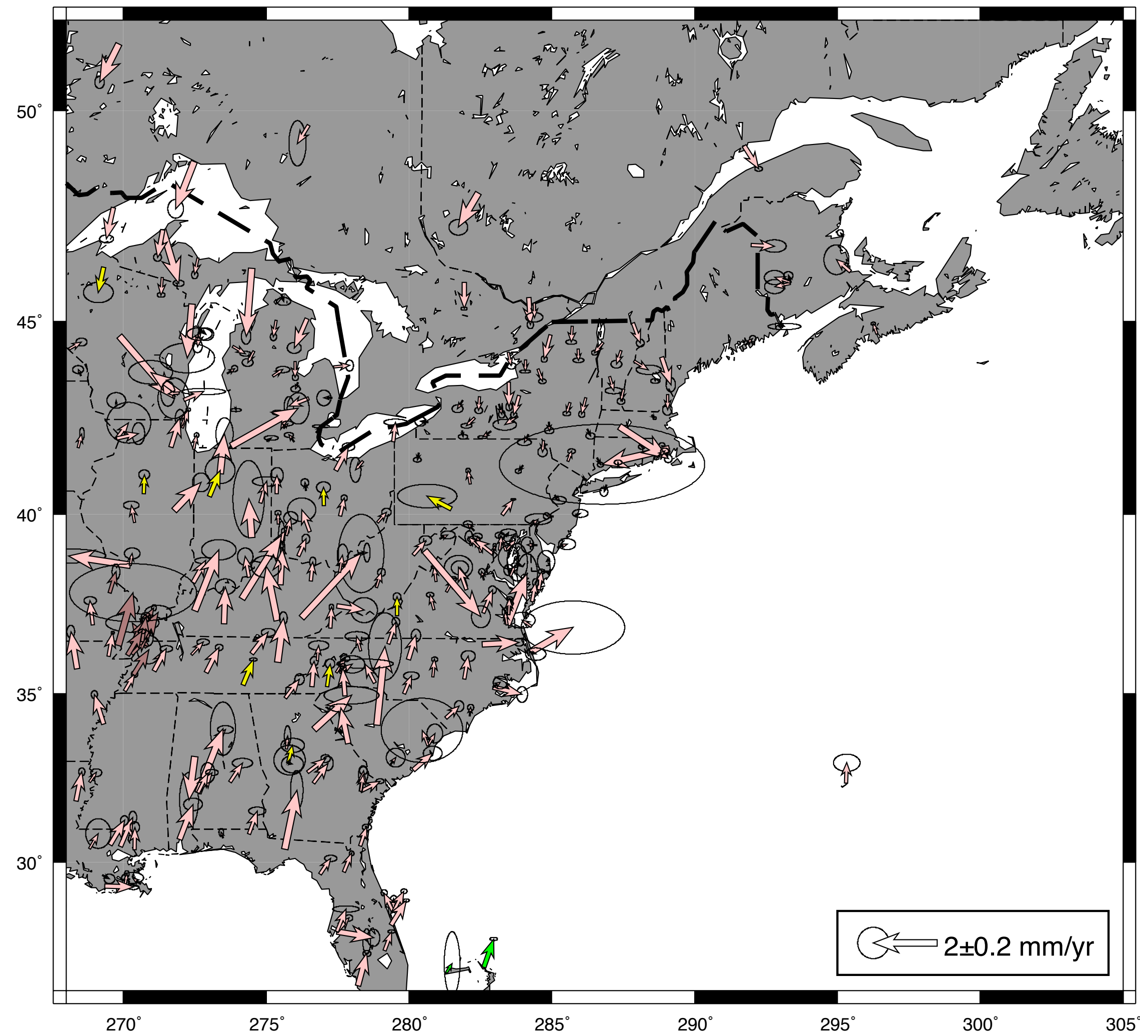


Figure 15: Same as Figure 10 except for the Eastern United States. Only velocities with horizontal standard deviations less than 2 mm/yr are shown. The systematic western velocity of sites in the Northeast is being investigated although profiles from Canada to the Gulf of Mexico indicate that horizontal glacial isostatic adjustment (GIA) horizontal signals may be seen in the velocity results. If this is the case, the North America Euler pole from ITRF2008 may be affected by these motions.

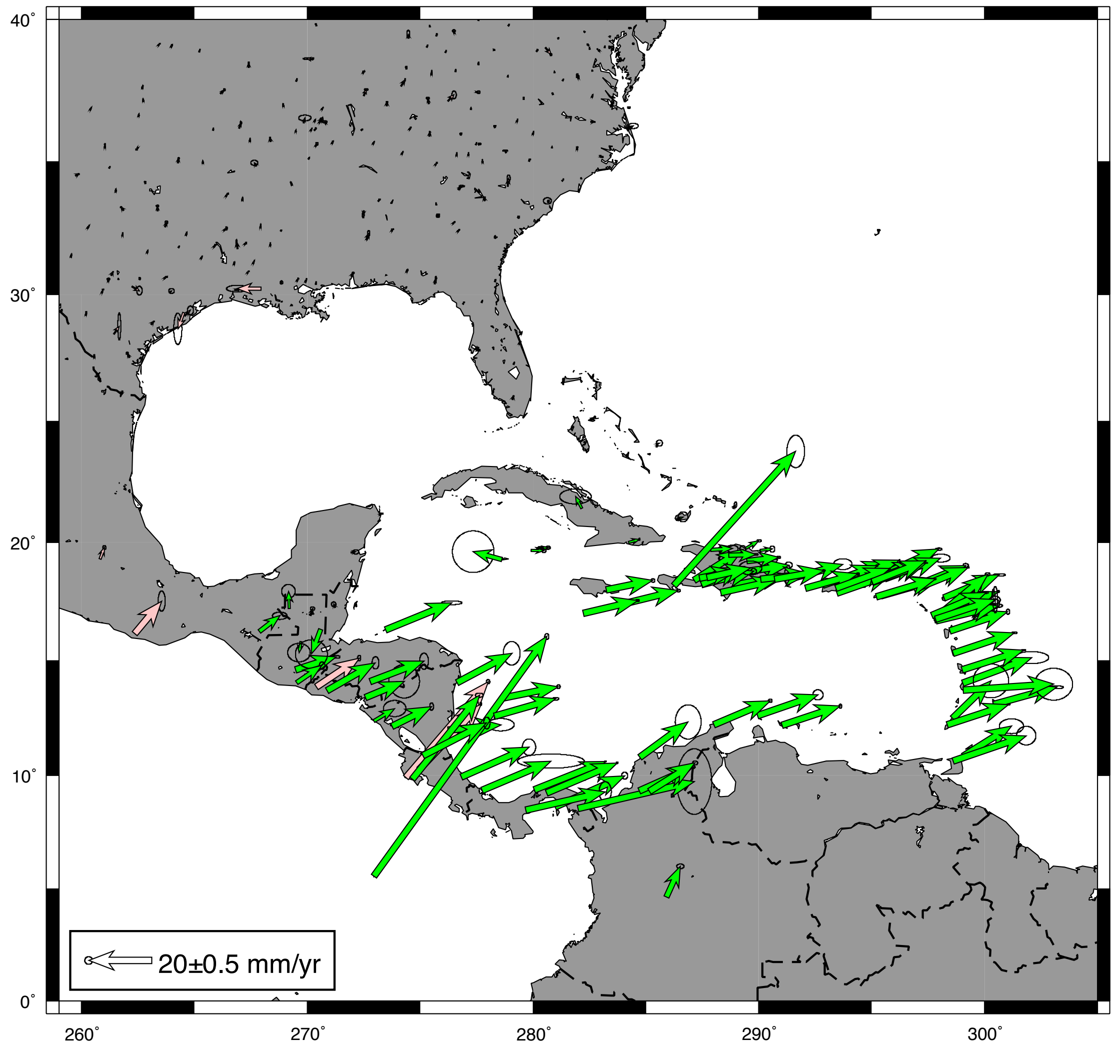


Figure 16: Same as Figure 10 except for the Caribbean region. Only velocities with horizontal standard deviations less than 5 mm/yr are shown.

Earthquake Analyses: 2015/01/01-2014/03/31.

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 site 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).

In December 2014/January 2015 we investigated the following events.

```
The following earthquakes we examined to see if there were any co-seismic
offsets.
* EQDEFS for 2014 12 11 to 2015 01 10 Generated Mon Jan 12 16:30:11 EST 2015
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 219 MOPR_GPS       5.79       8.70 CoS        0.0 mm
* EQ_DEF M3.5 75km SE of Punta Cana
 eq_def 01   18.0405  -67.9716      8.7 8 2014 12 19 19 59    0.000
 eq_rename 01
 eq_coseis 01  0.001 0.001 0.001      0.000      0.000      0.000
* ----------------------------------
* SEQ Earthquake # 2
* EQ 326 P507_GPS       1.72      10.10 CoS       21.7 mm
* EQ_DEF M4.2 10km SW of Niland
 eq_def 02   33.1852 -115.6085     10.1 8 2014 12 24 05 52    0.001
 eq_rename 02
 eq_coseis 02  0.001 0.001 0.001      0.001      0.001      0.001
* ----------------------------------
* SEQ Earthquake # 3
* EQ 327 P507_GPS       2.57       8.80 CoS        0.0 mm
* EQ_DEF M3.6 10km NW of Calipatria
 eq_def 03   33.1783 -115.6042      8.8 8 2014 12 24 06 01    0.000
 eq_rename 03
 eq_coseis 03  0.001 0.001 0.001      0.000      0.000      0.000
* ----------------------------------
* SEQ Earthquake # 4
* EQ 407 P108_GPS       8.65       8.90 CoS        0.0 mm
* EQ_DEF M3.7 12km WSW of Nephi
 eq_def 04   39.6640 -111.9718      8.9 8 2014 12 29 06 09    0.000
 eq_rename 04
 eq_coseis 04  0.001 0.001 0.001      0.000      0.000      0.000
* ----------------------------------
* SEQ Earthquake # 5
* EQ 518 BRPK_GPS       8.66      10.30 CoS        1.7 mm
* EQ 518 P555_GPS       9.41      10.30 CoS        1.4 mm
* EQ_DEF M4.2 14km N of Castaic
 eq_def 05   34.6173 -118.6302     10.3 8 2015 01 04 03 19    0.002
 eq_rename 05
 eq_coseis 05  0.001 0.001 0.001      0.002      0.002      0.002
```

No significant offset were found for these events although there could be ~1mm east displacement at the time of the earthquake but within the systematic noise level this offset is not so definitive. When estimated, the height shows an offsets but this is almost certainly due to systematic variations in the months before the earthquake.

In January/February 2015, the following events were investigated

```
* EQDEFS for 2015 01 09 to 2015 02 15 Generated Mon Feb 16 17:47:31 EST 2015
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 125 TNPJ_GPS      16.50      22.90 CoS        7.3 mm
* EQ_DEF M5.4 16km SE of Pijijiapan
 eq_def 01   15.5992  -93.1120     22.9 8 2015 01 12 07 58    0.031
 eq_rename 01
 eq_coseis 01  0.001 0.001 0.001      0.031      0.031      0.031
* ----------------------------------
* SEQ Earthquake # 2
* EQ 283 P486_GPS       8.73       8.90 CoS        0.0 mm
* EQ_DEF M3.7 10km NNE of Borrego Springs
```

```
 eq_def 02   33.3383 -116.3317      8.9 8 2015 01 18 13 24    0.000
 eq_rename 02
 eq_coseis 02  0.001 0.001 0.001      0.000      0.000      0.000
* ----------------------------------
* SEQ Earthquake # 3
* EQ 341 P285_GPS       2.10      11.10 CoS       43.3 mm
* EQ_DEF M4.4 27km ENE of Greenfield
 eq_def 03   36.4335 -120.9710     11.1 8 2015 01 20 13 22    0.003
 eq_rename 03
 eq_coseis 03  0.001 0.001 0.001      0.003      0.003      0.003
* ----------------------------------
* SEQ Earthquake # 4
* EQ 537 P157_GPS      26.43      33.30 CoS        6.6 mm
* EQ_DEF M5.7 40km SW of Ferndale
 eq_def 04   40.3178 -124.6067     33.3 8 2015 01 28 21 09    0.072
 eq_rename 04
 eq_coseis 04  0.001 0.001 0.001      0.072      0.072      0.072
```

We have no data for TNPJ for event 1 so we could assess this earthquake.
No significant offset seen at P486 for event 2.
P285 may have a small vertical offset (dU -2.14 ± 5.45 mm WLS, -5.12 ±1.08 KF with error model computed from the FOGMEX model. Horizontal offsets are <0.5 mm. We have decided not to explicitly model this earthquake.
Event 4 shows no offset from the earthquake but there are offsets 13 days before from an antenna change at the site.
Overall: No significant earthquake events this month.

In February/March 2015, the following events were investigated but none show co-seismic offsets.

```
* EQDEFS for 2015 02 12 to 2015 03 15 Generated Mon Mar 16 07:51:20 EDT 2015
* Proximity based on Week_All.Pos file
* ----------------------------------
* SEQ Earthquake # 1
* EQ 417 BEMT_GPS       7.49       8.90 CoS        0.0 mm
* EQ 417 P601_GPS       5.46       8.90 CoS        0.0 mm
* EQ_DEF M3.7 23km S of Twentynine Palms
 eq_def 01   33.9377 -116.0285      8.9 8 2015 02 26 01 19    0.000
 eq_rename 01
 eq_coseis 01  0.001 0.001 0.001      0.000      0.000      0.000
* ----------------------------------
* SEQ Earthquake # 2
* EQ 470 CN48_GPS      11.35      12.10 CoS        2.0 mm
* EQ 470 DOMI_GPS       5.94      12.10 CoS        7.3 mm
* EQ_DEF M4.6 3km E of Mahaut
 eq_def 02   15.3536  -61.3650     12.1 8 2015 02 28 12 29    0.004
 eq_rename 02
 eq_coseis 02  0.001 0.001 0.001      0.004      0.004      0.004
* ----------------------------------
* SEQ Earthquake # 3
* EQ 632 AC74_GPS       5.75       9.60 CoS        1.9 mm
* EQ_DEF M4.0 14km N of Cantwell
 eq_def 03   63.4751 -148.9217      9.6 8 2015 03 08 19 44    0.001
 eq_rename 03
 eq_coseis 03  0.001 0.001 0.001      0.001      0.001      0.001
* ----------------------------------
* SEQ Earthquake # 4
* EQ 647 LMNO_GPS       6.67       8.70 CoS        0.0 mm
* EQ_DEF M3.5 19km WNW of Tonkawa
 eq_def 04   36.7369  -97.5204      8.7 8 2015 03 10 04 22    0.000
 eq_rename 04
 eq_coseis 04  0.001 0.001 0.001      0.000      0.000      0.000
```

No offsets were seen form these earthquakes. However, while examining the time-series CN48 appears to have excessive noise despite the site appearing to have an unobstructed view of the sky. The north and height components appear to be correlate with nearby site DOMI. There are no photographs of this site that could be found.
There are no results for LMNO since early 2012 so we could not test this offset. Given the expected magnitude it is likely to be small. Overall: No significant earthquake events this month.

Antenna Change Offsets: 2015/01/01-2014/03/31

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

Site	Date					From	To
P181	2014	12	9	21	20	TRM29659.00	TRM59800.80
P199	2014	12	10	19	54	TRM29659.00	TRM59800.80
P484	2014	12	10	23	23	TRM29659.00	TRM59800.80
EOUT	2014	12	11	0	0	Radome UNAV	SCIS
P181	2014	12	9	21	20	TRM29659.00	TRM59800.80
P199	2014	12	10	19	54	TRM29659.00	TRM59800.80
P224	2014	12	24	0	0	TRM29659.00	TRM59800.00
P262	2014	12	30	21	1	TRM29659.00	TRM59800.80
P484	2014	12	10	23	23	TRM29659.00	TRM59800.80
SCUB	2014	12	19	0	0	ASH700936C_M	JAV_RINGANT_G3T
YESX	2014	12	7	0	0	ASH701945B_M	TRM59800.00
BGGY	2015	1	31	0	0	TRM29659.00	TRM59800.00
CN40	2015	1	13	0	0	TRM57971.00	TRM59800.00
KBRC	2015	1	23	0	0	ASH701945C_M	TRM59800.00
P066	2015	1	12	0	0	TRM29659.00	TRM59800.00
P157	2015	1	15	20	42	TRM29659.00	TRM59800.00
P176	2015	1	26	20	3	TRM29659.00	TRM59800.80
P197	2015	1	29	20	58	TRM29659.00	TRM59800.80
P201	2015	1	14	0	0	TRM29659.00	TRM59800.80
P248	2015	1	7	22	33	TRM29659.00	TRM59800.00
P429	2015	1	22	19	25	TRM29659.00	TRM59800.80
P480	2015	1	13	0	0	TRM29659.00	TRM59800.00
P543	2015	1	10	20	22	TRM29659.00	TRM59800.00
SOMT	2015	1	23	0	0	TRM29659.00	TRM59800.80
CACT	2015	2	10	19	42	TPSCR.G3	TRM57971.00
CN00	2015	2	3	0	2	TRM57971.00	TRM59800.00
CN15	2015	2	17	0	0	TRM57971.00	TRM59800.00
CN38	2015	2	28	20	36	TRM57971.00	TRM59800.00
NWCC	2015	2	11	0	0	ASH700936D_M	TRM57971.00
P198	2015	2	12	20	59	TRM29659.00	TRM59800.80
P206	2015	2	26	0	0	TRM29659.00	TRM59800.80
P272	2015	2	25	0	0	TRM29659.00	TRM59800.80
P612	2015	2	12	19	53	TRM29659.00	TRM59800.80
P790	2015	2	2	0	0	TRM29659.00	TRM59800.80
PTAX	2015	2	13	23	54	ASH701945B_M	TRM29659.00

The analyses of the effects of these changes were reported in the monthly reports.
P181: Clear offset in East at the time of the antenna change. There is a North offset on 2014-08-24 due M6.0 6km NW of American Canyon(4.22 ± 0.09 mm) which is larger than the offset at the time of the antenna change. We have not added the 2014-08-24

offset to the All_PBO_unkn.eq because this may be signal. The antenna-offset changes are dNEU -0.71 ± 0.17, 5.29 ± 0.22, -1.80 ± 0.70 mm.
P199: Clear offset in East at the time of the antenna change and the 2014-08-24 earthquake can be clearly seen at this site. The offsets are dNEU 0.63 ± 0.30, -6.34 ± 1.89, -10.07 ± 1.15 mm. The height offset maybe affected by systematics similar to that seen at P181. (height deviation is common to sites in the region).
P484: Small offsets associated with change. dNEU -2.11 ± 0.19, 2.47 ± 0.19, -5.21 ± 0.73 mm.

Starting in January we use both weighted least squares (WLS) and a Kalman filter (KF) estimator to determine the offset. The KF handles systematic variations in the time series and typically generates offset estimates that are closer to values estimated by differencing positions averaged over a few days before and after the antenna change. The error estimates are smaller for the KF estimator than the WLS estimator with the FOGMEX algorithm. In the summaries below give both estimates.
EOUT: WLS dNEU 3.32 ± 1.56, 3.89 ± 3.35, -7.94 ± 5.64 mm, KF dNEU 2.20 ± 0.24, 5.03 ± 0.24, -8.06 ± 0.86 mm. Significant
P225: WLS dNEU 4.18 ± 1.88, 0.45 ± 1.63, 0.05 ± 2.14 mm, KF dNEU 1.36 ± 0.22, 0.10 ± 0.20, -0.94 ± 0.64 mm. There are systematic variations which cause the WLS estimate to over estimate the jump in North. The KF residuals are smooth.
P262: WLS dNEU -1.57 ± 8.31, 5.96 ± 6.23, -3.34 ± 5.53 mm , KF dNEU -1.53 ± 0.34, 5.98 ± 0.28, -3.22 ± 0.82 mm. Significant. Additional break at gap in data that end 2014 10 15. Offset for this first break are: WLS dNEU -1.32 ± 5.60, 5.84 ± 4.30, 4.46 ± 3.77 mm , KF dNEU -3.45 ± 0.52, 6.55 ± 0.41, 1.56 ± 0.74 mm
SCUB: WLS dNEU 1.22 ± 3.40, -3.09 ± 2.82, 7.45 ± 5.23 mm , KF dNEU -1.83 ± 0.77, -1.47 ± 0.72, 8.44 ± 1.75 mm . Significant
YESX: This antenna change occurs before any processed data.
BGGY: WLS dNEU 3.07 ± 7.04, 7.35 ± 6.79, 9.63 ± 14.67 mm, KF dNEU 1.96 ± 0.72, 6.66 ± 0.82, 9.52 ± 3.01 mm . Significant
CN40: WLS dNEU -0.40 ± 1.49, -8.23 ± 0.86, 11.70 ± 4.57 mm, KF dNEU 0.98 ± 0.38, -8.51 ± 0.41, 13.84 ± 1.58 mm . East shift is very apparent in the time-series.
KBRC: WLS dNEU 5.30 ± 7.65, 1.90 ± 4.13, 3.39 ± 7.79 mm , KF dNEU 7.77 ± 0.38, -0.03 ± 0.32, 2.27 ± 1.22, mm . Significant
P066: WLS dNEU 2.67 ± 0.73, 5.04 ± 0.88, -0.51 ± 4.08 mm , KF dNEU 2.92 ± 0.28, 5.56 ± 0.26, -2.33 ± 1.05 mm . Significant
P157: WLS dNEU 6.01 ± 2.42, -1.69 ± 2.85, -0.17 ± 3.19 mm KF dNEU 5.70 ± 0.31, -2.11 ± 0.28, -0.14 ± 0.92 mm . There is an earthquake shortly after this antenna change but the earthquake offset looks small.
P176: WLS dNEU -2.39 ± 0.99, 4.26 ± 1.20, -2.85 ± 6.52, mm KF dNEU -3.00 ± 0.44, 4.01 ± 0.36, -4.19 ± 1.54 mm
P197: WLS dNEU 1.99 ± 9.11, -0.44 ± 8.76, -3.92 ± 11.31 mm KF dNEU 1.46 ± 0.44, -0.32 ± 0.38, -3.39 ± 1.39 mm . There is a significant earthquake on 2014 08 24 that also offsets this site.
P201: WLS dNEU 1.64 ± 0.66, 0.24 ± 0.55, -0.81 ± 4.30 mm KF dNEU 1.65 ± 0.29, 0.23 ± 0.25, -0.53 ± 1.00 mm . Also effected by 2014 08 24 earthquake.

P248: WLS dNEU -0.37 ± 0.83, -1.47 ± 1.28, -2.03 ± 6.67 mm. KF dNEU 0.08 ± 0.23, -3.00 ± 0.22, -4.14 ± 0.87 mm
P429: WLS dNEU 4.45 ± 1.18, -6.74 ± 1.93, 1.36 ± 4.95 mm , KF dNEU 5.00 ± 0.40, -7.21 ± 0.32, -0.33 ± 1.26 mm
P480: WLS dNEU 0.42 ± 0.81, -2.03 ± 0.79, 0.49 ± 2.11 mm , KF dNEU 0.65 ± 0.27, -1.49 ± 0.26, -0.50 ± 0.95 mm
P543: WLS dNEU -4.15 ± 0.96, 2.91 ± 0.86, 12.26 ± 6.66 mm , KF dNEU -4.03 ± 0.35, 3.00 ± 0.31, 10.91 ± 1.32 mm
SOMT: WLS dNEU -6.42 ± 5.90, 8.03 ± 2.66, 0.74 ± 6.66 mm, KF dNEU -5.13 ± 0.37, 7.46 ± 0.29, -1.87 ± 1.10 mm .

CACT: WLS dNEU -2.72 ± 6.05, 1.44 ± 2.34, -12.83 ± 5.05, mm , KF dNEU 1.50 ± 0.45, 0.19 ± 0.35, -11.97 ± 1.35, mm . There systematic height changes in the last 1 year that effect the estimate of the height change.
CN00: WLS dNEU 1.38 ± 0.61, -5.05 ± 2.76, 22.85 ± 4.72, mm , KF dNEU 1.51 ± 0.42, -3.59 ± 0.69, 23.78 ± 2.00, mm . Height offset looks significant.
CN15: WLS dNEU 3.33 ± 0.44, -1.91 ± 0.39, 14.70 ± 1.59, mm, KF dNEU 3.50 ± 0.43, -2.01 ± 0.38, 15.10 ± 1.54, mm . Height offset looks significant; the North offset might be due to an earlier non-documented break around the end of May 2014. Time-series is not that clear. Adding additional break did not effect the estimates.
CN38: WLS dNEU 0.35 ± 1.39, -1.90 ± 1.61, 12.26 ± 6.73, mm , KF dNEU 0.49 ± 0.50, -2.25 ± 0.63, 10.18 ± 2.25, mm . Height is significant
NWCC: WLS dNEU 4.08 ± 3.36, 9.63 ± 6.41, -15.26 ± 10.41, mm , KF dNEU 2.24 ± 0.35, 8.36 ± 0.38, -15.23 ± 1.27, mm . Significant
P198: WLS dNEU 0.18 ± 3.66, 1.55 ± 3.89, -7.32 ± 14.48, mm , KF dNEU -0.21 ± 0.32, 1.70 ± 0.29, -5.56 ± 1.15, mm . Time-series effected by 2014 08 24 earthquake. East offset looks significant.
P206: WLS dNEU 4.57 ± 1.48, 3.40 ± 3.88, -3.03 ± 8.62, mm , KF dNEU 4.80 ± 0.43, 1.76 ± 0.38, -4.74 ± 1.51, mm . North looks significant but there are systematics in the time-series with annual signals in all components.
P272: WLS dNEU 1.17 ± 1.41, 3.01 ± 3.57, -1.56 ± 5.85, mm , KF dNEU 1.67 ± 0.34, 3.74 ± 0.31, -1.06 ± 1.17, mm . Systematic deviation between 04/2014-11/2014 may effect these estimates.
P612: WLS dNEU 0.25 ± 3.52, 1.29 ± 1.94, -0.82 ± 4.22, mm , KF dNEU -0.99 ± 0.32, 1.00 ± 0.28, -2.19 ± 1.05, mm . Estimates are affected by what appear to be snow outliers.
P790: WLS dNEU 1.47 ± 1.37, -1.01 ± 1.05, -0.85 ± 7.25, mm , KF dNEU 1.01 ± 0.42, -1.02 ± 0.35, -2.14 ± 1.69, mm . Does appear significant but discontinuity retained for consistency.
PTAX: WLS dNEU 3.16 ± 0.48, -0.40 ± 0.42, -3.21 ± 1.68, mm , KF dNEU 2.56 ± 0.28, -0.31 ± 0.26, -2.10 ± 0.96, mm . Gaps in data make

We have added the following unknown cause discontinuities and data edits to the PBO analyses. If there is no end date in time range, the change is ongoing. In some cases here these entries will record the failure time of an antenna that is later noted in the site logs to have changed.

Rename	Date Range	Explanation
P110 P110_APS	2007 9 31 2009 5 7	Unlisted (maybe broken antenna) replaced 2009 5 7
P262 P262_APS	2014 10 15	Jump at end of gap. Antenna change later.

Effects of 2nd order ionospheric delay model.

The CWU AC changed their processing at November 7, 2014 (GPS week 1817, day of week 5) to incorporate 2nd order ionospheric corrections to be consistent with the orbit and clock products being generated at JPL. The processing scheme is consistent with the models used for the ITRF2014 orbit and clocks generated by the IGS analysis centers. To evaluate the effects of these changes, both PBO ACs processed GPS week 1800 and 1801 (July 6-19, 2014) with and without the 2nd order ionospheric corrections applied. The summary of the effects of the change is given in Tables 6a-d.
The general effects of the change in processing are small with the square-root of χ^2 per degree of freedom (normalized RMS or Chi) less than 0.1 (i.e., the changes are less than a tenth of the standard deviation over all). The mean values are also small when each solution is aligned to the PBO reference frame as they are in standard processing except for CWU heights, which vary between 0.80 and 1.50 mm for daily estimates, and is 0.64 mm for the combined solution. For CWU the RMS of the height differences is dominated by the mean differences. When solutions are allowed to rotate and translate (Table 6b) the mean height difference is reduced and the RMS decreases from ~1.0 mm to 0.3 mm. The CWU solution also behaves strangely in the combination. For the NMT solution, the RMS value of the combined (1800A in Table 6c) solution is very similar to the daily values but for the CWU solution the North and East differences are much larger for the combined solution than for the daily values. This behavior is not understood currently but is can be reduced considerably by allowing scale changes between the PBO frame and the daily CWU solution. The statistics for this combined solution is labeled 1880S.

The overall conclusion is that when daily solutions are aligned to the regional PBO reference frame each day as is done in the standard processing the impact of applying the 2nd order ionospheric corrections is small for recent ionospheric delay levels. This conclusion also suggested at there should not be major problems with the correction not being applied in the rapid processing where the IONEX files needed to apply the correction are not available.

Table 6a: WRMS and NRMS (labeled Chi) of the differences in position estimates from the CWU solution with and without the 2nd order ionospheric corrections applied. The means are computed in the sense of correction applied minus not applied. The last two rows (labeled 1800A and 1800S) are differences between the solutions when all two weeks of data are combined in single solution. The 1800A uses the standard PBO processing standards while 1800S allows scale changes between each day (hence zero for the mean height difference). For this table, the position estimates are directly differenced.

*				NORTH			EAST			HEIGHT		
*Day	#X	#Y	#	Mean	RMS	Chi	Mean	RMS	Chi	Mean	RMS	Chi
*				(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	
18000	1845	1840	1840	-0.02	0.13	0.045	0.01	0.07	0.029	1.45	1.47	0.145
18001	1846	1842	1842	-0.03	0.12	0.043	0.01	0.06	0.028	1.43	1.45	0.142
18002	1849	1844	1844	-0.02	0.14	0.047	0.00	0.13	0.056	1.50	1.54	0.147
18003	1858	1854	1854	-0.05	0.16	0.055	0.01	0.07	0.033	1.43	1.45	0.141
18004	1859	1854	1854	-0.03	0.10	0.035	0.02	0.06	0.024	1.22	1.25	0.120
18005	1856	1851	1851	-0.05	0.14	0.050	0.02	0.05	0.024	1.17	1.19	0.117
18006	1846	1841	1841	-0.03	0.13	0.047	0.03	0.09	0.038	1.21	1.24	0.122
18010	1843	1841	1841	-0.01	0.08	0.027	0.01	0.06	0.027	1.11	1.14	0.112
18011	1850	1848	1848	-0.06	0.15	0.052	0.01	0.07	0.031	1.11	1.13	0.110
18012	1850	1847	1847	-0.05	0.13	0.047	0.01	0.06	0.029	0.93	0.97	0.094
18013	1840	1837	1837	-0.03	0.08	0.027	-0.00	0.05	0.021	0.86	0.88	0.086
18014	1843	1839	1839	-0.02	0.08	0.027	-0.00	0.04	0.020	0.84	0.86	0.083
18015	1845	1841	1841	-0.03	0.29	0.103	0.00	0.19	0.084	0.84	0.97	0.095
18016	1843	1839	1839	-0.03	0.08	0.028	0.00	0.04	0.019	0.80	0.82	0.081
1800A	1872	1868	1868	-0.12	0.38	0.495	0.09	0.28	0.461	0.64	0.74	0.270
1800S	1872	1868	1868	0.01	0.12	0.163	0.04	0.17	0.283	0.00	0.18	0.067

Table 6b: WRMS and NRMS of the differences in position estimates from the CWU solution with and without the 2nd order ionospheric corrections applied. For this table, a rotation and translated is estimated between the two solutions (thus near zero estimates for the means) before the RMS and NRMS are computed. For the 1800S solution, scale is also estimated in the transformation. #X, #Y and # are the numbers of stations in the 2nd order ionospheric corrections not applied (#X), applied (#Y) and the difference. The two CWU solutions were not consistent with different numbers of stations included in the two types of solutions.

*				NORTH			EAST			HEIGHT		
*Day	#X	#Y	#	Mean	RMS	Chi	Mean	RMS	Chi	Mean	RMS	Chi
*				(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	
18000	1845	1840	1840	0.01	0.12	0.044	0.00	0.06	0.028	0.00	0.27	0.027
18001	1846	1842	1842	0.00	0.11	0.040	0.00	0.06	0.028	-0.00	0.23	0.023
18002	1849	1844	1844	0.00	0.12	0.041	0.00	0.13	0.055	-0.00	0.29	0.028
18003	1858	1854	1854	0.01	0.15	0.052	0.00	0.07	0.031	-0.00	0.26	0.025
18004	1859	1854	1854	0.01	0.10	0.034	0.00	0.05	0.022	-0.00	0.25	0.024
18005	1856	1851	1851	0.01	0.13	0.045	0.00	0.04	0.020	-0.00	0.19	0.019
18006	1846	1841	1841	0.01	0.13	0.046	0.00	0.08	0.034	-0.00	0.26	0.026
18010	1843	1841	1841	0.00	0.08	0.028	-0.00	0.06	0.025	-0.00	0.29	0.028
18011	1850	1848	1848	0.01	0.13	0.045	0.01	0.07	0.030	-0.00	0.21	0.021
18012	1850	1847	1847	0.01	0.12	0.042	0.00	0.06	0.028	-0.00	0.26	0.026
18013	1840	1837	1837	0.00	0.07	0.025	0.00	0.04	0.020	-0.00	0.20	0.020
18014	1843	1839	1839	0.00	0.07	0.026	0.00	0.04	0.019	-0.00	0.20	0.019
18015	1845	1841	1841	0.00	0.29	0.102	0.00	0.19	0.084	-0.00	0.48	0.047
18016	1843	1839	1839	0.00	0.07	0.025	0.00	0.04	0.018	0.00	0.20	0.020
1800A	1872	1868	1868	0.01	0.36	0.468	-0.00	0.25	0.420	0.00	0.33	0.119
1800S	1872	1868	1868	0.00	0.13	0.172	-0.00	0.15	0.256	0.00	0.20	0.072

Table 6c: WRMS and NRMS of the differences in position estimates from the NMT solution with and without the 2nd order ionospheric corrections applied. This table is the same as Table 6a. The numbers of stations in each solution type matches for the NMT solutions.

*				NORTH			EAST			HEIGHT		
*Day	#X	#Y	#	Mean	RMS	Chi	Mean	RMS	Chi	Mean	RMS	Chi
*				(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	
18000	1845	1845	1845	0.00	0.17	0.046	0.08	0.33	0.099	0.92	1.03	0.082
18001	1846	1846	1846	-0.01	0.16	0.044	-0.09	0.27	0.081	0.42	0.72	0.056
18002	1857	1857	1857	-0.02	0.15	0.046	-0.00	0.20	0.066	-0.24	0.63	0.052
18003	1857	1857	1857	-0.06	0.19	0.055	0.01	0.22	0.071	1.15	1.31	0.105
18004	1858	1858	1858	-0.01	0.16	0.046	-0.01	0.29	0.094	0.19	0.65	0.053
18005	1852	1852	1852	-0.04	0.15	0.046	0.01	0.14	0.050	0.53	0.67	0.057
18006	1845	1845	1845	-0.01	0.14	0.039	-0.06	0.21	0.063	0.20	0.56	0.044
18010	1843	1843	1843	-0.03	0.16	0.043	-0.10	0.25	0.079	0.96	1.16	0.093
18011	1851	1851	1851	-0.06	0.16	0.041	-0.01	0.24	0.069	0.72	0.90	0.068
18012	1851	1851	1851	-0.02	0.16	0.039	0.01	0.20	0.057	0.38	0.62	0.045
18013	1839	1839	1839	-0.02	0.19	0.053	-0.09	0.30	0.095	-0.63	1.01	0.083
18014	1843	1843	1843	-0.03	0.13	0.038	-0.04	0.19	0.061	0.27	0.47	0.040
18015	1845	1845	1845	-0.01	0.11	0.030	-0.00	0.23	0.072	0.38	0.62	0.052
18016	1844	1844	1844	-0.00	0.08	0.021	-0.03	0.18	0.056	0.33	0.46	0.037
1800A	1873	1873	1873	-0.02	0.06	0.082	-0.00	0.06	0.088	0.35	0.40	0.140
1800S	1873	1873	1873	-0.02	0.06	0.081	-0.00	0.06	0.089	-0.01	0.20	0.071

Table 6d: WRMS and NRMS of the differences in position estimates from the NMT solution with and without the 2nd order ionospheric corrections applied. This table is the same as Table 6b.

*Day	#X	#Y	#	Mean	RMS	Chi	Mean	RMS	Chi	Mean	RMS	Chi
*				(mm)	(mm)		(mm)	(mm)		(mm)	(mm)	
18000	1845	1845	1845	0.01	0.17	0.047	-0.01	0.31	0.093	0.00	0.47	0.038
18001	1846	1846	1846	0.01	0.15	0.043	0.01	0.26	0.077	-0.00	0.54	0.043
18002	1857	1857	1857	0.01	0.15	0.045	0.01	0.20	0.067	-0.00	0.51	0.042
18003	1857	1857	1857	0.01	0.18	0.051	-0.01	0.23	0.072	0.00	0.60	0.049
18004	1858	1858	1858	0.01	0.17	0.047	0.01	0.29	0.092	-0.00	0.62	0.050
18005	1852	1852	1852	0.01	0.14	0.044	0.00	0.15	0.050	-0.00	0.36	0.031
18006	1845	1845	1845	0.00	0.13	0.036	0.01	0.21	0.062	-0.00	0.46	0.036
18010	1843	1843	1843	0.00	0.14	0.038	0.01	0.25	0.076	-0.00	0.53	0.042
18011	1851	1851	1851	0.00	0.14	0.036	0.00	0.24	0.070	0.00	0.53	0.040
18012	1851	1851	1851	0.01	0.16	0.039	0.00	0.20	0.056	-0.00	0.46	0.034
18013	1839	1839	1839	0.01	0.18	0.051	0.02	0.30	0.094	-0.00	0.63	0.052
18014	1843	1843	1843	-0.00	0.12	0.036	0.00	0.18	0.060	-0.00	0.37	0.031
18015	1845	1845	1845	-0.00	0.11	0.030	-0.00	0.23	0.073	0.00	0.44	0.036
18016	1844	1844	1844	-0.00	0.08	0.021	0.01	0.18	0.055	-0.00	0.30	0.024
1800A	1873	1873	1873	0.00	0.06	0.075	0.00	0.06	0.091	-0.00	0.15	0.051
1800S	1873	1873	1873	0.00	0.06	0.075	0.00	0.06	0.092	-0.00	0.14	0.052

Script updates

No major changes have been to the scripts.

GAMIT/GLOBK Community Support

During this quarter we finished the structural modifications to GAMIT to support GNSS observations other than GPS. Still to do are implementation of the satellite yaw models and, for Glonass, multiple frequency observables. The initial code will allow only one type of GNSS at a time to be processed with GAMIT, but the solution (h-) files from the GAMIT processing can be combined in GLOBK, thus allowing multiple-system contribut6ions to the estimation of site coordinates. During this quarter we upgraded the magnetic field model for higher-order ionospheric corrections to IGRF12, added support for three receivers and five antennas , and continued to update our files containing precise a priori coordinates and discontinuities for over 1800 global continuous tracking stations, and global grid files for atmospheric loading and meteorological data.

There were no UNAVCO-sponsored data-analysis workshops during this period, but we continue to spend 5-10 hours per week in email support of users. During the quarter we issued 23 royalty-free licenses to educational and research institutions,